Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin
Appendix A - Statistical Hydrology

July 2021

INTERAGENCY FLOOD RISK MANAGEMENT

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1. Statistical Hydrology

1.1 INTRODUCTION TO STATISTICAL HYDROLOGY

Statistical analysis of the observational record (systematic and historical) at USGS streamflow-gaging stations (stream gages) provides an informative means of estimating flood flow frequency. The annual peak streamflow data as part of systematic operation of a stream gage provide the foundation, but additional historical information or anticipated flow contexts also can be used. An annual peak streamflow is defined as the maximum instantaneous streamflow for a stream gage for a given water year, and annual peak streamflow data for USGS stream gages can be acquired through the USGS National Water Information System (NWIS) (USGS, 2017). The statistical analyses are based on water year increments. A water year is the 12 month period October 1 through September 30 designated by the calendar year in which it ends.

For the statistical hydrology portion of the multi-layered analysis, InFRM team members from the USGS analyzed annual peak streamflow gage records for the selected USGS stream gages listed in Table 1. These stream gages are important to the InFRM study objectives, and the locations of the stream gages are shown in Figures 1a and 1b. In August of 2017, Hurricane Harvey made landfall on the Texas Gulf Coast and slowly moved northeast. As it did so, it produced 60 inches (in.) of rainfall in some areas, which is approximately 15 in. more than the average annual amount of rainfall for eastern Texas and the Texas Coast (Blake & Zelinsky, 2018). As a result of Hurricane Harvey, four of the gages included in the Trinity River basin analysis recorded annual peak streamflow rankings in the top five of all annual peaks for that given station. Therefore, the period of record analyzed at those gages was extended through 2017 to include this exceptional event.

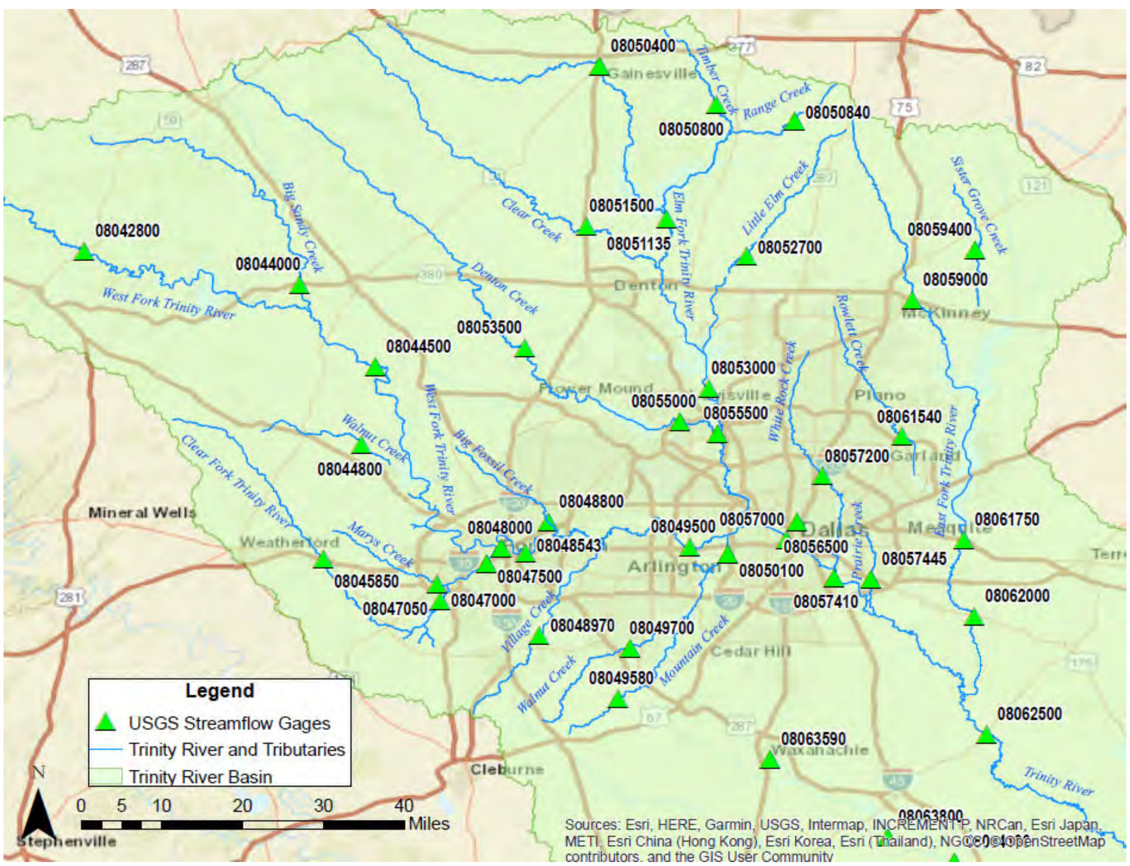

Figure 1a: Map of USGS Streamflow-gaging stations included in the Statistical Analysis (Dallas-Fort Worth Detail)

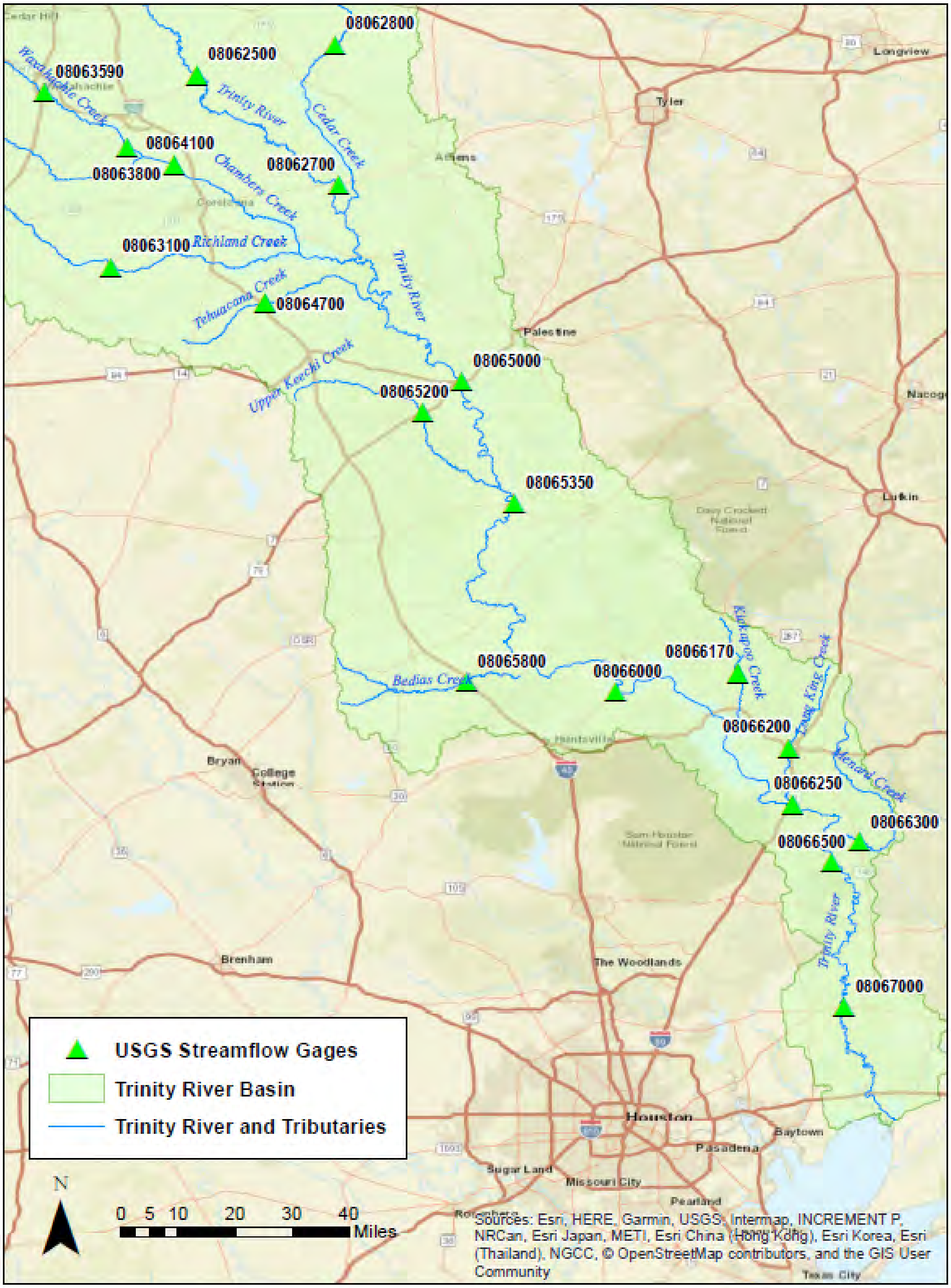

Figure 1b: Map of USGS Streamflow-gaging stations included in the Statistical Analysis – CONTINUED (below Dallas-Fort Worth detail)

Table 1: Summary of Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trintiy River Basin

Station number	Station name	Latitude	Longitude	Horizontal datum as reported by NWISWeb public interface	Beginning water year of analyzed annual peak stream-flows	Ending water year of analyzed annual peak stream-flows	Contri-buting drainage area (mi^2)	Low-outlier threshold used (ft^3/s)	Kendall's Tau of analyzed annual peak streamflows	Kendall's Tau p-value of analyzed annual peak streamflows (--)
08042800	West Fork Trinity River near Jacksboro, Tex.	33.291779	-98.080598	NAD83	1974	2016	683.0	279	-0.014	0.900
08044000	Big Sandy Creek near Bridgeport, Tex.	33.231782	-97.694754	NAD83	1937	2016	333.0	MGBT-0	-0.094	0.247
08044500	West Fork Trinity River near Boyd, Tex.	33.085399	-97.558636	NAD83	1948	2016	1,725.0	MGBT-0	-0.026	0.752
08044800	Walnut Creek at Reno, Tex.	32.945680	-97.583080	NAD83	1993	2016	75.6	MGBT-0	-0.123	0.413
08045850	Clear Fork Trinity River near Weatherford, Tex.	32.740407	-97.651971	NAD83	1981	2016	121.0	MGBT-0	0.029	0.817
08047000	Clear Fork Trinity River near Benbrook, Tex.	32.665133	-97.441964	NAD83	1953	2016	431.0	703	0.076	0.378
08047050	Marys Creek at Benbrook, Tex.	32.695132	-97.447242	NAD83	1999	2016	54.0	MGBT-0	-0.137	0.449
08047500	Clear Fork Trinity River at Fort Worth, Tex.	32.732353	-97.358906	NAD83	1953	2016	518.0	7,690	0.353	<0.001
08048000	West Fork Trinity River at Fort Worth, Tex.	32.760963	-97.332517	NAD83	1933	2016	2,615.0	MGBT-0	0.184	0.013
08048543	West Fork Trinity River at Beach Street, Fort Worth, Tex.	32.751797	-97.289460	NAD83	1977	2016	2,685.0	0	0.104	0.351
08048800	Big Fossil Creek at Haltom City, Tex.	32.807351	-97.248626	NAD83	1960	2016	52.8	MGBT-0	-0.238	0.235
08048970	Village Creek at Everman, Tex.	32.603469	-97.265014	NAD83	1990	2016	84.5	5,260	0.043	0.770
08049500	West Fork Trinity River at Grand Prairie, Tex.	32.762500	-96.994444	NAD83	1933	2016	3,065.0	MGBT-0	0.155	0.037
08049580	Mountain Creek near Venus, Tex.	32.490972	-97.123065	NAD83	1986	2016	25.5	1,400	0.082	0.529
08049700	Walnut Creek near Mansfield, Tex.	32.580970	-97.101953	NAD83	1961	2016	62.8	1,160	0.128	0.166
08050100	Mountain Creek at Grand Prairie, Tex.	32.749861	-96.926111	NAD83	1986	2016	298.0	7,000	0.017	0.905
08050400	Elm Fork Trinity River at Gainesville, Tex.	33.624275	-97.156402	NAD83	1986	2016	174.0	MGBT-0	-0.131	0.308
08050800	Timber Creek near Collinsville, Tex.	33.554554	-96.947227	NAD83	1986	2016	38.8	MGBT-0	-0.112	0.386
08050840	Range Creek near Collinsville, Tex.	33.526220	-96.807219	NAD83	1993	2016	29.2	438	-0.069	0.655
08051135	Elm Fork Trinity River at Greenbelt near Pilot Point, Tex.	33.349722	-97.035556	NAD83	2010	2016	694.0	MGBT-0	0.333	0.368

Table 1: Summary of Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trinity River Basin with Ancillary Information Concerning Statistical Analyses—Continued

Station number	Station name	Latitude	Longitude	Horizontal datum as reported by NWISWeb public interface	Beginning water year of analyzed annual peak stream-flows	Ending water year of analyzed annual peak stream-flows	Contri-buting drainage area (mi²)	Low-outlier threshold used (ft³/s)	Kendall's Tau of analyzed annual peak streamflows	Kendall's Tau p-value of analyzed annual peak streamflows (--)
08051500	Clear Creek near Sanger, Tex.	33.336227	-97.179459	NAD83	1949	2016	295.0	3,130	-0.039	0.645
08052700	Little Elm Creek near Aubrey, Tex.	33.283450	-96.892781	NAD83	1957	2016	75.5	MGBT-0	-0.087	0.342
08053000	Elm Fork Trinity River near Lewisville, Tex.	33.045677	-96.961117	NAD83	1986	2016	1,673.0	MGBT-0	-0.080	0.541
08053500	Denton Creek near Justin, Tex.	33.119010	-97.290573	NAD83	1950	2016	400.0	MGBT-0	-0.023	0.791
08055000	Denton Creek near Grapevine, Tex.	32.987068	-97.012786	NAD83	1953	2016	705.0	900	0.135	0.165
08055500	Elm Fork Trinity River near Carrollton, Tex.	32.965957	-96.944450	NAD83	1955	2016	2,459.0	4,000	0.047	0.593
08056500	Turtle Creek at Dallas, Tex.	32.807351	-96.802501	NAD83	1947	1991	8.0	MGBT-0	0.285	0.005
08057000	Trinity River at Dallas, Tex.	32.774852	-96.821946	NAD83	1955	2016	6,106.0	19,600	0.161	0.066
08057200	White Rk Creek at Greenville Avenue, Dallas, Tex.	32.889292	-96.756666	NAD83	1962	2016	66.4	7,700	-0.044	0.655
08057410	Trinity River below Dallas, Tex.	32.707631	-96.735832	NAD83	1957	2016	6,278.0	MGBT-0	0.140	0.125
08057445	Prairie Creek at U.S. Highway 175, Dallas, Tex.	32.704853	-96.669996	NAD83	1976	2011	9.0	800	0.218	0.083
08059000	East Fork Trinity River near McKinney, Tex.	33.203727	-96.595824	NAD83	1950	2016	190.0	MGBT-0	-0.052	0.685
08059400	Sister Grove Creek near Blue Ridge, Tex.	33.294558	-96.483597	NAD83	1976	2016	83.1	MGBT-0	0.191	0.080
08061540	Rowlett Creek near Sachse, Tex.	32.959844	-96.614438	NAD83	1969	2016	120.0	MGBT-0	0.100	0.319
08061750	East Fork Trinity River near Forney, Tex.	32.774295	-96.503599	NAD83	1974	2016	1,118.0	5,140	0.010	0.933
08062000	East Fork Trinity River near Crandall, Tex.	32.638744	-96.485265	NAD83	1954	2016	1,256.0	4,500	0.109	0.209
08062500	Trinity River near Rosser, Tex.	32.426530	-96.463042	NAD83	1954	2016	8,147.0	MGBT-0	0.187	0.030
08062700	Trinity River at Trinidad, Tex.	32.147653	-96.102471	NAD83	1965	2016	8,538.0	20,000	-0.006	0.956
08062800	Cedar Creek near Kemp, Tex.	32.503471	-96.112751	NAD83	1970	2016	189.0	MGBT-0	-0.089	0.486
08063100	Richland Creek near Dawson, Tex.	31.938491	-96.681379	NAD83	1963	2016	333.0	718	0.122	0.194

Table 1: Summary of Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trinity River Basin, Texas with Ancillary Information Concerning Statistical Analyses—Continued

Station number	Station name	Latitude	Longitude	Horizontal datum as reported by NWISWeb public interface	Beginning water year of analyzed annual peak stream-flows	Ending water year of analyzed annual peak stream-flows	Contri-buting drainage area (mi^2)	Low-outlier threshold used (ft^3/s)	Kendall's Tau of analyzed annual peak streamflows	Kendall's Tau p-value of analyzed annual peak streamflows (--)
08063590	Waxahachie Creek at Waxahachie, Tex.	32.382222	-96.850556	NAD83	2009	2016	60.4	MGBT-0	-0.250	0.454
08063800	Waxahachie Creek near Bardwell, Tex.	32.243481	-96.640268	NAD83	1964	2016	178.0	881	-0.009	0.927
08064100	Chambers Creek near Rice, Tex.	32.198482	-96.520264	NAD83	1984	2016	807.0	MGBT-0	0.023	0.865
08064700	Tehuacana Creek near Streetman, Tex.	31.848496	-96.289976	NAD83	1969	2016	142.0	2,000	0.195	0.052
08065000	Trinity River near Oakwood, Tex.	31.648506	-95.789403	NAD83	1924	2016	12,833.0	20,000	-0.009	0.897
08065200	Upper Keechi Creek near Oakwood, Tex.	31.569896	-95.888294	NAD83	1962	2016	150.0	362	-0.028	0.766
08065350	Trinity River near Crockett, Tex.	31.338513	-95.656341	NAD83	1942	2016	13,911.0	10,000	0.025	0.794
08065800	Bedias Creek near Madisonville, Tex.	30.884722	-95.777778	NAD83	1922	2017	321.0	937	-0.001	1.000
08066000	Trinity River at Riverside, Tex.	30.859355	-95.398830	NAD83	1903	1968	15,589.0	MGBT-0	-0.037	0.662
08066170	Kickapoo Creek near Onalaska, Tex.	30.907132	-95.088547	NAD83	1942	2016	57.0	1,090	0.125	0.219
08066200	Long King Creek at Livingston, Tex.	30.716306	-94.958824	NAD83	1942	2016	141.0	1,540	0.161	0.088
08066250	Trinity River near Goodrich, Tex.	30.572145	-94.948822	NAD83	1903	2017	16,844.0	31,600	0.078	0.416
08066300	Menard Creek near Rye, Tex.	30.481389	-94.779722	NAD83	1966	2017	152.0	915	0.128	0.182
08066500	Trinity River at Romayor, Tex.	30.425207	-94.850762	NAD83	1903	2016	17,186.0	21,300	0.107	0.129
08067000	Trinity River at Liberty, Tex.	30.057715	-94.818257	NAD83	1903	2017	17,468.0	24,300	0.060	0.446

The remainder of this appendix is organized as follows: Section 1.2 provides a brief review of statistical methods pertinent to this chapter. Section 1.3 provides a review of stream gage data and settings for computations and a review with discussion of statistical flood flow frequency results. Section 1.4 provides examples of how statistical flood flow frequency estimates change over time as the amount and nature of information changes. Lastly, section 1.5 provides perspective of the sensitivity of statistical estimates of flood flow frequency to historic climate variability in the study area.

1.2 STATISTICAL METHODS

The statistical methods involved in this appendix include the fitting of a log-Pearson type III probability distribution (LPIII) to the data. The general purpose of fitting a probability distribution is to provide an objective mechanism to extrapolate to hazard levels (as represented by annual exceedance probabilities and equivalently expressed as annual recurrence interval or recurrence interval measured in years) beyond those represented by the sample size of annual peak streamflow data for a given stream gage. A distribution, such as the LPIII, can be fit by numerous methods, and the logarithms (base-10) of the annual peak streamflow data are most commonly used in practice. The USGS-PeakFQ software version 7.1 (Veilleux et al., 2013; USGS, 2014) provides the foundation for the results of the flood frequency flows which are specified by average annual recurrence intervals computed and extracted from software output at 2, 5, 10, 25, 100, 200, and 500 years and accompanied by the 95-percent confidence limits.

Flood flow frequency analyses were conducted for the stream gages using the annual peak data from the USGS NWIS website (USGS, 2017) with historical information when available and data augmentation when required. The Interagency Advisory Committee on Water Data (IACWD, 1982) describes a Bulletin 17B method (B17B) to conduct the frequency analysis (USGS, 2014), but the statistical frequency analysis performed for the Trinity River Basin is singularly focused on updated guidelines from Bulletin 17C (England et al., 2017).

Wide-spread reservoir construction in the Trinity River basin has occurred and is attested by the USACE National Inventory of Dams. There are almost 1,700 dams listed in the USACE National Inventory of Dams for the entire Trinity River basin. A "major" reservoir is defined only for this chapter as one either with geographic importance, notably large normal capacity, or flood storage capacity. These major reservoirs and their general time of construction/filling serve as points of reference for decision making for time periods analyzed. Eighteen major reservoirs have been built in the entire Trinity River basin: Lake Worth in 1914, Lake Bridgeport in 1931, Eagle Mountain Lake in 1932, Benbrook Lake in 1951, Lake Grapevine in 1952, Lake Lavon in 1953, Lake Lewisville in 1954, Lake Arlington in 1955, Lake Amon Carter in 1956, Lake Weatherford in 1957, Navarro Mills Lake in 1963, Bardwell Lake in 1965, Cedar Creek Reservoir in 1966, Lake Livingston in 1969, Lake Ray Hubbard in 1969, Joe Pool Lake in 1986, Lake Ray Roberts in 1986, and Richland-Chambers in 1987. It is difficult to disaggregate the statistical impact of these reservoirs in a systematic way for most of the stream gages of this study. Further, the primary statistical approach using the USGS-PeakFQ software has no capacity for the cumulative and temporal integration of all of these reservoirs. The analyst is left with decisions on what time periods to analyze, weighing factors such as sample size available for the estimation of rare events through flood flow frequency analyses.

Another complication to be addressed is that periods of record between stream gages are seldom identical. However, in the Trinity River basin this is partially mitigated by the tendency for analyses to be made for "modern times" of streamflow regulation. There is a complex and difficult-to-interpret history of reservoir construction throughout the Trinity River basin. The USACE National Inventory of Dams was used as a reference for data review in consultation with USGS "code 6" (substantial regulated effects anticipated) or "code C" (substantial urban effects anticipated). An effort to somewhat normalize the years of data input into statistical methods amongst the stream gages was made for two primary purposes to (1) foster similar sample sizes yet consult information on timing of reservoir flood-storage capacity, and (2) use historical information to extended record lengths as defendable from nearby stream gage or meteorological data. However, because of wide spread reservoir construction in the Trinity River basin, it is difficult to use all of the historical (outside-of-gaged record) information contained in the USGS Peak-Values File. The details of analysis are further described on a gage-by-gage basis. A code “C” in the database indicates an urban peak. PeakFQ does not distinguish between a code 6 and a code C in its graphical output.

Other statistical techniques used for data evaluation included the Kendall Test. The Kendall’s tau test (Helsel & Hirsch, 2002) was used through the USGS-PeakFQ software to detect for the presence of monotonic trends in the annual peak streamflow data. Kendall’s tau test is a popular statistic for quantifying the presence of monotonic changes in the central tendency of streamflow data in time. The Kendall tau results are listed in Table 1, and only one of the stream gages shows a trend in annual peak streamflow for an alpha at the 0.10 probability significance level.

The use of the expected-moments algorithm (EMA)(England et al., 2017; USGS, 2014) permits sophisticated interpretations of the historical record that are intended to enhance the estimates of peak streamflow, especially for the rare frequency events such as the 100-year streamflow. This type of information is not often used for the analyses described herein because of the complex history of reservoir construction in the basin. Inclusion of historical record interpretations can have the net impact of lowering (decreasing) flood flow frequency estimates for the largest streamflows when they appear as outliers because the largest documented events are assigned lower empirical probabilities when historical information is available. EMA also permits inclusion of nonstandard information such as data censoring. For example, an annual peak might be known to be lower than a specified discharge threshold. EMA can also accommodate time varying discharge thresholds based on assigning a discharge threshold as a "highest since" (a term intrinsic to flood flow frequency analyses) within discrete blocks or intervals of time. This nonstandard information collectively can be thought of as a framework fostering record extension.

Two especially important options of the USGS-PeakFQ software are the choice of a low-outlier threshold and generalized skew, which are technical elements of the statistical analysis. The skew involves the decision as to incorporate a weighting in the analyses between the generalized skew and that computed using the site-specific data. Low outliers (potentially influential low floods, PILFs in USGS-PeakFQ paralance) within a time series of peak streamflow, such as annual peaks that in reality were likely not storm flows or highly localized storm flow, often require removal from the analysis using a form of conditional probability adjustment. To this end, the so-called Multiple Grubbs-Beck low-outlier threshold (MGBT) was used with some cases of user-substituted (manual) override. For location-specific reasons, the analyst manually specified a low-outlier threshold. The settings for low-outlier detection or the results of the MGBT are identified in Section 1.1 and listed in Table 1.

Skew is an expression of the curvature or shape of the LPIII distribution intended to mimic that of the data (Asquith, 2011a,b). The importance of a generalized or regional skew is stressed in IACWD (1982) to mitigate for high sampling variance using typical record lengths available for stream gages. A substantial motivation for a generalized skew is to compensate for inefficient estimation of the product moment skew for highly variable and skewed data such as annual peak streamflow. The generalized skew coefficient is a built-in feature of USGS-PeakFQ but can be overridden by the user. Because of age as well as study objectives for the present (2016) study, the maps of generalized skew for Texas in IACWD (1982) or Judd et al. (1996) are of uncertain applicability for this study. The former reference represents a highly generalized estimate of skew dating from about the late 1970s, the later reference represents a substantially more recent, but still dated, estimate of generalized skew for Texas. Low-outlier thresholds can greatly affect the estimate of skewness; for this study, the station-skew option in USGS-PeakFQ almost exclusively was used. In fact, only for stream gages proximal to Richland-Chambers reservoir were weighted-skew options made; this was deliberate because a very short record station in that major subbasin of the Trinity River was included and holistic treatment for analysis consistency around this reservoir was made. Details are described later. Lastly, and as a general rule, the widespread reservoir construction in the Trinity River basin further complicates skew assessment.

Confidence limits of flood flow frequency can be informative to decision makers. The lower and upper limits of 95-percent confidence intervals were computed for this study. Confidence intervals can be expected to encompass the true value 95 percent of the time (Good & Hardin, 2003, p. 100). The range in these numbers for the lower and upper 95-percent confidence limits increases with the more extreme events.

1.3 STREAM GAGE DATA AND STATISTICAL FLOOD FLOW FREQUENCY RESULTS

This section presents the results of the statistical analysis of the annual peak streamflow data at each analyzed stream gage. Statistical flow frequency estimates, along with associated uncertainty intervals, are presented in both graphical and tabular formats. Tables of flood flow frequency values with attendant confidence limits are listed in Table 2 (located at the end of the section). This table contains the preferred values for the statistical analysis computed using USGS-PeakFQ software with EMA-LPIII methods.

In this chapter, some specific terms are used for specific reference to periods of available annual peak streamflow values. The term "gaged record" refers to the total number of years for which the gage was operational and annual peaks were recorded. This does not reflect historical record, which are peaks outside gage operation. The term, "systematic record" refers to the years within the gaged record that were used in the USGS-PeakFQ analysis. Historical record often refers to large and notable floods in the area later represented by an operational stream gage. These floods are often recorded by people living in the area before the installation of the gage. The term "inferred historical record" refers to years in which the peak streamflow thresholds for EMA were inferred using outside information (such as precipitation data or peaks from a nearby gage that is equivalent). A few other terms are needed as they are used for specific purposes. The use of "systematic record" is consistent with parlance inside USGS-PeakFQ software output files. Lastly, the wording "period of record" is inherently mutable and dependent hereinafter on context.

Record length or the number of peaks and historical periods included in flood flow frequency analyses has a substantial impact on inference of flood potential. Short record lengths, which are defined herein as less than 20 years, imply greater error in flood flow frequency estimates than moderate record lengths, which are defined herein as less than 30 years.

08042800 West Fork Trinity River near Jacksboro, Texas

The gage record for West Fork Trinity River near Jacksboro is 1955–2016. The systematic record for statistical analysis is 1974–2016, which represents a period of generalized static reservoir flood storage capacity and is coincident with code 6 (regulated) beginning in the USGS Peak-Values File. As a result, peaks for 1955–1973 are not used in the analysis. The maximum peak streamflow of record occurred in 1957 at 35,100 cubic feet per second (ft^3/s) at a stage of 32.10 feet (ft), though this peak was not used in analysis. The maximum peak streamflow used in analysis was in 1989 at 33,300 ft^3/s at a stage of 31.52 ft. There are two historical peaks in 1915 and 1941 that are both 27,000 ft^3/s at a stage of about 30.00 ft; these peaks are not used but are plotting also in Figure 2a. The data as set up for statistical frequency analysis are shown in Figure 2a. Visually there might be a slight variance inflation (spread of the peaks) in more modern times than earlier in the record. Specifically, there visually seems to be a trend of the smaller events becoming smaller for the larger period 1955–2016 and for the analyzed period 1974–2016. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for the West Fork Trinity River near Jacksboro is shown in Figure 2b. A low outlier is removed from the analyses by the Multiple Grubbs-Beck outlier test. In general visually, the combination of substantial systematic record leads to a reliable flood flow frequency curve. Mixed population effects do not appear present in the empirical distribution of the data.

An alternative analysis for this stream gage was made for a systematic period of 1955–2016, which encompasses the entire period of record. The analysis was made because there exists ambiguity in the importance of upstream flood-flow regulation by numerous small but passive floodwater retention structures. Tabulated and graphical results of this analysis are not reported here. However, comparison to select quantiles of the 100-, 200-, and 500-year average return periods (recurrence intervals) between the two analyses is informative. For the 1974–2016 period discussed above, the respective estimates are 52,080; 76,390; and 122,700 ft^3/s for the 100-, 200-, and 500-year return periods. For the 1955–2016 period, the respective estimates are 52,360; 75,590; and 119,000 ft^3/s. Collectively, these results are very compatible with one another.

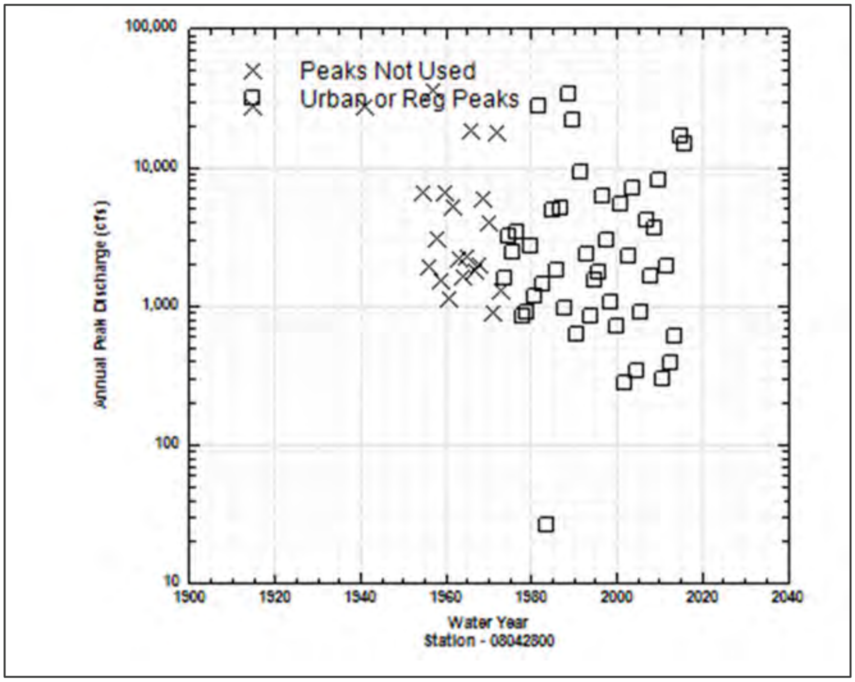

Figure 2a: Annual Peak Streamflow Data for station 08042800 West Fork Trinity River near Jacksboro, TX

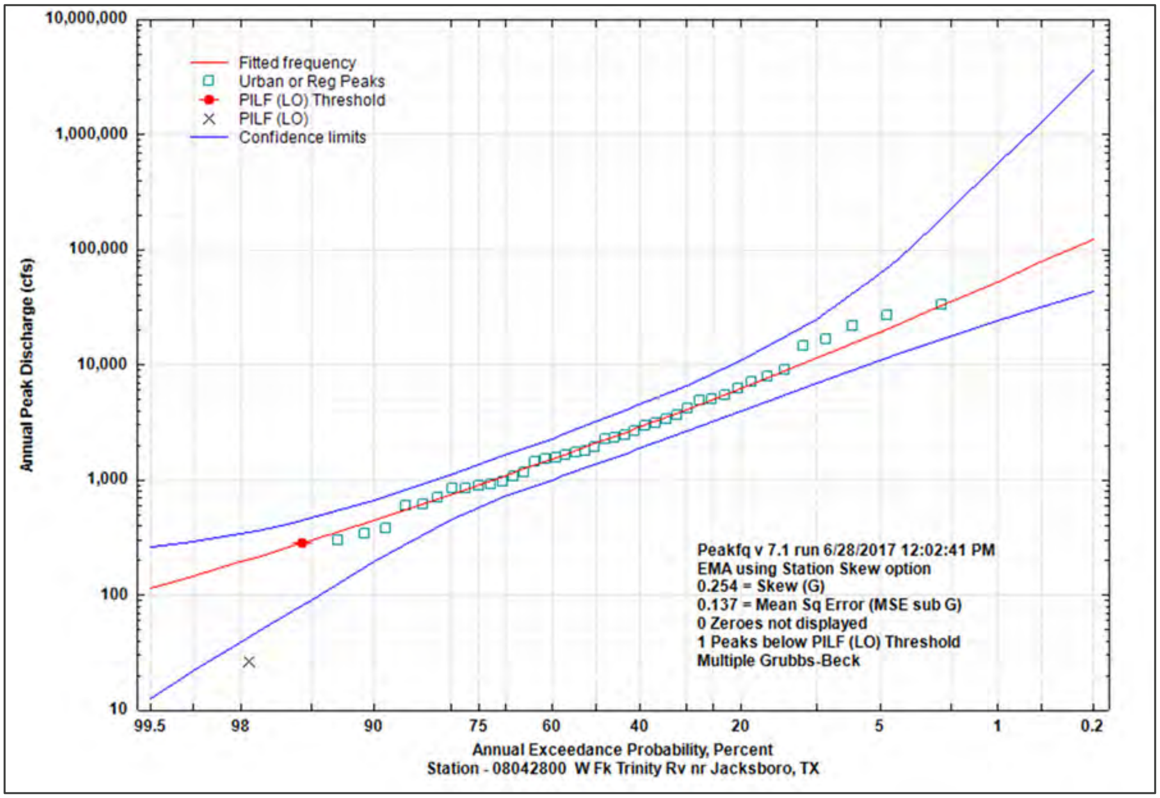

Figure 2b: Flood Flow Frequency Curve for station 08042800 West Fork Trinity River near Jacksboro, TX

08044000 Big Sandy Creek near Bridgeport, Texas

The gage record and the systematic record for analysis for the Big Sandy Creek near Bridgeport are both 1937–2016 with a gap in record from 1996–2004. The code 6 in the USGS Peak-Values File begins in 1956. The maximum peak streamflow in water year 1982 of 45,000 ft^3/s at a stage of 14.78 ft is the highest at the gage. There are two historical peaks in 1908 and 1915 of 53,000 ft^3/s at stages of 15.69 ft. The 1942 peak is also 53,000 ft^3/s at a stage of 15.69 ft and is used to the infer history during the 1996–2004 record gap in which the gage was not operational. The data as set up for statistal frequency analysis are shown in Figure 3a. Records for 08042800 (West Fork Trinity River near Jacksboro) and 08044500 (West Fork Trinity River near Boyd) do not show extremely large peaks for 1996–2004, which supports the use of the 1942 peak for the record gap. All of the gage record data were used for analysis because visually there is compatability throughout 1937–2016. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for the Big Sandy Creek near Bridgeport is shown in Figure 3b. No low outliers though were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data. There is some slight undulation in the empirical distribution of the data, which suggests that some impact from mixed populations might be present. For example, the far left tail appears to flatten somewhat at about 600 ft^3/s and again at about 5,000 ft^3/s.

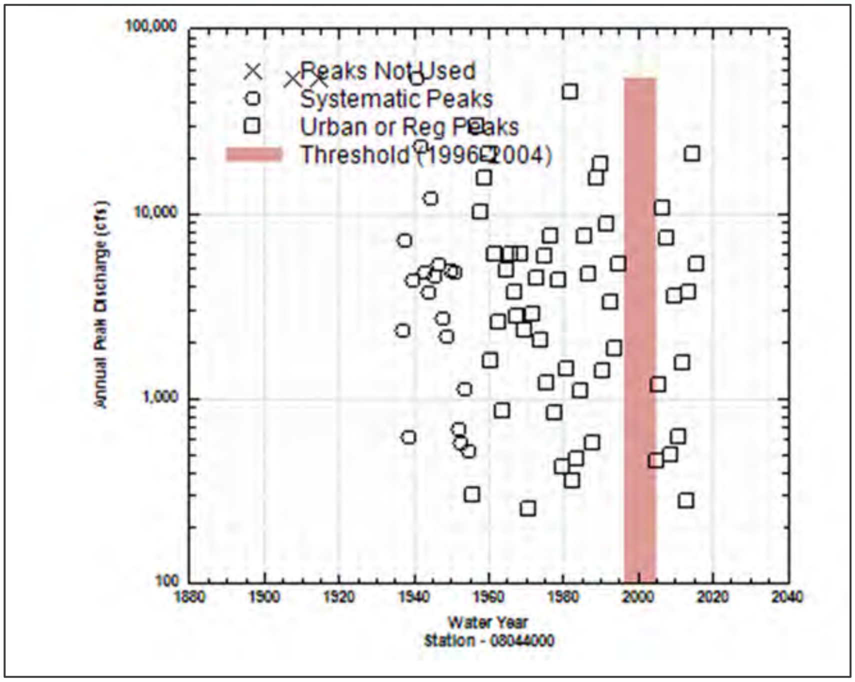

Figure 3a: Annual Peak Streamflow Data for station 08044000 Big Sand Creek near Bridgeport, TX

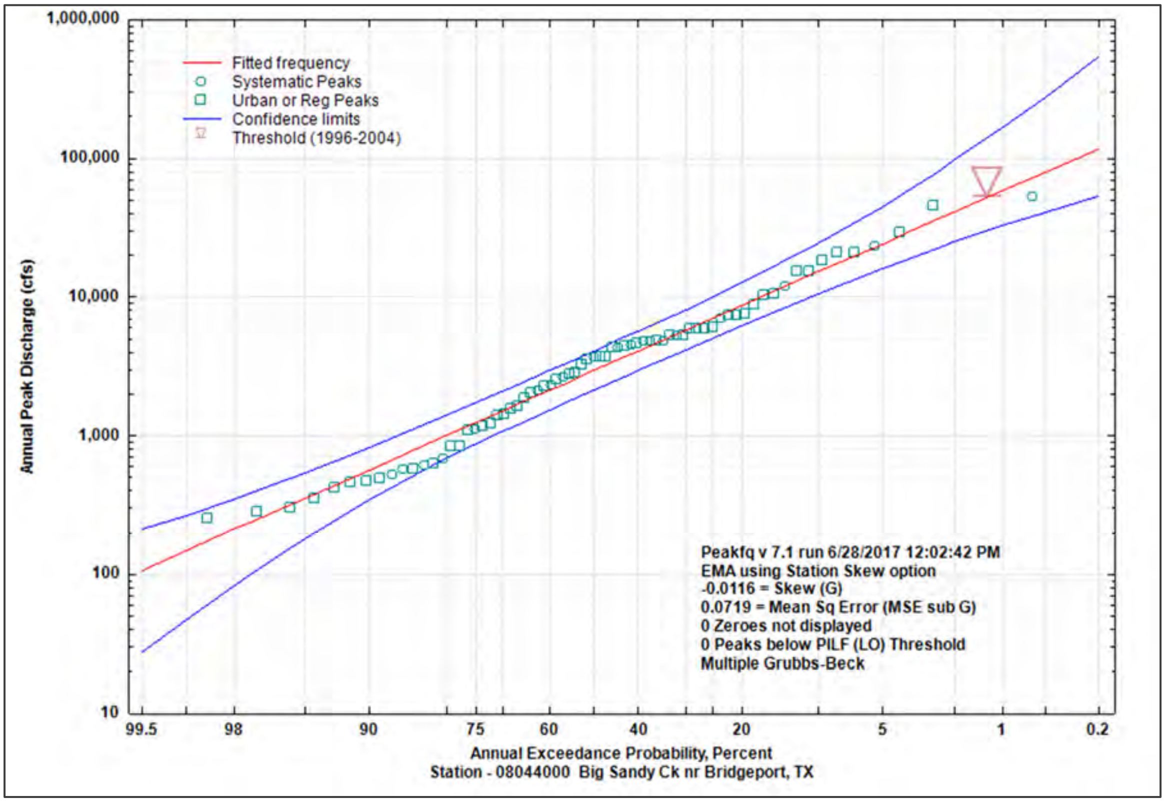

Figure 3b: Flood Flow Frequency Curve for station 08044000 Big Sand Creek near Bridgeport , TX

08044500 West Fork Trinity River near Boyd, Texas

The gage record and the systematic record for analysis for the West Fork Trinity River near Boyd are both 1948–2016. The peak in 1982 of 60,400 ft^3/s at a stage of 25.87 ft is the largest peak for the period of record. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistical frequency analysis are shown in Figure 4a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for the West Fork Trinity River near Boyd is shown in Figure 4b. Mixed population effects do not appear present in the empirical distribution of the data. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, visually, the flood flow frequency curve looks reliable to the inputted data.

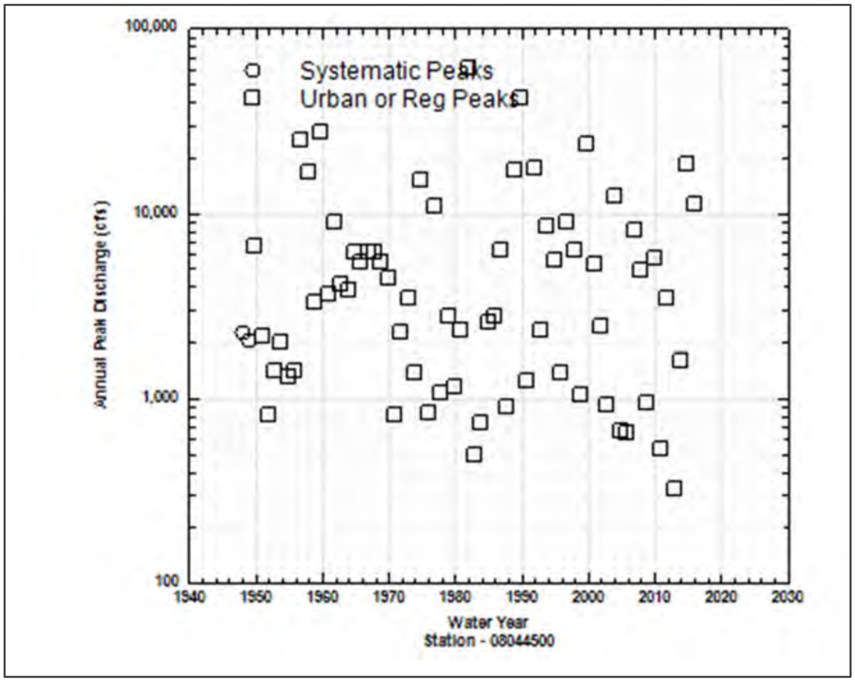

Figure 4a: Annual Peak Streamflow Data for station 08044500 West Fork Trinity River near Boyd, TX

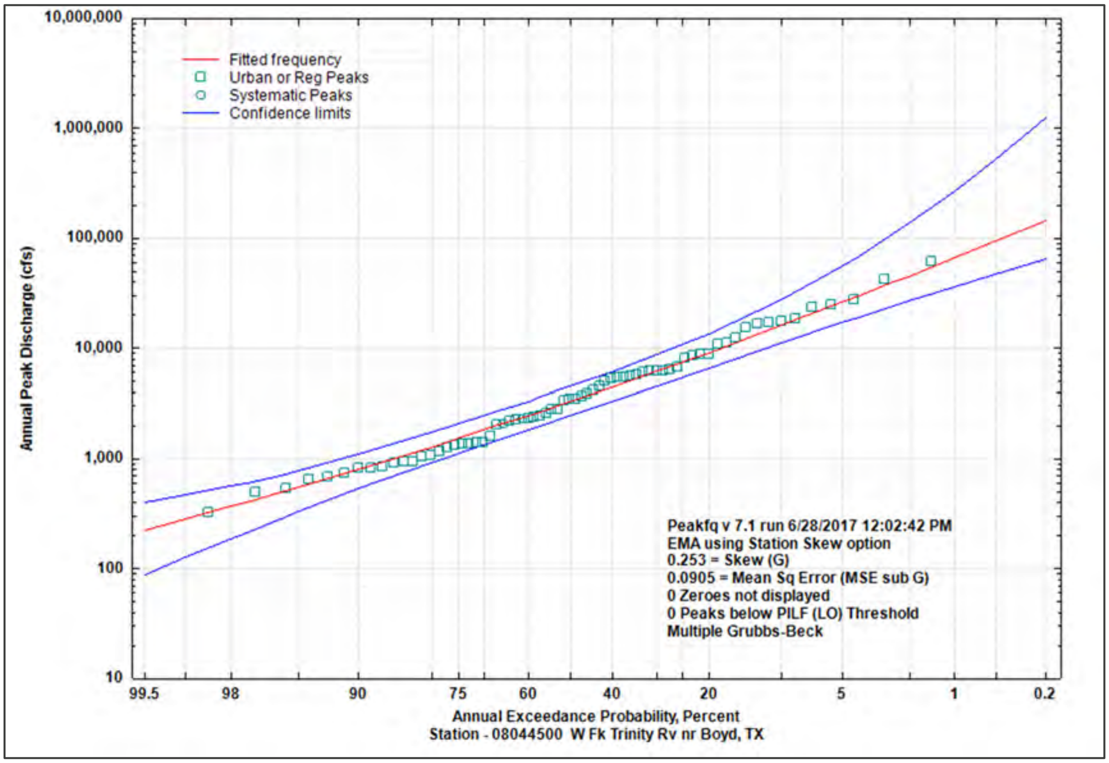

Figure 4b: Flood Flow Frequency Curve for station 08044500 West Fork Trinity River near Boyd , TX

08044800 Walnut Creek at Reno, Texas

The gage record and the systematic record for analysis for the Walnut Creet at Reno are both 1993–2016. The 2004 peak streamflow of 26,300 ft^3/s at a stage of 23.26 ft is the maximum peak of record. The peaks are considered unregulated. The data as set up for statistical frequency analysis are shown in Figure 5a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for the Walnut Creek at Reno is shown in Figure 5b. The record length is comparatively short. Mixed population effects do not appear present in the empirical distribution of the data. No low outliers though were detected by the Multiple Grubbs-Beck outlier test. It is possible that should many more years of data be available in the future that low-outlier detection might suggest a threshold, which might have the effect of reducing curvature of the fitted distribution. In general, visually, the flood flow frequency curve looks reliable to the inputted data. However, this is difficult to assess because of the moderate record length (less than 30 years).

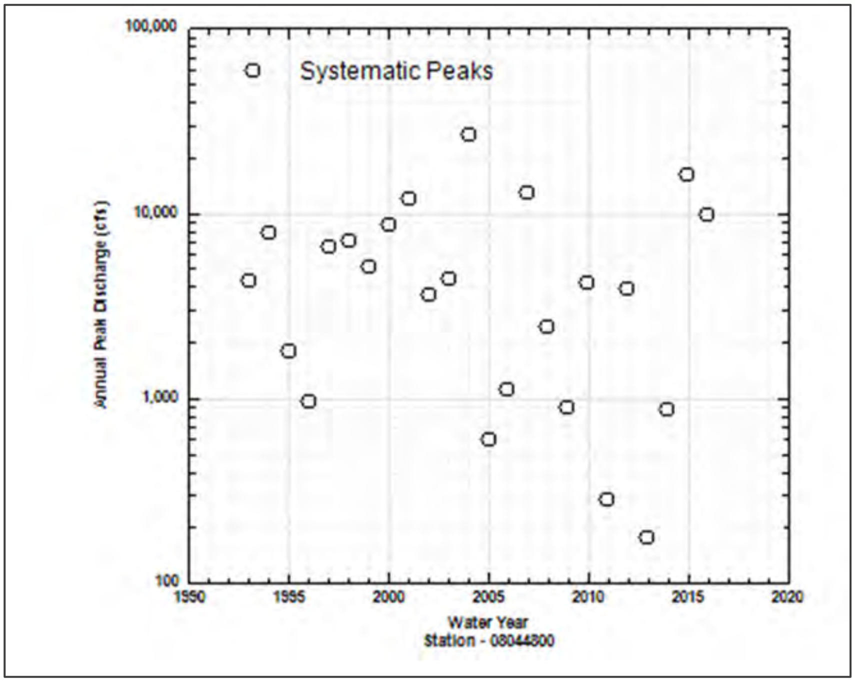

Figure 5a: Annual Peak Streamflow Data for station 08044800 Walnut Creek at Reno, TX

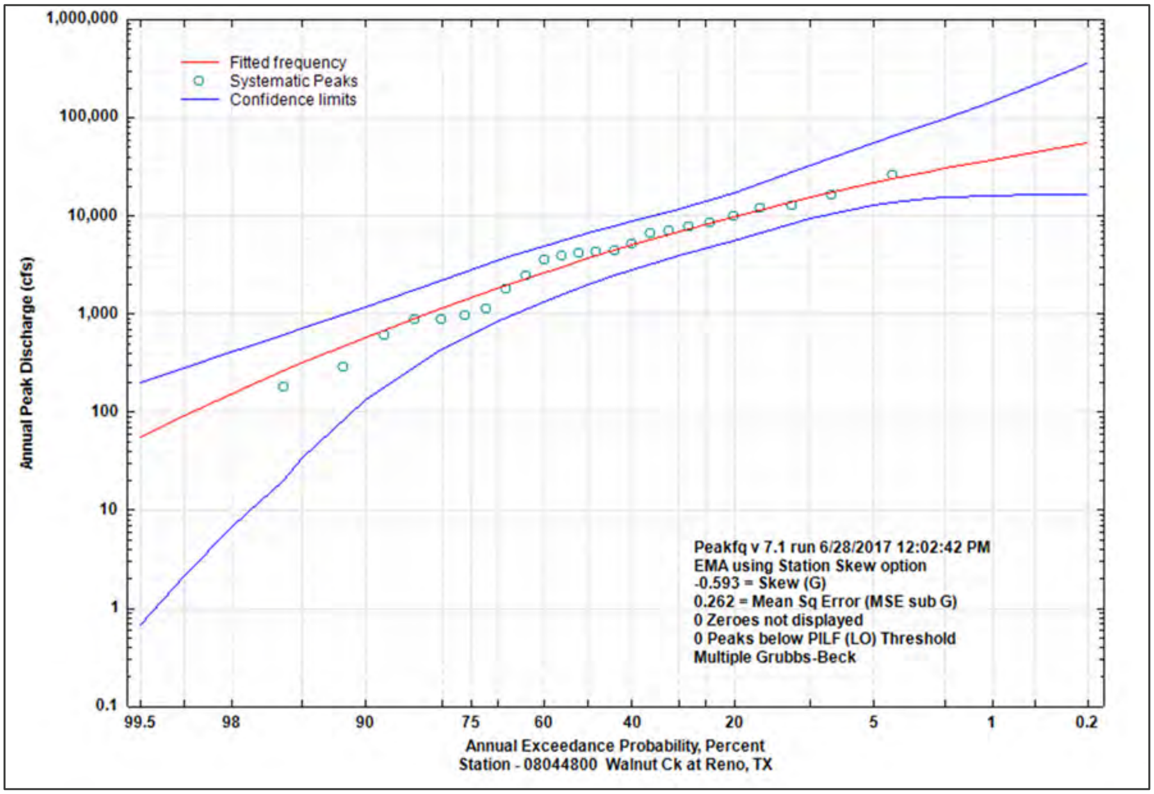

Figure 5b: Flood Flow Frequency Curve for station 08044800 Walnut Creek at Reno, TX

08045850 Clear Fork Trinity River near Weatherford, Texas

The gage record and the systematic record for Clear Fork Trinity River near Weatherford are both 1981–2016. The 2004 peak streamflow of 3,980 ft^3/s at a stage of 22.07 ft is the largest for the period of record. The 2006 peak is less than 190 ft^3/s, but this is readily processed by EMA of USGS-PeakFQ software. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistical frequency analysis are shown in Figure 6a, in which the rectangular region demarks the discharge threshold of the 2006 peak. The discharge interval for the 2006 peak is represented as a green bar in the figure. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for the Clear Fork Trinity River near Weatherford is shown in Figure 6b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. It is difficult to assess reliability of the flood flow frequency curve. Mixed population or data censoring (peak supression) effects might be evident. For example, there visually seems an excess of many peaks about 3,000–4,000 ft^3/s (the largests in the sample). These flatten the empirical distribution of the data in the right tail.

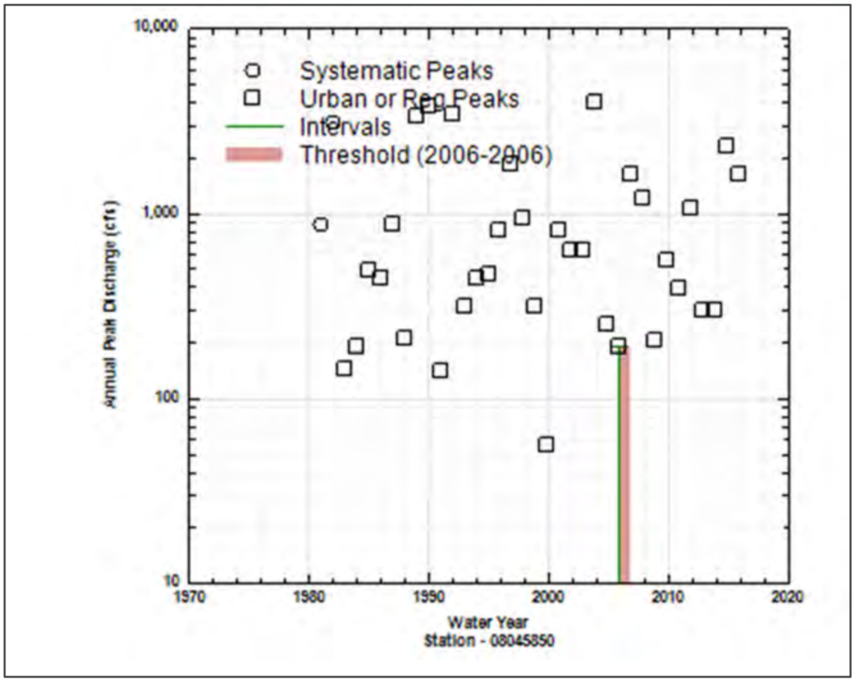

Figure 6a: Annual Peak Streamflow Data for station 08045850 Clear Fork Trinity River near Weatherford, TX

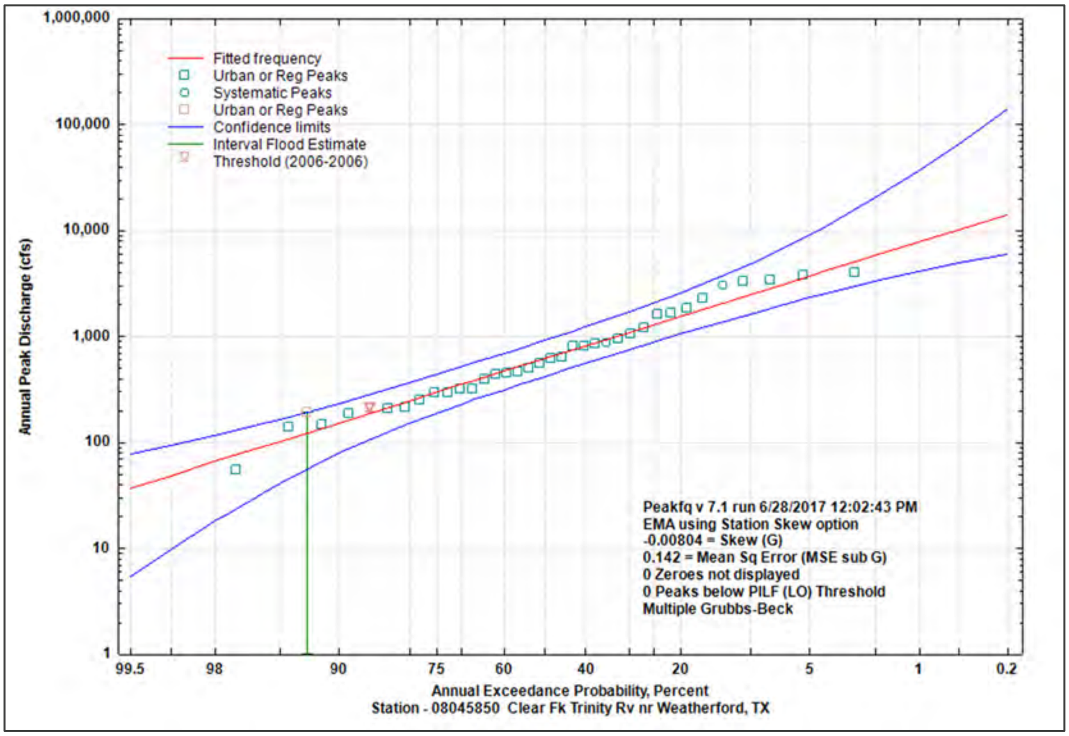

Figure 6b: Flood Flow Frequency Curve for station 08045850 Clear Fork Trinity River near Weatherford, TX

08047000 Clear Fork Trinity River near Benbrook, Texas

The gage record for the Clear Fork Trinity River near Benbrook is 1948–2016. The systematic record is 1953–2016, and thus, peaks for 1948–1953 are not used in the analysis. The 1990 peak streamflow of 6,740 ft^3/s at a stage of 14.71 ft is the maximum peak for the systematic record. Peaks for 1948–1952 are not considered because deliberate empoundment of water for the Benbrook Lake dam began in September 1952, and code 6 in the USGS Peak-Values File began in 1953. Benbrook Lake for this analysis is treated as a general feature of the river and 1953 to present represents a period of generalized static reservoir flood storage capacity. The data as set up for statistical frequency analysis are shown in Figure 7a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for the Clear Fork Trinity River near Benbrook is shown in Figure 7b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data.

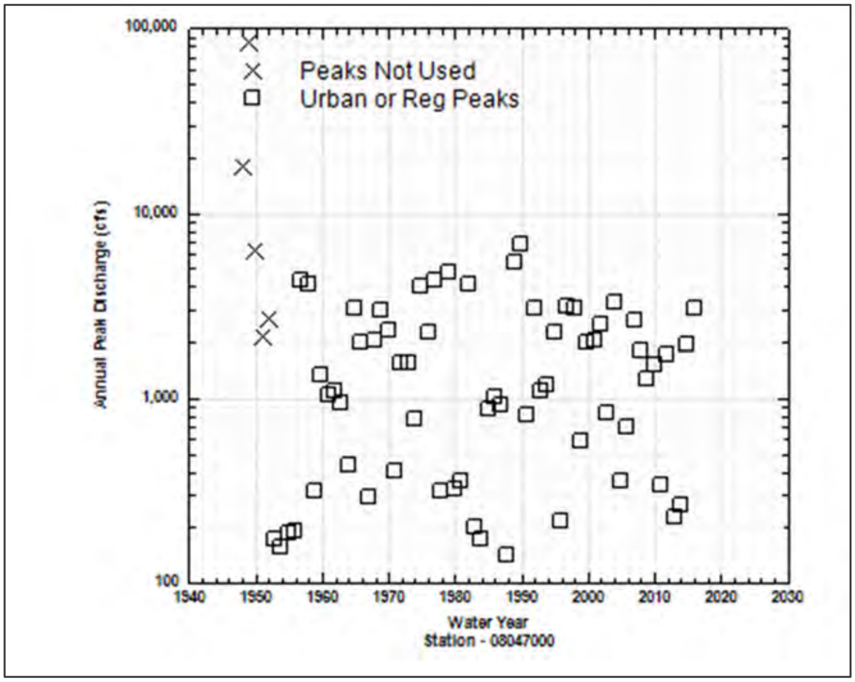

Figure 7a: Annual Peak Streamflow Data for station 08047000 Clear Fork Trinity River near Benbrook, TX

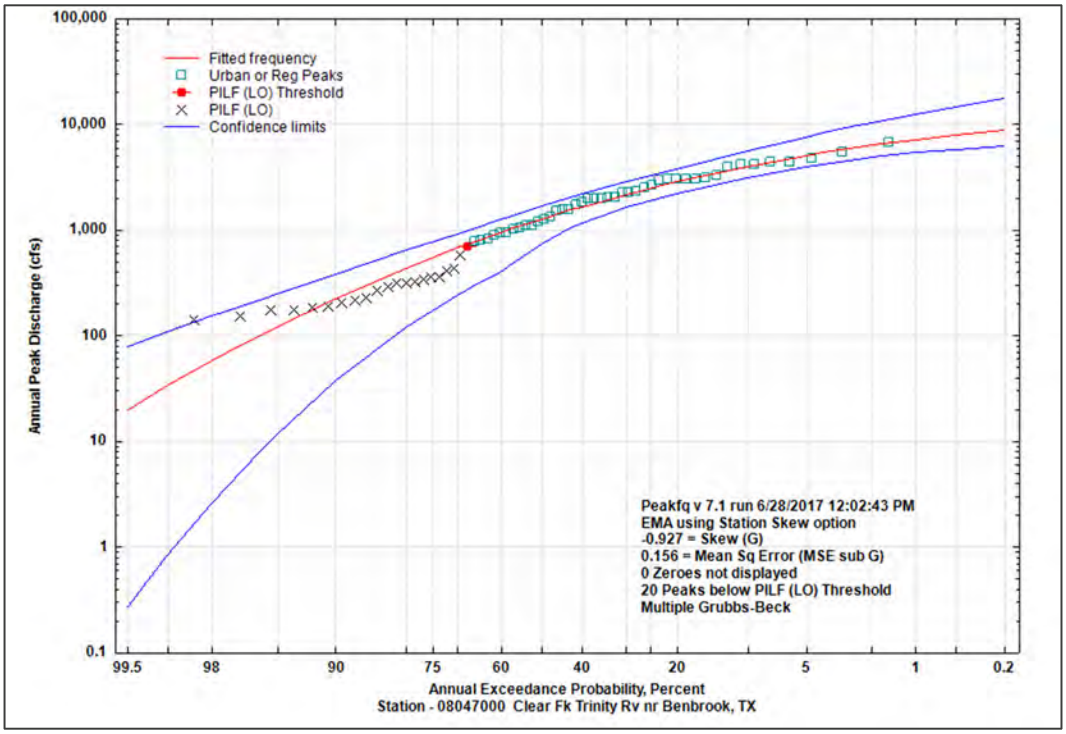

Figure 7b: Flood Flow Frequency Curve for station 08047000 Clear Fork Trinity River near Benbrook, TX

08047050 Marys Creek at Benbrook, Texas

The gage record and the systematic record for Marys Creek at Benbrook are both 1999–2016. The 2004 peak streamflow of 23,900 ft^3/s at a stage of 18.11 ft is the maximum peak for the systematic record. The USGS Peak-Values File flags the entire record with a code C (urban), but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistical frequency analysis are shown in Figure 8a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for the Marys Creek at Benbrook is shown in Figure 8b. No low outliers though were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks reliable to the inputted data. However, this is difficult to assess because of the short record length (less than 20 years).

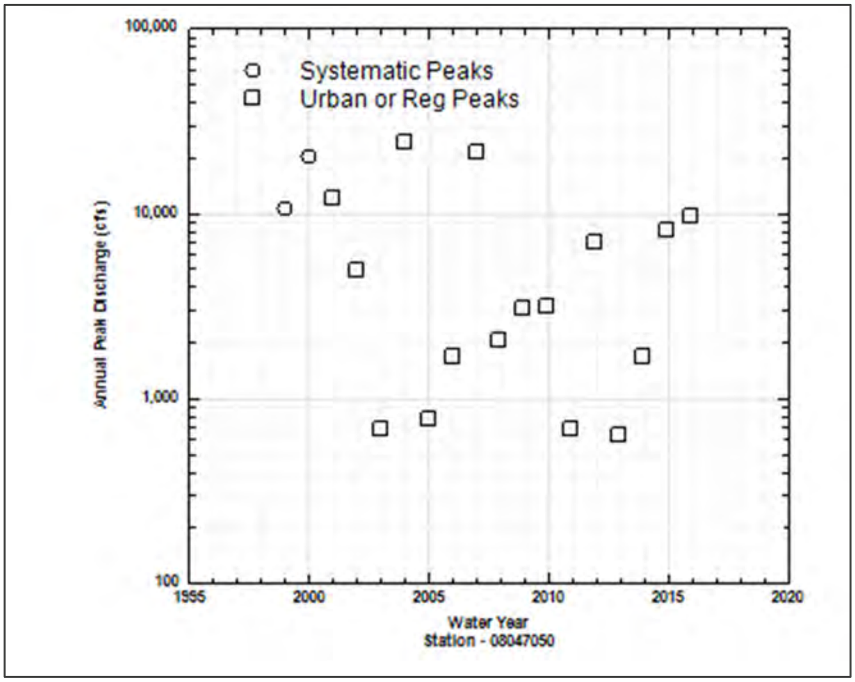

Figure 8a: Annual Peak Streamflow Data for station 08047050 Marys Creek at Benbrook, TX

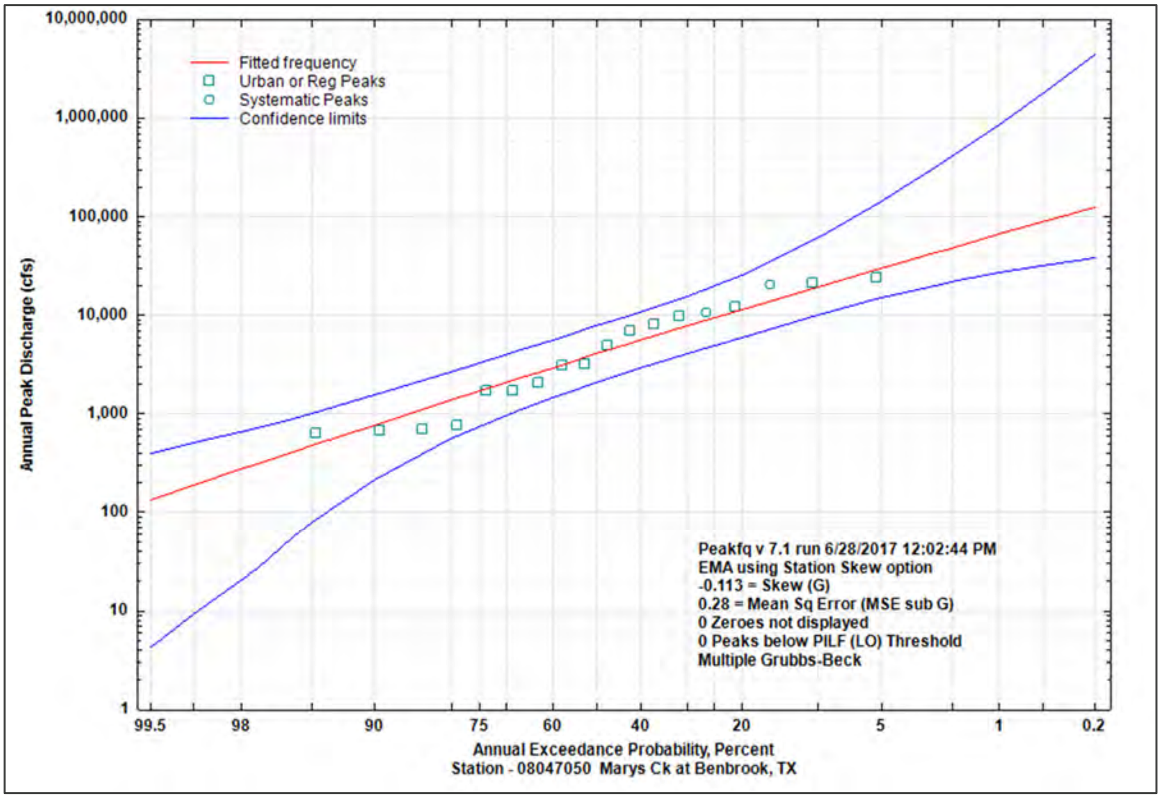

Figure 8b: Flood Flow Frequency Curve for station 08047050 Marys Creek at Benbrook, TX

08047500 Clear Fork Trinity River at Fort Worth, Texas

The gage record for the Clear Fork Trinity River at Fort Worth is 1924–2016 with a historic peak in 1922. The systematic record is 1953–2016; thus, peaks for 1924–1952 are not used in the analysis. The peak streamflow in 1990 of 20,900 ft^3/s at a stage of 16.80 ft is the largest peak for the systematic record. The 1922 peak is 74,300 ft^3/s at a stage of 27.50 ft. The USGS Peak-Values File begins code 6 in 1953 because of Benbrook Lake. The data as set up for statistical frequency analysis are shown in Figure 9a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value < 0.001), and this is readily seen by visual inspection of the data. This might be indicative of watershed urbanization.

The flood flow frequency for the Clear Fork Trinity River at Fort Worth is shown in Figure 9b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data. However, this conclusion is weakened by the upward trend in streamflow for the period analyzed.

Additional discussion of this analysis is needed. No peak streamflows exist that are in excess of about 21,000 ft^3/s since at least 1953 and post Benbrook Lake. Yet, there are numerous discharges between about 10,000 ft^3/s and 20,000 ft^3/s. This narrow range causes considerable flattening of the flood flow frequency curve thus estimates for the 100-, 200-, 500-year average return periods (recurrence intervals) are not greatly in excess of about 21,000 ft^3/s. Lastly, it is suggested that hydrologic and hydraulic modeling would be especially informative to assess the possibility of substantially larger estimates than those provided by the statistical analysis.

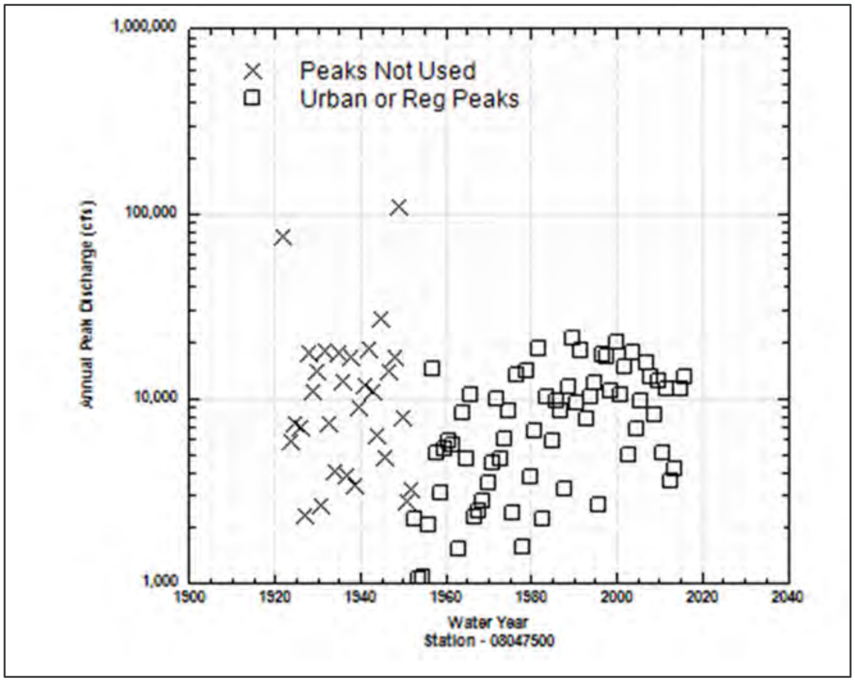

Figure 9a: Annual Peak Streamflow Data for station 08047500 Clear Fork Trinity River at Fort Worth, TX

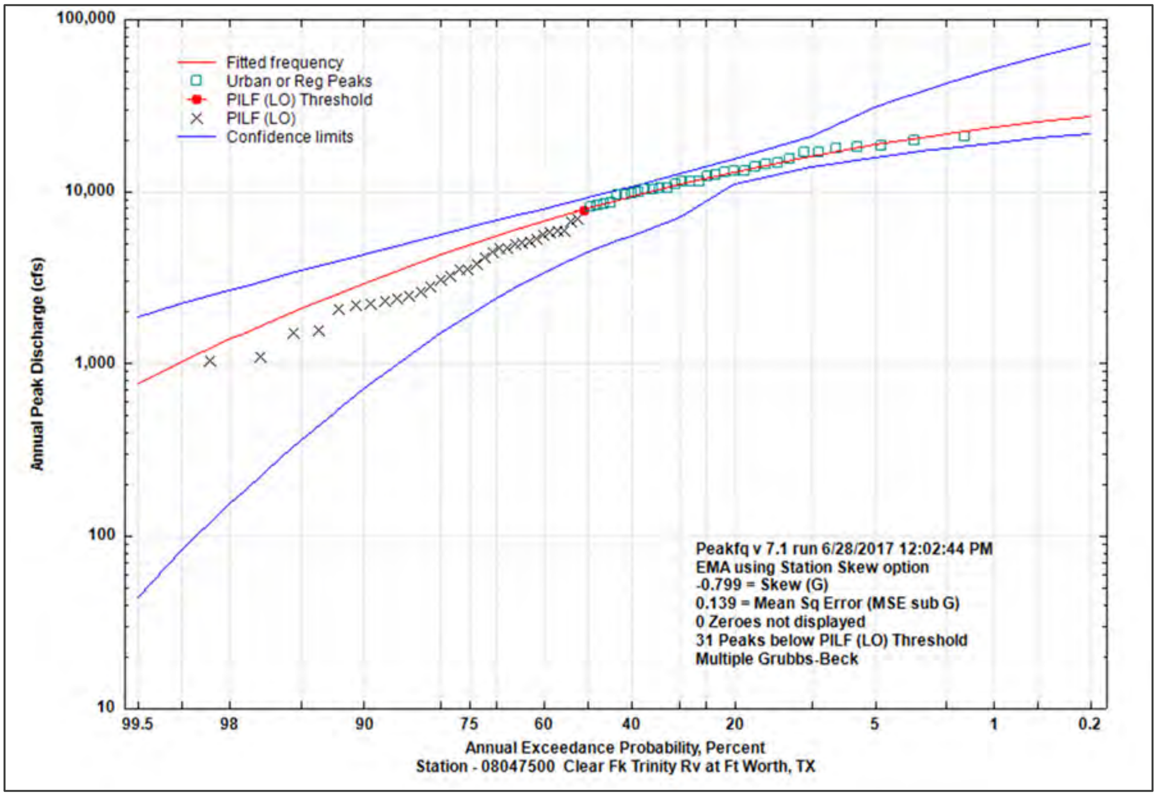

Figure 9b: Flood Flow Frequency Curve for station 08047500 Clear Fork Trinity River at Fort Worth, TX

08048000 West Fork Trinity River at Fort Worth, Texas

The gage record for the West Fork Trinity River at Fort Worth is 1921–2016. The systematic record is 1933–2016; thus, peaks for 1921–1932 are not used in the analysis. The 1949 peak streamflow of 64,300 ft^3/s at a stage of 25.91 ft is the maximum peak for the systematic record. All of the peaks at the site (1921–2016) are flagged with code 6 in the USGS Peak-Values File), but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. Three major reservoirs have been built upstream of the gage: Bridgeport Lake in 1931, Eagle Mountain Lake in 1932, and Benbrook Lake in 1953. The peaks for 1922–1932 are not used because of the construction of Eagle Mountain Lake. The data as set up in the statistical frequency analysis are shown in Figure 10a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.013), and this is seen by visual inspection of the data. This might be indicative of watershed urbanization.

The flood flow frequency for the West Fork Trinity River at Fort Worth is shown in Figure 10b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks reliable to the inputted data. However, this conclusion is weakened by the upward trend in streamflow for the period analyzed. The largest peak (1949) predates Benbrook Lake. This peak plots well above the fitted frequency curve. It is outside the scope of these data to provide further inference of the 1949 peak.

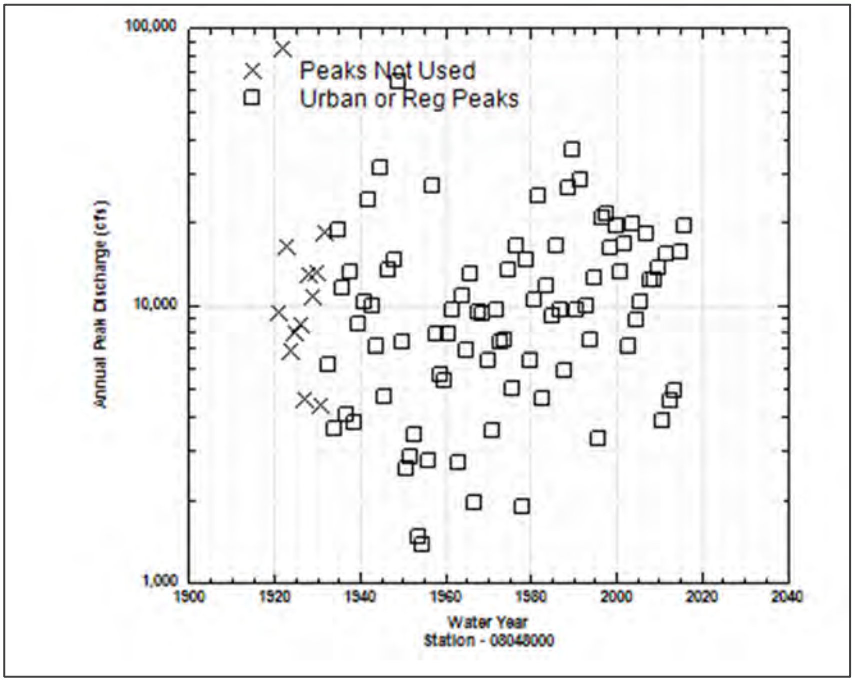

Figure 10a: Annual Peak Streamflow Data for station 08048000 West Fork Trinity River at Fort Worth, TX

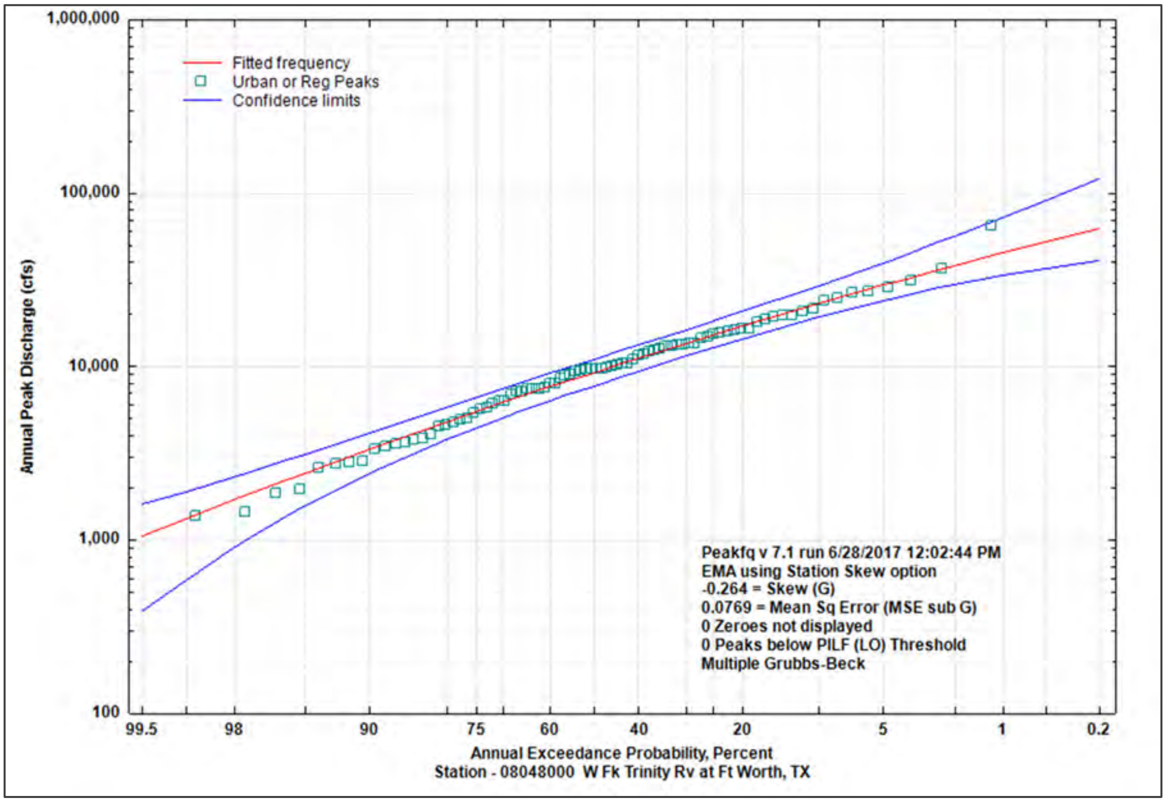

Figure 10b: Flood Flow Frequency Curve for station 08048000 West Fork Trinity River at Fort Worth, TX

08048543 West Fork Trinity River at Beach Street, Fort Worth, Texas

The gage record and the systematic record for West Fork Trinity River at Beach Street, Fort Worth are both 1977–2016. The 1990 peak streamflow of 46,600 ft^3/s at a stage of 38.02 ft is the maximum peak for the systematic record. The data as set up for statistical frequency analysis are shown in Figure 11a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for West Fork Trinity River at Beach Street, Fort Worth is shown in Figure 11b. The single Grubbs-Beck test was deliberately used for this station with a purpose to have some computational similarity with stream gage 08048000. For both stream gages no outliers were identified. In general, the substantial systematic record leads to a reliable flood flow frequency curve. However, some mixed population impacts might be seen in the leveling off of the empirical distribution at about 8,000–10,000 ft^3/s and again at about 12,000–13,000 ft^3/s.

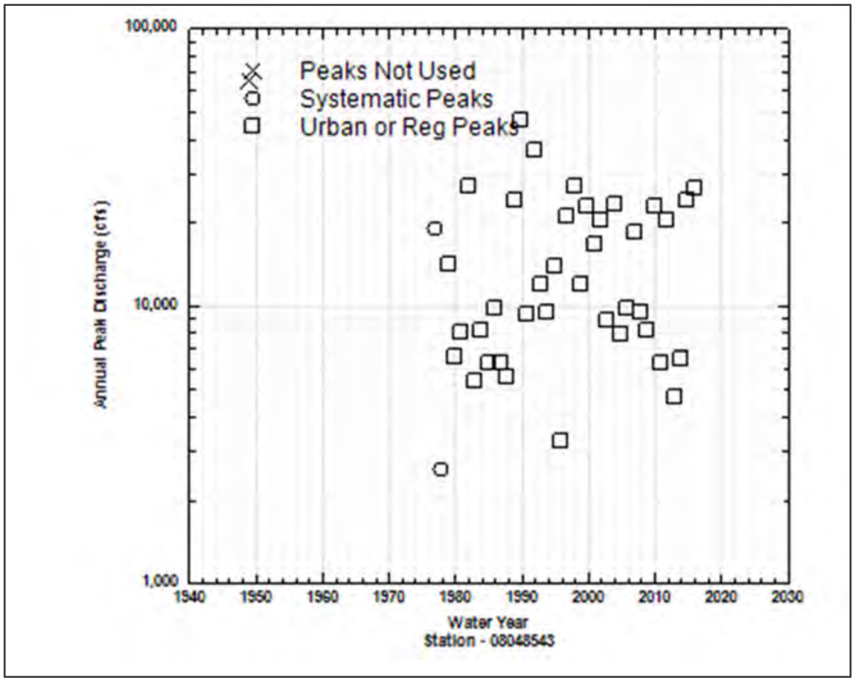

Figure 11a: Annual Peak Streamflow Data for station 08048543 West Fork Trinity River at Beach Street, Fort Worth, TX

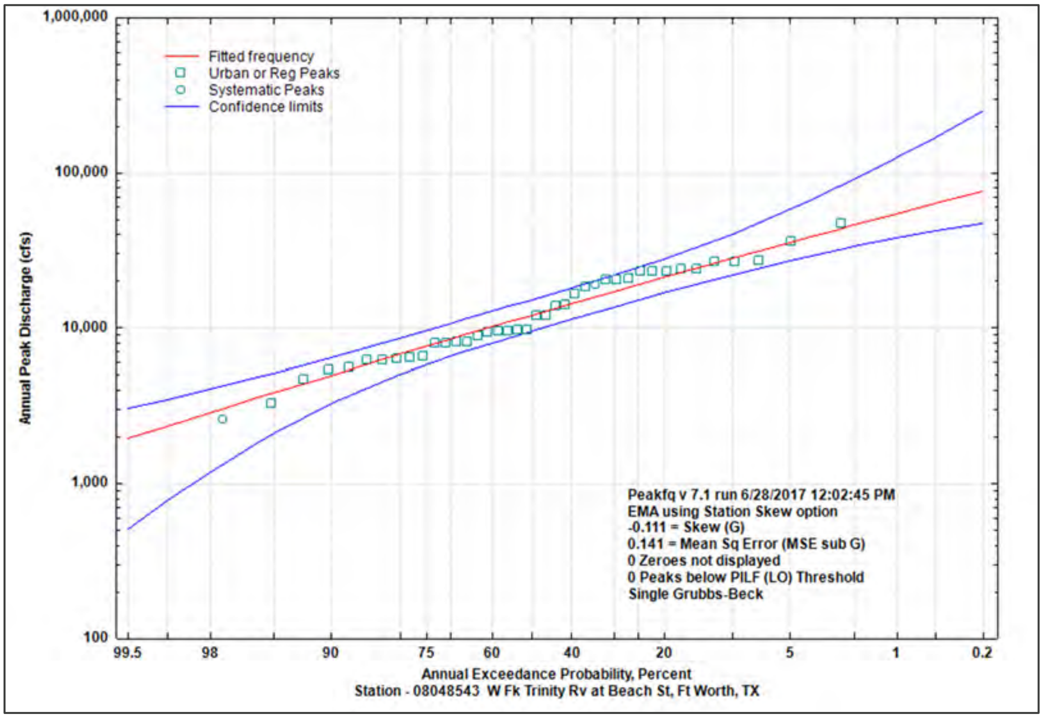

Figure 11b: Flood Flow Frequency Curve for station 08048543 West Fork Trinity River at Beach Street, Fort Worth, TX

08048800 Big Fossil Creek at Haltom City, Texas

The gage record and the systematic record for Big Fossil Creek at Haltom City are both 1960–2016 with a gap in years of record from 1973–2015 for which only peak stages are available for 1990–2012. No inference of peak for the record gap is made, though the highest stage for 1990–2012 is 13.97 ft in 2011. The 1962 peak streamflow of 27,000 ft^3/s at a stage of 26.90 ft is the largest peak for the systematic record. The USGS Peak-Values File flags the entire record with a code C (urban), but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistical frequency analysis are shown in Figure 12a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Big Fossil Creek at Haltom City is shown in Figure 12b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks reliable to the inputted data. However, this is difficult to assess because of the short record length (less than 20 years).

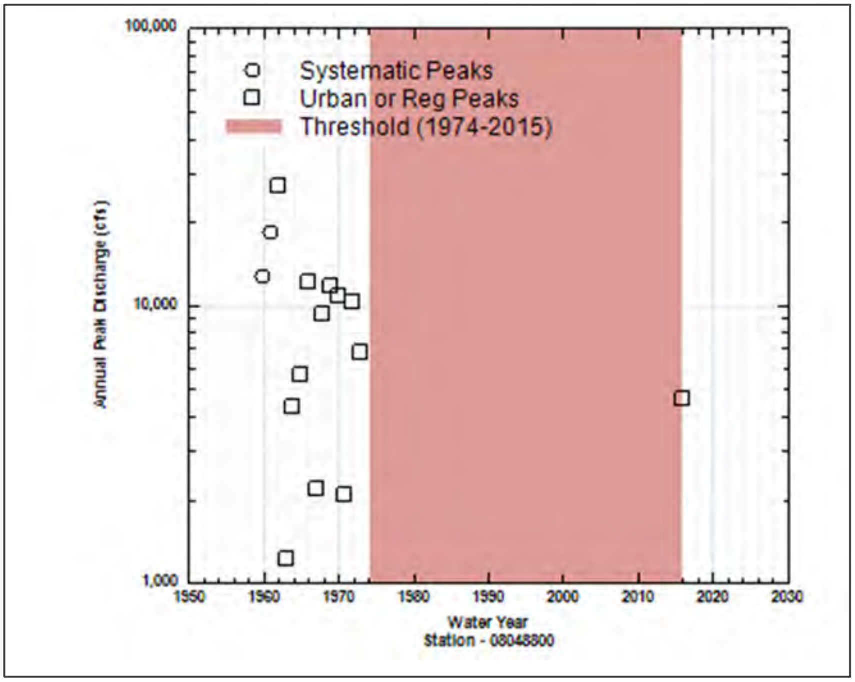

Figure 12a: Annual Peak Streamflow Data for station 08048800 Big Fossil Creek at Haltom City, TX

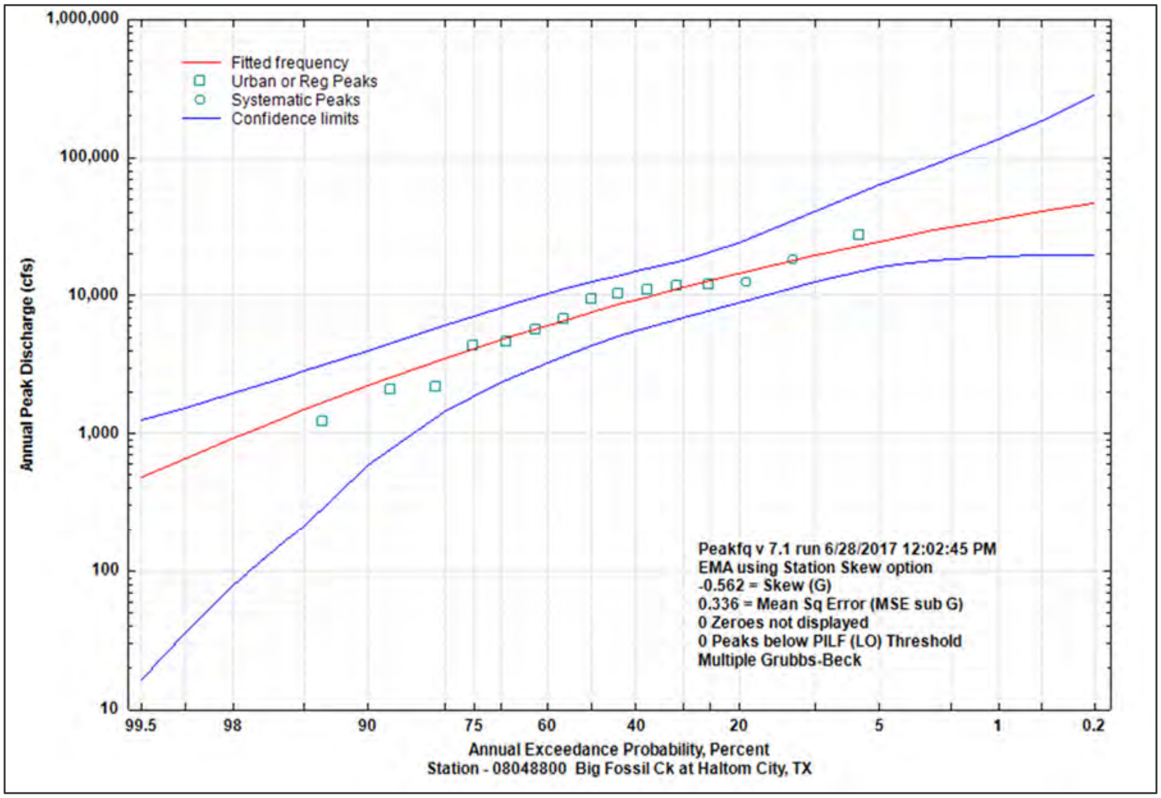

Figure 12b: Flood Flow Frequency Curve for station 08048800 Big Fossil Creek at Haltom City, TX

08048970 Village Creek at Everman, Texas

The gage record and the systematic record for Village Creek at Everman are both 1990–2016. The 2000 streamflow peak of 16,000 ft^3/s with a stage of 21.44 ft is the largest peak in the systematic record. All the peaks are natural and not substantially impacted by urbanization or reservoir construction. The data as set up for statistical frequency analysis are shown in Figure 13a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Village Creek at Everman is shown in Figure 13b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data. The upper end of the curve becomes quite flat. More annual peak streamflow data would be required to determine if this is fully reflective of the flood production potential of the watershed.

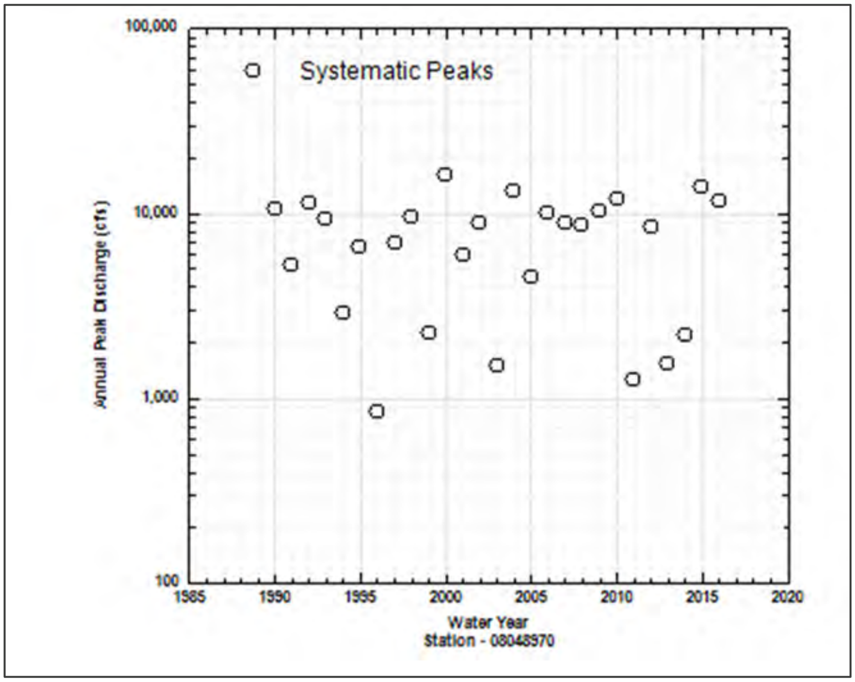

Figure 13a: Annual Peak Streamflow Data for station 08048970 Village Creek at Everman, TX

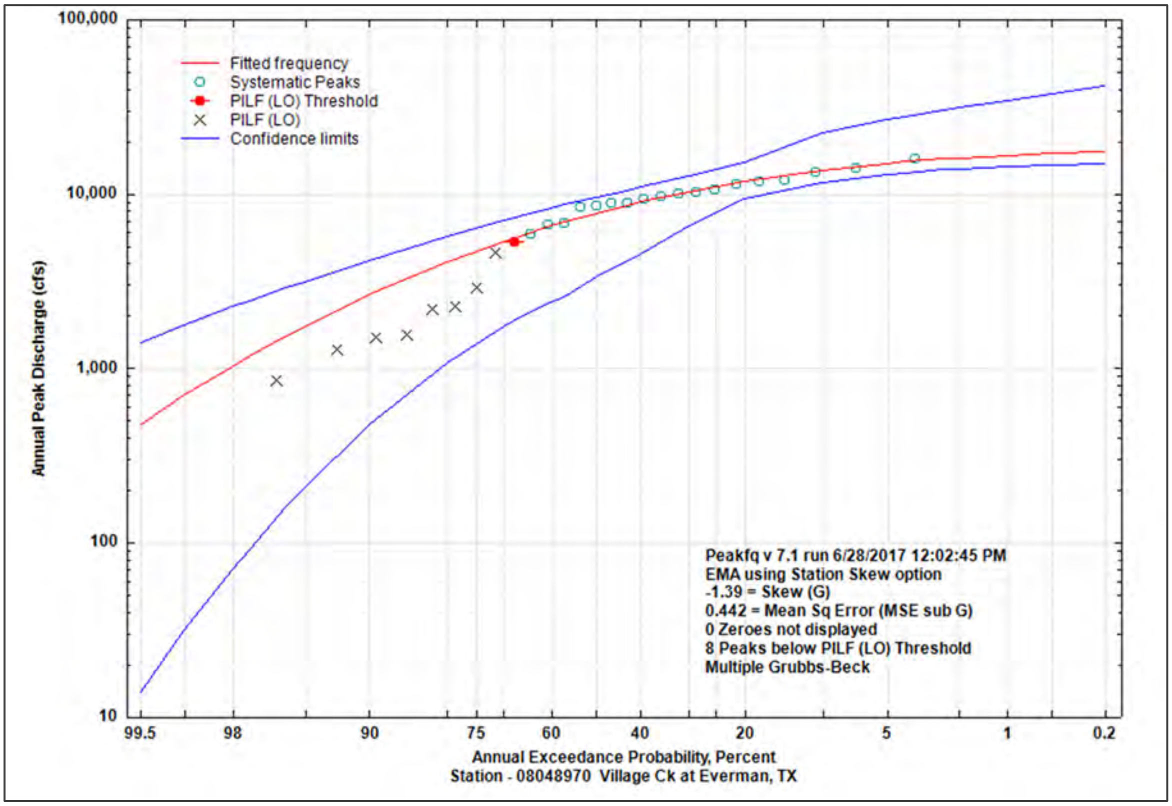

Figure 13b: Flood Flow Frequency Curve for station 08048970 Village Creek at Everman, TX

08049500 West Fork Trinity River at Grand Prairie, Texas

The gage record for the West Fork Trinity River at Grand Prairie is 1925–2016. The systematic record is 1933–2016; thus, peaks between 1925–1932 are not used in the analysis. The 1990 streamflow peak of 64,400 ft^3/s at a stage of 33.88 ft is the largest peak in the systematic record. The 1925–1932 peaks are not used because the construction of the Eagle Mountain Lake and USGS Peak-Values File flagging the record as code 6. The data as set up for statistical frequency analysis are shown in Figure 14a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.037), and this is seen by visual inspection of the data. This might be indicative of watershed urbanization.

The flood flow frequency for West Fork Trinity River at Grand Prairie is shown in Figure 14b. No low outliers though were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks reliable to the inputted data. However, this conclusion is weakened by the upward trend in streamflow for the period analyzed. An additiona caveat is that the empirical distribution might be breaking apart from the fitted curve for the largest five peak streamflows.

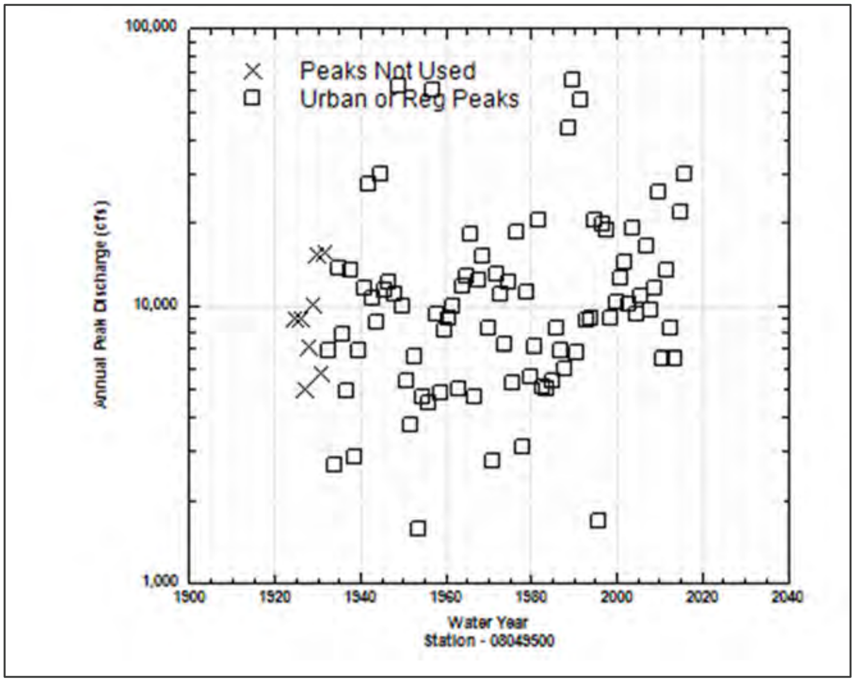

Figure 14a: Annual Peak Streamflow Data for station 08049500 West Fork Trinity River at Grand Prairie, TX

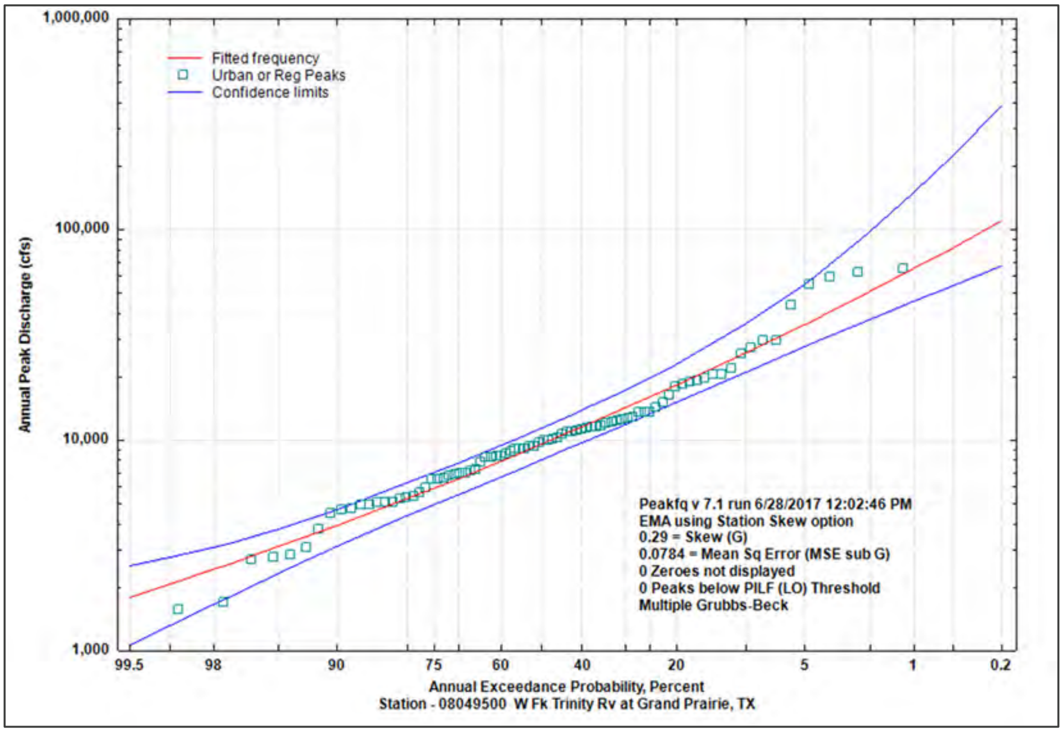

Figure 14b: Flood Flow Frequency Curve for station 08049500 West Fork Trinity River at Grand Prairie, TX

08049580 Mountain Creek near Venus, Texas

The systematic record and the gage record for the Mountain Creek near Venus is 1986–2016. The 2015 streamflow peak of 13,000 ft^3/s at a stage of 16.44 ft is the peak of record for the station. The 1994 and 1996 peaks are less than 580 ft^3/s, but this is readily processed by EMA using USGS-PeakFQ software. The data as set up for statistical frequency analysis are shown in Figure 15a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Mountain Creek near Venus is shown in Figure 15b. The 1994 and 1996 peaks are less than the stated value and are denoted in pink and green bars showing a maximum possible peak value. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data.

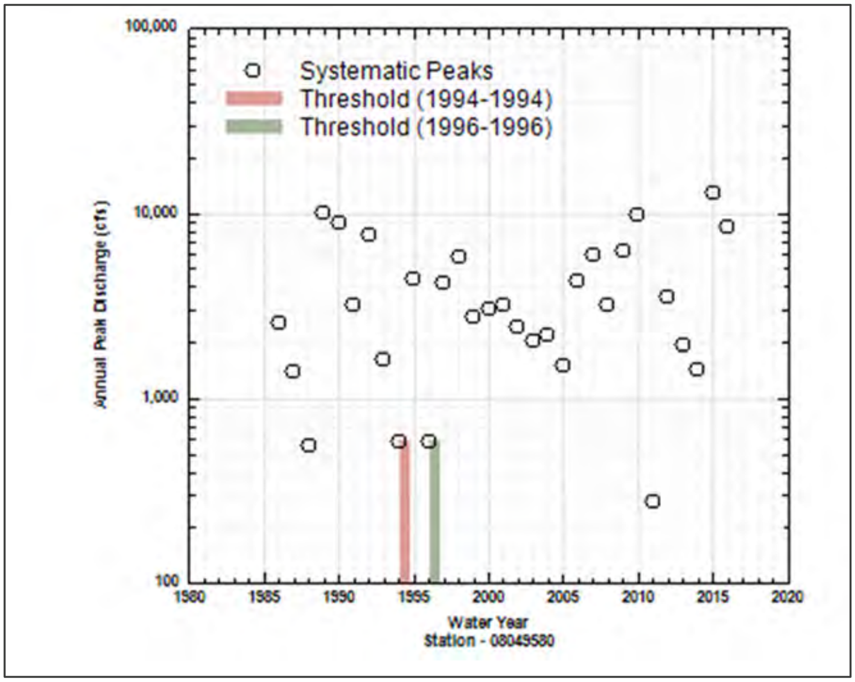

Figure 15a: Annual Peak Streamflow Data for station 08049580 Mountain Creek near Venus, TX

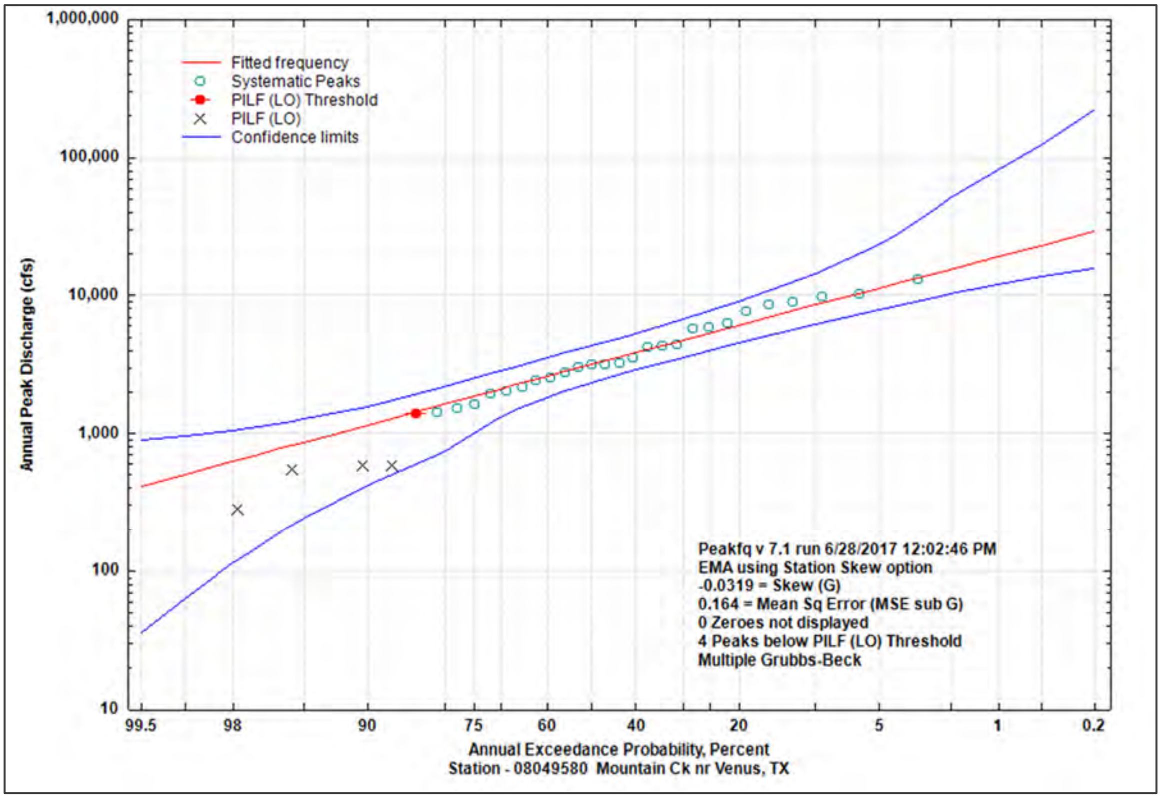

Figure 15b: Flood Flow Frequency Curve Results for station 08049580 Mountain Creek near Venus, TX

08049700 Walnut Creek near Mansfield, Texas

The gage record and the systematic record for Walnut Creek near Mansfield are both 1961–2016. The 1989 streamflow peak of 22,800 ft^3/s at a stage of 33.77 ft is the largest peak for the gage. The data as set up for statistical frequency analysis are shown in Figure 16a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Walnut Creek near Mansfield is shown in Figure 16b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data.

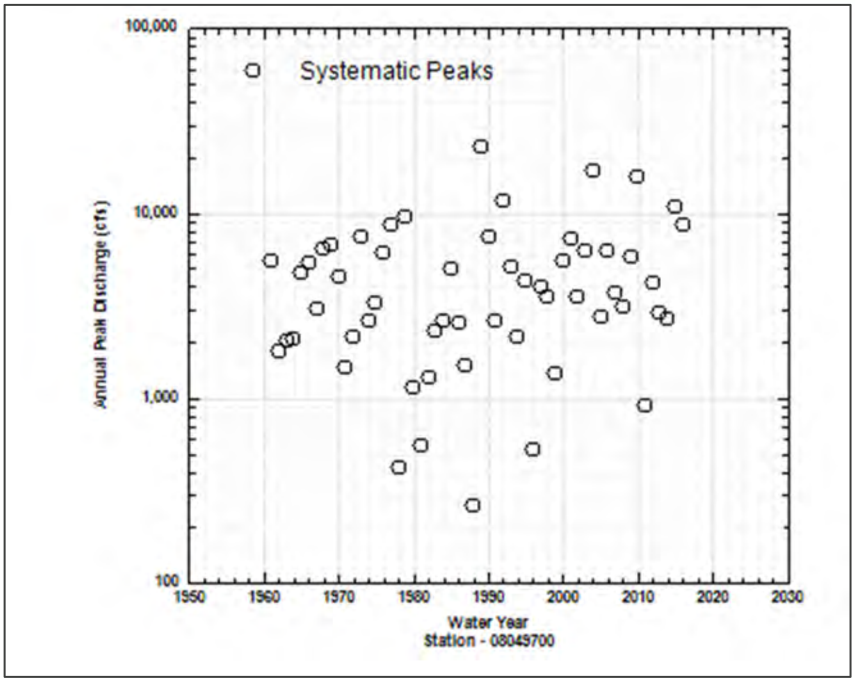

Figure 16a: Annual Peak Streamflow Data for station 08049700 Walnut Creek near Mansfield, TX

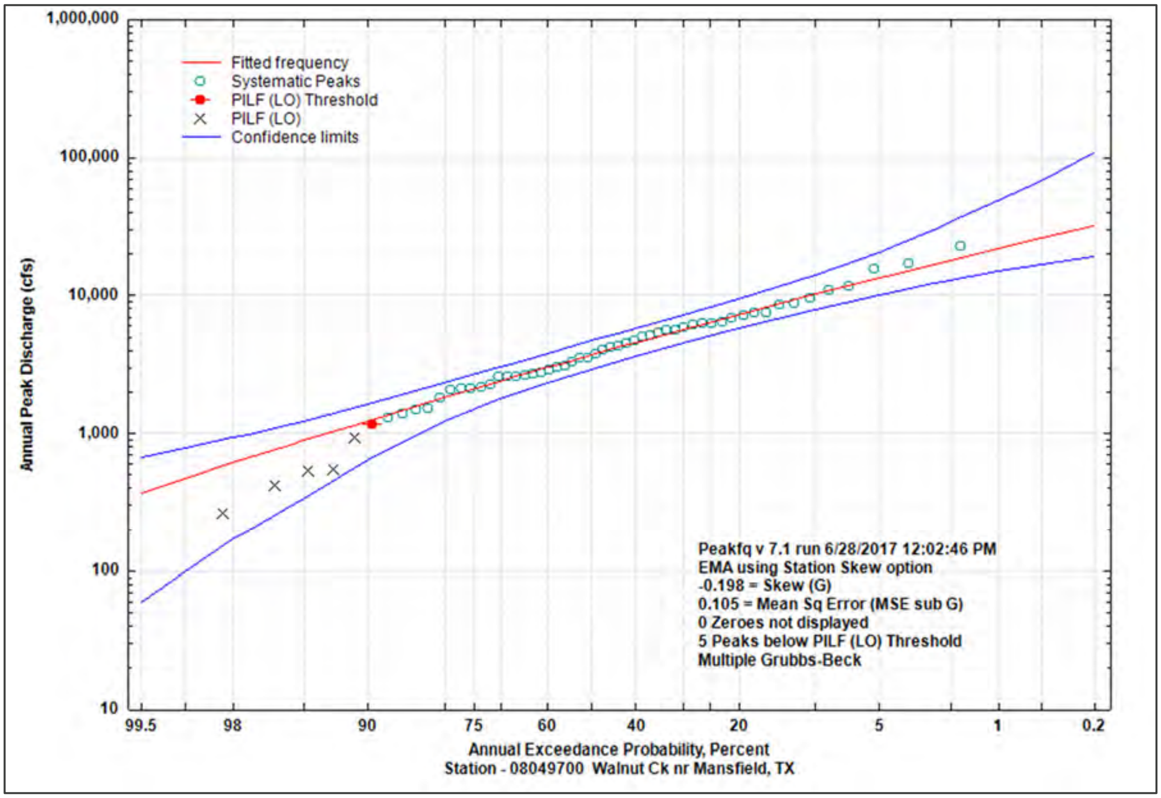

Figure 16b: Flood Flow Frequency Curve for station 08049700 Walnut Creek near Mansfield, TX

08050100 Mountain Creek at Grand Prairie, Texas

The gage record for the Mountain Creek at Grand Prairie is 1961–2016. The systematic record is 1986–2016; thus, peaks for 1961–1985 are not used in the analysis. The USGS Peak-Values File flags the entire record as regulated. The 1992 peak streamflow of 17,900 ft^3/s at a stage of 25.12 ft is the largest peak during the systematic record. Joe Pool Lake built in 1986 is the only major reservoir built upstream of the gage, and the impact of Joe Pool Lake on the annual peaks is readily seen. The peaks from 1961–1985 are not used because the construction of Joe Pool dam represents a change in the watershed. Visually, a substantial change in the distribution of the data before and after Joe Pool is visible. The data as set up for statistical frequency analysis are shown in Figure 17a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Mountain Creek at Grand Prairie is shown in Figure 17b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data.

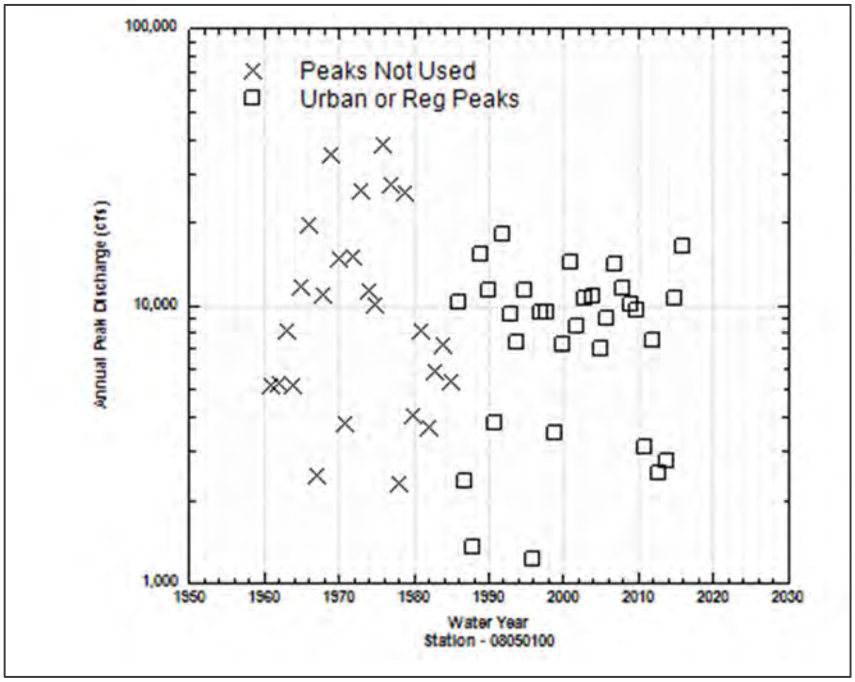

Figure 17a: Annual Peak Streamflow Data for station 08050100 Mountain Creek at Grand Prairie, TX

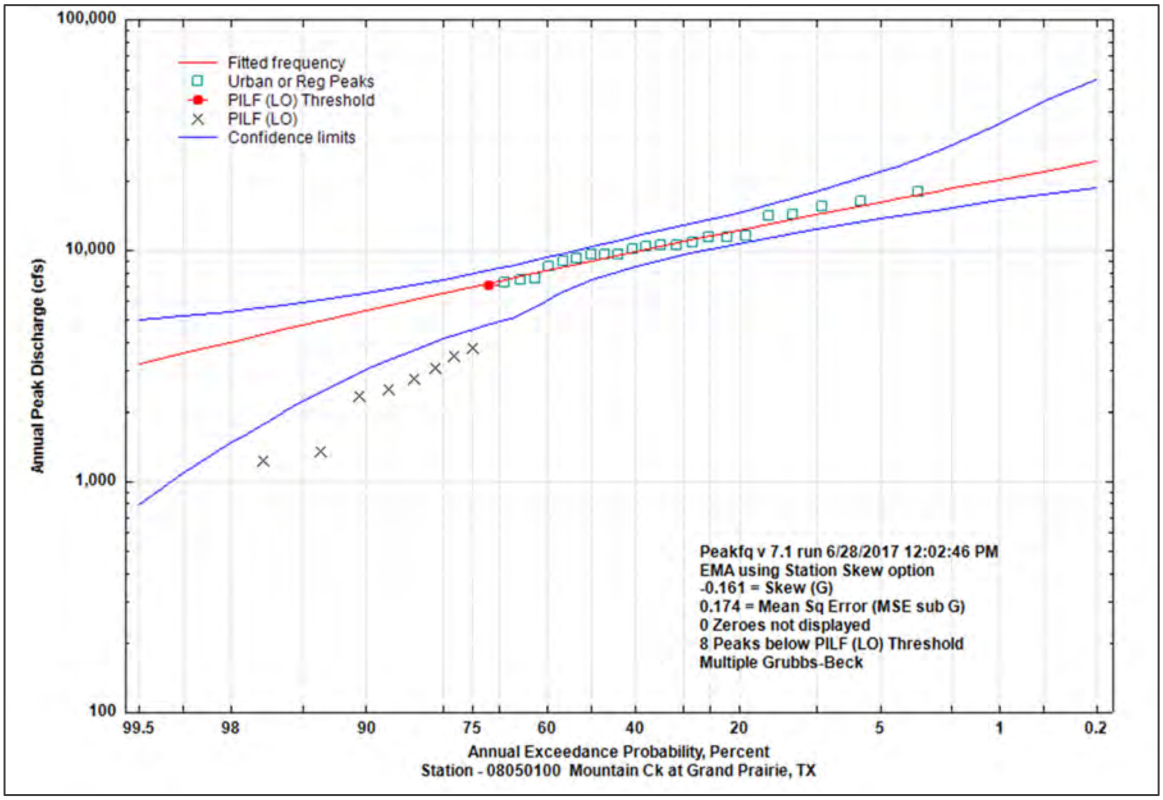

Figure 17b. Flood Flow Frequency Curve for station 08050100 Mountain Creek at Grand Prairie, TX

08050400 Elm Fork Trinity River at Gainesville, Texas

The gage record and the systematic record for Elm Fork Trinity River at Gainesville are both 1986–2016. The 2007 peak streamflow of 72,000 ft^3/s at a stage of 28.01 ft is the largest peak for the site. The data as set up for statistical frequency analysis are shown in Figure 18a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Elm Fork Trinity River at Gainesville is shown in Figure 18b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks reliable to the inputted data.

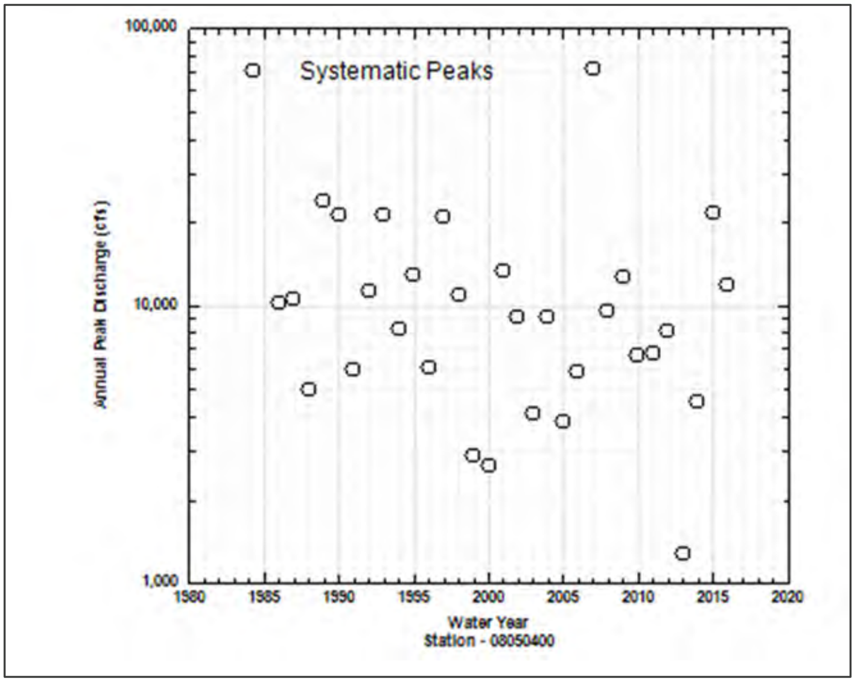

Figure 18a: Annual Peak Streamflow Data for station 08050400 Elm Fork Trinity River at Gainesville, TX

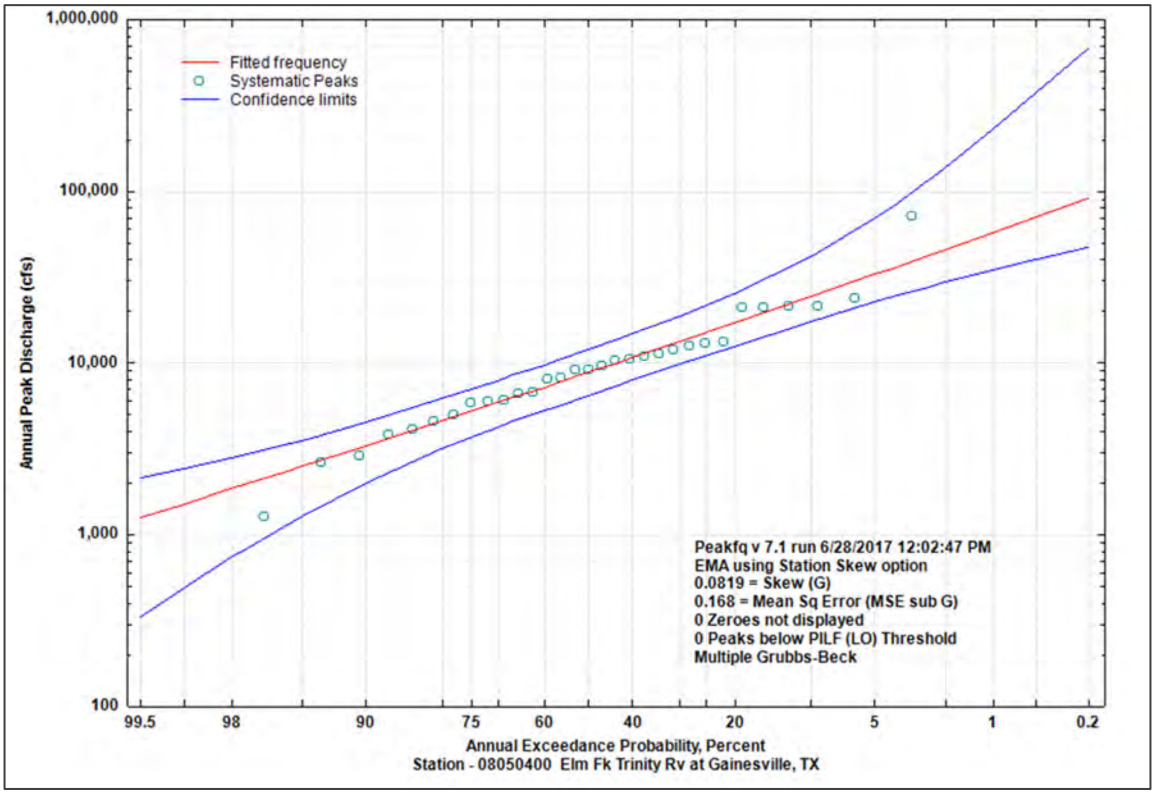

Figure 18b: Flood Flow Frequency Curve for station 08050400 Elm Fork Trinity River at Gainesville, TX

08050800 Timber Creek near Collinsville, Texas

The gage record and the systematic record for Timber Creek near Collinsville are both 1986–2016. The 2007 peak streamflow of 21,900 ft^3/s at a stage of 14.96 ft is the largest peak for the site. All peaks are unregulated and reflect the natural behavior of the creek. The data as set up for statistical frequency analysis are shown in Figure 19a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Timber Creek near Collinsville is shown in Figure 19b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks reliable to the inputted data.

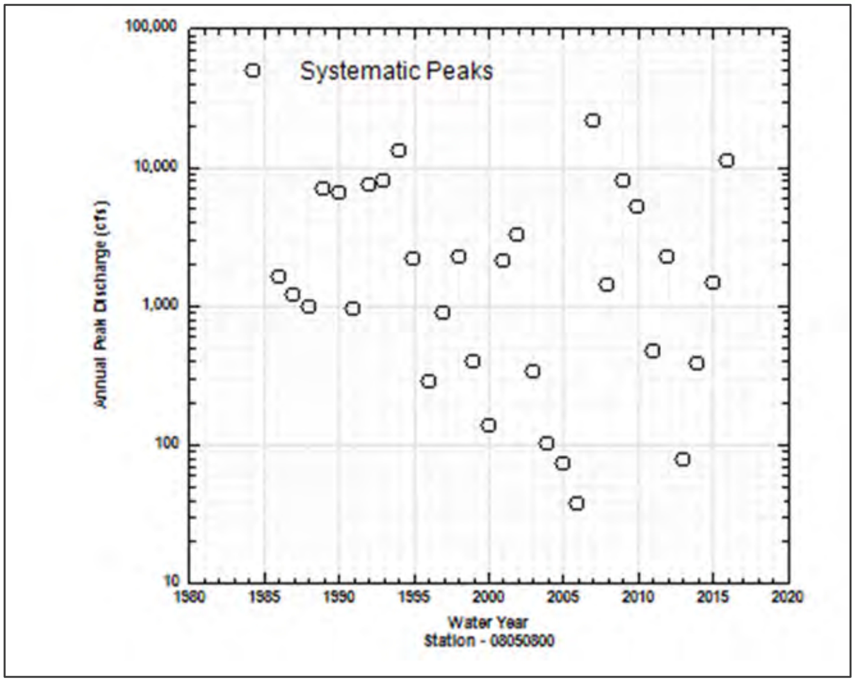

Figure 19a: Annual Peak Streamflow Data for station 08050800 Timber Creek near Collinsville, TX

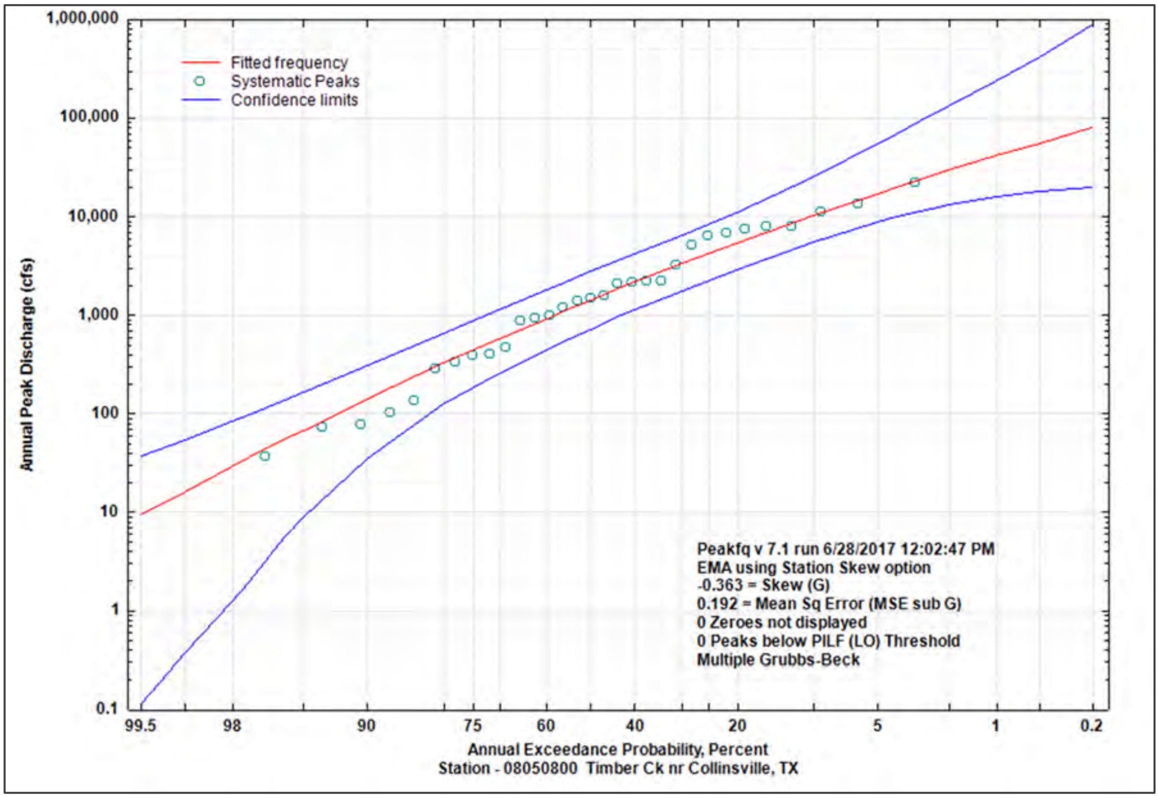

Figure 19b: Flood Flow Frequency Curve for station 08050800 Timber Creek near Collinsville, TX

08050840 Range Creek near Collinsville, Texas

The gage record and the systematic record for Range Creek near Collinsville are both 1993–2016. The 2007 peak streamflow of 35,300 ft^3/s at a stage of 24.98 ft is the historic peak for the site. The data as set up for statistical frequency analysis are shown in Figure 20a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Range Creek near Collinsville is shown in Figure 20b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data. However, this is difficult to assess because of the moderate record length (less than 30 years).

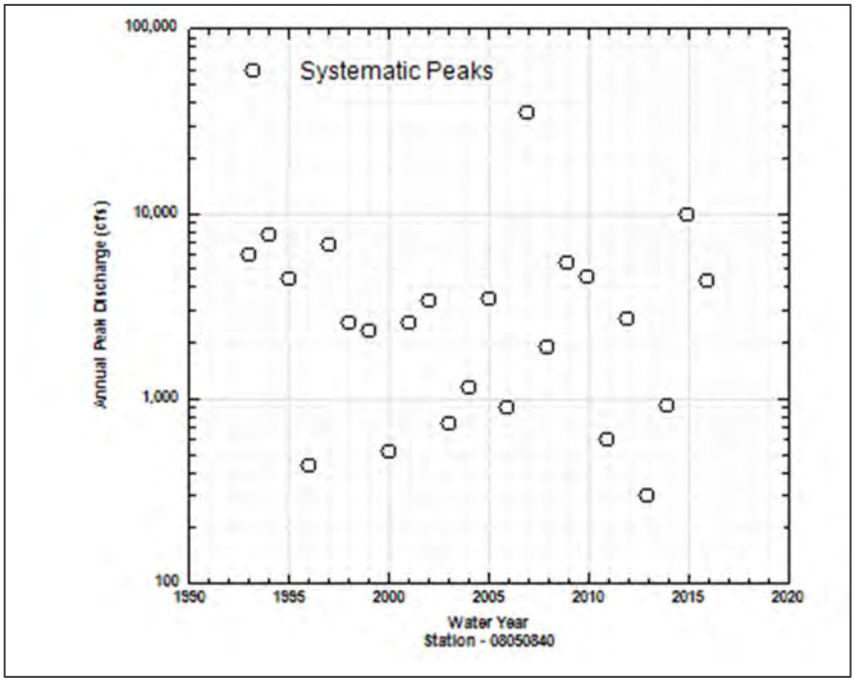

Figure 20a: Annual Peak Streamflow Data for station 08050840 Range Creek near Collinsville, TX

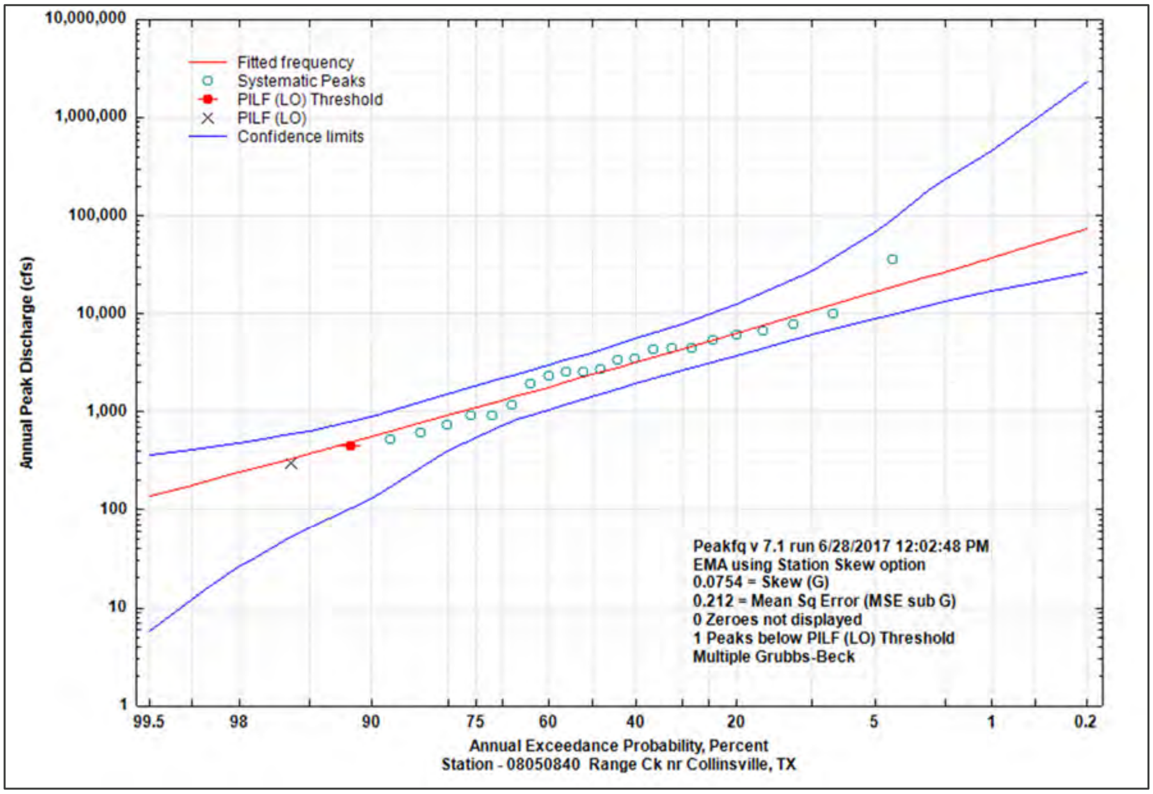

Figure 20b: Flood Flow Frequency Curve for station 08050840 Range Creek near Collinsville, TX

08051135 Elm Fork Trinity River at Greenbelt near Pilot Point, Texas

The gage record and the systematic record for Elm Fork Trinity River at Greenbelt near Pilot Point are both 2010–2016. The 2015 peak streamflow of 8,240 ft^3/s at a stage of 30.98 ft is the largest peak for the site. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. Ray Roberts Reservoir was built in 1986 before the installation of the site. For this reason, all of the peaks in the analysis are considered regulated peaks. The data as set up for statistical frequency analysis are shown in Figure 21a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Elm Fork Trinity River at Greenbelt near Pilot Point is shown in Figure 21b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. The record is so short at this site that it is extremely uncertain how much inference on flood potential should be made from the fitted distribution.

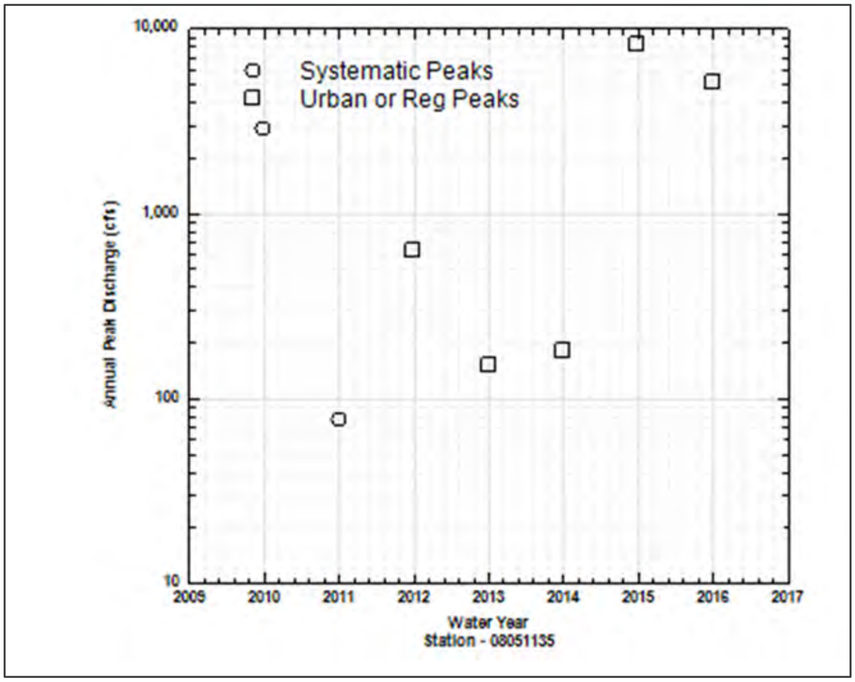

Figure 21a: Annual Peak Streamflow Data for station 08051135 Elm Fork Trinity River at Greenbelt near Pilot Point, TX

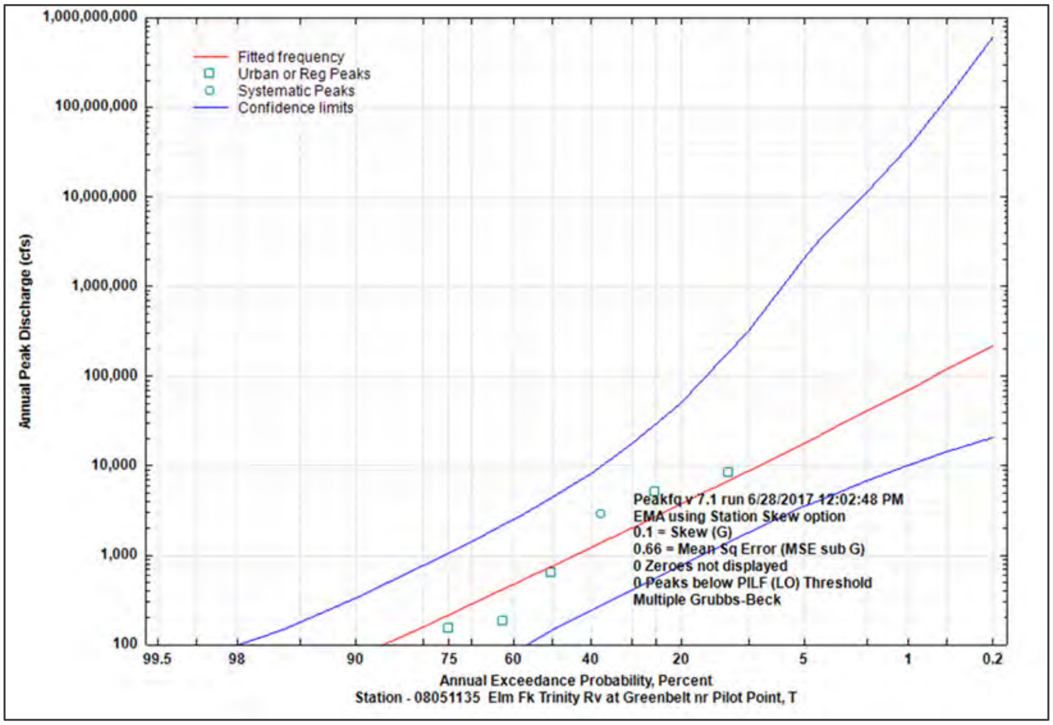

Figure 21b: Flood Flow Frequency Curve for station 08051135 Elm Fork Trinity River at Greenbelt near Pilot Point, TX

08051500 Clear Creek near Sanger, Texas

The gage record and the systematic record for Clear Creek near Sanger are both 1949–2016. The 1982 peak streamflow of 104,000 ft^3/s at a stage of 35.70 ft is the largest peak for the site. The data includes both unregulated and regulated peaks. USGS Peak-Values File flags the record with code 6 in 1981. The data as set up for statistical frequency analysis are shown in Figure 22a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Clear Creek near Sanger is shown in Figure 22b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data. However, the 1982 peak breaks considerably away from the curve. Presumably, the 1982 peak has a real, but unknown, annual exceedance probability larger than implied by its empirical value from the whole sample available.

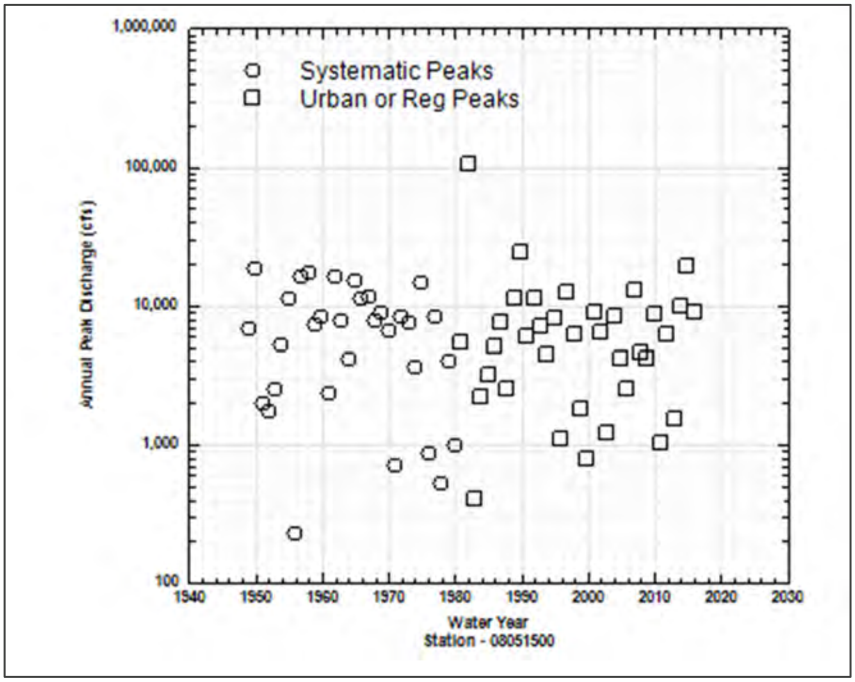

Figure 22a: Annual Peak Streamflow Data for station 08051500 Clear Creek near Sanger, TX

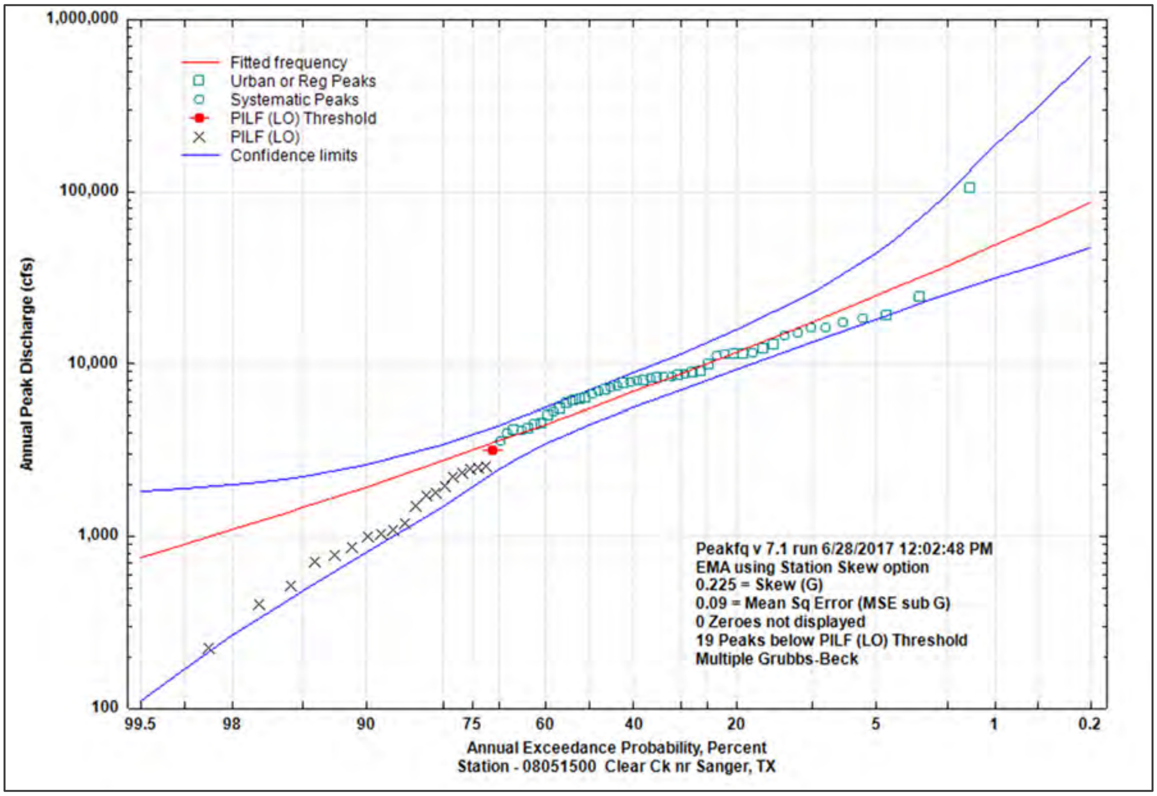

Figure 22b: Flood Flow Frequency Curve for station 08051500 Clear Creek near Sanger, TX

08052700 Little Elm Creek near Aubrey, Texas

The gage record and the systematic record for Little Elm Creek near Aubrey are both 1957–2016 with a gap in record from 1977–1979. No inference for peaks in the record gap is made. The 1994 peak streamflow of 36,200 ft^3/s at a stage of 18.27 ft is the largest peak for the site. USGS Peak-Values File flags the record with code 6 in 1966. The data as set up for statistical frequency analysis are shown in Figure 23a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Little Elm Creek near Aubrey is shown in Figure 23b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks reliable to the inputted data.

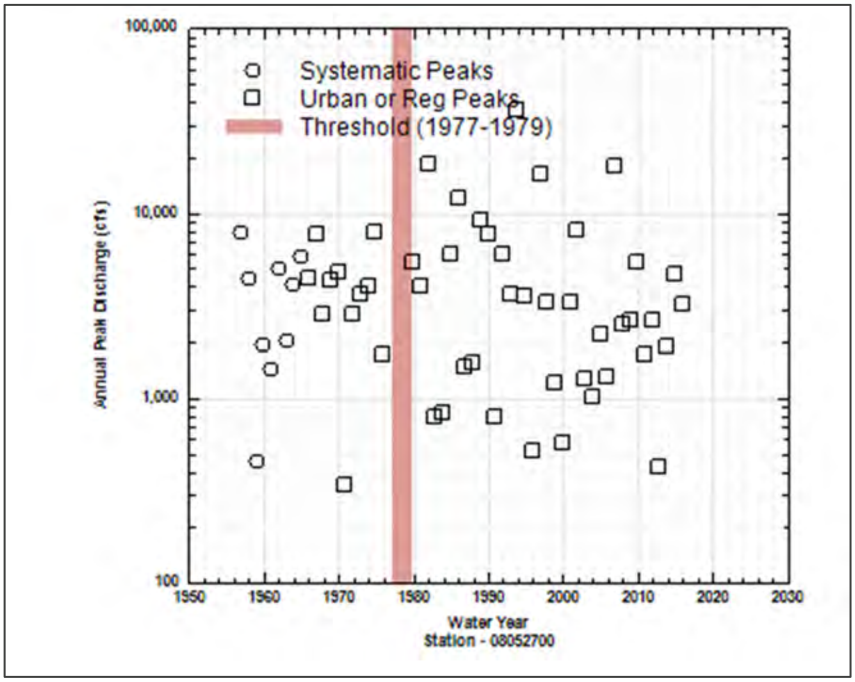

Figure 23a: Annual Peak Streamflow Data for station 08052700 Little Elm Creek near Aubrey, TX

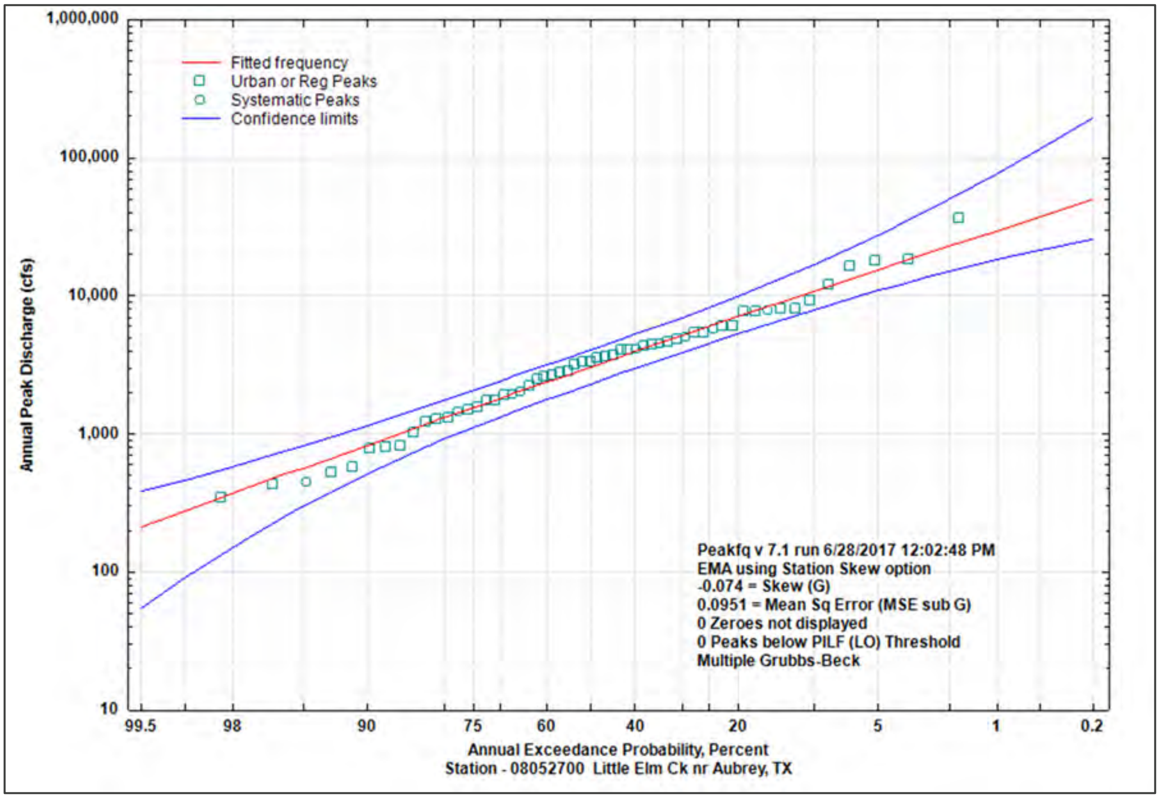

Figure 23b: Flood Flow Frequency Curve for station 08052700 Little Elm Creek near Aubrey, TX

08053000 Elm Fork Trinity River near Lewisville, Texas

The gage record for Elm Fork Trinity River near Lewisville is 1950–2016. They systematic record is 1986–2016; thus, peaks for 1950–1985 are not used in the analysis. The 1990 peak streamflow of 19,600 ft^3/s at a stage of 30.15 ft is the largest peak of the systematic record. There is a larger peak in 1950 that is outside of the systematic record of 21,700 ft^3/s at a stage of 30.75 ft. Two major reservoirs have been built upstream of the gage: Lewisville Lake in 1954 and Ray Roberts in 1986. The peaks for 1950–1985 are not used because the construction of the Ray Roberts dam represents a change in the watershed and a change to a generalized period of static flood storage capacity. The data as set up for statistical frequency analysis are shown in Figure 24a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1). The peaks that are not used show a strong bimodal distribution with central tendencies at about 5,000 ft^3/s and again at about 600–700 ft^3/s. The is the potential that this bimodal behavior continues for the period analyzed.

The flood flow frequency for Elm Fork Trinity River near Lewisville is shown in Figure 24b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, the flood flow frequency curve looks questionable to the inputted data. The bimodal behavior (mixed population) seems evident with the flatter portion of the empirical distribution at about 1,000–2,000 ft^3/s and again at 4,000–6,000 ft^3/s. This suggests a substantial regulation "signal" caused by upstream reservoirs.

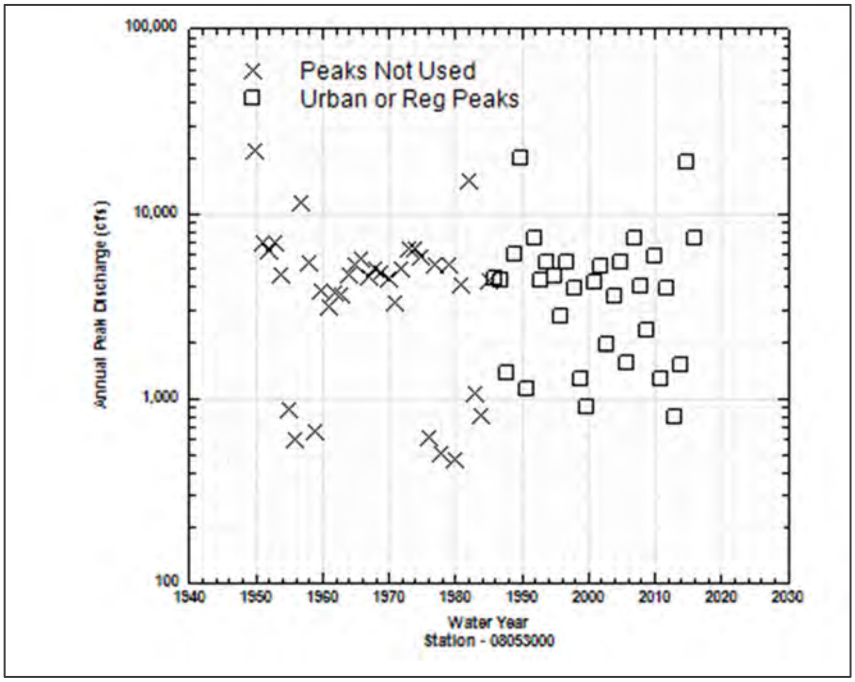

Figure 24a: Annual Peak Streamflow Data for station 08053000 Elm Fork Trinity River near Lewisville, TX

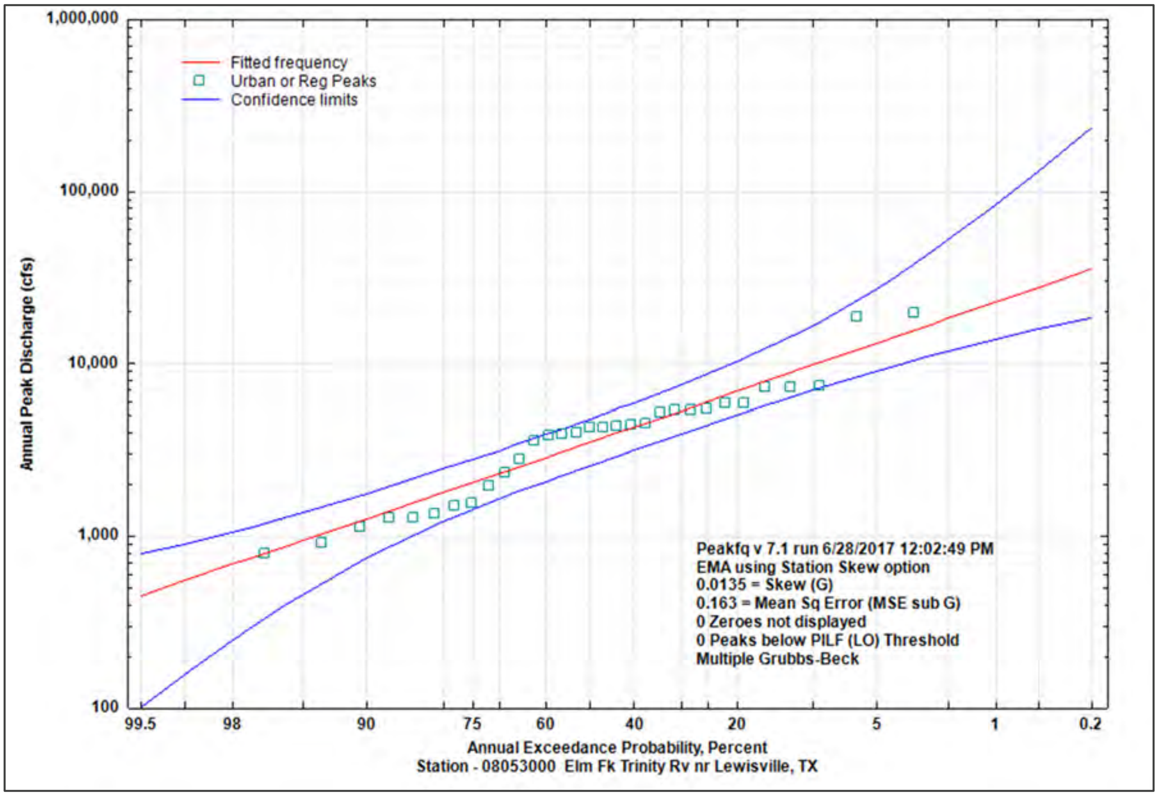

Figure 24b: Flood Flow Frequency Curve for 08053000 Elm Fork Trinity River near Lewisville, TX

08053500 Denton Creek near Justin, Texas

The gage record and the systematic record for Denton Creek near Justin are both 1950–2016. The 1982 peak stream flow of 34,700 ft^3/s at a stage of 18.68 ft is the largest peak for the site. This site includes unregulated and regulated peaks. The USGS Peak-Values File flags the peaks with code 6 beginning in 1965. The data as set up for statistical frequency analysis are shown in Figure 25a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1). Visually the entire gage record seems compatible and thus used.

The flood flow frequency for Denton Creek near Justin is shown in Figure 25b. No low outliers were detected by the MGBT method. In general, the flood flow frequency curve looks reliable to the inputted data.

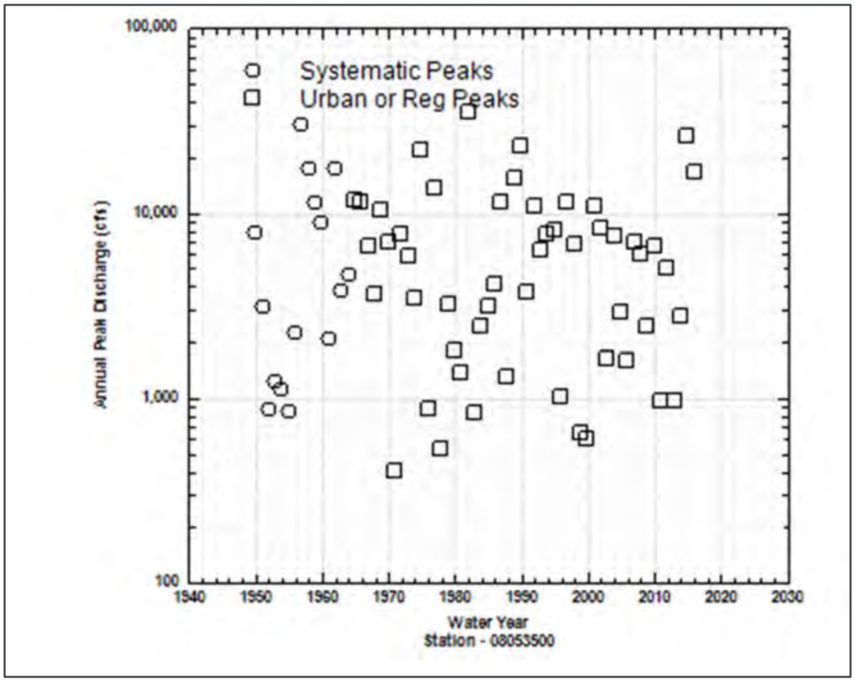

Figure 25a: Annual Peak Streamflow Data for station 08053500 Denton Creek near Justin, TX

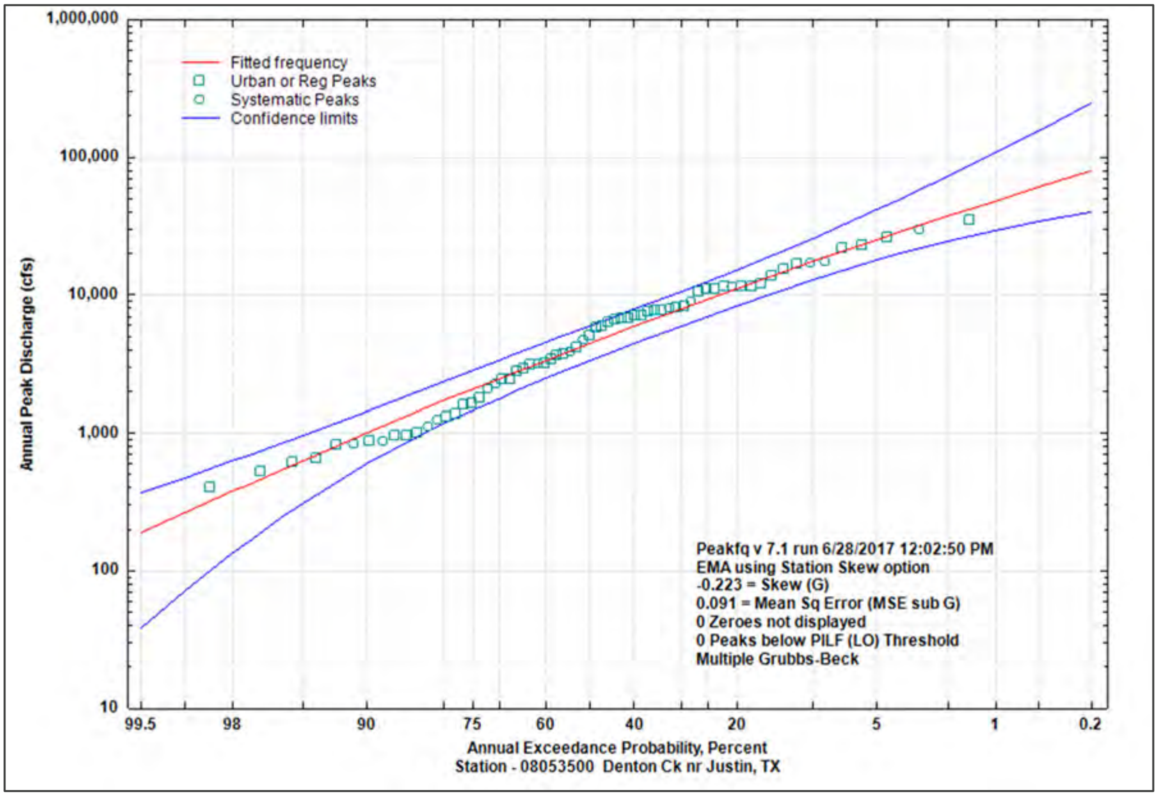

Figure 25b: Flood Flow Frequency Curve for station 08053500 Denton Creek near Justin, TX

08055000 Denton Creek near Grapevine, Texas

The gage record for the Denton Creek near Grapevine is 1948–2016 with gaps in record at 1963 and from 1992–2003. The systematic record is 1953–2016; thus, the peaks for 1948–1952 are not used in the analysis. No historical inference of peaks is made for the record gaps. The 1982 peak streamflow of 9,700 ft^3/s at a stage of 27.93 ft is the largest peak for the systematic record. The 1948 peak of 13,900 ft^3/s at a stage of 30.28 ft is outside of the systemic record. Lake Grapevine was built in 1952 and is the only major reservoir built upstream of the gage. The 1948–1952 peaks are not used because the construction of the Lake Grapevine dam represents a change in the watershed. The data as set up for statistical frequency analysis are shown in Figure 26a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1). Visually, the peaks prior to the systematic record are not compatible and not used.

The flood flow frequency for Denton Creek near Grapevine is shown in Figure 26b. A low-outlier threshold was manually fixed at 900 ft^3/s, which does an appropriate job of removing low outliers. In general, the flood flow frequency curve looks reliable to the inputted data. However, it is possible that the largest peaks are breaking away from the fitted distribution.

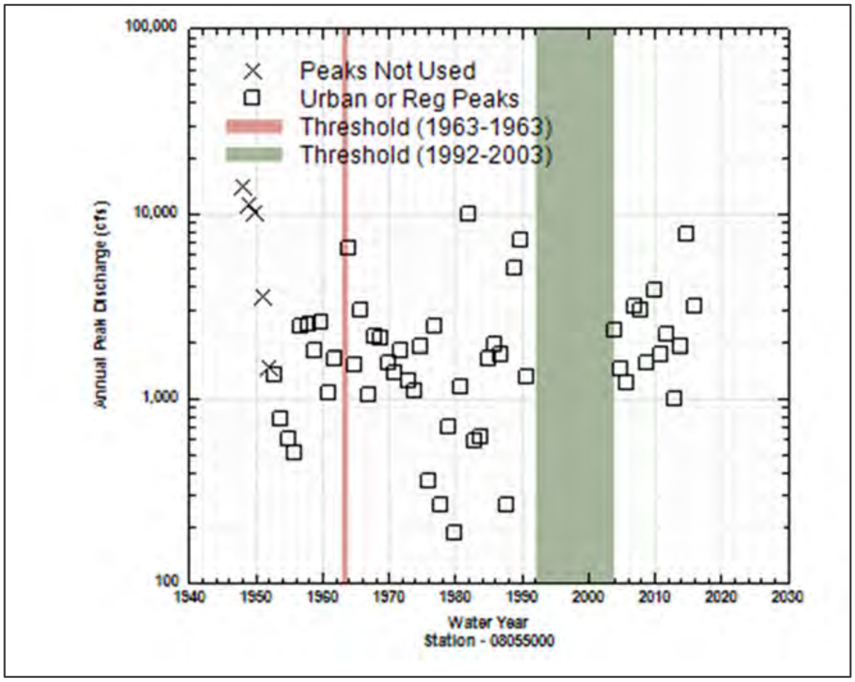

Figure 26a: Annual Peak Streamflow Data for station 08055000 Denton Creek near Grapevine, TX

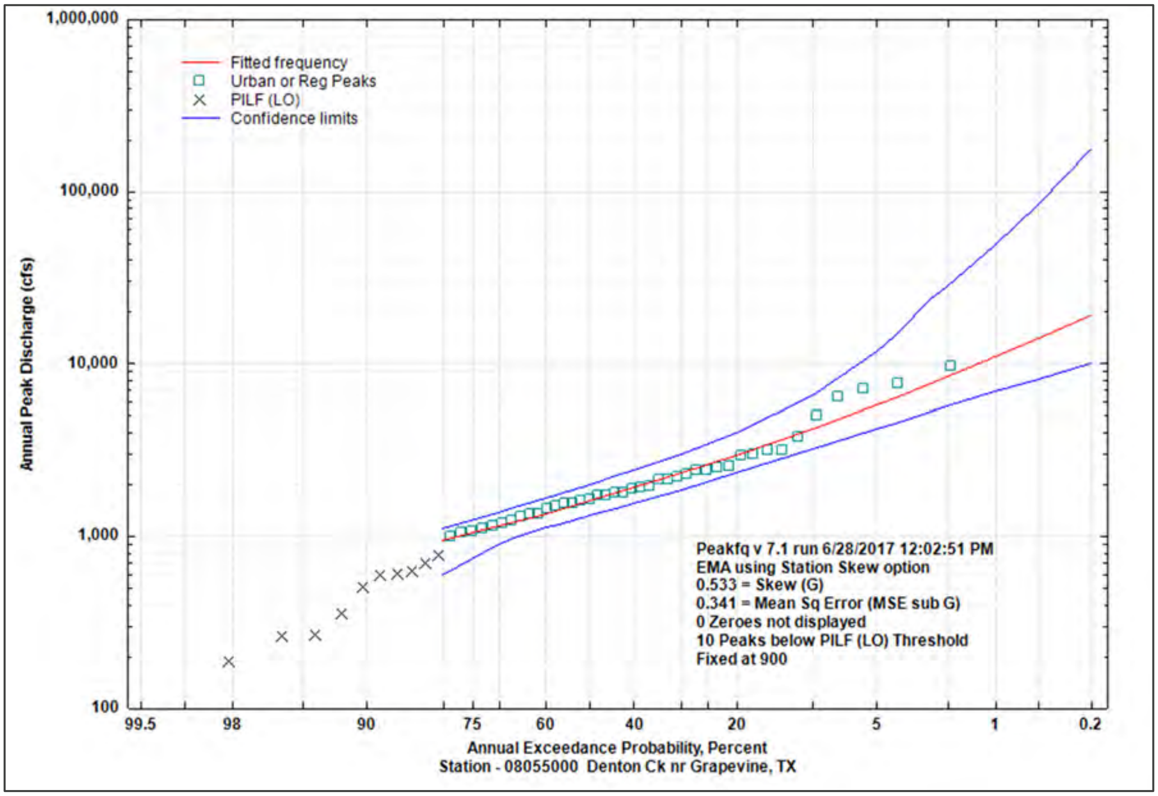

Figure 26b: Flood Flow Frequency Curve for station 08055000 Denton Creek near Grapevine, TX

08055500 Elm Fork Trinity River near Carrollton, Texas

The gage record for Elm Fork Trinity River near Carrollton is 1924–2016. The systematic record is 1955–2016; thus, peaks for 1924–1954 are not used in the analysis. The 1964 peak streamflow of 33,000 ft^3/s at a stage of 10.95 ft is the largest for the systematic record. The 1908 historic peak is 145,000 ft^3/s at a stage of 19.00 ft; this peak is not used but is shown in Figure 27a. The peaks from 1924–1954 are not used because the construction of the Lewisville Lake dam represents a change in the watershed. The data as set up for statistical frequency analysis are shown in Figure 27a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Elm Fork Trinity River near Carrollton is shown in Figure 27b. A low-outlier threshold was manually fixed at 4,000 ft^3/s, which does an appropriate job of removing low outliers. In general, the flood flow frequency curve looks reliable to the inputted data. However, it is possible that the largest peaks are breaking away from the fitted distribution.

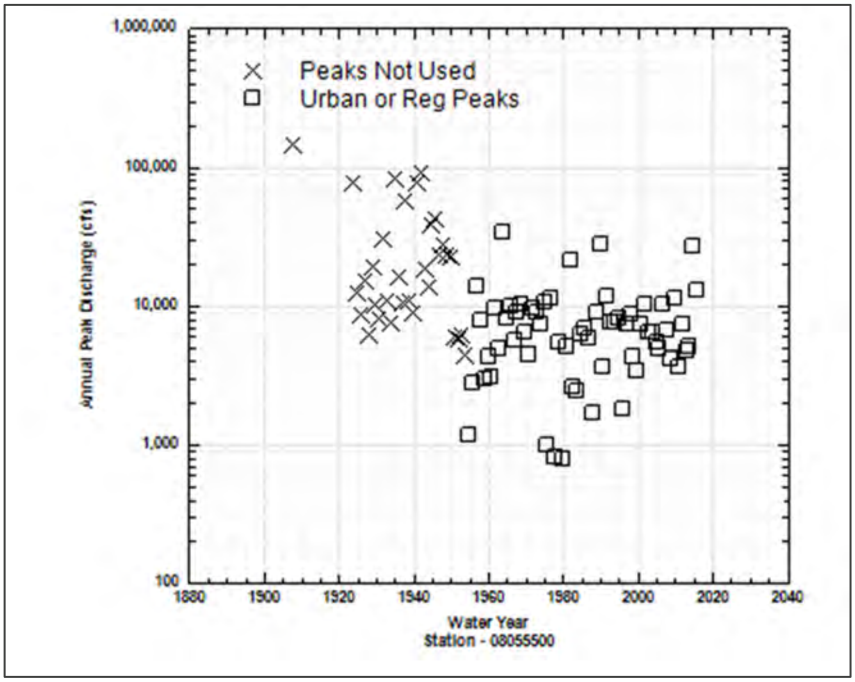

Figure 27a: Annual Peak Streamflow Data for station 08055500 Elm Fork Trinity River near Carrollton, TX

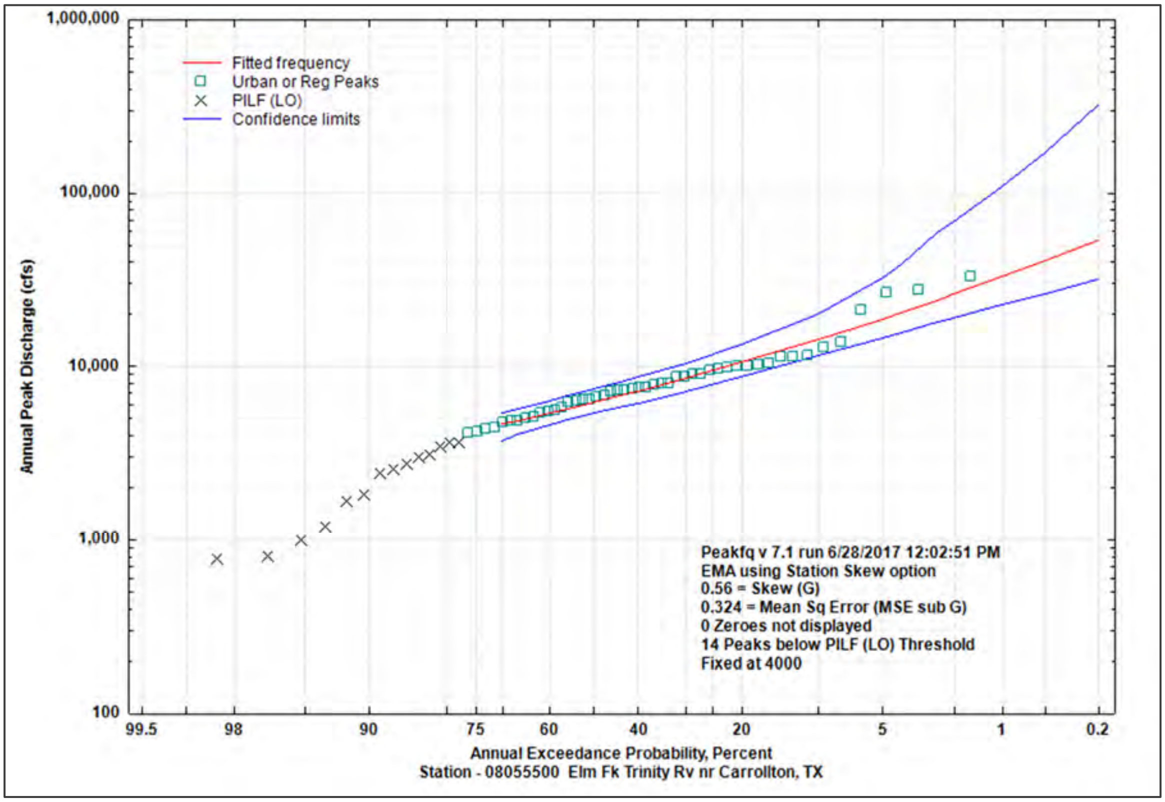

Figure 27b: Flood Flow Frequency Curve for station 08055500 Elm Fork Trinity River near Carrollton, TX

08056500 Turtle Creek at Dallas, Texas

The gage record for the Turtle Creek at Dallas is 1947–2016 with a gap in record from 1981–1984. The systematic record is 1947–1991. No inference for the gap in record from 1981–1984 was made. The 1966 peak streamflow of 12,200 ft^3/s at a stage of 10.54 ft is the largest peak for the site. The USGS Peak-Values File flags the entire record with a code C, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. This stream gage was reactivated in 2011, but the 2011–2016 peaks are not used in the analysis because they are noticeably different from the earlier period. The data as set up for statistical frequency analysis are shown in Figure 28a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.005), and this is seen by visual inspection of the data. This likely is indicative of watershed urbanization.

The flood flow frequency for Turtle Creek at Dallas is shown in Figure 28b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. The degree to which inference of flood potential can be made for this site through statistical analysis is quite limited. First, historically there is an obviously upward trend in peak magnitude, which hinders statistical assessment using the USGS-PeakFQ software. Second, the 2011–2016 peaks are visually divergent in that their variation appears quite small compared to that expected for the earlier time period. Lastly, it is suggested that hydrologic and hydraulic modeling would be especially informative to assess "modern" flood potential for this site.

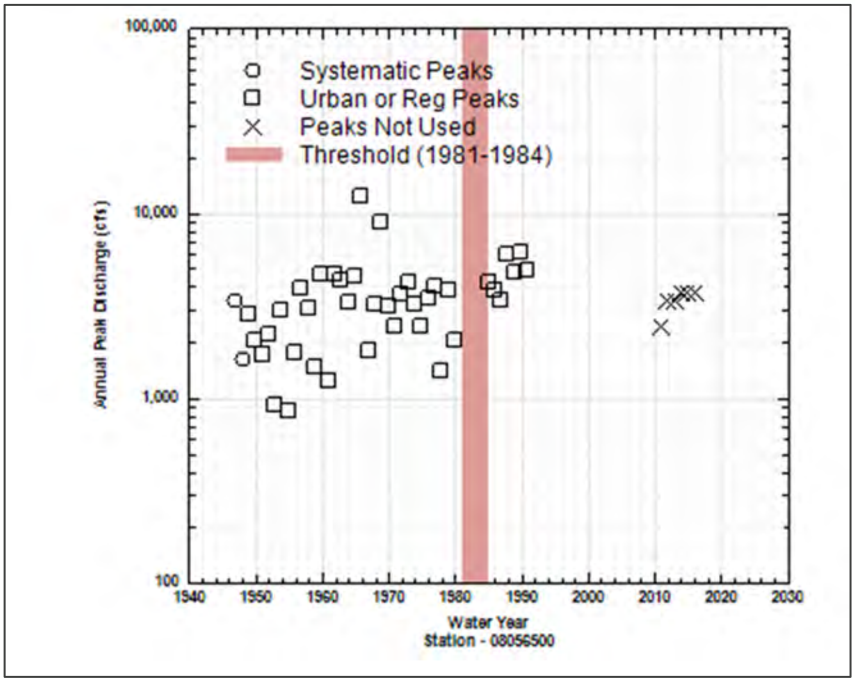

Figure 28a: Annual Peak Streamflow Data for station 08056500 Turtle Creek at Dallas, TX

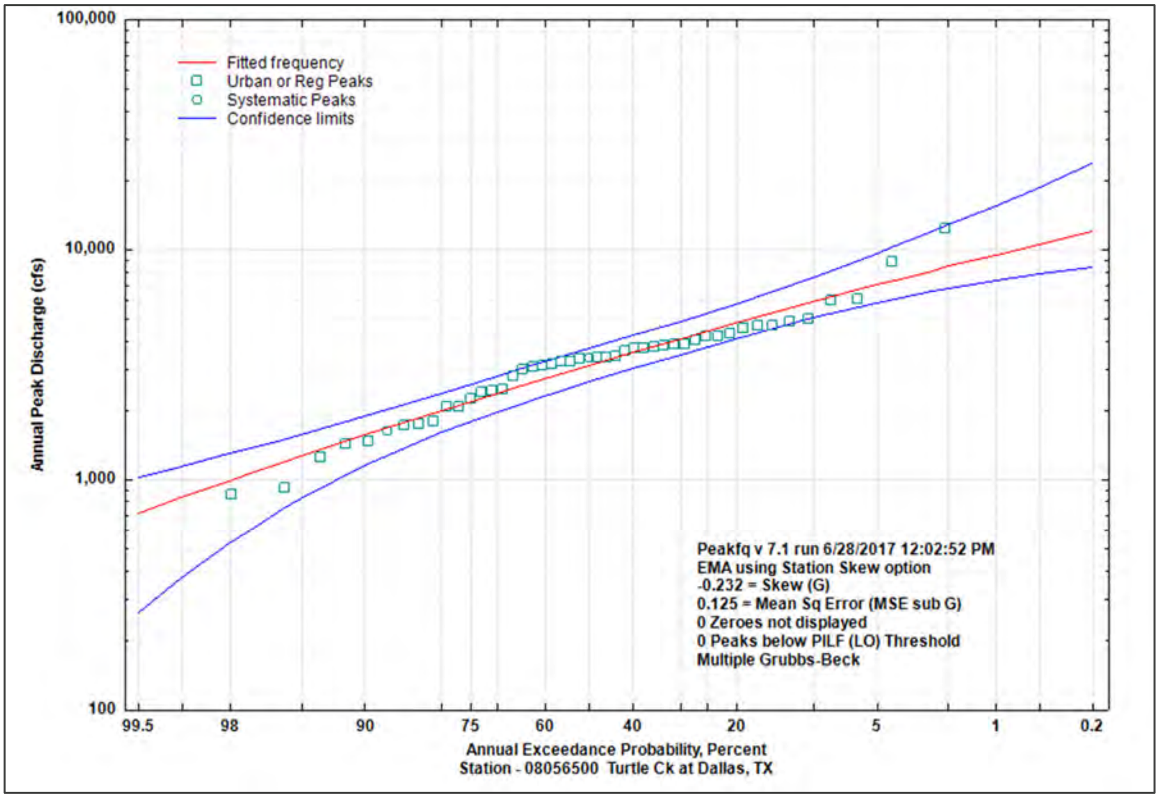

Figure 28b: Flood Flow Frequency Curve for station 08056500 Turtle Creek at Dallas, TX

08057000 Trinity River at Dallas, Texas

The gage record for Trinity River at Dallas is 1904–2016. The systematic record is 1955–2016 thus peaks for 1904–1954 are not used in the analysis. The 1990 peak streamflow of 82,300 ft^3/s at a stage of 47.10 ft is the peak for the systematic record. There is a very large peak in 1908 of 184,000 ft^3/s at a stage of 52.6 ft but is outside of the systematic record. Eleven major reservoirs have been built upstream of the gage: Lake Worth in 1914, Lake Bridgeport in 1931, Eagle Mountain Lake in 1932, Benbrook Lake in 1951, Lake Grapevine in 1952, Lake Lewisville in 1954, Lake Arlington in 1955, Lake Amon Carter in 1956, Lake Weatherford in 1957, Joe Pool Lake in 1986, and Lake Ray Roberts in 1986. It is difficult to disaggregate this complex history, but in short, the peaks from 1904–1954 are not used because the construction of the Lake Lewisville dam. The data as set up for statistical frequency analysis are shown in Figure 29a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.066), and this is seen by visual inspection of the data. This might be indicative of watershed urbanization. It is possible that the effects of Joe Pool Lake and Lake Ray Roberts in 1986 can be seen from that year onward, yet the largest peak in the systematic record was in 1990.

The flood flow frequency for Trinity River at Dallas is shown in Figure 29b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, the flood flow frequency curve looks reliable to the inputted data. However, it is possible that the largest peaks are breaking away from the fitted distribution. The flat regions of the empirical data at about 13,000 ft^3/s and again 30,000 ft^3/s suggest some mixed population effects.

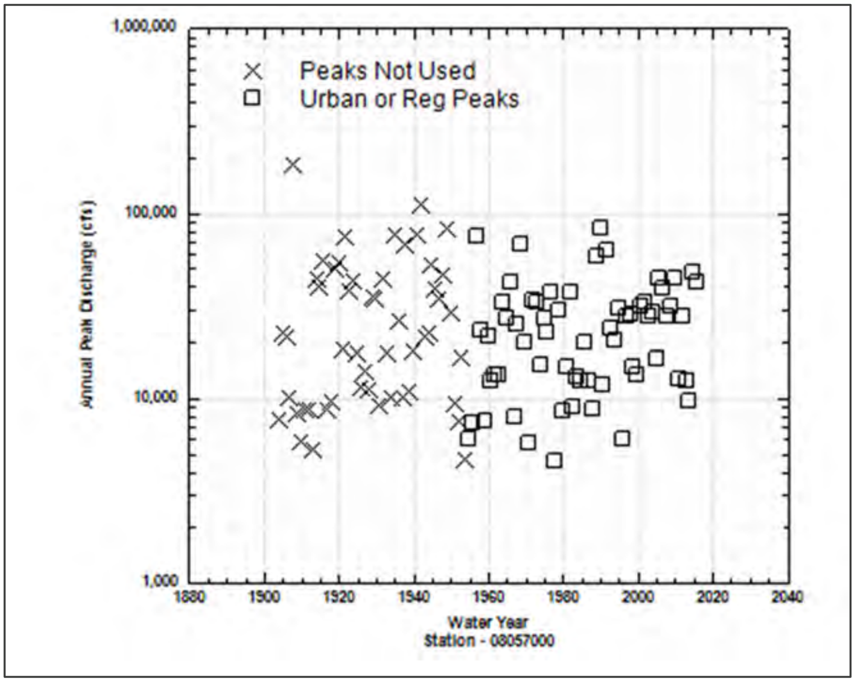

Figure 29a: Annual Peak Streamflow Data for station 08057000 Trinity River at Dallas, TX

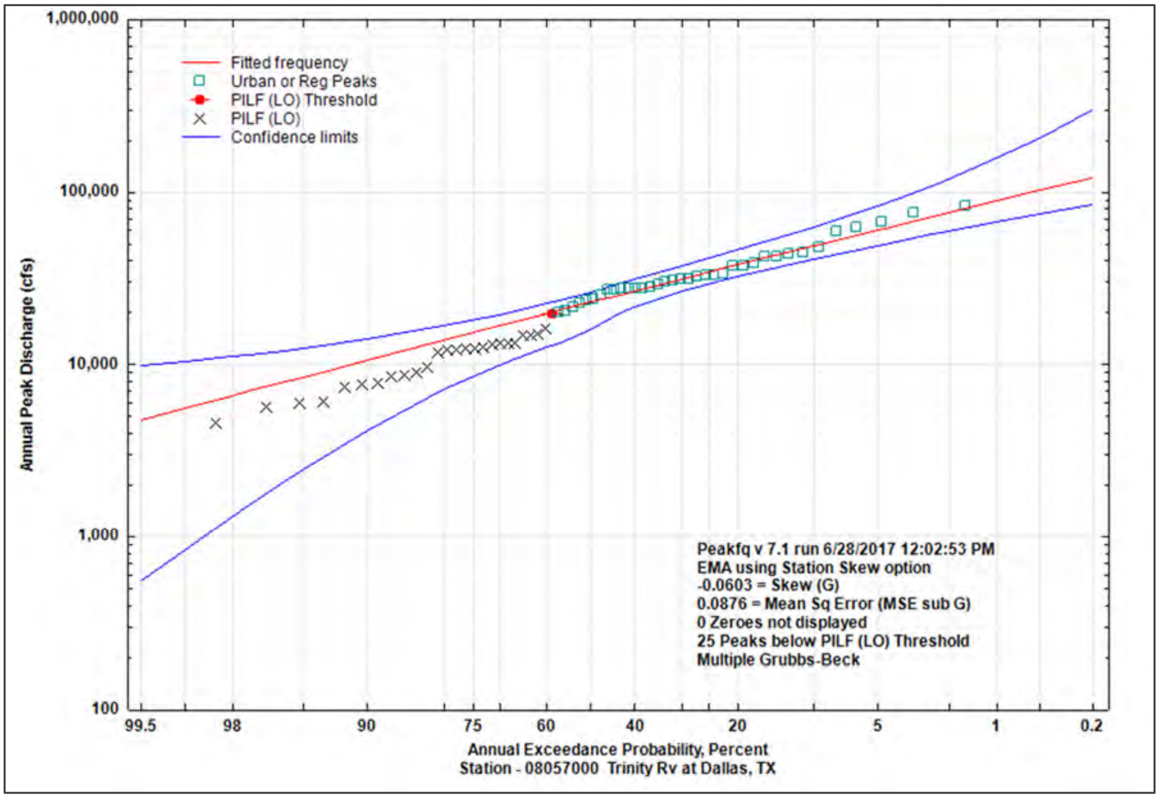

Figure 29b: Flood Flow Frequency Curve for station 08057000 Trinity River at Dallas, TX

08057200 White Rock Creek at Greenville Ave, Dallas, Texas

The gage record and the systematic record for White Rock Creek at Greenville Ave, Dallas are both 1962–2016 with a gap in record from 1981–1984. No inference of peaks for the record gap is made. The 1990 peak streamflow of 39,200 ft^3/s at a stage of 90.59 ft is the largest peak for the site. The USGS Peak-Values File flags the entire record with a code C, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. In the USGS Peak-Values File, the code 6 flag begins in 1980. The data as set up for statistical frequency analysis are shown in Figure 30a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for White Rock Creek at Greenville Ave, Dallas is shown in Figure 30b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general, visually, the flood flow frequency curve looks reliable to the inputted data. However, for the time series, whereas not having a statistical significant Kendall's Tau, the data clearly show nonstationarity (time-changing statistics). The data might show a declining trend up to the record gap, but certainly after the record gap the distribution of the data visually is distinct with what appears to be a much more pronouced declining trend. Inference of the flood potential for these data is quite uncertain, and further the largest five peaks are all about the same magnitude. Lastly, it is suggested that hydrologic and hydraulic modeling would be especially informative to assess "modern" flood potential for this site, and Figure 30b is provided mostly for historical perspective.

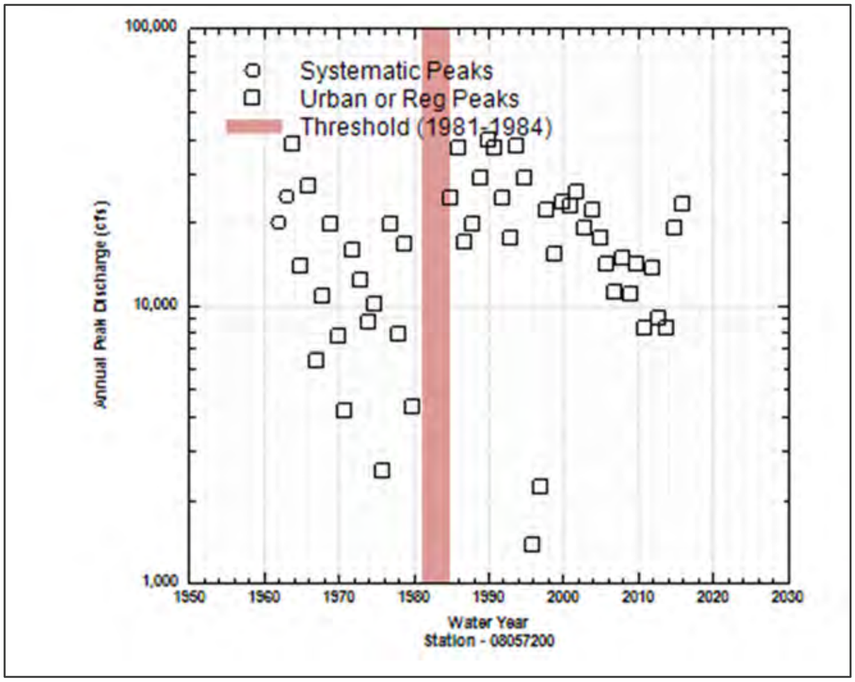

Figure 30a: Annual Peak Streamflow Data for station 08057200 White Rock Creek at Greenville Ave, Dallas, TX

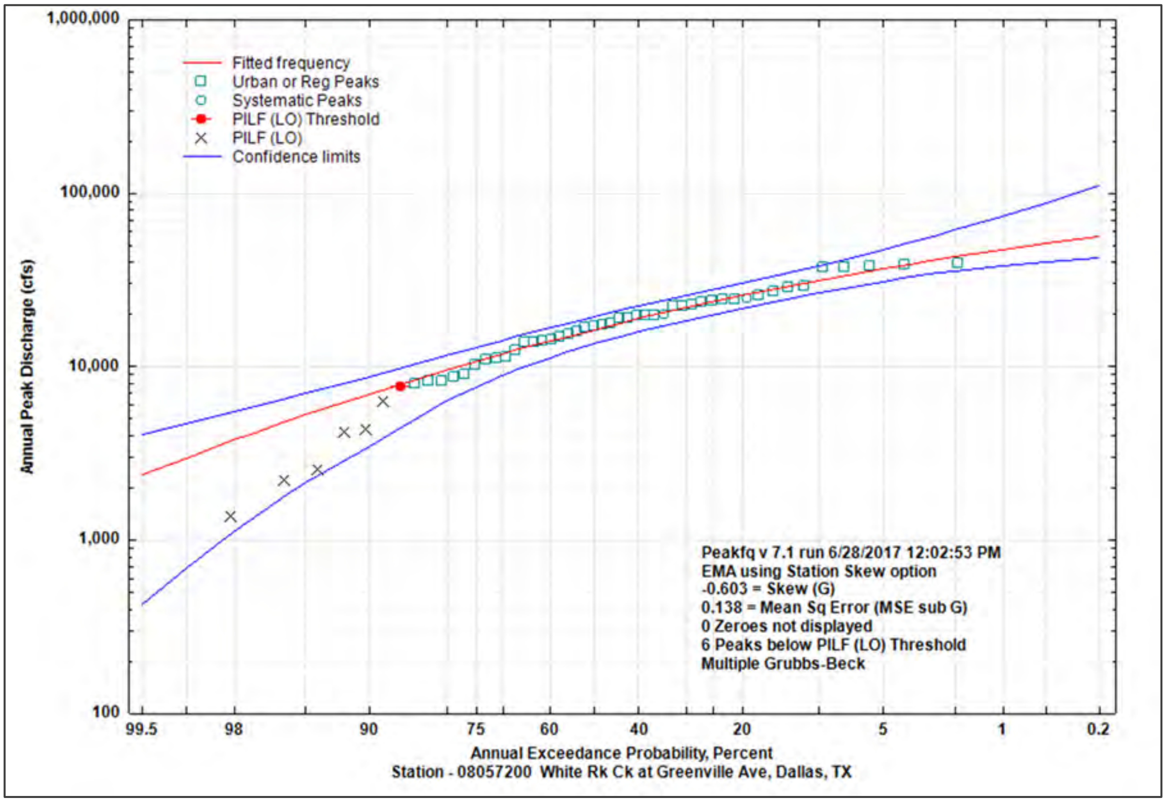

Figure 30b: Flood Flow Frequency Curve for station 08057200 White Rock Creek at Greenville Ave, Dallas, TX

08057410 Trinity River below Dallas, TX

The gage record and the systematic record for Trinity River below Dallas are both 1957–2016 with a gap in record from 2000–2002. No inference of peaks for the record gap is made. The 1990 peak of 87,000 ft^3/s at a stage of 34.79 ft is the largest peak for the site. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. Eleven major reservoirs have been built upstream of the gage: Lake Worth in 1914, Lake Bridgeport in 1931, Eagle Mountain Lake in 1932, Benbrook Lake in 1951, Lake Grapevine in 1952, Lake Lewisville in 1954, Lake Arlington in 1955, Lake Amon Carter in 1956, Lake Weatherford in 1957, Joe Pool Lake in 1986, and Lake Ray Roberts in 1986. The data as set up for statistical frequency analysis are shown in Figure 31a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Trinity River below Dallas is shown in Figure 31b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general, visually, the flood flow frequency curve appears reliable to the inputted data.

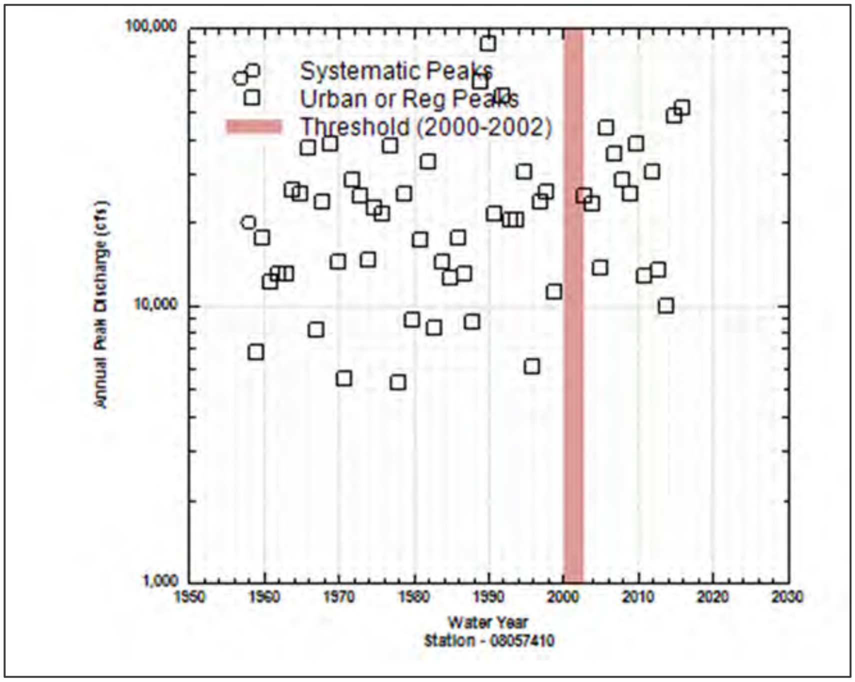

Figure 31a: Annual Peak Streamflow Data for station 08057410 Trinity River below Dallas, TX

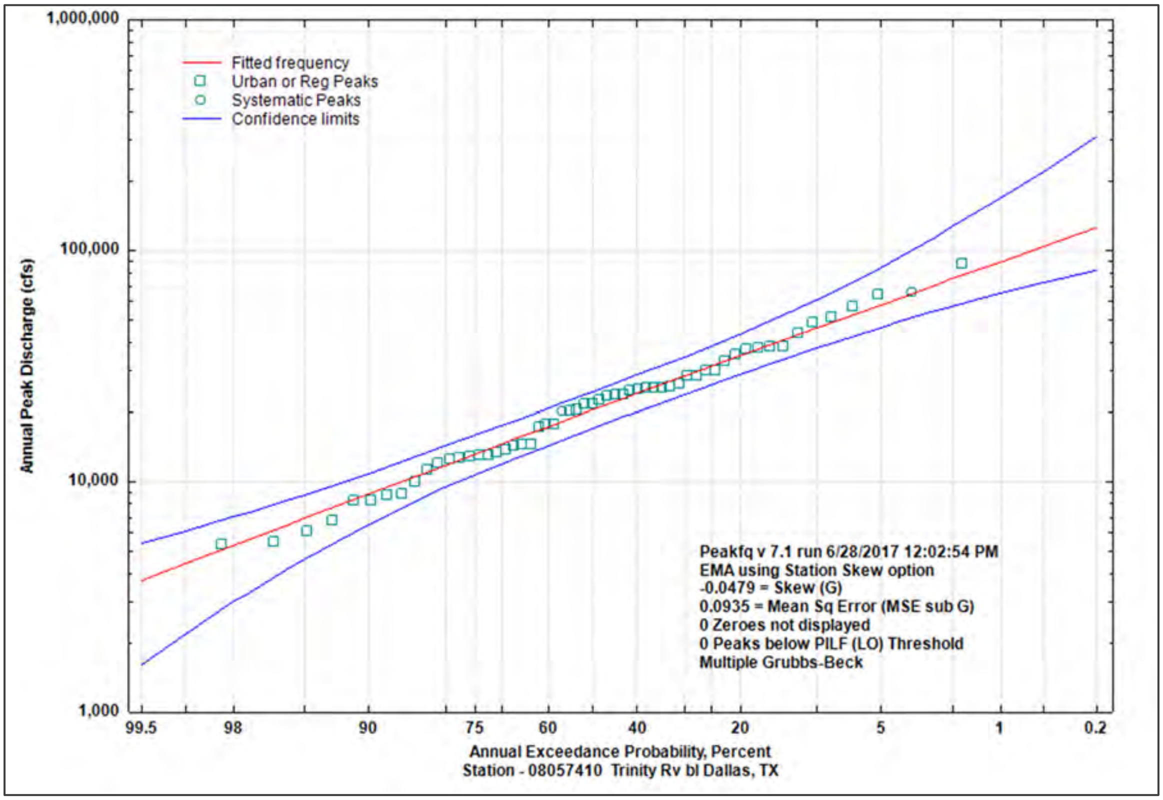

Figure 31b: Flood Flow Frequency Curve for station 08057410 Trinity River below Dallas, TX

08057445 Prairie Creek at U.S. Highway 175, Dallas, Texas

The gage record and the systematic record for Prairie Creek at U.S. Highway 175, Dallas are both 1976–2016 with a gap in the record from 1981–1984. No inference of peaks for the record gap is made. The 2004 peak streamflow is 7,050 ft^3/s at a stage of 30.51 ft is the largest peak streamflow for the site. The USGS Peak-Values File flags the entire record with a code C, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for stastistical frequency analysis are shown in Figure 32a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.066), and this is seen by visual inspection of the data. This might be indicative of watershed urbanization.

The flood flow frequency for Prairie Creek at U.S. Highway 175, Dallas is shown in Figure 32b. A low-outlier threshold was manually fixed at 800 ft^3/s, which does an appropriate job of removing low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data though inference is limited by the presence of an upward trend in the data.

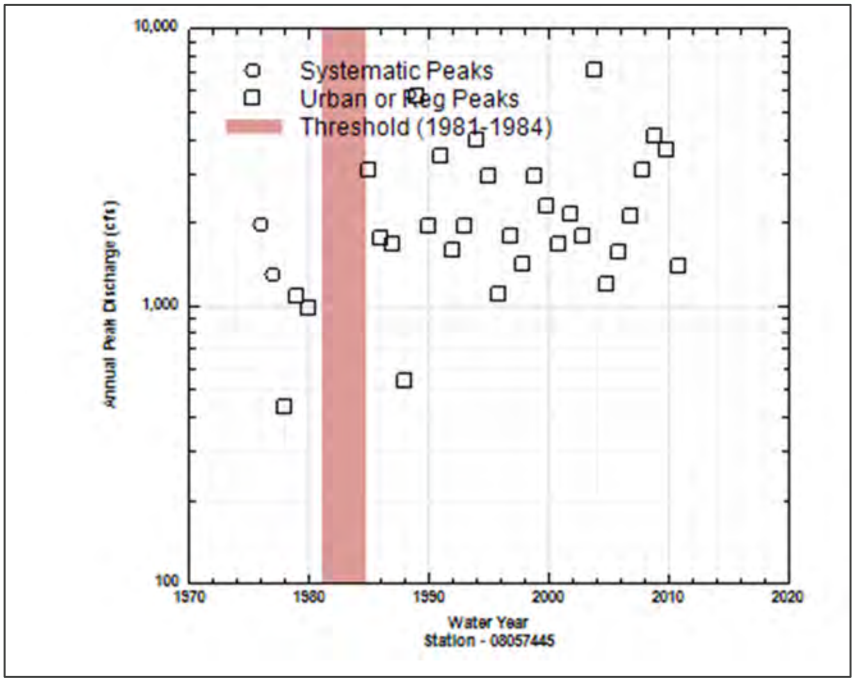

Figure 32a: Annual Peak Streamflow Data for station 08057445 Prairie Creek at U.S. Highway 175, Dallas, TX

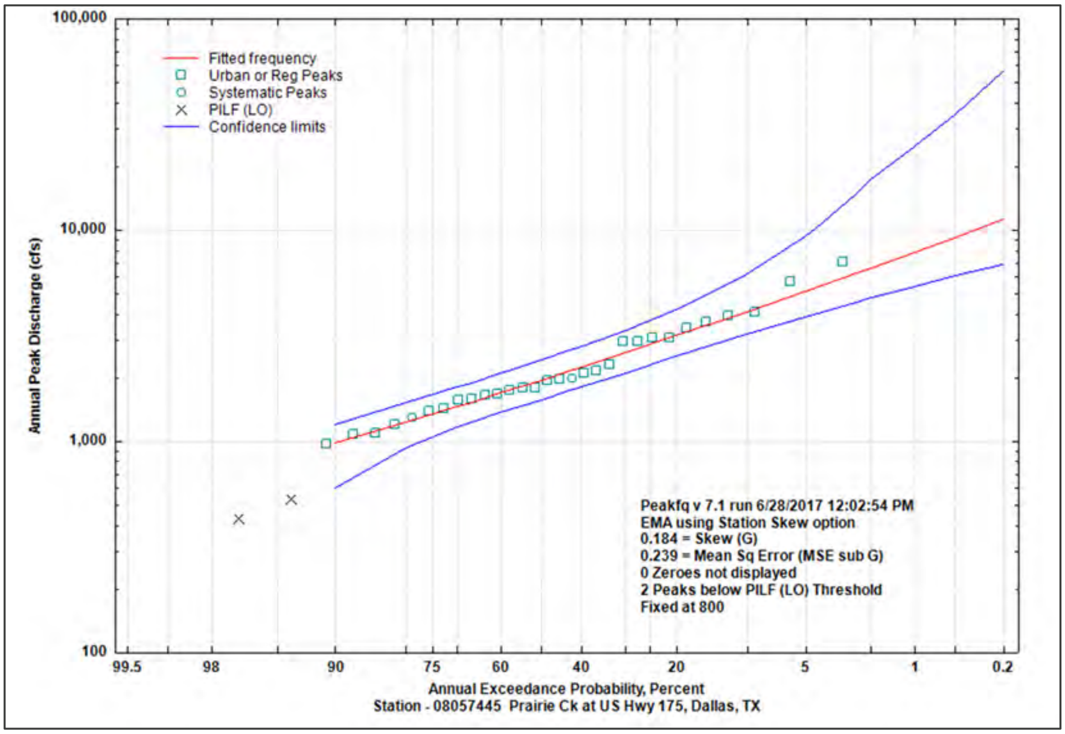

Figure 32b: Flood Flow Frequency Curve for station 08057445 Prairie Creek at U.S. Highway 175, Dallas, TX

08059000 East Fork Trinity River near McKinney, Texas

The systematic record for East Fork Trinity River near McKinney is 1950–2016 with a gap in record from 1976–2010. No inference of peaks for the record gap is made. The 1957 peak streamflow of 23,900 ft^3/s at a stage of 16.65 ft is the largest peak available for the site. However, there was a historical peak lacking a discharge in 1942 at a stage of 21.00 ft. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistical frequency analysis are shown in Figure 33a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for East Fork Trinity River near McKinney is shown in Figure 33b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data though it might be limited by the relatively short record after the 1976–2010 gap which potentially appears different from the earlier time period.

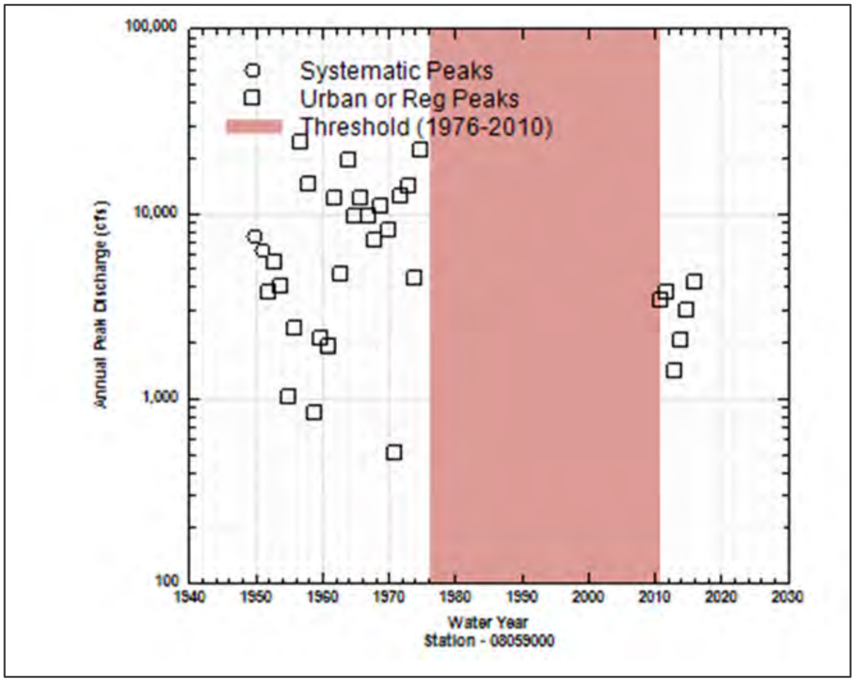

Figure 33a: Annual Peak Streamflow Data for station 08059000 East Fork Trinity River near McKinney, TX

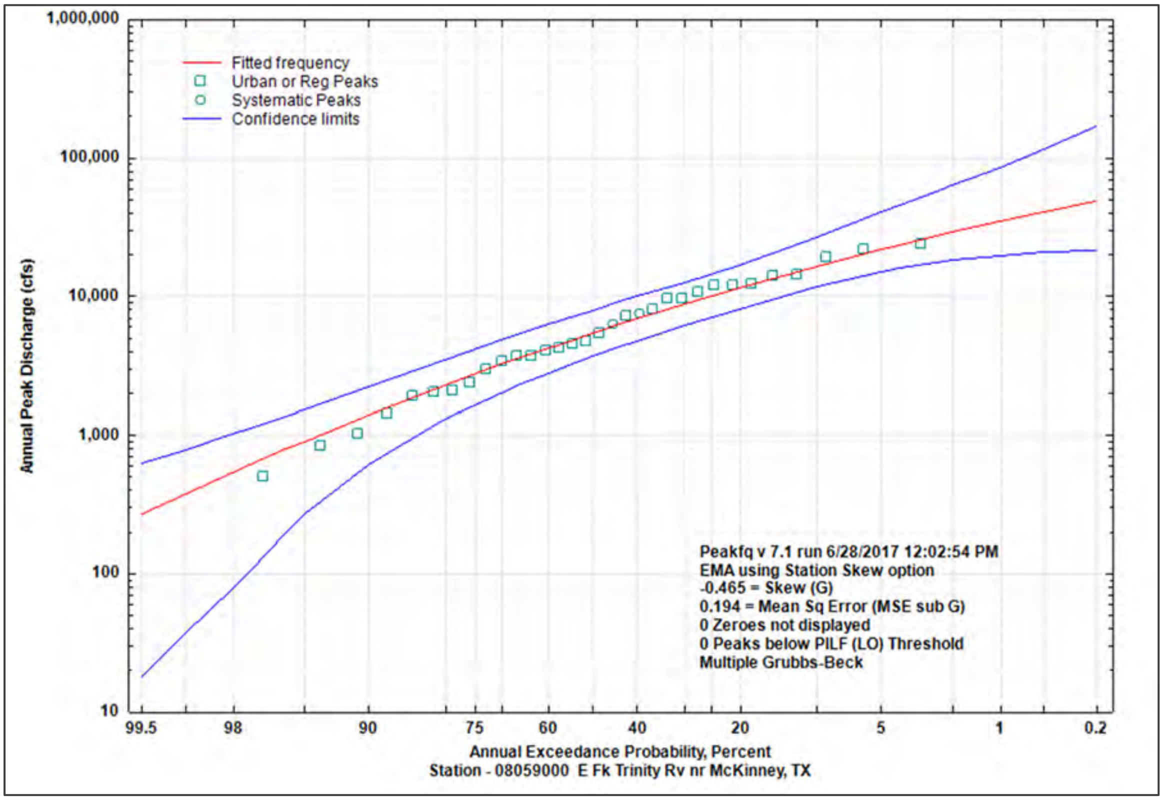

Figure 33b: Flood Flow Frequency Curve for station 08059000 East Fork Trinity River near McKinney, TX

08059400 Sister Grove Creek near Blue Ridge, Texas

The gage record and the systematic record for Sister Grove Creek near Blue Ridge are both 1976–2016. The 1982 peak streamflow of 13,300 ft^3/s at a stage of 22.50 ft is the largest peak for the site. The 2013 peak is less than 692 ft^3/s, but this is readily processed by EMA The peaks for the site are all considered regulated or urban. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistical frequency analysis are shown in Figure 34a. The discharge interval for the 2013 peak is represented as a green bar in the figure. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.080), and this is seen by visual inspection of the data. General review of the watershed does not readily yield reasoning why the data are trending upward.

The flood flow frequency for Sister Grove Creek near Blue Ridge is shown in Figure 34b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data. The largest event does depart somewhat from the fitted curve, and increasing the sample size in the future would provide much better perspective.

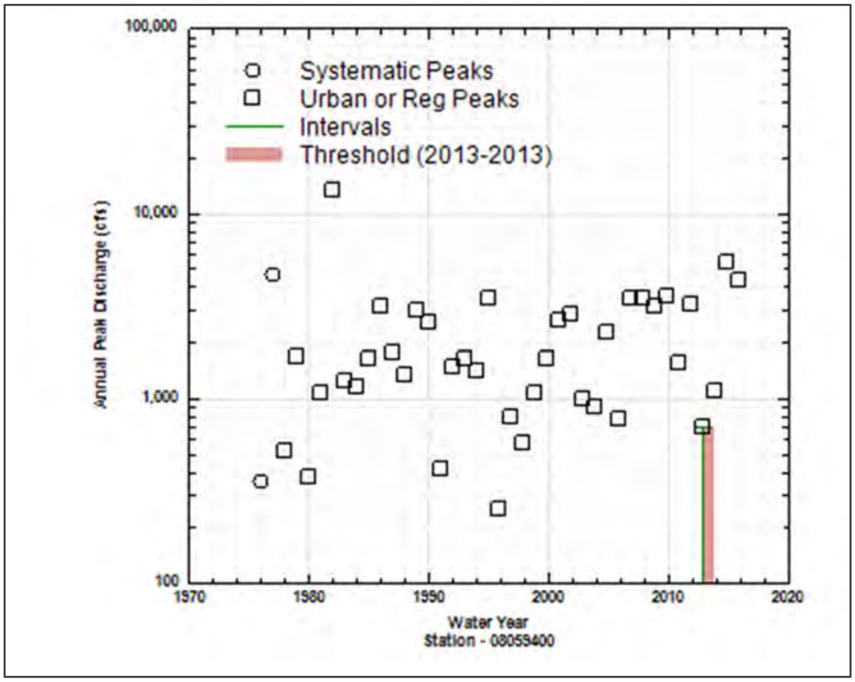

Figure 34a: Annual Peak Streamflow Data for station 08059400 Sister Grove Creek near Blue Ridge, TX

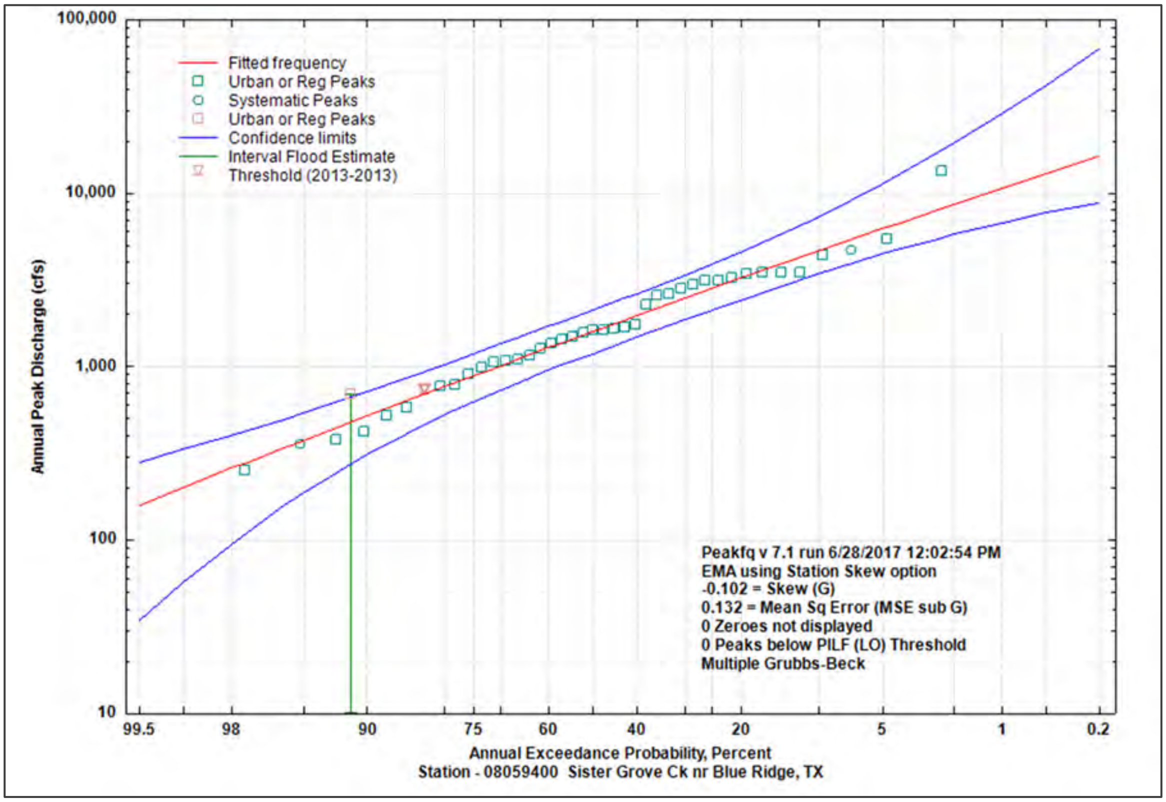

Figure 34b: Flood Flow Frequency Curve for station 08059400 Sister Grove Creek near Blue Ridge, TX

08061540 Rowlett Creek near Sachse, Texas

The gage record and the systematic record for Rowlett Creek near Sachse are both 1969–2016. The 2015 peak streamflow of 47,900 ft^3/s at a stage of 31.18 ft is the largest peak at the site. The peaks are considered unregulated. The data as set up for statistical frequency analysis are shown in Figure 35a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1). However, visually an upward (increasing) pattern of discharge with time might be occuring, and geographic review of the watershed suggests that urban and suburban development might have occurred and could be a causitive factor.

The flood flow frequency for Rowlett Creek near Sachse is shown in Figure 35b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data.

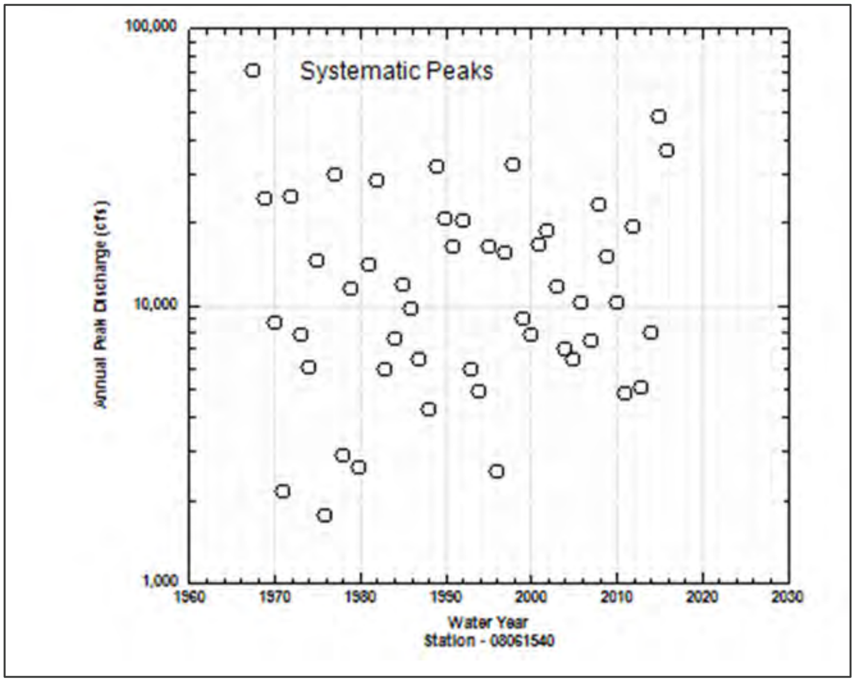

Figure 35a: Annual Peak Streamflow Data for station 08061540 Rowlett Creek near Sachse, TX

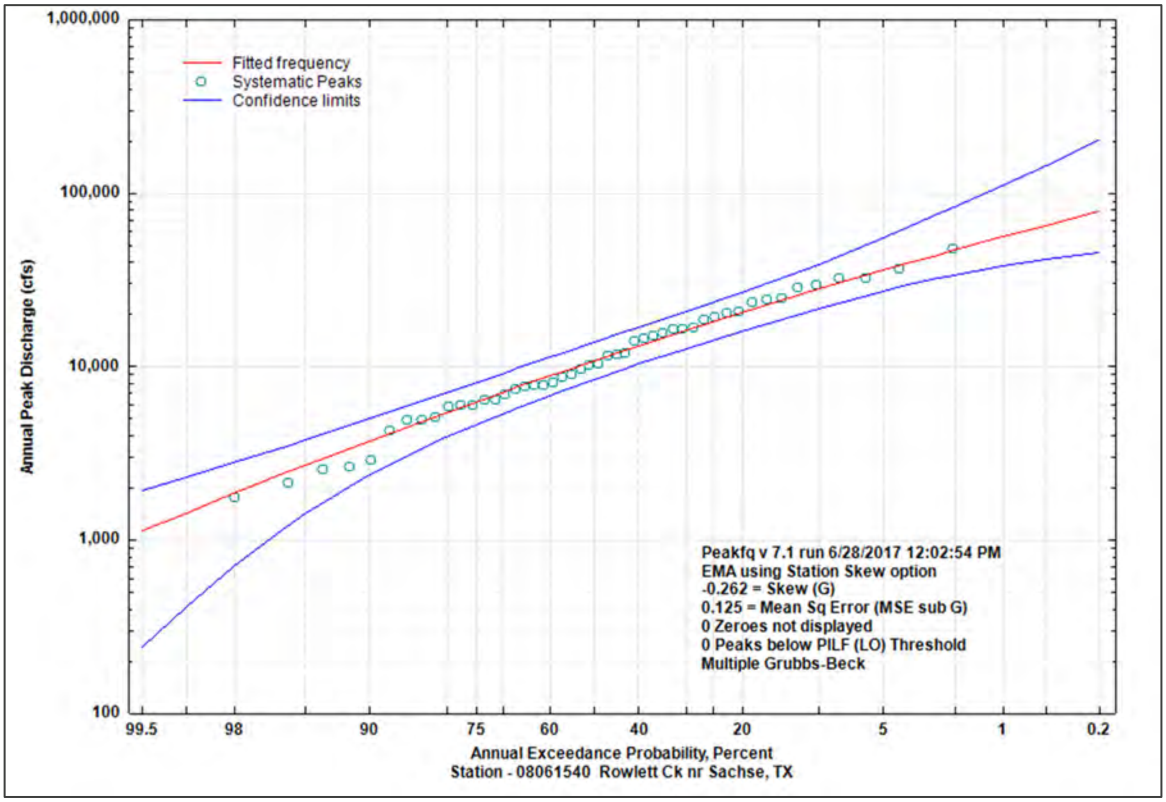

Figure 35b: Flood Flow Frequency Curve for station 08061540 Rowlett Creek near Sachse, TX

08061750 East Fork Trinity River near Forney, Texas

The gage record and the systematic record for East Fork Trinity River near Forney are both 1974–2016. The 1990 peak streamflow of 53,000 ft^3/s at a stage of 22.01 ft is the largest peak for the site. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. Two major reservoirs have been built upstream of the gage: Lake Lavon in 1953 and Lake Ray Hubbard in 1969. The data as set up for statistical frequency analysis are shown in Figure 36a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for East Fork Trinity River near Forney is shown in Figure 36b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. There appears to be a strong bimodal distribution of low streamflow at about 2,000 ft^3/s and the remainder of the data. In general visually, the flood flow frequency curve looks reliable to the inputted data. There is a possible tendency for mixed population impacts with the nine largest events somewhat larger than the fitted distribution. Increasing the sample size in the future would provide a much better perspective.

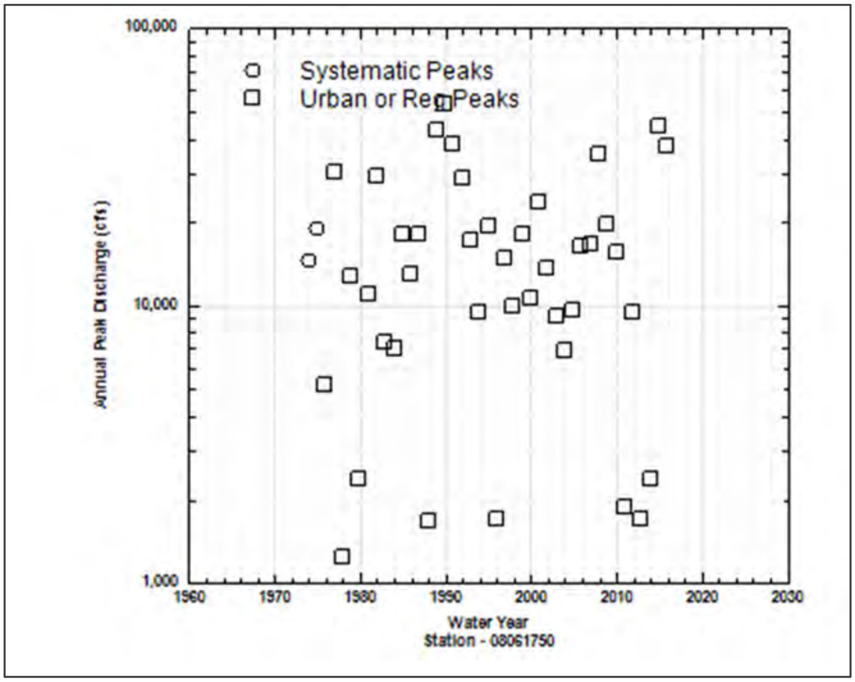

Figure 36a: Annual Peak Streamflow Data for station 08061750 East Fork Trinity River near Forney, TX

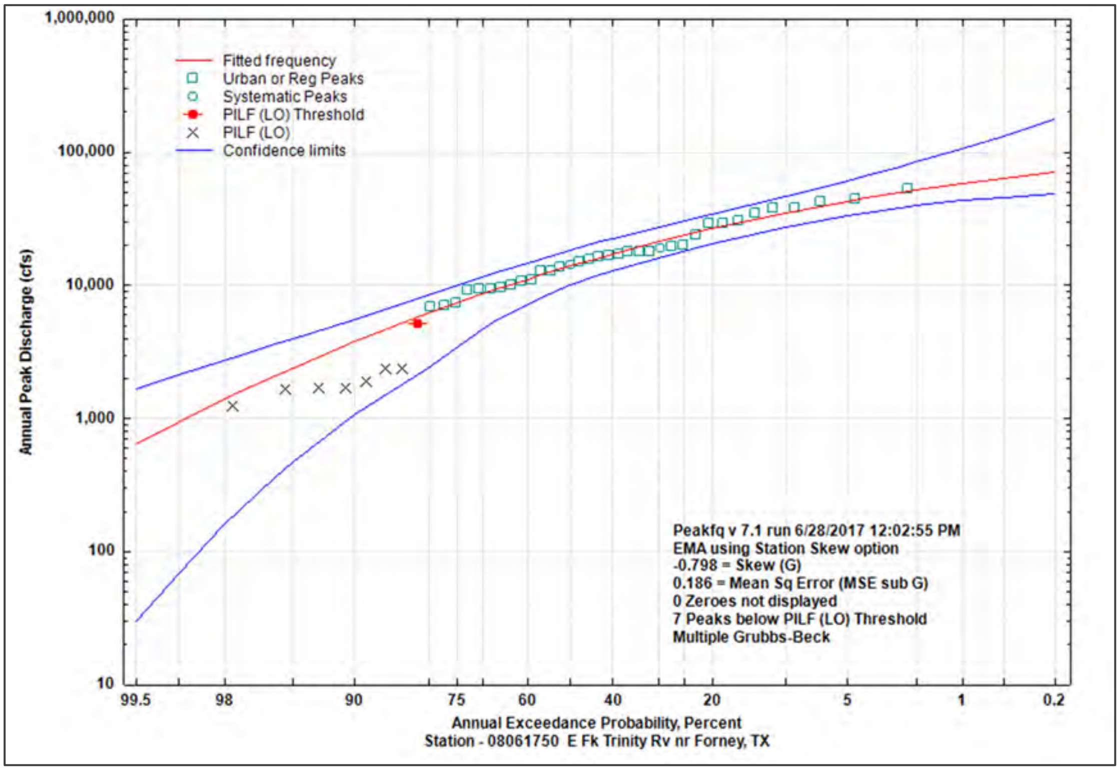

Figure 36b: Flood Flow Frequency Curve for station 08061750 East Fork Trinity River near Forney, TX

08062000 East Fork Trinity River near Crandall, Texas

The gage record for the East Fork Trinity River near Crandall is 1950–2016. The systematic record is 1954–2016 thus, peaks for 1950–1953 are not used in the analysis. The 1990 peak streamflow of 59,900 ft^3/s at a stage of 27.17 ft is the largest peak for the site. Two major reservoirs have been built upstream of the gage: Lake Lavon in 1953 and Lake Ray Hubbard in 1969. The peaks for 1950–1953 are not used because the construction of Lake Lavon dam represents a change in the watershed. The data as set up for statistical frequency analysis are shown in Figure 37a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for East Fork Trinity River near Crandall is shown in Figure 37b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

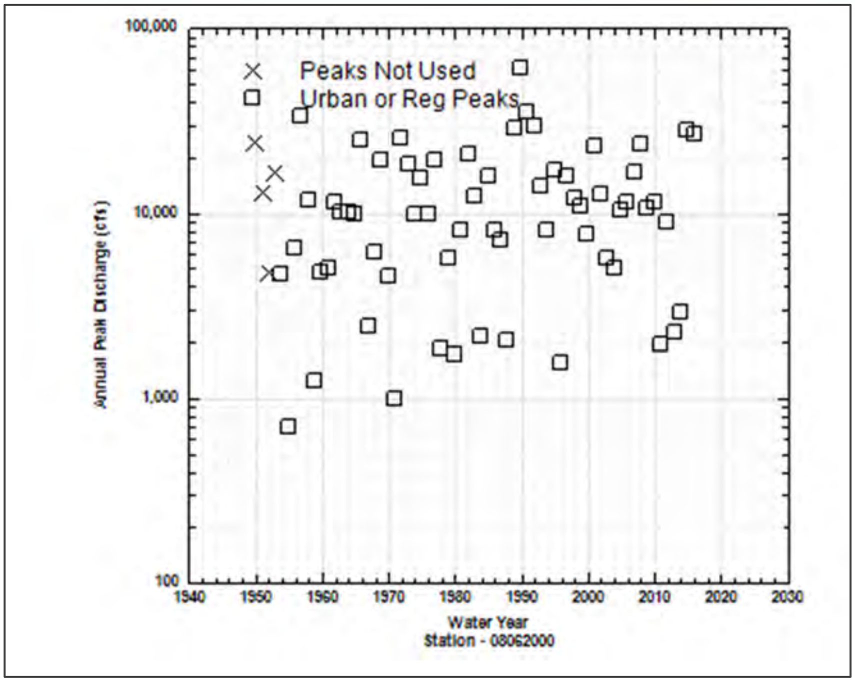

Figure 37a: Annual Peak Streamflow Data for station 08062000 East Fork Trinity River near Crandall, TX

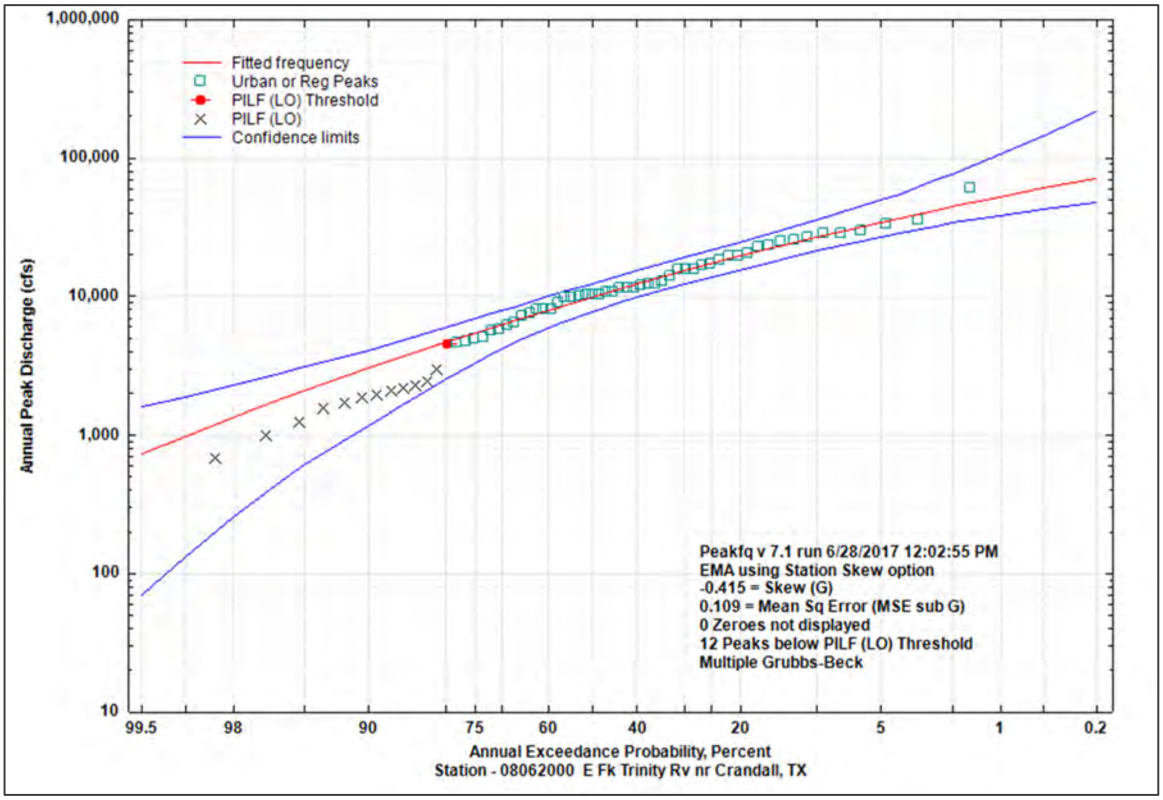

Figure 37b: Flood Flow Frequency Curve for station 08062000 East Fork Trinity River near Crandall, TX

08062500 Trinity River near Rosser, Texas

The gage record for the Trinity River near Rosser is 1925–2016. The systematic record is 1954–2016. Thus, peaks for 1908, 1925, and 1939–1953 are not used in the analysis. There are two historic peaks outside of the gage record in 1908 of 133,000 ft^3/s at a stage of 32.80 ft and in 1925 of 16,800 ft^3/s at a stage of 27.30 ft. Thirteen major reservoirs have been built upstream of the gage: Lake Worth in 1914, Lake Bridgeport in 1931, Eagle Mountain Lake in 1932, Benbrook Lake in 1951, Lake Grapevine in 1952, Lake Lavon in 1953, Lake Lewisville in 1954, Lake Arlington in 1955, Lake Amon Carter in 1956, Lake Weatherford in 1957, Lake Ray Hubbard in 1969, Joe Pool Lake in 1986, and Lake Ray Roberts in 1986. The peaks for 1908, 1925, and 1939–1953 are not used because of the construction of the Lake Lewisville dam and some temporal consistency with decisions made for upstream stream gages. The data as set up for statistical frequency analysis are shown in Figure 38a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.030), and this is seen by visual inspection of the data. However, visualy it is difficult to discern that the detected trend would be statistically significant.

The flood flow frequency for Trinity River near Rosser is shown in Figure 38b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data.

An alternative analysis for this stream gage was made for a systematic period of 1939–2016, which encompasses the entire period of record. The analysis was made because there exists ambiguity in the importance of upstream flood-flow regulation because of so much of it being quite far upstream. Tabulated and graphical results of this analysis are not reported here. However, comparison to select quantiles of the 100-, 200-, and 500-year average return periods (recurrence intervals) between the two analysis is informative. For the 1954–2016 period discussed above, the respective estimates are 114,900; 133,700; and 160,400 ft^3/s for the 100-, 200-, and 500-year return periods. For the 1939–2016 period, the respective estimates are 129,800; 153,200; and 187,200 ft^3/s. Collectively, these results are compatible with one another when acknowledging the inherent uncertainties, but the longer analysis of 1939–2016 produces larger estimates, which is consistent with the inclusion of about 15 years of record predating the establishment of substantial flood-flow regulatory capacity in the upper Trinity River basin.

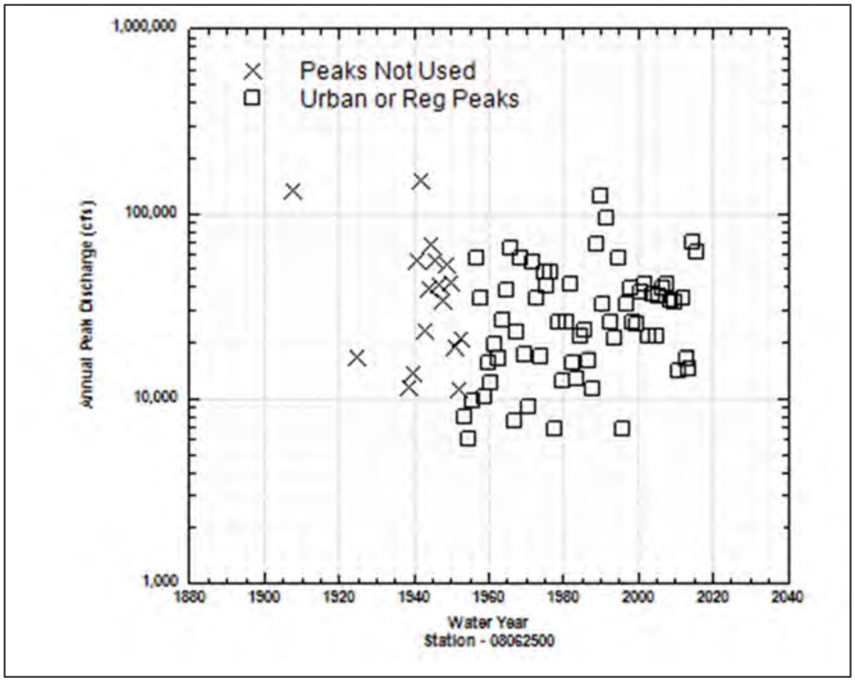

Figure 38a: Annual Peak Streamflow Data for station 08062500 Trinity River near Rosser, TX

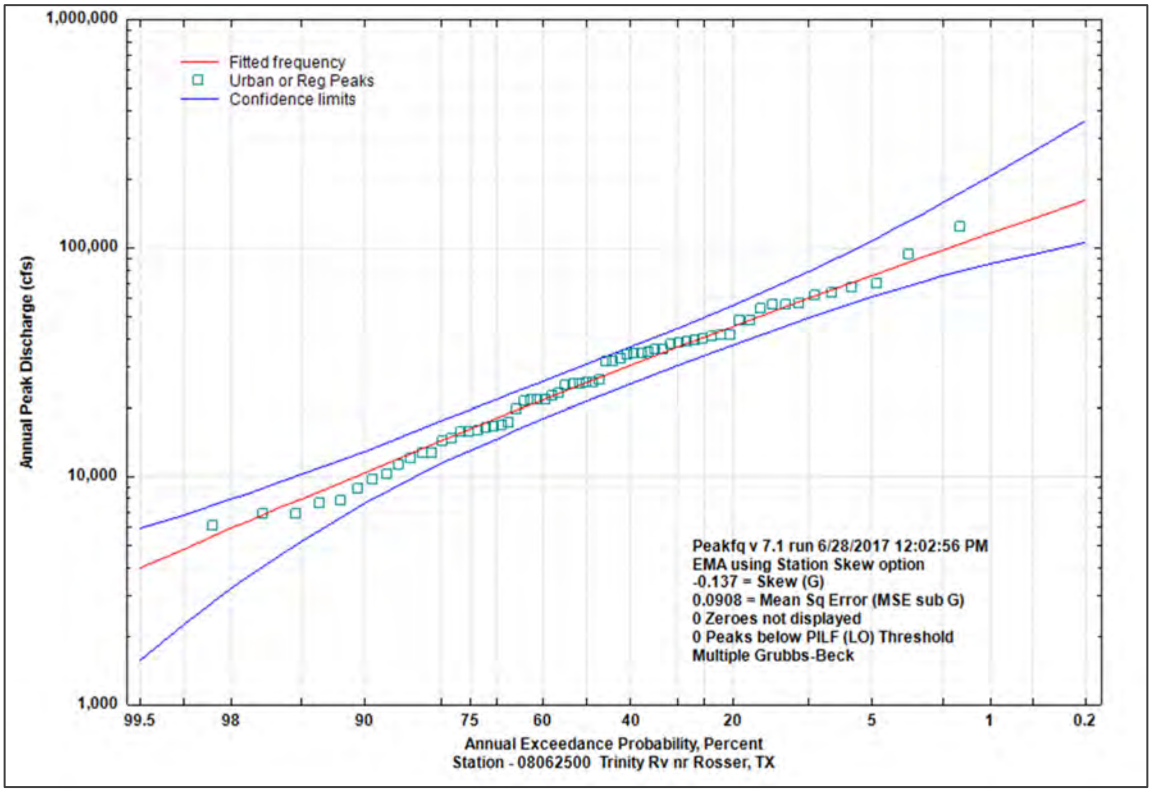

Figure 38b: Flood Flow Frequency Curve for station 08062500 Trinity River near Rosser, TX

08062700 Trinity River at Trinidad, Texas

The gage record and the systematic record for Trinity River at Trinidad are both 1965–2016. The 1990 peak streamflow of 94,500 ft^3/s at a stage of 48.11 ft is the largest peak for the site. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. Thirteen major reservoirs have been built upstream of the gage: Lake Worth in 1914, Lake Bridgeport in 1931, Eagle Mountain Lake in 1932, Benbrook Lake in 1951, Lake Grapevine in 1952, Lake Lavon in 1953, Lake Lewisville in 1954, Lake Arlington in 1955, Lake Amon Carter in 1956, Lake Weatherford in 1957, Lake Ray Hubbard in 1969, Joe Pool Lake in 1986, and Lake Ray Roberts in 1986. While Cedar Creek Reservoir is geographically downstream of the gage, it is unorthodox in that its spillway is oriented so that spillway flow laterally exits the reservoir and enters the Trinity River upstream of the Trinidad stream gage. The data as set up for statistical frequency analysis are shown in Figure 39a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Trinity River at Trinidad is shown in Figure 39b. A low-outlier threshold was manually fixed at 20,000 ft^3/s, which does an appropriate job of removing low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

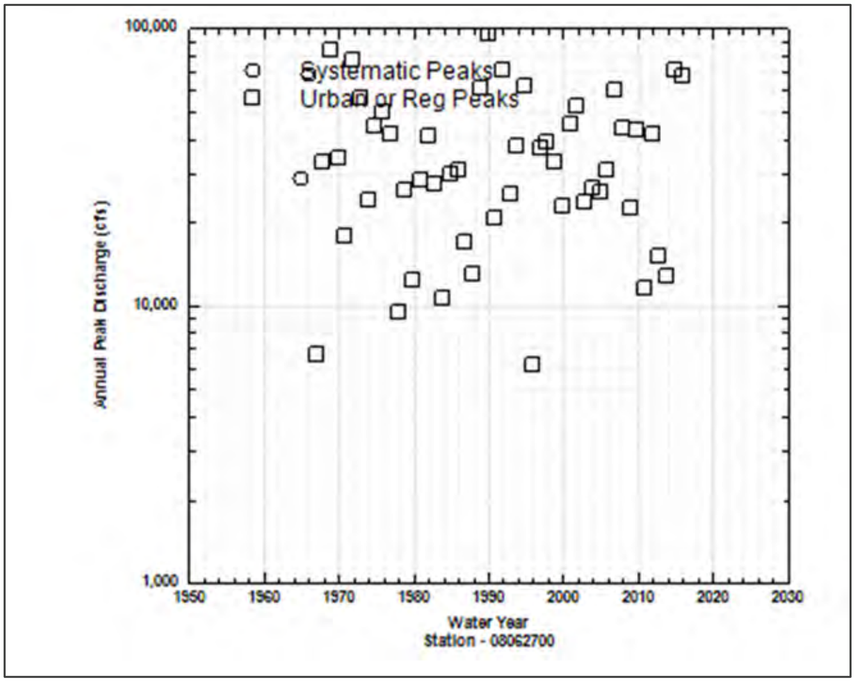

Figure 39a: Annual Peak Streamflow Data for station 08062700 Trinity River at Trinidad, TX

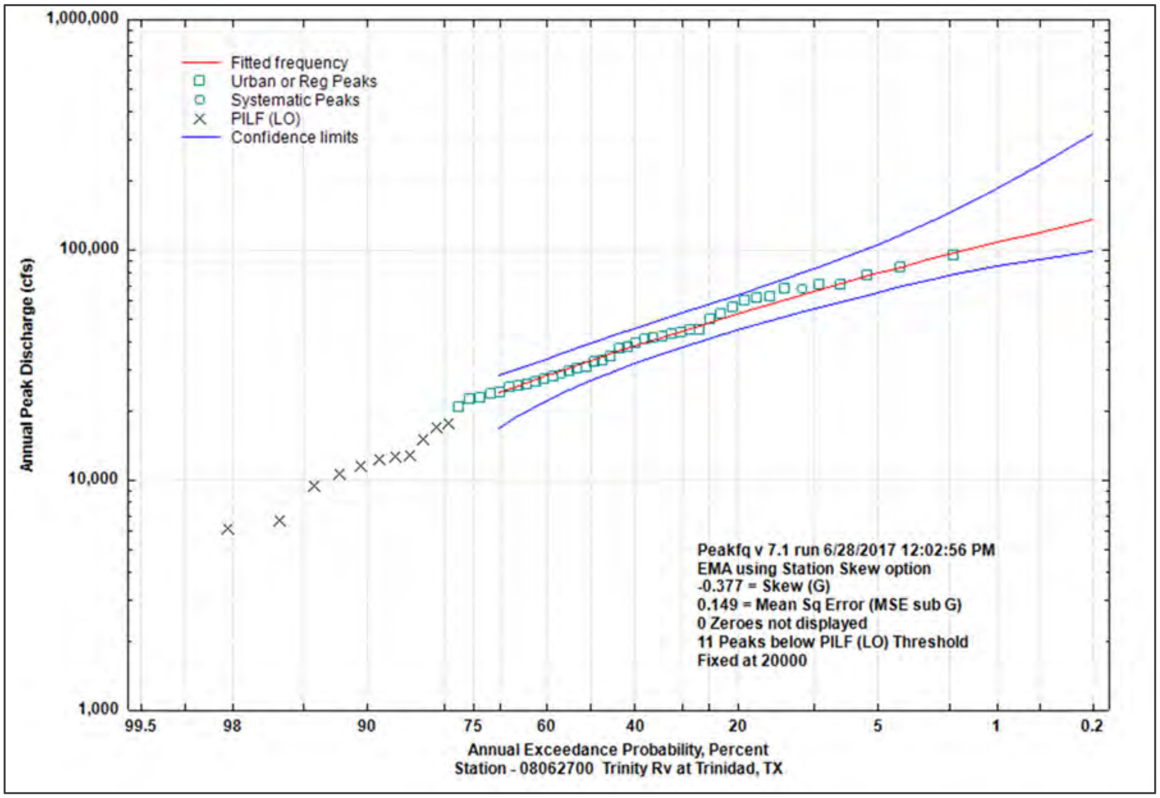

Figure 39b: Flood Flow Frequency Curve for station 08062700 Trinity River at Trinidad, TX

08062800 Cedar Creek near Kemp, Texas

The gage record for the Cedar Creek near Kemp is 1963–2016 with a gap in record from 1988–2002. The systematic record is 1970–2016; thus, peaks for 1963–1969 are not used in the analysis. The 1983 peak streamflow of 15,900 ft^3/s at a stage of 14.90 ft is the largest peak of the systematic record. The largest observed peak is 27,000 ft^3/s at a stage of 16.00 ft in 1966 within the gage record. The 1970–2016 period represents for the watershed a generalized static flood storage capacity, and code 6 in the USGS Peak-Values File began in 1970. The data as set up for statistically frequency analysis are shown in Figure 40a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Cedar Creek near Kemp is shown in Figure 40b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data.

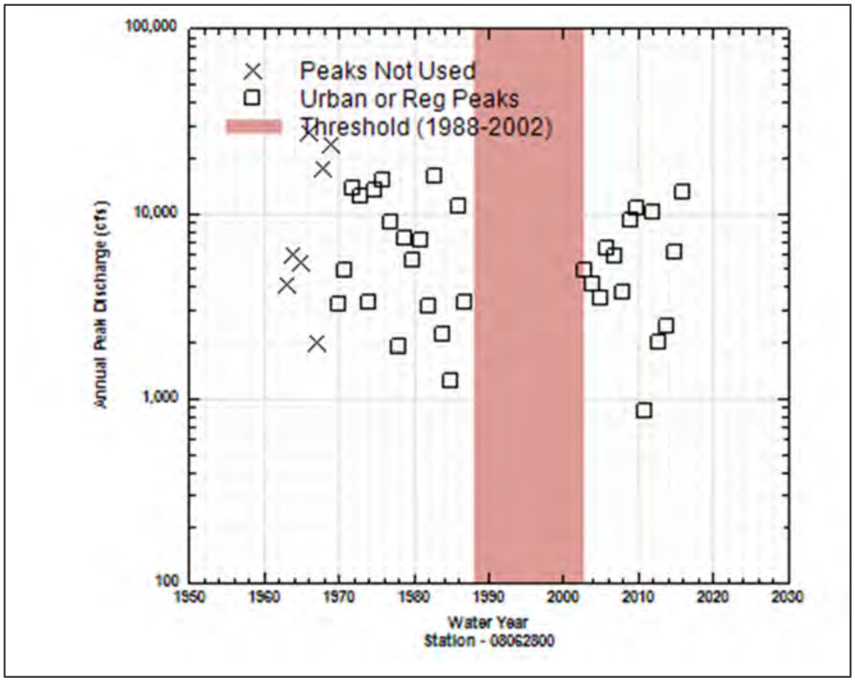

Figure 40a: Annual Peak Streamflow Data for station 08062800 Cedar Creek near Kemp, TX

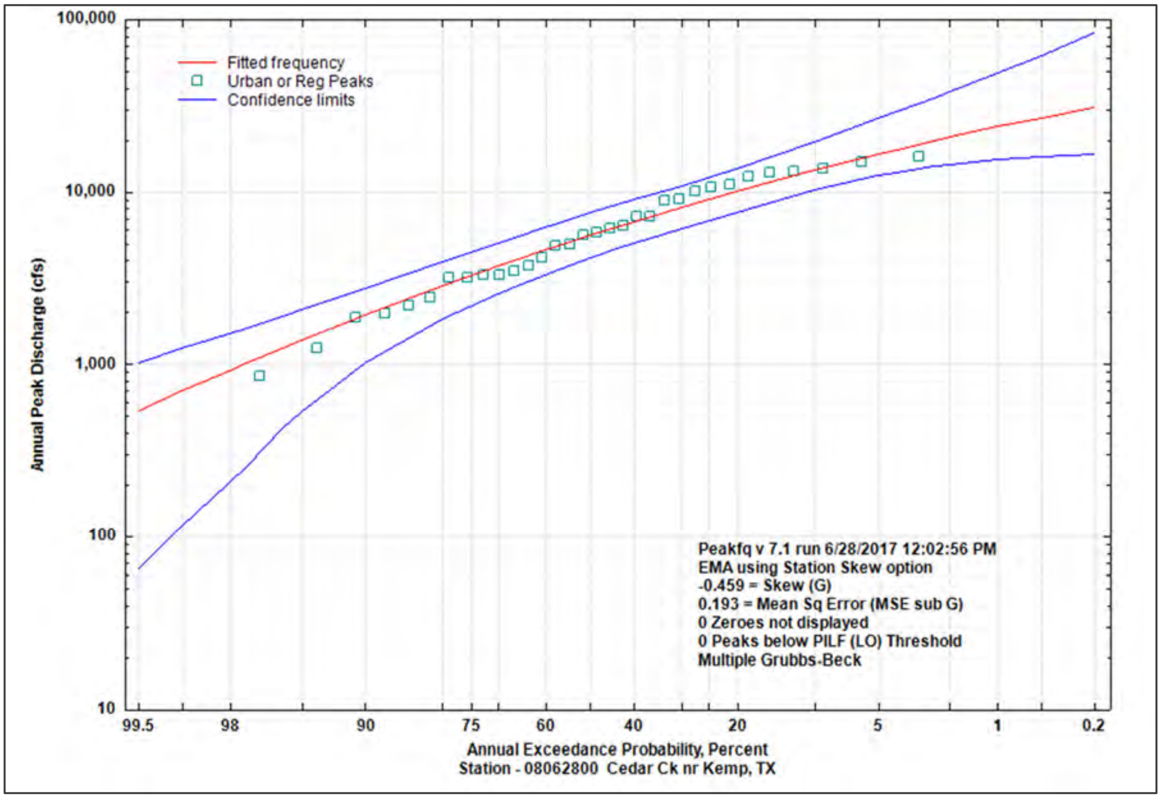

Figure 40b: Flood Flow Frequency Curve for station 08062800 Cedar Creek near Kemp, TX

08063100 Richland Creek near Dawson, Texas

The gage record for the Richland Creek near Dawson is 1961–2016. The systematic record is 1963–2016; thus, peaks for 1961–1962 are not used in the analysis. The USGS Peak-Values File began a code 6 designation in 1963 because of nearby Navarro Mills Lake. The 1961 peak streamflow of 25,500 ft^3/s at a stage of 22.5 ft is a record at the location, and the 1962 peak streamflow of 15,800 ft^3/s at a stage of 21.64 ft is the second highest. Both of these peaks predate the current (“modern”) regulated record. The 2016 peak streamflow of 5,520 ft^3/s at a stage of 23.74 ft is the largest during the systematic record. The data as set up for statistically frequency analysis are shown in Figure 41a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Richland Creek near Dawson is shown in Figure 41b. A weighted skew option was used with skew equal to -0.50 and a mean square error of 0.123 (Judd et al., 1996); this was done because stream gages in the Richland-Chambers reservoir watershed were treated as an ensemble due to a very short record for one of the sites. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data. A mixed population effect might cause the visible flattening at about 4,000 ft^3/s.

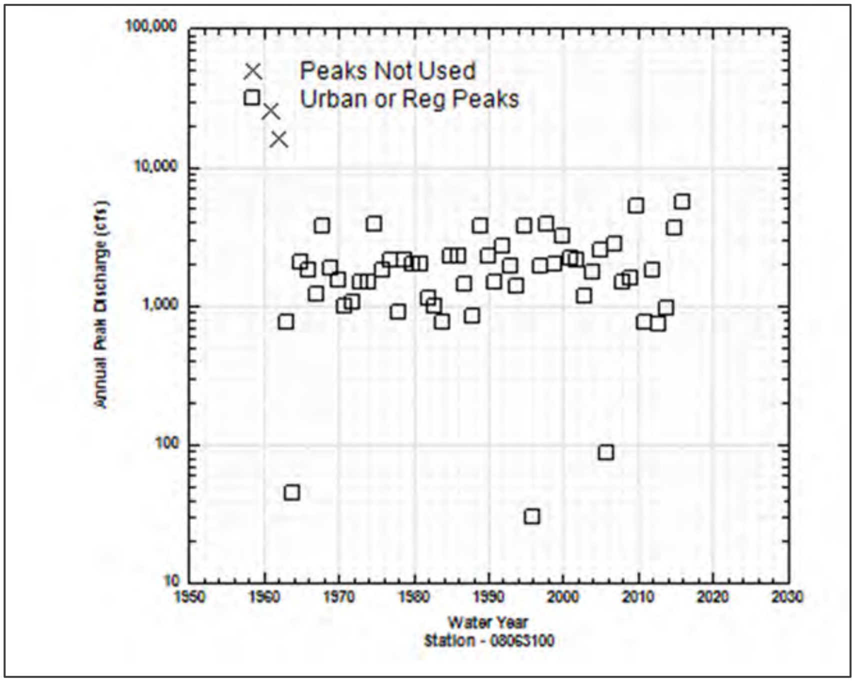

Figure 41a: Annual Peak Streamflow Data for station 08063100 Richland Creek near Dawson, TX

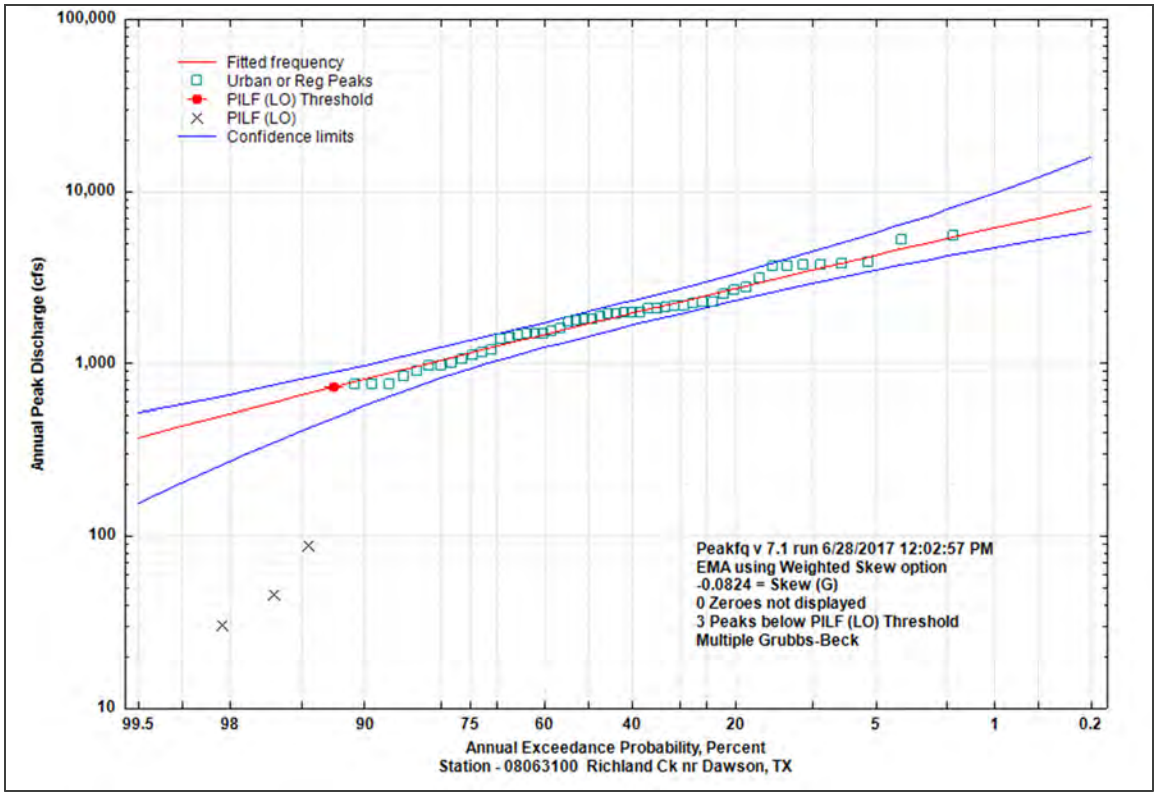

Figure 41b: Flood Flow Frequency Curve for station 08063100 Richland Creek near Dawson, TX

08063590 Waxahachie Creek at Waxahachie, Texas

The gage record and the systematic record for Waxahachie Creek at Waxahachie are both 2009–2016. The 2009 peak streamflow of 3,270 ft^3/s at a stage of 23.98 ft is the largest peak in the gage record. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistically frequency analysis are shown in Figure 42a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Waxahachi Creek at Waxahachie is shown in Figure 42b. A weighted skew option was used with skew equal to 0.00 and mean square error of 0.123 (Judd and others, 1996); this was done because stream gages in the Richland-Chambers reservoir watershed were treated as an ensemble due to a short record for one of the sites. The Waxahachie Creek at Waxahachie is this short record site. No low outliers were detected by the Multiple Grubbs-Beck outlier test. Inference of flood potential for this site is problematic because of extremely short record. Mixed population effects might be visible by the flattening of the data at about 3,000 ft^3/s.

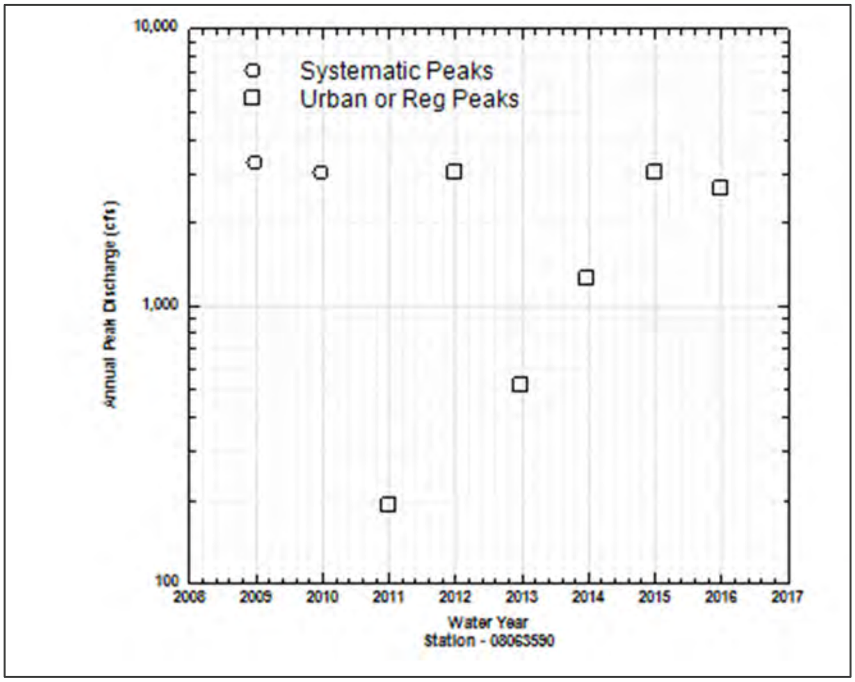

Figure 42a: Annual Peak Streamflow Data for station 08063590 Waxahachie Creek at Waxahachie, TX

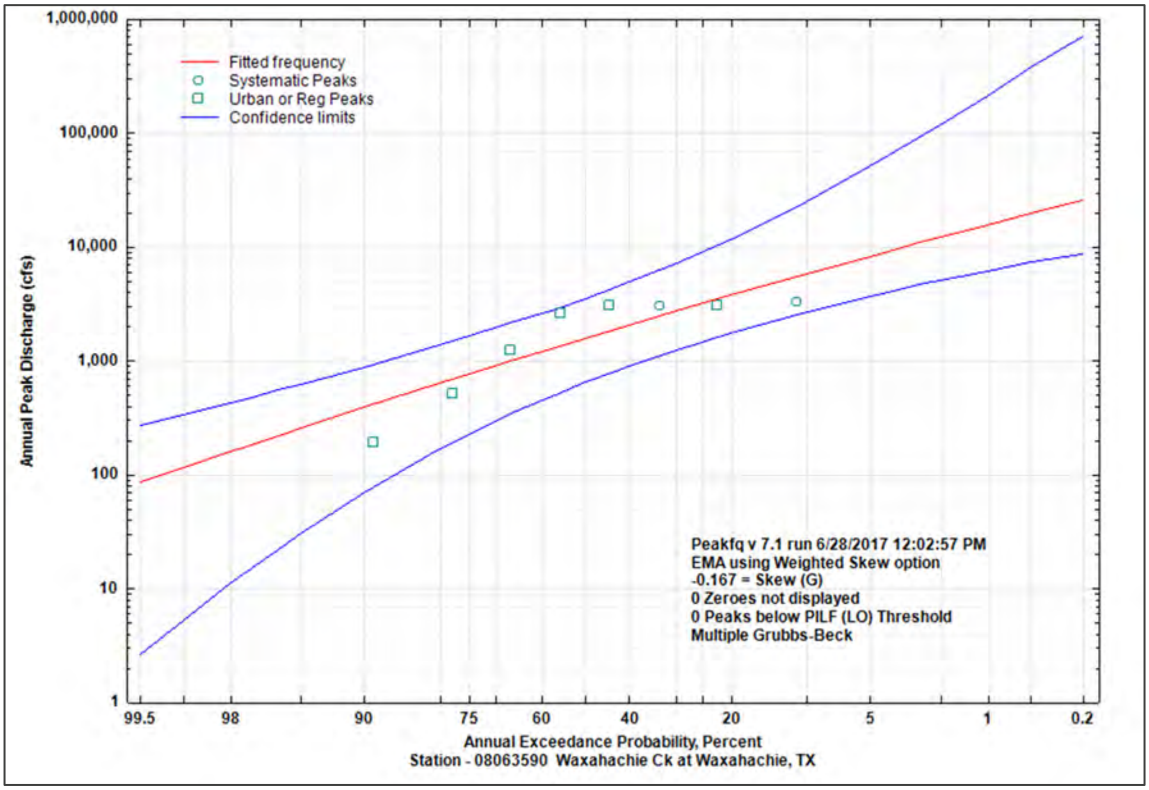

Figure 42b: Flood Flow Frequency Curve for station 08063590 Waxahachie Creek at Waxahachie, TX

08063800 Waxahachie Creek near Bardwell, Texas

The gage record and the systematic record for Waxahachie Creek near Bardwell are both 1964–2016. The 1965 peak streamflow of 2,960 ft^3/s at a stage of 17.55 ft is the largest peak streamflow in the gage record. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. The data as set up for statistical frequency analysis are shown in Figure 43a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Waxahachie Creek near Bardwell is shown in Figure 43b. A weighted skew option was used with skew equal to 0.00 and mean square error of 0.123 (Judd and others, 1996); this was done because stream gages in the Richland-Chambers reservoir watershed were treated as an ensemble due to a short record for one of the sites. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

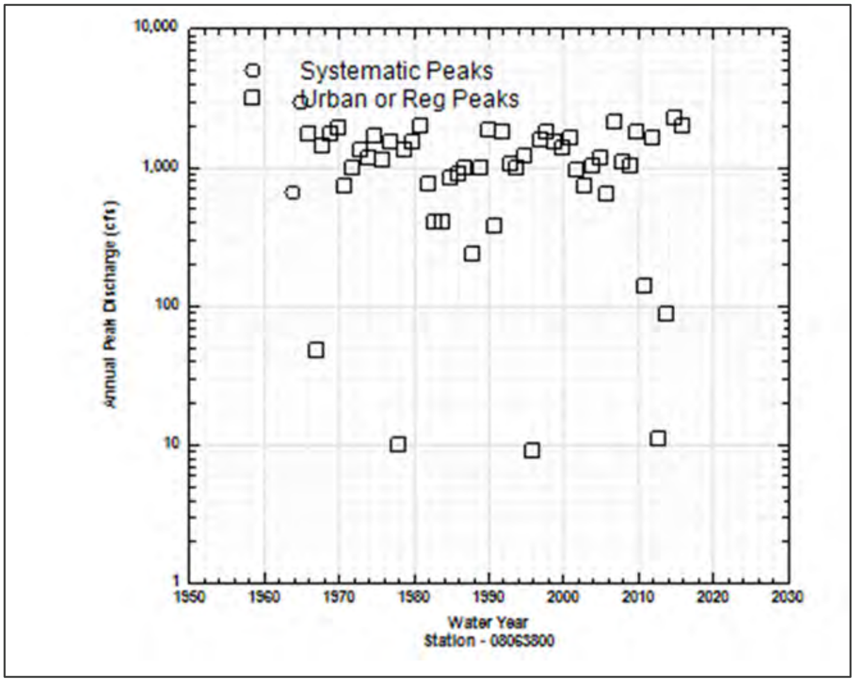

Figure 43a: Annual Peak Streamflow Data for station 08063800 Waxahachie Creek near Bardwell, TX

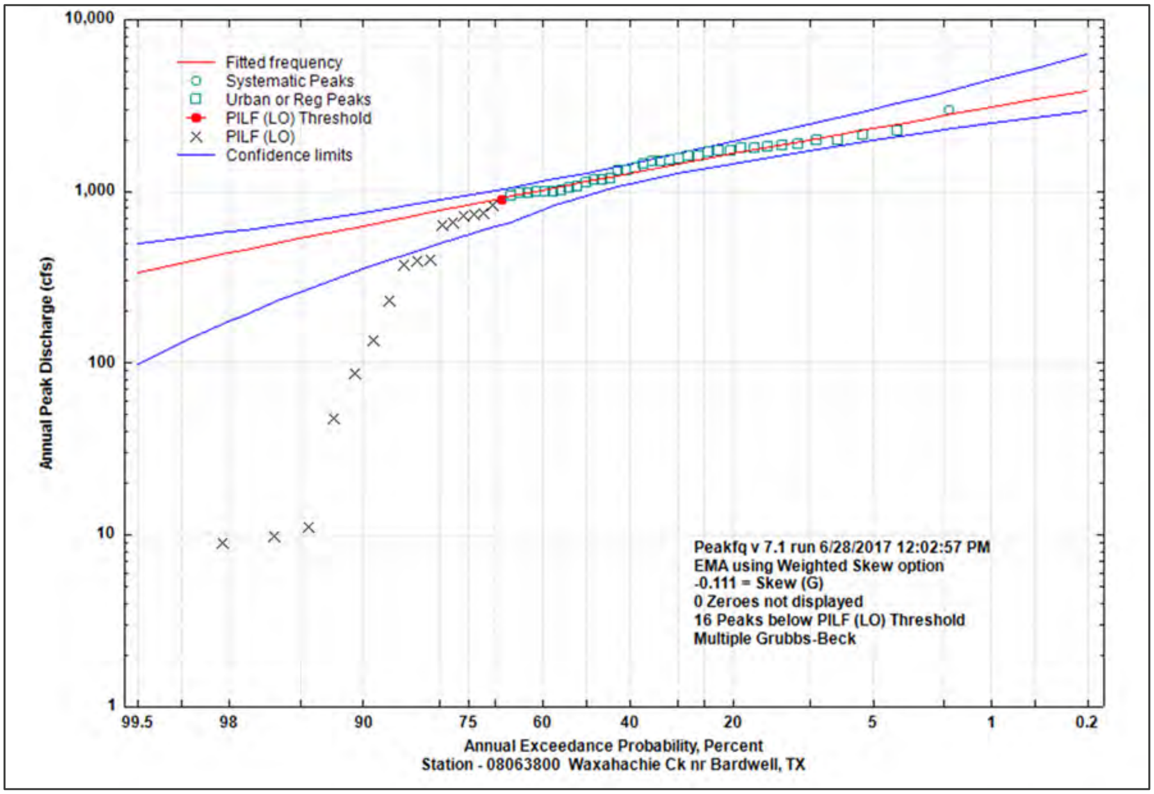

Figure 43b: Flood Flow Frequency Curve for station 08063800 Waxahachie Creek near Bardwell, TX

08064100 Chambers Creek near Rice, Texas

The gage record and the systematic record for Chambers Creek near Rice are both 1984–2016. The 1986 peak streamflow of 43,400 ft^3/s at a stage of 31.12 ft is the largest peak for the site. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. Bardwell Lake was installed before the stream gage making all of the peaks in this analysis regulated peaks. The data as set up for statistical frequency analysis are shown in Figure 44a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Chambers Creek near Rice is shown in Figure 44b. A weighted skew option was used with skew equal to 0.00 and mean square error of 0.123 (Judd and others, 1996); this was done because stream gages in the Richland-Chambers reservoir watershed were treated as an ensemble due to a short record for one of the sites. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data.

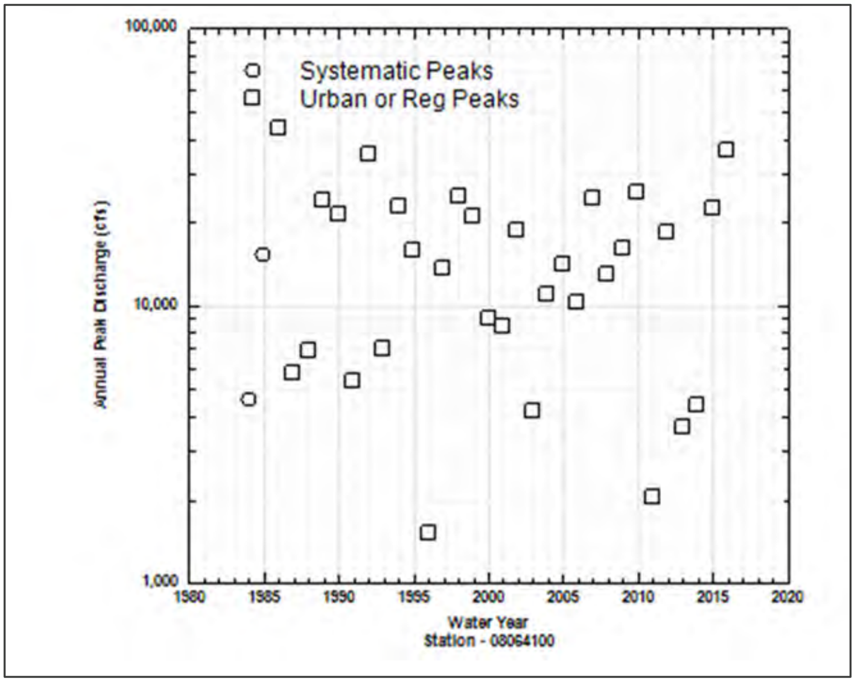

Figure 44a: Annual Peak Streamflow Data for station 08064100 Chambers Creek near Rice, TX

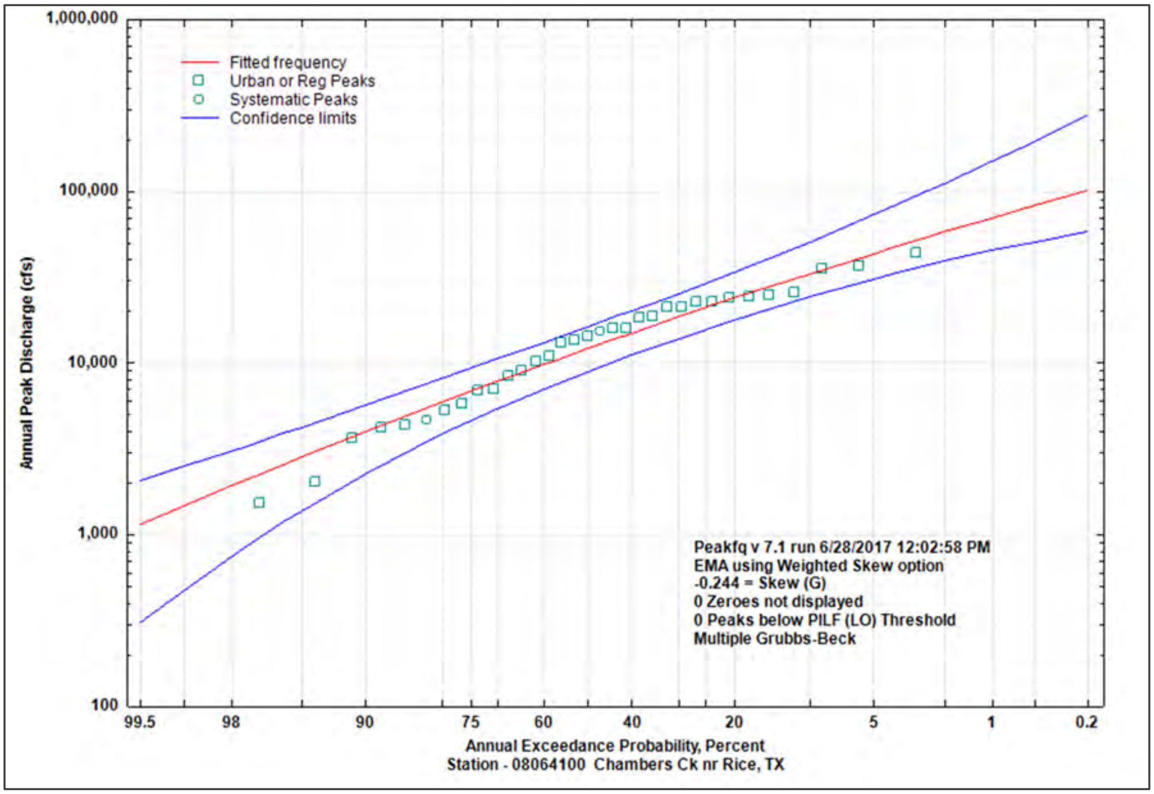

Figure 44b: Flood Flow Frequency Curve for station 08064100 Chambers Creek near Rice, TX

08064700 Tehuacana Creek near Streetman, Texas

The gage record and the systematic record for Tehuacana Creek near Streetman are both 1969–2016. The 1989 peak streamflow of 85,700 ft^3/s at a stage of 30.20 ft is the largest peak streamflow for the site. The data as set up for statistical frequency analysis are shown in Figure 45a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.052), and this is seen by visual inspection of the data. The data appear to show a change in their spread or distribution on the time series plot starting about 1988. USGS stream gage description does not yield any pertinent information suggesting a change. Further speculation as to whether this is true and offering a hypothesis as to why are outside the scope of this study.

The flood flow frequency for Tehuacana Creek near Streetman is shown in Figure 45b. A low-outlier threshold was manually fixed at 2,000 ft^3/s, which does an appropriate job of removing low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data; though it is possible that the largest peaks are breaking away from the fitted distribution. Because of the appearance of a hinge point at about 10,000 ft^3/s in the figure, it is possible that mixed population effects might be occurring.

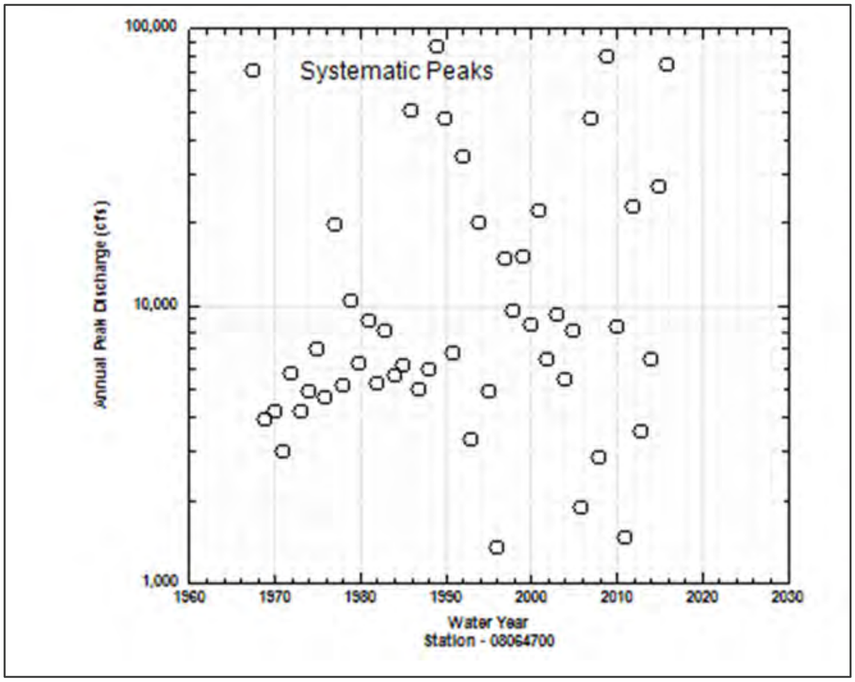

Figure 45a: Annual Peak Streamflow Data for station 08064700 Tehuacana Creek near Streetman, TX

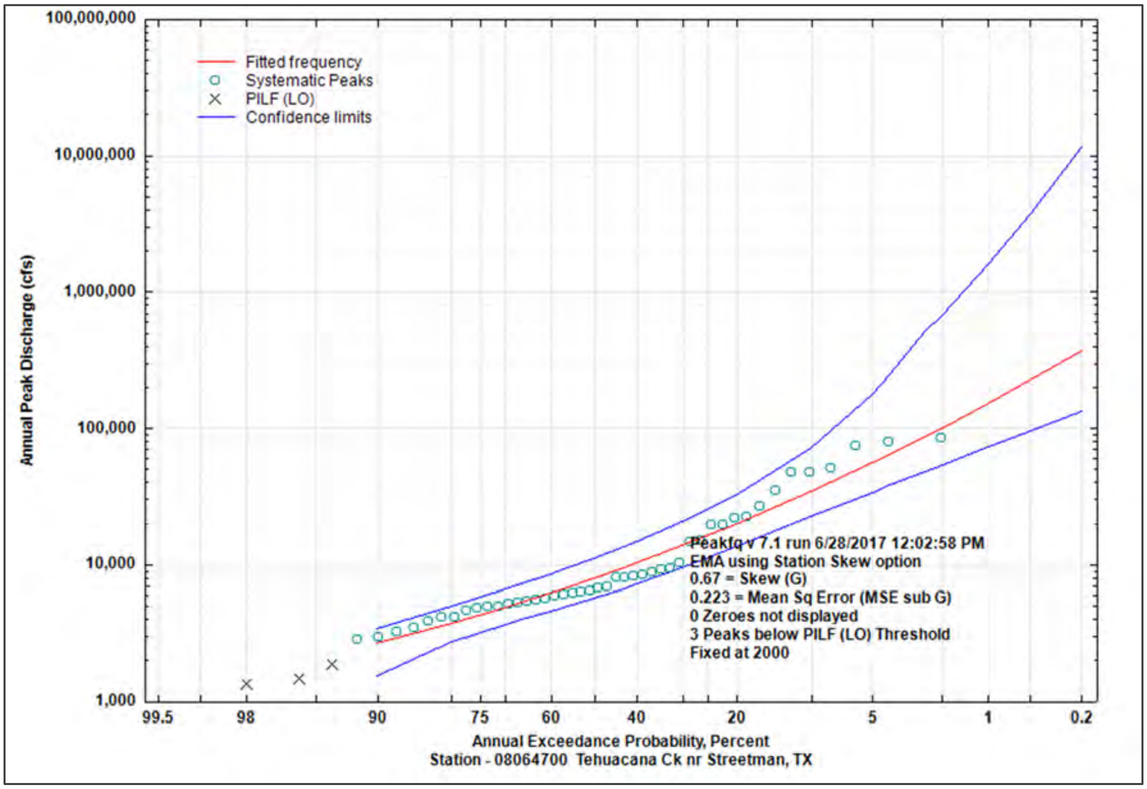

Figure 45b: Flood Flow Frequency Curve for station 08064700 Tehuacana Creek near Streetman, TX

08065000 Trinity River near Oakwood, Texas

The gage record and the systematic record for Trinity River near Oakwood are both 1924–2016. The 1942 peak streamflow of 153,000 ft^3/s at a stage of 51.64 ft is the largest peak in the systematic record for the site. There are two historical peaks of 180,000 ft^3/s in 1890 at a stage of 53.00 ft and 164,000 ft^3/s in 1908 at a stage of 52.20 ft. The data as set up for statistical frequency analysis are shown in Figure 46a. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. In addition to the reservoirs in the Upper Trinity River basin (see discussion for stream gage Trinity River at Trinidad), four major reservoirs have been built upstream of the gage: Navarro Mills Lake in 1963, Bardwell Lake in 1965, Cedar Creek Reservoir in 1966, and Richland-Chambers Reservoir in 1987. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1). However, visually it could be judged that a subtle decline in peak streamflow is present.

The flood flow frequency for Trinity River near Oakwood is shown in Figure 46b. A low-outlier threshold was manually fixed at 20,000 ft^3/s, which does an appropriate job of removing low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data. However, it is possible that there is too much curvature in the far right tail of the distribution as evidenced by the two largest peaks plotting above the fitted frequency curve. A low outlier threshold of 50,000 could be considered given a possible change in slope of the empirical data; however, over half of the data would be conditionally removed with this threshold.

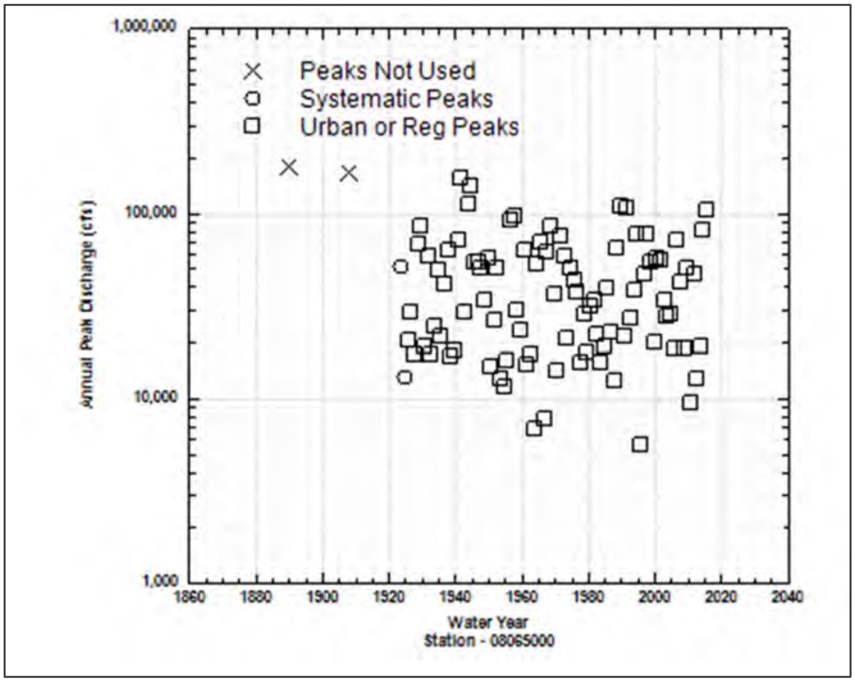

Figure 46a: Annual Peak Streamflow Data for station 08065000 Trinity River near Oakwood, TX

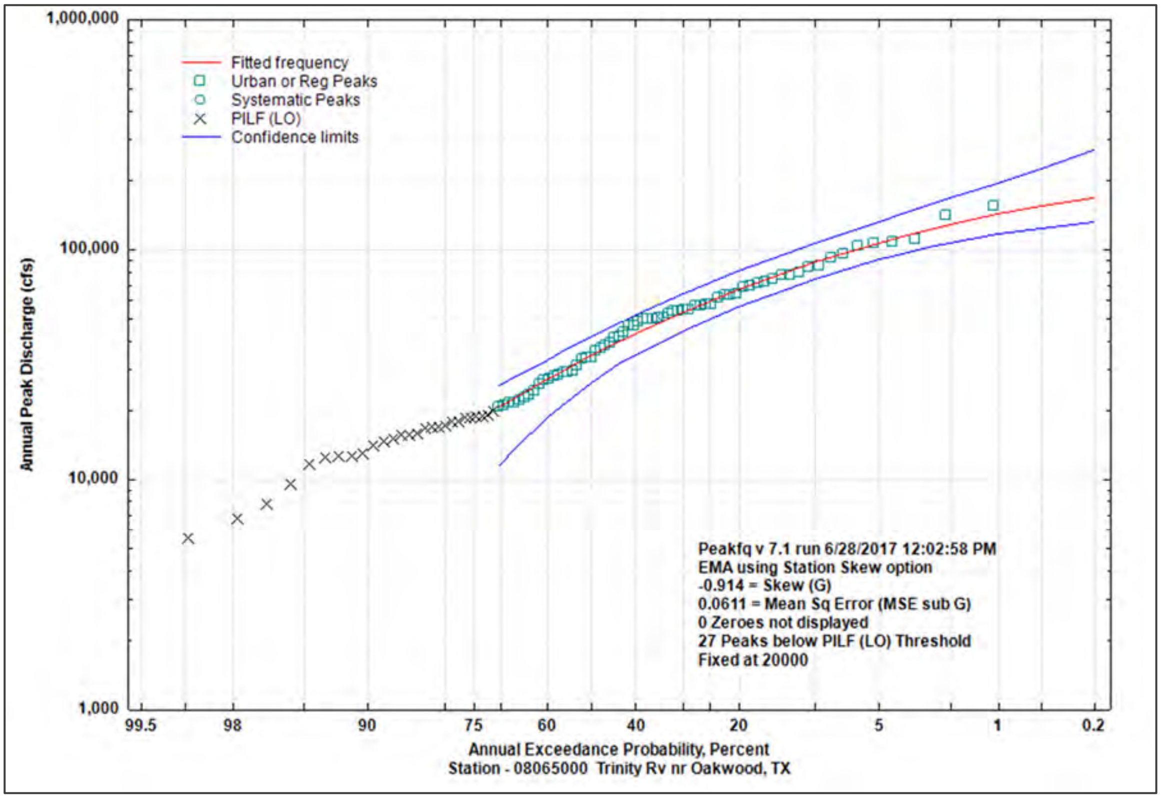

Figure 46b: Flood Flow Frequency Curve for station 08065000 Trinity River near Oakwood, TX

08065200 Upper Keechi Creek near Oakwood, Texas

The gage record and the systematic record for Upper Keechi Creek near Oakwood are both 1962–2016. The 2014 peak streamflow of 45,000 ft^3/s at a stage of 18.98 ft is the largest peak streamflow for the site. The data as set up for statistical frequency analysis are shown in Figure 47a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Upper Keechi Creek near Oakwood is shown in Figure 47b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

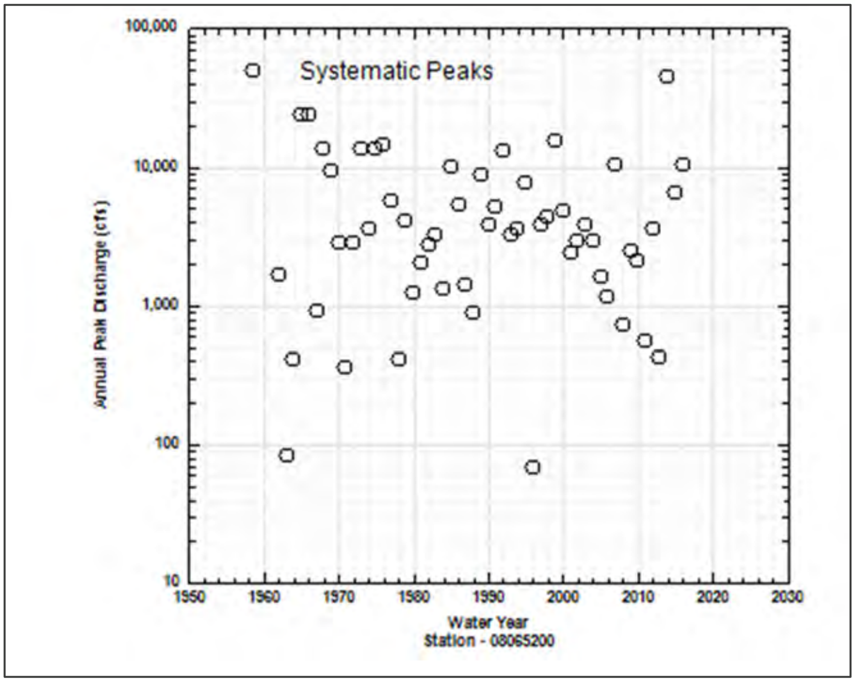

Figure 47a: Annual Peak Streamflow Data for station 08065200 Upper Keechi Creek near Oakwood, TX

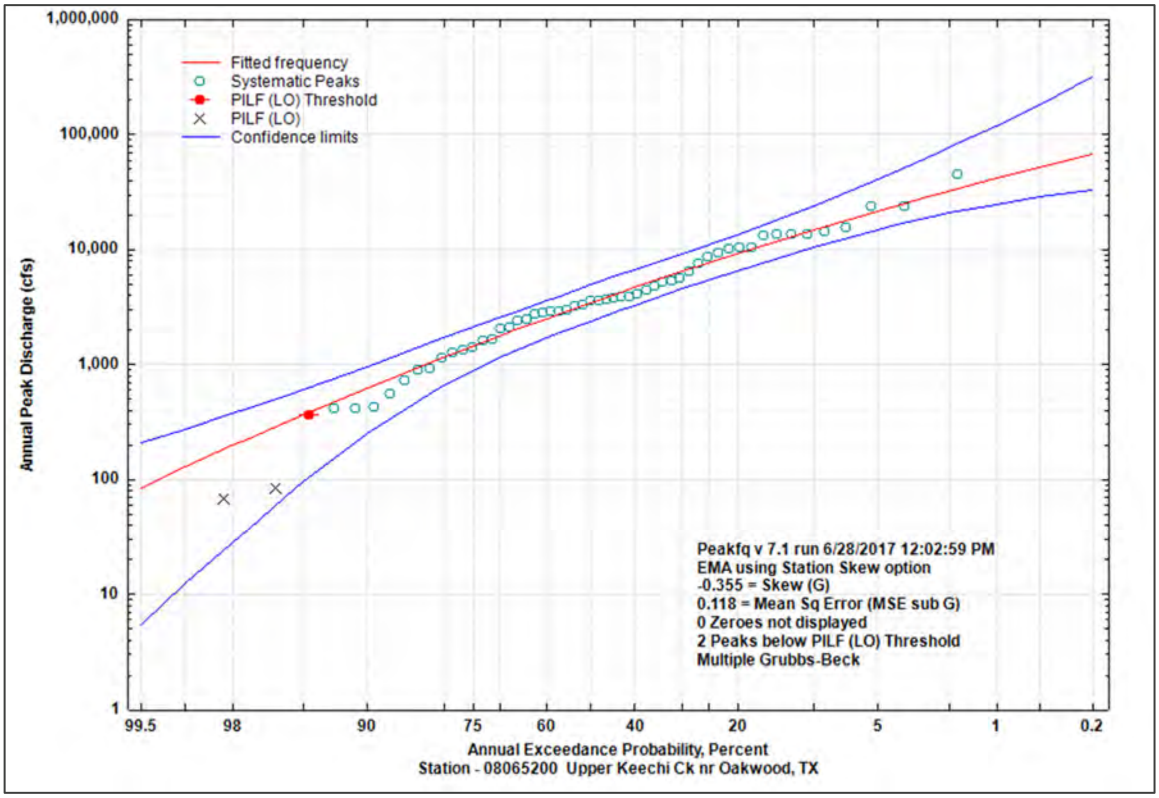

Figure 47b: Flood Flow Frequency Curve for station 08065200 Upper Keechi Creek near Oakwood, TX

08065350 Trinity River near Crockett, Texas

The gage record and the systematic record for Trinity River near Crockett are both 1964–2016. There is a peak streamflow of 109,000 ft^3/s at a stage of 48.54 ft in 1990 and another peak streamflow of 109,000 ft^3/s at a stage of 48.50 ft in 1992. These two peaks are the largest peak streamflows for the site. There is a historical peak with an unknown discharge in 1942 at a stage of 56.10 ft that is the highest since 1900. No inference for peaks in the gap for 1942–1963 is made. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. In addition to the reservoirs in the Upper Trinity River basin (see discussion for stream gage Trinity River at Trinidad), four major reservoirs have been built upstream of the gage: Navarro Mills Lake in 1963; Bardwell Lake in 1965, Cedar Creek Reservoir in 1966, and Richland-Chambers Reservoir in 1987. The data as set up for statistical frequency analysis are shown in Figure 48a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Trinity River near Crockett is shown in Figure 49b. A low-outlier threshold was manually fixed at 10,000 ft^3/s, which does an appropriate job of removing low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

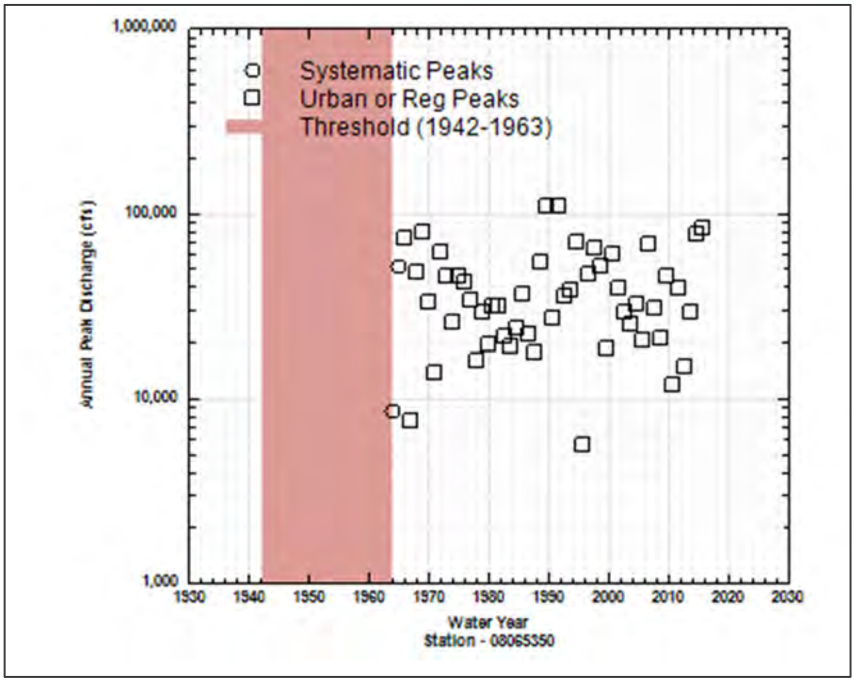

Figure 48a: Annual Peak Streamflow Data for station 08065350 Trinity River near Crockett, TX

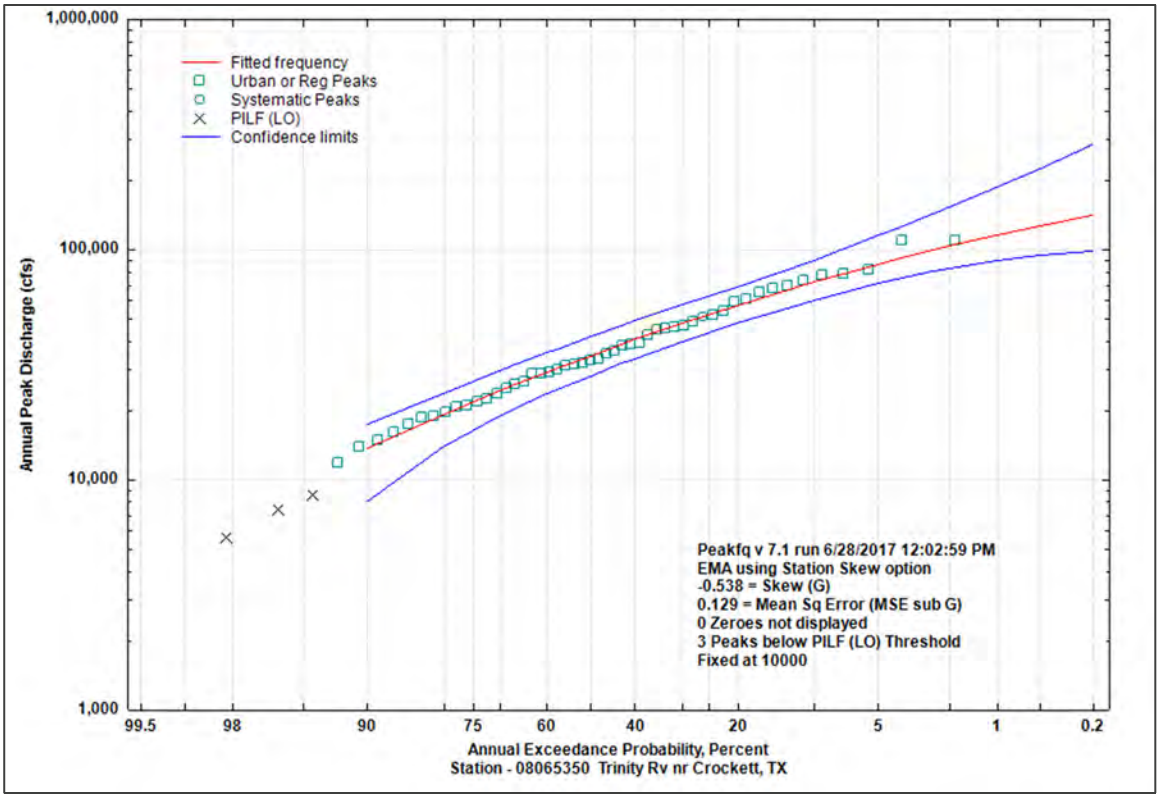

Figure 48b: Flood Flow Frequency Curve for station 08065350 Trinity River near Crockett, TX

08065800 Bedias Creek near Madisonville, Texas

The gage record and the systematic record for Bedias Creek near Madisonville are both 1968–2017, extended to include the peak streamflow from Hurricane Harvey, which resulted in the third highest peak of record at the gage. The 2016 peak streamflow of 40,800 ft^3/s at a stage of 26.05 ft is the largest peak streamflow for the site. There is a historical peak with an unknown discharge in 1922 at a stage of 34.00 ft that is the highest since 1910. The data as set up for statistical frequency analysis are shown in Figure 49a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Bedias Creek near Madisonville is shown in Figure 49b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

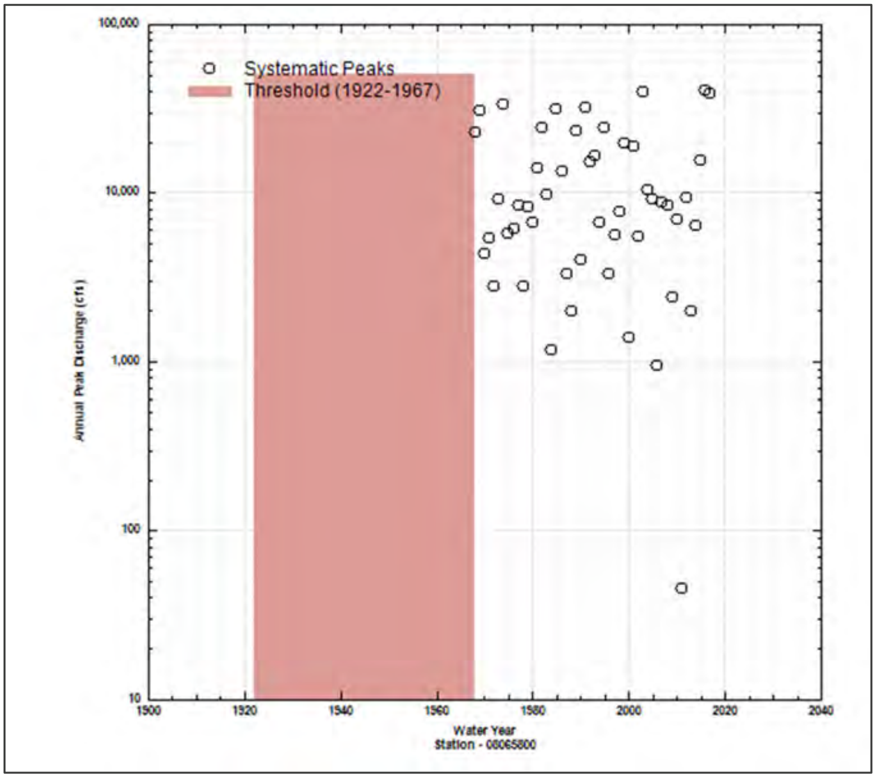

Figure 49a: Annual Peak Streamflow Data for station 08065800 Bedias Creek near Madisonville, TX

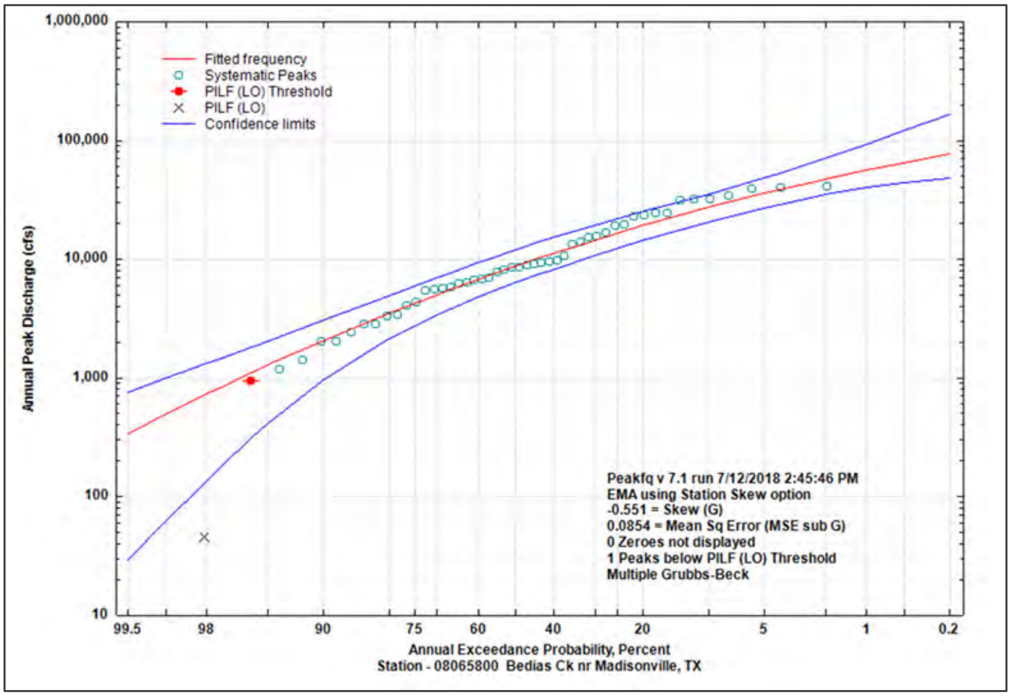

Figure 49b: Flood Flow Frequency Curve for station 08065800 Bedias Creek near Madisonville, TX

08066000 Trinity River at Riverside, Texas

The gage record and the systematic record for Trinity River at Riverside are both 1903–1968. The 1942 peak streamflow of 121,000 ft^3/s at a stage of 52.75 ft is the highest peak streamflow for the site. In addition to the reservoirs in the Upper Trinity River basin (see discussion for stream gage Trinity River at Trinidad), four major reservoirs have been built upstream of the gage: Navarro Mills in 1963, Bardwell Lake in 1965, Cedar Creek Reservoir in 1966, and Richland-Chambers Reservoir in 1987. The data as set up for statistical frequency analysis are shown in Figure 50a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Trinity River at Riverside is shown in Figure 50b. No low outliers were detected by the Multiple Grubbs-Beck outlier test. In general visually, the flood flow frequency curve looks reliable to the inputted data. There appears to a mode in the discharge at about 40,000–50,000 ft^3/s, which visually is the flatter part of the empirical distribution of the data for that approximate discharge range.

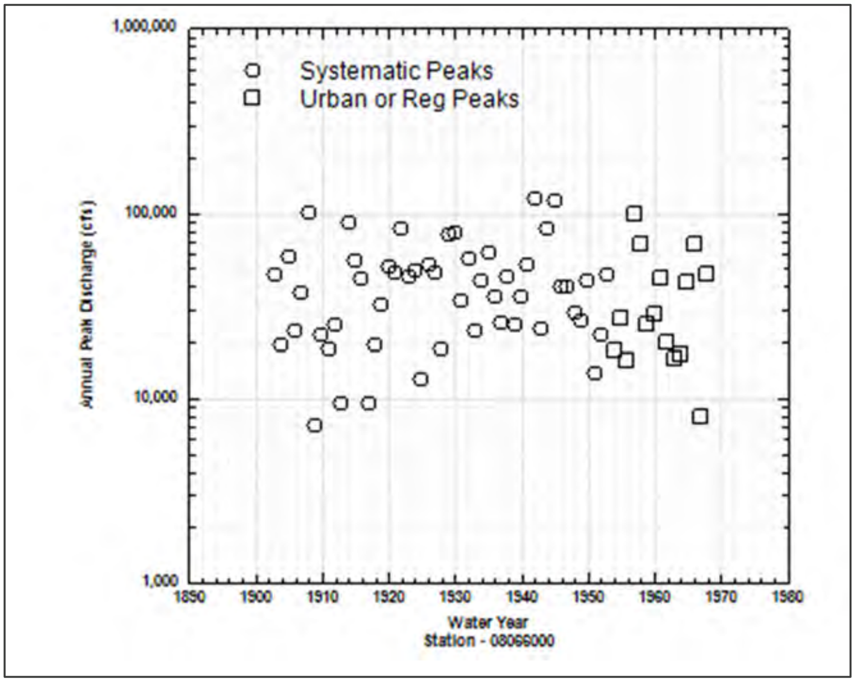

Figure 50a: Annual Peak Streamflow Data for station 08066000 Trinity River at Riverside, TX

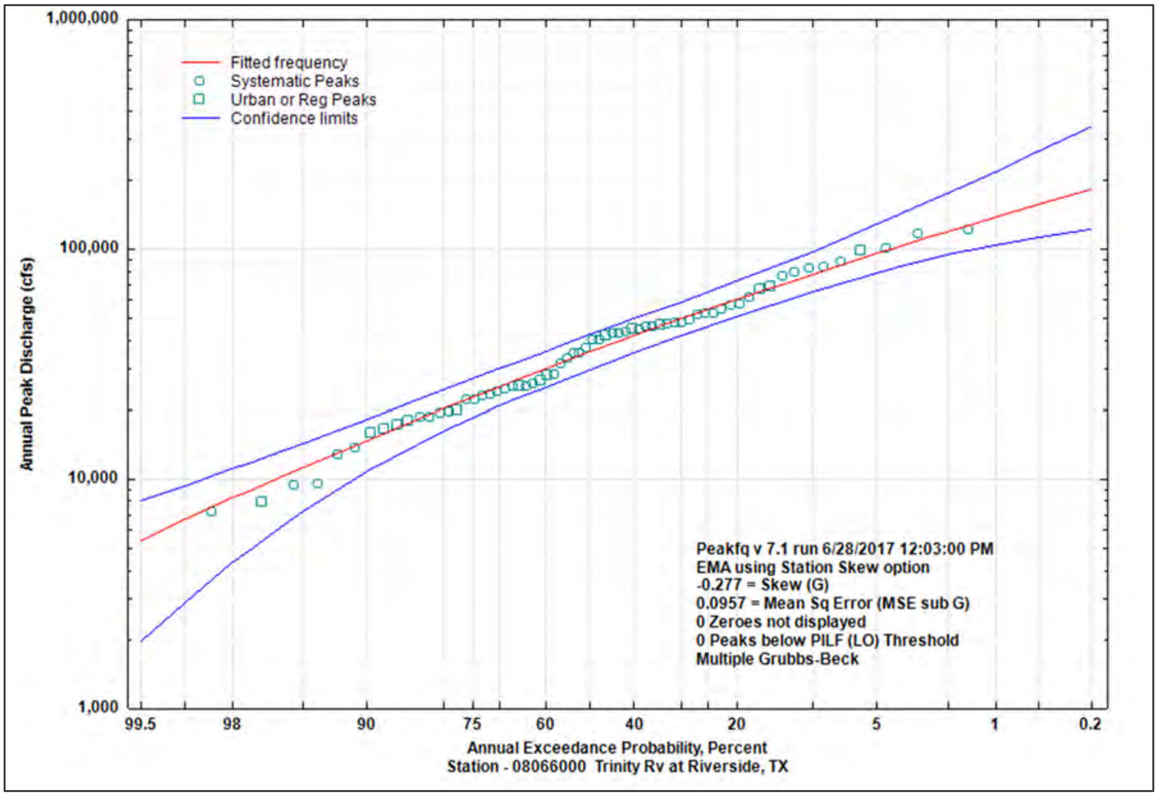

Figure 50b: Flood Flow Frequency Curve for station 08066000 Trinity River at Riverside, TX

08066170 Kickapoo Creek near Onalaska, Texas

The gage record and the systematic record for Kickapoo Creek near Onalaska are both 1966–2012. The historical and systematic record is 1942– 2016 for which the periods 1942–1965 and 2013–2016 are inferred from the peak streamflow and long-term daily precipitation data for Livingston. The 1995 peak streamflow of 84,600 ft^3/s at a stage of 41.85 ft is the largest peak streamflow in the gage and systematic record. The data as set up for statistical frequency analysis are shown in Figure 51a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Kickapoo Creek near Onalaska is shown in Figure 51b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

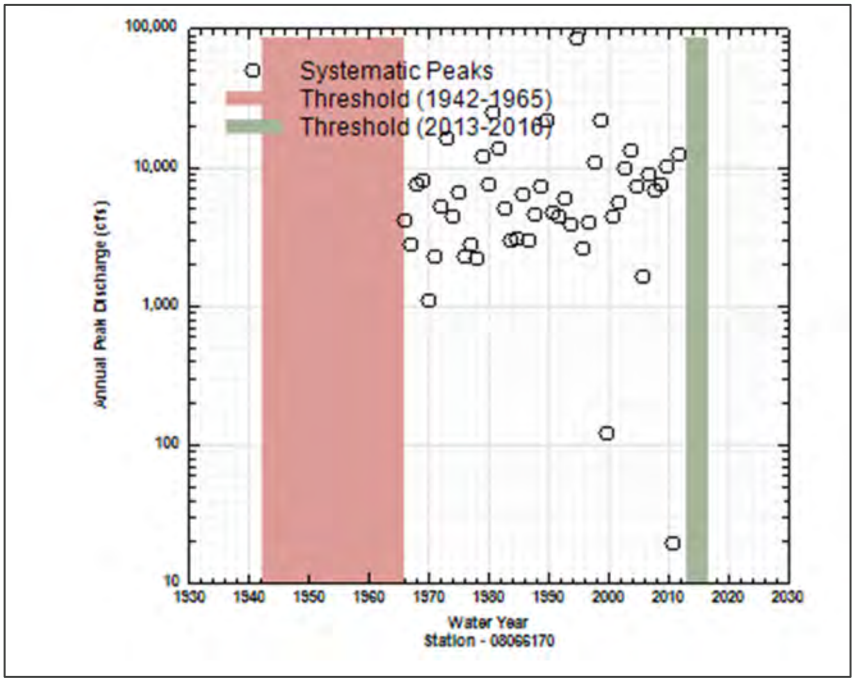

Figure 51a: Annual Peak Streamflow Data for station 08066170 Kickapoo Creek near Onalaska, TX

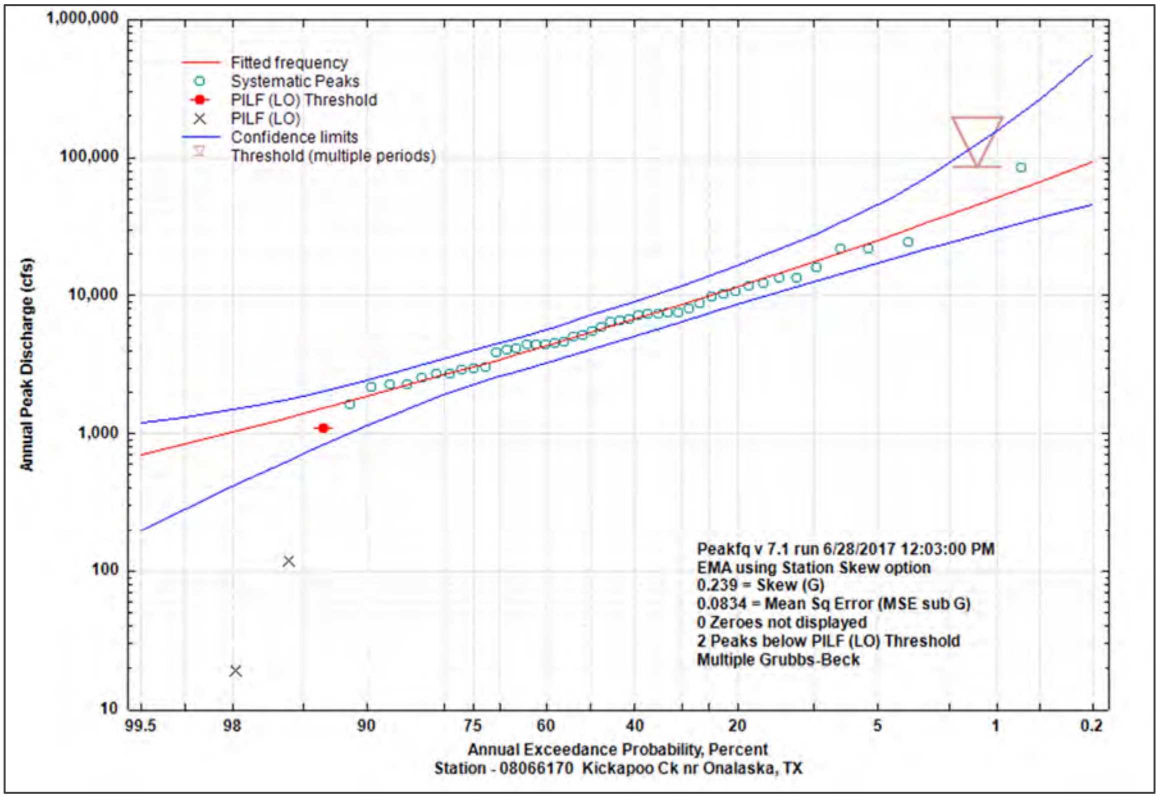

Figure 51b: Flood Flow Frequency Curve for station 08066170 Kickapoo Creek near Onalaska, TX

08066200 Long King Creek at Livingston, Texas

The gage record and the systematic record for Long King Creek at Livingston are both 1963–2016. The historical and systematic record is 1942–2016 for which the period 1942–1962 is inferred from the peak streamflow and long-term precipitation data for Livingston. The 1995 peak streamflow of 50,900 ft^3/s at a stage of 30.49 ft is the largest peak streamflow for the site. There is a historical peak with unknown discharge in 1929 at a stage of 41.00 ft, which is the highest since 1870. The data as set up for statistical frequency analysis are shown in Figure 52a. The Kendall's Tau for monotonic trend is statistically significant (alpha = 0.1; Table 1) and shows an upward trend (p-value = 0.088), and this is seen by visual inspection of the data. However, visually it is difficult to discern this increase in peak streamflow with time.

The flood flow frequency for Long King Creek at Livingston is shown in Figure 52b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data. It is noted that the empirical probability of the 1995 event plots almost exactly on the fitted frequency curve.

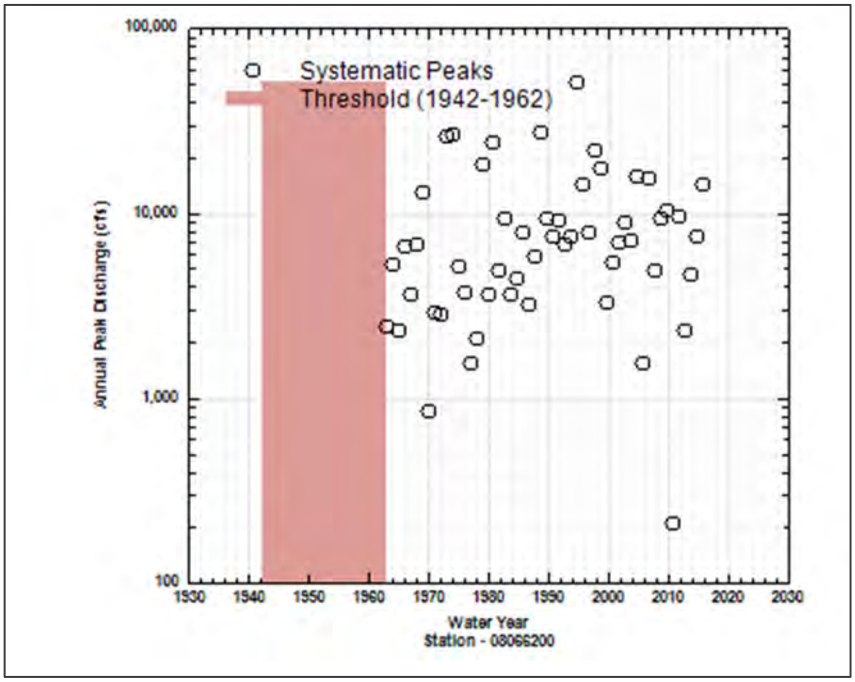

Figure 52a: Annual Peak Streamflow Data for station 08066200 Long King Creek at Livingston, TX

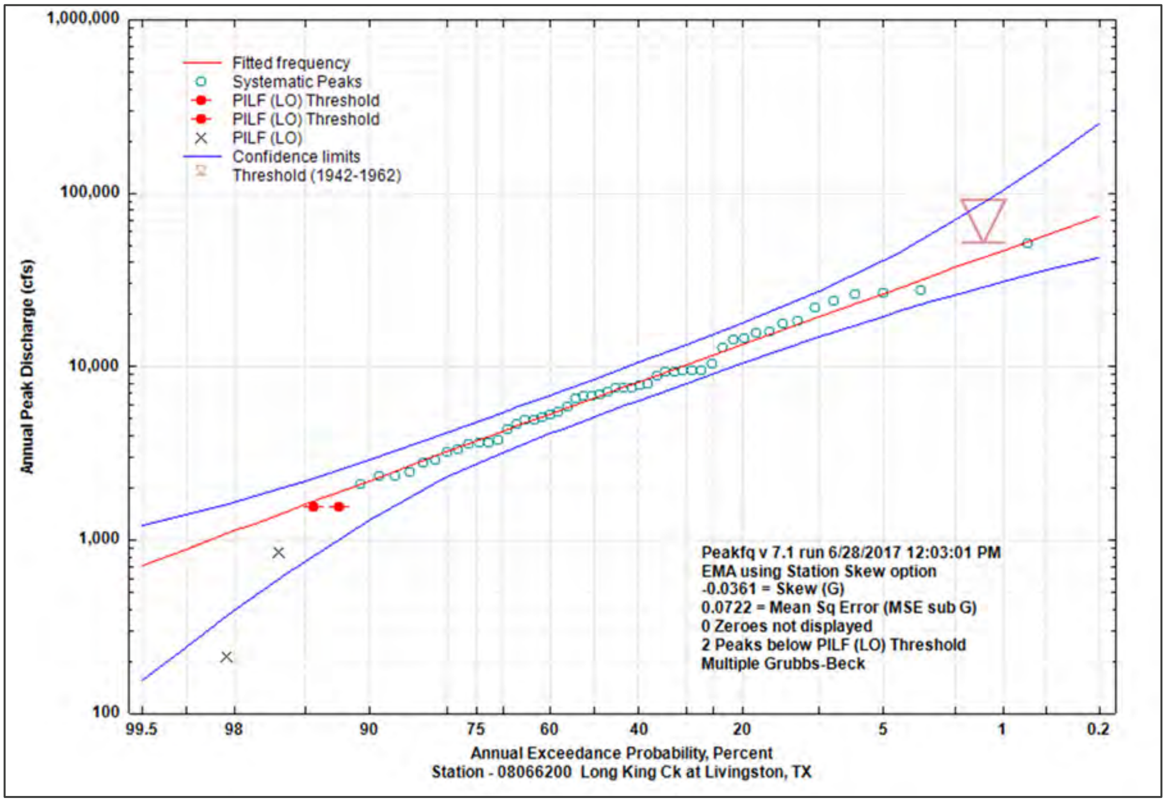

Figure 52b: Flood Flow Frequency Curve for station 08066200 Long King Creek at Livingston, TX

08066250 Trinity River near Goodrich, Texas

The gage record and systematic record for the Trinity River near Goodrich are both 1966–2017, extended to include the peak streamflow from Hurricane Harvey, which resulted in the second highest peak of record at the gage. The 1995 peak streamflow of 125,000 ft^3/s at a stage of 48.97 ft is the largest peak for the site and is treated as the highest since at least 1903 based on historical information available for Trinity River at Liberty. There is a historical peak for Trinity River near Goodrich lacking a discharge in 1942 with a stage of 52.00 ft. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. In addition to the reservoirs in the Upper Trinity River basin (see discussion for stream gage Trinity River at Trinidad), five major reservoirs have been built upstream of the gage: Navarro Mills in 1963, Bardwell Lake in 1965, Cedar Creek Reservoir in 1966, Lake Livingston in 1969, and Richland-Chambers Reservoir in 1987. Lake Livingston is immediately upstream and is primarily a pass-through reservoir. The data as set up for statistical frequency analysis are shown in Figure 53a. Visually the record before and after Lake Livingston appear compatible with each other, which is consistent with Livingston Reservoir functioning in a pass-through manner though it is relatively close upstream. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Trinity River near Goodrich is shown in Figure 53b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data. It is noted that the empirical probability of the 1995 event plots almost exactly on the fitted frequency curve.

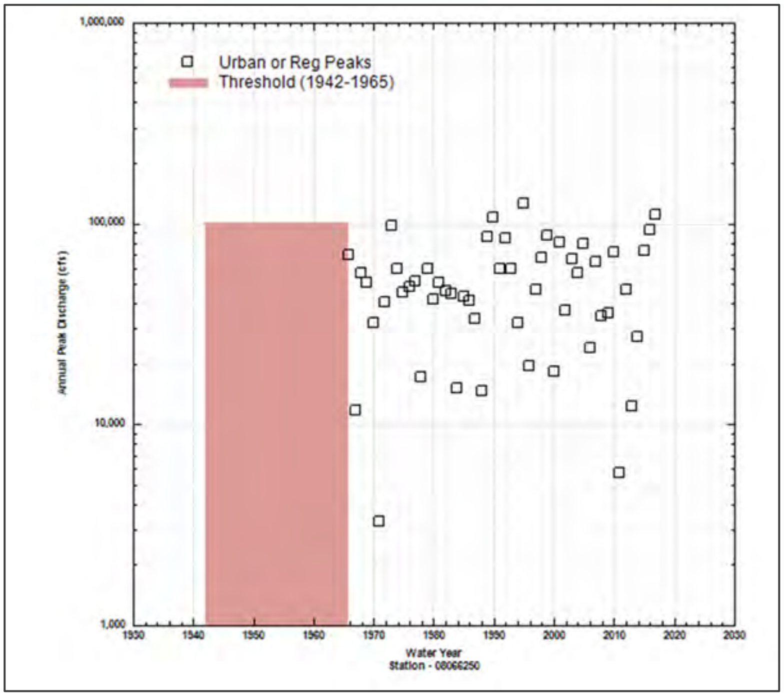

Figure 53a: Annual Peak Streamflow Data for station 08066250 Trinity River near Goodrich, TX

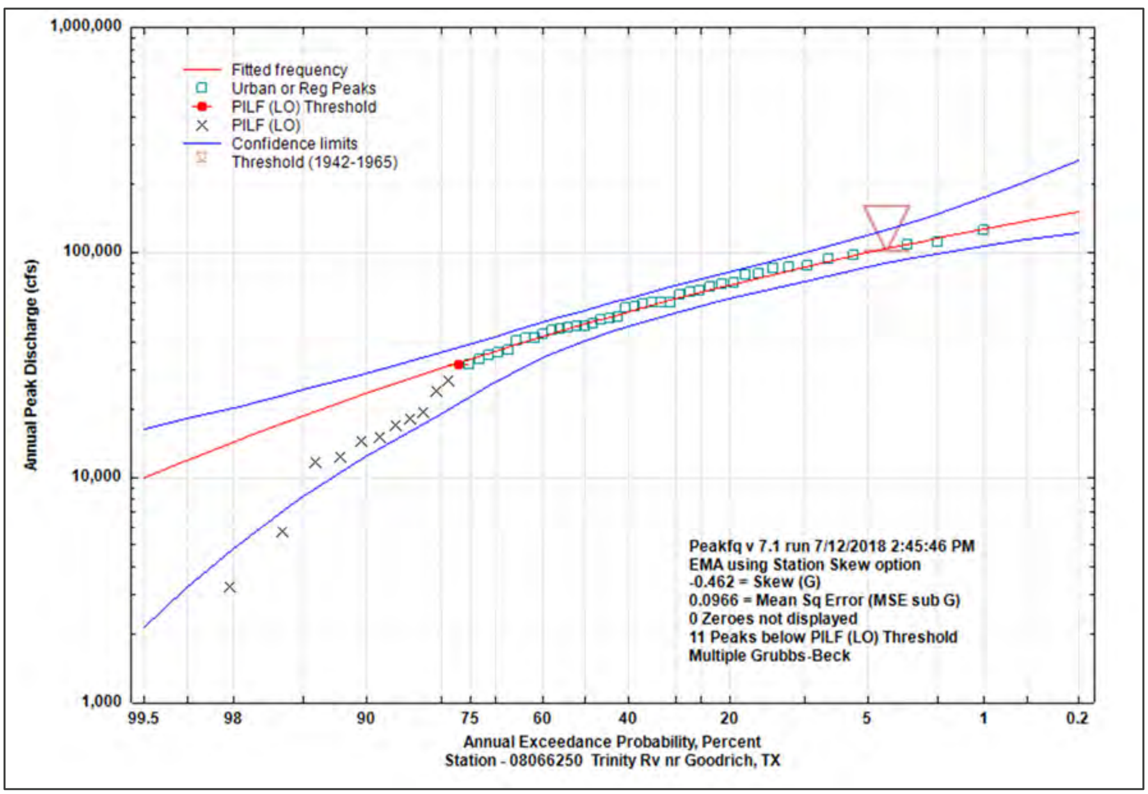

Figure 53b: Flood Flow Frequency Curve for station 08066250 Trinity River near Goodrich, TX

08066300 Menard Creek near Rye, Texas

The gage record and the systematic record for Menard Creek near Rye are both 1966–2017 and thus are extended to include the peak streamflow from Hurricane Harvey which resulted in the highest peak of record at the gage. The 2017 peak streamflow of 15,700 ft^3/s at a stage of 36.11 ft is the largest peak for the systematic record. There are two historical peaks lacking discharges in 1929 at a stage of 39.04 ft and 1961 at a stage of 34.00 ft. The data as set up for statistical frequency analysis are shown in Figure 54a. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Menard Creek near Rye is shown in Figure 54b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data.

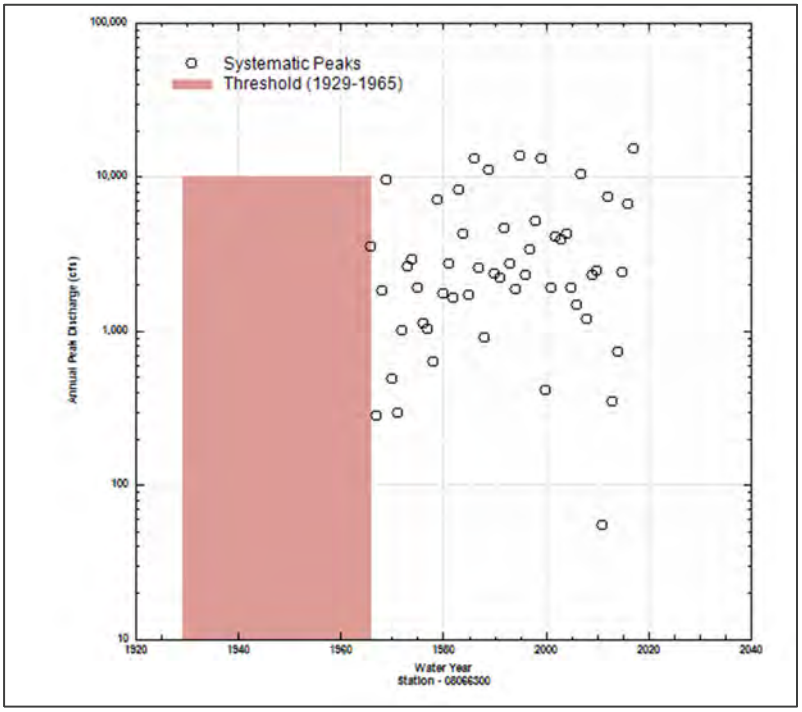

Figure 54a: Annual Peak Streamflow Data for station 08066300 Menard Creek near Rye, TX

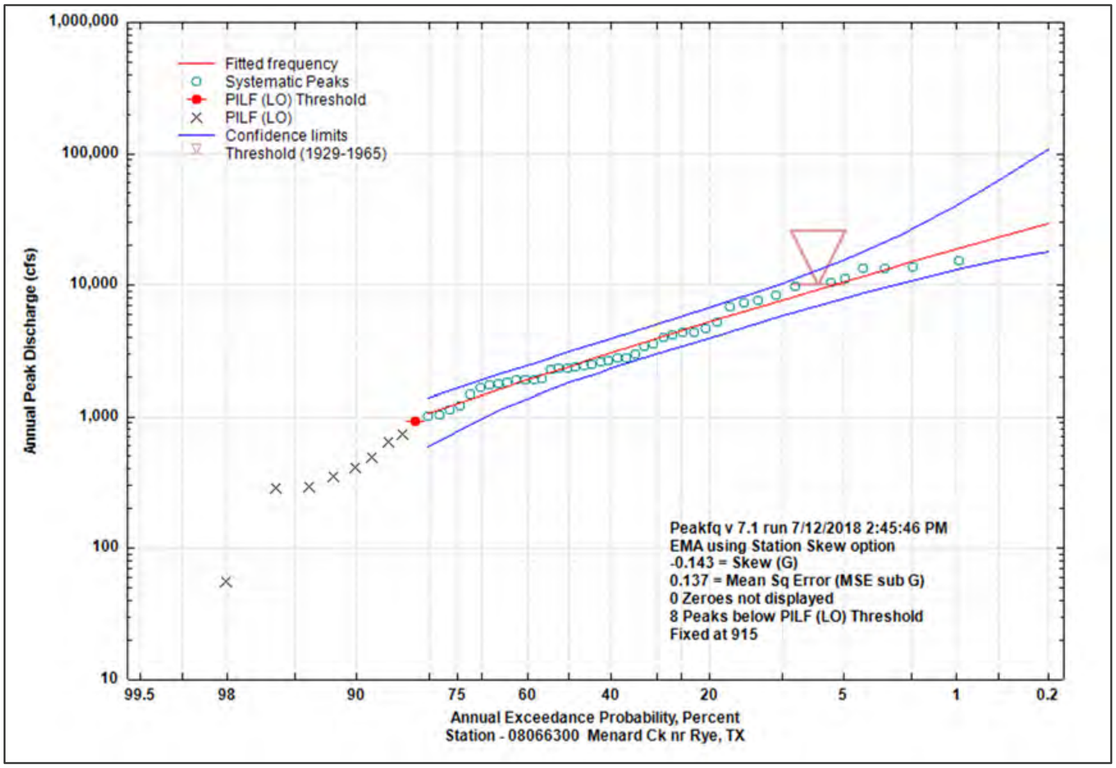

Figure 54b: Flood Flow Frequency Curve for station 08066300 Menard Creek near Rye, TX

08066500 Trinity River at Romayor, Texas

The gage record and the systematic record for Trinity River at Romayor are both 1924–2016. The 1995 peak of 122,000 ft^3/s at a stage of 42.70 ft is the largest peak of the systematic record and is treated as the highest since at least 1903 based on historical information available for Trinity River at Liberty. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. In addition to the reservoirs in the Upper Trinity River basin (see discussion for stream gage Trinity River at Trinidad), five major reservoirs have been built upstream of the gage: Navarro Mills in 1963, Bardwell Lake in 1965, Cedar Creek Reservoir in 1966, Lake Livingston in 1969, and Richland-Chambers Reservoir in 1987. Lake Livingston is the closest and is primarily a pass-through reservoir. The data as set up for statistical frequency analysis are shown in Figure 55a. Visually the record before and after Lake Livingston appear compatible, which is consistent with Livingston Reservoir acting in a pass-through manner though it is relatively close upstream. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Trinity River at Romayor is shown in Figure 55b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data. It is noted that the empirical probability of the 1995 event plots almost exactly on the fitted frequency curve.

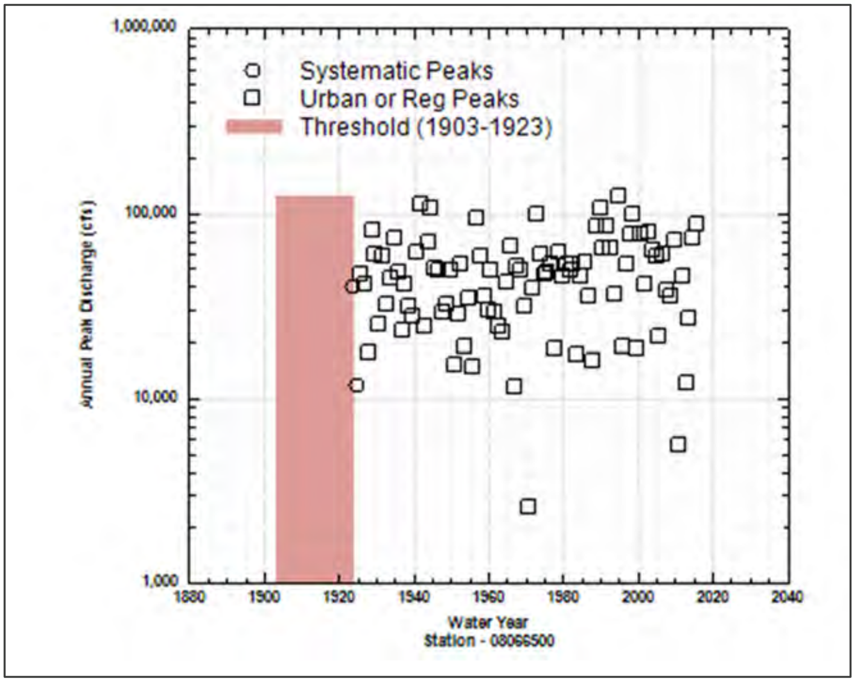

Figure 55a: Annual Peak Streamflow Data for station 08066500 Trinity River at Romayor, TX

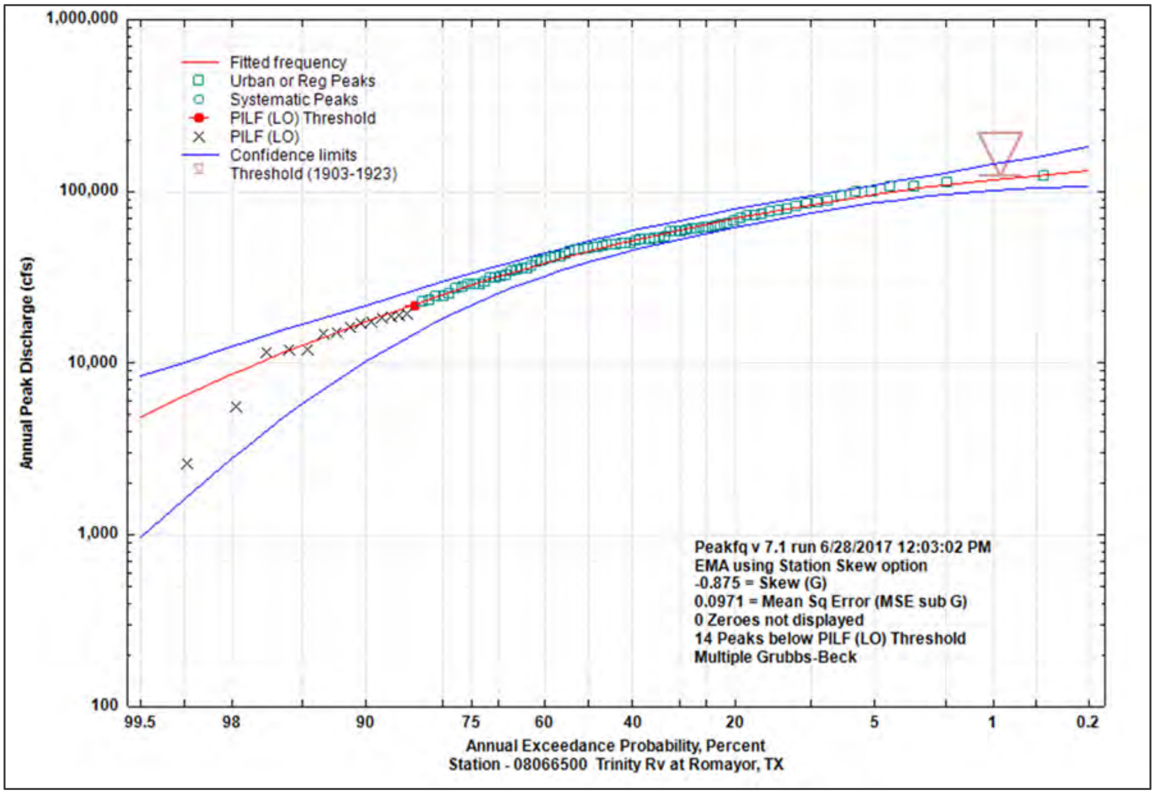

Figure 55b: Flood Flow Frequency Curve for station 08066500 Trinity River at Romayor, TX

08067000 Trinity River at Liberty, Texas

The gage record and the systematic record for Trinity River at Liberty are both 1940–2017 and are thus extended to include the peak streamflow from Hurricane Harvey which resulted in the second highest peak of record at the gage. The 1995 peak of 135,000 ft^3/s at a stage of 31.00 ft is the largest peak of the systematic record and is the highest since at least 1903. The 2011 peak is less than 10,000 ft^3/s and is readily processed by EMA. The USGS Peak-Values File flags the entire record with a code 6, but manual intervention was required to remove the code for the first two peaks so that the USGS-PeakFQ software would operate. This does not affect the statistical analysis—only the visual depiction of the input data. In addition to the reservoirs in the Upper Trinity River basin (see discussion for stream gage Trinity River at Trinidad), five major reservoirs have been built upstream of the gage: Navarro Mills in 1963, Bardwell Lake in 1965, Cedar Creek Reservoir in 1966, Lake Livingston in 1969, and Richland-Chambers Reservoir in 1987. Lake Livingston is the closest and is primarily a pass-through reservoir. The discharge interval for the 1971, 1972, and 2011 peaks are represented as green bars in the figure. The data as set up for statistical frequency analysis are shown in Figure 56a. Visually the record before and after Lake Livingston appear compatible, which is consistent with Livingston Reservoir functioning in a pass-through manner though it is relatively close upstream. The Kendall's Tau for monotonic trend is not statistically significant (alpha = 0.1; Table 1).

The flood flow frequency for Trinity River at Liberty is shown in Figure 56b. The multiple Grubbs-Beck outlier test does an acceptable job identifying low outliers. In general visually, the flood flow frequency curve looks reliable to the inputted data. It is noted that the empirical probability of the 1995 event plots almost exactly on the fitted frequency curve. Some mixed population effects might be evidenced by the flattening of the data at about 40,000–50,000 ft^3/s and again at about 60,000–70,000 ft^3/s.

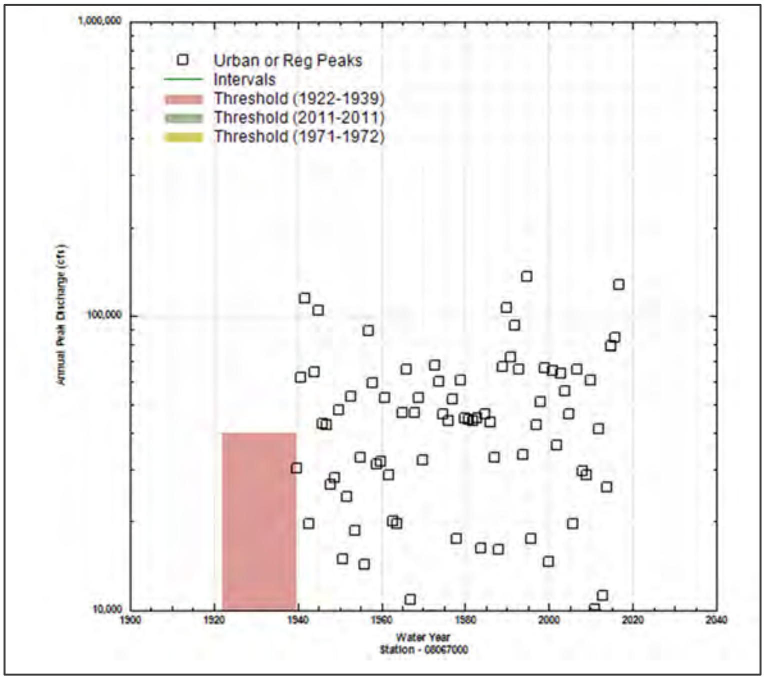

Figure 56a: Annual Peak Streamflow Data for station 08067000 Trinity River at Liberty, TX

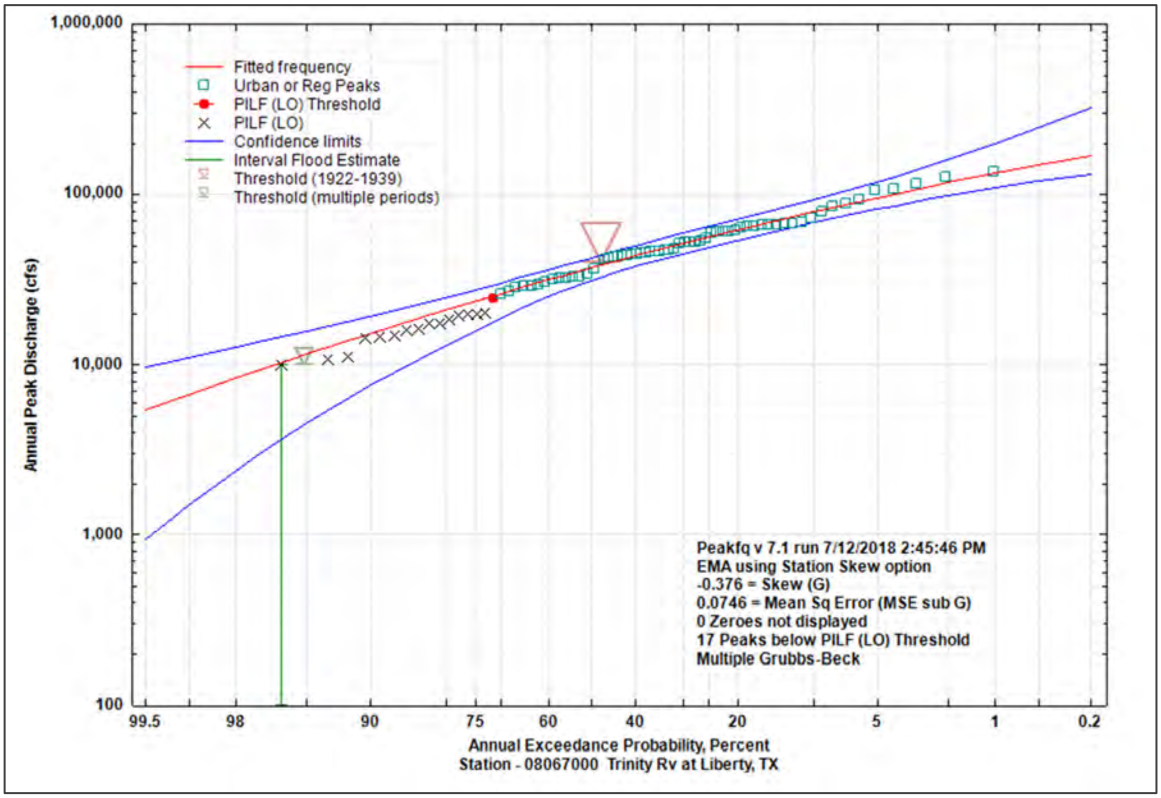

Figure 56b: Flood Flow Frequency Curve for station 08067000 Trinity River at Liberty, TX

Table 2: Statistically Estimated Annual Flood Flow Frequency Results for Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trinity River Basin, Texas based on the USGS-PeakFQ EMA-LPIII Computations

Station number and name	Peak-streamflow frequency by corresponding average return period (recurrence interval) in years							
	2 year (ft^3/s)	5 year (ft^3/s)	10 year (ft^3/s)	25 year (ft^3/s)	50 year (ft^3/s)	100 year (ft^3/s)	200 year (ft^3/s)	500 year (ft^3/s)
08042800 West Fork Trinity River near Jacksboro, Tex.								
Lower 95%-CI	1,347	3,936	6,904	12,280	17,510	23,800	31,180	42,670
Estimate	**2,049**	**6,165**	**11,310**	**22,110**	**34,550**	**52,080**	**76,390**	**122,700**
Upper 95%-CI	3,142	10,820	24,850	82,070	220,700	562,100	1,245,000	3,539,000
08044000 Big Sandy Creek near Bridgeport, Tex.								
Lower 95%-CI	2,112	6,163	10,490	17,870	24,590	32,180	40,540	52,690
Estimate	**2,926**	**8,598**	**15,080**	**27,440**	**40,360**	**57,090**	**78,390**	**115,100**
Upper 95%-CI	4,051	12,470	24,120	53,860	95,250	163,800	275,500	533,300
08044500 West Fork Trinity River near Boyd, Tex.								
Lower 95%-CI	2,407	6,547	11,020	18,910	26,500	35,620	46,410	63,500
Estimate	**3,262**	**9,049**	**15,870**	**29,530**	**44,640**	**65,280**	**93,070**	**144,300**
Upper 95%-CI	4,427	13,430	27,240	67,870	134,400	264,100	514,700	1,230,000
08044800 Walnut Creek at Reno, Tex.								
Lower 95%-CI	1,948	5,541	9,197	13,410	15,150	16,000	16,370	16,440
Estimate	**3,632**	**9,727**	**15,210**	**23,330**	**29,990**	**36,970**	**44,190**	**53,970**
Upper 95%-CI	6,629	16,860	32,380	63,260	95,780	142,700	211,500	354,600
08045850 Clear Fork Trinity River near Weatherford, Tex.								
Lower 95%-CI	415	1,036	1,626	2,541	3,300	4,092	4,903	5,993
Estimate	**615**	**1,541**	**2,487**	**4,141**	**5,754**	**7,734**	**10,140**	**14,060**
Upper 95%-CI	913	2,497	4,763	11,030	20,310	36,620	65,010	136,800
08047000 Clear Fork Trinity River near Benbrook, Tex.								
Lower 95%-CI	732	2,196	3,100	4,163	4,822	5,348	5,757	6,165
Estimate	**1,261**	**2,846**	**3,977**	**5,343**	**6,266**	**7,096**	**7,836**	**8,685**
Upper 95%-CI	1,658	3,743	5,488	8,187	10,290	12,330	14,410	17,360
08047050 Marys Creek at Benbrook, Tex.								
Lower 95%-CI	2,045	5,934	9,942	16,400	21,550	26,620	31,460	37,400
Estimate	**3,977**	**11,270**	**19,160**	**33,430**	**47,630**	**65,250**	**86,780**	**122,100**
Upper 95%-CI	7,645	25,380	59,390	181,500	400,600	842,000	1,743,000	4,324,000
08047500 Clear Fork Trinity River at Fort Worth, Tex.								
Lower 95%-CI	4,396	10,920	13,710	16,260	17,840	19,170	20,310	21,560
Estimate	**7,897**	**12,920**	**15,950**	**19,320**	**21,510**	**23,450**	**25,170**	**27,150**
Upper 95%-CI	9,124	15,430	20,780	33,550	42,250	51,450	60,350	71,870
08048000 West Fork Trinity River at Fort Worth, Tex.								
Lower 95%-CI	7,690	14,270	19,150	25,310	29,520	33,280	36,660	40,600
Estimate	**9,194**	**16,980**	**22,980**	**31,290**	**37,920**	**44,850**	**52,100**	**62,140**
Upper 95%-CI	10,990	20,470	28,950	43,110	56,190	71,620	89,880	119,300

Table 2: Statistically Estimated Annual Flood Flow Frequency Results for Selected U.S. Geological Survey Streamflow-Gaging stations in the Trinity River Basin, Texas based on the USGS-PeakFQ EMA-LPIII Computations—Continued

Station number and name	Peak-streamflow frequency by corresponding average return period (recurrence interval) in years							
	2 year (ft^3/s)	5 year (ft^3/s)	10 year (ft^3/s)	25 year (ft^3/s)	50 year (ft^3/s)	100 year (ft^3/s)	200 year (ft^3/s)	500 year (ft^3/s)
08048543 West Fork Trinity River at Beach Street, Fort Worth, Tex.								
Lower 95%-CI	9,511	16,690	21,930	28,620	33,330	37,670	41,650	46,430
Estimate	**12,000**	**21,030**	**27,990**	**37,780**	**45,720**	**54,180**	**63,190**	**75,980**
Upper 95%-CI	15,120	27,520	39,920	64,130	89,700	123,300	167,400	247,900
08048800 Big Fossil Creek at Haltom City, Tex.								
Lower 95%-CI	4,295	8,745	12,530	16,730	18,350	19,120	19,380	19,380
Estimate	**7,449**	**14,390**	**19,450**	**26,010**	**30,870**	**35,630**	**40,300**	**46,290**
Upper 95%-CI	12,350	23,540	40,780	71,110	98,010	133,400	182,100	276,700
08048970 Village Creek at Everman, Tex.								
Lower 95%-CI	3,311	9,307	11,590	13,200	13,860	14,270	14,510	14,700
Estimate	**7,723**	**11,770**	**13,630**	**15,220**	**16,010**	**16,570**	**16,970**	**17,320**
Upper 95%-CI	9,513	15,100	22,460	27,830	31,160	34,350	37,460	41,350
08049500 West Fork Trinity River at Grand Prairie, Tex.								
Lower 95%-CI	7,968	15,030	20,970	29,740	37,090	45,070	53,730	66,270
Estimate	**9,484**	**18,130**	**25,960**	**38,700**	**50,530**	**64,630**	**81,350**	**108,200**
Upper 95%-CI	11,300	22,720	35,450	62,870	96,450	147,100	222,800	382,800
08049580 Mountain Creek near Venus, Tex.								
Lower 95%-CI	2,316	4,448	6,116	8,407	10,150	11,860	13,520	15,640
Estimate	**3,140**	**6,047**	**8,498**	**12,190**	**15,380**	**18,940**	**22,910**	**28,820**
Upper 95%-CI	4,294	8,841	14,140	27,940	50,070	80,830	124,100	216,500
08049700 Walnut Creek near Mansfield, Tex.								
Lower 95%-CI	2,895	5,686	7,853	10,750	12,860	14,860	16,720	19,000
Estimate	**3,677**	**7,212**	**10,100**	**14,310**	**17,820**	**21,610**	**25,700**	**31,570**
Upper 95%-CI	4,662	9,374	13,990	23,180	33,570	48,030	68,060	107,000
08050100 Mountain Creek at Grand Prairie, Tex.								
Lower 95%-CI	7,383	10,590	12,200	14,040	15,260	16,350	17,330	18,490
Estimate	**8,937**	**12,150**	**14,180**	**16,650**	**18,440**	**20,170**	**21,870**	**24,090**
Upper 95%-CI	10,310	14,490	17,750	23,080	28,300	35,080	43,930	54,820
08050400 Elm Fork Trinity River at Gainesville, Tex.								
Lower 95%-CI	6,439	12,440	17,310	24,090	29,330	34,610	39,890	46,840
Estimate	**8,730**	**16,970**	**24,170**	**35,410**	**45,430**	**56,930**	**70,100**	**90,370**
Upper 95%-CI	11,860	25,170	41,510	81,460	136,300	226,200	373,900	666,400
08050800 Timber Creek near Collinsville, Tex.								
Lower 95%-CI	714	2,852	5,473	9,820	12,920	15,550	17,690	19,890
Estimate	**1,409**	**5,382**	**10,260**	**19,590**	**29,110**	**40,970**	**55,380**	**78,610**
Upper 95%-CI	2,742	10,730	25,410	68,960	130,500	235,900	416,800	869,300

Table 2: Statistically Estimated Annual Flood Flow Frequency Results for Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trinity River Basin, Texas based on the USGS-PeakFQ EMA-LPIII Computations—Continued

Station number and name	Peak-streamflow frequency by corresponding average return period (recurrence interval) in years							
	2 year (ft^3/s)	5 year (ft^3/s)	10 year (ft^3/s)	25 year (ft^3/s)	50 year (ft^3/s)	100 year (ft^3/s)	200 year (ft^3/s)	500 year (ft^3/s)
08050840 Range Creek near Collinsville, Tex.								
Lower 95%-CI	1,413	3,692	6,002	9,771	13,060	16,630	20,410	25,690
Estimate	**2,346**	**6,228**	**10,460**	**18,290**	**26,340**	**36,650**	**49,680**	**72,010**
Upper 95%-CI	3,967	12,260	27,070	90,360	225,700	456,400	923,500	2,321,000
08051135 Elm Fork Trinity River at Greenbelt near Pilot Point, Tex.								
Lower 95%-CI	139	757	1,768	4,098	6,671	9,940	13,860	20,080
Estimate	**744**	**3,684**	**8,651**	**21,790**	**39,880**	**69,040**	**114,500**	**212,700**
Upper 95%-CI	4,355	48,900	300,900	3,376,000	10,930,000	35,840,000	120,800,000	599,300,000
08051500 Clear Creek near Sanger, Tex.								
Lower 95%-CI	4,415	9,071	13,210	19,560	24,990	30,920	37,300	46,410
Estimate	**5,488**	**11,560**	**17,390**	**27,250**	**36,720**	**48,280**	**62,300**	**85,330**
Upper 95%-CI	6,932	15,520	25,690	52,110	95,600	184,400	307,800	604,200
08052700 Little Elm Creek near Aubrey, Tex.								
Lower 95%-CI	2,278	5,240	7,877	11,770	14,880	18,030	21,190	25,340
Estimate	**3,031**	**6,986**	**10,730**	**16,880**	**22,560**	**29,220**	**36,960**	**49,050**
Upper 95%-CI	4,030	9,717	16,480	31,480	49,530	75,950	114,200	191,700
08053000 Elm Fork Trinity River near Lewisville, Tex.								
Lower 95%-CI	2,544	4,976	6,940	9,649	11,700	13,720	15,690	18,210
Estimate	**3,475**	**6,817**	**9,706**	**14,160**	**18,070**	**22,520**	**27,550**	**35,190**
Upper 95%-CI	4,749	10,080	16,520	31,770	51,580	82,560	131,000	232,700
08053500 Denton Creek near Justin, Tex.								
Lower 95%-CI	3,285	8,201	12,680	19,240	24,240	29,080	33,670	39,330
Estimate	**4,413**	**10,970**	**17,260**	**27,500**	**36,820**	**47,580**	**59,860**	**78,570**
Upper 95%-CI	5,919	15,020	25,570	47,720	72,700	107,300	154,800	245,200
08055000 Denton Creek near Grapevine, Tex.								
Lower 95%-CI	1,311	2,305	3,190	4,503	5,611	6,815	8,113	9,988
Estimate	**1,590**	**2,934**	**4,188**	**6,295**	**8,320**	**10,810**	**13,850**	**18,940**
Upper 95%-CI	1,993	3,977	6,492	14,470	28,120	48,540	84,280	174,800
08055500 Elm Fork Trinity River near Carrollton, Tex.								
Lower 95%-CI	5,311	8,651	11,490	15,570	18,890	22,420	26,180	31,500
Estimate	**6,157**	**10,450**	**14,230**	**20,280**	**25,870**	**32,520**	**40,410**	**53,140**
Upper 95%-CI	7,345	13,250	20,050	38,670	67,790	107,800	171,700	319,300
08056500 Turtle Creek at Dallas, Tex.								
Lower 95%-CI	2,647	4,068	4,998	6,078	6,757	7,326	7,807	8,337
Estimate	**3,125**	**4,780**	**5,903**	**7,332**	**8,396**	**9,456**	**10,520**	**11,930**
Upper 95%-CI	3,685	5,725	7,462	10,270	12,710	15,470	18,630	23,580

Table 2: Statistically Estimated Annual Flood Flow Frequency Results for Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trinity River Basin, Texas based on the USGS-PeakFQ EMA-LPIII Computations—Continued

Station number and name	Peak-streamflow frequency by corresponding average return period (recurrence interval) in years							
	2 year (ft^3/s)	5 year (ft^3/s)	10 year (ft^3/s)	25 year (ft^3/s)	50 year (ft^3/s)	100 year (ft^3/s)	200 year (ft^3/s)	500 year (ft^3/s)
08057000 Trinity River at Dallas, Tex.								
Lower 95%-CI	15,730	32,060	40,390	51,060	59,030	66,880	74,580	84,520
Estimate	**22,770**	**37,420**	**48,350**	**63,390**	**75,400**	**88,060**	**101,400**	**120,200**
Upper 95%-CI	26,200	45,770	62,360	90,350	118,300	155,000	204,200	297,800
08057200 White Rk Creek at Greenville Avenue, Dallas, Tex.								
Lower 95%-CI	13,410	21,530	26,460	31,970	35,220	37,770	39,770	41,790
Estimate	**16,200**	**25,450**	**31,220**	**37,950**	**42,540**	**46,780**	**50,720**	**55,530**
Upper 95%-CI	19,330	30,150	37,940	50,030	60,730	72,830	86,770	109,000
08057410 Trinity River below Dallas, Tex.								
Lower 95%-CI	16,800	28,770	37,470	48,700	56,790	64,480	71,800	80,940
Estimate	**20,190**	**34,650**	**45,830**	**61,600**	**74,480**	**88,280**	**103,100**	**124,300**
Upper 95%-CI	24,260	42,960	60,670	92,790	125,300	166,400	218,500	308,900
08057445 Prairie Creek at U.S. Highway 175, Dallas, Tex.								
Lower 95%-CI	1,561	2,501	3,190	4,085	4,747	5,391	6,024	6,839
Estimate	**1,934**	**3,134**	**4,073**	**5,427**	**6,559**	**7,800**	**9,162**	**11,170**
Upper 95%-CI	2,411	4,184	6,116	10,730	17,290	24,700	35,100	55,770
08059000 East Fork Trinity River near McKinney, Tex.								
Lower 95%-CI	3,654	8,034	11,630	15,890	18,090	19,560	20,550	21,380
Estimate	**5,393**	**11,510**	**16,420**	**23,300**	**28,750**	**34,390**	**40,170**	**48,000**
Upper 95%-CI	7,904	16,680	26,700	44,990	62,470	84,860	114,000	167,200
08059400 Sister Grove Creek near Blue Ridge, Tex.								
Lower 95%-CI	1,179	2,398	3,388	4,744	5,750	6,709	7,616	8,735
Estimate	**1,574**	**3,198**	**4,593**	**6,718**	**8,560**	**10,620**	**12,910**	**16,330**
Upper 95%-CI	2,099	4,474	7,151	12,870	19,410	28,600	41,460	66,670
08061540 Rowlett Creek near Sachse, Tex.								
Lower 95%-CI	8,350	15,900	21,560	28,730	33,490	37,580	41,100	45,030
Estimate	**10,700**	**20,220**	**27,680**	**38,140**	**46,560**	**55,440**	**64,770**	**77,810**
Upper 95%-CI	13,680	26,290	38,670	61,210	83,110	110,200	144,000	202,100
08061750 East Fork Trinity River near Forney, Tex.								
Lower 95%-CI	9,885	20,280	27,110	34,960	39,480	42,900	45,470	47,940
Estimate	**13,810**	**26,340**	**34,730**	**44,690**	**51,460**	**57,630**	**63,240**	**69,870**
Upper 95%-CI	18,310	34,080	46,300	65,740	83,430	104,400	130,100	174,500
08062000 East Fork Trinity River near Crandall, Tex.								
Lower 95%-CI	7,680	15,390	21,020	28,360	33,530	38,240	42,460	47,340
Estimate	**9,807**	**19,230**	**26,470**	**36,370**	**44,100**	**52,020**	**60,110**	**71,030**
Upper 95%-CI	12,310	24,420	35,080	54,510	75,680	104,000	142,000	213,100

Table 2: Statistically Estimated Annual Flood Flow Frequency Results for Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trinity River Basin, Texas based on the USGS-PeakFQ EMA-LPIII Computations—Continued

Station number and name	Peak-streamflow frequency by corresponding average return period (recurrence interval) in years							
	2 year (ft^3/s)	5 year (ft^3/s)	10 year (ft^3/s)	25 year (ft^3/s)	50 year (ft^3/s)	100 year (ft^3/s)	200 year (ft^3/s)	500 year (ft^3/s)
08062500 Trinity River near Rosser, Tex.								
Lower 95%-CI	21,170	37,230	48,950	63,920	74,470	84,260	93,320	104,300
Estimate	**25,480**	**44,780**	**59,620**	**80,380**	**97,140**	**114,900**	**133,700**	**160,400**
Upper 95%-CI	30,640	55,100	77,740	117,400	156,000	203,200	261,200	358,400
08062700 Trinity River at Trinidad, Tex.								
Lower 95%-CI	27,010	44,320	55,130	68,020	76,580	84,140	90,770	98,320
Estimate	**32,810**	**52,560**	**65,890**	**82,610**	**94,840**	**106,800**	**118,600**	**133,900**
Upper 95%-CI	39,050	63,460	82,440	113,400	144,000	182,500	231,400	317,500
08062800 Cedar Creek near Kemp, Tex.								
Lower 95%-CI	4,101	7,597	10,150	12,960	14,360	15,290	15,910	16,430
Estimate	**5,559**	**10,060**	**13,300**	**17,510**	**20,650**	**23,770**	**26,870**	**30,910**
Upper 95%-CI	7,495	13,460	19,470	29,340	37,980	48,320	60,960	82,310
08063100 Richland Creek near Dawson, Tex.								
Lower 95%-CI	1,432	2,297	2,888	3,630	4,166	4,682	5,179	5,808
Estimate	**1,687**	**2,712**	**3,460**	**4,472**	**5,268**	**6,097**	**6,963**	**8,169**
Upper 95%-CI	1,983	3,296	4,401	6,154	7,766	9,680	11,950	15,610
08063590 Waxahachie Creek at Waxahachie, Tex.								
Lower 95%-CI	642	1,745	2,686	4,026	5,086	6,167	7,250	8,690
Estimate	**1,571**	**3,743**	**5,797**	**9,129**	**12,160**	**15,670**	**19,690**	**25,850**
Upper 95%-CI	3,521	11,680	25,180	62,690	117,700	212,900	377,300	700,800
08063800 Waxahachie Creek near Bardwell, Tex.								
Lower 95%-CI	937	1,438	1,710	2,031	2,255	2,465	2,664	2,912
Estimate	**1,127**	**1,635**	**1,976**	**2,411**	**2,736**	**3,062**	**3,391**	**3,831**
Upper 95%-CI	1,271	1,921	2,425	3,155	3,765	4,433	5,168	6,267
08064100 Chambers Creek near Rice, Tex.								
Lower 95%-CI	8,830	17,630	24,200	32,740	38,970	44,920	50,570	57,560
Estimate	**12,070**	**23,670**	**33,030**	**46,490**	**57,540**	**69,370**	**81,980**	**99,850**
Upper 95%-CI	16,200	33,480	50,450	80,470	110,400	148,000	195,200	275,700
08064700 Tehuacana Creek near Streetman, Tex.								
Lower 95%-CI	5,650	13,550	22,350	37,920	53,230	72,210	95,400	133,600
Estimate	**7,886**	**19,700**	**34,000**	**64,130**	**99,550**	**150,900**	**224,500**	**371,700**
Upper 95%-CI	11,020	32,200	71,000	247,000	677,100	1,583,000	3,718,000	11,570,000
08065000 Trinity River near Oakwood, Tex.								
Lower 95%-CI	26,340	55,980	74,050	94,440	106,700	116,100	123,400	130,500
Estimate	**34,410**	**66,800**	**87,840**	**111,900**	**127,600**	**141,500**	**153,600**	**167,300**
Upper 95%-CI	41,630	79,960	106,100	140,000	166,100	193,700	223,600	268,100

Table 2: Statistically Estimated Annual Flood Flow Frequency Results for Selected U.S. Geological Survey Streamflow-Gaging Stations in the Trinity River Basin, Texas based on the USGS-PeakFQ EMA-LPIII Computations—Continued

Station number and name	Peak-streamflow frequency by corresponding average return period (recurrence interval) in years							
	2 year (ft^3/s)	5 year (ft^3/s)	10 year (ft^3/s)	25 year (ft^3/s)	50 year (ft^3/s)	100 year (ft^3/s)	200 year (ft^3/s)	500 year (ft^3/s)
08065200 Upper Keechi Creek near Oakwood, Tex.								
Lower 95%-CI	2,356	6,454	10,320	16,100	20,460	24,550	28,290	32,720
Estimate	**3,404**	**9,168**	**14,780**	**23,890**	**32,070**	**41,350**	**51,750**	**67,190**
Upper 95%-CI	4,880	13,330	23,490	47,030	75,890	118,500	181,200	312,000
08065350 Trinity River near Crockett, Tex.								
Lower 95%-CI	28,160	47,400	59,970	74,170	82,370	88,670	93,540	98,430
Estimate	**34,390**	**56,910**	**71,760**	**89,840**	**102,600**	**114,800**	**126,400**	**141,000**
Upper 95%-CI	41,720	68,480	89,620	123,400	152,500	185,300	223,300	283,400
08065800 Bedias Creek near Madisonville, Tex.								
Lower 95%-CI	6,260	14,200	20,300	28,600	34,600	39,700	43,800	48,200
Estimate	**8,610**	**18,800**	**26,900**	**38,000**	**46,700**	**55,400**	**64,300**	**75,900**
Upper 95%-CI	11,800	24,700	34,900	52,400	70,100	92,000	119,000	163,000
08066000 Trinity River at Riverside, Tex.								
Lower 95%-CI	29,700	50,540	65,010	82,390	93,570	103,100	111,300	120,500
Estimate	**35,340**	**59,790**	**77,410**	**100,700**	**118,600**	**136,800**	**155,300**	**180,400**
Upper 95%-CI	42,010	71,710	97,180	138,100	174,400	216,000	264,100	340,000
08066170 Kickapoo Creek near Onalaska, Tex.								
Lower 95%-CI	4,037	8,547	12,590	18,710	23,940	29,680	35,910	44,870
Estimate	**5,343**	**11,500**	**17,530**	**27,900**	**38,000**	**50,460**	**65,740**	**91,150**
Upper 95%-CI	7,088	16,270	27,170	53,240	89,940	153,500	263,600	541,700
08066200 Long King Creek at Livingston, Tex.								
Lower 95%-CI	5,085	10,330	14,670	20,830	25,690	30,630	35,560	42,040
Estimate	**6,533**	**13,330**	**19,300**	**28,580**	**36,780**	**46,110**	**56,680**	**72,720**
Upper 95%-CI	8,391	17,610	26,970	46,110	68,820	102,000	149,900	246,900
08066250 Trinity River near Goodrich, Tex.								
Lower 95%-CI	40,200	61,700	74,200	88,600	98,100	106,000	113,000	121,000
Estimate	**47,800**	**71,100**	**85,600**	**103,000**	**115,000**	**126,000**	**137,000**	**150,000**
Upper 95%-CI	55,100	81,500	99,200	125,000	148,000	174,000	206,000	256,000
08066300 Menard Creek near Rye, Tex.								
Lower 95%-CI	1,780	3,890	5,720	8,430	10,600	12,900	15,100	17,900
Estimate	**2,360**	**5,110**	**7,550**	**11,400**	**14,700**	**18,500**	**22,800**	**29,100**
Upper 95%-CI	3,060	6,620	10,100	17,300	26,300	40,100	61,100	106,000
08066500 Trinity River at Romayor, Tex.								
Lower 95%-CI	38,210	61,080	74,170	87,680	94,770	99,750	103,300	106,600
Estimate	**44,180**	**69,040**	**83,190**	**98,300**	**107,700**	**115,800**	**122,700**	**130,500**
Upper 95%-CI	50,610	77,530	93,160	112,600	127,200	142,000	157,300	178,700
08067000 Trinity River at Liberty, Tex.								
Lower 95%-CI	31,100	53,400	67,700	85,100	97,100	108,000	118,000	130,000
Estimate	**36,800**	**61,300**	**78,200**	**99,900**	**116,000**	**132,000**	**148,000**	**169,000**
Upper 95%-CI	42,100	71,100	92,900	126,000	158,000	197,000	244,000	322,000

1.4 CHANGES TO FLOOD FLOW FREQUENCY ESTIMATES OVER TIME

Statistically based flow frequency estimates are dependent on observational data and historical information. Collectively, these are shown in Figures 57–74 (18 stream gages). The annual recurrence intervals of interest here are 2, 10, 100, and 500 years. The 18 stream gages were selected as those of particular interest of InFRM team members for this type of analysis because they represent locations with especially long record and (or) represent important waypoints in the study of Trinity River basin flood flow hydrology. The stream gage numbers and names are 08042800 (West Fork Trinity River near Jacksboro), 08044500 (West Fork Trinity River near Boyd), 08047500 (Clear Fork Trinity River at Fort Worth), 08048000 (West Fork Trinity River at Fort Worth), 08049500 (West Fork Trinity River at Grand Prairie), 08049700 (Walnut Creek near Mansfield), 08050100 (Mountain Creek at Grand Prairie), 08051500 (Clear Creek near Sanger), 08053500 (Denton Creek near Justin), 08055500 (Elm Fork Trinity River near Carrolton), 08057000 (Trinity River at Dallas), 08057200 (White Rock Creek at Greenville, Avenue, Dallas), 08061540 (Rowlett Creek near Sachse), 08062000 (East Fork Trinity River near Crandall), 08062500 (Trinity River near Rosser), 08065000 (Trinity River near Oakwood), 08066000 (Trinity River at Riverside), and 08066500 (Trinity River at Romayor).

Each of these figures is presented in downstream order. Discussion for each stream gage is not proferred because of considerable similarity or parallelism among the figures. As a result, the earlier listed stream gages have more attendant discussion than later ones. Each of these examples is intended to illustrate that there is a progression in statistical estimates over time as flood events are observed and the sample size available changes. As a note, peaks outside the period of record are not shown.

A progression in the estimates occurs because the total sample size as a measure of information content of flood flows increases at a proportionally smaller rate. For example, one more year of data for a sample of 10 years represents a 10-percent increase information, whereas, one more year of data for a sample of 50 years is only a 2 percent increase in information. In other words, as the record length increases, given other factors remaining relatively constant, the estimates should vary year to year to a lesser degree for the simple reason that proportionally less information is included with each successive year. A striking feature of the figures is the sensitivity of estimates of the 100- and 500-year return period when large floods are observed (included) in the record.

The USGS-PeakFQ software when setup for data processing by EMA does not readily facilitate computations such as those required for similar graphics. The computations involved were based on fitting the LPIII to the L-moments (Asquith, 2011a,b) of the data points shown from a given year backwards in time. The computations included a minimum of 10 years. As a result, the actual starting year varies amongst the figures. The results of USGS-PeakFQ software as listed in Table 5.2 provide the ordinates for 2016 (right-most side of curves ending between 2010 and 2020 in the figures), and logarithmic-derived offsets between the L-moment-based LPIII fit in 2016 were used to adjust the curves in prior years for each of the four recurrence intervals.

The estimates are necessarily sensitive to the coefficient of skewness computed. For example, a postitive value for skewness and the LPIII distribution can lead to rapidly increasing flood flow estimates. The 500-year return period streamflow can be much larger than the 100-year return period. Conversely, a negative value of skewness can lead to only a modest increase in streamflow between the 100-year and 500-year return period. The LPIII shows a finite upper bound. Skewness can abruptly change magnitude and even its sign (negative or positive) when large flood events become included in the record.

West Fork Trinity River near Jacksboro, Texas

Relative impact of record length and magnitudes of substantial floods for the West Fork Trinity River near Jacksboro are shown in Figure 57. The estimates for the 2-, 10-, 100-, and 500-year return period show a couple of tendencies that will be shown in many of the other 17 figures. First, the estimates tend to stabilize in time as the record length increases. Second, the 2-year return period does not vary much and this is because this estimate is largely the median annual peak, and in succession, as return period increases the variation in the estimates increase. In fact, the 500-year estimate at one point greatly exceeds the chosen upper limit of the vertical axis. For the design of this and the other figures, the limits were set at a minimum to encompass the 100-year return period. Third, there often is an asymmetrical saw tooth pattern to the curves. Focusing on the 100-year estimates, it is seen that the estimates tend to jump when large floods occur in the record and then gradual decline as more typical flood events occur. For this stream gage, large jumps and subsequent tappering off of the estimates are seen near 1990 and again near 2015 as seemingly back-to-back large events occur and change the statistics fitting the LPIII distribution accordingly.

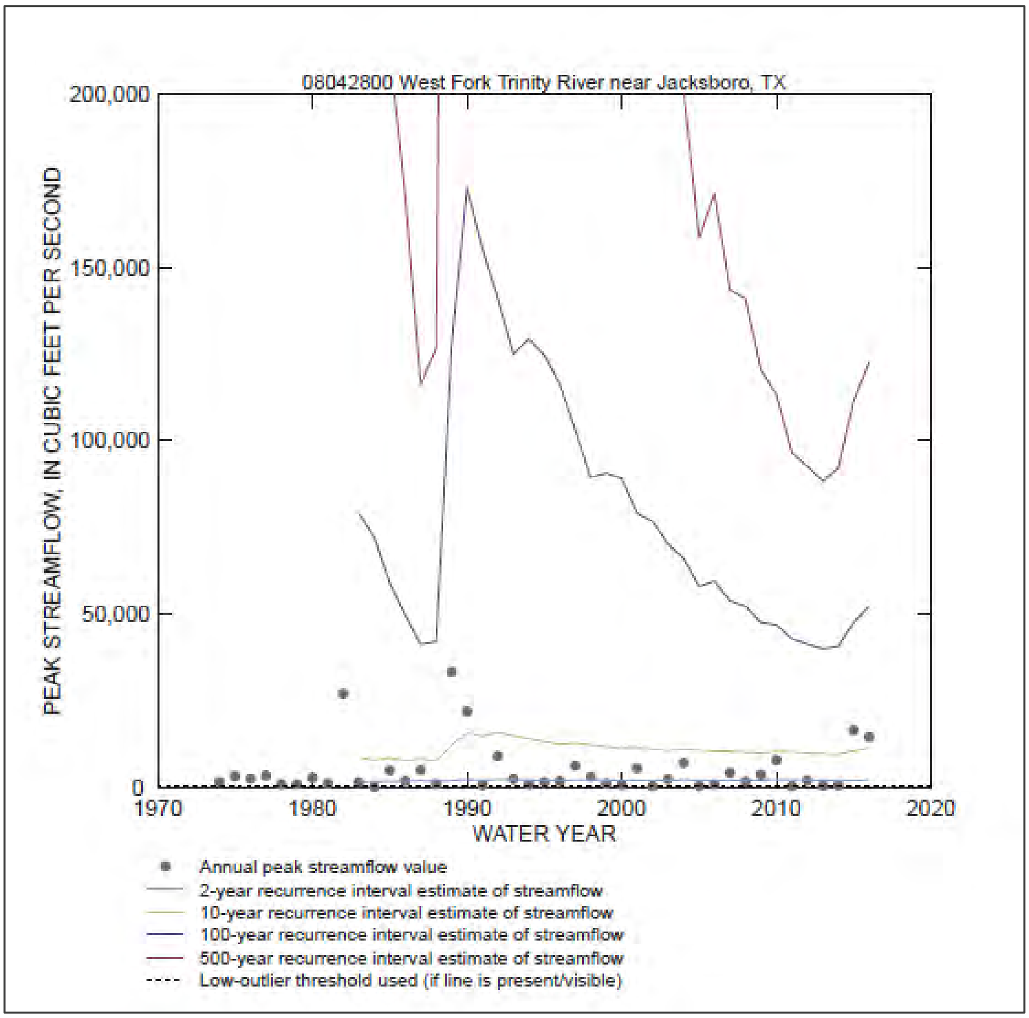

Figure 57: Statistical Frequency Flow Estimates versus Time for 08042800 West Fork Trinity River near Jacksboro, TX

West Fork Trinity River near Boyd, Texas

Relative impact of record length and magnitudes of substantial floods for the West Fork Trinity River near Boyd, TX are shown in Figure 58. Similar discussion as for Figure 57 is applicable. Perhaps the most notable feature shown in Figure 58 is the relative stability of the 100-year estimate since about 1983.

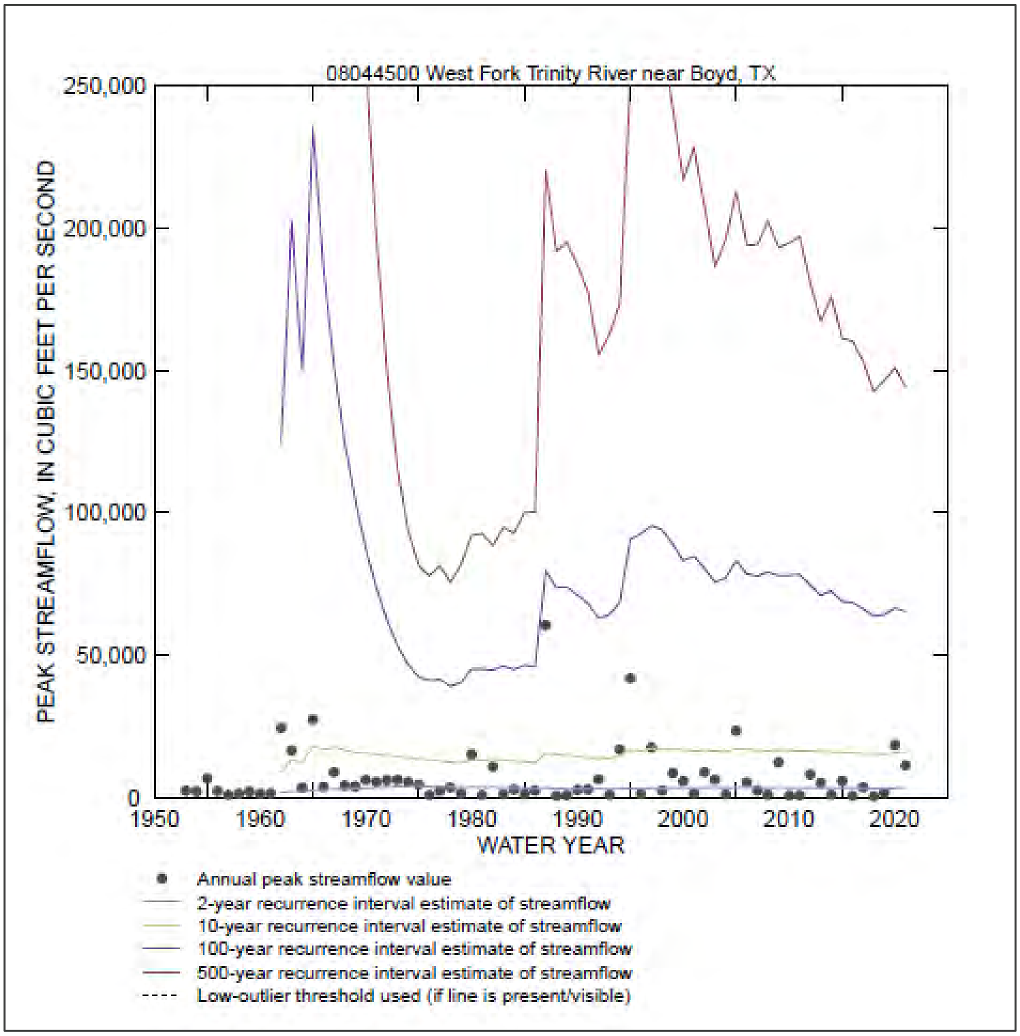

Figure 58: Statistical Frequency Flow Estimates versus Time for 08044500 West Fork Trinity River near Boyd, TX

Clear Fork Trinity River at Fort Worth, Texas

Relative impact of record length and magnitudes of substantial floods for the Clear Fork Trinity River at Fort Worth, TX are shown in Figure 59. Similar discussion as for figure 57 is applicable. A notable difference is that the low-outlier threshold is visible in this analysis. This has an effect of not computing the estimates until the mid 1980s because of the 10-value minimum for computation described previously. The estimates seem to be relatively stable throughout the period of record. This is partly attributable to the absence of very large events observed in the record.

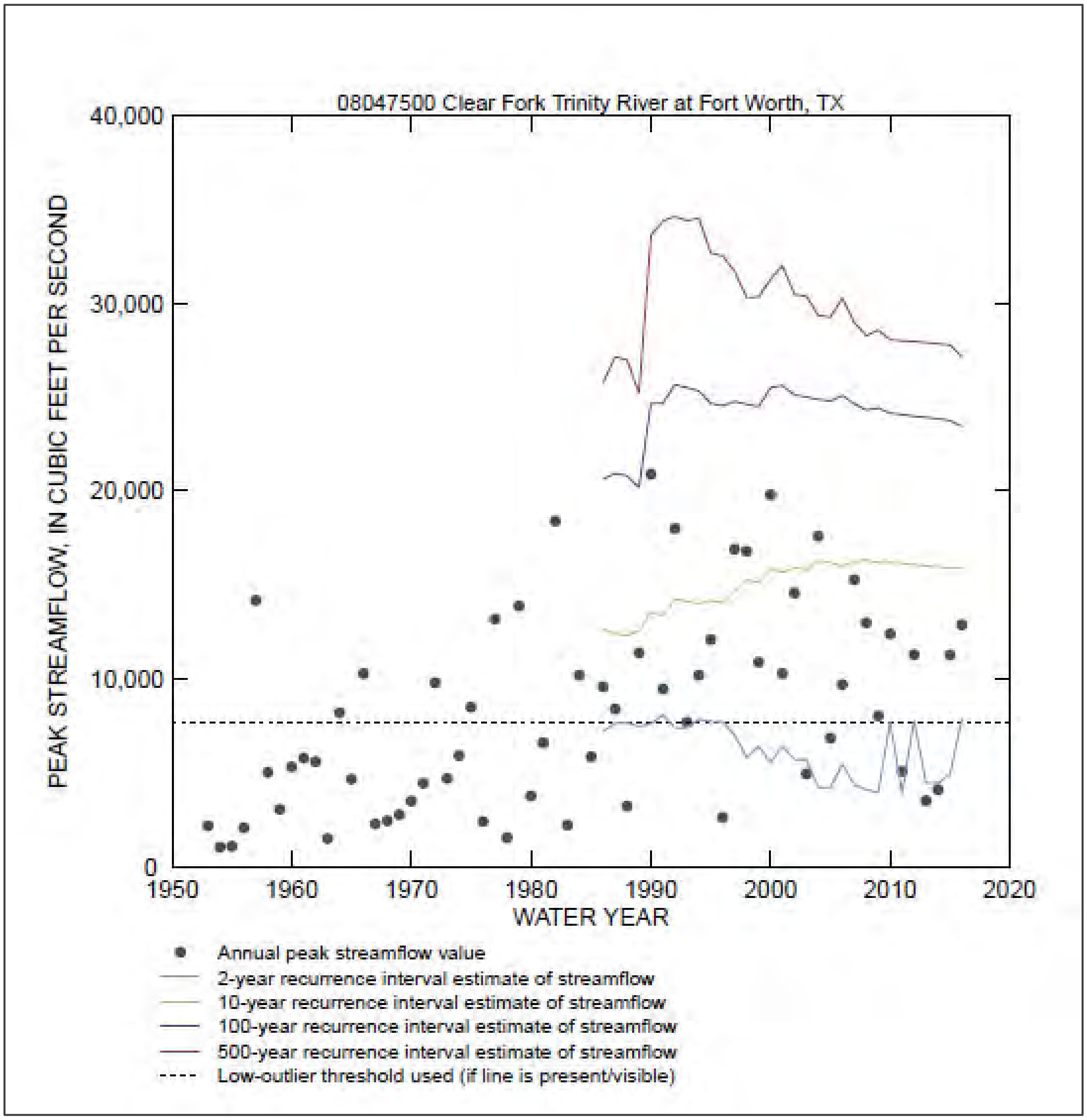

Figure 59: Statistical Frequency Flow Estimates versus Time for 08047500 Clear Fork Trinity River at Fort Worth, TX

West Fork Trinity River at Fort Worth, Texas

Relative impact of record length and magnitudes of substantial flood impacts for West Fork Trinity River at Fort Worth are shown in Figure 60. Similar discussion as for Figure 57 is applicable. An especially interesting aspect of the estimates in Figure 60 are the generalized and persistent decline in the estimates until about the 1990s with general stability in the estimates since that time.

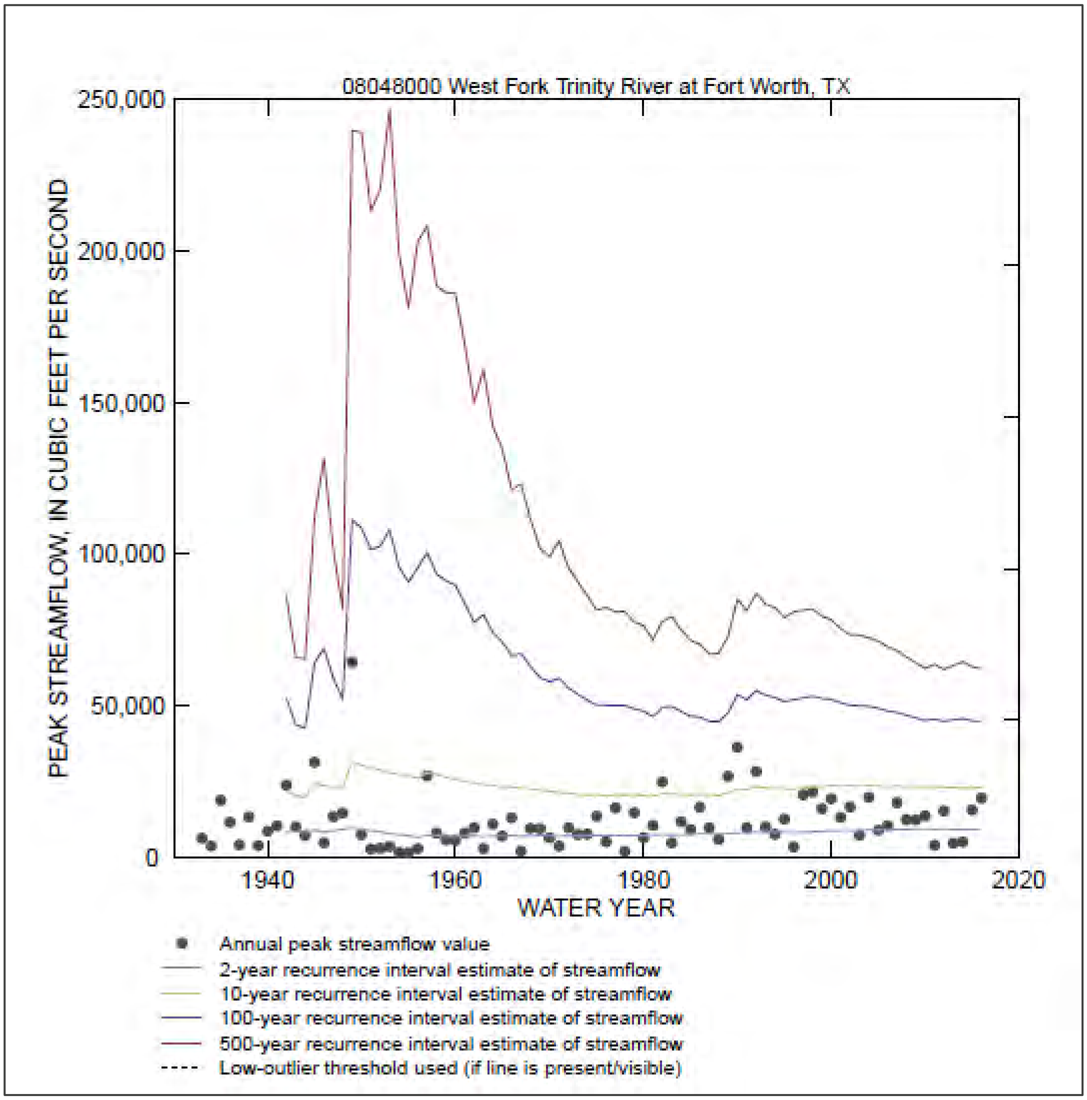

Figure 60: Statistical Frequency Flow Estimates versus Time for 08048000 West Fork Trinity River at Fort Worth, TX

West Fork Trinity River at Grand Prairie, Texas

Relative impact of record length and magnitudes of substantial floods for West Fork Trinity River at Grand Prairie are shown in Figure 61. Similar discussion as for Figure 57 is applicable. There are two notable upswings in the estimates in about 1960 and again in about 1990, which show the impacts of the top five events in the observational record.

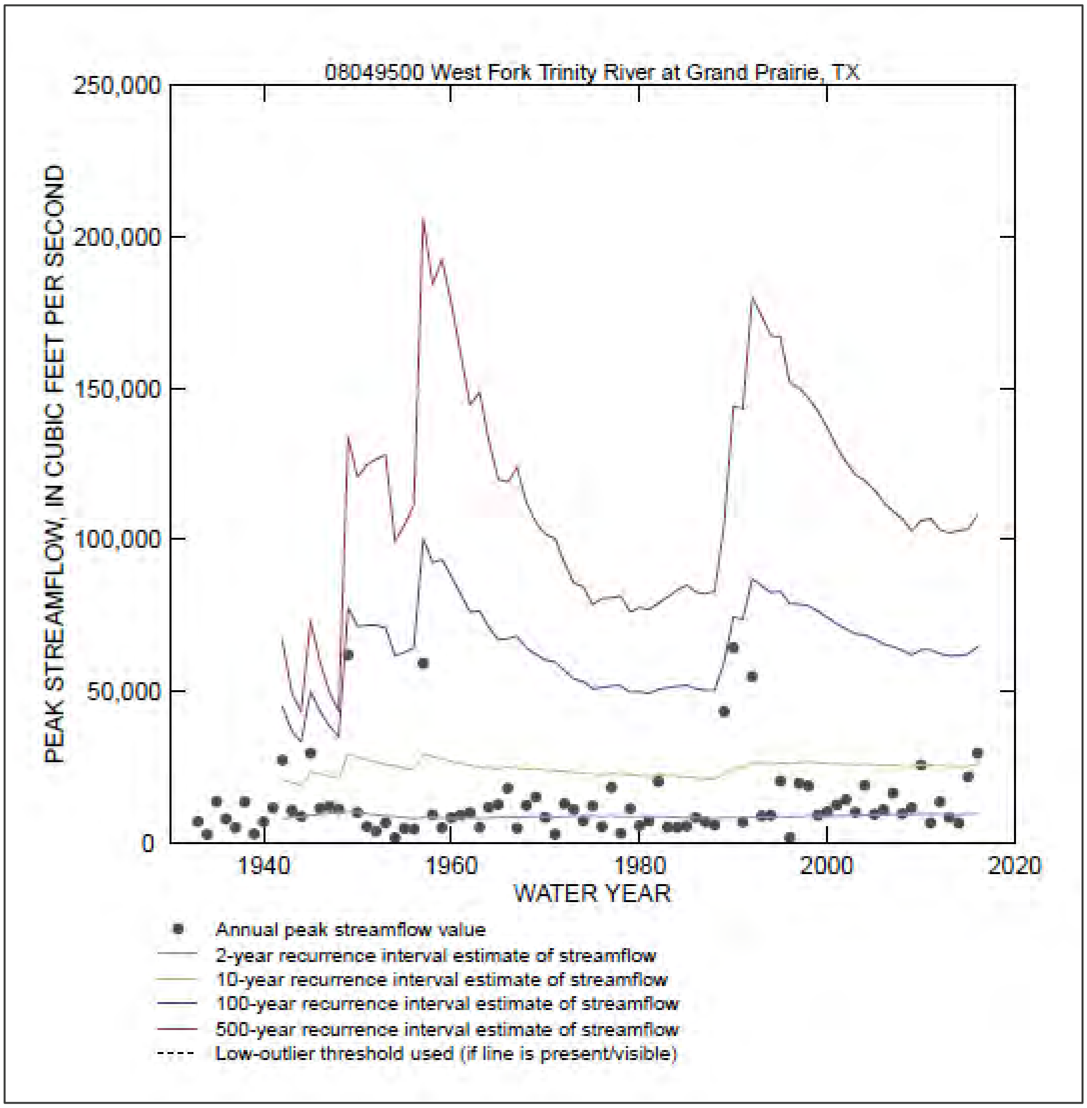

Figure 61: Statistical Frequency Flow Estimates versus Time for 08049500 West Fork Trinity River at Grand Prairie, TX

Walnut Creek near Mansfield, Texas

Relative impact of record length and magnitudes of substantial floods for Walnut Creek near Mansfield are shown in Figure 62. Similar discussion as for Figure 57 is applicable. There appears to be an upward trend in the estimates until about 1990 with general stability since that time.

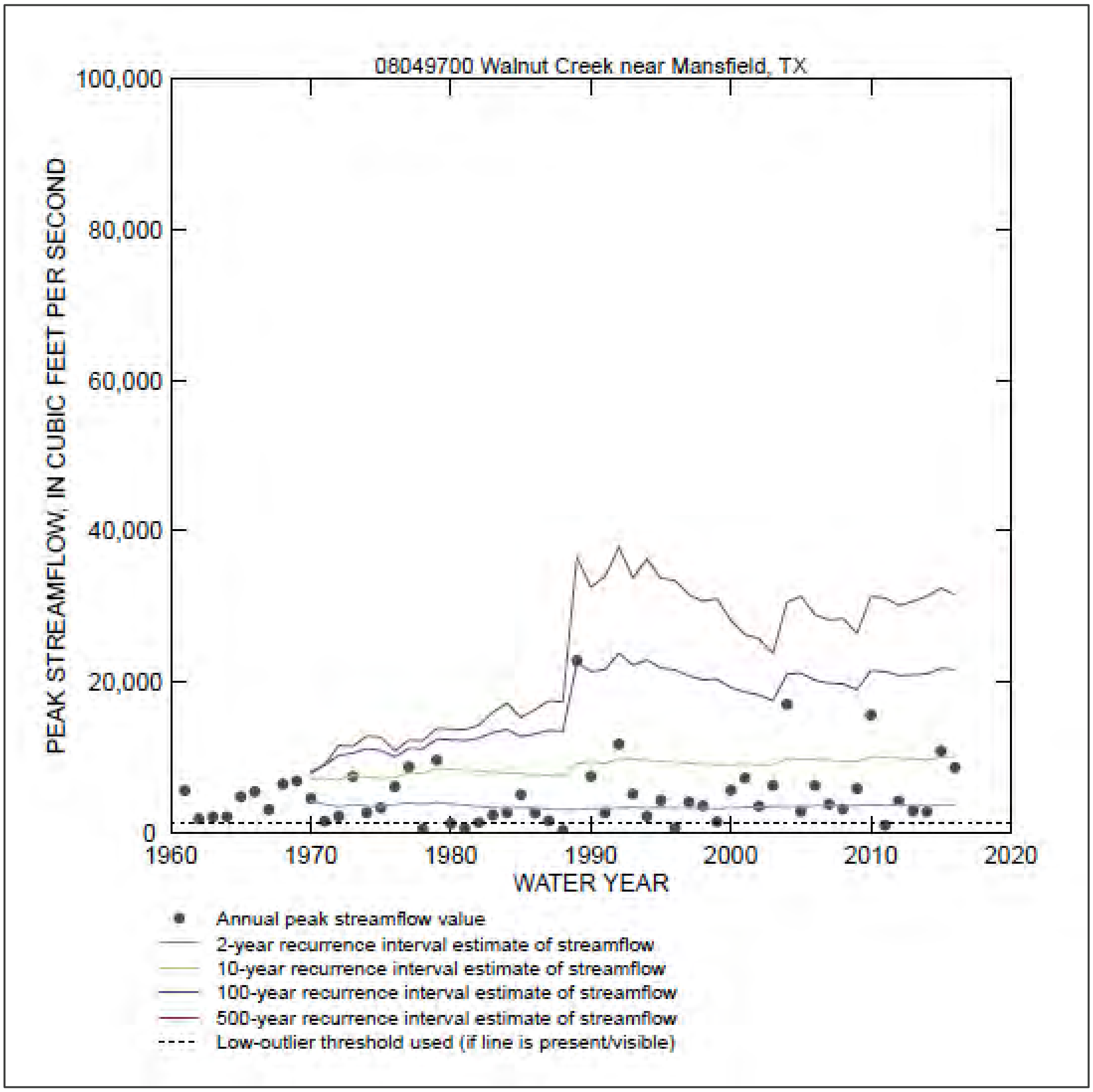

Figure 62: Statistical Frequency Flow Estimates versus Time for 08049700 Walnut Creek near Mansfield, TX

Mountain Creek at Grand Prairie, Texas

Relative impact of record length and magnitudes of substantial floods for Mountain Creek at Grand Prairie are shown in Figure 63. The data are comparatively short for this streamgage compared to the others in this section. In general, it seems that the estimates are stable, which is reflected in the general scatter of the data shown.

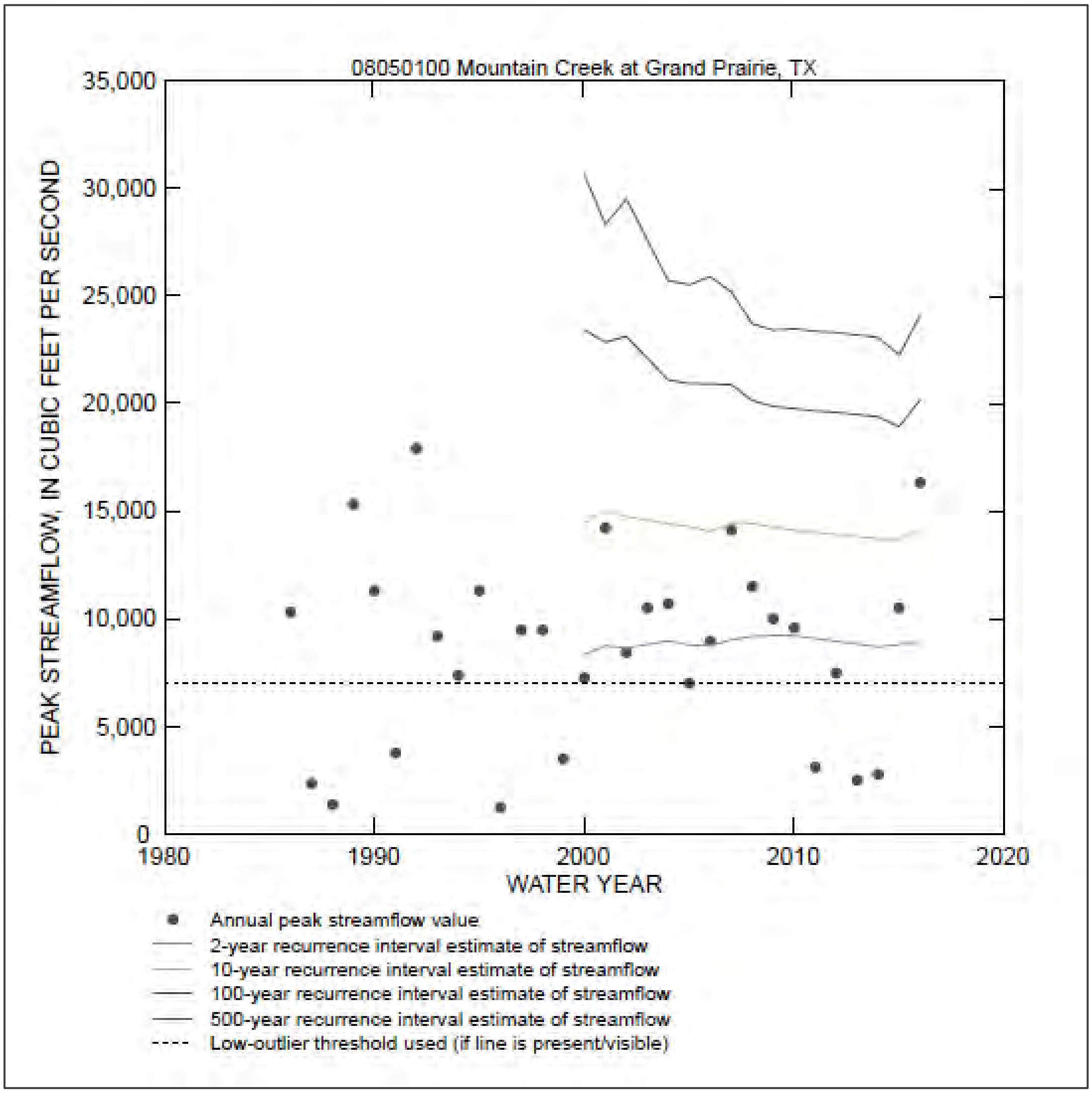

Figure 63: Statistical Frequency Flow Estimates versus Time for 08050100 Mountain Creek at Grand Prairie, TX

Clear Creek near Sanger, Texas

Relative impact of record length and magnitudes of substantial floods for Clear Creek near Sanger are shown in Figure 64. Similar discussion as for Figure 57 is applicable. The impacts of the solitary events in 1982 are substantial. For example, the percent change in the 100-year estimate is approximately 133 percent although the estimates have a continual decline since then. However, it is clear that the presence of this one event in the observational record results in a 2016 estimate of the 100-year return period that is nearly double the general estimate leading up to 1982.

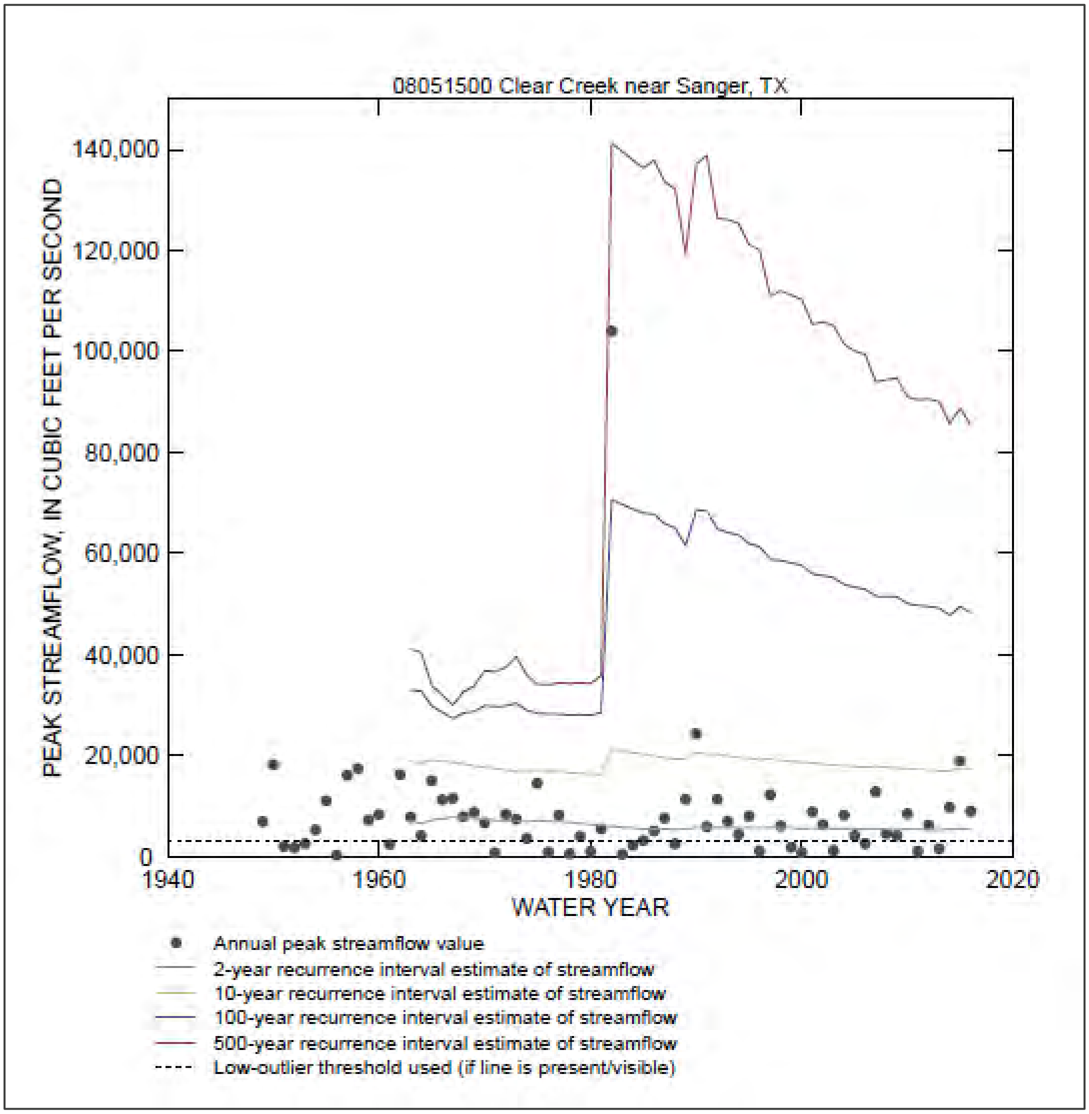

Figure 64: Statistical Frequency Flow Estimates versus Time for 08051500 Clear Creek near Sanger, TX

Denton Creek near Justin, Texas

Relative impact of record length and magnitudes of substantial floods for Denton Creek near Justin are shown in Figure 65. Similar discussion as for Figure 57 is applicable.

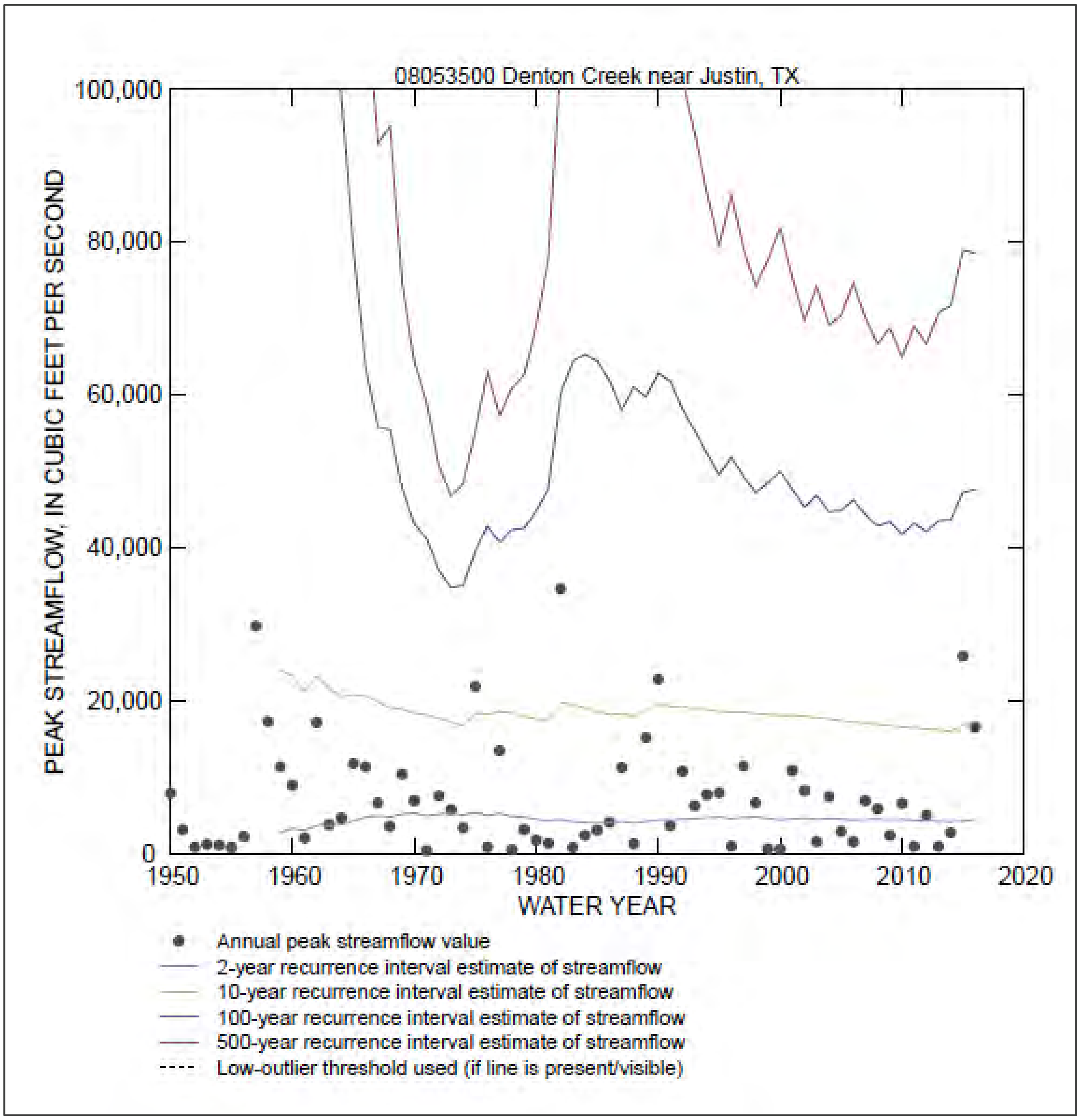

Figure 65: Statistical Frequency Flow Estimates versus Time for 08053500 Denton Creek near Justin, TX

Elm Fork Trinity River near Carrollton, Texas

Relative impact of record length and magnitudes of substantial floods for Elm Fork Trinity River near Carrollton are shown in Figure 66. Similar discussion as for Figure 57 is applicable.

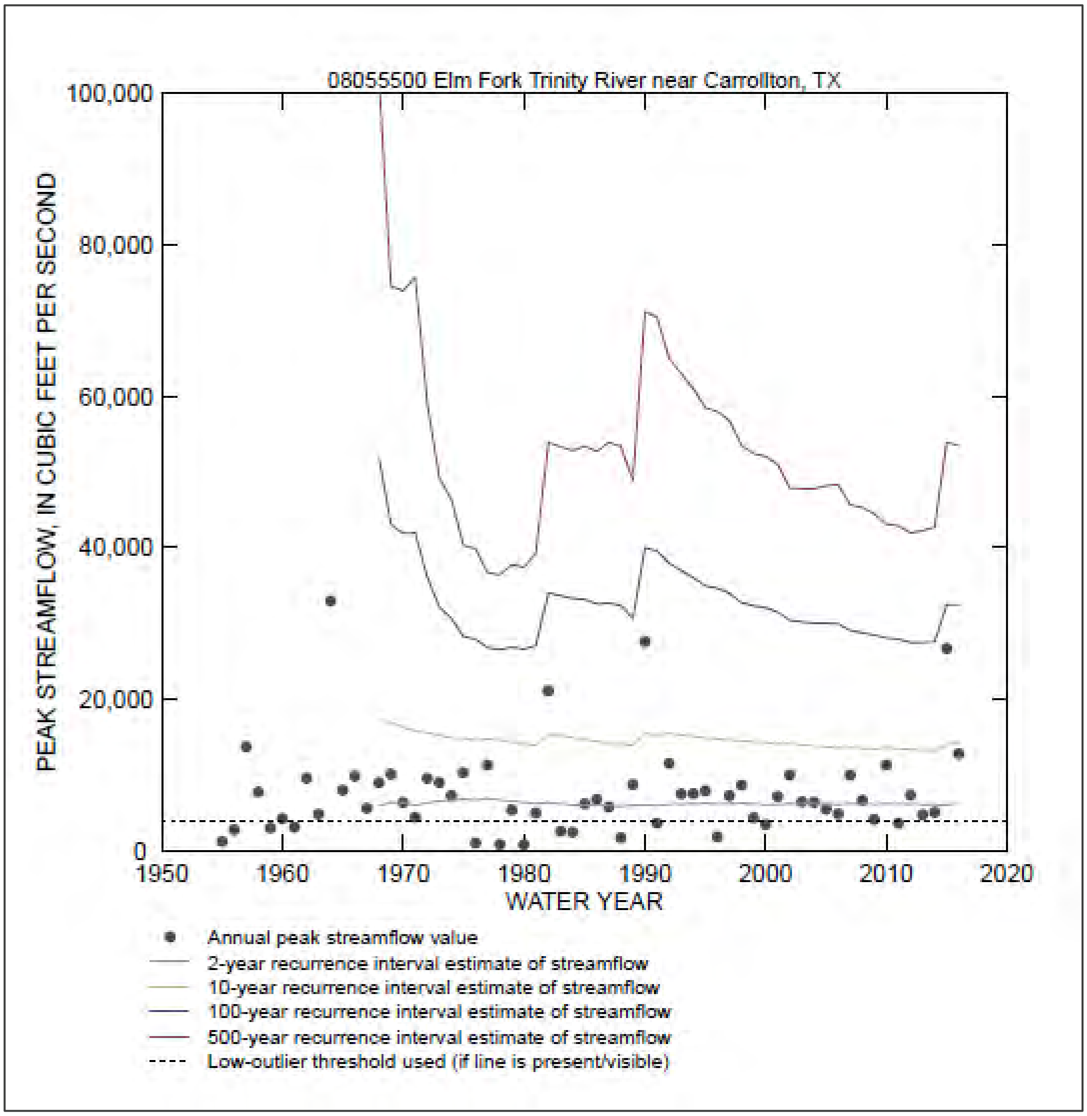

Figure 66: Statistical Frequency Flow Estimates versus Time for 08055500 Elm Fork Trinity River near Carrollton, TX

Trinity River at Dallas, Texas

Relative impact of record length and magnitudes of substantial floods for Trinity River at Dallas are shown in Figure 67. Similar discussion as for Figure 57 is applicable. Perhaps the most striking feature of the estimates are a generalized decline for the data shown with only a modest increase with the cluster of three large events in about 1990.

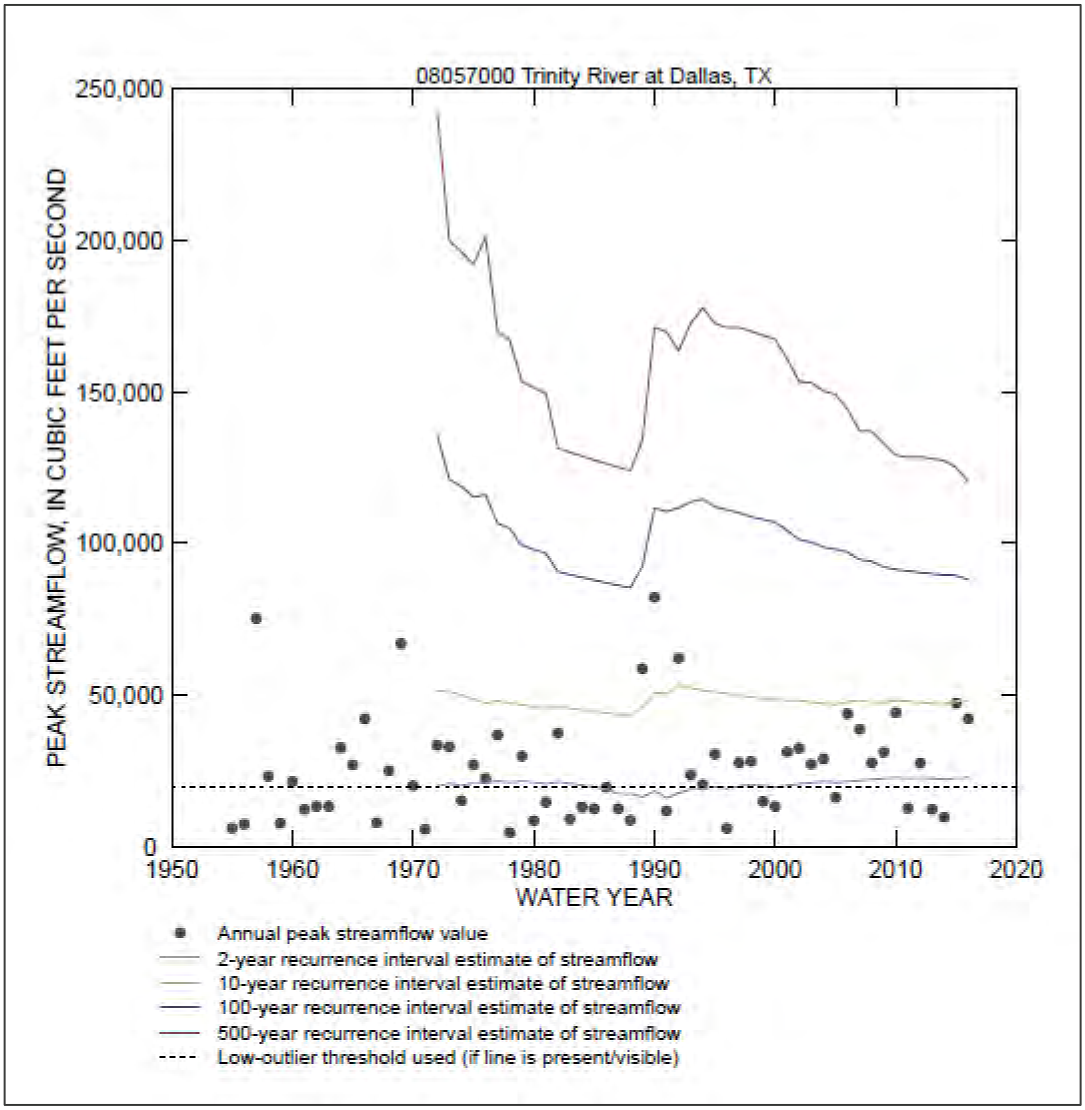

Figure 67: Statistical Frequency Flow Estimates versus Time for 08057000 Trinity River at Dallas, TX

White Rock Creek at Greenville Avenue, Dallas, Texas

Relative impact of record length and magnitudes of substantial floods for White Rock Creek at Greenville Avenue, Dallas are shown in Figure 68. Similar discussion as for Figure 57 is applicable.

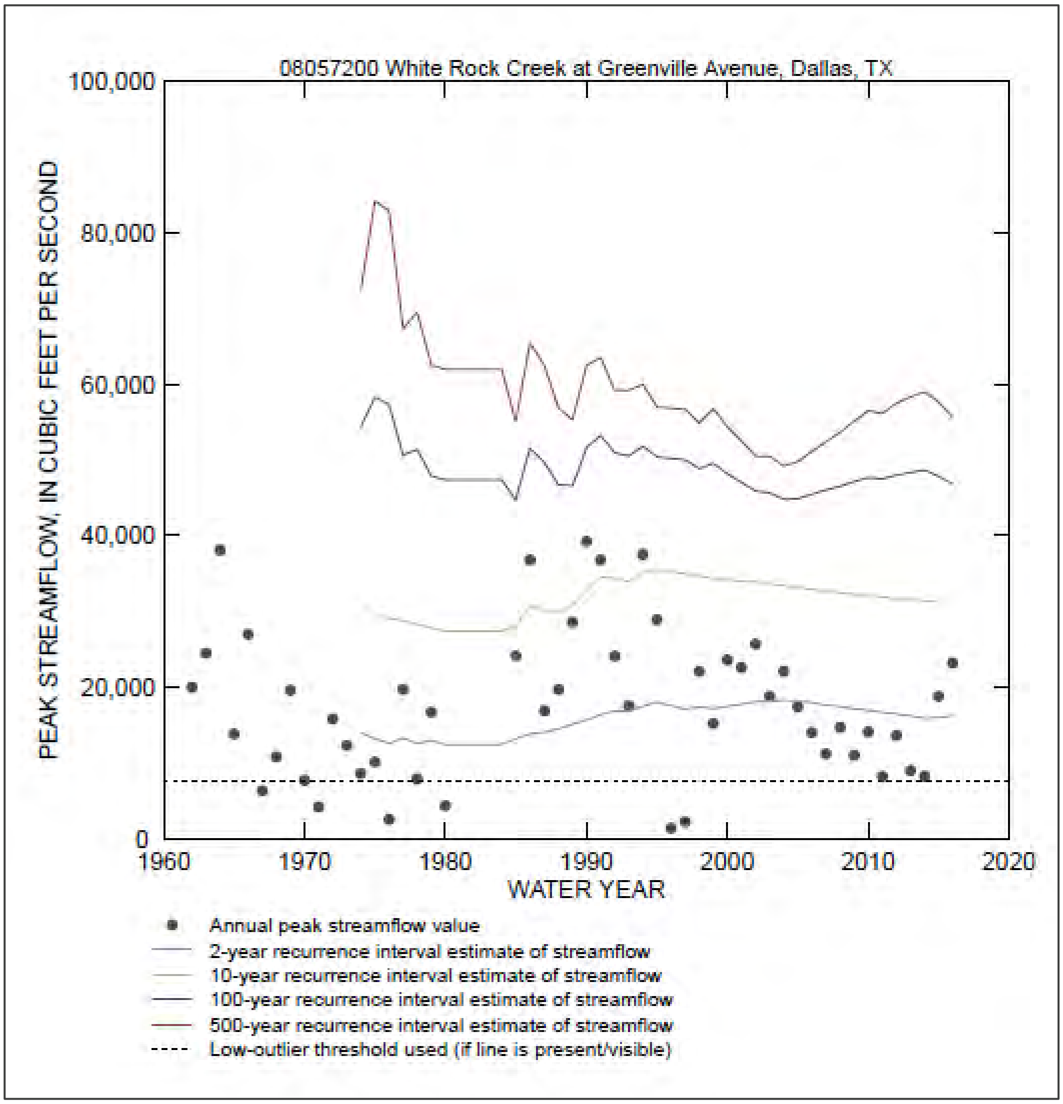

Figure 68: Statistical Frequency Flow Estimates versus Time for 08057200 White Rock Creek at Greenville Avenue, Dallas, TX

Rowlett Creek near Sachse, Texas

Relative impact of record length and magnitudes of substantial floods for Rowlett Creek near Sachse are shown in Figure 69. Similar discussion as for Figure 57 is applicable. The recent large events in 2015 and again in 2016 show an increase in the estimates. If patterns similar to other analyses in this section hold, then it might be anticipated that a period of decline will occur for some years after 2016.

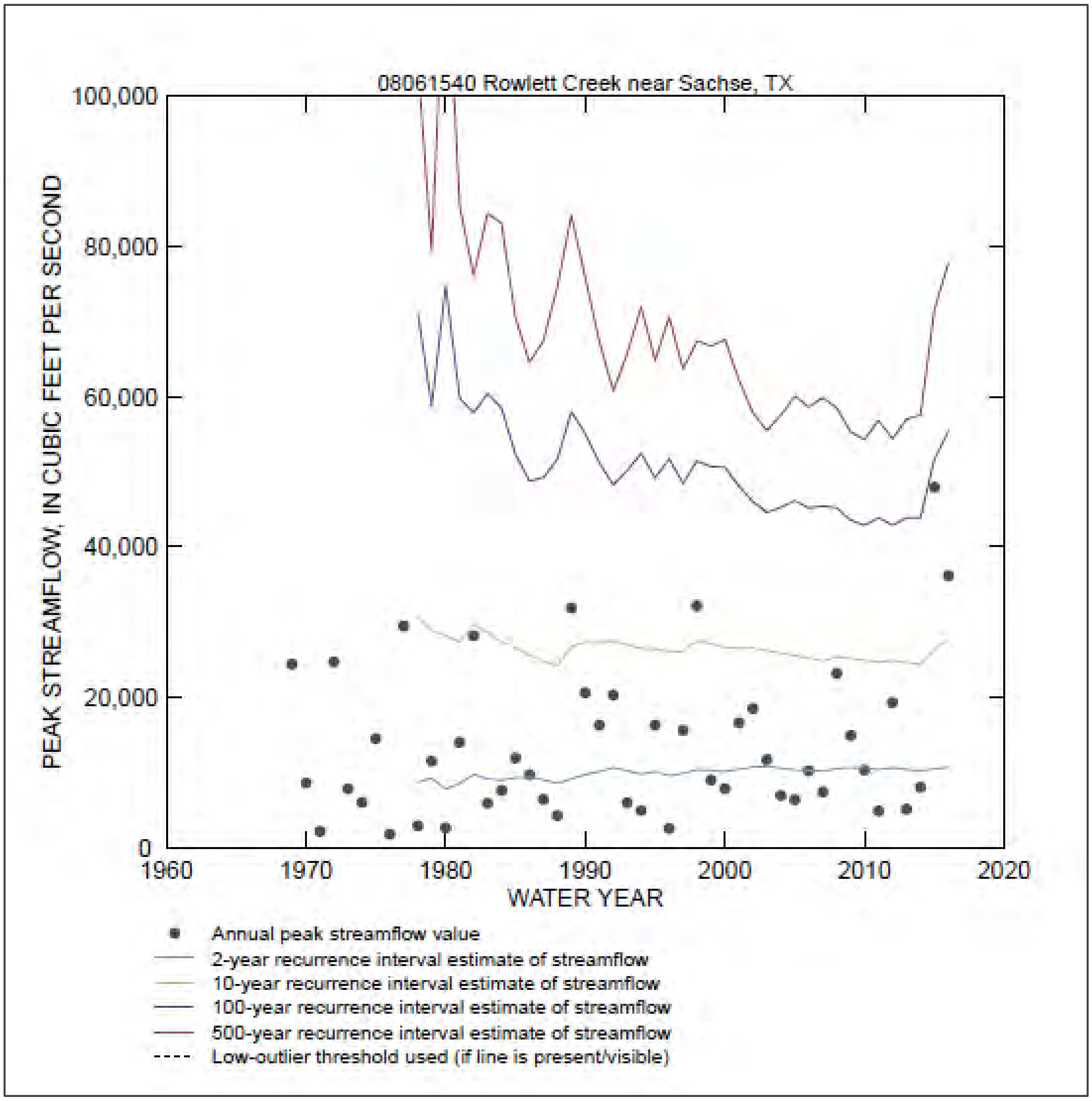

Figure 69: Statistical Frequency Flow Estimates versus Time for 08061540 Rowlett Creek near Sachse, TX

East Fork Trinity River near Crandall, Texas

Relative impact of record length and magnitudes of substantial floods for East Trinity River near Crandall are shown in Figure 70. Similar discussion as for Figure 57 is applicable.

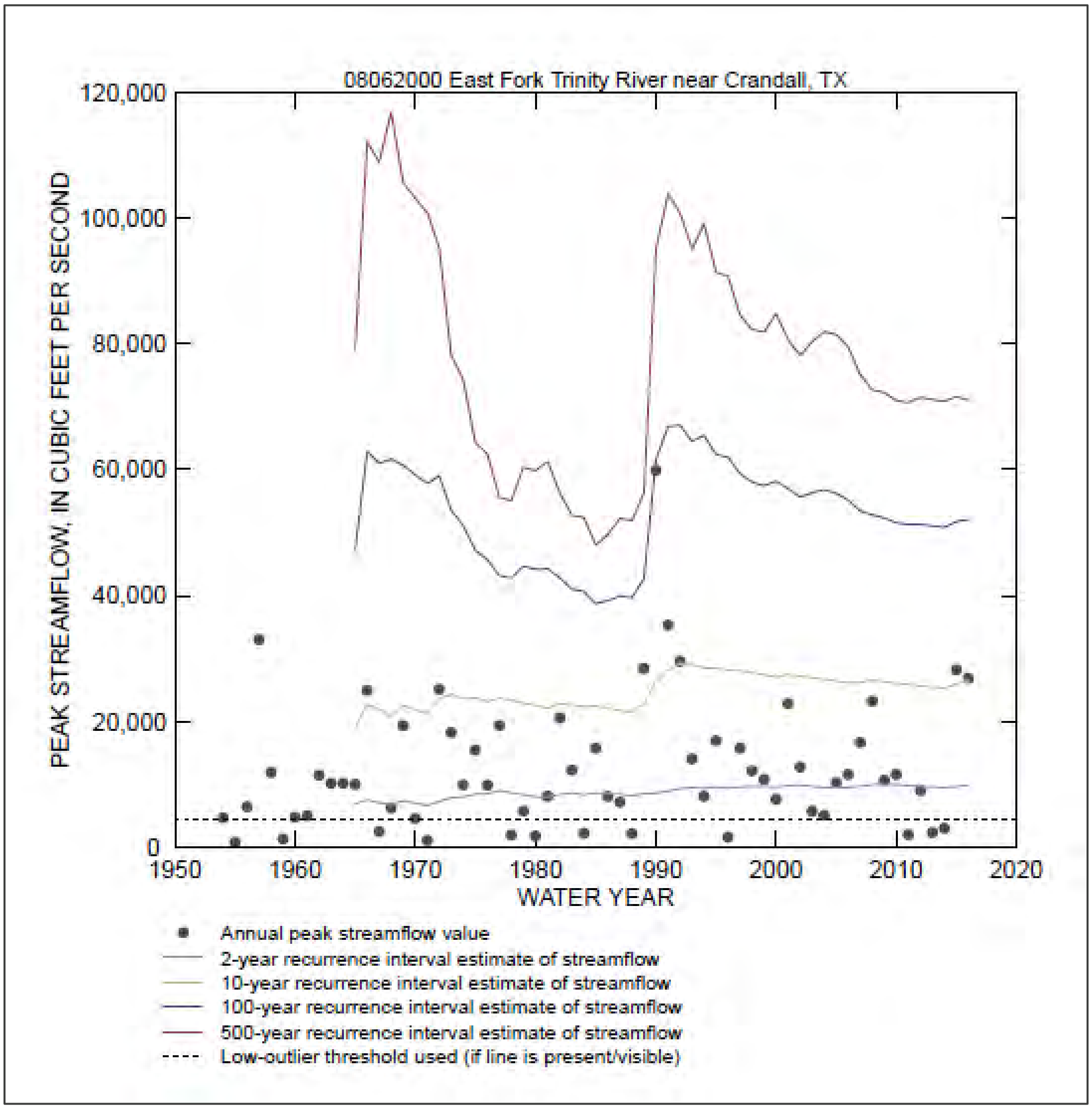

Figure 70: Statistical Frequency Flow Estimates versus Time for 08062000 East Fork Trinity River near Crandall, TX

Trinity River near Rosser, Texas

Relative impact of record length and magnitudes of substantial floods for Trinity River near Rosser are shown in Figure 71. Similar discussion as for Figure 57 is applicable. It is notable that there appears to be a persistent generalized decline in estimates throughout the period of data even in the context of two large events at the end of the record in 2015 and 2016.

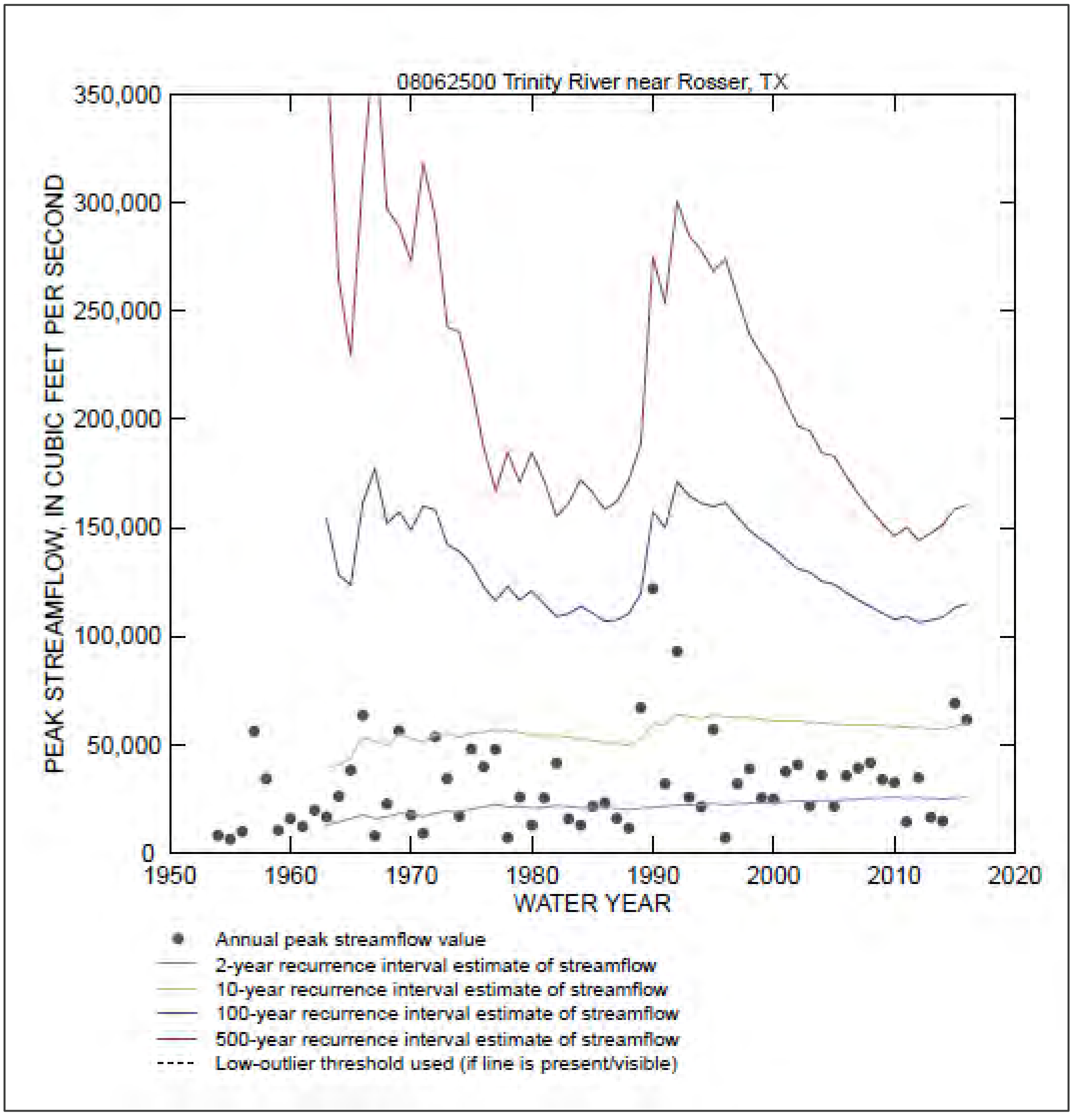

Figure 71: Statistical Frequency Flow Estimates versus Time for 08062500 Trinity River near Rosser, TX

Trinity River near Oakwood, Texas

Relative impact of record length and magnitudes of substantial floods for the Trinity River near Oakwood are shown in Figure 72. Similar discussion as for Figure 57 is applicable. It is notable that the estimates have been generally stable since about 1970 to 2016.

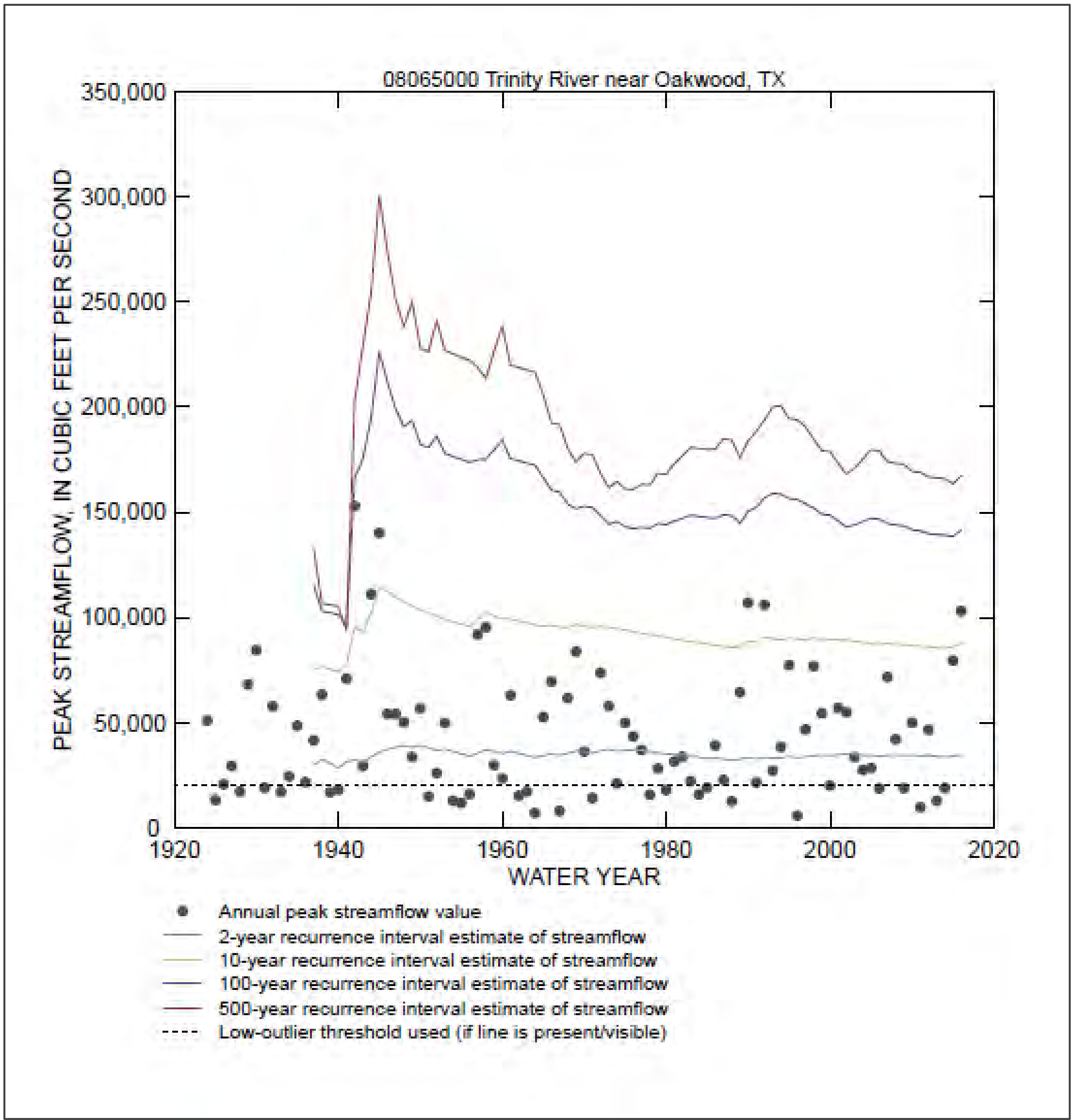

Figure 72: Statistical Frequency Flow Estimates versus Time for 08065000 Trinity River near Oakwood, TX

Trinity River at Riverside, Texas

Relative impact of record length and magnitudes of substantial floods for the Trinity River at Riverside are shown in Figure 73. Similar discussion as for Figure 57 is applicable. It is notable that the estimates have a generalized increase since about 1940 to the discontinuation of this stream gage in 1969.

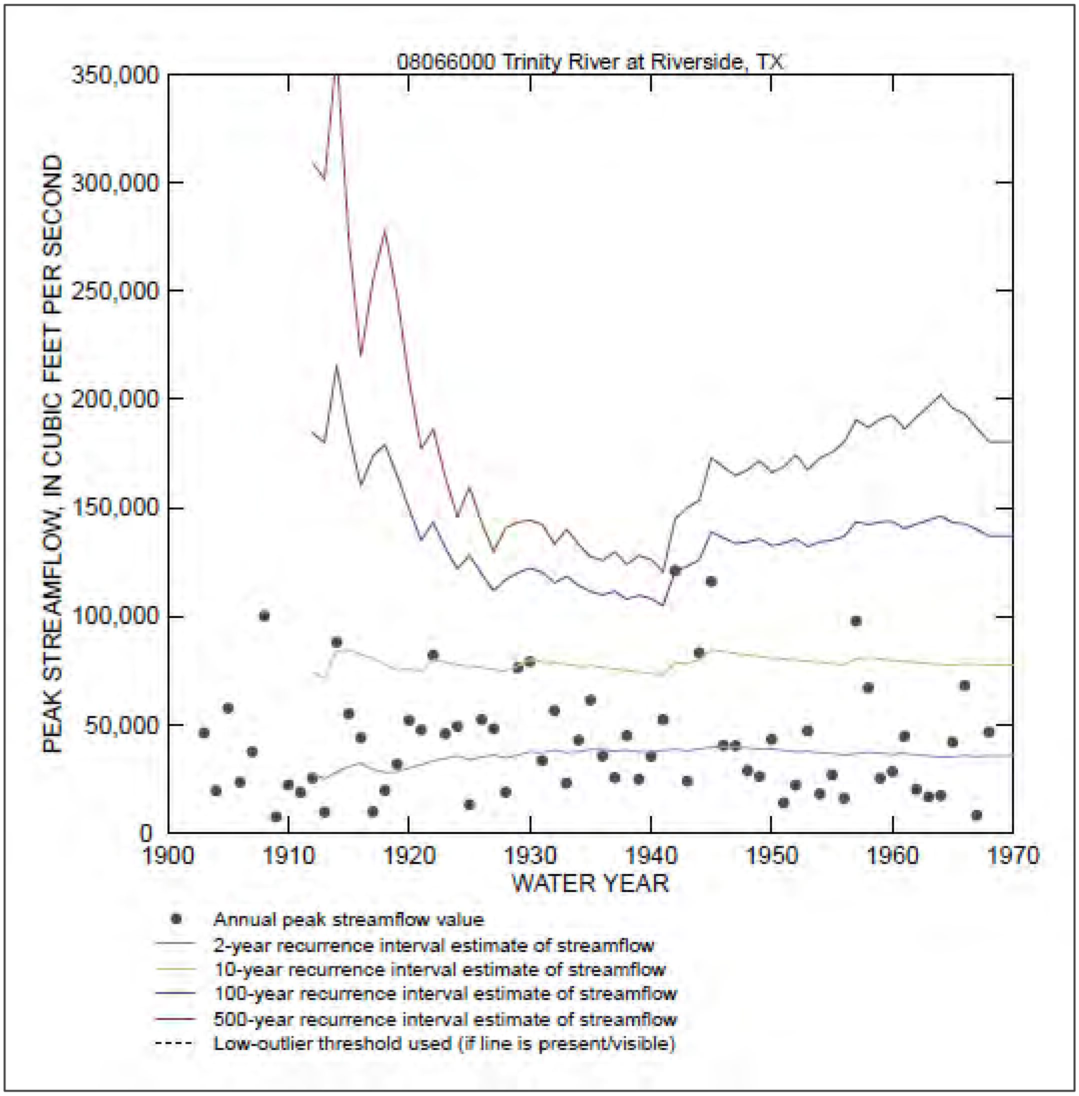

Figure 73: Statistical Frequency Flow Estimates versus Time for 08066000 Trinity River at Riverside, TX

Trinity River at Romayor, Texas

Relative impact of record length and magnitudes of substantial floods for the Trinity River at Romayor are shown in Figure 74. Similar discussion as for Figure 57 is applicable. This is a long record site. It is possible that a generalized decline in the estimates since the late 1960s is correlated with the nearby, upstream construction of Lake Livingston. The lake may have led to peak hydrograph suppression after the 1960s. With the large 1995 event, the estimates have increased and have remained relatively stable for the past 20 years (2016-1996). It seems that today's (2016) estimates with substantial data are somewhat smaller than estimates for the period of 1940 to the late 1960s.

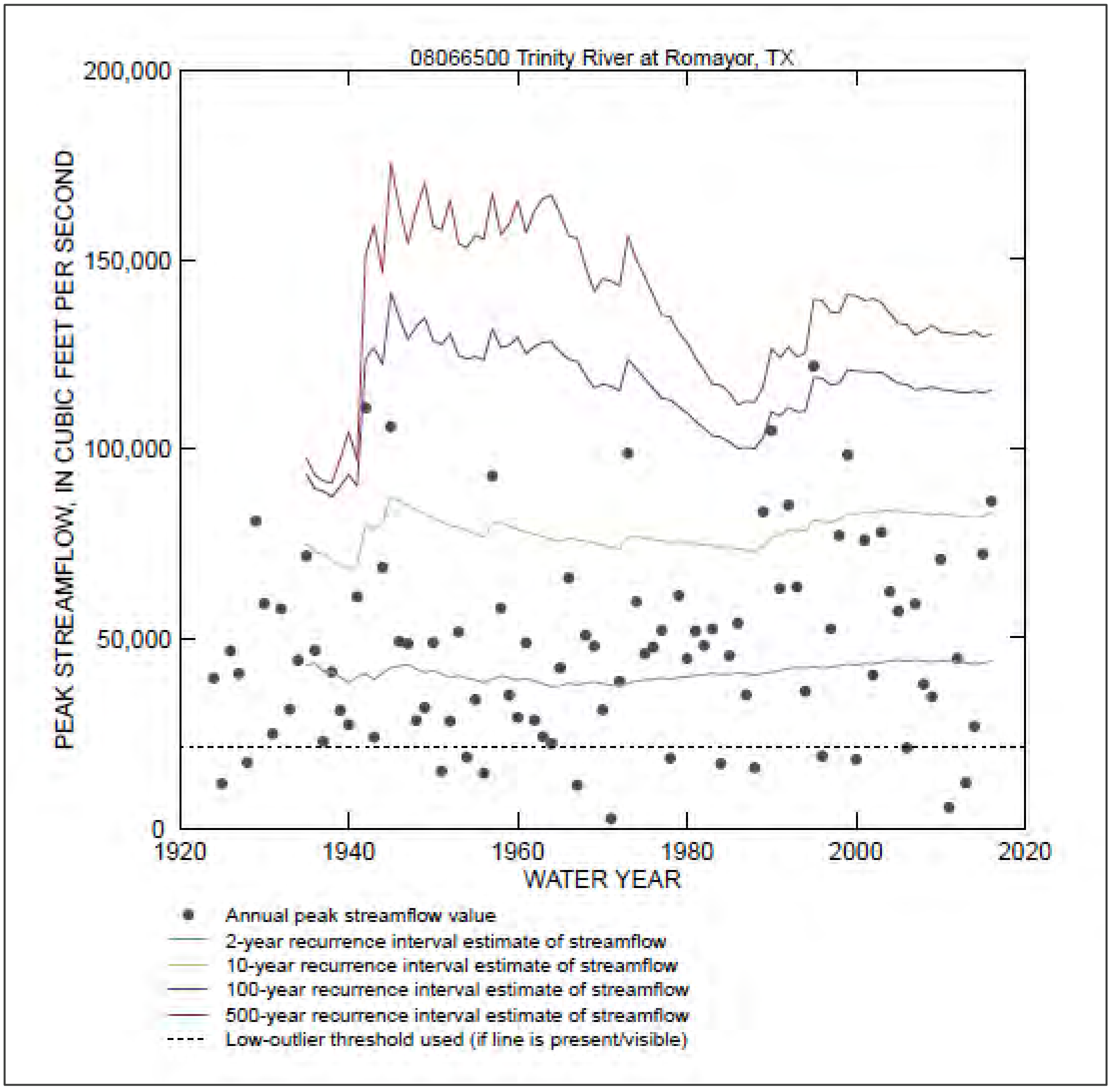

Figure 74: Statistical Frequency Flow Estimates versus Time for 08066500 Trinity River at Romayor, TX

1.5 INFLUENCE OF CLIMATIC VARIABILITY

Stochastically, annual peak streamflow does not occur at the same time in each water year. Each year the annual peak streamflow for a stream gage is generated by the watershed from immensely complex interactions. These interactions include weather patterns and discrete rainfall events and physical aspects of the terrain coupled with the amalgamation of the arrival times of flood waves amongst tributaries. Arrivial times are simultaneously dependent on conditional storage conditions, infiltration capacity conditions, antecedent moisture, and also the pre-existing fullness of channels when the peak-producing rains occur. Storage conditions represent both manmade structures (reservoirs and detention basins) but also nonpoint storage such as initial watershed losses and depression storage. Conversely, some water years might effectively have such limited rainfall input that residual waters draining for many months or longer periods of previous rainfall episodes would not be considered as “flood events.” The conditional status of the watershed is influenced by general climate conditions because such conditions express antecedent moisture conditions.

A sensitivity study was conducted to evaluate the effects of climate variability on the record. Runoff and soil loss rates in Texas have been observed to vary greatly from one storm to another, depending on the antecedent moisture conditions of the soil at the time of the storm. Therefore, for this sensitivity test, the Palmer Drought Severity Index (PDSI) was used at the time of each recorded annual peak to divide the streamflow-gaging stations record into a “wet” peak series and a “dry” peak series. For each of the 55 stream gages of this greater study, a threshold of PDSI demarking dry and wet conditions for the month of each annual peak streamflow was selected as PDSI = 1.6, which approximately bifurcates the data. An annual peak occurring in a month having PDSI less than or equal to 1.6 was classified as a dry condition peak and conversely an annual peak occurring in a month having PDSI greater than 1.6 was classified as a wet condition peak. In particular, the PDSI is used to distinguish between periods of below typical and abundant moisture conditions. Details about the PDSI are described by Palmer (1965) and other information is available from the National Centers for Environmental Information ([NCEI], 2017a,b,c,d).

The PDSI treshold of 1.6, though for all of the 55 gages, was logically held for just the 18 stream gages in this section. Finally, the influence of climate variations on flood flow frequency are shown in Figures 75–92 (18 stream gages). These are the same stream gages used in the previous section for purposes of parallelism. It is necessary to clarify a subtle point when interpreting the below figures. The exceedance probability (recurrence interval) axis (horizontal) can be considered correct in regards to the entire sample. This axis is correct for the smaller samples if one imagines a scenario where all peaks, although now about half the original sample, were for wet conditions and vice versa for the dry conditions. Though the samples are about equal sizes, it is technically complicated to remix the frequency curves for wet and dry conditions into the same probability scale as all the data. Thus, the primary purpose of these figures is to show how substantial or not the coupling between PDSI (the index of climate conditions) and annual peak streamflow in the study might be.

West Fork Trinity River near Jacksboro, Texas

West Fork Trinity River near Jacksboro was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 75. The LPIIII distribution was fit to each type of peak streamflow using L-moments. The low-outlier threshold as reported in Table 1 was used and was held constant for each wet condition (blue circles) or dry condition (red circles) sample. Several interpretations of the results shown (Figure 75) can be made, which are also generally applicable to the other 17 figures. First, on average, wet condition peaks are larger than dry condition peaks and as a typical rule these peaks plot above or further up the vertical axis than the dry condition peaks. This is the case for this stream gage. Second, if wet condition peaks are larger than dry condition peaks then, in general, for the whole sample (open circles) the blue open circles will tend to plot towards the right. Third, often the dry condition peaks represent the smallest values in the sample and conversely the wet condition peaks represent the largest values. This is not completely the case in Figure 75 because the largest peak in the whole sample is tagged as a dry condition peak. Further investigation is not made, but it is important to consider that the PDSI is an index associated for an entire month and the peak occurs on a discrete day of the month. Also consider that a peak occurring on the first of a month might be more associated to the prior month. Alternatively, consider that the PDSI is representative of a large region and not precisely the watershed, which might receive locally intense rainfall responsible for the large peak. Finally, for the data in Figure 75, the curvature of the dry condition peaks is upward compared to that for the wet conditions.

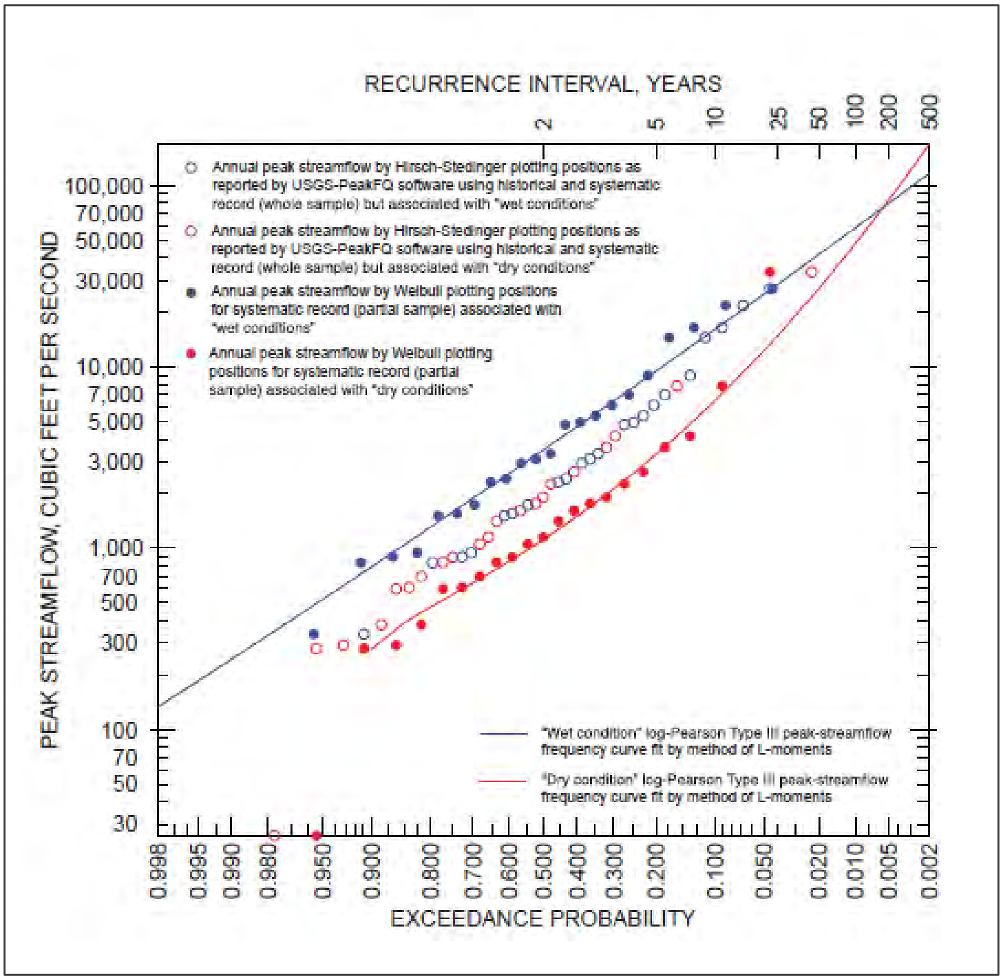

Figure 75: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08042800 West Fork Trinity River near Jacksboro, TX

West Fork Trinity River near Boyd, Texas

West Fork Trinity River near Boyd was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 76. Similar discussion as for Figure 75 is applicable. This is a long record site. The curvature or skewness of the wet and dry conditions are of opposite sign; so the curves will intersect and eventually do outside of the deplicted plot towards the right (low frequency end of the plot).

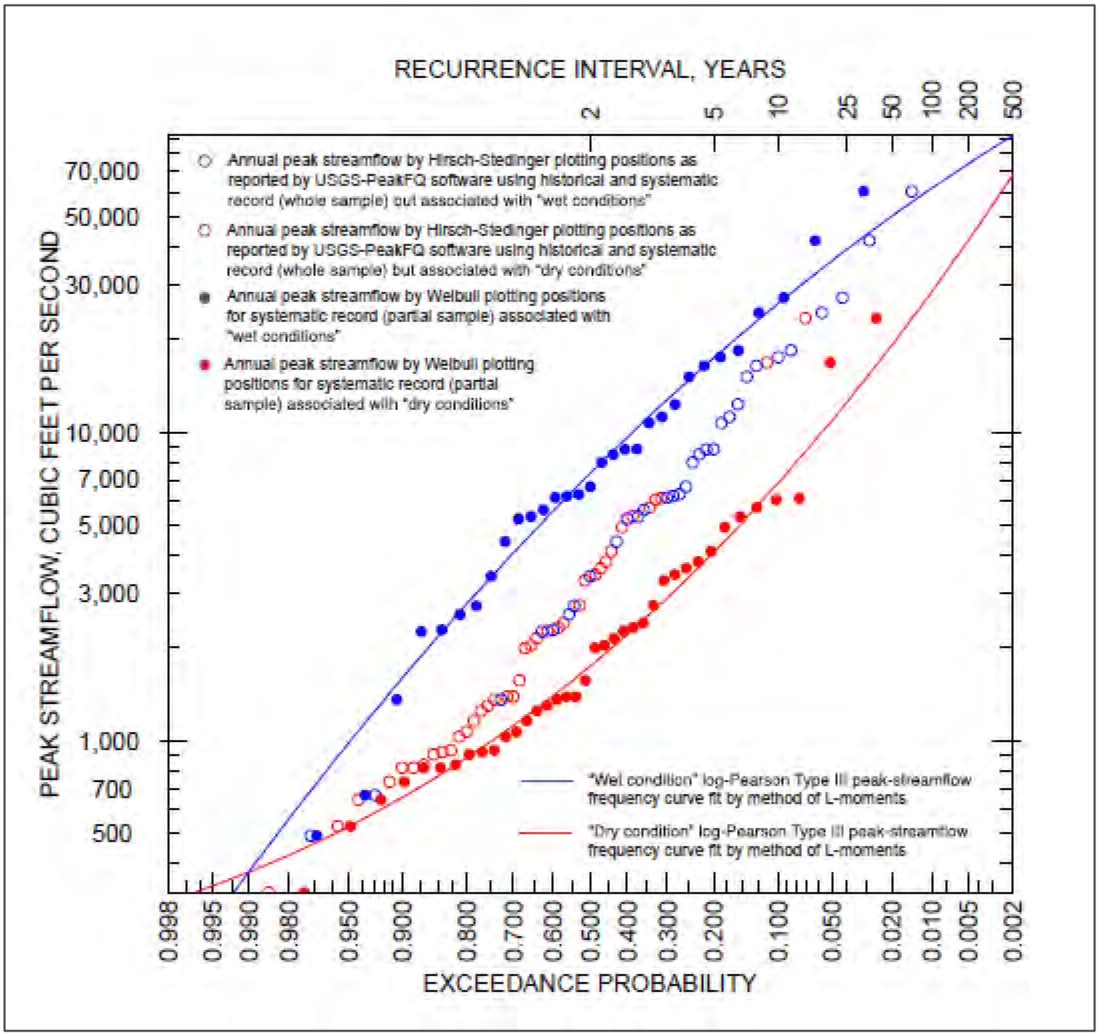

Figure 76: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08044500 West Fork Trinity River near Boyd, TX

Clear Fork Trinity River at Fort Worth, Texas

Clear Fork Trinity River at Fort Worth was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 77. Similar discussion as for Figure 75 is applicable. This is a long record site. The curves both have negative skewness and curve over towards the right and are subparallel to each other.

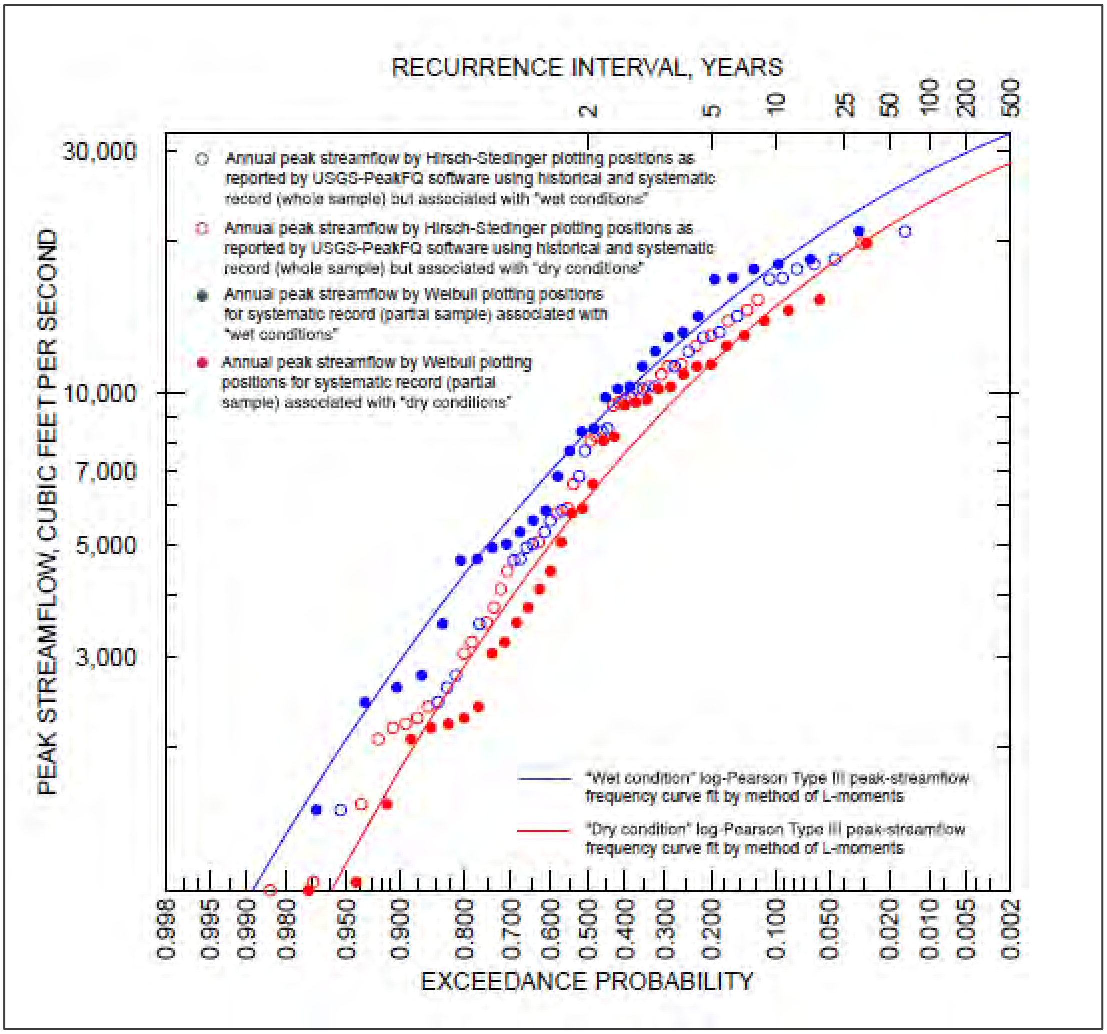

Figure 77: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08047500 Clear Fork Trinity River near Weatherford, TX

West Fork Trinity River at Fort Worth, Texas

West Fork Trinity River at Fort Worth was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 78. Similar discussion as for Figure 75 is applicable. This is a long record site. The curves appear to become parallel towards the right. The largest peak in the record is classified as a dry condition peak and, in relation to the other dry peaks, is clearly an outlier.

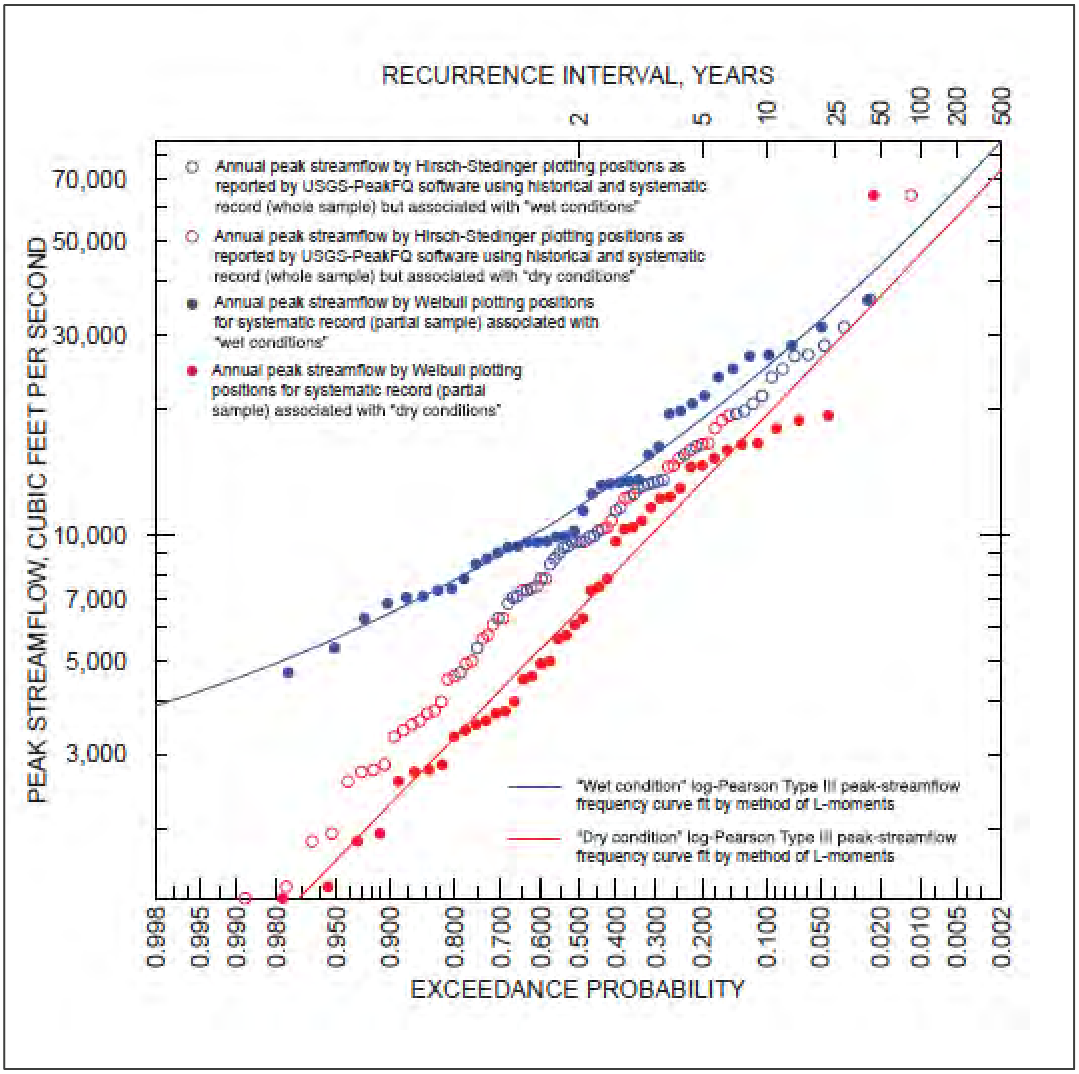

Figure 78: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08048000 West Fork Trinity River at Fort Worth, TX

West Fork Trinity River at Grand Prairie, Texas

West Fork Trinity River at Grand Prairie was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 79. Similar discussion as for Figure 75 is applicable. This is a long record site. The curves both have positive skewness and curve upwards on the right and are subparallel to each other.

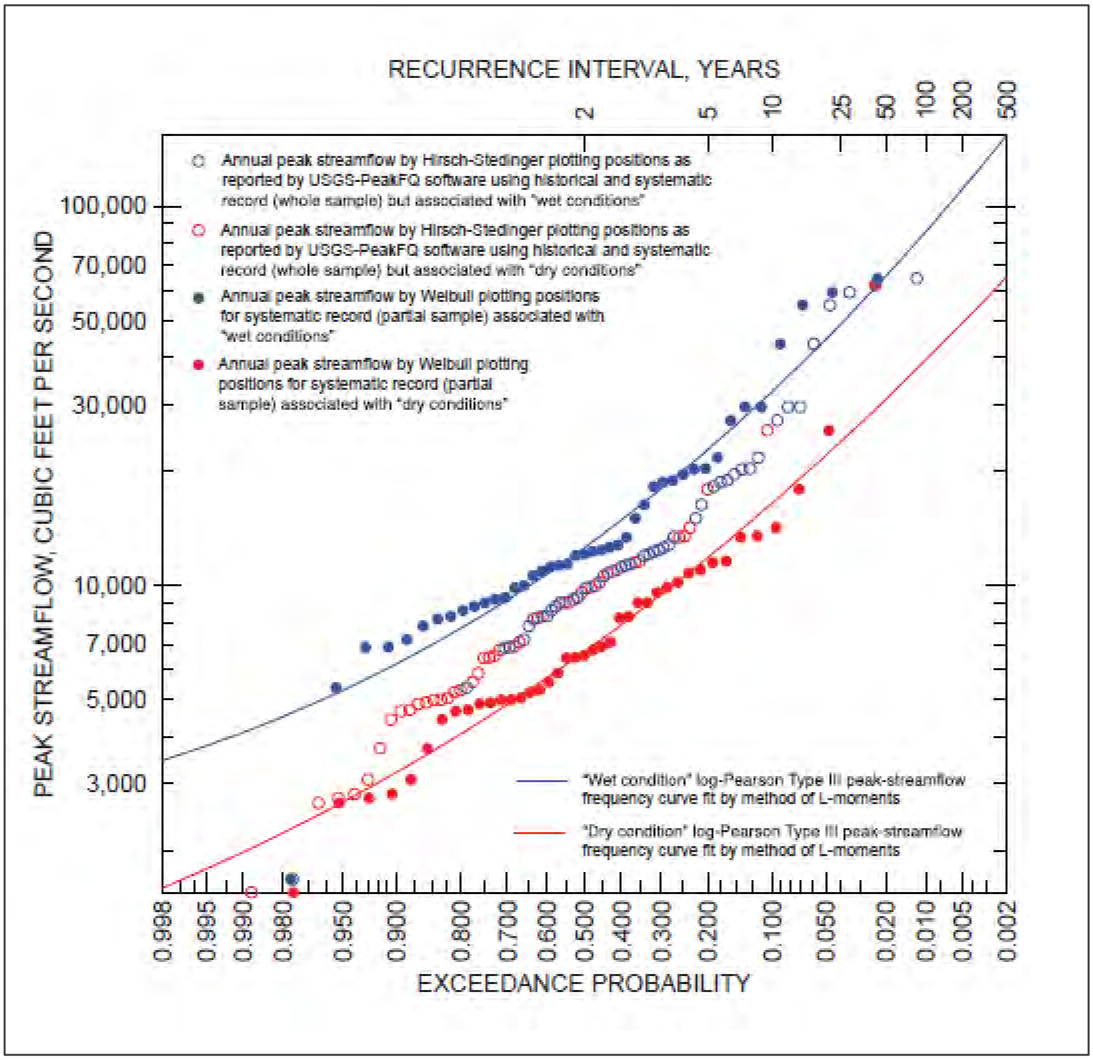

Figure 79: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08049500 West Fork Trinity River at Grand Prairie, TX

Walnut Creek near Mansfield, Texas

Walnut Creek near Mansfield was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 80. Similar discussion as for Figure 75 is applicable. This is a notable site in the sense that there is not as much proportional separation between the wet and dry condition peaks as otherwise generally seen in the other figures.

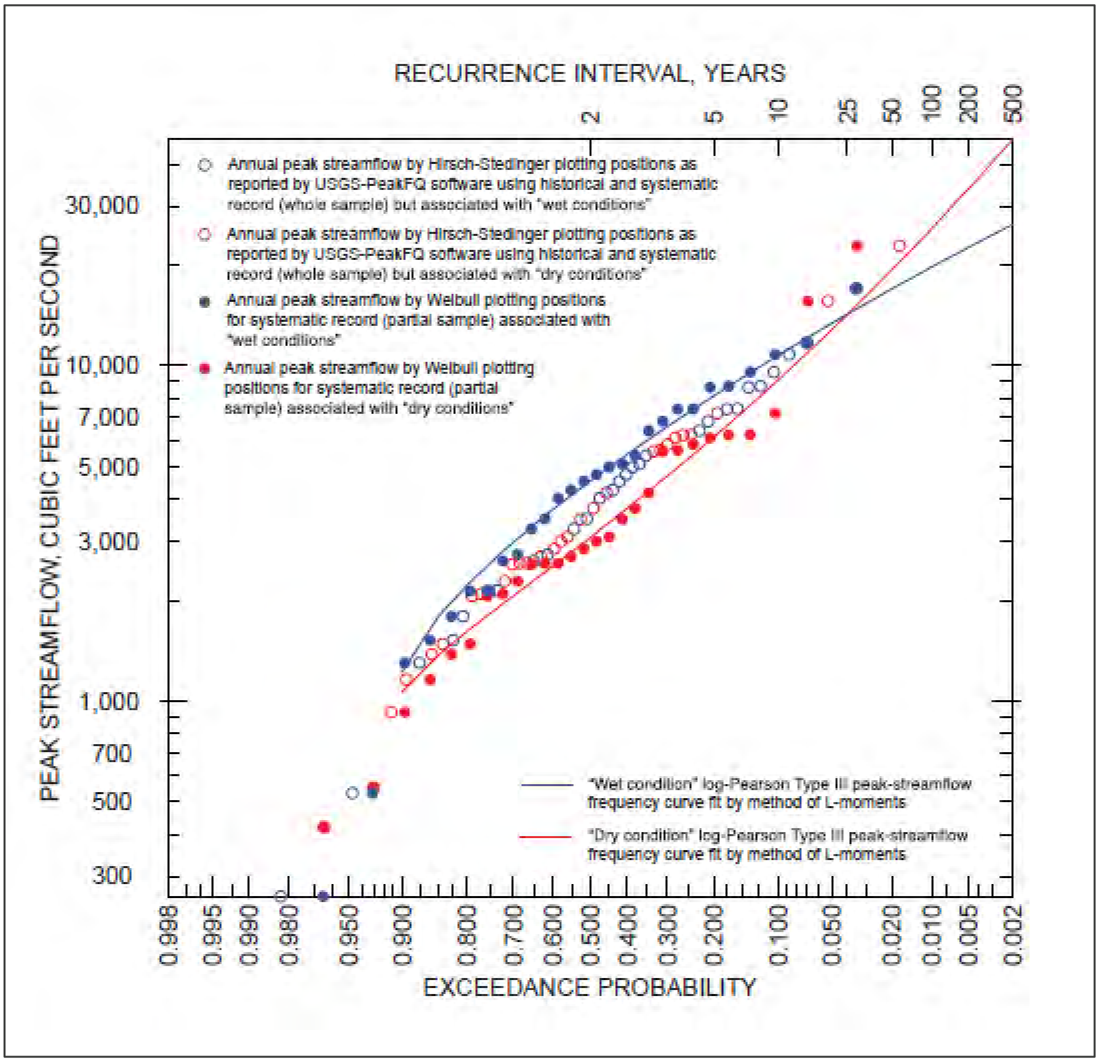

Figure 80: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08049700 Walnut Creek near Mansfield, TX

Mountain Creek at Grand Prairie, Texas

Mountain Creek at Grand Prairie was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 81. Similar discussion as for Figure 75 is applicable. This is a comparatively short record site, and interpretions are difficult to make.

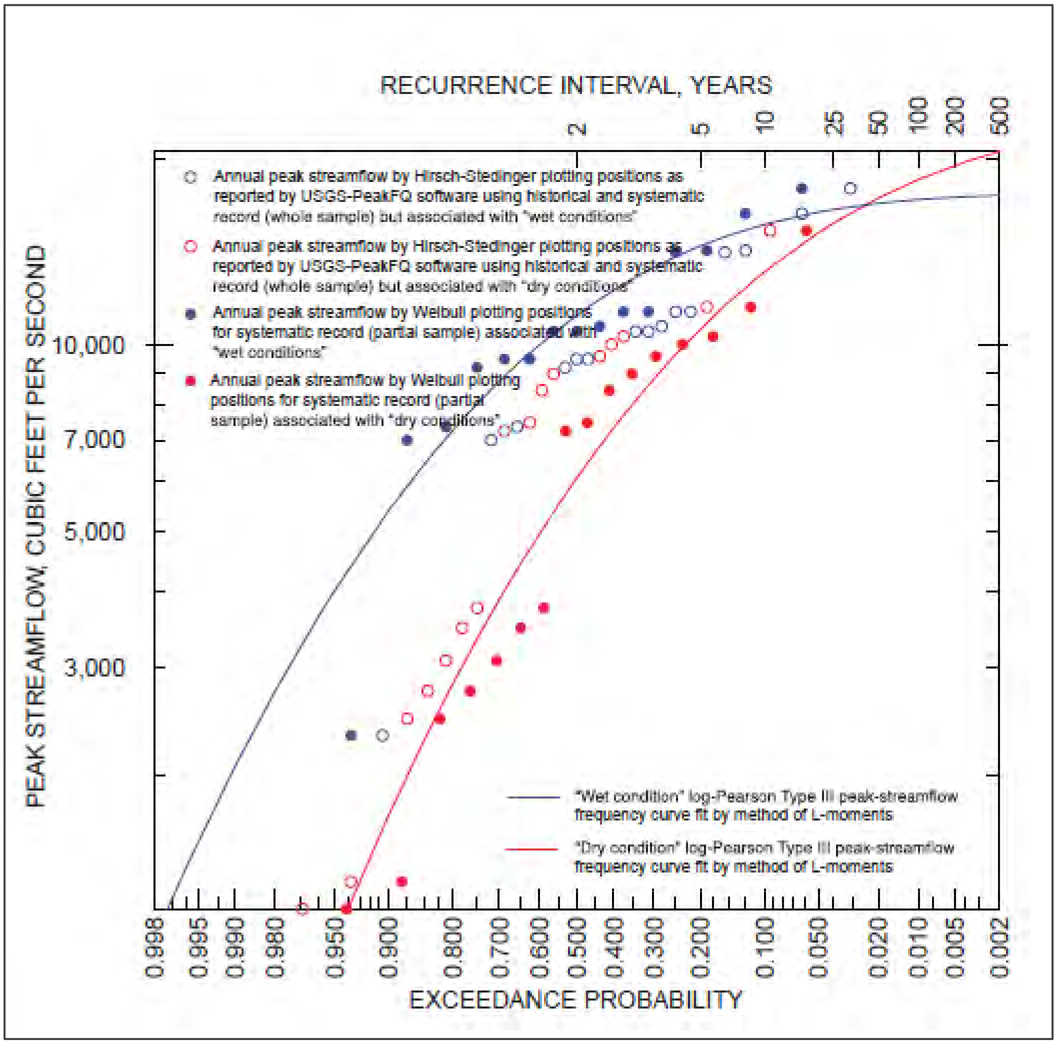

Figure 81: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08050100 Mountain Creek at Grand Prairie, TX

Clear Creek near Sanger, Texas

Clear Creek near Sanger was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 82. Similar discussion as for Figure 75 is applicable. This is a long record site. Based on the visual distribution of the data as well as the fitted curves, this particular streamgage seems to indicate very divergent results in the right-tail of the distribution based on the wet and dry classification. The seven largest events in the period of record are all wet condition peaks.

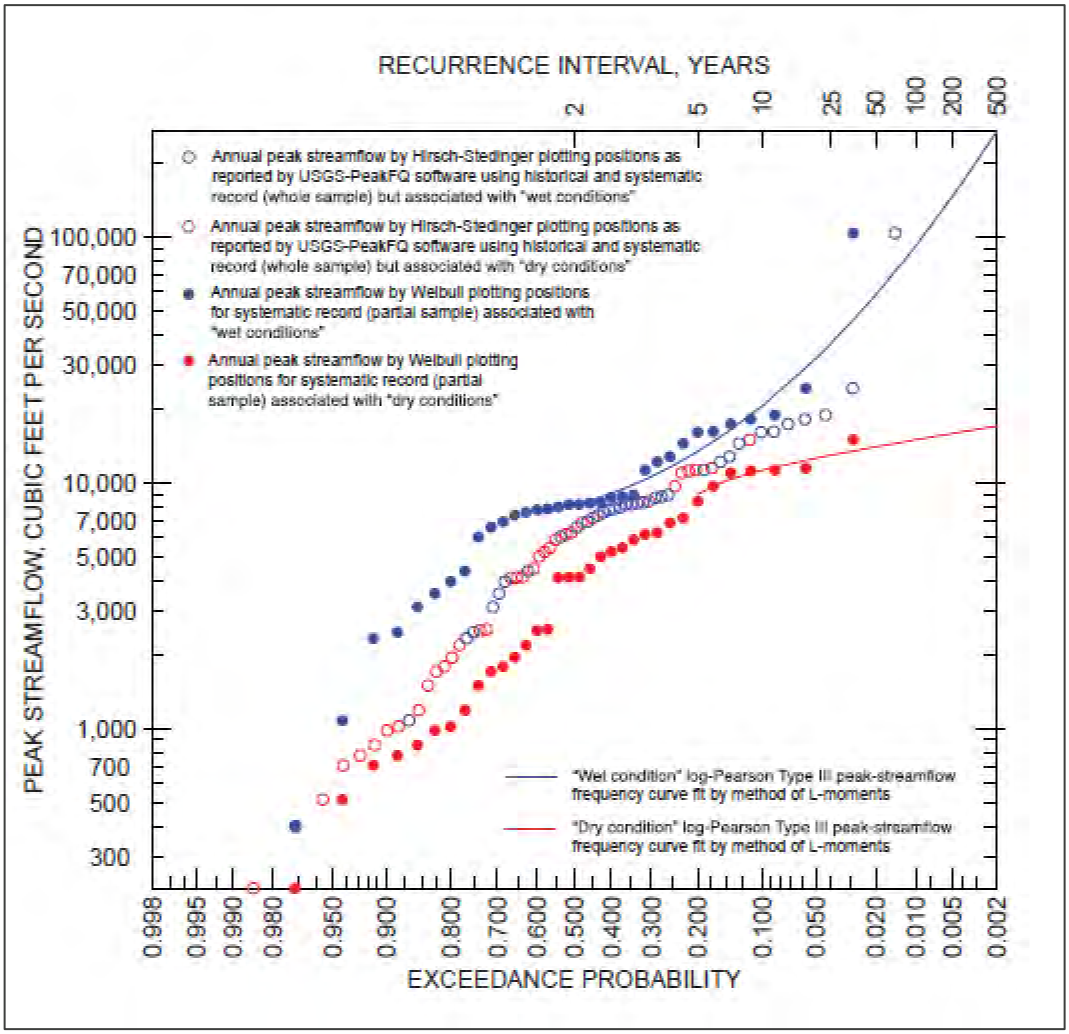

Figure 82: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08051500 Clear Creek near Sanger, TX

Denton Creek near Justin, Texas

Dentron Creek near Justin was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 83. Similar discussion as for Figure 75 is applicable. This is a long record site. The 10 largest events in the period of record are all wet condition peaks.

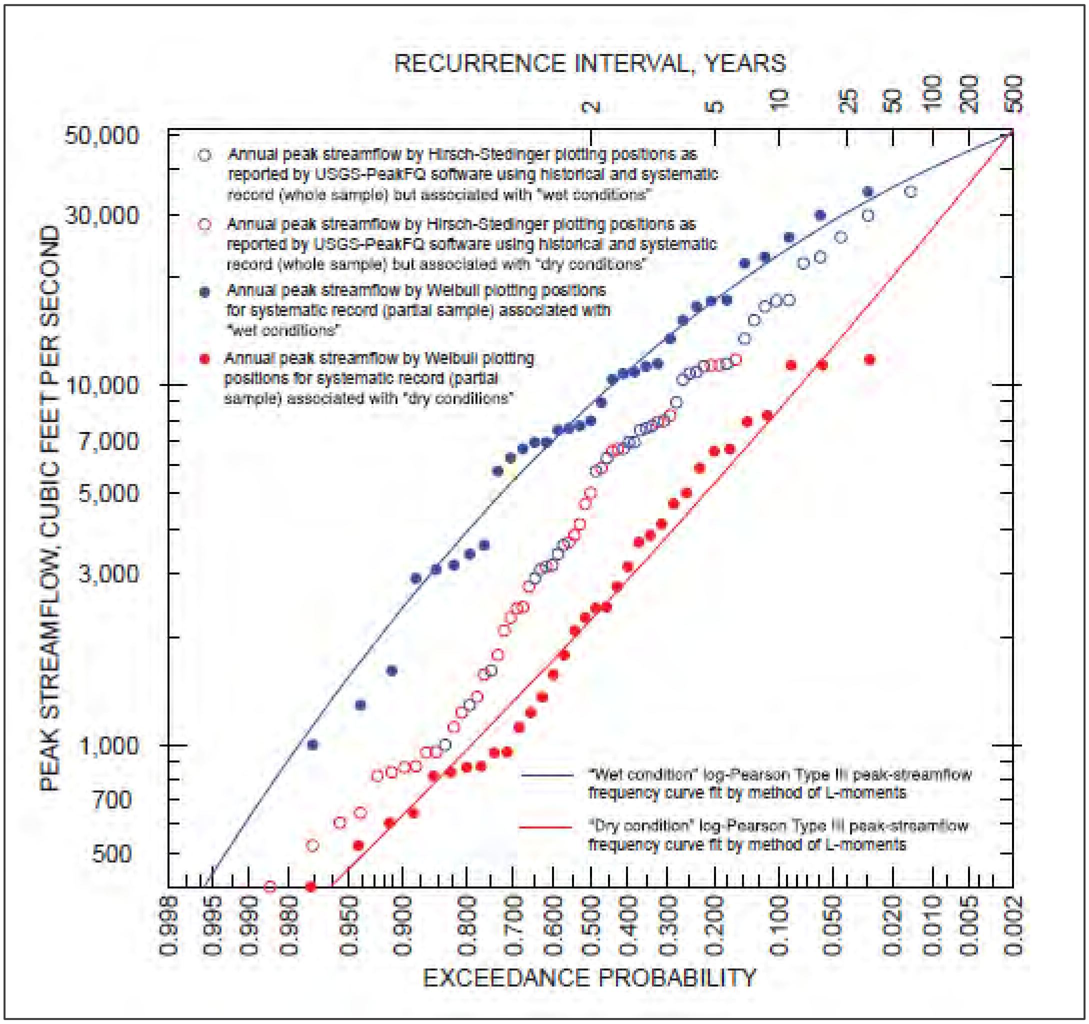

Figure 83: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08053500 Denton Creek near Justin, TX

Elm Fork Trinity River near Carrollton, Texas

The Elm Fork Trinity River near Carrollton was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 84. Similar discussion as for Figure 75 is applicable. The curves are subparallel to each other. The largest peak in the record is classified as a dry condition peak and in relation to the other dry peaks is clearly an outlier.

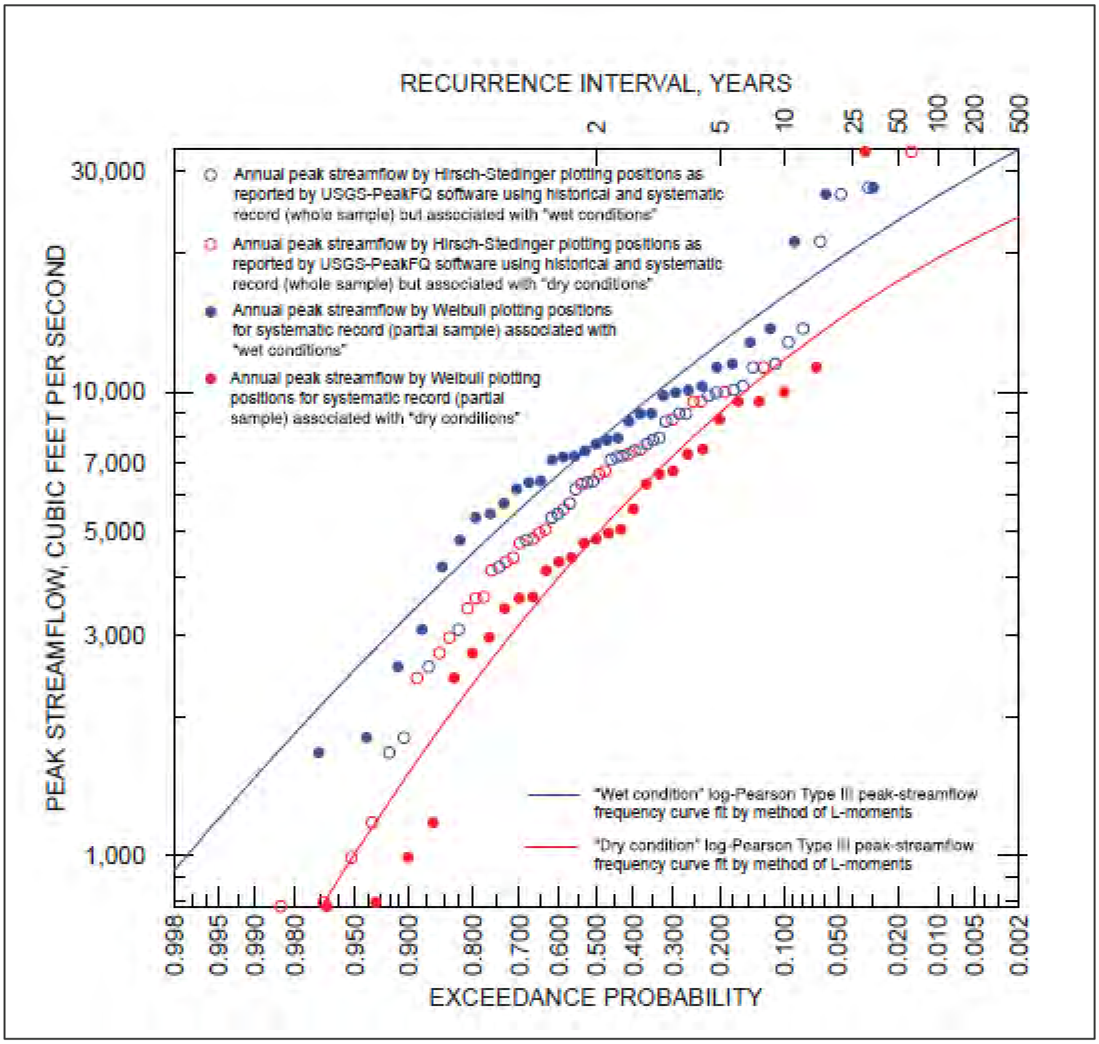

Figure 84: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08055500 Elm Fork Trinity River near Carrollton, TX

Trinity River at Dallas, Texas

Trinity River at Dallas was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 85. Similar discussion as for Figure 75 is applicable. The curves intersect each other for a comparatively small recurrence interval. This is caused by the steeper right tail of the dry condition peaks relative to the wet condition peaks.

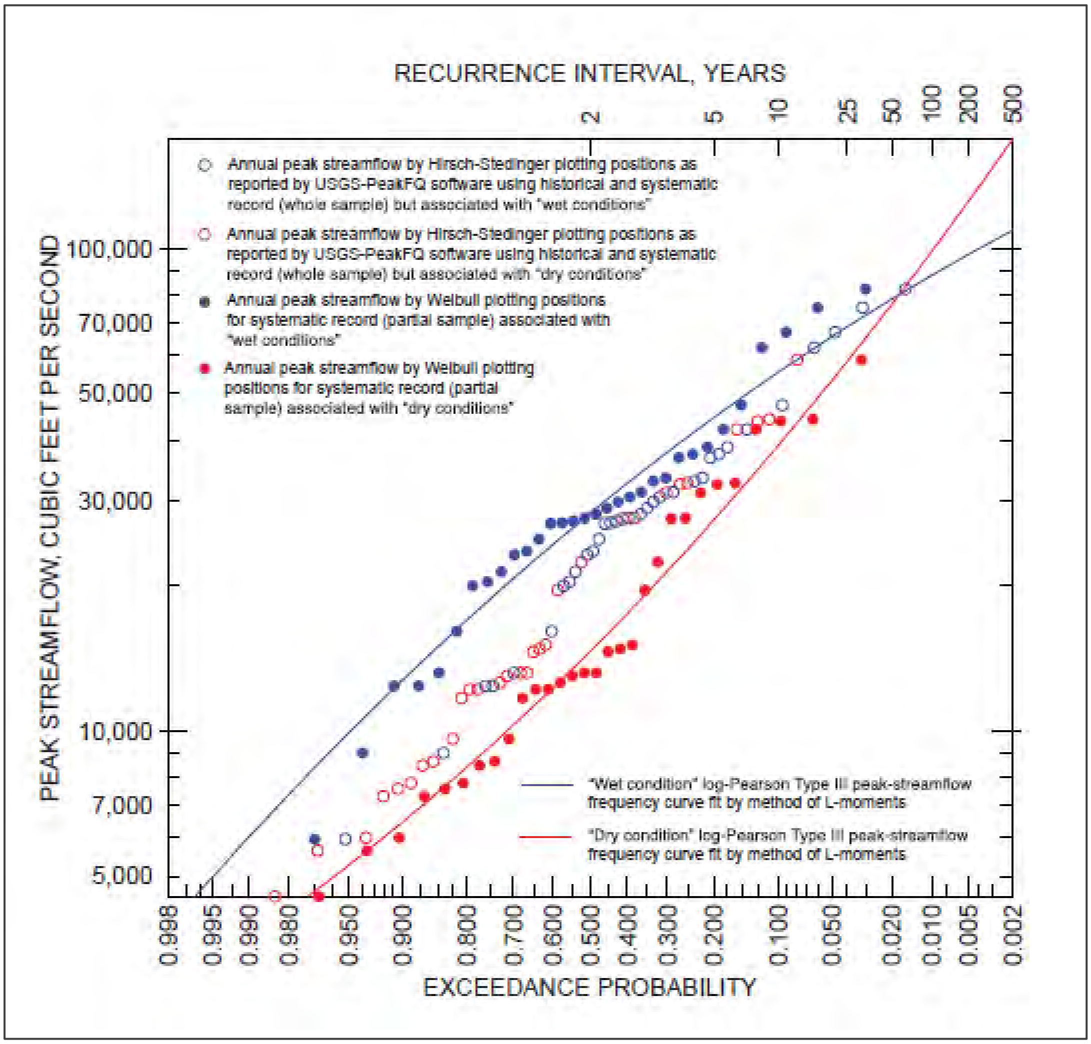

Figure 85: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08057000 Trinity River at Dallas, TX

White Rock Creek at Greenville Avenue, Dallas, Texas

White Rock Creek at Greenville Avenue, Dallas was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 86. Similar discussion as for Figure 75 is applicable. The curves intersect each other for a comparatively small recurrence interval. This is caused by a relatively small difference on average between dry and wet peaks, the steeper right tail of dry condition peaks, and the flatter right tail of the wet condition peaks.

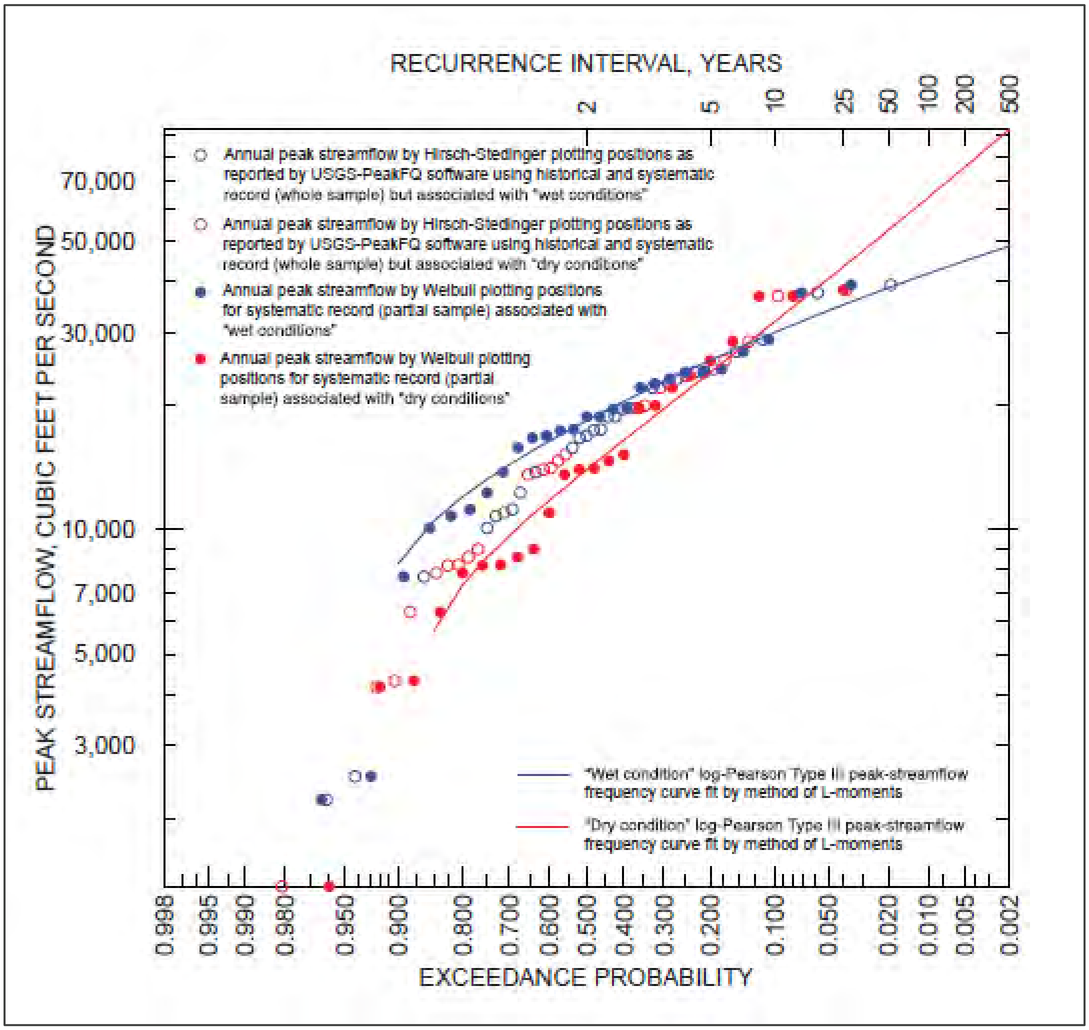

Figure 86: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08057200 White Rock Creek at Greenville Avenue, Dallas, TX

Rowlett Creek near Sachse, Texas

Rowlett Creek near Sachse was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 87. Similar discussion as for Figure 75 is applicable. There does not appear to be substantial separation between wet and dry condition peaks when the relatively small range in the vertical axis is considered.

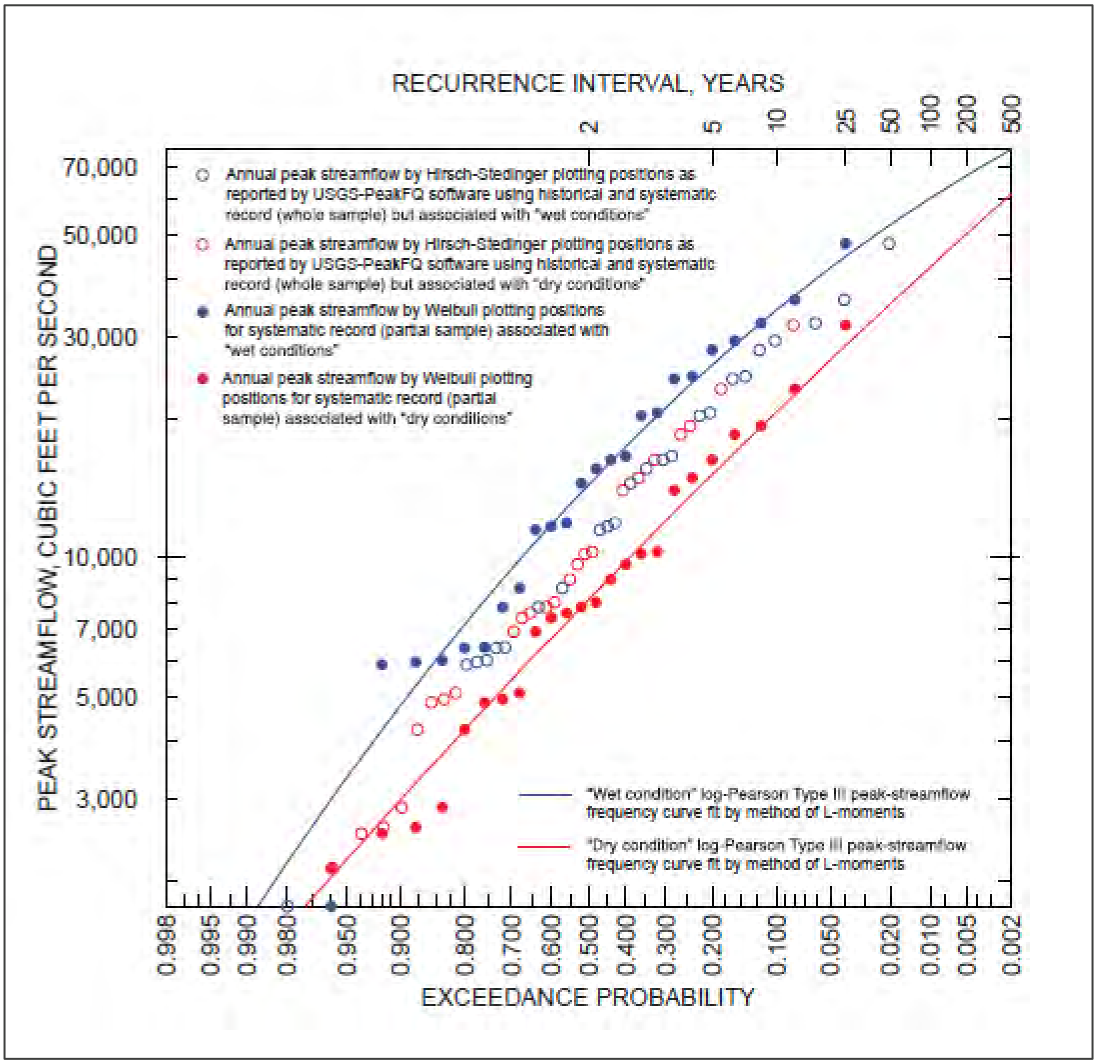

Figure 87: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08061540 Rowlett Creek near Sachse, TX

East Fork Trinity River near Crandall, Texas

East Fork Trinity River near Crandall, Texas was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 88. Similar discussion as for Figure 75 is applicable. The curves intersect each other for a comparatively small recurrence interval. This is caused by the steeper right tail of the dry condition peaks relative to the wet condition peaks.

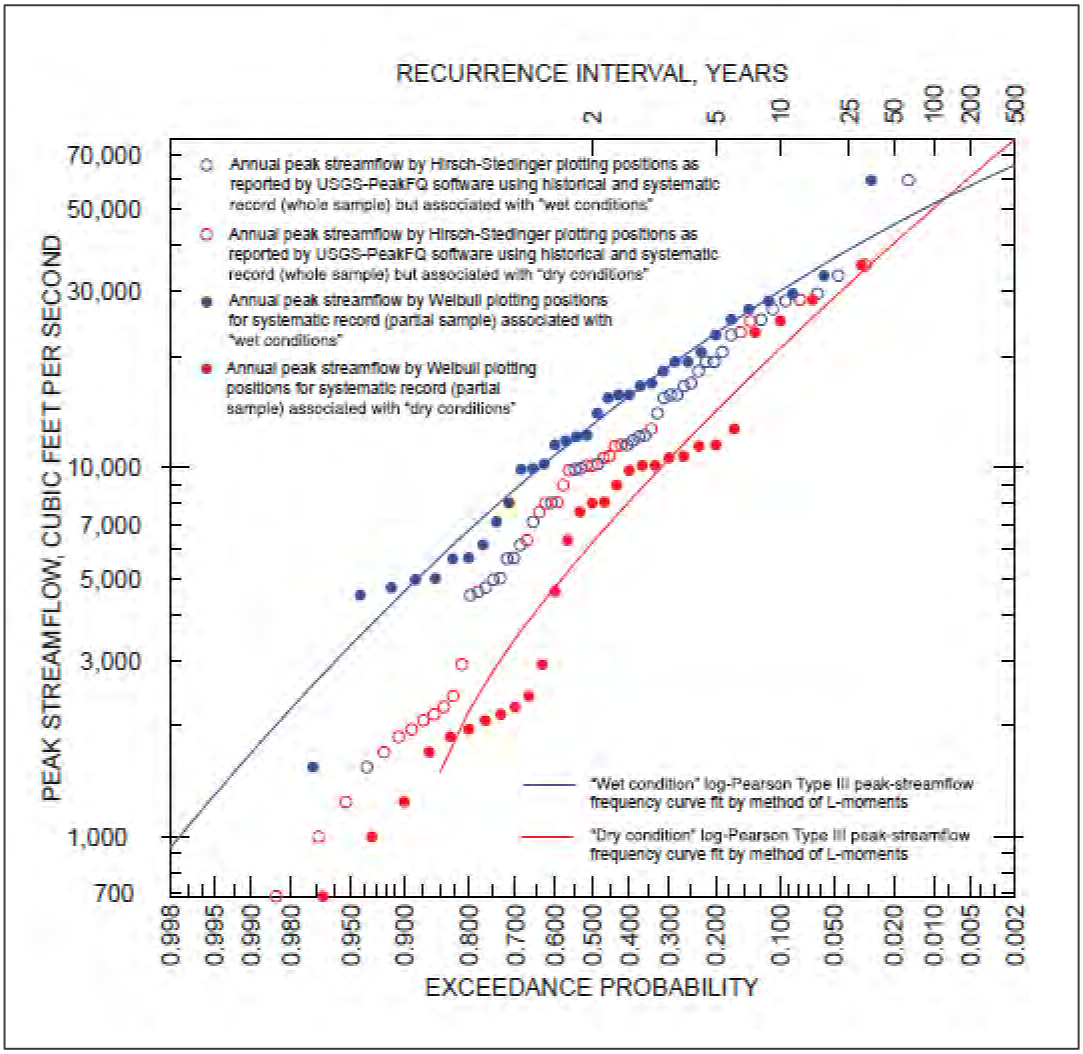

Figure 88: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08062000 East Fork Trinity River near Crandall, TX

Trinity River near Rosser, Texas

Trinity River near Rosser was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 89. Similar discussion as for Figure 75 is applicable. The curves are subparallel to each other.

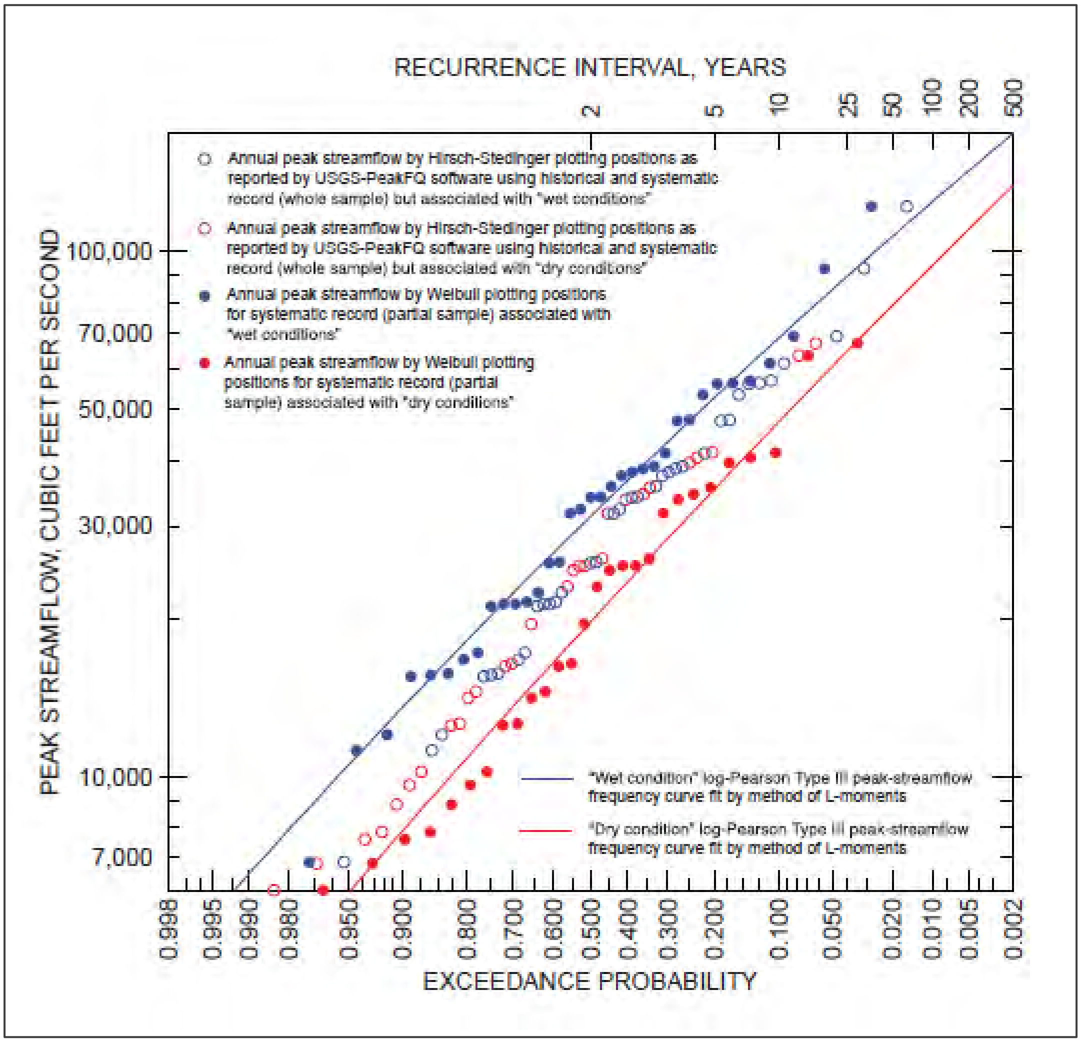

Figure 89: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08062500 Trinity River near Rosser, TX

Trinity River near Oakwood, Texas

Trinity River near Oakwood was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 90. Similar discussion as for Figure 75 is applicable. The curves intersect each other, and this is caused by the steeper right tail of dry condition peaks and the flatter right tail of the wet condition peaks.

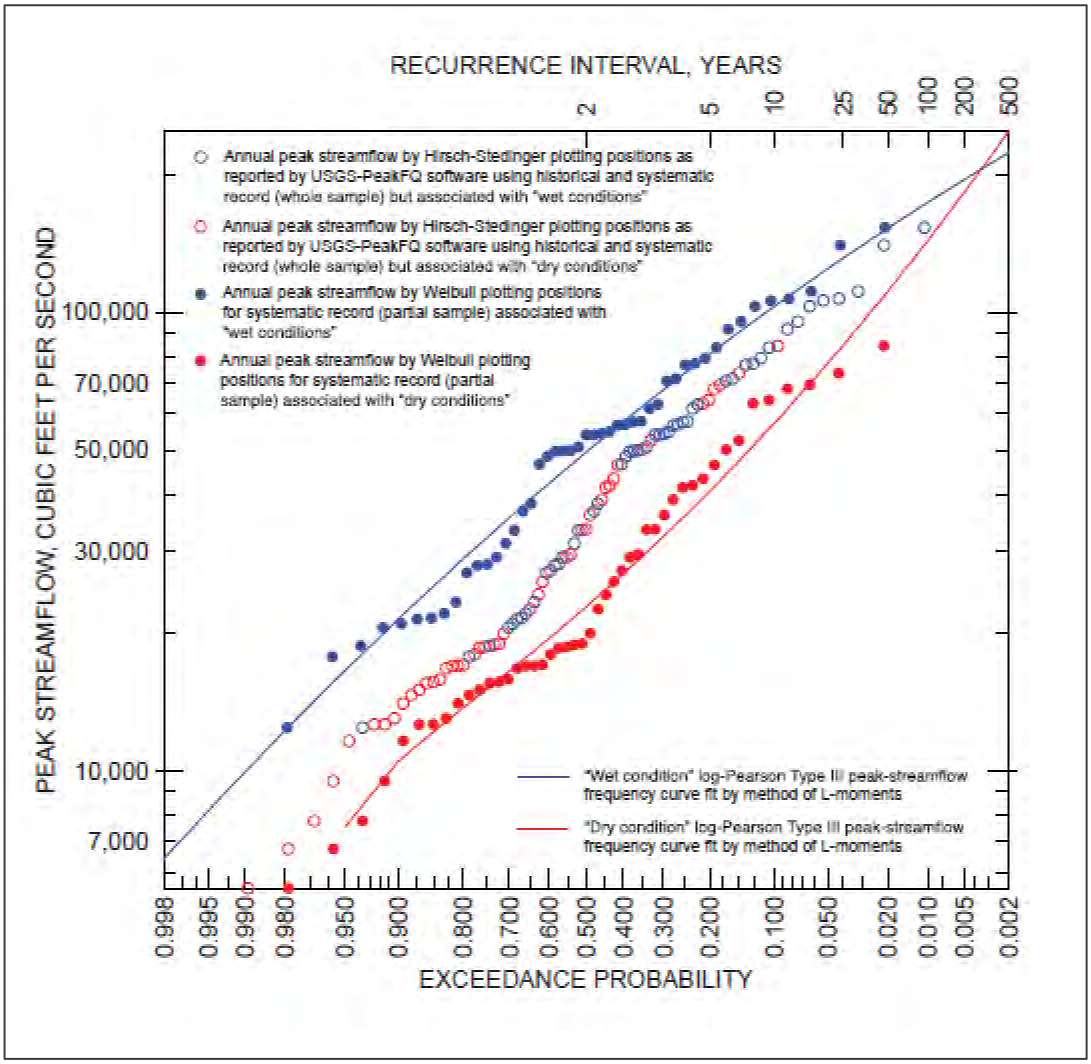

Figure 90: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08065000 Trinity River near Oakwood, TX

Trinity River at Riverside, Texas

Trinity River at Riverside was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 91. Similar discussion as for Figure 75 is applicable. The curves appear to become parallel towards the right

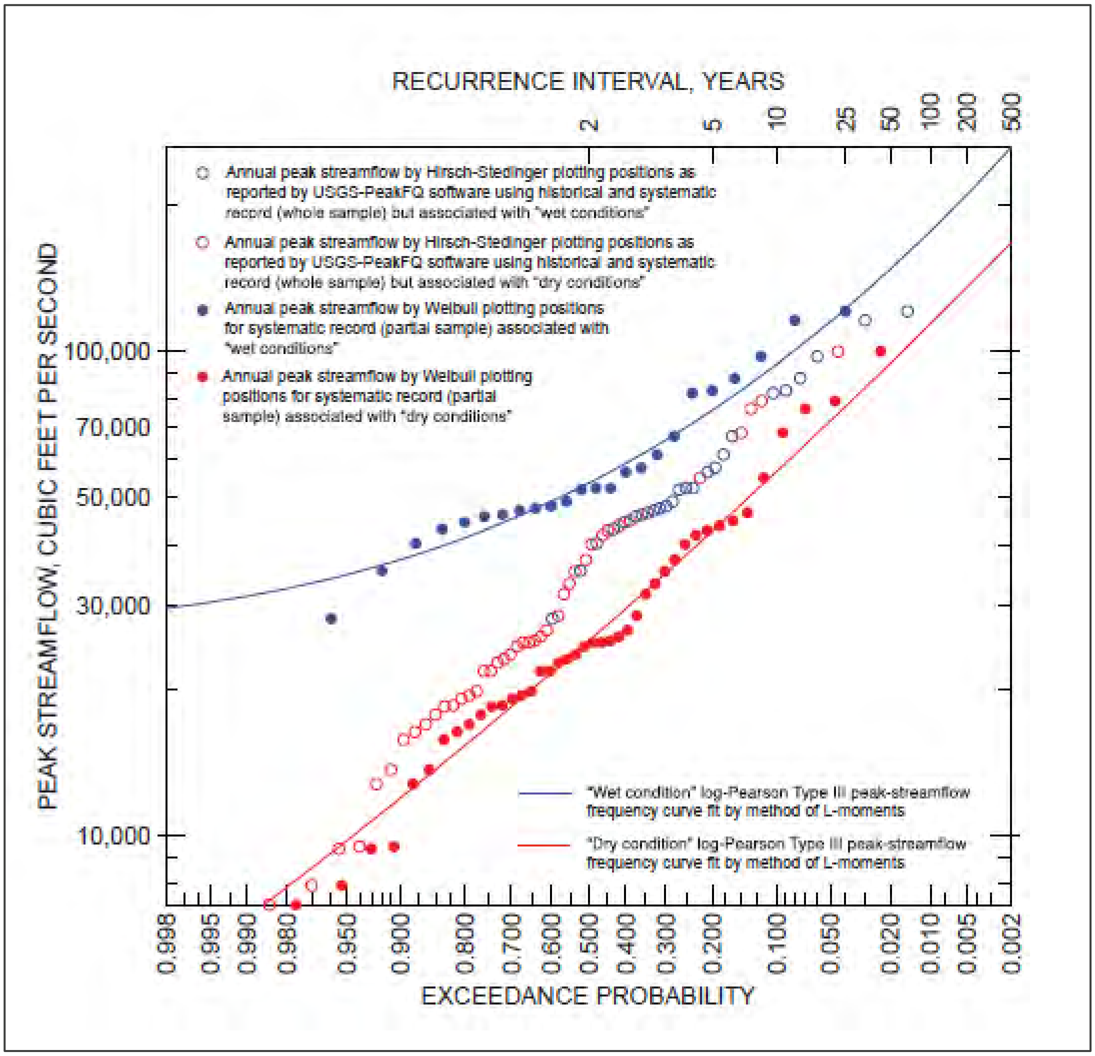

Figure 91: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08066000 Trinity River at Riverside, TX

Trinity River at Romayor, Texas

Trinity River at Romayor was selected as one example. Annual peak streamflow data split between wet and dry conditions are shown in Figure 92. Similar discussion as for Figure 75 is applicable. This is a long record site. The curves appear to be parallel near the center of the distribution. There appears to be a large and clear offset between the wet and dry condition peaks. Whether this can be attributable to conditions in Lake Livingston is unknown and outside the scope of this review. For this site it is clear that the wet conditions control the shape of the upper tail and that the dry conditions control the shape of the lower tail.

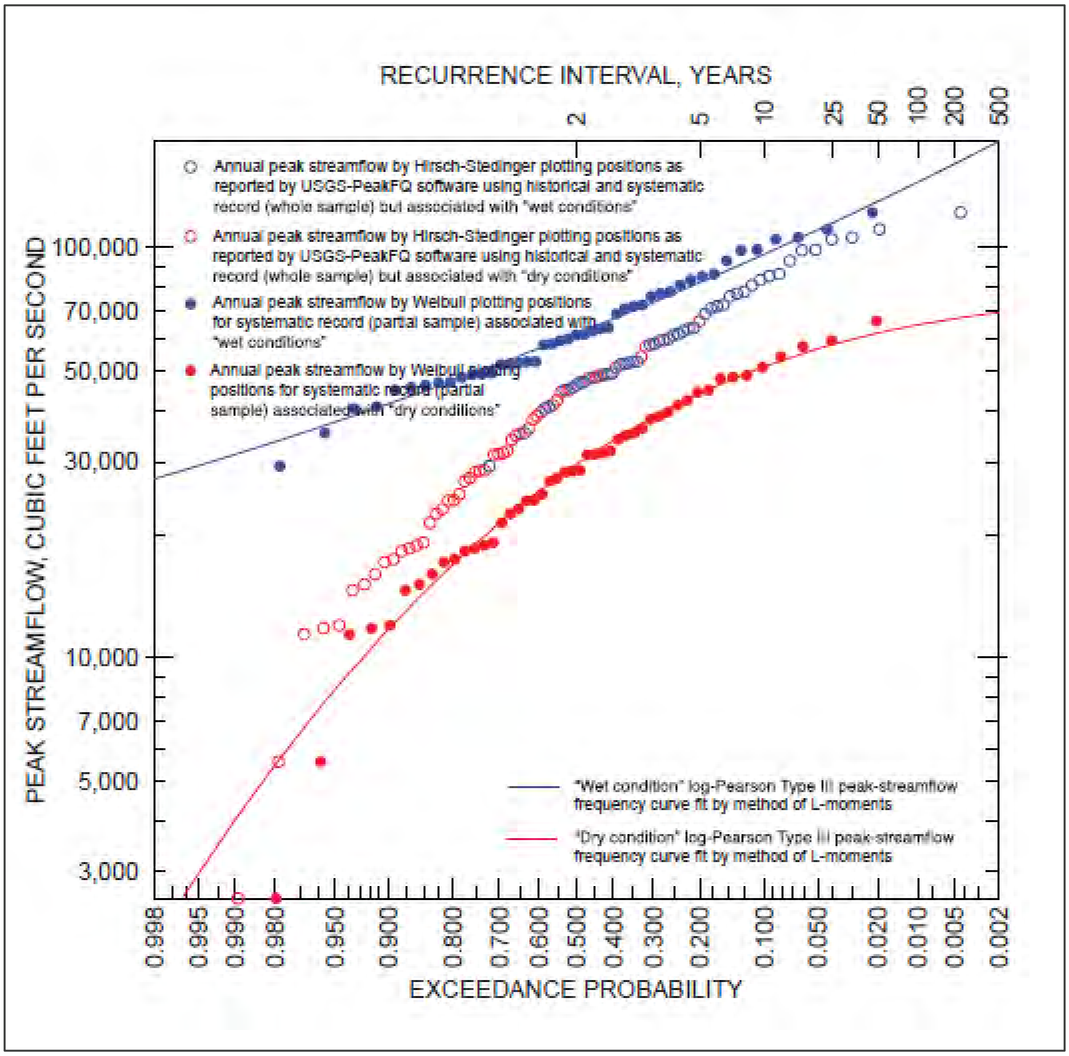

Figure 92: Effects of Climate Variability as Expressed by a Threshold of the Palmer Drought Severity Index of 1.6 on the Flow Frequency Curve for 08066500 Trinity River at Romayor, TX

2 References and Resources

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2.2 SOFTWARE

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3 Terms of Reference

AEP	Annual Exceedance Probability
B17B	Bulletin 17B
B17C	Bulletin 17C
cfs	cubic feet per second
EMA	expected moments algorithm
ft	feet
in	inches
InFRM	Interagency Flood Risk Management
LPIII	Log Pearson Type III
MGBT	Multiple Grubbs-Beck Test
National Water Information System	NWIS
PILF	Potentially Influencing Low Floods
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin

Appendix B – Rainfall-Runoff Modeling in HEC-HMS

July 2021

InFRM
INTERAGENCY FLOOD RISK MANAGEMENT

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1 Rainfall-Runoff Modeling in HEC-HMS

Watershed rainfall-runoff modeling is often used to estimate the rare frequency events whose return periods exceed the gaged period of record as well as to account for non-stationary watershed conditions such as urban development, reservoir storage and regulation, and climate variability. Rainfall-runoff modeling also provides a means of estimating flood frequency flows at other locations throughout the watershed that do not coincide with a stream flow gage. Rainfall-runoff watershed modeling is used to simulate the physical processes that occur during storm events that move water across the land surface and through the streams and rivers.

In this phase of the multi-layered hydrologic analysis, a watershed model was built for the Trinity River Basin with input parameters that represented the physical characteristics of the watershed. The rainfall-runoff model for the basin was completed using the basin-wide Hydrologic Engineering Center – Hydrologic Modeling System (HEC-HMS) model developed for the 2015 Trinity Basin Corps Water Management System (CWMS) implementation as a starting point. This model was further refined by adding additional detailed data, updating the land use, and calibrating the model to multiple recent flood events. Through calibration, the updated HEC-HMS model was verified to accurately reproduce the response of the watershed to multiple, recently observed storm events, including those similar in magnitude to a 1% annual chance (100-yr) storm. Finally, frequency storms were built using the depth area analysis in HEC-HMS and the latest published frequency rainfall depths from National Oceanic and Atmospheric Administriation (NOAA) Atlas 14 (NOAA, 2018). These frequency storms were run through the verified model, yielding consistent estimates of the 1% annual chance (100-yr) and other frequency peak flows at various locations throughout the basin.

1.1 HEC-HMS MODEL FROM THE TRINITY CWMS IMPLEMENTATION

The HEC-HMS model from the Trinity CWMS Implementation was used as the starting point for the current study. The CWMS model contained 289 subbasins in the Trinity River Basin and totaled approximately 17,889 square miles. The model extended from the headwaters to Trinity Bay The subbasins were delineated using the HEC-GeoHMS program and utilized 30-meter National Elevation Dataset (NED) terrain data. The Trinity CWMS HEC-HMS model used the following methods.

- **Losses** – Initial and Constant
- **Transform** – Snyder Unit Hydrograph
- **Baseflow** – Recession
- **Routing** – Lag, Modified Puls, Muskingum, and Straddle Stagger
- **Computation Interval** – 60 minutes

A map of the Trinity CWMS subbasins are shown in Figure 1. More information on the CWMS model development is given in the final CWMS report for the Trinity River Basin (USACE, 2015).

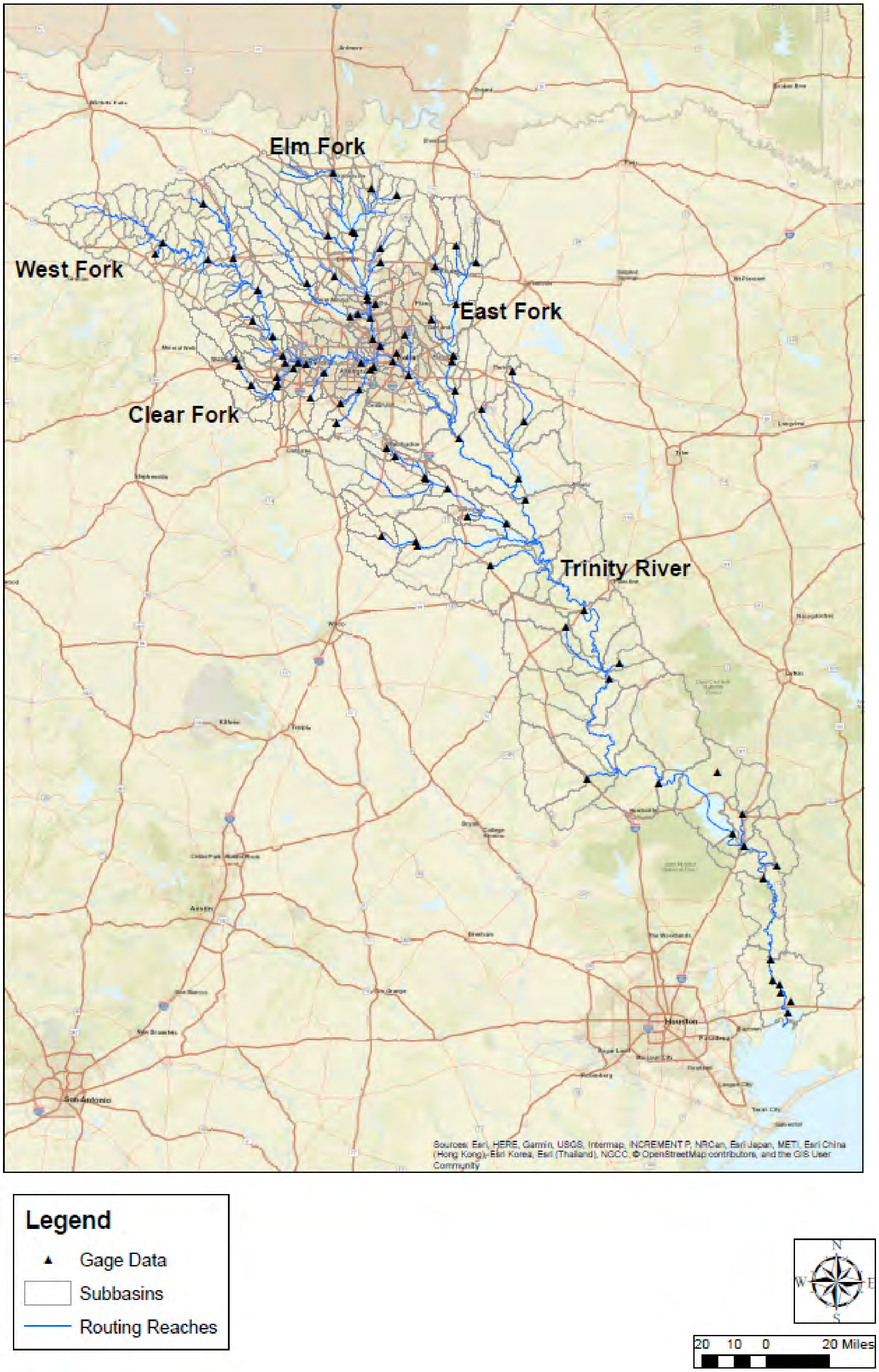

Figure 1: CWMS subbasins for the Trinity River Basin

1.2 UPDATES TO THE HEC-HMS MODEL

The subbasin layout was reviewed and determined sufficient for the study. One of the important components of this study is to utilize information at U.S. Geological Survey (USGS) gages for model calibration and results comparison. Inclusion of the gage locations in the model was a priority during the CWMS modeling and so additional subdivision was not required.

During the study, Federal Emergency Management Agency (FEMA) Base Level Engineering (BLE) hydraulic HEC-RAS models became available and were utilized to improve the hydraulic routing data within the Richland-Chambers watershed where detailed hydraulic modeling was available. These models were built off of detailed topographic data as opposed to the 10m NED digital elevation model (DEM) data used in the 2015 CWMS model used to develop routing data below Bardwell and Navarro Mills dams. This hydraulic routing data includes storage-dischare tables which are extracted from the hydraulic models and are used for the Modified-Puls routing method which calculates the change in flow through the reach based on the volume of floodplain storage through that reach.

Finally, after updating the above data within the Richland-Chambers watershed, the computation interval of the model was also increased from 60 to 15 minutes.

1.3 HEC-HMS MODEL INITIAL PARAMETERS

The Trinity River HEC-HMS model contains 289 subbasins totaling about 17,889 square miles. The subbasins were delineated using the HEC-GeoHMS program and utilized 30-meter NED terrain data. The InFRM Trinity River HEC-HMS model methods includes initial and constant losses, Snyder unit hydrograph transform parameters, recession baseflows, and Modified Puls, Muskingum, Straddle Stagger, and Lag routing. The sources of the initial estimates for these parameters are described below. All of the model parameters, excluding the percent impervious values, were adjusted during model calibration.

- Initial Loss and Constant Loss Rate –.Initial estimates of losses were made using NRCS soil data and recommended values from the HEC-HMS Technical Reference Manual. The recommended values (inches per hour) were 0.3-0.45 for Group A, 0.15-0.30 for Group B, 0.05-0.15 for Group C, and 0.00-0.05 for Group D. The constant loss rate estimates in the model ranged from 0.03 to 0.26 depending on soil type. These losses were adjusted during calibration and varied significantly between events. The initial estimates for the constant loss rates for the calibration runs were based on National Resources Conservation Service (NRCS) soil type. These differ slightly from the Fort Worth District Loss Rates in that the Fort Worth District Loss Rates vary by frequency. The constant losses were very different for each calibration event based on the soil moisture condition. The initial loss rate estimates as well as the final frequency loss rates fell within the range of the events observed during calibration.
- Percent Impervious – The percent impervious values were developed based on the 2011 National Landcover Database (NLCD) percent developed impervious dataset. The 2011 data was available upon study initiation but was superceded with 2016 data before study completion.
- Snyder Transform Parameters – Initial estimates of transform parameters utilized existing models as much as possible. The methods used to develop parameter estimates as well as the level of calibration applied to each model varied. A table of the existing models utilized to develop initial parameter estimates is shown below.

Table 1: Existing Models Utilized to Develop Initial Parameter Estimates

Location	Initial Method/Model Type	Agency	Year	Calibrated
West Fork upstream of Lake Worth Dam	Regional Ct/Forecast Model (HEC-1)	TRWD	2013	Yes
Clear Fork upstream of Benbrook Dam	Urban Curves/Upper Trinity Feasibility Model(HEC-1)	USACE	1995	Yes
Area between Lake Worth Dam, Benbrook Dam, and Lewisville Dam downstream to Trinity at Five Mile Creek	Urban Curves/CDC Model (Model parameters recomputed using existing condition (2005) land use)	USACE	2013	No
Elm Fork Trinity upstream of Lewisville Dam	Urban Curves/Lewisville Dam Safety Mod. Study	USACE	2010	Yes
East Fork Trinity upstream of Crandall Gage	Regional Ct/Forecast Model (HEC-1)	USACE	1996	Yes
Area between Trinity nr Rosser Gage downstream to confluence with Chambers Creek.	Regional Ct/Lower Trinity Reconaissance Study (HEC-1)	USACE	1991	No

Where existing models were not available, engineering judgement was utilized in assigning initial parameter estimates.

Of the existing models, the majority of the models utilized the U.S. Army Corps of Engineers (USACE) Fort Worth District urban curves to develop initial parameter estimates. These curves recommend time to peak and peaking coefficients and are based on length and slope watershed characteristics extracted from HEC-GeoHMS, percent urban values taken from land cover data, and percent sand values estimated from the NRCS soil data. From this data, the following regional equation, which was developed as part of the Fort Worth District urban studies (Nelson, 1979) (Rodman, 1977) (USACE, 1989), was used to calculate lag time:

$$\log(tp) = .383\log(L*Lca/(Sst \wedge .5))+(Sand*(\log 1.81-\log .92)+\log .92)-(BW*Urban./100)$$

where: tp = Snyder's lag time (hours)

L = longest flow path within the subbasin (miles)

Lca = distance along the stream from the subbasin centroid to outlet (miles)

Sst = stream slope over reach between 10% and 85% of L (feet per mile)

Sand = percentage of sand factor as related to the permeability of the soils

(0% Sand = low permeability, 100% Sand = high permeability)

BW = log(tp) bandwidth between 0% and 100% urbanization = 0.266 (log hours)

Urban. = percentage urbanization factor

The remaining models utilized regional Ct and peaking coefficient values which were developed regionally.

- **Baseflow Parameters** – Initial baseflow parameters were taken from the existing USACE Trinity CWMS HEC-HMS model, which utilized values from existing models. The existing models that were used are identified in Table 1 above.
- **Routing Parameters** (Modified Puls, Muskingum, Straddle Stagger, and Lag) – Routing parameters were taken from the existing USACE Trinity CWMS HEC-HMS model, which utilized values from existing models that are listed in Table 1 above.

The initial subbasin and routing parameters that were entered into the HEC-HMS model are shown in Tables 2 through 8. Some of these parameters were adjusted during calibration.

Table 2: Subbasin Area, Percent Impervious and Initial Estimate of Loss Rates

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
West_Fork_S020	66.786	0	0.08	0
West_Fork_S010	61.994	0	0.08	0
West_Fork_S030	62.292	0	0.06	0
West_Fork_S040	40.404	0	0.07	0
West_Fork_S050	31.856	0	0.08	0
West_Fork_S060	69.086	0	0.07	0
West_Fork_S070	50.349	0	0.09	0
West_Fork_S080	20.329	0	0.07	0
West_Fork_S090	36.124	0	0.09	0
West_Fork_S100	38.843	0	0.08	0
West_Fork_S120	49.759	0	0.08	1
West_Fork_S110	21.591	0	0.10	0
Big_Cleveland_S010	52.559	0	0.09	0
Big_Cleveland_S020	46.104	0	0.10	1
West_Fork_S130	20.65	0	0.07	0
Lost_Ck_S010	28.818	0	0.06	3
Lost_Ck_S020	13.637	0	0.10	0
West_Fork_S140	39.6	0	0.08	1
West_Fork_S150	41.295	0	0.07	0
West_Fork_S160	35.598	0	0.08	2
Beans_Ck_S010	36.233	0	0.09	1
Beans_Ck_S020	10.718	0	0.07	1
Big_Ck_S010	50.689	0	0.10	0

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
Big_Ck_S030	19.583	0	0.11	2
Big_Ck_S020	13.252	0	0.09	2
Bridgeport_S030	43.633	0	0.16	1
Bridgeport_S010	35.711	0	0.05	42
Bridgeport_S040	33.433	0	0.15	3
Bridgeport_S020	24.808	0	0.13	1
West_Fork_S170	40.426	0	0.12	5
Dry_Ck_S010	26.744	0	0.12	4
West_Fork_S180	6.6336	0	0.19	1
Amon_G_Carter_S030	40.302	0	0.11	8
Amon_G_Carter_S010	38.589	0	0.10	1
Amon_G_Carter_S020	30.616	0	0.10	0
Big_Sandy_Ck_S010	41.989	0	0.14	3
Big_Sandy_Ck_S020	40.704	0	0.14	1
Brushy_Ck_S010	30.876	0	0.13	3
Brushy_Ck_S020	27.856	0	0.17	1
Brushy_Ck_S030	11.859	0	0.19	1
Big_Sandy_Ck_S030	24.915	0	0.16	2
Big_Sandy_Ck_S040	46.602	0	0.20	1
Big_Sandy_Ck_S050	19.631	0	0.19	4
West_Fork_S190	28.287	0	0.19	4
West_Fork_S200	21.943	0	0.20	1
Garrett_Ck_S020	23.217	0	0.16	1
Garrett_Ck_S010	22.758	0	0.16	1
Garrett_Ck_S030	7.7349	0	0.18	1
Salt_Ck_S010	28.167	0	0.18	1
Salt_Ck_S020	24.8	0	0.20	1
West_Fork_S210	30.4	0	0.18	1
West_Fork_S220	41.104	0	0.16	2
Eagle_Mountain_S010	36.129	0	0.14	9
Eagle_Mountain_S020	18.265	0	0.06	6
Walnut_Ck_S020	31.434	0	0.17	1
Walnut_Ck_S010	31.306	0	0.16	3
Walnut_Ck_S030	18.624	0	0.15	6
Eagle_Mountain_S040	42.467	0	0.07	30
Eagle_Mountain_S030	26.439	0	0.11	4

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
Silver_Ck_S020	34.745	0	0.09	8
Silver_Ck_S010	27.84	0	0.11	2
Lake_Worth_S010	24.097	0	0.12	19
Lake_Worth_S020	7.5243	0	0.05	43
West_Fork_S230	27.927	0	0.07	35
Lk_Weatherford_S010	95.903	0	0.15	1
Lk_Weatherford_S020	12.819	0	0.09	17
Clear_Fork_S010	136.33	0	0.11	6
Clear_Fork_S020	18.791	0	0.09	4
Bear_Ck_S010	58.923	0	0.08	1
Bear_Ck_S020	5.488	0	0.07	4
Benbrook_S010	34.538	0	0.05	1
Benbrook_S020	34.232	0	0.07	2
Benbrook_S030	32.149	0	0.04	22
Clear_Fork_S030	9.432	0	0.08	26
Marys_Ck_S010	54.161	0	0.06	8
Clear_Fork_S040	25.372	0	0.05	39
Clear_Fork_S050	4.8892	0	0.05	57
West_Fork_S240	1.1676	0	0.11	39
Marine_Ck_S020	12.613	0	0.04	38
Marine_Ck_S010	9.1106	0	0.03	28
West_Fork_S250	9.1582	0	0.07	50
West_Fork_S260	39.237	0	0.05	36
West_Fork_S270	12.962	0	0.10	27
Big_Fossil_Ck_S010	56.863	0	0.05	30
LittleFossil_Ck_S010	19.724	0	0.06	39
West_Fork_S280	28.915	0	0.12	34
Village_Ck_S010	90.4	0	0.11	10
Village_Ck_S020	34.614	0	0.10	19
Lake_Arlington_S010	18.132	0	0.09	42
Village_Ck_S030	48.52	0	0.13	28
West_Fork_S290	43.905	0	0.14	34
West_Fork_S300	20.735	0	0.09	52
West_Fork_S310	4.7638	0	0.11	29
West_Fork_S320	2.1579	0	0.18	19
Big_Bear_Ck_S010	82.535	0	0.11	31

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
Big_Bear_Ck_S020	10.78	0	0.18	34
West_Fork_S330	8.5845	0	0.17	33
Joe_Pool_S020	111.69	0	0.03	14
Joe_Pool_S030	62.877	0	0.10	8
Joe_Pool_S040	4.3638	0	0.12	30
Joe_Pool_S010	25.953	0	0.03	3
Joe_Pool_S050	19.287	0	0.05	43
Mountain_Ck_S010	41.498	0	0.05	32
Mountain_Ck_S020	29.121	0	0.05	44
Mountain_Ck_S030	9.5825	0	0.05	31
West_Fork_S340	13.268	0	0.08	37
Elm_Fork_S020	33.952	0	0.04	1
Elm_Fork_S010	33.399	0	0.06	2
Brushy_Elm_Ck_S010	13.953	0	0.03	1
Brushy_Elm_Ck_S020	11.585	0	0.03	5
Elm_Fork_S030	44.131	0	0.04	1
Elm_Fork_S040	40.168	0	0.04	3
Elm_Fork_S050	39.582	0	0.10	6
Elm_Fork_S070	28.099	0	0.08	2
Elm_Fork_S060	20.13	0	0.03	1
Spring_Ck_S010	40.625	0	0.04	0
Spring_Ck_S020	22.069	0	0.05	6
Ray_Roberts_S010	26.116	0	0.07	19
Timber_Ck_S010	39.041	0	0.16	1
Timber_Ck_S030	21.944	0	0.09	2
Timber_Ck_S020	3.1688	0	0.16	0
Ray_Roberts_S030	56.628	0	0.12	30
Range_Ck_S010	29.306	0	0.04	0
Range_Ck_S020	21.245	0	0.03	1
Lake_Kiowa_S020	22.138	0	0.15	11
Lake_Kiowa_S010	16.824	0	0.18	7
Ray_Roberts_S020	37.459	0	0.04	32
Range_Ck_S030	31.128	0	0.05	3
Buck_Ck_S010	23.091	0	0.03	0
Ray_Roberts_S050	15.763	0	0.04	12
Ray_Roberts_S040	11.221	0	0.07	31

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
Ray_Roberts_S060	7.2967	0	0.08	34
Timber_Ck_S040	2.5225	0	0.08	7
Elm_Fork_S080	36.867	0	0.11	2
Clear_Ck_S010	50.564	0	0.13	0
Clear_Ck_S020	33.309	0	0.15	1
Clear_Ck_S030	16.059	0	0.12	1
Clear_Ck_S040	51.636	0	0.08	1
Clear_Ck_S050	35.613	0	0.05	0
Clear_Ck_S070	24.721	0	0.05	1
Clear_Ck_S060	2.561	0	0.10	0
Clear_Ck_S080	45.063	0	0.08	1
Clear_Ck_S090	35.1	0	0.05	2
Clear_Ck_S110	15.304	0	0.06	6
Clear_Ck_S100	12.82	0	0.06	2
Clear_Ck_S120	28.433	0	0.08	2
Little_Elm_Ck_S010	42.284	0	0.03	2
Little_Elm_Ck_S020	30.566	0	0.04	2
Little_Elm_Ck_S030	22.952	0	0.03	1
Pecan_Ck_S010	43.069	0	0.11	2
Doe_Branch_S010	38.401	0	0.04	4
Doe_Branch_S020	32.613	0	0.04	14
Lewisville_S030	21.388	0	0.11	10
Hickory_Ck_S020	41.143	0	0.05	1
Hickory_Ck_S010	39.534	0	0.05	1
Hickory_Ck_S030	18.092	0	0.07	11
Hickory_Ck_S040	30.172	0	0.08	6
Hickory_Ck_S050	19.984	0	0.14	11
Lewisville_S010	89.013	0	0.11	18
Lewisville_S040	43.47	0	0.04	27
Lewisville_S050	34.958	0	0.04	28
Lewisville_S020	32.483	0	0.09	26
Elm_Fork_S090	21.401	0	0.08	28
Elm_Fork_S110	16.052	0	0.04	34
Elm_Fork_S100	24.07	0	0.12	36
Elm_Fork_S120	18.411	0	0.06	50
Denton_Ck_S010	116.04	0	0.15	1

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
Denton_Ck_S020	169.01	0	0.15	1
Denton_Ck_S030	61.584	0	0.12	2
Denton_Ck_S040	53.408	0	0.07	1
Denton_Ck_S050	75.302	0	0.06	2
Denton_Ck_S060	30.783	0	0.07	5
Denton_Ck_S070	93.553	0	0.05	8
Grapevine_S010	94.746	0	0.11	21
Denton_Ck_S080	24.302	0	0.11	33
Elm_Fork_S130	39.176	0	0.06	50
Hackberry_Ck_S010	14.676	0	0.03	42
Hackberry_Ck_S020	4.6175	0	0.03	43
Hackberry_Ck_S030	1.5901	0	0.04	45
Elm_Fork_S140	16.129	0	0.08	47
Elm_Fork_S150	22.195	0	0.09	47
Bachman_Branch_S010	12.676	0	0.05	33
Bachman_Branch_S020	1.4028	0	0.08	44
Elm_Fork_S160	6.0919	0	0.09	45
Trinity_River_S010	12.471	0	0.05	38
Trinity_River_S020	42.888	0	0.06	54
White_Rock_Ck_S010	66.661	0	0.06	49
White_Rock_Ck_S020	17.611	0	0.08	49
White_Rock_Ck_S030	10.77	0	0.07	48
White_Rock_Ck_S040	39.838	0	0.08	30
Trinity_River_S030	22.538	0	0.09	30
Fivemile_Ck_S010	43.493	0	0.07	29
Trinity_River_S040	28.855	0	0.09	17
Trinity_River_S050	38.875	0	0.10	18
Tenmile_Ck_S010	74.205	0	0.06	21
Tenmile_Ck_S020	27.911	0	0.08	6
Trinity_River_S060	59.61	0	0.13	8
Indian_Ck_S010	104.6	0	0.04	2
Indian_Ck_S030	85.214	0	0.06	1
Indian_Ck_S020	15.956	0	0.03	1
Indian_Ck_S040	30.154	0	0.05	6
Sister_Grove_S010	83.154	0	0.07	2
Sister_Grove_S020	38.04	0	0.06	6

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
East_Fork_S020	118.24	0	0.06	2
East_Fork_S010	49.637	0	0.06	3
East_Fork_S030	22.229	0	0.07	9
East_Fork_S040	24.674	0	0.06	10
Wilson_Ck_S010	77.486	0	0.07	19
Lavon_S010	85.736	0	0.04	26
Lavon_S020	33.092	0	0.05	32
Rowlett_Ck_S010	119.88	0	0.06	38
Ray_Hubbard_S010	137.97	0	0.05	32
Ray_Hubbard_S020	43.943	0	0.05	48
East_Fork_S050	48.092	0	0.05	36
East_Fork_S070	9.6301	0	0.04	11
East_Fork_S060	34.344	0	0.04	13
East_Fork_S080	23.001	0	0.04	21
East_Fork_S090	29.546	0	0.04	34
East_Fork_S110	19.138	0	0.05	6
East_Fork_S100	19.268	0	0.04	15
Trinity_River_S070	231.25	0	0.05	4
East_Fork_S120	104.18	0	0.05	3
Kings_Ck_S020	133.14	0	0.03	3
Kings_Ck_S010	89.439	0	0.04	5
Kings_Ck_S030	120.56	0	0.04	6
Cedar_Ck_S040	285.73	0	0.10	17
Cedar_Ck_S010	176.13	0	0.06	2
New_Terrell_City_Lake_S010	14.019	0	0.03	9
Cedar_Ck_S020	93.332	0	0.05	5
Cedar_Ck_S030	98.44	0	0.09	4
Trinity_River_S080	398.9	0	0.05	1
Trinity_River_S090	283.46	0	0.08	2
Chambers_Ck_S010	161.82	0	0.06	1
Chambers_Ck_S020	146.57	0	0.06	1
Chambers_Ck_S040	105.96	0	0.05	1
Chambers_Ck_S030	97.554	0	0.06	1
Waxahachie_Ck_S010	60.388	0	0.06	7
Waxahachie_Ck_S020	30.598	0	0.06	1.7
Waxahachie_Ck_S030	30.048	0	0.06	4

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
Mustang_Ck_S010	29.914	0	0.03	7
Bardwell_S010	23.442	0	0.04	29
Chambers_Ck_S050	75.82	0	0.04	0
Chambers_Ck_S060	33.261	0	0.06	0
Chambers_Ck_S070	29.085	0	0.04	1
Chambers_Ck_S080	145.13	0	0.05	34
Post_Oak_Ck_S010	29.49	0	0.04	13
Lake_Halbert_S010	11.534	0	0.03	5
Navarro_Mills_S020	143.52	0	0.04	1
Navarro_Mills_S030	74.878	0	0.05	1
Navarro_Mills_S010	65.75	0	0.06	1
Navarro_Mills_S040	35.712	0	0.04	23
Richland_Ck_S010	220.05	0	0.05	1
Richland_Ck_S020	174.9	0	0.04	0
Richland-Chambers_S010	141.82	0	0.04	23
Richland-Chambers_S020	92.537	0	0.04	47
Tehuacana_Ck_S020	245.04	0	0.11	2
Tehuacana_Ck_S010	141.34	0	0.07	1
Trinity_River_S100	70.586	0	0.10	2
Fairfield_Lake_S010	36.167	0	0.11	12
Trinity_River_S110	305.13	0	0.23	3
Big_Brown_Ck_S010	46.426	0	0.19	1
Trinity_River_S120	240	0	0.16	3
Trinity_River_S130	256.66	0	0.15	2
Upper_Keechi_Ck_S030	272.69	0	0.19	3
Upper_Keechi_Ck_S010	150.34	0	0.13	4
Upper_Keechi_Ck_S020	36.468	0	0.20	1
Upper_Keechi_Ck_S040	49.746	0	0.14	1
Trinity_River_S140	0.60116	0	0.04	1
Little_Elkhart_S010	95.014	0	0.22	1
Houston_County_Lake_S010	47.982	0	0.26	6
Trinity_River_S150	112.48	0	0.10	2
Trinity_River_S160	176.66	0	0.13	1
Trinity_River_S170	187.6	0	0.20	1
Trinity_River_S180	395.03	0	0.12	2
Bedias_Ck_S010	330.55	0	0.09	1

Subbasin Name	Drainage Area (sq mi)	Initial Loss (in)	Constant Loss (in/hr)	Percent Impervious (%)
Bedias_Ck_S020	273.7	0	0.10	1
Trinity_River_S190	328.14	0	0.11	4
Livingston_S010	509.39	0	0.07	3
Livingston_S030	414.8	0	0.09	27
Livingston_S020	70.271	0	0.09	17
Trinity_River_S200	39.412	0	0.14	3
Long_King_Ck_S010	141.11	0	0.12	1
Long_King_Ck_S020	85.25	0	0.15	4
Trinity_River_S210	61.113	0	0.18	4
Menard_Ck_S010	148.14	0	0.17	1
Trinity_River_S220	97.556	0	0.15	2
Trinity_River_S230	72.024	0	0.07	4
Trinity_River_S240	230.77	0	0.07	2
Trinity_River_S250	441.84	0	0.05	8

Table 3: Initial Estimates of Snyder's Transform Parameters

Subbasin Name	Lag Time (hr)	Peaking Coefficient
West_Fork_S020	8.43	0.36
West_Fork_S010	7	0.36
West_Fork_S030	9.49	0.36
West_Fork_S040	8.51	0.36
West_Fork_S050	6.22	0.43
West_Fork_S060	8.68	0.43
West_Fork_S070	6.95	0.43
West_Fork_S080	5.07	0.43
West_Fork_S090	7.08	0.43
West_Fork_S100	7.18	0.43
West_Fork_S120	8.57	0.43
West_Fork_S110	6.44	0.43
Big_Cleveland_S010	9.18	0.43
Big_Cleveland_S020	6.41	0.43
West_Fork_S130	4.88	0.43
Lost_Ck_S010	4	0.5
Lost_Ck_S020	4.4	0.53

Subbasin Name	Lag Time (hr)	Peaking Coefficient
West_Fork_S140	5.38	0.53
West_Fork_S150	6.06	0.53
West_Fork_S160	5.13	0.53
Beans_Ck_S010	4.98	0.53
Beans_Ck_S020	3.12	0.53
Big_Ck_S010	5.64	0.53
Big_Ck_S030	4.23	0.53
Big_Ck_S020	4.1	0.53
Bridgeport_S030	6.22	0.53
Bridgeport_S010	5.31	0.53
Bridgeport_S040	5.51	0.53
Bridgeport_S020	4.96	0.53
West_Fork_S170	6.74	0.77
Dry_Ck_S010	6.52	0.77
West_Fork_S180	2	0.64
Amon_G_Carter_S030	5.19	0.7
Amon_G_Carter_S010	5.61	0.7
Amon_G_Carter_S020	5.3	0.7
Big_Sandy_Ck_S010	6.52	0.42
Big_Sandy_Ck_S020	7.68	0.42
Brushy_Ck_S010	7.93	0.42
Brushy_Ck_S020	6.86	0.42
Brushy_Ck_S030	5.74	0.42
Big_Sandy_Ck_S030	4.52	0.64
Big_Sandy_Ck_S040	7.12	0.64
Big_Sandy_Ck_S050	5.44	0.77
West_Fork_S190	2.44	0.77
West_Fork_S200	4.42	0.77
Garrett_Ck_S020	6.01	0.77
Garrett_Ck_S010	6.79	0.77
Garrett_Ck_S030	3.74	0.77
Salt_Ck_S010	5.73	0.77
Salt_Ck_S020	4.91	0.77
West_Fork_S210	4.64	0.77
West_Fork_S220	6.46	0.43
Eagle_Mountain_S010	5.29	0.43

Subbasin Name	Lag Time (hr)	Peaking Coefficient
Eagle_Mountain_S020	5.11	0.43
Walnut_Ck_S020	3.63	0.76
Walnut_Ck_S010	3.44	0.76
Walnut_Ck_S030	5.47	0.43
Eagle_Mountain_S040	5.91	0.43
Eagle_Mountain_S030	7.3	0.43
Silver_Ck_S020	4.99	0.59
Silver_Ck_S010	4.91	0.59
Lake_Worth_S010	4.5	0.59
Lake_Worth_S020	3.6	0.59
West_Fork_S230	3.55	0.7
Lk_Weatherford_S010	8	0.66
Lk_Weatherford_S020	2	0.68
Clear_Fork_S010	11	0.65
Clear_Fork_S020	2.9	0.63
Bear_Ck_S010	6	0.68
Bear_Ck_S020	1.7	0.62
Benbrook_S010	5	0.62
Benbrook_S020	2.4	0.62
Benbrook_S030	1.8	0.63
Clear_Fork_S030	1.44	0.7
Marys_Ck_S010	3.19	0.7
Clear_Fork_S040	1.7	0.7
Clear_Fork_S050	0.94	0.7
West_Fork_S240	0.87	0.7
Marine_Ck_S020	1.24	0.7
Marine_Ck_S010	1.02	0.7
West_Fork_S250	1.85	0.7
West_Fork_S260	2.53	0.53
West_Fork_S270	1.86	0.7
Big_Fossil_Ck_S010	3.62	0.7
LittleFossil_Ck_S010	2.26	0.7
West_Fork_S280	3.05	0.7
Village_Ck_S010	5.87	0.7
Village_Ck_S020	1.64	0.7
Lake_Arlington_S010	1.36	0.7

Subbasin Name	Lag Time (hr)	Peaking Coefficient
Village_Ck_S030	5.36	0.7
West_Fork_S290	1.42	0.7
West_Fork_S300	3.47	0.7
West_Fork_S310	0.78	0.7
West_Fork_S320	1.4	0.7
Big_Bear_Ck_S010	8.56	0.7
Big_Bear_Ck_S020	3.18	0.7
West_Fork_S330	2.26	0.7
Joe_Pool_S020	2.59	0.7
Joe_Pool_S030	5.62	0.7
Joe_Pool_S040	1.44	0.7
Joe_Pool_S010	2.92	0.7
Joe_Pool_S050	3	0.68
Mountain_Ck_S010	2.3	0.7
Mountain_Ck_S020	1.33	0.7
Mountain_Ck_S030	1.27	0.7
West_Fork_S340	2.38	0.7
Elm_Fork_S020	4.41	0.7
Elm_Fork_S010	3.63	0.7
Brushy_Elm_Ck_S010	2.71	0.7
Brushy_Elm_Ck_S020	2.99	0.7
Elm_Fork_S030	3.87	0.7
Elm_Fork_S040	3.69	0.7
Elm_Fork_S050	4.4	0.7
Elm_Fork_S070	5.06	0.7
Elm_Fork_S060	3.67	0.7
Spring_Ck_S010	3.57	0.7
Spring_Ck_S020	2.47	0.7
Ray_Roberts_S010	1.47	0.7
Timber_Ck_S010	6.26	0.7
Timber_Ck_S030	4.1	0.7
Timber_Ck_S020	1.85	0.7
Ray_Roberts_S030	1.53	0.7
Range_Ck_S010	2.79	0.7
Range_Ck_S020	4.9	0.7
Lake_Kiowa_S020	2.41	0.7

Subbasin Name	Lag Time (hr)	Peaking Coefficient
Lake_Kiowa_S010	3.1	0.7
Ray_Roberts_S020	1	0.7
Range_Ck_S030	3.8	0.7
Buck_Ck_S010	4.46	0.7
Ray_Roberts_S050	1	0.7
Ray_Roberts_S040	1.65	0.7
Ray_Roberts_S060	1	0.7
Timber_Ck_S040	2	0.62
Elm_Fork_S080	3.86	0.62
Clear_Ck_S010	5.13	0.62
Clear_Ck_S020	4.43	0.62
Clear_Ck_S030	2.03	0.62
Clear_Ck_S040	3.87	0.62
Clear_Ck_S050	6.2	0.62
Clear_Ck_S070	3.7	0.62
Clear_Ck_S060	1.1	0.62
Clear_Ck_S080	6.83	0.62
Clear_Ck_S090	4.99	0.62
Clear_Ck_S110	2.89	0.62
Clear_Ck_S100	3.2	0.62
Clear_Ck_S120	4.31	0.62
Little_Elm_Ck_S010	4.02	0.62
Little_Elm_Ck_S020	4.66	0.62
Little_Elm_Ck_S030	6.09	0.62
Pecan_Ck_S010	6.35	0.62
Doe_Branch_S010	4.44	0.62
Doe_Branch_S020	3.58	0.62
Lewisville_S030	2.3	0.62
Hickory_Ck_S020	5.36	0.62
Hickory_Ck_S010	3.95	0.62
Hickory_Ck_S030	3.48	0.62
Hickory_Ck_S040	3.14	0.62
Hickory_Ck_S050	2.08	0.62
Lewisville_S010	3.54	0.62
Lewisville_S040	2.33	0.62
Lewisville_S050	2.19	0.62

Subbasin Name	Lag Time (hr)	Peaking Coefficient
Lewisville_S020	1.63	0.62
Elm_Fork_S090	3.11	0.7
Elm_Fork_S110	2.23	0.7
Elm_Fork_S100	4.28	0.7
Elm_Fork_S120	4.6	0.62
Denton_Ck_S010	7	0.7
Denton_Ck_S020	7	0.7
Denton_Ck_S030	3.96	0.7
Denton_Ck_S040	3.91	0.7
Denton_Ck_S050	4.84	0.7
Denton_Ck_S060	4.9	0.7
Denton_Ck_S070	6.73	0.7
Grapevine_S010	2.75	0.7
Denton_Ck_S080	3.56	0.7
Elm_Fork_S130	1.28	0.7
Hackberry_Ck_S010	1.76	0.7
Hackberry_Ck_S020	1.14	0.7
Hackberry_Ck_S030	0.88	0.7
Elm_Fork_S140	1.18	0.7
Elm_Fork_S150	1.09	0.7
Bachman_Branch_S010	1.01	0.7
Bachman_Branch_S020	1.01	0.7
Elm_Fork_S160	0.74	0.7
Trinity_River_S010	1.5	0.7
Trinity_River_S020	1.98	0.7
White_Rock_Ck_S010	3.1	0.7
White_Rock_Ck_S020	1.1	0.7
White_Rock_Ck_S030	1.3	0.7
White_Rock_Ck_S040	1.9	0.7
Trinity_River_S030	1.62	0.7
Fivemile_Ck_S010	2.4	0.7
Trinity_River_S040	5.6	0.72
Trinity_River_S050	11.1	0.72
Tenmile_Ck_S010	10.8	0.72
Tenmile_Ck_S020	7.4	0.72
Trinity_River_S060	11	0.72

Subbasin Name	Lag Time (hr)	Peaking Coefficient
Indian_Ck_S010	9	0.7
Indian_Ck_S030	10	0.7
Indian_Ck_S020	9	0.7
Indian_Ck_S040	5	0.7
Sister_Grove_S010	9	0.7
Sister_Grove_S020	6	0.7
East_Fork_S020	13	0.7
East_Fork_S010	10	0.7
East_Fork_S030	8	0.7
East_Fork_S040	5	0.7
Wilson_Ck_S010	10	0.7
Lavon_S010	5	0.7
Lavon_S020	4	0.7
Rowlett_Ck_S010	10	0.7
Ray_Hubbard_S010	4	0.7
Ray_Hubbard_S020	4	0.7
East_Fork_S050	6	0.7
East_Fork_S070	4	0.7
East_Fork_S060	9	0.7
East_Fork_S080	7	0.7
East_Fork_S090	6	0.7
East_Fork_S110	5	0.7
East_Fork_S100	9	0.7
Trinity_River_S070	21.6	0.72
East_Fork_S120	13	0.7
Kings_Ck_S020	19.6	0.72
Kings_Ck_S010	16.2	0.72
Kings_Ck_S030	19.4	0.72
Cedar_Ck_S040	20.6	0.72
Cedar_Ck_S010	16.4	0.72
New_Terrell_City_Lake_S010	7.5	0.72
Cedar_Ck_S020	17.2	0.72
Cedar_Ck_S030	18.3	0.72
Trinity_River_S080	27	0.72
Trinity_River_S090	17	0.72
Chambers_Ck_S010	9	0.72

Subbasin Name	Lag Time (hr)	Peaking Coefficient
Chambers_Ck_S020	6.4	0.72
Chambers_Ck_S040	6.3	0.72
Chambers_Ck_S030	6.9	0.72
Waxahachie_Ck_S010	4.3	0.7
Waxahachie_Ck_S020	4	0.7
Waxahachie_Ck_S030	3.7	0.7
Mustang_Ck_S010	3.6	0.7
Bardwell_S010	2.3	0.7
Chambers_Ck_S050	5.1	0.72
Chambers_Ck_S060	3	0.72
Chambers_Ck_S070	3	0.72
Chambers_Ck_S080	7.4	0.72
Post_Oak_Ck_S010	3.9	0.72
Lake_Halbert_S010	1.9	0.72
Navarro_Mills_S020	4.8	0.72
Navarro_Mills_S030	6.9	0.72
Navarro_Mills_S010	4.4	0.72
Navarro_Mills_S040	3.8	0.72
Richland_Ck_S010	9	0.72
Richland_Ck_S020	8.1	0.72
Richland-Chambers_S010	9.2	0.72
Richland-Chambers_S020	8.1	0.72
Tehuacana_Ck_S020	24.9	0.72
Tehuacana_Ck_S010	17.2	0.72
Trinity_River_S100	19.6	0.72
Fairfield_Lake_S010	11.3	0.72
Trinity_River_S110	24.1	0.72
Big_Brown_Ck_S010	17	0.72
Trinity_River_S120	21.6	0.72
Trinity_River_S130	7	0.35
Upper_Keechi_Ck_S030	5.4	0.35
Upper_Keechi_Ck_S010	4.3	0.35
Upper_Keechi_Ck_S020	2	0.36
Upper_Keechi_Ck_S040	2	0.36
Trinity_River_S140	1.1	0.35
Little_Elkhart_S010	2.9	0.36

Subbasin Name	Lag Time (hr)	Peaking Coefficient
Houston_County_Lake_S010	1.7	0.36
Trinity_River_S150	7	0.35
Trinity_River_S160	4.3	0.5
Trinity_River_S170	5.4	0.5
Trinity_River_S180	7.9	0.5
Bedias_Ck_S010	16.5	0.5
Bedias_Ck_S020	7.4	0.5
Trinity_River_S190	4.3	0.5
Livingston_S010	5.4	0.5
Livingston_S030	3.7	0.35
Livingston_S020	1.4	0.37
Trinity_River_S200	2.2	0.49
Long_King_Ck_S010	5.1	0.35
Long_King_Ck_S020	3.2	0.49
Trinity_River_S210	2.2	0.35
Menard_Ck_S010	6.3	0.35
Trinity_River_S220	3.7	0.5
Trinity_River_S230	4	0.49
Trinity_River_S240	2.2	0.49
Trinity_River_S250	2.8	0.5

Table 4: Initial Estimates of Baseflow Parameters

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
West_Fork_S020	Discharge	na	10	0.55	0.02
West_Fork_S010	Discharge	na	10	0.55	0.02
West_Fork_S030	Discharge	na	10	0.55	0.02
West_Fork_S040	Discharge	na	10	0.55	0.02
West_Fork_S050	Discharge	na	10	0.55	0.02
West_Fork_S060	Discharge	na	10	0.53	0.01
West_Fork_S070	Discharge	na	10	0.53	0.04
West_Fork_S080	Discharge	na	10	0.55	0.02
West_Fork_S090	Discharge	na	10	0.55	0.02
West_Fork_S100	Discharge	na	10	0.53	0.04
West_Fork_S120	Discharge	na	10	0.53	0.01
West_Fork_S110	Discharge	na	10	0.55	0.02
Big_Cleveland_S010	Discharge	na	10	0.53	0.04
Big_Cleveland_S020	Discharge	na	10	0.55	0.09
West_Fork_S130	Discharge	na	10	0.55	0.02
Lost_Ck_S010	Discharge	na	10	0.53	0.04
Lost_Ck_S020	Discharge	na	10	0.53	0.05
West_Fork_S140	Discharge	na	0	0.55	0.05
West_Fork_S150	Discharge	na	0	0.53	0.05
West_Fork_S160	Discharge	na	0	0.70	0.05
Beans_Ck_S010	Discharge	na	0	0.73	0.05
Beans_Ck_S020	Discharge	na	0	0.73	0.05
Big_Ck_S010	Discharge	na	0	0.89	0.05
Big_Ck_S030	Discharge	na	0	0.80	0.05
Big_Ck_S020	Discharge	na	0	0.89	0.05
Bridgeport_S030	Discharge	na	0	0.89	0.05
Bridgeport_S010	Discharge	na	0	0.70	0.05
Bridgeport_S040	Discharge	na	0	0.55	0.05
Bridgeport_S020	Discharge	na	0	0.53	0.05
West_Fork_S170	Discharge	na	0	0.70	0.02
Dry_Ck_S010	Discharge	na	0	0.70	0.01
West_Fork_S180	Discharge	na	0	0.70	0.02
Amon_G_Carter_S030	Discharge	na	0	0.53	0.05
Amon_G_Carter_S010	Discharge	na	0	0.53	0.05

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Amon_G_Carter_S020	Discharge	na	0	0.65	0.05
Big_Sandy_Ck_S010	Discharge	na	0	0.53	0.01
Big_Sandy_Ck_S020	Discharge	na	0	0.53	0.01
Brushy_Ck_S010	Discharge	na	0	0.53	0.02
Brushy_Ck_S020	Discharge	na	0	0.53	0.02
Brushy_Ck_S030	Discharge	na	0	0.53	0.05
Big_Sandy_Ck_S030	Discharge	na	0	0.53	0.01
Big_Sandy_Ck_S040	Discharge	na	0	0.53	0.01
Big_Sandy_Ck_S050	Discharge	na	0	0.80	0.2
West_Fork_S190	Discharge	na	0	0.70	0.02
West_Fork_S200	Discharge	na	0	0.70	0.02
Garrett_Ck_S020	Discharge	na	0	0.70	0.04
Garrett_Ck_S010	Discharge	na	0	0.70	0.01
Garrett_Ck_S030	Discharge	na	0	0.70	0.01
Salt_Ck_S010	Discharge	na	0	0.70	0.04
Salt_Ck_S020	Discharge	na	0	0.70	0.04
West_Fork_S210	Discharge	na	0	0.70	0.02
West_Fork_S220	Discharge	na	0	0.50	0.02
Eagle_Mountain_S010	Discharge	na	0	0.50	0.02
Eagle_Mountain_S020	Discharge	na	0	0.50	0.01
Walnut_Ck_S020	Discharge	na	0	0.50	0.02
Walnut_Ck_S010	Discharge	na	0	0.50	0.02
Walnut_Ck_S030	Discharge	na	0	0.50	0.02
Eagle_Mountain_S040	Discharge	na	0	0.50	0.02
Eagle_Mountain_S030	Discharge	na	0	0.50	0.02
Silver_Ck_S020	Discharge	na	0	0.50	0.02
Silver_Ck_S010	Discharge	na	0	0.50	0.02
Lake_Worth_S010	Discharge	na	0	0.50	0.02
Lake_Worth_S020	Discharge	na	0	0.50	0.02
West_Fork_S230	Discharge Per Area	0.77	na	0.70	0.05
Lk_Weatherford_S010	Discharge Per Area	0.77	na	0.70	0.05
Lk_Weatherford_S020	Discharge Per Area	0.77	na	0.70	0.05
Clear_Fork_S010	Discharge Per Area	0.77	na	0.67	0.085
Clear_Fork_S020	Discharge Per Area	0.77	na	0.67	0.085
Bear_Ck_S010	Discharge Per Area	0.77	na	0.67	0.085

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Bear_Ck_S020	Discharge Per Area	0.77	na	0.67	0.085
Benbrook_S010	Discharge Per Area	0.77	na	0.67	0.085
Benbrook_S020	Discharge Per Area	0.77	na	0.67	0.085
Benbrook_S030	Discharge Per Area	0.77	na	0.67	0.085
Clear_Fork_S030	Discharge Per Area	0.77	na	0.70	0.05
Marys_Ck_S010	Discharge Per Area	0.77	na	0.71	0.05
Clear_Fork_S040	Discharge Per Area	0.77	na	0.70	0.05
Clear_Fork_S050	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S240	Discharge Per Area	0.77	na	0.70	0.05
Marine_Ck_S020	Discharge Per Area	0.77	na	0.70	0.05
Marine_Ck_S010	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S250	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S260	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S270	Discharge Per Area	0.77	na	0.70	0.05
Big_Fossil_Ck_S010	Discharge Per Area	0.77	na	0.70	0.05
LittleFossil_Ck_S010	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S280	Discharge Per Area	0.77	na	0.70	0.05
Village_Ck_S010	Discharge Per Area	0.77	na	0.40	0.05
Village_Ck_S020	Discharge Per Area	0.77	na	0.50	0.02
Lake_Arlington_S010	Discharge Per Area	0.77	na	0.53	0.02
Village_Ck_S030	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S290	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S300	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S310	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S320	Discharge Per Area	0.77	na	0.70	0.05
Big_Bear_Ck_S010	Discharge Per Area	0.77	na	0.70	0.05
Big_Bear_Ck_S020	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S330	Discharge Per Area	0.77	na	0.70	0.05
Joe_Pool_S020	Discharge Per Area	0.77	na	0.70	0.01
Joe_Pool_S030	Discharge Per Area	0.77	na	0.53	0.05
Joe_Pool_S040	Discharge Per Area	0.77	na	0.70	0.01
Joe_Pool_S010	Discharge Per Area	0.77	na	0.05	0.1
Joe_Pool_S050	Discharge Per Area	0.77	na	0.70	0.01
Mountain_Ck_S010	Discharge Per Area	0.77	na	0.70	0.05
Mountain_Ck_S020	Discharge Per Area	0.77	na	0.70	0.05

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Mountain_Ck_S030	Discharge Per Area	0.77	na	0.70	0.05
West_Fork_S340	Discharge	na	150	0.80	0.05
Elm_Fork_S020	Discharge Per Area	0.3	na	0.70	0.05
Elm_Fork_S010	Discharge Per Area	0.3	na	0.70	0.05
Brushy_Elm_Ck_S010	Discharge Per Area	0.3	na	0.70	0.05
Brushy_Elm_Ck_S020	Discharge Per Area	0.3	na	0.70	0.05
Elm_Fork_S030	Discharge Per Area	0.3	na	0.70	0.05
Elm_Fork_S040	Discharge Per Area	0.2	na	0.70	0.05
Elm_Fork_S050	Discharge Per Area	0.4	na	0.70	0.05
Elm_Fork_S070	Discharge Per Area	0.4	na	0.70	0.05
Elm_Fork_S060	Discharge Per Area	0.4	na	0.70	0.05
Spring_Ck_S010	Discharge Per Area	0.75	na	0.70	0.05
Spring_Ck_S020	Discharge Per Area	0.75	na	0.70	0.05
Ray_Roberts_S010	Discharge Per Area	0.75	na	0.70	0.05
Timber_Ck_S010	Discharge Per Area	0.75	na	0.70	0.01
Timber_Ck_S030	Discharge Per Area	0.75	na	0.70	0.05
Timber_Ck_S020	Discharge Per Area	0.75	na	0.70	0.05
Ray_Roberts_S030	Discharge Per Area	0.75	na	0.70	0.05
Range_Ck_S010	Discharge Per Area	0.7	na	0.40	0.03
Range_Ck_S020	Discharge Per Area	0.75	na	0.70	0.05
Lake_Kiowa_S020	Discharge Per Area	0.75	na	0.70	0.05
Lake_Kiowa_S010	Discharge Per Area	0.75	na	0.70	0.05
Ray_Roberts_S020	Discharge Per Area	0.75	na	0.70	0.05
Range_Ck_S030	Discharge Per Area	0.75	na	0.70	0.05
Buck_Ck_S010	Discharge Per Area	0.75	na	0.70	0.05
Ray_Roberts_S050	Discharge Per Area	0.75	na	0.70	0.05
Ray_Roberts_S040	Discharge Per Area	0.75	na	0.70	0.05
Ray_Roberts_S060	Discharge Per Area	0.75	na	0.70	0.05
Timber_Ck_S040	Discharge Per Area	0.75	na	0.70	0.05
Elm_Fork_S080	Discharge Per Area	0.77	na	0.70	0.05
Clear_Ck_S010	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S020	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S030	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S040	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S050	Discharge Per Area	0.2	na	0.70	0.17

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Clear_Ck_S070	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S060	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S080	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S090	Discharge Per Area	0.2	na	0.70	0.17
Clear_Ck_S110	Discharge Per Area	0.77	na	0.70	0.05
Clear_Ck_S100	Discharge Per Area	0.77	na	0.70	0.05
Clear_Ck_S120	Discharge Per Area	0.77	na	0.70	0.05
Little_Elm_Ck_S010	Discharge Per Area	0.77	na	0.70	0.1
Little_Elm_Ck_S020	Discharge Per Area	0.77	na	0.70	0.1
Little_Elm_Ck_S030	Discharge Per Area	0.77	na	0.70	0.05
Pecan_Ck_S010	Discharge Per Area	0.77	na	0.70	0.05
Doe_Branch_S010	Discharge Per Area	0.77	na	0.75	0.1
Doe_Branch_S020	Discharge Per Area	0.77	na	0.70	0.05
Lewisville_S030	Discharge Per Area	0.77	na	0.70	0.05
Hickory_Ck_S020	Discharge Per Area	0.77	na	0.70	0.05
Hickory_Ck_S010	Discharge Per Area	0.77	na	0.70	0.05
Hickory_Ck_S030	Discharge Per Area	0.77	na	0.70	0.05
Hickory_Ck_S040	Discharge Per Area	0.77	na	0.70	0.05
Hickory_Ck_S050	Discharge Per Area	0.77	na	0.70	0.05
Lewisville_S010	Discharge Per Area	0.77	na	0.70	0.05
Lewisville_S040	Discharge Per Area	0.77	na	0.70	0.05
Lewisville_S050	Discharge Per Area	0.77	na	0.70	0.05
Lewisville_S020	Discharge Per Area	0.77	na	0.70	0.05
Elm_Fork_S090	Discharge Per Area	0.77	na	0.50	0.15
Elm_Fork_S110	Discharge Per Area	0.77	na	0.50	0.15
Elm_Fork_S100	Discharge Per Area	0.77	na	0.50	0.15
Elm_Fork_S120	Discharge Per Area	0.77	na	0.80	0.15
Denton_Ck_S010	Discharge Per Area	0.1	na	0.40	0.5
Denton_Ck_S020	Discharge Per Area	0.1	na	0.40	0.5
Denton_Ck_S030	Discharge Per Area	0.1	na	0.40	0.5
Denton_Ck_S040	Discharge Per Area	0.1	na	0.30	0.7
Denton_Ck_S050	Discharge Per Area	0.1	na	0.40	0.02
Denton_Ck_S060	Discharge Per Area	0.1	na	0.89	0.02
Denton_Ck_S070	Discharge Per Area	0.1	na	0.89	0.02
Grapevine_S010	Discharge Per Area	0.2	na	0.89	0.02

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Denton_Ck_S080	Discharge Per Area	0.77	na	0.80	0.15
Elm_Fork_S130	Discharge Per Area	0.77	na	0.80	0.05
Hackberry_Ck_S010	Discharge Per Area	0.77	na	0.80	0.05
Hackberry_Ck_S020	Discharge Per Area	0.77	na	0.80	0.05
Hackberry_Ck_S030	Discharge Per Area	0.77	na	0.80	0.05
Elm_Fork_S140	Discharge Per Area	0.77	na	0.80	0.05
Elm_Fork_S150	Discharge	na	100	0.80	0.05
Bachman_Branch_S010	Discharge	na	100	0.80	0.05
Bachman_Branch_S020	Discharge	na	100	0.80	0.05
Elm_Fork_S160	Discharge	na	150	0.80	0.05
Trinity_River_S010	Discharge	na	150	0.80	0.05
Trinity_River_S020	Discharge	na	150	0.80	0.05
White_Rock_Ck_S010	Discharge	na	100	0.70	0.01
White_Rock_Ck_S020	Discharge	na	100	0.70	0.01
White_Rock_Ck_S030	Discharge	na	100	0.70	0.01
White_Rock_Ck_S040	Discharge	na	150	0.70	0.01
Trinity_River_S030	Discharge	na	150	1.00	0.05
Fivemile_Ck_S010	Discharge	na	150	1.00	0.05
Trinity_River_S040	Discharge Per Area	0.1	na	0.89	0.05
Trinity_River_S050	Discharge Per Area	0.1	na	0.89	0.05
Tenmile_Ck_S010	Discharge Per Area	0.1	na	0.89	0.05
Tenmile_Ck_S020	Discharge Per Area	0.1	na	0.89	0.05
Trinity_River_S060	Discharge Per Area	0.1	na	0.89	0.05
Indian_Ck_S010	Discharge Per Area	5	na	0.79	0.1
Indian_Ck_S030	Discharge Per Area	0.6	na	0.70	0.2
Indian_Ck_S020	Discharge Per Area	0.6	na	0.70	0.2
Indian_Ck_S040	Discharge Per Area	0.6	na	0.70	0.2
Sister_Grove_S010	Discharge Per Area	4	na	0.85	0.08
Sister_Grove_S020	Discharge Per Area	0.6	na	0.90	0.1
East_Fork_S020	Discharge Per Area	1.8	na	0.70	0.2
East_Fork_S010	Discharge Per Area	1.8	na	0.70	0.2
East_Fork_S030	Discharge Per Area	0.6	na	0.90	0.1
East_Fork_S040	Discharge Per Area	0.6	na	0.90	0.1
Wilson_Ck_S010	Discharge Per Area	0.6	na	0.90	0.1
Lavon_S010	Discharge Per Area	0.6	na	0.79	0.1

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Lavon_S020	Discharge Per Area	0.6	na	0.79	0.1
Rowlett_Ck_S010	Discharge Per Area	2	na	0.79	0.05
Ray_Hubbard_S010	Discharge Per Area	0.2	na	0.79	0.05
Ray_Hubbard_S020	Discharge Per Area	0.2	na	0.79	0.05
East_Fork_S050	Discharge Per Area	5	na	0.79	0.2
East_Fork_S070	Discharge Per Area	0.1	na	0.79	0.1
East_Fork_S060	Discharge Per Area	0.1	na	0.62	0.1
East_Fork_S080	Discharge Per Area	0.1	na	0.62	0.1
East_Fork_S090	Discharge Per Area	0.1	na	0.62	0.1
East_Fork_S110	Discharge Per Area	0.1	na	0.62	0.1
East_Fork_S100	Discharge Per Area	0.1	na	0.62	0.1
Trinity_River_S070	Discharge Per Area	0.1	na	0.89	0.05
East_Fork_S120	Discharge Per Area	0.1	na	0.89	0.05
Kings_Ck_S020	Discharge Per Area	0.1	na	0.90	0.12
Kings_Ck_S010	Discharge Per Area	0.1	na	0.90	0.12
Kings_Ck_S030	Discharge Per Area	0.1	na	0.90	0.12
Cedar_Ck_S040	Discharge Per Area	0.1	na	0.90	0.12
Cedar_Ck_S010	Discharge Per Area	0.1	na	1.00	0.1
New_Terrell_City_Lake_S010	Discharge Per Area	0.1	na	0.90	0.1
Cedar_Ck_S020	Discharge Per Area	0.1	na	0.90	0.12
Cedar_Ck_S030	Discharge Per Area	0.1	na	0.90	0.12
Trinity_River_S080	Discharge Per Area	0.1	na	0.89	0.05
Trinity_River_S090	Discharge Per Area	0.1	na	0.89	0.05
Chambers_Ck_S010	Discharge Per Area	0.1	na	0.79	0.1
Chambers_Ck_S020	Discharge Per Area	0.1	na	0.79	0.1
Chambers_Ck_S040	Discharge Per Area	0.1	na	0.79	0.1
Chambers_Ck_S030	Discharge Per Area	0.1	na	0.79	0.1
Waxahachie_Ck_S010	Discharge Per Area	0.1	na	0.89	0.05
Waxahachie_Ck_S020	Discharge Per Area	0.1	na	0.89	0.05
Waxahachie_Ck_S030	Discharge Per Area	0.1	na	0.89	0.05
Mustang_Ck_S010	Discharge Per Area	0.1	na	0.89	0.05
Bardwell_S010	Discharge Per Area	0.1	na	0.89	0.05
Chambers_Ck_S050	Discharge Per Area	0.1	na	0.79	0.1
Chambers_Ck_S060	Discharge Per Area	0.1	na	0.79	0.1
Chambers_Ck_S070	Discharge Per Area	0.1	na	0.79	0.1

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Chambers_Ck_S080	Discharge Per Area	0.1	na	0.79	0.1
Post_Oak_Ck_S010	Discharge	na	0	1.00	0.05
Lake_Halbert_S010	Discharge Per Area	0.1	na	0.79	0.1
Navarro_Mills_S020	Discharge Per Area	0.1	na	0.89	0.05
Navarro_Mills_S030	Discharge Per Area	0.1	na	0.89	0.05
Navarro_Mills_S010	Discharge Per Area	0.1	na	0.89	0.05
Navarro_Mills_S040	Discharge Per Area	0.1	na	0.89	0.05
Richland_Ck_S010	Discharge Per Area	0.1	na	0.79	0.1
Richland_Ck_S020	Discharge	na	0	1.00	0.05
Richland-Chambers_S010	Discharge Per Area	0.1	na	0.79	0.1
Richland-Chambers_S020	Discharge Per Area	0.1	na	0.79	0.1
Tehuacana_Ck_S020	Discharge Per Area	0.1	na	0.89	0.05
Tehuacana_Ck_S010	Discharge Per Area	0.1	na	0.89	0.05
Trinity_River_S100	Discharge Per Area	0.1	na	0.89	0.05
Fairfield_Lake_S010	Discharge Per Area	0.1	na	0.89	0.05
Trinity_River_S110	Discharge Per Area	0.1	na	0.89	0.05
Big_Brown_Ck_S010	Discharge Per Area	0.1	na	0.89	0.05
Trinity_River_S120	Discharge Per Area	0.1	na	0.89	0.05
Trinity_River_S130	Discharge Per Area	0.1	na	0.79	0.1
Upper_Keechi_Ck_S030	Discharge Per Area	0.1	na	0.79	0.1
Upper_Keechi_Ck_S010	Discharge Per Area	2	na	0.79	0.1
Upper_Keechi_Ck_S020	Discharge Per Area	0.1	na	0.79	0.1
Upper_Keechi_Ck_S040	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S140	Discharge Per Area	0.1	na	0.79	0.1
Little_Elkhart_S010	Discharge Per Area	0.1	na	0.79	0.1
Houston_County_Lake_S010	Discharge Per Area	1	na	0.79	0.1
Trinity_River_S150	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S160	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S170	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S180	Discharge Per Area	0.1	na	0.79	0.1
Bedias_Ck_S010	Discharge Per Area	0.3	na	0.79	0.1
Bedias_Ck_S020	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S190	Discharge Per Area	0.1	na	0.79	0.1
Livingston_S010	Discharge Per Area	0.1	na	0.79	0.1
Livingston_S030	Discharge Per Area	0.1	na	0.79	0.1

Subbasin Name	Initial Type	Initial Discharge (CFS/MI2)	Initial Discharge (CFS)	Recession Constant	Ratio to Peak
Livingston_S020	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S200	Discharge Per Area	0.1	na	0.79	0.1
Long_King_Ck_S010	Discharge Per Area	1.5	na	0.90	0.1
Long_King_Ck_S020	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S210	Discharge Per Area	0.1	na	0.79	0.1
Menard_Ck_S010	Discharge Per Area	0.3	na	0.79	0.1
Trinity_River_S220	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S230	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S240	Discharge Per Area	0.1	na	0.79	0.1
Trinity_River_S250	Discharge Per Area	0.1	na	0.79	0.1

Table 5: Modified Puls Routing Data

HEC-HMS Reach Name	Initial Subreaches
West_Fork_R010	1
West_Fork_R020	1
West_Fork_R030	1
West_Fork_R040	1
West_Fork_R050	1
West_Fork_R060	1
West_Fork_R070	1
Big_Cleveland_R010	1
West_Fork_R080	1
Lost_Ck_R010	5
Beans_Ck_R010	1
Big_Ck_R010	3
Big_Ck_R020	1
West_Fork_R120	7
West_Fork_R130	4
Big_Sandy_Ck_R020	4
Big_Sandy_Ck_R030	5
Brushy_Ck_R010	9
Brushy_Ck_R020	1

HEC-HMS Reach Name	Initial Subreaches
Big_Sandy_Ck_R040	3
Big_Sandy_Ck_R050	3
Big_Sandy_Ck_R060	6
West_Fork_R140	5
West_Fork_R150	4
Garrett_Ck_R010	4
Garrett_Ck_R020	5
Salt_Ck_R010	7
Salt_Ck_R020	5
Salt_Ck_R030	4
West_Fork_R160	5
Walnut_Ck_R020	1
Silver_Ck_R010	10
West_Fork_R200	2
West_Fork_R201	1
Clear_Fork_R030	1
Clear_Fork_R040	100
Clear_Fork_R050	1
West_Fork_R210	1
Marine_Ck_R010	1
West_Fork_R220	1
West_Fork_R230	1
West_Fork_R231	1
West_Fork_R240	1
West_Fork_R250	2
Village_Ck_R020	2
West_Fork_R260	1
West_Fork_R261	1
West_Fork_R262	2
West_Fork_R264	1
West_Fork_R270	1
West_Fork_R280	2
Big_Bear_Ck_R010	2
West_Fork_R290	2
Mountain_Ck_R020	2
Mountain_Ck_R030	2

HEC-HMS Reach Name	Initial Subreaches
West_Fork_R300	1
Elm_Fork_R060	8
Elm_Fork_R070	6
Elm_Fork_R080	10
Denton_Ck_R010	14
Denton_Ck_R030	8
Denton_Ck_R040	2
Denton_Ck_R050	3
Denton_Ck_R060	8
Elm_Fork_R090	2
Elm_Fork_R100	2
Elm_Fork_R120	7
Bachman_Branch_R010	1
Elm_Fork_R130	3
Trinity_River_R010	3
Trinity_River_R020	1
Trinity_River_R030	2
White_Rock_Ck_R020	5
Trinity_River_R040	1
Trinity_River_R050	2
Trinity_River_R060	8
Trinity_River_R070	6
East_Fork_R040	1
East_Fork_R050	4
East_Fork_R060	8
East_Fork_R070	10
East_Fork_R080	6
Trinity_River_R100	45
Trinity_River_R120	6
Chambers_Ck_R030	5
Chambers_Ck_R040	9
Richland_Ck_R020	14
Trinity_River_R130	5
Trinity_River_R140	4
Trinity_River_R150	4
Trinity_River_R160	8

HEC-HMS Reach Name	Initial Subreaches
Trinity_River_R170	12
Trinity_River_R180	1
Trinity_River_R190	1
Trinity_River_R200	12
Trinity_River_R210	10
Trinity_River_R220	6
Trinity_River_R230	4
Trinity_River_R240	5
Trinity_River_R250	4
Trinity_River_R260	10
Trinity_River_R270	10
Trinity_River_R280	12

Table 6: Muskingum Routing Data

HEC-HMS Reach Name	K (hrs)	X	Initial Subreaches
West_Fork_R090	1	0.25	1
West_Fork_R100	3	0.25	1
West_Fork_R110	3	0.25	1
West_Fork_R170	3	0.25	2
West_Fork_R180	2	0.25	2
Walnut_Ck_R010	1	0.25	1
West_Fork_R190	2	0.25	2
Bear_Ck_R010	1	0.25	1
Marys_Ck_R010	1	0.25	1
Village_Ck_R010	2	0.25	2
JPL_Walnut_Ck_R010	2	0.25	2
Mountain_Ck_R010	4	0.25	3
Clear_Ck_R010	0.8	0.3	1
Clear_Ck_R020	3.6	0.3	4
Spring_Ck_R010	1.5	0.4	2
Timber_Ck_R010	1.1	0.3	1
Elm_Fork_R030	2	0.3	2
Range_Ck_R010	5.5	0.2	6

HEC-HMS Reach Name	K (hrs)	X	Initial Subreaches
Elm_Fork_R020	1.1	0.3	1
Elm_Fork_R010	3.9	0.3	4
Brushy_Elm_Ck_R010	3.9	0.3	4
Elm_Fork_R050	3.7	0.2	4
Lake_Kiowa_R010	1.3	0.3	1
Elm_Fork_R040	1.6	0.3	2
Clear_Ck_R030	1.2	0.3	1
Clear_Ck_R040	7.7	0.2	8
Clear_Ck_R050	2.8	0.2	3
Clear_Ck_R060	5.8	0.2	6
Little_Elm_Ck_R010	6	0.2	6
Little_Elm_Ck_R020	0.5	0.2	1
Little_Elm_Ck_R030	1.8	0.2	2
Doe_Branch_R010	1.1	0.2	1
Hickory_Ck_R010	2	0.3	2
Hickory_Ck_R020	2	0.3	1
Hickory_Ck_R030	1.1	0.3	1
Denton_Ck_R020	2	0.25	1
Hackberry_Ck_R010	1	0.25	1
Elm_Fork_R110	1	0.25	1
White_Rock_Ck_R010	3	0.25	3
Five_Mile_Ck_R010	5	0.4	3
Tenmile_Ck_R010	5	0.4	3
Indian_Ck_R010	2	0.25	1
Indian_Ck_R020	2	0.2	2
Sister_Grove_Ck_R010	8	0.2	8
East_Fork_R010	4	0.2	4
East_Fork_R020	8	0.2	8
East_Fork_R030	1	0.2	1
Lavon_RayHubbard_R010	1	0.2	1
Rowlett_Ck_R010	4	0.2	4
Trinity_River_R080	1	0.4	1
Trinity_River_R090	1.5	0.4	1
Kings_Ck_R010	1	0.4	1
Kings_Ck_R020	6	0.4	3

HEC-HMS Reach Name	K (hrs)	X	Initial Subreaches
Cedar_Ck_R010	12	0.3	6
Cedar_Ck_R020	8	0.4	4
Cedar_Ck_R030	10	0.1	10
Chambers_Ck_R010	12	0.3	5
Chambers_Ck_R020	10	0.3	6
Waxahachie_Ck_R010	4	0.1	2
Waxahachie_Ck_R020	6	0.1	3
Waxahachie_Ck_R030	6	0.3	2
Post_Oak_Ck_R010	1.5	0.3	4
Richland_Ck_R010	4	0.1	2
Richland_CK_R030	7	0.1	3
Richland_Ck_R040	1	0.4	1
Tehuacana_Ck_R010	8	0.4	4
Big _Brown_Ck_R010	2	0.4	1
Upper_Keechi_Ck_R010	6	0.25	3
Upper_Keechi_Ck_R020	8	0.25	1
Big_Elkhart_R010	1	0.25	1
Bedias_Ck_R010	6	0.25	3
Long_King_Ck_R010	8	0.25	4
Menard_Ck_R010	2	0.25	2

Table 7: Lag Routing Data

HEC-HMS Reach Name	Lag (Min)
Clear_Fork_R041	60
West_Fork_R251	60
West_Fork_R263	60

Table 8: Straddle Stagger Routing Data

HEC-HMS Reach Name	Lag (Min)	Duration (Min)
Clear_Fork_R010	60	60
Clear_Fork_R020	60	60

1.4 HEC-HMS MODEL CALIBRATION

After building the HEC-HMS model with its initial parameters, the Interagency Flood Risk Management (InFRM) team calibrated the model to verify it was accurately simulating the response of the watershed to a range of observed flood events, including large events similar to a 1% annual chance (100-yr) flood. A total of 17 recent storm events were used throughout different parts of the watershed to fine tune the model, as shown in Table 9. The model calibration and verification process undertaken during this study exceeds the standards of a typical FEMA floodplain study.

For these storms, the National Weather Service (NWS) hourly rainfall radar data allowed the team to fine tune the watershed model through detailed calibration. Prior to the late 1990s, the NWS radar data was not available for use during earlier modeling efforts. The final model results accurately simulate the observed response of the watershed, as it generally reproduced the timing, shape, and magnitudes of the observed floods. Table 9 lists the storms that were used to calibrate each portion of the watershed, and Figures 2 through 18 illustrate the total depth of rain for the major calibration storms and how that rain was distributed spatially throughout the Trinity River watershed. These plots were extracted from the HEC-MetVue meteorological program for visualizing and processing rainfall data.

Since the rain fell on different parts of the basin from one event to another, the calibration of each storm was focused on those areas of the basin that received the greatest and most intense rainfall. Calibration was also only performed when the USGS stream gages were recording for that event. Table 10 shows which storms were calibrated for each USGS stream gage.

Table 9: Storm Events Used for Model Calibration

Storm Event	West Fork above Grand Praire Gage	Elm Fork to Trinity Below Dallas Gage	Above Richland-Chambers Reservoir	Trinity below Dallas Gage and below Richland-Chambers Reservoir
Dec-91		Yes		
Apr-99				Yes
Jun-00	Yes			
Jun-04	Yes			
Nov-04				Yes
Oct-06				Yes
Mar-07	Yes			
Jun-07		Yes		Yes
Jul-07				Yes
Sep-09			Yes	
Oct-09			Yes	
Sep-10		Yes		Yes
May-15	Yes		Yes	Yes
Jun-15	Yes			
Oct-15			Yes	
Nov-15	Yes	Yes		Yes
Dec-15				Yes

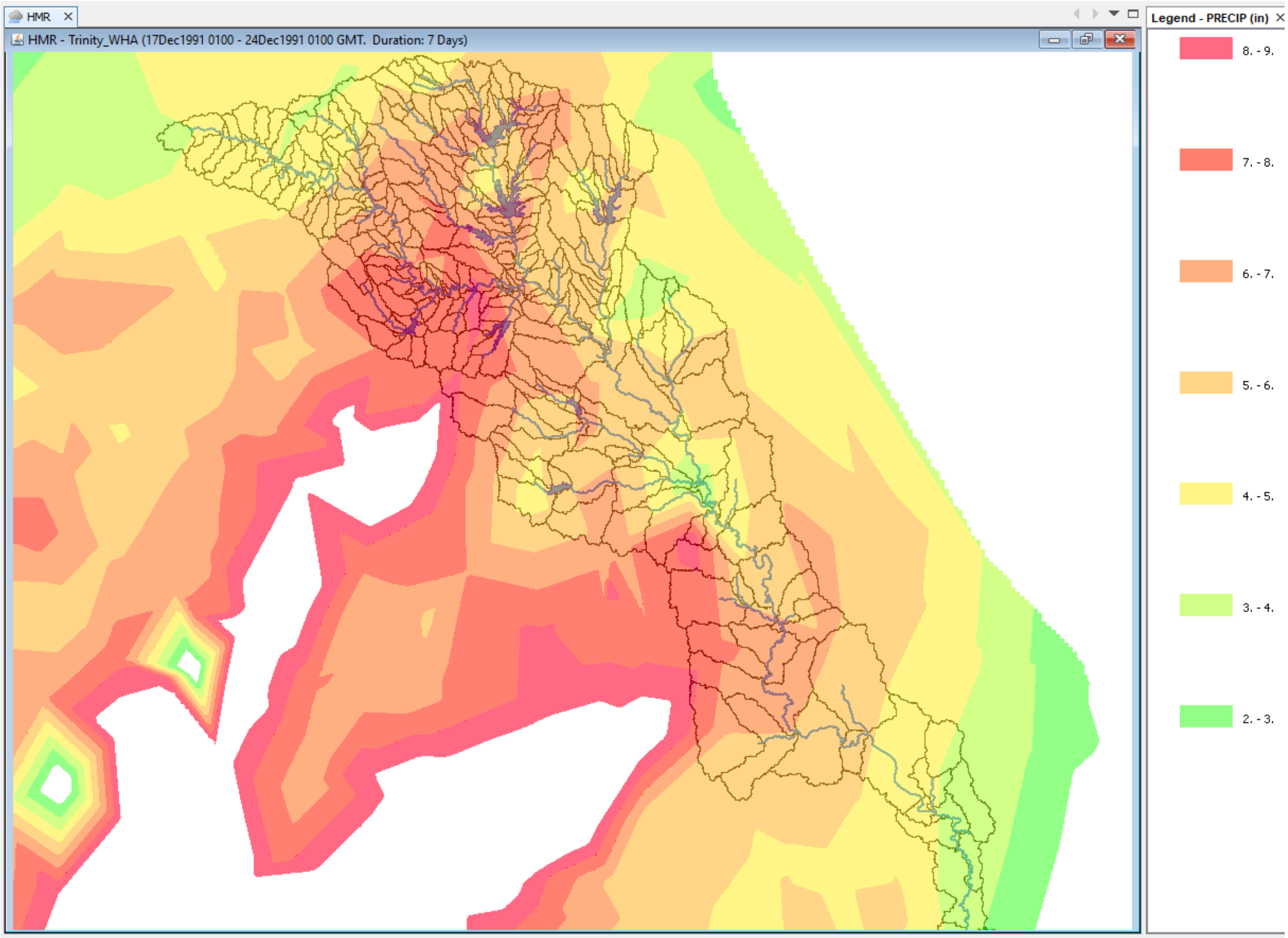

Figure 2: Rainfall Depths (inches) for the December 1991 Calibration Storm

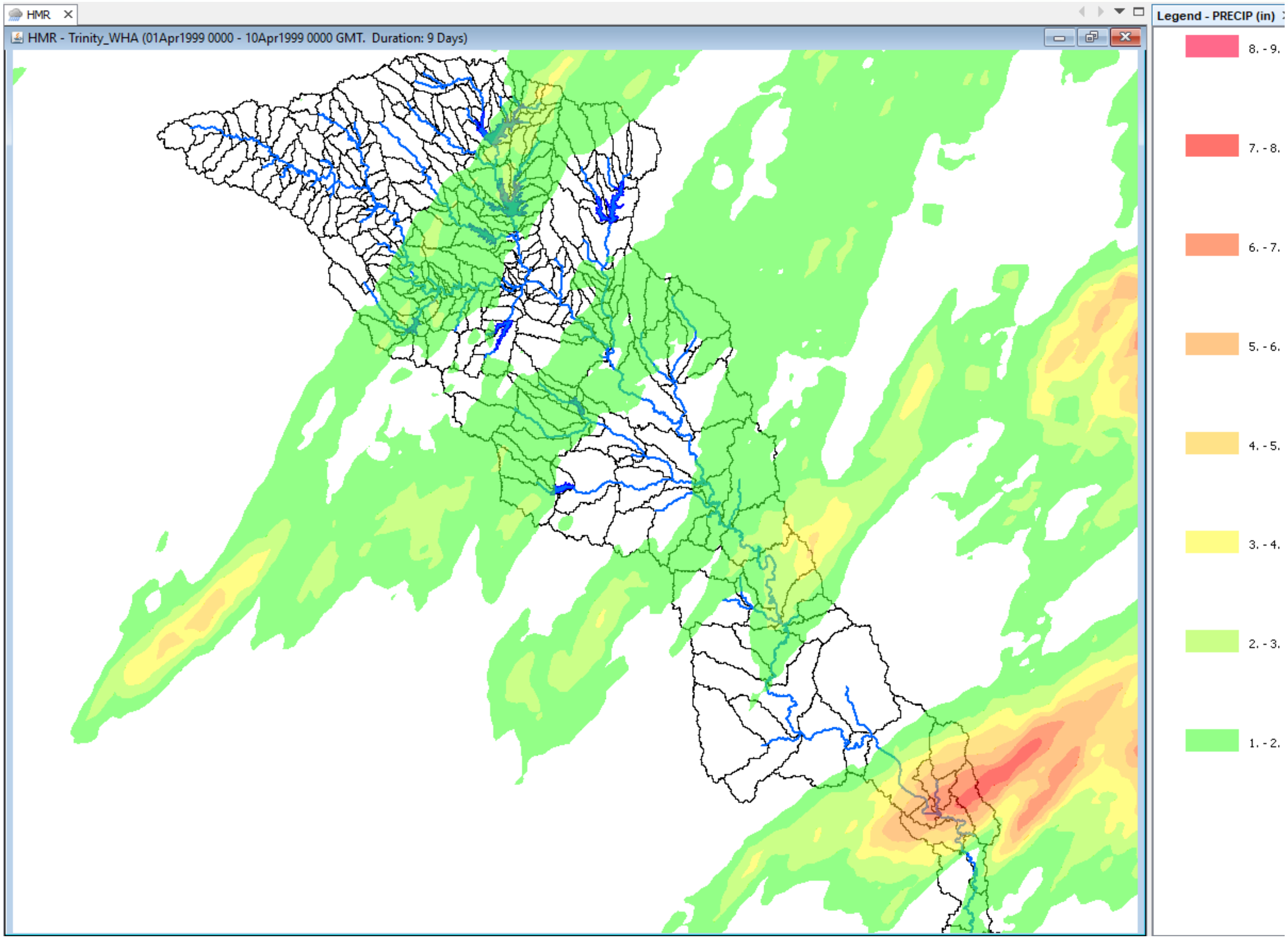

Figure 3: Rainfall Depths (inches) for the April 1999 Calibration Storm

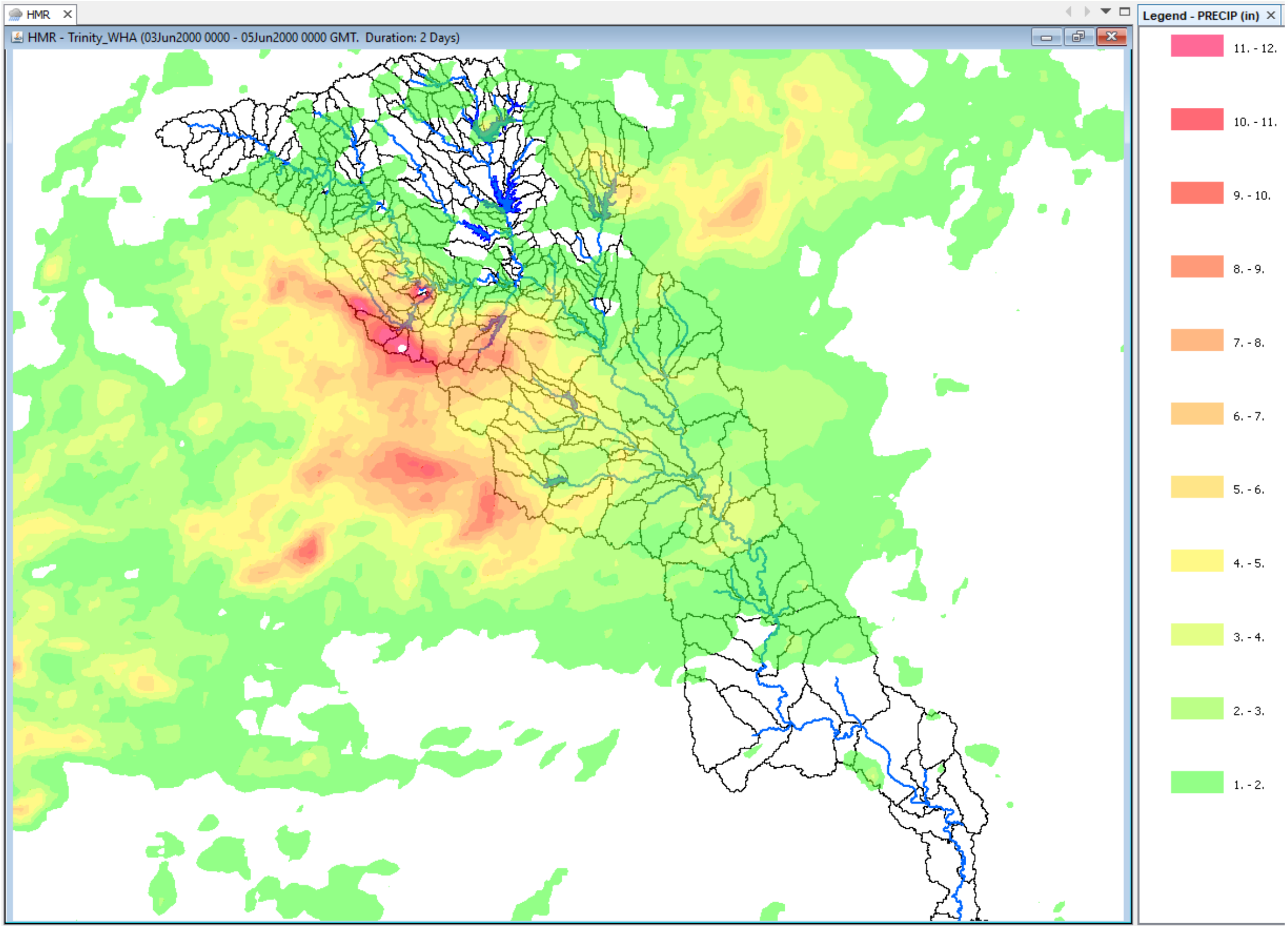

Figure 4: Rainfall Depths (inches) for the June 2000 Calibration Storm

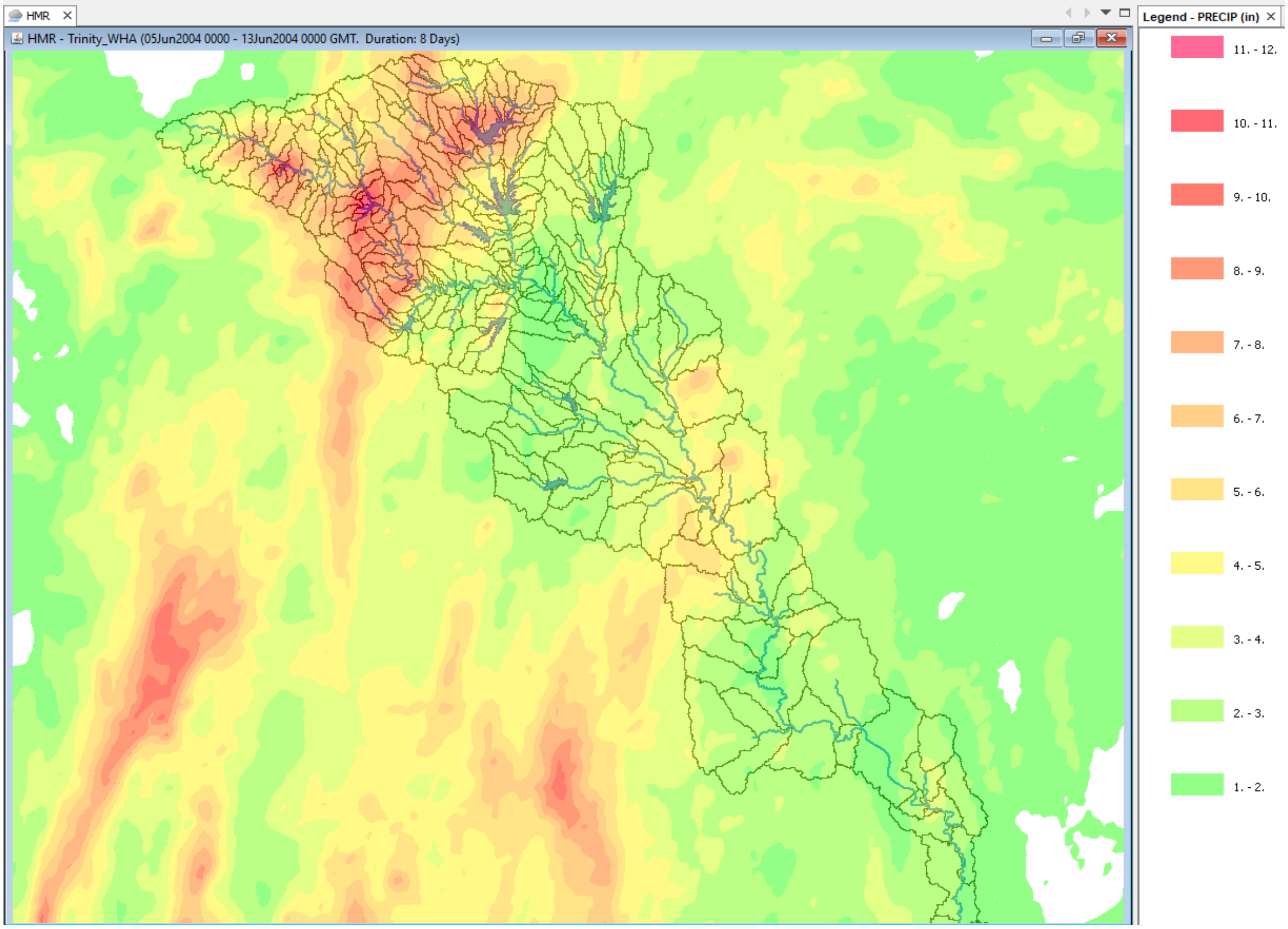

Figure 5: Rainfall Depths (inches) for the June 2004 Calibration Storm

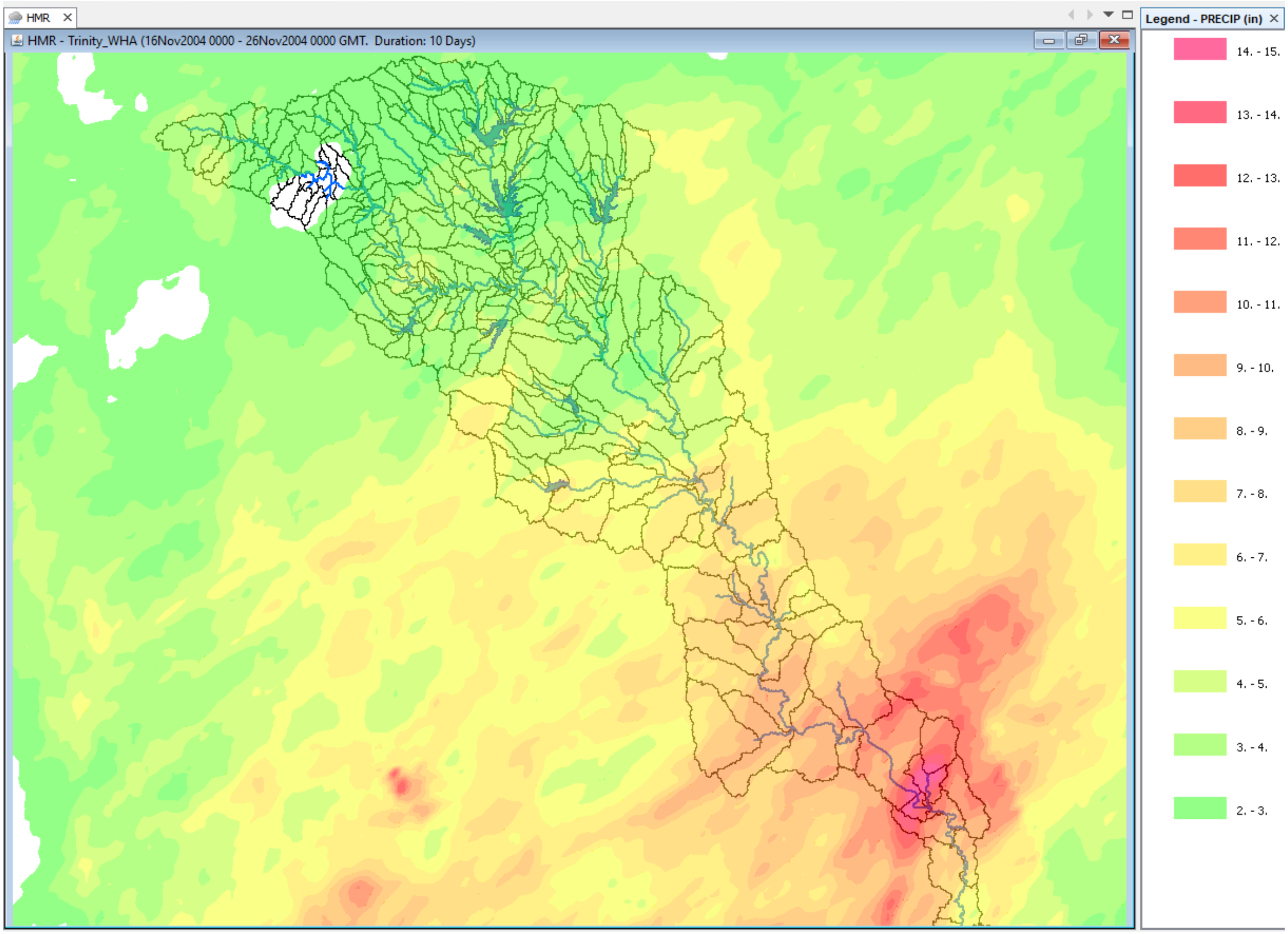

Figure 6: Rainfall Depths (inches) for the Novemberr 2004 Calibration Storm

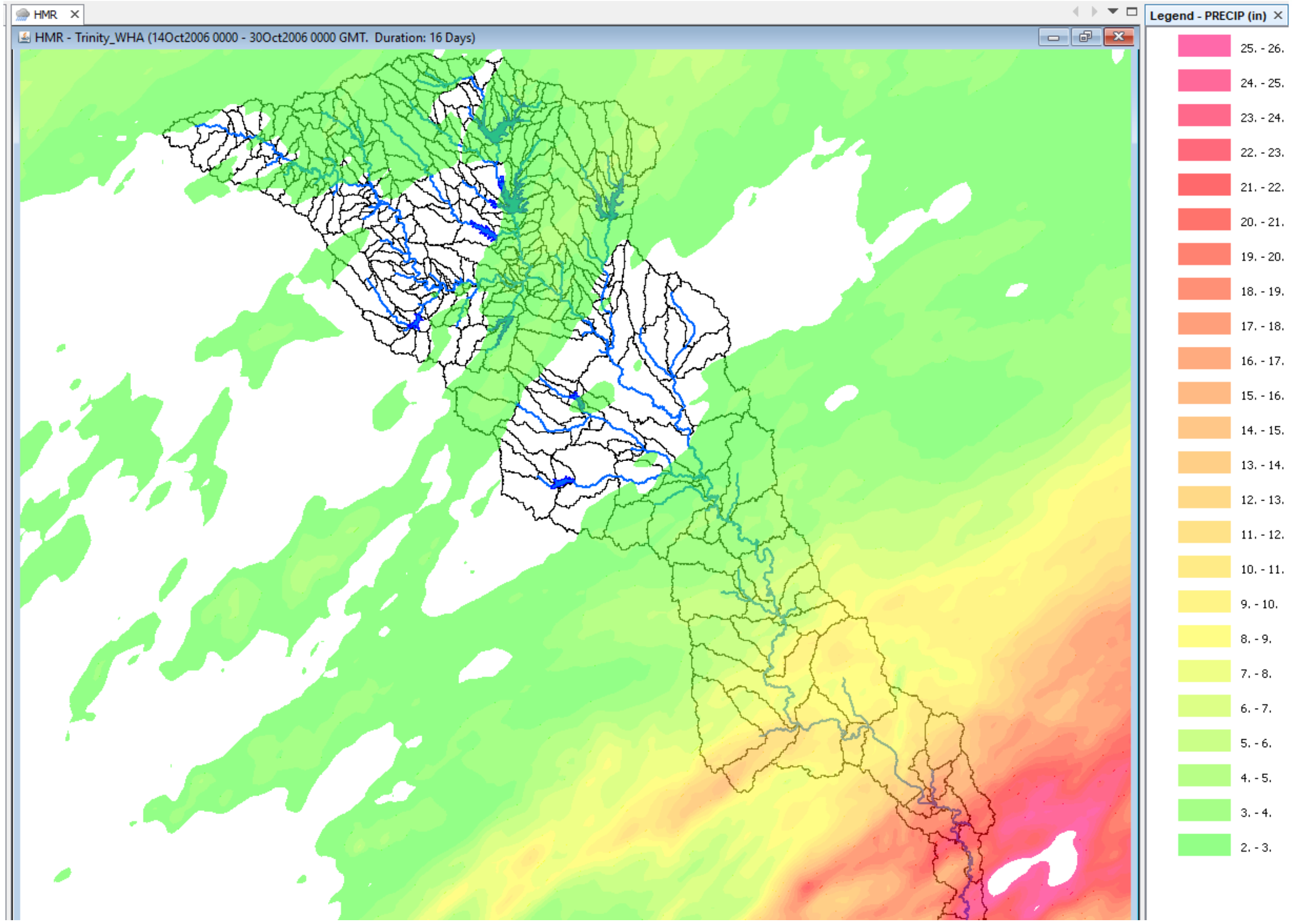

Figure 7: Rainfall Depths (inches) for the October 2006 Calibration Storm

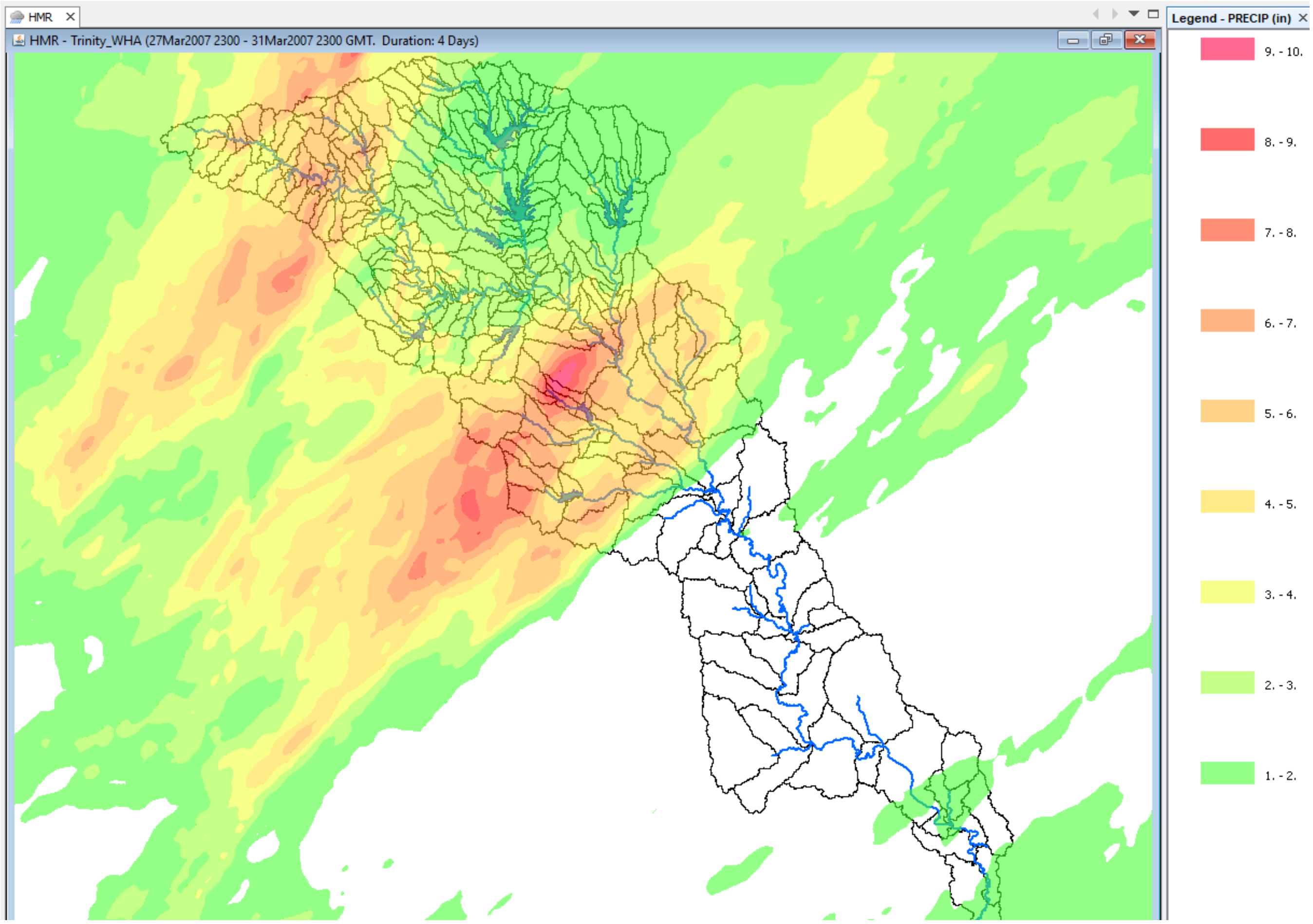

Figure 8: Rainfall Depths (inches) for the March 2007 Calibration Storm

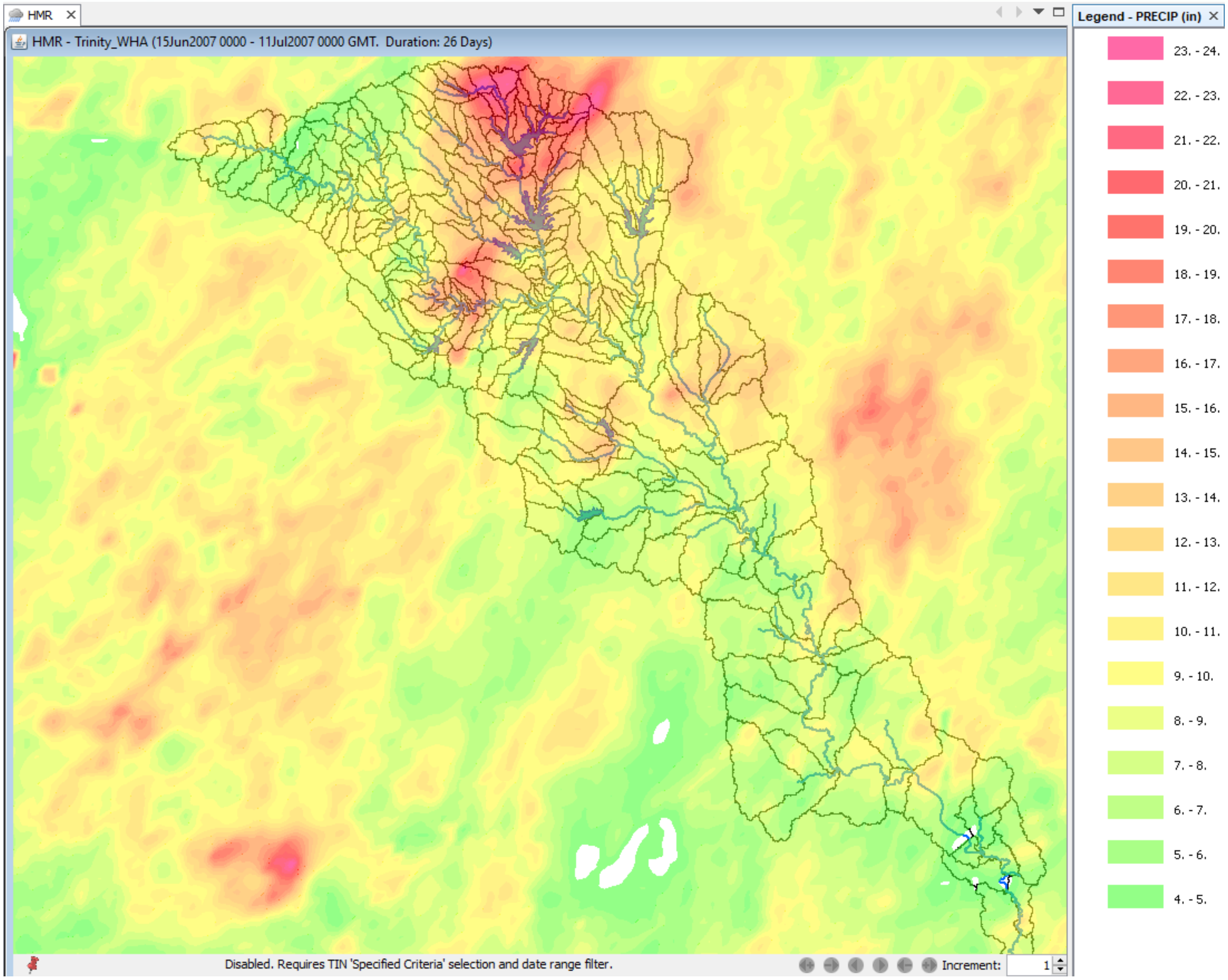

Figure 9: Rainfall Depths (inches) for the June 2007 Calibration Storm

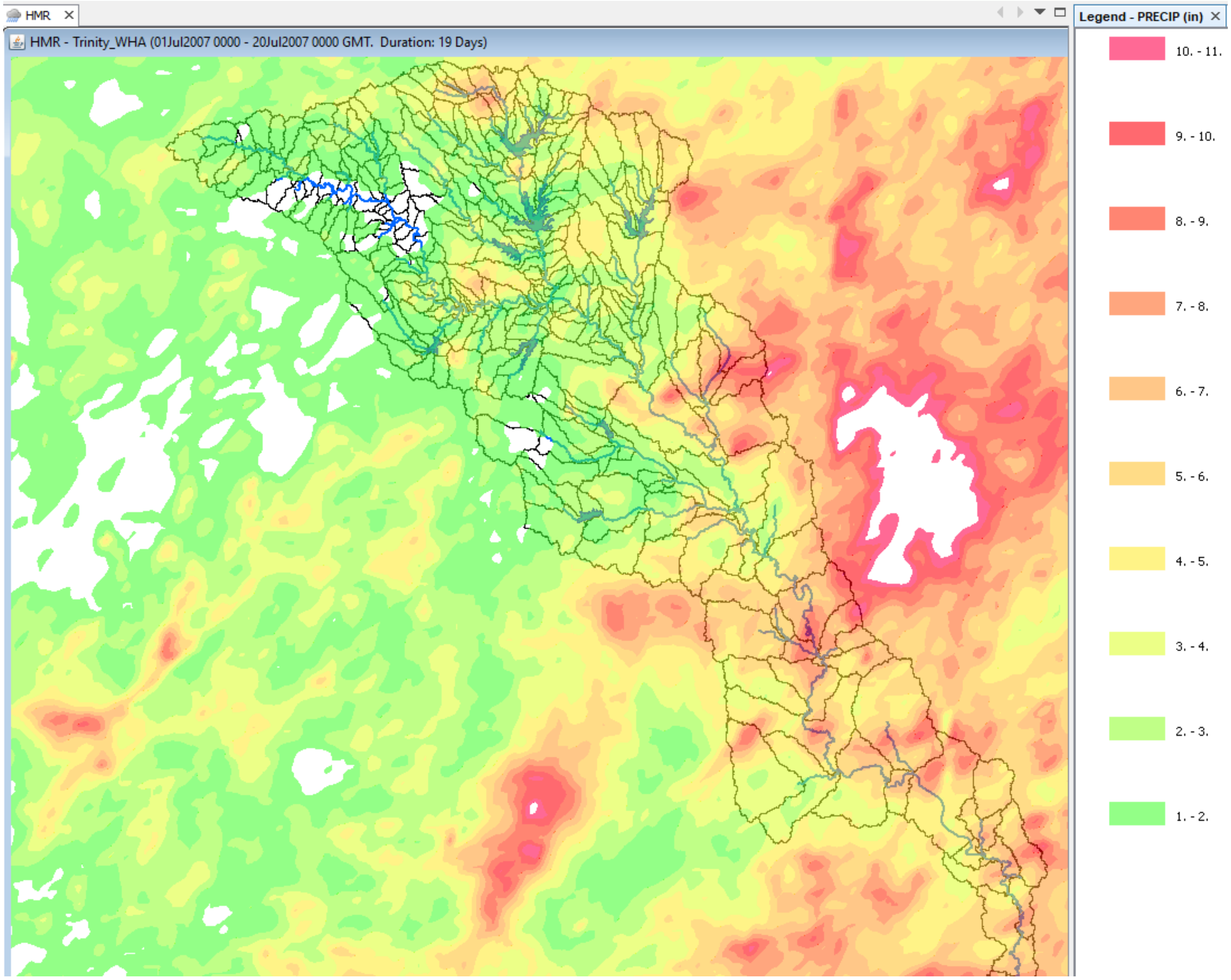

Figure 10: Rainfall Depths (inches) for the July 2007 Calibration Storm

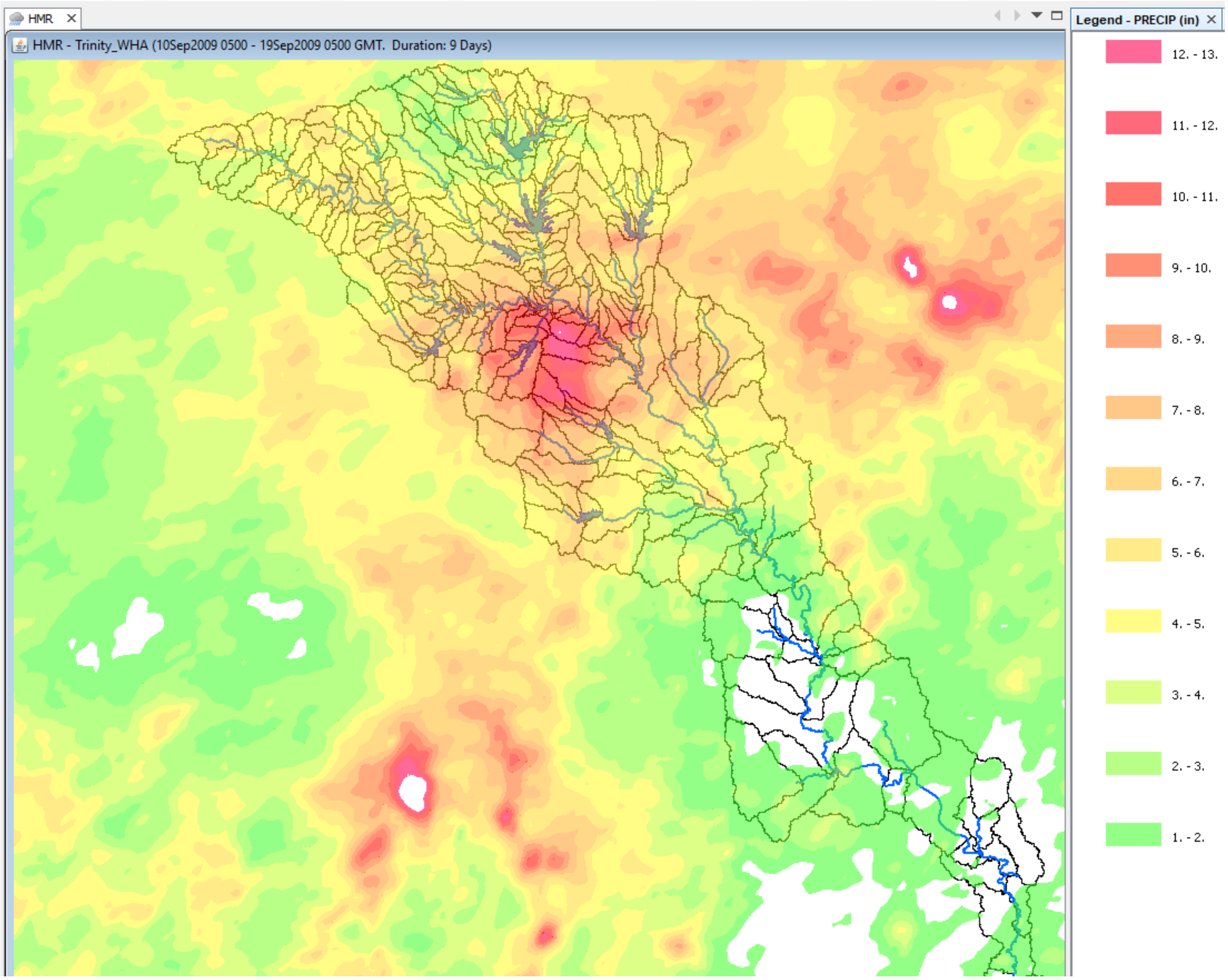

Figure 11: Rainfall Depths (inches) for the September 2009 Calibration Storm

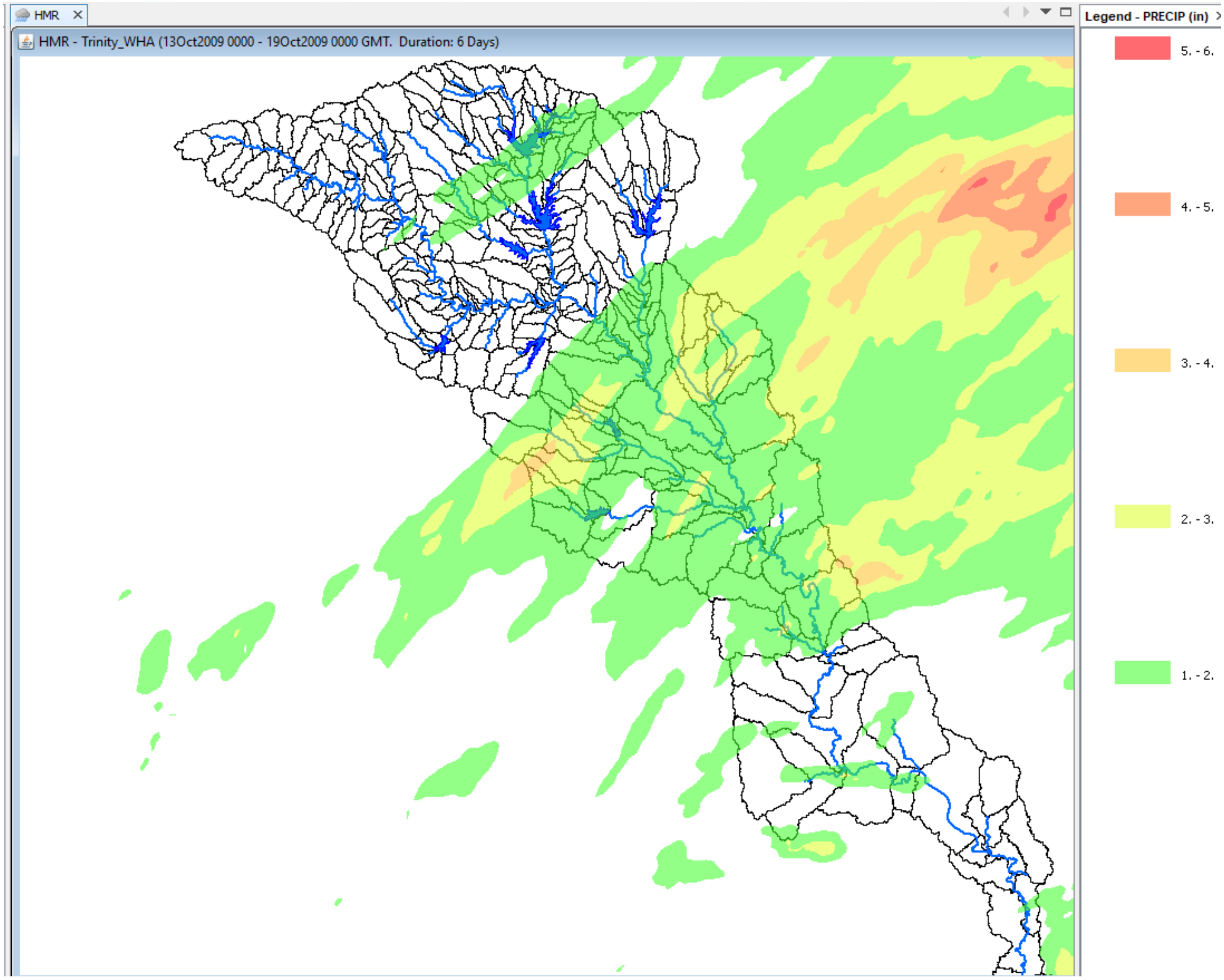

Figure 12: Rainfall Depths (inches) for the October 2009 Calibration Storm

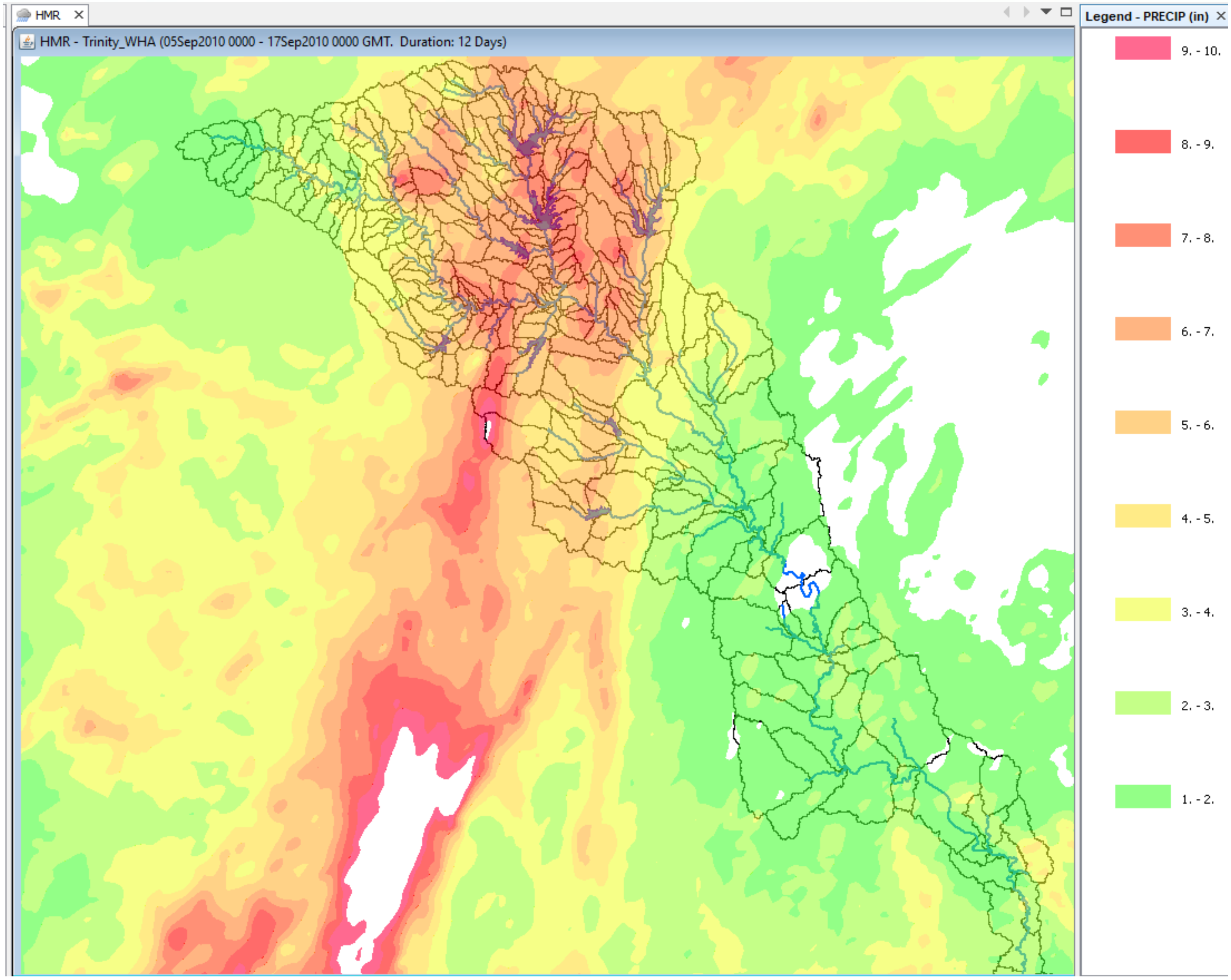

Figure 13: Rainfall Depths (inches) for the September 2010 Calibration Storm

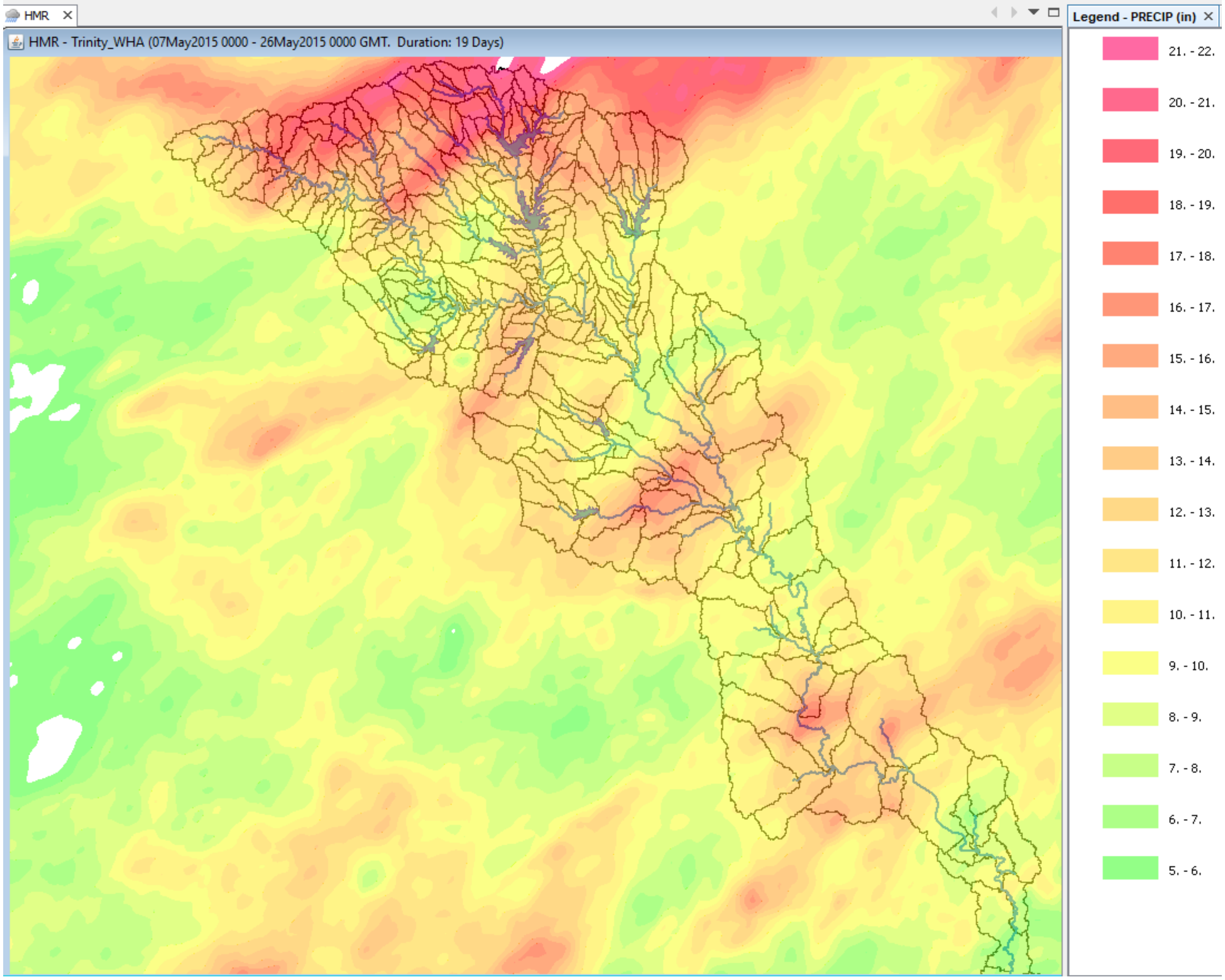

Figure 14: Rainfall Depths (inches) for the May 2015 Calibration Storm

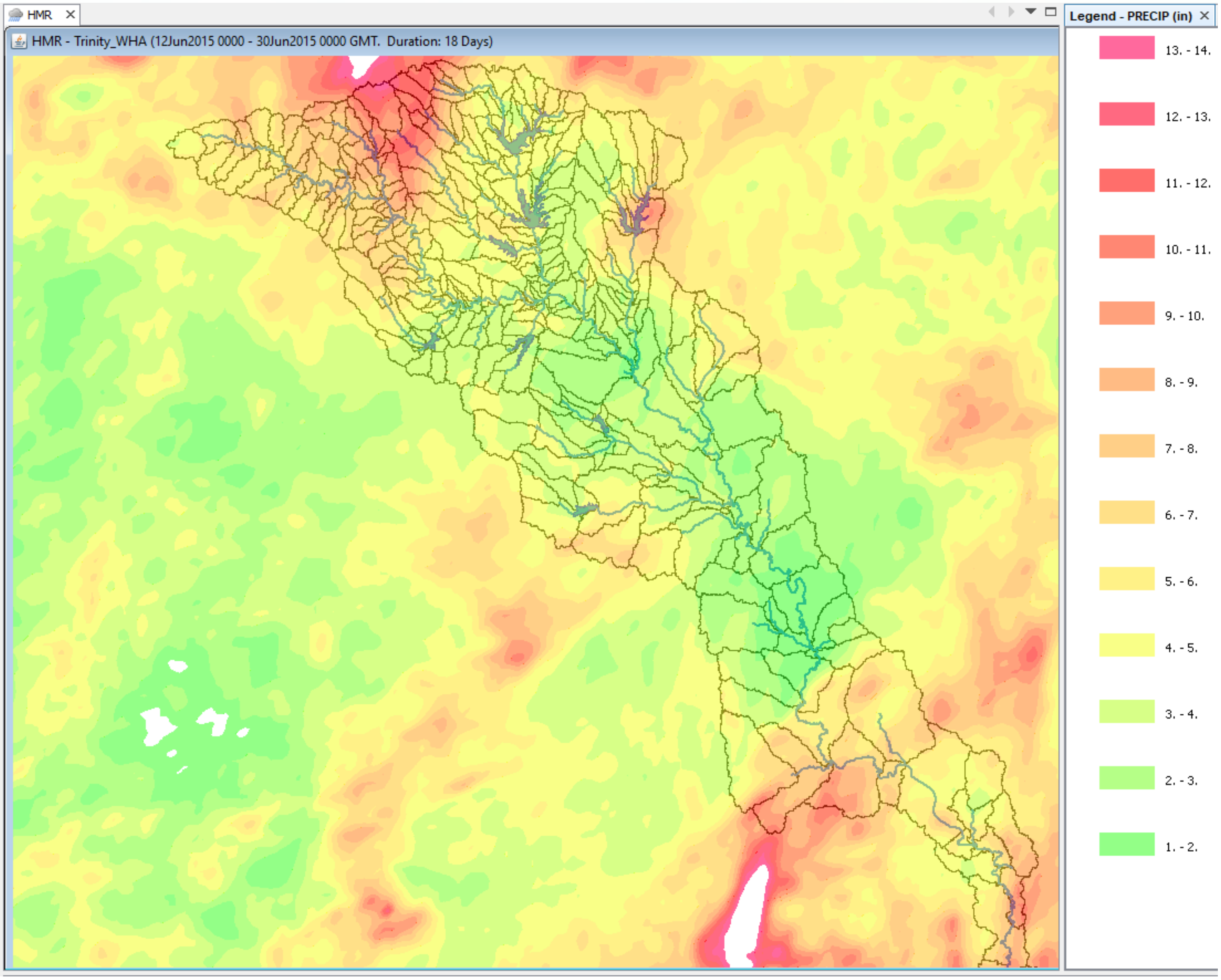

Figure 15: Rainfall Depths (inches) for the June 2015 Calibration Storm

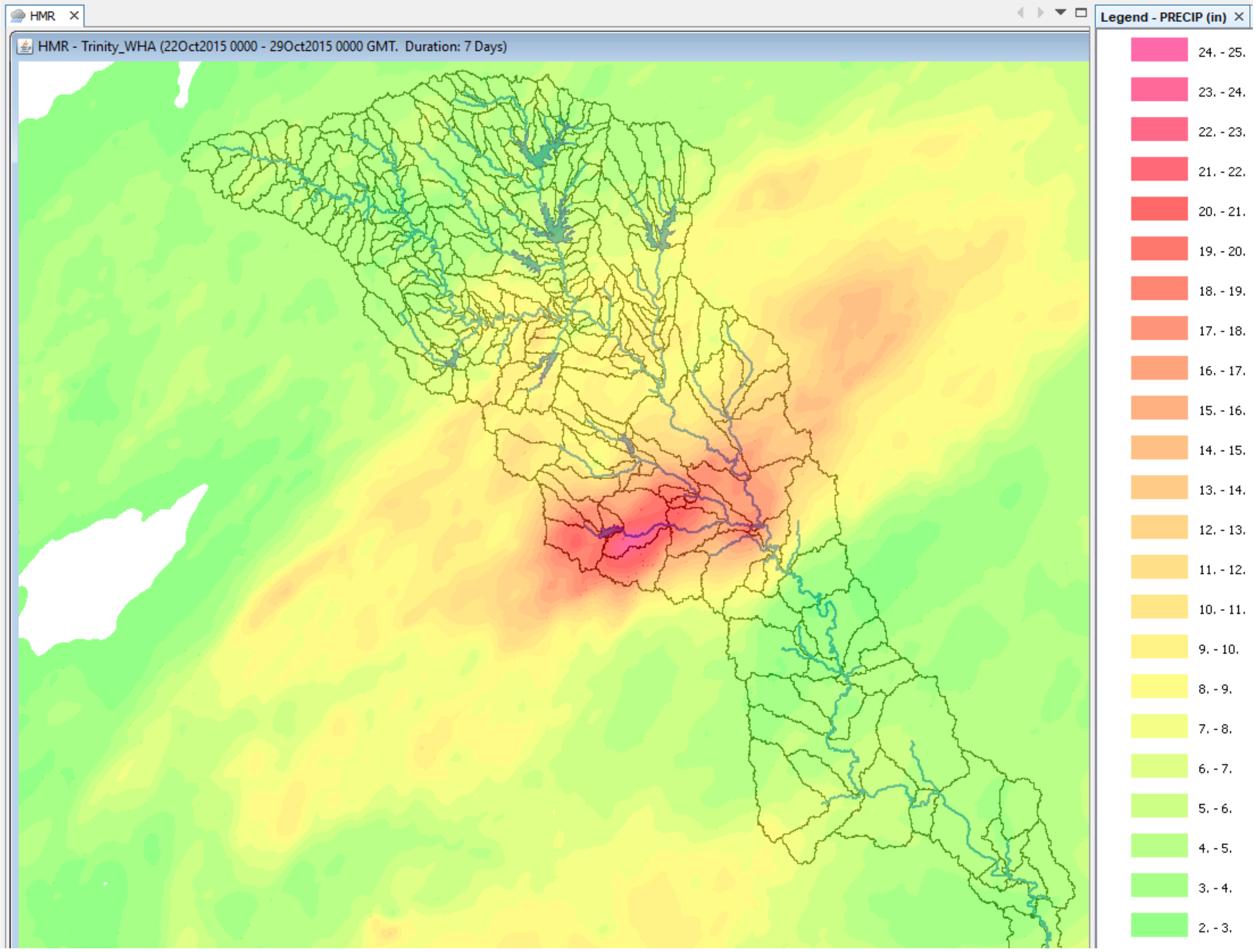

Figure 16: Rainfall Depths (inches) for the October 2015 Calibration Storm

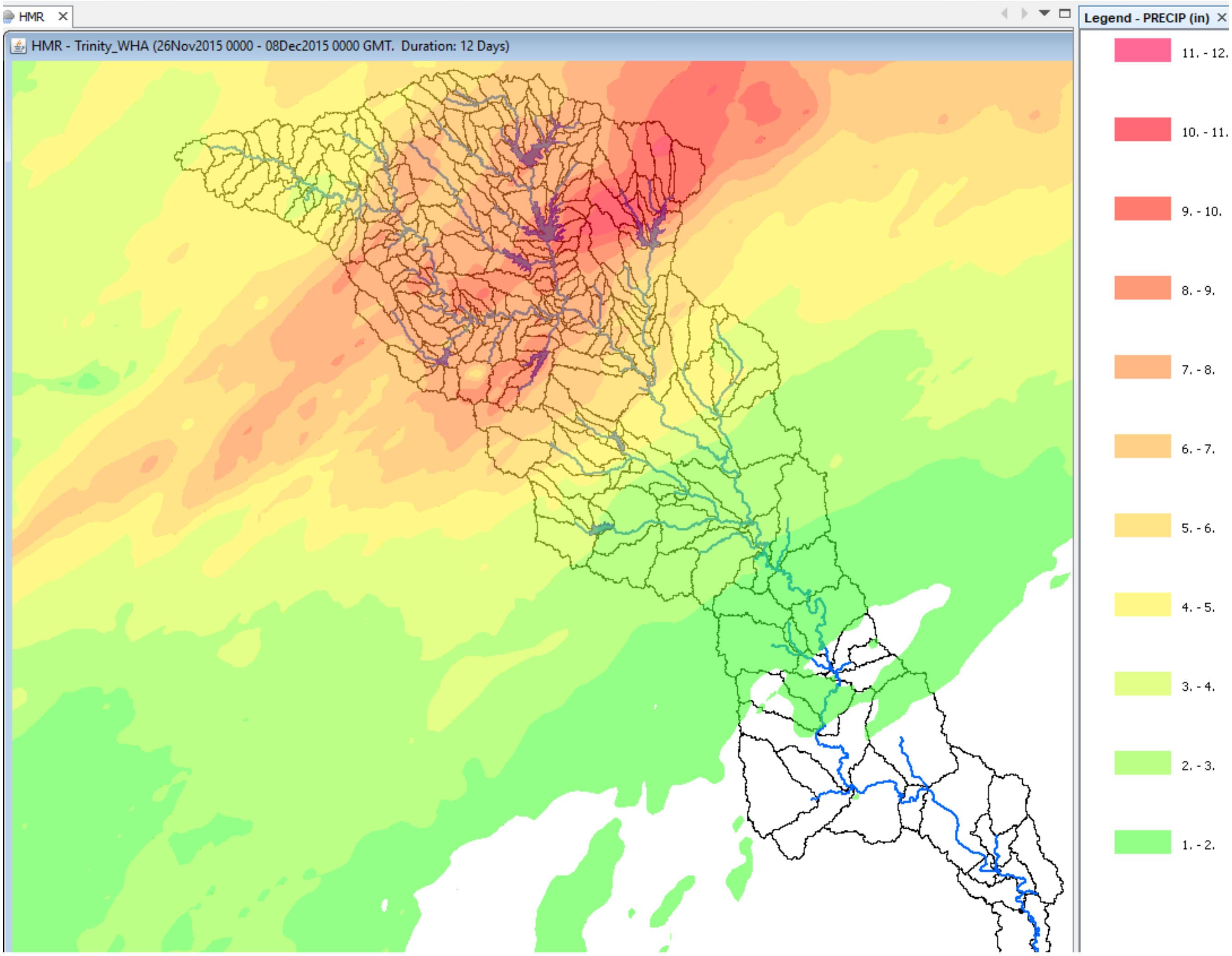

Figure 17: Rainfall Depths (inches) for the November 2015 Calibration Storm

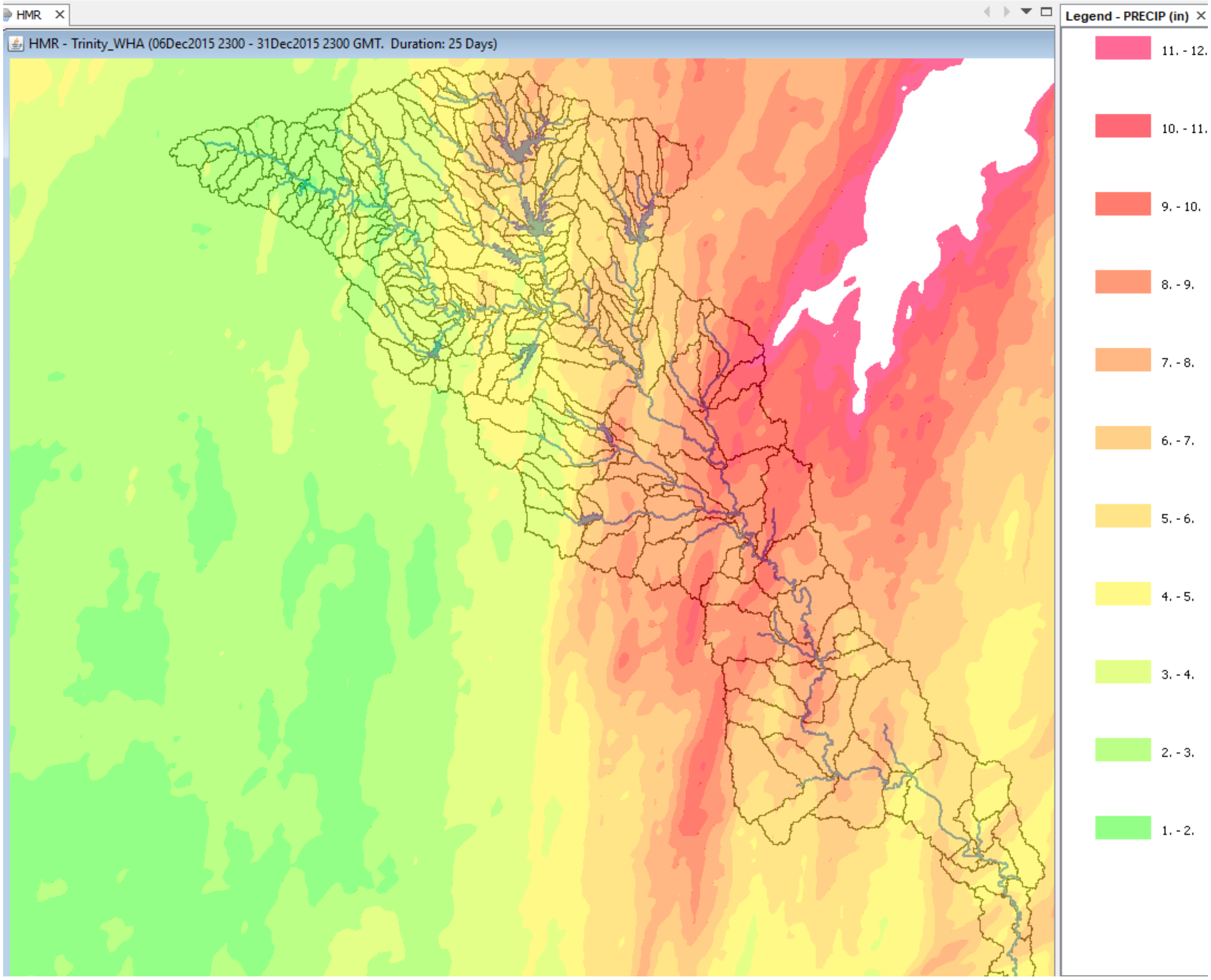

Figure 18: Rainfall Depths (inches) for the December 2015 Calibration Storm

Table 10: Calibrated Storm Events for Specific Gage Locations

USGS Gage Location	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West Fork Trinity River near Jacksboro, TX				Yes			Yes						Yes	Yes		Yes	
Big Sandy Creek nr Bridgeport at Hwy 114 bridge				Yes			Yes						Yes	Yes		Yes	
West Fork Trinity River near Boyd, TX - at FM 730 bridge				Yes			Yes						Yes	Yes		Yes	
Walnut Creek at Reno, TX at FM1542 bridge in Parker County				Yes			Yes						Yes	Yes		Yes	
Marys Creek at Benbrook			Yes	Yes			Yes									Yes	
Clear Fork Trinity River at Fort Worth				Yes			Yes						Yes	Yes		Yes	
West Fork Trinity River below the Clear Fork (West Fork at Fort Worth)				Yes			Yes						Yes	Yes		Yes	
West Fork Trinity River below Sycamore Creek (West Fork Trinity River at Beach Street)				Yes			Yes						Yes	Yes		Yes	
West Fork Trinity River at Grand Prairie				Yes			Yes						Yes	Yes		Yes	
Walnut Creek near Mansfield, TX	Yes											Yes				Yes	
Mountain Ck near Venus, TX	Yes							Yes				Yes				Yes	
Elm Fk Trinity Rv at Gainesville, TX	Yes							Yes				Yes				Yes	
Timber Ck nr Collinsville, TX	Yes							Yes				Yes				Yes	
Range Creek nr Collinsville, TX	Yes							Yes				Yes				Yes	
Clear Ck nr Sanger, TX	Yes							Yes				Yes				Yes	
Little Elm Ck nr Aubrey, TX								Yes				Yes				Yes	
Doe Br at Hwy 380 nr Prosper, TX								Yes				Yes				Yes	
Hickory Creek at Denton, TX												Yes				Yes	
Indian Creek at Carrolton, TX								Yes				Yes				Yes	
Denton Creek nr Justin, TX	Yes							Yes				Yes				Yes	

USGS Gage Location	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Elm Fork Trinity River near Carrollton	Yes							Yes				Yes				Yes	
Elm Fork Trinity River at Spur 348	Yes											Yes				Yes	
Trinity River at Dallas, TX	Yes							Yes				Yes				Yes	
White Rock Creek at Greenville Ave	Yes							Yes				Yes				Yes	
Trinity River below Honey Springs Branch (Trinity River below Dallas, TX)								Yes				Yes				Yes	
East Fork Trinity River near McKinney, TX								Yes					Yes			Yes	
Sister Grove Creek near Blue Ridge								Yes			Yes		Yes			Yes	
Indian Creek at SH 78 nr Farmersville, TX								Yes					Yes			Yes	Yes
Rowlett Creek near Sachse, TX								Yes					Yes			Yes	
East Fork Trinity River near Forney								Yes					Yes			Yes	
East Fork Trinity River near Crandall, TX					Yes			Yes				Yes					
Trinity River near Rosser, TX									Yes			Yes				Yes	
Kings Creek at SH34 near Kaufman, TX													Yes			Yes	Yes
Cedar Creek near Kemp, TX								Yes					Yes				Yes
Trinity River at Trinidad, TX									Yes				Yes				Yes
Chambers Creek near Rice, TX										Yes	Yes		Yes		Yes		
White Rock Creek at FM 308 near Irene, TX										Yes	Yes		Yes		Yes		
Tehuacana Creek near Streetman, TX					Yes				Yes				Yes	Yes			Yes
Trinity River near Oakwood, TX								Yes					Yes			Yes	
Upper Keechi Creek near Oakwood, TX									Yes				Yes				Yes
Trinity River near Crockett, TX									Yes				Yes			Yes	
Bedias Creek near Madisonville, TX													Yes	Yes			Yes

USGS Gage Location	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Long King Creek at Livingston, TX		Yes			Yes	Yes											
Menard Creek near Rye, TX		Yes				Yes							Yes				
Trinity River at Romayor, TX								Yes					Yes			Yes	
Trinity River at Liberty, TX								Yes					Yes			Yes	

1.4.1 Calibration Methodology

Following the initial parameter estimates, calibration simulations were made using observed hourly Next-Generation Radar (NEXRAD) Stage III gridded precipitation data obtained from the West Gulf River Forecast Center (WGRFC). For each storm event, the model's calculated flow hydrographs were compared to the observed USGS stream flow data at the gages. The model's parameters were then adjusted to improve the match between the simulated and observed hydrographs for the observed events. Calibration was performed for the 17 storm events previously listed in Table 9. Subbasin parameters that were adjusted during calibration included the subbasins' initial and constant loss rates, lag time, peaking coefficients, and baseflow parameters. For the routing reaches, the Muskingum parameters and the Modified Puls number of subreaches were adjusted as needed.

Calibration was generally performed from upstream to downstream, with all subbasins upstream of a specific gage receiving uniform adjustments, unless specific rainfall or observed flow patterns necessitated adjusting subbasin parameters on an individual basis. Generally, subbasin parameters were adjusted in a consistent order: first baseflow parameters, then loss rates, and then lag times and peaking coefficients. Routing subreaches were the last to be adjusted. The methods of adjustment for each parameter are summarized in Table 11.

To the extent possible, effort was made to calibrate the model's results to the volume, timing, peak magnitude, and shape of the observed flow hydrograph. However, imperfections in the observed rainfall data and streamflow data did not always allow for a perfect match. For example, the gridded NEXRAD rainfall data from the National Weather Service was only available on an hourly basis. This meant that intense bursts of rain that occurred in 15-min or 30-min timespans might not be adequately represented in the hourly rainfall data. It also meant that even though the model was being run on a 15-min time step, the timing of the hydrographs could only be calibrated to the nearest hour. Likewise, the observed flow values at the gages are calculated indirectly from the observed stage and a limited number of flow measurements. While abundant flow measurements were usually available in the low flow range, the number and quality of USGS flow measurements were often very limited in the high flow range, leading to uncertainty in some of the observed flow hydrographs. In cases where all aspects of the observed flow hydrograph could not be calibrated simultaneously, priority was given to matching the peak flow magnitude first, followed by the peak timing, which are the aspects of model calibration that are most relevant to the 1% annual chance (100-yr) flood estimation.

Table 11: HEC-HMS Calibration Approach

Parameter	Calibration Approach
Baseflow Parameters	First, the baseflow parameters were adjusted to match the observed flow rates at the start and end of each calibration event. The initial discharges for the subbasins upstream of a certain gage were adjusted uniformly up or down to match the initial observed discharge at that gage. Similarly, the recession constant was adjusted to match the slope of the recession limb of the observed hydrograph, and the ratio to peak was adjusted to match the observed discharge at the end of the calibration event. All baseflow parameters were adjusted uniformly for all subbasins upstream of a given gage
Initial Loss (in)	After adjusting the baseflow parameters, the initial and constant losses were adjusted to calibrate the total volume of the flood hydrograph. The initial loss was increased or decreased until the timing and volume of the initial runoff generally matched the observed arrival of the flow hydrograph at the nearest downstream gage. All subbasins that were upstream of each gage were generally adjusted uniformly, unless specific rainfall and observed flow patterns necessitated adjusting the subbasin initial losses on an individual basis.
Constant Loss Rate (in/hr)	After adjusting the baseflow and initial loss parameters, the constant losses were adjusted to calibrate the total volume of the flood hydrograph. The subbasins' constant loss rates were increased or decreased until the volume and magnitude of the simulated hydrographs generally matched the observed volume of the flow hydrograph at the nearest downstream gage. The combination of the adjusted baseflow and loss rate parameters led to the total calibrated volume at the gage.
Lag Time (hours)	After adjusting the loss rates, the Snyder's lag times were the next parameters to be adjusted upstream of an individual gage. The Snyder's lag times were adjusted to match the timing of the observed peak flow at the gage. Normally, all of the subbasin lag times upstream of an individual gage were adjusted uniformly and proportionally to one another, unless the magnitude or shape of the observed hydrograph necessitated making individual adjustments. Efforts were also made to ensure that the adjusted lag times still fell within a reasonable range, using the lag times corresponding to 0% sand and 100% sand in the Fort Worth District regional lag time equation as a guide.
Peaking Coefficient	Peaking coefficients were adjusted to match the general shape of the observed flow hydrograph as higher peaking coefficients produce steeper, narrower flood hydrographs, and lower peaking coefficients produce flatter, wider flood hydrographs. An attempt was made to use the same peaking coefficient for all subbasins with similar watershed characteristics. For example, steep, hilly subbasins were given a higher peaking coefficient, whereas flatter subbasins, such as those near the coast, were given lower peaking coefficients. Efforts were also made to ensure that the adjusted peaking coefficients fell within the typical range of 0.4 to 0.8. In most cases, peaking coefficients were adjusted once and left alone between subsequent events.
Modified Puls Routing Subreaches	The number of subreaches in the Modified Puls routing reaches were the final parameters to be adjusted when necessary. Calibration of routing parameters focused on storms that fell near the upstream end of the watershed and were routed downstream with little intervening subbasin flow. Adjustments to the number of subreaches in a given routing reach were made in order to match the amount of attenuation in the peak flow that occurred from the upstream end of a reach to the downstream gage. In a very few cases, where an adjustment to the subreaches was not sufficient to match the observed downstream hydrograph, a factor was also applied to the reach's storage volume in the storage-discharge curve.

Parameter	Calibration Approach
Muskingum Routing Parameters	For areas of the model that included Muskingum routing, the Muskingum k, X and subreach values were adjusted as needed. Calibration of the routing parameters focused on storms that fell near the upstream end of the watershed and were routed downstream with little intervening local flow. The Muskingum k values were adjusted to match the timing of the observed peak flow at the gage, while the Muskingum X values were adjusted to match the relative flatness or steepness of the hydrograph. Finally, adjustments to the number of subreaches were made in order to match the amount of attenuation in the peak flow that occurred from the upstream end of a reach to the downstream gage.

1.4.2 Calibrated Parameters

The resulting calibrated subbasin and routing reach parameters that were adjusted for each storm event are shown in Tables 12 through 22.

Table 12: Calibrated Initial Losses (inches)

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S020				1.9			3						2.2	2.2		1.5	
West_Fork_S010				1.9			2.2						2.2	2.2		1.5	
West_Fork_S030				1.9			3						2.2	2.2		1.5	
West_Fork_S040				2.2			3						2.2	2.2		1.5	
West_Fork_S050				2.2			3						1.5	2.2		1.5	
West_Fork_S060				2.2			3						2.2	2.2		1.5	
West_Fork_S070				2.2			3						1.5	2.2		0.8	
West_Fork_S080				2.2			3						1.5	2.2		0.8	
West_Fork_S090				2.2			3						1.5	2.2		0.8	
West_Fork_S100				2.2			3						1.5	2.2		0.8	
West_Fork_S120				2.4			2.7						2.5	2.7		2.4	
West_Fork_S110				2.4			2.7						2.5	2.7		2.4	
Big_Cleveland_S010				2.4			2.7						2.5	2.2		2.4	
Big_Cleveland_S020				2.4			2.7						1.3	2.7		2.4	
West_Fork_S130				3			2.2						1.5	2.9		1	
Lost_Ck_S010				2.2			1.3						2.5	2.3		1.1	
Lost_Ck_S020				2.9			1.2						5	2		0.8	
West_Fork_S140				2.9			1.2						3	2		0.8	
West_Fork_S150				2.9			1.2						5	2		0.8	
West_Fork_S160				2.9			1.2						5	2		0.8	
Beans_Ck_S010				2.9			1.2						5	2		0.8	
Beans_Ck_S020				2.9			1.2						5	2		0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Big_Ck_S010				2.9			1.2						3.5	2		0.8	
Big_Ck_S030				2.9			1.2						5	2		0.8	
Big_Ck_S020				2.9			1.2						5	2		0.8	
Bridgeport_S030				2.9			1.2						5	2		0.8	
Bridgeport_S010				2.9			1.2						5	2		0.8	
Bridgeport_S040				2.9			1.2						5	2		0.8	
Bridgeport_S020				2.9			1.2						5	2		0.8	
West_Fork_S170				1.6			0.8						5	5		2.2	
Dry_Ck_S010				1.6			0.8						5	5		2.2	
West_Fork_S180				1.6			0.8						5	5		2.2	
Amon_G_Carter_S030				2.2			1.3						3.5	1.5		0.9	
Amon_G_Carter_S010				2.2			1.3						3.5	1.5		0.9	
Amon_G_Carter_S020				2.2			1.3						3.5	1.5		0.9	
Big_Sandy_Ck_S010				1.5			1.6						0.5	2.5		1.5	
Big_Sandy_Ck_S020				1.5			2.5						1.7	2.5		1.5	
Brushy_Ck_S010				1.5			1.6						0.5	2.5		1.5	
Brushy_Ck_S020				1.5			2.5						2	2.5		1.5	
Brushy_Ck_S030				1.5			2.5						1.8	2.5		1.5	
Big_Sandy_Ck_S030				1.5			0.8						1.6	2.5		1.5	
Big_Sandy_Ck_S040				1.5			0.8						1.6	2.5		1.5	
Big_Sandy_Ck_S050				1.6			0.8						5	5		2.2	
West_Fork_S190				1.5			0.8						5	5		2.2	
West_Fork_S200				1.5			0.8						5	5		2.2	
Garrett_Ck_S020				1			0.8						5	5		2.2	
Garrett_Ck_S010				1			0.8						5	5		2.2	
Garrett_Ck_S030				1			0.8						5	5		2.2	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Salt_Ck_S010				1			0.8						5	5		2.2	
Salt_Ck_S020				1			0.8						5	5		2.2	
West_Fork_S210				1.5			2						5	3.5		2.4	
West_Fork_S220				2			0.3						4.5	2.5		2	
Eagle_Mountain_S010				2.5			0.3						4.5	2.5		2.5	
Eagle_Mountain_S020				2.5			0.3						4.5	2.5		2.5	
Walnut_Ck_S020				1.2			0.92						2	2.2		1.7	
Walnut_Ck_S010				1.2			0.92						2	2.2		3.7	
Walnut_Ck_S030				2			0.3						4.5	2.5		2.5	
Eagle_Mountain_S040				3			0.3						4.5	2.5		2.5	
Eagle_Mountain_S030				3			0.3						4.5	2.5		2.5	
Silver_Ck_S020				3.3			2.25						3.5	3		3	
Silver_Ck_S010				3.3			2.25						4.5	3		3	
Lake_Worth_S010				3.3			2.25						3.5	3		3	
Lake_Worth_S020				3.3			2.25						3.5	3		3	
West_Fork_S230				2			2						3	3		1.7	
Lk_Weatherford_S010				2.6			2.2						3.2	3.8		3	
Lk_Weatherford_S020				2.3			2.2						2.5	3.5		2.5	
Clear_Fork_S010				2.8			0.65						3	3		2.5	
Clear_Fork_S020				2.5			0.65						3	3		2.5	
Bear_Ck_S010				2.4			0.65						3	3		2.5	
Bear_Ck_S020				2.3			0.65						3	3		2.5	
Benbrook_S010				2.3			0.65						3	3		2.5	
Benbrook_S020				2.3			0.65						3	3		2.5	
Benbrook_S030				2.3			0.65						3	3		2.5	
Clear_Fork_S030				2			2.5						1	2.6		1.5	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Marys_Ck_S010			2.5	2.3			0.5						3.6	3.1		0.9	
Clear_Fork_S040				2			2.5						1.1	2.6		1.4	
Clear_Fork_S050				2			1.8						3	3		1.7	
West_Fork_S240				0			0						0.6	3		0.1	
Marine_Ck_S020				0			0						0.6	3		0.1	
Marine_Ck_S010				0			0						0.4	3		0.1	
West_Fork_S250				0			0						0.6	3		0.1	
West_Fork_S260				0			0						0.4	2.2		0.1	
West_Fork_S270				0			3						0.5	2.5		3.5	
Big_Fossil_Ck_S010				0			3						0.5	2.5		3.5	
LittleFossil_Ck_S010				0			3						0.5	2.5		3.5	
West_Fork_S280				3			3						0.5	2.5		3.5	
Village_Ck_S010				1			1.6						2.2	2.5		2.3	
Village_Ck_S020				2			0.5						1.5	3.5		0.5	
Lake_Arlington_S010				2			0.5						1.5	3.5		0.5	
Village_Ck_S030				3			3						0.5	2.5		3.5	
West_Fork_S290				2.5			2						3	1		0.5	
West_Fork_S300				2.5			2						3	1		0.5	
West_Fork_S310				2.5			2						3	1		0.5	
West_Fork_S320	3											2				3	
Big_Bear_Ck_S010	4											2				1.7	
Big_Bear_Ck_S020	3											2				3	
West_Fork_S330	3											2				3	
Joe_Pool_S020	1											3.5				1	
Joe_Pool_S030	0.4											3.7				2	
Joe_Pool_S040	0.2											3.5				0.2	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Joe_Pool_S010	0.6											3.2				0.7	
Joe_Pool_S050	0.2											3.5				0.2	
Mountain_Ck_S010	1.6											5				2.5	
Mountain_Ck_S020	1.6											5				2.5	
Mountain_Ck_S030	3											2				3	
West_Fork_S340	3											3				3	
Elm_Fork_S020	1							2				2				1.3	
Elm_Fork_S010	1							2				2				1.3	
Brushy_Elm_Ck_S010	1							2				2				1.2	
Brushy_Elm_Ck_S020	1							2				2				1.2	
Elm_Fork_S030	0.5							1.5				2				1.2	
Elm_Fork_S040	0.5							1.2				2.7				1	
Elm_Fork_S050	0.5							1.5				2				1	
Elm_Fork_S070	0.5							1.5				2				1	
Elm_Fork_S060	0.5							1.5				2				1	
Spring_Ck_S010	0.5							4.5				2				1	
Spring_Ck_S020	0.5							4				2				1	
Ray_Roberts_S010	0.5							5				2				1	
Timber_Ck_S010	0.5							1.6				2.9				2	
Timber_Ck_S030	0.5							1.5				2				1	
Timber_Ck_S020	0.5							4.5				2				1	
Ray_Roberts_S030	0.5							4				2				1	
Range_Ck_S010	0.5							1				2.84				0.9	
Range_Ck_S020	0.5							1.5				2				1	
Lake_Kiowa_S020	0.5							4				2				1	
Lake_Kiowa_S010	0.5							1.5				2				1	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Ray_Roberts_S020	0.5							4				2				1	
Range_Ck_S030	0.5							4				2				1	
Buck_Ck_S010	0.5							4.5				2				1	
Ray_Roberts_S050	0.5							4.5				2				1	
Ray_Roberts_S040	0.5							5				2				1	
Ray_Roberts_S060	0.5							4.5				2				1	
Timber_Ck_S040	0.5							4.5				2				1	
Elm_Fork_S080	0.1							2				2.8				2.5	
Clear_Ck_S010	0.3							1.5				1.45				2.5	
Clear_Ck_S020	0.3							1.5				1.45				2.5	
Clear_Ck_S030	0.3							1.5				1.45				2.5	
Clear_Ck_S040	0.3							3				2				2.5	
Clear_Ck_S050	0.3							3				2				2.5	
Clear_Ck_S070	0.3							2.5				1.45				2	
Clear_Ck_S060	0.5							2.5				1.45				1	
Clear_Ck_S080	0.3							3				2				0.8	
Clear_Ck_S090	0.3							3				2				1.4	
Clear_Ck_S110	0.3							2				2.8				2.5	
Clear_Ck_S100	0.3							2				2.8				2.5	
Clear_Ck_S120	0.3							2				2.8				2.5	
Little_Elm_Ck_S010	0.3							3.75				3.5				2.5	
Little_Elm_Ck_S020	0.3							1.3				3.7				2.5	
Little_Elm_Ck_S030	0.1							3				3				2.5	
Pecan_Ck_S010	0.1							3				3				2.5	
Doe_Branch_S010	0.1							0.35				2.7				2	
Doe_Branch_S020	0.1							2				3				2.7	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Lewisville_S030	0.1							2				3				2.5	
Hickory_Ck_S020	0.3							2				2.3				1.2	
Hickory_Ck_S010	0.3							2				2.9				1.2	
Hickory_Ck_S030	0.3							2				2.8				1.2	
Hickory_Ck_S040	0.3							2				2.1				1.4	
Hickory_Ck_S050	0.1							2				3				2.5	
Lewisville_S010	0.1							2				3				2.5	
Lewisville_S040	0.1							2				3				2.5	
Lewisville_S050	0.1							2				3				2.5	
Lewisville_S020	0.1							2				3				2.5	
Elm_Fork_S090	3											5				4.2	
Elm_Fork_S110	3.95											5.5				4.1	
Elm_Fork_S100	3											5.5				4.2	
Elm_Fork_S120	4.5											5.5				4.5	
Denton_Ck_S010	0.7							1				3				2	
Denton_Ck_S020	0.7							1				3				3	
Denton_Ck_S030	0.4							1				3				3	
Denton_Ck_S040	0.35							2.1				2.5				1.3	
Denton_Ck_S050	0.5							1.4				2.7				1.3	
Denton_Ck_S060	0.5							1.4				2.7				1.3	
Denton_Ck_S070	0.5							1.4				2.7				1.3	
Grapevine_S010	0.5							1.4				2.4				1	
Denton_Ck_S080	3.5											5				3.6	
Elm_Fork_S130	4											5.5				3	
Hackberry_Ck_S010	3											5.5				3.5	
Hackberry_Ck_S020	3											5.5				3	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Hackberry_Ck_S030	3											5				3	
Elm_Fork_S140	5											5				4	
Elm_Fork_S150	3											3				3	
Bachman_Branch_S010	3											2				3	
Bachman_Branch_S020	3											2				3	
Elm_Fork_S160	3											2				3	
Trinity_River_S010	4											4				3	
Trinity_River_S020	5											6				5	
White_Rock_Ck_S010	0.5											5				3	
White_Rock_Ck_S020	3											5				2	
White_Rock_Ck_S030	3											5				2	
White_Rock_Ck_S040	3											5				2	
Trinity_River_S030	3											5				3	
Fivemile_Ck_S010									1			1.5				0.8	
Trinity_River_S040									1			1.5				0.8	
Trinity_River_S050									1			1.5				0.8	
Tenmile_Ck_S010									1			1.5				0.8	
Tenmile_Ck_S020									1			1.5				0.8	
Trinity_River_S060									1			1.5				0.5	
Indian_Ck_S010								0					0.5			1	1.5
Indian_Ck_S030								1.5					1.5			1.5	
Indian_Ck_S020								1.5					1.5			1.5	
Indian_Ck_S040								1.5					1.5			1.5	
Sister_Grove_S010								0.1					0.8			1	
Sister_Grove_S020								1.5					1.5			1.5	
East_Fork_S020								1.5					0			0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
East_Fork_S010								1.5					0			0	
East_Fork_S030								0.5					0			0	
East_Fork_S040								1.5					1.5			1.5	
Wilson_Ck_S010								1.5					1.5			1.5	
Lavon_S010								1.5					1.5			1.5	
Lavon_S020								1.5					1.5			1.5	
Rowlett_Ck_S010								0.5					1			1.2	
Ray_Hubbard_S010								0.5					1.5			2	
Ray_Hubbard_S020								0.5					1.5			2	
East_Fork_S050								0.4					0			0	
East_Fork_S070					1.5			2				8					
East_Fork_S060					1.5			2				8					
East_Fork_S080					1.5			2				8					
East_Fork_S090					1.5			2				8					
East_Fork_S110					1.5			2				8					
East_Fork_S100					1.5			2				8					
Trinity_River_S070									1.5			2				0.5	
East_Fork_S120									1.5			2				1	
Kings_Ck_S020													0.4			0.6	0.8
Kings_Ck_S010													0.3			0.4	0.8
Kings_Ck_S030								1.6					1.2			1.2	0
Cedar_Ck_S040								1.6					3			1.2	0
Cedar_Ck_S010								1					0.4				0.8
New_Terrell_City_Lake_S010								3					1			0	0
Cedar_Ck_S020								1.6					1.2			1.2	0
Cedar_Ck_S030								1.6					1.2			1.2	0

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S080									2				3				2
Trinity_River_S090								2					2.5			2	
Chambers_Ck_S010										4.1	0		1.2		3		
Chambers_Ck_S020										4.2	0		1.2		3		
Chambers_Ck_S040										4	0		1.2		3.5		
Chambers_Ck_S030										4	0		1.2		3.5		
Waxahachie_Ck_S010										5	0.15		3		1.5		
Waxahachie_Ck_S020										3.2	0		1.2		1		
Waxahachie_Ck_S030										4.5	0		2		2		
Mustang_Ck_S010										4.5	0		2		2		
Bardwell_S010										4.5	0		2		2		
Chambers_Ck_S050										4	0.1		2		3.5		
Chambers_Ck_S060										3.5	0.1		2		3.5		
Chambers_Ck_S070										3.5	0.1		2.5		5		
Chambers_Ck_S080										0	0		3		2		
Post_Oak_Ck_S010										0	0		3		2		
Lake_Halbert_S010										1.2	0		0.01		0		
Navarro_Mills_S020										2.2	0.02		2		1.5		
Navarro_Mills_S030										2.2	0.02		2		1.5		
Navarro_Mills_S010										2.98	0.2		4.3		1.5		
Navarro_Mills_S040										2.2	0.02		1		1.5		
Richland_Ck_S010										0	0		3		2		
Richland_Ck_S020										0	0		3		2		
Richland-Chambers_S010										0	0		3		2		
Richland-Chambers_S020										0	0		3		2		
Tehuacana_Ck_S020								2					2.5			2	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Tehuacana_Ck_S010					0.1				0.1				0.1				0.1
Trinity_River_S100								1					2.5			2	
Fairfield_Lake_S010								1					2.5			2	
Trinity_River_S110								1					2.5			2	
Big_Brown_Ck_S010								1					2.5			2	
Trinity_River_S120													2.5			2	
Trinity_River_S130									2				2			2	
Upper_Keechi_Ck_S030									2				2			2	
Upper_Keechi_Ck_S010									0.8				1.5				1.4
Upper_Keechi_Ck_S020									2				2			2	
Upper_Keechi_Ck_S040									2				2			2	
Trinity_River_S140									2				2			2	
Little_Elkhart_S010									2				2			2	
Houston_County_Lake_S010					5								5			0	
Trinity_River_S150									2				2			2	
Trinity_River_S160					0.6			2					0.6				0.5
Trinity_River_S170					0.6			2					0.6				0.5
Trinity_River_S180					0.6			2					0.6				0.5
Bedias_Ck_S010													0				0.6
Bedias_Ck_S020					0.6			2					0.6				0.5
Trinity_River_S190					0.6			2					0.6				0.5
Livingston_S010					0.6			2					0.6				0.5
Livingston_S030					0.6			2					0.6				0.5
Livingston_S020					0.6			2					0.6				0.5
Trinity_River_S200								0					3.5			1	
Long_King_Ck_S010		0.9			1.2	1.6											

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Long_King_Ck_S020								0					3.5			1	
Trinity_River_S210								0					3.5			1	
Menard_Ck_S010		0.1				1.4							0.1				
Trinity_River_S220								0					3.5			1	
Trinity_River_S230								0					1.5			1	
Trinity_River_S240								0					1.5			1	
Trinity_River_S250								0					1.5			1	

Table 13: Calibrated Constant Losses (inches per hour)

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S020				0.14			0.22						0.25	0.16		0.06	
West_Fork_S010				0.14			0.22						0.25	0.16		0.06	
West_Fork_S030				0.14			0.22						0.17	0.12		0.06	
West_Fork_S040				0.14			0.22						0.2	0.14		0.06	
West_Fork_S050				0.14			0.22						0.23	0.16		0.06	
West_Fork_S060				0.14			0.22						0.22	0.14		0.06	
West_Fork_S070				0.14			0.2						0.26	0.16		0.04	
West_Fork_S080				0.14			0.2						0.2	0.14		0.04	
West_Fork_S090				0.14			0.2						0.27	0.16		0.04	
West_Fork_S100				0.14			0.2						0.23	0.16		0.04	
West_Fork_S120				0.18			0.16						0.23	0.24		0.05	
West_Fork_S110				0.18			0.16						0.29	0.24		0.05	
Big_Cleveland_S010				0.18			0.16						0.23	0.24		0.05	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Big_Cleveland_S020				0.18			0.16						0.24	0.24		0.05	
West_Fork_S130				0.3			0.1						0.5	0.14		0.06	
Lost_Ck_S010				0.225			0.02						0.5	0.08		0.04	
Lost_Ck_S020				0.22			0.26						0.5	0.25		0.15	
West_Fork_S140				0.22			0.26						0.5	0.25		0.15	
West_Fork_S150				0.22			0.26						0.5	0.25		0.15	
West_Fork_S160				0.22			0.26						0.5	0.25		0.15	
Beans_Ck_S010				0.22			0.26						0.5	0.25		0.15	
Beans_Ck_S020				0.22			0.26						0.5	0.25		0.15	
Big_Ck_S010				0.22			0.26						0.5	0.26		0.15	
Big_Ck_S030				0.22			0.26						0.5	0.26		0.15	
Big_Ck_S020				0.22			0.26						0.5	0.26		0.15	
Bridgeport_S030				0.22			0.26						0.5	0.25		0.15	
Bridgeport_S010				0.22			0.26						0.5	0.26		0.15	
Bridgeport_S040				0.22			0.26						0.5	0.25		0.15	
Bridgeport_S020				0.22			0.26						0.5	0.25		0.15	
West_Fork_S170				0.22			0.4						0.45	0.5		0.12	
Dry_Ck_S010				0.22			0.4						0.45	0.5		0.12	
West_Fork_S180				0.42			0.4						0.45	0.5		0.19	
Amon_G_Carter_S030				0.2			0.16						0.28	0.13		0.05	
Amon_G_Carter_S010				0.2			0.16						0.2	0.13		0.06	
Amon_G_Carter_S020				0.2			0.16						0.28	0.13		0.06	
Big_Sandy_Ck_S010				0.14			0.04						0.3	0.2		0.05	
Big_Sandy_Ck_S020				0.14			0.09						0.2	0.2		0.07	
Brushy_Ck_S010				0.14			0.04						0.3	0.19		0.05	
Brushy_Ck_S020				0.14			0.12						0.22	0.23		0.07	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Brushy_Ck_S030				0.14			0.12						0.23	0.25		0.2	
Big_Sandy_Ck_S030				0.14			0.32						0.2	0.24		0.2	
Big_Sandy_Ck_S040				0.14			0.32						0.2	0.26		0.2	
Big_Sandy_Ck_S050				0.42			0.4						0.45	0.5		0.19	
West_Fork_S190				0.42			0.4						0.45	0.5		0.19	
West_Fork_S200				0.18			0.32						0.5	0.5		0.2	
Garrett_Ck_S020				0.23			0.32						0.5	0.5		0.16	
Garrett_Ck_S010				0.23			0.32						0.5	0.5		0.16	
Garrett_Ck_S030				0.26			0.32						0.5	0.5		0.18	
Salt_Ck_S010				0.26			0.32						0.5	0.5		0.18	
Salt_Ck_S020				0.28			0.32						0.5	0.5		0.2	
West_Fork_S210				0.08			0.32						0.17	0.16		0.22	
West_Fork_S220				0.16			0.36						0.5	0.16		0.09	
Eagle_Mountain_S010				0.16			0.36						0.5	0.16		0.09	
Eagle_Mountain_S020				0.16			0.36						0.5	0.16		0.09	
Walnut_Ck_S020				0.01			0.26						0.1	0.17		0.08	
Walnut_Ck_S010				0.01			0.24						0.1	0.16		0.07	
Walnut_Ck_S030				0.16			0.36						0.5	0.3		0.09	
Eagle_Mountain_S040				0.16			0.36						0.5	0.3		0.09	
Eagle_Mountain_S030				0.16			0.36						0.5	0.45		0.09	
Silver_Ck_S020				0.01			0.5						0.2	0.2		0.12	
Silver_Ck_S010				0.01			0.5						0.2	0.2		0.12	
Lake_Worth_S010				0.01			0.5						0.2	0.2		0.12	
Lake_Worth_S020				0.01			0.5						0.2	0.2		0.12	
West_Fork_S230				0.2			0.14						0.15	0.09		0.08	
Lk_Weatherford_S010				0.23			0.24						0.48	0.32		0.16	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Lk_Weatherford_S020				0.22			0.13						0.24	0.18		0.14	
Clear_Fork_S010				0.09			0.26						0.23	0.11		0.09	
Clear_Fork_S020				0.09			0.15						0.17	0.09		0.09	
Bear_Ck_S010				0.09			0.23						0.18	0.08		0.07	
Bear_Ck_S020				0.09			0.22						0.14	0.07		0.06	
Benbrook_S010				0.09			0.13						0.12	0.05		0.04	
Benbrook_S020				0.09			0.22						0.14	0.07		0.06	
Benbrook_S030				0.09			0.19						0.1	0.04		0.03	
Clear_Fork_S030				0.12			0.14						0.12	0.12		0.08	
Marys_Ck_S010			0.5	0.15			0.01						0.3	0.1		0.01	
Clear_Fork_S040				0.12			0.14						0.24	0.08		0.05	
Clear_Fork_S050				0.2			0.1						0.15	0.07		0.08	
West_Fork_S240				0.11			0.01						0.05	0.24		0.04	
Marine_Ck_S020				0.04			0.01						0.05	0.24		0.04	
Marine_Ck_S010				0.03			0.01						0.05	0.24		0.04	
West_Fork_S250				0.07			0.01						0.05	0.24		0.04	
West_Fork_S260				0.05			0.01						0.08	0.16		0.04	
West_Fork_S270				0.12			0.16						0.3	0.16		0.07	
Big_Fossil_Ck_S010				0.12			0.16						0.3	0.16		0.07	
LittleFossil_Ck_S010				0.12			0.16						0.3	0.16		0.07	
West_Fork_S280				0.12			0.16						0.2	0.16		0.07	
Village_Ck_S010				0.05			0.16						0.12	0.16		0.04	
Village_Ck_S020				0.01			0.01						0.12	0.15		0.03	
Lake_Arlington_S010				0.01			0.01						0.12	0.13		0.02	
Village_Ck_S030				0.12			0.16						0.2	0.16		0.07	
West_Fork_S290				0.12			0.16						0.3	0.15		0.2	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S300				0.12			0.16						0.3	0.15		0.2	
West_Fork_S310				0.12			0.16						0.3	0.15		0.2	
West_Fork_S320	0.2											0.2				0.3	
Big_Bear_Ck_S010	0.1											0.2				0.08	
Big_Bear_Ck_S020	0.2											0.2				0.3	
West_Fork_S330	0.2											0.2				0.3	
Joe_Pool_S020	0.01											0.1				0.04	
Joe_Pool_S030	0.06											0.09				0.03	
Joe_Pool_S040	0.01											0.05				0.03	
Joe_Pool_S010	0.01											0.04				0.04	
Joe_Pool_S050	0.01											0.05				0.03	
Mountain_Ck_S010	0.1											0.2				0.06	
Mountain_Ck_S020	0.1											0.2				0.06	
Mountain_Ck_S030	0.2											0.2				0.3	
West_Fork_S340	0.3											0.3				0.3	
Elm_Fork_S020	0.04							0.3				0.25				0.1	
Elm_Fork_S010	0.04							0.3				0.25				0.1	
Brushy_Elm_Ck_S010	0.04							0.3				0.2				0.1	
Brushy_Elm_Ck_S020	0.03							0.2				0.2				0.02	
Elm_Fork_S030	0.03							0.15				0.28				0.1	
Elm_Fork_S040	0.02							0.01				0.28				0.02	
Elm_Fork_S050	0.04							0.05				0.25				0.02	
Elm_Fork_S070	0.04							0.05				0.25				0.02	
Elm_Fork_S060	0.03							0.05				0.25				0.02	
Spring_Ck_S010	0.03							0.15				0.25				0.02	
Spring_Ck_S020	0.03							0.15				0.25				0.02	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Ray_Roberts_S010	0.04							0.2				0.25				0.1	
Timber_Ck_S010	0.01							0.04				0.1				0.02	
Timber_Ck_S030	0.03							0.05				0.25				0.02	
Timber_Ck_S020	0.03							0.05				0.25				0.02	
Ray_Roberts_S030	0.04							0.1				0.25				0.02	
Range_Ck_S010	0.03							0.05				0.11				0.02	
Range_Ck_S020	0.04							0.05				0.25				0.02	
Lake_Kiowa_S020	0.04							0.15				0.25				0.02	
Lake_Kiowa_S010	0.04							0.15				0.25				0.02	
Ray_Roberts_S020	0.03							0.15				0.25				0.02	
Range_Ck_S030	0.04							0.15				0.25				0.02	
Buck_Ck_S010	0.04							0.15				0.25				0.02	
Ray_Roberts_S050	0.03							0.15				0.25				0.02	
Ray_Roberts_S040	0.04							0.2				0.25				0.02	
Ray_Roberts_S060	0.04							0.15				0.25				0.02	
Timber_Ck_S040	0.03							0.15				0.25				0.02	
Elm_Fork_S080	0.01							0.2				0.35				0.02	
Clear_Ck_S010	0.12							0.2				0.4				0.05	
Clear_Ck_S020	0.12							0.2				0.4				0.05	
Clear_Ck_S030	0.12							0.2				0.4				0.05	
Clear_Ck_S040	0.12							0.2				0.24				0.15	
Clear_Ck_S050	0.12							0.25				0.24				0.2	
Clear_Ck_S070	0.12							0.2				0.2				0.2	
Clear_Ck_S060	0.12							0.2				0.2				0.1	
Clear_Ck_S080	0.08							0.35				0.1				0.07	
Clear_Ck_S090	0.08							0.35				0.1				0.06	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Clear_Ck_S110	0.01							0.2				0.35				0.02	
Clear_Ck_S100	0.01							0.2				0.35				0.02	
Clear_Ck_S120	0.01							0.2				0.35				0.02	
Little_Elm_Ck_S010	0.1							0.04				0.18				0.07	
Little_Elm_Ck_S020	0.1							0.2				0.18				0.04	
Little_Elm_Ck_S030	0.01							0.2				0.35				0.02	
Pecan_Ck_S010	0.01							0.2				0.35				0.02	
Doe_Branch_S010	0.01							0.15				0.2				0.2	
Doe_Branch_S020	0.01							0.15				0.35				0.02	
Lewisville_S030	0.01							0.15				0.35				0.02	
Hickory_Ck_S020	0.01							0.2				0.06				0.03	
Hickory_Ck_S010	0.01							0.2				0.06				0.03	
Hickory_Ck_S030	0.01							0.2				0.08				0.03	
Hickory_Ck_S040	0.01							0.2				0.18				0.09	
Hickory_Ck_S050	0.01							0.2				0.35				0.02	
Lewisville_S010	0.01							0.1				0.35				0.02	
Lewisville_S040	0.01							0.1				0.35				0.02	
Lewisville_S050	0.01							0.1				0.35				0.02	
Lewisville_S020	0.01							0.1				0.35				0.02	
Elm_Fork_S090	0.05											0.5				0.04	
Elm_Fork_S110	0.05											0.5				0.06	
Elm_Fork_S100	0.05											0.5				0.04	
Elm_Fork_S120	0.05											0.5				0.04	
Denton_Ck_S010	0.22							0.15				0.28				0.2	
Denton_Ck_S020	0.28							0.15				0.28				0.02	
Denton_Ck_S030	0.1							0.15				0.29				0.02	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Denton_Ck_S040	0.01							0.23				0.18				0.02	
Denton_Ck_S050	0.03							0.15				0.15				0.1	
Denton_Ck_S060	0.02							0.15				0.14				0.09	
Denton_Ck_S070	0.02							0.15				0.15				0.04	
Grapevine_S010	0.02							0.21				0.12				0.02	
Denton_Ck_S080	0.05											0.5				0.06	
Elm_Fork_S130	0.1											0.5				0.04	
Hackberry_Ck_S010	0.05											0.5				0.04	
Hackberry_Ck_S020	0.05											0.5				0.04	
Hackberry_Ck_S030	0.05											0.5				0.04	
Elm_Fork_S140	0.15											0.5				0.04	
Elm_Fork_S150	0.3											0.3				0.3	
Bachman_Branch_S010	0.1											0.1				0.3	
Bachman_Branch_S020	0.1											0.1				0.3	
Elm_Fork_S160	0.2											0.1				0.3	
Trinity_River_S010	0.3											0.3				0.3	
Trinity_River_S020	0.3											0.5				0.3	
White_Rock_Ck_S010	0.02											0.5				0.02	
White_Rock_Ck_S020	0.05											0.5				0.02	
White_Rock_Ck_S030	0.05											0.5				0.02	
White_Rock_Ck_S040	0.15											0.5				0.15	
Trinity_River_S030	0.15											0.5				0.1	
Fivemile_Ck_S010									0.12			0.35				0.22	
Trinity_River_S040									0.12			0.35				0.22	
Trinity_River_S050									0.12			0.35				0.22	
Tenmile_Ck_S010									0.12			0.35				0.22	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Tenmile_Ck_S020									0.12			0.35				0.22	
Trinity_River_S060									0.12			0.35				0.16	
Indian_Ck_S010								0.08					0.08			0.18	0.18
Indian_Ck_S030								0.12					0.11			0.05	
Indian_Ck_S020								0.12					0.08			0.02	
Indian_Ck_S040								0.12					0.08			0.04	
Sister_Grove_S010								0.2					0.14			0.19	
Sister_Grove_S020								0.12					0.08			0.07	
East_Fork_S020								0.08					0.55			0.28	
East_Fork_S010								0.08					0.55			0.28	
East_Fork_S030								0.08					0.4			0.3	
East_Fork_S040								0.08					0.06			0.05	
Wilson_Ck_S010								0.08					0.06			0.06	
Lavon_S010								0.08					0.06			0.02	
Lavon_S020								0.08					0.06			0.04	
Rowlett_Ck_S010								0.06					0.1			0.02	
Ray_Hubbard_S010								0.05					0.15			0.03	
Ray_Hubbard_S020								0.05					0.15			0.03	
East_Fork_S050								0.01					0.03			0.03	
East_Fork_S070					0.08			0.04				0.2					
East_Fork_S060					0.08			0.04				0.2					
East_Fork_S080					0.08			0.04				0.2					
East_Fork_S090					0.08			0.04				0.2					
East_Fork_S110					0.1			0.04				0.25					
East_Fork_S100					0.08			0.04				0.2					
Trinity_River_S070									0.2			0.35				0.22	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
East_Fork_S120									0.2			0.35				0.13	
Kings_Ck_S020													0.05			0.03	0.08
Kings_Ck_S010													0.05			0.01	0.09
Kings_Ck_S030								0.06					0.4			0.02	0.2
Cedar_Ck_S040								0.1					0.4			0.02	0.24
Cedar_Ck_S010								0.05					0.03				0.04
New_Terrell_City_Lake_S010								0.06					0.06			0	0.03
Cedar_Ck_S020								0.06					0.4			0.02	0.2
Cedar_Ck_S030								0.06					0.4			0.02	0.2
Trinity_River_S080									0.06				0.1				0.05
Trinity_River_S090								0.04					0.16			0.28	
Chambers_Ck_S010										0.04	0		0.15		0.24		
Chambers_Ck_S020										0.04	0		0.15		0.24		
Chambers_Ck_S040										0.35	0		0.1		0.16		
Chambers_Ck_S030										0.3	0		0.1		0.16		
Waxahachie_Ck_S010										0.1	0.22		0.1		0.65		
Waxahachie_Ck_S020										0.1	0		0.1		0.5		
Waxahachie_Ck_S030										0.01	0.05		0.2		0.3		
Mustang_Ck_S010										0.01	0.05		0.2		0.3		
Bardwell_S010										0.01	0.05		0.2		0.3		
Chambers_Ck_S050										0.15	0		0.1		0.24		
Chambers_Ck_S060										0.15	0		0.1		0.24		
Chambers_Ck_S070										0.15	0		0.1		0.4		
Chambers_Ck_S080										0.1	0.01		0.4		0.1		
Post_Oak_Ck_S010										0.1	0.01		0.4		0.1		
Lake_Halbert_S010										0.22	0.01		0.11		0.01		

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Navarro_Mills_S020										0.45	0.01		0.08		0.1		
Navarro_Mills_S030										0.45	0.01		0.08		0.1		
Navarro_Mills_S010										0.01	0.13		0.12		0.6		
Navarro_Mills_S040										0.45	0.01		0.08		0.1		
Richland_Ck_S010										0.1	0.01		0.4		0.1		
Richland_Ck_S020										0.1	0.01		0.4		0.1		
Richland-Chambers_S010										0.1	0.01		0.4		0.1		
Richland-Chambers_S020										0.1	0.01		0.4		0.1		
Tehuacana_Ck_S020								0.04					0.16			0.28	
Tehuacana_Ck_S010					0.01				0				0.01				0.05
Trinity_River_S100								0.04					0.16			0.28	
Fairfield_Lake_S010								0.04					0.16			0.28	
Trinity_River_S110								0.04					0.16			0.28	
Big_Brown_Ck_S010								0.04					0.16			0.32	
Trinity_River_S120													0.16			0.32	
Trinity_River_S130									0.4				0.24			0.3	
Upper_Keechi_Ck_S030									0.4				0.24			0.3	
Upper_Keechi_Ck_S010									0.1				0.3				0.04
Upper_Keechi_Ck_S020									0.4				0.24			0.3	
Upper_Keechi_Ck_S040									0.4				0.24			0.3	
Trinity_River_S140									0.4				0.24			0.3	
Little_Elkhart_S010									0.4				0.24			0.3	
Houston_County_Lake_S010					0.08								0.4			0.3	
Trinity_River_S150									0.4				0.24			0.3	
Trinity_River_S160					0.22			0.32					0.2				0.1
Trinity_River_S170					0.22			0.32					0.2				0.1

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S180					0.22			0.32					0.2				0.1
Bedias_Ck_S010													0.01				0.02
Bedias_Ck_S020					0.22			0.32					0.2				0.1
Trinity_River_S190					0.22			0.32					0.2				0.1
Livingston_S010					0.22			0.32					0.2				0.1
Livingston_S030					0.22			0.32					0.2				0.1
Livingston_S020					0.22			0.32					0.2				0.1
Trinity_River_S200								0.32					0.4			0.2	
Long_King_Ck_S010		0.12			0.12	0.15											
Long_King_Ck_S020								0.32					0.4			0.2	
Trinity_River_S210								0.32					0.4			0.2	
Menard_Ck_S010		0.01				0.26							0.7				
Trinity_River_S220								0.32					0.4			0.2	
Trinity_River_S230								0.2					0.07			0.21	
Trinity_River_S240								0.2					0.07			0.21	
Trinity_River_S250								0.2					0.07			0.21	

Table 14: Calibrated Snyder's Lag Time (hours)

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S020				7.6			7.6						7.6	7.6		7.6	
West_Fork_S010				6.2			6.2						6.2	6.2		6.2	
West_Fork_S030				8.6			8.6						8.6	8.6		8.6	
West_Fork_S040				7.6			7.6						7.6	7.6		6.6	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S050				6.2			6.2						6.2	6.2		4.5	
West_Fork_S060				8.7			8.7						8.7	7.8		6.7	
West_Fork_S070				6.7			6.7						7.0	6.7		7.0	
West_Fork_S080				4.3			4.3						4.3	4.3		4.3	
West_Fork_S090				7.3			7.3						7.1	7.3		7.1	
West_Fork_S100				7.2			6.1						6.1	7.2		6.1	
West_Fork_S120				8.5			8.5						8.5	8.5		8.5	
West_Fork_S110				7.6			7.6						6.4	7.6		6.4	
Big_Cleveland_S010				7.7			7.7						7.7	7.7		7.7	
Big_Cleveland_S020				7.4			7.4						6.4	7.4		6.4	
West_Fork_S130				5.0			5.0						3.5	5.0		5.0	
Lost_Ck_S010				4.0			4.0						4.0	4.0		4.8	
Lost_Ck_S020				4.4			4.4						3.6	3.6		3.6	
West_Fork_S140				5.4			5.4						5.0	5.0		5.0	
West_Fork_S150				6.1			6.1						5.5	5.5		5.5	
West_Fork_S160				5.1			5.1						5.2	5.2		5.2	
Beans_Ck_S010				5.0			5.0						4.7	4.7		4.7	
Beans_Ck_S020				3.1			3.1						2.2	2.2		2.2	
Big_Ck_S010				5.6			5.6						5.6	5.6		5.6	
Big_Ck_S030				4.2			4.2						3.7	3.7		3.7	
Big_Ck_S020				4.1			4.1						3.3	3.3		3.3	
Bridgeport_S030				6.2			6.2						6.1	6.1		6.1	
Bridgeport_S010				5.3			5.3						5.5	5.5		5.5	
Bridgeport_S040				5.5			5.5						5.2	5.2		5.2	
Bridgeport_S020				5.0			5.0						4.3	4.3		4.3	
West_Fork_S170				6.7			6.7						4.0	4.5		4.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Dry_Ck_S010				6.5			6.5						4.4	4.4		4.4	
West_Fork_S180				2.9			2.0						2.0	2.0		2.0	
Amon_G_Carter_S030				5.2			5.2						5.2	5.2		5.2	
Amon_G_Carter_S010				5.6			5.6						5.6	5.6		5.6	
Amon_G_Carter_S020				5.3			5.3						5.3	5.3		5.3	
Big_Sandy_Ck_S010				6.5			5.4						6.5	5.4		6.5	
Big_Sandy_Ck_S020				7.7			7.3						7.7	7.7		7.7	
Brushy_Ck_S010				6.8			6.8						6.8	6.8		6.8	
Brushy_Ck_S020				6.9			5.9						6.9	6.9		6.9	
Brushy_Ck_S030				5.7			5.7						3.7	5.7		5.7	
Big_Sandy_Ck_S030				5.0			5.0						5.0	5.0		5.0	
Big_Sandy_Ck_S040				7.5			7.5						7.5	7.5		7.5	
Big_Sandy_Ck_S050				4.2			4.2						4.2	4.2		4.2	
West_Fork_S190				3.6			3.6						2.4	2.4		2.4	
West_Fork_S200				4.4			4.4						4.4	4.4		4.4	
Garrett_Ck_S020				5.9			5.9						3.0	3.0		3.0	
Garrett_Ck_S010				6.8			6.8						3.5	3.5		3.5	
Garrett_Ck_S030				2.9			2.9						1.5	1.5		1.5	
Salt_Ck_S010				5.7			4.7						2.4	2.4		2.4	
Salt_Ck_S020				4.9			4.2						2.1	2.1		2.1	
West_Fork_S210				4.6			4.6						4.1	4.6		4.6	
West_Fork_S220				4.5			6.4						6.5	6.5		5.2	
Eagle_Mountain_S010				3.5			5.3						5.3	5.3		4.2	
Eagle_Mountain_S020				2.5			5.1						5.1	5.1		4.1	
Walnut_Ck_S020				2.6			3.6						2.9	3.6		3.6	
Walnut_Ck_S010				2.5			3.4						2.5	3.4		3.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Walnut_Ck_S030				2.8			2.8						3.3	3.3		3.3	
Eagle_Mountain_S040				3.0			3.0						3.6	3.6		3.6	
Eagle_Mountain_S030				3.4			3.4						4.4	4.4		4.4	
Silver_Ck_S020				5.0			5.0						5.0	5.0		5.0	
Silver_Ck_S010				4.9			4.9						4.9	4.9		4.9	
Lake_Worth_S010				4.5			4.5						4.5	4.5		4.5	
Lake_Worth_S020				3.0			3.0						3.0	3.6		3.6	
West_Fork_S230				3.6			3.6						3.6	3.6		4.5	
Lk_Weatherford_S010				6.2			8.0						8.0	8.0		7.0	
Lk_Weatherford_S020				2.0			2.0						2.5	2.5		2.0	
Clear_Fork_S010				11.0			11.0						11.0	11.0		11.0	
Clear_Fork_S020				2.9			2.9						2.9	2.9		2.9	
Bear_Ck_S010				5.0			6.0						6.0	6.0		6.0	
Bear_Ck_S020				1.7			1.7						1.7	1.7		1.7	
Benbrook_S010				4.0			5.0						5.0	5.0		5.0	
Benbrook_S020				3.5			2.4						2.4	2.4		2.4	
Benbrook_S030				1.8			1.8						1.8	1.8		1.8	
Clear_Fork_S030				0.9			0.9						0.9	0.9		0.9	
Marys_Ck_S010			1.9	1.9			2.4									2.5	
Clear_Fork_S040				1.7			1.7						1.2	1.2		1.5	
Clear_Fork_S050				0.9			0.9						0.9	0.9		1.5	
West_Fork_S240				0.7			0.6						0.7	0.9		0.7	
Marine_Ck_S020				1.0			0.7						1.0	1.2		1.0	
Marine_Ck_S010				1.0			1.0						1.0	1.0		1.0	
West_Fork_S250				1.7			1.7						1.7	1.9		1.7	
West_Fork_S260				2.3			2.3						2.3	2.3		2.3	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S270				1.9			1.9						1.9	1.9		1.9	
Big_Fossil_Ck_S010				3.6			3.6						3.6	3.6		3.6	
LittleFossil_Ck_S010				2.3			2.3						2.3	2.3		2.3	
West_Fork_S280				2.9			2.9						2.9	2.9		2.9	
Village_Ck_S010				5.9			5.0						3.5	3.5		5.0	
Village_Ck_S020				1.6			1.6						1.6	1.6		1.6	
Lake_Arlington_S010				1.4			1.4						1.4	1.4		1.4	
Village_Ck_S030				5.4			5.4						5.4	5.4		5.4	
West_Fork_S290				4.9			4.9						4.9	4.9		4.9	
West_Fork_S300				3.5			3.5						3.5	3.5		3.5	
West_Fork_S310				0.8			0.8						0.8	0.8		0.8	
West_Fork_S320	2.0											1.4				1.4	
Big_Bear_Ck_S010	8.0											8.6				8.0	
Big_Bear_Ck_S020	3.2											3.2				3.2	
West_Fork_S330	2.3											2.3				2.3	
Joe_Pool_S020	6.1											6.1				6.1	
Joe_Pool_S030	5.6											6.6				8.0	
Joe_Pool_S040	1.0											1.0				1.0	
Joe_Pool_S010	3.2											4.5				4.3	
Joe_Pool_S050	1.5											2.0				1.5	
Mountain_Ck_S010	2.3											2.3				2.3	
Mountain_Ck_S020	1.3											1.3				1.3	
Mountain_Ck_S030	1.8											1.3				1.3	
West_Fork_S340	0.7											2.4				2.4	
Elm_Fork_S020	6.3							4.4				4.4				4.4	
Elm_Fork_S010	4.2							3.6				3.6				3.6	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Brushy_Elm_Ck_S010	2.7							2.7				2.7				2.7	
Brushy_Elm_Ck_S020	3.0							3.0				3.0				3.0	
Elm_Fork_S030	3.9							3.9				3.9				3.9	
Elm_Fork_S040	3.7							3.7				3.7				3.7	
Elm_Fork_S050	4.4							4.4				4.4				4.4	
Elm_Fork_S070	5.1							5.1				5.1				5.1	
Elm_Fork_S060	3.7							3.7				3.7				3.7	
Spring_Ck_S010	3.6							3.6				3.6				3.6	
Spring_Ck_S020	2.5							2.5				2.5				2.5	
Ray_Roberts_S010	1.5							1.5				1.5				1.5	
Timber_Ck_S010	7.5							5.1				7.5				7.5	
Timber_Ck_S030	4.1							4.1				4.1				4.1	
Timber_Ck_S020	1.9							1.9				1.9				1.9	
Ray_Roberts_S030	1.5							1.5				1.5				1.5	
Range_Ck_S010	7.0							2.8				7.0				7.0	
Range_Ck_S020	4.9							4.9				4.9				4.9	
Lake_Kiowa_S020	2.4							2.4				2.4				2.4	
Lake_Kiowa_S010	3.1							3.1				3.1				3.1	
Ray_Roberts_S020	1.0							1.0				1.0				1.0	
Range_Ck_S030	3.8							3.8				3.8				3.8	
Buck_Ck_S010	4.5							4.5				4.5				4.5	
Ray_Roberts_S050	1.0							1.0				1.0				1.0	
Ray_Roberts_S040	1.7							1.7				1.7				1.7	
Ray_Roberts_S060	1.0							1.0				1.0				1.0	
Timber_Ck_S040	2.0							2.0				2.0				2.0	
Elm_Fork_S080	3.9							5.9				3.9				5.9	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Clear_Ck_S010	5.1							5.1				5.1				5.1	
Clear_Ck_S020	4.4							4.4				4.4				4.4	
Clear_Ck_S030	2.0							2.0				2.0				2.0	
Clear_Ck_S040	3.9							3.9				3.9				3.9	
Clear_Ck_S050	6.2							6.2				6.2				6.2	
Clear_Ck_S070	3.7							3.7				3.7				3.7	
Clear_Ck_S060	1.5							1.1				1.1				1.1	
Clear_Ck_S080	9.0							8.5				9.0				6.5	
Clear_Ck_S090	8.0							7.5				8.0				4.5	
Clear_Ck_S110	2.9							4.8				2.9				4.8	
Clear_Ck_S100	3.2							5.2				3.2				5.2	
Clear_Ck_S120	4.3							6.9				4.3				6.9	
Little_Elm_Ck_S010	4.0							4.0				7.0				7.0	
Little_Elm_Ck_S020	4.7							4.7				8.0				8.0	
Little_Elm_Ck_S030	6.1							6.1				6.1				8.4	
Pecan_Ck_S010	6.4							6.4				6.4				6.4	
Doe_Branch_S010	5.3							4.4				5.5				5.3	
Doe_Branch_S020	3.6							3.6				3.6				7.0	
Lewisville_S030	2.3							4.4				2.3				4.4	
Hickory_Ck_S020	5.4							5.4				4.5				5.4	
Hickory_Ck_S010	4.0							4.0				3.5				4.0	
Hickory_Ck_S030	3.5							3.5				3.5				3.5	
Hickory_Ck_S040	3.1							3.1				3.1				3.1	
Hickory_Ck_S050	2.1							2.1				2.1				2.1	
Lewisville_S010	3.5							3.5				3.5				4.5	
Lewisville_S040	2.3							2.3				2.3				2.3	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Lewisville_S050	2.2							2.2				2.2				2.2	
Lewisville_S020	1.6							1.6				1.6				1.6	
Elm_Fork_S090	5.1											5.1				5.1	
Elm_Fork_S110	3.0											3.0				3.0	
Elm_Fork_S100	5.3											6.5				6.0	
Elm_Fork_S120	6.6											6.6				6.6	
Denton_Ck_S010	7.0							7.0				7.0				7.0	
Denton_Ck_S020	7.0							7.0				7.0				7.0	
Denton_Ck_S030	4.0							4.0				4.0				4.0	
Denton_Ck_S040	6.0							3.9				3.9				3.9	
Denton_Ck_S050	5.0							4.8				4.8				4.8	
Denton_Ck_S060	6.0							4.9				4.9				4.9	
Denton_Ck_S070	8.0							6.7				6.7				6.7	
Grapevine_S010	4.0							2.5				2.0				2.0	
Denton_Ck_S080	4.6											4.6				4.6	
Elm_Fork_S130	3.0											3.0				2.3	
Hackberry_Ck_S010	2.1											2.1				1.8	
Hackberry_Ck_S020	1.6											1.6				1.1	
Hackberry_Ck_S030	1.2											1.2				0.9	
Elm_Fork_S140	2.9											2.9				2.2	
Elm_Fork_S150	1.5											1.5				1.1	
Bachman_Branch_S010	1.4											1.4				1.0	
Bachman_Branch_S020	1.3											1.3				1.0	
Elm_Fork_S160	1.0											1.0				0.7	
Trinity_River_S010	2.0											2.0				1.5	
Trinity_River_S020	2.0											2.0				2.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
White_Rock_Ck_S010	2.6											2.6				2.6	
White_Rock_Ck_S020	1.1											1.1				1.1	
White_Rock_Ck_S030	1.3											1.3				1.3	
White_Rock_Ck_S040	1.9											2.5				1.9	
Trinity_River_S030	1.6											2.7				1.6	
Fivemile_Ck_S010												3.1				3.1	
Trinity_River_S040												3.0				3.0	
Trinity_River_S050												9.0				9.0	
Tenmile_Ck_S010												6.5				6.5	
Tenmile_Ck_S020												5.0				5.0	
Trinity_River_S060												10.0				10.0	
Indian_Ck_S010								13.0					13.0			12.0	13.0
Indian_Ck_S030								10.0					13.0			10.0	
Indian_Ck_S020								7.1					9.0			7.1	
Indian_Ck_S040								5.0					6.3			5.0	
Sister_Grove_S010								12.0					13.0			12.5	
Sister_Grove_S020								6.0					7.8			6.0	
East_Fork_S020								13.0					13.0			12.0	
East_Fork_S010								8.5					6.0			7.8	
East_Fork_S030								4.8					4.8			4.8	
East_Fork_S040								5.0					7.2			5.0	
Wilson_Ck_S010								10.0					11.4			10.0	
Lavon_S010								5.0					6.7			5.0	
Lavon_S020								4.0					6.1			4.0	
Rowlett_Ck_S010								5.3					3.3			4.0	
Ray_Hubbard_S010								4.0					6.0			6.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Ray_Hubbard_S020								4.0					6.5			6.5	
East_Fork_S050								9.9					9.9			9.9	
East_Fork_S070					3.5			3.5				3.5					
East_Fork_S060					7.9			7.9				7.9					
East_Fork_S080					5.4			5.4				5.4					
East_Fork_S090					7.4			7.4				7.4					
East_Fork_S110					5.2			5.2				5.2					
East_Fork_S100					5.7			5.7				5.7					
Trinity_River_S070												9.5				9.5	
East_Fork_S120												9.0				9.0	
Kings_Ck_S020													28.0			28.0	28.0
Kings_Ck_S010													22.0			22.0	22.0
Kings_Ck_S030								7.3					7.3			9.0	7.3
Cedar_Ck_S040								8.2					7.0			10.0	6.0
Cedar_Ck_S010								23.0					25.0				19.0
New_Terrell_City_Lake_S010								3.7					3.7			3.7	
Cedar_Ck_S020								6.0					6.0			7.5	6.0
Cedar_Ck_S030								6.5					6.5			8.0	6.5
Trinity_River_S080													28.0				
Trinity_River_S090								12.0					12.0			12.0	
Chambers_Ck_S010										16.0	10.0		11.0		9.0		
Chambers_Ck_S020										11.8	8.0		8.5		6.5		
Chambers_Ck_S040										11.5	11.5		11.5		11.5		
Chambers_Ck_S030										13.0	13.0		13.0		13.0		
Waxahachie_Ck_S010										3.9	3.9		3.9		5.2		
Waxahachie_Ck_S020										3.0	3.0		3.0		3.0		

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Waxahachie_Ck_S030										5.6	5.6		5.6		4.4		
Mustang_Ck_S010										5.4	5.4		5.4		4.3		
Bardwell_S010										3.5	3.5		3.5		2.8		
Chambers_Ck_S050										10.0	10.0		10.0		10.0		
Chambers_Ck_S060										5.5	5.5		5.5		5.5		
Chambers_Ck_S070										5.5	5.5		5.5		5.5		
Chambers_Ck_S080											7.7		7.7		5.2		
Post_Oak_Ck_S010											4.0		4.0		2.7		
Lake_Halbert_S010										1.9	1.9		1.9		1.9		
Navarro_Mills_S020										7.2	7.2		7.2		6.2		
Navarro_Mills_S030										10.4	10.4		10.4		9.0		
Navarro_Mills_S010										3.5	3.5		3.5		4.4		
Navarro_Mills_S040										5.7	5.7		5.7		4.9		
Richland_Ck_S010											9.3		9.3		6.3		
Richland_Ck_S020											8.4		8.4		5.7		
Richland-Chambers_S010											9.5		9.5		6.4		
Richland-Chambers_S020											8.4		8.4		5.7		
Tehuacana_Ck_S020								16.0					16.0			16.0	
Tehuacana_Ck_S010					7.4				7.4				7.4				7.8
Trinity_River_S100								17.0					17.0			17.0	
Fairfield_Lake_S010								5.5					5.5			5.5	
Trinity_River_S110								19.3					19.3			19.3	
Big_Brown_Ck_S010								11.1					11.1			11.1	
Trinity_River_S120								18.7					18.7			18.7	
Trinity_River_S130								28.5					28.5			28.5	
Upper_Keechi_Ck_S030								17.3					17.3			17.3	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Upper_Keechi_Ck_S010									7.0				9.0				8.0
Upper_Keechi_Ck_S020								9.0					9.0			9.0	
Upper_Keechi_Ck_S040								7.7					7.7			7.7	
Trinity_River_S140								1.6					1.6			1.6	
Little_Elkhart_S010								11.6					11.6			11.6	
Houston_County_Lake_S010					3.5								3.5			3.5	
Trinity_River_S150								11.6					11.6			11.6	
Trinity_River_S160					14.0			14.0					14.0				14.0
Trinity_River_S170					17.8			17.8					17.8				17.8
Trinity_River_S180					24.2			24.2					24.2				24.2
Bedias_Ck_S010													32.5				40.0
Bedias_Ck_S020					16.2			16.2					16.2				16.2
Trinity_River_S190					17.8			17.8					17.8				17.8
Livingston_S010					17.1			17.1					17.1				17.1
Livingston_S030					6.0			6.0					6.0				6.0
Livingston_S020					5.0			5.0					5.0				5.0
Trinity_River_S200								5.5					5.5			5.5	
Long_King_Ck_S010		7.5			7.5	7.3											
Long_King_Ck_S020								10.8					10.8			10.8	
Trinity_River_S210								8.5					8.5			8.5	
Menard_Ck_S010		31.0				27.0							24.0				
Trinity_River_S220								13.0					13.0			13.0	
Trinity_River_S230								16.6					16.6			16.6	
Trinity_River_S240								20.5					20.5			20.5	
Trinity_River_S250								19.0					19.0			19.0	

Table 15: Calibrated Snyder's Peaking Coefficient

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S020				0.72			0.72						0.70	0.72		0.70	
West_Fork_S010				0.72			0.72						0.70	0.72		0.70	
West_Fork_S030				0.72			0.72						0.70	0.72		0.70	
West_Fork_S040				0.72			0.72						0.70	0.72		0.70	
West_Fork_S050				0.72			0.72						0.70	0.72		0.70	
West_Fork_S060				0.72			0.72						0.70	0.72		0.70	
West_Fork_S070				0.72			0.72						0.70	0.72		0.70	
West_Fork_S080				0.65			0.72						0.70	0.72		0.65	
West_Fork_S090				0.65			0.72						0.70	0.72		0.65	
West_Fork_S100				0.65			0.72						0.70	0.72		0.65	
West_Fork_S120				0.56			0.72						0.65	0.72		0.65	
West_Fork_S110				0.56			0.72						0.56	0.72		0.65	
Big_Cleveland_S010				0.56			0.72						0.65	0.72		0.65	
Big_Cleveland_S020				0.56			0.72						0.65	0.72		0.65	
West_Fork_S130				0.56			0.56						0.56	0.65		0.56	
Lost_Ck_S010				0.50			0.55						0.50	0.55		0.50	
Lost_Ck_S020				0.70			0.72						0.60	0.70		0.70	
West_Fork_S140				0.70			0.72						0.60	0.70		0.70	
West_Fork_S150				0.70			0.72						0.60	0.70		0.70	
West_Fork_S160				0.70			0.72						0.60	0.70		0.70	
Beans_Ck_S010				0.70			0.72						0.60	0.70		0.70	
Beans_Ck_S020				0.70			0.72						0.60	0.70		0.70	
Big_Ck_S010				0.70			0.72						0.60	0.70		0.70	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Big_Ck_S030				0.70			0.72						0.60	0.70		0.70	
Big_Ck_S020				0.70			0.72						0.60	0.70		0.70	
Bridgeport_S030				0.70			0.72						0.60	0.70		0.70	
Bridgeport_S010				0.70			0.72						0.60	0.70		0.70	
Bridgeport_S040				0.70			0.72						0.60	0.70		0.70	
Bridgeport_S020				0.70			0.72						0.60	0.70		0.70	
West_Fork_S170				0.70			0.70						0.60	0.60		0.60	
Dry_Ck_S010				0.70			0.70						0.60	0.60		0.60	
West_Fork_S180				0.70			0.70						0.60	0.60		0.60	
Amon_G_Carter_S030				0.70			0.70						0.60	0.60		0.60	
Amon_G_Carter_S010				0.70			0.70						0.60	0.60		0.60	
Amon_G_Carter_S020				0.70			0.70						0.60	0.60		0.60	
Big_Sandy_Ck_S010				0.42			0.72						0.60	0.70		0.70	
Big_Sandy_Ck_S020				0.42			0.72						0.72	0.60		0.70	
Brushy_Ck_S010				0.42			0.72						0.72	0.70		0.70	
Brushy_Ck_S020				0.42			0.72						0.72	0.60		0.70	
Brushy_Ck_S030				0.42			0.72						0.72	0.60		0.70	
Big_Sandy_Ck_S030				0.60			0.60						0.70	0.60		0.60	
Big_Sandy_Ck_S040				0.56			0.60						0.70	0.60		0.60	
Big_Sandy_Ck_S050				0.70			0.70						0.60	0.60		0.60	
West_Fork_S190				0.70			0.70						0.60	0.60		0.60	
West_Fork_S200				0.70			0.70						0.60	0.60		0.60	
Garrett_Ck_S020				0.70			0.70						0.60	0.60		0.60	
Garrett_Ck_S010				0.70			0.70						0.60	0.60		0.60	
Garrett_Ck_S030				0.70			0.70						0.60	0.60		0.60	
Salt_Ck_S010				0.70			0.70						0.60	0.60		0.60	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Salt_Ck_S020				0.70			0.70						0.60	0.60		0.60	
West_Fork_S210				0.70			0.70						0.60	0.60		0.60	
West_Fork_S220				0.72			0.72						0.65	0.65		0.65	
Eagle_Mountain_S010				0.72			0.72						0.65	0.65		0.65	
Eagle_Mountain_S020				0.72			0.72						0.65	0.65		0.65	
Walnut_Ck_S020				0.78			0.76						0.78	0.76		0.78	
Walnut_Ck_S010				0.78			0.76						0.78	0.76		0.78	
Walnut_Ck_S030				0.72			0.72						0.65	0.65		0.65	
Eagle_Mountain_S040				0.72			0.72						0.65	0.65		0.65	
Eagle_Mountain_S030				0.72			0.72						0.65	0.65		0.65	
Silver_Ck_S020				0.59			0.59						0.59	0.59		0.59	
Silver_Ck_S010				0.59			0.59						0.59	0.59		0.59	
Lake_Worth_S010				0.59			0.59						0.59	0.59		0.59	
Lake_Worth_S020				0.59			0.59						0.59	0.59		0.59	
West_Fork_S230				0.70			0.70						0.72	0.70		0.72	
Lk_Weatherford_S010				0.66			0.66						0.66	0.50		0.60	
Lk_Weatherford_S020				0.68			0.68						0.68	0.60		0.60	
Clear_Fork_S010				0.65			0.65						0.65	0.65		0.65	
Clear_Fork_S020				0.65			0.63						0.63	0.63		0.63	
Bear_Ck_S010				0.68			0.68						0.68	0.68		0.68	
Bear_Ck_S020				0.65			0.62						0.62	0.62		0.62	
Benbrook_S010				0.65			0.62						0.62	0.62		0.62	
Benbrook_S020				0.65			0.62						0.62	0.62		0.62	
Benbrook_S030				0.65			0.63						0.63	0.63		0.63	
Clear_Fork_S030				0.70			0.70						0.70	0.70		0.70	
Marys_Ck_S010			0.78	0.78			0.83									0.83	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Clear_Fork_S040				0.70			0.70						0.70	0.60		0.70	
Clear_Fork_S050				0.70			0.70						0.72	0.70		0.72	
West_Fork_S240				0.70			0.72						0.72	0.70		0.70	
Marine_Ck_S020				0.70			0.72						0.72	0.70		0.70	
Marine_Ck_S010				0.70			0.72						0.72	0.70		0.70	
West_Fork_S250				0.70			0.72						0.72	0.70		0.70	
West_Fork_S260				0.53			0.53						0.53	0.53		0.50	
West_Fork_S270				0.70			0.70						0.70	0.70		0.70	
Big_Fossil_Ck_S010				0.70			0.70						0.70	0.70		0.70	
LittleFossil_Ck_S010				0.70			0.70						0.70	0.70		0.70	
West_Fork_S280				0.70			0.70						0.70	0.70		0.70	
Village_Ck_S010				0.70			0.65						0.60	0.60		0.60	
Village_Ck_S020				0.70			0.70						0.60	0.70		0.70	
Lake_Arlington_S010				0.70			0.70						0.60	0.70		0.70	
Village_Ck_S030				0.70			0.70						0.70	0.70		0.70	
West_Fork_S290				0.70			0.70						0.70	0.70		0.70	
West_Fork_S300				0.70			0.70						0.70	0.70		0.70	
West_Fork_S310				0.70			0.70						0.70	0.70		0.70	
West_Fork_S320	0.70											0.70				0.70	
Big_Bear_Ck_S010	0.70											0.70				0.70	
Big_Bear_Ck_S020	0.70											0.70				0.70	
West_Fork_S330	0.70											0.70				0.70	
Joe_Pool_S020	0.70											0.70				0.70	
Joe_Pool_S030	0.70											0.70				0.70	
Joe_Pool_S040	0.70											0.70				0.70	
Joe_Pool_S010	0.70											0.70				0.70	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Joe_Pool_S050	0.70											0.70				0.70	
Mountain_Ck_S010	0.70											0.70				0.70	
Mountain_Ck_S020	0.70											0.70				0.70	
Mountain_Ck_S030	0.70											0.70				0.70	
West_Fork_S340	0.70											0.70				0.70	
Elm_Fork_S020	0.70							0.70				0.70				0.70	
Elm_Fork_S010	0.70							0.70				0.70				0.70	
Brushy_Elm_Ck_S010	0.70							0.70				0.70				0.70	
Brushy_Elm_Ck_S020	0.70							0.70				0.70				0.70	
Elm_Fork_S030	0.70							0.70				0.70				0.70	
Elm_Fork_S040	0.70							0.70				0.70				0.70	
Elm_Fork_S050	0.70							0.70				0.70				0.70	
Elm_Fork_S070	0.70							0.70				0.70				0.70	
Elm_Fork_S060	0.70							0.70				0.70				0.70	
Spring_Ck_S010	0.70							0.70				0.70				0.70	
Spring_Ck_S020	0.70							0.70				0.70				0.70	
Ray_Roberts_S010	0.70							0.70				0.70				0.70	
Timber_Ck_S010	0.75							0.78				0.75				0.75	
Timber_Ck_S030	0.70							0.70				0.70				0.70	
Timber_Ck_S020	0.70							0.70				0.70				0.70	
Ray_Roberts_S030	0.70							0.70				0.70				0.70	
Range_Ck_S010	0.75							0.75				0.75				0.75	
Range_Ck_S020	0.70							0.70				0.70				0.70	
Lake_Kiowa_S020	0.70							0.70				0.70				0.70	
Lake_Kiowa_S010	0.70							0.70				0.70				0.70	
Ray_Roberts_S020	0.70							0.70				0.70				0.70	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Range_Ck_S030	0.70							0.70				0.70				0.70	
Buck_Ck_S010	0.70							0.70				0.70				0.70	
Ray_Roberts_S050	0.70							0.70				0.70				0.70	
Ray_Roberts_S040	0.70							0.70				0.70				0.70	
Ray_Roberts_S060	0.70							0.70				0.70				0.70	
Timber_Ck_S040	0.62							0.62				0.62				0.62	
Elm_Fork_S080	0.62							0.62				0.62				0.62	
Clear_Ck_S010	0.62							0.62				0.62				0.62	
Clear_Ck_S020	0.65							0.65				0.65				0.65	
Clear_Ck_S030	0.62							0.62				0.62				0.62	
Clear_Ck_S040	0.65							0.65				0.65				0.65	
Clear_Ck_S050	0.60							0.60				0.60				0.60	
Clear_Ck_S070	0.65							0.65				0.65				0.65	
Clear_Ck_S060	0.62							0.62				0.62				0.62	
Clear_Ck_S080	0.62							0.62				0.65				0.62	
Clear_Ck_S090	0.62							0.62				0.65				0.62	
Clear_Ck_S110	0.62							0.62				0.62				0.62	
Clear_Ck_S100	0.62							0.62				0.62				0.62	
Clear_Ck_S120	0.62							0.62				0.62				0.62	
Little_Elm_Ck_S010	0.62							0.70				0.69				0.69	
Little_Elm_Ck_S020	0.62							0.62				0.68				0.68	
Little_Elm_Ck_S030	0.62							0.62				0.62				0.62	
Pecan_Ck_S010	0.62							0.62				0.62				0.62	
Doe_Branch_S010	0.47							0.62				0.40				0.47	
Doe_Branch_S020	0.62							0.62				0.62				0.62	
Lewisville_S030	0.62							0.62				0.62				0.62	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Hickory_Ck_S020	0.72							0.72				0.72				0.72	
Hickory_Ck_S010	0.72							0.72				0.72				0.72	
Hickory_Ck_S030	0.72							0.72				0.72				0.72	
Hickory_Ck_S040	0.72							0.72				0.72				0.72	
Hickory_Ck_S050	0.62							0.62				0.62				0.62	
Lewisville_S010	0.62							0.62				0.62				0.62	
Lewisville_S040	0.62							0.62				0.62				0.62	
Lewisville_S050	0.62							0.62				0.62				0.62	
Lewisville_S020	0.62							0.62				0.62				0.62	
Elm_Fork_S090	0.62											0.62				0.62	
Elm_Fork_S110	0.70											0.70				0.70	
Elm_Fork_S100	0.70											0.62				0.70	
Elm_Fork_S120	0.62											0.62				0.62	
Denton_Ck_S010	0.70							0.70				0.70				0.70	
Denton_Ck_S020	0.70							0.70				0.70				0.70	
Denton_Ck_S030	0.70							0.70				0.70				0.70	
Denton_Ck_S040	0.70							0.62				0.70				0.70	
Denton_Ck_S050	0.70							0.70				0.70				0.70	
Denton_Ck_S060	0.70							0.70				0.70				0.70	
Denton_Ck_S070	0.70							0.70				0.70				0.70	
Grapevine_S010	0.70							0.70				0.70				0.70	
Denton_Ck_S080	0.70											0.70				0.70	
Elm_Fork_S130	0.70											0.70				0.70	
Hackberry_Ck_S010	0.70											0.70				0.70	
Hackberry_Ck_S020	0.70											0.70				0.70	
Hackberry_Ck_S030	0.70											0.70				0.70	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Elm_Fork_S140	0.70											0.70				0.70	
Elm_Fork_S150	0.70											0.70				0.70	
Bachman_Branch_S010	0.70											0.70				0.70	
Bachman_Branch_S020	0.70											0.70				0.70	
Elm_Fork_S160	0.70											0.70				0.70	
Trinity_River_S010	0.70											0.70				0.70	
Trinity_River_S020	0.70											0.70				0.70	
White_Rock_Ck_S010	0.70											0.70				0.70	
White_Rock_Ck_S020	0.70											0.70				0.70	
White_Rock_Ck_S030	0.70											0.70				0.70	
White_Rock_Ck_S040	0.70											0.70				0.70	
Trinity_River_S030	0.70											0.70				0.70	
Fivemile_Ck_S010												0.72				0.72	
Trinity_River_S040												0.72				0.72	
Trinity_River_S050												0.72				0.72	
Tenmile_Ck_S010												0.72				0.72	
Tenmile_Ck_S020												0.72				0.72	
Trinity_River_S060												0.72				0.72	
Indian_Ck_S010								0.53					0.40			0.45	0.45
Indian_Ck_S030								0.60					0.60			0.60	
Indian_Ck_S020								0.60					0.60			0.60	
Indian_Ck_S040								0.60					0.60			0.60	
Sister_Grove_S010								0.50					0.40			0.45	
Sister_Grove_S020								0.60					0.60			0.60	
East_Fork_S020								0.60					0.35			0.55	
East_Fork_S010								0.60					0.35			0.55	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
East_Fork_S030								0.55					0.55			0.55	
East_Fork_S040								0.60					0.60			0.60	
Wilson_Ck_S010								0.60					0.45			0.60	
Lavon_S010								0.60					0.60			0.60	
Lavon_S020								0.60					0.60			0.60	
Rowlett_Ck_S010								0.55					0.55			0.72	
Ray_Hubbard_S010								0.50					0.40			0.55	
Ray_Hubbard_S020								0.50					0.40			0.55	
East_Fork_S050								0.70					0.70			0.70	
East_Fork_S070					0.30			0.35				0.25					
East_Fork_S060					0.30			0.35				0.25					
East_Fork_S080					0.30			0.35				0.25					
East_Fork_S090					0.30			0.35				0.25					
East_Fork_S110					0.30			0.35				0.25					
East_Fork_S100					0.30			0.35				0.25					
Trinity_River_S070												0.72				0.72	
East_Fork_S120												0.72				0.72	
Kings_Ck_S020													0.63			0.63	0.63
Kings_Ck_S010													0.63			0.63	0.63
Kings_Ck_S030								0.63					0.65			0.55	0.60
Cedar_Ck_S040								0.50					0.70			0.55	0.60
Cedar_Ck_S010								0.55					0.75				0.60
New_Terrell_City_Lake_S010								0.45					0.45			0.55	
Cedar_Ck_S020								0.55					0.65			0.55	0.60
Cedar_Ck_S030								0.55					0.65			0.55	0.60
Trinity_River_S080													0.70				

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S090								0.65					0.65			0.65	
Chambers_Ck_S010										0.60	0.70		0.60		0.70		
Chambers_Ck_S020										0.60	0.70		0.60		0.70		
Chambers_Ck_S040										0.60	0.70		0.60		0.70		
Chambers_Ck_S030										0.60	0.70		0.60		0.70		
Waxahachie_Ck_S010										0.42	0.42		0.42		0.78		
Waxahachie_Ck_S020										0.50	0.50		0.50		0.50		
Waxahachie_Ck_S030										0.47	0.47		0.47		0.47		
Mustang_Ck_S010										0.47	0.47		0.47		0.47		
Bardwell_S010										0.38	0.38		0.38		0.38		
Chambers_Ck_S050										0.60	0.70		0.60		0.70		
Chambers_Ck_S060										0.60	0.70		0.60		0.70		
Chambers_Ck_S070										0.60	0.70		0.60		0.70		
Chambers_Ck_S080											0.46		0.46		0.53		
Post_Oak_Ck_S010											0.32		0.32		0.37		
Lake_Halbert_S010										0.46	0.46		0.46		0.46		
Navarro_Mills_S020										0.38	0.38		0.38		0.71		
Navarro_Mills_S030										0.38	0.38		0.38		0.70		
Navarro_Mills_S010										0.42	0.42		0.42		0.76		
Navarro_Mills_S040										0.40	0.40		0.40		0.75		
Richland_Ck_S010											0.43		0.43		0.50		
Richland_Ck_S020											0.41		0.41		0.47		
Richland-Chambers_S010											0.39		0.39		0.46		
Richland-Chambers_S020											0.39		0.39		0.46		
Tehuacana_Ck_S020								0.65					0.65			0.65	
Tehuacana_Ck_S010					0.72				0.72				0.72				0.72

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S100								0.65					0.65			0.65	
Fairfield_Lake_S010								0.65					0.65			0.65	
Trinity_River_S110								0.65					0.65			0.65	
Big_Brown_Ck_S010								0.65					0.65			0.65	
Trinity_River_S120								0.65					0.65			0.65	
Trinity_River_S130								0.60					0.60			0.60	
Upper_Keechi_Ck_S030								0.60					0.60			0.60	
Upper_Keechi_Ck_S010									0.55				0.70				0.60
Upper_Keechi_Ck_S020								0.60					0.60			0.60	
Upper_Keechi_Ck_S040								0.60					0.60			0.60	
Trinity_River_S140								0.60					0.60			0.60	
Little_Elkhart_S010								0.60					0.60			0.60	
Houston_County_Lake_S010					0.45								0.45			0.45	
Trinity_River_S150								0.60					0.60			0.60	
Trinity_River_S160					0.55			0.55					0.55				0.55
Trinity_River_S170					0.55			0.55					0.55				0.55
Trinity_River_S180					0.55			0.55					0.55				0.55
Bedias_Ck_S010													0.70				0.74
Bedias_Ck_S020					0.55			0.55					0.55				0.55
Trinity_River_S190					0.55			0.55					0.55				0.55
Livingston_S010					0.55			0.55					0.55				0.55
Livingston_S030					0.55			0.55					0.55				0.55
Livingston_S020					0.55			0.55					0.55				0.55
Trinity_River_S200								0.50					0.50			0.50	
Long_King_Ck_S010		0.55			0.36	0.35											
Long_King_Ck_S020								0.50					0.50			0.50	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S210								0.50					0.50			0.50	
Menard_Ck_S010		0.80				0.78							0.40				
Trinity_River_S220								0.50					0.50			0.50	
Trinity_River_S230								0.49					0.49			0.49	
Trinity_River_S240								0.49					0.49			0.49	
Trinity_River_S250								0.50					0.50			0.50	

Table 16: Calibrated Initial Baseflow (cfs per sq mi)

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S020				0.1			0.0						0.0	0.1		0.0	
West_Fork_S010				0.2			0.0						0.0	0.1		0.0	
West_Fork_S030				0.2			0.0						0.0	0.1		0.0	
West_Fork_S040				0.2			0.0						0.0	0.2		0.0	
West_Fork_S050				0.3			0.0						0.0	0.3		0.0	
West_Fork_S060				0.1			0.0						0.0	0.1		0.0	
West_Fork_S070				0.2			0.0						0.0	0.2		0.0	
West_Fork_S080				0.5			0.0						0.0	0.4		0.0	
West_Fork_S090				0.3			0.0						0.0	0.2		0.0	
West_Fork_S100				0.3			0.0						0.0	0.2		0.0	
West_Fork_S120				0.2			0.0						0.0	0.2		0.0	
West_Fork_S110				0.5			0.0						0.0	0.4		0.0	
Big_Cleveland_S010				0.2			0.0						0.0	0.2		0.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Big_Cleveland_S020				0.2			0.0						0.0	0.2		0.0	
West_Fork_S130				0.5			0.0						0.0	0.4		0.0	
Lost_Ck_S010				0.2			0.3						0.2	0.2		0.2	
Lost_Ck_S020				0.7			0.0						0.7	0.7		0.7	
West_Fork_S140				0.0			0.0						0.0	0.0		0.0	
West_Fork_S150				0.0			0.0						0.0	0.0		0.0	
West_Fork_S160				0.0			0.0						0.0	0.0		0.0	
Beans_Ck_S010				0.0			0.0						0.0	0.0		0.0	
Beans_Ck_S020				0.0			0.0						0.0	0.0		0.0	
Big_Ck_S010				0.0			0.0						0.0	0.0		0.0	
Big_Ck_S030				0.0			0.0						0.0	0.0		0.0	
Big_Ck_S020				0.0			0.0						0.0	0.0		0.0	
Bridgeport_S030				0.0			0.0						0.0	0.0		0.0	
Bridgeport_S010				0.0			0.0						0.0	0.0		0.0	
Bridgeport_S040				0.0			0.0						0.0	0.0		0.0	
Bridgeport_S020				0.0			0.0						0.0	0.0		0.0	
West_Fork_S170				0.0			0.1						0.0	0.0		0.0	
Dry_Ck_S010				0.0			0.2						0.0	0.0		0.0	
West_Fork_S180				0.0			0.0						0.0	0.0		0.0	
Amon_G_Carter_S030				0.0			0.0						0.0	0.0		0.0	
Amon_G_Carter_S010				0.0			0.0						0.0	0.0		0.0	
Amon_G_Carter_S020				0.0			0.0						0.0	0.0		0.0	
Big_Sandy_Ck_S010				0.0			0.0						0.0	0.0		0.0	
Big_Sandy_Ck_S020				0.0			0.0						0.0	0.0		0.0	
Brushy_Ck_S010				0.0			0.0						0.0	0.0		0.0	
Brushy_Ck_S020				0.0			0.0						0.0	0.0		0.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Brushy_Ck_S030				0.0			0.0						0.0	0.0		0.0	
Big_Sandy_Ck_S030				0.0			0.0						0.0	0.0		0.0	
Big_Sandy_Ck_S040				0.0			0.0						0.0	0.0		0.0	
Big_Sandy_Ck_S050				0.0			0.3						0.0	0.0		0.0	
West_Fork_S190				0.0			0.2						0.0	0.0		0.0	
West_Fork_S200				0.0			0.0						0.0	0.0		0.0	
Garrett_Ck_S020				0.0			0.2						0.0	0.0		0.0	
Garrett_Ck_S010				0.0			0.2						0.0	0.0		0.0	
Garrett_Ck_S030				0.0			0.0						0.0	0.0		0.0	
Salt_Ck_S010				0.0			0.2						0.0	0.0		0.0	
Salt_Ck_S020				0.0			0.0						0.0	0.0		0.0	
West_Fork_S210				0.0			0.0						0.0	0.0		0.0	
West_Fork_S220				0.0			0.0						0.0	0.0		0.0	
Eagle_Mountain_S010				0.0			0.0						0.0	0.0		0.0	
Eagle_Mountain_S020				0.0			0.0						0.0	0.0		0.0	
Walnut_Ck_S020				0.0			0.0						0.0	0.0		0.0	
Walnut_Ck_S010				0.0			0.0						0.0	0.0		0.0	
Walnut_Ck_S030				0.0			0.0						0.0	0.0		0.0	
Eagle_Mountain_S040				0.0			0.0						0.0	0.0		0.0	
Eagle_Mountain_S030				0.0			0.0						0.0	0.0		0.0	
Silver_Ck_S020				0.0			0.0						0.0	0.0		0.0	
Silver_Ck_S010				0.0			0.0						0.0	0.0		0.0	
Lake_Worth_S010				0.0			0.0						0.0	0.0		0.0	
Lake_Worth_S020				0.0			0.0						0.0	0.0		0.0	
West_Fork_S230				0.3			1.4						0.8	0.8		2.0	
Lk_Weatherford_S010				0.0			0.0						0.8	0.0		0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Lk_Weatherford_S020				0.1			0.1						0.8	0.0		0.8	
Clear_Fork_S010				0.1			0.1						0.8	0.0		0.8	
Clear_Fork_S020				0.8			0.8						0.8	0.0		0.8	
Bear_Ck_S010				0.8			0.8						0.8	0.0		0.8	
Bear_Ck_S020				0.8			0.8						0.8	0.0		0.8	
Benbrook_S010				0.8			0.8						0.8	0.0		0.8	
Benbrook_S020				0.8			0.8						0.8	0.0		0.8	
Benbrook_S030				0.8			0.8						0.8	0.0		0.8	
Clear_Fork_S030				0.8			0.4						0.8	0.8		0.4	
Marys_Ck_S010			0.1	0.8			0.8						0.5	0.5		0.1	
Clear_Fork_S040				0.3			1.4						0.8	0.4		0.4	
Clear_Fork_S050				0.4			0.8						0.8	0.8		2.0	
West_Fork_S240				2.0			0.8						0.8	5.0		0.8	
Marine_Ck_S020				0.4			0.8						0.8	5.0		0.8	
Marine_Ck_S010				2.0			0.8						0.8	5.0		0.8	
West_Fork_S250				2.0			0.8						0.8	5.0		0.8	
West_Fork_S260				2.0			0.8						0.8	5.0		0.8	
West_Fork_S270				0.8			1.5						3.0	3.0		0.9	
Big_Fossil_Ck_S010				2.0			0.8						3.0	3.0		0.9	
LittleFossil_Ck_S010				0.8			1.5						3.0	3.0		0.9	
West_Fork_S280				0.8			1.5						3.0	3.0		0.9	
Village_Ck_S010				0.8			1.5						0.2	0.2		0.1	
Village_Ck_S020				0.4			1.1						0.8	0.8		0.8	
Lake_Arlington_S010				0.8			0.8						0.8	0.8		0.8	
Village_Ck_S030				0.8			0.8						3.0	3.0		0.9	
West_Fork_S290				0.8			1.5						3.0	3.0		0.9	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S300				0.8			1.5						3.0	3.0		0.9	
West_Fork_S310				0.8			1.5						3.0	3.0		0.9	
West_Fork_S320	0.0											0.0				0.0	
Big_Bear_Ck_S010	0.0											0.0				0.0	
Big_Bear_Ck_S020	0.0											0.0				0.0	
West_Fork_S330	0.0											0.0				0.0	
Joe_Pool_S020	0.1											0.1				0.1	
Joe_Pool_S030	0.2											0.0				0.0	
Joe_Pool_S040	0.1											0.1				0.1	
Joe_Pool_S010	0.0											0.0				0.1	
Joe_Pool_S050	0.1											0.1				0.1	
Mountain_Ck_S010	0.1											0.0				0.1	
Mountain_Ck_S020	0.1											0.0				0.1	
Mountain_Ck_S030	0.0											0.0				0.0	
West_Fork_S340	0.0											0.0				0.0	
Elm_Fork_S020	0.8							0.2				0.0				0.1	
Elm_Fork_S010	0.8							0.2				0.0				0.1	
Brushy_Elm_Ck_S010	0.8							0.2				0.0				0.1	
Brushy_Elm_Ck_S020	0.8							0.2				0.0				0.1	
Elm_Fork_S030	0.8							0.2				0.0				0.1	
Elm_Fork_S040	0.8							0.2				0.0				0.1	
Elm_Fork_S050	0.1							0.0				0.0				0.1	
Elm_Fork_S070	0.1							0.0				0.0				0.1	
Elm_Fork_S060	0.1							0.0				0.0				0.1	
Spring_Ck_S010	0.1							0.0				0.0				0.1	
Spring_Ck_S020	0.1							0.0				0.0				0.1	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Ray_Roberts_S010	0.1							0.0				0.0				0.1	
Timber_Ck_S010	0.1							0.0				0.0				0.0	
Timber_Ck_S030	0.1							0.0				0.0				0.0	
Timber_Ck_S020	0.1							0.0				0.0				0.0	
Ray_Roberts_S030	0.1							0.0				0.0				0.0	
Range_Ck_S010	0.1							0.0				0.0				0.0	
Range_Ck_S020	0.1							0.0				0.0				0.0	
Lake_Kiowa_S020	0.1							0.0				0.0				0.0	
Lake_Kiowa_S010	0.1							0.0				0.0				0.0	
Ray_Roberts_S020	0.1							0.0				0.0				0.1	
Range_Ck_S030	0.1							0.0				0.0				0.0	
Buck_Ck_S010	0.1							0.0				0.0				0.0	
Ray_Roberts_S050	0.1							0.0				0.0				0.0	
Ray_Roberts_S040	0.8							0.0				0.8				0.0	
Ray_Roberts_S060	0.1							0.0				0.0				0.0	
Timber_Ck_S040	0.1							0.0				0.0				0.0	
Elm_Fork_S080	0.1							0.1				0.0				0.1	
Clear_Ck_S010	0.5							0.1				0.1				0.1	
Clear_Ck_S020	0.5							0.1				0.1				0.1	
Clear_Ck_S030	0.5							0.1				0.1				0.1	
Clear_Ck_S040	0.5							0.1				0.1				0.1	
Clear_Ck_S050	0.5							0.1				0.1				0.1	
Clear_Ck_S070	0.5							0.1				0.1				0.1	
Clear_Ck_S060	0.5							0.1				0.1				0.1	
Clear_Ck_S080	0.5							0.1				0.1				0.1	
Clear_Ck_S090	0.5							0.1				0.1				0.1	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Clear_Ck_S110	0.1							0.1				0.0				0.1	
Clear_Ck_S100	0.1							0.1				0.0				0.1	
Clear_Ck_S120	0.1							0.1				0.0				0.1	
Little_Elm_Ck_S010	0.1							0.0				0.0				0.1	
Little_Elm_Ck_S020	0.1							0.0				0.0				0.1	
Little_Elm_Ck_S030	0.1							0.1				0.0				0.1	
Pecan_Ck_S010	0.1							0.1				0.0				0.1	
Doe_Branch_S010	0.1							0.1				2.0				0.4	
Doe_Branch_S020	0.1							0.1				0.0				0.1	
Lewisville_S030	0.1							0.1				0.0				0.1	
Hickory_Ck_S020	0.1							0.1				0.0				0.1	
Hickory_Ck_S010	0.1							0.1				0.0				0.1	
Hickory_Ck_S030	0.1							0.1				0.0				0.1	
Hickory_Ck_S040	0.1							0.1				0.0				0.1	
Hickory_Ck_S050	0.1							0.1				0.0				0.1	
Lewisville_S010	0.1							0.1				0.0				0.1	
Lewisville_S040	0.1							0.1				0.0				0.1	
Lewisville_S050	0.1							0.1				0.0				0.1	
Lewisville_S020	0.1							0.1				0.0				0.1	
Elm_Fork_S090	6.0											0.0				0.0	
Elm_Fork_S110	6.0											0.2				0.4	
Elm_Fork_S100	6.0											0.0				0.0	
Elm_Fork_S120	6.0											0.0				0.0	
Denton_Ck_S010	0.4							0.2				0.1				0.0	
Denton_Ck_S020	0.4							0.2				0.1				0.0	
Denton_Ck_S030	0.4							0.2				0.1				0.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Denton_Ck_S040	0.4							0.2				0.1				0.0	
Denton_Ck_S050	0.0							0.3				0.2				0.3	
Denton_Ck_S060	0.0							0.3				0.2				0.3	
Denton_Ck_S070	0.0							0.3				0.2				0.3	
Grapevine_S010	0.0							0.3				0.2				0.3	
Denton_Ck_S080	6.0											0.0				6.0	
Elm_Fork_S130	0.0											0.0				0.0	
Hackberry_Ck_S010	0.0											0.0				0.0	
Hackberry_Ck_S020	0.0											0.0				0.0	
Hackberry_Ck_S030	0.0											0.0				0.0	
Elm_Fork_S140	0.0											0.0				0.0	
Elm_Fork_S150	0.0											0.0				0.0	
Bachman_Branch_S010	0.0											0.0				0.0	
Bachman_Branch_S020	0.0											0.0				0.0	
Elm_Fork_S160	0.0											0.0				0.0	
Trinity_River_S010	0.0											0.0				0.0	
Trinity_River_S020	0.0											0.0				0.0	
White_Rock_Ck_S010	1.0											0.3				0.5	
White_Rock_Ck_S020	1.0											0.0				0.5	
White_Rock_Ck_S030	1.0											0.0				0.5	
White_Rock_Ck_S040	0.0											0.0				0.0	
Trinity_River_S030	0.0											0.0				0.0	
Fivemile_Ck_S010												1.7				3.4	
Trinity_River_S040												0.0				3.0	
Trinity_River_S050												0.0				3.0	
Tenmile_Ck_S010												0.0				3.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Tenmile_Ck_S020												0.0				3.0	
Trinity_River_S060												0.0				3.0	
Indian_Ck_S010								3.6					2.5			0.1	0.2
Indian_Ck_S030								0.6					0.6			0.6	
Indian_Ck_S020								0.6					0.6			0.6	
Indian_Ck_S040								0.6					0.6			0.3	
Sister_Grove_S010								4.0					1.0			0.3	
Sister_Grove_S020								0.6					0.6			0.3	
East_Fork_S020								1.7					0.4			0.1	
East_Fork_S010								1.6					0.4			0.1	
East_Fork_S030								0.6					0.4			0.6	
East_Fork_S040								0.6					0.6			0.6	
Wilson_Ck_S010								0.6					0.6			0.6	
Lavon_S010								0.6					0.6			0.6	
Lavon_S020								0.6					0.6			0.6	
Rowlett_Ck_S010								1.0					2.6			1.4	
Ray_Hubbard_S010								0.2					0.2			0.2	
Ray_Hubbard_S020								0.2					0.2			0.2	
East_Fork_S050								0.1					5.0			0.1	
East_Fork_S070					1.2			0.1				0.0					
East_Fork_S060					1.2			0.1				0.0					
East_Fork_S080					1.2			0.1				0.0					
East_Fork_S090					1.2			0.1				0.0					
East_Fork_S110					1.2			0.1				0.0					
East_Fork_S100					1.2			0.1				0.0					
Trinity_River_S070												0.0				3.0	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
East_Fork_S120												0.0				3.0	
Kings_Ck_S020													0.8			0.2	0.1
Kings_Ck_S010													0.8			0.2	0.1
Kings_Ck_S030								0.1					0.1			0.1	0.3
Cedar_Ck_S040								0.1					0.1			0.1	0.3
Cedar_Ck_S010								0.0					0.1				0.0
New_Terrell_City_Lake_S010								0.1					0.1			0.1	
Cedar_Ck_S020								0.1					0.1			0.1	0.3
Cedar_Ck_S030								0.1					0.1			0.1	0.3
Trinity_River_S080													0.0				
Trinity_River_S090								1.0					1.0			0.0	
Chambers_Ck_S010										0.0	6.0		0.1		0.1		
Chambers_Ck_S020										0.0	6.0		0.1		0.1		
Chambers_Ck_S040										0.0	5.0		0.1		0.1		
Chambers_Ck_S030										0.0	5.0		0.1		0.1		
Waxahachie_Ck_S010										0.1	7.8		0.2		0.1		
Waxahachie_Ck_S020										0.1	30.0		12.0		0.1		
Waxahachie_Ck_S030										0.1	0.1		0.1		0.1		
Mustang_Ck_S010										0.1	0.1		0.1		0.1		
Bardwell_S010										0.1	0.1		0.1		0.1		
Chambers_Ck_S050										0.0	5.0		0.1		0.1		
Chambers_Ck_S060										0.0	5.0		0.1		0.1		
Chambers_Ck_S070										0.1	5.0		0.1		0.1		
Chambers_Ck_S080											0.1		0.1		0.1		
Post_Oak_Ck_S010											0.1		0.1		0.1		
Lake_Halbert_S010										0.1	0.0		0.1		2.0		

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Navarro_Mills_S020										0.1	3.0		0.1		0.1		
Navarro_Mills_S030										0.1	3.0		0.1		0.1		
Navarro_Mills_S010										0.1	5.0		1.5		0.1		
Navarro_Mills_S040										0.1	3.0		0.1		0.1		
Richland_Ck_S010											0.1		0.1		0.1		
Richland_Ck_S020											0.1		0.1		0.1		
Richland-Chambers_S010											0.1		0.1		0.1		
Richland-Chambers_S020											0.1		0.1		0.1		
Tehuacana_Ck_S020								1.0					1.0			0.0	
Tehuacana_Ck_S010					0.3				0.9				0.7				0.1
Trinity_River_S100								1.0					1.0			0.0	
Fairfield_Lake_S010								1.0					1.0			0.0	
Trinity_River_S110								1.0					1.0			0.0	
Big_Brown_Ck_S010								1.0					1.0			0.0	
Trinity_River_S120								1.0					1.0			0.0	
Trinity_River_S130								0.1					5.0			0.0	
Upper_Keechi_Ck_S030								0.1					5.0			0.0	
Upper_Keechi_Ck_S010									0.3				0.6				0.4
Upper_Keechi_Ck_S020								0.1					5.0			0.0	
Upper_Keechi_Ck_S040								0.1					5.0			0.0	
Trinity_River_S140								0.1					5.0			0.0	
Little_Elkhart_S010								0.1					5.0			0.0	
Houston_County_Lake_S010					1.0								1.0			1.0	
Trinity_River_S150								0.1					5.0			0.0	
Trinity_River_S160					3.0			0.1					6.0				0.1
Trinity_River_S170					3.0			0.1					6.0				0.1

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S180					3.0			0.1					6.0				0.1
Bedias_Ck_S010													2.9				0.0
Bedias_Ck_S020					3.0			0.1					6.0				0.1
Trinity_River_S190					3.0			0.1					6.0				0.1
Livingston_S010					3.0			0.1					6.0				0.1
Livingston_S030					3.0			0.1					6.0				0.1
Livingston_S020					3.0			0.1					6.0				0.1
Trinity_River_S200								0.1					3.0			0.0	
Long_King_Ck_S010		0.3			0.1	0.1											
Long_King_Ck_S020								0.1					3.0			0.0	
Trinity_River_S210								0.1					3.0			0.0	
Menard_Ck_S010		0.8				0.5							0.7				
Trinity_River_S220								0.1					3.0			0.0	
Trinity_River_S230								0.1					0.0			0.0	
Trinity_River_S240								0.1					0.0			0.0	
Trinity_River_S250								0.1					0.1			0.0	

Table 17: Calibrated Baseflow Recession Constant

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S020				0.6			0.6						0.6	0.8		0.8	
West_Fork_S010				0.6			0.6						0.6	0.8		0.8	
West_Fork_S030				0.6			0.6						0.6	0.8		0.8	
West_Fork_S040				0.6			0.6						0.6	0.8		0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S050				0.6			0.6						0.6	0.8		0.8	
West_Fork_S060				0.6			0.5						0.5	0.8		0.8	
West_Fork_S070				0.6			0.5						0.5	0.8		0.8	
West_Fork_S080				0.6			0.6						0.6	0.8		0.8	
West_Fork_S090				0.6			0.6						0.6	0.8		0.8	
West_Fork_S100				0.6			0.5						0.5	0.8		0.8	
West_Fork_S120				0.6			0.5						0.5	0.8		0.8	
West_Fork_S110				0.6			0.6						0.6	0.7		0.7	
Big_Cleveland_S010				0.6			0.5						0.5	0.8		0.8	
Big_Cleveland_S020				0.6			0.6						0.6	0.8		0.8	
West_Fork_S130				0.6			0.6						0.6	0.7		0.7	
Lost_Ck_S010				0.8			0.7						0.8	0.8		0.8	
Lost_Ck_S020				0.8			0.6						0.4	0.8		0.6	
West_Fork_S140				0.8			0.6						0.4	0.8		0.7	
West_Fork_S150				0.8			0.6						0.4	0.8		0.6	
West_Fork_S160				0.8			0.6						0.6	0.8		0.8	
Beans_Ck_S010				0.8			0.6						0.6	0.8		0.9	
Beans_Ck_S020				0.8			0.6						0.6	0.8		0.9	
Big_Ck_S010				0.8			0.6						0.7	0.8		0.9	
Big_Ck_S030				0.8			0.6						0.6	0.8		1.0	
Big_Ck_S020				0.8			0.6						0.7	0.8		0.9	
Bridgeport_S030				0.8			0.6						0.7	0.8		0.9	
Bridgeport_S010				0.8			0.6						0.6	0.8		0.8	
Bridgeport_S040				0.8			0.6						0.4	0.8		0.7	
Bridgeport_S020				0.8			0.6						0.4	0.8		0.6	
West_Fork_S170				0.7			0.7						0.7	0.7		0.7	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Dry_Ck_S010				0.7			0.7						0.7	0.7		0.7	
West_Fork_S180				0.7			0.7						0.7	0.7		0.7	
Amon_G_Carter_S030				0.7			0.7						0.7	0.8		0.8	
Amon_G_Carter_S010				0.7			0.7						0.7	0.8		0.8	
Amon_G_Carter_S020				0.7			0.7						0.7	0.8		0.8	
Big_Sandy_Ck_S010				0.7			0.7						0.5	0.7		0.7	
Big_Sandy_Ck_S020				0.7			0.7						0.5	0.7		0.7	
Brushy_Ck_S010				0.7			0.7						0.5	0.7		0.7	
Brushy_Ck_S020				0.7			0.7						0.5	0.7		0.7	
Brushy_Ck_S030				0.7			0.7						0.5	0.7		0.7	
Big_Sandy_Ck_S030				0.7			0.7						0.5	0.7		0.7	
Big_Sandy_Ck_S040				0.7			0.7						0.5	0.7		0.7	
Big_Sandy_Ck_S050				0.7			0.7						0.7	0.7		0.7	
West_Fork_S190				0.7			0.7						0.7	0.7		0.7	
West_Fork_S200				0.7			0.7						0.7	0.7		0.7	
Garrett_Ck_S020				0.7			0.7						0.7	0.7		0.7	
Garrett_Ck_S010				0.7			0.7						0.7	0.7		0.7	
Garrett_Ck_S030				0.7			0.7						0.7	0.7		0.7	
Salt_Ck_S010				0.7			0.7						0.7	0.7		0.7	
Salt_Ck_S020				0.7			0.7						0.7	0.7		0.7	
West_Fork_S210				0.7			0.7						0.7	0.7		0.7	
West_Fork_S220				0.5			0.5						0.5	0.7		0.7	
Eagle_Mountain_S010				0.5			0.5						0.5	0.7		0.7	
Eagle_Mountain_S020				0.5			0.5						0.5	0.7		0.7	
Walnut_Ck_S020				0.5			0.5						0.7	0.7		0.7	
Walnut_Ck_S010				0.5			0.5						0.7	0.7		0.7	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Walnut_Ck_S030				0.5			0.5						0.5	0.7		0.7	
Eagle_Mountain_S040				0.5			0.5						0.5	0.7		0.7	
Eagle_Mountain_S030				0.5			0.5						0.5	0.7		0.7	
Silver_Ck_S020				0.8			0.5						0.5	0.5		0.5	
Silver_Ck_S010				0.8			0.5						0.5	0.5		0.5	
Lake_Worth_S010				0.8			0.5						0.5	0.5		0.5	
Lake_Worth_S020				0.8			0.5						0.5	0.5		0.5	
West_Fork_S230				0.7			0.7						0.7	0.7		0.7	
Lk_Weatherford_S010				0.7			0.7						0.7	0.8		0.7	
Lk_Weatherford_S020				0.7			0.7						0.7	0.8		0.7	
Clear_Fork_S010				0.7			0.7						0.7	0.7		0.7	
Clear_Fork_S020				0.7			0.7						0.7	0.7		0.7	
Bear_Ck_S010				0.7			0.7						0.7	0.7		0.7	
Bear_Ck_S020				0.7			0.7						0.7	0.7		0.7	
Benbrook_S010				0.7			0.7						0.7	0.7		0.7	
Benbrook_S020				0.7			0.7						0.7	0.7		0.7	
Benbrook_S030				0.7			0.7						0.7	0.7		0.7	
Clear_Fork_S030				0.7			0.7						0.7	0.7		0.8	
Marys_Ck_S010			0.7	0.7			0.7						0.8	0.8		0.7	
Clear_Fork_S040				0.7			0.7						0.7	0.7		0.8	
Clear_Fork_S050				0.7			0.7						0.7	0.7		0.7	
West_Fork_S240				0.7			0.7						0.7	0.7		0.7	
Marine_Ck_S020				0.7			0.7						0.7	0.7		0.7	
Marine_Ck_S010				0.7			0.7						0.7	0.7		0.7	
West_Fork_S250				0.7			0.7						0.7	0.7		0.7	
West_Fork_S260				0.7			0.7						0.7	0.7		0.7	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S270				0.7			0.7						0.7	0.7		0.7	
Big_Fossil_Ck_S010				0.7			0.7						0.7	0.7		0.7	
LittleFossil_Ck_S010				0.7			0.7						0.7	0.7		0.7	
West_Fork_S280				0.7			0.7						0.7	0.7		0.7	
Village_Ck_S010				0.6			0.6						0.6	0.7		0.6	
Village_Ck_S020				0.5			0.5						0.6	0.5		0.6	
Lake_Arlington_S010				0.5			0.5						0.6	0.5		0.6	
Village_Ck_S030				0.7			0.7						0.7	0.7		0.7	
West_Fork_S290				0.7			0.7						0.7	0.7		0.7	
West_Fork_S300				0.7			0.7						0.7	0.7		0.7	
West_Fork_S310				0.7			0.7						0.7	0.7		0.7	
West_Fork_S320	0.7											0.7				0.7	
Big_Bear_Ck_S010	0.4											0.7				0.4	
Big_Bear_Ck_S020	0.4											0.7				0.4	
West_Fork_S330	0.7											0.7				0.7	
Joe_Pool_S020	0.5											0.3				0.5	
Joe_Pool_S030	0.5											0.5				0.7	
Joe_Pool_S040	0.5											0.3				0.5	
Joe_Pool_S010	0.5											0.3				0.5	
Joe_Pool_S050	0.5											0.3				0.5	
Mountain_Ck_S010	0.5											0.7				0.7	
Mountain_Ck_S020	0.5											0.7				0.7	
Mountain_Ck_S030	0.7											0.7				0.7	
West_Fork_S340	0.8											0.8				0.8	
Elm_Fork_S020	0.9							0.8				0.8				0.8	
Elm_Fork_S010	0.9							0.8				0.8				0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Brushy_Elm_Ck_S010	0.9							0.8				0.8				0.8	
Brushy_Elm_Ck_S020	0.9							0.8				0.8				0.8	
Elm_Fork_S030	0.9							0.8				0.8				0.8	
Elm_Fork_S040	0.9							0.8				0.8				0.8	
Elm_Fork_S050	0.2							0.2				0.2				0.2	
Elm_Fork_S070	0.2							0.2				0.2				0.2	
Elm_Fork_S060	0.2							0.2				0.2				0.2	
Spring_Ck_S010	0.2							0.2				0.2				0.2	
Spring_Ck_S020	0.2							0.2				0.2				0.2	
Ray_Roberts_S010	0.2							0.2				0.2				0.2	
Timber_Ck_S010	0.8							0.5				0.2				0.5	
Timber_Ck_S030	0.2							0.2				0.2				0.2	
Timber_Ck_S020	0.2							0.2				0.2				0.2	
Ray_Roberts_S030	0.2							0.2				0.2				0.2	
Range_Ck_S010	0.4							0.3				0.2				0.4	
Range_Ck_S020	0.2							0.2				0.2				0.2	
Lake_Kiowa_S020	0.2							0.2				0.2				0.2	
Lake_Kiowa_S010	0.2							0.2				0.2				0.2	
Ray_Roberts_S020	0.2							0.2				0.2				0.2	
Range_Ck_S030	0.2							0.2				0.2				0.2	
Buck_Ck_S010	0.2							0.2				0.2				0.2	
Ray_Roberts_S050	0.2							0.2				0.2				0.2	
Ray_Roberts_S040	0.7							0.2				0.7				0.2	
Ray_Roberts_S060	0.2							0.2				0.2				0.2	
Timber_Ck_S040	0.2							0.2				0.2				0.2	
Elm_Fork_S080	0.8							0.8				0.7				0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Clear_Ck_S010	0.9							0.7				0.8				0.9	
Clear_Ck_S020	0.9							0.7				0.8				0.9	
Clear_Ck_S030	0.9							0.7				0.8				0.9	
Clear_Ck_S040	0.9							0.7				0.8				0.9	
Clear_Ck_S050	0.9							0.7				0.8				0.9	
Clear_Ck_S070	0.9							0.7				0.8				0.9	
Clear_Ck_S060	0.9							0.7				0.8				0.9	
Clear_Ck_S080	0.9							0.7				0.8				0.9	
Clear_Ck_S090	0.9							0.7				0.8				0.9	
Clear_Ck_S110	0.8							0.8				0.7				0.8	
Clear_Ck_S100	0.8							0.8				0.7				0.8	
Clear_Ck_S120	0.8							0.8				0.7				0.8	
Little_Elm_Ck_S010	0.9							0.8				0.8				0.9	
Little_Elm_Ck_S020	0.9							0.8				0.8				0.9	
Little_Elm_Ck_S030	0.7							0.8				0.7				0.8	
Pecan_Ck_S010	0.7							0.8				0.7				0.8	
Doe_Branch_S010	0.8							0.8				0.7				0.8	
Doe_Branch_S020	0.7							0.8				0.7				0.8	
Lewisville_S030	0.7							0.8				0.7				0.8	
Hickory_Ck_S020	0.8							0.8				0.7				0.8	
Hickory_Ck_S010	0.8							0.8				0.7				0.8	
Hickory_Ck_S030	0.8							0.8				0.7				0.8	
Hickory_Ck_S040	0.8							0.8				0.7				0.8	
Hickory_Ck_S050	0.8							0.8				0.7				0.8	
Lewisville_S010	0.7							0.8				0.7				0.8	
Lewisville_S040	0.7							0.8				0.7				0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Lewisville_S050	0.7							0.8				0.7				0.8	
Lewisville_S020	0.8							0.8				0.7				0.8	
Elm_Fork_S090	0.7											0.5				0.5	
Elm_Fork_S110	0.7											0.4				0.7	
Elm_Fork_S100	0.7											0.5				0.5	
Elm_Fork_S120	0.7											0.5				0.5	
Denton_Ck_S010	0.8							0.8				0.7				0.8	
Denton_Ck_S020	0.8							0.8				0.7				0.8	
Denton_Ck_S030	0.8							0.8				0.7				0.8	
Denton_Ck_S040	0.8							0.8				0.7				0.8	
Denton_Ck_S050	0.7							0.7				0.6				0.7	
Denton_Ck_S060	0.7							0.7				0.6				0.7	
Denton_Ck_S070	0.7							0.8				0.6				0.7	
Grapevine_S010	0.7							0.7				0.6				0.7	
Denton_Ck_S080	0.7											0.5				0.8	
Elm_Fork_S130	0.5											0.5				0.5	
Hackberry_Ck_S010	0.5											0.5				0.5	
Hackberry_Ck_S020	0.5											0.5				0.5	
Hackberry_Ck_S030	0.5											0.5				0.5	
Elm_Fork_S140	0.5											0.5				0.5	
Elm_Fork_S150	0.5											0.5				0.5	
Bachman_Branch_S010	0.8											0.8				0.8	
Bachman_Branch_S020	0.8											0.8				0.8	
Elm_Fork_S160	0.8											0.8				0.8	
Trinity_River_S010	0.8											0.8				0.8	
Trinity_River_S020	0.5											0.5				0.5	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
White_Rock_Ck_S010	0.8											0.6				0.7	
White_Rock_Ck_S020	0.8											0.6				0.7	
White_Rock_Ck_S030	0.8											0.6				0.7	
White_Rock_Ck_S040	0.8											0.5				0.5	
Trinity_River_S030	0.8											0.5				0.5	
Fivemile_Ck_S010												1.0				1.0	
Trinity_River_S040												0.6				0.6	
Trinity_River_S050												0.6				0.6	
Tenmile_Ck_S010												0.6				0.6	
Tenmile_Ck_S020												0.6				0.6	
Trinity_River_S060												0.6				0.6	
Indian_Ck_S010								0.8					0.8			0.9	0.7
Indian_Ck_S030								0.7					0.7			0.7	
Indian_Ck_S020								0.7					0.7			0.9	
Indian_Ck_S040								0.7					0.7			0.9	
Sister_Grove_S010								0.9					0.9			0.7	
Sister_Grove_S020								0.7					0.7			0.9	
East_Fork_S020								0.9					0.9			0.9	
East_Fork_S010								0.9					0.9			0.9	
East_Fork_S030								0.9					0.9			0.9	
East_Fork_S040								0.7					0.7			0.9	
Wilson_Ck_S010								0.7					0.7			0.9	
Lavon_S010								0.7					0.7			0.9	
Lavon_S020								0.7					0.7			0.9	
Rowlett_Ck_S010								0.9					0.8			0.7	
Ray_Hubbard_S010								0.8					0.7			0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Ray_Hubbard_S020								0.8					0.7			0.8	
East_Fork_S050								0.8					0.8			0.8	
East_Fork_S070					0.6			0.6				0.6					
East_Fork_S060					0.5			0.5				0.5					
East_Fork_S080					0.5			0.5				0.5					
East_Fork_S090					0.5			0.5				0.5					
East_Fork_S110					0.5			0.5				0.5					
East_Fork_S100					0.5			0.5				0.5					
Trinity_River_S070												0.6				0.6	
East_Fork_S120												0.6				0.6	
Kings_Ck_S020													0.8			0.8	0.8
Kings_Ck_S010													0.8			0.8	0.8
Kings_Ck_S030								0.9					0.8			0.8	0.8
Cedar_Ck_S040								0.9					0.8			0.8	0.8
Cedar_Ck_S010								0.9					0.9				0.7
New_Terrell_City_Lake_S010								0.9					0.9			0.9	
Cedar_Ck_S020								0.9					0.8			0.8	0.8
Cedar_Ck_S030								0.9					0.8			0.8	0.8
Trinity_River_S080													0.8				
Trinity_River_S090								0.9					0.9			0.9	
Chambers_Ck_S010										0.7	0.7		0.7		0.6		
Chambers_Ck_S020										0.7	0.7		0.7		0.6		
Chambers_Ck_S040										0.7	0.7		0.7		0.6		
Chambers_Ck_S030										0.7	0.7		0.7		0.6		
Waxahachie_Ck_S010										0.9	0.9		0.9		0.9		
Waxahachie_Ck_S020										1.0	0.9		1.0		1.0		

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Waxahachie_Ck_S030										0.8	0.6		0.6		0.6		
Mustang_Ck_S010										0.8	0.6		0.6		0.6		
Bardwell_S010										0.8	0.6		0.6		0.6		
Chambers_Ck_S050										0.7	0.7		0.7		0.6		
Chambers_Ck_S060										0.7	0.7		0.7		0.6		
Chambers_Ck_S070										0.7	0.7		0.7		0.6		
Chambers_Ck_S080											0.7		0.9		0.5		
Post_Oak_Ck_S010											0.7		0.9		0.8		
Lake_Halbert_S010										0.9	0.9		0.9		0.6		
Navarro_Mills_S020										0.6	0.6		0.9		0.9		
Navarro_Mills_S030										0.6	0.6		0.9		0.9		
Navarro_Mills_S010										0.6	0.8		0.1		0.7		
Navarro_Mills_S040										0.6	0.6		0.9		0.9		
Richland_Ck_S010											0.9		0.9		0.8		
Richland_Ck_S020											0.9		0.9		0.8		
Richland-Chambers_S010											0.9		0.9		0.8		
Richland-Chambers_S020											0.9		0.9		0.8		
Tehuacana_Ck_S020								0.9					0.9			0.9	
Tehuacana_Ck_S010					0.8				0.1				0.6				0.6
Trinity_River_S100								0.9					0.9			0.9	
Fairfield_Lake_S010								0.9					0.9			0.9	
Trinity_River_S110								0.9					0.9			0.9	
Big_Brown_Ck_S010								0.9					0.9			0.9	
Trinity_River_S120								0.9					0.9			0.9	
Trinity_River_S130								0.8					0.8			0.8	
Upper_Keechi_Ck_S030								0.8					0.8			0.8	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Upper_Keechi_Ck_S010									0.6				0.5				0.5
Upper_Keechi_Ck_S020								0.8					0.8			0.8	
Upper_Keechi_Ck_S040								0.8					0.8			0.8	
Trinity_River_S140								0.8					0.8			0.8	
Little_Elkhart_S010								0.8					0.8			0.8	
Houston_County_Lake_S010					0.7								0.8			0.8	
Trinity_River_S150								0.8					0.8			0.8	
Trinity_River_S160					0.6			0.6					0.6				0.6
Trinity_River_S170					0.6			0.6					0.6				0.6
Trinity_River_S180					0.6			0.6					0.6				0.6
Bedias_Ck_S010													0.8				0.9
Bedias_Ck_S020					0.6			0.6					0.6				0.6
Trinity_River_S190					0.6			0.6					0.6				0.6
Livingston_S010					0.6			0.6					0.6				0.6
Livingston_S030					0.6			0.6					0.6				0.6
Livingston_S020					0.6			0.6					0.6				0.6
Trinity_River_S200								0.6					0.6			0.6	
Long_King_Ck_S010		0.8			0.8	0.8											
Long_King_Ck_S020								0.6					0.6			0.6	
Trinity_River_S210								0.6					0.6			0.6	
Menard_Ck_S010		0.8				0.8							0.8				
Trinity_River_S220								0.6					0.6			0.6	
Trinity_River_S230								0.8					0.8			0.8	
Trinity_River_S240								0.8					0.8			0.8	
Trinity_River_S250								0.8					0.8			0.8	

Table 18: Calibrated Baseflow Ratio to Peak

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_S020				0.02			0.01						0.02	0.04		0.01	
West_Fork_S010				0.02			0.01						0.02	0.04		0.01	
West_Fork_S030				0.02			0.01						0.02	0.04		0.01	
West_Fork_S040				0.02			0.01						0.02	0.04		0.01	
West_Fork_S050				0.02			0.01						0.02	0.04		0.01	
West_Fork_S060				0.02			0.01						0.01	0.04		0.01	
West_Fork_S070				0.02			0.02						0.02	0.04		0.01	
West_Fork_S080				0.02			0.02						0.02	0.04		0.01	
West_Fork_S090				0.02			0.02						0.02	0.04		0.01	
West_Fork_S100				0.02			0.02						0.02	0.04		0.01	
West_Fork_S120				0.02			0.02						0.01	0.04		0.01	
West_Fork_S110				0.02			0.02						0.02	0.04		0.01	
Big_Cleveland_S010				0.02			0.02						0.02	0.04		0.01	
Big_Cleveland_S020				0.02			0.02						0.02	0.04		0.01	
West_Fork_S130				0.02			0.02						0.02	0.04		0.01	
Lost_Ck_S010				0.02			0.04						0.03	0.05		0.10	
Lost_Ck_S020				0.03			0.01						0.02	0.08		0.05	
West_Fork_S140				0.03			0.01						0.01	0.08		0.05	
West_Fork_S150				0.03			0.01						0.02	0.08		0.05	
West_Fork_S160				0.03			0.01						0.02	0.08		0.05	
Beans_Ck_S010				0.03			0.01						0.02	0.08		0.05	
Beans_Ck_S020				0.03			0.01						0.02	0.08		0.05	
Big_Ck_S010				0.03			0.01						0.01	0.08		0.05	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Big_Ck_S030				0.03			0.01						0.02	0.08		0.05	
Big_Ck_S020				0.03			0.01						0.02	0.08		0.05	
Bridgeport_S030				0.03			0.01						0.02	0.08		0.05	
Bridgeport_S010				0.03			0.01						0.02	0.08		0.05	
Bridgeport_S040				0.03			0.01						0.02	0.08		0.05	
Bridgeport_S020				0.03			0.01						0.02	0.08		0.05	
West_Fork_S170				0.01			0.02						0.02	0.01		0.02	
Dry_Ck_S010				0.01			0.02						0.01	0.01		0.01	
West_Fork_S180				0.01			0.02						0.02	0.01		0.02	
Amon_G_Carter_S030				0.04			0.05						0.04	0.05		0.08	
Amon_G_Carter_S010				0.04			0.05						0.04	0.05		0.08	
Amon_G_Carter_S020				0.04			0.05						0.04	0.05		0.08	
Big_Sandy_Ck_S010				0.04			0.02						0.04	0.02		0.02	
Big_Sandy_Ck_S020				0.04			0.01						0.04	0.02		0.02	
Brushy_Ck_S010				0.04			0.02						0.04	0.04		0.02	
Brushy_Ck_S020				0.04			0.01						0.04	0.04		0.02	
Brushy_Ck_S030				0.04			0.01						0.04	0.10		0.02	
Big_Sandy_Ck_S030				0.04			0.01						0.04	0.02		0.02	
Big_Sandy_Ck_S040				0.04			0.01						0.04	0.02		0.02	
Big_Sandy_Ck_S050				0.01			0.02						0.02	0.01		0.02	
West_Fork_S190				0.01			0.02						0.02	0.01		0.02	
West_Fork_S200				0.01			0.02						0.02	0.01		0.02	
Garrett_Ck_S020				0.01			0.02						0.02	0.01		0.02	
Garrett_Ck_S010				0.01			0.02						0.01	0.01		0.01	
Garrett_Ck_S030				0.01			0.02						0.01	0.01		0.01	
Salt_Ck_S010				0.01			0.02						0.02	0.01		0.02	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Salt_Ck_S020				0.01			0.02						0.02	0.01		0.02	
West_Fork_S210				0.01			0.02						0.02	0.01		0.02	
West_Fork_S220				0.04			0.01						0.01	0.01		0.04	
Eagle_Mountain_S010				0.04			0.01						0.01	0.01		0.04	
Eagle_Mountain_S020				0.04			0.01						0.01	0.01		0.04	
Walnut_Ck_S020				0.02			0.02						0.02	0.01		0.02	
Walnut_Ck_S010				0.02			0.02						0.02	0.01		0.02	
Walnut_Ck_S030				0.04			0.01						0.01	0.01		0.04	
Eagle_Mountain_S040				0.04			0.01						0.01	0.01		0.04	
Eagle_Mountain_S030				0.04			0.01						0.01	0.01		0.04	
Silver_Ck_S020				0.05			0.01						0.01	0.02		0.02	
Silver_Ck_S010				0.05			0.01						0.01	0.02		0.02	
Lake_Worth_S010				0.05			0.01						0.01	0.02		0.02	
Lake_Worth_S020				0.05			0.01						0.01	0.02		0.02	
West_Fork_S230				0.05			0.05						0.05	0.05		0.10	
Lk_Weatherford_S010				0.05			0.05						0.05	0.01		0.05	
Lk_Weatherford_S020				0.05			0.05						0.05	0.02		0.05	
Clear_Fork_S010				0.09			0.02						0.09	0.09		0.09	
Clear_Fork_S020				0.09			0.02						0.09	0.09		0.09	
Bear_Ck_S010				0.09			0.02						0.09	0.09		0.09	
Bear_Ck_S020				0.09			0.02						0.09	0.09		0.09	
Benbrook_S010				0.09			0.02						0.09	0.09		0.09	
Benbrook_S020				0.09			0.02						0.09	0.09		0.09	
Benbrook_S030				0.09			0.02						0.09	0.09		0.09	
Clear_Fork_S030				0.04			0.02						0.02	0.05		0.05	
Marys_Ck_S010			0.02	0.02			0.02						0.10	0.02		0.03	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Clear_Fork_S040				0.04			0.02						0.02	0.05		0.05	
Clear_Fork_S050				0.05			0.05						0.05	0.05		0.10	
West_Fork_S240				0.05			0.01						0.05	0.05		0.05	
Marine_Ck_S020				0.05			0.01						0.05	0.05		0.05	
Marine_Ck_S010				0.05			0.01						0.05	0.05		0.05	
West_Fork_S250				0.05			0.01						0.05	0.05		0.05	
West_Fork_S260				0.05			0.01						0.05	0.05		0.05	
West_Fork_S270				0.01			0.05						0.01	0.01		0.05	
Big_Fossil_Ck_S010				0.01			0.05						0.01	0.01		0.05	
LittleFossil_Ck_S010				0.01			0.05						0.01	0.01		0.05	
West_Fork_S280				0.01			0.05						0.01	0.01		0.05	
Village_Ck_S010				0.07			0.04						0.05	0.05		0.05	
Village_Ck_S020				0.01			0.01						0.02	0.02		0.03	
Lake_Arlington_S010				0.01			0.01						0.02	0.02		0.03	
Village_Ck_S030				0.01			0.05						0.01	0.01		0.05	
West_Fork_S290				0.01			0.05						0.01	0.01		0.05	
West_Fork_S300				0.01			0.05						0.01	0.01		0.05	
West_Fork_S310				0.01			0.05						0.01	0.01		0.05	
West_Fork_S320	0.02											0.02				0.02	
Big_Bear_Ck_S010	0.01											0.02				0.01	
Big_Bear_Ck_S020	0.01											0.02				0.01	
West_Fork_S330	0.02											0.02				0.02	
Joe_Pool_S020	0.03											0.01				0.03	
Joe_Pool_S030	0.02											0.01				0.02	
Joe_Pool_S040	0.03											0.01				0.03	
Joe_Pool_S010	0.02											0.01				0.02	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Joe_Pool_S050	0.03											0.01				0.03	
Mountain_Ck_S010	0.02											0.01				0.02	
Mountain_Ck_S020	0.02											0.01				0.02	
Mountain_Ck_S030	0.02											0.02				0.02	
West_Fork_S340	0.02											0.02				0.02	
Elm_Fork_S020	0.06							0.04				0.16				0.09	
Elm_Fork_S010	0.06							0.04				0.16				0.09	
Brushy_Elm_Ck_S010	0.06							0.04				0.16				0.09	
Brushy_Elm_Ck_S020	0.06							0.04				0.16				0.09	
Elm_Fork_S030	0.06							0.04				0.16				0.09	
Elm_Fork_S040	0.06							0.04				0.16				0.09	
Elm_Fork_S050	0.03							0.02				0.01				0.03	
Elm_Fork_S070	0.03							0.02				0.01				0.03	
Elm_Fork_S060	0.03							0.02				0.01				0.03	
Spring_Ck_S010	0.03							0.02				0.01				0.03	
Spring_Ck_S020	0.03							0.02				0.01				0.03	
Ray_Roberts_S010	0.03							0.02				0.01				0.03	
Timber_Ck_S010	0.03							0.02				0.01				0.03	
Timber_Ck_S030	0.03							0.02				0.01				0.03	
Timber_Ck_S020	0.03							0.02				0.01				0.03	
Ray_Roberts_S030	0.03							0.02				0.01				0.03	
Range_Ck_S010	0.03							0.02				0.01				0.05	
Range_Ck_S020	0.03							0.02				0.01				0.03	
Lake_Kiowa_S020	0.03							0.02				0.01				0.03	
Lake_Kiowa_S010	0.03							0.02				0.01				0.03	
Ray_Roberts_S020	0.03							0.02				0.01				0.03	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Range_Ck_S030	0.03							0.02				0.01				0.03	
Buck_Ck_S010	0.03							0.02				0.01				0.03	
Ray_Roberts_S050	0.03							0.02				0.01				0.03	
Ray_Roberts_S040	0.05							0.03				0.05				0.03	
Ray_Roberts_S060	0.03							0.02				0.01				0.03	
Timber_Ck_S040	0.03							0.03				0.01				0.03	
Elm_Fork_S080	0.03							0.03				0.01				0.09	
Clear_Ck_S010	0.12							0.06				0.06				0.11	
Clear_Ck_S020	0.12							0.06				0.06				0.11	
Clear_Ck_S030	0.12							0.06				0.06				0.11	
Clear_Ck_S040	0.12							0.06				0.06				0.11	
Clear_Ck_S050	0.12							0.06				0.06				0.11	
Clear_Ck_S070	0.12							0.06				0.06				0.11	
Clear_Ck_S060	0.12							0.06				0.06				0.11	
Clear_Ck_S080	0.12							0.06				0.06				0.11	
Clear_Ck_S090	0.12							0.06				0.06				0.11	
Clear_Ck_S110	0.03							0.03				0.01				0.09	
Clear_Ck_S100	0.03							0.03				0.01				0.09	
Clear_Ck_S120	0.03							0.03				0.01				0.09	
Little_Elm_Ck_S010	0.10							0.08				0.07				0.13	
Little_Elm_Ck_S020	0.10							0.08				0.07				0.13	
Little_Elm_Ck_S030	0.03							0.02				0.01				0.09	
Pecan_Ck_S010	0.03							0.02				0.01				0.09	
Doe_Branch_S010	0.03							0.03				0.01				0.02	
Doe_Branch_S020	0.03							0.02				0.01				0.02	
Lewisville_S030	0.03							0.03				0.01				0.09	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Hickory_Ck_S020	0.03							0.02				0.02				0.04	
Hickory_Ck_S010	0.03							0.02				0.02				0.04	
Hickory_Ck_S030	0.03							0.02				0.02				0.04	
Hickory_Ck_S040	0.03							0.02				0.02				0.04	
Hickory_Ck_S050	0.03							0.02				0.01				0.09	
Lewisville_S010	0.03							0.02				0.01				0.09	
Lewisville_S040	0.03							0.02				0.01				0.09	
Lewisville_S050	0.03							0.02				0.01				0.09	
Lewisville_S020	0.03							0.02				0.01				0.09	
Elm_Fork_S090	0.05											0.05				0.02	
Elm_Fork_S110	0.05											0.02				0.03	
Elm_Fork_S100	0.05											0.02				0.02	
Elm_Fork_S120	0.05											0.02				0.02	
Denton_Ck_S010	0.15							0.03				0.09				0.10	
Denton_Ck_S020	0.15							0.03				0.09				0.10	
Denton_Ck_S030	0.15							0.03				0.09				0.10	
Denton_Ck_S040	0.15							0.03				0.09				0.10	
Denton_Ck_S050	0.01							0.01				0.01				0.02	
Denton_Ck_S060	0.01							0.01				0.01				0.02	
Denton_Ck_S070	0.01							0.01				0.01				0.02	
Grapevine_S010	0.01							0.01				0.01				0.02	
Denton_Ck_S080	0.05											0.02				0.02	
Elm_Fork_S130	0.02											0.02				0.02	
Hackberry_Ck_S010	0.02											0.02				0.02	
Hackberry_Ck_S020	0.02											0.02				0.02	
Hackberry_Ck_S030	0.02											0.02				0.02	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Elm_Fork_S140	0.02											0.02				0.02	
Elm_Fork_S150	0.02											0.02				0.02	
Bachman_Branch_S010	0.02											0.02				0.02	
Bachman_Branch_S020	0.02											0.02				0.02	
Elm_Fork_S160	0.02											0.02				0.02	
Trinity_River_S010	0.02											0.02				0.02	
Trinity_River_S020	0.02											0.02				0.02	
White_Rock_Ck_S010	0.03											0.02				0.02	
White_Rock_Ck_S020	0.03											0.02				0.02	
White_Rock_Ck_S030	0.03											0.02				0.02	
White_Rock_Ck_S040	0.03											0.02				0.02	
Trinity_River_S030	0.03											0.02				0.02	
Fivemile_Ck_S010												0.04				0.05	
Trinity_River_S040												0.04				0.05	
Trinity_River_S050												0.04				0.05	
Tenmile_Ck_S010												0.04				0.05	
Tenmile_Ck_S020												0.04				0.05	
Trinity_River_S060												0.04				0.05	
Indian_Ck_S010								0.10					0.10			0.20	0.20
Indian_Ck_S030								0.01					0.05			0.20	
Indian_Ck_S020								0.01					0.05			0.10	
Indian_Ck_S040								0.01					0.05			0.10	
Sister_Grove_S010								0.08					0.15			0.45	
Sister_Grove_S020								0.01					0.05			0.10	
East_Fork_S020								0.10					0.50			0.05	
East_Fork_S010								0.10					0.50			0.05	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
East_Fork_S030								0.10					0.10			0.05	
East_Fork_S040								0.01					0.07			0.10	
Wilson_Ck_S010								0.01					0.07			0.10	
Lavon_S010								0.01					0.08			0.10	
Lavon_S020								0.01					0.07			0.10	
Rowlett_Ck_S010								0.05					0.07			0.04	
Ray_Hubbard_S010								0.05					0.05			0.10	
Ray_Hubbard_S020								0.05					0.05			0.10	
East_Fork_S050								0.05					0.10			0.10	
East_Fork_S070					0.20			0.30				0.30					
East_Fork_S060					0.20			0.30				0.30					
East_Fork_S080					0.20			0.30				0.30					
East_Fork_S090					0.20			0.30				0.30					
East_Fork_S110					0.20			0.30				0.30					
East_Fork_S100					0.20			0.30				0.30					
Trinity_River_S070												0.04				0.05	
East_Fork_S120												0.04				0.05	
Kings_Ck_S020													0.05			0.10	0.05
Kings_Ck_S010													0.05			0.10	0.05
Kings_Ck_S030								0.10					0.04			0.35	0.09
Cedar_Ck_S040								0.10					0.04			0.35	0.09
Cedar_Ck_S010								0.01					0.05				0.23
New_Terrell_City_Lake_S010								0.10					0.10			0.10	
Cedar_Ck_S020								0.10					0.04			0.35	0.09
Cedar_Ck_S030								0.10					0.04			0.35	0.09
Trinity_River_S080													0.05				

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S090								0.16					0.05			0.05	
Chambers_Ck_S010										0.00	0.10		0.12		0.10		
Chambers_Ck_S020										0.00	0.10		0.12		0.10		
Chambers_Ck_S040										0.00	0.08		0.12		0.10		
Chambers_Ck_S030										0.00	0.08		0.12		0.10		
Waxahachie_Ck_S010										0.00	0.18		0.20		0.32		
Waxahachie_Ck_S020										0.00	0.15		0.20		0.30		
Waxahachie_Ck_S030										0.00	0.01		0.03		0.10		
Mustang_Ck_S010										0.00	0.01		0.03		0.10		
Bardwell_S010										0.00	0.01		0.03		0.10		
Chambers_Ck_S050										0.00	0.08		0.12		0.10		
Chambers_Ck_S060										0.00	0.08		0.12		0.10		
Chambers_Ck_S070										0.00	0.08		0.12		0.10		
Chambers_Ck_S080											0.20		0.05		0.20		
Post_Oak_Ck_S010											0.20		0.05		0.20		
Lake_Halbert_S010										0.00	0.01		0.01		0.10		
Navarro_Mills_S020										0.00	0.10		0.05		0.05		
Navarro_Mills_S030										0.00	0.10		0.05		0.05		
Navarro_Mills_S010										0.00	0.26		0.35		0.11		
Navarro_Mills_S040										0.00	0.10		0.05		0.05		
Richland_Ck_S010											0.20		0.05		0.10		
Richland_Ck_S020											0.20		0.05		0.10		
Richland-Chambers_S010											0.20		0.05		0.10		
Richland-Chambers_S020											0.20		0.05		0.10		
Tehuacana_Ck_S020								0.16					0.05			0.05	
Tehuacana_Ck_S010					0.02				0.50				0.02				0.01

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S100								0.16					0.05			0.05	
Fairfield_Lake_S010								0.16					0.05			0.05	
Trinity_River_S110								0.16					0.05			0.05	
Big_Brown_Ck_S010								0.16					0.05			0.05	
Trinity_River_S120								0.16					0.05			0.05	
Trinity_River_S130								0.00					0.05			0.00	
Upper_Keechi_Ck_S030								0.00					0.05			0.00	
Upper_Keechi_Ck_S010									0.20				0.70				0.20
Upper_Keechi_Ck_S020								0.00					0.05			0.00	
Upper_Keechi_Ck_S040								0.00					0.05			0.00	
Trinity_River_S140								0.00					0.05			0.00	
Little_Elkhart_S010								0.00					0.05			0.00	
Houston_County_Lake_S010					0.05								0.05			0.05	
Trinity_River_S150								0.00					0.05			0.00	
Trinity_River_S160					0.05			0.05					0.05				0.05
Trinity_River_S170					0.05			0.05					0.05				0.05
Trinity_River_S180					0.05			0.05					0.05				0.05
Bedias_Ck_S010													0.05				0.02
Bedias_Ck_S020					0.05			0.05					0.05				0.05
Trinity_River_S190					0.05			0.05					0.05				0.05
Livingston_S010					0.05			0.05					0.05				0.05
Livingston_S030					0.05			0.05					0.05				0.05
Livingston_S020					0.05			0.05					0.05				0.05
Trinity_River_S200								0.01					0.02			0.01	
Long_King_Ck_S010		0.01			0.05	0.05											
Long_King_Ck_S020								0.01					0.02			0.01	

Subbasin Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_S210								0.01					0.02			0.01	
Menard_Ck_S010		0.10				0.05							0.10				
Trinity_River_S220								0.01					0.02			0.01	
Trinity_River_S230								0.06					0.10			0.05	
Trinity_River_S240								0.06					0.10			0.05	
Trinity_River_S250								0.06					0.10			0.05	

Table 19: Calibrated Routing Reach Modified Puls Subreaches

Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_R010				4			4						4	4		4	
West_Fork_R020				1			1						1	1		1	
West_Fork_R030				2			1						1	2		2	
West_Fork_R040				1			1						1	1		1	
West_Fork_R050				2			2						2	2		2	
West_Fork_R060				2			2						2	2		2	
West_Fork_R070				2			4						3	3		4	
Big_Cleveland_R010				2			3						2	2		2	
West_Fork_R080				2			2						1	1		3	
Lost_Ck_R010				5			5						5	5		5	
Beans_Ck_R010				1			1						1	1		1	
Big_Ck_R010				3			3						3	3		3	
Big_Ck_R020				1			1						1	1		1	
West_Fork_R120				5			5						5	5		5	

Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_R130				2			2						2	2		2	
Big_Sandy_Ck_R020				4			4						4	4		4	
Big_Sandy_Ck_R030				1			10						8	10		10	
Brushy_Ck_R010				1			8						6	6		8	
Brushy_Ck_R020				1			1						1	1		1	
Big_Sandy_Ck_R040				1			4						4	4		4	
Big_Sandy_Ck_R050				2			4						4	4		4	
Big_Sandy_Ck_R060				1			1						2	2		2	
West_Fork_R140				2			1						2	2		2	
West_Fork_R150				1			1						1	1		1	
Garrett_Ck_R010				2			1						1	1		1	
Garrett_Ck_R020				2			1						1	1		1	
Salt_Ck_R010				5			3						3	3		3	
Salt_Ck_R020				2			1						2	2		1	
Salt_Ck_R030				1			1						1	1		1	
West_Fork_R160				2			1						2	2		2	
Walnut_Ck_R020				3			3						3	1		2	
Silver_Ck_R010				3			6						6	10		10	
West_Fork_R200				1			2						1	2		2	
West_Fork_R201				1			1						1	1		1	
Clear_Fork_R030				1			1						1	1		1	
Clear_Fork_R040				6			6						6	10		10	
Clear_Fork_R050				1			1						1	1		1	
West_Fork_R210				1			3						1	1		3	
Marine_Ck_R010				1			5						1	1		1	
West_Fork_R220				1			5						1	1		4	

Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_R230				1			3						1	1		1	
West_Fork_R231				1			3						1	1		1	
West_Fork_R240				1			1						1	1		1	
West_Fork_R250				2			1						1	1		1	
Village_Ck_R020				1			2						1	1		1	
West_Fork_R260				1			1						1	1		1	
West_Fork_R261				1			1						1	1		1	
West_Fork_R262				1			1						1	1		1	
West_Fork_R264				1			1						1	1		1	
West_Fork_R270				1			1						1	1		1	
West_Fork_R280	1											1				1	
Big_Bear_Ck_R010	2											2				1	
West_Fork_R290	1											1				1	
Mountain_Ck_R020	6											6				6	
Mountain_Ck_R030	2											2				1	
West_Fork_R300	1											1				1	
Elm_Fork_R060	8							8				8				8	
Clear_Ck_R050	1							1								1	
Clear_Ck_R060	3							3								3	
Elm_Fork_R065	1							1								1	
Little_Elm_Ck_R030	1							1								1	
Doe_Branch_R010	1							1								1	
Hickory_Ck_R030	1							1								1	
Elm_Fork_R070	6											4				6	
Elm_Fork_R080	4											1				2	
Denton_Ck_R010	14							14				14				14	

Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Denton_Ck_R030	8							4				8				1	
Denton_Ck_R040	2							1				2				2	
Denton_Ck_R050	3							2				3				3	
Denton_Ck_R055	2							1				2				2	
Denton_Ck_R060	6											8				8	
Elm_Fork_R090	4											2				8	
Elm_Fork_R100	4											2				8	
Elm_Fork_R120	5											5				1	
Bachman_Branch_R010	1											1				1	
Elm_Fork_R130	3											2				1	
Trinity_River_R010	1											3				1	
Trinity_River_R020	1											1				1	
Trinity_River_R030	2											1				2	
White_Rock_Ck_R020	4											2				5	
Trinity_River_R040	1											1				1	
Trinity_River_R050								1				1				1	
Trinity_River_R060								1				1				1	
Trinity_River_R070								1				1				1	
East_Fork_R040								6					6			6	
East_Fork_R050								1				1				1	
East_Fork_R060								1				1				1	
East_Fork_R070								1				1				1	
East_Fork_R080								1				1				1	
Trinity_River_R090								1				1				1	
Trinity_River_R100								40					40			10	
Trinity_River_R110								1					2			1	

Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Trinity_River_R120								9					2			5	
Chambers_Ck_R009										5	5		5		5		
Chambers_Ck_R010										20	20		20		20		
Chambers_Ck_R020										7	7		7		7		
Chambers_Ck_R030										8	8		8		8		
Chambers_Ck_R040										12	12		12		12		
Richland_Ck_R020										14	7		7		14		
Trinity_River_R130								8					1			1	
Tehuacana_Ck_R009					1			1					1			1	
Trinity_River_R140								6					1			1	
Trinity_River_R150								6					1			1	
Trinity_River_R160								12					3			7	
Trinity_River_R170								1					1			1	
Trinity_River_R180								1					1			1	
Trinity_River_R190								1					1			1	
Trinity_River_R200					1			1					1			1	
Trinity_River_R210					1			1					1			1	
Trinity_River_R220					1			1					1			1	
Trinity_River_R230								1					1			1	
Trinity_River_R240								1					1			1	
Trinity_River_R250								1					1			1	
Trinity_River_R260								4					10			1	
Trinity_River_R270								4					10			1	
Trinity_River_R280								4					10			1	

Table 20: Calibrated Routing Reach Modified Puls Storage Adjustments from Initial Estimates

Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
West_Fork_R262				0.3-1.0			1.0						0.3-1.0	1.0		1.0	
Trinity_River_R060								0.8-1.0				0.8-1.2				0.8-1.2	
Trinity_River_R070								0.8-1.0				0.8-1.2				0.8-1.2	
East_Fork_R080								1.0				1.0-1.2				1.0-1.2	
Trinity_River_R090								0.8-1.0				0.8-1.2				0.8-1.2	
Trinity_River_R100								0.8-1.0					0.8-1.0			0.8-1.0	
Trinity_River_R160								0.8-1					0.8-1			0.8-1	
Trinity_River_R170								0.8-1.1					0.8-1.1			0.8-1.1	
Trinity_River_R200					0.8-1.25			0.8-1.25					0.8-1.25			0.8-1.25	
Trinity_River_R210					0.8-1.25			0.8-1.25					0.8-1.25			0.8-1.25	
Trinity_River_R220					0.8-1.25			0.8-1.25					0.8-1.25			0.8-1.25	

Table 21: Calibrated Routing Reach Muskingum Parameters

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
K (hrs)	West_Fork_R090				1.0			1.0						1.0	1.0		1.0	
K (hrs)	West_Fork_R100				3.0			3.0						3.0	3.0		3.0	
K (hrs)	West_Fork_R110				3.0			3.0						3.0	3.0		3.0	
K (hrs)	West_Fork_R170				3.0			7.0						5.0	5.0		7.0	
K (hrs)	West_Fork_R180				2.0			6.0						4.0	4.0		6.0	
K (hrs)	Walnut_Ck_R010				1.0			1.8						1.0	1.0		1.0	
K (hrs)	West_Fork_R190				2.0			9.0						9.0	9.0		9.0	

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
K (hrs)	Bear_Ck_R010				1.0			1.0						1.0	1.0		1.0	
K (hrs)	Marys_Ck_R010				1.0			1.0						1.0	1.0		1.0	
K (hrs)	Village_Ck_R010				4.0			2.0						6.0	6.0		6.0	
K (hrs)	JPL_Walnut_Ck_R010	1.0											1.0				1.0	
K (hrs)	Mountain_Ck_R010	5.0											5.0				5.0	
K (hrs)	Elm_Fork_R010	3.9							1.0				3.9				3.9	
K (hrs)	Brushy_Elm_Ck_R010	3.9							3.9				3.9				3.9	
K (hrs)	Elm_Fork_R020	1.1							1.0				1.1				1.1	
K (hrs)	Elm_Fork_R030	2.0							1.0				2.0				2.0	
K (hrs)	Elm_Fork_R040	1.6							3.0				1.6				6.0	
K (hrs)	Elm_Fork_R050	3.7							4.0				3.7				8.0	
K (hrs)	Spring_Ck_R010	2.0							5.0				2.0				5.0	
K (hrs)	Timber_Ck_R010	1.1							1.1				1.1				3.0	
K (hrs)	Timber_Ck_R020								2.0									
K (hrs)	Range_Ck_R010	5.5							5.5				5.5				7.0	
K (hrs)	Range_Ck_R020								2.0									
K (hrs)	Lake_Kiowa_R010	1.3							1.3				1.3				4.0	
K (hrs)	Clear_Ck_R010	1.0							1.0				1.0				1.0	
K (hrs)	Clear_Ck_R020	3.0							3.0				3.0				6.0	
K (hrs)	Clear_Ck_R030	1.2							1.0				1.2				1.0	
K (hrs)	Clear_Ck_R040	4.0							3.0				7.7				7.0	
K (hrs)	Little_Elm_Ck_R010	6.0							7.0				6.0				6.0	
K (hrs)	Little_Elm_Ck_R035	2.0							2.0								4.0	
K (hrs)	Hickory_Ck_R010	4.0							2.0				4.0				4.0	
K (hrs)	Hickory_Ck_R020	3.0							2.0				3.0				3.0	
K (hrs)	Hickory_Ck_R035	8.0							4.0								8.0	

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
K (hrs)	Denton_Ck_R020	2.0							2.0				2.0				2.0	
K (hrs)	Hackberry_Ck_R010	1.0											1.0				1.0	
K (hrs)	Elm_Fork_R110	1.0											1.0				1.0	
K (hrs)	White_Rock_Ck_R010	3.0											6.0				3.0	
K (hrs)	Five_Mile_Ck_R010								0.5				0.5				0.5	
K (hrs)	Tenmile_Ck_R010								2.0				1.5				1.5	
K (hrs)	Indian_Ck_R010								5.1					5.1			5.1	
K (hrs)	Indian_Ck_R020								3.1					3.1			3.1	
K (hrs)	Sister_Grove_Ck_R010								7.1					7.1			7.1	
K (hrs)	East_Fork_R010								2.0					3.0			2.0	
K (hrs)	East_Fork_R020								5.8					5.8			5.8	
K (hrs)	East_Fork_R030								2.0					3.8			2.0	
K (hrs)	Lavon_RayHubbard_R010								1.0					4.0			4.0	
K (hrs)	Rowlett_Ck_R010								4.0					4.0			4.0	
K (hrs)	Trinity_River_R080								1.0				1.0				1.0	
K (hrs)	Kings_Ck_R010								1.0					1.0			1.0	
K (hrs)	Kings_Ck_R020								6.0					6.0			6.0	6.0
K (hrs)	Cedar_Ck_R010								12.0					12.0			12.0	
K (hrs)	Cedar_Ck_R020								8.0					8.0			8.0	8.0
K (hrs)	Cedar_Ck_R030								14.0					10.0			10.0	
K (hrs)	Waxahachie_Ck_R010										3.6	3.0		4.2		3.0		
K (hrs)	Waxahachie_Ck_R020										5.4	6.0		7.0		10.0		
K (hrs)	Waxahachie_Ck_R030										6.0	1.0		1.0		5.0		
K (hrs)	Post_Oak_Ck_R010										1.5	1.5		1.5		1.5		
K (hrs)	Richland_Ck_R010										10.5	10.5		10.5		7.0		
K (hrs)	Richland_CK_R030										7.0	3.5		10.5		3.5		

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
K (hrs)	Richland_Ck_R040								1.0					1.0			1.0	
K (hrs)	Tehuacana_Ck_R010								6.0					6.0			6.0	
K (hrs)	Big _Brown_Ck_R010								1.0					1.0			1.0	
K (hrs)	Upper_Keechi_Ck_R010								3.0					3.0			3.0	
K (hrs)	Upper_Keechi_Ck_R020								3.5					3.5			3.5	
K (hrs)	Big_Elkhart_R010								2.5					2.5			2.5	
K (hrs)	Bedias_Ck_R010					6.0			6.0					6.0				6.0
K (hrs)	Long_King_Ck_R010								4.0					4.0			4.0	
X	West_Fork_R090				0.25			0.25						0.25	0.25		0.25	
X	West_Fork_R100				0.40			0.40						0.40	0.25		0.25	
X	West_Fork_R110				0.40			0.40						0.40	0.25		0.25	
X	West_Fork_R170				0.25			0.10						0.25	0.25		0.25	
X	West_Fork_R180				0.25			0.10						0.25	0.25		0.25	
X	Walnut_Ck_R010				0.40			0.25						0.25	0.25		0.25	
X	West_Fork_R190				0.10			0.15						0.10	0.10		0.15	
X	Bear_Ck_R010				0.25			0.25						0.25	0.25		0.25	
X	Marys_Ck_R010				0.10			0.25						0.25	0.25		0.25	
X	Village_Ck_R010				0.40			0.40						0.40	0.40		0.40	
X	JPL_Walnut_Ck_R010	0.20											0.20				0.20	
X	Mountain_Ck_R010	0.20											0.20				0.20	
X	Elm_Fork_R010	0.30							0.30				0.30				0.30	
X	Brushy_Elm_Ck_R010	0.30							0.30				0.30				0.30	
X	Elm_Fork_R020	0.30							0.30				0.30				0.30	
X	Elm_Fork_R030	0.30							0.30				0.30				0.30	
X	Elm_Fork_R040	0.20							0.20				0.20				0.20	
X	Elm_Fork_R050	0.20							0.20				0.20				0.20	

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
X	Spring_Ck_R010	0.20							0.20				0.20				0.20	
X	Timber_Ck_R010	0.20							0.20				0.20				0.20	
X	Timber_Ck_R020								0.20									
X	Range_Ck_R010	0.20							0.20				0.20				0.20	
X	Range_Ck_R020								0.20									
X	Lake_Kiowa_R010	0.20							0.20				0.20				0.20	
X	Clear_Ck_R010	0.30							0.30				0.30				0.30	
X	Clear_Ck_R020	0.30							0.30				0.30				0.30	
X	Clear_Ck_R030	0.30							0.30				0.30				0.30	
X	Clear_Ck_R040	0.30							0.30				0.30				0.30	
X	Little_Elm_Ck_R010	0.20							0.40				0.20				0.20	
X	Little_Elm_Ck_R035	0.10							0.10								0.10	
X	Hickory_Ck_R010	0.30							0.30				0.30				0.30	
X	Hickory_Ck_R020	0.30							0.30				0.30				0.30	
X	Hickory_Ck_R035	0.10							0.10								0.10	
X	Denton_Ck_R020	0.25							0.25				0.25				0.25	
X	Hackberry_Ck_R010	0.25											0.25				0.25	
X	Elm_Fork_R110	0.25											0.25				0.25	
X	White_Rock_Ck_R010	0.30											0.10				0.30	
X	Five_Mile_Ck_R010								0.30				0.30				0.30	
X	Tenmile_Ck_R010								0.30				0.30				0.30	
X	Indian_Ck_R010								0.25					0.25			0.25	
X	Indian_Ck_R020								0.20					0.20			0.20	
X	Sister_Grove_Ck_R010								0.20					0.20			0.20	
X	East_Fork_R010								0.10					0.10			0.20	
X	East_Fork_R020								0.20					0.20			0.20	

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
X	East_Fork_R030								0.20					0.20			0.20	
X	Lavon_RayHubbard_R010								0.20					0.20			0.20	
X	Rowlett_Ck_R010								0.20					0.20			0.20	
X	Trinity_River_R080								0.25				0.25				0.25	
X	Kings_Ck_R010								0.40					0.10			0.40	
X	Kings_Ck_R020								0.40					0.30			0.40	0.40
X	Cedar_Ck_R010								0.30					0.30			0.30	
X	Cedar_Ck_R020								0.40					0.30			0.40	0.40
X	Cedar_Ck_R030								0.10					0.10			0.10	
X	Waxahachie_Ck_R010										0.30	0.30		0.30		0.30		
X	Waxahachie_Ck_R020										0.30	0.30		0.39		0.30		
X	Waxahachie_Ck_R030										0.10	0.40		0.30		0.30		
X	Post_Oak_Ck_R010										0.30	0.30		0.30		0.30		
X	Richland_Ck_R010										0.40	0.40		0.40		0.30		
X	Richland_CK_R030										0.10	0.30		0.30		0.10		
X	Richland_Ck_R040								0.10					0.10			0.10	
X	Tehuacana_Ck_R010								0.10					0.10			0.10	
X	Big _Brown_Ck_R010								0.10					0.10			0.10	
X	Upper_Keechi_Ck_R010								0.10					0.25			0.10	
X	Upper_Keechi_Ck_R020								0.10					0.25			0.10	
X	Big_Elkhart_R010								0.10					0.25			0.10	
X	Bedias_Ck_R010					0.25			0.25					0.25				0.25
X	Long_King_Ck_R010								0.10					0.10			0.10	
Subreaches	West_Fork_R090				1			1						1	1		1	
Subreaches	West_Fork_R100				3			1						4	4		3	
Subreaches	West_Fork_R110				3			1						5	5		3	

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Subreaches	West_Fork_R170				2			1						2	4		4	
Subreaches	West_Fork_R180				2			1						1	3		3	
Subreaches	Walnut_Ck_R010				2			1						1	1		1	
Subreaches	West_Fork_R190				4			6						2	4		4	
Subreaches	Bear_Ck_R010				1			1						1	1		1	
Subreaches	Marys_Ck_R010				1			1						1	1		1	
Subreaches	Village_Ck_R010				4			4						4	4		4	
Subreaches	JPL_Walnut_Ck_R010	1											1				1	
Subreaches	Mountain_Ck_R010	3											2				3	
Subreaches	Elm_Fork_R010	4							1				4				4	
Subreaches	Brushy_Elm_Ck_R010	4							4				4				4	
Subreaches	Elm_Fork_R020	1							1				1				1	
Subreaches	Elm_Fork_R030	2							1				2				2	
Subreaches	Elm_Fork_R040	2							2				2				4	
Subreaches	Elm_Fork_R050	4							3				4				5	
Subreaches	Spring_Ck_R010	2							3				2				3	
Subreaches	Timber_Ck_R010	1							1				1				2	
Subreaches	Timber_Ck_R020								1									
Subreaches	Range_Ck_R010	6							4				6				5	
Subreaches	Range_Ck_R020								1									
Subreaches	Lake_Kiowa_R010	1							1				1				2	
Subreaches	Clear_Ck_R010	1							1				1				1	
Subreaches	Clear_Ck_R020	2							2				4				4	
Subreaches	Clear_Ck_R030	1							1				1				1	
Subreaches	Clear_Ck_R040	3							2				3				5	
Subreaches	Little_Elm_Ck_R010	5							10				5				5	

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Subreaches	Little_Elm_Ck_R035	1							1								2	
Subreaches	Hickory_Ck_R010	3							2				4				3	
Subreaches	Hickory_Ck_R020	2							1				2				2	
Subreaches	Hickory_Ck_R035	4							2								4	
Subreaches	Denton_Ck_R020	1							1				1				1	
Subreaches	Hackberry_Ck_R010	1											1				1	
Subreaches	Elm_Fork_R110	1											1				1	
Subreaches	White_Rock_Ck_R010	2											3				2	
Subreaches	Five_Mile_Ck_R010								2				1				1	
Subreaches	Tenmile_Ck_R010								3				1				1	
Subreaches	Indian_Ck_R010								3					3			3	
Subreaches	Indian_Ck_R020								2					2			2	
Subreaches	Sister_Grove_Ck_R010								4					4			4	
Subreaches	East_Fork_R010								1					1			1	
Subreaches	East_Fork_R020								3					3			3	
Subreaches	East_Fork_R030								2					2			2	
Subreaches	Lavon_RayHubbard_R010								8					4			8	
Subreaches	Rowlett_Ck_R010								3					3			3	
Subreaches	Trinity_River_R080								1				1				1	
Subreaches	Kings_Ck_R010								1					1			1	
Subreaches	Kings_Ck_R020								3					3			3	3
Subreaches	Cedar_Ck_R010								6					6			6	
Subreaches	Cedar_Ck_R020								4					4			4	4
Subreaches	Cedar_Ck_R030								4					1			1	
Subreaches	Waxahachie_Ck_R010										4	3		4		4		
Subreaches	Waxahachie_Ck_R020										6	6		7		10		

Muskingum Parameter	Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Subreaches	Waxahachie_Ck_R030										6	1		1		5		
Subreaches	Post_Oak_Ck_R010										2	2		2		2		
Subreaches	Richland_Ck_R010										10	11		11		7		
Subreaches	Richland_CK_R030										1	4		11		4		
Subreaches	Richland_Ck_R040								1					1			1	
Subreaches	Tehuacana_Ck_R010								3					3			3	
Subreaches	Big _Brown_Ck_R010								1					1			1	
Subreaches	Upper_Keechi_Ck_R010								1					1			1	
Subreaches	Upper_Keechi_Ck_R020								1					1			1	
Subreaches	Big_Elkhart_R010								1					1			1	
Subreaches	Bedias_Ck_R010					1			1					3				3
Subreaches	Long_King_Ck_R010								1					1			1	

Table 22: Calibrated Routing Reach Lag Time (minutes) Estimates

Reach Name	Dec-91	Apr-99	Jun-00	Jun-04	Nov-04	Oct-06	Mar-07	Jun-07	Jul-07	Sep-09	Oct-09	Sep-10	Oct-13	May-15	Jun-15	Oct-15	Nov-15	Dec-15
Clear_Fork_R041				60			0							0	30		60	
West_Fork_R251				0			0							0	60		60	
West_Fork_R263				0			0							0	60		60	
Denton_Ck_Lag	120							60				180					180	
Tehuacana_Ck_R008					430			430						430	430		430	430
Upper_Keechi_Ck_R001								600					300					600

1.4.3 Calibration Results

The final calibration results showed that the HEC-HMS model was able to accurately simulate the response of the watershed, as it reproduced the volume, timing, shape, and peak magnitudes of most observed floods very well. The resulting hydrograph comparisons can be seen in the following figures of this section. The figures show the HEC-HMS computed versus the USGS observed flow hydrographs at each gage location. Figures are only shown for the locations where the USGS stream gages were recording for that event and where the magnitude of the flow was significant enough to warrant calibration.

The Mary's Creek at Benbrook gage was a location that received additional investigation following the preliminary calibration results. The investigation included a unit hydrograph peaking study performed to improve the accuracy of flood frequency estimates in the watershed by improving the unit hydrograph parameter estimates within the hydrologic modeling. There were 3 primary reasons for this investigation. The first reason is that the calibration events available for HMS model calibration were very limited and much smaller in magnitude than those used to administer the National Flood Insurance Program (NFIP) program such as the 1% Annual Exceedance Probability (AEP) (100-yr) event. The calibration events had 24-hour runoff totals between 1-2 inches , while the 1% AEP 24-hour design runoff amount is 6+ inches for a 24-hour storm event based on the USACE Fort Worth District losses being used in this study. It is well documented in literature that more intense storm events have a more rapid and severe runoff response than smaller less intense events (Snyder; Minshall; USACE, 1991). This introduced some concern that the calibrated HMS parameters would not sufficiently represent physical watershed response to a much more intense storm event, such as the 1% AEP event. The second reason for the additional investigation is the significant level of new development planned for this area, increasing the importance of accurate flood frequency estimates. The final reason for the investigation was the 2015 release of HEC-RAS version 5.0, which includes the ability to apply excess-precipitation onto a 2-dimensional mesh and simulate the excess-runoff being routed throught the system with the unsteady 2D equations in RAS.

The RAS 2D model utilized 2015 Light, Detection, and Ranging (LiDAR) data obtained from the City of Fort Worth. Large culverts were field measured and added into the model to improve the models ability to route flow through significant constrictions within the watershed. The model was calibrated and validated, with there being a very small difference between the calibrated model and the uncalibrated model. The uncalibrated model resulted in a peak discharge 6% less than the calibrated model. Comparision of the hydrographs is located within Figure 4.3 of Appendix F - USACE 2-Dimensional HEC-RAS Analysis of Mary's Creek. The results of the sudy indicated significant peaking occurs to unit hydrograph parameters as storm intensity increases. For example, the 10% AEP (10-yr) lag time from the RAS 2D study was approximately 2.1 hours, while the 1% AEP (100-y) lag time from the RAS 2D study came out to 1.5 hours. The 10% AEP lag time of 2.1 hours matches that developed during HMS calibration of the smaller storm events, This trend is consistent with additional storm calibrations of smaller events, not performed during the original calibration effort within the watershed.

Excess precipitation from hypothetical 24-hour storms, with an alternating block distribution was appled to the RAS 2D mesh and was routed to the watershed outlet. Within HMS, the same storm was applied and the resulting flow hydrograph was calibrated to the RAS 2D hydrograph for that event (Figure 19). This resulted in HMS unit hydrograph parameters that approximates the routing through the RAS 2D mesh representing the watershed. This process was performed for the 50% AEP (2-yr) to 0.2% (500-yr) event. The resulting unit hydrograph parameters were then used to develop flood frequency estimates.

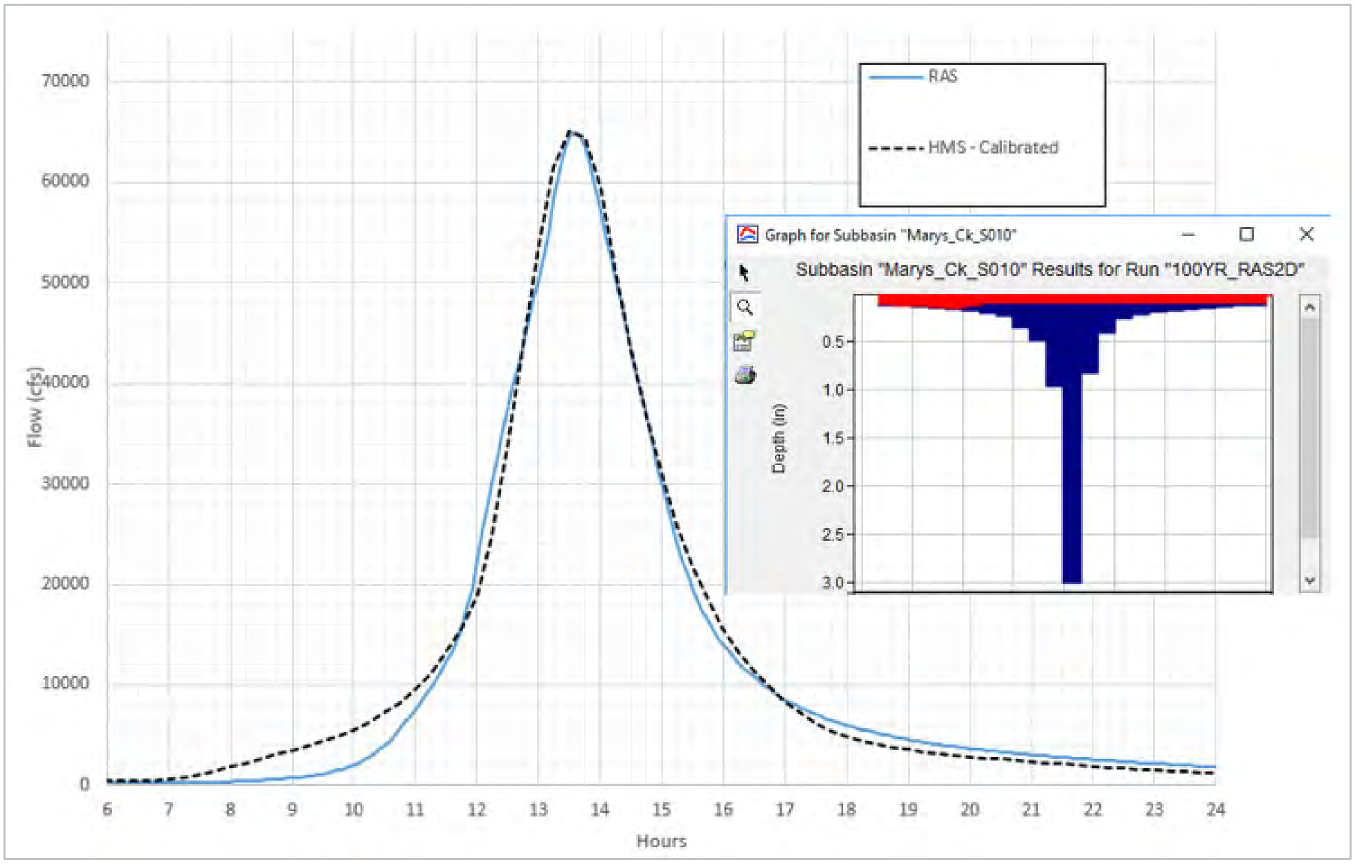

Figure 19. HMS Calibration to RAS 2D Results for Hypothetical Storm Events

The results of the study will be included with the HMS results for the Mary's Creek gage. In addition to unit hydrograph parameters specifically for the single subbasin above the Marys Creek gage, regression equations were developed for the watershed for use in future studies within the Mary's Creek watershed where additional subbasins will be added (Figure 20).

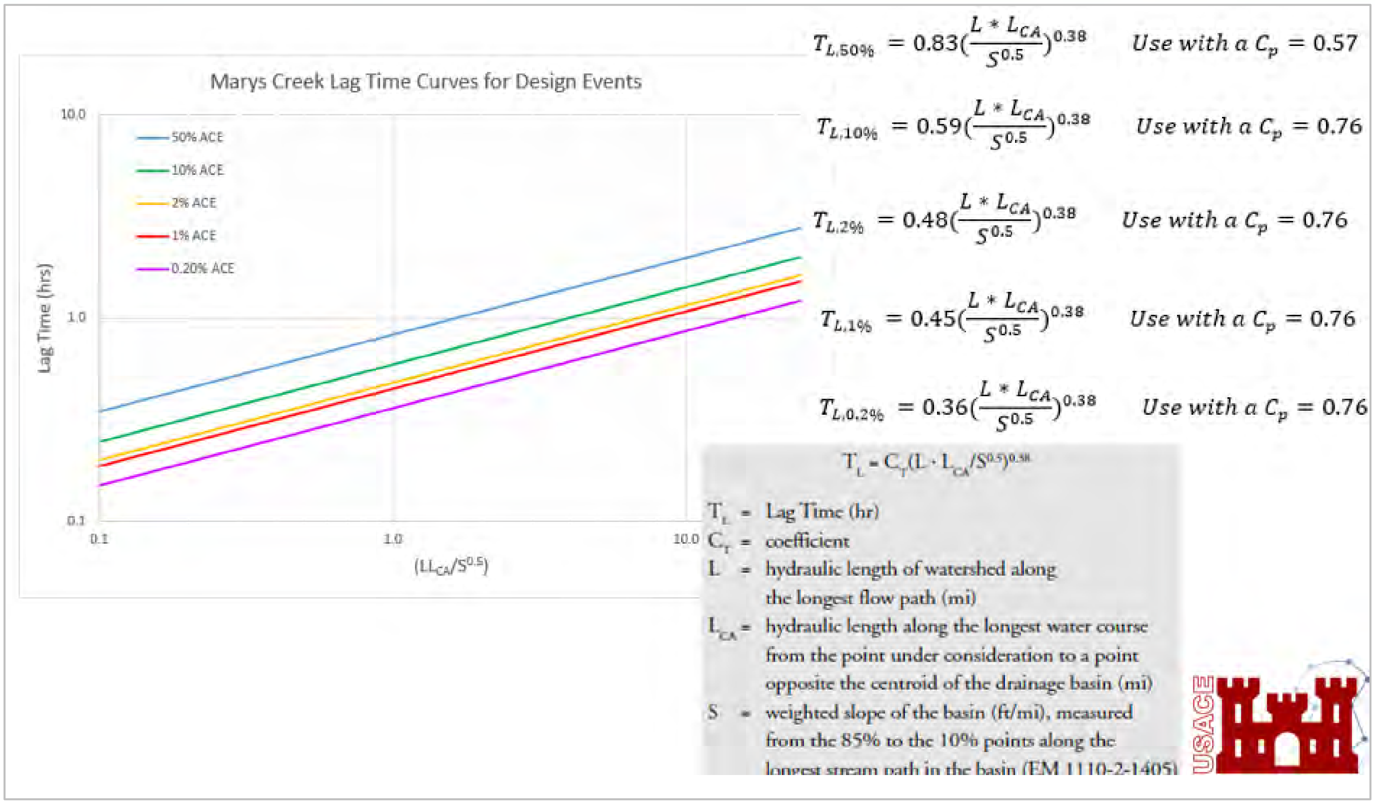

Figure 1. Lag Time Equations Approximating RAS 2D Routing through the Marys Creek Watershed

Oversight and review for this study was performed by members from the USACE Hydrologic Engineering Center (HEC) and USACE Dam Safety Modification Mandatory Center of Expertise (DSMMX). Additional information about the unit hydrograph peaking study performed within Mary's Creek can be found in Appendix F – 2-Dimensional HEC-RAS Analysis of Mary's Creek.

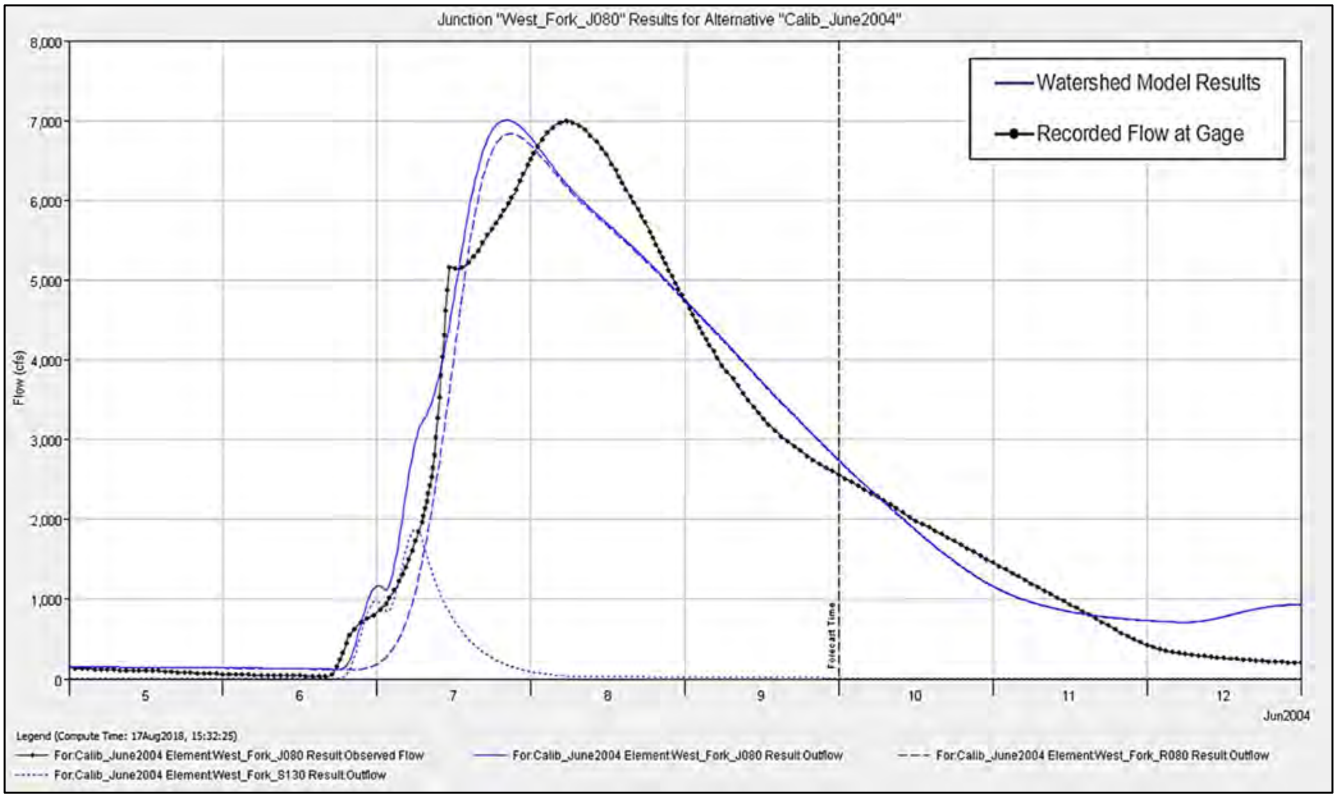

Figure 21a. June 8, 2004 Calibration Results for the West Fork at Jacksboro, TX Gage.

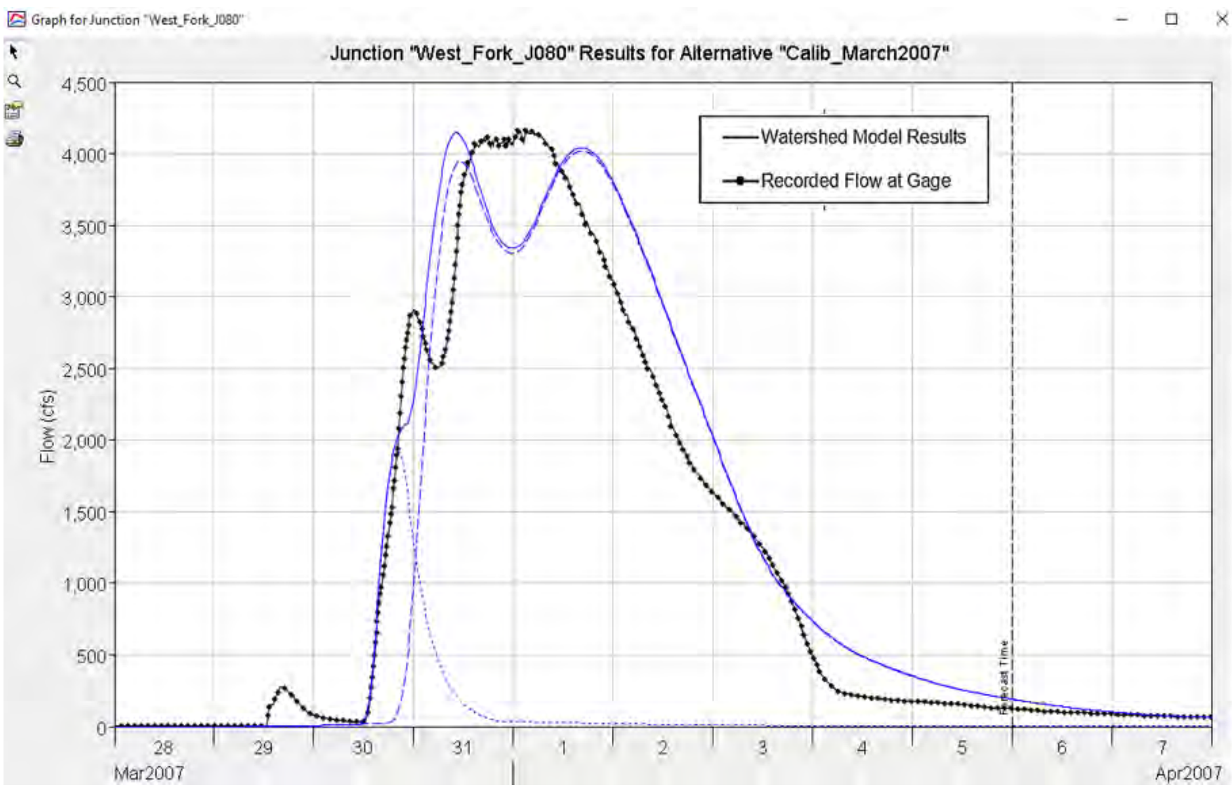

Figure 21b. March 28, 2007 Calibration Results for the West Fork at Jacksboro, TX Gage

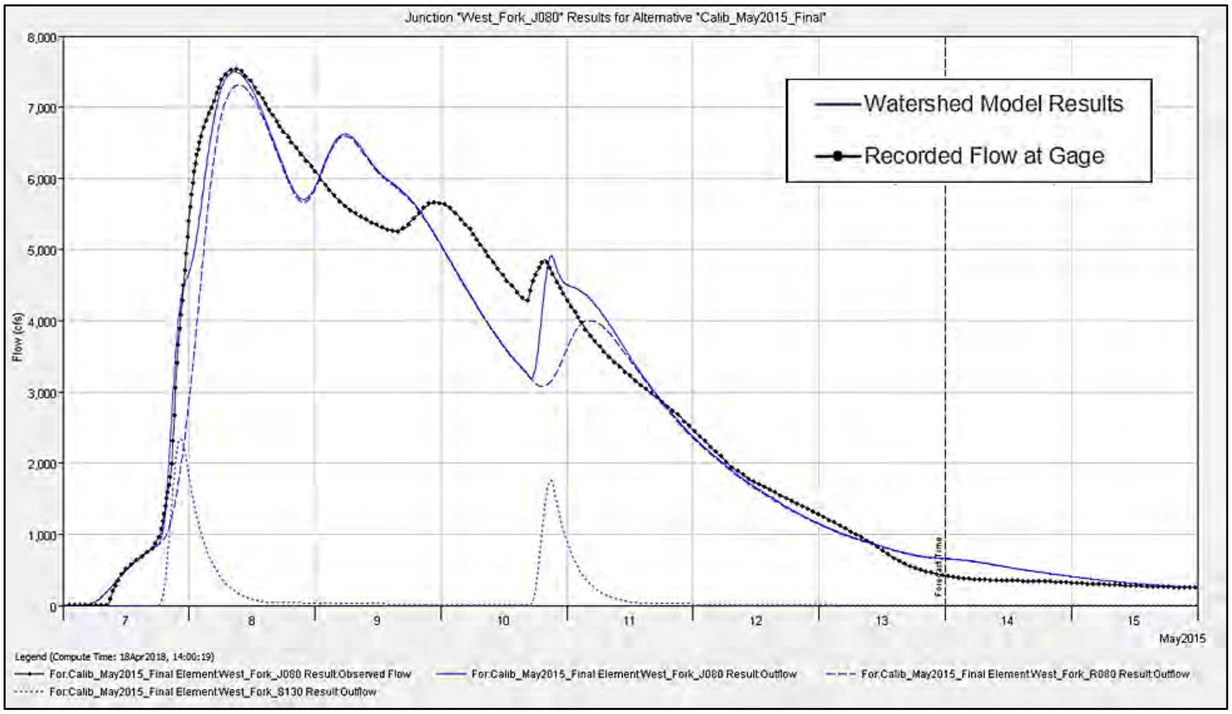

Figure 21c. May 8, 2015 Calibration Results for the West Fork Trinity River at Jacksboro, TX.

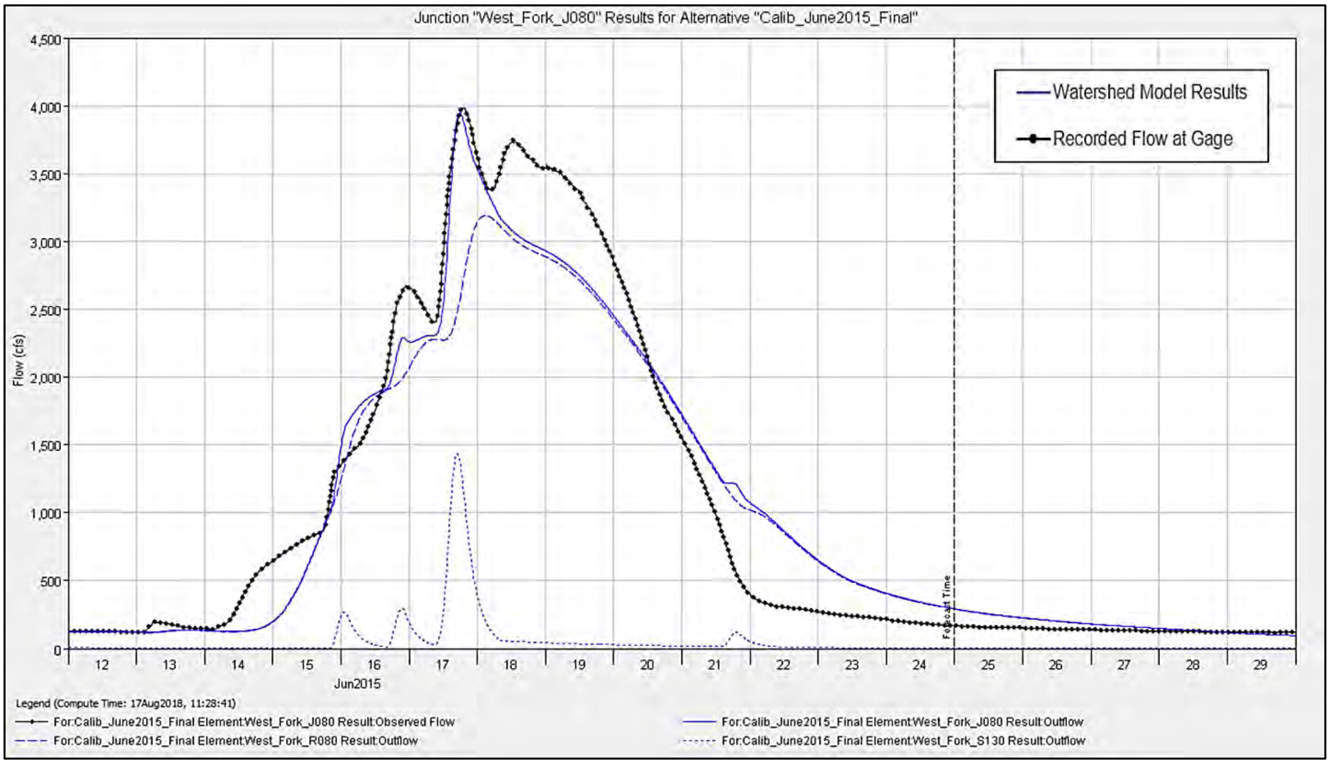

Figure 22a. June 18, 2015 Calibration Results for the West Fork near Jacksboro, TX Gage

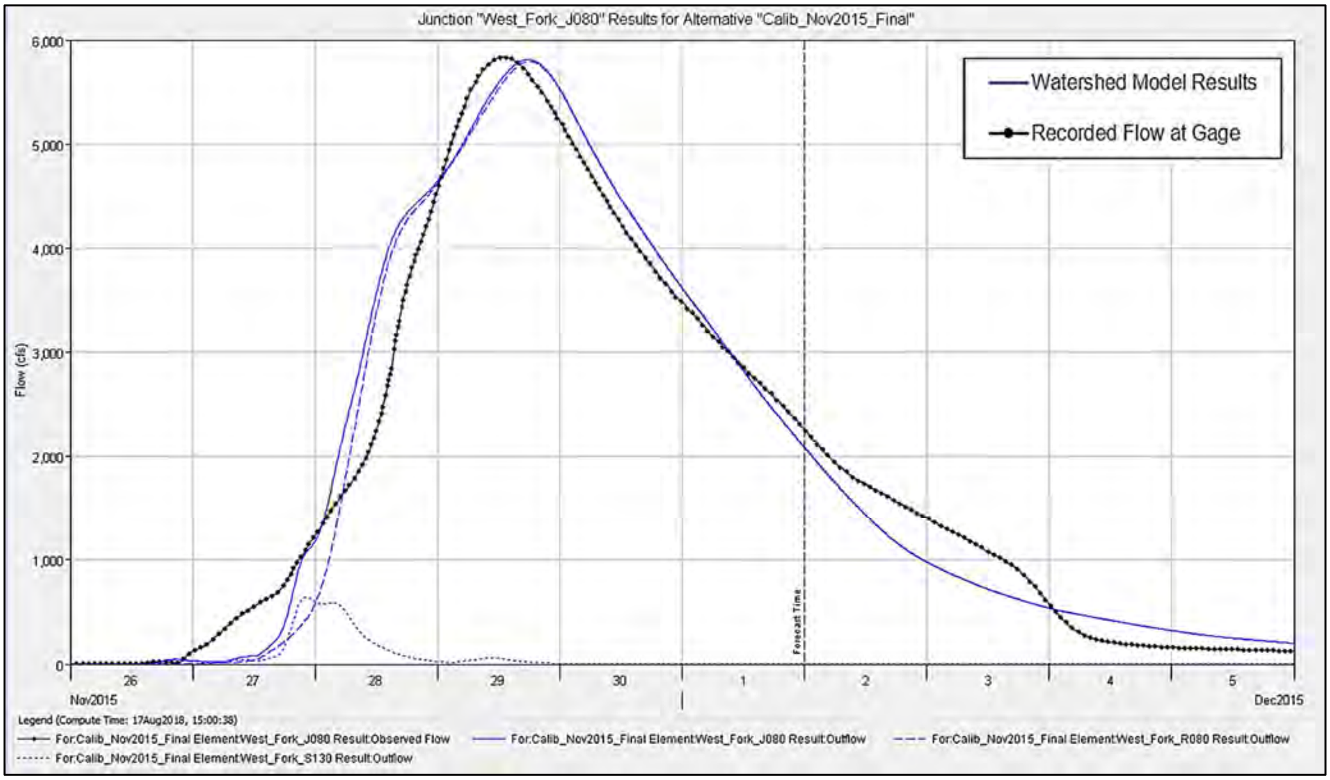

Figure 22b. November 29, 2015 Calibration Results for the West Fork near Jacksboro, TX Gage

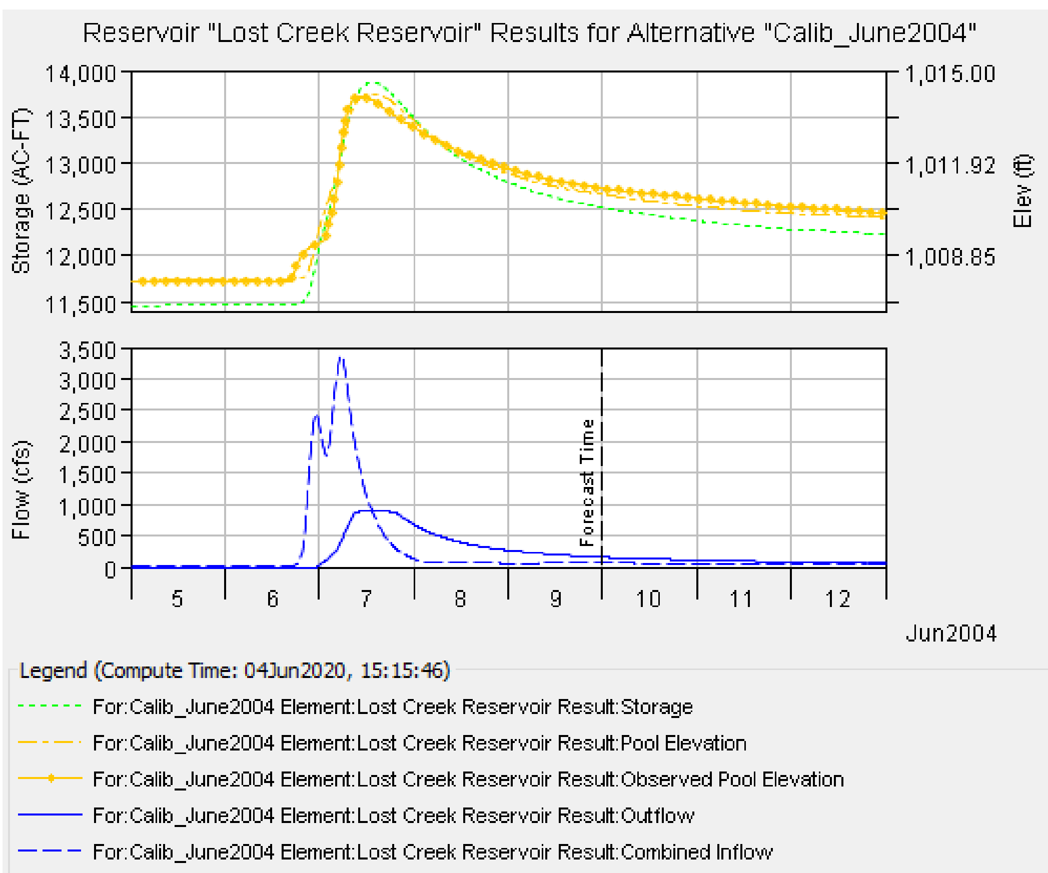

Figure 23a. June 2004 Calibration Results for Lost Creek Reservoir

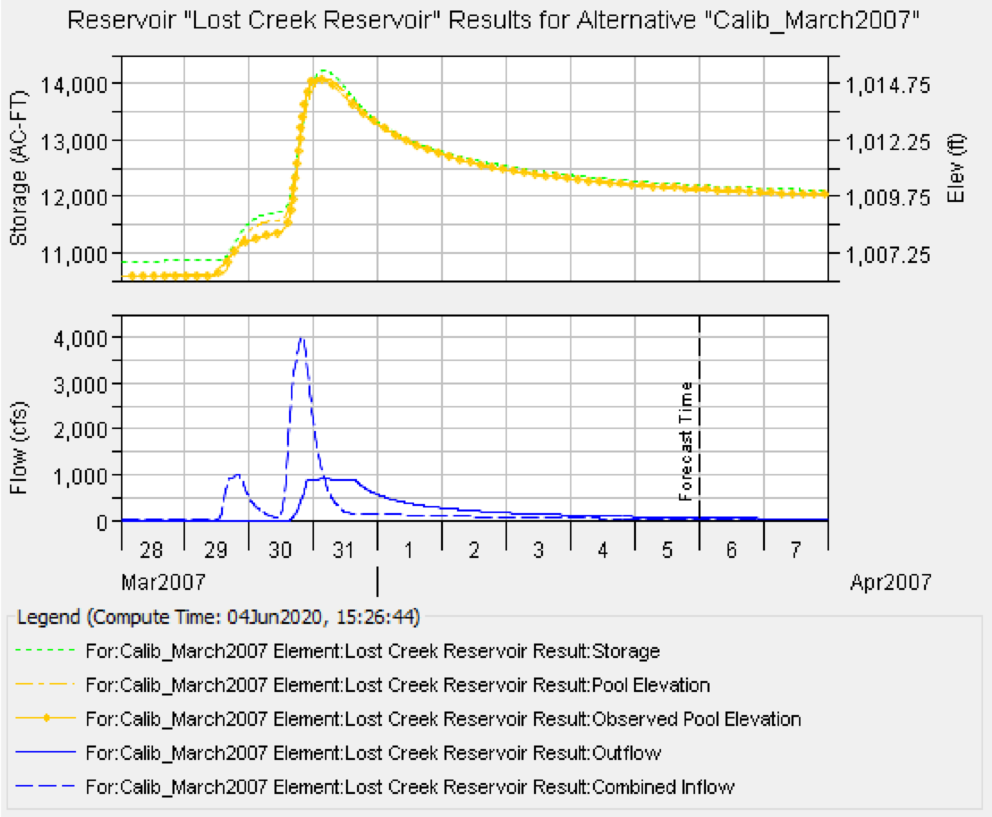

Figure 23b. March 2007 Calibration Results for Lost Creek Reservoir

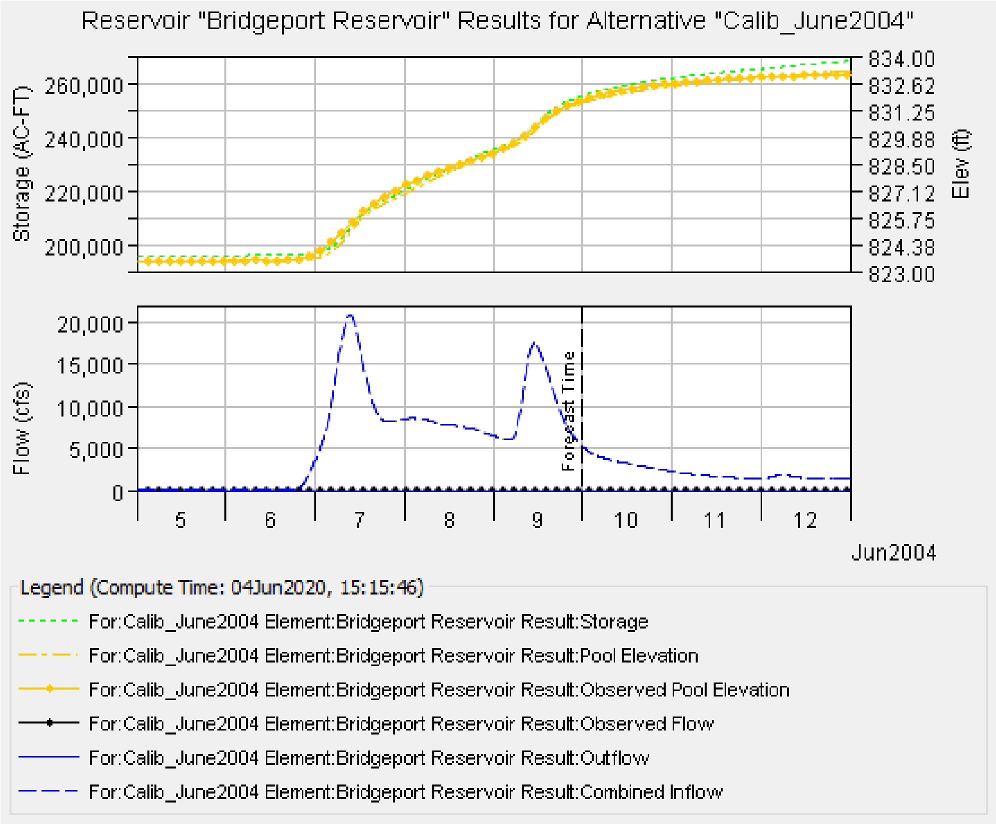

Figure 24a. June 2004 Calibration Results for Bridgeport Reservoir

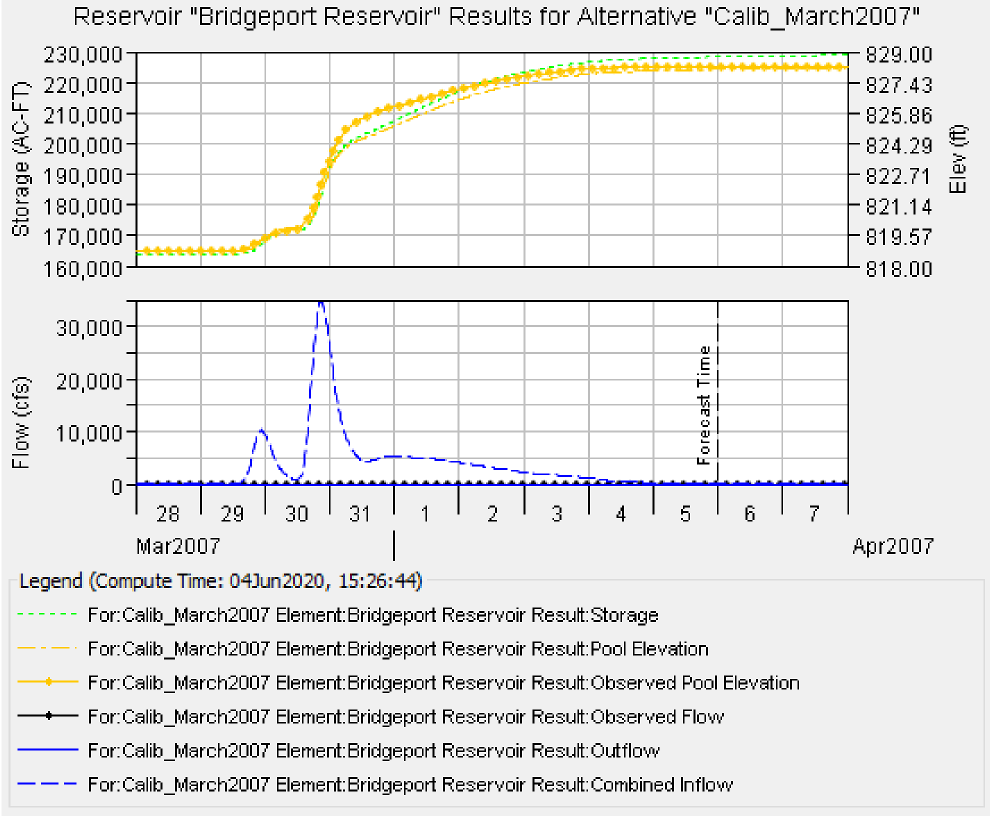

Figure 24b. March 2007 Calibration Results for Bridgeport Reservoir

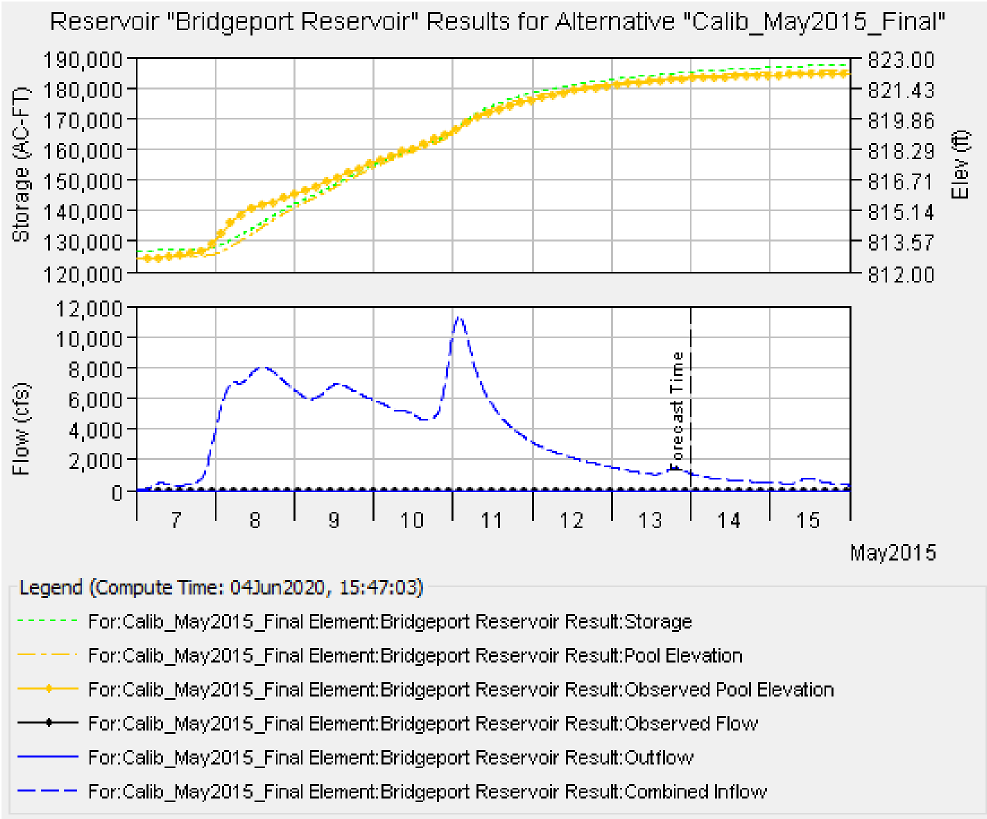

Figure 24c. May 2015 Calibration Results for Bridgeport Reservoir

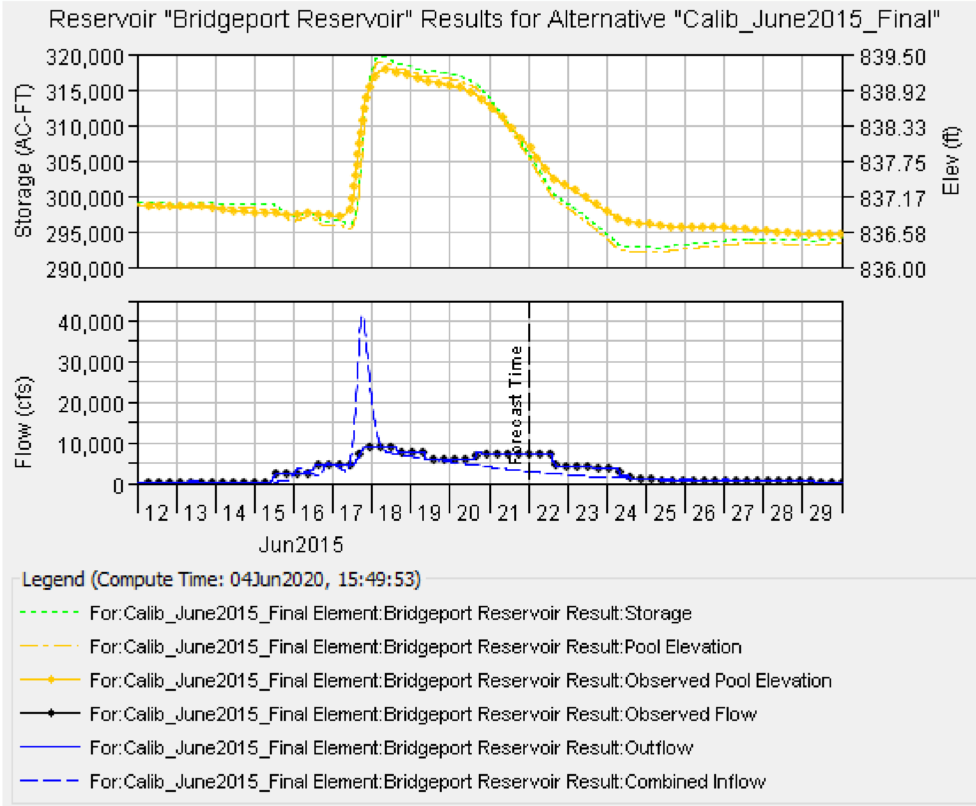

Figure 24d. June 2015 Calibration Results for Bridgeport Reservoir

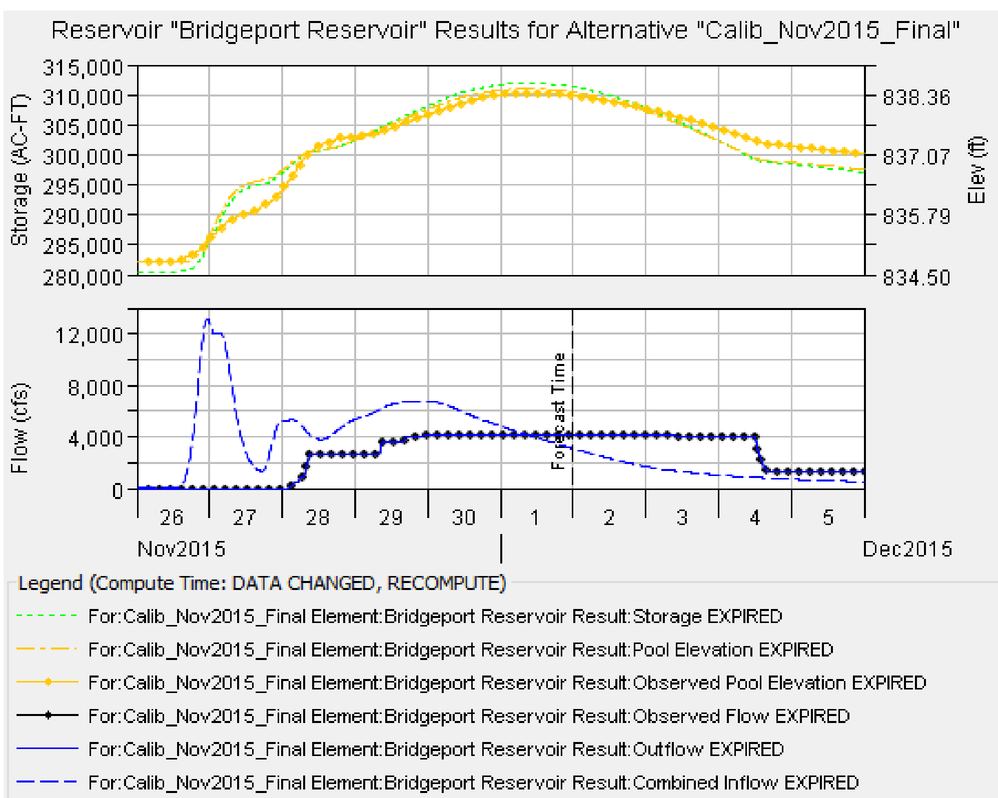

Figure 24e. November 2015 Calibration Results for Bridgeport Reservoir

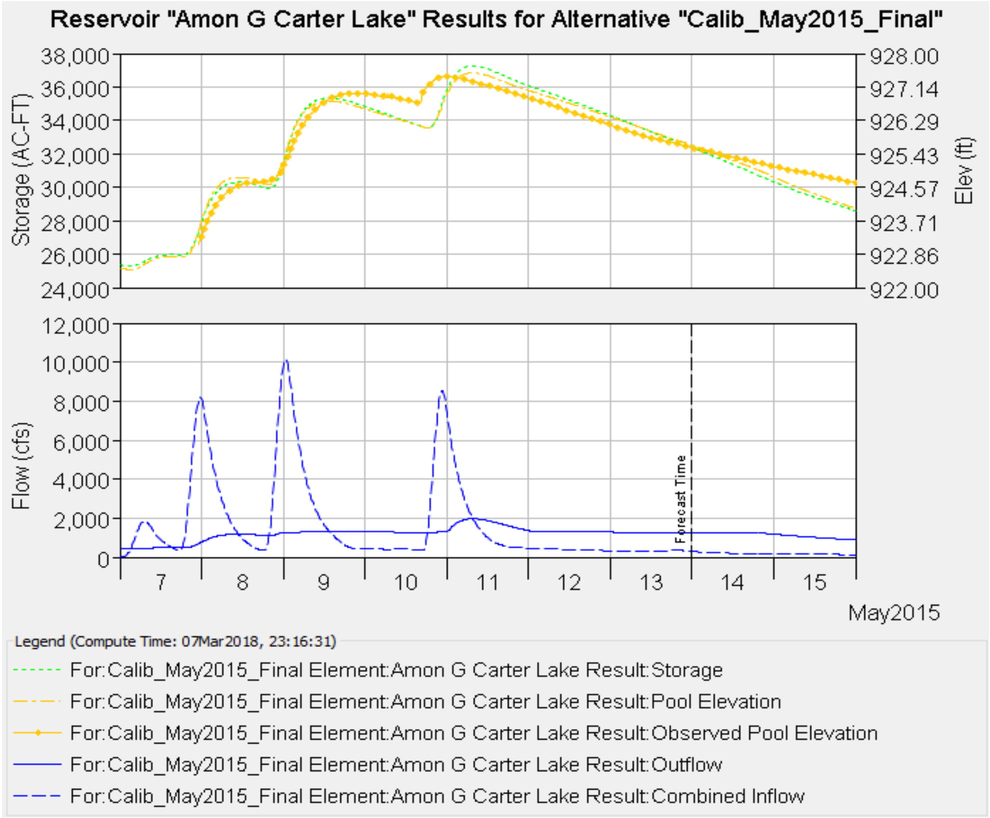

Figure 25a. March 2015 Calibration Results for Amon G Carter Reservoir

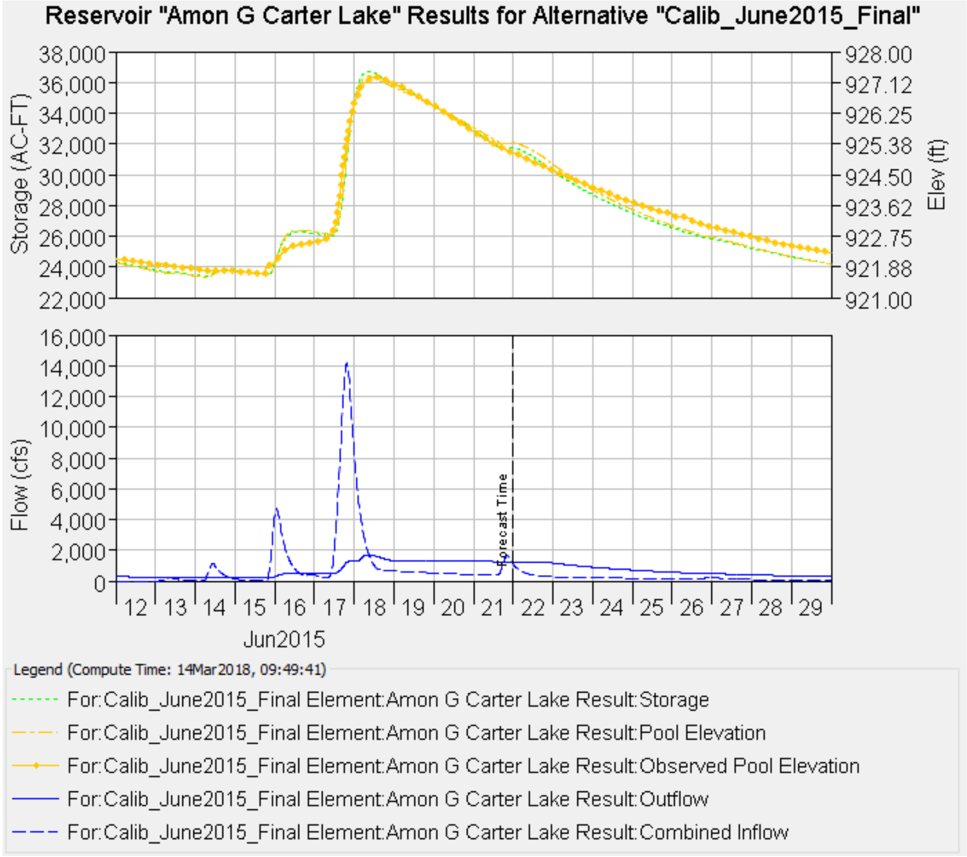

Figure 25b. June 2015 Calibration Results for Amon G Carter Reservoir

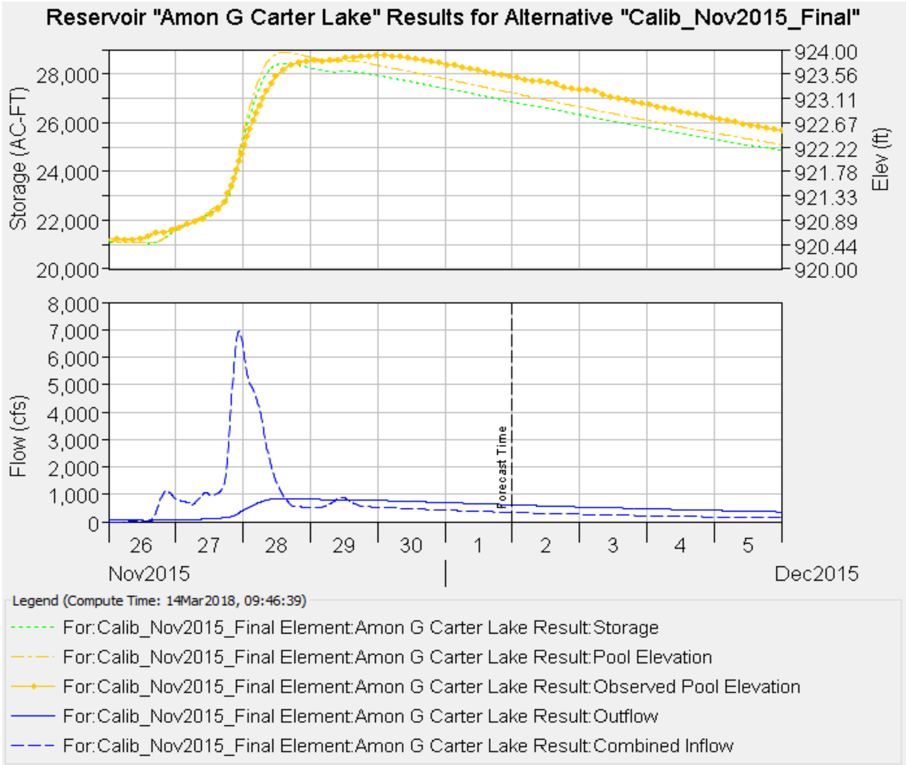

Figure 25c. November 2015 Calibration Results for Amon G Carter Reservoir

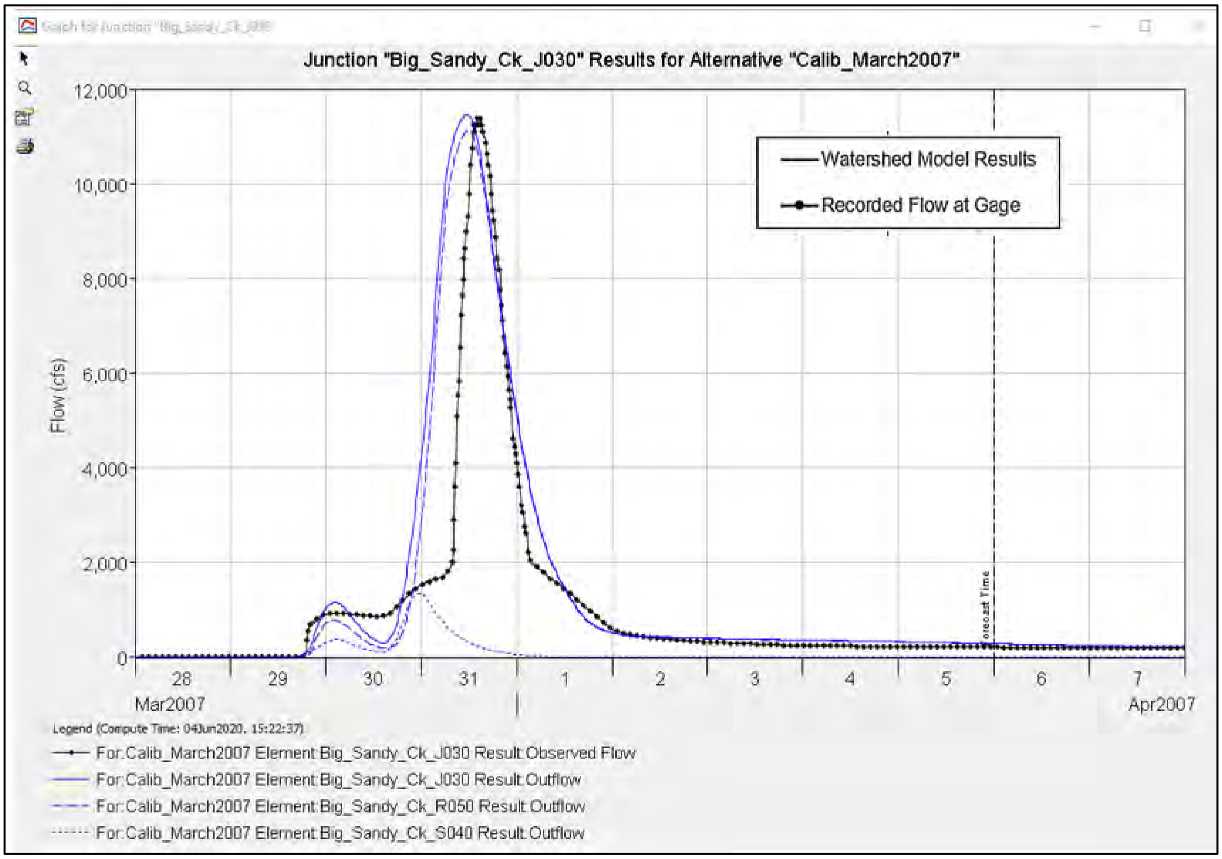

Figure 26a. March 28, 2007 Calibration Results for Sandy Creek nr Bridgeport, TX Gage

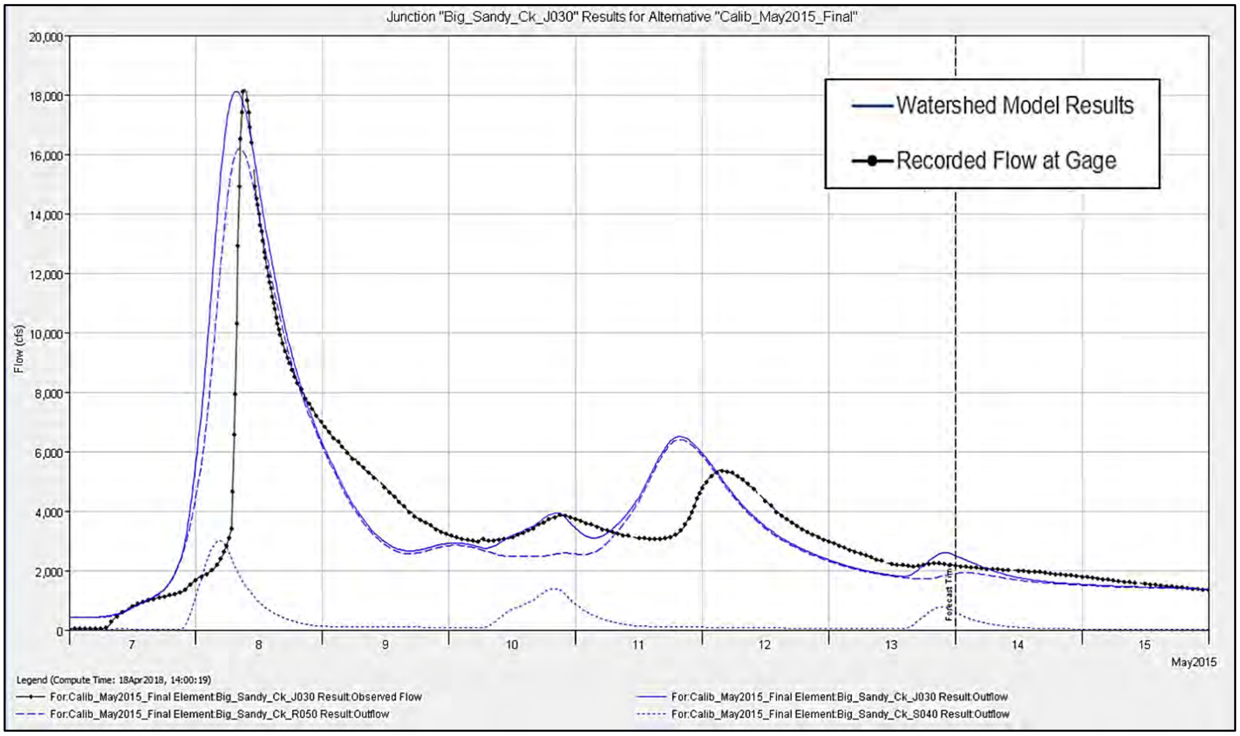

Figure 26b. May 8, 2015 Calibration Results for Sandy Creek nr Bridgeport, TX Gage

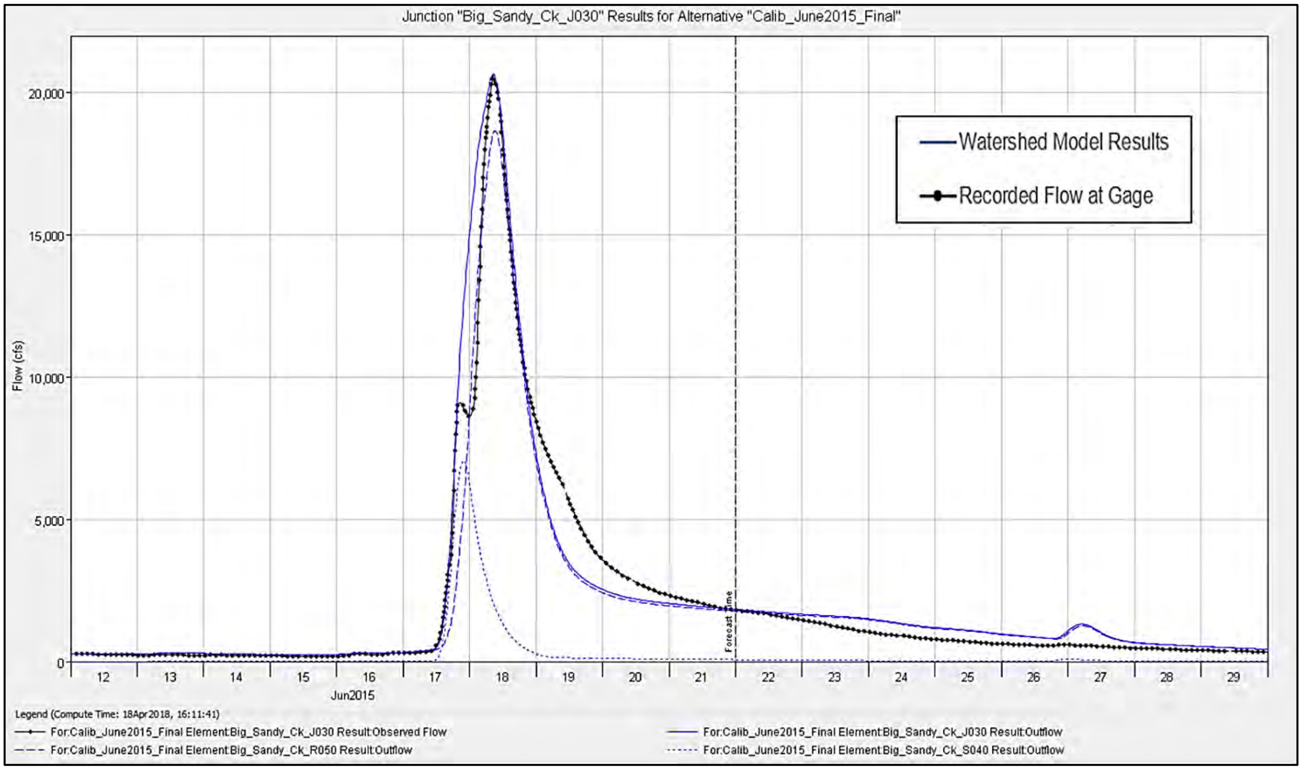

Figure 26c. June 18, 2015 Calibration Results for the Sandy Creek nr Bridgeport, TX Gage

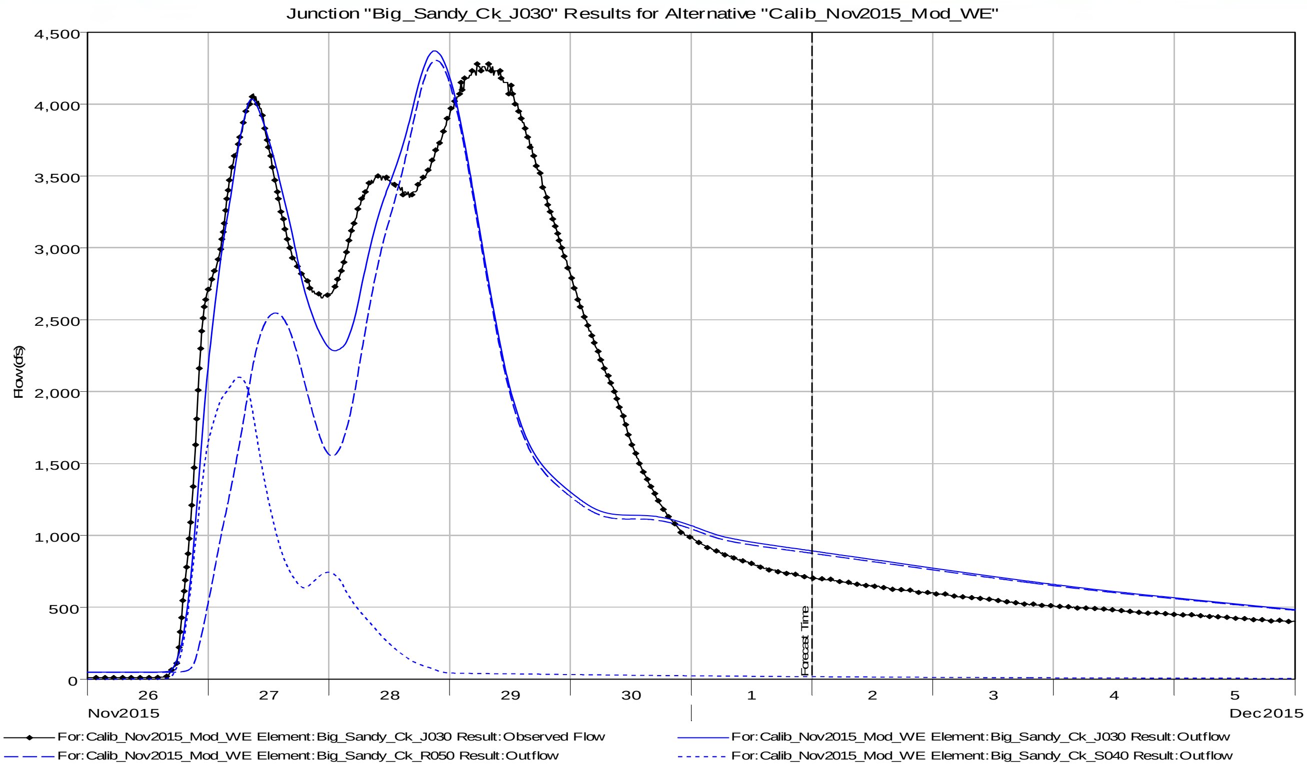

Figure 26d. November 29, 2015 Calibration Results for the Sandy Creek nr Bridgeport, TX Gage

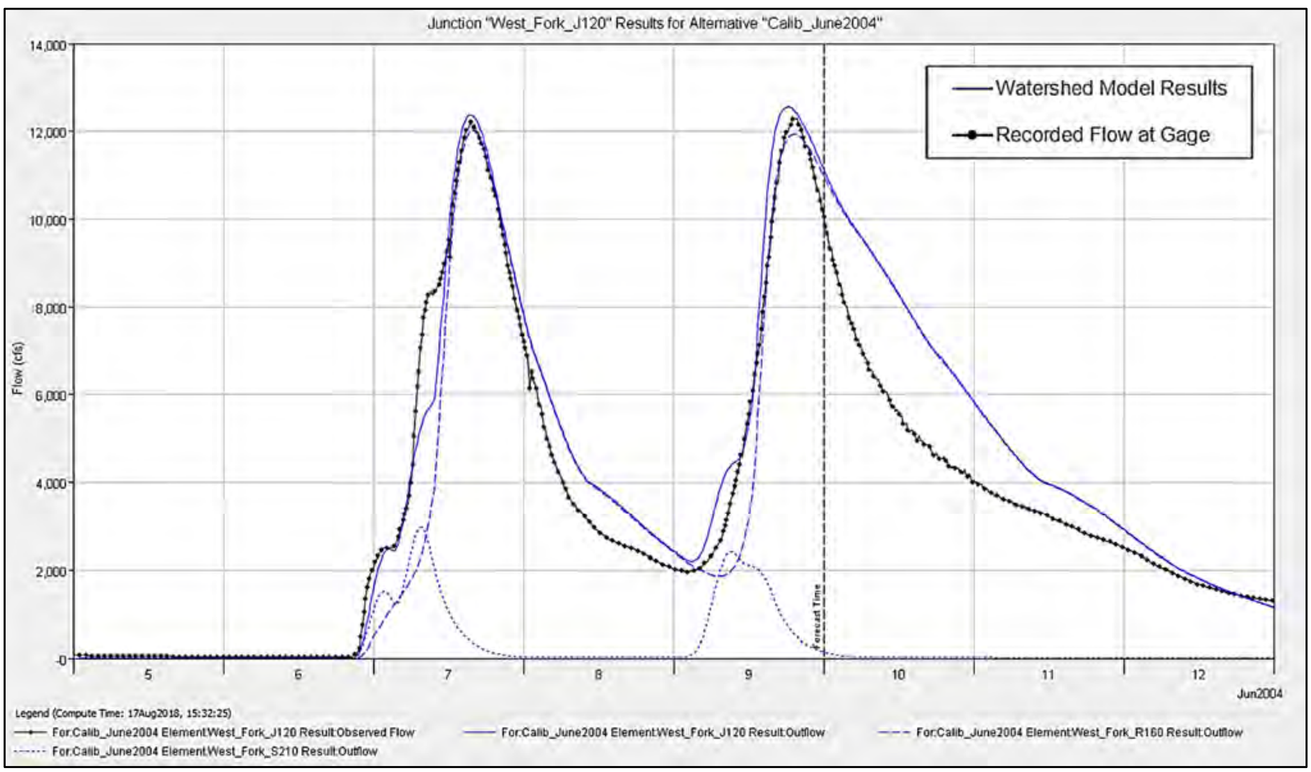

Figure 27a. June 8, 2004 Calibration Results for the West Fork near Boyd, TX Gage

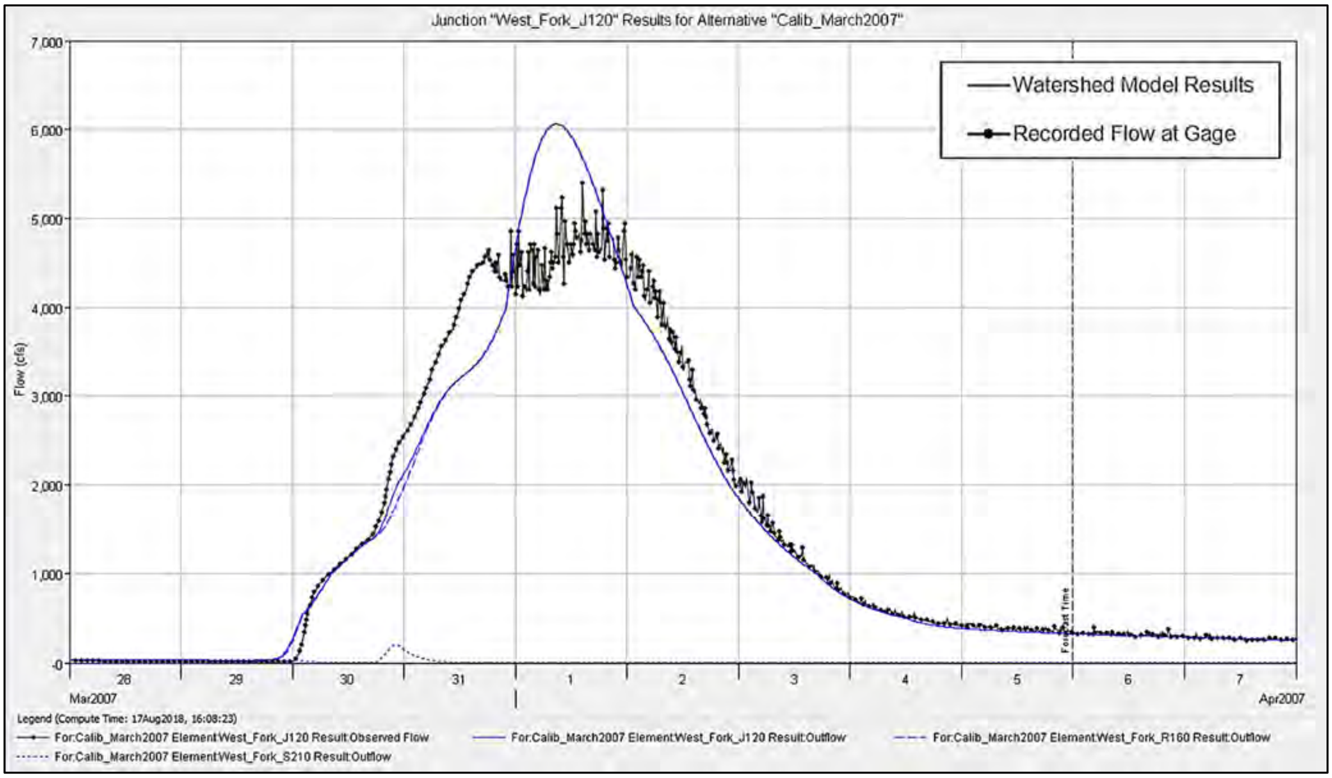

Figure 27b. March 28, 2007 Calibration Results for the West Fork near Boyd, TX Gage

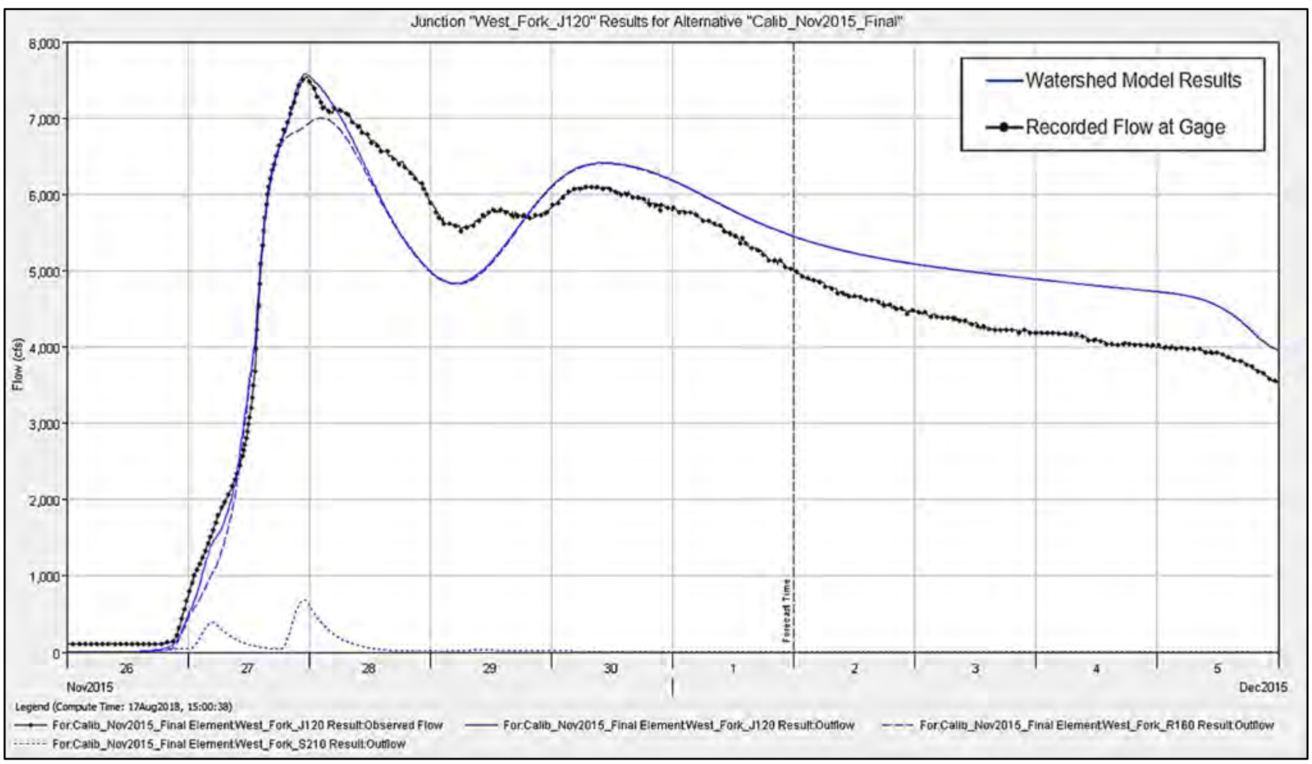

Figure 27c. November 29, 2015 Calibration Results for the West Fort near Boyd, TX Gage

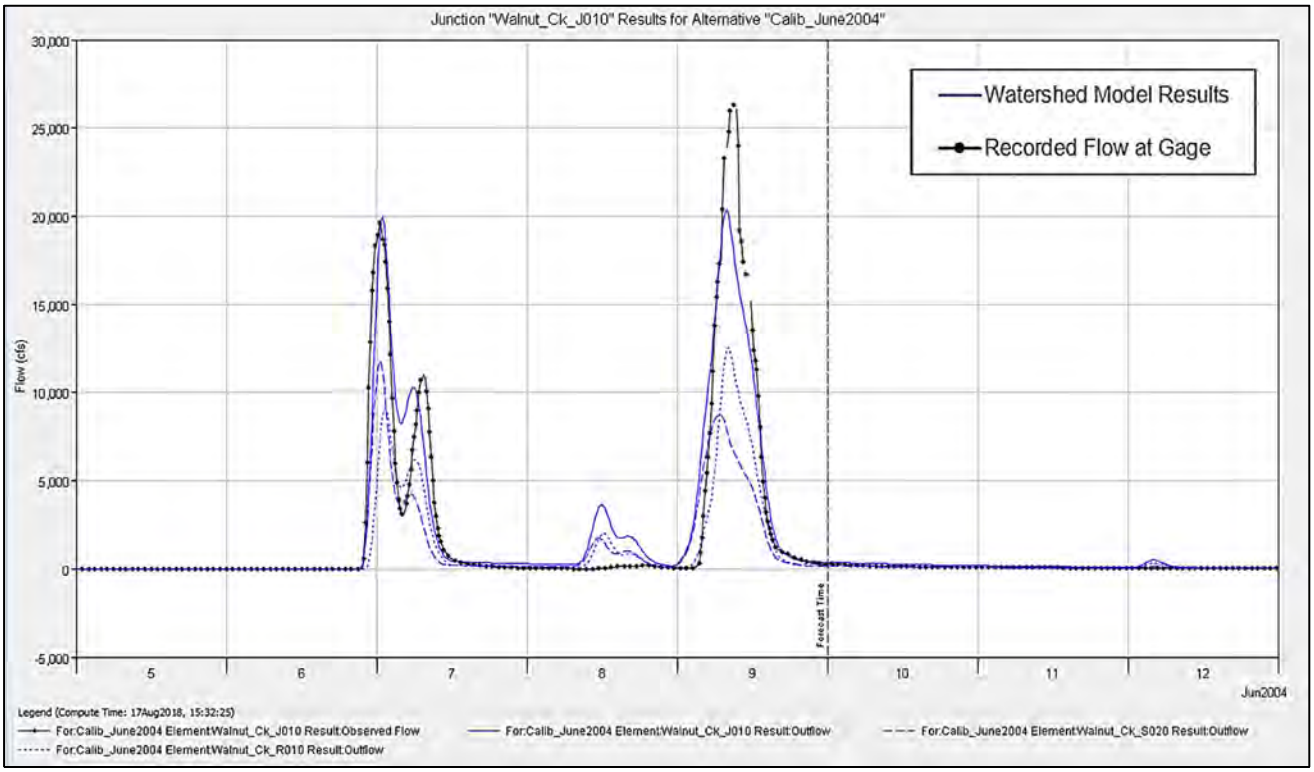

Figure 28a. June 8, 2004 Calibration Results for the Walnut Creek at Reno, TX Gage

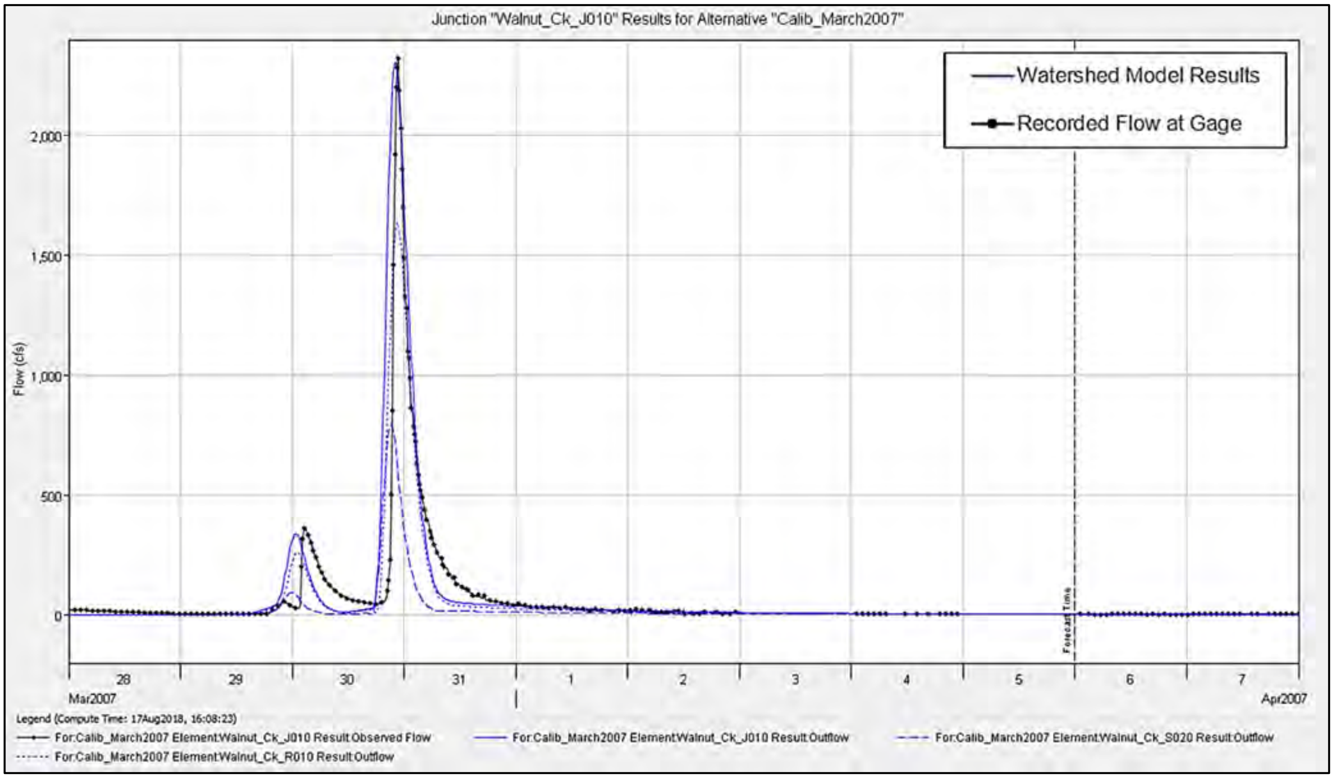

Figure 28b. March 28, 2007 Calibration Results for the Walnut Creek at Reno, TX Gage

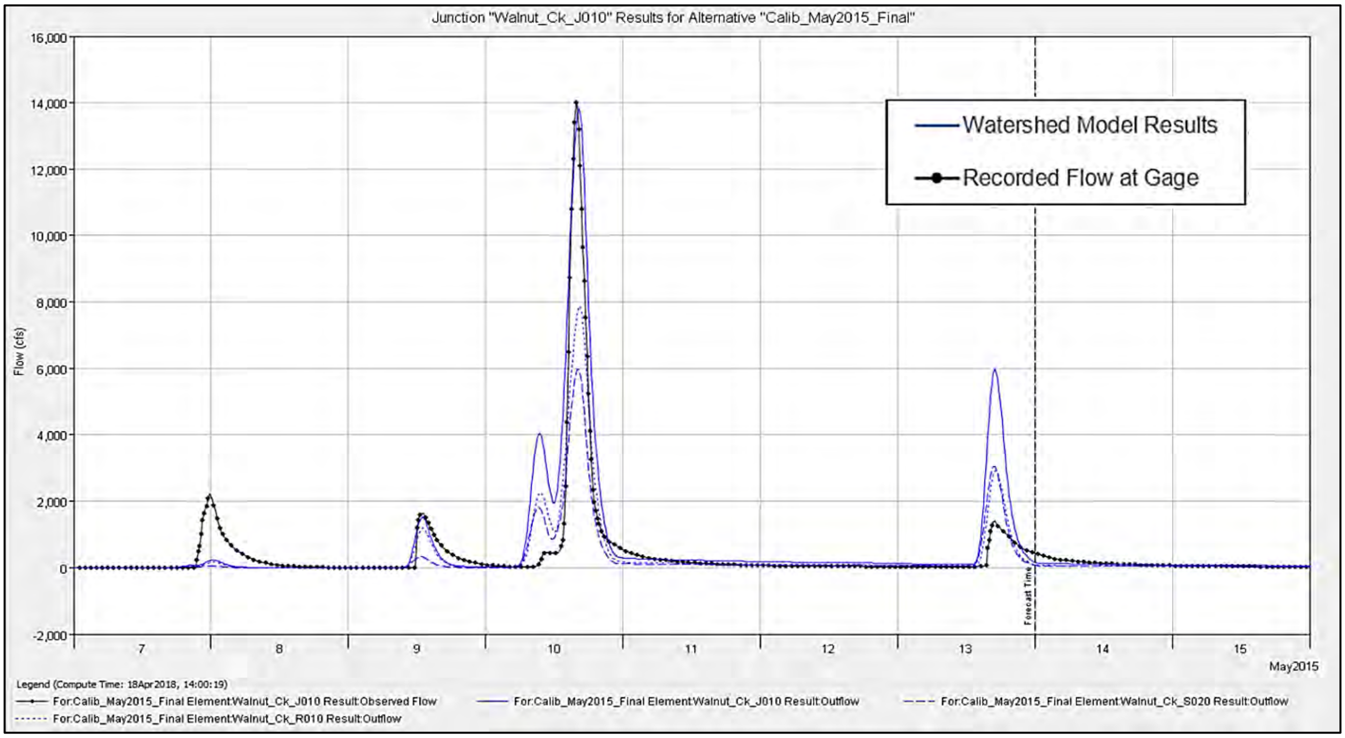

Figure 28c. May 8, 2015 Calibration Results for the Walnut Creek at Reno, TX.

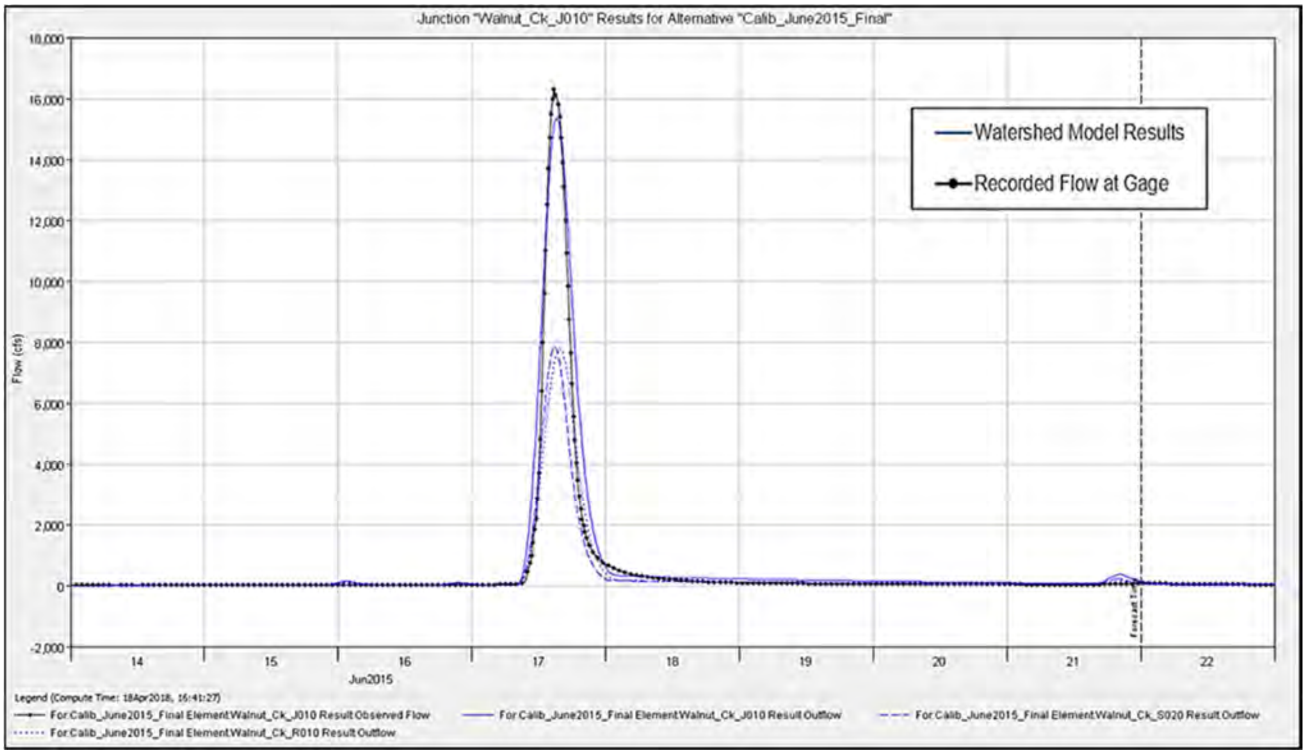

Figure 28d. June 18, 2015 Calibration Results for the Walnut Creek at Reno, TX.

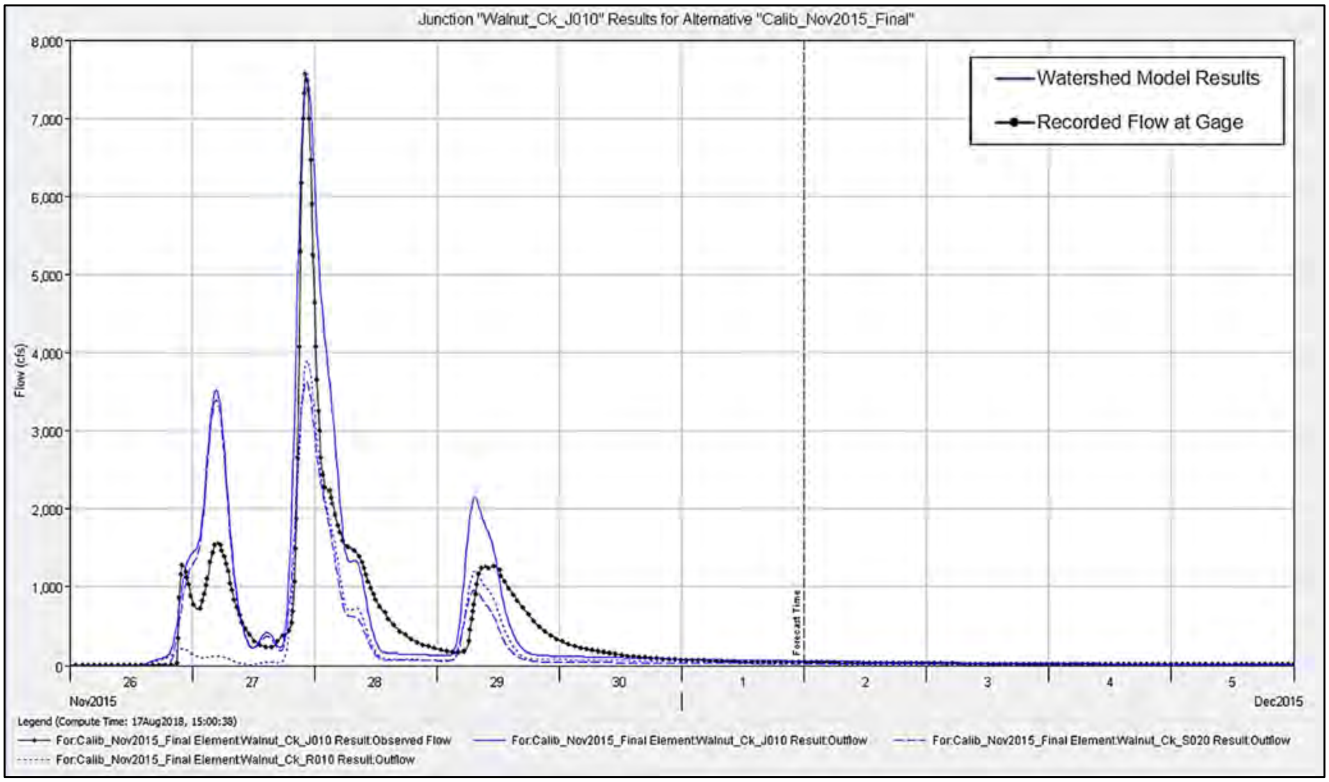

Figure 28e. November 29, 2015 Calibration Results for the Walnut Creek at Reno, TX.

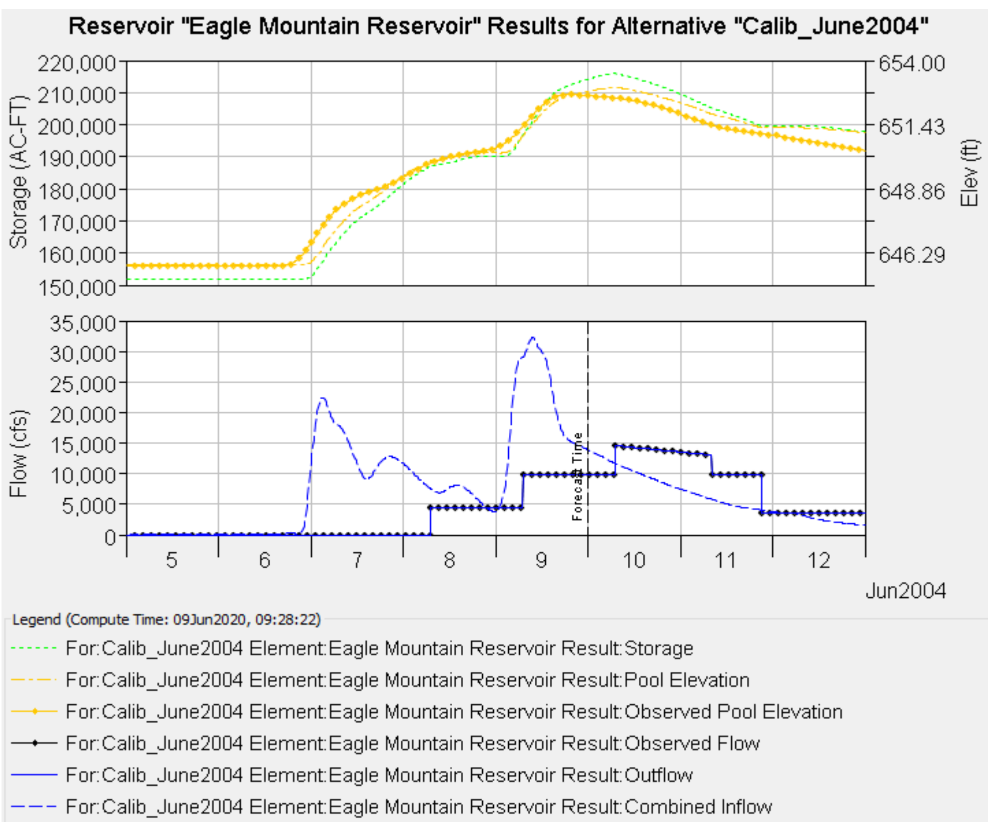

Figure 29a. June 2004 Calibration Results for Eagle Mountain Reservoir

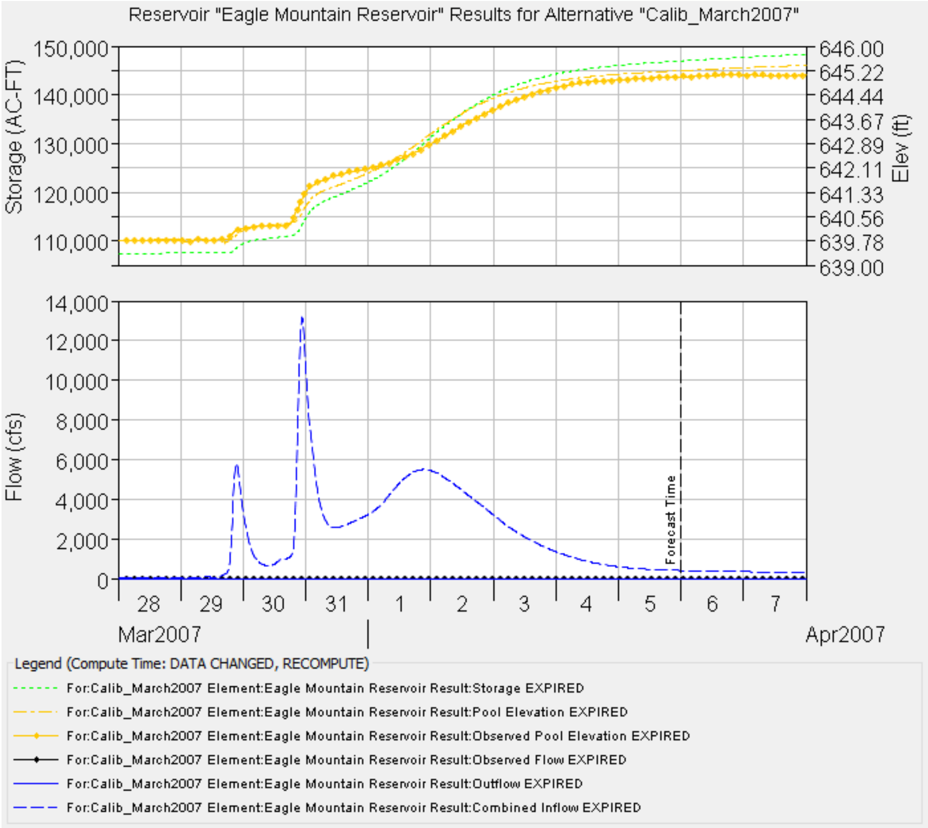

Figure 29b. March 2007 Calibration Results for Eagle Mountain Reservoir

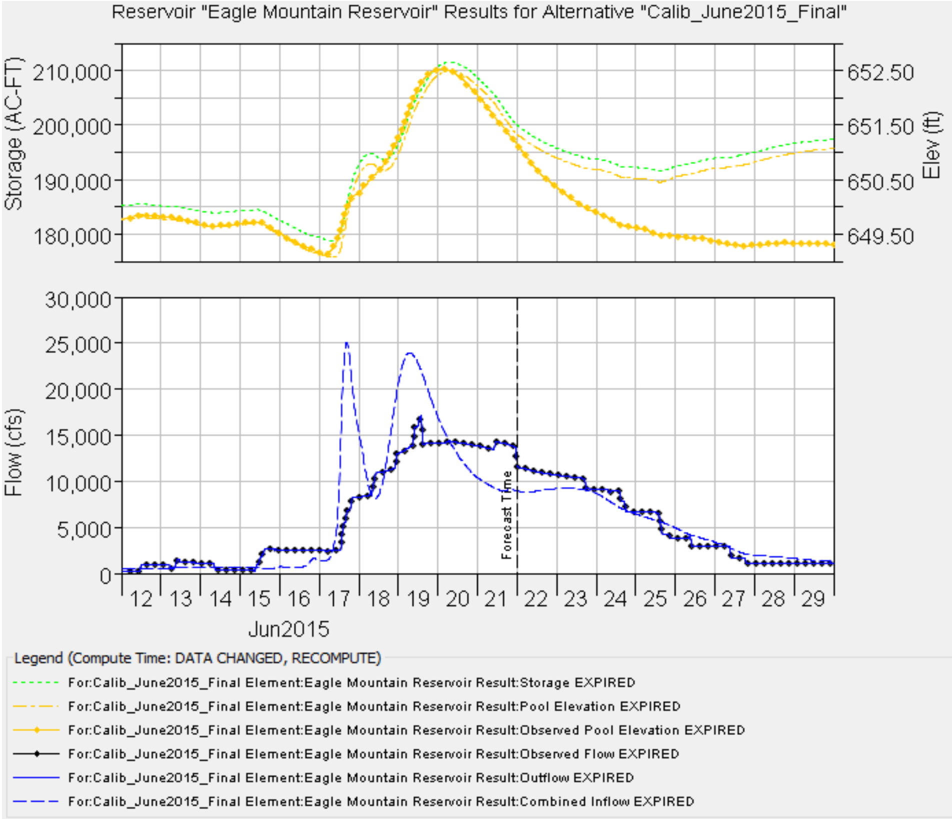

Figure 29c. June 2015 Calibration Results for Eagle Mountain Reservoir

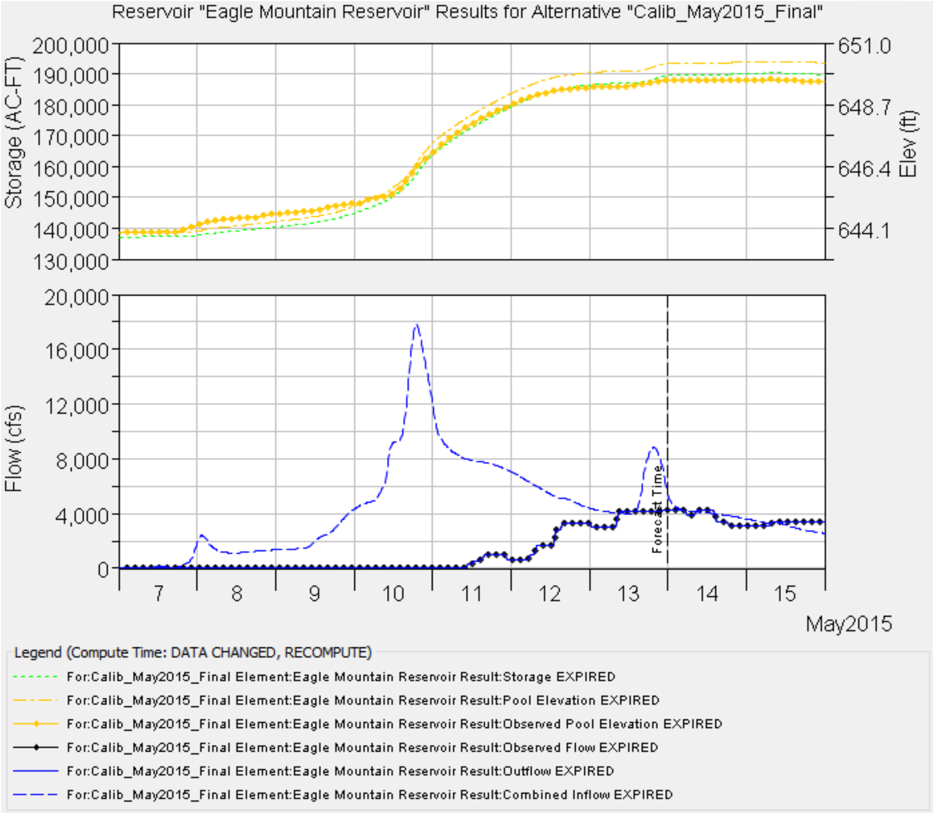

Figure 29d. May 2015 Calibration Results for Eagle Mountain Reservoir

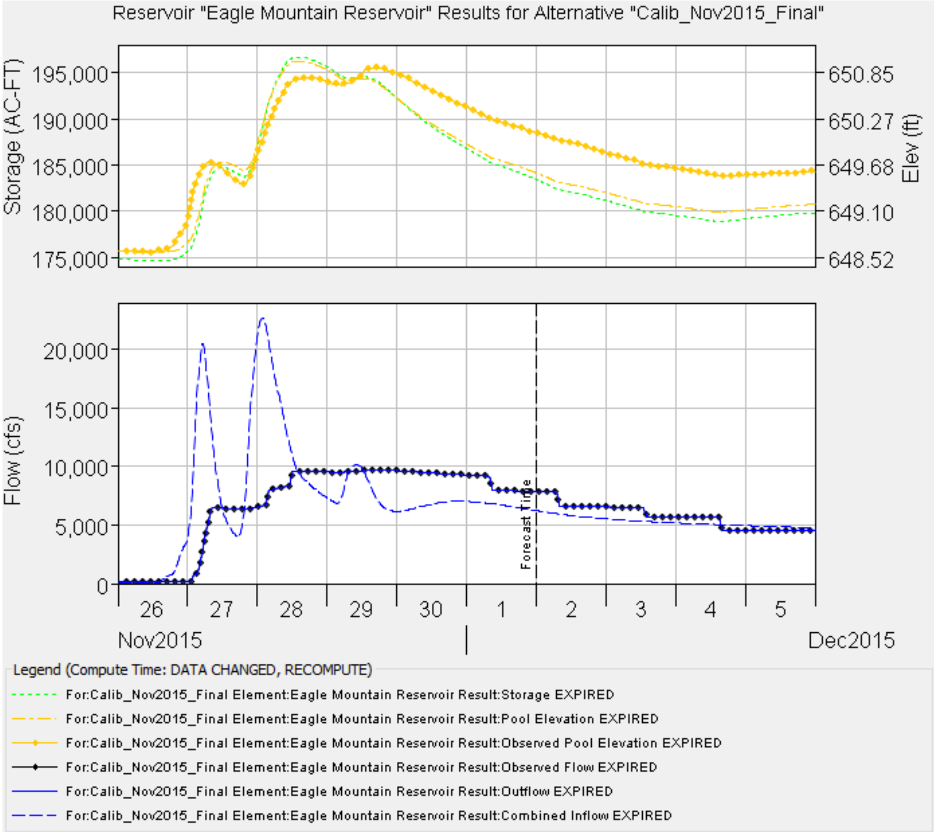

Figure 29e. November 2015 Calibration Results for Eagle Mountain Reservoir

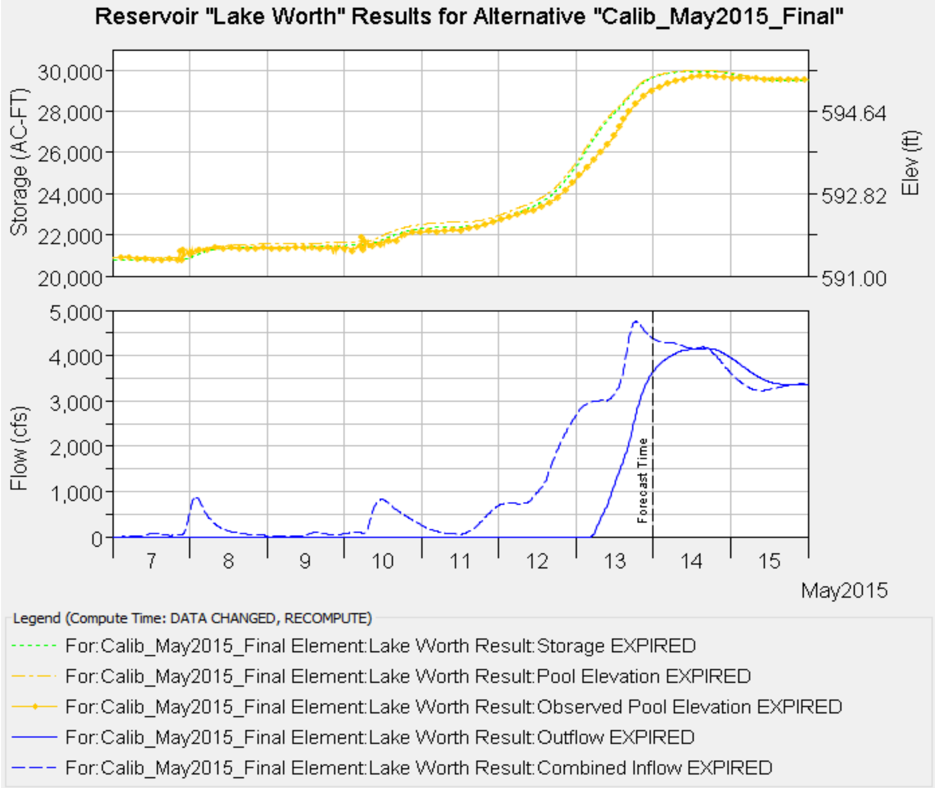

Figure 30a. May 2015 Calibration Results for Lake Worth

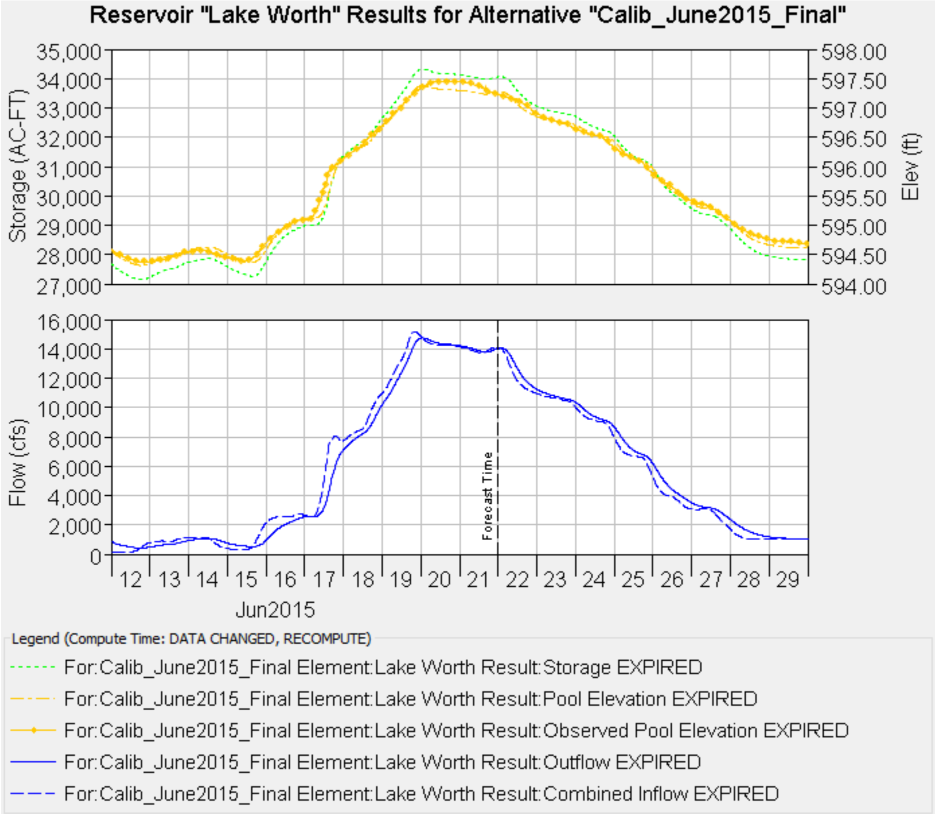

Figure 30b. June 2015 Calibration Results for Lake Worth

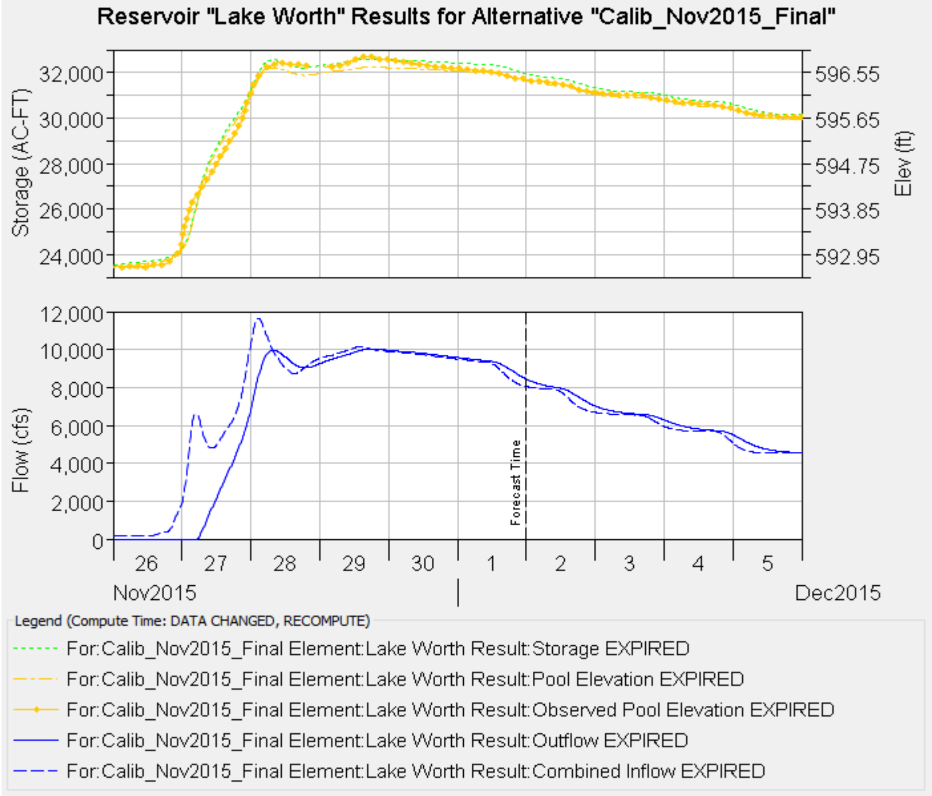

Figure 30c. November 2015 Calibration Results for Lake Worth

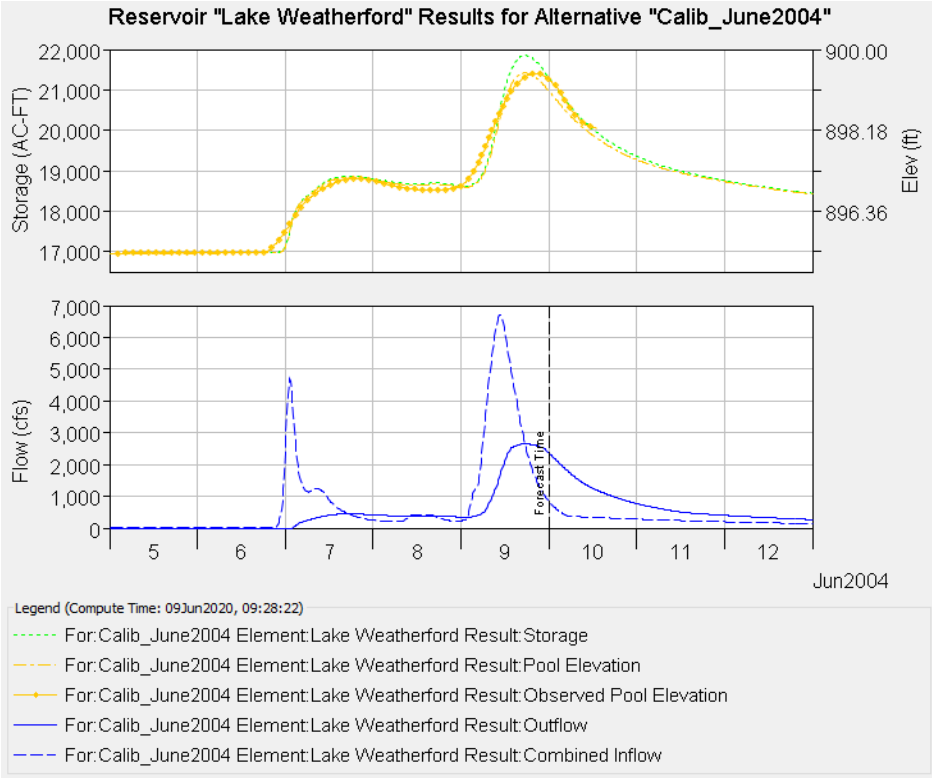

Figure 31a. June 2004 Calibration Results for Lake Weatherford

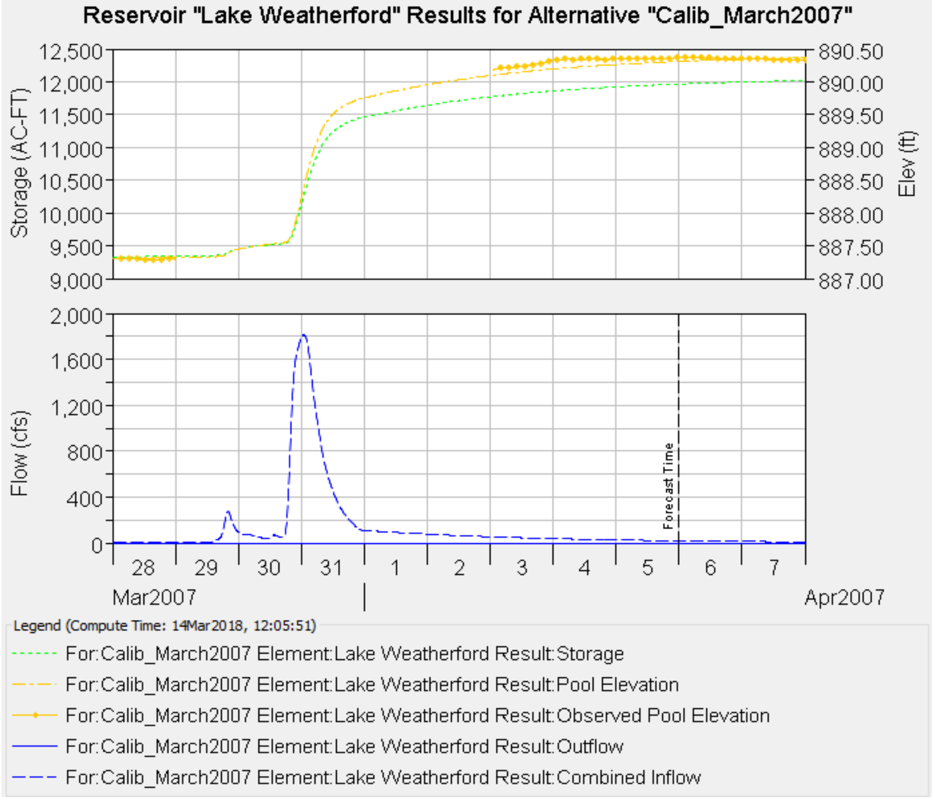

Figure 31b. March 2007 Calibration Results for Lake Weatherford

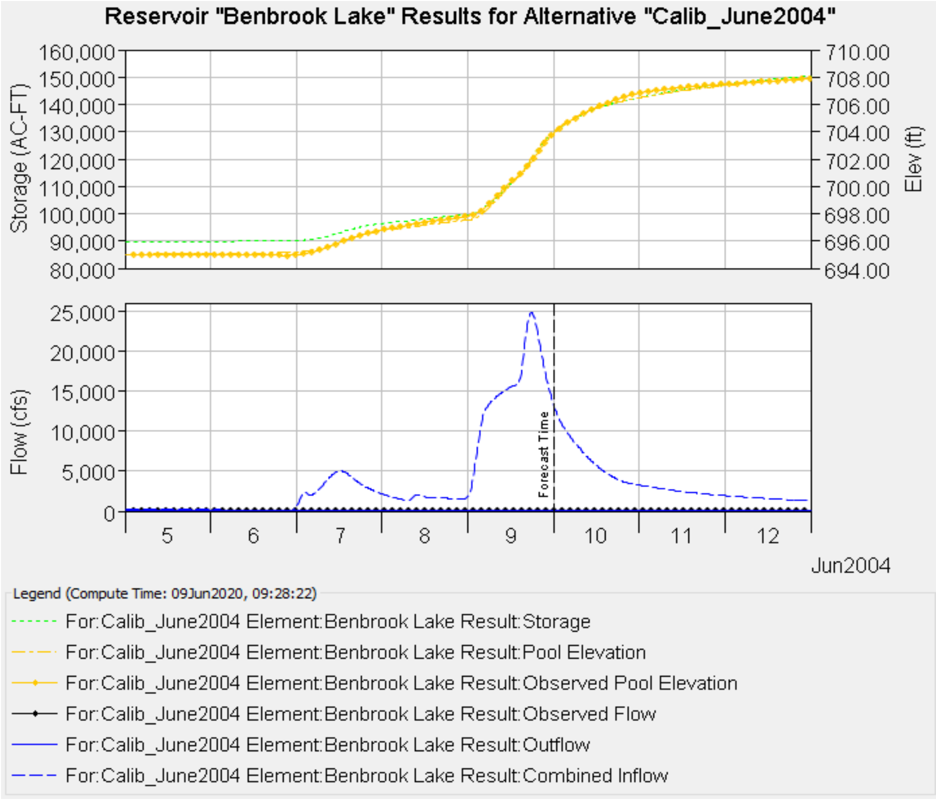

Figure 32a. June 2004 Calibration Results for Benbrook Reservoir

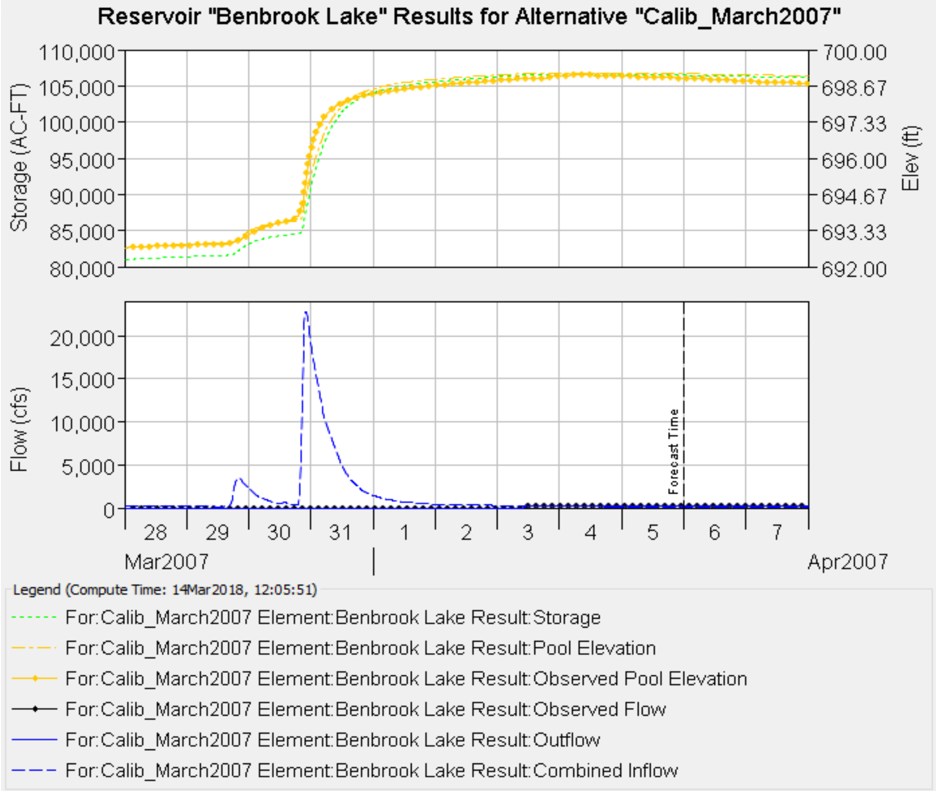

Figure 32b. March 2007 Calibration Results for Benbrook Reservoir

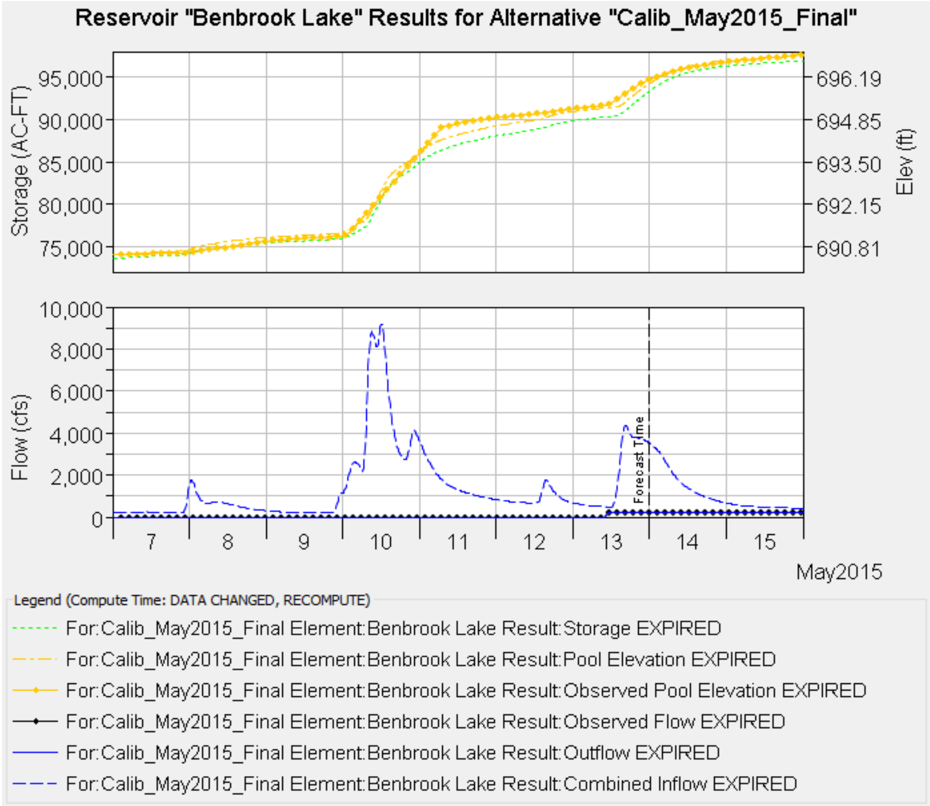

Figure 32c. May 2015 Calibration Results for Benbrook Reservoir

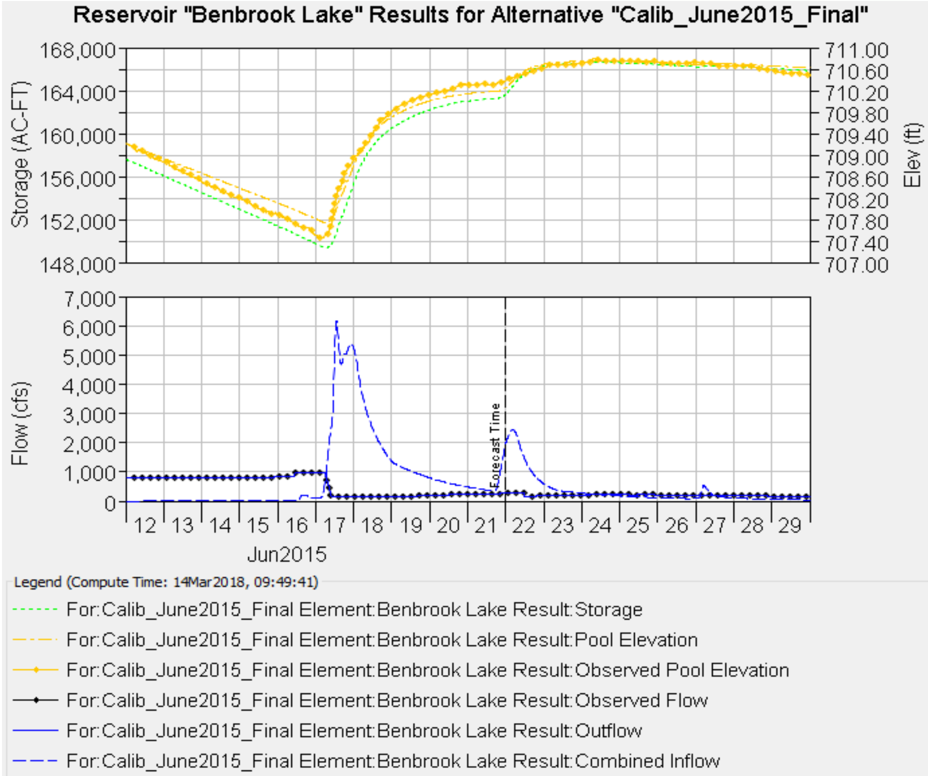

Figure 32d. June 2015 Calibration Results for Benbrook Reservoir

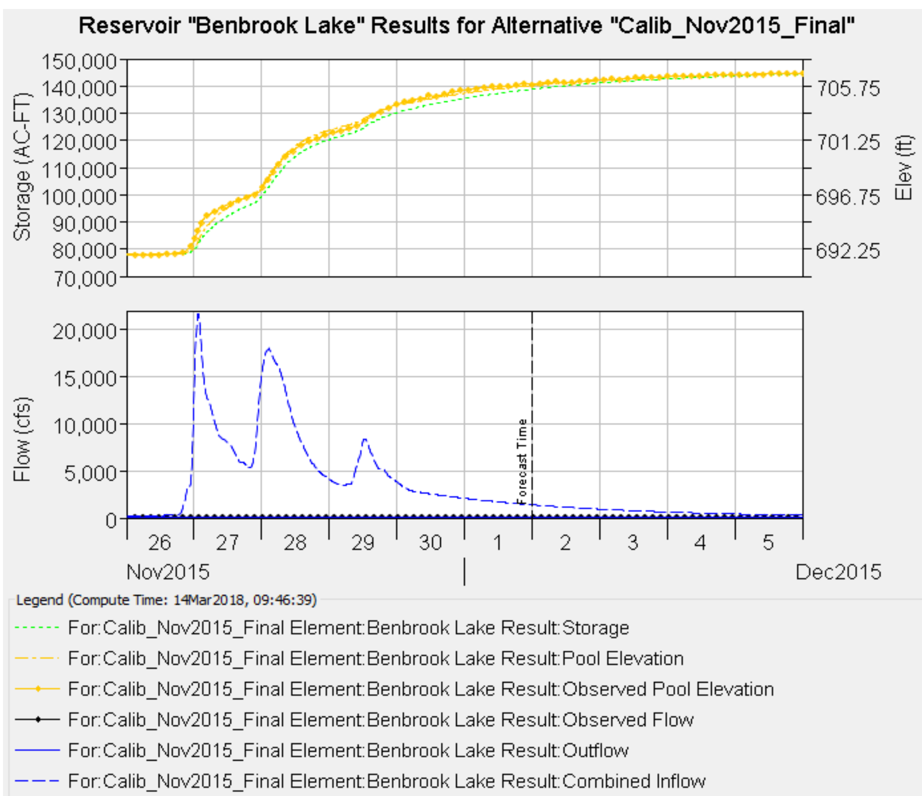

Figure 32e. November 2015 Calibration Results for Benbrook Reservoir

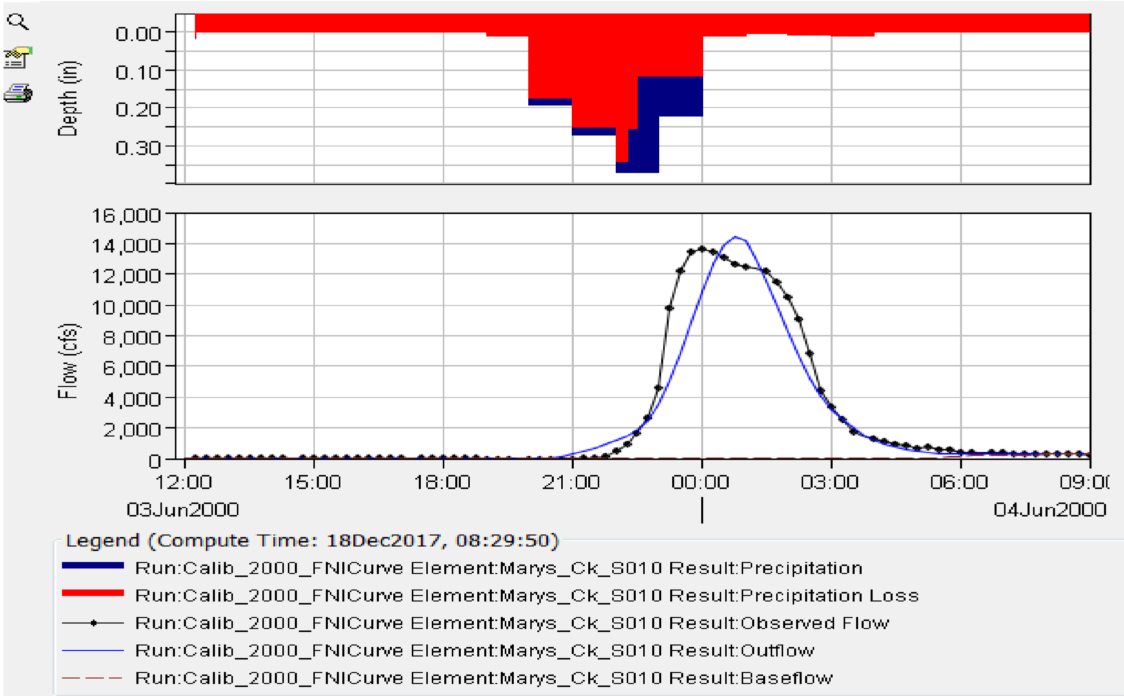

Figure 2. June 2000 Calibration Results for the Marys Creek at Benbrook, TX Gage

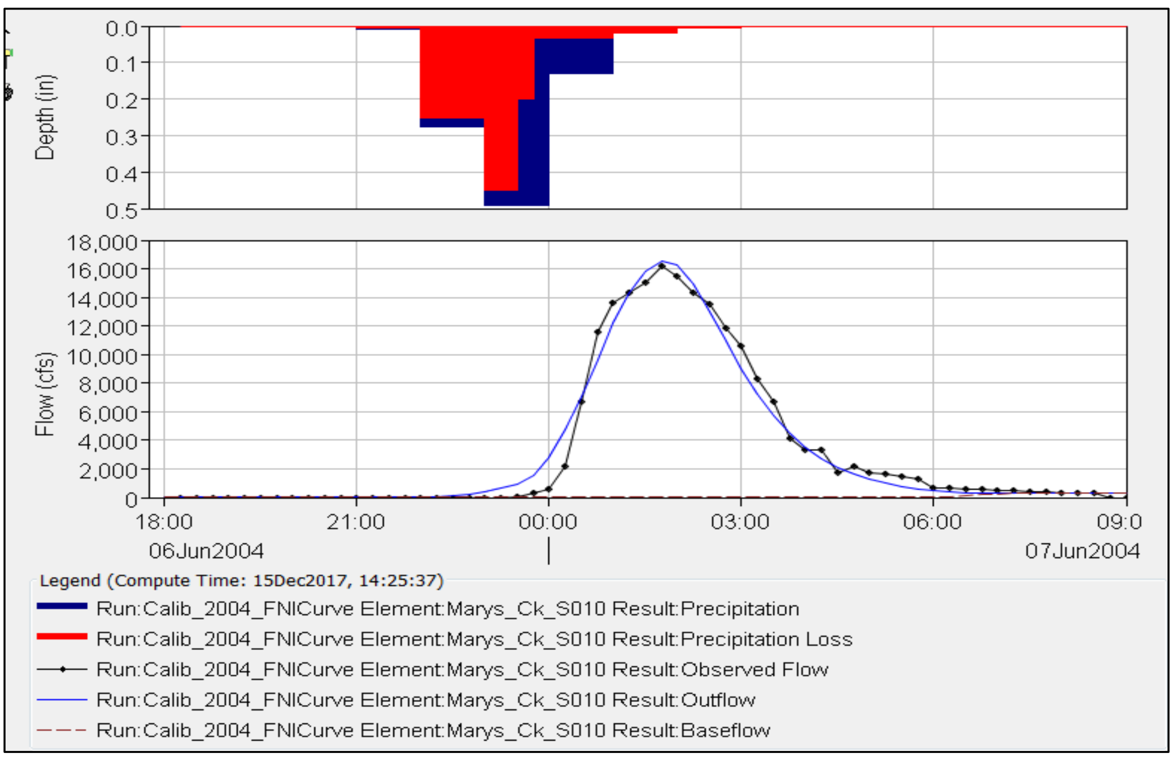

Figure 3. June 2004 Calibration Results for the Marys Creek at Benbrook, TX Gage

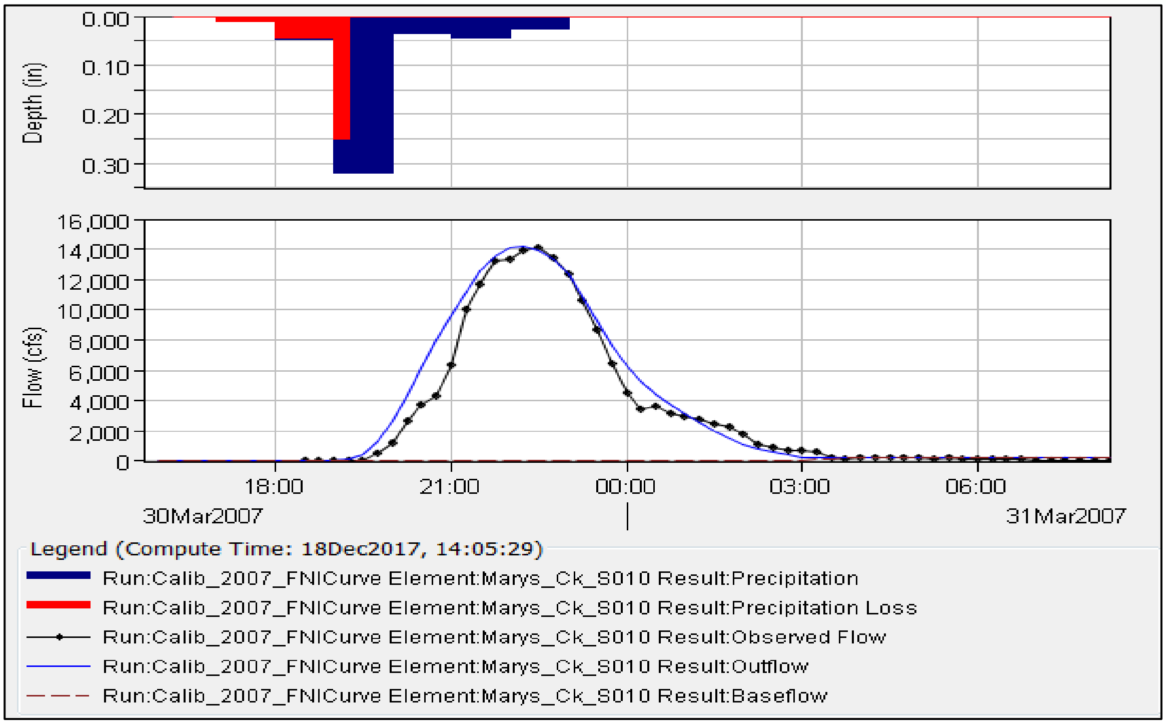

Figure 4. March 2007 Calibration Results for the Marys Creek at Benbrook, TX Gage

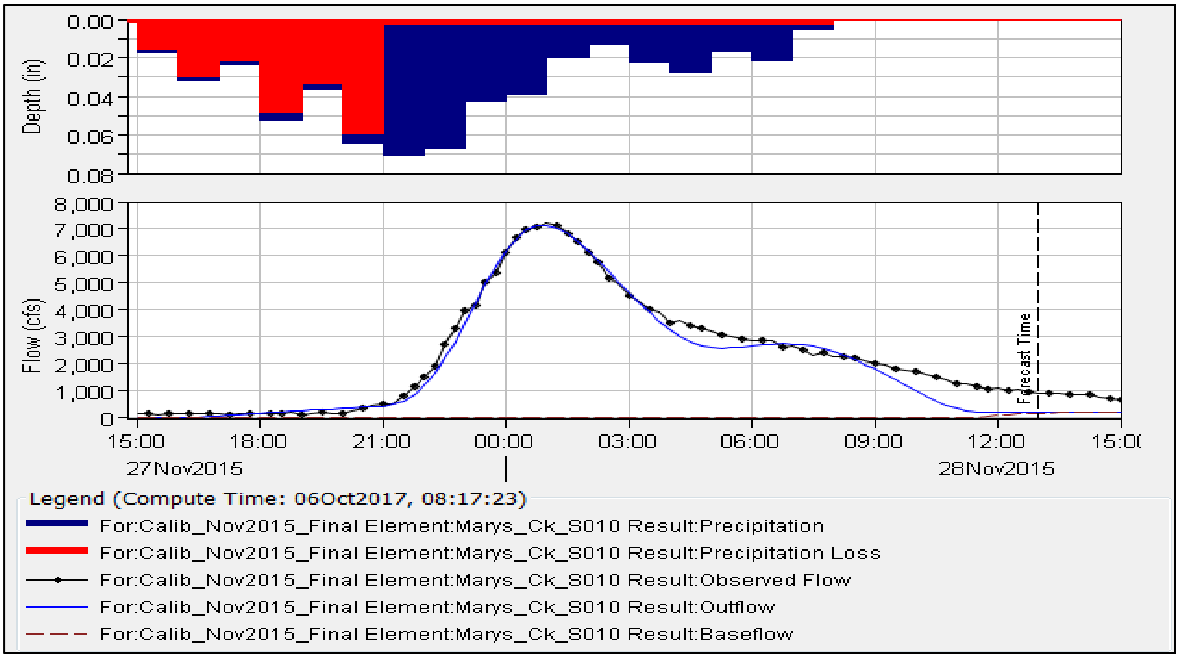

Figure 5. May 2015 Calibration Results for the Marys Creek at Benbrook, TX Gage

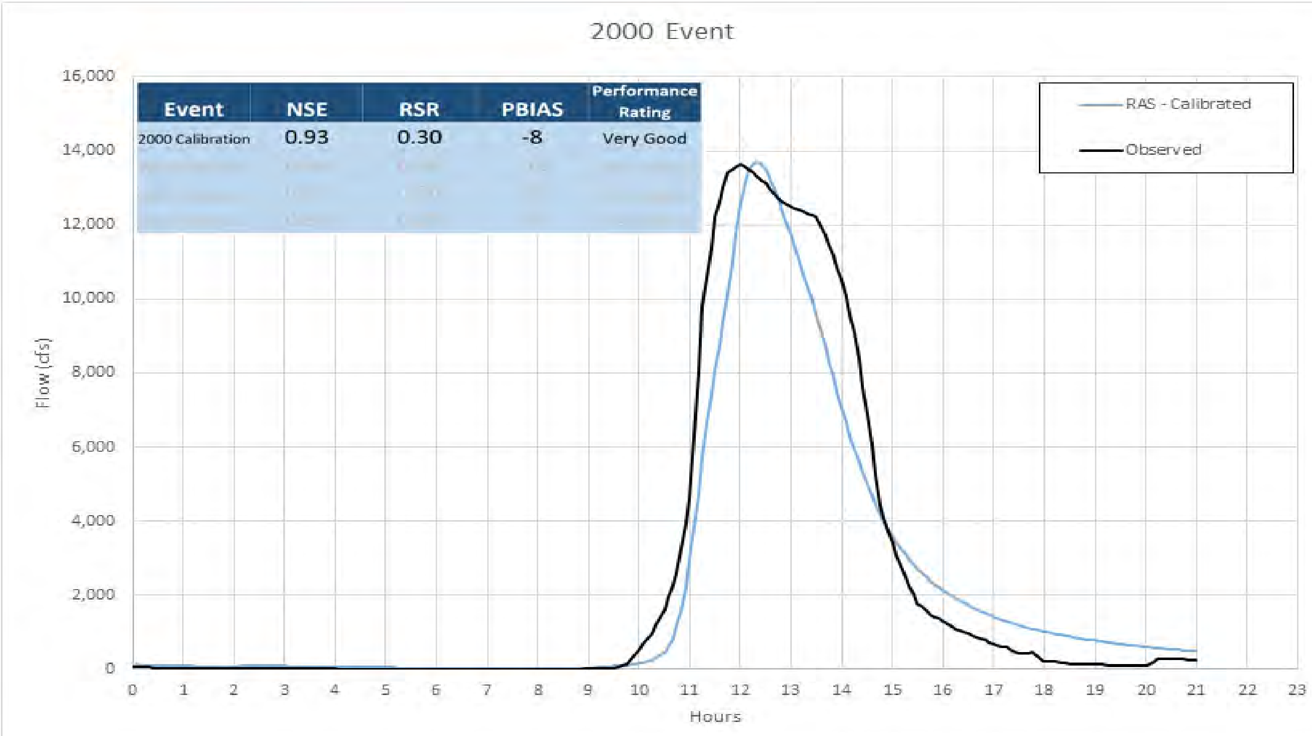

Figure 6. June 2000 RAS 2D Calibration Results for the Marys Creek at Benbrook, TX Gage

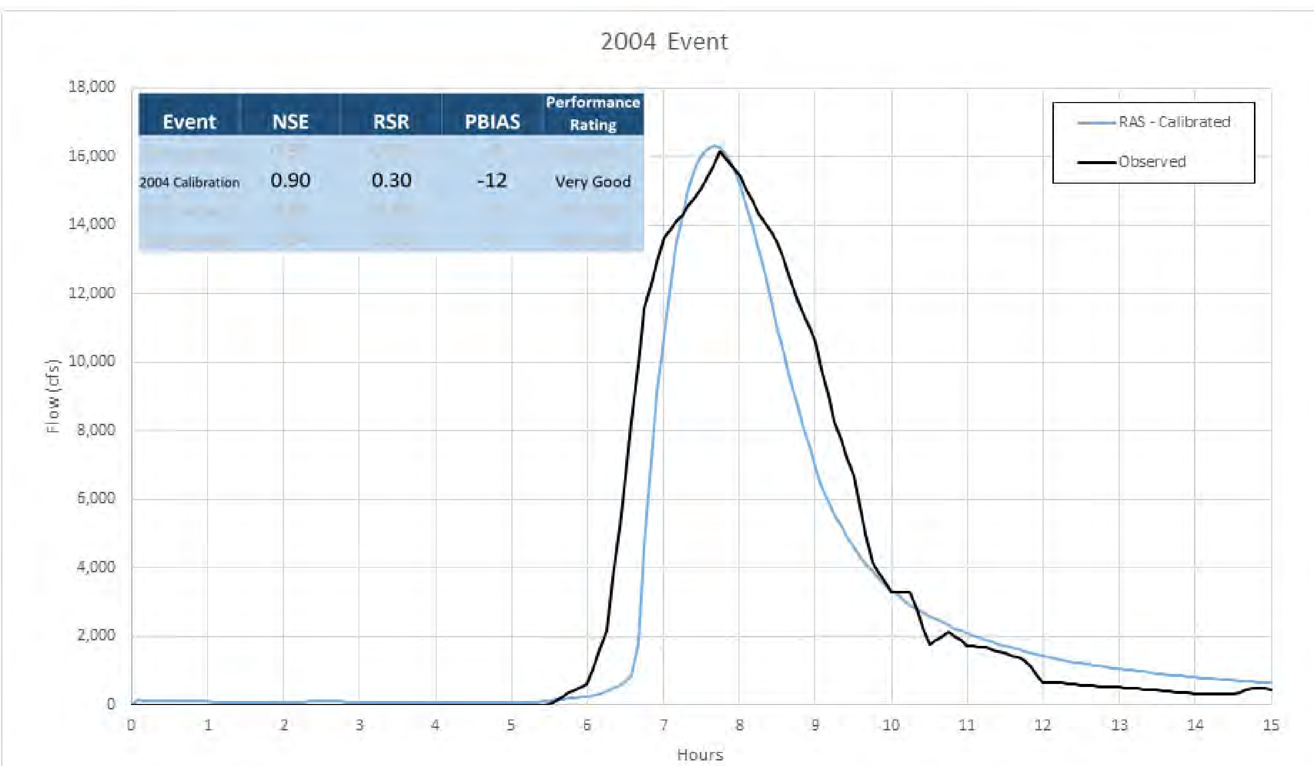

Figure 7. June 2000 RAS 2D Calibration Results for the Marys Creek at Benbrook, TX Gage

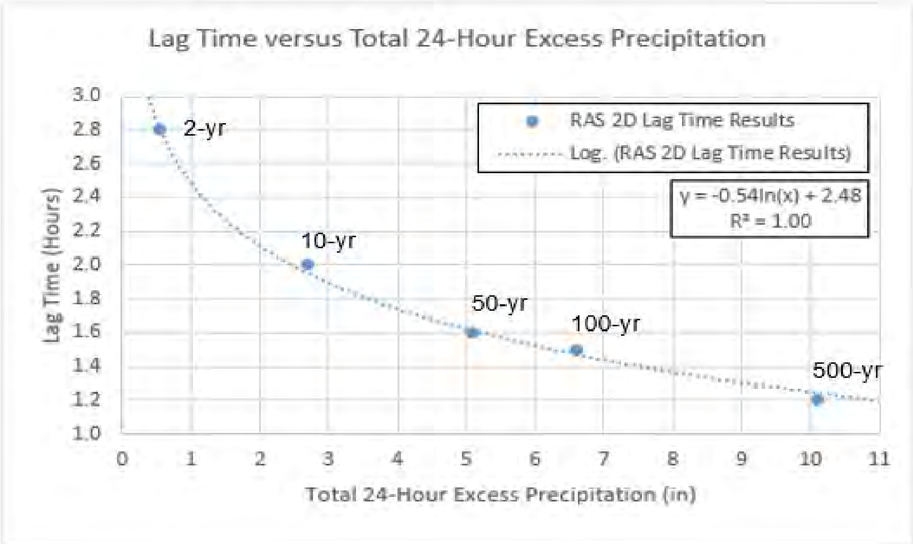

Figure 8. RAS 2D Snyder Lag Times for the Marys Creek at Benbrook, TX Gage

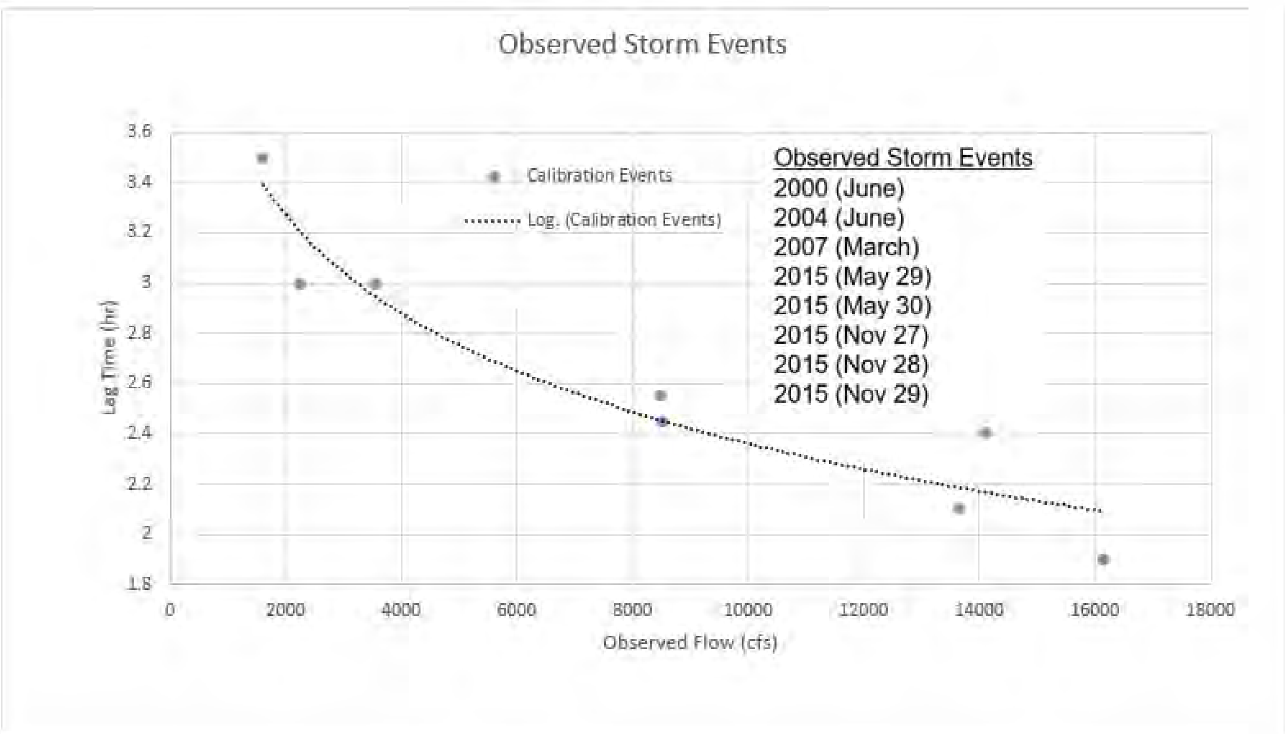

Figure 9. Calibrated Snyder Lag Times for the Marys Creek at Benbrook, TX Gage

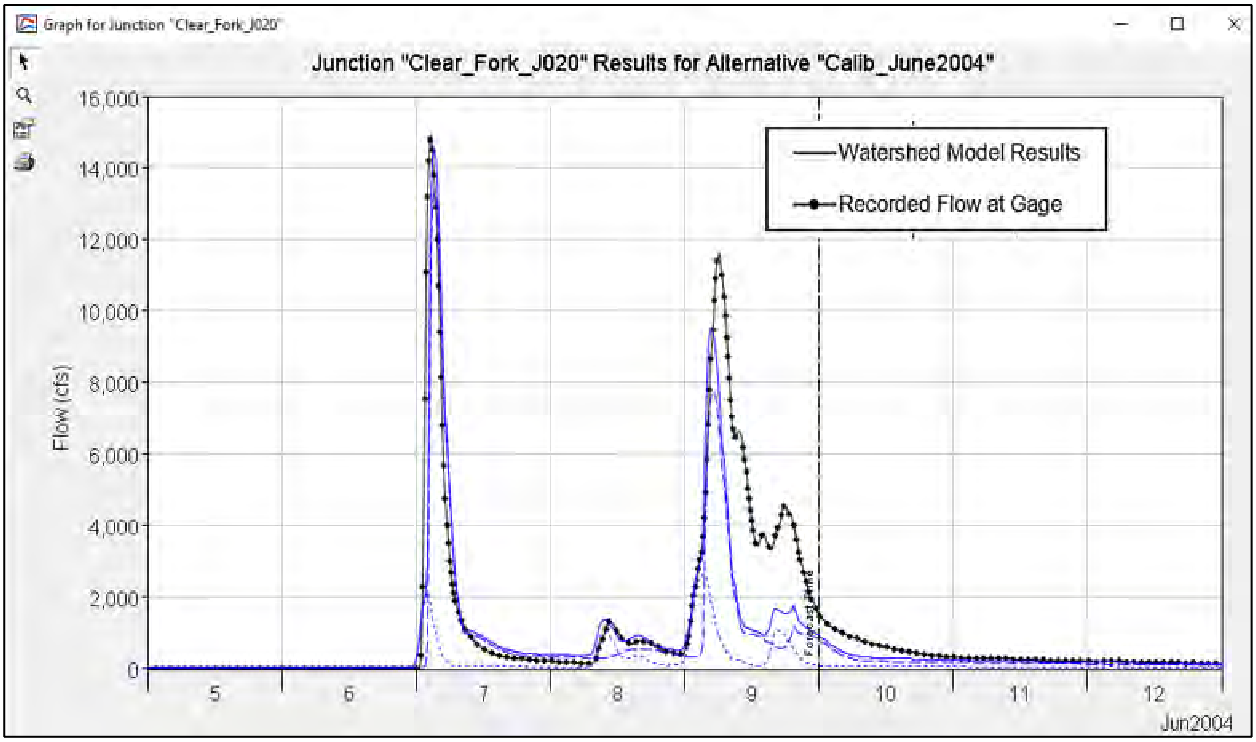

Figure 34a. June 2004 Calibration Results for the Clear Fork at Fort Worth, TX Gage

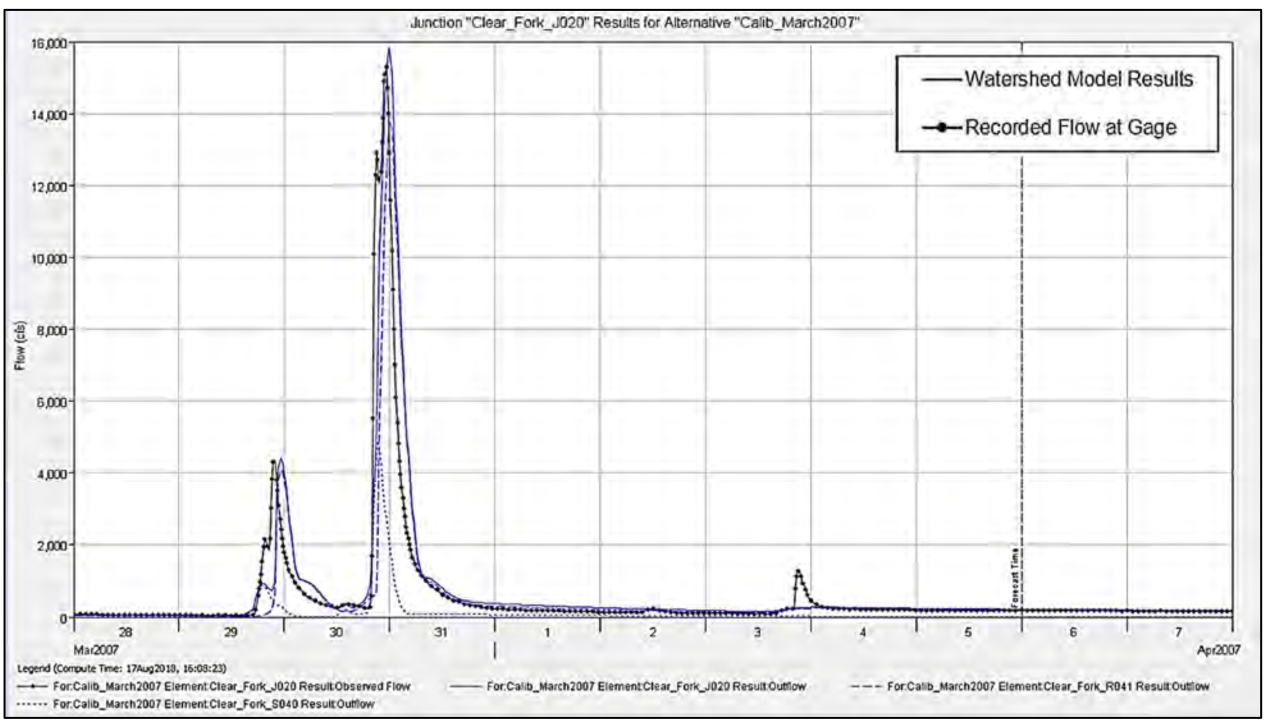

Figure 34b. March 28, 2007 Calibration Results for the Clear Fork at Fort Worth, TX Gage

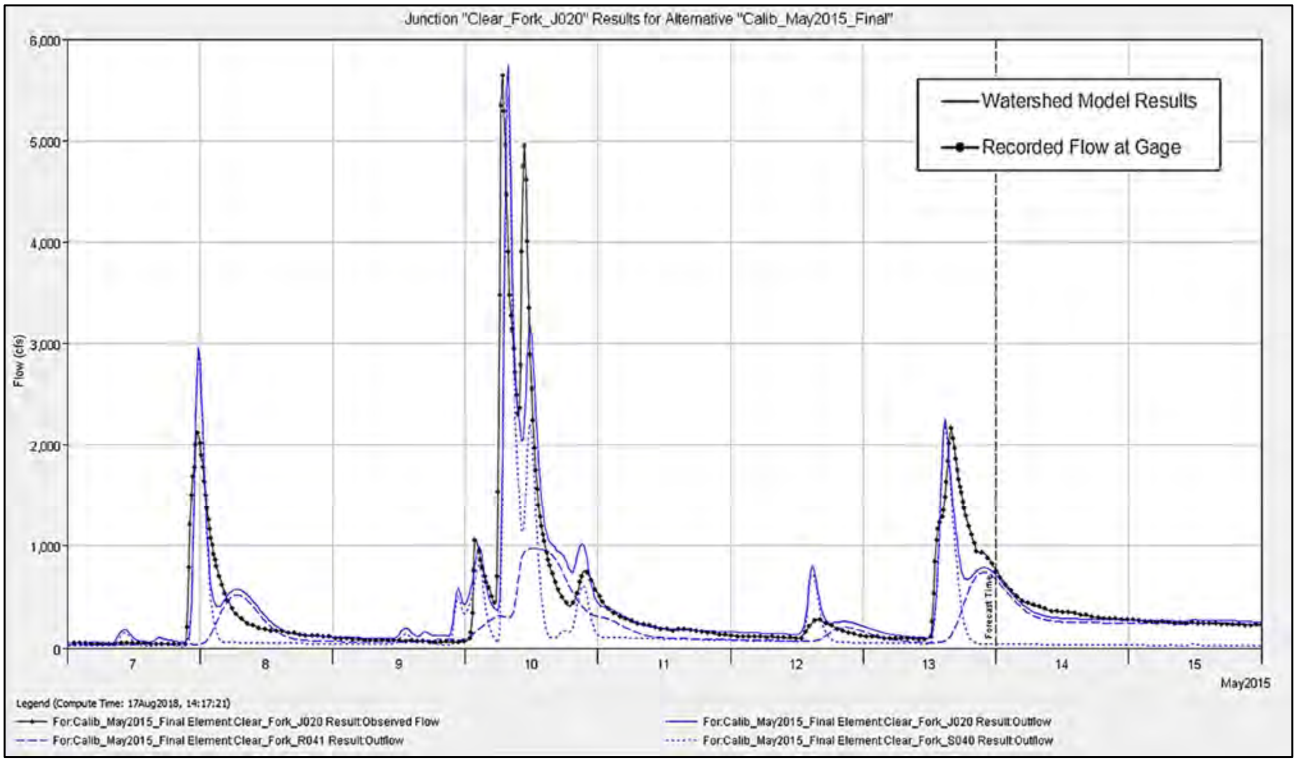

Figure 34c. May 8, 2015 Calibration Results for the Clear Fork at Fort Worth, TX Gage

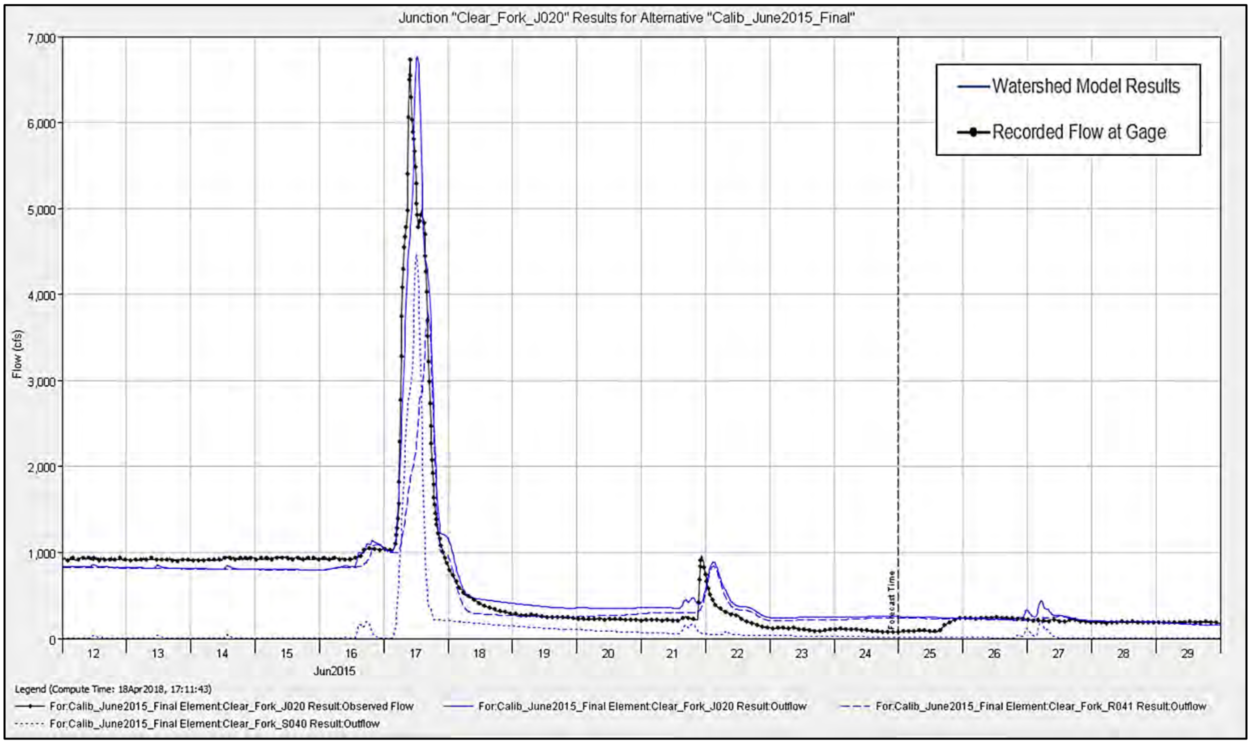

Figure 34d. June 18, 2015 Calibration Results for the Clear Fork at Fort Worth, TX Gage

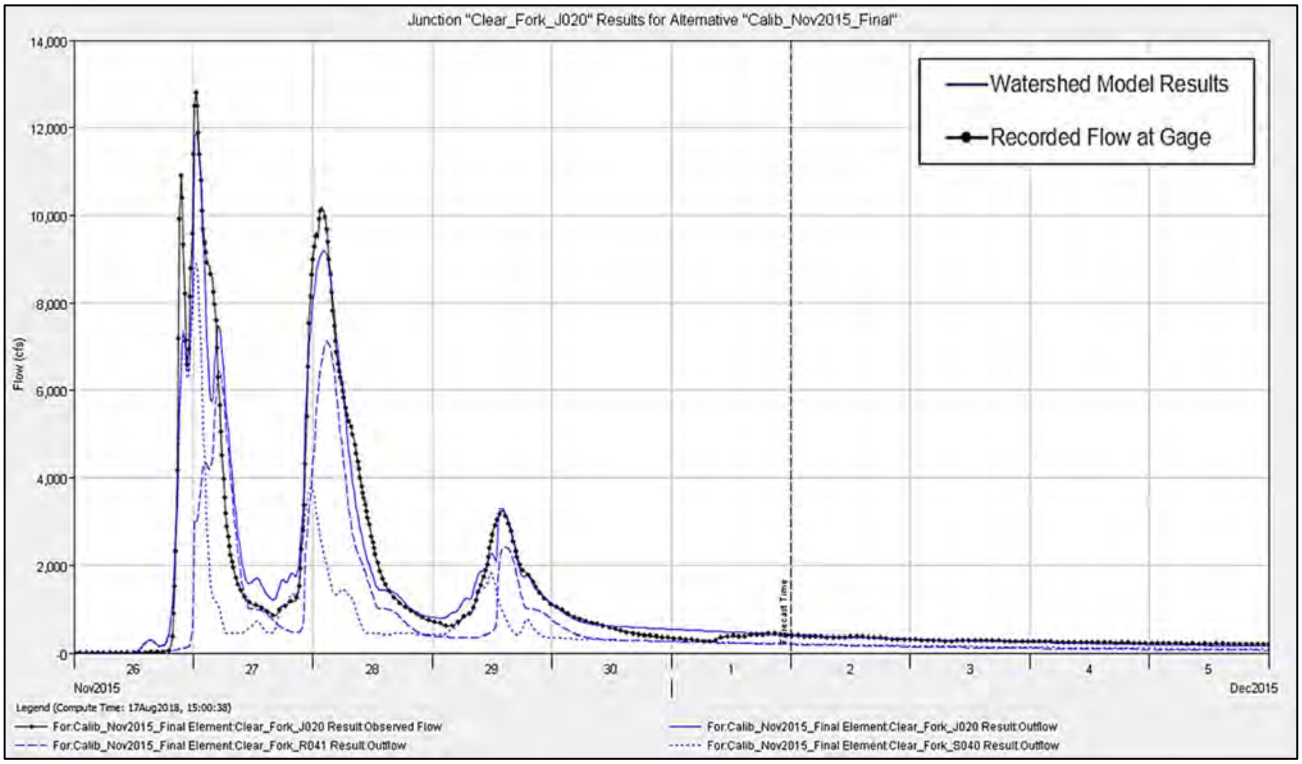

Figure 34e. November 29, 2015 Calibration Results for the Clear Fork at Fort Worth, TX Gage

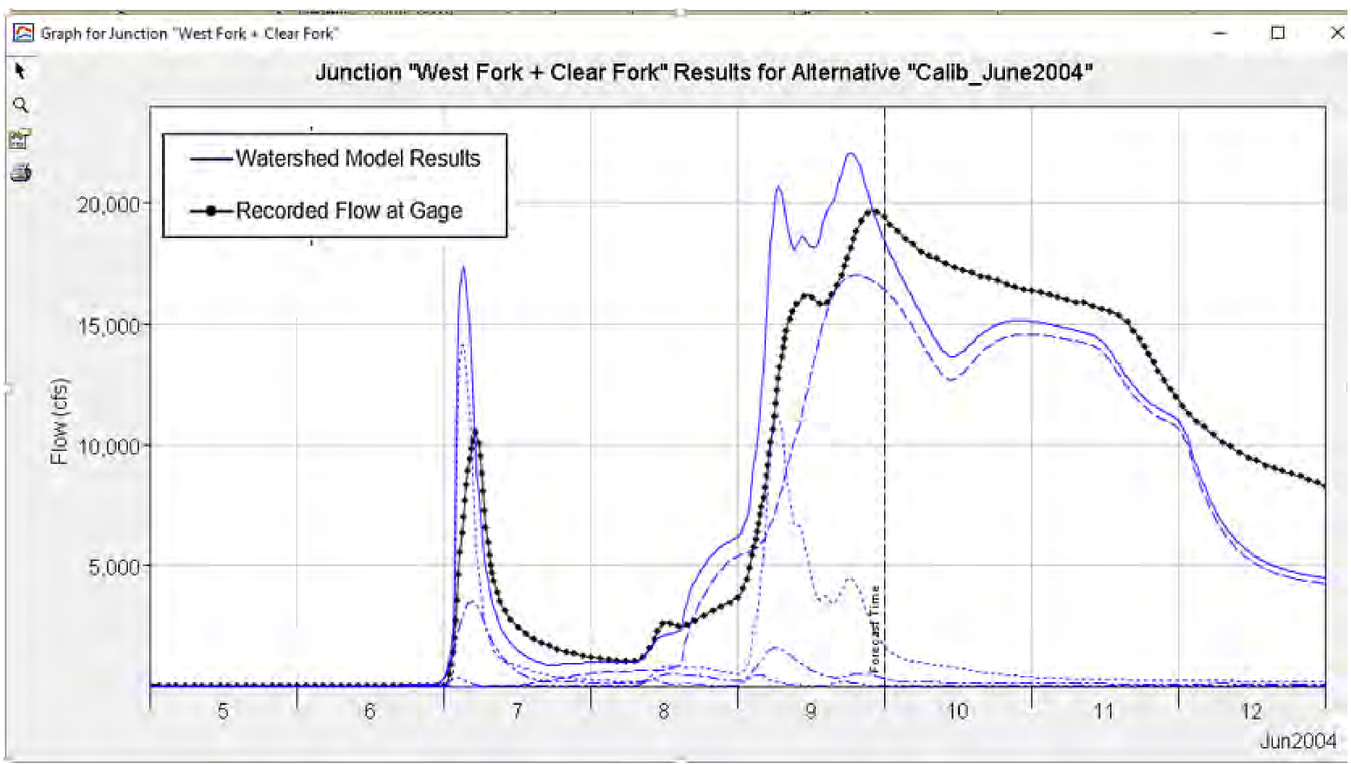

Figure 35a. June 8, 2004 Calibration Results for the West Fork at Fort Worth, TX Gage

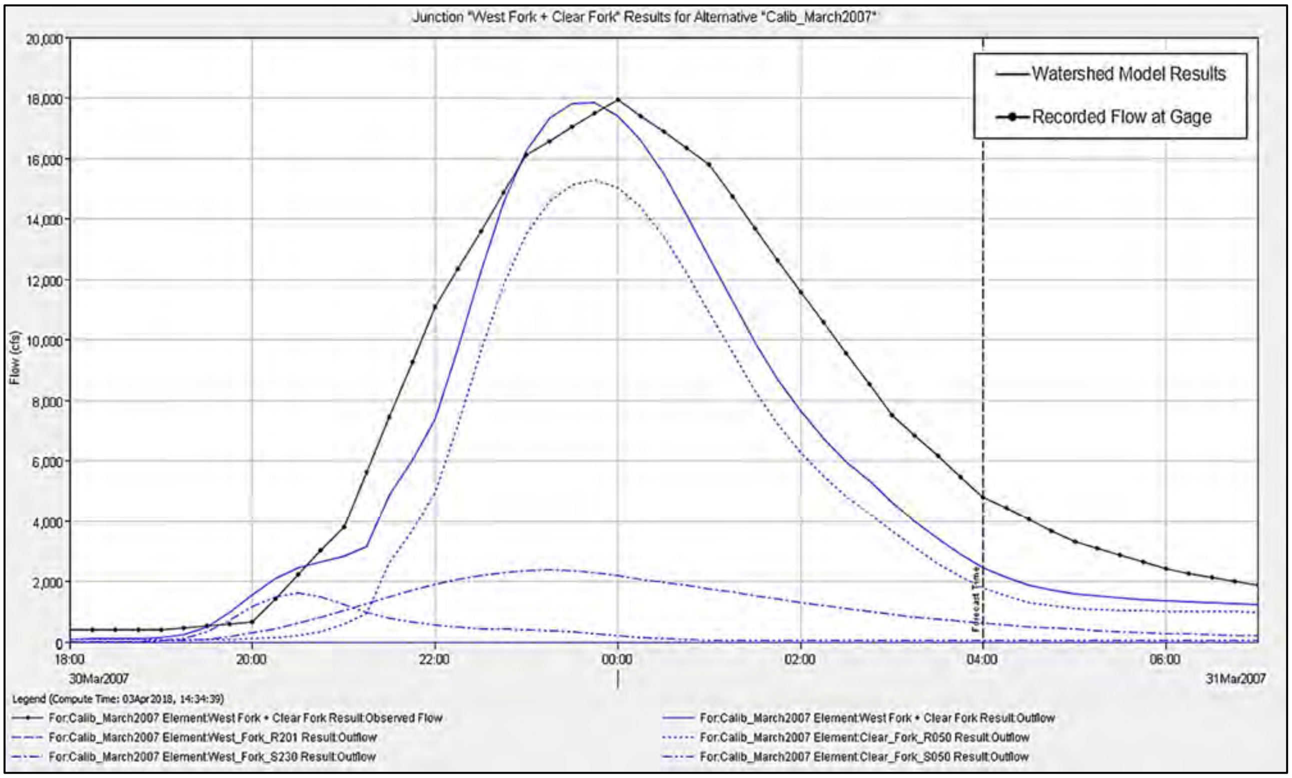

Figure 35b. March 28, 2007 Calibration Results for the West Fork at Fort Worth, TX Gage

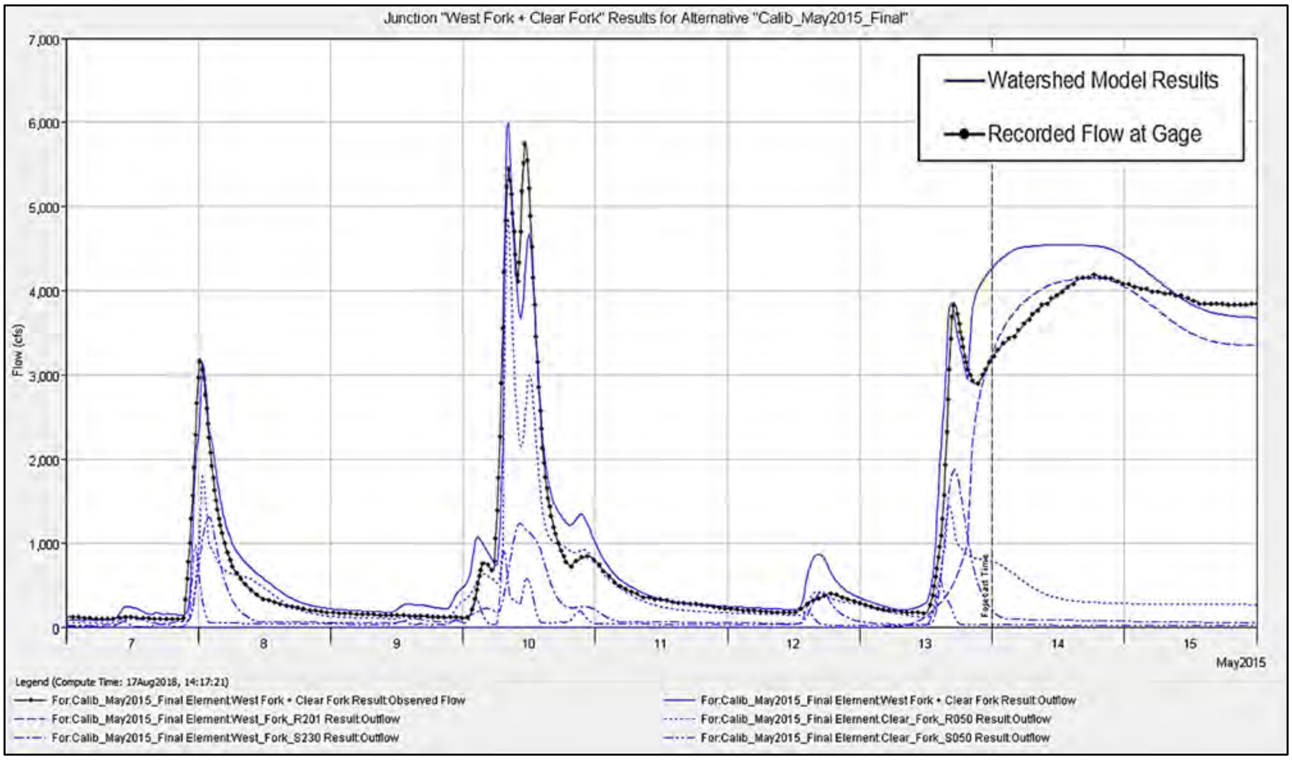

Figure 35c. May 8, 2015 Calibration Results for the West Fork at Fort Worth, TX Gage

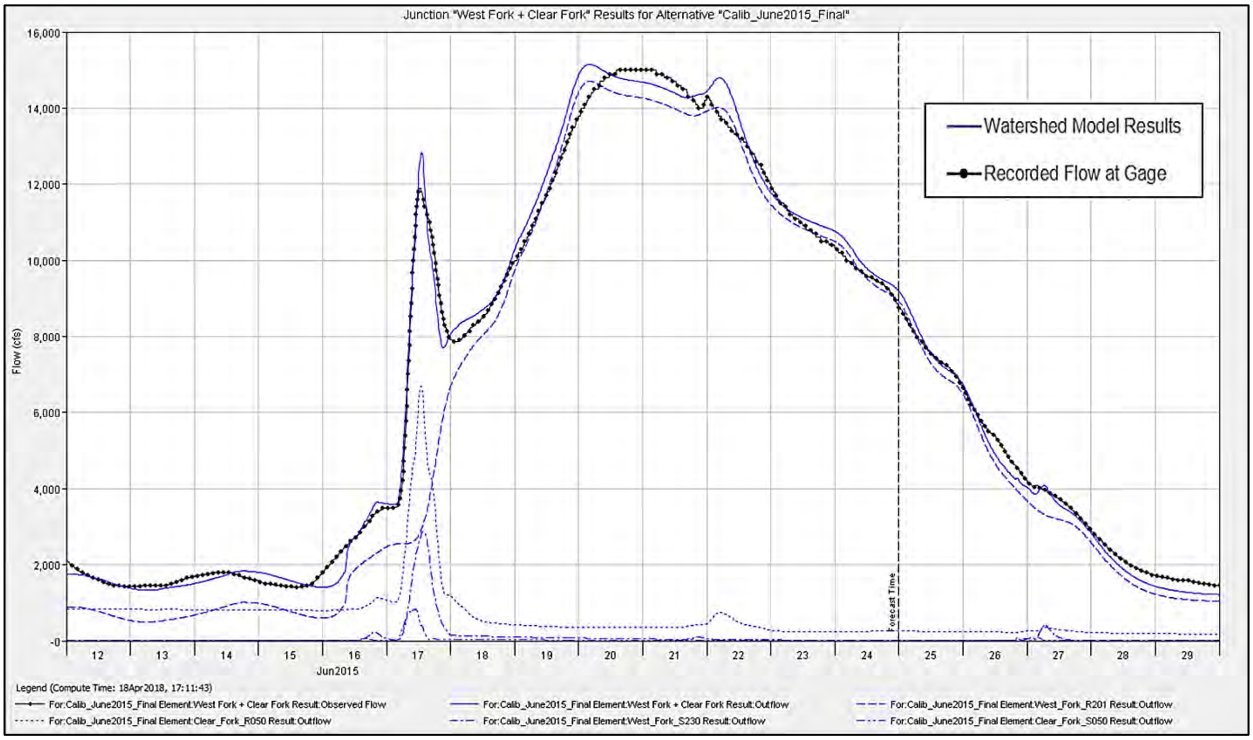

Figure 35d. June 18, 2015 Calibration Results for the West Fork at Fort Worth, TX Gage

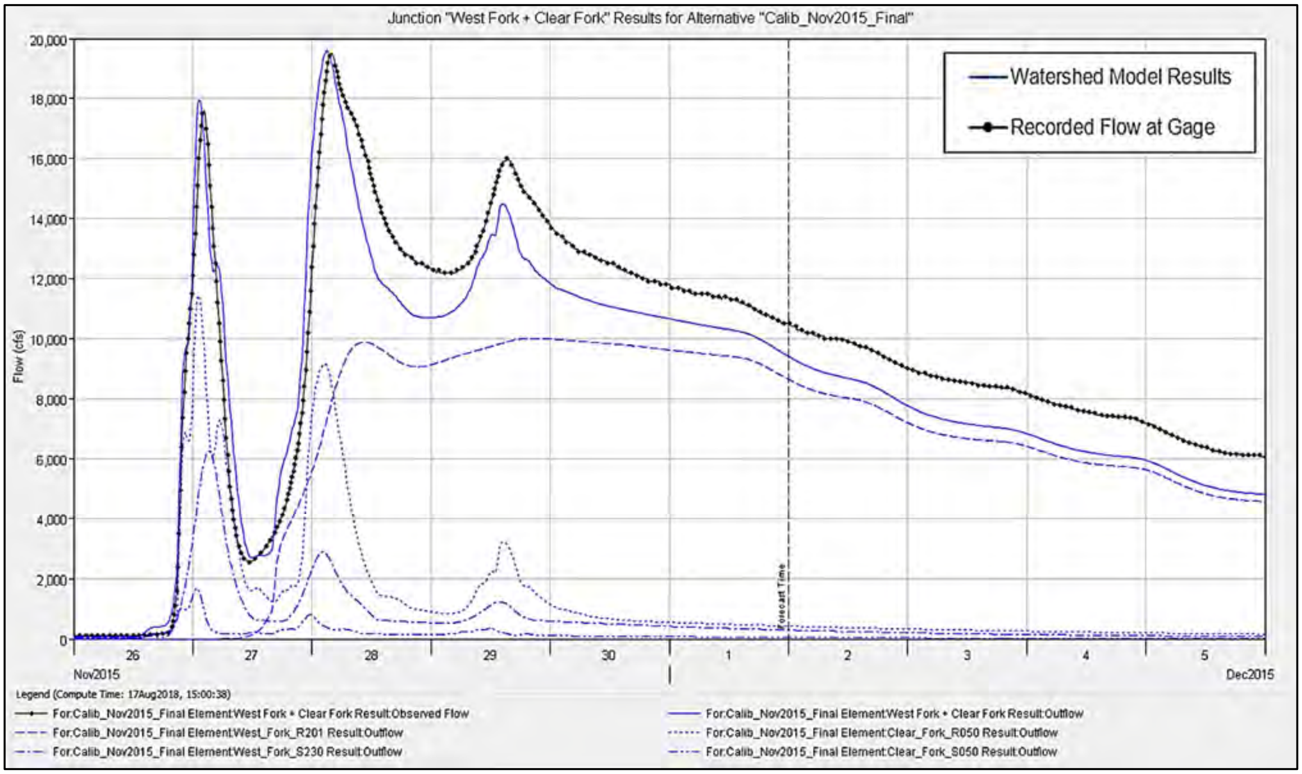

Figure 35e. November 29, 2015 Calibration Results for the West Fork at Fort Worth, TX Gage

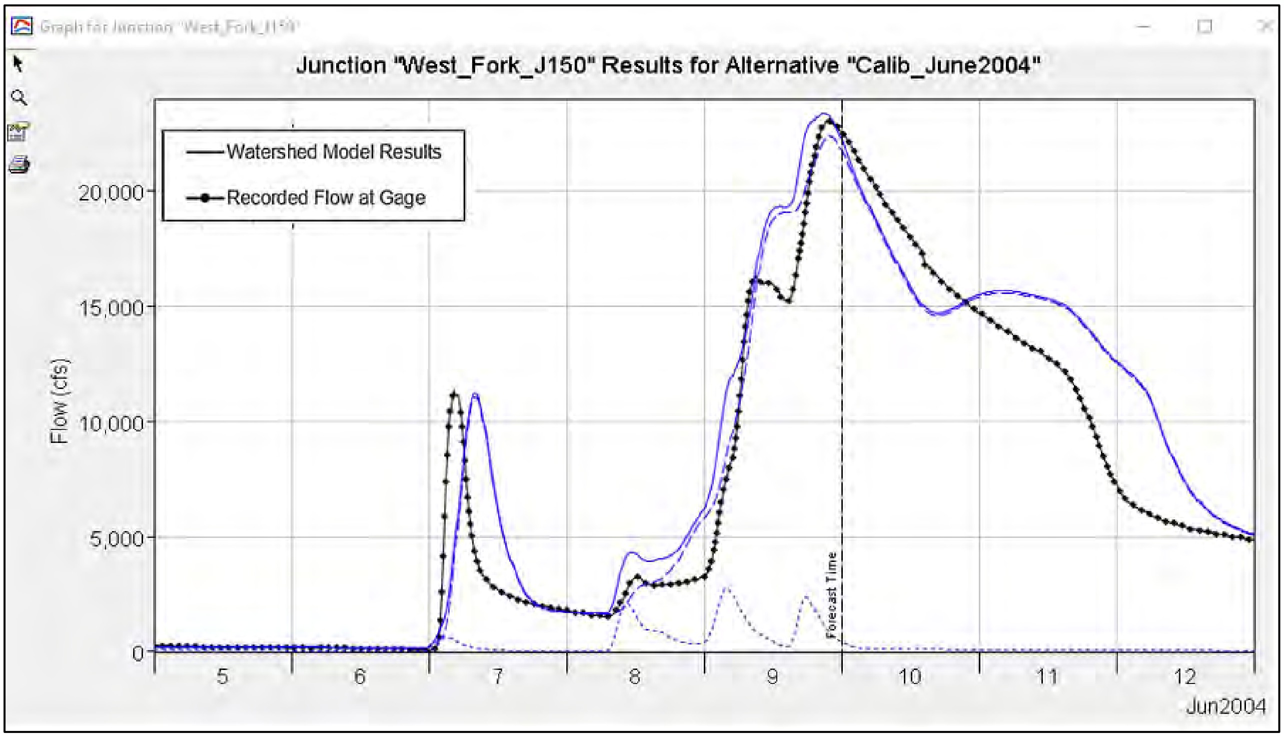

Figure 36a. June 2004 Calibration Results for the West Fork at Beach Street Gage

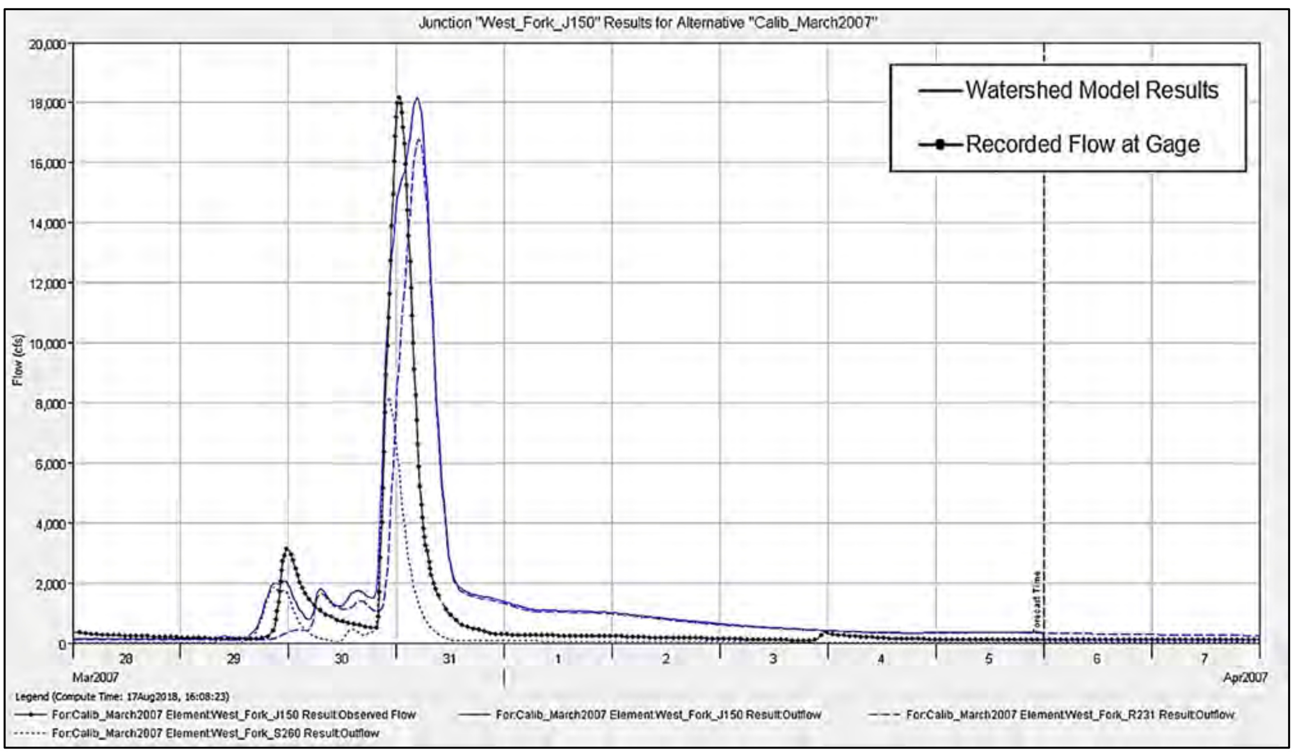

Figure 36b. March 28, 2007 Calibration Results for the West Fork at Beach Street Gage

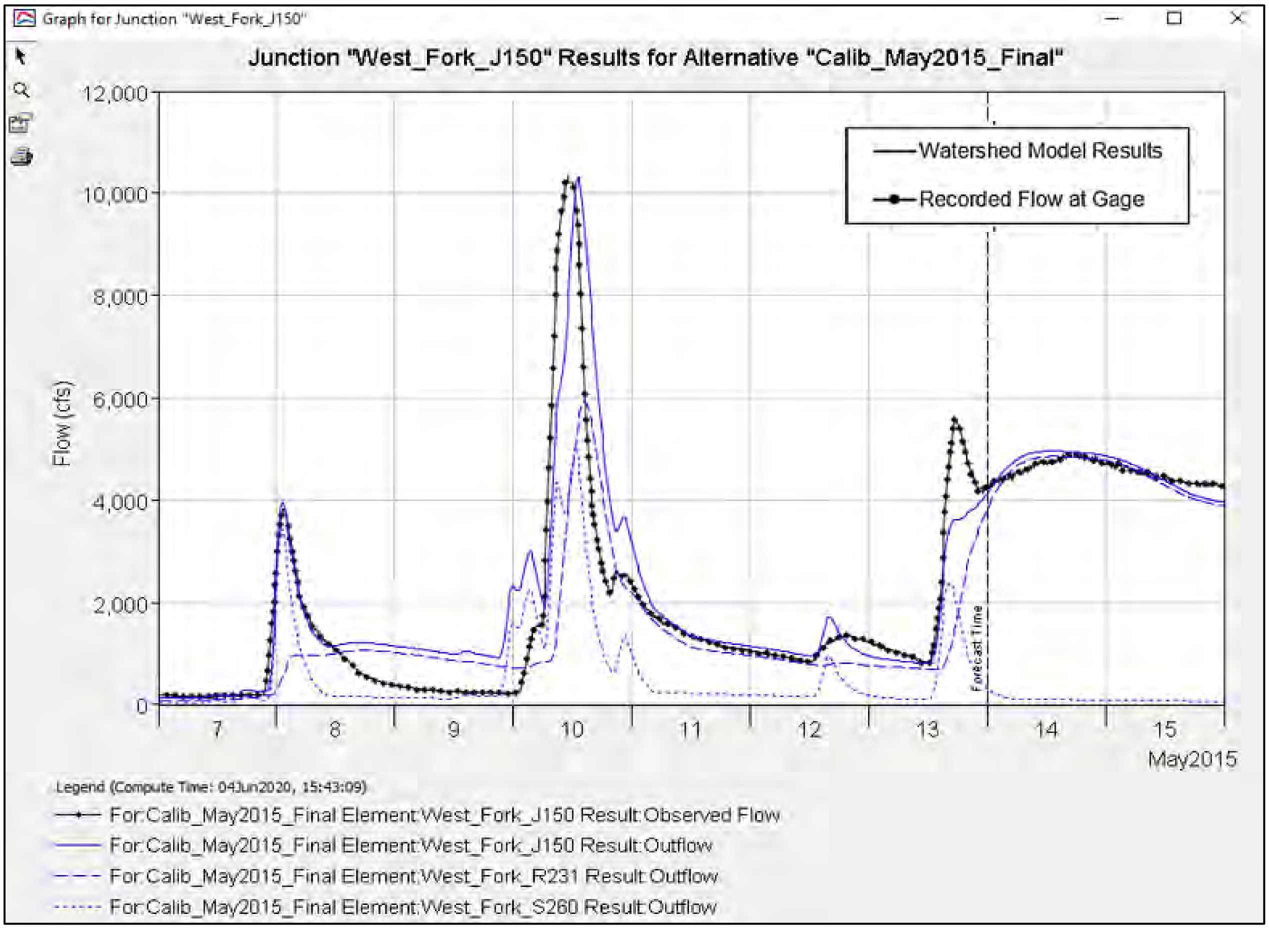

Figure 36c. May 2015 Calibration Results for the West Fork at Beach Street Gage

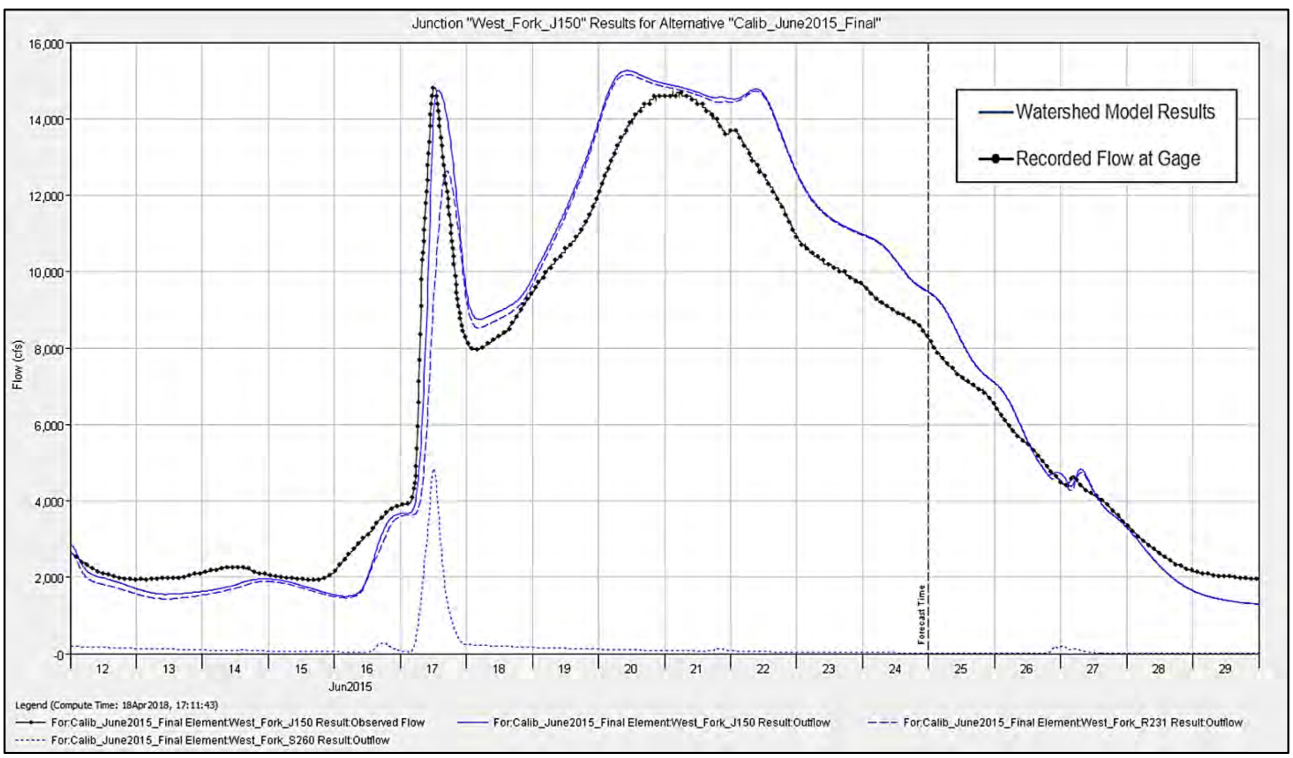

Figure 36d. June 18, 2015 Calibration Results for the West Fork at Beach Street Gage

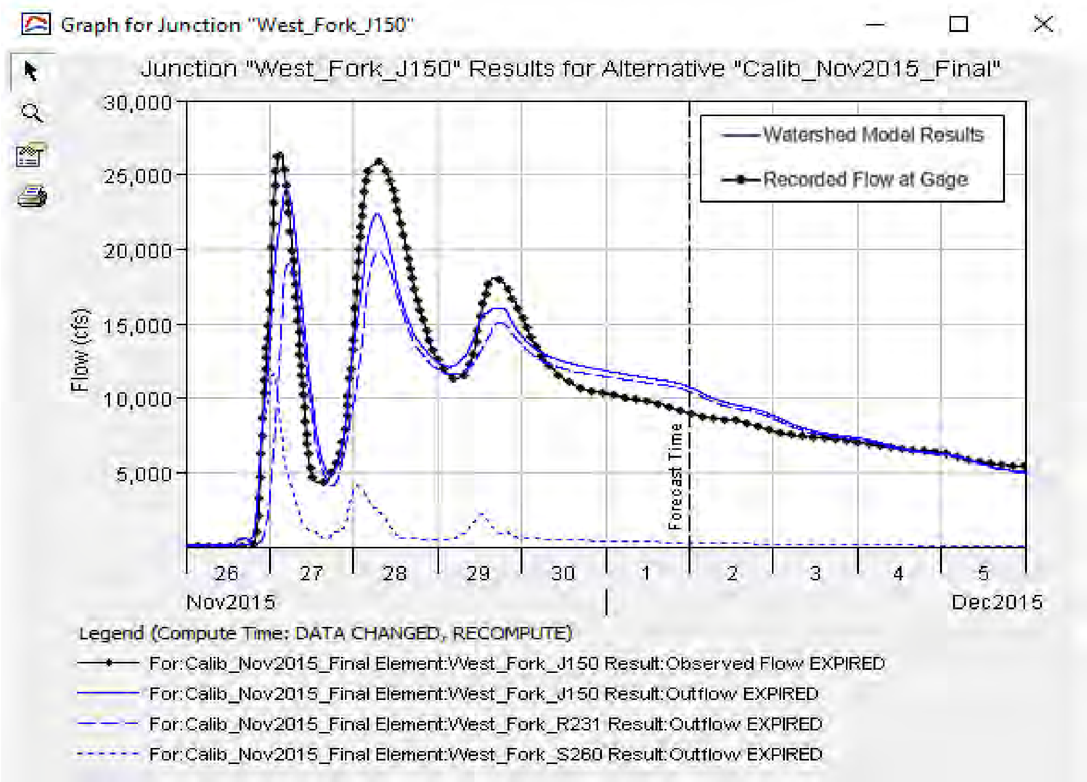

Figure 36e. November 29, 2015 Calibration Results for the West Fork at Beach Street Gage

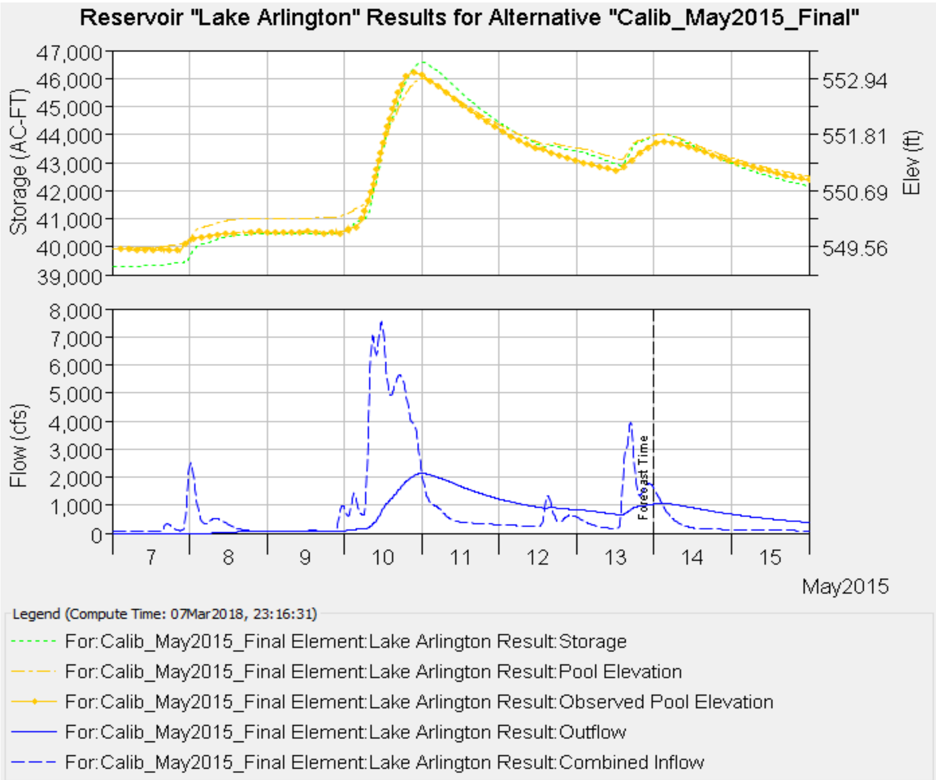

Figure 37a. May 2015 Calibration Results for Lake Arlington

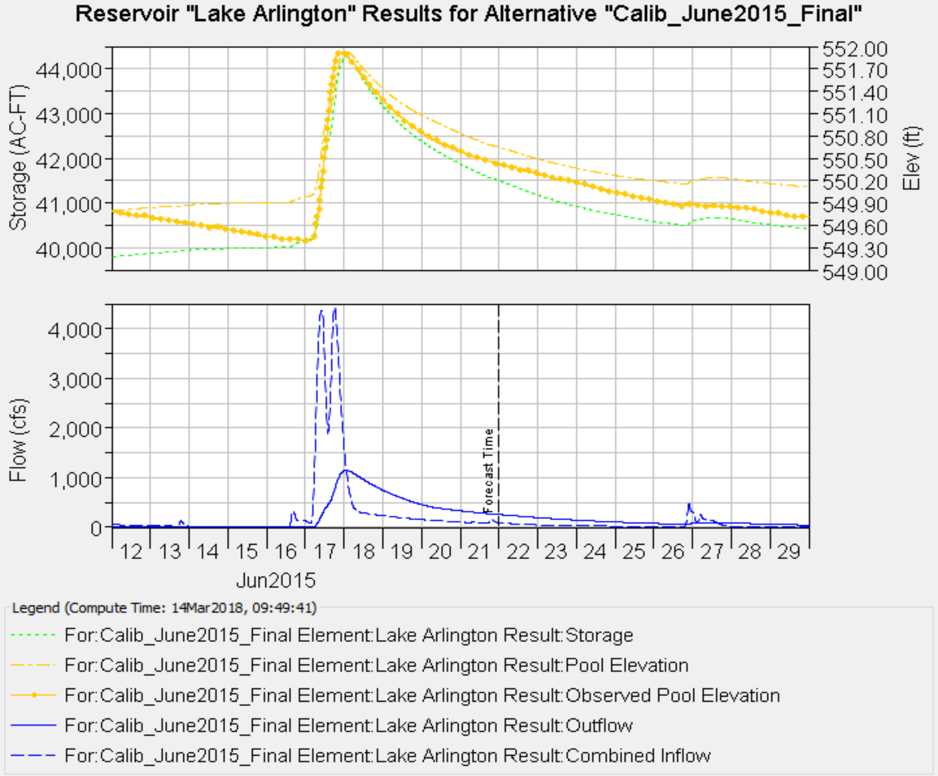

Figure 37b. June 2015 Calibration Results for Lake Arlington

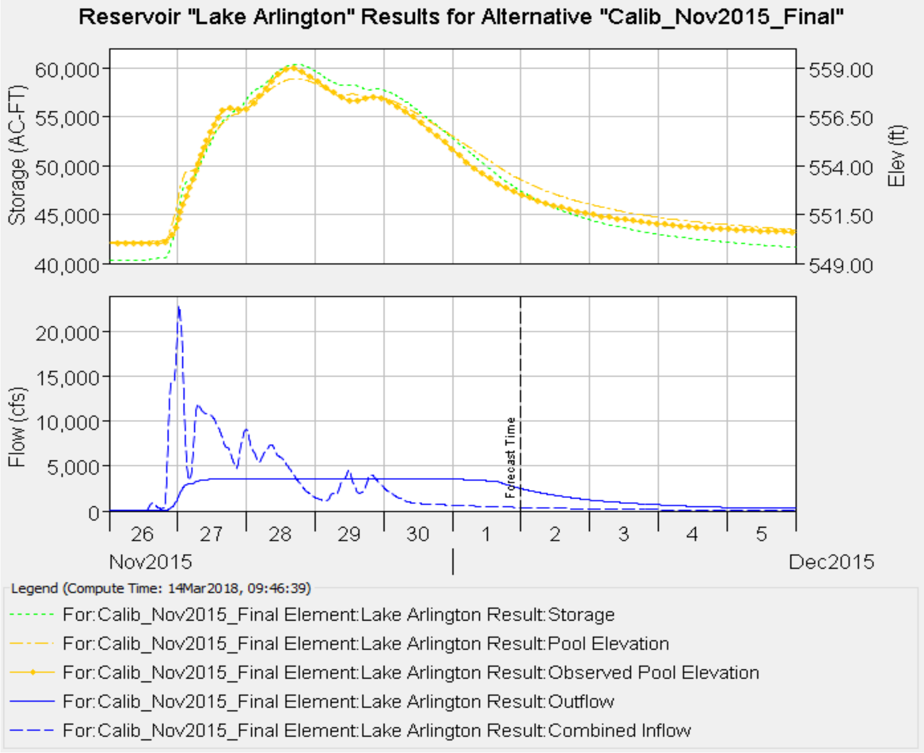

Figure 37c. November 2015 Calibration Results for Lake Arlington

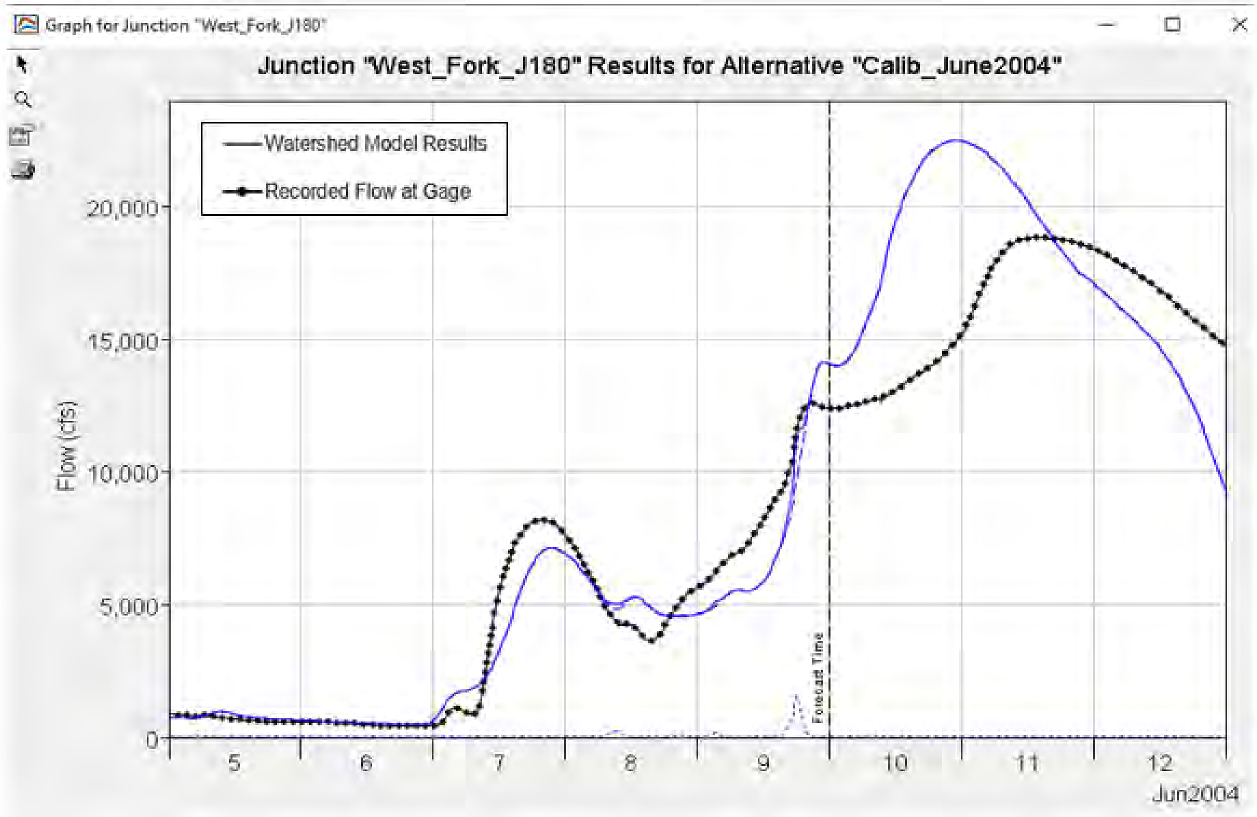

Figure 38a. June 8, 2004 Calibration Results for the West Fork at Grand Prairie, TX Gage

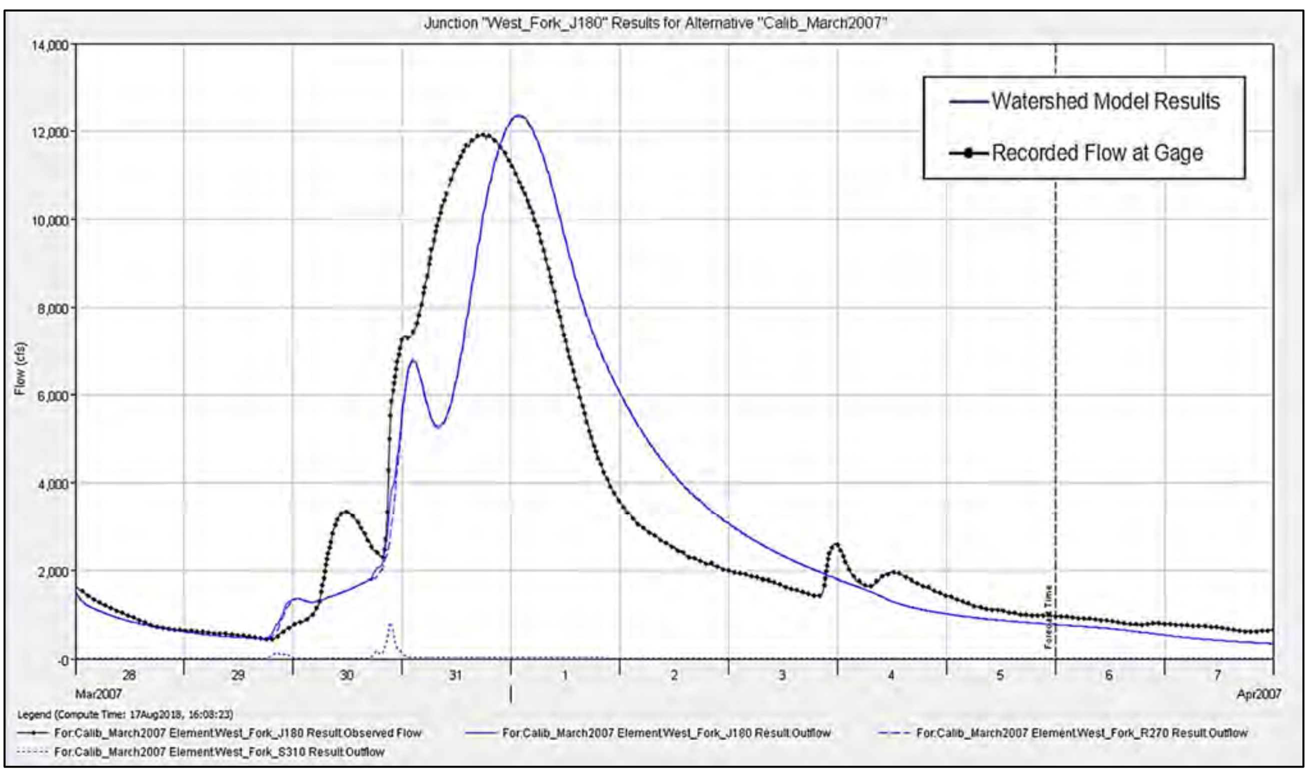

Figure 38b. March 28, 2007 Calibration Results for the West Fork at Grand Prairie, TX Gage

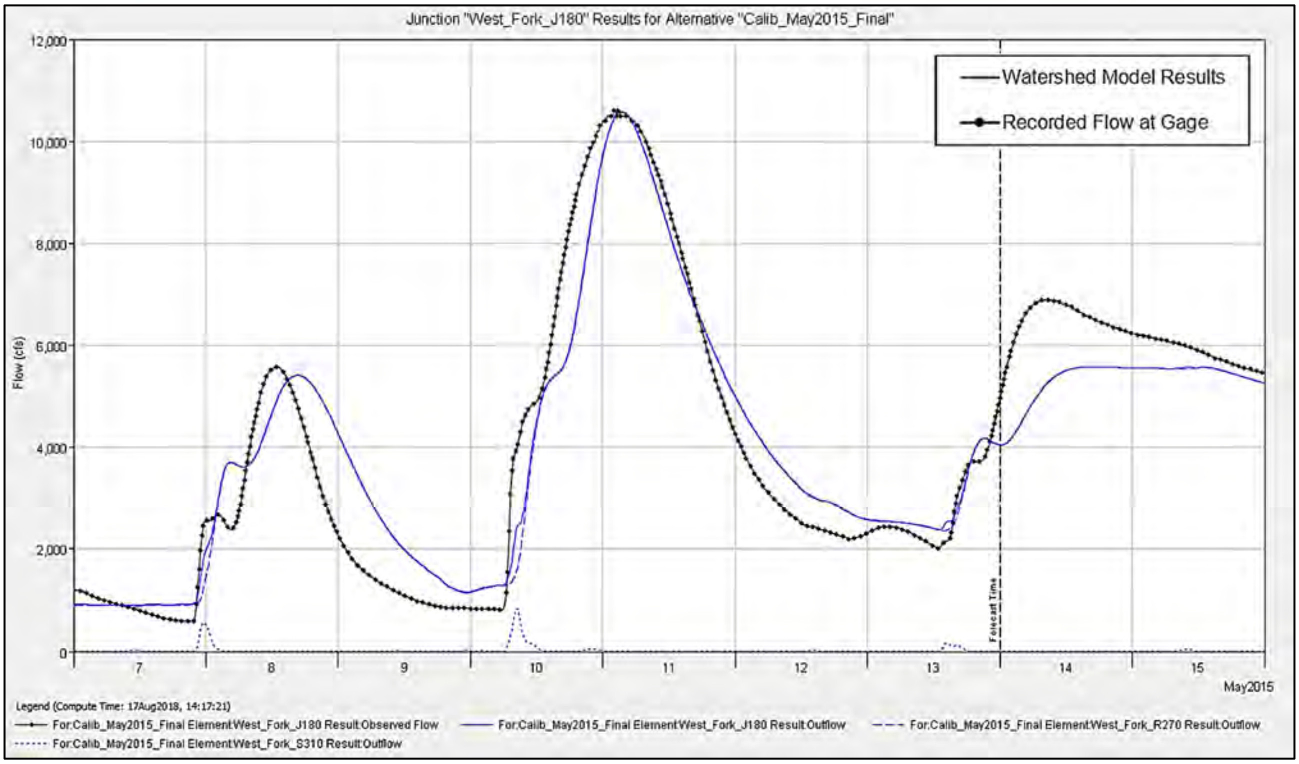

Figure 38c. May 8, 2015 Calibration Results for the West Fork at Grand Prairie, TX Gage

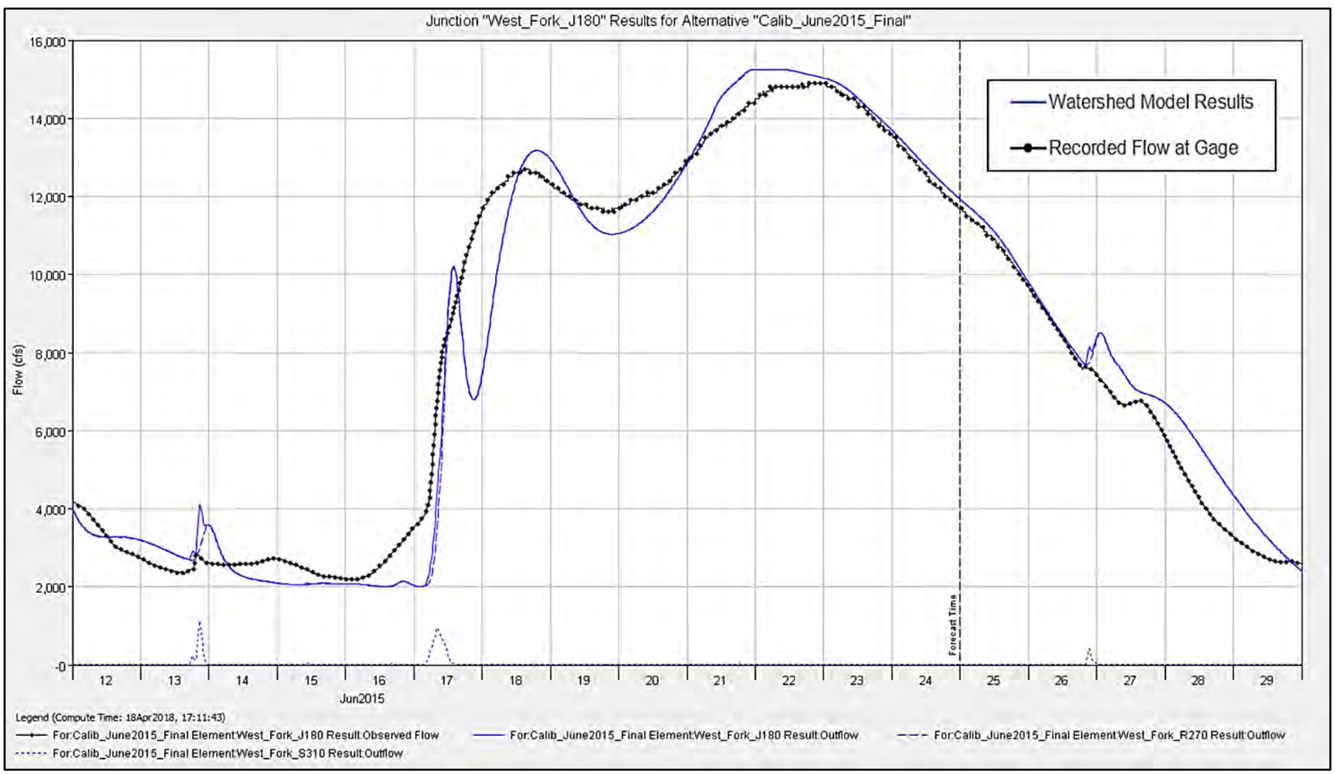

Figure 38d. June 18, 2015 Calibration Results for the West Fork at Grand Prairie, TX Gage

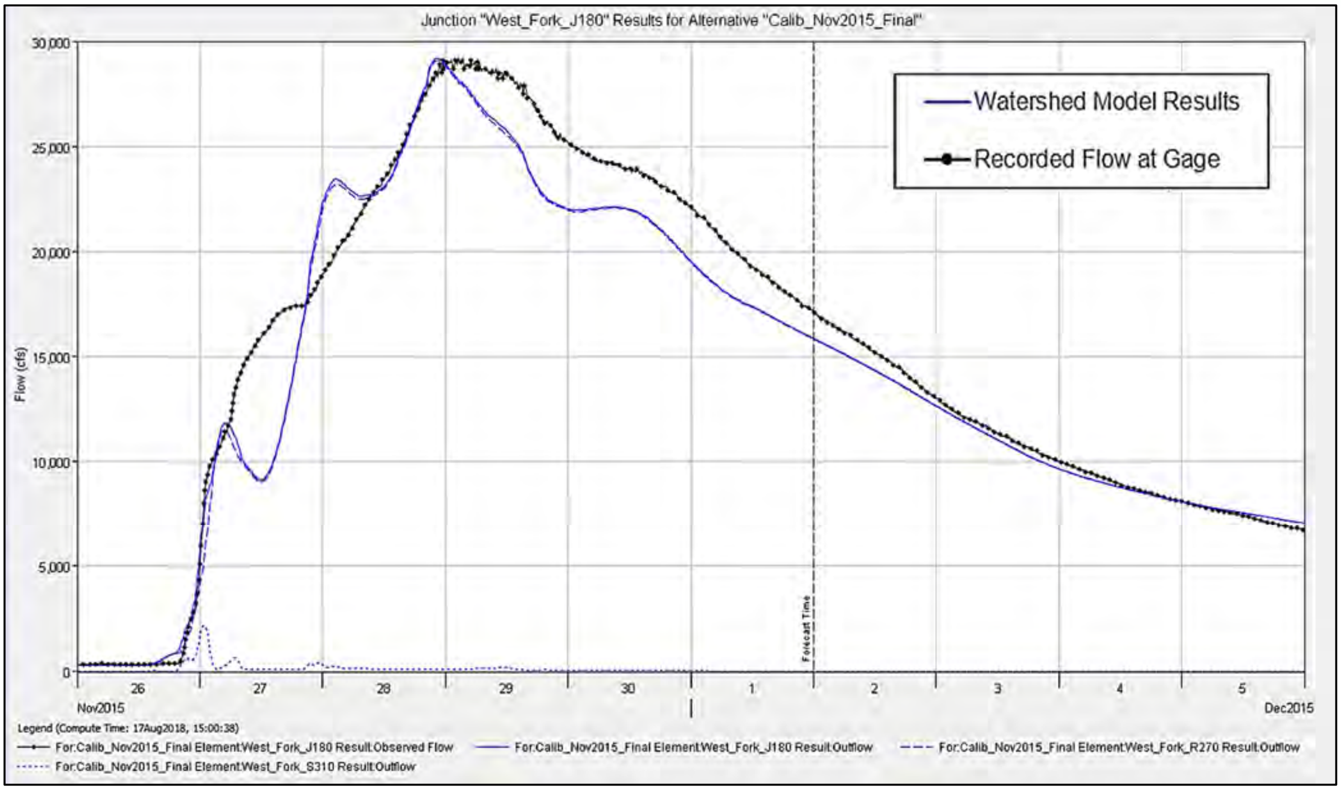

Figure 10. November 29, 2015 Calibration Results for the West Fork at Grand Prairie, TX Gage

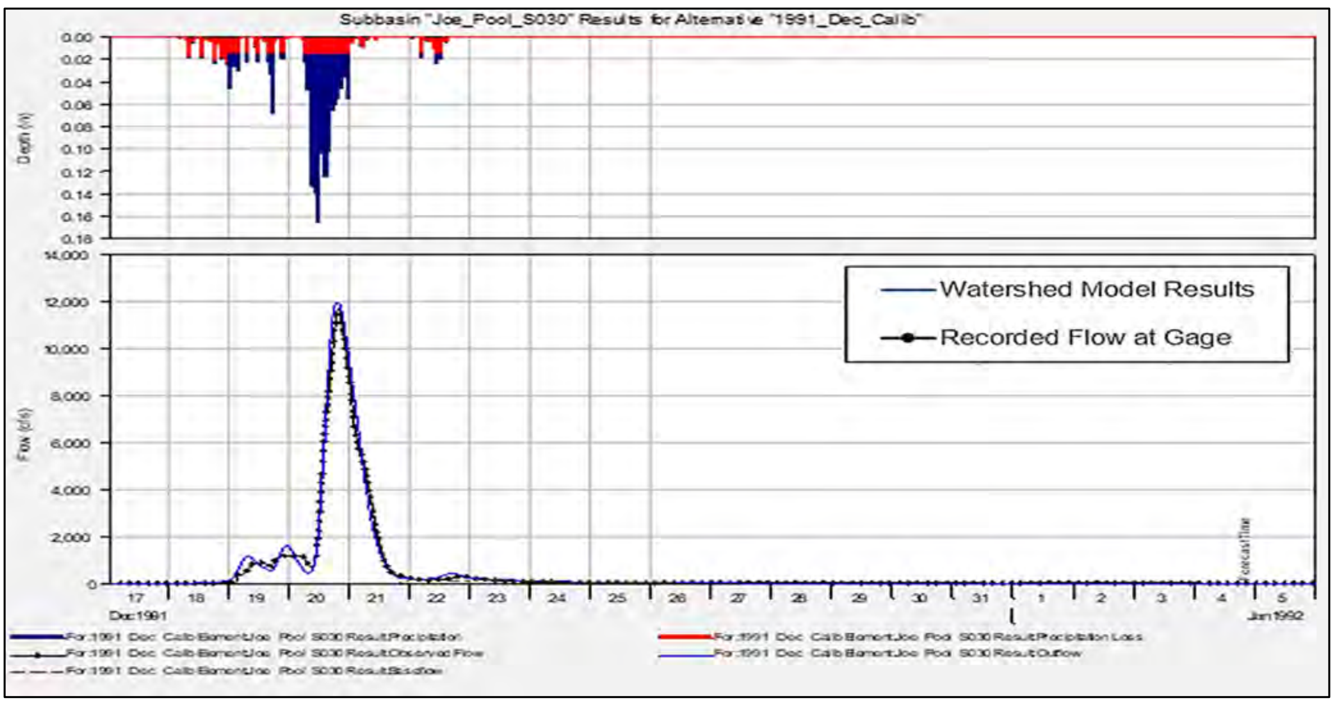

Figure 39a. December 20, 1991 Calibration Results for the Walnut Creek near Mansfield, TX Gage

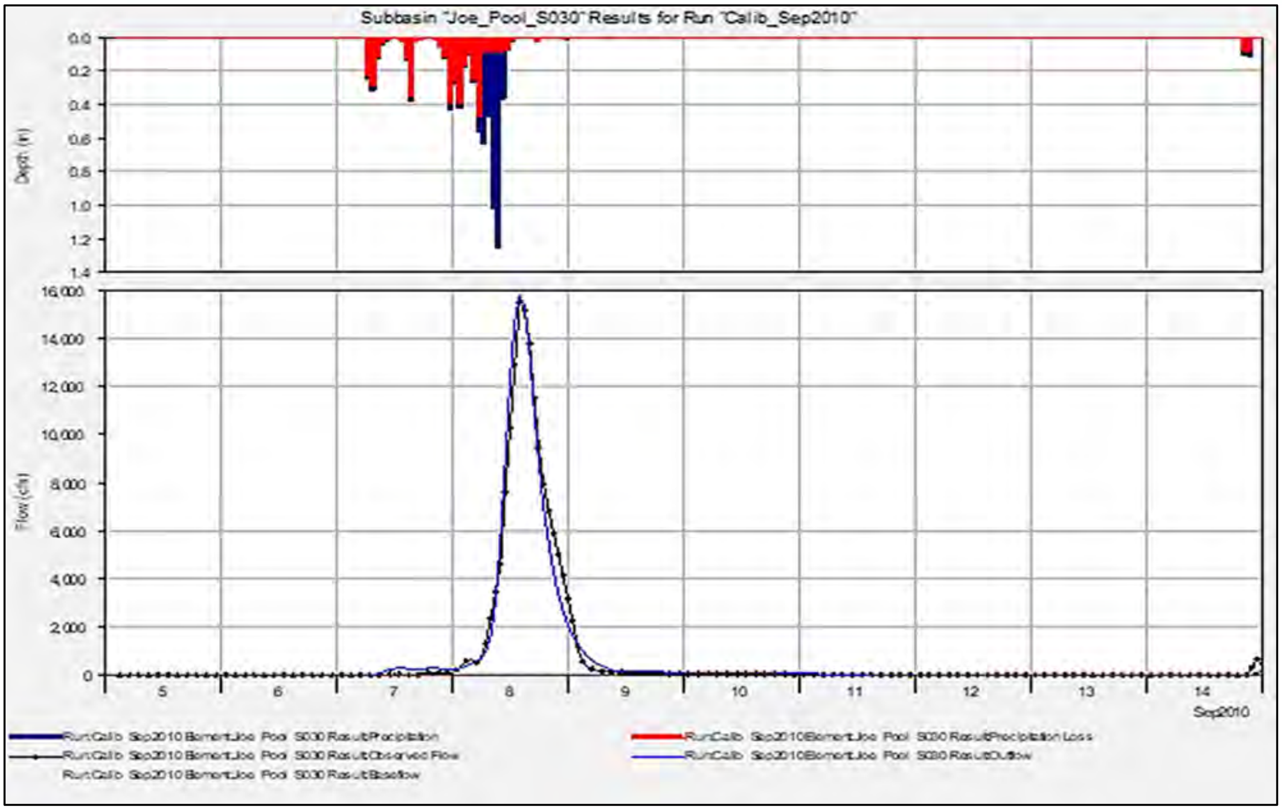

Figure 39b. September 8, 2010 Calibration Results for the Walnut Creek near Mansfield, TX Gage

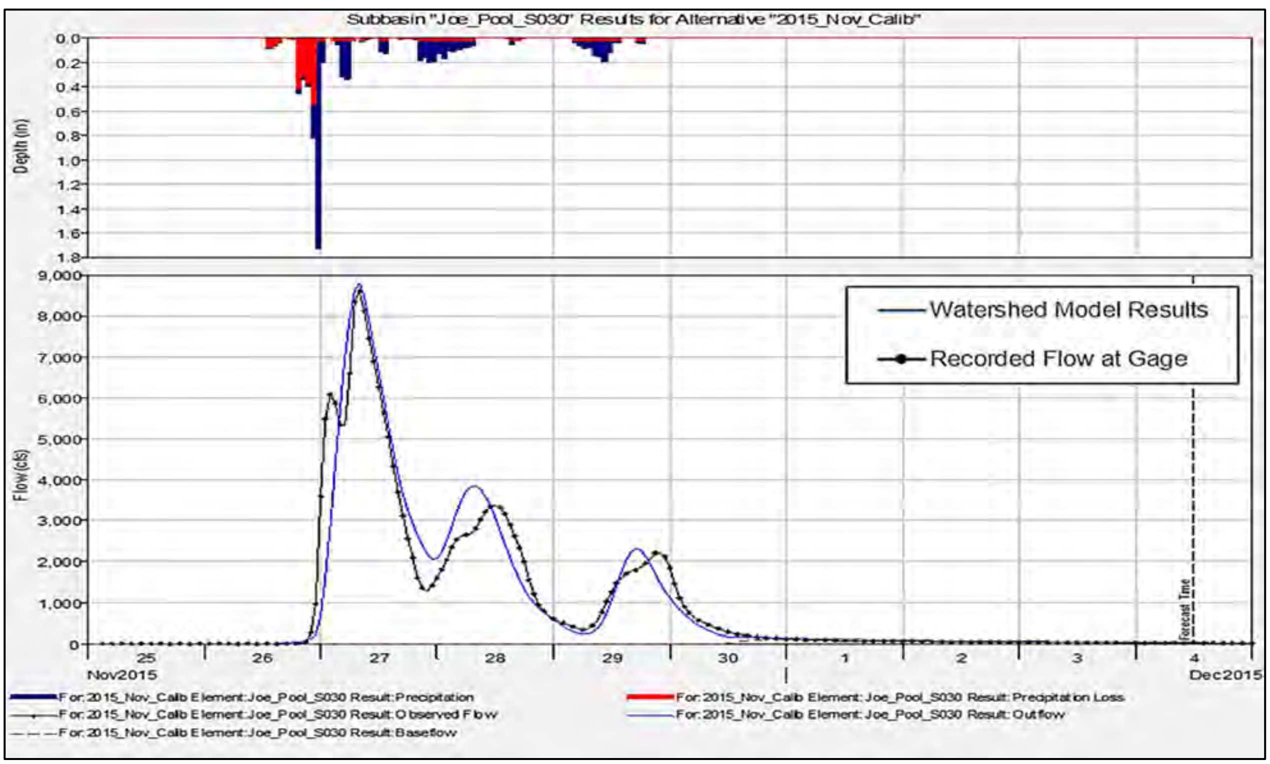

Figure 39c. November 27, 2015 Calibration Results for the Walnut Creek near Mansfield, TX Gage

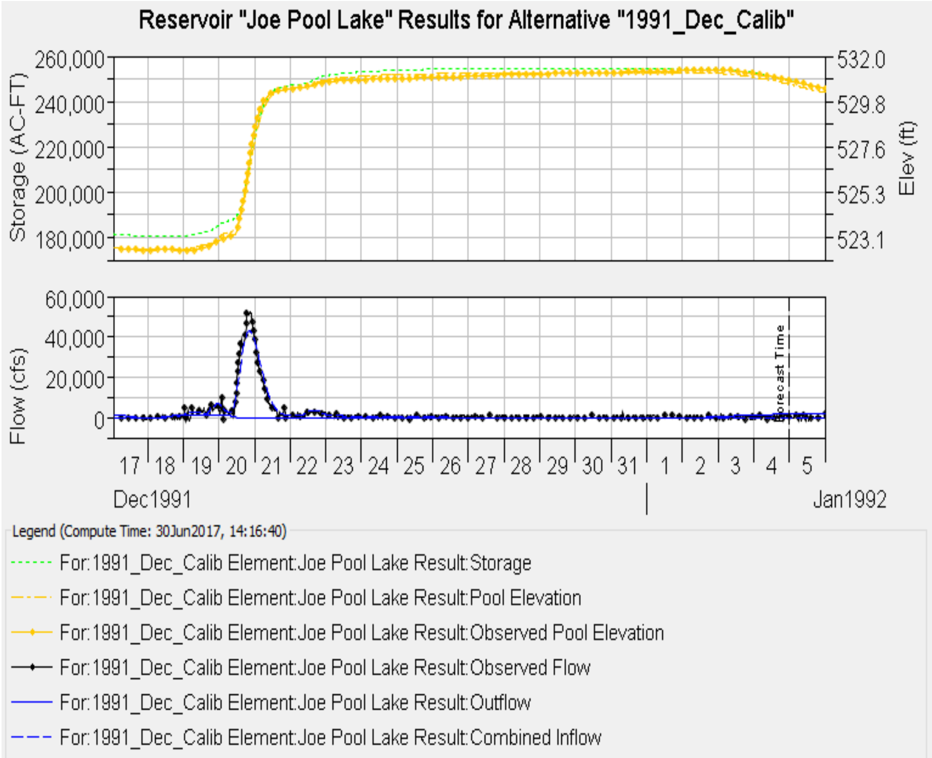

Figure 40a. December 1991 Calibration Results for Joe Pool Reservoir

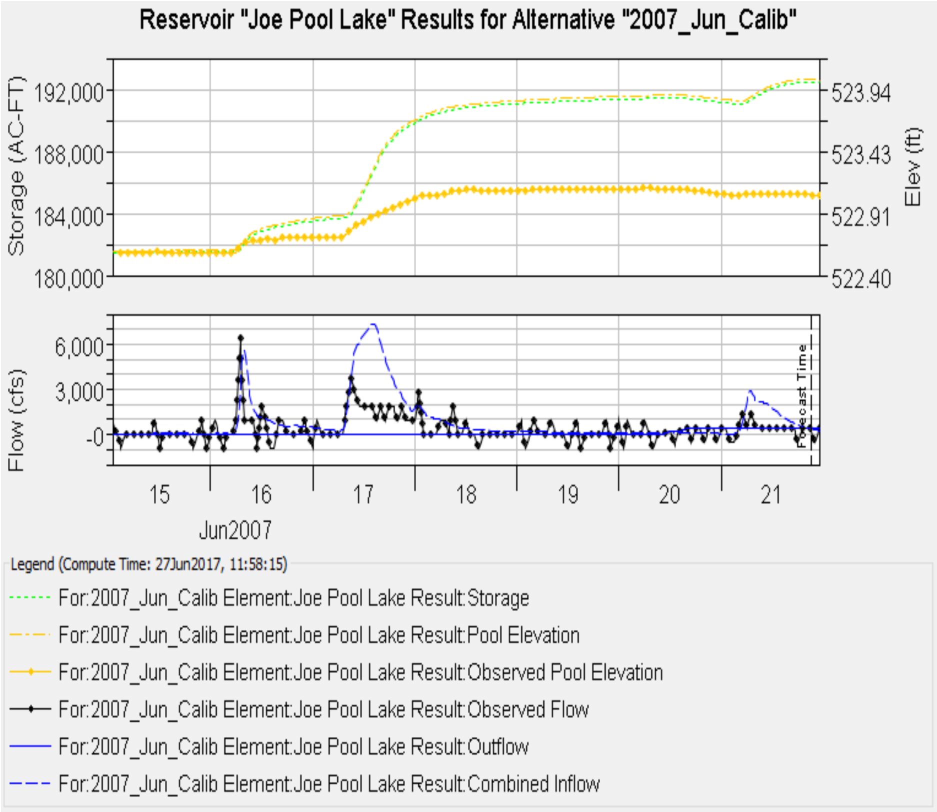

Figure 40b. June 2007 Calibration Results for Joe Pool Reservoir

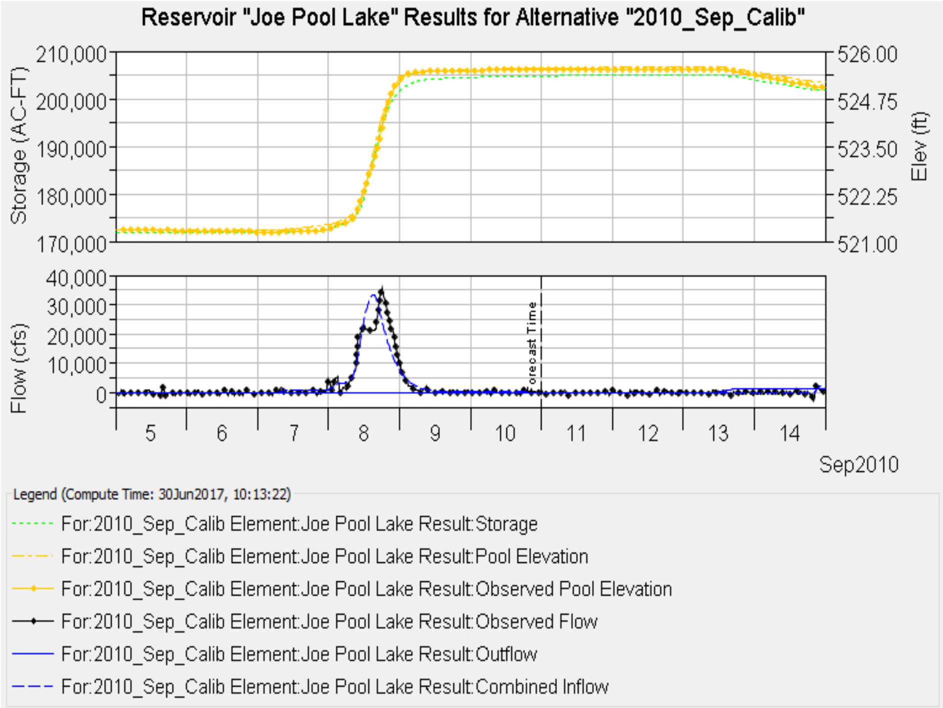

Figure 40c. September 2010 Calibration Results for Joe Pool Reservoir

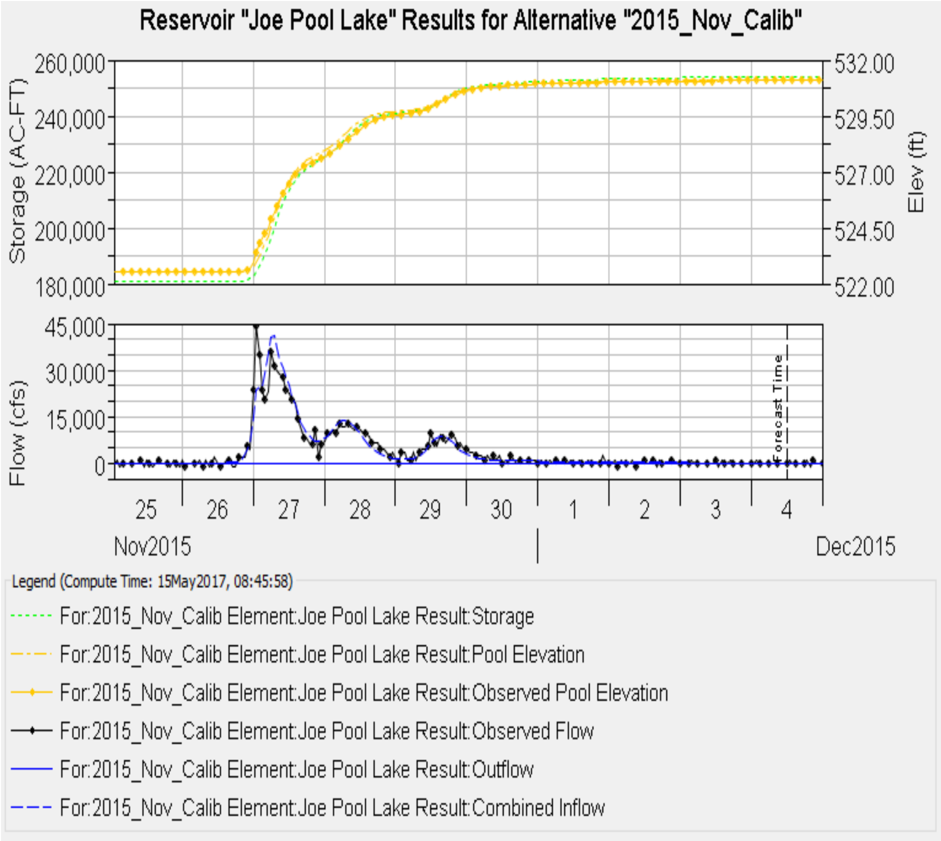

Figure 40d. November 2015 Calibration Results for Joe Pool Reservoir

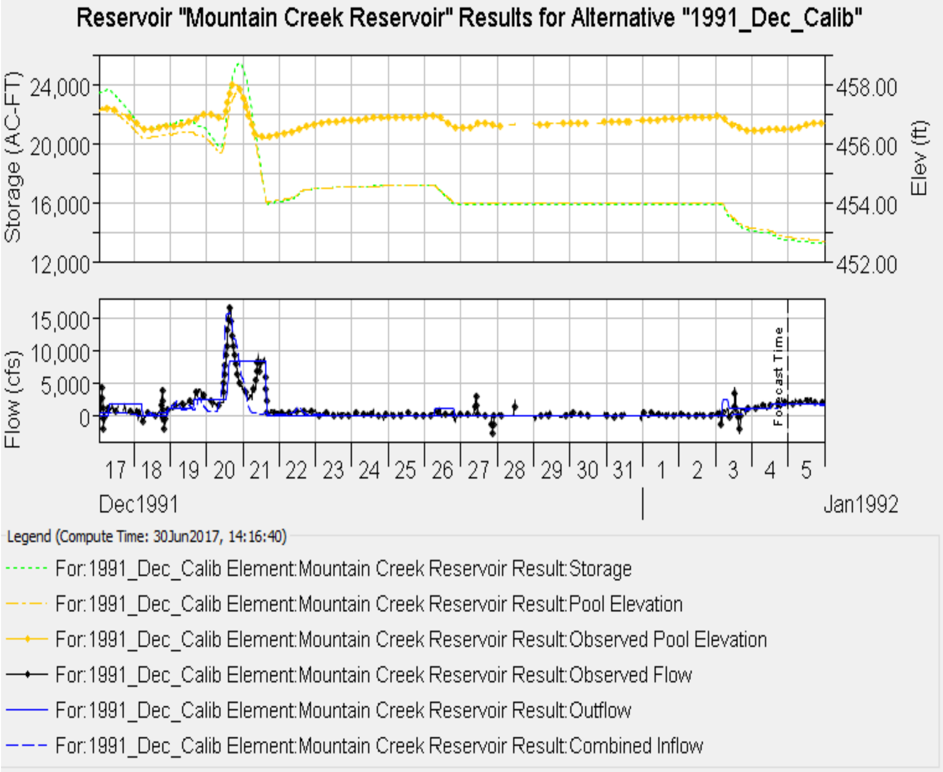

Figure 41a. December 1991 Calibration Results for Mountain Creek Reservoir

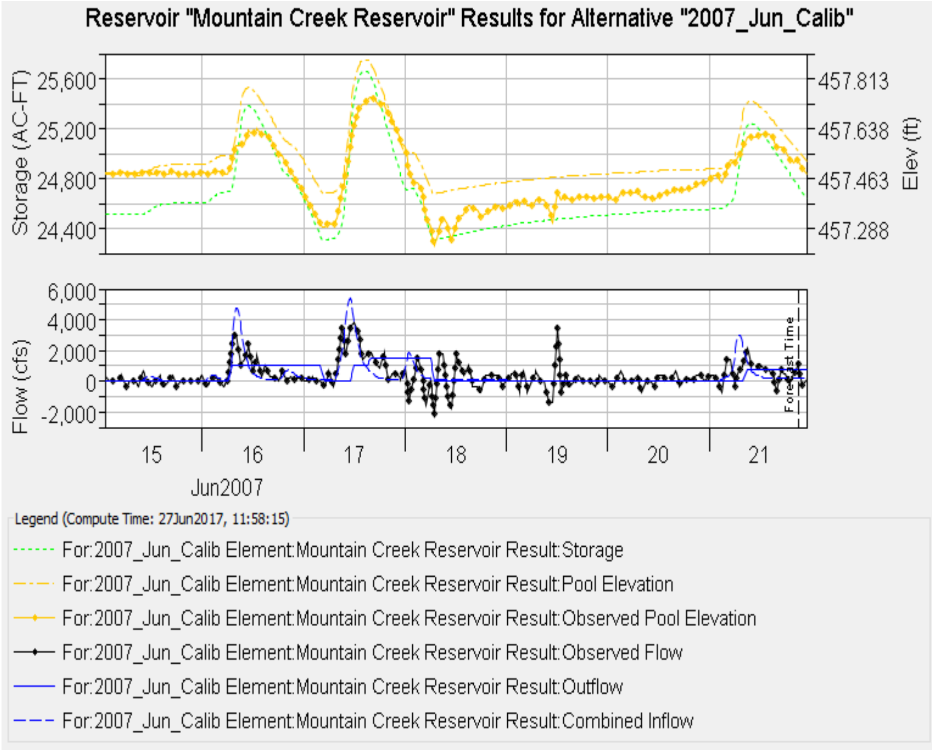

Figure 41b. June 2007 Calibration Results for Mountain Creek Reservoir

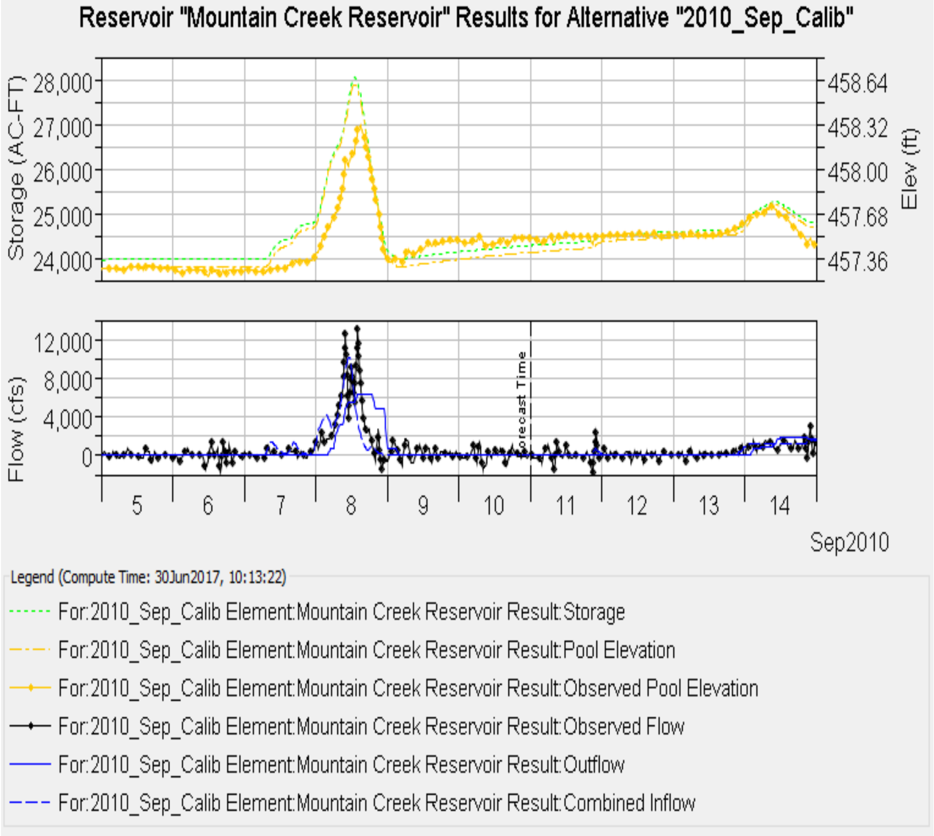

Figure 41c. September 2010 Calibration Results for Mountain Creek Reservoir

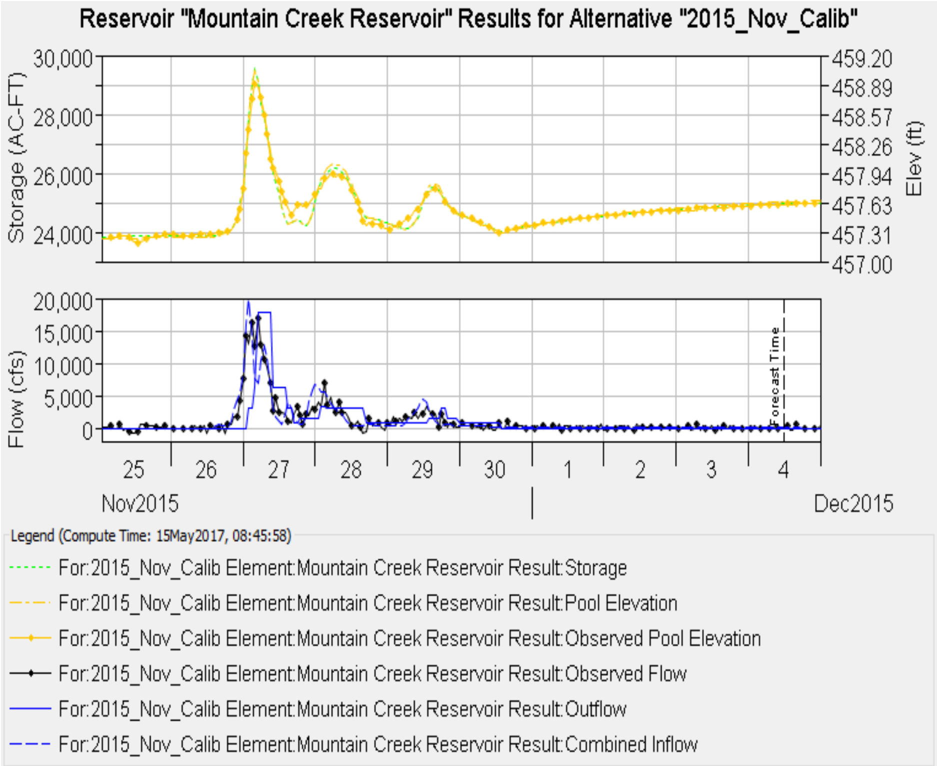

Figure 41d. November 2015 Calibration Results for Mountain Creek Reservoir

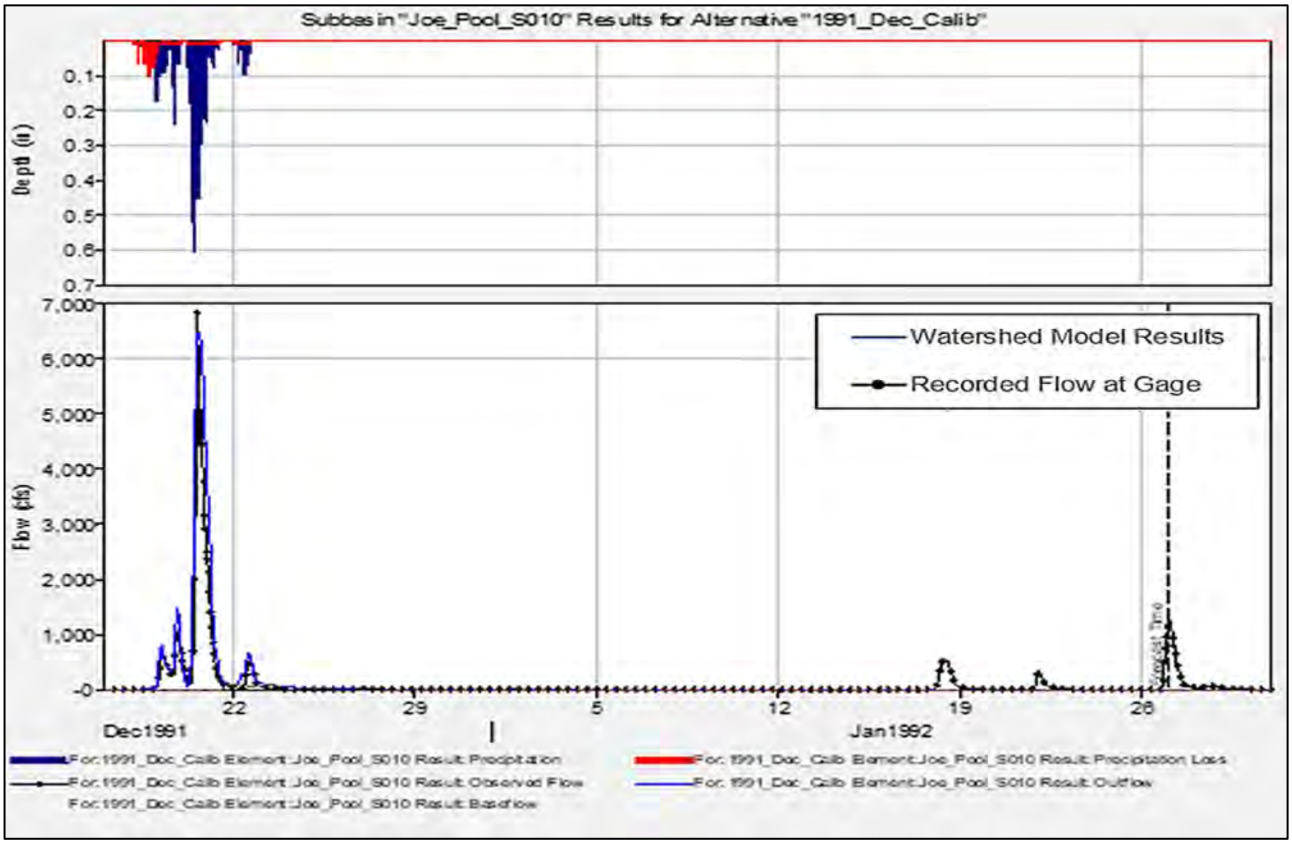

Figure 42a. December 20, 1991 Calibration Results for the Mountain Creek near Venus, TX Gage

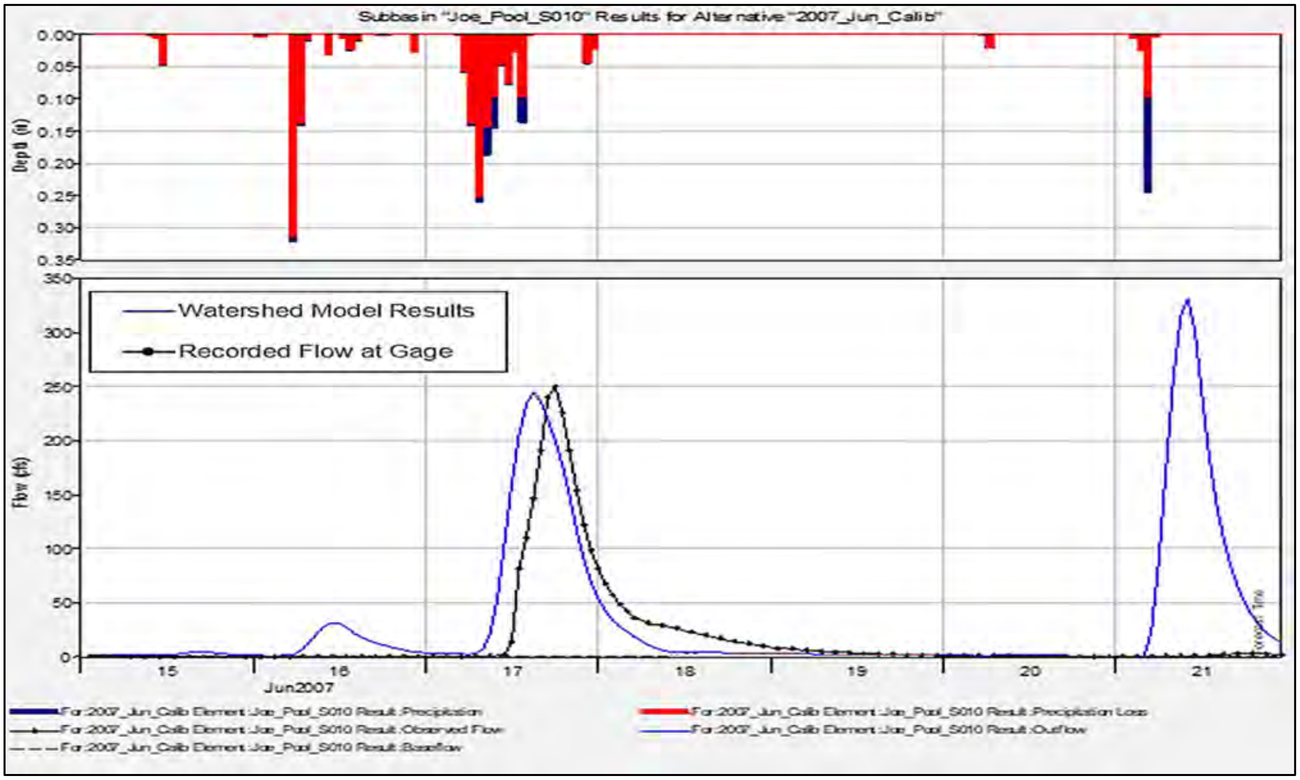

Figure 42b. June 17, 2007 Calibration Results for the Mountain Creek near Venus, TX Gage

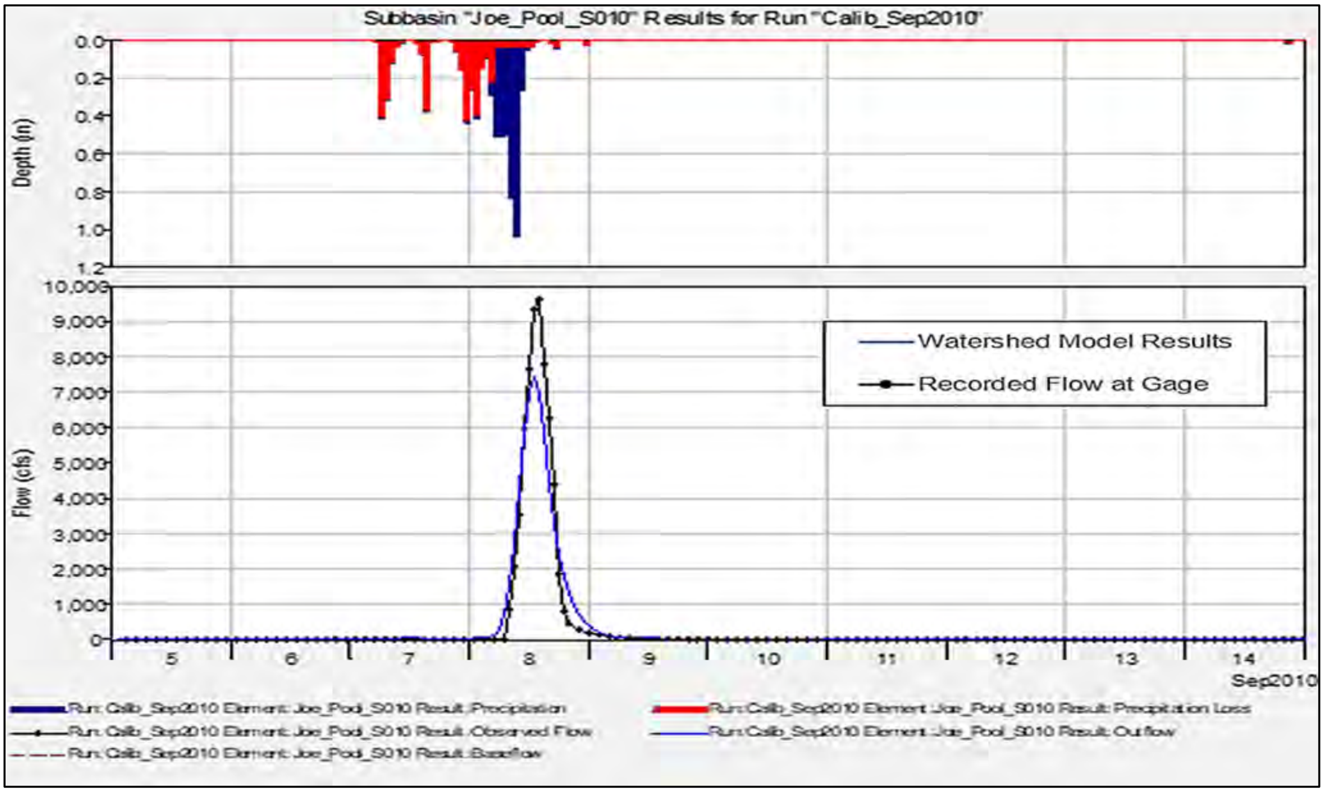

Figure 42c. September 8, 2010 Calibration Results for the Mountain Creek near Venus, TX Gage

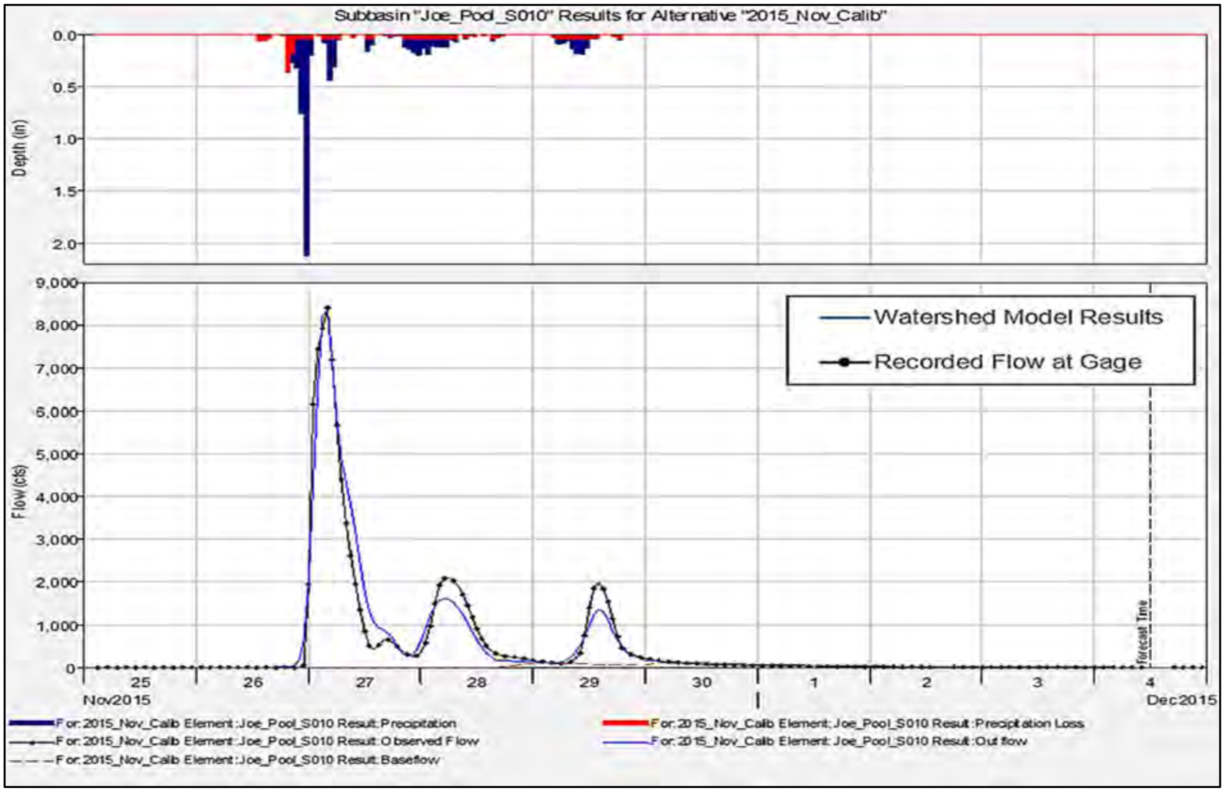

Figure 11. November 27, 2015 Calibration Results for the Mountain Creek near Venus, TX Gage

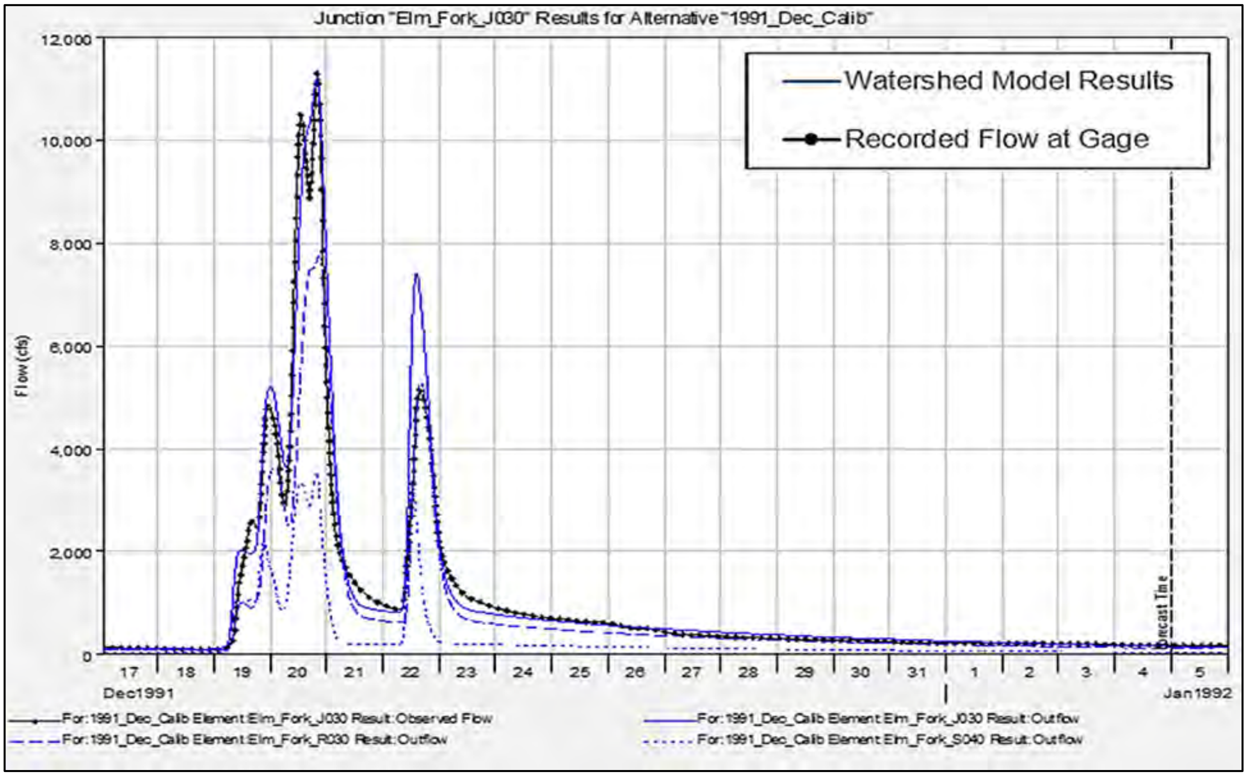

Figure 43a. December 20, 1991 Calibration Results for the Elm Fork at Gainesville, TX Gage

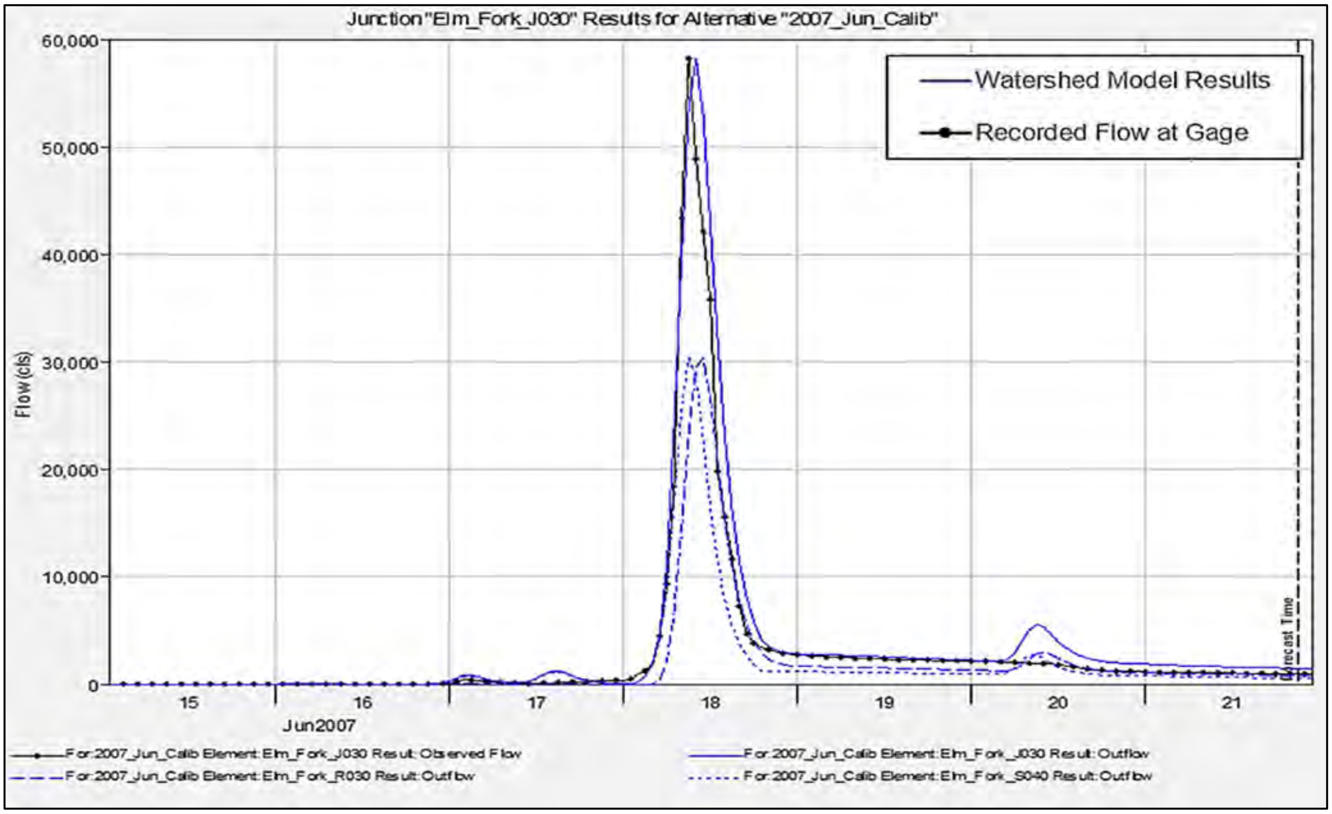

Figure 43b. June 17, 2007 Calibration Results for the Elm Fork at Gainesville, TX Gage

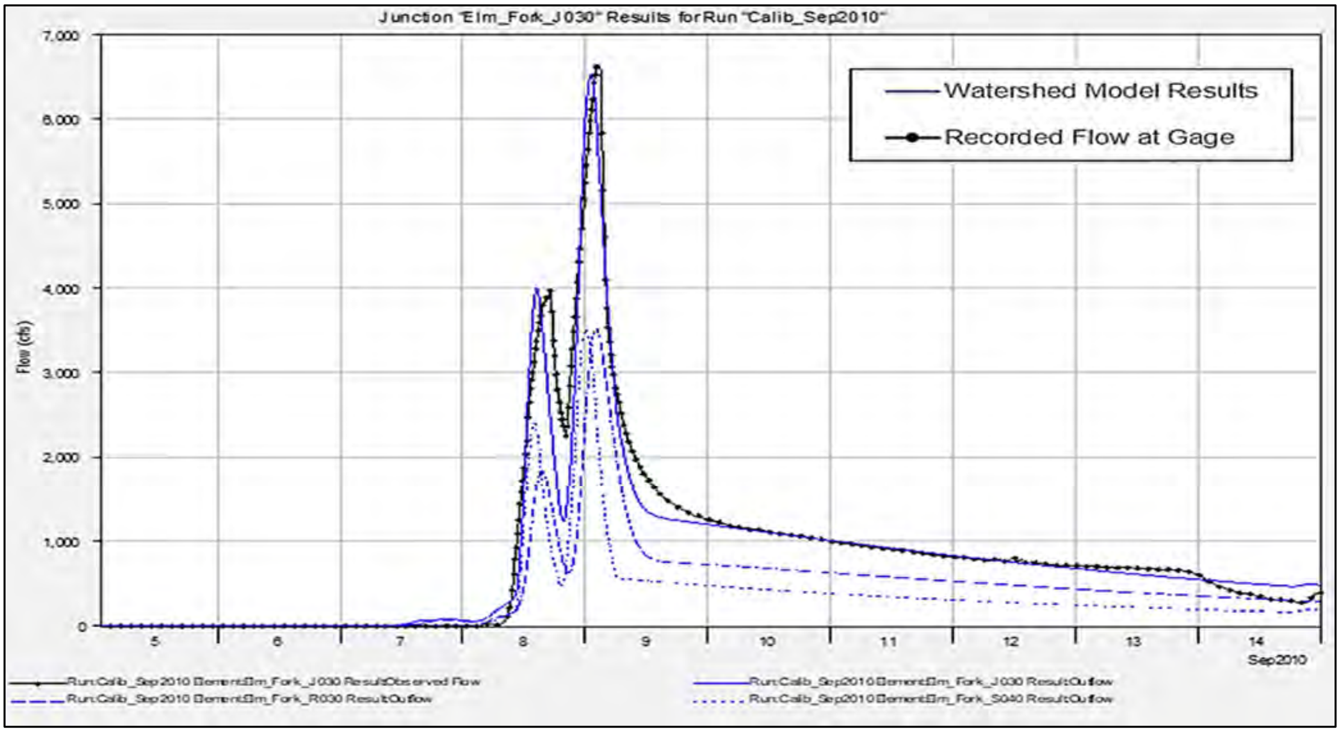

Figure 43c. September 8, 2010 Calibration Results for the Elm Fork at Gainesville, TX Gage

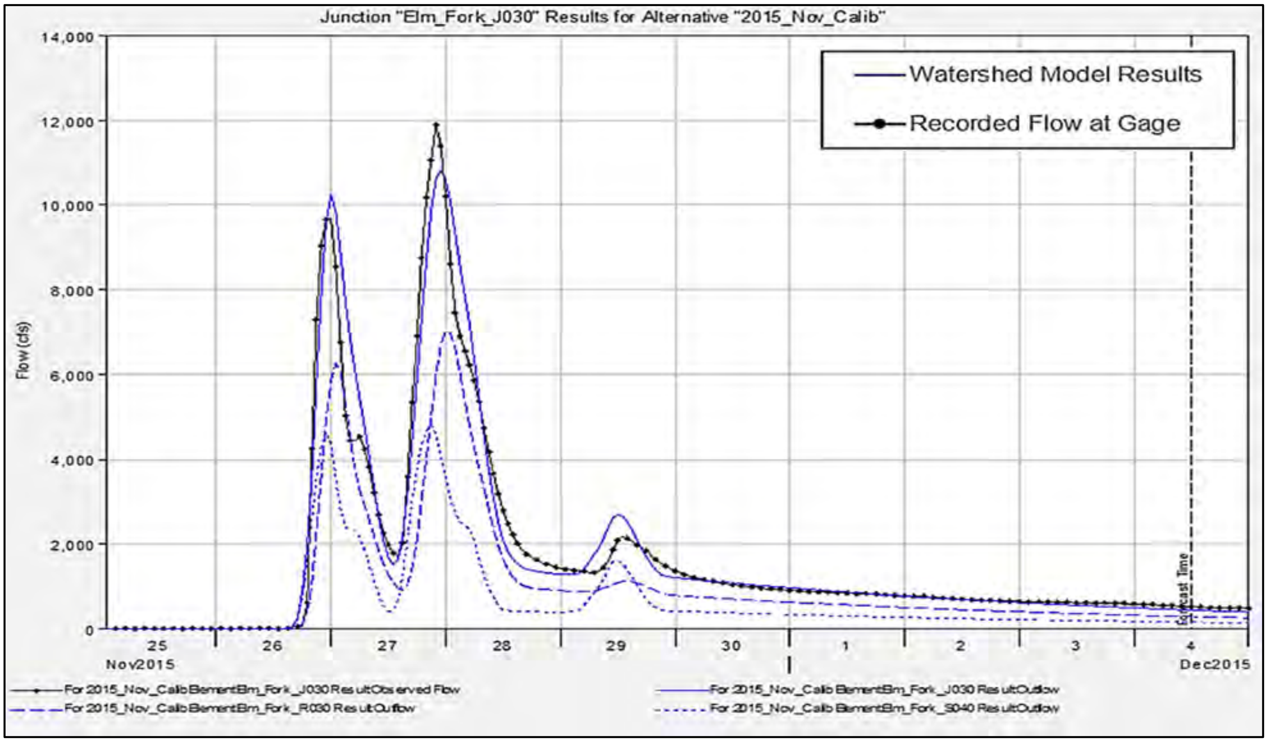

Figure 43d. November 27, 2015 Calibration Results for the Elm Fork at Gainesville, TX Gage

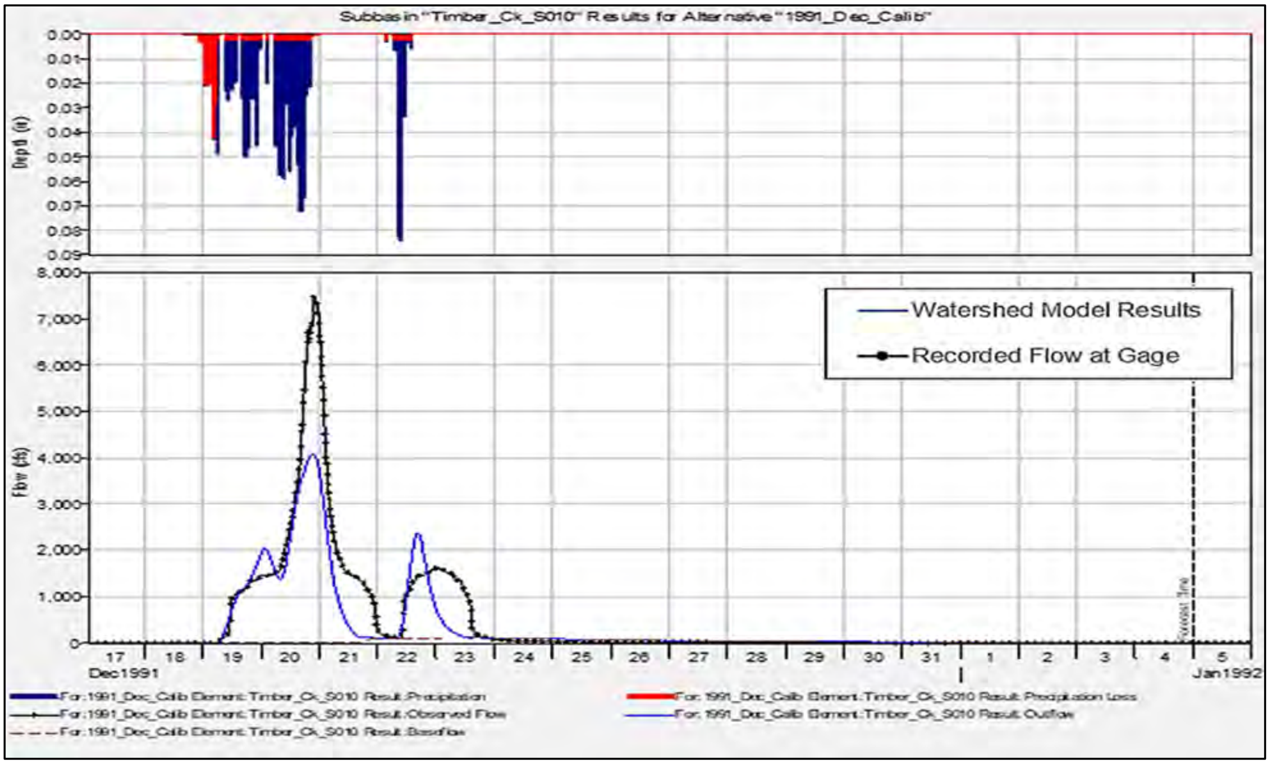

Figure 44a. December 20, 1991 Calibration Results for the Timber Creek near Collinsville, TX Gage

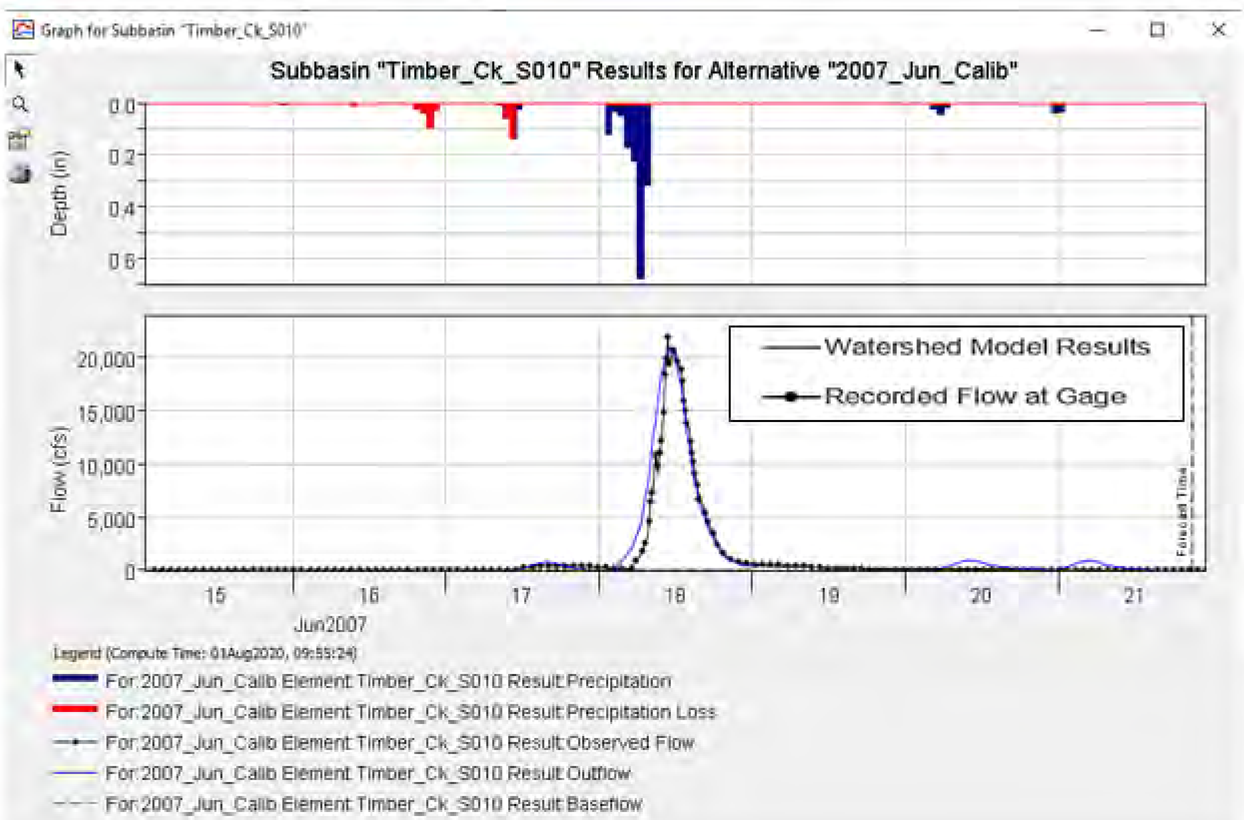

Figure 44b. June 17, 2007 Calibration Results for the Timber Creek near Collinsville, TX Gage

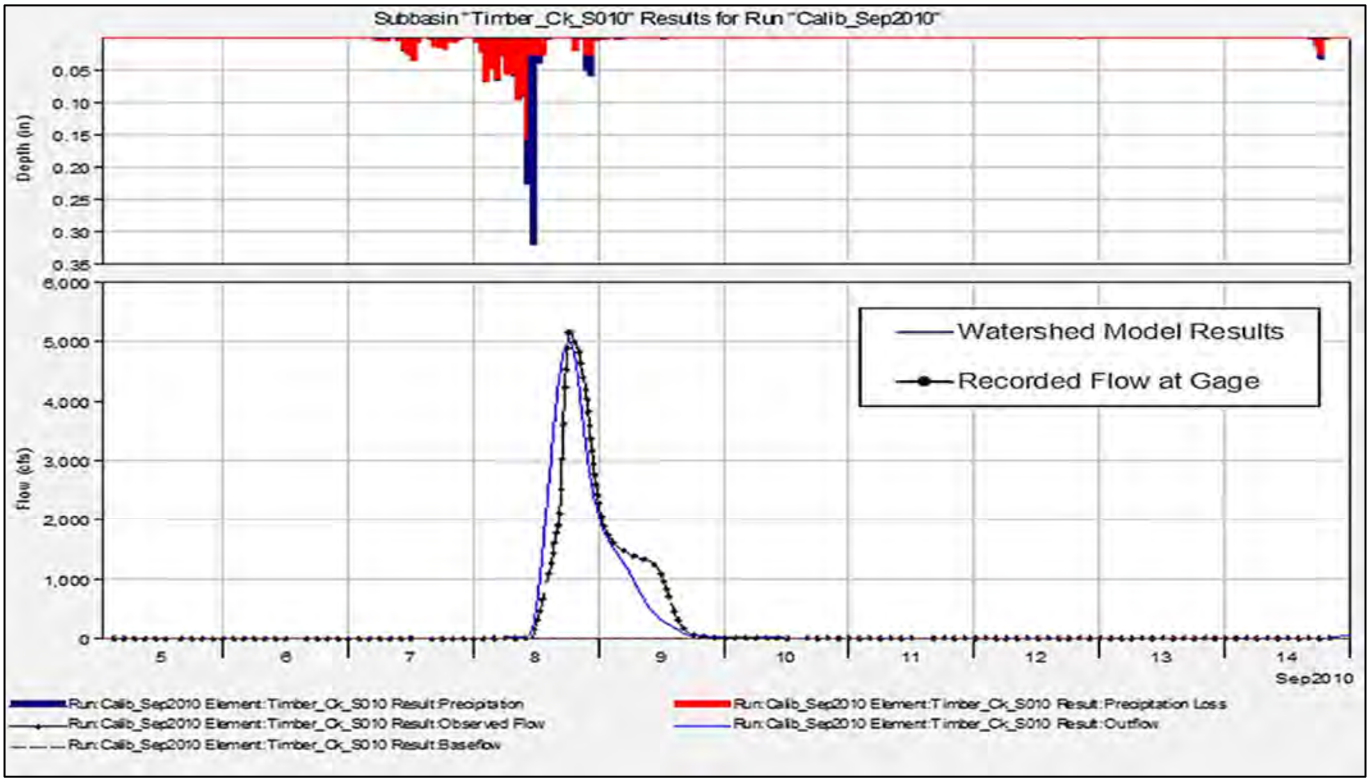

Figure 44c. September 8, 2010 Calibration Results for the Timber Creek near Collinsville, TX Gage

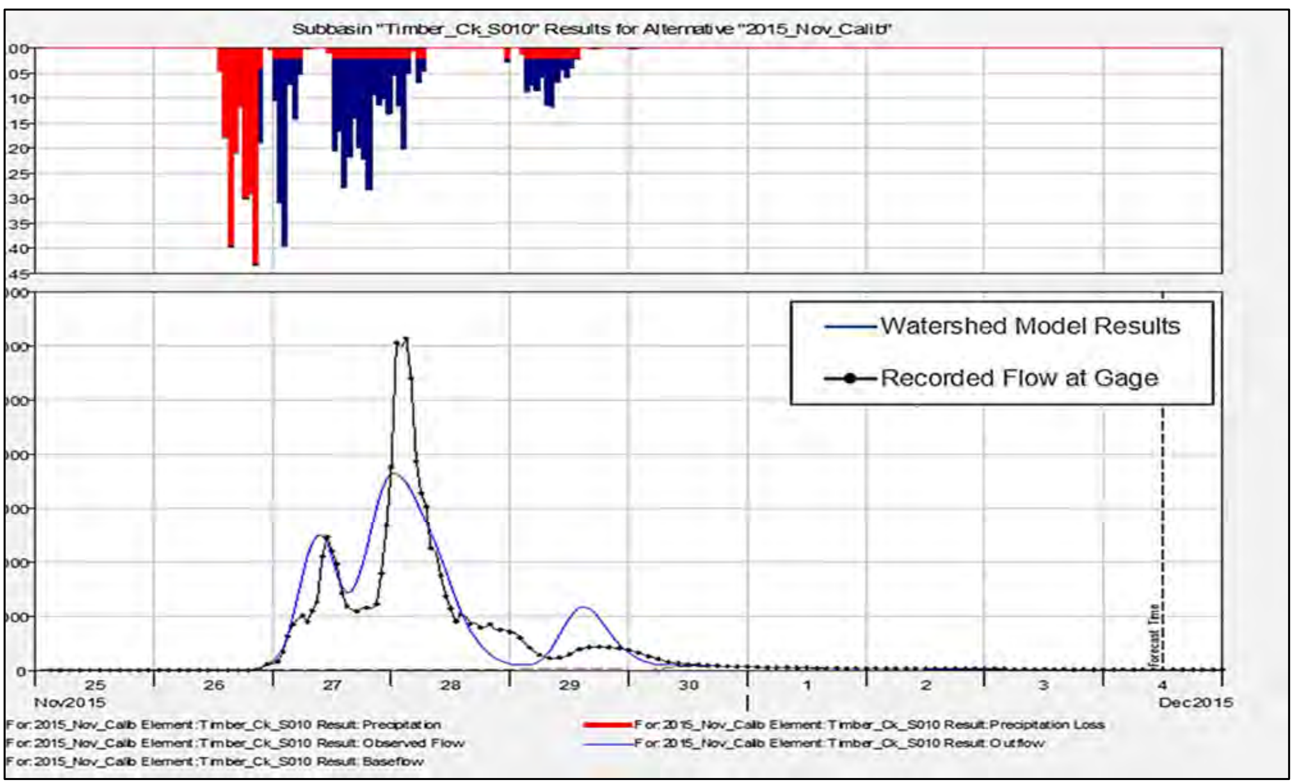

Figure 44d. November 27, 2015 Calibration Results for the Timber Creek near Collinsville, TX Gage

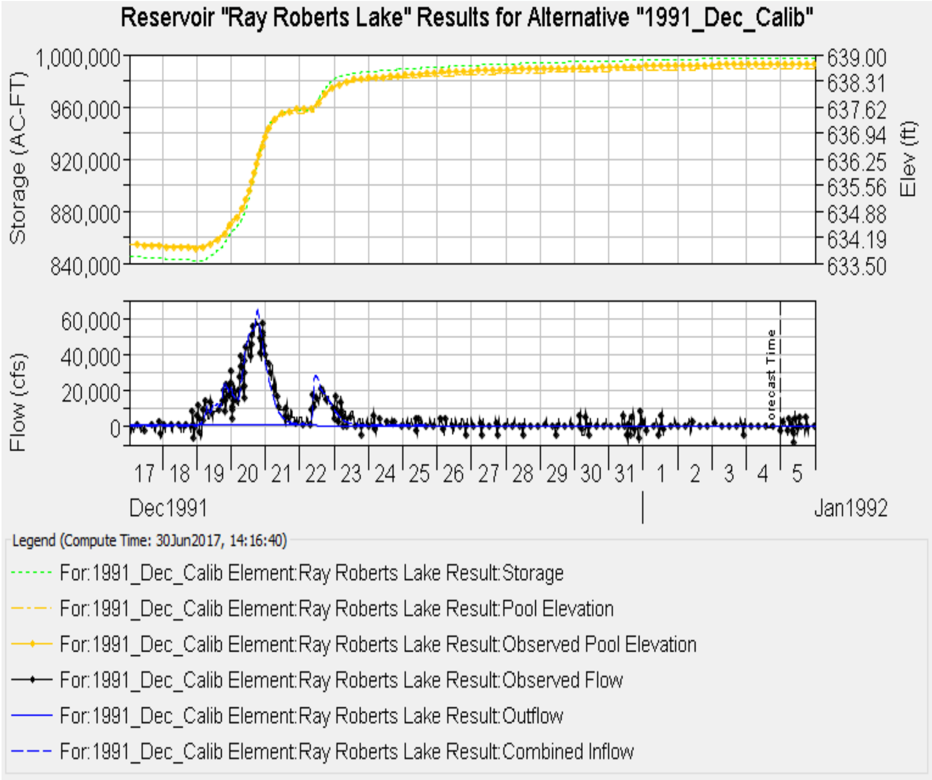

Figure 45a. December 1991 Calibration Results for Ray Roberts Reservoir

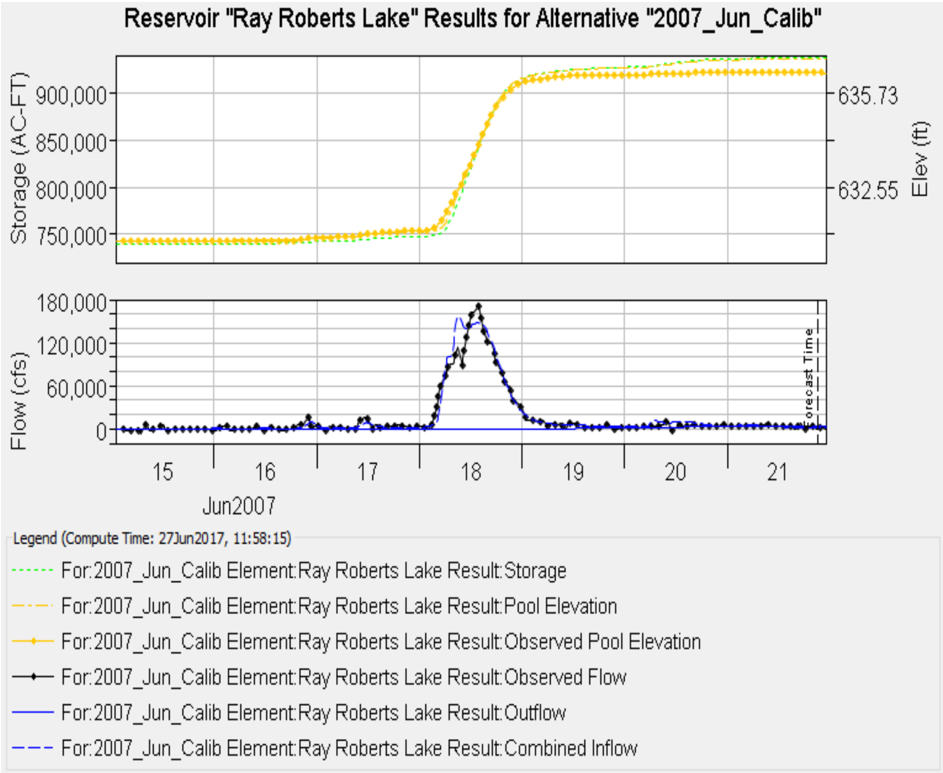

Figure 45b. June 2007 Calibration Results for Ray Roberts Reservoir

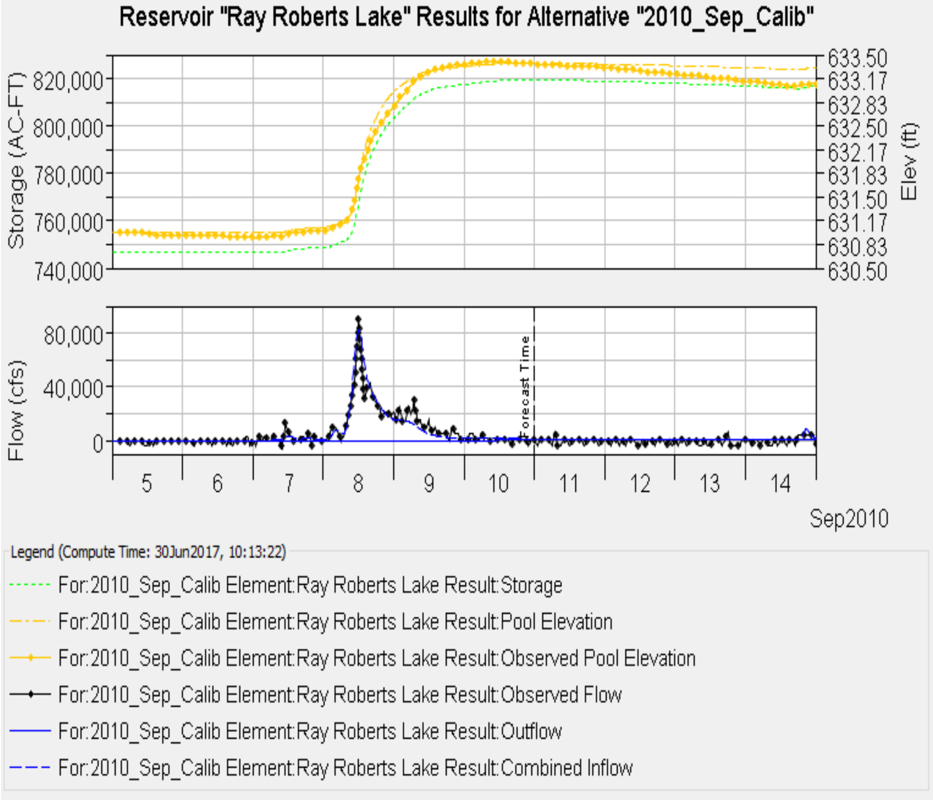

Figure 45c. September 2010 Calibration Results for Ray Roberts Reservoir

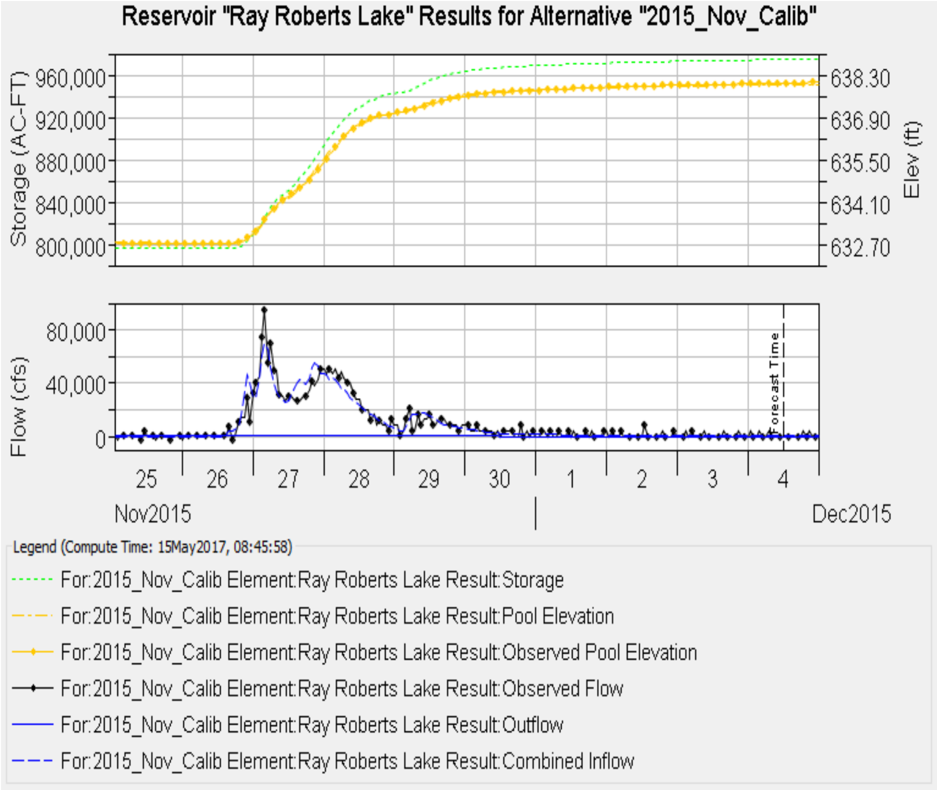

Figure 45d. November 2015 Calibration Results for Ray Roberts Reservoir

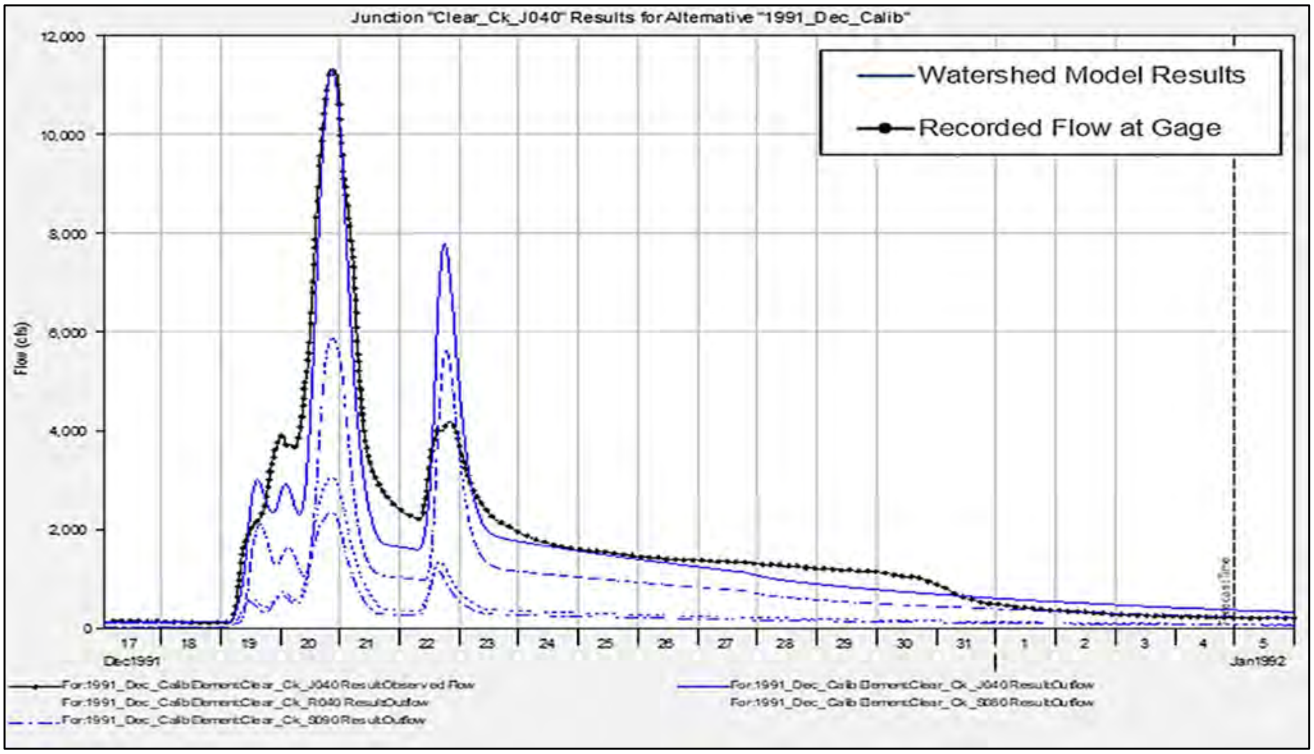

Figure 46a. December 20, 1991 Calibration Results for the Clear Creek near Sanger, TX Gage

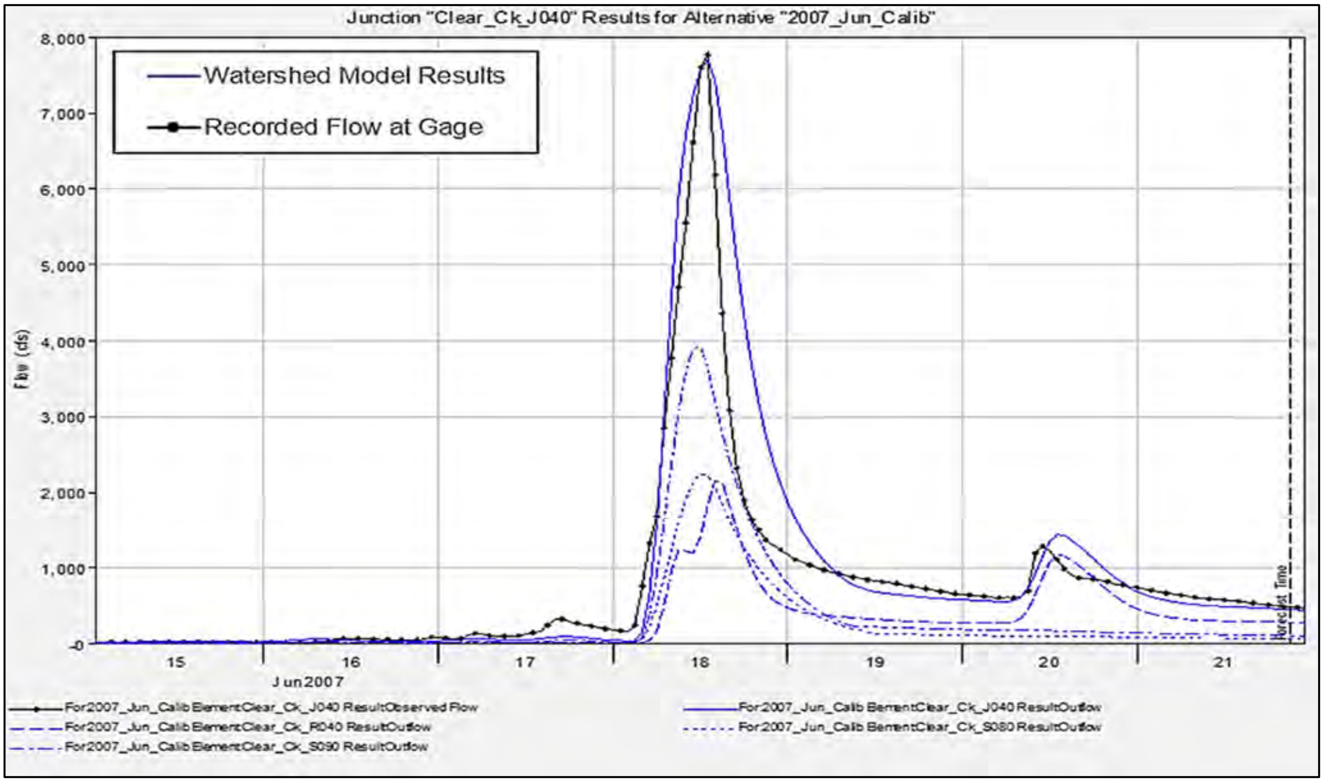

Figure 46b. June 17, 2007 Calibration Results for the Clear Creek near Sanger, TX Gage

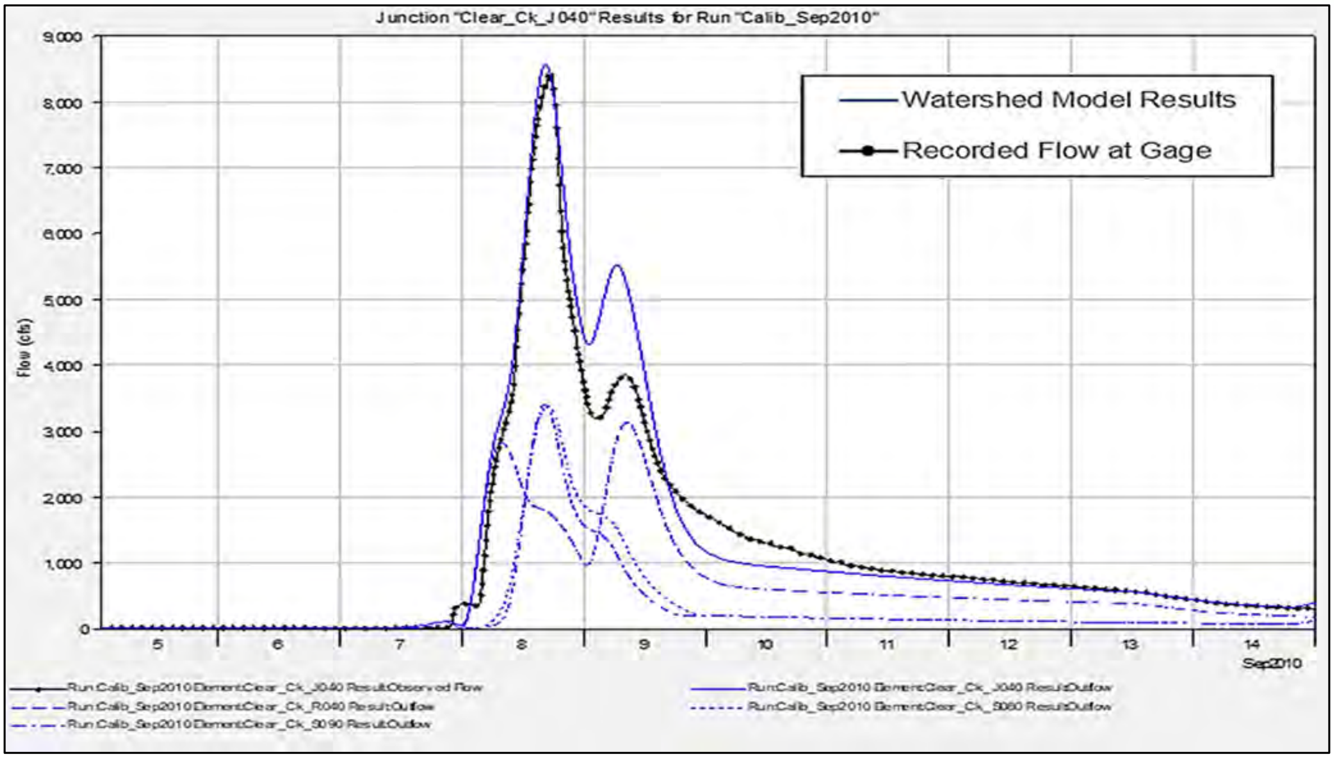

Figure 46c. September 8, 2010 Calibration Results for the Clear Creek near Sanger, TX Gage

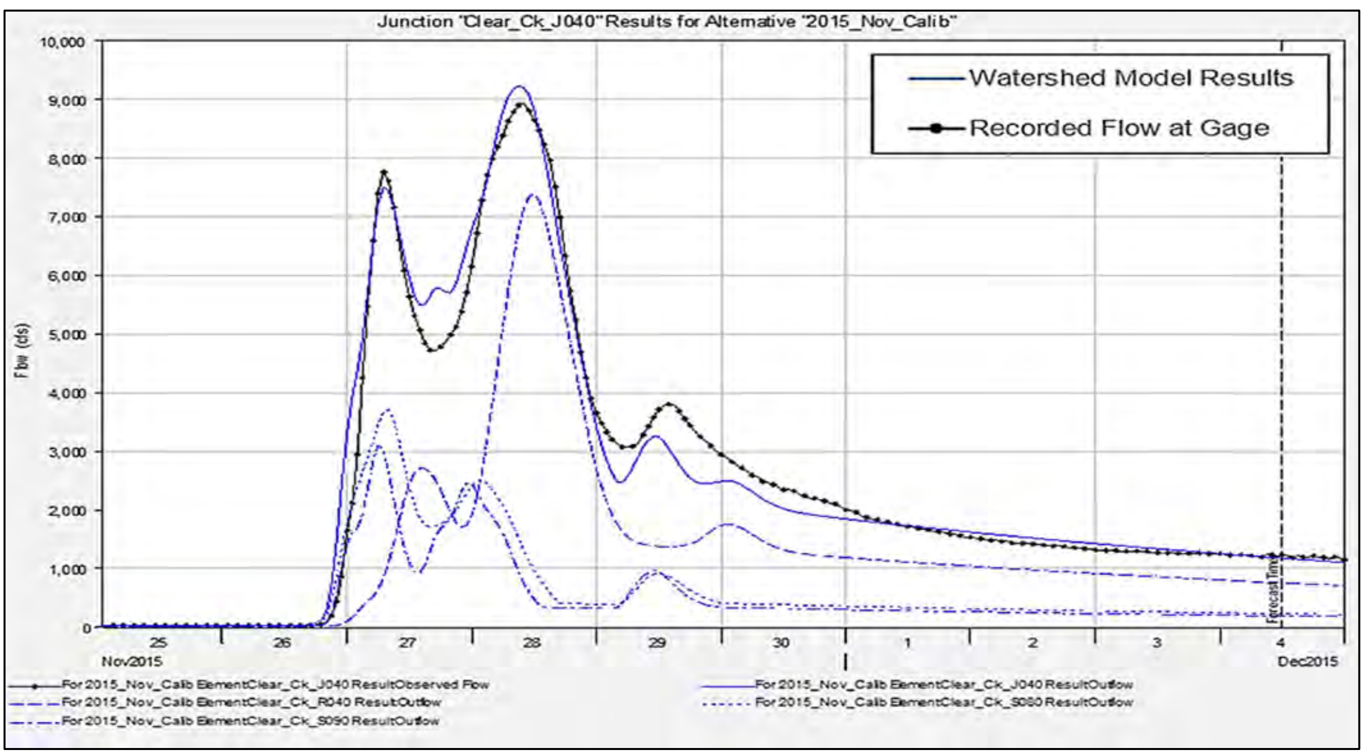

Figure 46d. November 27, 2015 Calibration Results for the Clear Creek near Sanger, TX Gage

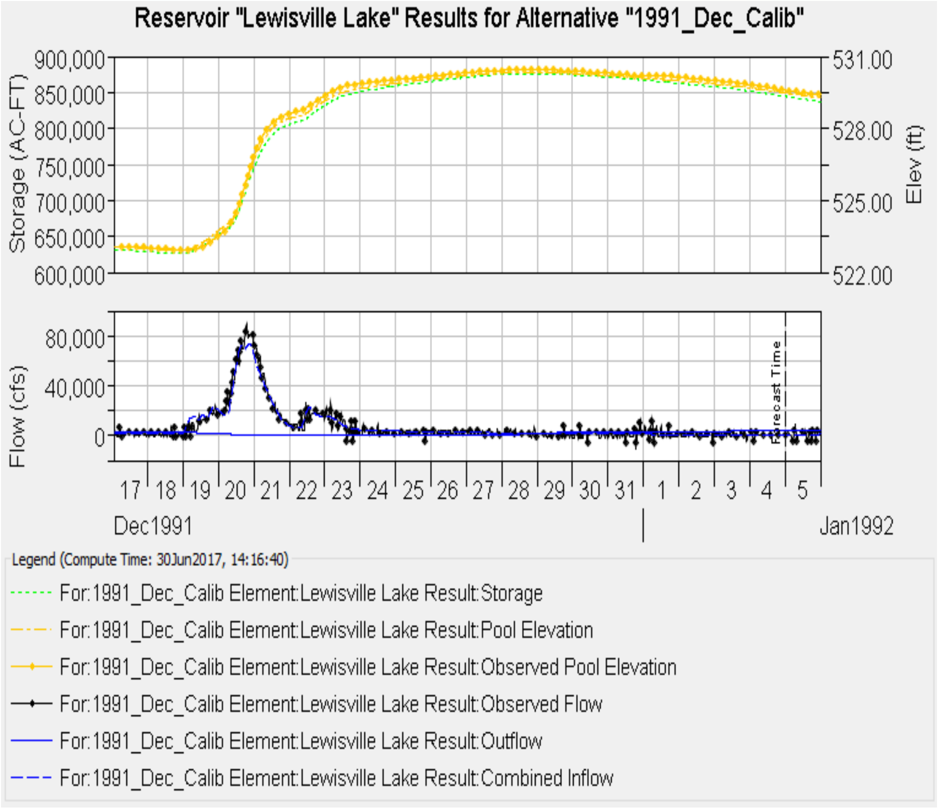

Figure 47a. December 1991 Calibration Results for Lewisville Reservoir

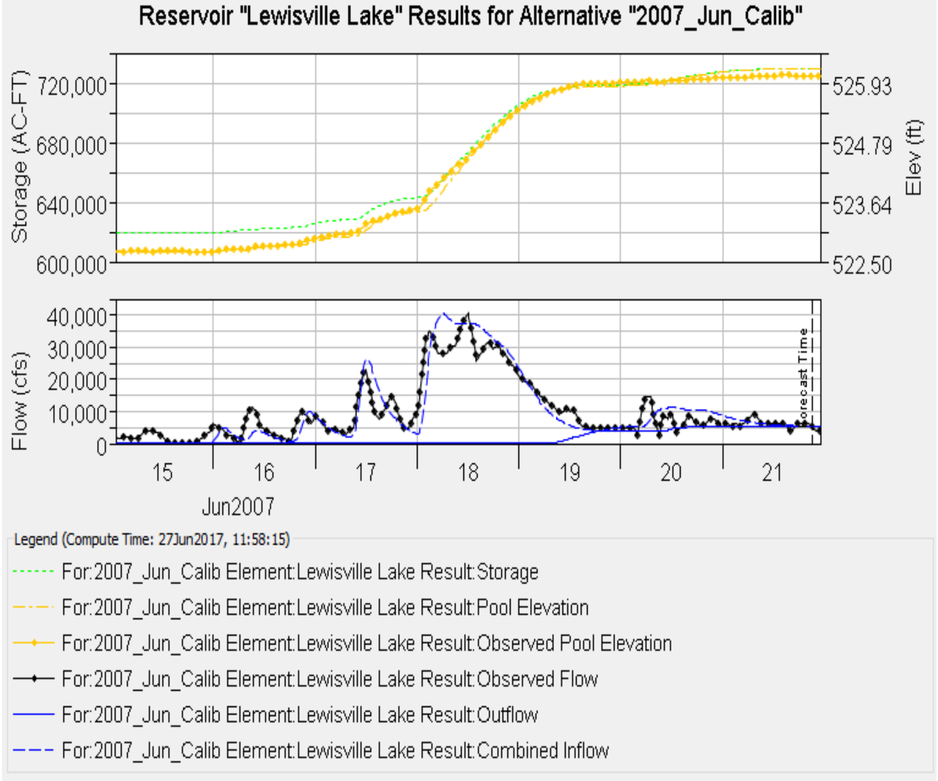

Figure 47b. June 2007 Calibration Results for Lewisville Reservoir

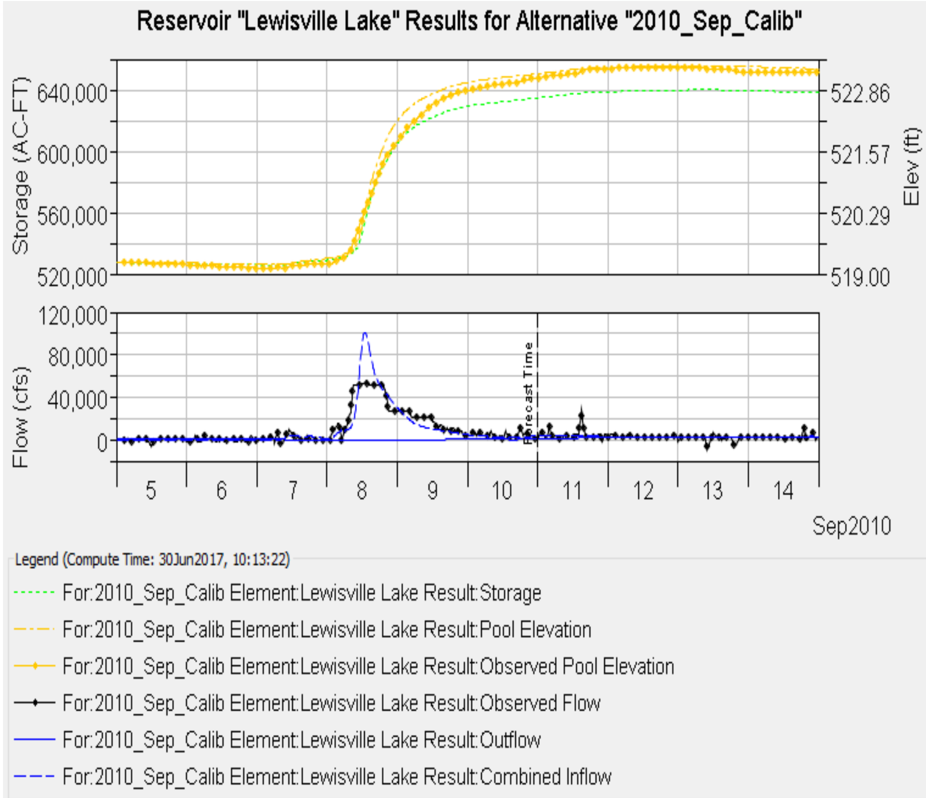

Figure 47c. September 2010 Calibration Results for Lewisville Reservoir

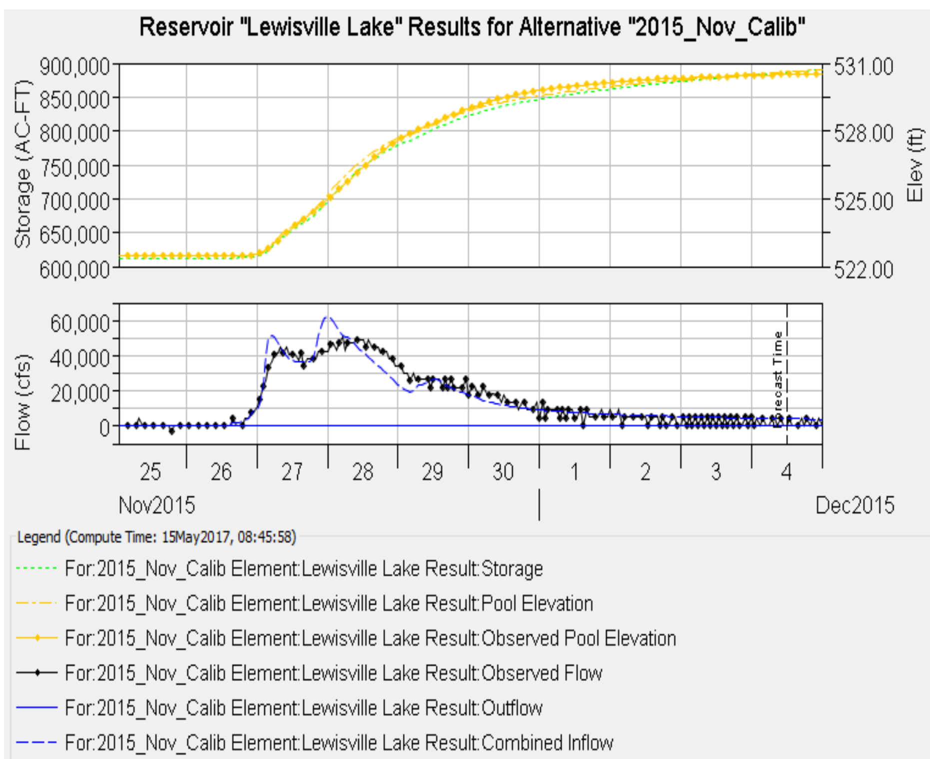

Figure 47d. November 2015 Calibration Results for Lewisville Reservoir

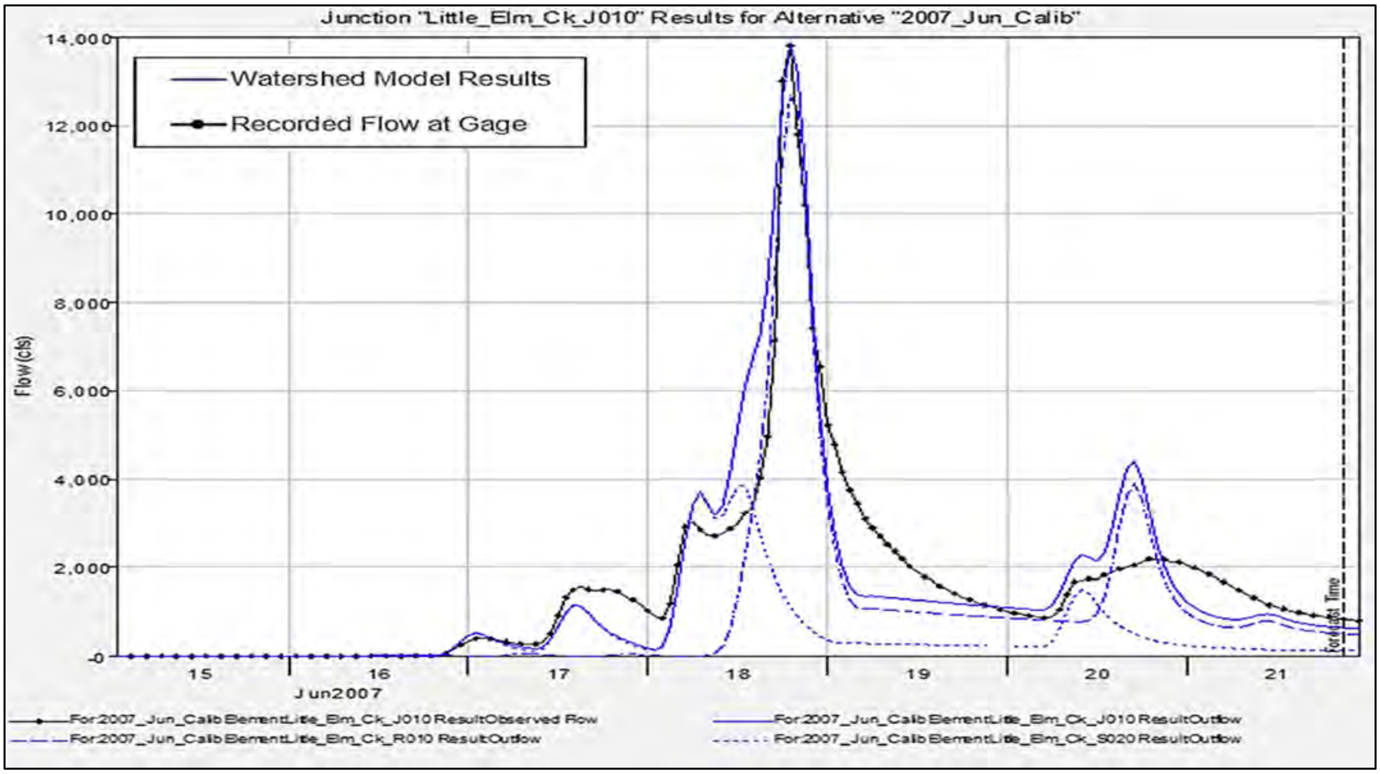

Figure 48a. June 17, 2007 Calibration Results for the Little Elm near Aubrey, TX Gage

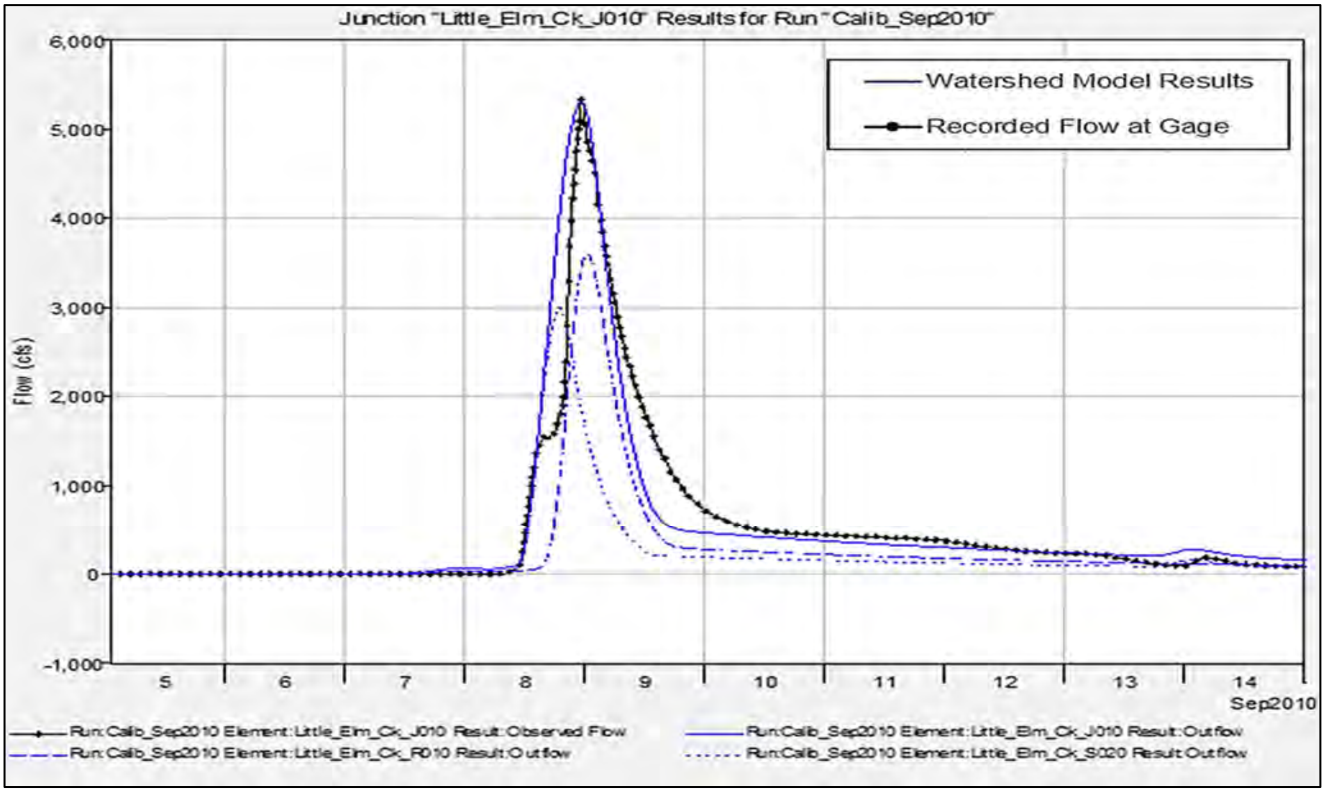

Figure 48b. September 8, 2010 Calibration Results for the Little Elm near Aubrey, TX Gage

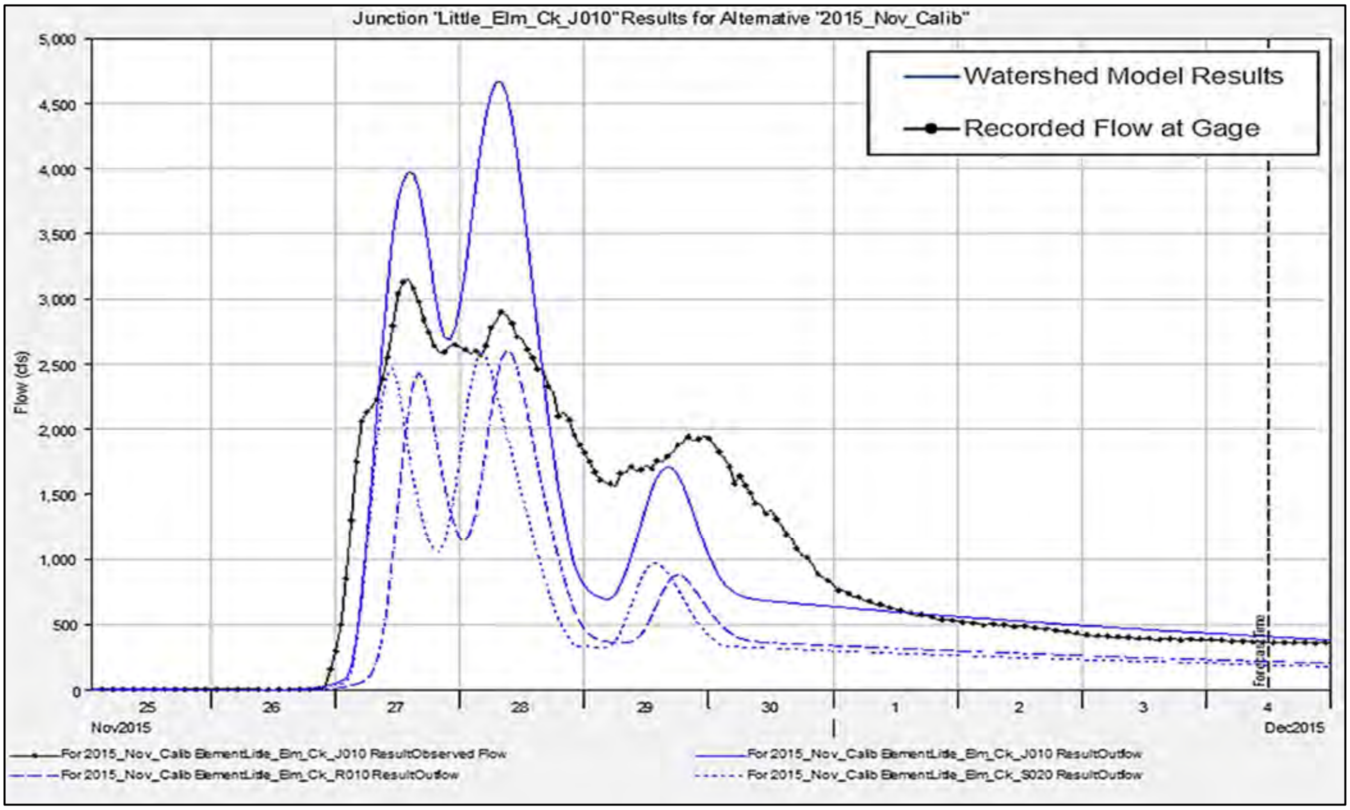

Figure 12. November 27, 2015 Calibration Results for the Little Elm near Aubrey, TX Gage

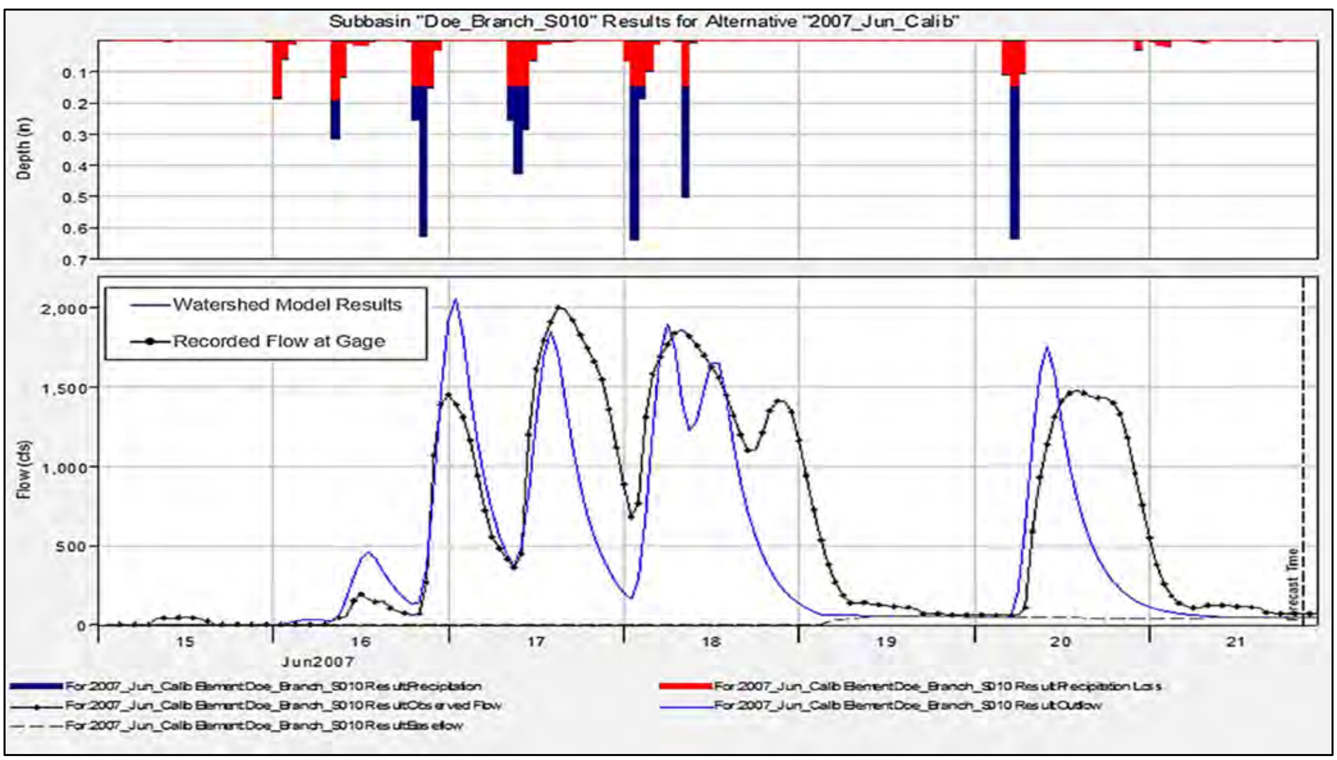

Figure 49a. June 17, 2007 Calibration Results for the Doe Branch near Prosper, TX Gage

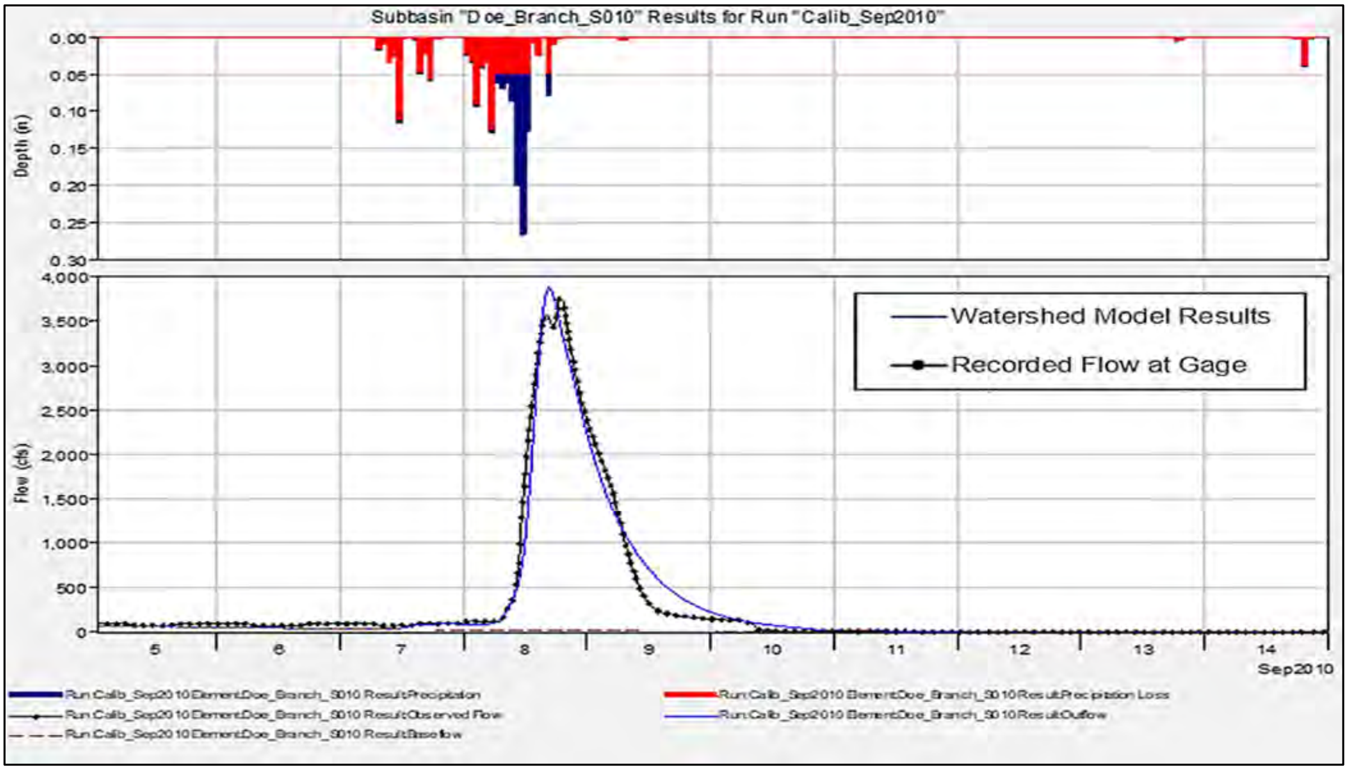

Figure 49b. September 8, 2010 Calibration Results for the Doe Branch near Prosper, TX Gage

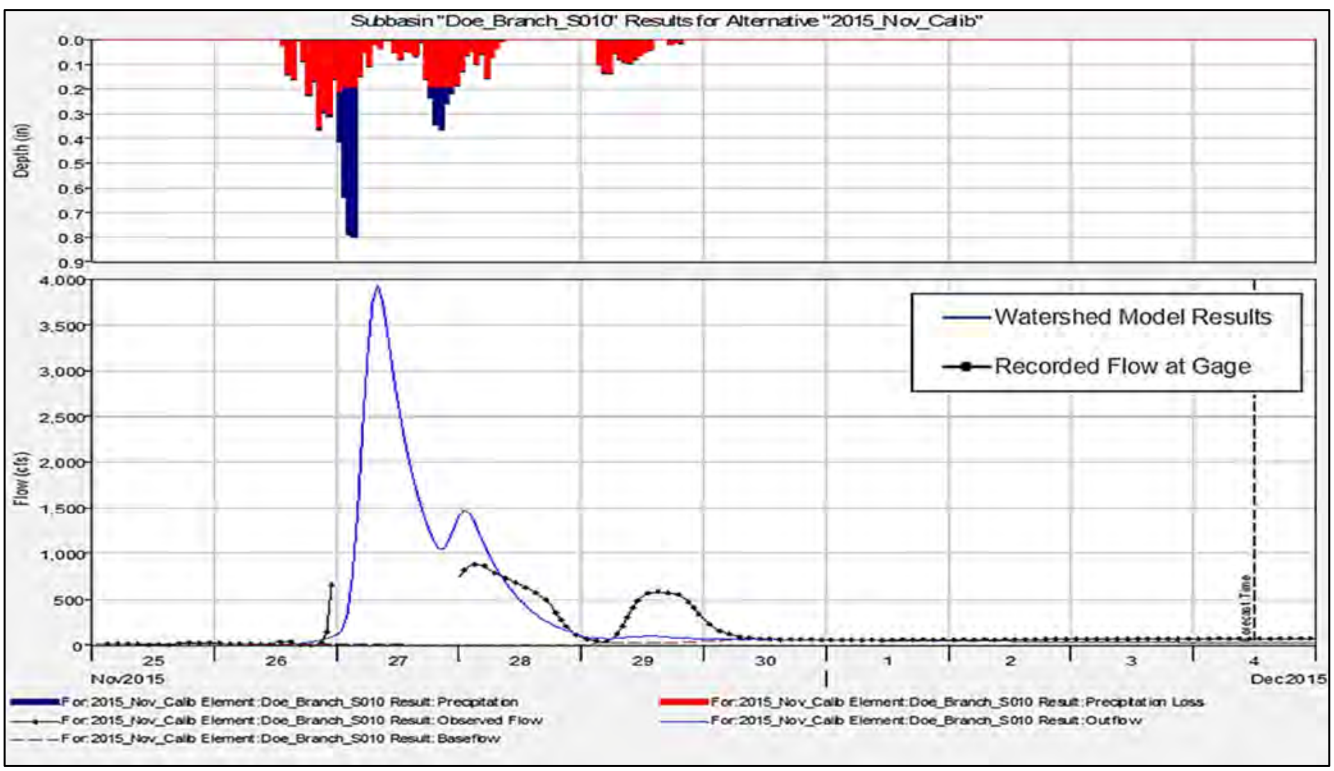

Figure 49c. November 27, 2015 Calibration Results for the Doe Branch near Prosper, TX Gage

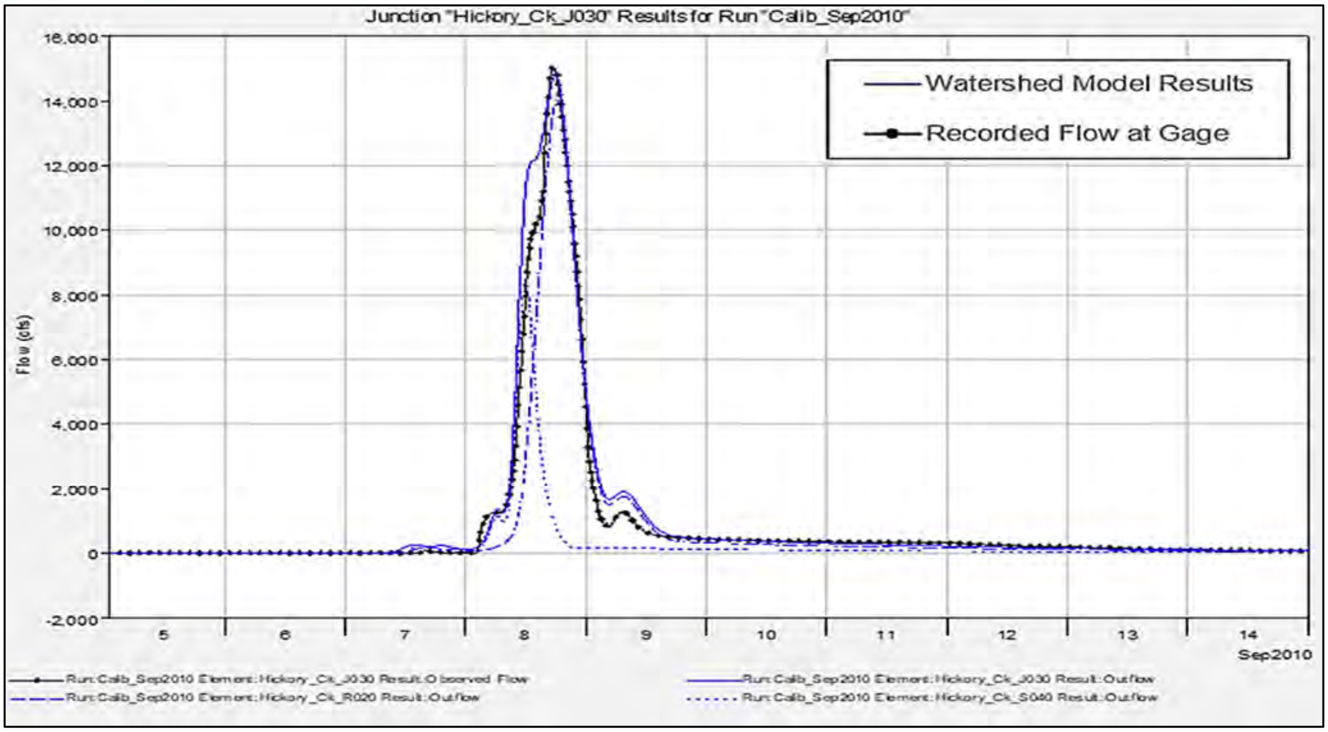

Figure 50a. September 8, 2010 Calibration Results for the Hickory Creek at Denton, TX Gage

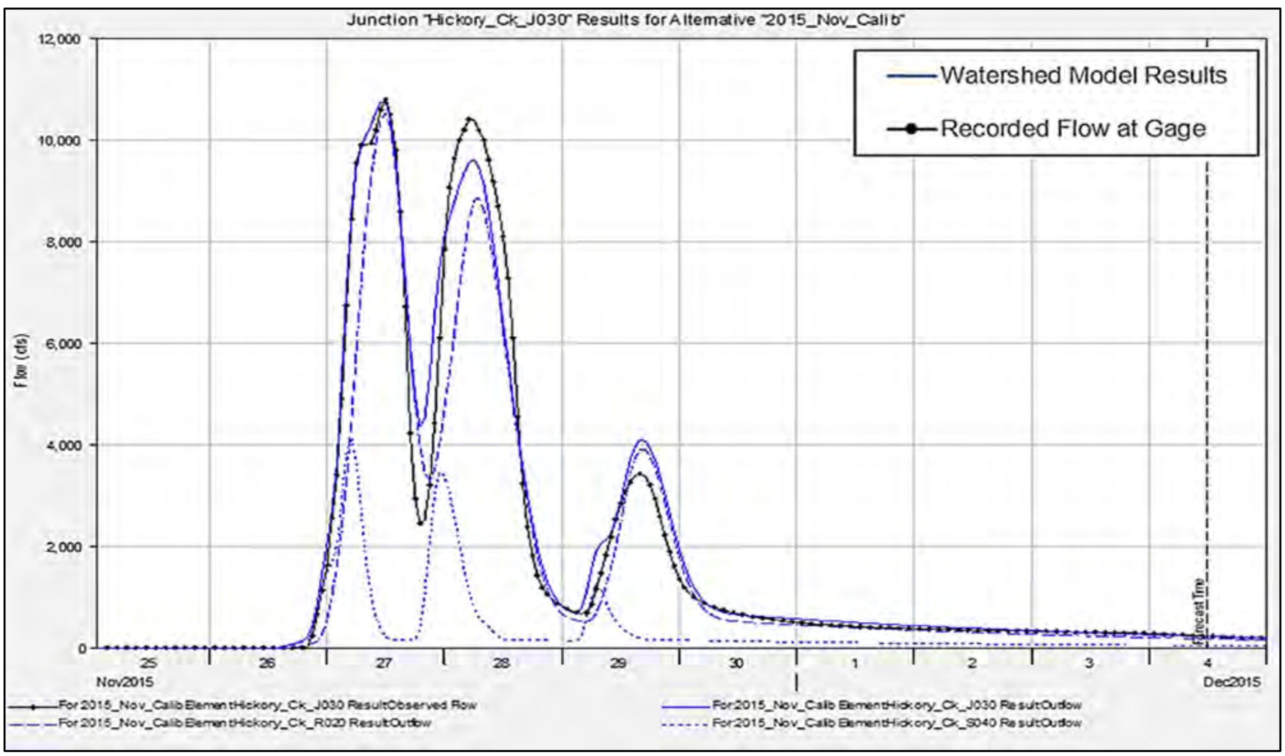

Figure 50b. November 27, 2015 Calibration Results for the Hickory Creek at Denton, TX Gage

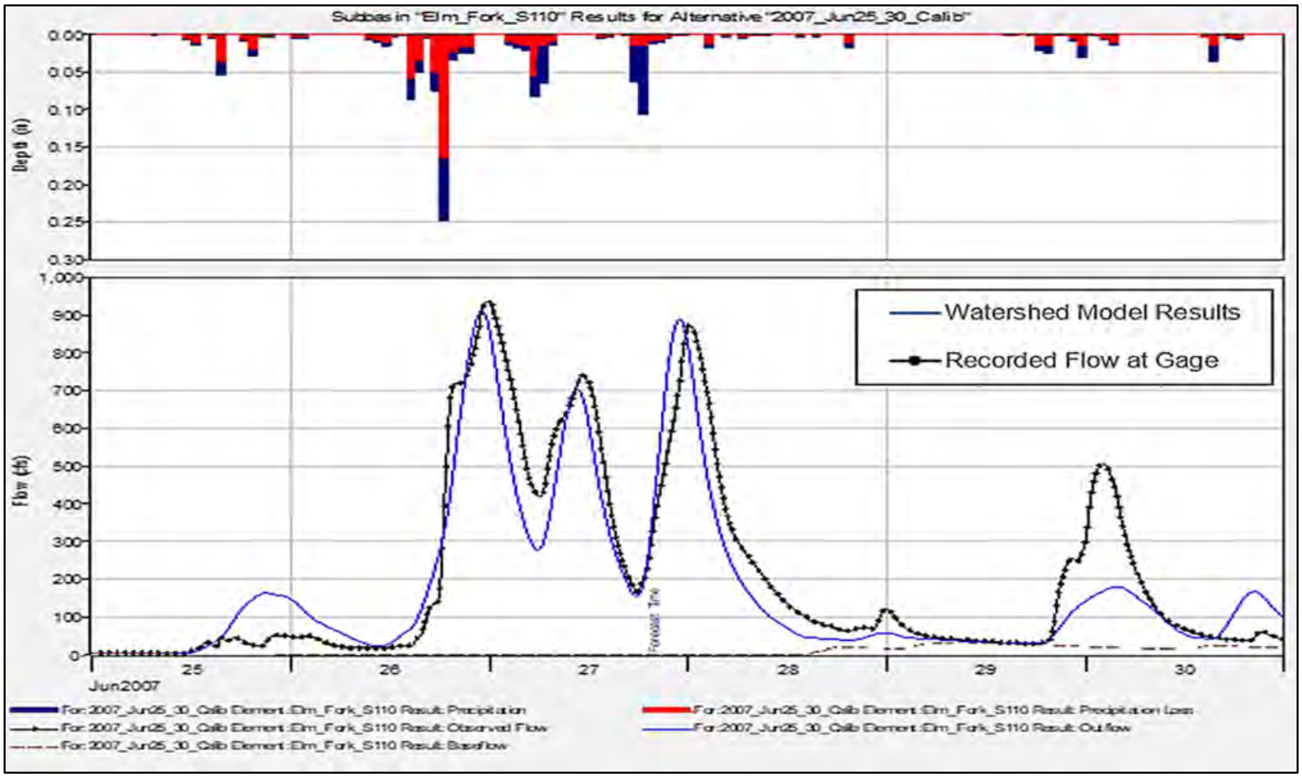

Figure 51a. June 26, 2007 Calibration Results for the Indian Creek at Carrolton, TX Gage

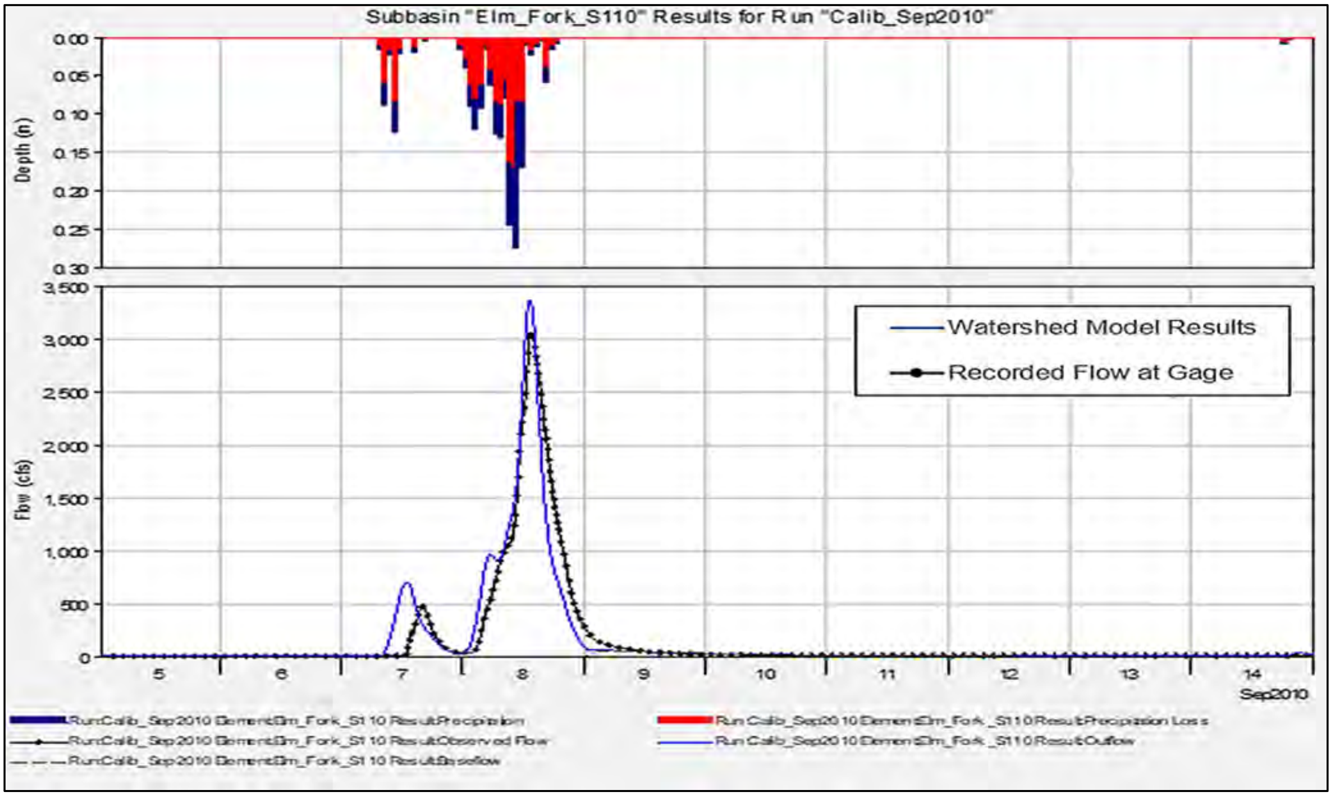

Figure 51b. September 8, 2010 Calibration Results for the Indian Creek at Carrolton, TX Gage

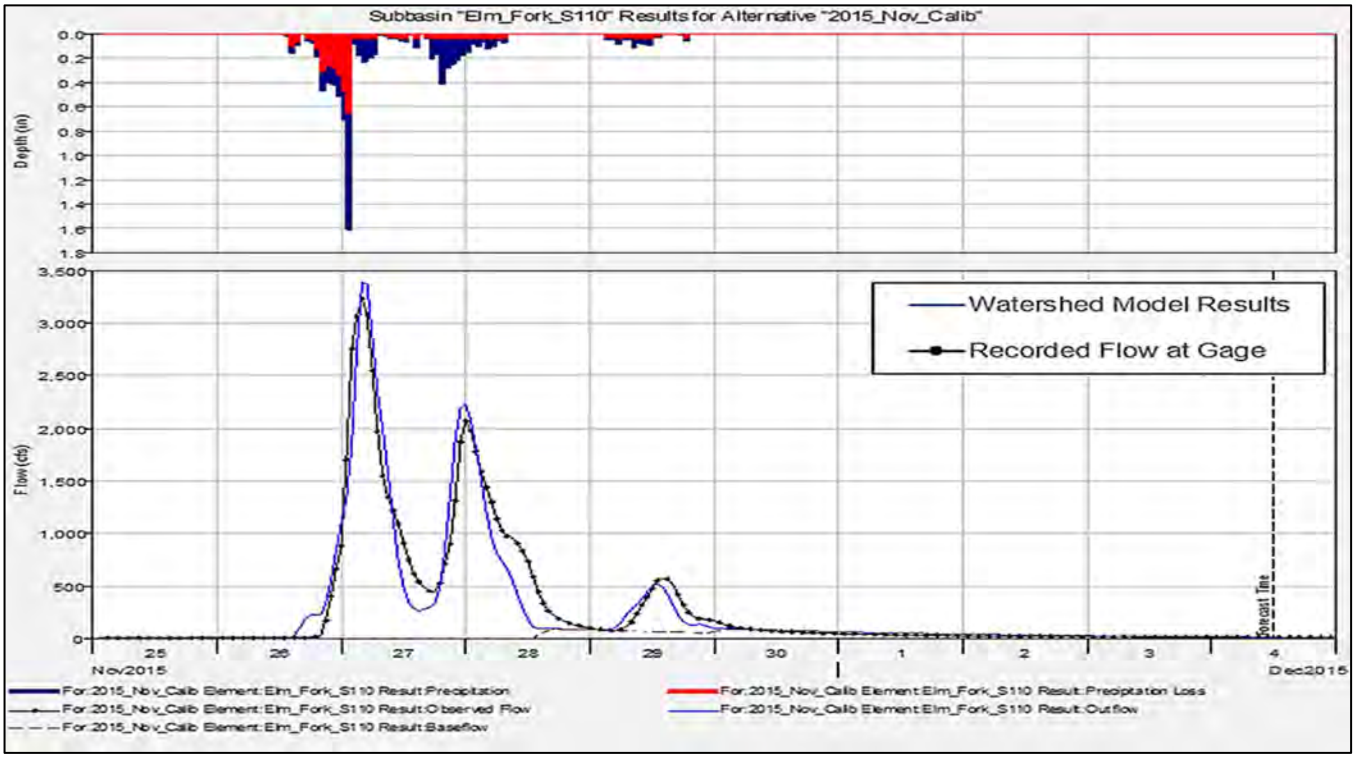

Figure 51c. November 27, 2015 Calibration Results for the Indian Creek near Carrolton, TX Gage

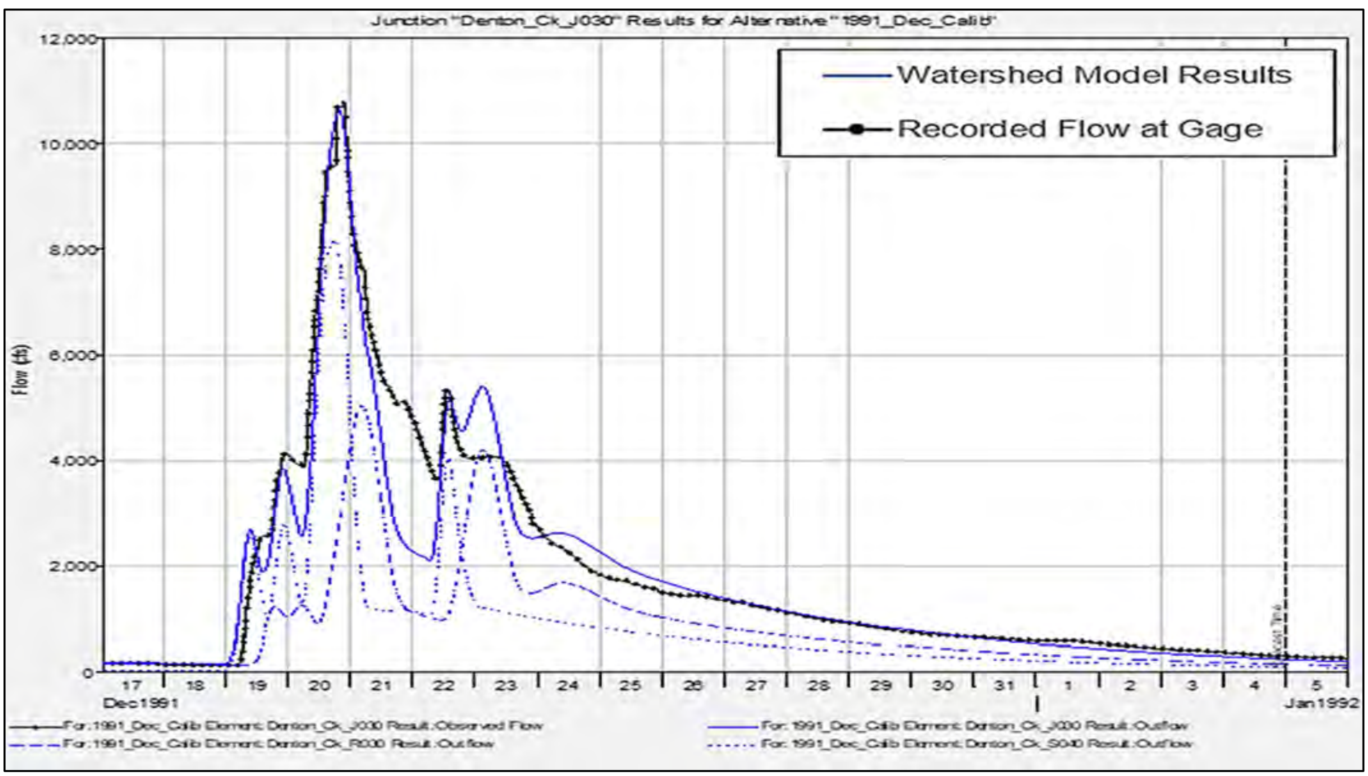

Figure 52a. December 20, 1991 Calibration Results for the Denton Creek near Justin, TX Gage

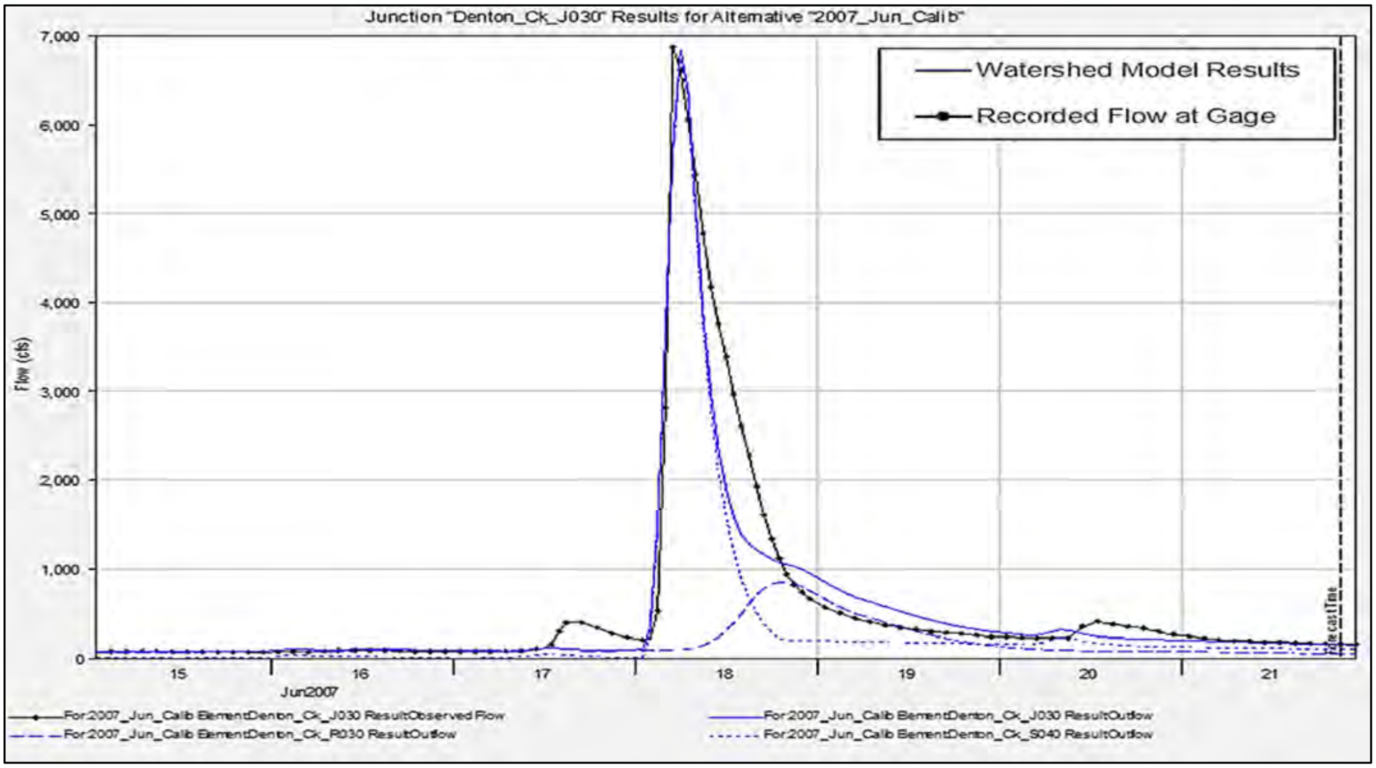

Figure 52b. June 17, 2007 Calibration Results for the Denton Creek near Justin, TX Gage

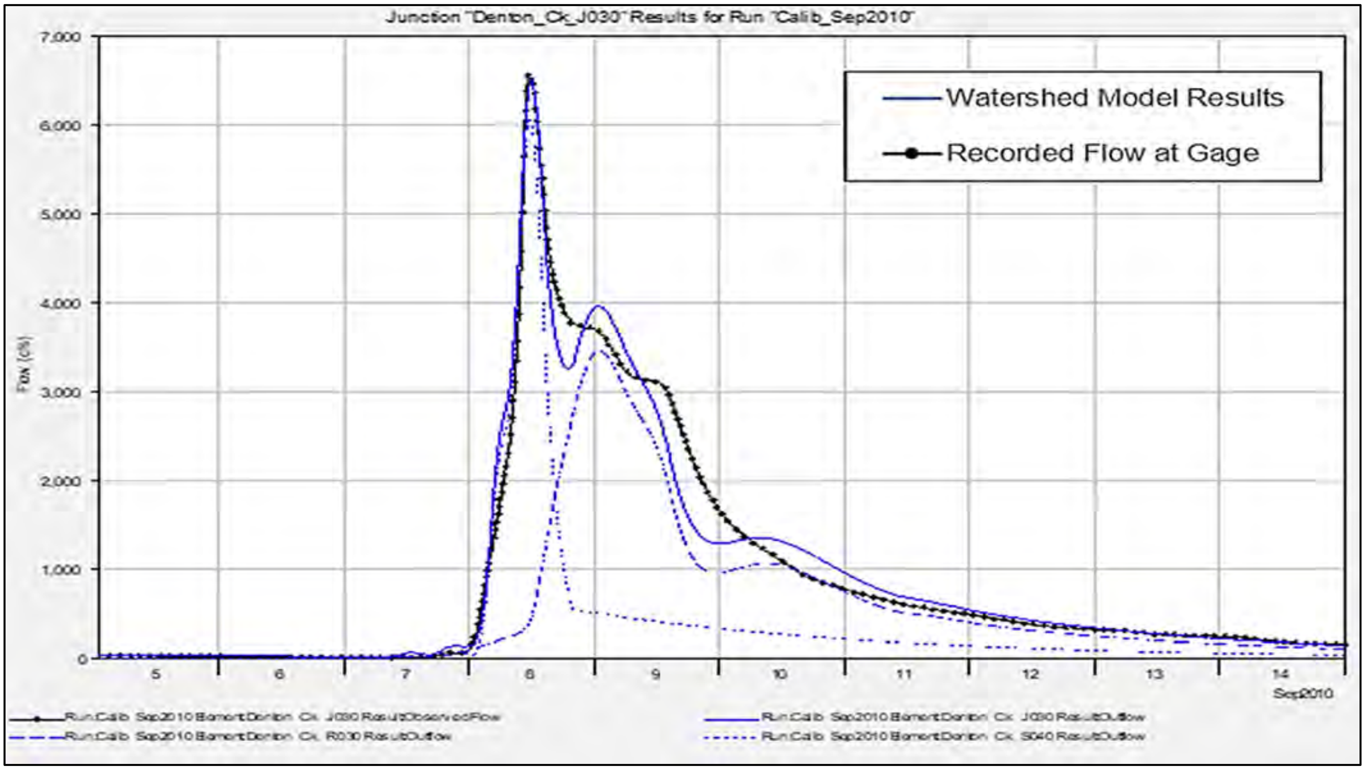

Figure 52c. September 8, 2010 Calibration Results for the Denton Creek near Justin, TX Gage

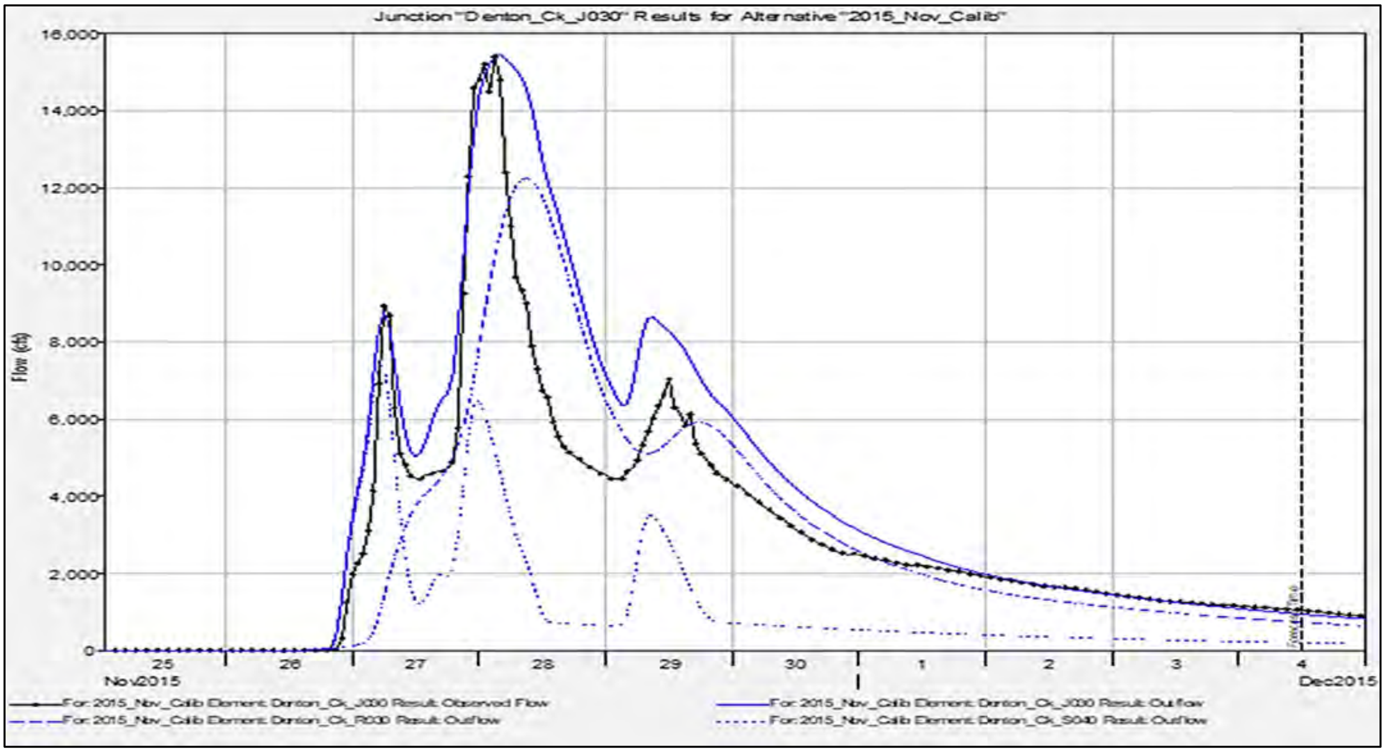

Figure 52d. November 27, 2015 Calibration Results for the Denton Creek near Justin, TX Gage

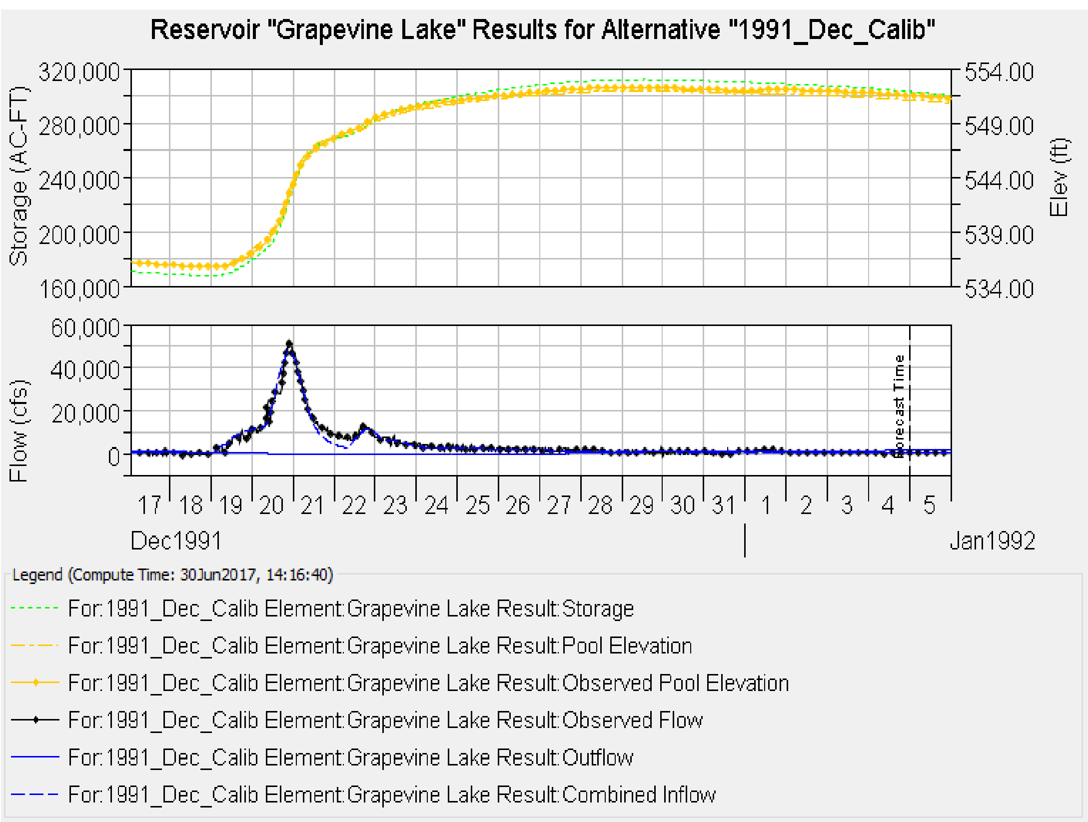

Figure 53a. December 1991 Calibration Results for Grapevine Reservoir

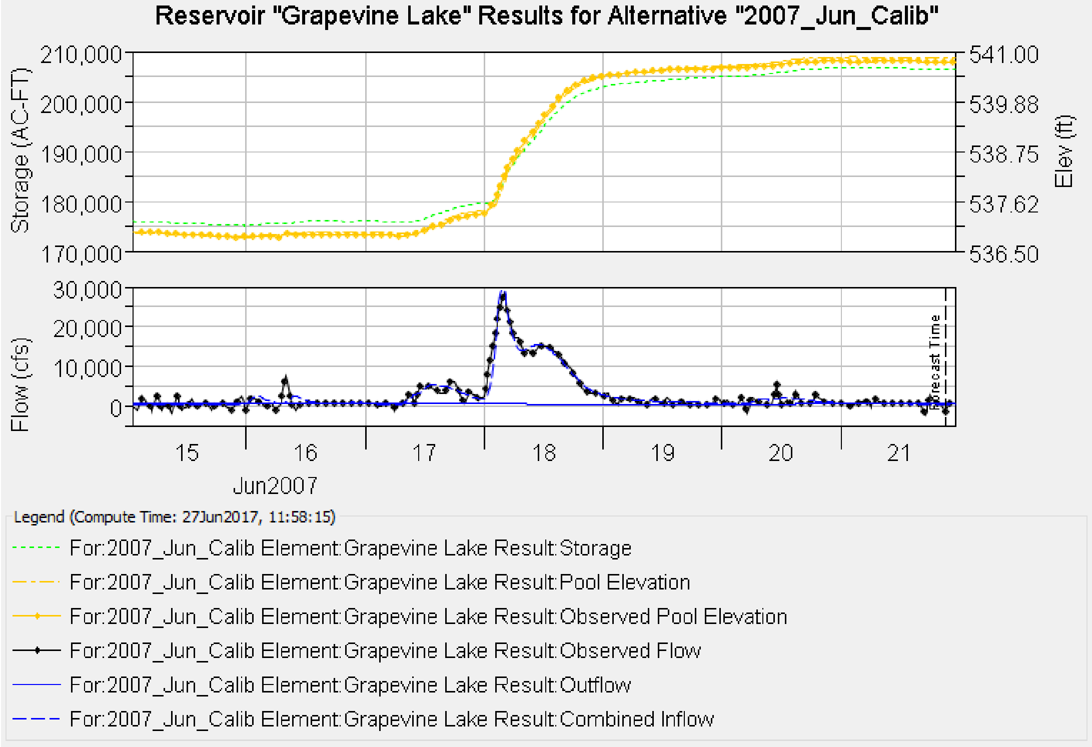

Figure 53b. June 2007 Calibration Results for Grapevine Reservoir

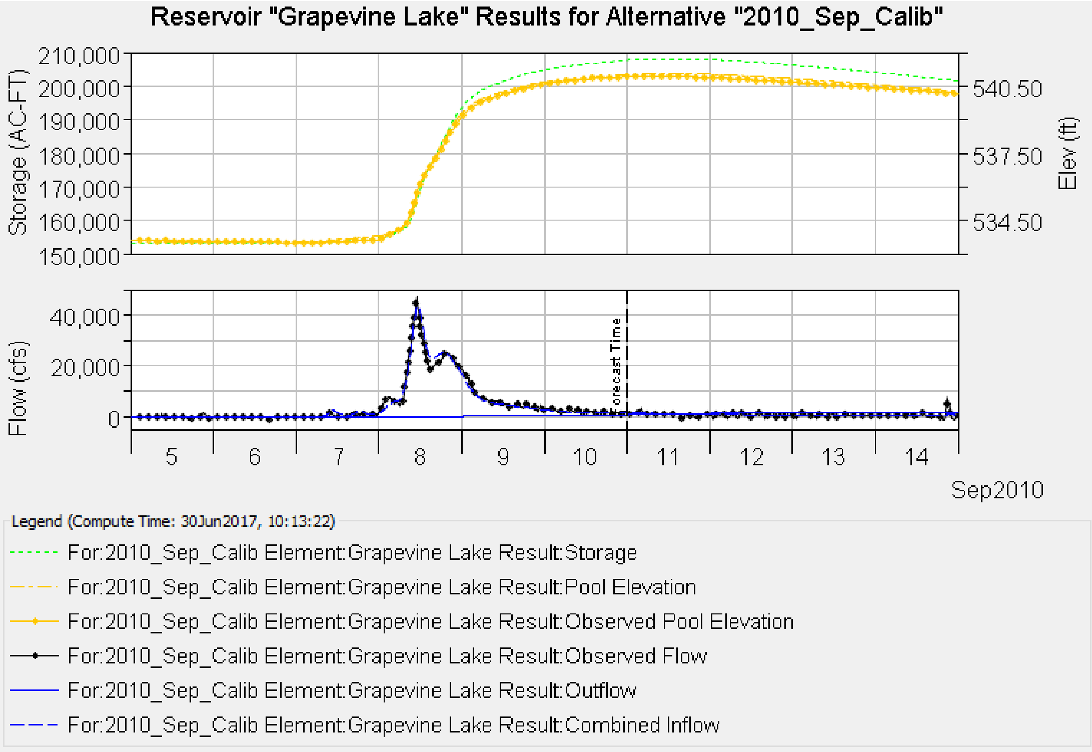

Figure 53c. September 2010 Calibration Results for Grapevine Reservoir

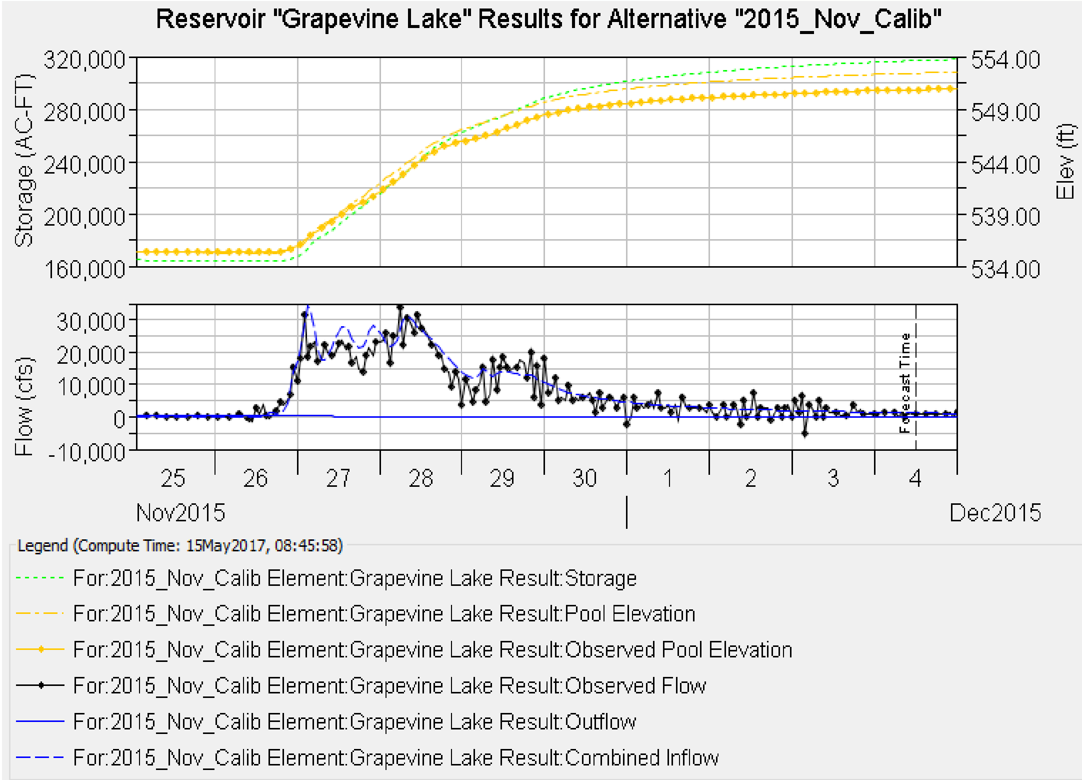

Figure 53d. November 2015 Calibration Results for Grapevine Reservoir

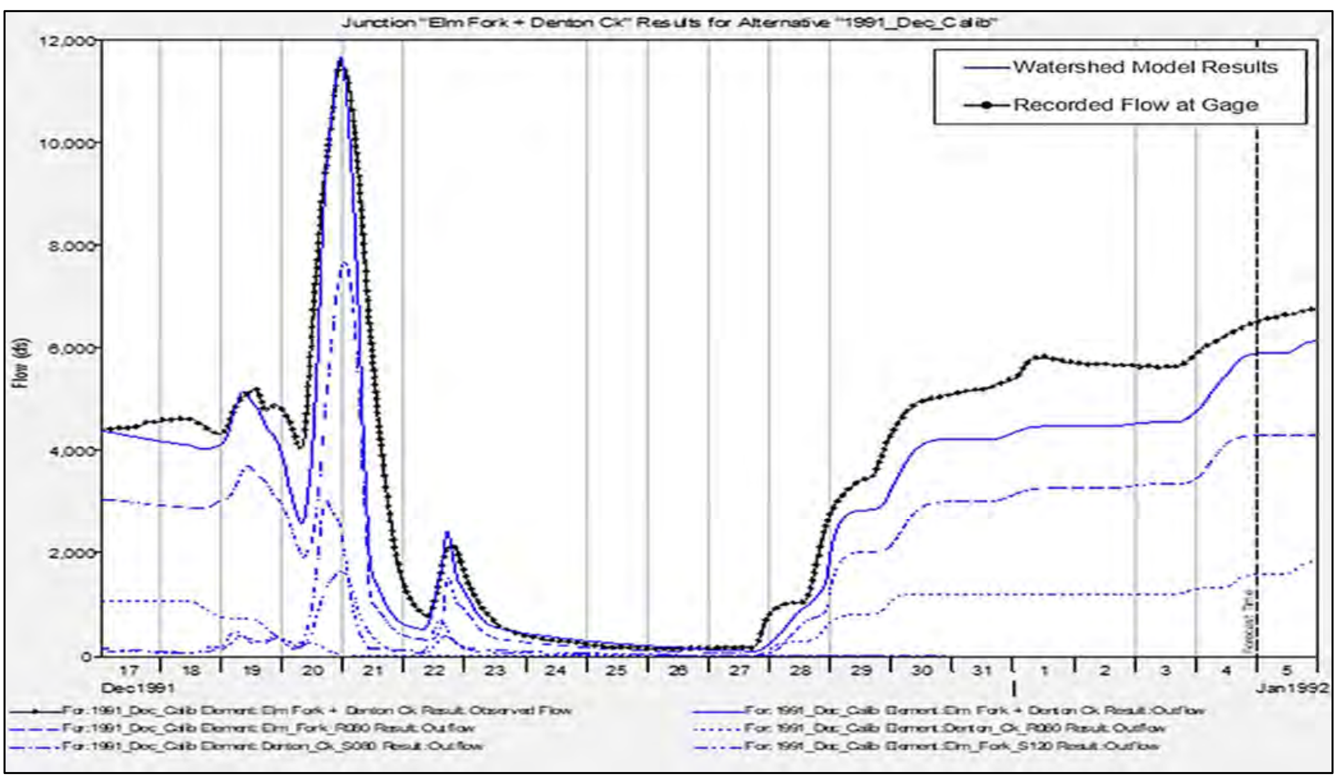

Figure 54a. December 20, 1991 Calibration Results for the Elm Fork near Carrollton, TX Gage

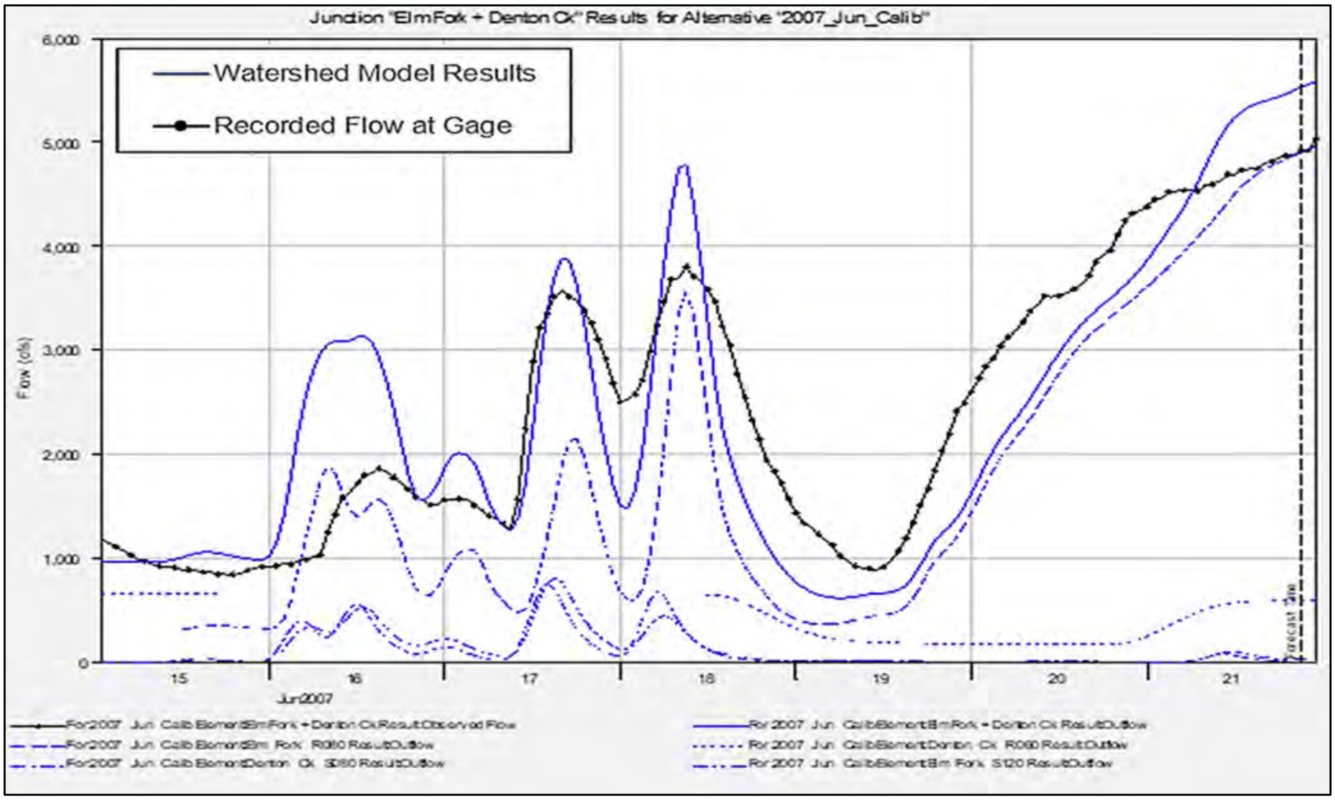

Figure 54b. June 17, 2007 Calibration Results for the Elm Fork near Carrollton, TX Gage

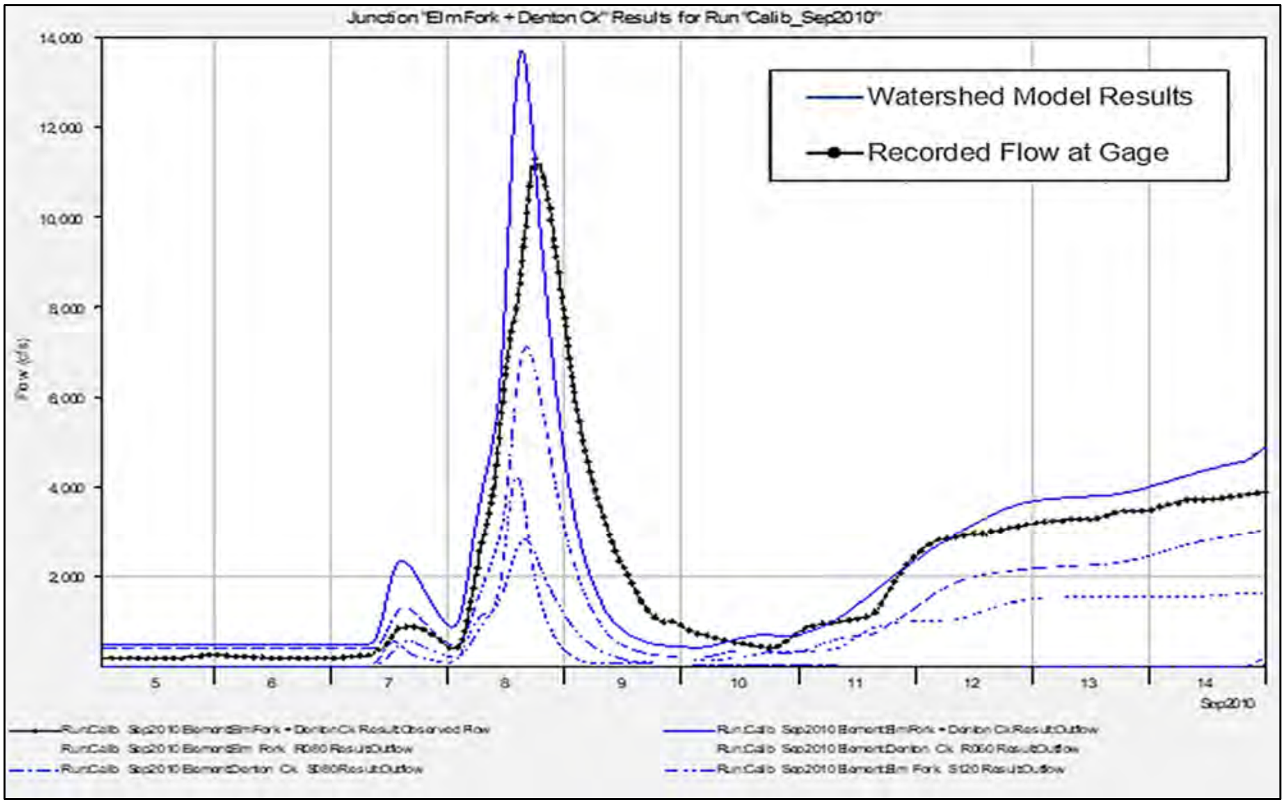

Figure 54c. September 8, 2010 Calibration Results for the Elm Fork near Carrollton, TX Gage

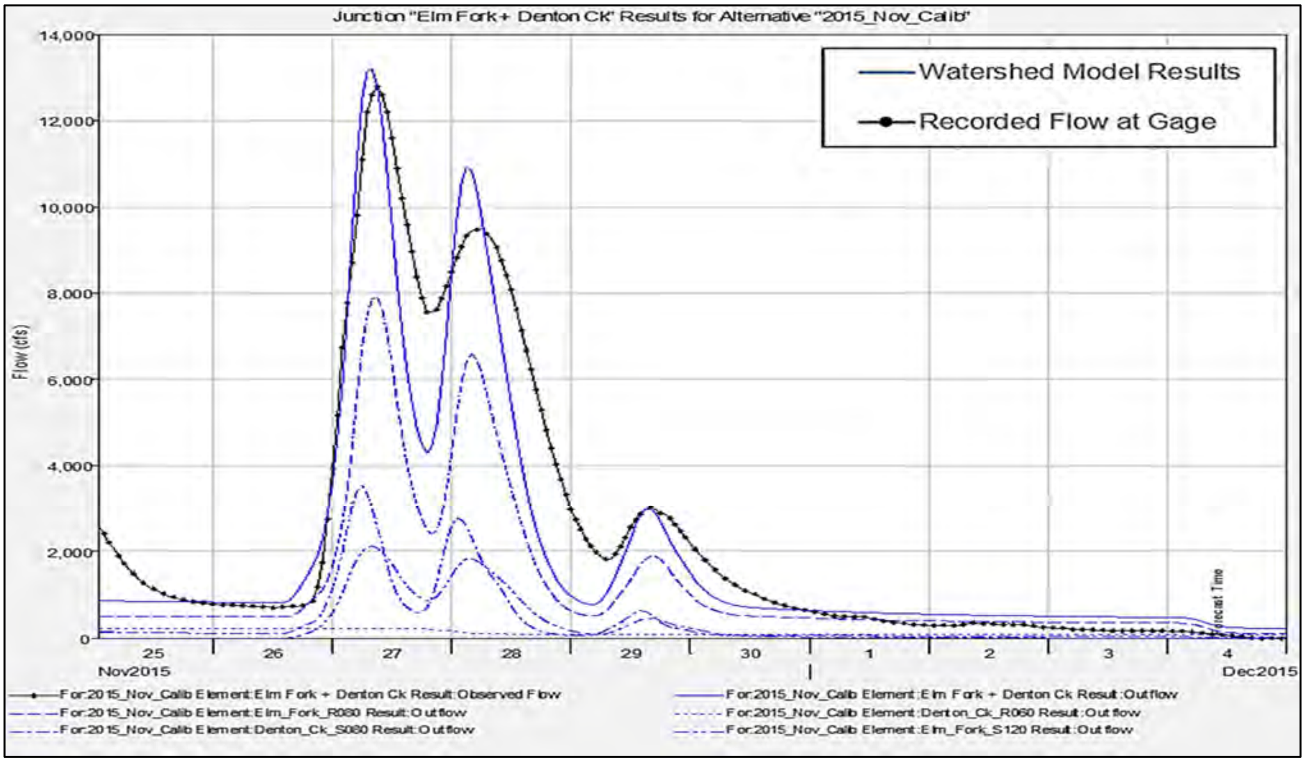

Figure 54d. November 27, 2015 Calibration Results for the Elm Fork near Carrollton, TX Gage

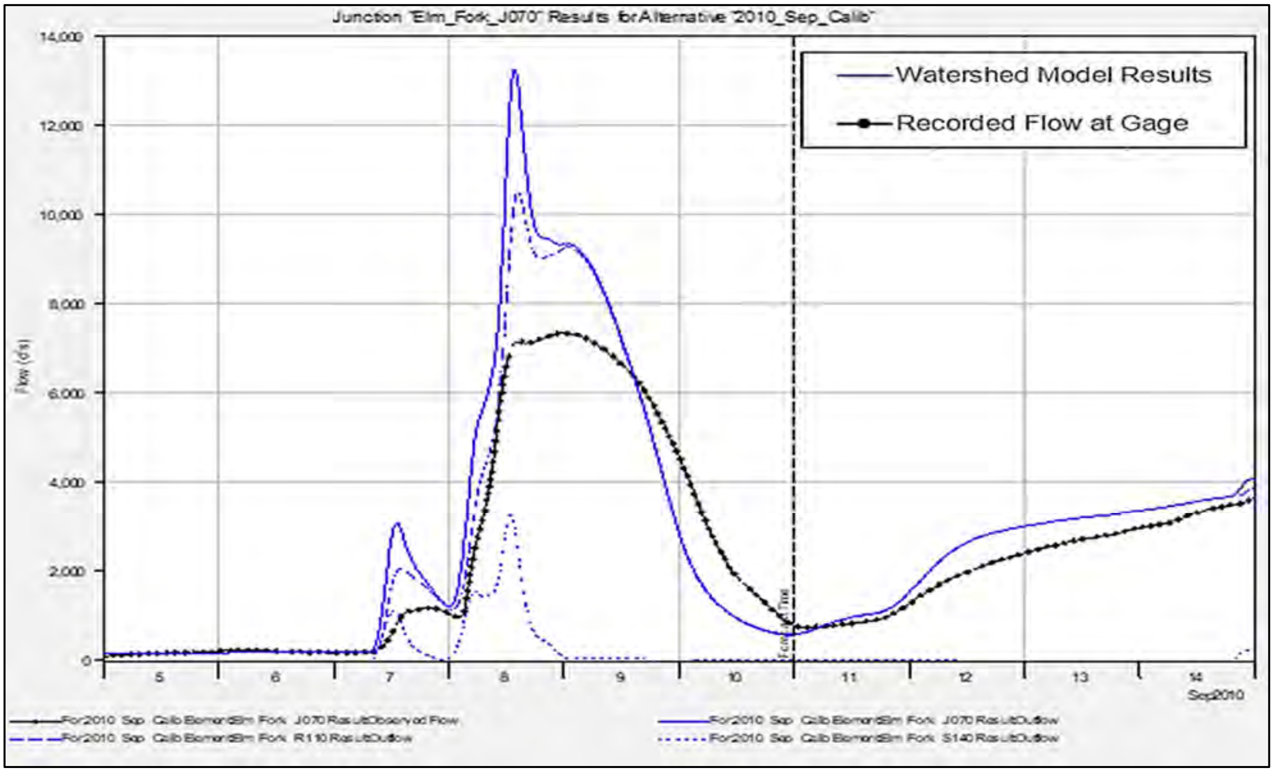

Figure 55a. September 8, 2010 Calibration Results for the Elm Fork at Spur 348, Irving Gage

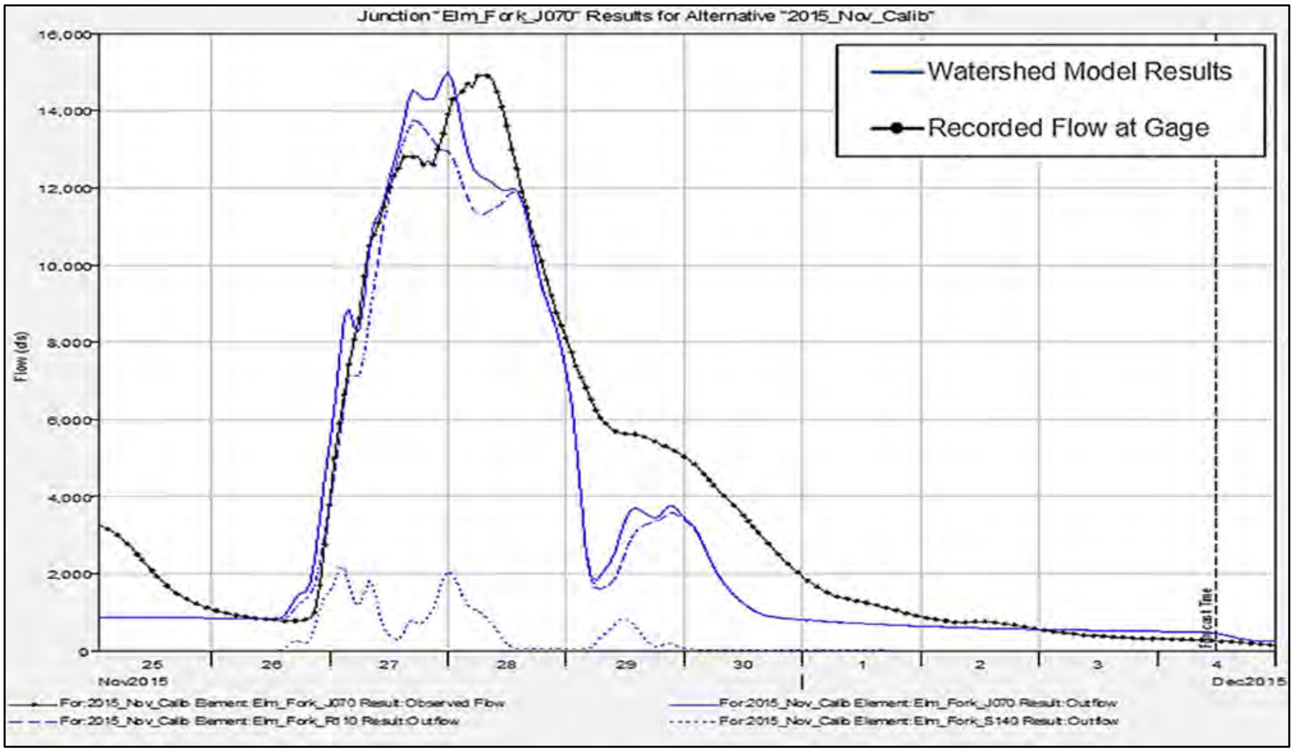

Figure 55b. November 27, 2015 Calibration Results for the Elm Fork at Spur 348, Irving Gage

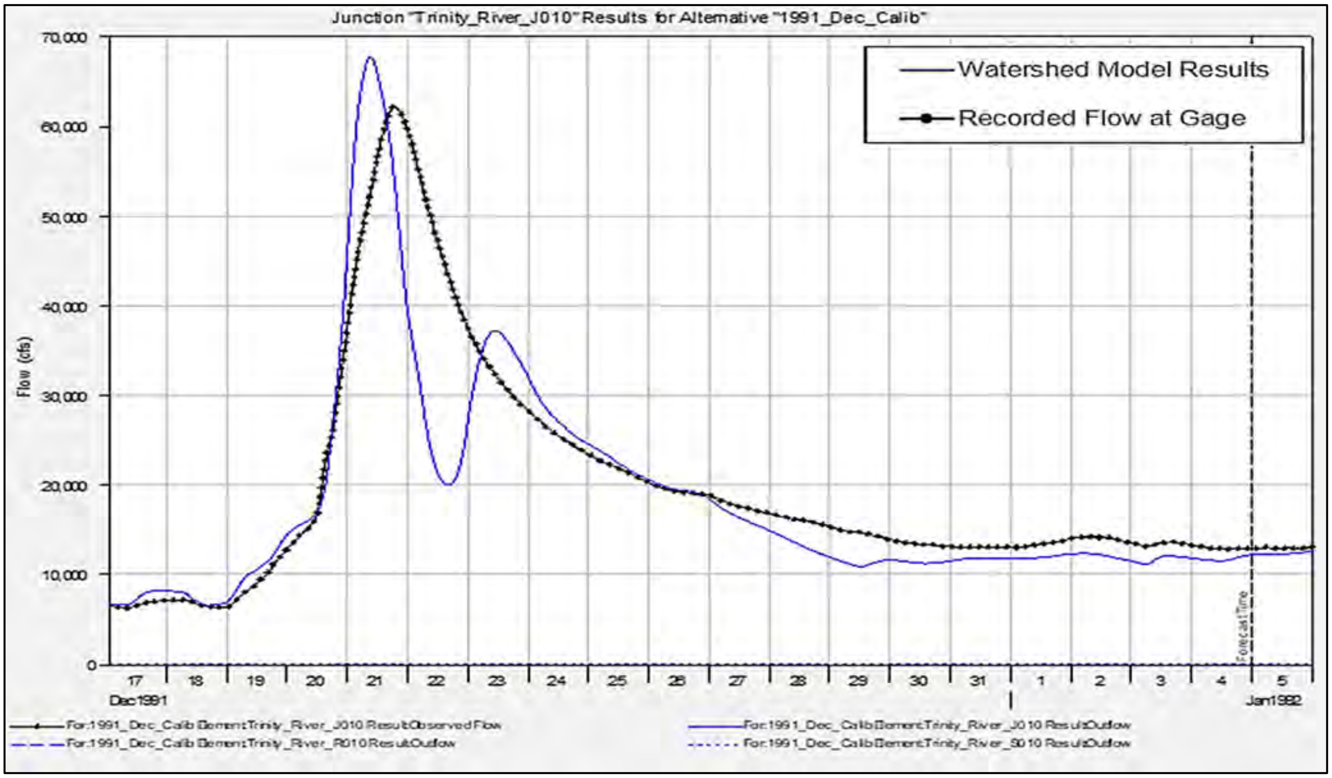

Figure 56a. December 20, 1991 Calibration Results for the Trinity River at Dallas, TX Gage

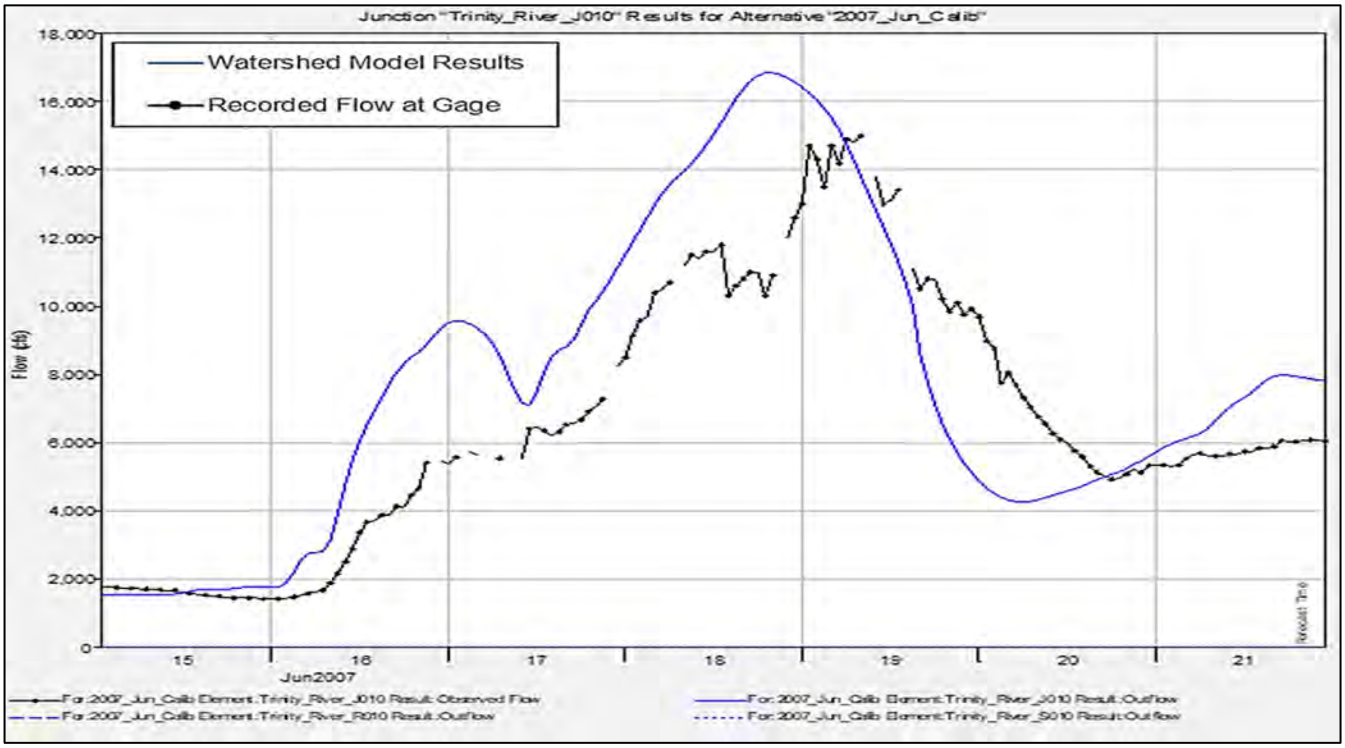

Figure 56b. June 17, 2007 Calibration Results for the Trinity River at Dallas, TX Gage

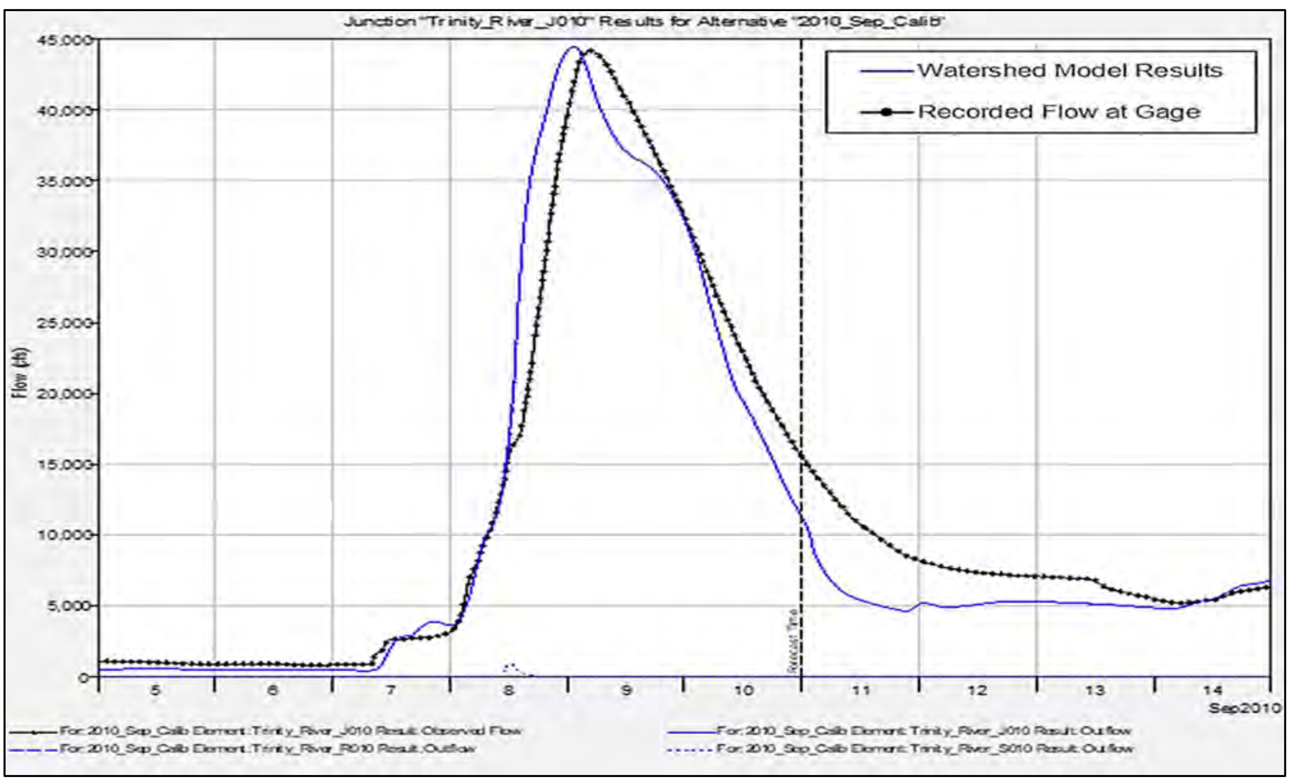

Figure 56c. September 8, 2010 Calibration Results for the Trinity River at Dallas, TX Gage

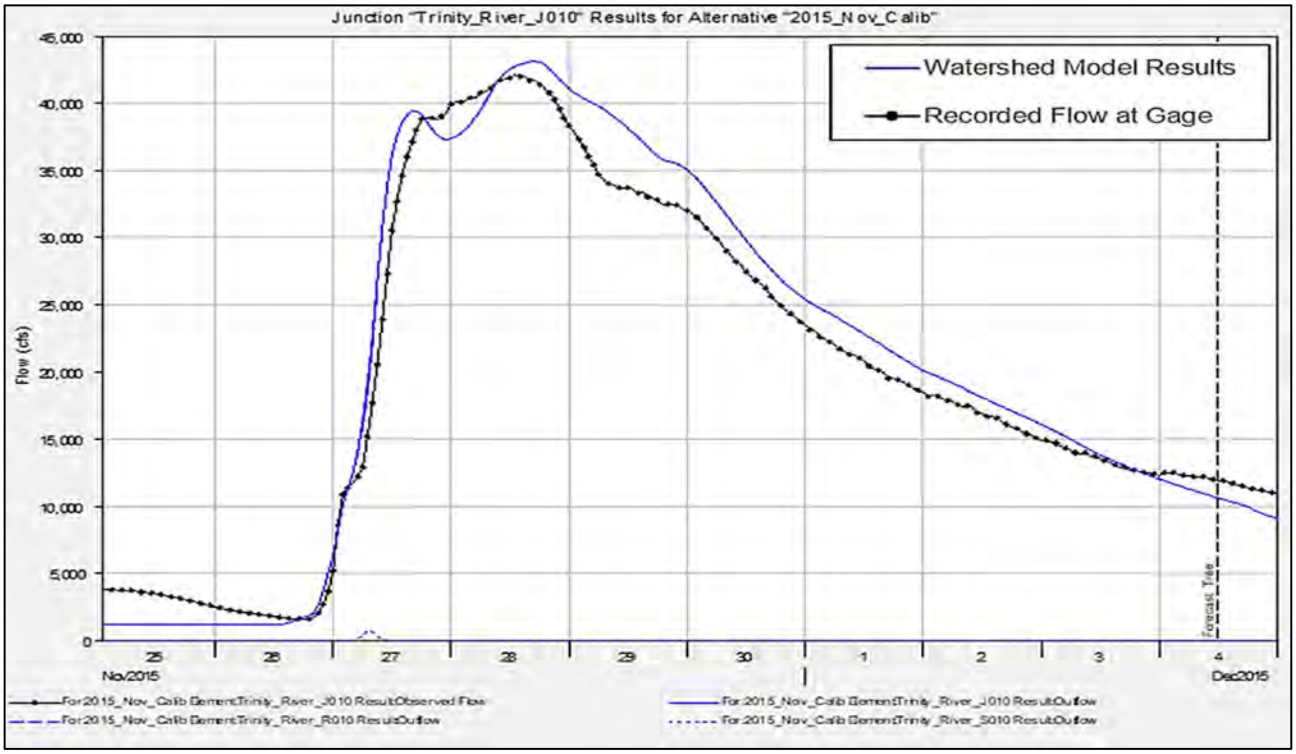

Figure 56d. November 27, 2015 Calibration Results for the Trinity River at Dallas Gage

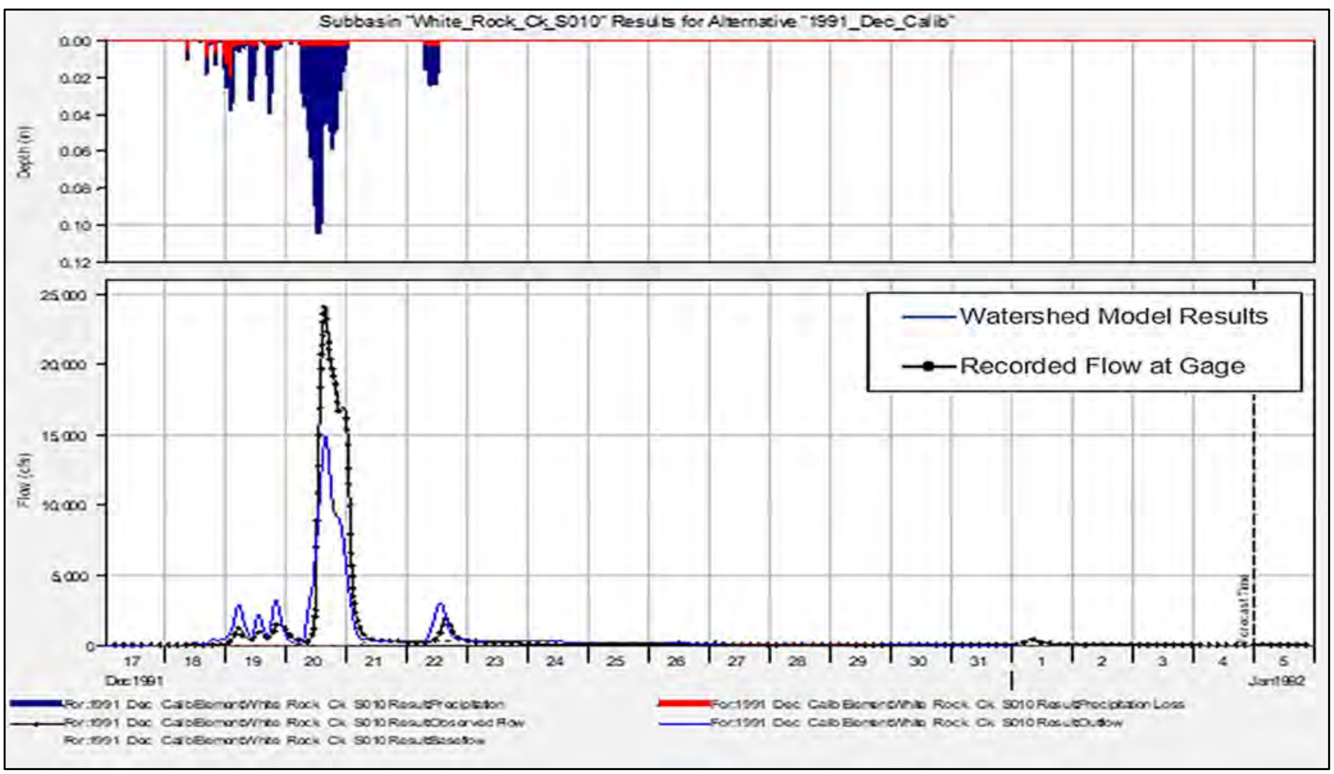

Figure 57a. December 20, 1991 Calibration Results for the White Rock Creek at Greenville Avenue Gage

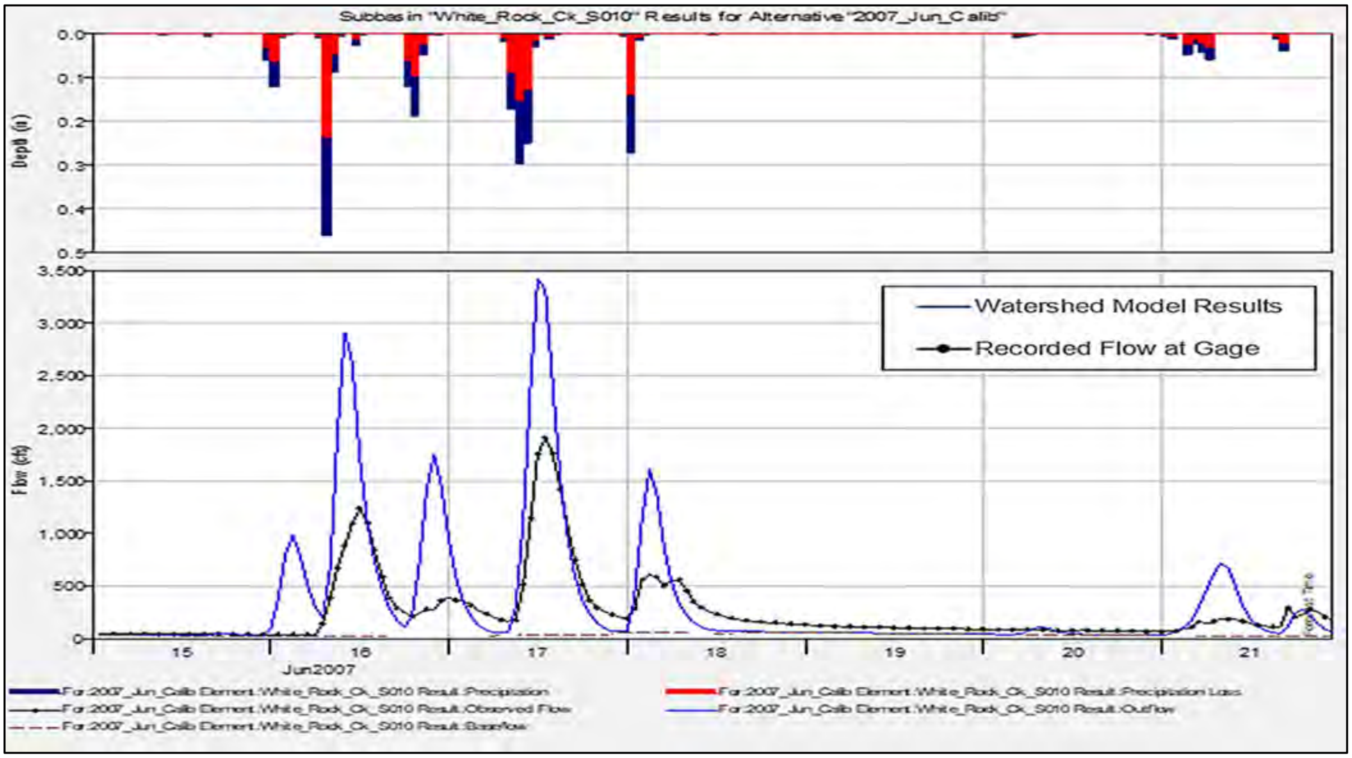

Figure 57b. June 17, 2007 Calibration Results for the White Rock Creek at Greenville Avenue Gage

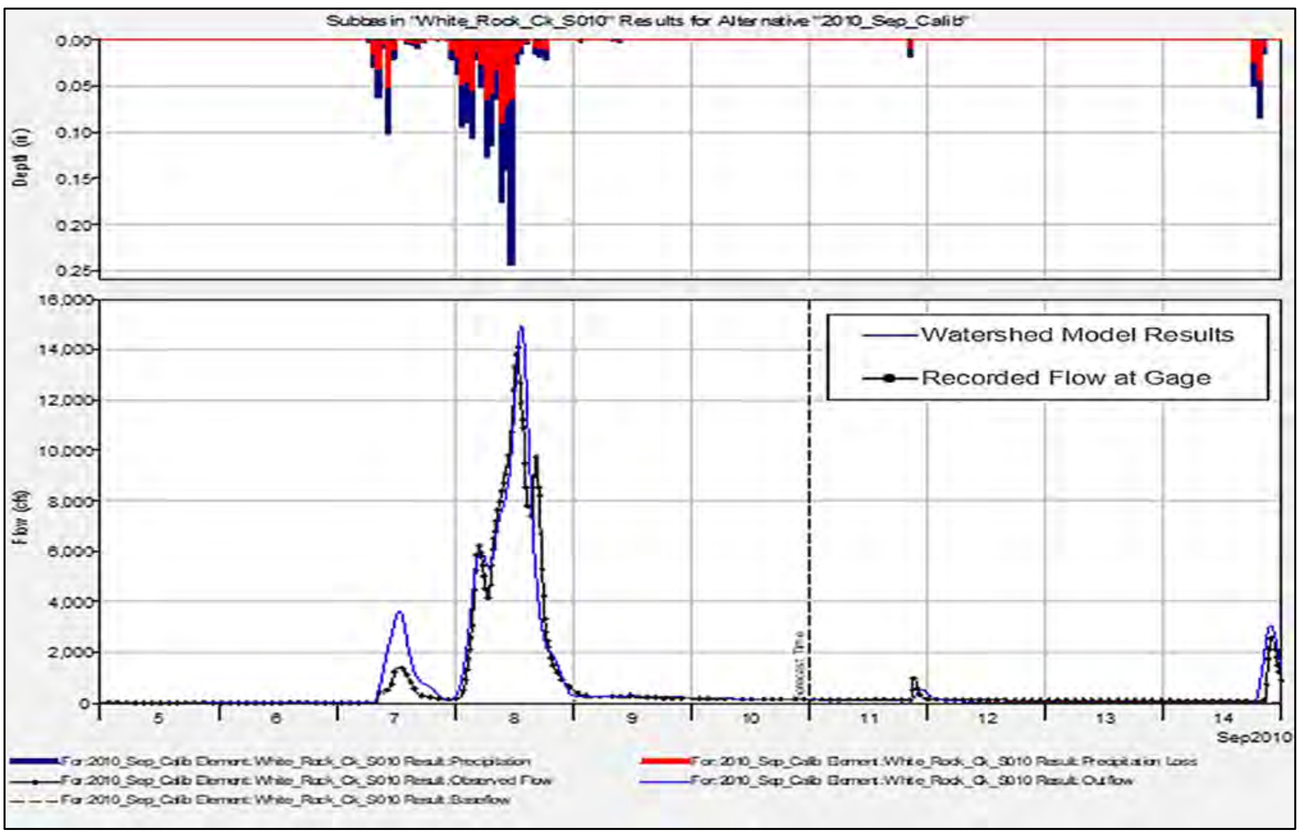

Figure 57c. September 8, 2010 Calibration Results for the White Rock Creek at Greenville, TX Gage

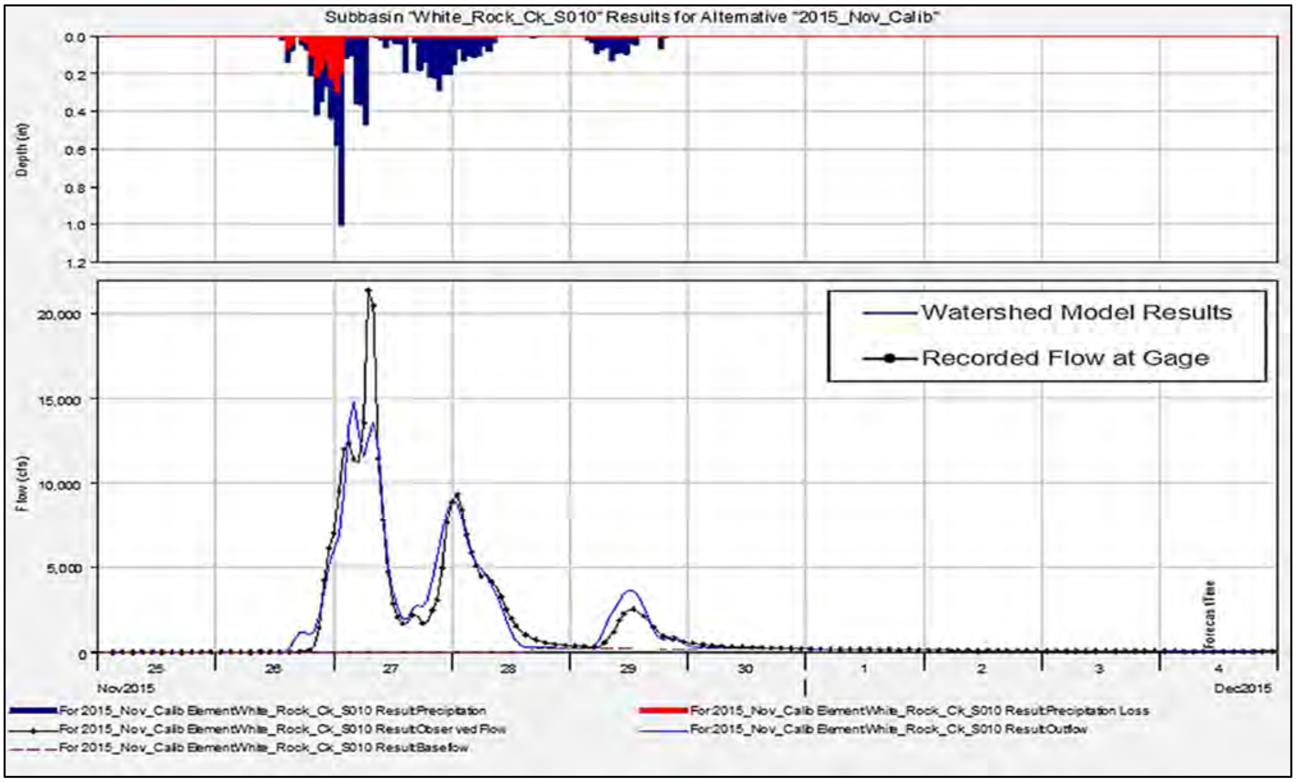

Figure 57d. November 27, 2015 Calibration Results for the White Rock Creek at Greenville Avenue Gage

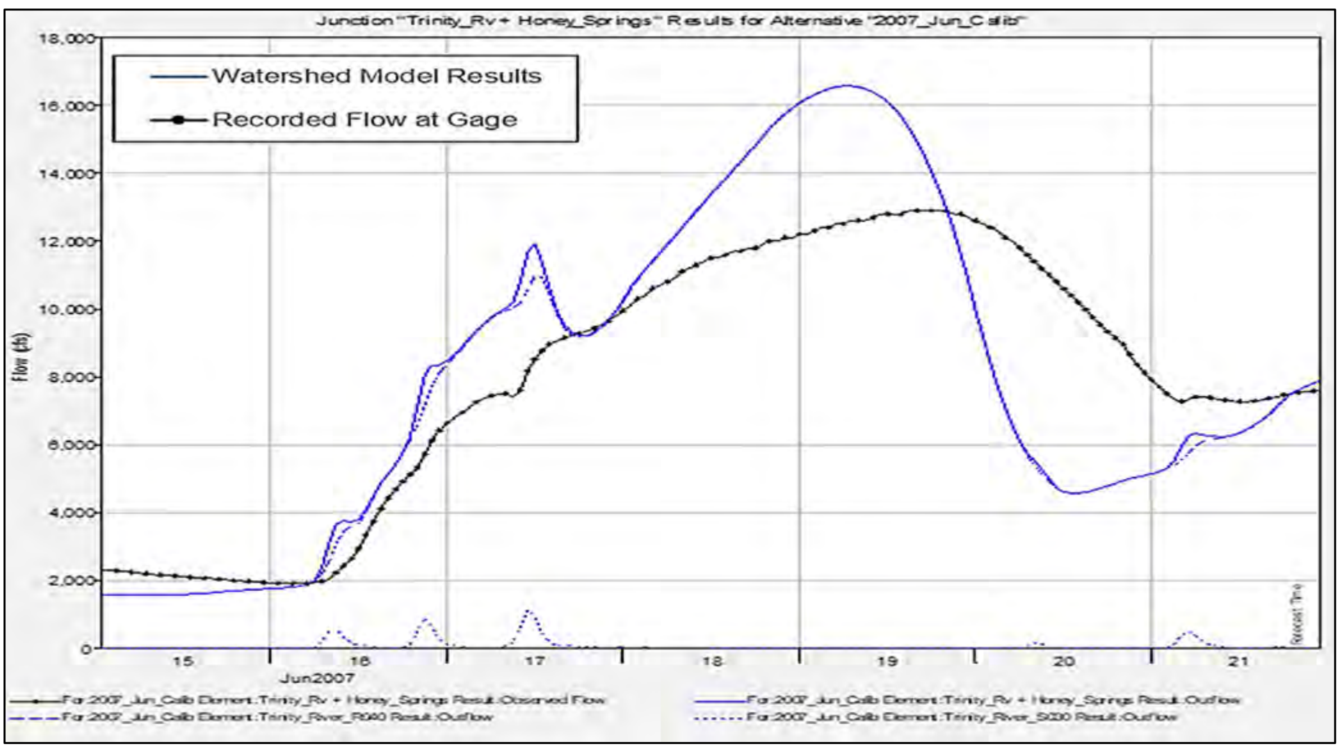

Figure 58a. June 17, 2007 Calibration Results for the Trinity River below Dallas, TX Gage

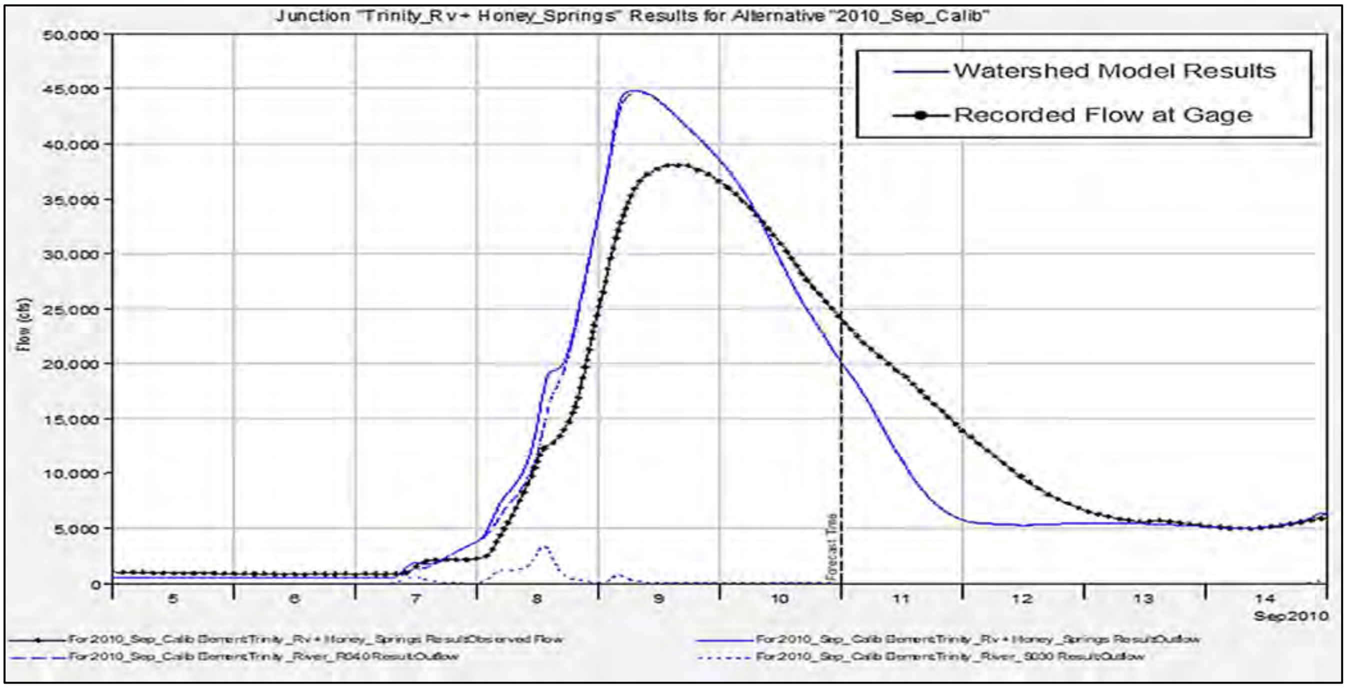

Figure 58b. September 8, 2010 Calibration Results for the Trinity River below Dallas, TX Gage

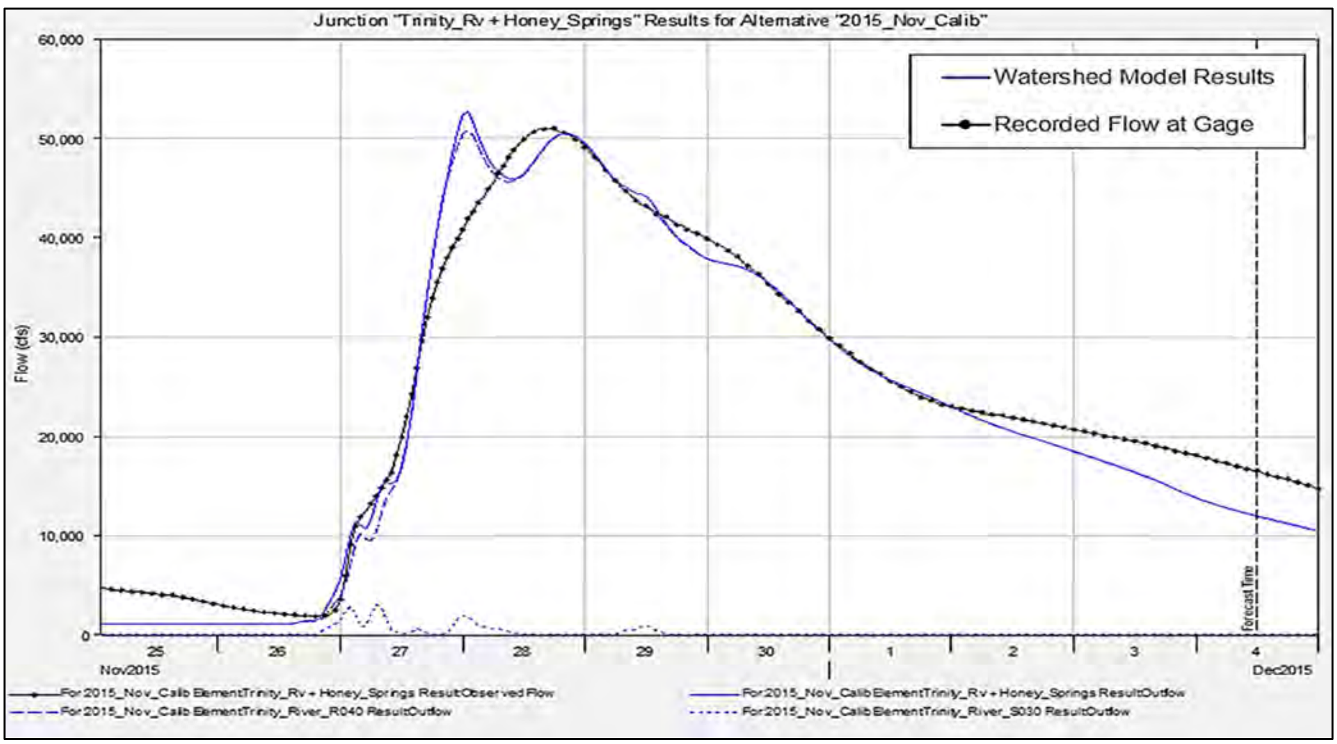

Figure 58c. November 27, 2015 Calibration Results for the Trinity River below Dallas, TX Gage

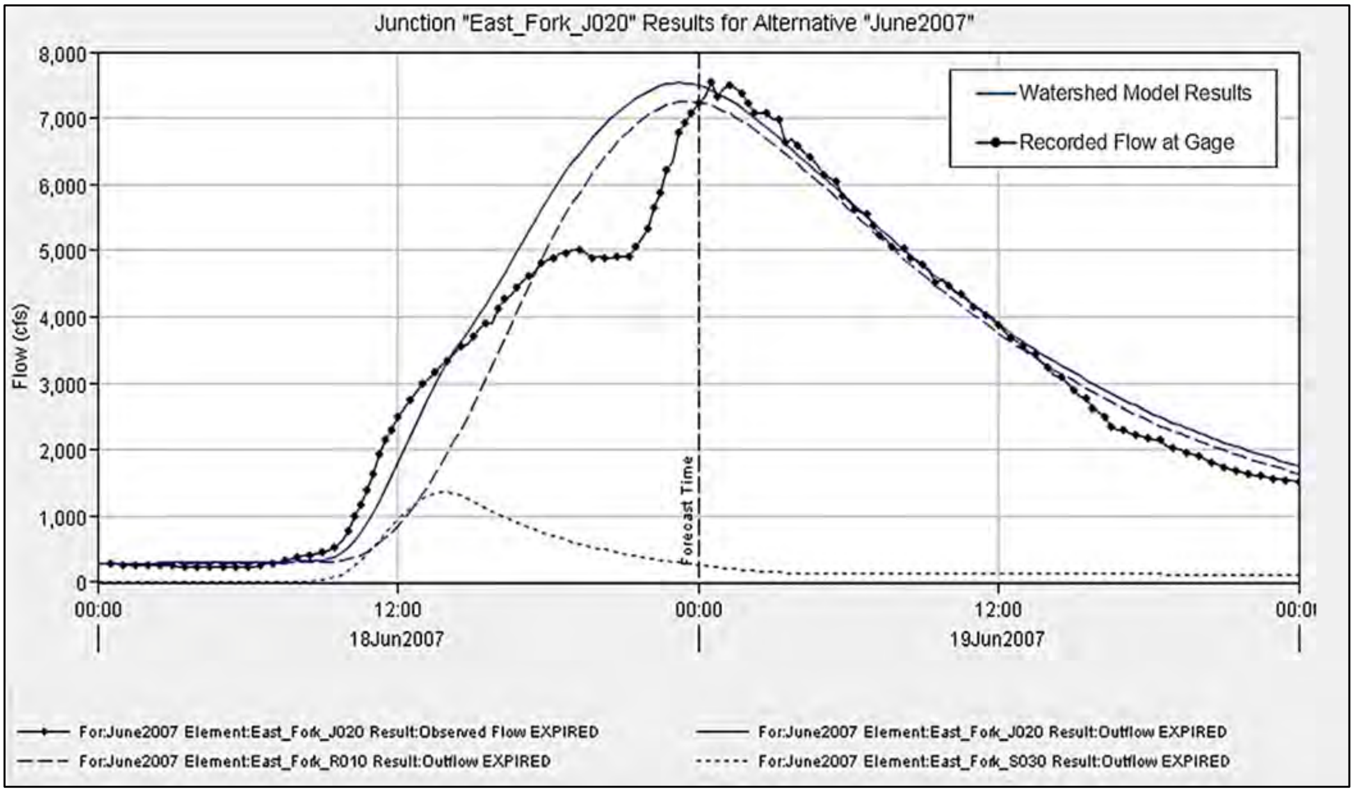

Figure 59a. June 19, 2007 Calibration for the East Fork Trinity River near McKinney, TX Gage

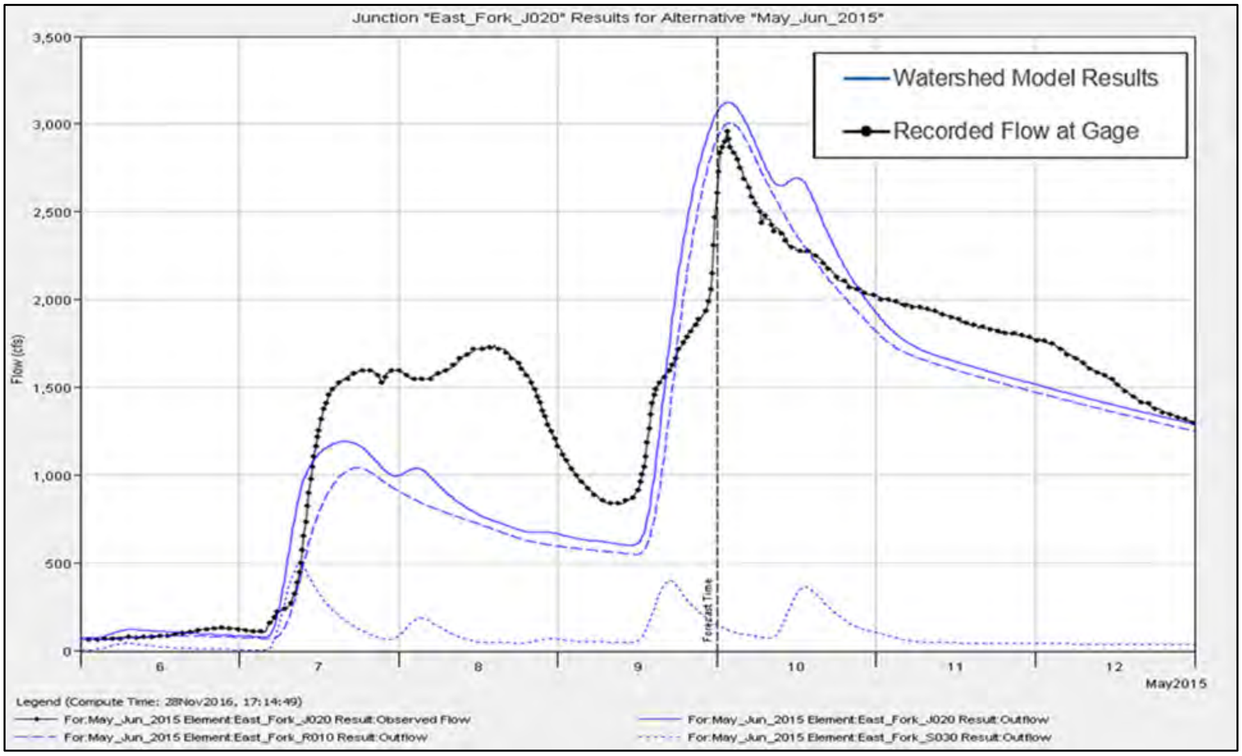

Figure 59b. May 9, 2015 Calibration for the East Fork Trinity River near McKinney, TX Gage

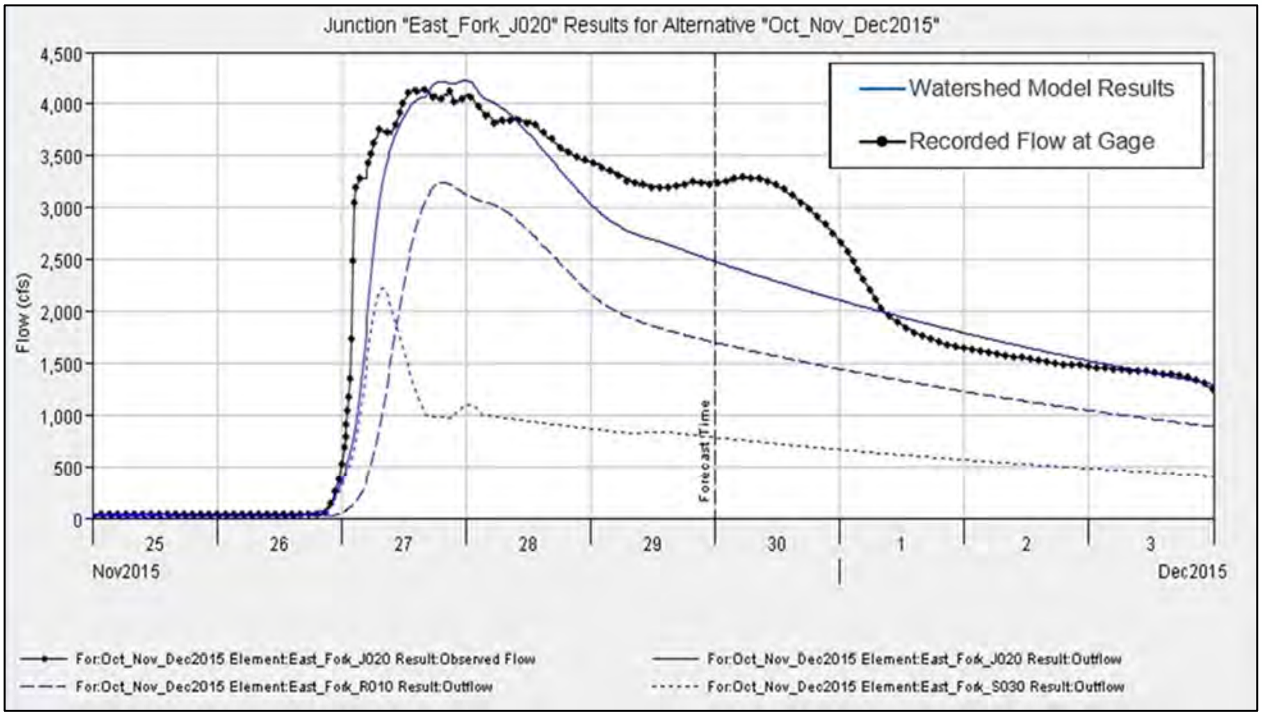

Figure 59c. November 27, 2015 Calibration for the East Fork Trinity River near McKinney, TX Gage

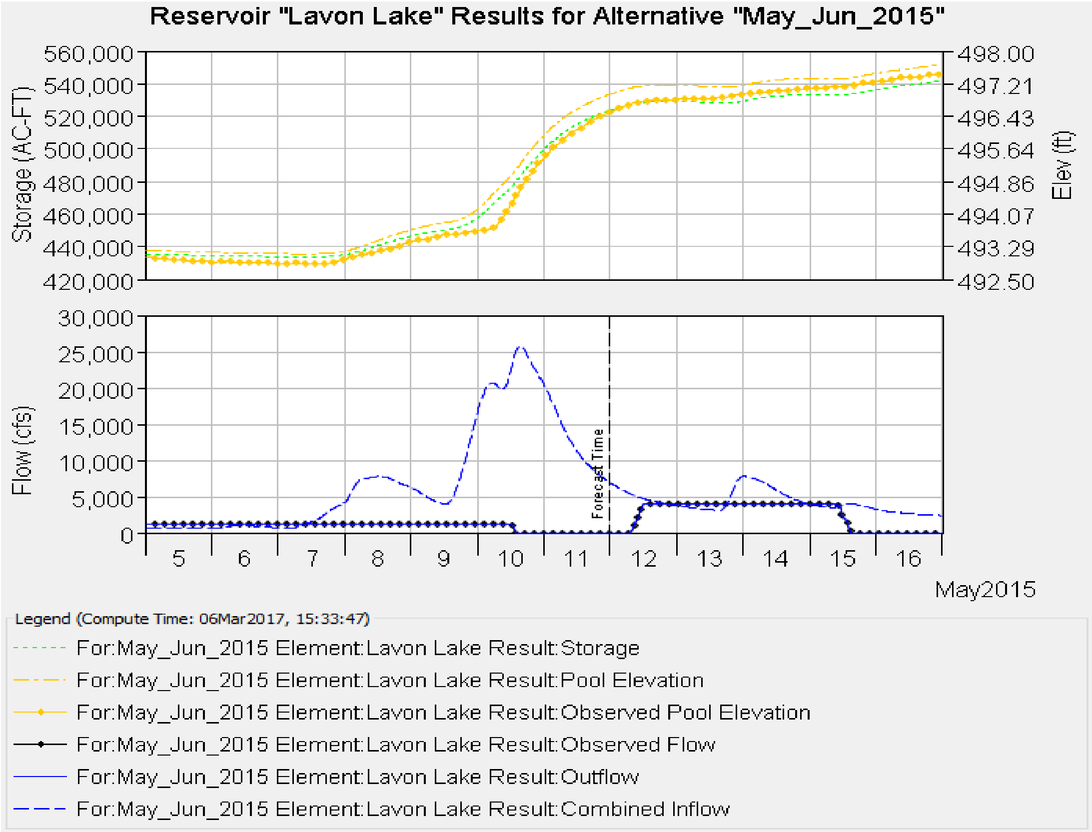

Figure 60a. May 2015 Calibration Results for Lavon Reservoir

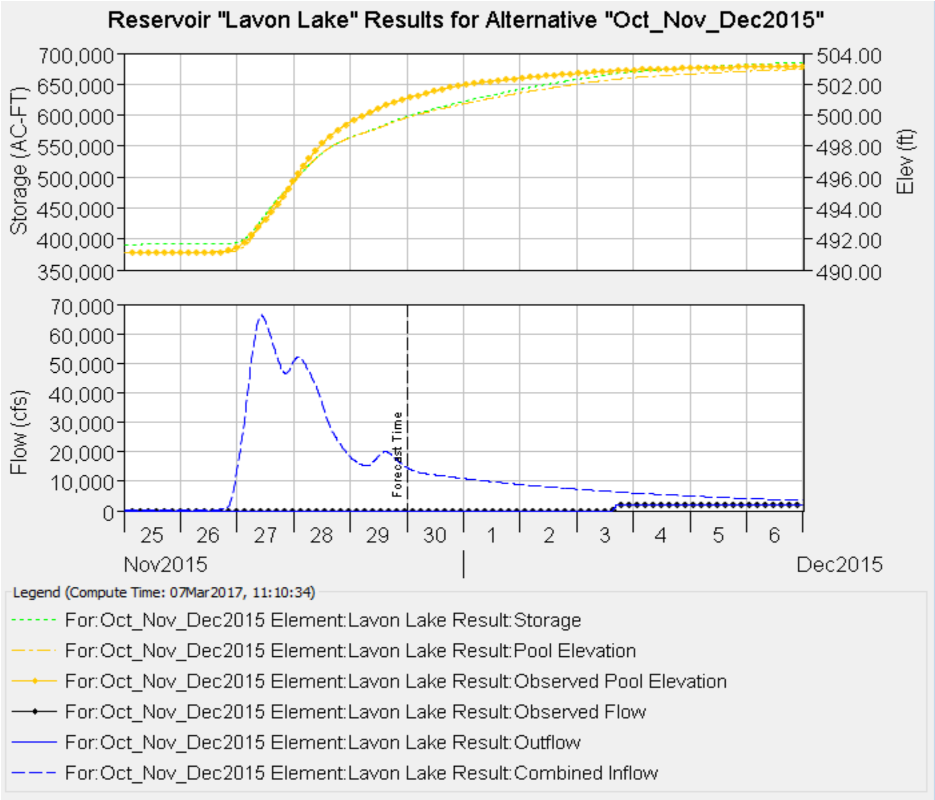

Figure 60b. November 2015 Calibration Results for Lavon Reservoir

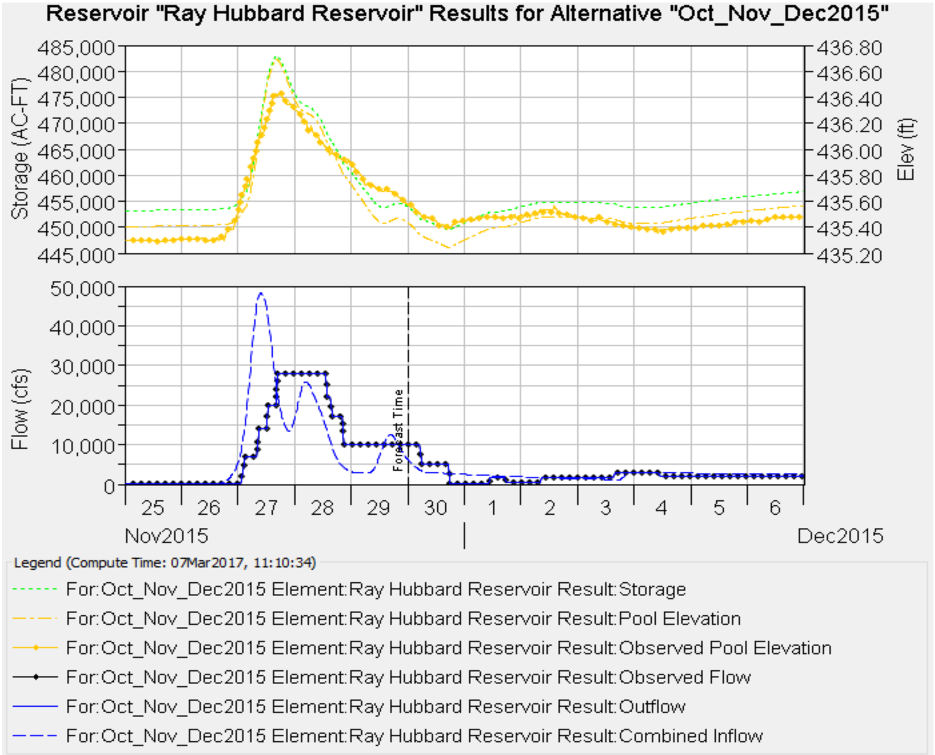

Figure 61a. November 2015 Calibration Results for Ray Hubbard Reservoir

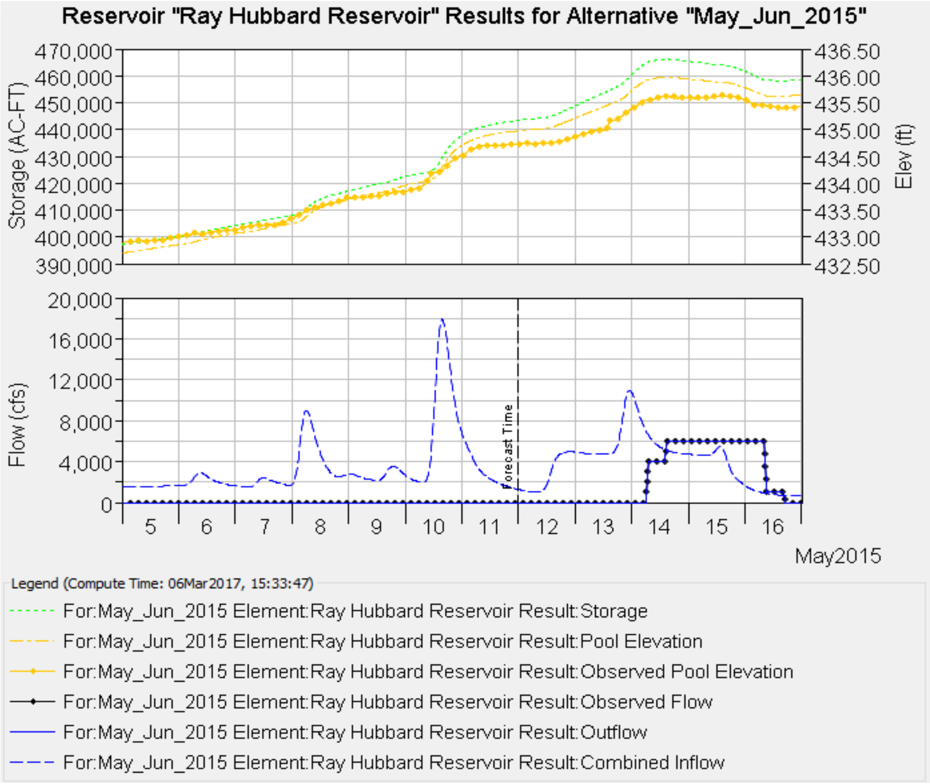

Figure 61b. May 2015 Calibration Results for Ray Hubbard Reservoir

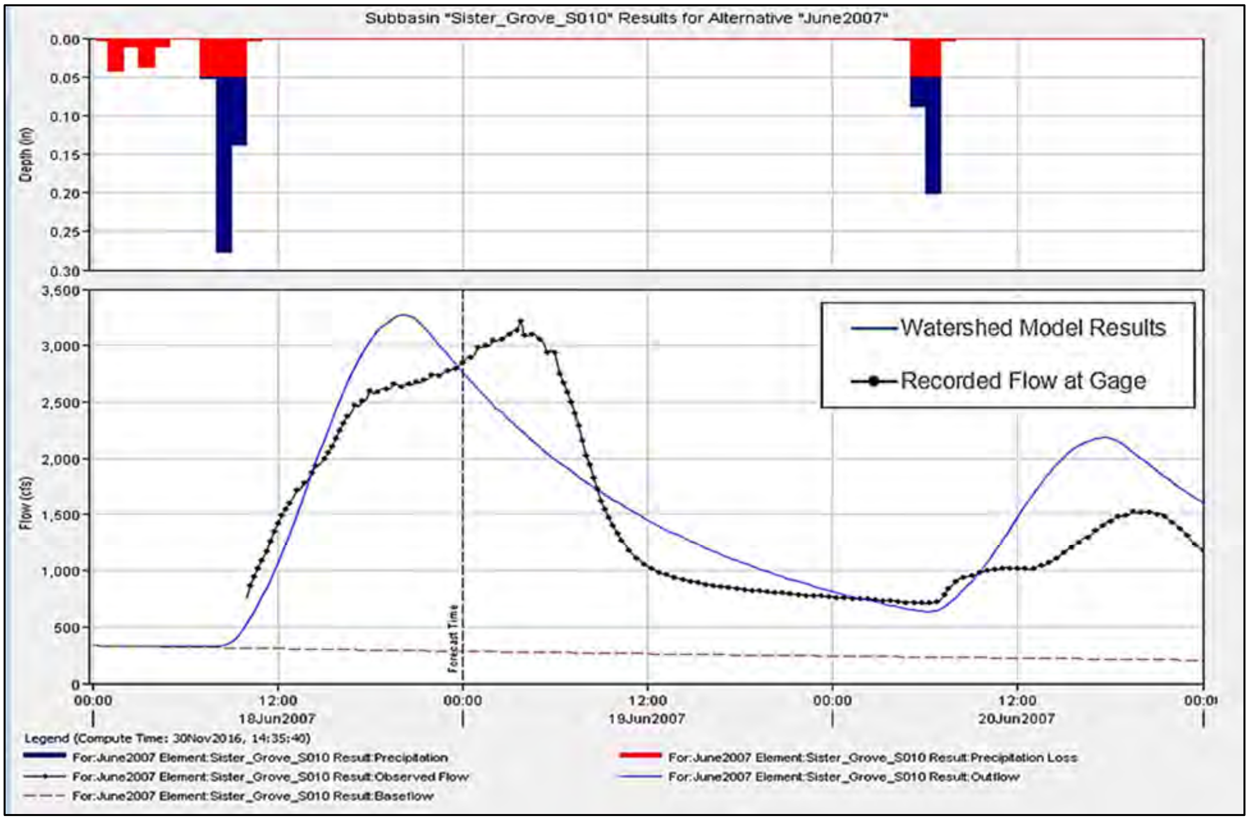

Figure 62a. June 19, 2007 Calibration for the Sister Grove near Blue Ridge, TX Gage

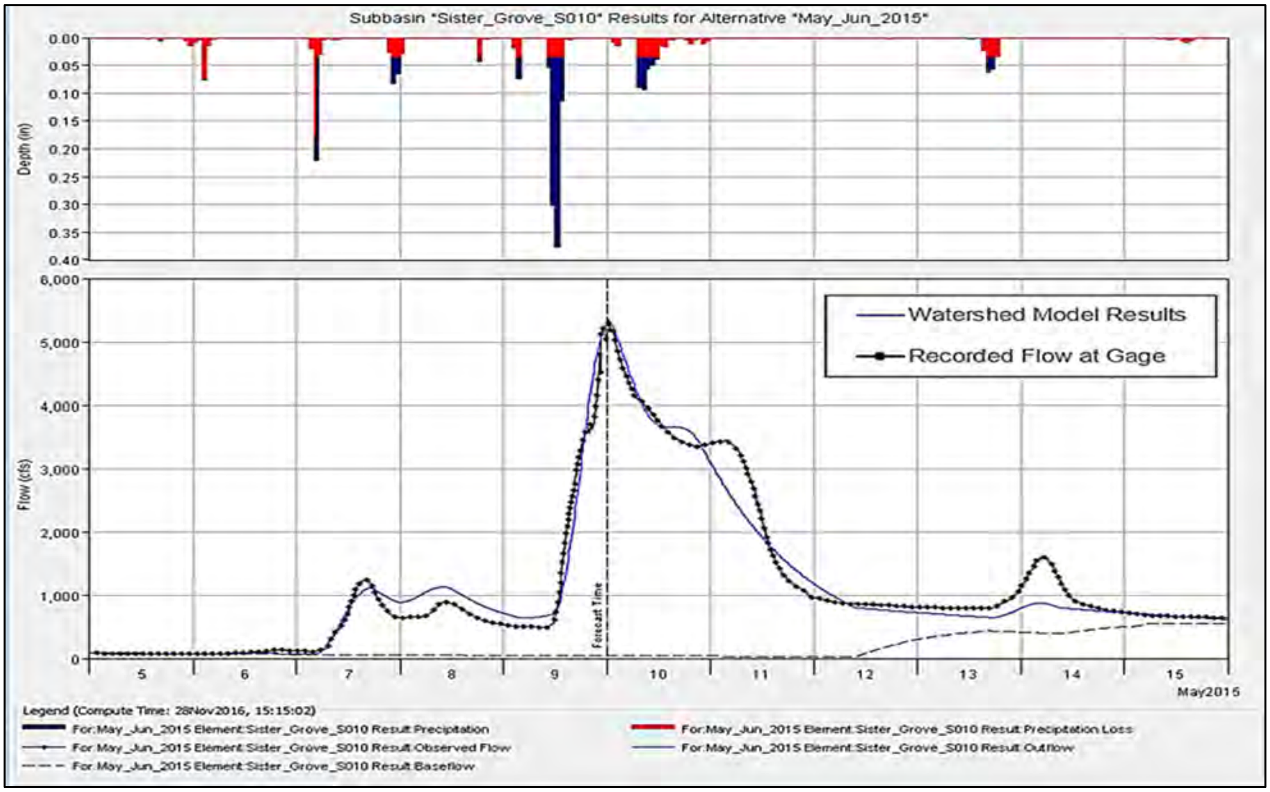

Figure 62b. May 10, 2015 Calibration for the Sister Grove near Blue Ridge, TX Gage

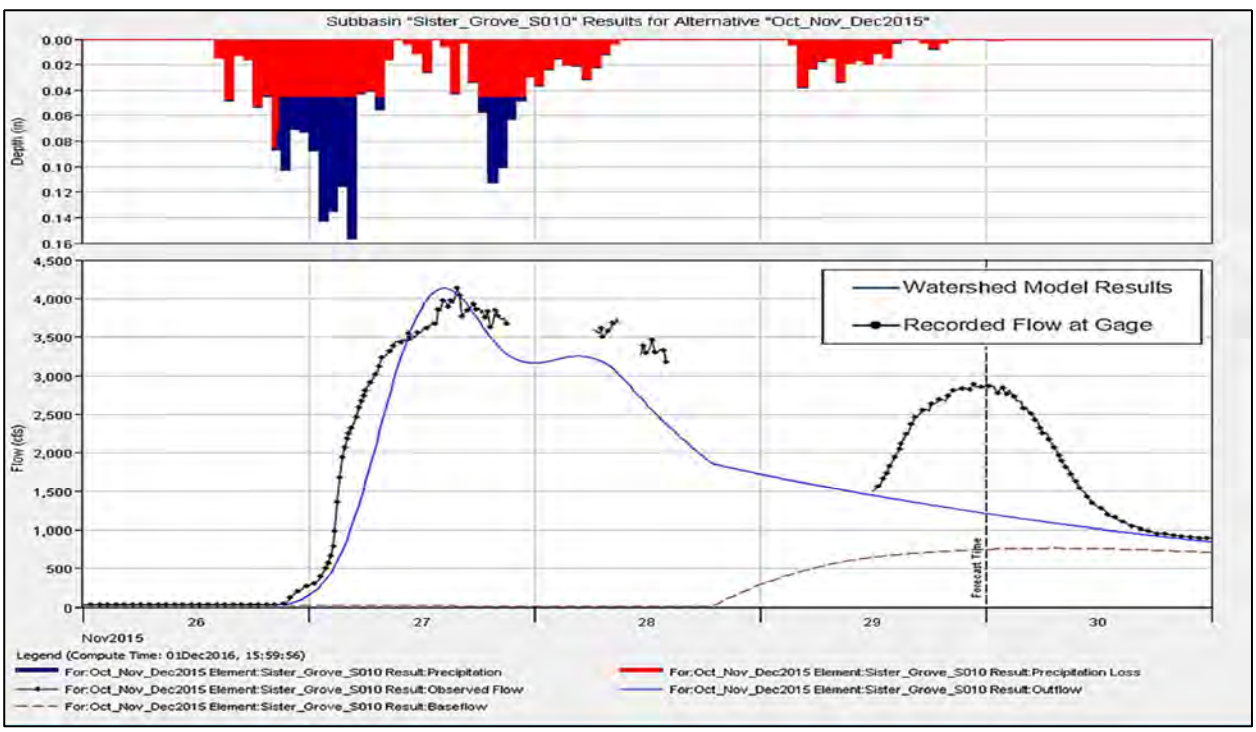

Figure 62c. November 27, 2015 Calibration for the Sister Grove near Blue Ridge, TX Gage

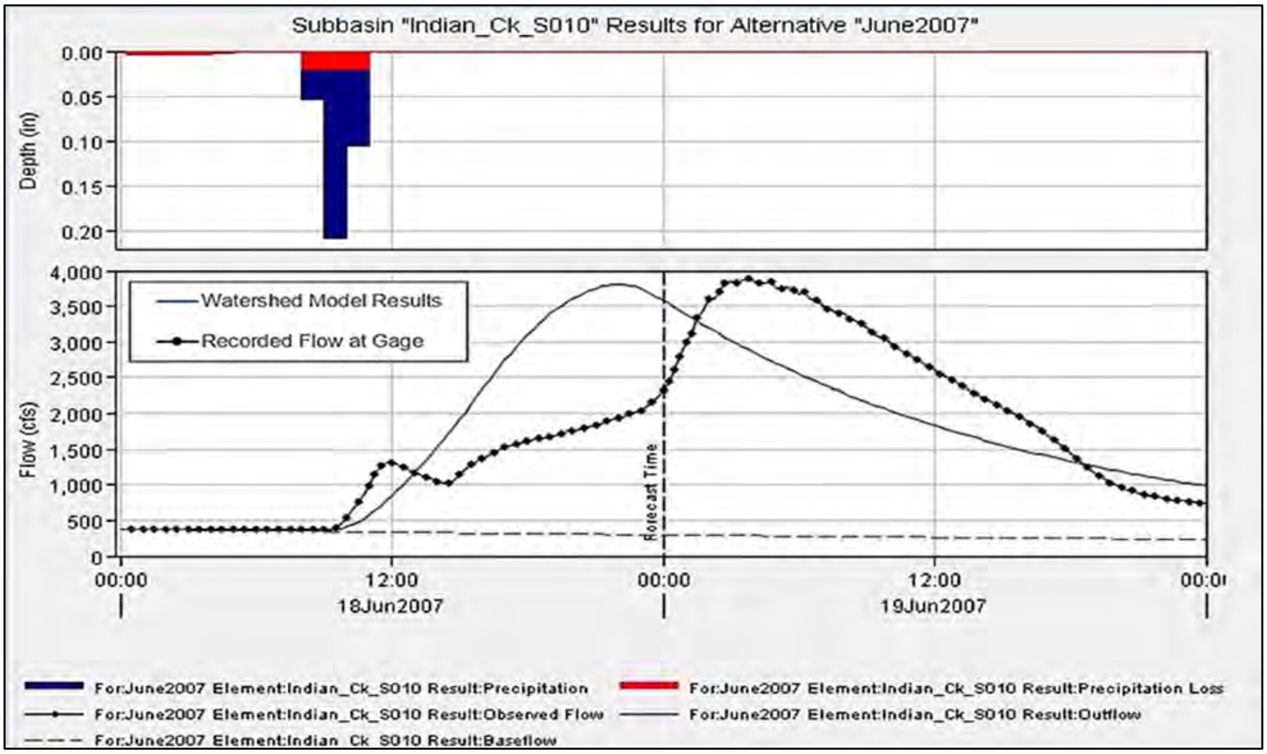

Figure 63a. June 19, 2007 Calibration for the Indian Creek at SH 78 near Farmersville, TX Gage

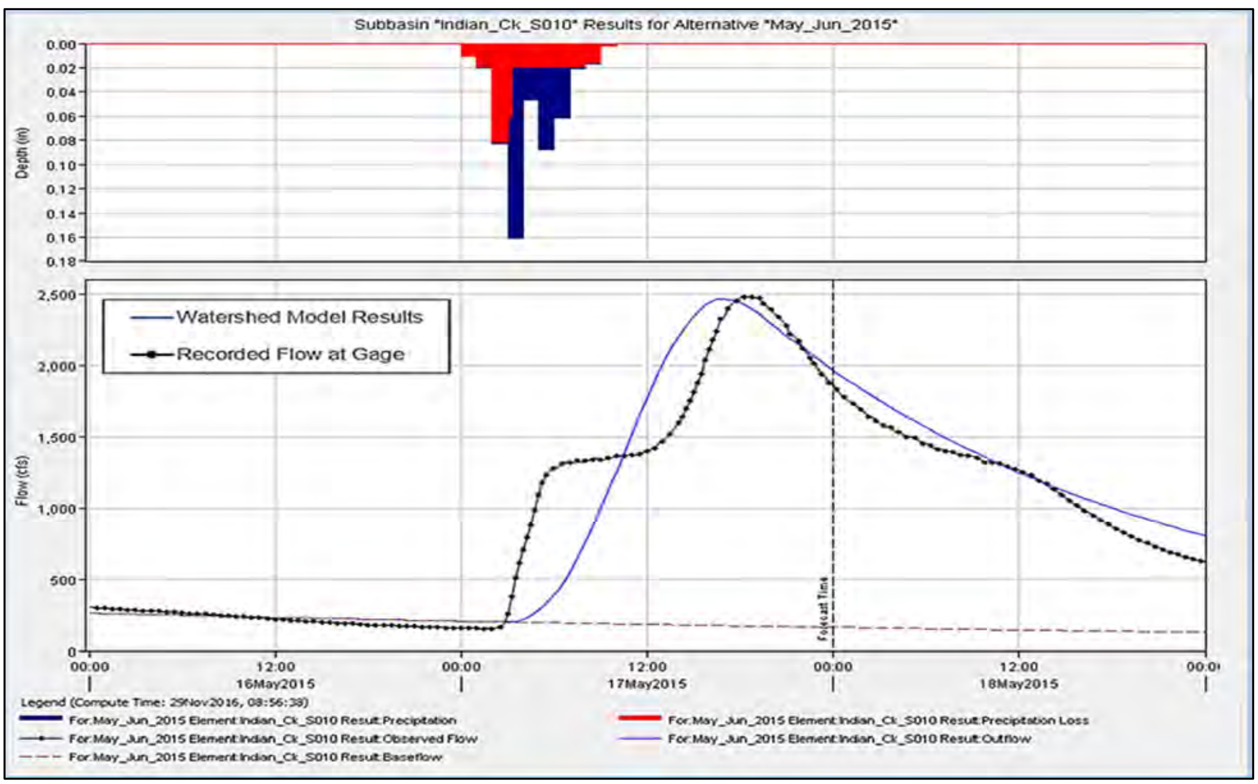

Figure 63b. May 17, 2015 Calibration for the Indian Creek at SH 78 near Farmersville, TX Gage

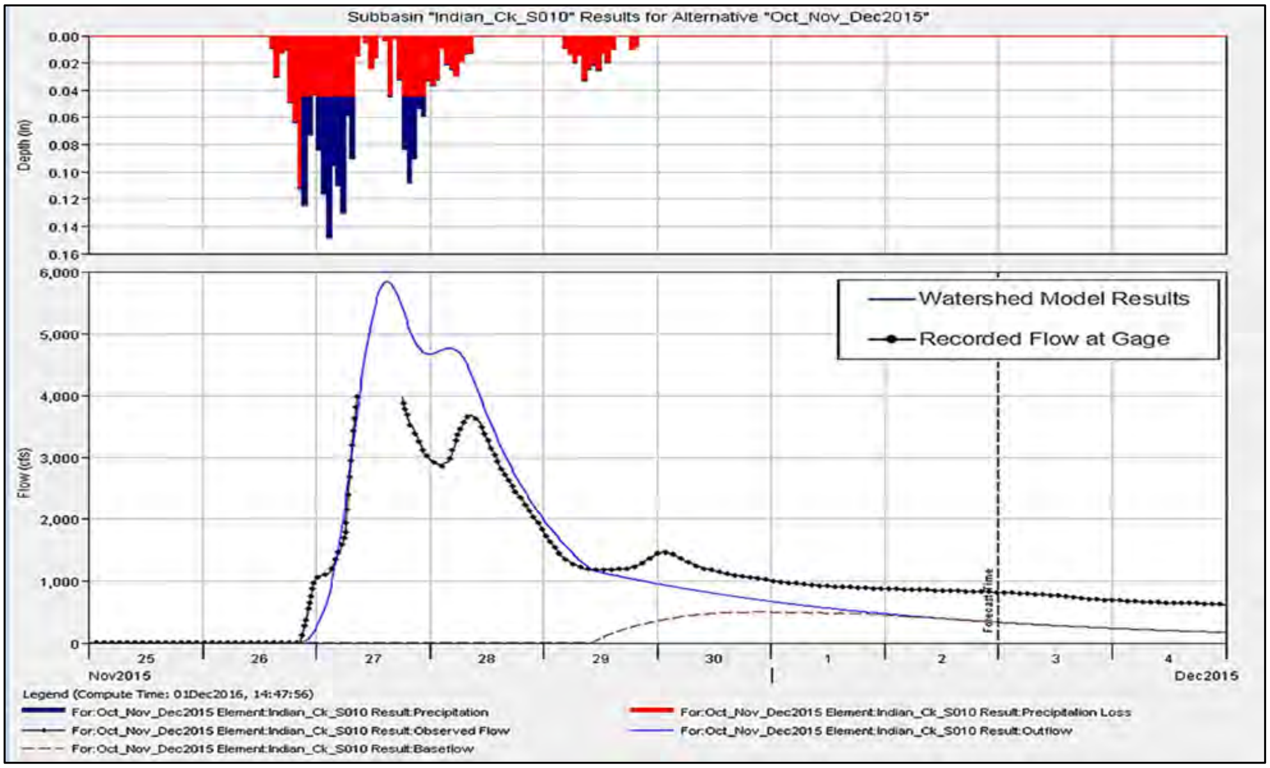

Figure 63c. November 27, 2015 Calibration for the Indian Creek at SH 78 near Farmersville, TX Gage

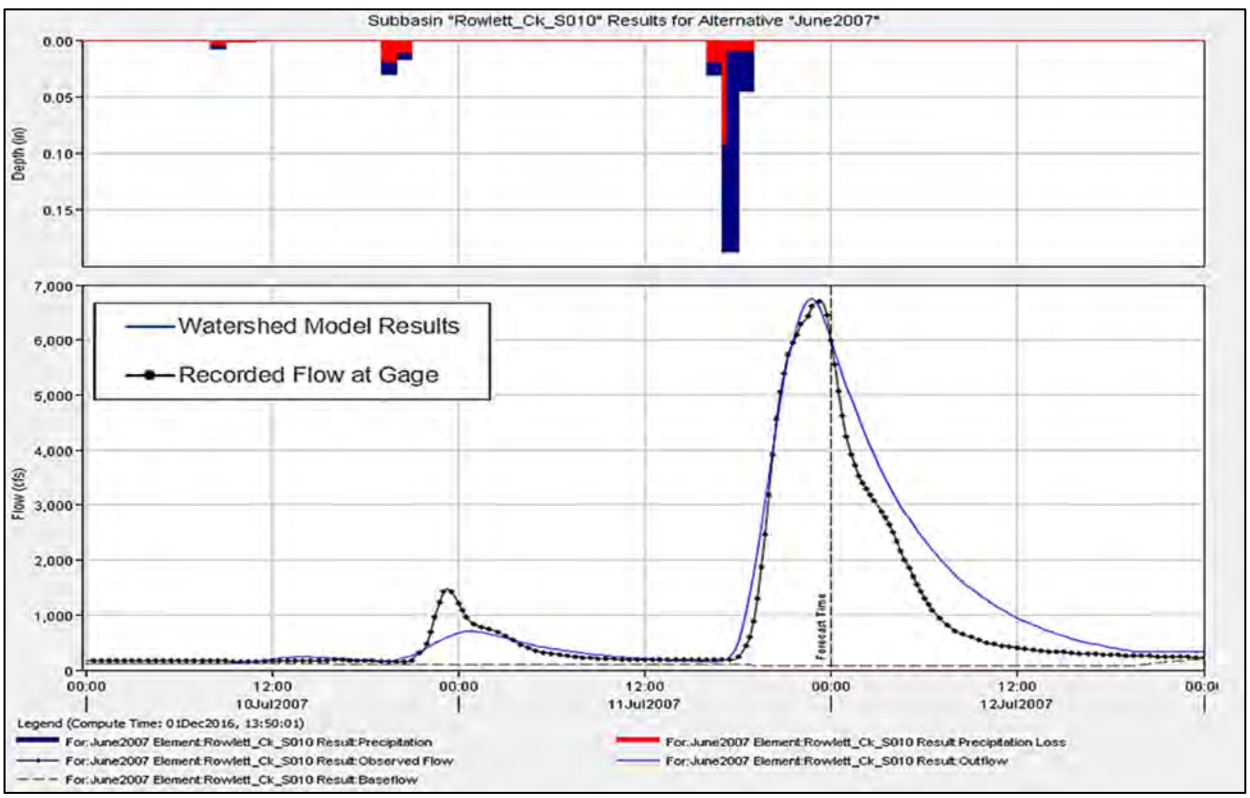

Figure 64a. July 11, 2007 Calibration for the Rowlett Creek near Sachse, TX Gage

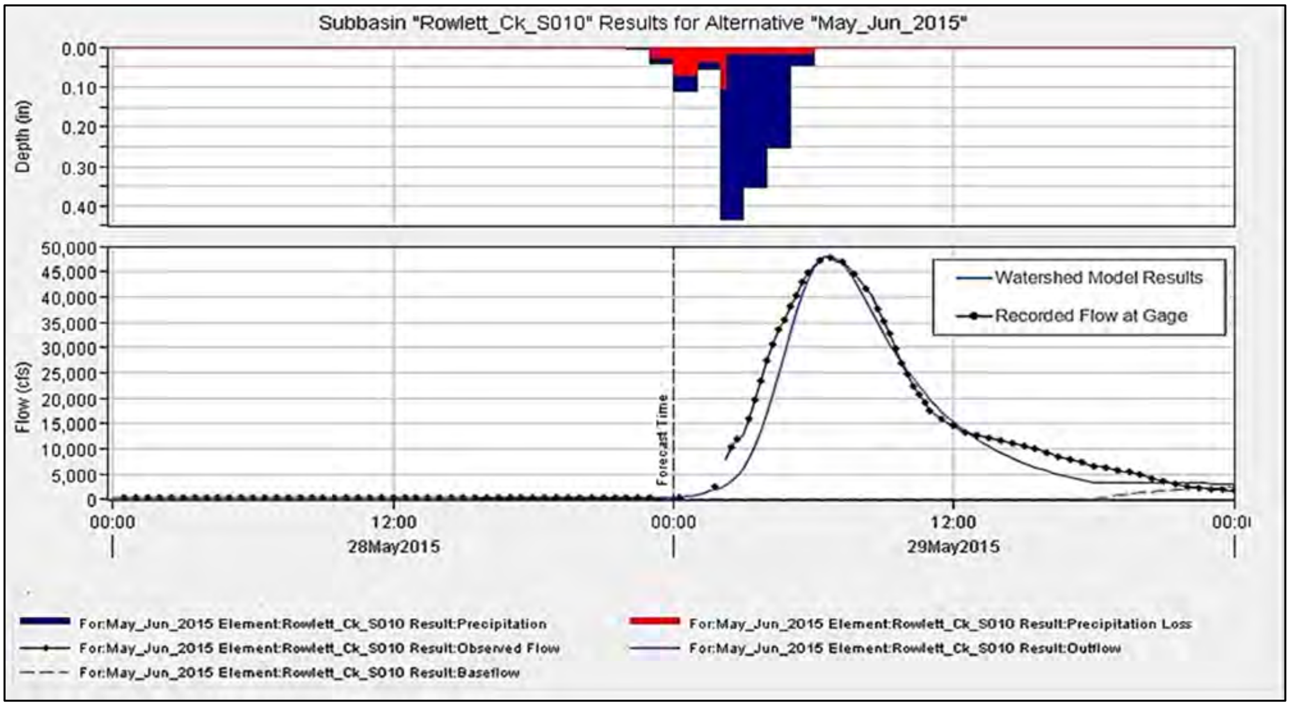

Figure 64b. May 29, 2015 Calibration for the Rowlett Creek near Sachse, TX Gage

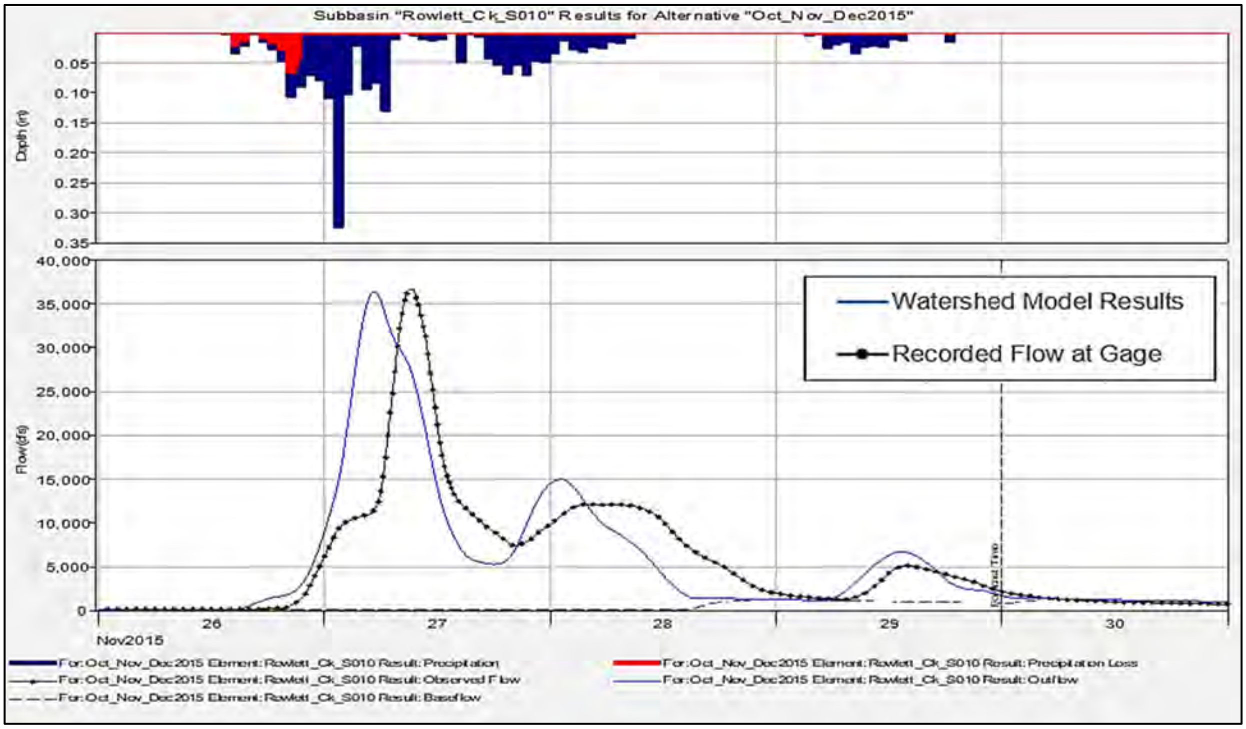

Figure 64c. November 27, 2015 Calibration for the Rowlett Creek near Sachse, TX Gage

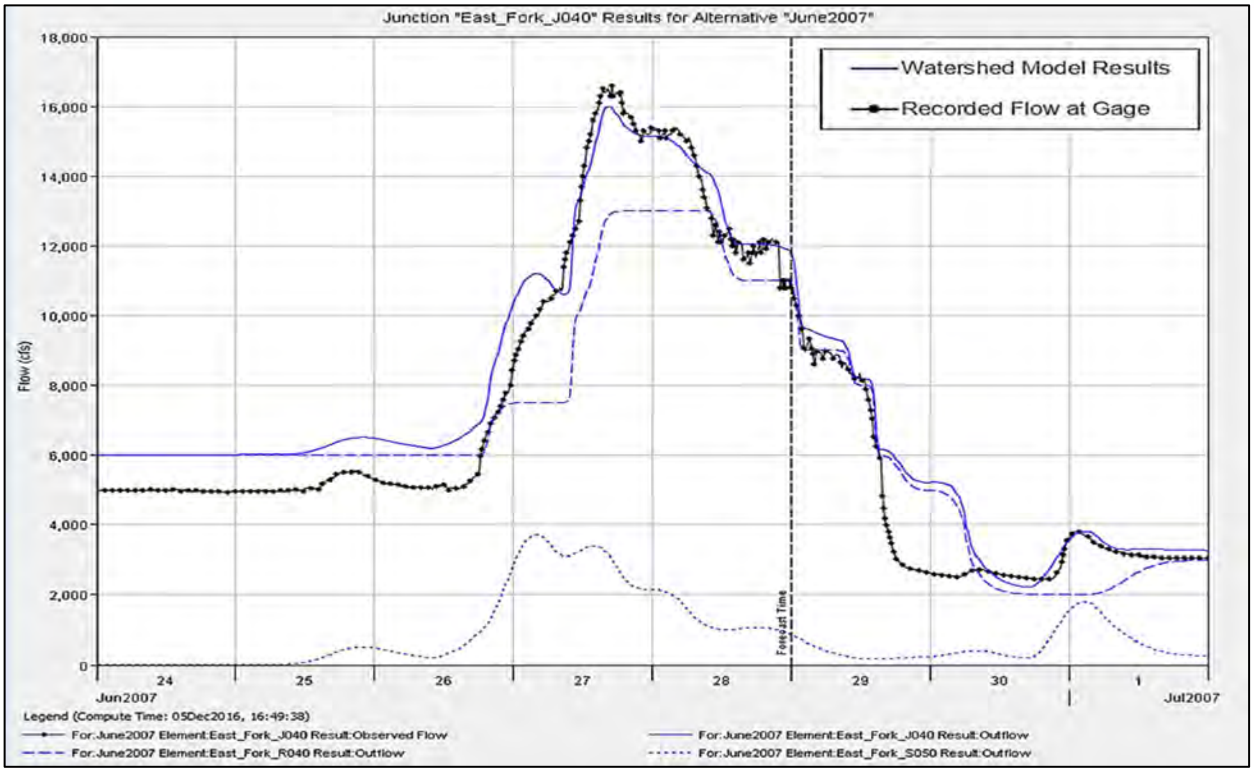

Figure 65a. June 27, 2007 Calibration for the East Fork Trinity River near Forney, TX Gage

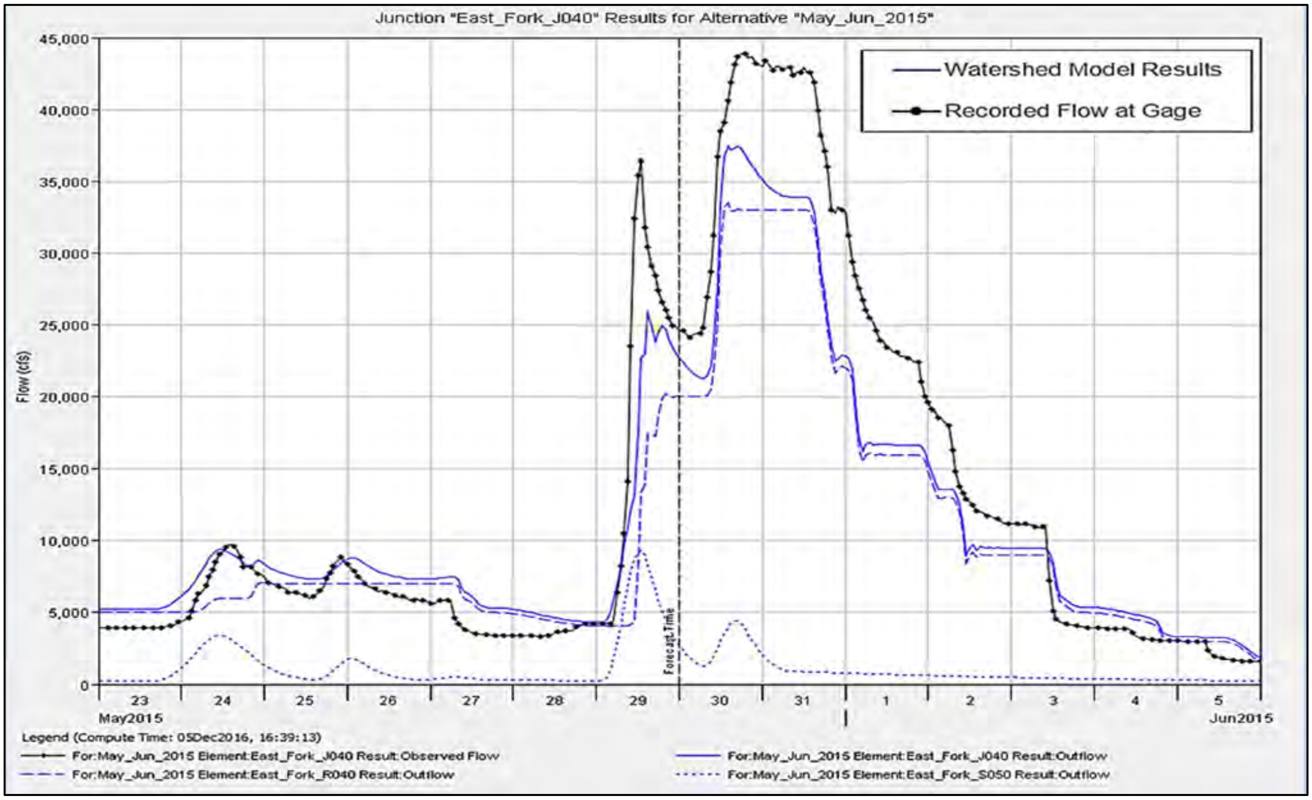

Figure 65b. May 30, 2015 Calibration for the East Fork Trinity River near Forney, TX Gage

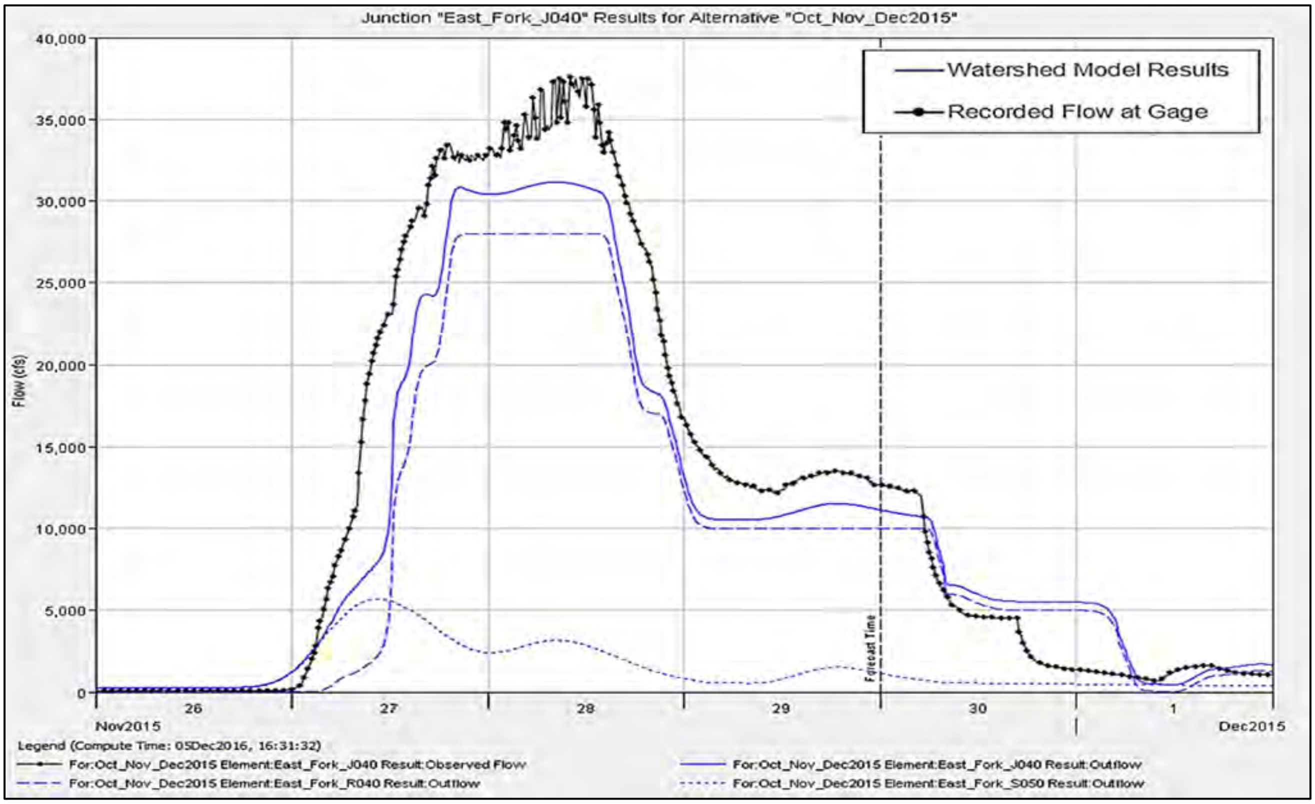

Figure 65c. November 28, 2015 Calibration for the East Fork Trinity River near Forney, TX Gage

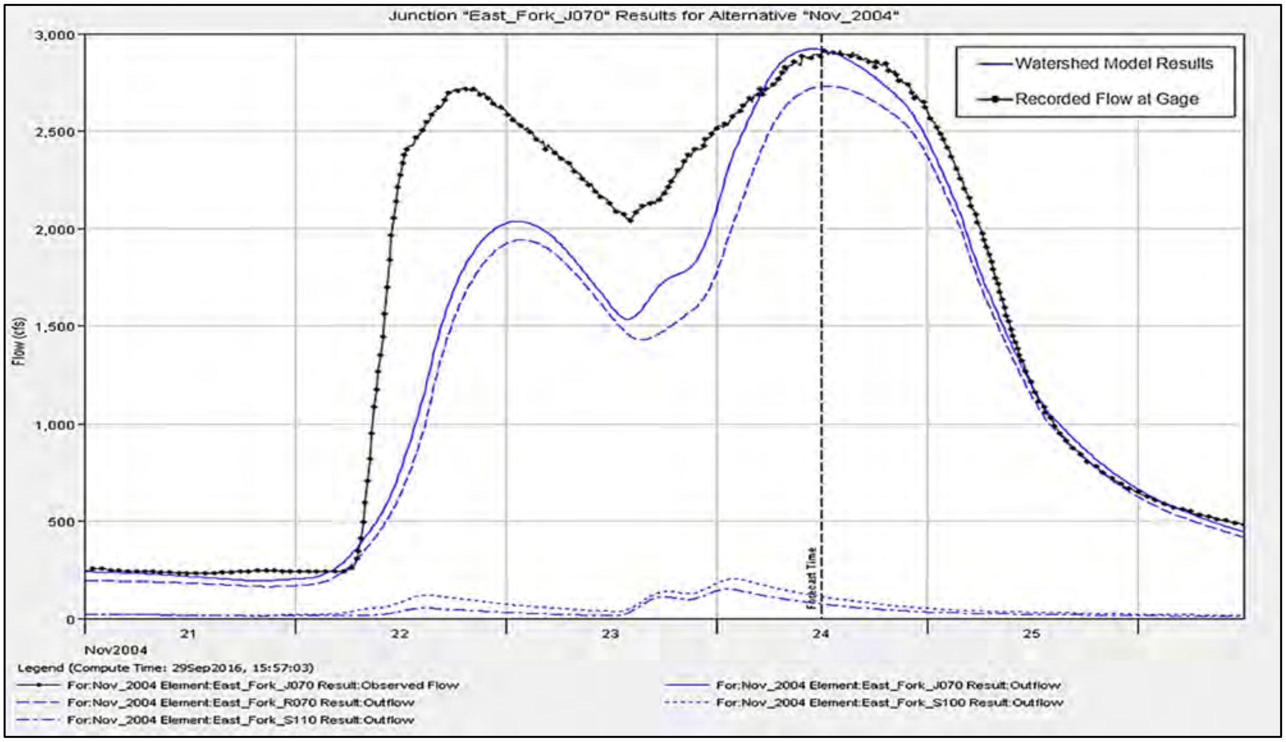

Figure 66a. November 24, 2004 Calibration for the East Fork Trinity River near Crandall, TX Gage

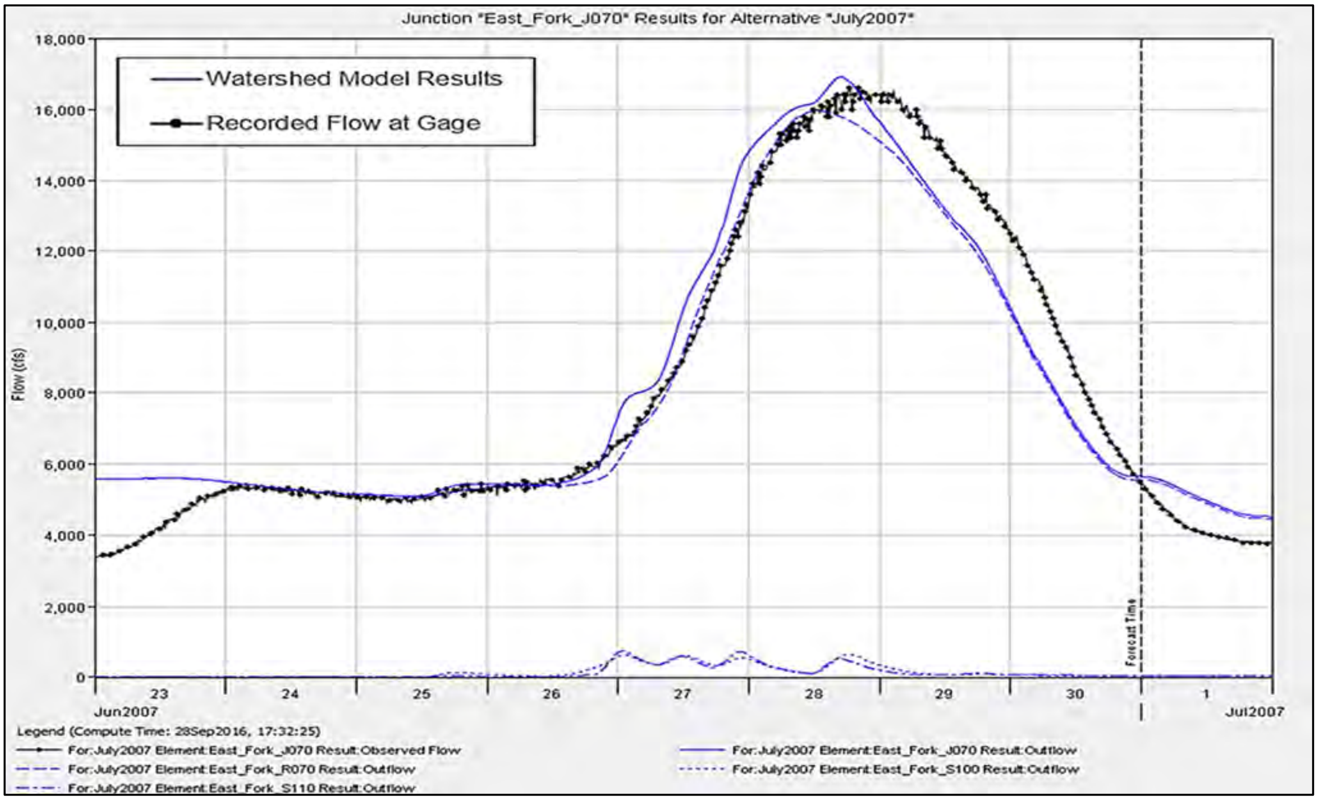

Figure 66b. June 28, 2007 Calibration for the East Fork Trinity River near Crandall, TX Gage

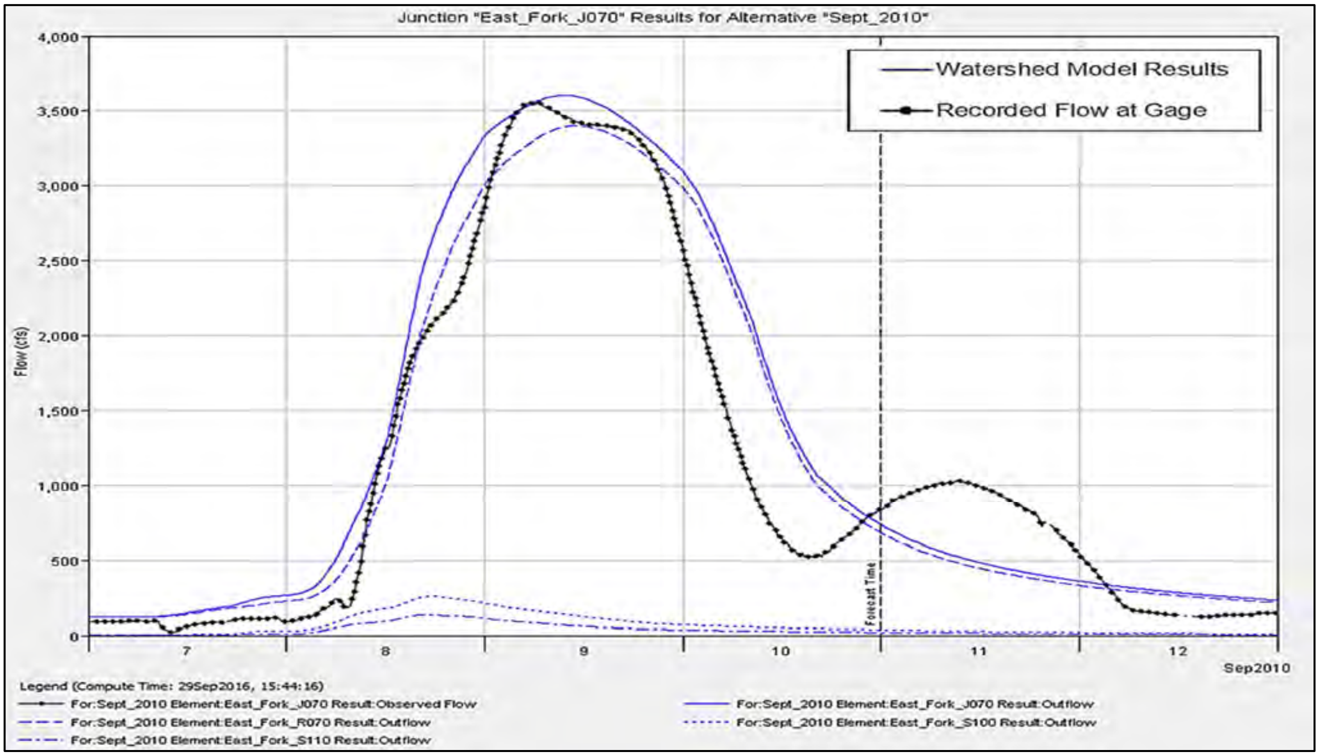

Figure 66c. September 9, 2010 Calibration for the East Fork Trinity River near Crandall, TX Gage

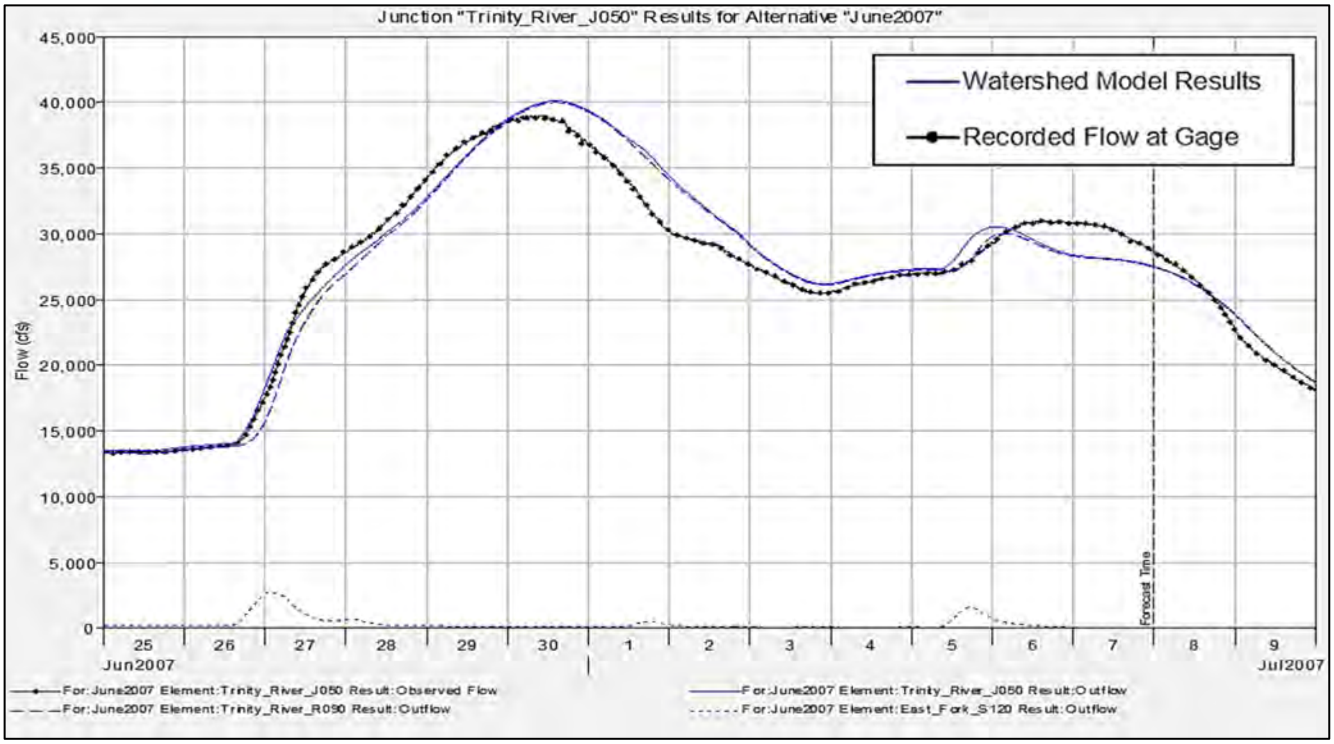

Figure 67a. June 29, 2007 Calibration for the Trinity River near Rosser, TX Gage

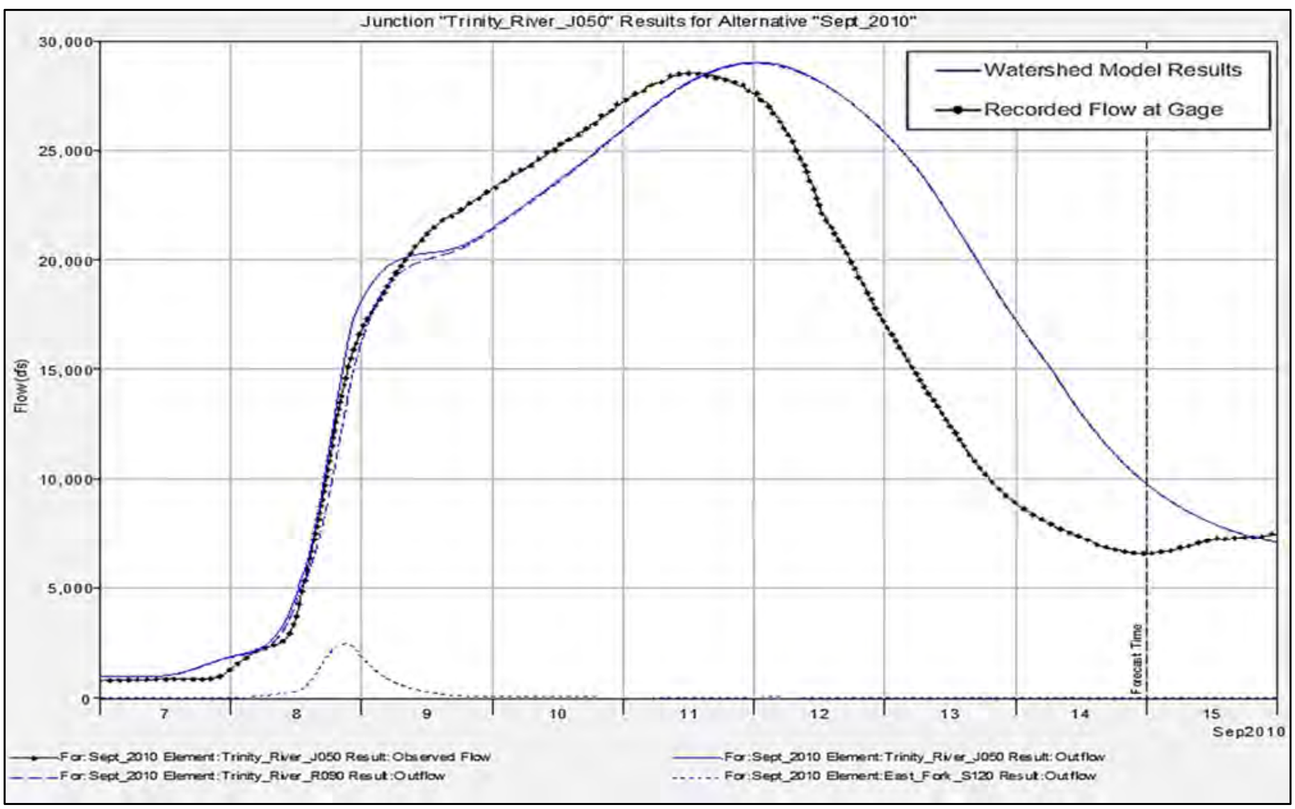

Figure 67b. September 11, 2010 Calibration for the Trinity River near Rosser, TX Gage

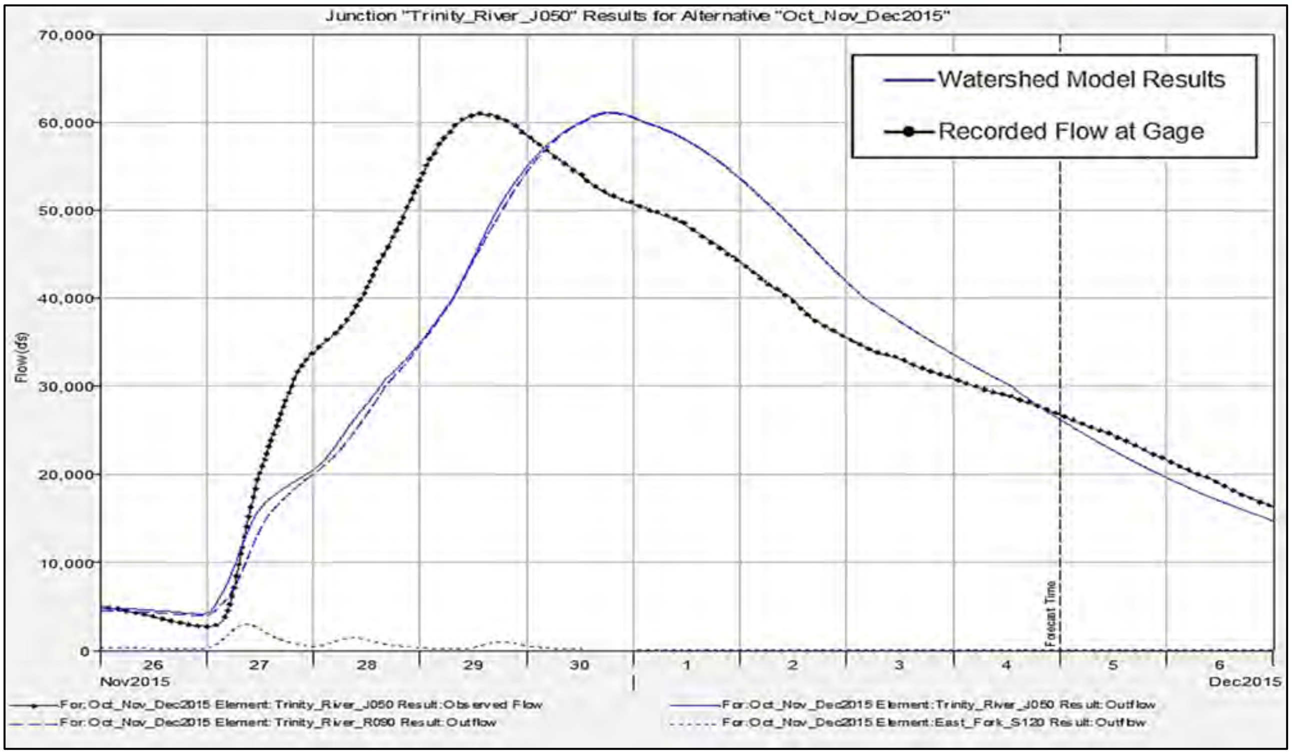

Figure 67c. November 29, 2015 Calibration for the Trinity River near Rosser, TX Gage

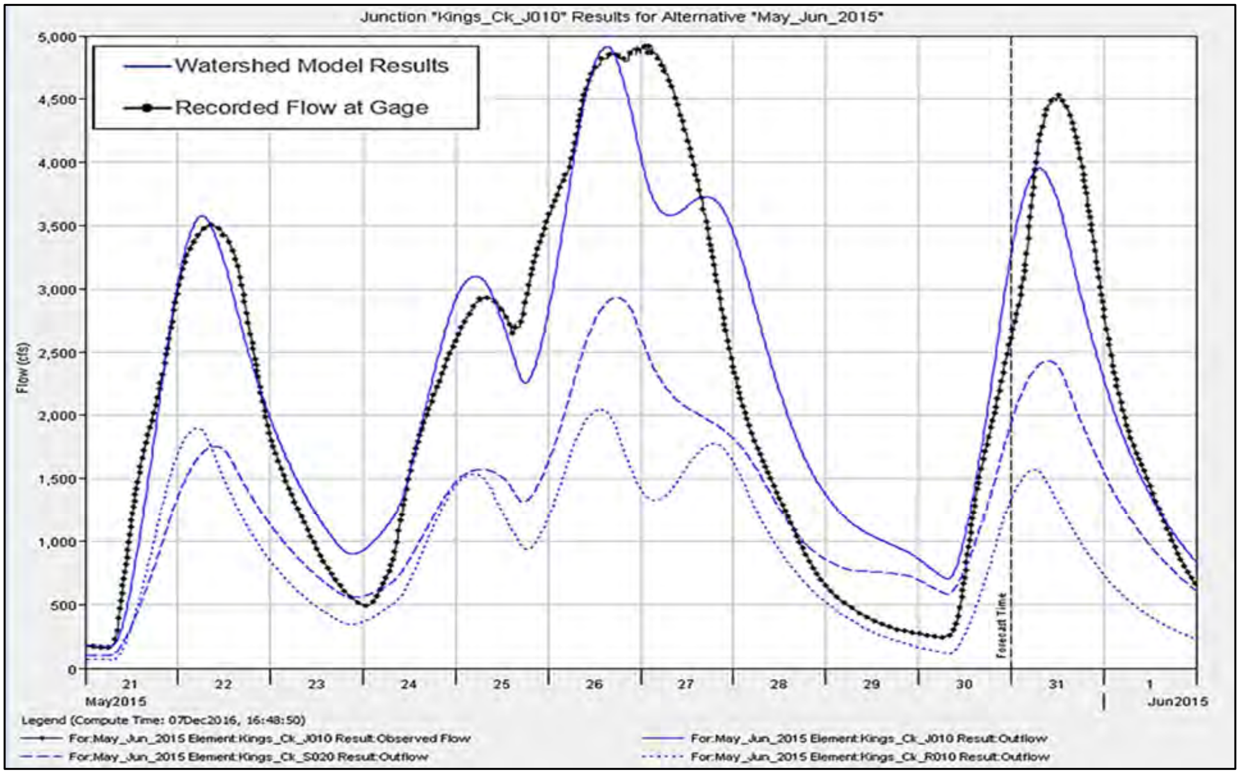

Figure 68a. May 26, 2015 Calibration for the Kings Creek at SH 34 near Kaufman Gage

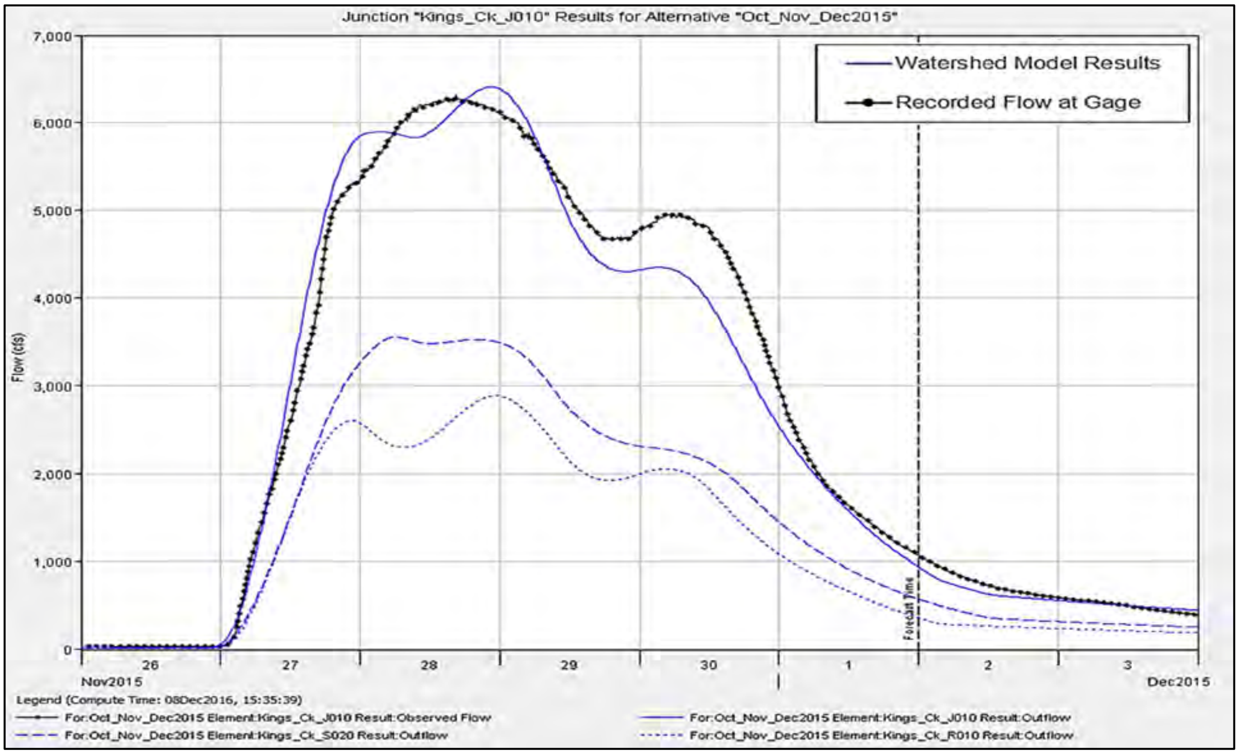

Figure 68b. November 27, 2015 Calibration for the Kings Creek at SH 34 near Kaufman Gage

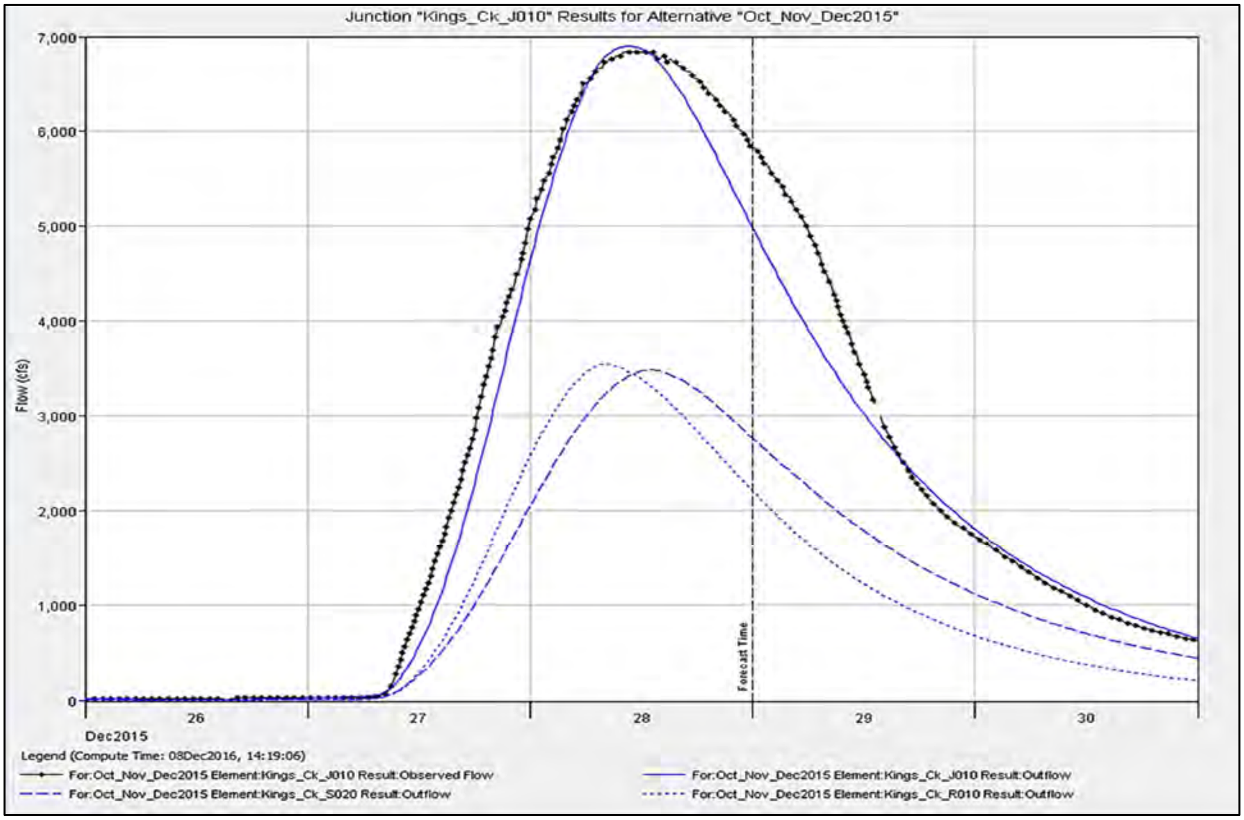

Figure 68c. December 28, 2015 Calibration for the Kings Creek at SH 34 near Kaufman Gage

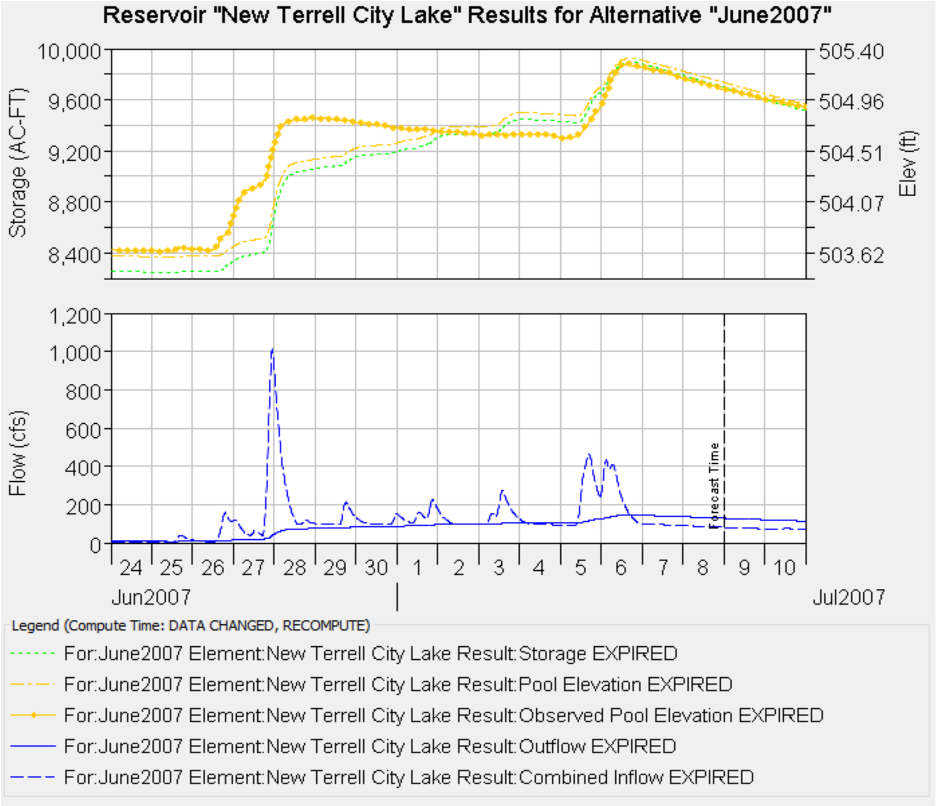

Figure 69a. June 2007 Calibration Results for New Terrell City Lake

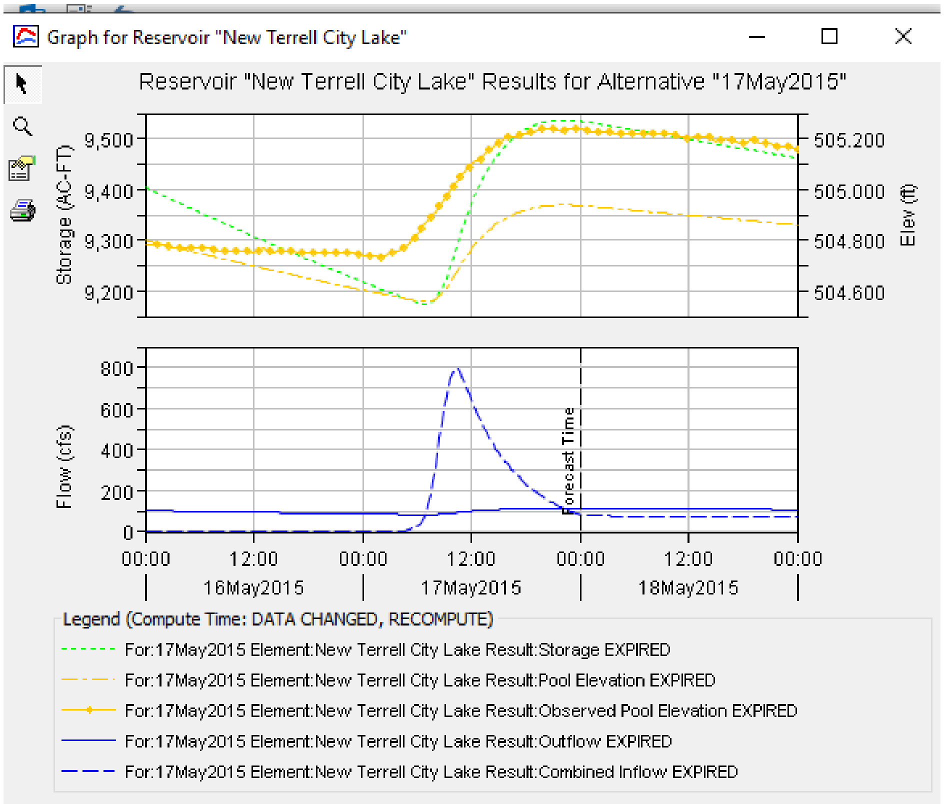

Figure 69b. May 2015 Calibration Results for New Terrell City Lake

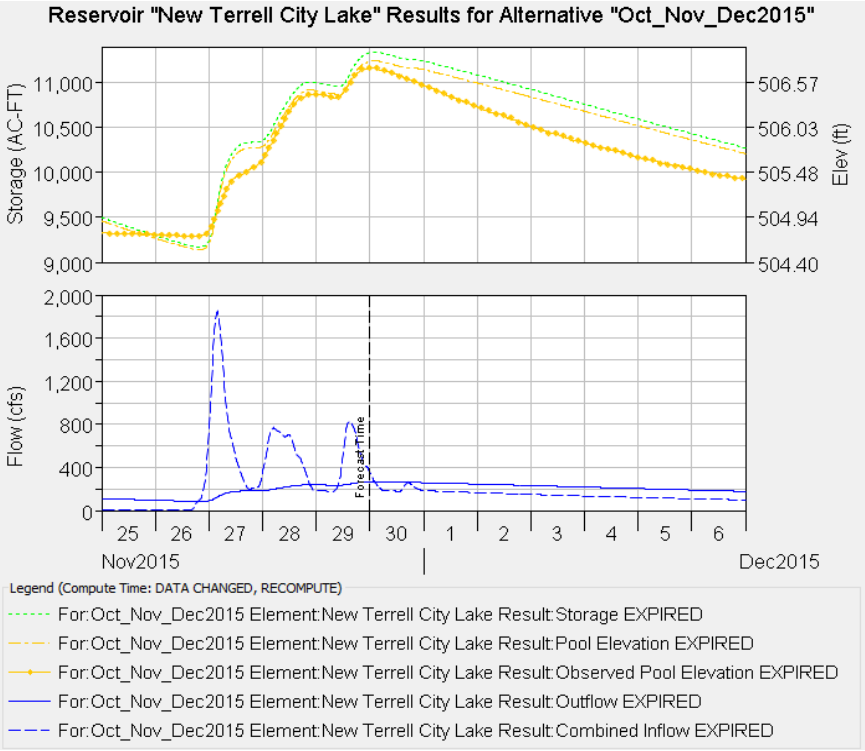

Figure 69c. November 2015 Calibration Results for New Terrell City Lake

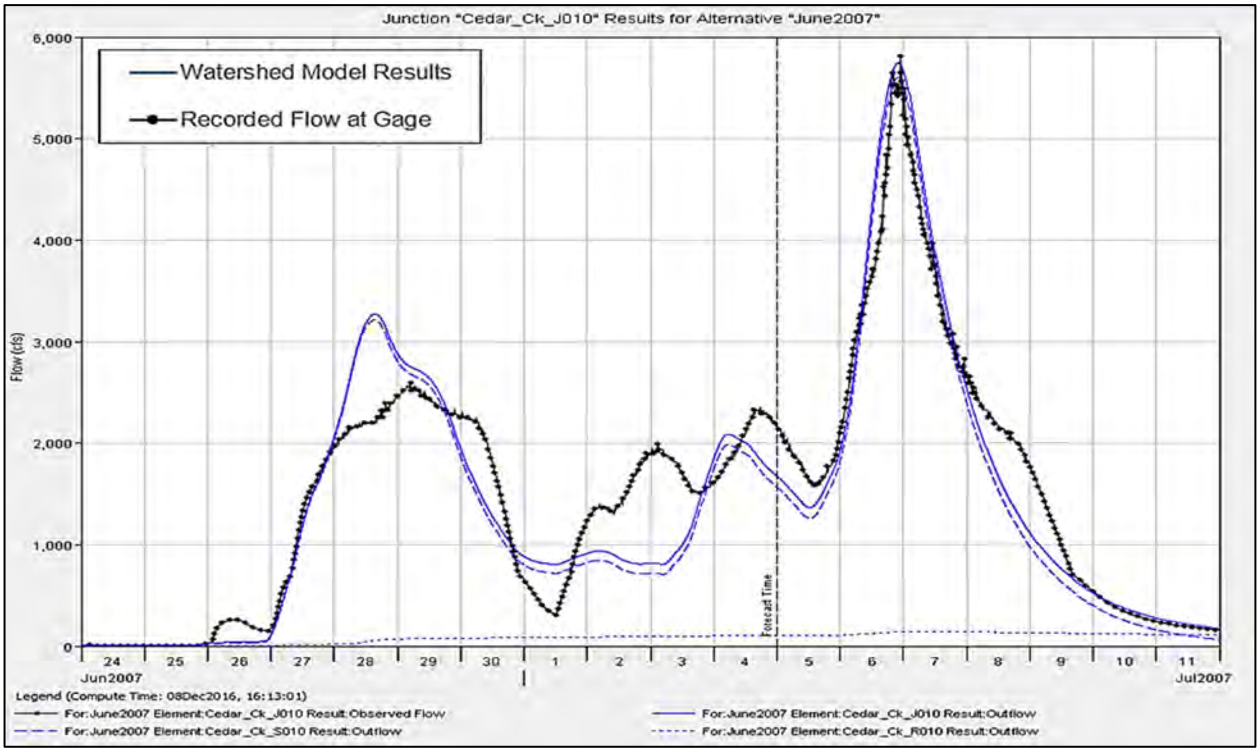

Figure 70a. July 6, 2007 Calibration for the Cedar Creek near Kemp, TX Gage

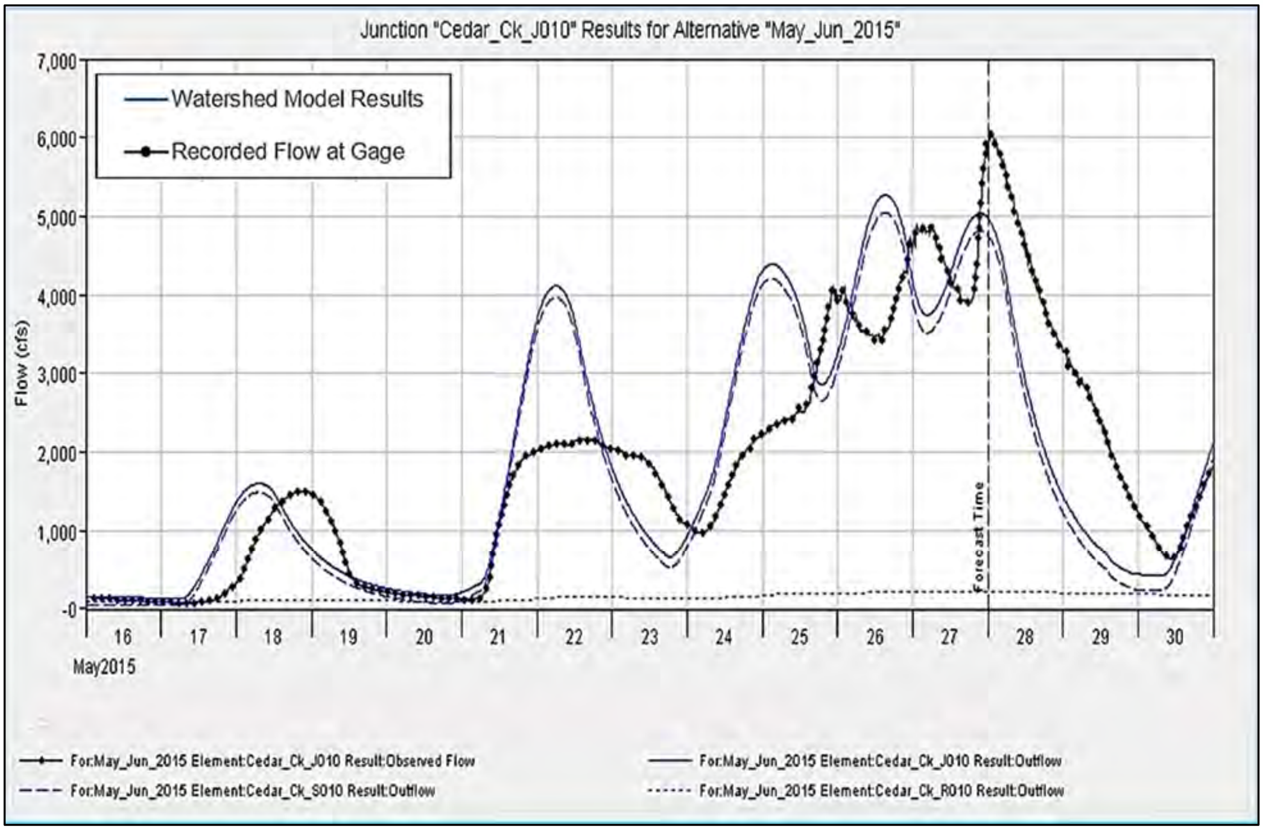

Figure 70b. May 27, 2015 Calibration for the Cedar Creek near Kemp, TX Gage

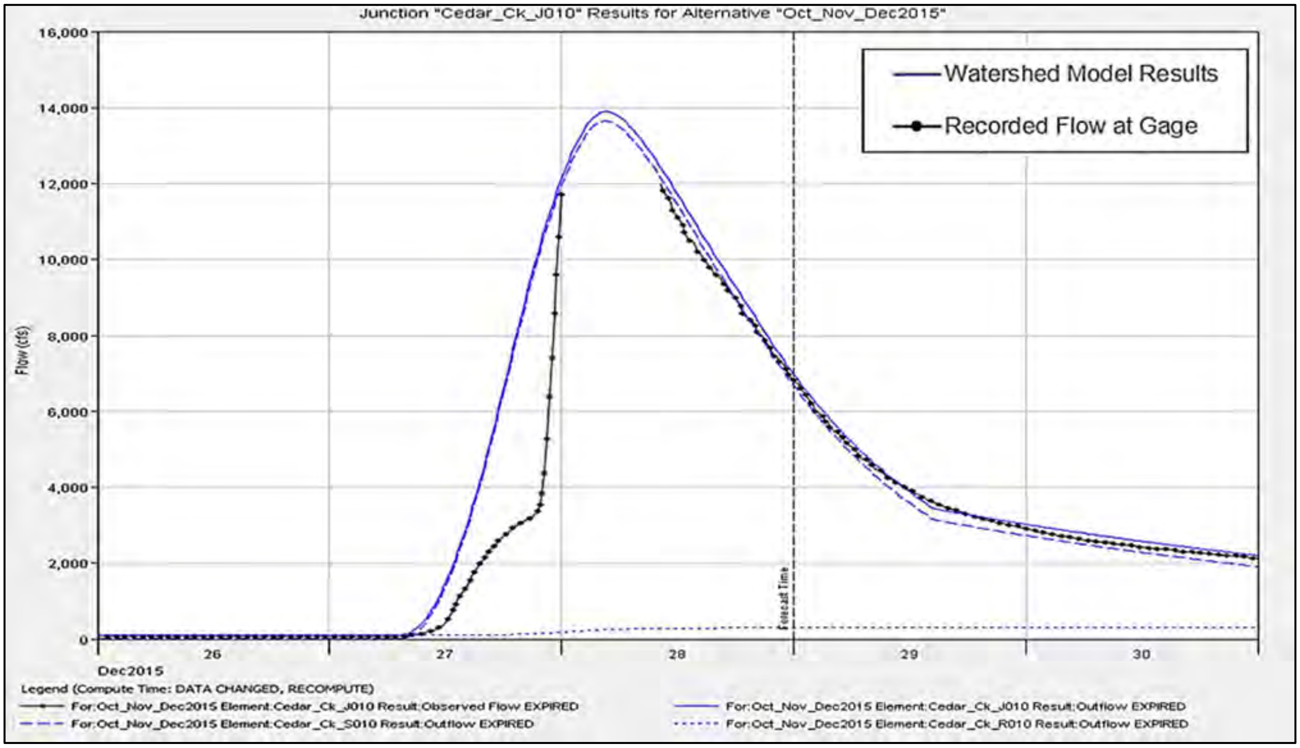

Figure 70c. December 28, 2015 Calibration for the Cedar Creek near Kemp, TX Gage

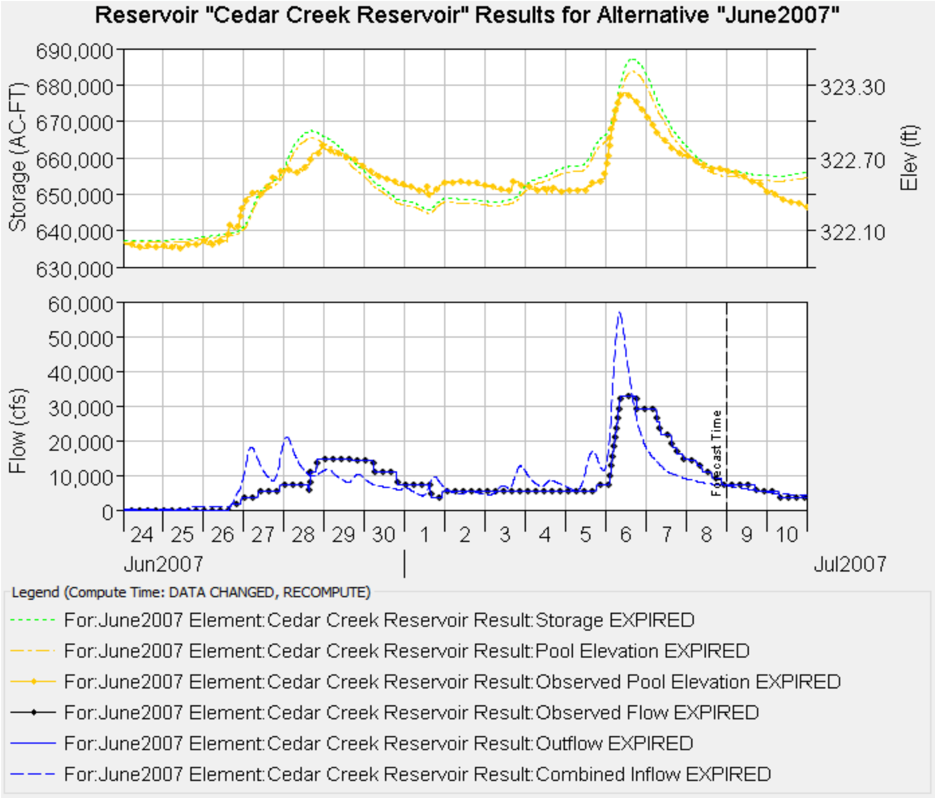

Figure 71a. June 2007 Calibration Results for Cedar Creek Reservoir

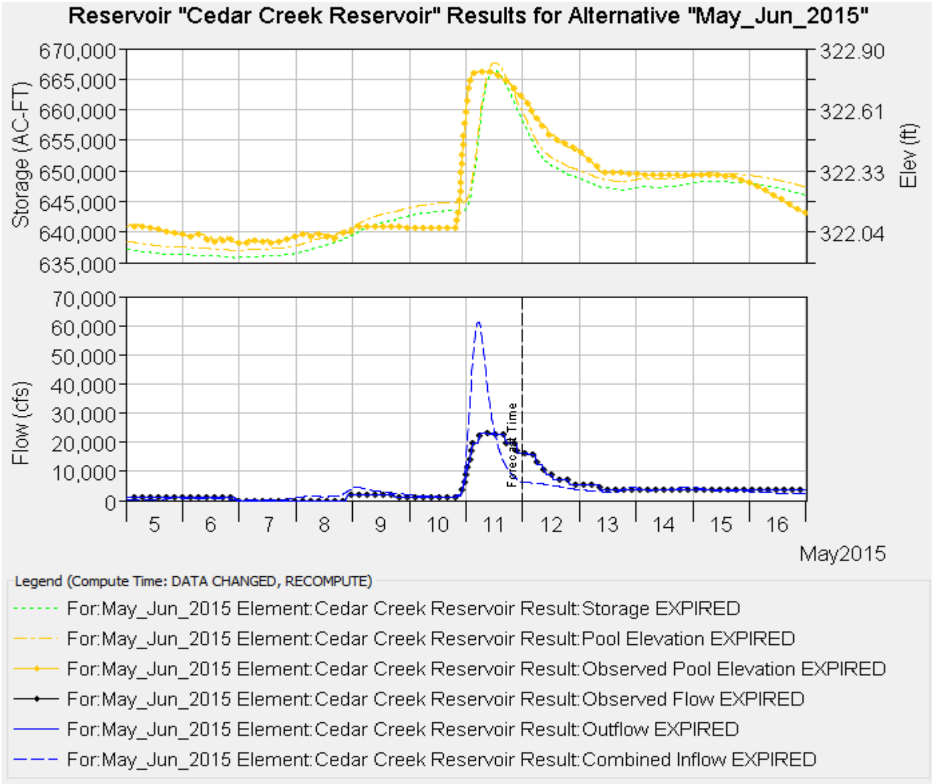

Figure 71b. May 2015 Calibration Results for Cedar Creek Reservoir

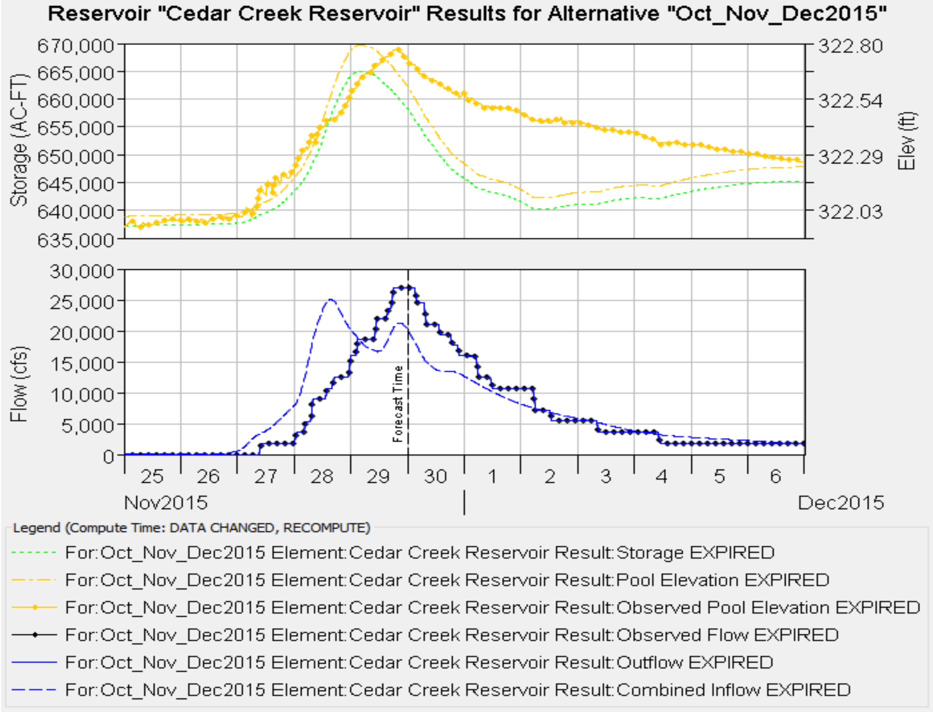

Figure 71c. November 2015 Calibration Results for Cedar Creek Reservoir

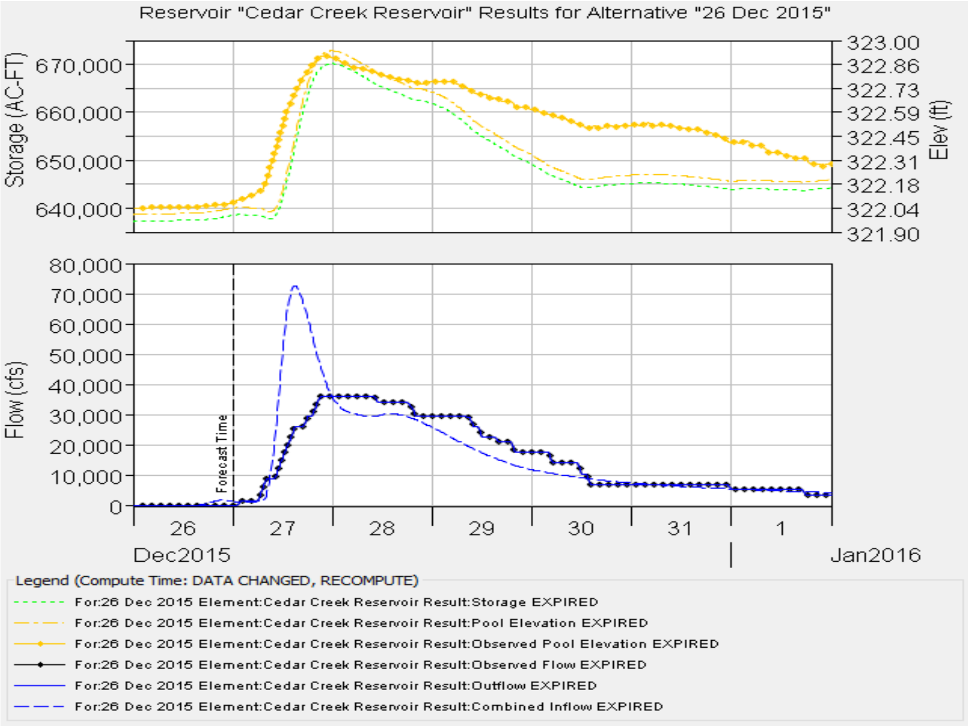

Figure 71d. December 2015 Calibration Results for Cedar Creek Reservoir

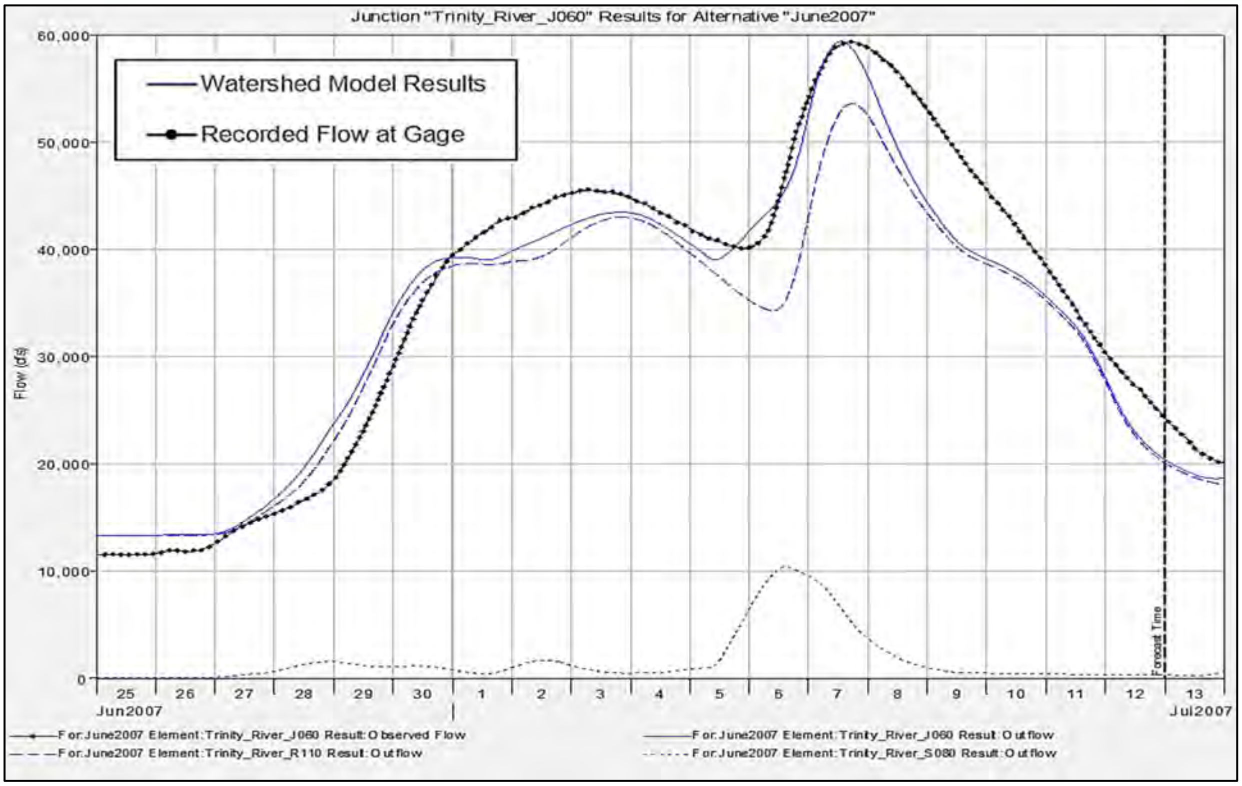

Figure 72a. July 7, 2007 Calibration for the Trinity River at Trinidad, TX Gage

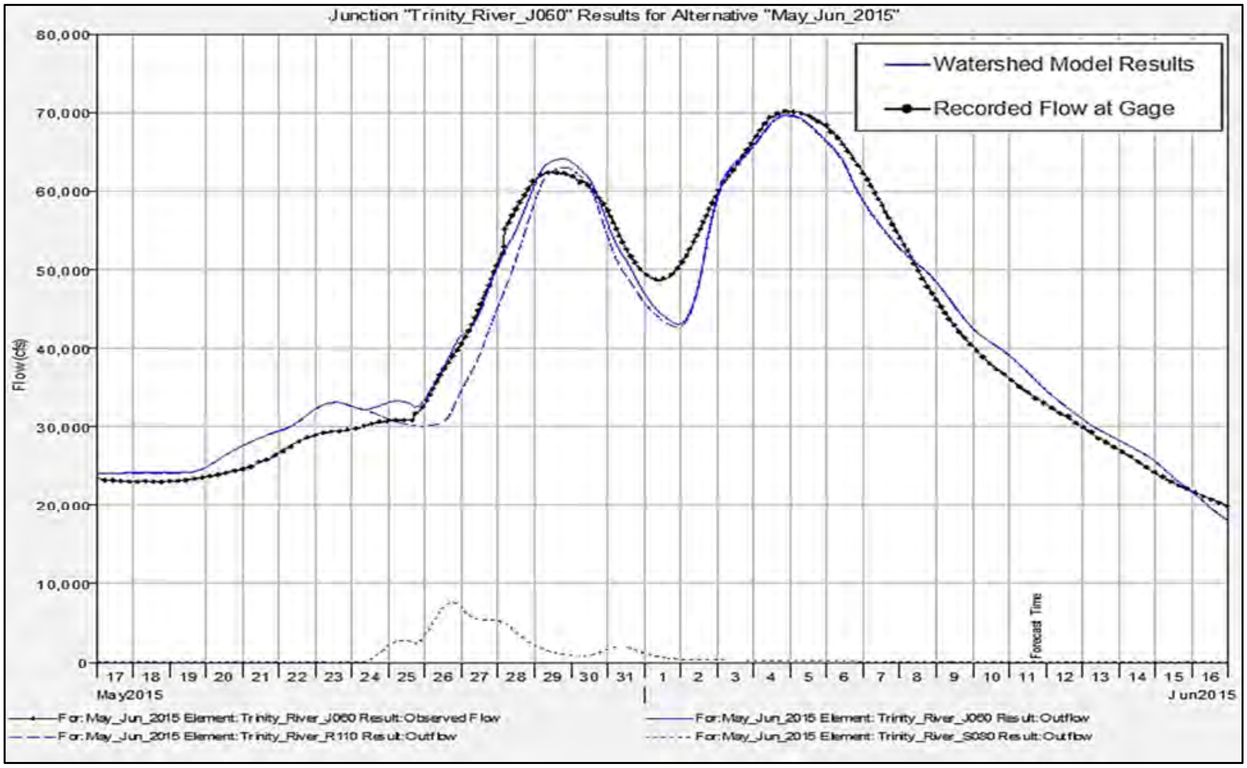

Figure 72b. June 4, 2015 Calibration for the Trinity River at Trinidad, TX Gage

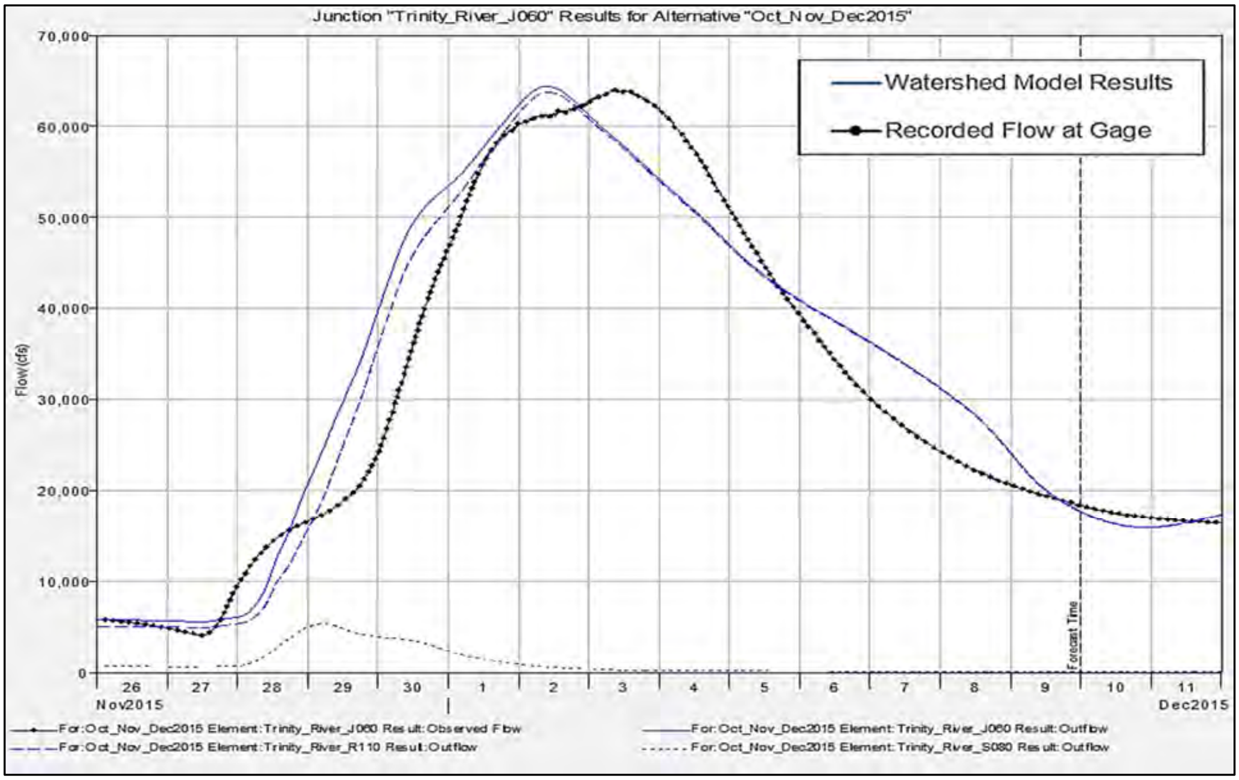

Figure 72c. December 3, 2015 Calibration for the Trinity River at Trinidad, TX Gage

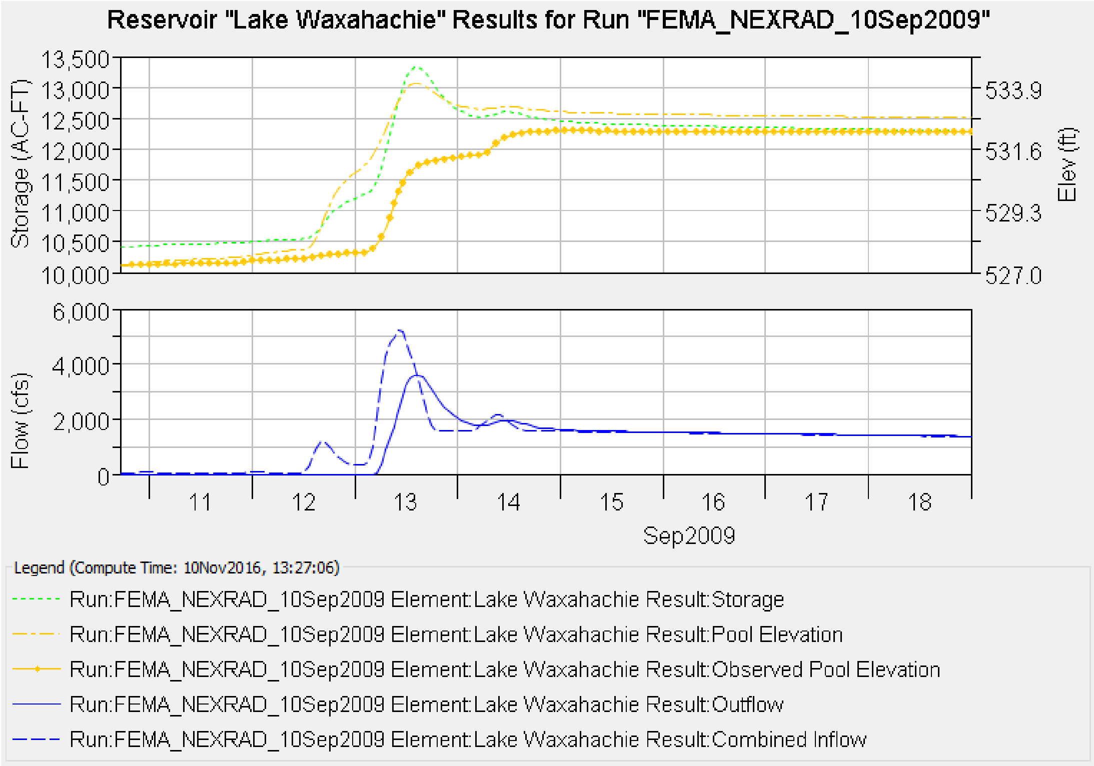

Figure 73a. September 2009 Calibration Results for Lake Waxahachie

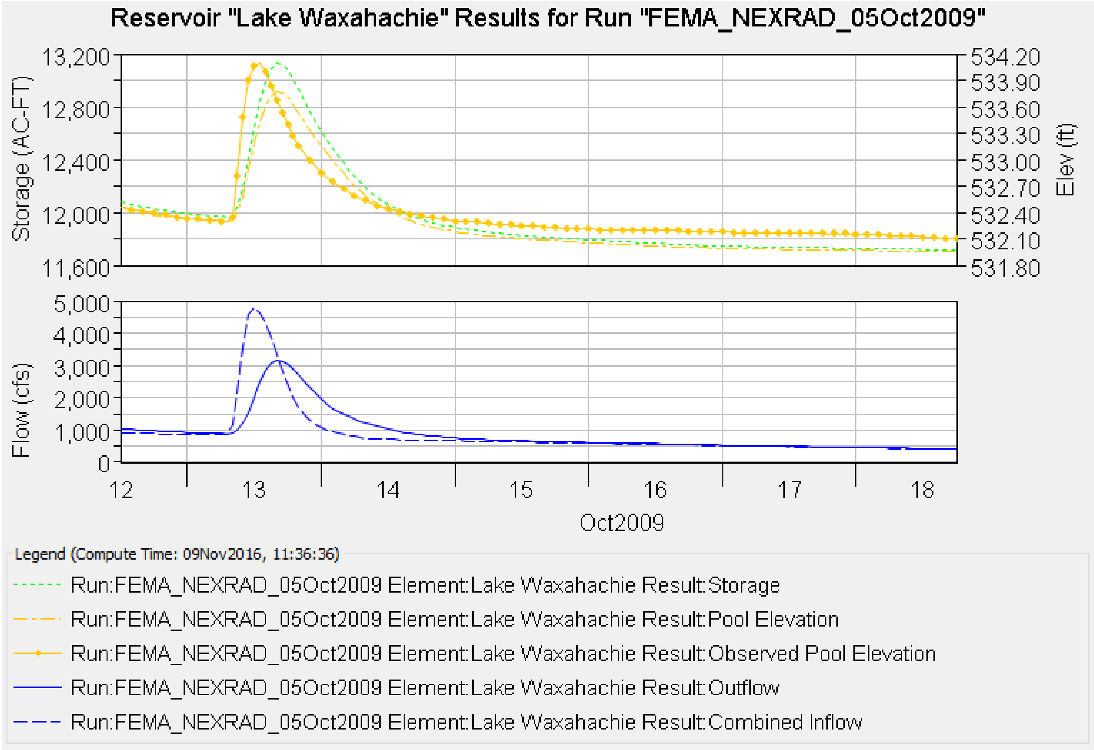

Figure 73b. October 2009 Calibration Results for Lake Waxahachie

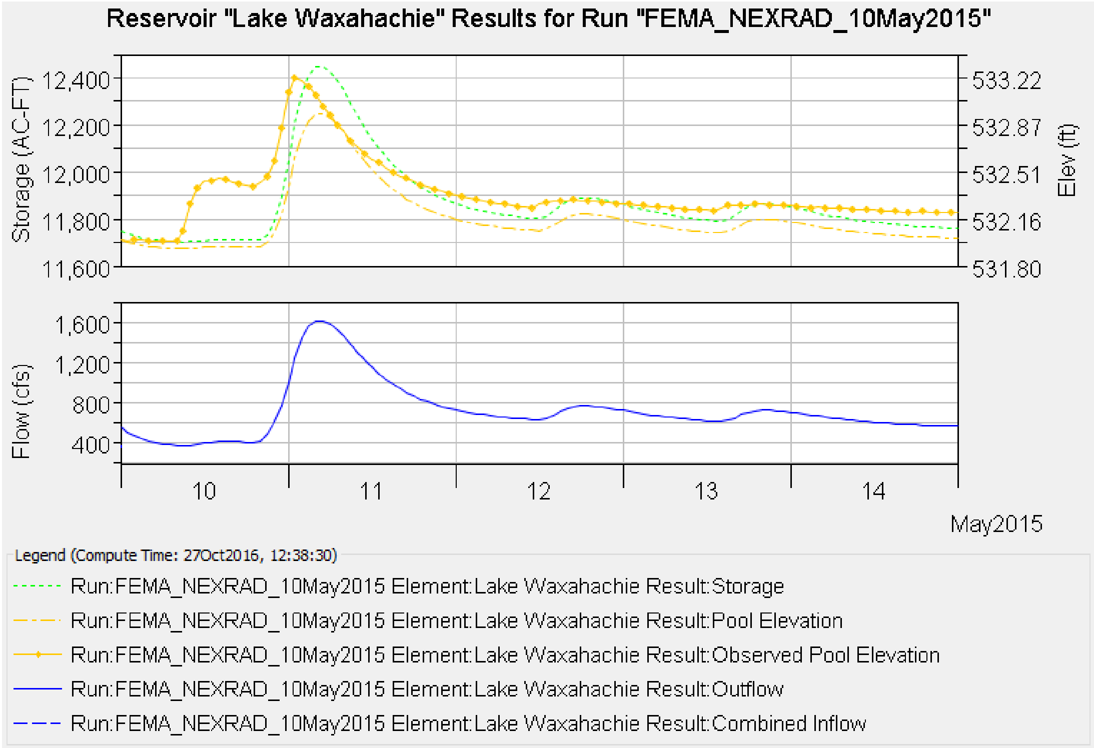

Figure 73c. May 2015 Calibration Results for Lake Waxahachie

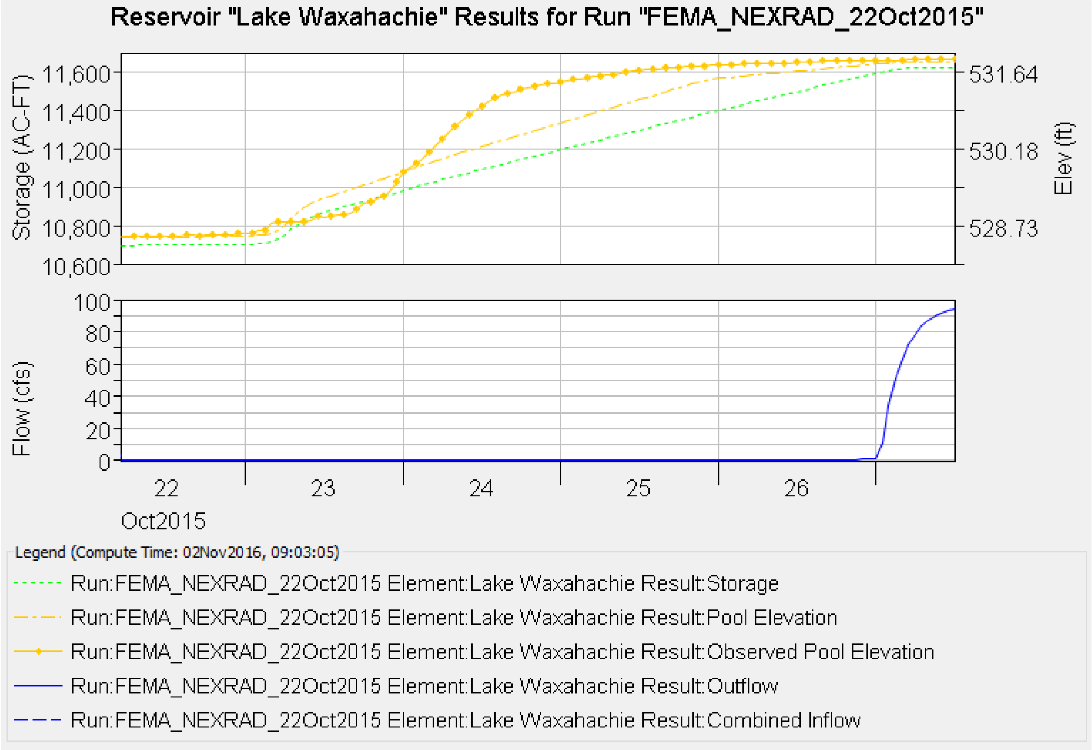

Figure 73d. October 2015 Calibration Results for Lake Waxahachie

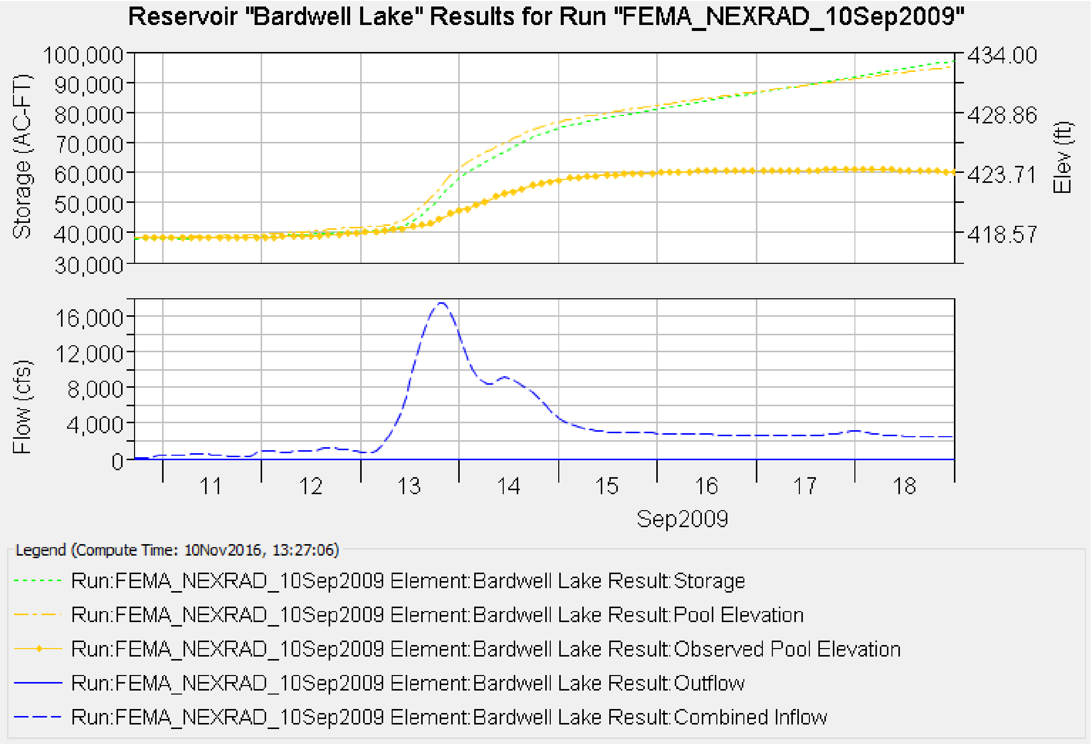

Figure 74a. September 2009 Calibration Results for Bardwell Lake

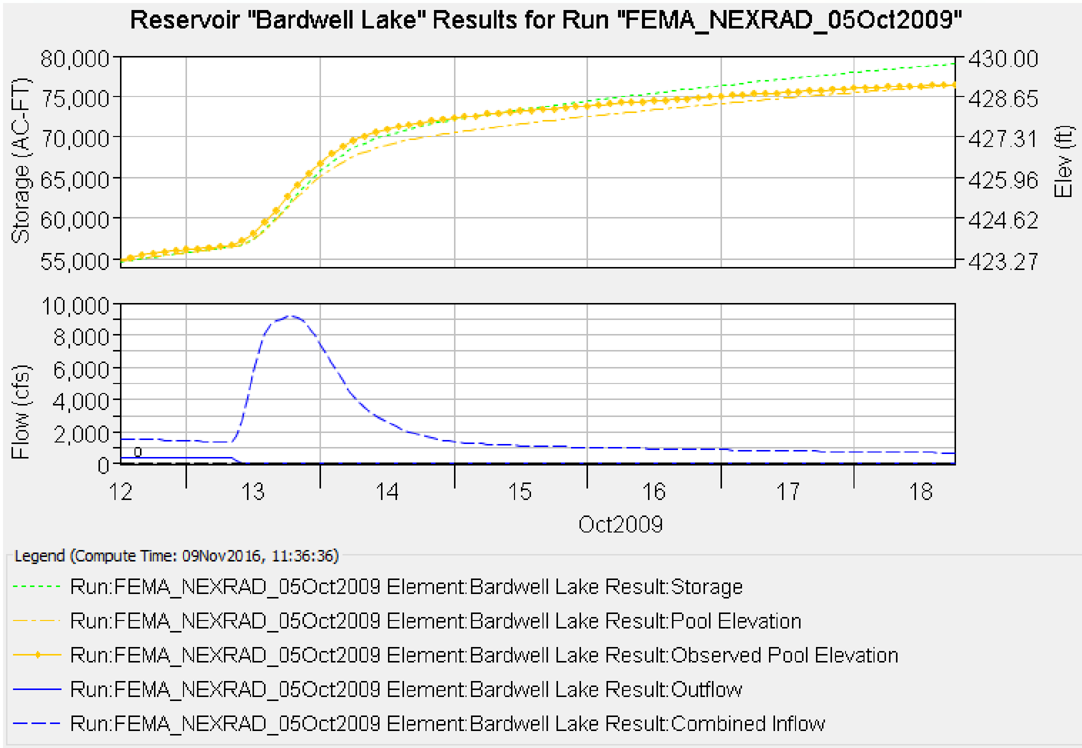

Figure 74b. October 2009 Calibration Results for Bardwell Lake

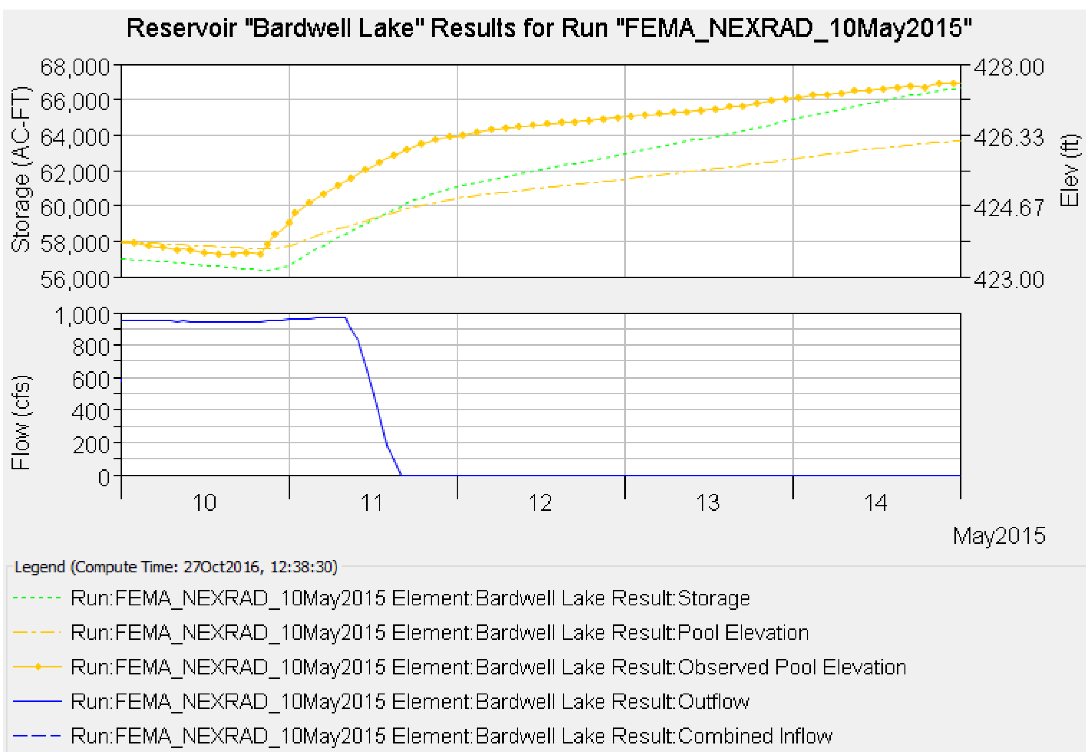

Figure 74c. May 2015 Calibration Results for Bardwell Lake

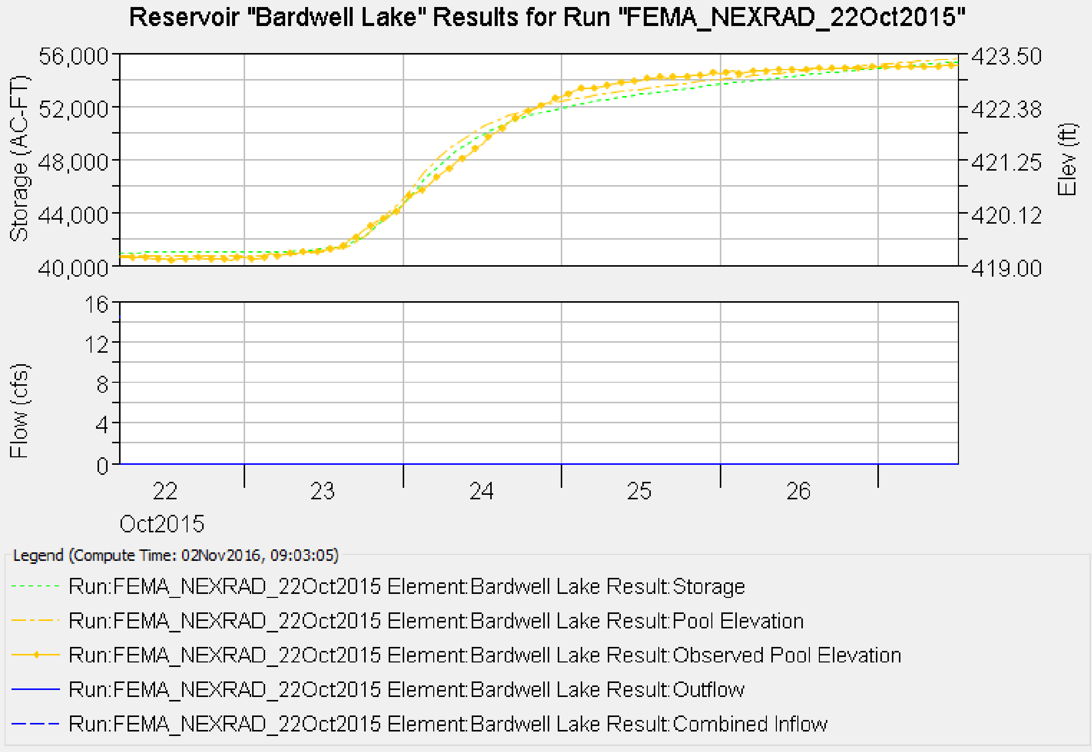

Figure 74d. October 2015 Calibration Results for Bardwell Lake

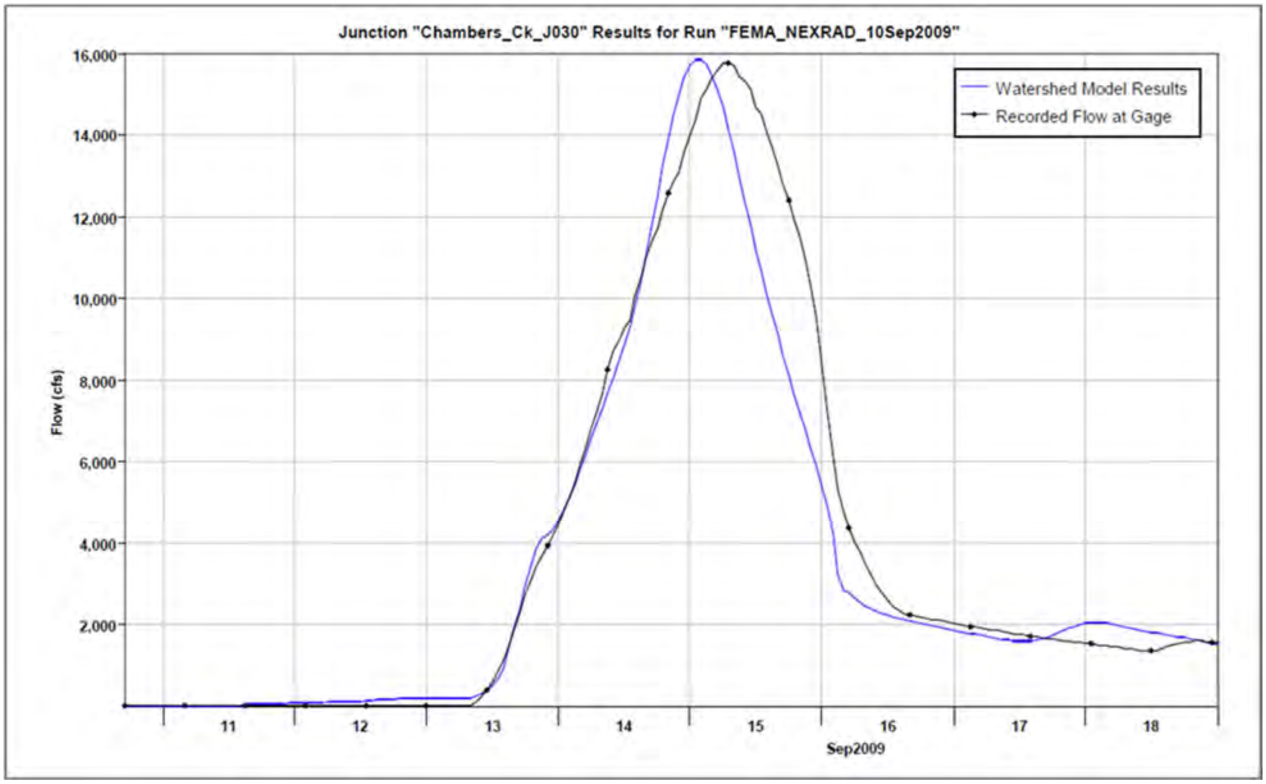

Figure 75a. September 10, 2009 Calibration Results for Chambers Creek near Rice, TX Gage

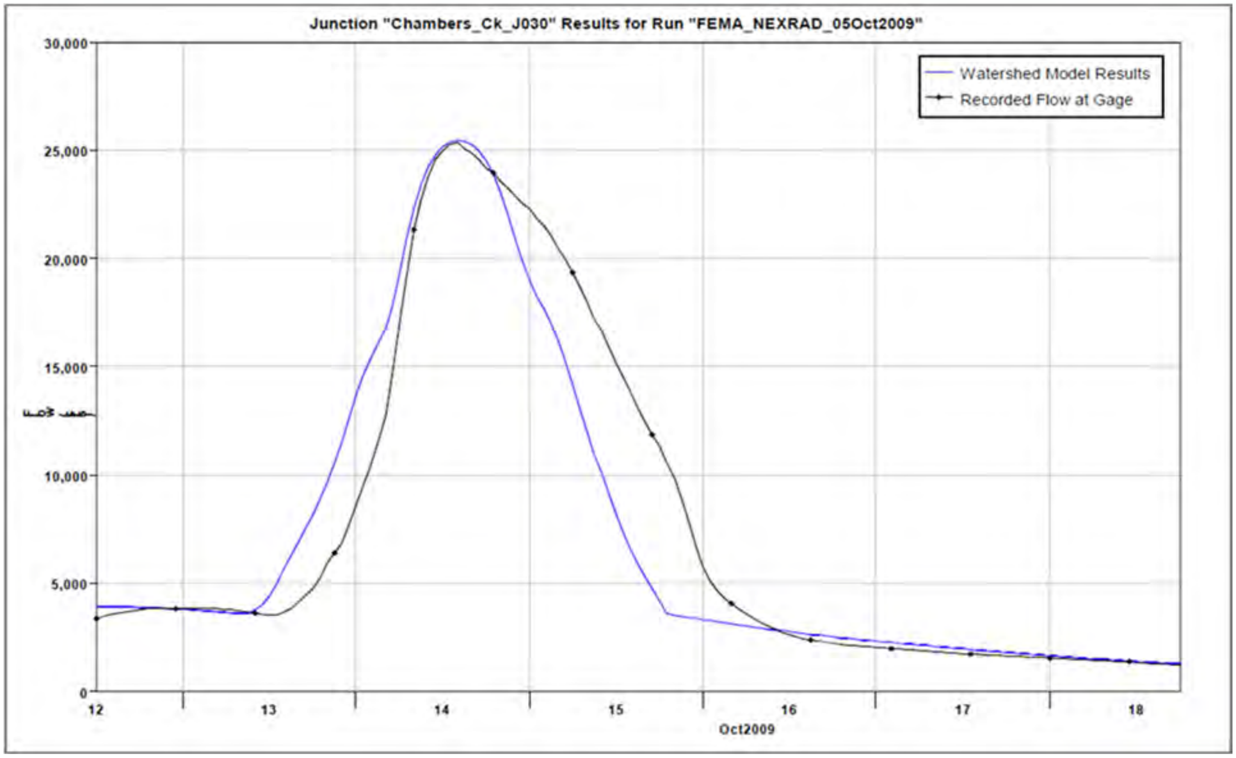

Figure 75b. October 5, 2009 Calibration Results for Chambers Creek near Rice, TX Gage

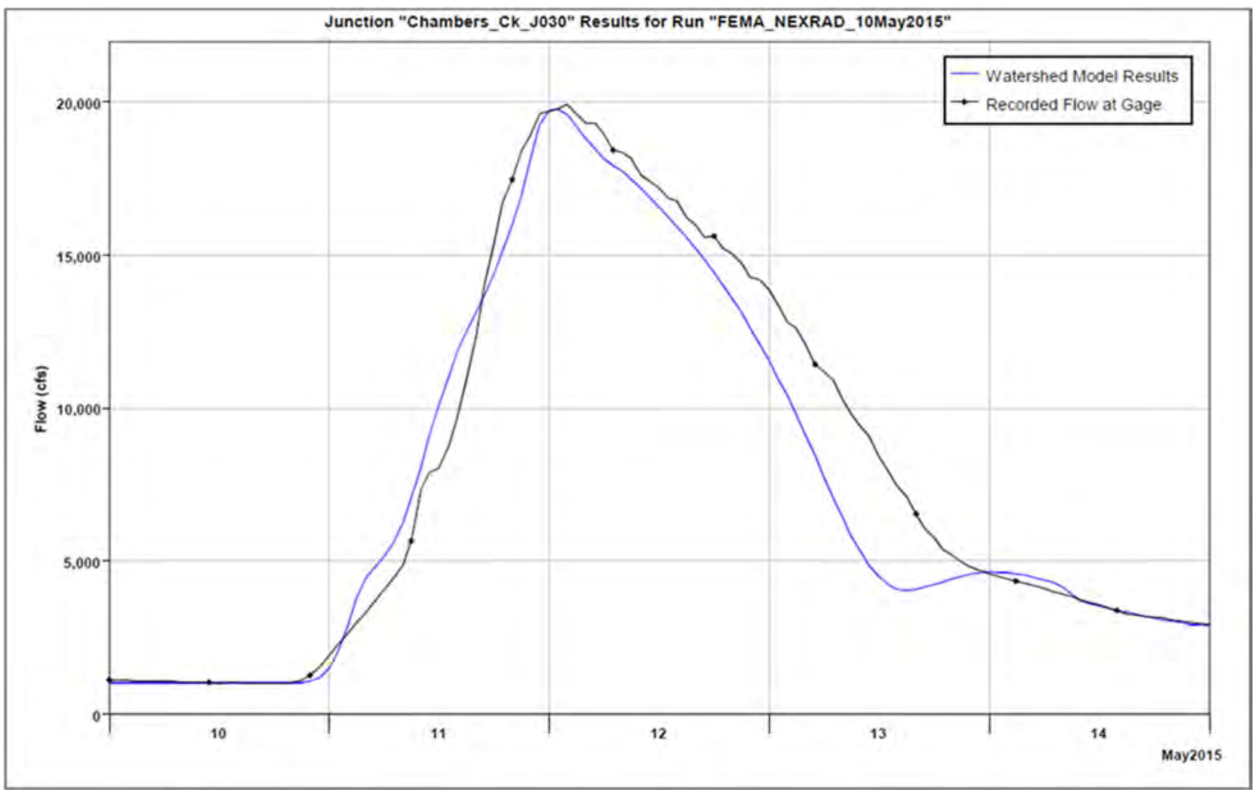

Figure 75c. May 10, 2015 Calibration Results for Chambers Creek near Rice, TX Gage

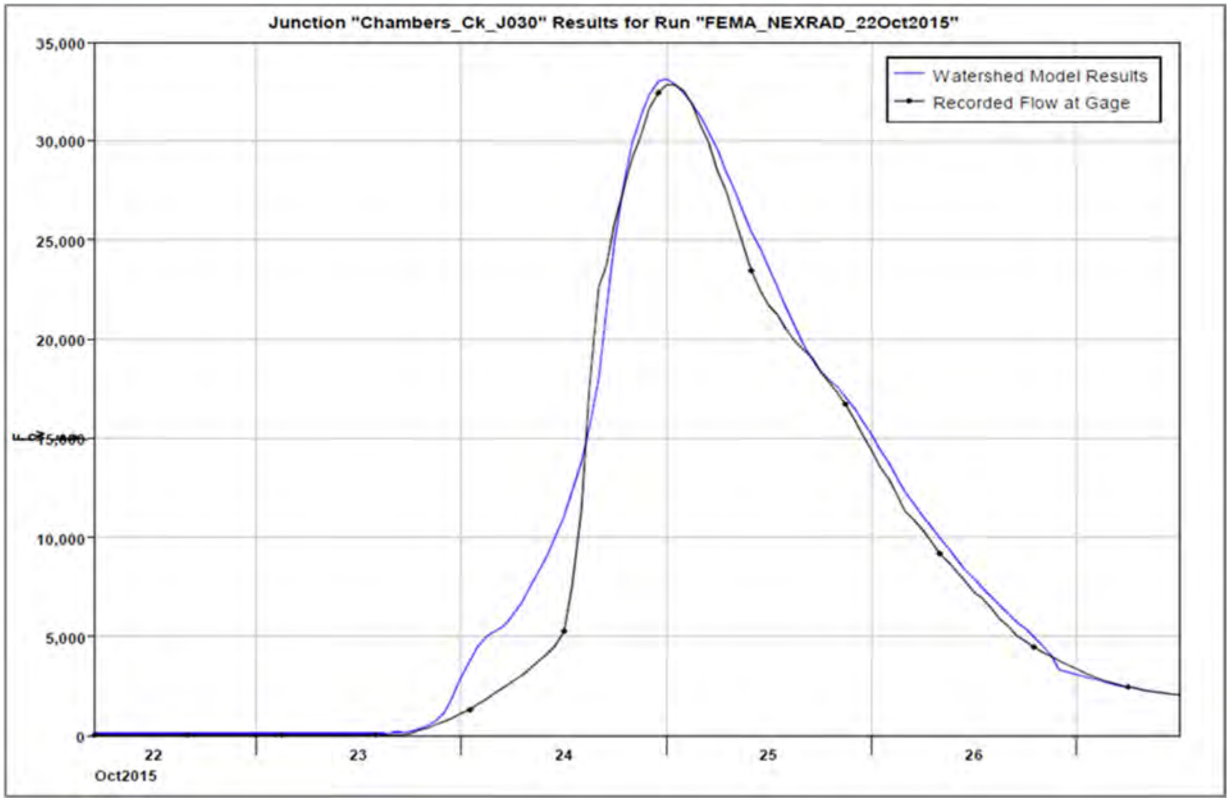

Figure 75d. October 22, 2015 Calibration Results for Chambers Creek near Rice, TX Gage

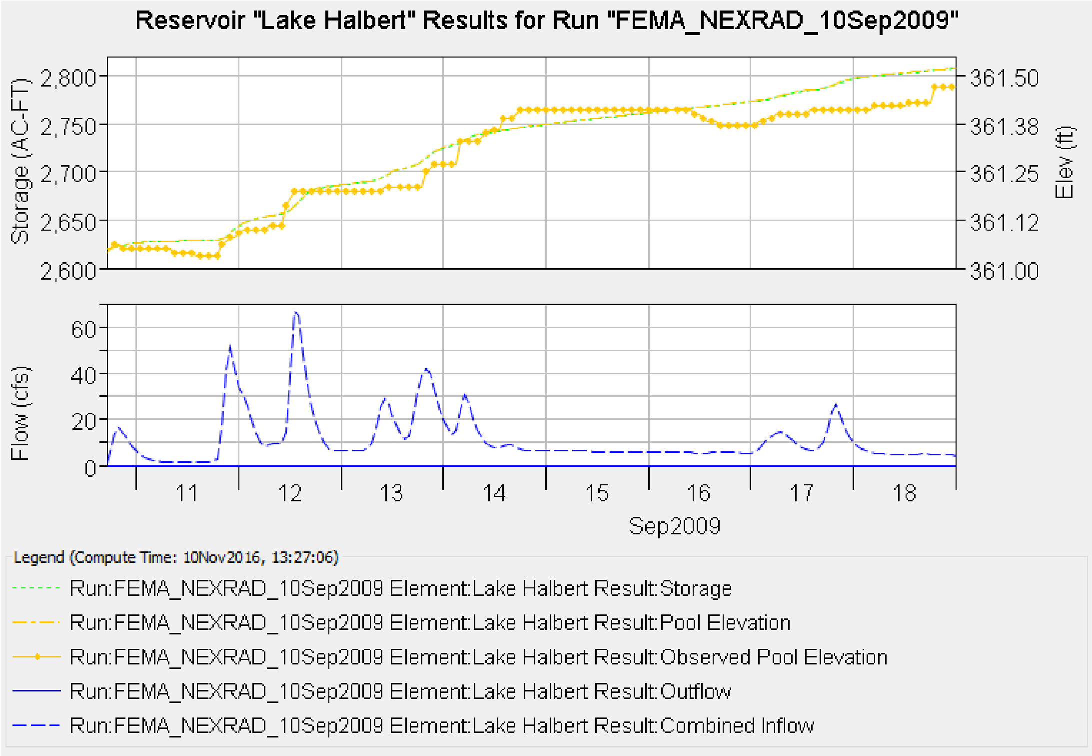

Figure 76a. September 2009 Calibration Results for Lake Halbert

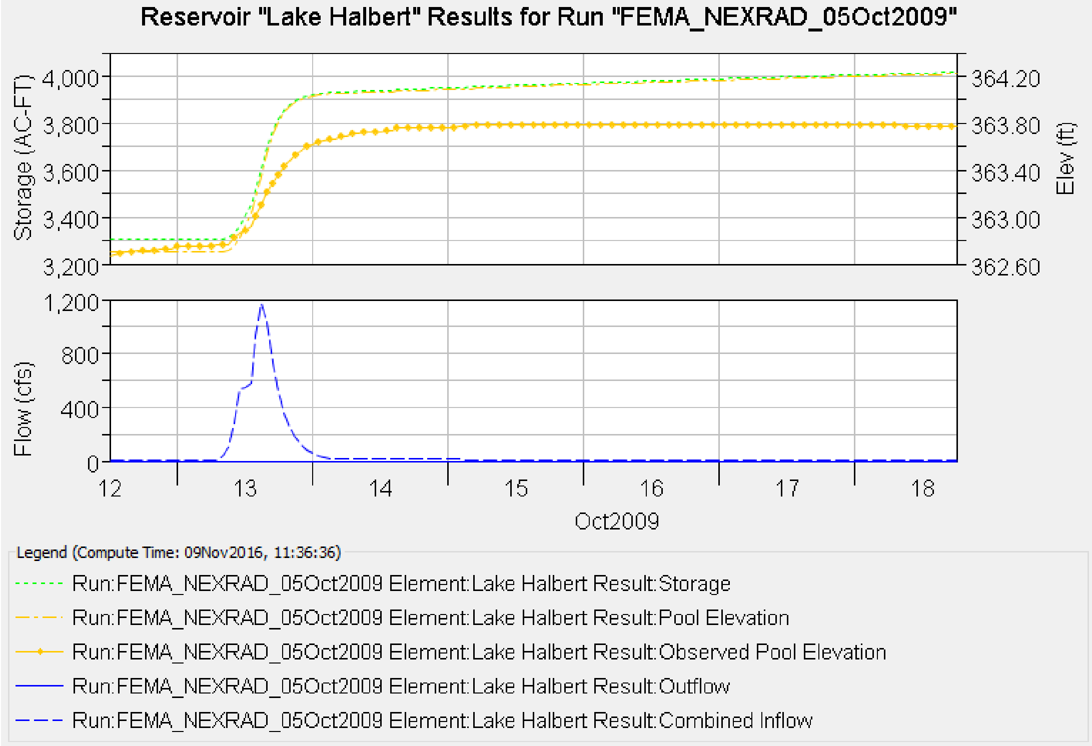

Figure 76b. October 2009 Calibration Results for Lake Halbert

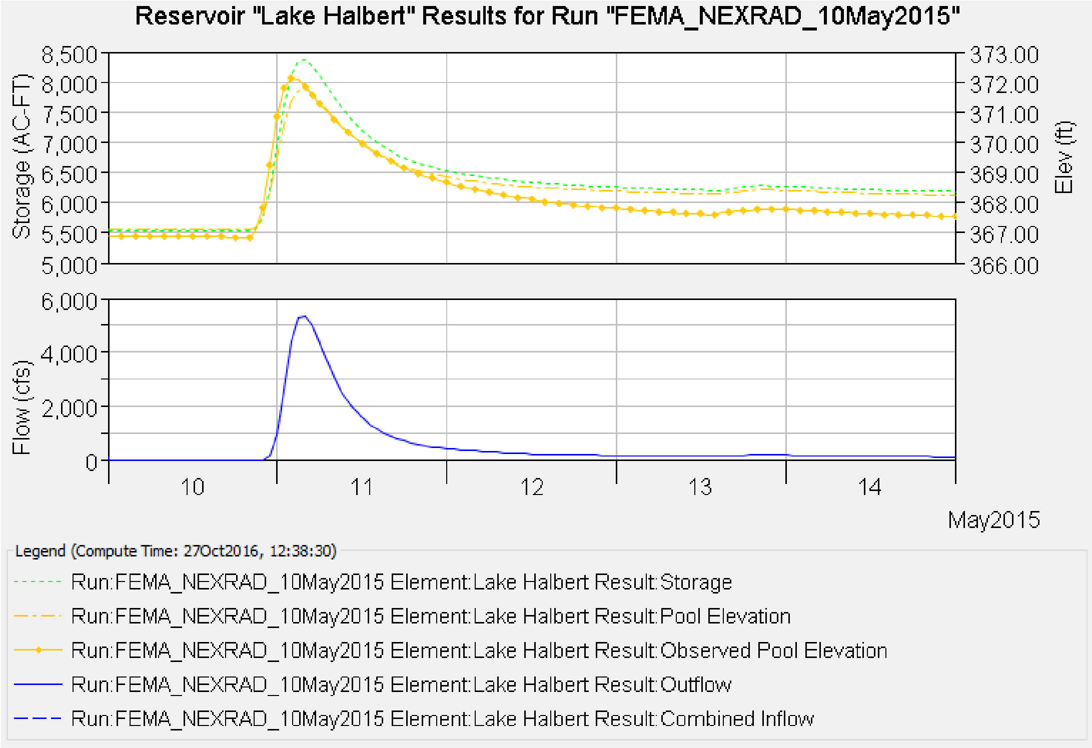

Figure 76c. May 2015 Calibration Results for Lake Halbert

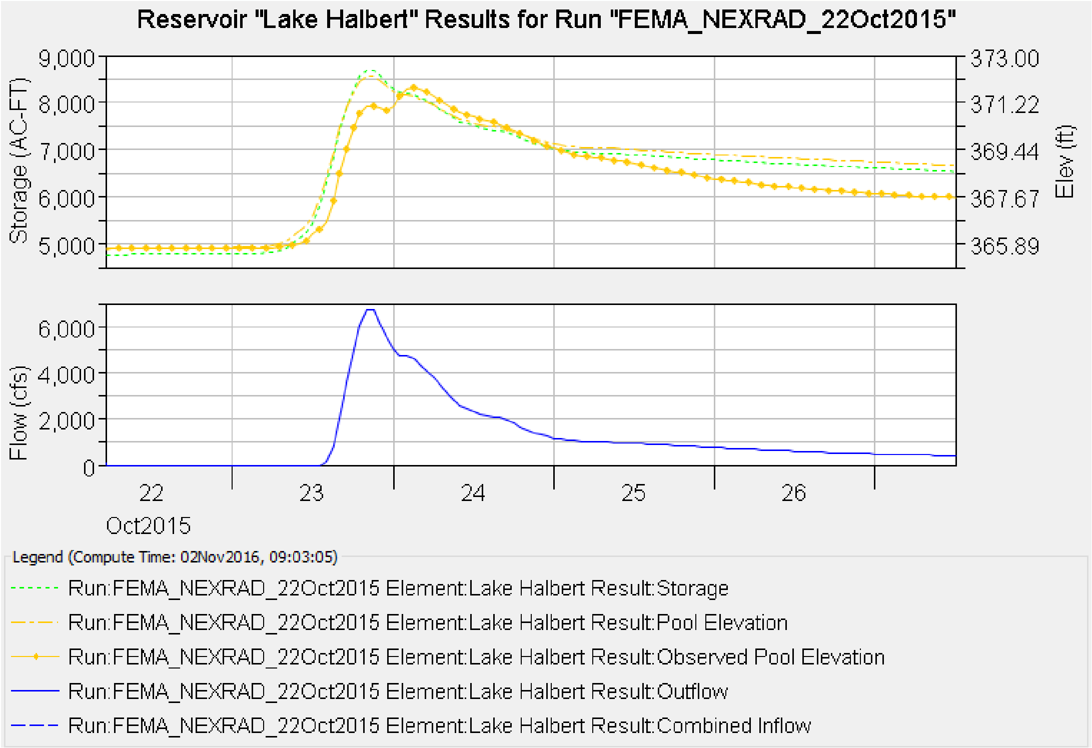

Figure 76d. October 2015 Calibration Results for Lake Halbert

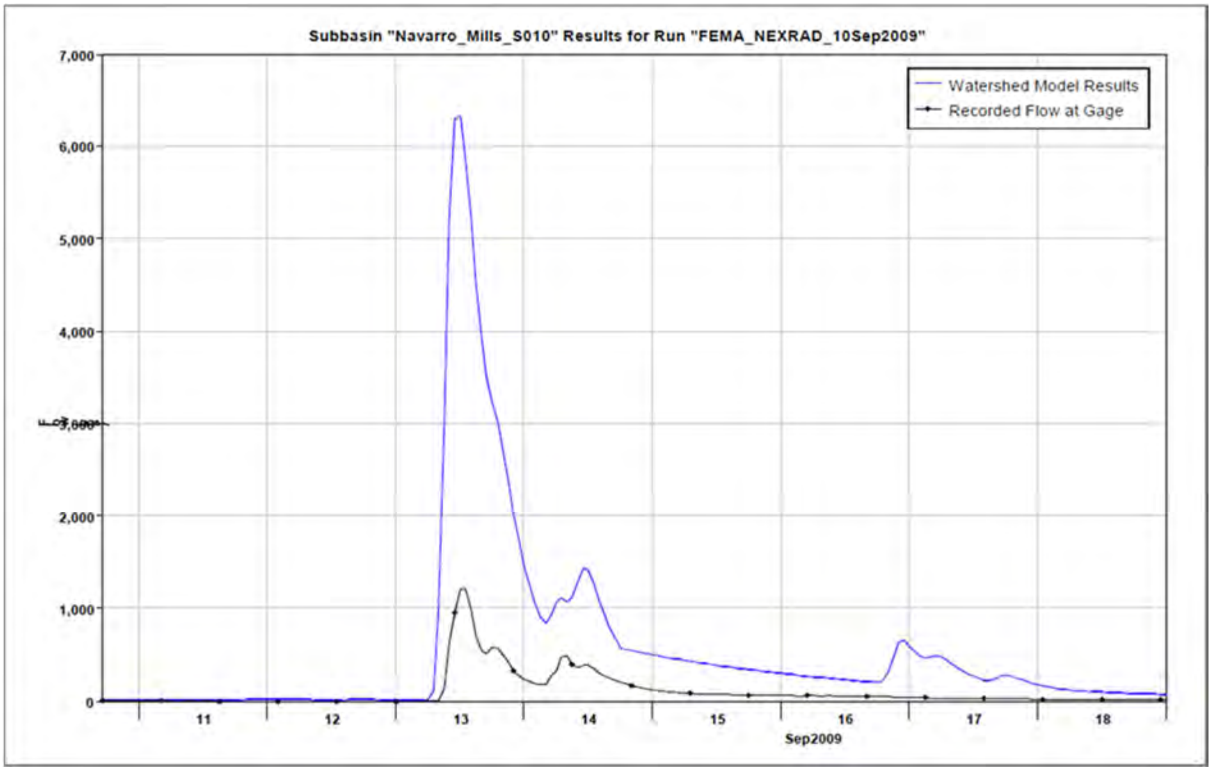

Figure 77a. September 10, 2009 Calibration Results for White Rock Creek near Irene, TX Gage

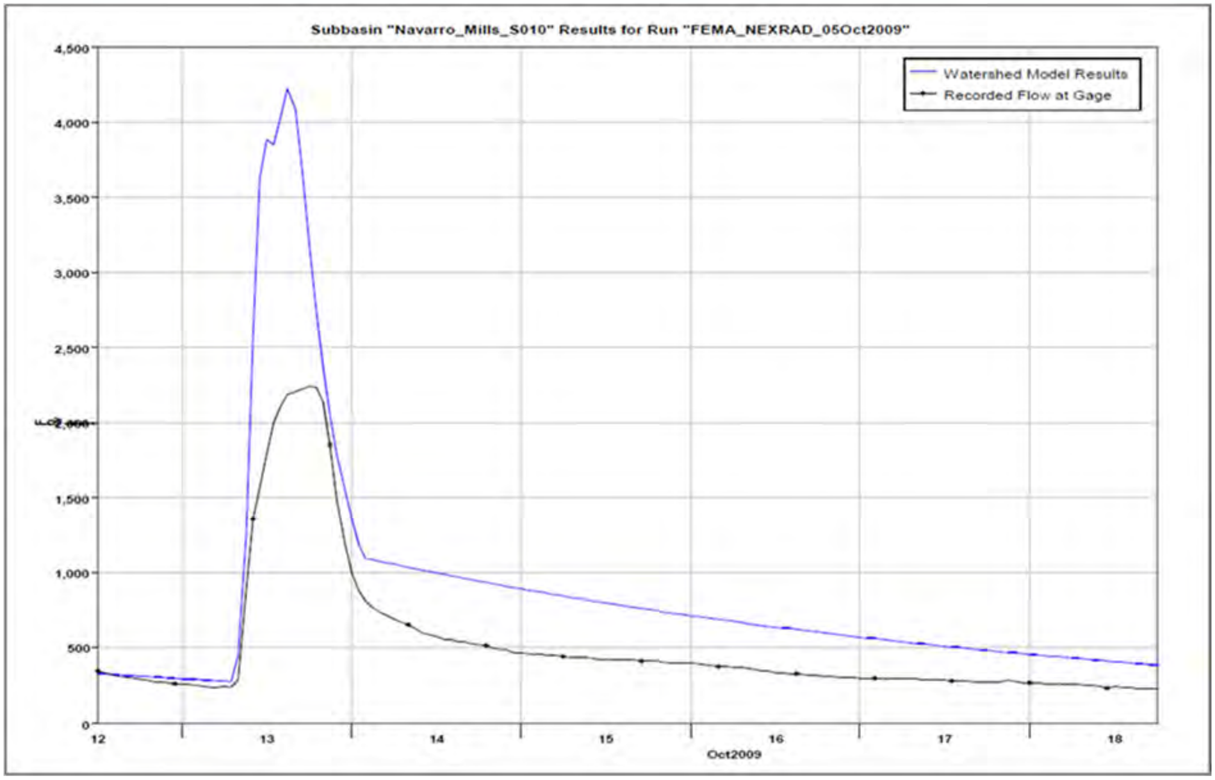

Figure 77b. October 5, 2009 Calibration Results for White Rock Creek near Irene, TX Gage

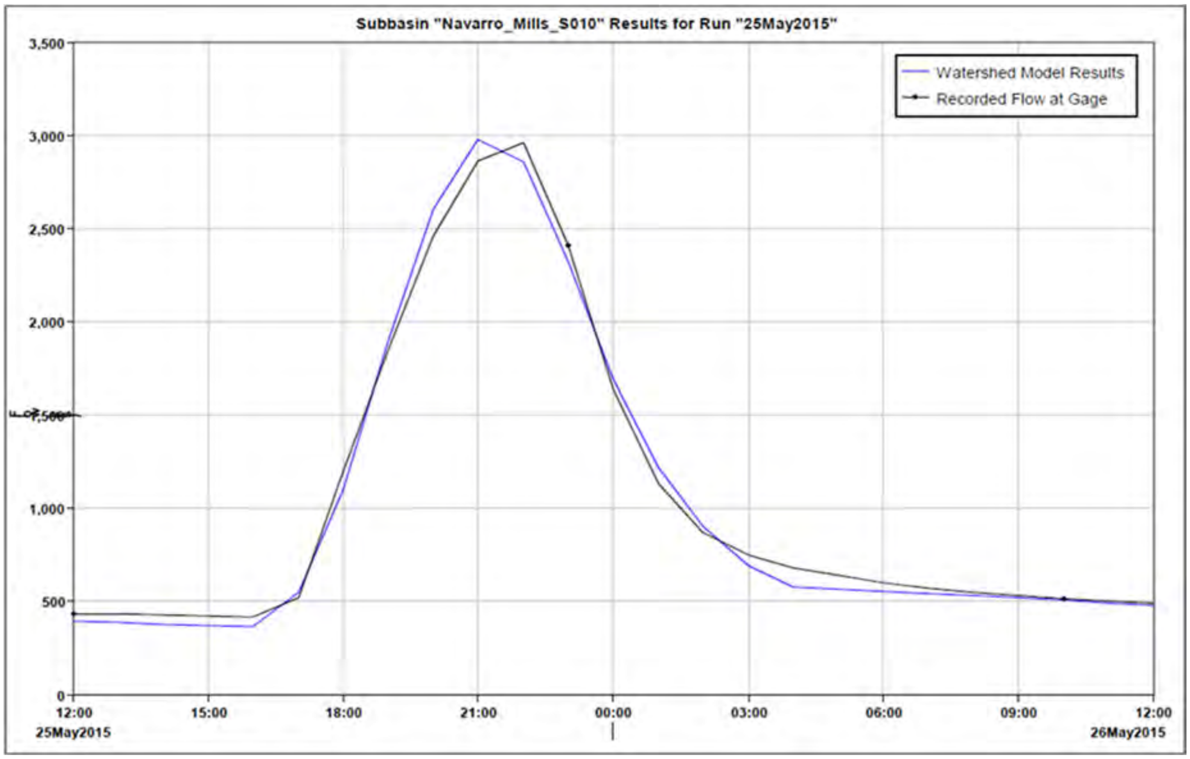

Figure 77c. May 25, 2015 Calibration Results for White Rock Creek near Irene, TX Gage

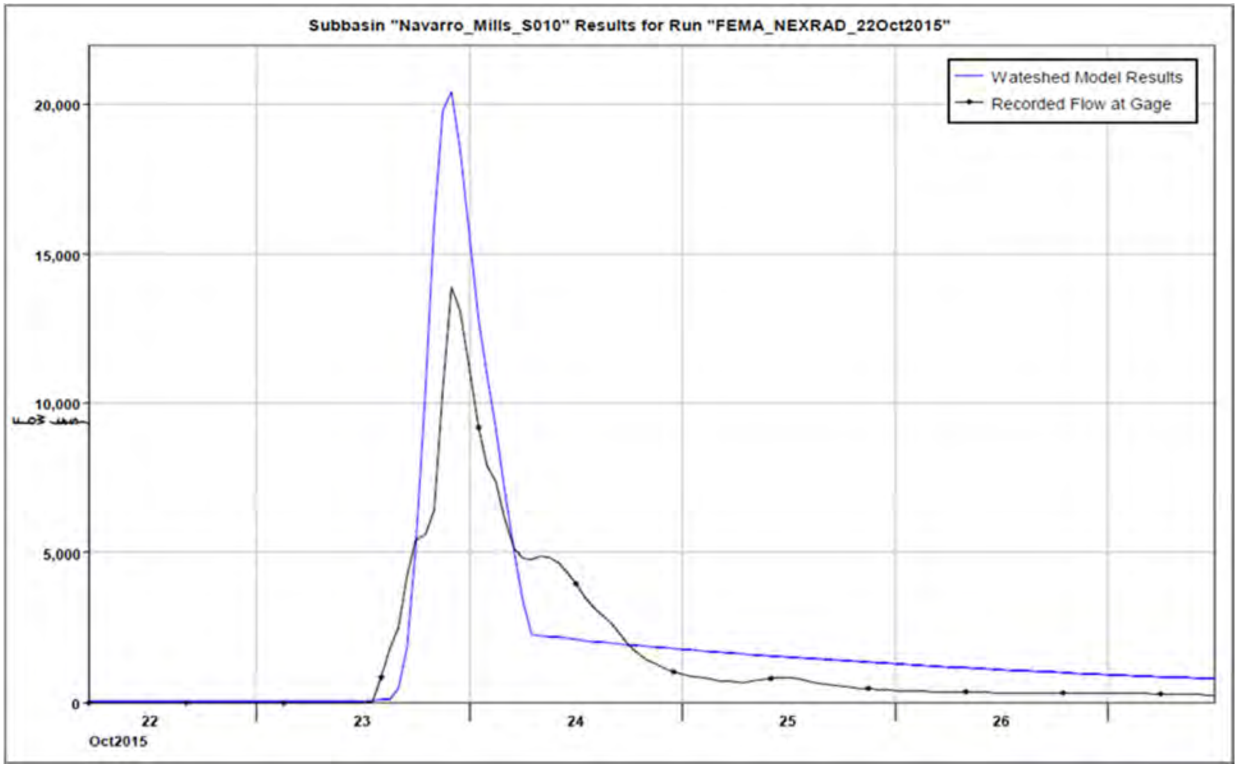

Figure 77d. October 22, 2015 Calibration Results for White Rock Creek near Irene, TX Gage

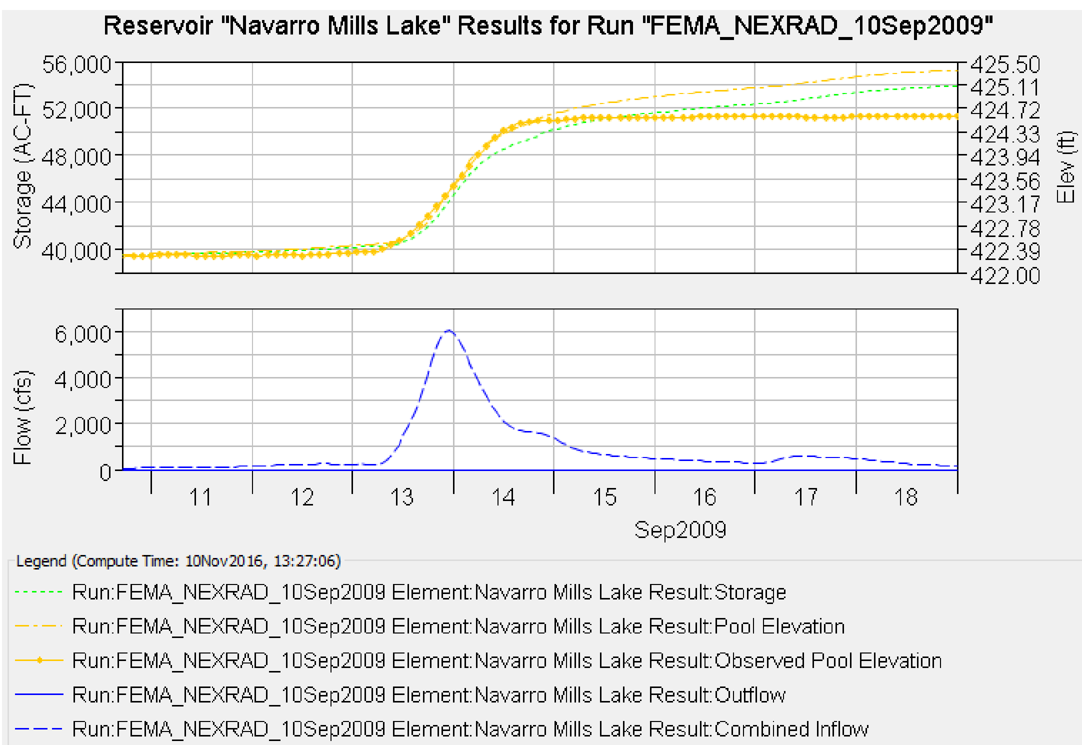

Figure 78a. September 2009 Calibration Results for Navarro Mills Reservoir

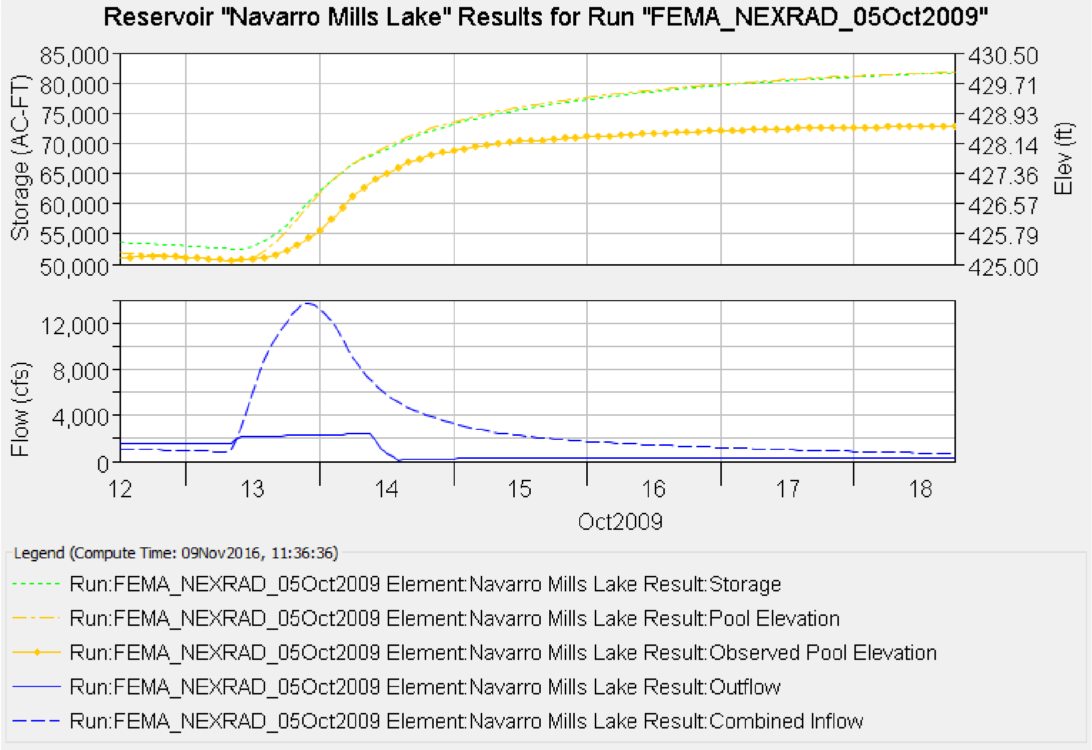

Figure 78b. October 2009 Calibration Results for Navarro Mills Reservoir

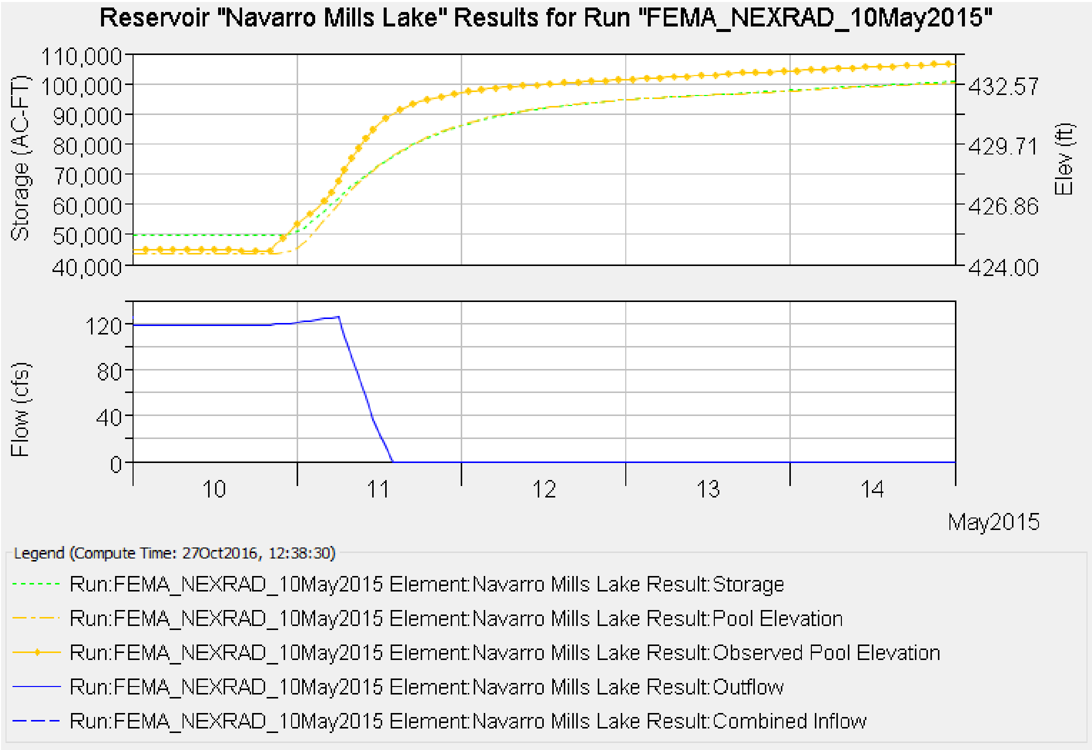

Figure 78c. May 2015 Calibration Results for Navarro Mills Reservoir

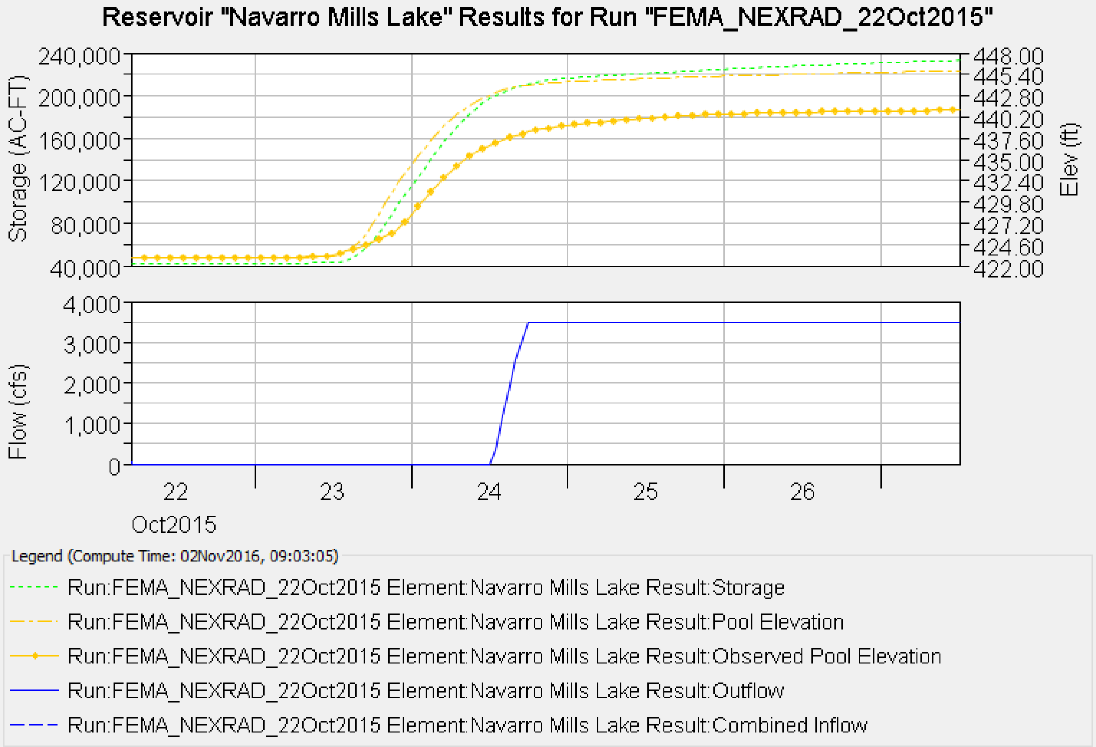

Figure 78d. October 2015 Calibration Results for Navarro Mills Reservoir

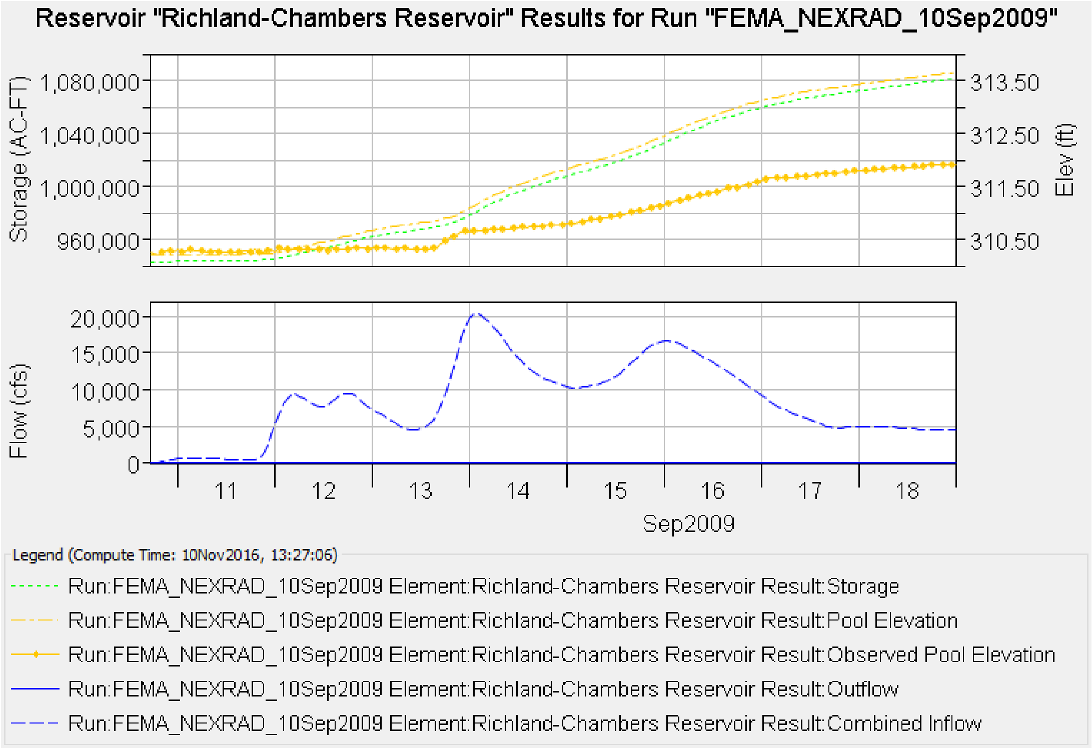

Figure 79a. September 2009 Calibration Results for Richland-Chambers Reservoir

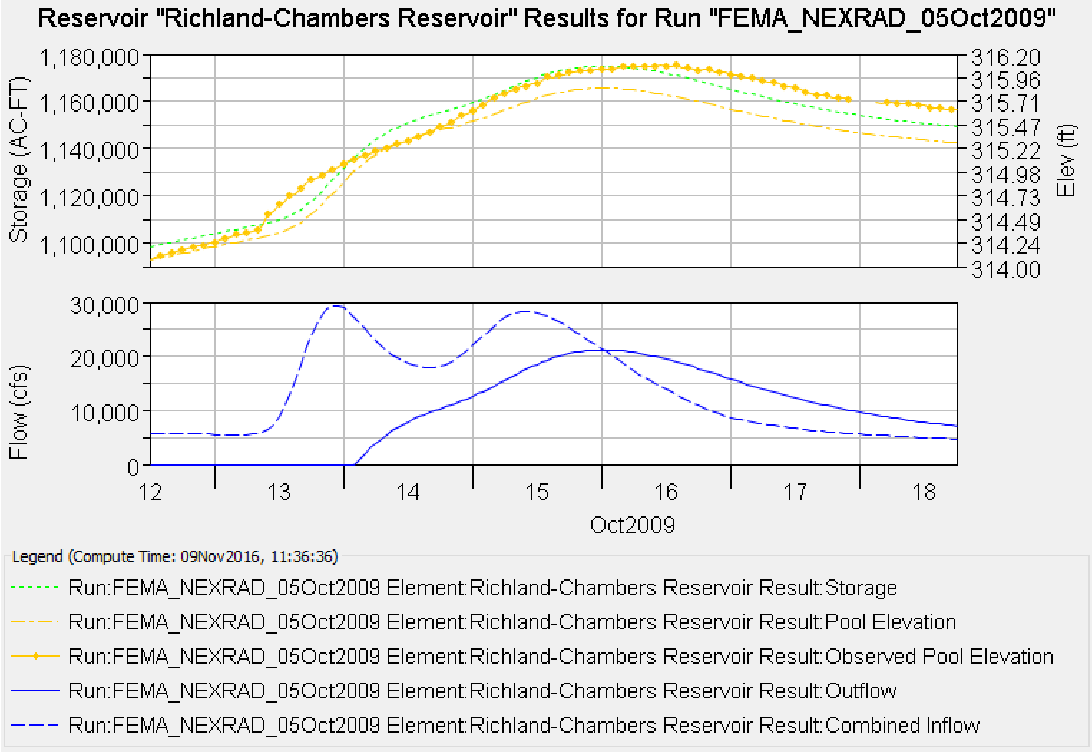

Figure 79b. October 2009 Calibration Results for Richland-Chambers Reservoir

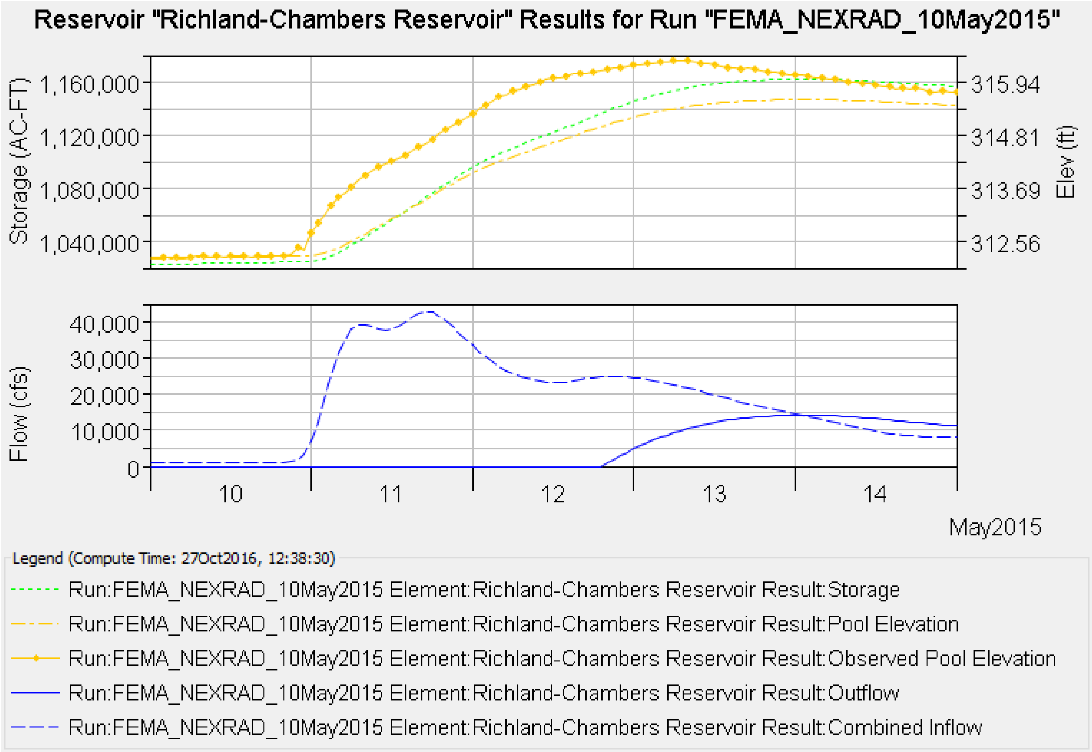

Figure 79c. May 2015 Calibration Results for Richland-Chambers Reservoir

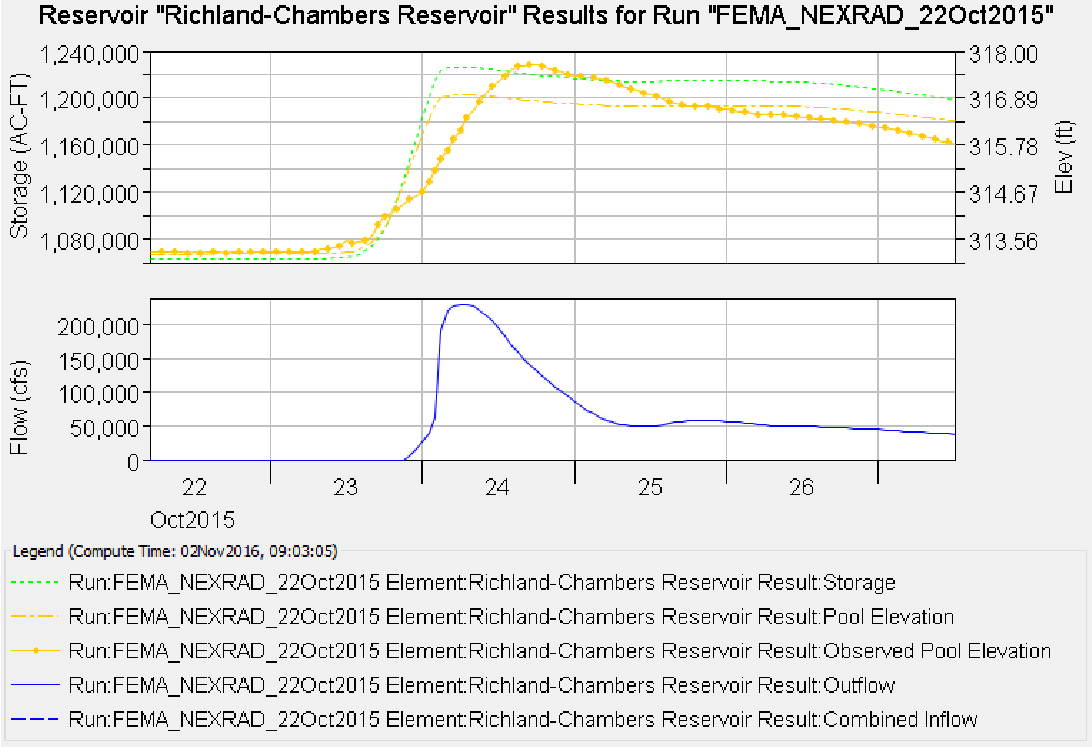

Figure 79d. October 2015 Calibration Results for Richland-Chambers Reservoir

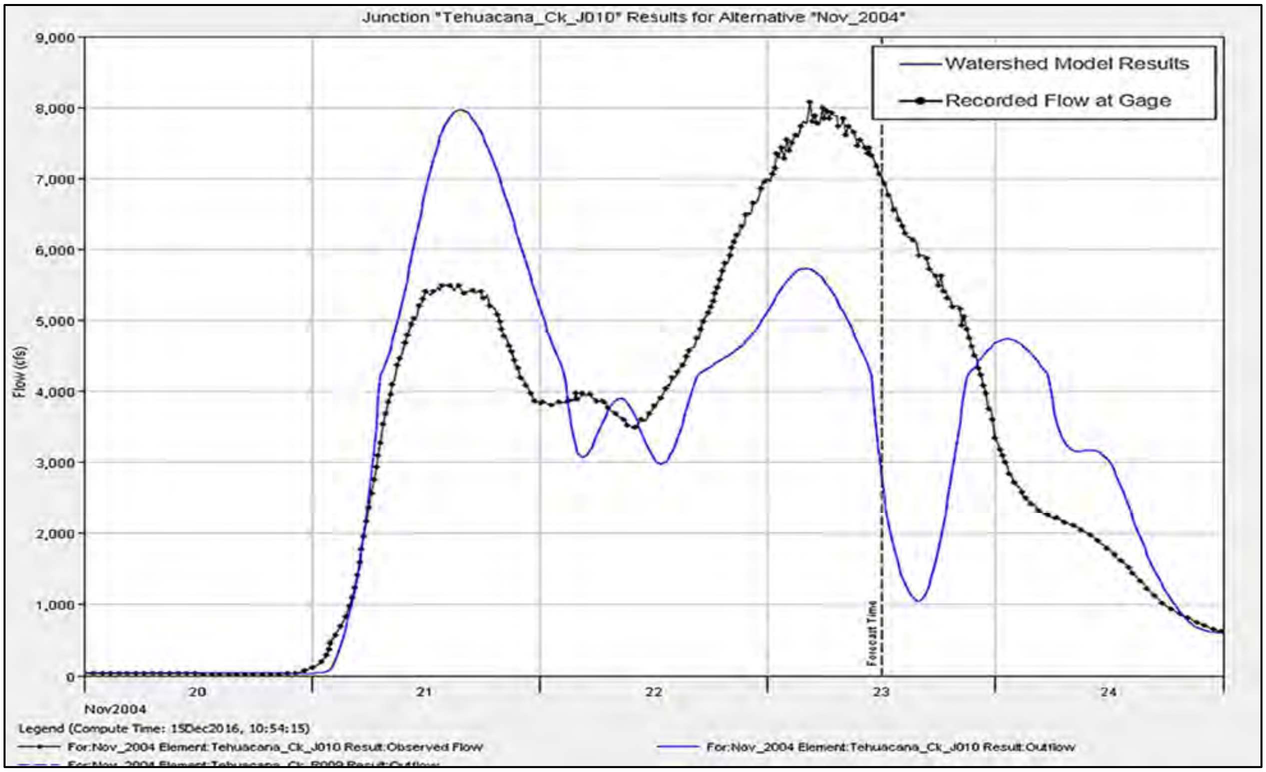

Figure 80a. November 23, 2004 Calibration for the Tehuacana Creek near Streetman, TX Gage

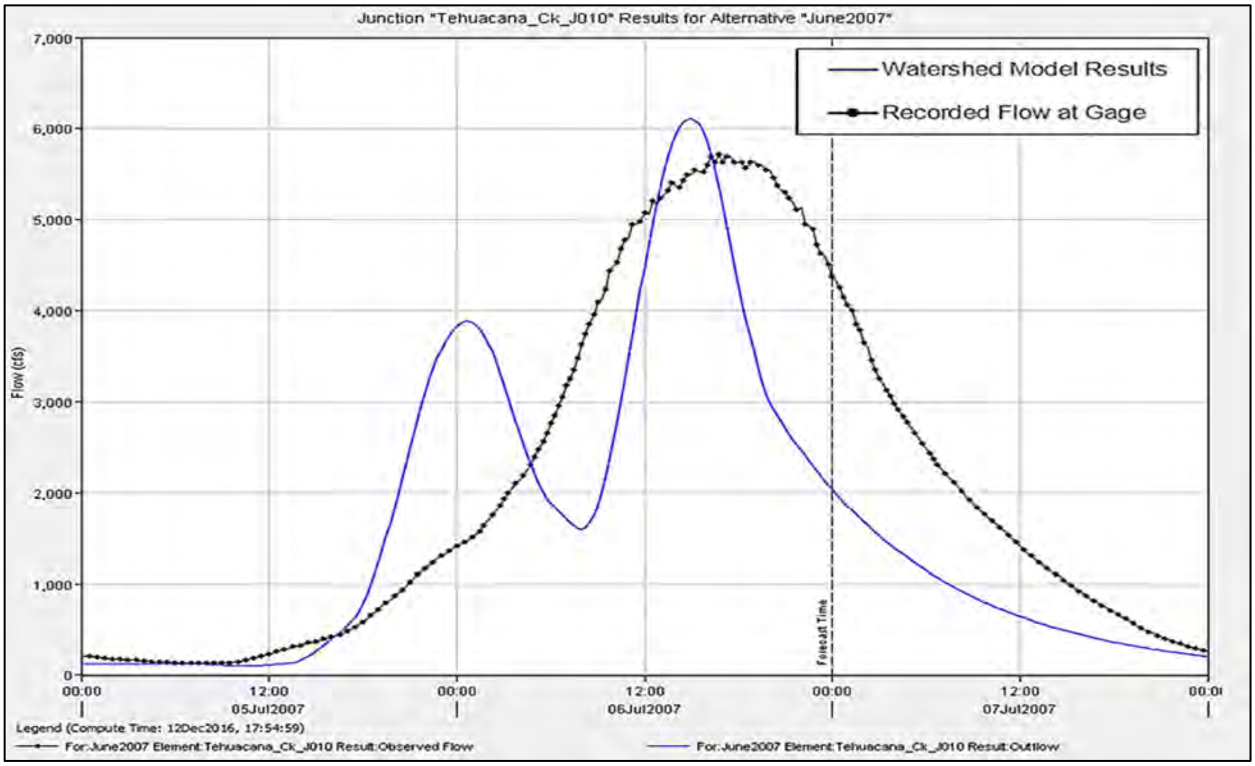

Figure 80b. July 6, 2007 Calibration for the Tehuacana Creek near Streetman, TX Gage

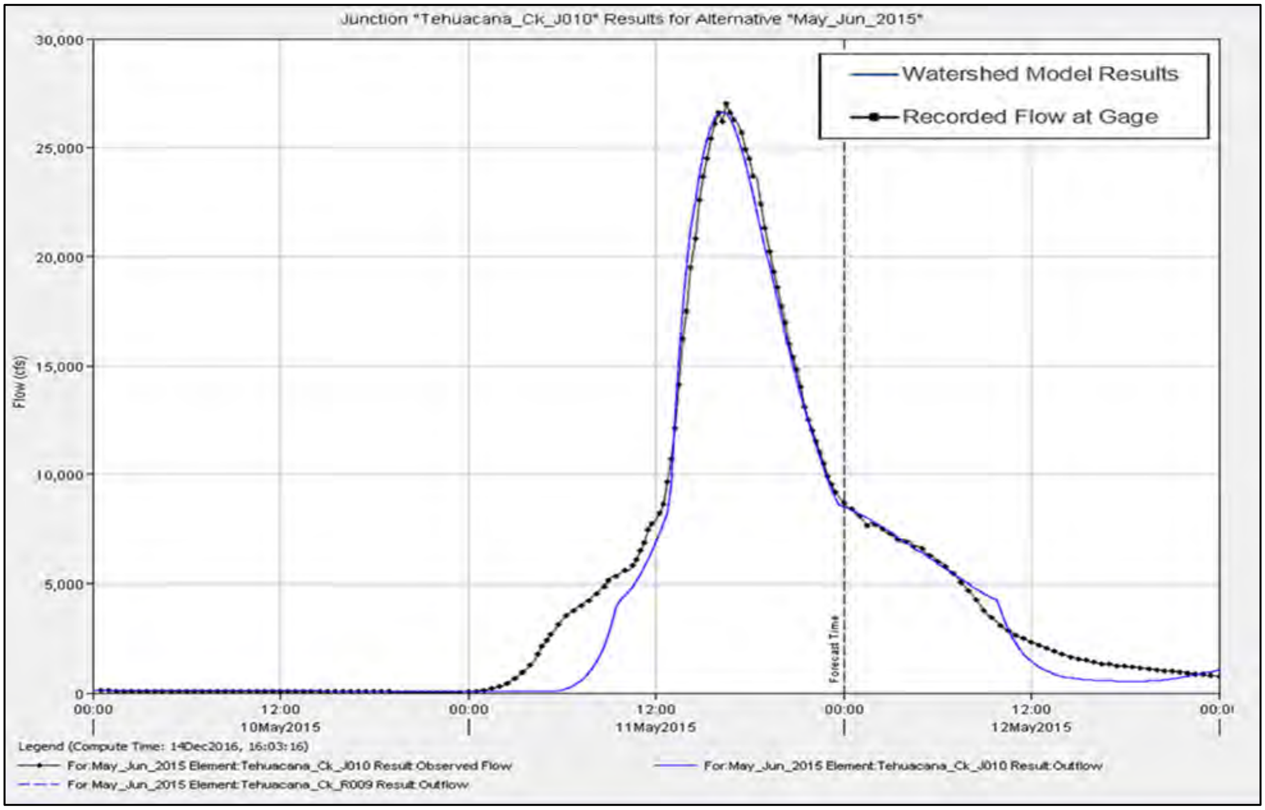

Figure 80c. May 11, 2015 Calibration for the Tehuacana Creek near Streetman, TX Gage

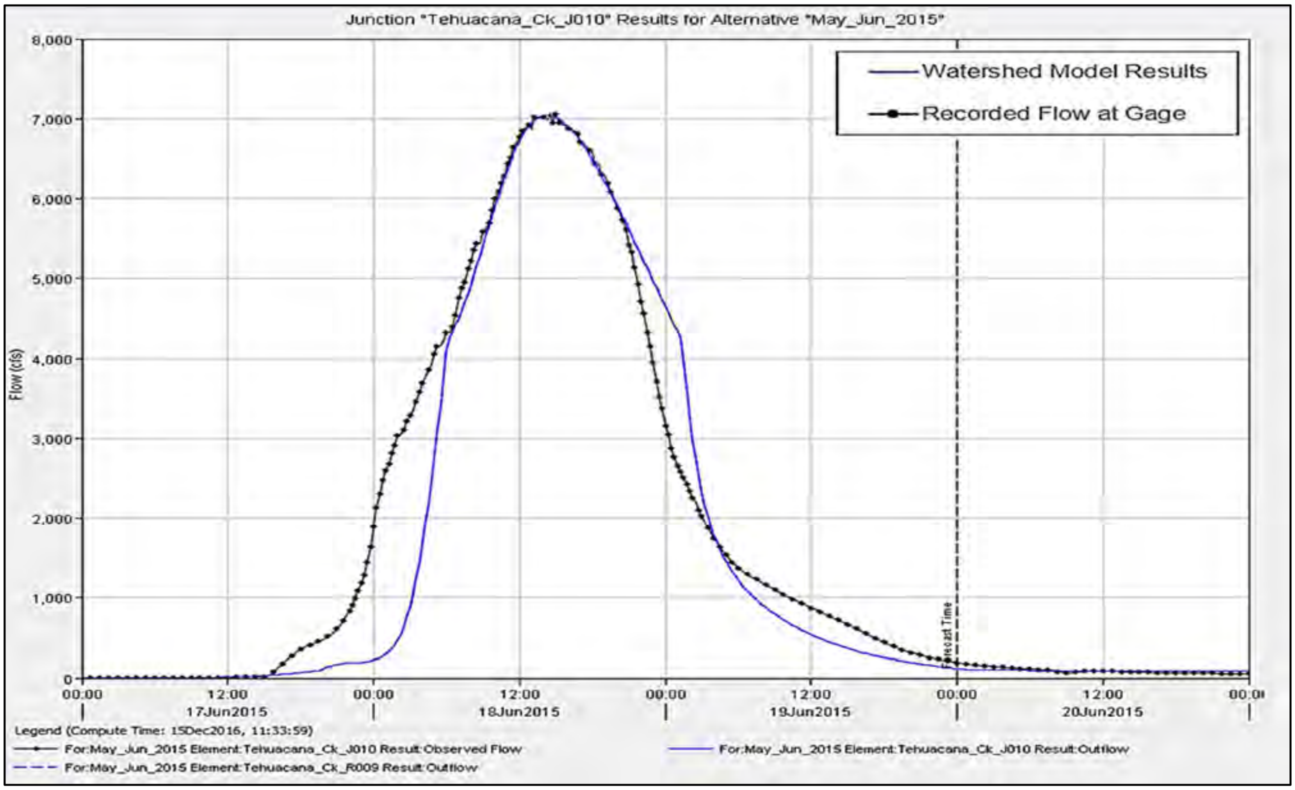

Figure 80d. June 18, 2015 Calibration for the Tehuacana Creek near Streetman, TX Gage

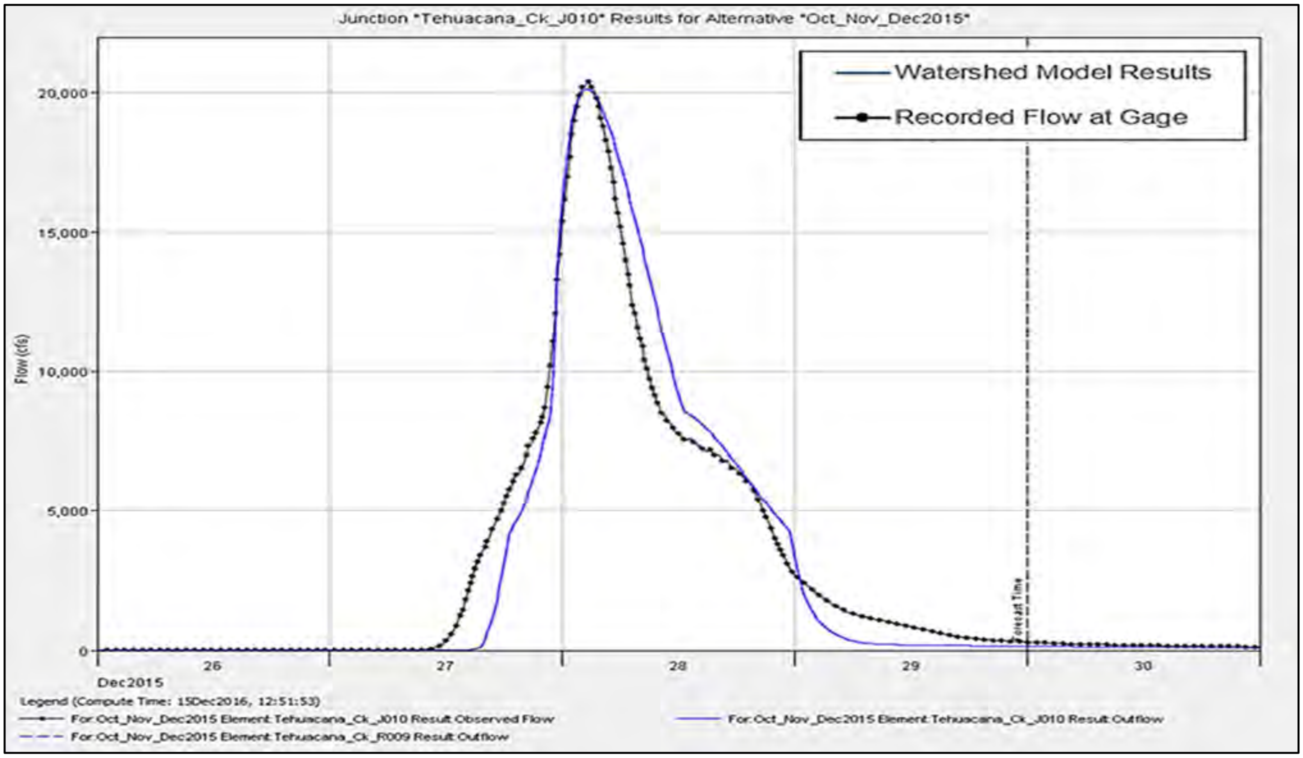

Figure 80e. December 28, 2015 Calibration for the Tehuacana Creek near Streetman, TX Gage

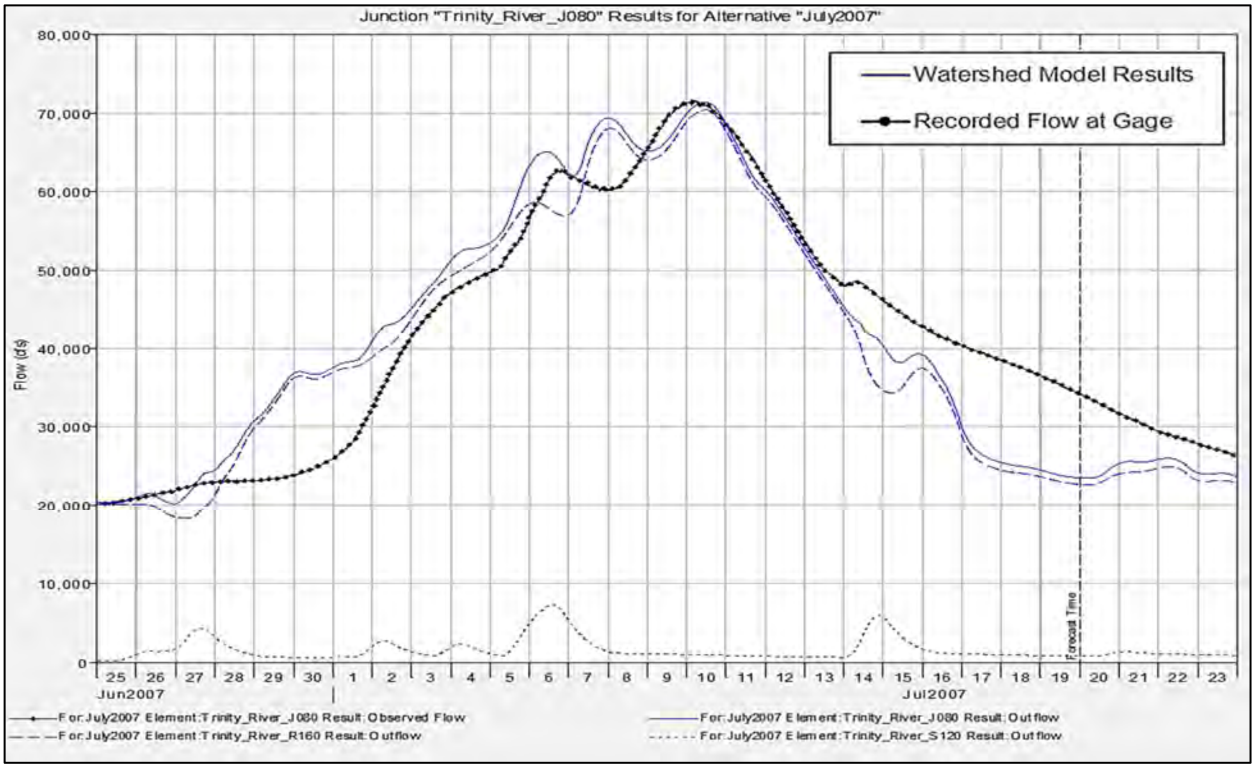

Figure 81a. July 9, 2007 Calibration for the Trinity River near Oakwood, TX Gage

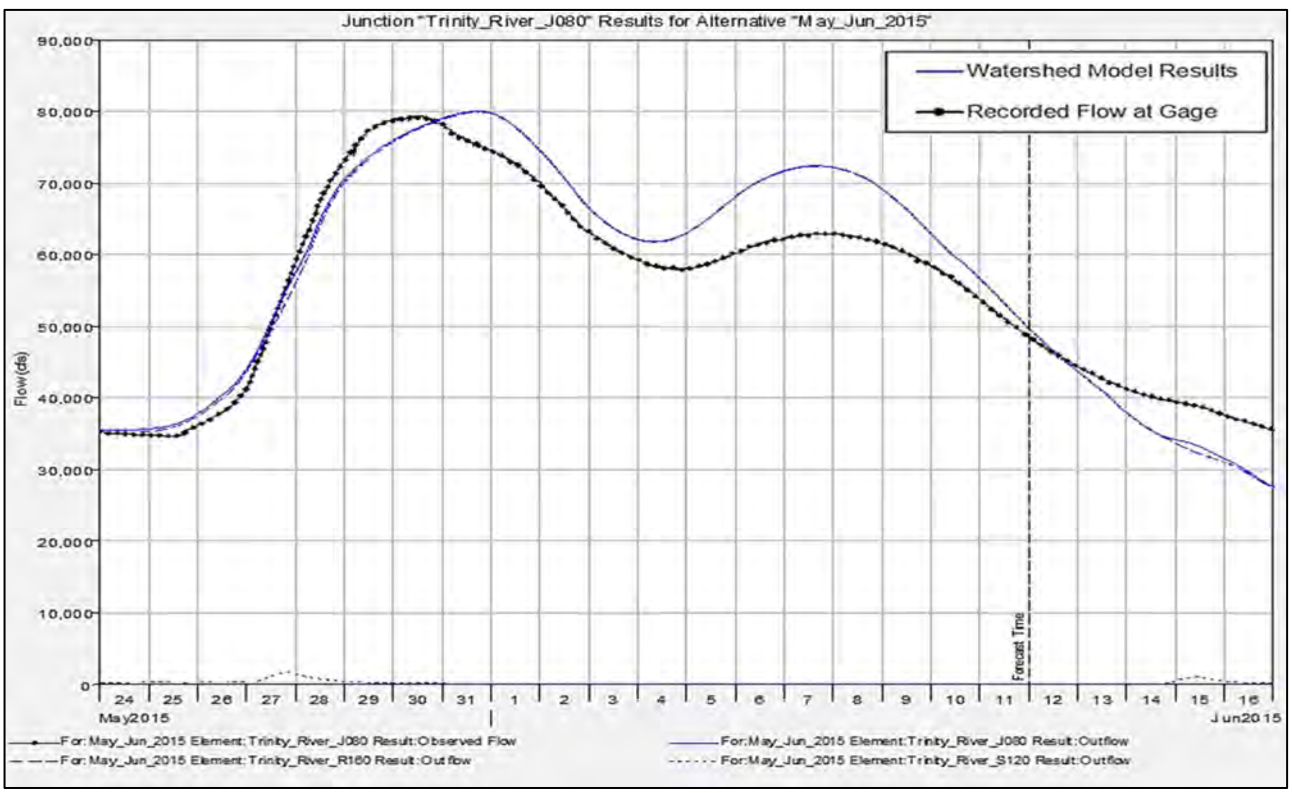

Figure 81b. May 29, 2015 Calibration for the Trinity River near Oakwood, TX Gage

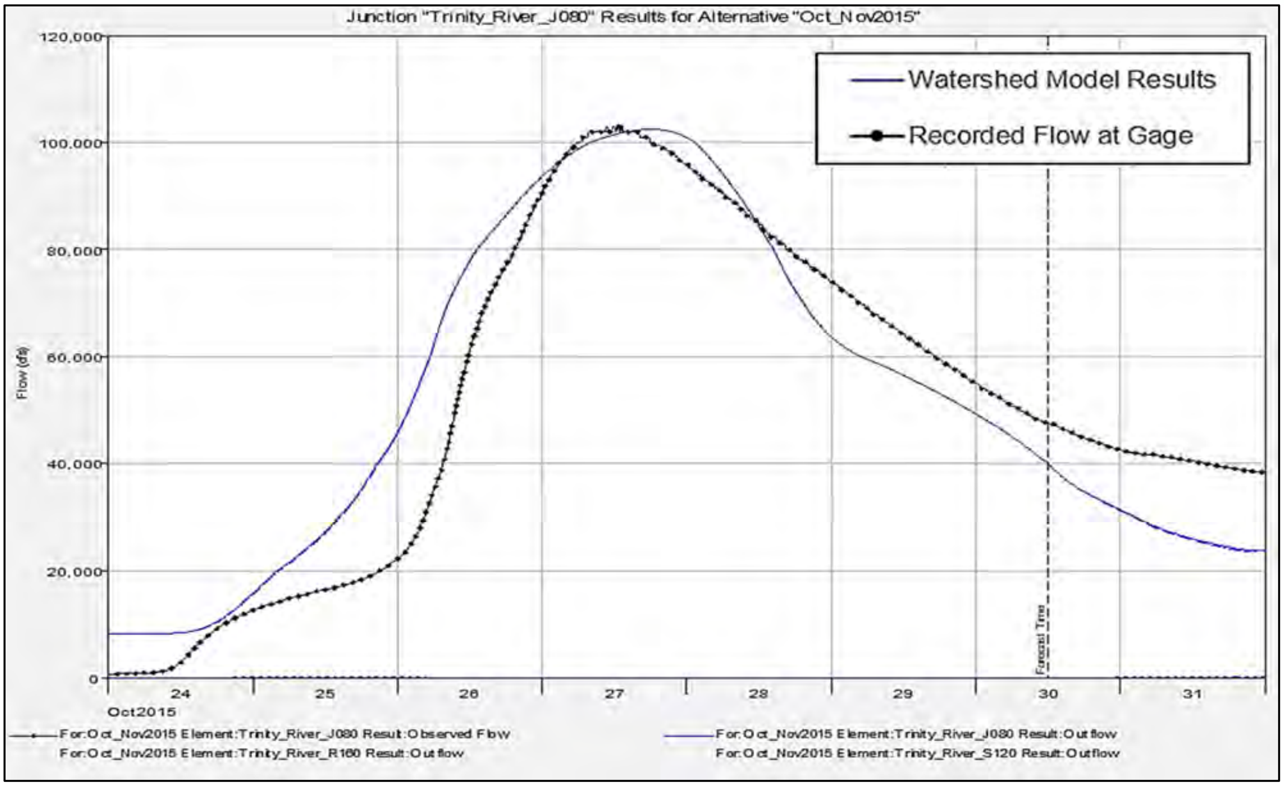

Figure 81c. October 27, 2015 Calibration for the Trinity River near Oakwood, TX Gage

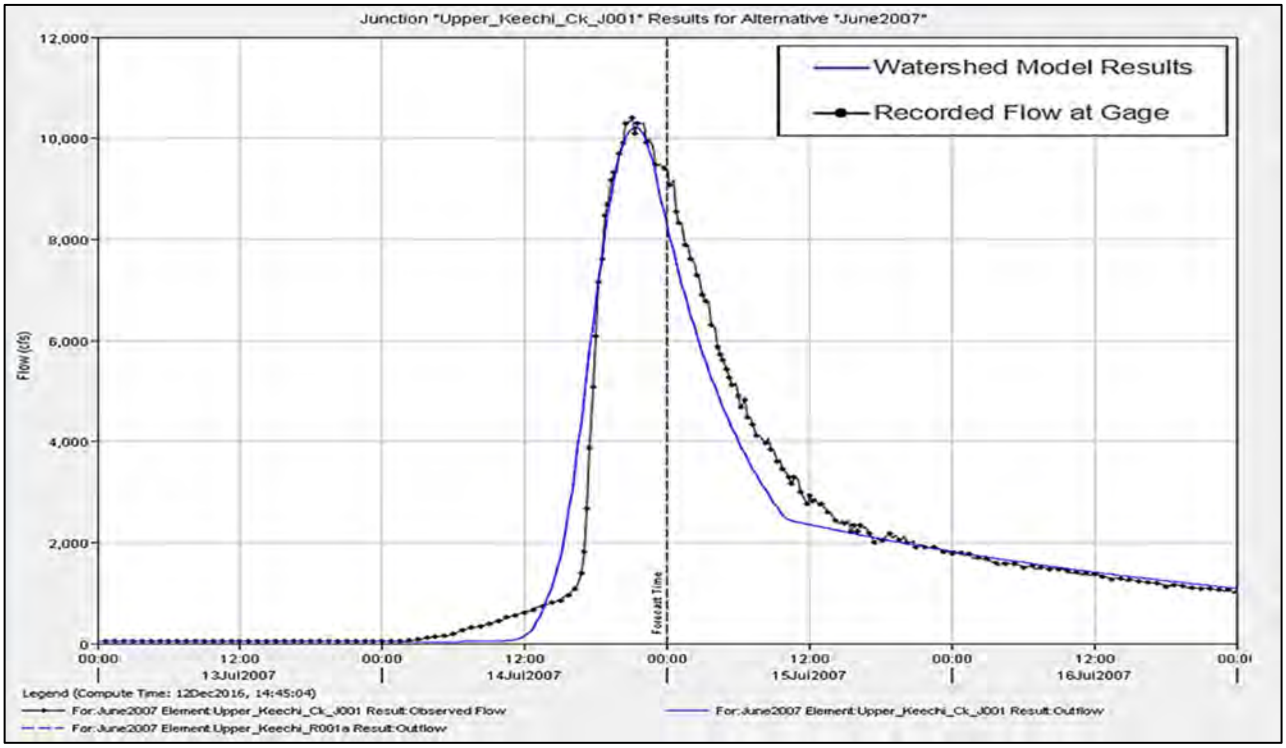

Figure 82a. July 14, 2007 Calibration for the Upper Keechi Creek near Oakwood, TX Gage

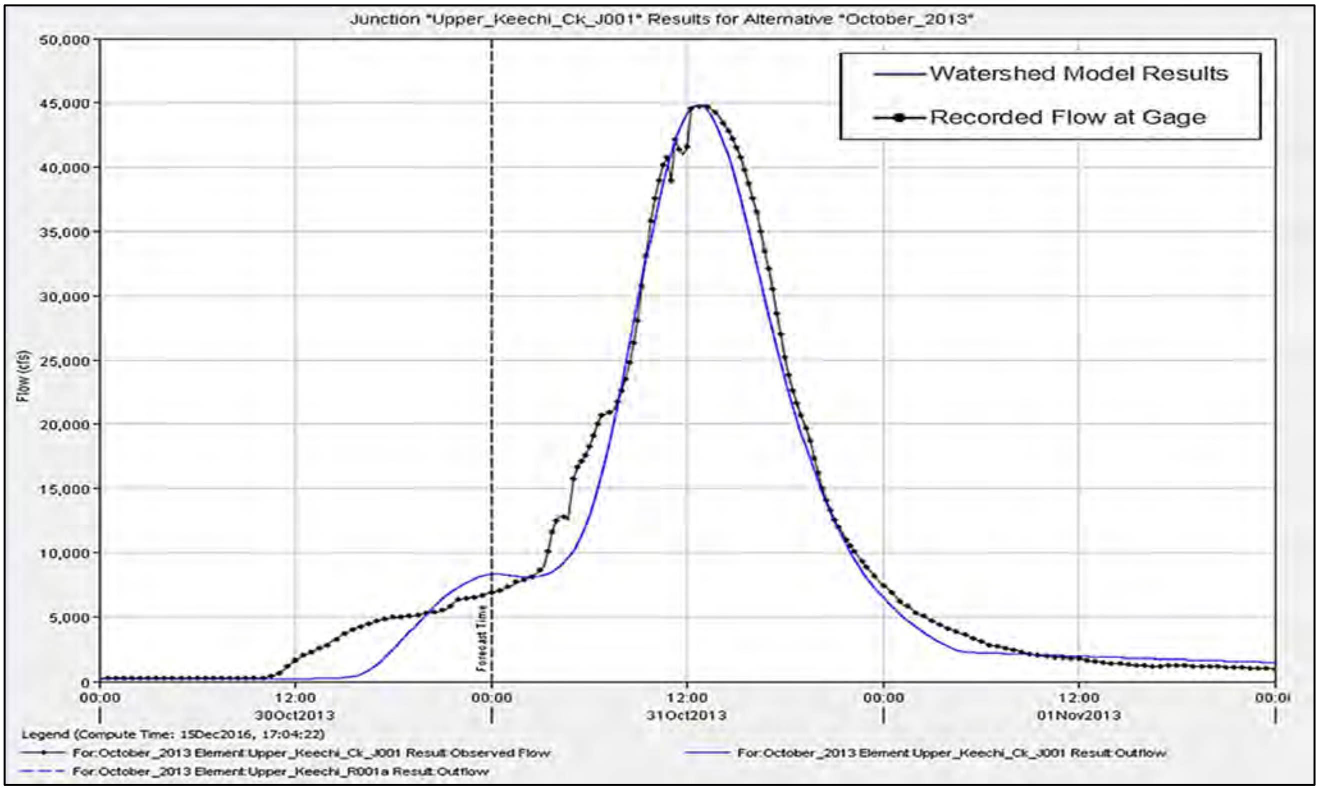

Figure 82b. October 31, 2013 Calibration for the Upper Keechi Creek near Oakwood, TX Gage

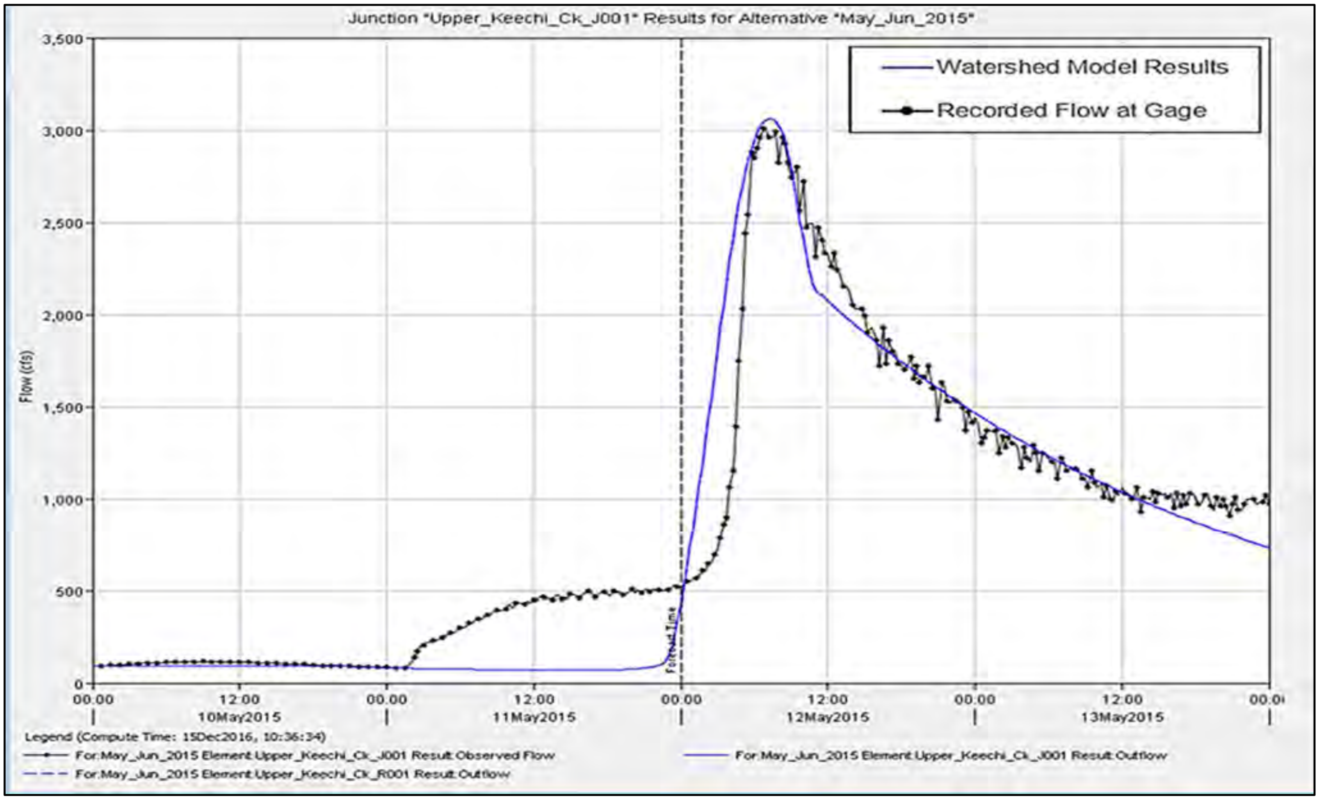

Figure 82c. May 12, 2015 Calibration for the Upper Keechi Creek near Oakwood, TX Gage

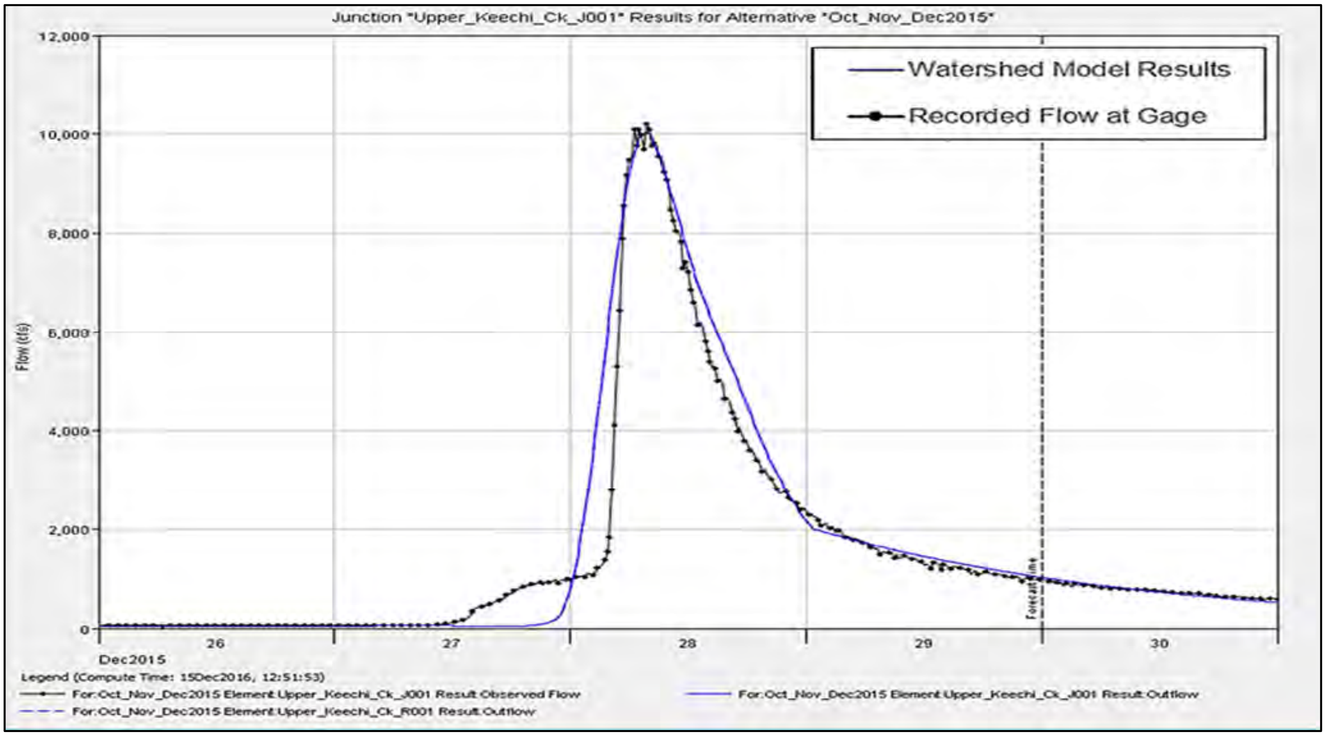

Figure 82d. December 28, 2015 Calibration for the Upper Keechi Creek near Oakwood, TX Gage

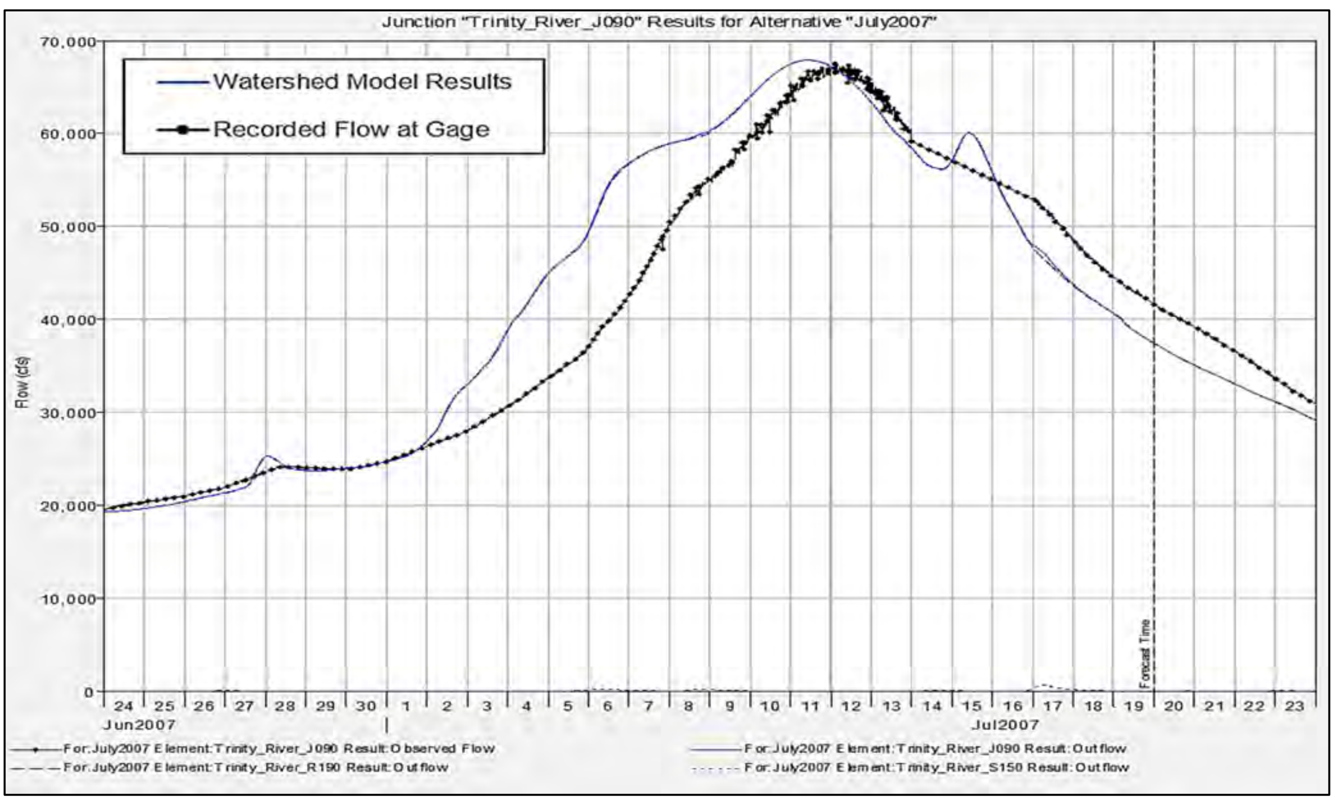

Figure 83a. July 11, 2007 Calibration for the Trinity River near Crockett, TX Gage

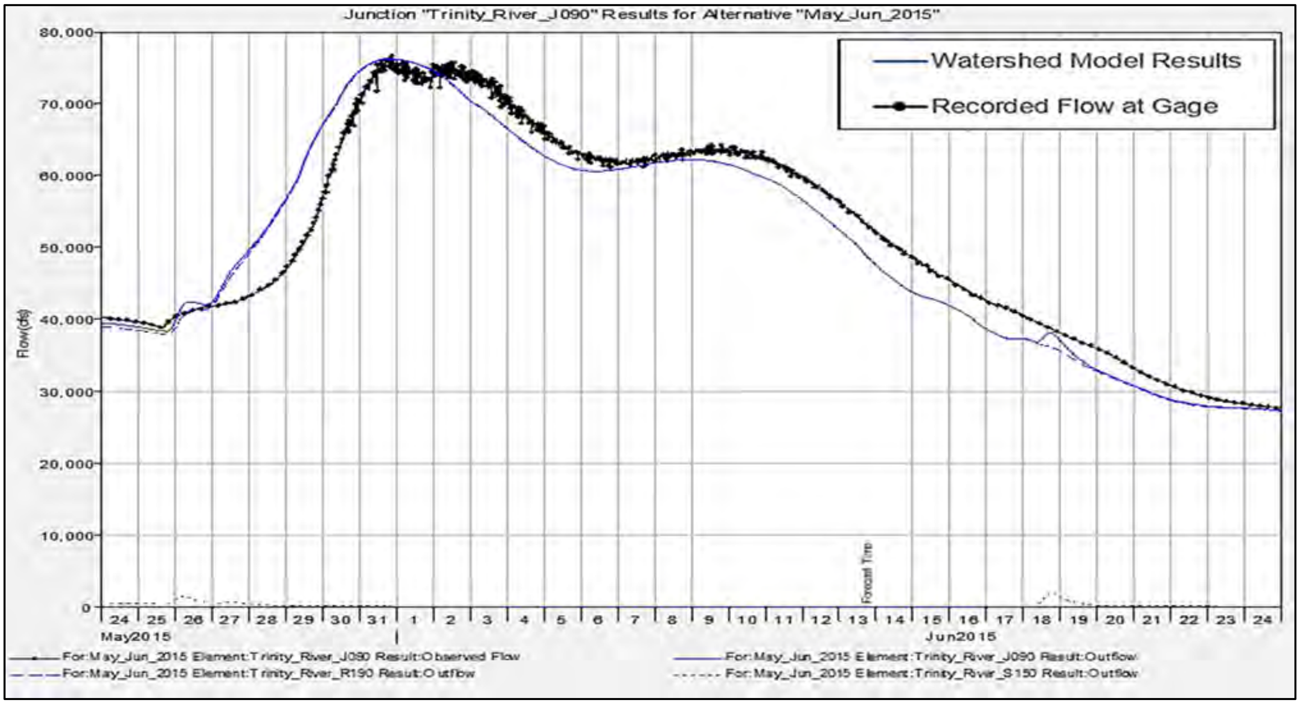

Figure 83b. May 31, 2015 Calibration for the Trinity River near Crockett, TX Gage

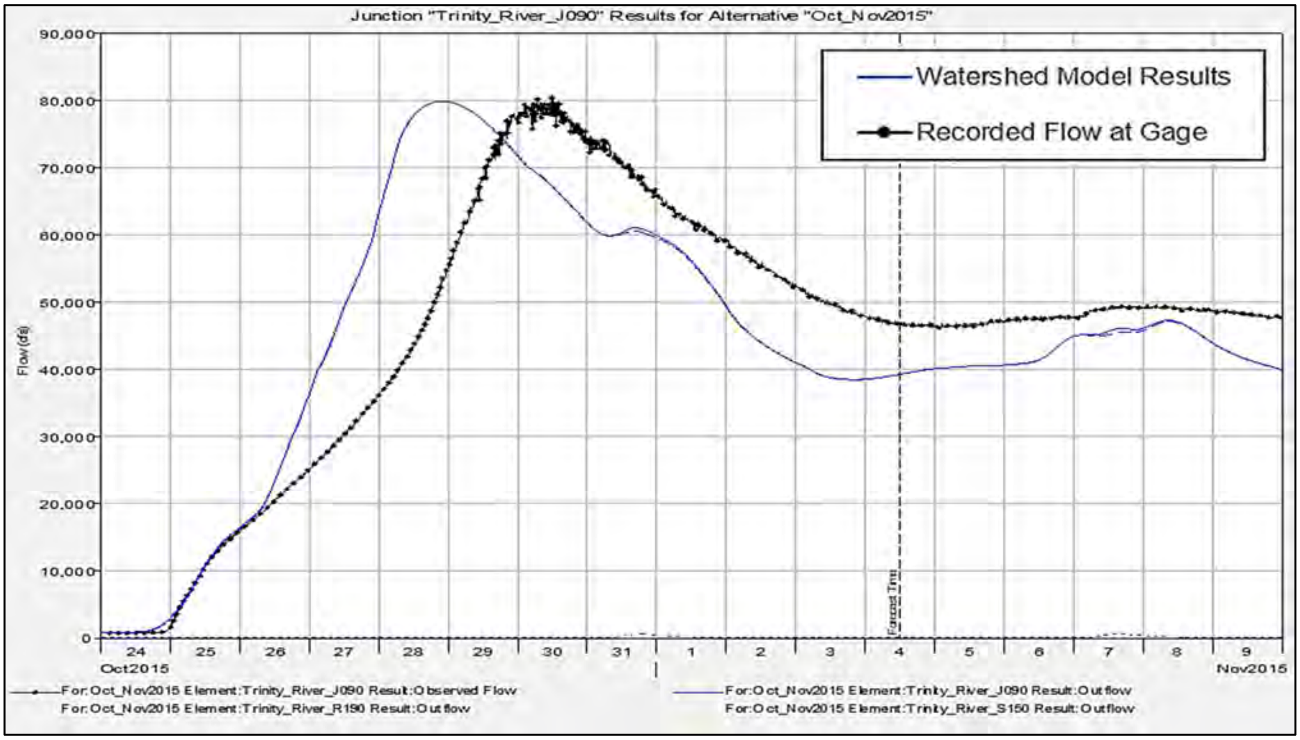

Figure 83c. October 29, 2015 Calibration for the Trinity River near Crockett, TX Gage

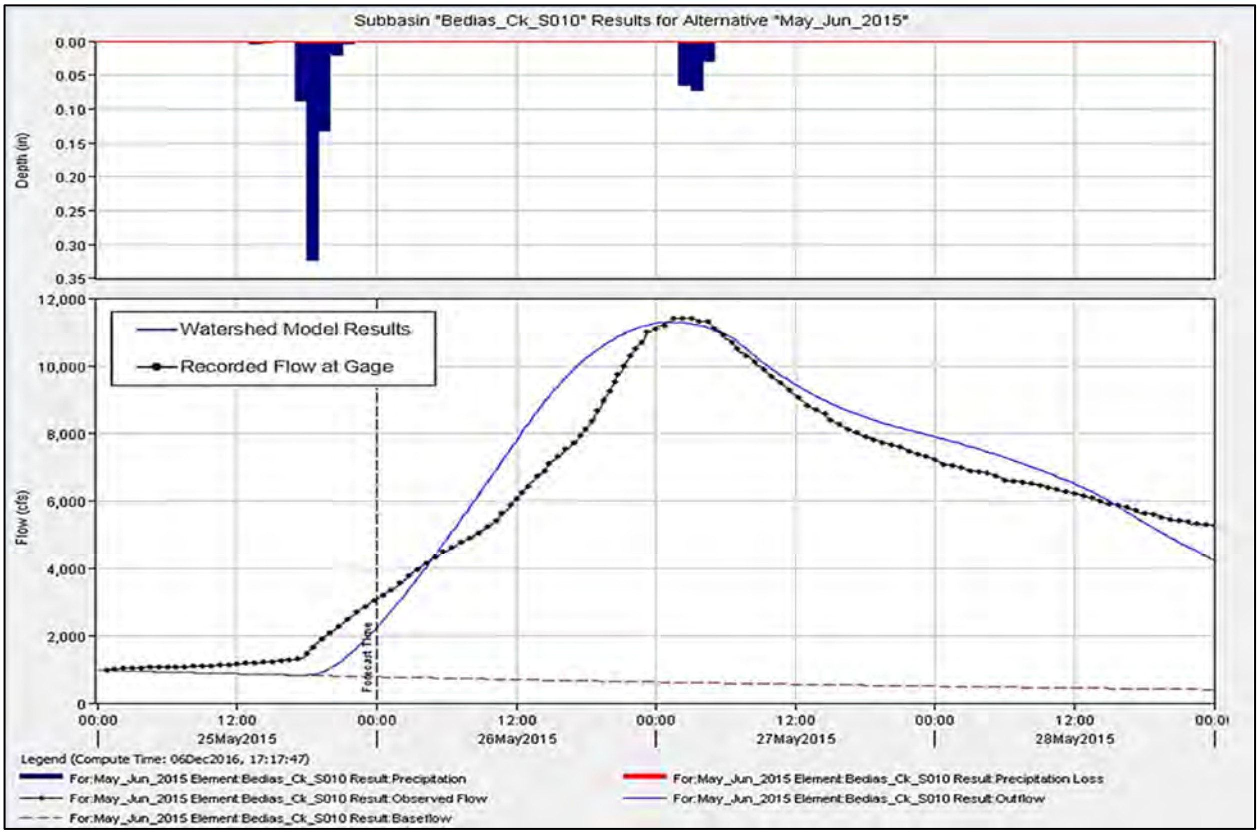

Figure 84a. May 26, 2015 Calibration for the Bedias Creek near Madisonville, TX Gage

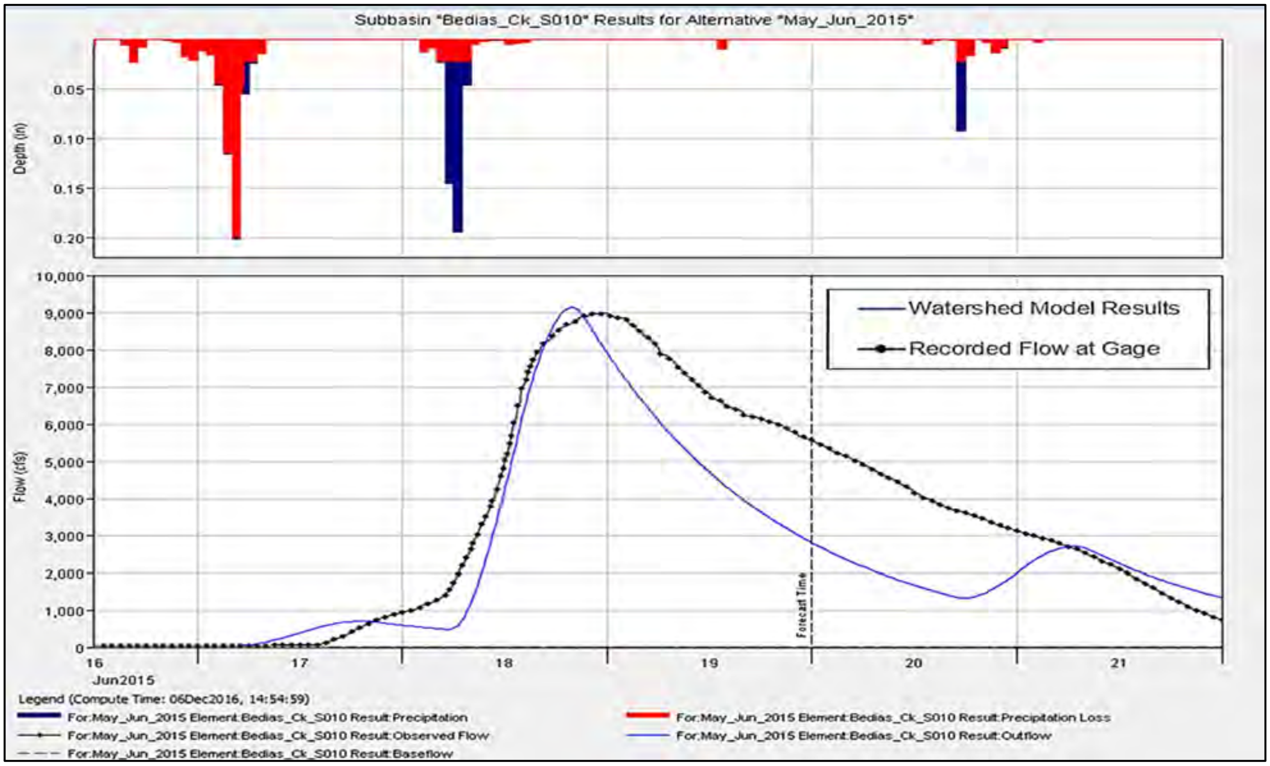

Figure 84b. June 18, 2015 Calibration for the Bedias Creek near Madisonville, TX Gage

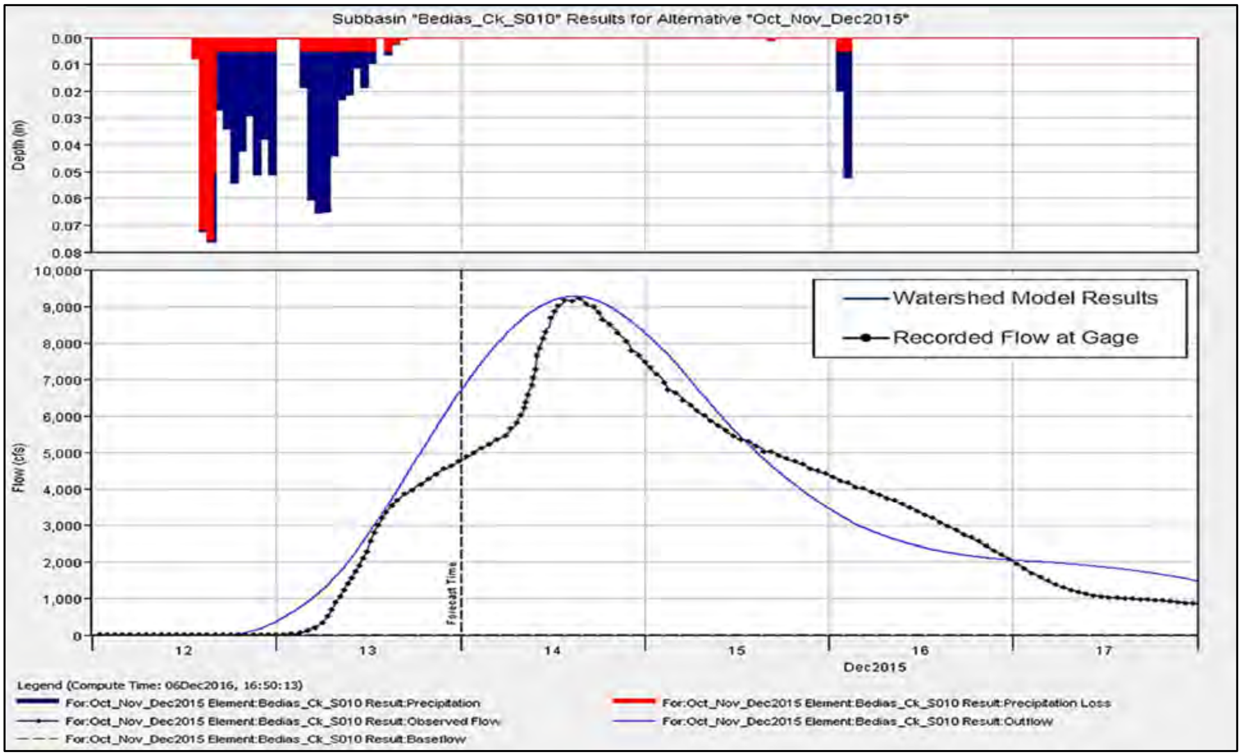

Figure 84c. December 14, 2015 Calibration for the Bedias Creek near Madisonville, TX Gage

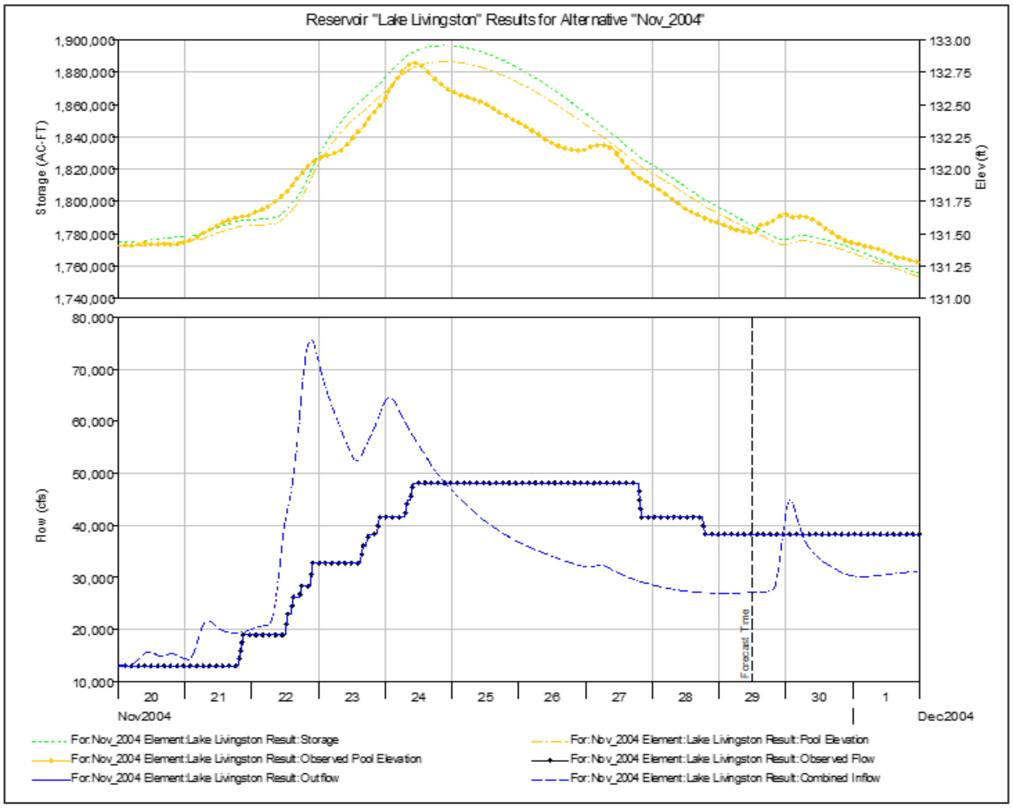

Figure 85a. November 2004 Calibration Results for Lake Livingston

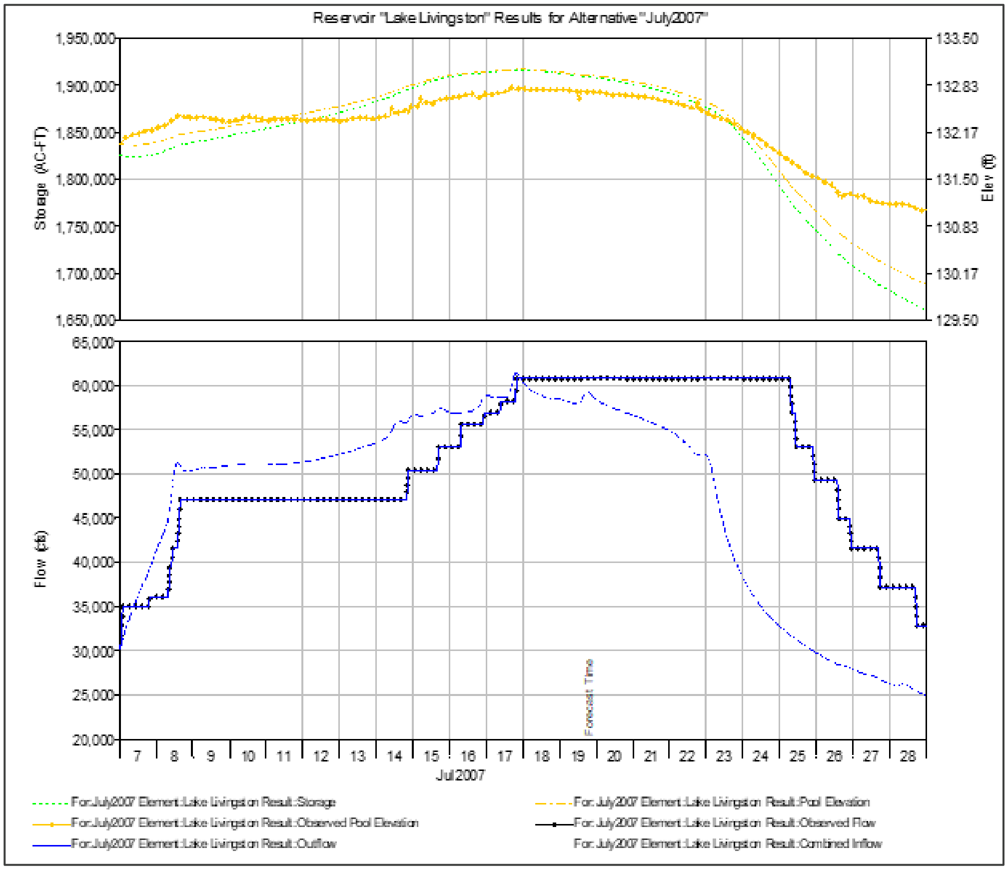

Figure 85b. July 2007 Calibration Results for Lake Livingston

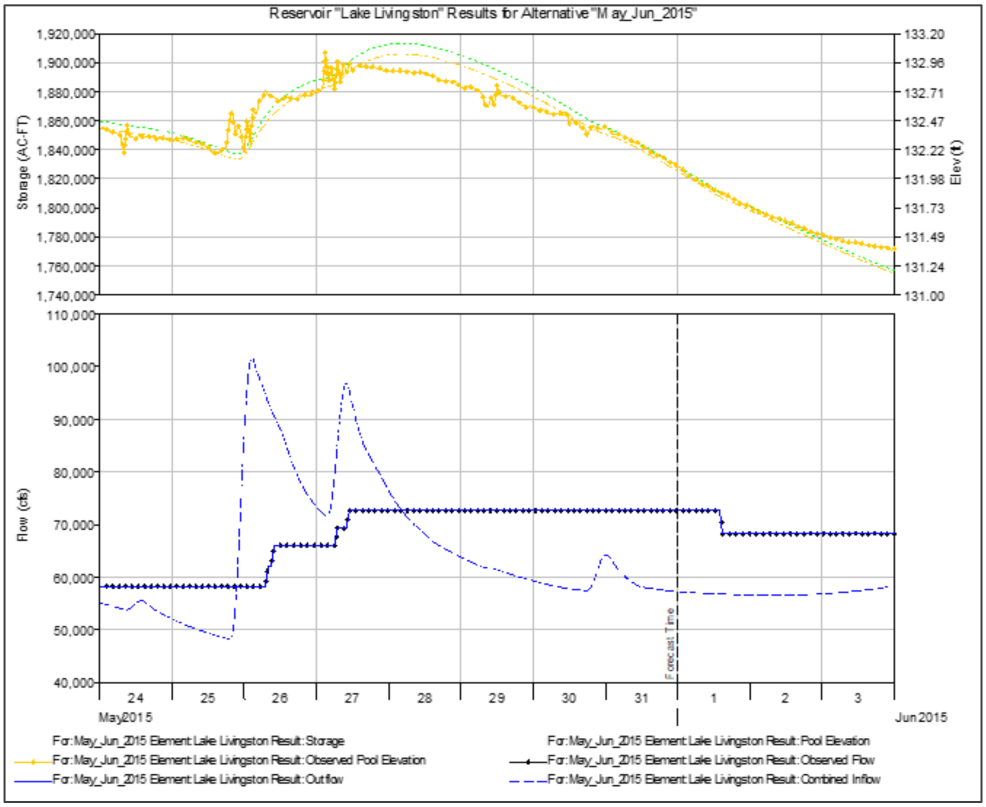

Figure 85c. May 2015 Calibration Results for Lake Livingston

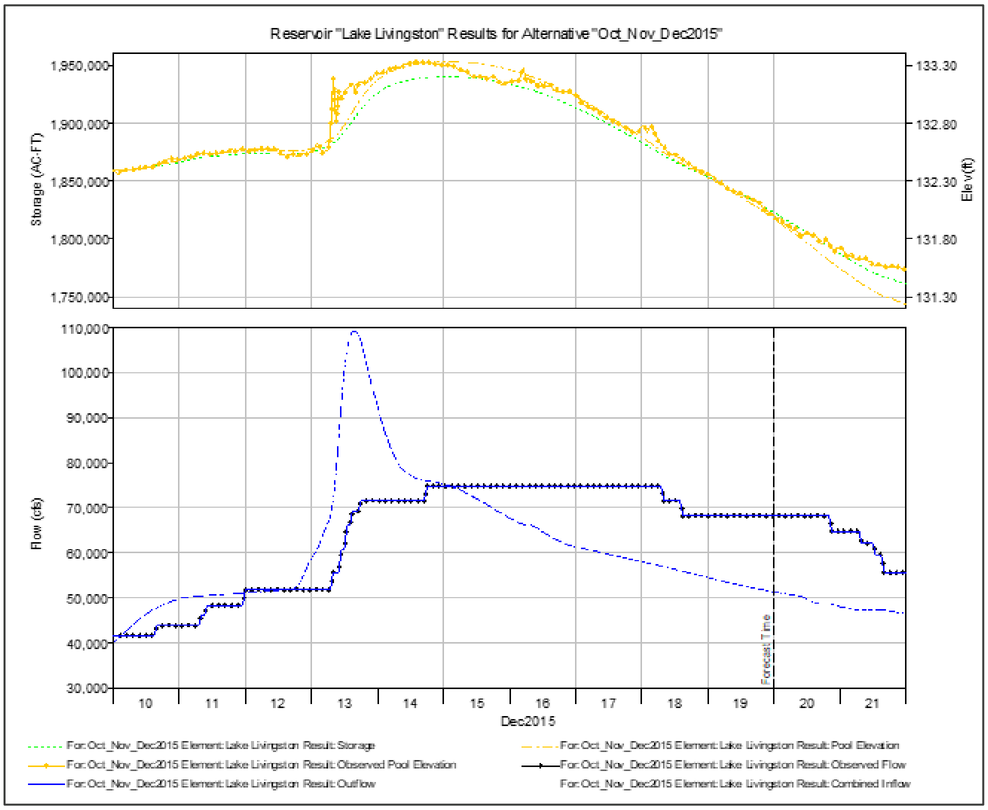

Figure 85d. December 2015 Calibration Results for Lake Livingston

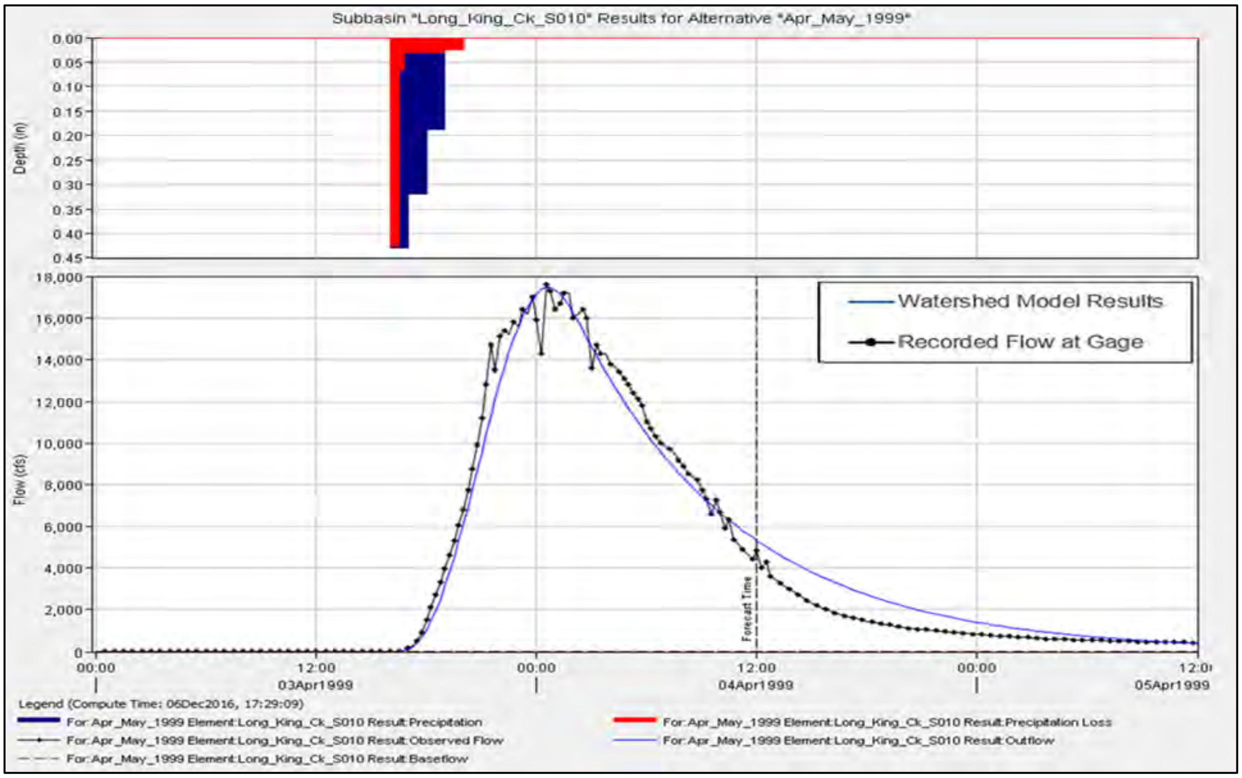

Figure 86a. April 4, 1999 Calibration for the Long King Creek at Livington, TX Gage

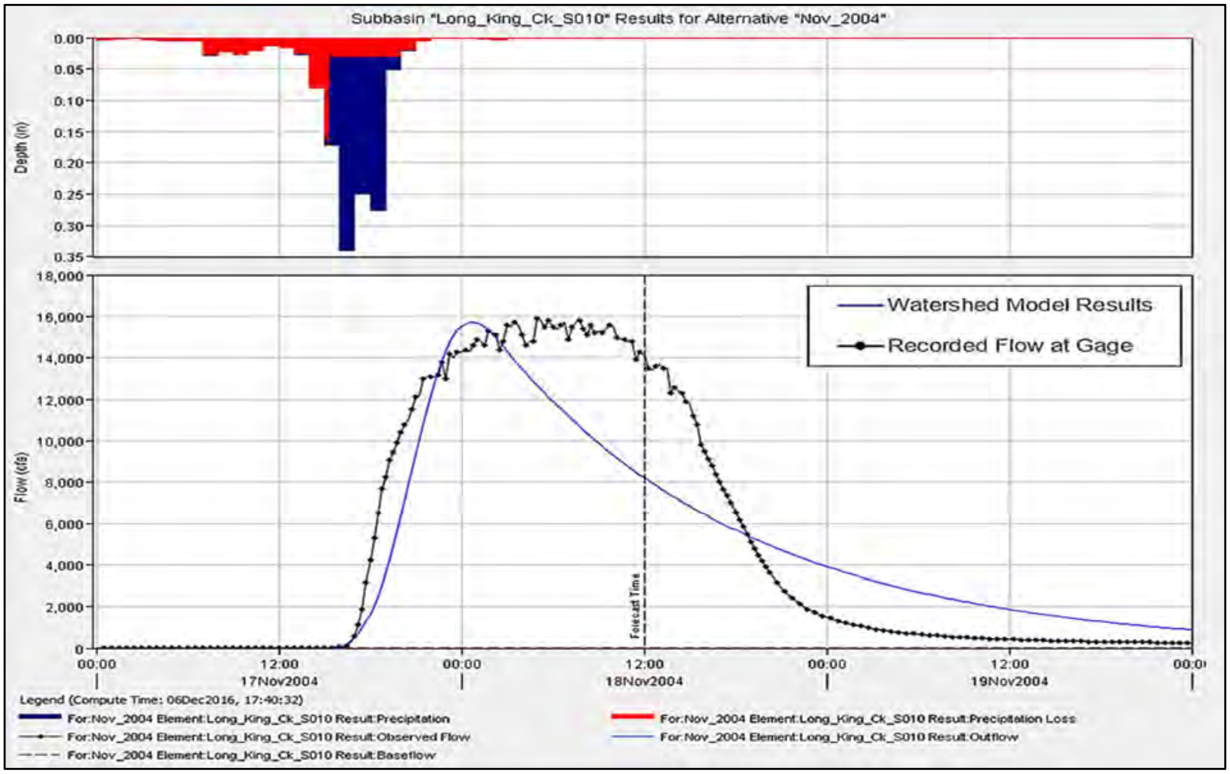

Figure 86b. November 17, 2004 Calibration for the Long King Creek at Livington, TX Gage

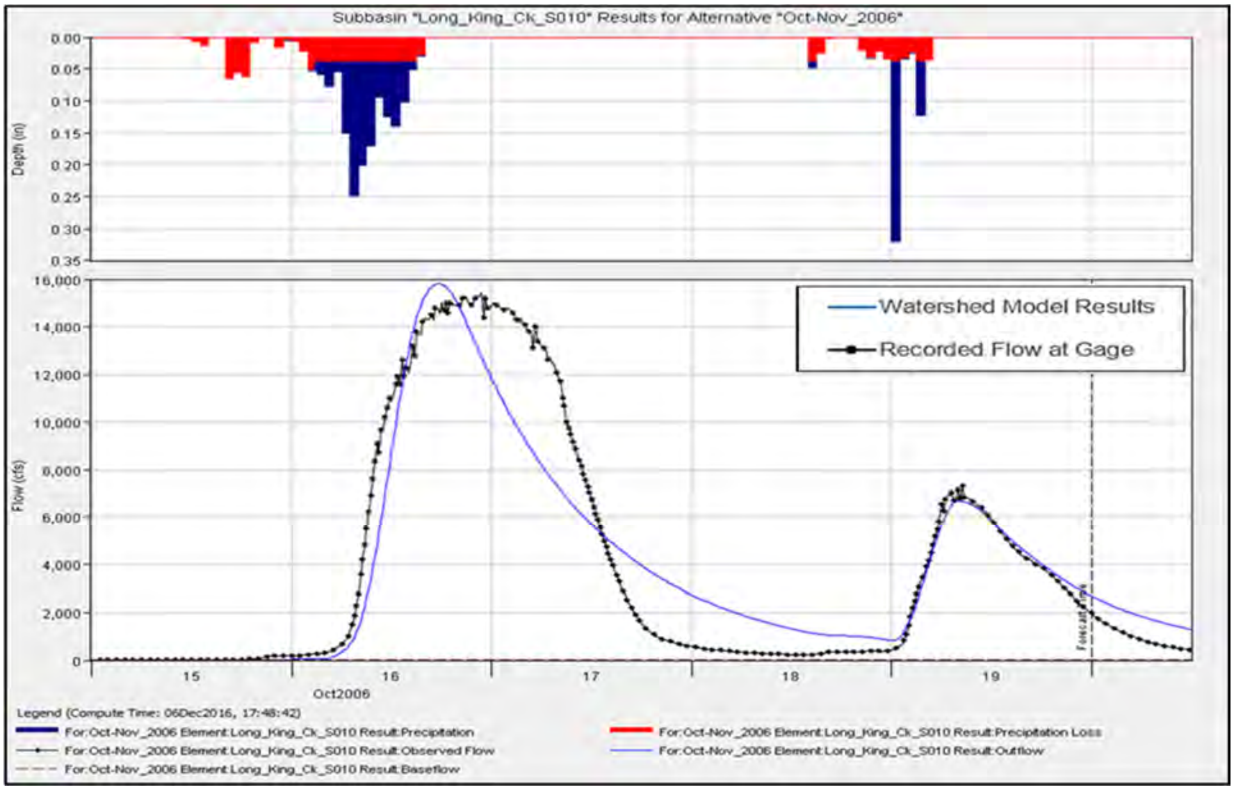

Figure 86c. October 16, 2006 Calibration for the Long King Creek at Livington, TX Gage

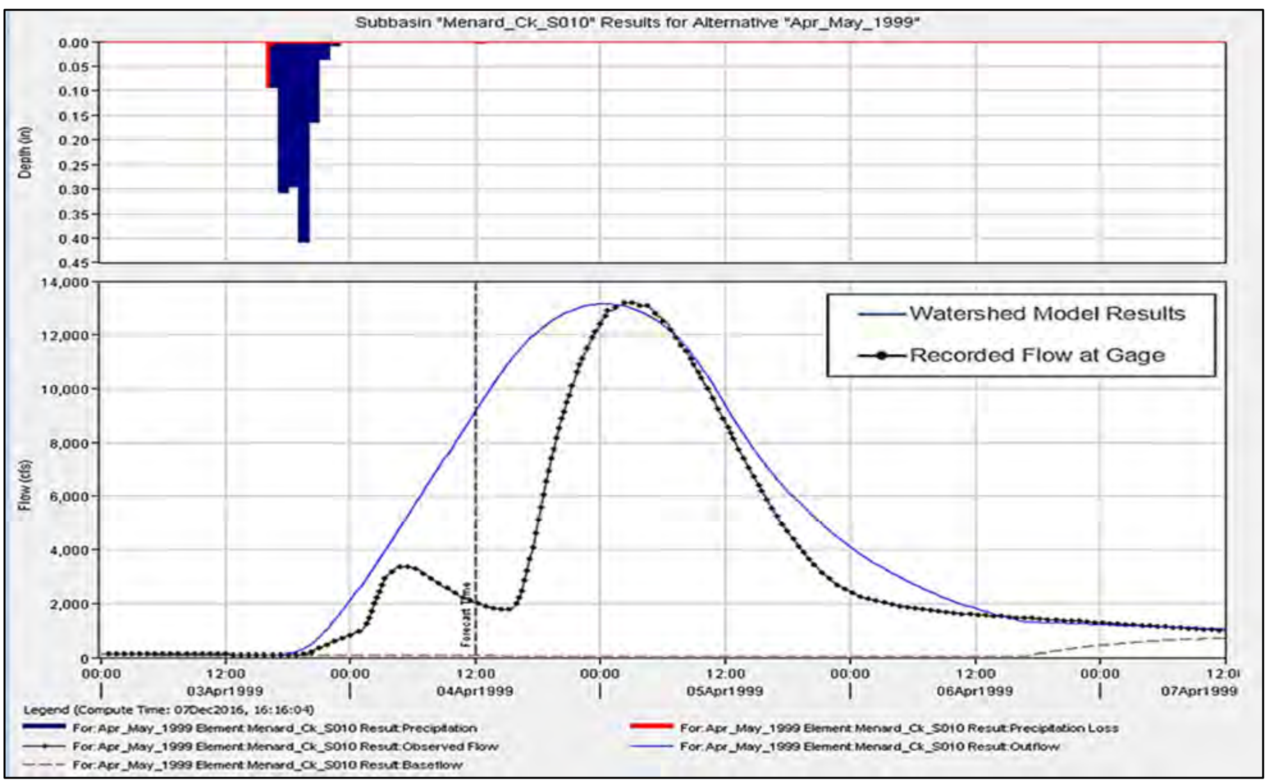

Figure 87a. April 4, 1999 Calibration for the Menard Creek near Rye, TX Gage

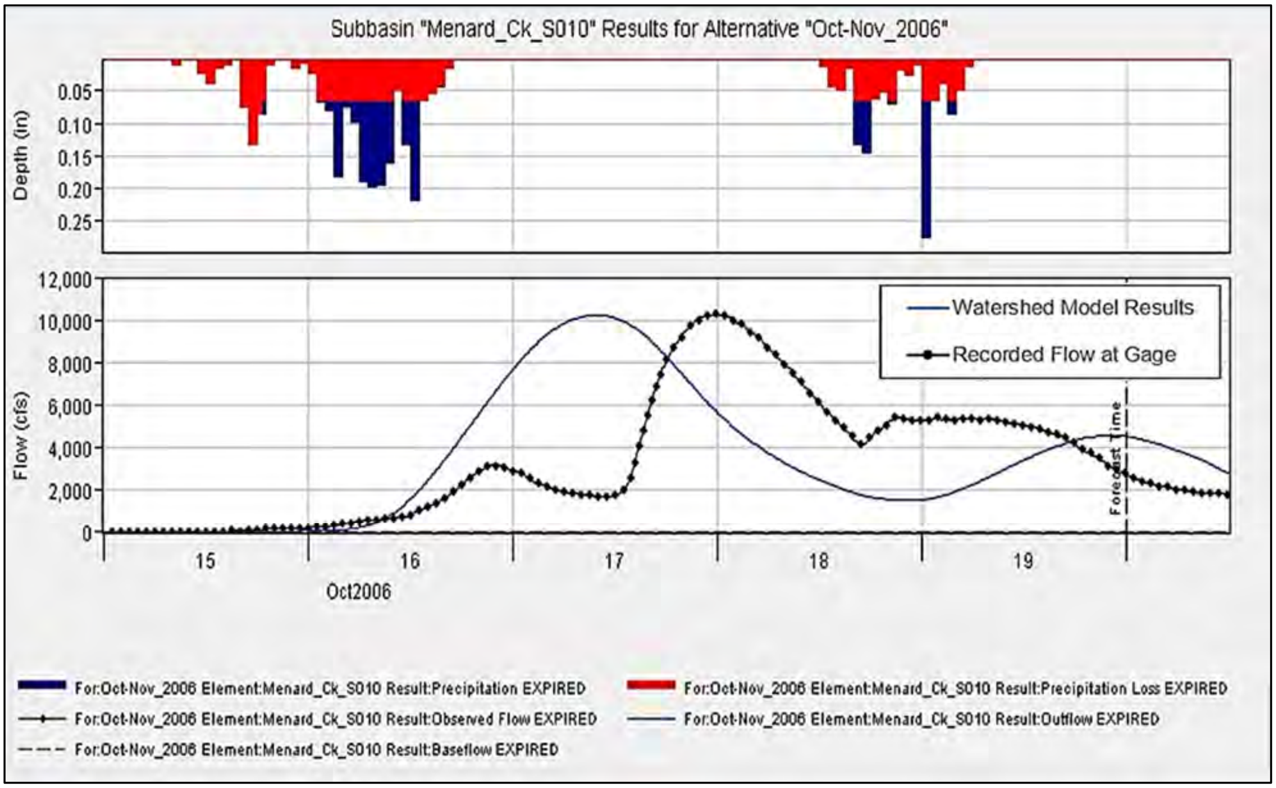

Figure 87b. October 17, 2006 Calibration for the Menard Creek near Rye, TX Gage

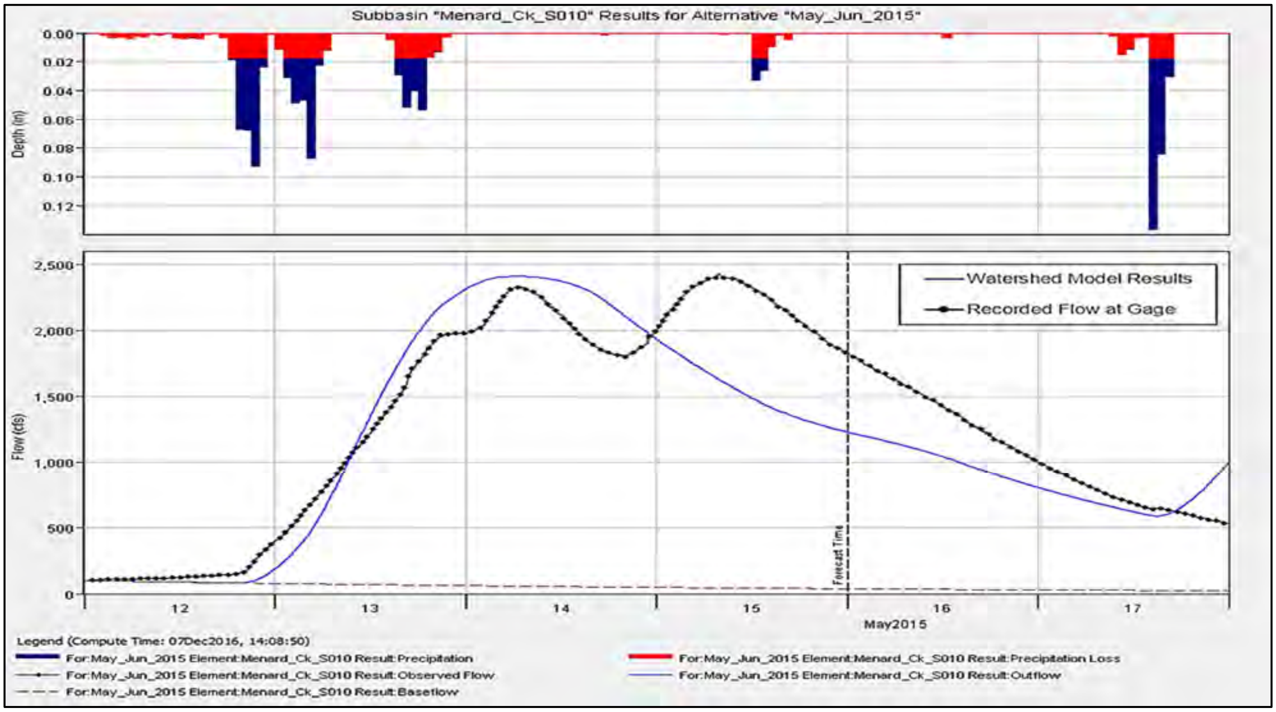

Figure 87c. May 13, 2015 Calibration for the Menard Creek near Rye, TX Gage

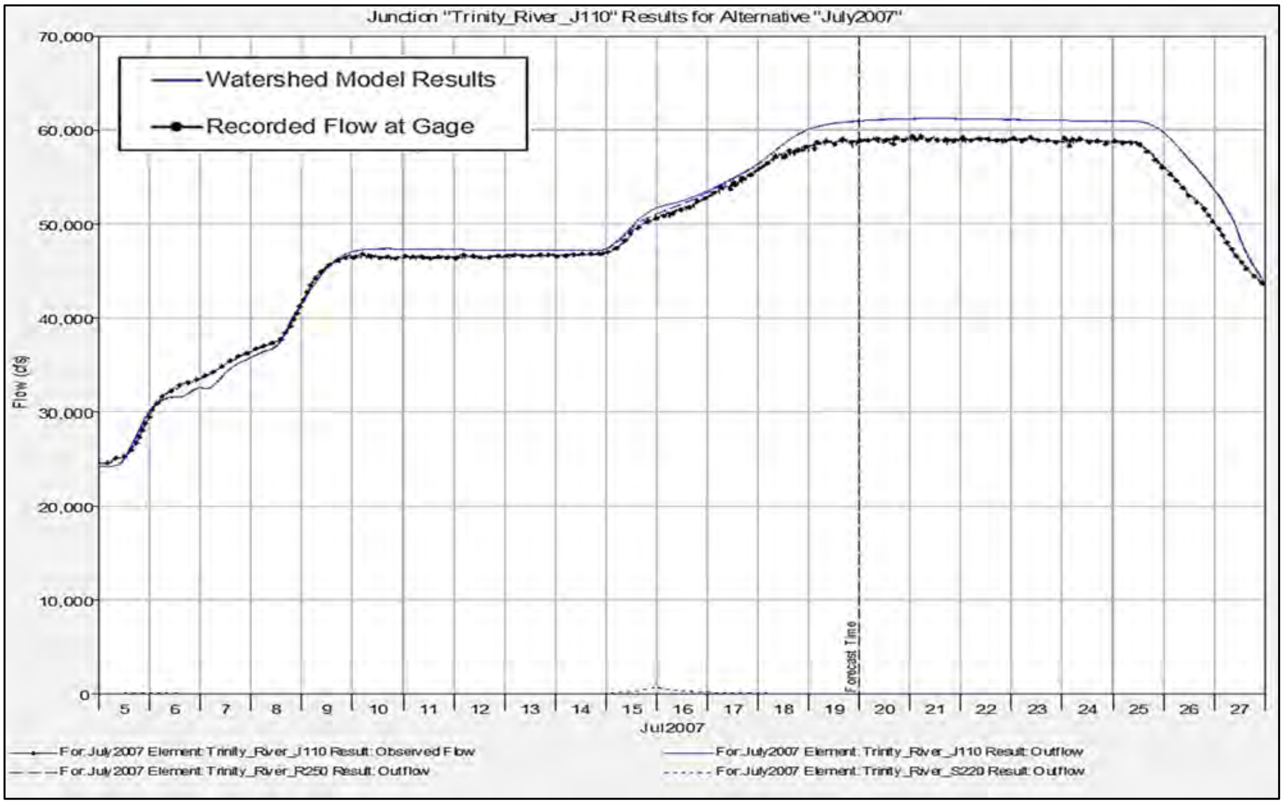

Figure 88a. July 19, 2007 Calibration for the Trinity River at Romayor, TX Gage

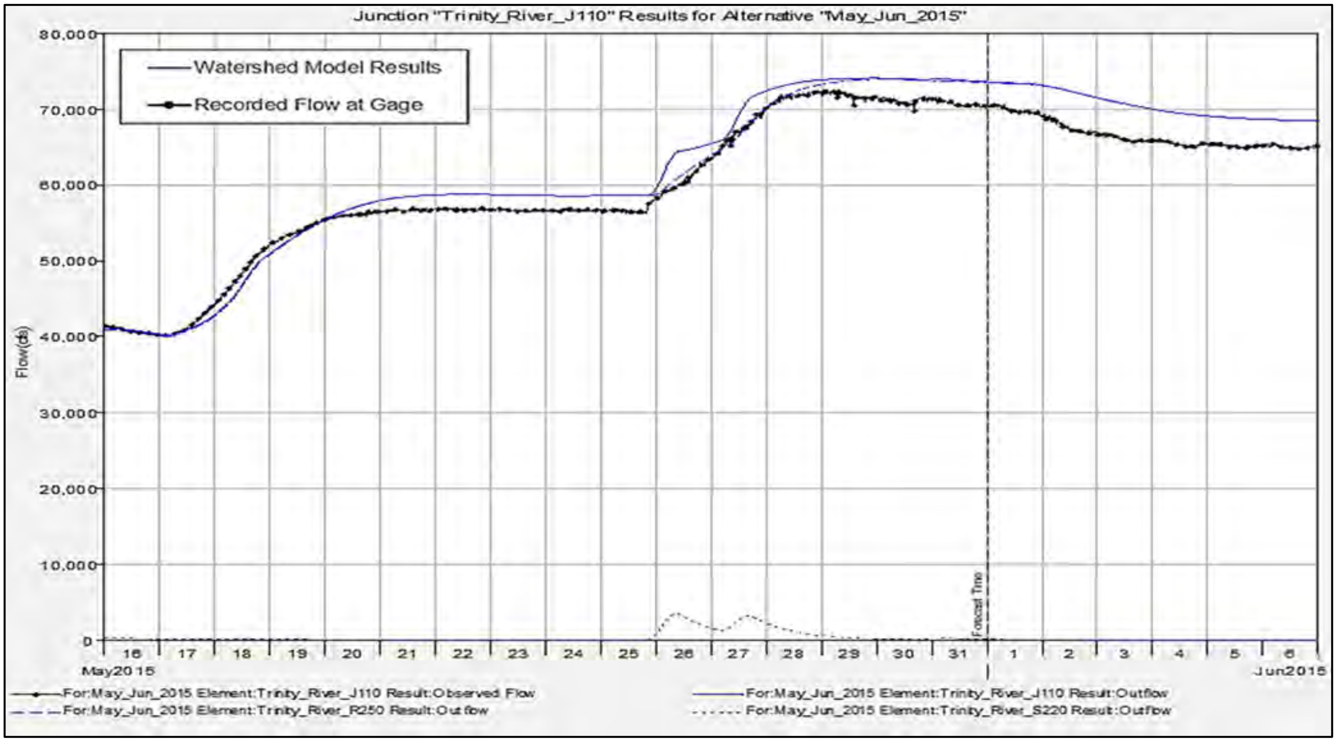

Figure 88b. May 28, 2015 Calibration for the Trinity River at Romayor, TX Gage

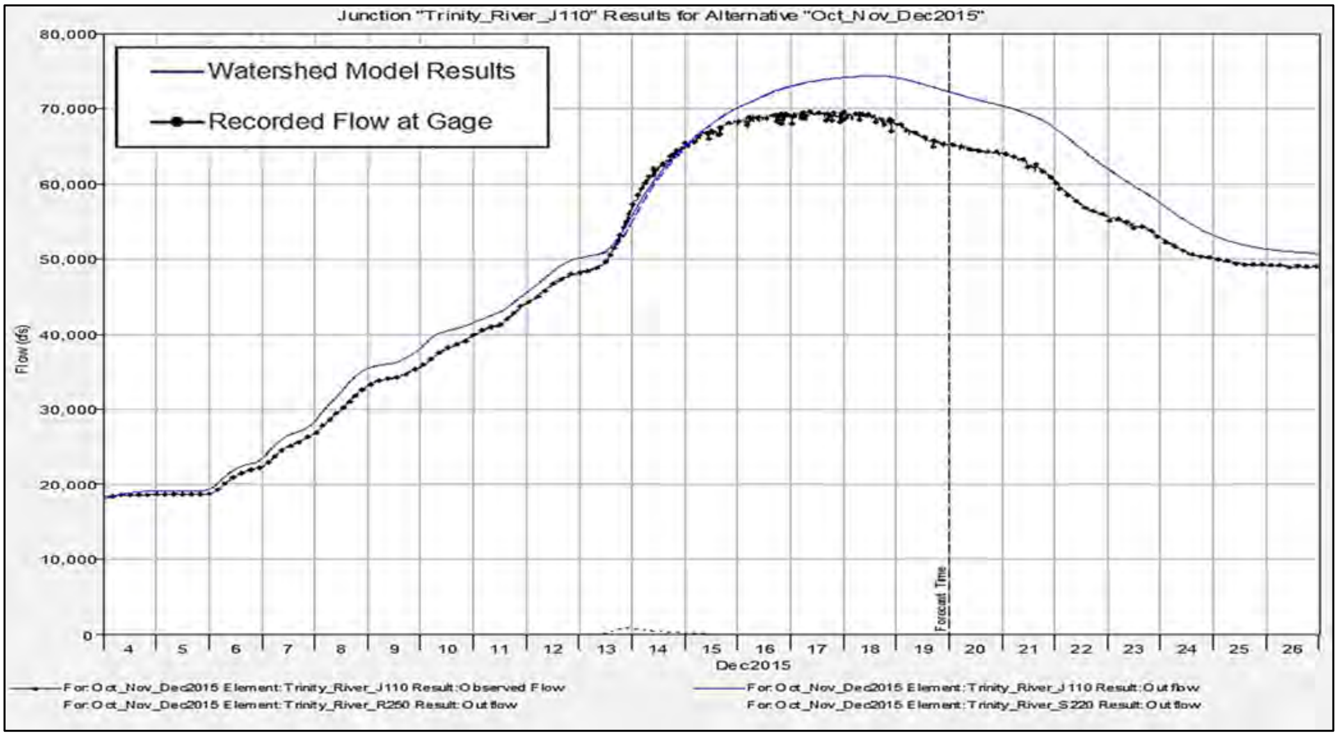

Figure 88c. December 17, 2015 Calibration for the Trinity River at Romayor, TX Gage

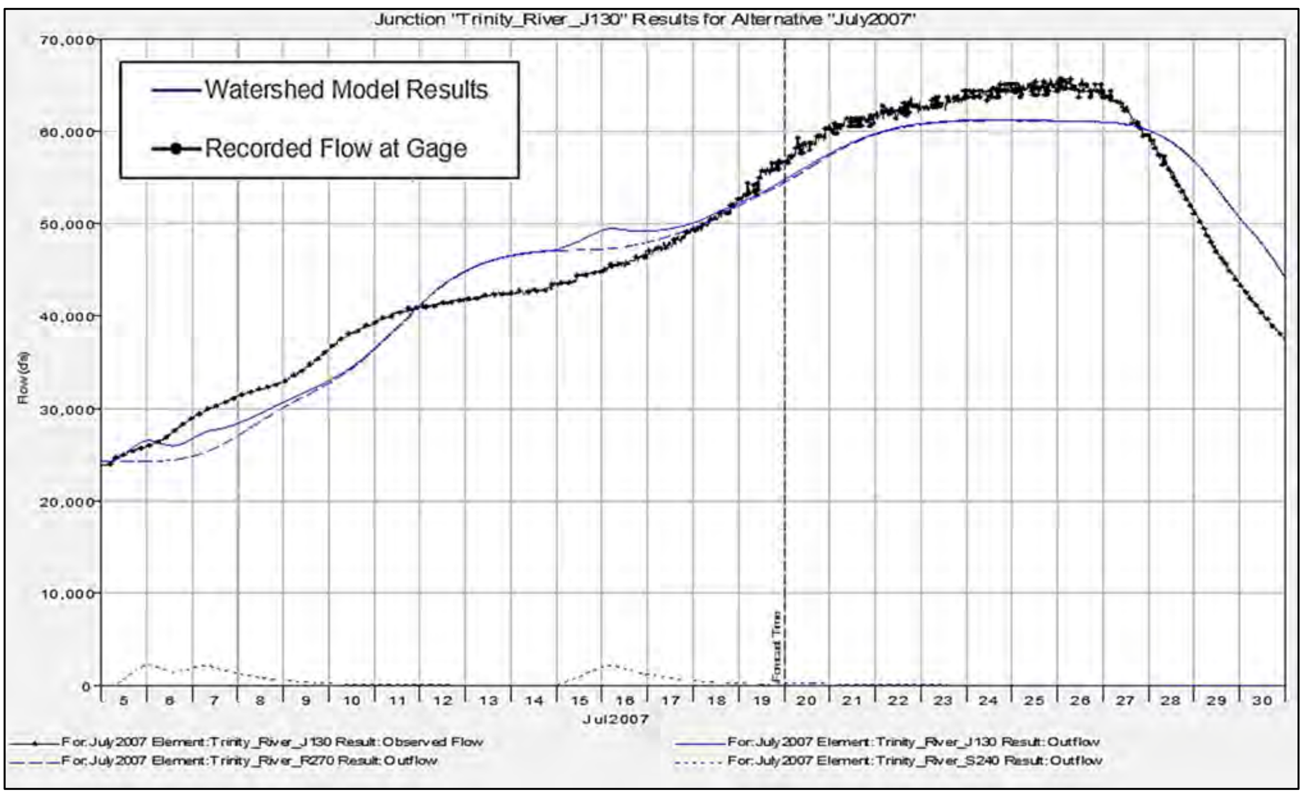

Figure 89a. July 25, 2007 Calibration for the Trinity River at Liberty, TX Gage

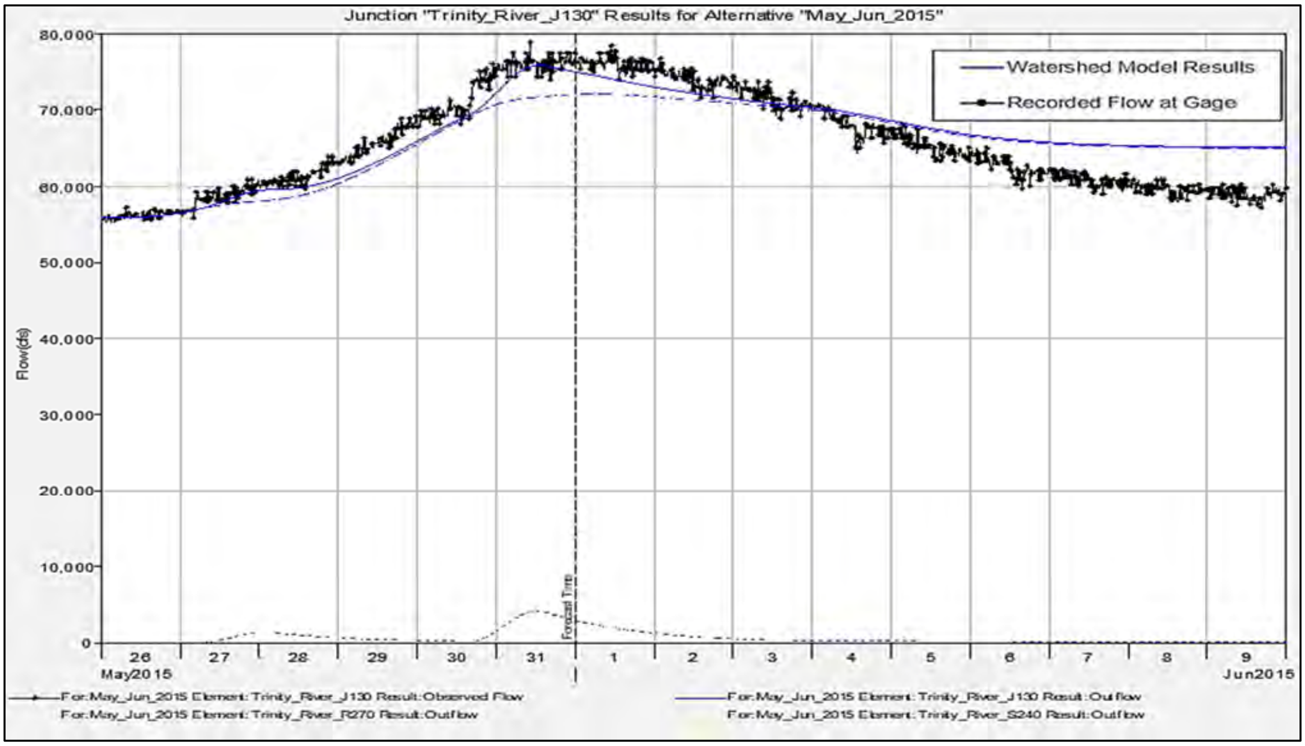

Figure 89b. May 31, 2015 Calibration for the Trinity River at Liberty, TX Gage

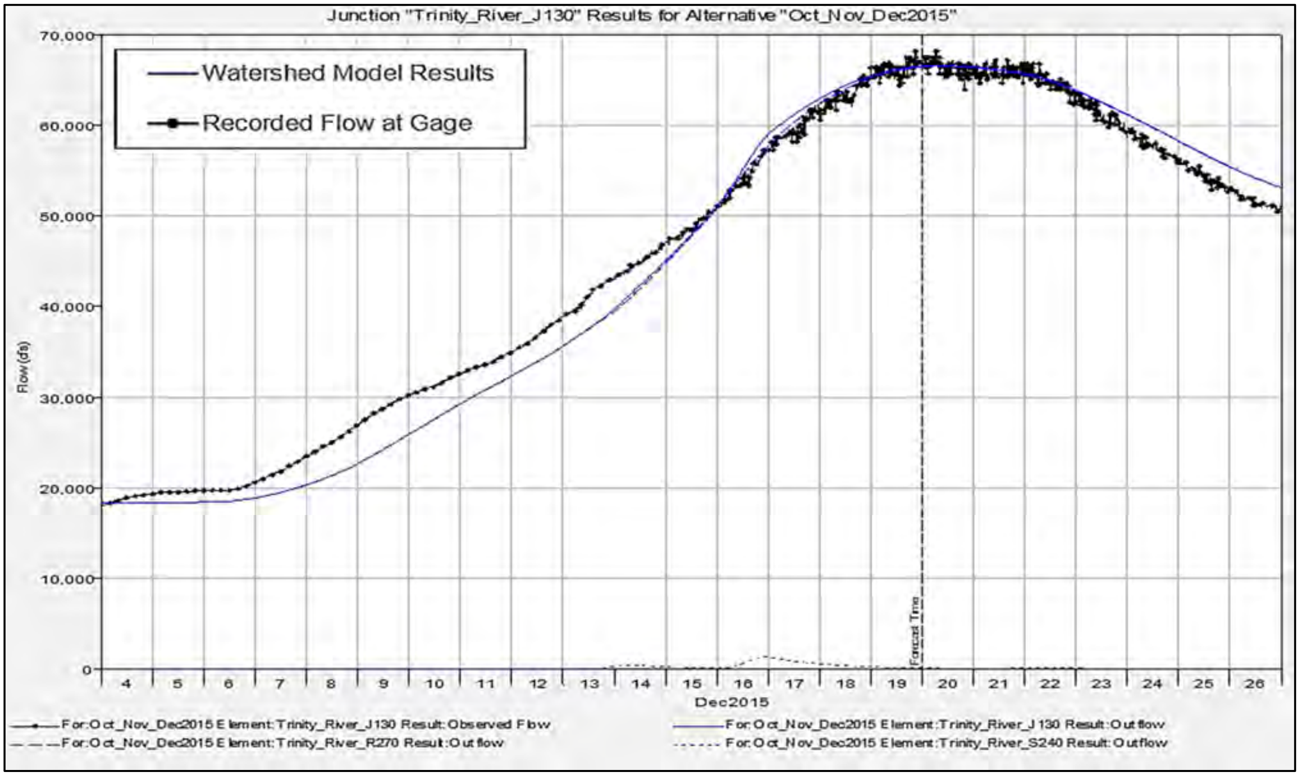

Figure 89c. December 19, 2015 Calibration for the Trinity River at Liberty, TX Gage

1.5 FINAL MODEL PARAMETERS

After the initial parameter estimates were made and the calibration process was completed, the final parameters were established. The final lag times and peaking coefficients were developed by taking a weighted average of the lag times and peaking coefficients from the calibration events. The peak discharge from the subbasin for that event was used to weight the calibrated lag times. This method has the effect of granting a higher weight to the lag times that were calibrated from larger, more intense storms, and it ignores the storms that generated no runoff from a particular subbasin. The final Snyder's lag times and peaking coefficients are shown in Table 23.

The final baseflow parameters were selected based on the results of the calibration runs. Specifically, initial flows were selected based on typical flow rates observed on each reach of the river, and the recession constant and ratio to peak were selected based on the slope and shape of the receding limb of the hydrograph at the downstream gages. The final baseflow parameters are also shown in Table 23.

A select few routing reaches used lag routing parameters. The final lag times are shown in Table 24.

The final Mod Puls storage discharge relationships were calculated from steady flow HEC-RAS models, and the final number of subreaches were selected based on calibration to the observed attenuation of the flood hydrograph in between stream gages. The final routing subreach values are shown in Table 25.

The final parameters for routing reaches using Muskingum and the final parameters for routing reaches using the straddle stagger approach can be found in Tables 26 and 27 respectively.

In observed storm events, the initial and constant losses vary from storm to storm according to the antecedent moisture conditions of the soil. The losses for the frequency storms were developed using the USACE Fort Worth District Method for determining losses based on percent sand (Rodman, 1977). This method produces a different set of loss rates for each storm frequency. These losses also fall well within the band of observed losses from the calibration storms. Some areas within the Trinity WHA model exhibit more variation in calibrated loss rates than others but the variation is present across the different soil types. For example, there are soils with high runoff potential (Group D, Clay) that have both high and low losses for each of the different events. See subbasins above Richland-Chambers reservoir as an example for soil group D. It should also be noted that while the calibration events do provide some information about observed losses, the limited number of calibration events that were used are not necessarily a complete picture of what loss rates are possible across the watershed. See Tables 11 and 12 for the losses identified during model calibration.

The default initial and constant losses for the 2-yr through 10-yr storms were adjusted for each given frequency in order to have a better correlation with the statistical frequency curves estimated from the USGS gage records. This was done because of the increased confidence level in the statistical frequency curve for the 2 through 10-yr recurrence intervals. The 25-yr losses were adjusted when needed to create a smooth transition between the 50-yr to the 10-yr values. The final loss rates used for each frequency storm event are given in Tables 28 and 29.

Table 23: Final Subbasin Parameters

Subbasin Name	Drainage Area (sqmi)	Percent Imperv. (%)	Snyder's Lag Time (hr)	Snyder's Peaking Coefficient	Initial Baseflow (cfs / sqmi)	Initial Baseflow (cfs)	Baseflow Recession Constant	Baseflow Ratio to Peak
West_Fork_S020	66.79	0	7.2	0.72		9.28	0.74	0.01
West_Fork_S010	61.99	0	5.5	0.72		8.79	0.75	0.01
West_Fork_S030	62.29	0	8	0.72		8.78	0.74	0.01
West_Fork_S040	40.40	0	6.8	0.72		9.29	0.72	0.01
West_Fork_S050	31.86	0	5.8	0.72		8.19	0.71	0.01
West_Fork_S060	69.09	0	8.4	0.72		9.44	0.7	0.01
West_Fork_S070	50.35	0	6.7	0.72		8.52	0.72	0.01
West_Fork_S080	20.33	0	4	0.69		8.42	0.67	0.02
West_Fork_S090	36.12	0	6.8	0.7		8.24	0.7	0.01
West_Fork_S100	38.84	0	6	0.7		7.68	0.66	0.02
West_Fork_S120	49.76	1	7.8	0.65		6.84	0.64	0.01
West_Fork_S110	21.59	0	6.6	0.66		7.55	0.61	0.01
Big_Cleveland_S010	52.56	0	7.3	0.65		6.88	0.64	0.02
Big_Cleveland_S020	46.10	1	6.7	0.64		5.34	0.61	0.02
West_Fork_S130	20.65	0	3.6	0.63		6.97	0.6	0.02
Lost_Ck_S010	28.82	3	4	0.53		6.92	0.76	0.04
Lost_Ck_S020	13.64	0	4.3	0.71		6.63	0.72	0.03
West_Fork_S140	39.60	1	5.3	0.71		0	0.69	0.03
West_Fork_S150	41.30	0	6	0.71		0	0.72	0.03
West_Fork_S160	35.60	2	5.2	0.71		0	0.67	0.04
Beans_Ck_S010	36.23	1	4.9	0.71		0	0.7	0.04
Beans_Ck_S020	10.72	1	2.7	0.71		0	0.71	0.05
Big_Ck_S010	50.69	0	5.6	0.71		0	0.68	0.04
Big_Ck_S030	19.58	2	3.9	0.71		0	0.72	0.05
Big_Ck_S020	13.25	2	3.7	0.71		0	0.7	0.04
Bridgeport_S030	43.63	1	6.1	0.7		0	0.74	0.05
Bridgeport_S010	35.71	42	5.4	0.71		0	0.73	0.05
Bridgeport_S040	33.43	3	5.3	0.7		0	0.76	0.05
Bridgeport_S020	24.81	1	4.6	0.71		0	0.71	0.05
West_Fork_S170	40.43	5	5.5	0.65		0.77	0.7	0.02
Dry_Ck_S010	26.74	4	5.7	0.66		1.02	0.7	0.01
West_Fork_S180	6.63	1	2.4	0.66		0	0.7	0.02
Amon_G_Carter_S030	40.30	8	5.2	0.62		0	0.74	0.05
Amon_G_Carter_S010	38.59	1	5.6	0.63		0	0.73	0.05
Amon_G_Carter_S020	30.62	0	5.3	0.63		0	0.74	0.05
Big_Sandy_Ck_S010	41.99	3	5.8	0.66		0	0.66	0.03
Big_Sandy_Ck_S020	40.70	1	7.7	0.66		0	0.63	0.03
Brushy_Ck_S010	30.88	3	6.8	0.71		0	0.65	0.04
Brushy_Ck_S020	27.86	1	6.9	0.66		0	0.63	0.04

Subbasin Name	Drainage Area (sqmi)	Percent Imperv. (%)	Snyder's Lag Time (hr)	Snyder's Peaking Coefficient	Initial Baseflow (cfs / sqmi)	Initial Baseflow (cfs)	Baseflow Recession Constant	Baseflow Ratio to Peak
Brushy_Ck_S030	11.86	1	4.8	0.65		0	0.64	0.07
Big_Sandy_Ck_S030	24.92	2	5	0.65		0	0.64	0.03
Big_Sandy_Ck_S040	46.60	1	7.5	0.63		0	0.67	0.03
Big_Sandy_Ck_S050	19.63	4	4.2	0.68		0.76	0.7	0.01
West_Fork_S190	28.29	4	3.3	0.68		0.65	0.7	0.01
West_Fork_S200	21.94	1	4.4	0.69		0	0.7	0.01
Garrett_Ck_S020	23.22	1	4.7	0.66		0.52	0.7	0.02
Garrett_Ck_S010	22.76	1	5.3	0.65		0.57	0.7	0.01
Garrett_Ck_S030	7.73	1	2.5	0.67		0	0.7	0.01
Salt_Ck_S010	28.17	1	4.3	0.66		1.02	0.7	0.02
Salt_Ck_S020	24.80	1	4.4	0.69		0	0.7	0.01
West_Fork_S210	30.40	1	4.6	0.68		0	0.7	0.01
West_Fork_S220	41.10	2	5	0.71		0	0.5	0.03
Eagle_Mountain_S010	36.13	9	3.9	0.72		0	0.5	0.03
Eagle_Mountain_S020	18.27	6	3.3	0.72		0	0.5	0.03
Walnut_Ck_S020	31.43	1	3.4	0.77		0.02	0.66	0.02
Walnut_Ck_S010	31.31	3	3	0.77		0.04	0.66	0.02
Walnut_Ck_S030	18.62	6	2.8	0.72		0	0.5	0.03
Eagle_Mountain_S040	42.47	30	3.1	0.71		0	0.5	0.02
Eagle_Mountain_S030	26.44	4	3.4	0.72		0	0.5	0.03
Silver_Ck_S020	34.75	8	5	0.59		0	0.66	0.04
Silver_Ck_S010	27.84	2	4.9	0.59		0	0.65	0.03
Lake_Worth_S010	24.10	19	4.5	0.59		0	0.64	0.03
Lake_Worth_S020	7.52	43	3.3	0.59		0	0.65	0.04
West_Fork_S230	27.93	35	4.1	0.71	1.42		0.7	0.08
Lk_Weatherford_S010	95.90	1	6.8	0.64	0.43		0.7	0.05
Lk_Weatherford_S020	12.82	17	2.1	0.66	0.37		0.7	0.05
Clear_Fork_S010	136.33	6	11	0.65	0.77		0.67	0.07
Clear_Fork_S020	18.79	4	2.9	0.64	0.77		0.67	0.06
Bear_Ck_S010	58.92	1	2.75	0.76	0.77		0.67	0.06
Bear_Ck_S020	5.49	4	0.85	0.76	0.77		0.67	0.05
Benbrook_S010	34.54	1	2.4	0..76	0.77		0.67	0.06
Benbrook_S020	34.23	2	2.7	0.63	0.77		0.67	0.06
Benbrook_S030	32.15	22	1.8	0.63	0.77		0.67	0.06
Clear_Fork_S030	9.43	26	0.9	0.7	0.91		0.75	0.03
Marys_Ck_S010	54.16	8	1.5	0.76	0.54		0.71	0.02
Clear_Fork_S040	25.37	39	1.6	0.7	0.75		0.76	0.04
Clear_Fork_S050	4.89	57	1.2	0.71	1.28		0.7	0.07
West_Fork_S240	1.17	39	0.6	0.72	1.49		0.7	0.02
Marine_Ck_S020	12.61	38	0.8	0.72	1.42		0.7	0.02
Marine_Ck_S010	9.11	28	1	0.72	1.37		0.7	0.02

Subbasin Name	Drainage Area (sqmi)	Percent Imperv. (%)	Snyder's Lag Time (hr)	Snyder's Peaking Coefficient	Initial Baseflow (cfs / sqmi)	Initial Baseflow (cfs)	Baseflow Recession Constant	Baseflow Ratio to Peak
West_Fork_S250	9.16	50	1.7	0.71	2		0.7	0.02
West_Fork_S260	39.24	36	2.3	0.53	2.34		0.7	0.02
West_Fork_S270	12.96	27	1.9	0.7	1.96		0.7	0.03
Big_Fossil_Ck_S010	56.86	30	3.6	0.7	1.65		0.7	0.04
LittleFossil_Ck_S010	19.72	39	2.3	0.7	1.69		0.7	0.03
West_Fork_S280	28.92	34	2.9	0.7	1.94		0.7	0.03
Village_Ck_S010	90.40	10	5.2	0.64	0.49		0.6	0.05
Village_Ck_S020	34.61	19	1.6	0.7	0.77		0.54	0.02
Lake_Arlington_S010	18.13	42	1.4	0.7	0.77		0.55	0.02
Village_Ck_S030	48.52	28	5.4	0.7	1.81		0.7	0.03
West_Fork_S290	43.91	34	4.9	0.7	1.81		0.7	0.03
West_Fork_S300	20.74	52	3.5	0.7	1.74		0.7	0.03
West_Fork_S310	4.76	29	0.8	0.7	1.61		0.7	0.04
West_Fork_S320	2.16	19	1.51	0.7	0.01		0.7	0.02
Big_Bear_Ck_S010	82.54	31	8.27	0.7	0.02		0.54	0.01
Big_Bear_Ck_S020	10.78	34	3.18	0.7	0.01		0.58	0.02
West_Fork_S330	8.58	33	2.26	0.7	0.01		0.7	0.02
Joe_Pool_S020	111.69	14	6.1	0.7	0.06		0.46	0.03
Joe_Pool_S030	62.88	8	6.7	0.7	0.06		0.54	0.02
Joe_Pool_S040	4.36	30	1	0.7	0.06		0.46	0.03
Joe_Pool_S010	25.95	3	4.07	0.7	0.02		0.4	0.02
Joe_Pool_S050	19.29	43	1.62	0.7	0.06		0.45	0.03
Mountain_Ck_S010	41.50	32	2.3	0.7	0.05		0.64	0.02
Mountain_Ck_S020	29.12	44	1.3	0.7	0.05		0.63	0.02
Mountain_Ck_S030	9.58	31	1.39	0.7	0.01		0.7	0.02
West_Fork_S340	13.27	37	2	0.7	0.01		0.8	0.02
Elm_Fork_S020	33.95	1	4.72	0.7	0.22		0.81	0.06
Elm_Fork_S010	33.40	2	3.86	0.7	0.35		0.83	0.08
Brushy_Elm_Ck_S010	13.95	1	2.71	0.7	0.21		0.81	0.08
Brushy_Elm_Ck_S020	11.59	5	2.99	0.7	0.19		0.81	0.06
Elm_Fork_S030	44.13	1	3.87	0.7	0.2		0.81	0.06
Elm_Fork_S040	40.17	3	3.69	0.7	0.18		0.81	0.06
Elm_Fork_S050	39.58	6	4.4	0.7	0.03		0.16	0.02
Elm_Fork_S070	28.10	2	5.06	0.7	0.03		0.16	0.02
Elm_Fork_S060	20.13	1	3.67	0.7	0.03		0.16	0.02
Spring_Ck_S010	40.63	0	3.57	0.7	0.04		0.17	0.02
Spring_Ck_S020	22.07	6	2.47	0.7	0.03		0.16	0.02
Ray_Roberts_S010	26.12	19	1.47	0.7	0.03		0.16	0.02
Timber_Ck_S010	39.04	1	5.1	0.78	0.03		0.49	0.02
Timber_Ck_S030	21.94	2	4.1	0.7	0.03		0.16	0.02
Timber_Ck_S020	3.17	0	1.85	0.7	0.03		0.19	0.02

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Ray_Roberts_S030	56.63	30	1.53	0.7	0.03		0.16	0.02
Range_Ck_S010	29.31	0	2.4	0.75	0.01		0.31	0.02
Range_Ck_S020	21.25	1	4.9	0.7	0.03		0.16	0.02
Lake_Kiowa_S020	22.14	11	2.41	0.7	0.03		0.16	0.02
Lake_Kiowa_S010	16.82	7	3.1	0.7	0.03		0.16	0.02
Ray_Roberts_S020	37.46	32	1	0.7	0.03		0.16	0.02
Range_Ck_S030	31.13	3	3.8	0.7	0.03		0.16	0.02
Buck_Ck_S010	23.09	0	4.46	0.7	0.03		0.16	0.02
Ray_Roberts_S050	15.76	12	1	0.7	0.03		0.16	0.02
Ray_Roberts_S040	11.22	31	1.65	0.7	0.3		0.39	0.04
Ray_Roberts_S060	7.30	34	1	0.7	0.03		0.16	0.02
Timber_Ck_S040	2.52	7	2	0.62	0.03		0.17	0.02
Elm_Fork_S080	36.87	2	4.65	0.62	0.06		0.76	0.03
Clear_Ck_S010	50.56	0	5.13	0.62	0.22		0.88	0.11
Clear_Ck_S020	33.31	1	4.43	0.65	0.2		0.86	0.1
Clear_Ck_S030	16.06	1	2.03	0.62	0.19		0.85	0.1
Clear_Ck_S040	51.64	1	3.87	0.65	0.2		0.84	0.09
Clear_Ck_S050	35.61	0	6.2	0.6	0.19		0.83	0.09
Clear_Ck_S070	24.72	1	3.7	0.65	0.14		0.77	0.07
Clear_Ck_S060	2.56	0	1.15	0.62	0.13		0.78	0.08
Clear_Ck_S080	45.06	1	8.13	0.63	0.18		0.84	0.09
Clear_Ck_S090	35.10	2	6.95	0.63	0.16		0.81	0.08
Clear_Ck_S110	15.30	6	3.77	0.62	0.07		0.77	0.04
Clear_Ck_S100	12.82	2	4.18	0.62	0.09		0.78	0.04
Clear_Ck_S120	28.43	2	5.6	0.62	0.08		0.78	0.04
Little_Elm_Ck_S010	42.28	2	5	0.7	0.03		0.78	0.08
Little_Elm_Ck_S020	30.57	2	6.59	0.65	0.04		0.8	0.09
Little_Elm_Ck_S030	22.95	1	6.68	0.62	0.08		0.78	0.04
Pecan_Ck_S010	43.07	2	6.35	0.62	0.08		0.75	0.03
Doe_Branch_S010	38.40	4	5.21	0.62	0.94		0.76	0.02
Doe_Branch_S020	32.61	14	4.48	0.62	0.07		0.74	0.02
Lewisville_S030	21.39	10	3.09	0.62	0.06		0.74	0.03
Hickory_Ck_S020	41.14	1	4.86	0.72	0.03		0.73	0.03
Hickory_Ck_S010	39.53	1	3.69	0.72	0.03		0.73	0.03
Hickory_Ck_S030	18.09	11	3.49	0.72	0.03		0.73	0.03
Hickory_Ck_S040	30.17	6	3.11	0.72	0.02		0.72	0.03
Hickory_Ck_S050	19.98	11	2.08	0.62	0.07		0.77	0.04
Lewisville_S010	89.01	18	3.71	0.62	0.07		0.74	0.03
Lewisville_S040	43.47	27	2.32	0.62	0.07		0.75	0.04
Lewisville_S050	34.96	28	2.19	0.62	0.07		0.75	0.04
Lewisville_S020	32.48	26	1.63	0.62	0.07		0.77	0.04

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Elm_Fork_S090	21.40	28	5.1	0.62	1.96		0.53	0.04
Elm_Fork_S110	16.05	34	3.15	0.7	0.28		0.52	0.03
Elm_Fork_S100	24.07	36	5.9	0.67	2.26		0.54	0.03
Elm_Fork_S120	18.41	50	6.6	0.62	1.51		0.52	0.03
Denton_Ck_S010	116.04	1	7	0.7	0.16		0.74	0.11
Denton_Ck_S020	169.01	1	7	0.7	0.1		0.75	0.11
Denton_Ck_S030	61.58	2	3.96	0.7	0.19		0.75	0.12
Denton_Ck_S040	53.41	1	4.55	0.69	0.19		0.76	0.1
Denton_Ck_S050	75.30	2	4.9	0.7	0.16		0.67	0.01
Denton_Ck_S060	30.78	5	5.25	0.7	0.16		0.67	0.01
Denton_Ck_S070	93.55	8	7.12	0.7	0.17		0.69	0.01
Grapevine_S010	94.75	21	2.44	0.7	0.2		0.67	0.01
Denton_Ck_S080	24.30	33	4.56	0.7	3.66		0.64	0.03
Elm_Fork_S130	39.18	50	2.66	0.7	0.01		0.5	0.02
Hackberry_Ck_S010	14.68	42	1.96	0.7	0.01		0.5	0.02
Hackberry_Ck_S020	4.62	43	1.37	0.7	0.01		0.5	0.02
Hackberry_Ck_S030	1.59	45	1.05	0.7	0.01		0.5	0.02
Elm_Fork_S140	16.13	47	2.61	0.7	0.01		0.5	0.02
Elm_Fork_S150	22.20	47	1.4	0.7	0.01		0.5	0.02
Bachman_Branch_S010	12.68	33	1.32	0.7	0.01		0.8	0.02
Bachman_Branch_S020	1.40	44	1.24	0.7	0.01		0.8	0.02
Elm_Fork_S160	6.09	45	0.94	0.7	0.01		0.8	0.02
Trinity_River_S010	12.47	38	1.79	0.7	0.01		0.8	0.02
Trinity_River_S020	42.89	54	1.98	0.7	0.01		0.5	0.02
White_Rock_Ck_S010	66.66	49	2.6	0.7	0.56		0.68	0.02
White_Rock_Ck_S020	17.61	49	1.1	0.7	0.45		0.68	0.02
White_Rock_Ck_S030	10.77	48	1.3	0.7	0.45		0.68	0.02
White_Rock_Ck_S040	39.84	30	2.1	0.7	0.01		0.5	0.02
Trinity_River_S030	22.54	30	2.1	0.7	0.01		0.5	0.02
Fivemile_Ck_S010	43.49	29	3.1	0.72		126	1	0.04
Trinity_River_S040	28.86	17	3	0.72	1.49		0.71	0.04
Trinity_River_S050	38.88	18	9	0.72	1.29		0.68	0.04
Tenmile_Ck_S010	74.21	21	6.5	0.72	1.51		0.69	0.04
Tenmile_Ck_S020	27.91	6	5	0.72	1.21		0.68	0.04
Trinity_River_S060	59.61	8	10	0.72	1.65		0.69	0.04
Indian_Ck_S010	104.60	2	12.7	0.45	1.37		0.82	0.15
Indian_Ck_S030	85.21	1	11.1	0.6	0.6		0.7	0.14
Indian_Ck_S020	15.96	1	7.5	0.6	0.6		0.81	0.08
Indian_Ck_S040	30.15	6	5.2	0.6	0.6		0.59	0.08
Sister_Grove_S010	83.15	2	12.7	0.43	1.19		0.79	0.25
Sister_Grove_S020	38.04	6	6.3	0.6	0.6		0.81	0.08

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East_Fork_S020	118.24	2	12	0.58	0.78		0.85	0.21
East_Fork_S010	49.64	3	7	0.58	0.69		0.85	0.2
East_Fork_S030	22.23	9	4.8	0.55	0.53		0.85	0.08
East_Fork_S040	24.67	10	5.3	0.6	0.6		0.81	0.08
Wilson_Ck_S010	77.49	19	10.2	0.57	0.6		0.81	0.09
Lavon_S010	85.74	26	5.3	0.6	0.6		0.79	0.08
Lavon_S020	33.09	32	4.3	0.6	0.6		0.79	0.07
Rowlett_Ck_S010	119.88	38	4.1	0.65	1.58		0.75	0.05
Ray_Hubbard_S010	137.97	32	5.1	0.51	0.2		0.78	0.07
Ray_Hubbard_S020	43.94	48	5.4	0.5	0.2		0.77	0.07
East_Fork_S050	48.09	36	9.9	0.7	1.33		0.79	0.09
East_Fork_S070	9.63	11	3.5	0.5	0.35		0.6	0.28
East_Fork_S060	34.34	13	7.9	0.5	0.36		0.5	0.28
East_Fork_S080	23.00	21	5.4	0.5	0.29		0.5	0.28
East_Fork_S090	29.55	34	7.4	0.5	0.27		0.5	0.28
East_Fork_S110	19.14	6	5.2	0.5	0.32		0.5	0.28
East_Fork_S100	19.27	15	5.7	0.5	0.31		0.5	0.28
Trinity_River_S070	231.25	4	9.5	0.72	1.73		0.67	0.04
East_Fork_S120	104.18	3	9	0.72	1.75		0.7	0.04
Kings_Ck_S020	133.14	3	28	0.63	0.43		0.8	0.05
Kings_Ck_S010	89.44	5	22	0.63	0.41		0.8	0.05
Kings_Ck_S030	120.56	6	7.6	0.6	0.1		0.83	0.14
Cedar_Ck_S040	285.73	17	7.1	0.62	0.1		0.82	0.08
Cedar_Ck_S010	176.13	2	22.4	0.63	0.04		0.8	0.09
New_Terrell_City_Lake_S010	14.02	9	3.7	0.49	0.1		0.9	0.1
Cedar_Ck_S020	93.33	5	6.2	0.58	0.1		0.83	0.12
Cedar_Ck_S030	98.44	4	6.6	0.59	0.1		0.83	0.1
Trinity_River_S080	398.90	1	27.7	0.71	1.31		0.81	0.05
Trinity_River_S090	283.46	2	12	0.65	0.62		0.89	0.08
Chambers_Ck_S010	161.82	1.59	11.5	0.65	0.1		0.68	0.11
Chambers_Ck_S020	146.57	0.57	8.7	0.65	0.1		0.68	0.11
Chambers_Ck_S040	105.96	1	11.5	0.65	0.1		0.68	0.1
Chambers_Ck_S030	97.55	0.76	13	0.65	0.1		0.68	0.1
Waxahachie_Ck_S010	60.39	7.21	4.13	0.59	6.23		0.88	0.23
Waxahachie_Ck_S020	30.60	1.7	2.37	0.64	19.4		0.94	0.2
Waxahachie_Ck_S030	30.05	3.68	3.5	0.49	0.1		0.7	0.04
Mustang_Ck_S010	29.91	6.75	3.38	0.49	0.1		0.72	0.03
Bardwell_S010	23.44	29.25	2.23	0.39	0.1		0.71	0.14
Chambers_Ck_S050	75.82	0.43	10	0.65	0.1		0.68	0.11
Chambers_Ck_S060	33.26	0.15	5.5	0.65	0.1		0.68	0.11

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Chambers_Ck_S070	29.09	1.01	5.5	0.65	0.1		0.68	0.11
Chambers_Ck_S080	145.13	3.57	5.81	0.51	0.1		0.58	0.19
Post_Oak_Ck_S010	29.49	13.16	3.3	0.34	0.1		0.81	0.16
Lake_Halbert_S010	11.53	4.53	1.9	0.48	1.11		0.83	0.06
Navarro_Mills_S020	143.52	1.46	6.54	0.6	0.23		0.83	0.09
Navarro_Mills_S030	74.88	1.17	9.29	0.6	0.43		0.83	0.08
Navarro_Mills_S010	65.75	0.5	4.8	0.66	2.14		0.7	0.16
Navarro_Mills_S040	35.71	22.5	5.33	0.62	0.22		0.81	0.1
Richland_Ck_S010	220.05	0.65	7.38	0.48	0.08		0.81	0.1
Richland_Ck_S020	174.90	0.38	7	0.44	0.08		0.81	0.1
Richland-Chambers_S010	141.82	22.68	8.12	0.42	0.07		0.82	0.09
Richland-Chambers_S020	92.54	47.06	7.23	0.42	0.07		0.82	0.09
Tehuacana_Ck_S020	245.04	2	16	0.65	0.79		0.89	0.1
Tehuacana_Ck_S010	141.34	1	7.6	0.72	0.52		0.46	0.15
Trinity_River_S100	70.59	2	17	0.65	0.63		0.89	0.1
Fairfield_Lake_S010	36.17	12	5.5	0.65	0.86		0.89	0.12
Trinity_River_S110	305.13	3	19.3	0.65	0.96		0.89	0.13
Big_Brown_Ck_S010	46.43	1	11.1	0.65	0.98		0.89	0.12
Trinity_River_S120	240.00	3	18.7	0.65	0.97		0.89	0.14
Trinity_River_S130	256.66	2	28.5	0.6	2.28		0.79	0.05
Upper_Keechi_Ck_S030	272.69	3	17.3	0.6	2.15		0.79	0.05
Upper_Keechi_Ck_S010	150.34	4	7.7	0.6	0.41		0.55	0.31
Upper_Keechi_Ck_S020	36.47	1	9	0.6	1.73		0.79	0.05
Upper_Keechi_Ck_S040	49.75	1	7.7	0.6	1.31		0.79	0.05
Trinity_River_S140	0.60	1	1.6	0.6	1.15		0.79	0.05
Little_Elkhart_S010	95.01	1	11.6	0.6	1.94		0.79	0.05
Houston_County_Lake_S010	47.98	6	3.5	0.45	1		0.79	0.05
Trinity_River_S150	112.48	2	11.6	0.6	3.07		0.79	0.05
Trinity_River_S160	176.66	1	14	0.55	3.34		0.6	0.05
Trinity_River_S170	187.60	1	17.8	0.55	2.87		0.6	0.05
Trinity_River_S180	395.03	2	24	0.55	3.52		0.6	0.05
Bedias_Ck_S010	330.55	1	16.5	0.72	1.67		0.82	0.04
Bedias_Ck_S020	273.70	1	16	0.55	3.76		0.6	0.05
Trinity_River_S190	328.14	4	18	0.55	3.12		0.6	0.05
Livingston_S010	509.39	3	17	0.55	3.31		0.6	0.05
Livingston_S030	414.80	27	6	0.55	3.05		0.6	0.05
Livingston_S020	70.27	17	5	0.55	3.78		0.6	0.05
Trinity_River_S200	39.41	3	5.5	0.5	1.71		0.6	0.02
Long_King_Ck_S010	141.11	1	7.5	0.44	0.09		0.8	0.03

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Long_King_Ck_S020	85.25	4	10.8	0.5	1.67		0.6	0.02
Trinity_River_S210	61.11	4	8.5	0.5	1.86		0.6	0.02
Menard_Ck_S010	148.14	1	27	0.78	0.67		0.79	0.08
Trinity_River_S220	97.56	2	13	0.5	2.08		0.6	0.02
Trinity_River_S230	72.02	4	16.6	0.49	0.05		0.78	0.07
Trinity_River_S240	230.77	2	20.5	0.49	0.03		0.78	0.08
Trinity_River_S250	441.84	8	19	0.5	0.09		0.78	0.09

Table 24: Final Lag Routing Parameters

HEC-HMS Reach Name	Lag Time (min)
Clear_Fork_R041	26
West_Fork_R251	60
West_Fork_R263	60
Denton_Ck_Lag	130
Tehuacana_Ck_R008	430
Upper_Keechi_R001a	400

Table 25: Final Modified Puls Routing Parameters

HEC-HMS Reach Name	Subreaches	Storage Volume Adjustment Factor
West_Fork_R010	4	1.0
West_Fork_R020	1	1.0
West_Fork_R030	2	1.0
West_Fork_R040	1	1.0
West_Fork_R050	2	1.0
West_Fork_R060	2	1.0
West_Fork_R070	2	1.0
Big_Cleveland_R010	3	1.0
West_Fork_R080	1	1.0
Lost_Ck_R010	5	1.0
Beans_Ck_R010	1	1.0
Big_Ck_R010	3	1.0
Big_Ck_R020	1	1.0
West_Fork_R120	5	1.0
West_Fork_R130	2	1.0

HEC-HMS Reach Name	Subreaches	Storage Volume Adjustment Factor
Big_Sandy_Ck_R020	4	1.0
Big_Sandy_Ck_R030	9	1.0
Brushy_Ck_R010	6	1.0
Brushy_Ck_R020	1	1.0
Big_Sandy_Ck_R040	4	1.0
Big_Sandy_Ck_R050	4	1.0
Big_Sandy_Ck_R060	1	1.0
West_Fork_R140	2	1.0
West_Fork_R150	1	1.0
Garrett_Ck_R010	2	1.0
Garrett_Ck_R020	2	1.0
Salt_Ck_R010	4	1.0
Salt_Ck_R020	2	1.0
Salt_Ck_R030	1	1.0
West_Fork_R160	2	1.0
Walnut_Ck_R020	3	1.0
Silver_Ck_R010	7	1.0
West_Fork_R200	2	1.0
West_Fork_R201	1	1.0
Clear_Fork_R030	1	1.0
Clear_Fork_R040	6	1.0
Clear_Fork_R050	1	1.0
West_Fork_R210	2	1.0
Marine_Ck_R010	3	1.0
West_Fork_R220	3	1.0
West_Fork_R230	2	1.0
West_Fork_R231	2	1.0
West_Fork_R240	1	1.0
West_Fork_R250	1	1.0
Village_Ck_R010	5	1.0
Village_Ck_R020	1	1.0
West_Fork_R260	1	1.0
West_Fork_R261	1	1.0
West_Fork_R262	1	1.0
West_Fork_R264	1	1.0
West_Fork_R270	1	1.0
West_Fork_R280	1	1.0
Big_Bear_Ck_R010	6	1.0
West_Fork_R290	1	1.0
Mountain_Ck_R020	6	1.0
Mountain_Ck_R030	1	1.0
West_Fork_R300	1	1.0

HEC-HMS Reach Name	Subreaches	Storage Volume Adjustment Factor
Elm_Fork_R060	8	1.0
Clear_Ck_R050	1	1.0
Clear_Ck_R060	3	1.0
Elm_Fork_R065	1	1.0
Little_Elm_Ck_R030	1	1.0
Doe_Branch_R010	1	1.0
Hickory_Ck_R030	1	1.0
Elm_Fork_R070	5	1.0
Elm_Fork_R080	2	1.0
Denton_Ck_R010	14	1.0
Denton_Ck_R030	4	1.0
Denton_Ck_R040	2	1.0
Denton_Ck_R050	3	1.0
Denton_Ck_R055	2	1.0
Denton_Ck_R060	7	1.0
Elm_Fork_R090	5	1.0
Elm_Fork_R100	5	1.0
Elm_Fork_R120	4	1.0
Bachman_Branch_R010	1	1.0
Elm_Fork_R130	2	1.0
Trinity_River_R010	2	1.0
Trinity_River_R020	1	1.0
Trinity_River_R030	2	1.0
White_Rock_Ck_R020	4	1.0
Trinity_River_R040	1	1.0
Trinity_River_R050	1	1.0
Trinity_River_R060	1	0.8 - 1.15
Trinity_River_R070	1	0.8 - 1.2
East_Fork_R040	6	1.0
East_Fork_R050	1	1.0
East_Fork_R060	1	1.0
East_Fork_R070	1	1.0
East_Fork_R080	1	1.0 - 1.2
Trinity_River_R090	1	0.8 - 1.2
Trinity_River_R100	40	0.8 - 1.0
Trinity_River_R110	1	1.0
Trinity_River_R120	5	1.0
Chambers_Ck_R009	5	1.0
Chambers_Ck_R010	20	1.0
Chambers_Ck_R020	7	1.0
Chambers_Ck_R030	8	1.0
Chambers_Ck_R040	10	1.0

HEC-HMS Reach Name	Subreaches	Storage Volume Adjustment Factor
Richland_Ck_R020	11	1.0
Trinity_River_R130	3	1.0
Tehuacana_Ck_R009	1	1.0
Trinity_River_R140	1	1.0
Trinity_River_R150	1	1.0
Trinity_River_R160	7	0.75 - 1.0
Trinity_River_R170	1	0.8 -1.1
Trinity_River_R180	1	1.0
Trinity_River_R190	1	1.0
Trinity_River_R200	1	0.8 - 1.25
Trinity_River_R210	1	0.8 - 1.25
Trinity_River_R220	1	0.8 - 1.25
Trinity_River_R230	1	1.0
Trinity_River_R240	1	1.0
Trinity_River_R250	1	1.0
Trinity_River_R260	3	1.0
Trinity_River_R270	3	1.0
Trinity_River_R280	3	1.0

Table 26: Final Muskingum Routing Parameters

HEC-HMS Reach Name	K (hrs)	X	Subreaches
West_Fork_R090	1	0.25	1
West_Fork_R100	3	0.34	3
West_Fork_R110	3	0.36	3
West_Fork_R170	5	0.22	2
West_Fork_R180	3	0.22	1
Walnut_Ck_R010	1	0.25	1
West_Fork_R190	6	0.11	4
Bear_Ck_R010	1	0.25	1
Marys_Ck_R010	0.33	0.25	1
JPL_Walnut_Ck_R010	1	0.2	1
Mountain_Ck_R010	5	0.2	3
Elm_Fork_R010	3.5	0.3	4
Brushy_Elm_Ck_R010	3.9	0.3	4
Elm_Fork_R020	1.1	0.3	1
Elm_Fork_R030	1.4	0.3	1
Elm_Fork_R040	3.1	0.2	2
Elm_Fork_R050	4.4	0.2	3
Spring_Ck_R010	3.7	0.2	3

HEC-HMS Reach Name	K (hrs)	X	Subreaches
Timber_Ck_R010	1.3	0.2	1
Timber_Ck_R020	2	0.2	1
Range_Ck_R010	5.7	0.2	5
Range_Ck_R020	2	0.2	1
Lake_Kiowa_R010	1.7	0.2	1
Clear_Ck_R010	1	0.3	1
Clear_Ck_R020	4.7	0.3	3
Clear_Ck_R030	1.1	0.3	1
Clear_Ck_R040	5.9	0.3	4
Little_Elm_Ck_R010	6.7	0.34	8
Little_Elm_Ck_R035	2.5	0.1	1
Hickory_Ck_R010	4	0.3	4
Hickory_Ck_R020	3	0.3	2
Hickory_Ck_R035	6.9	0.1	3
Denton_Ck_R020	2	0.25	1
Hackberry_Ck_R010	1	0.25	1
Elm_Fork_R110	1	0.25	1
White_Rock_Ck_R010	3	0.3	2
Five_Mile_Ck_R010	0.5	0.3	1
Tenmile_Ck_R010	1.7	0.3	2
Indian_Ck_R010	5.1	0.25	3
Indian_Ck_R020	3.1	0.2	2
Sister_Grove_Ck_R010	7.1	0.2	4
East_Fork_R010	2	0.2	1
East_Fork_R020	5.8	0.2	3
East_Fork_R030	2.6	0.2	2
Lavon_RayHubbard_R010	4	0.2	7
Rowlett_Ck_R010	4	0.2	3
Trinity_River_R080	1	0.25	1
Kings_Ck_R010	1	0.4	1
Kings_Ck_R020	6	0.4	3
Cedar_Ck_R010	12	0.3	6
Cedar_Ck_R020	8	0.4	4
Cedar_Ck_R030	10	0.1	2
Waxahachie_Ck_R010	3.92	0.3	4
Waxahachie_Ck_R020	6.15	0.32	6
Waxahachie_Ck_R030	3.61	0.27	4
Post_Oak_Ck_R010	1.5	0.3	2
Richland_Ck_R010	8.93	0.35	9
Richland_CK_R030	4.96	0.16	5
Richland_Ck_R040	1	0.1	1
Tehuacana_Ck_R010	6	0.1	3
Big__Brown_Ck_R010	1	0.1	1

HEC-HMS Reach Name	K (hrs)	X	Subreaches
Upper_Keechi_Ck_R010	3	0.1	1
Upper_Keechi_Ck_R020	3.5	0.1	1
Big_Elkhart_R010	2.5	0.1	1
Bedias_Ck_R010	6	0.25	2
Long_King_Ck_R010	4	0.1	1
Menard_Ck_R010	2	0.1	1

Table 27: Final Straddle Stagger Routing Parameters

HEC-HMS Reach Name	Lag Time (min)	Duration (min)
Clear_Fork_R010	360	120
Clear_Fork_R020	120	120

Table 28: Final Initial and Constant Losses for the 2-yr through 25-yr Frequency Storms

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
West_Fork_S020	1.63	0.24	1.63	0.19	1.37	0.17	1.18	0.14
West_Fork_S010	1.66	0.24	1.73	0.19	1.52	0.17	1.37	0.14
West_Fork_S030	1.65	0.24	1.65	0.2	1.39	0.17	1.2	0.14
West_Fork_S040	1.63	0.24	1.64	0.19	1.38	0.17	1.19	0.14
West_Fork_S050	1.64	0.24	1.64	0.19	1.38	0.17	1.19	0.14
West_Fork_S060	1.63	0.24	1.63	0.19	1.37	0.17	1.18	0.14
West_Fork_S070	1.66	0.24	1.66	0.2	1.39	0.17	1.2	0.14
West_Fork_S080	1.62	0.24	1.62	0.19	1.36	0.17	1.17	0.14
West_Fork_S090	1.67	0.24	1.67	0.2	1.4	0.17	1.21	0.14
West_Fork_S100	1.6	0.24	1.6	0.19	1.35	0.16	1.16	0.14
West_Fork_S120	1.85	0.24	2.43	0.19	2.55	0.17	2.64	0.14
West_Fork_S110	1.69	0.25	1.69	0.2	1.41	0.17	1.22	0.14
Big_Cleveland_S010	1.99	0.24	2.97	0.19	3.36	0.17	3.63	0.14
Big_Cleveland_S020	1.83	0.24	2.37	0.19	2.46	0.17	2.52	0.14
West_Fork_S130	1.61	0.24	1.61	0.19	1.36	0.16	1.17	0.14
Lost_Ck_S010	1.9	0.24	1.63	0.19	1.37	0.17	1.18	0.14
Lost_Ck_S020	2.43	0.26	2.32	0.21	1.35	0.16	1.16	0.14
West_Fork_S140	2.64	0.26	3	0.21	2.09	0.17	2.06	0.14
West_Fork_S150	2.44	0.26	2.35	0.21	1.36	0.17	1.17	0.14
West_Fork_S160	2.5	0.26	2.39	0.22	1.39	0.17	1.2	0.14
Beans_Ck_S010	2.48	0.26	2.41	0.21	1.4	0.17	1.22	0.14
Beans_Ck_S020	2.51	0.26	2.41	0.22	1.39	0.17	1.2	0.14
Big_Ck_S010	2.55	0.27	2.47	0.22	1.44	0.17	1.25	0.14
Big_Ck_S030	2.63	0.27	2.51	0.22	1.45	0.17	1.25	0.15
Big_Ck_S020	2.56	0.27	2.45	0.22	1.42	0.17	1.23	0.14
Bridgeport_S030	2.68	0.28	2.55	0.23	1.47	0.18	1.27	0.15
Bridgeport_S010	2.22	0.24	2.13	0.19	1.25	0.15	1.07	0.13
Bridgeport_S040	2.65	0.27	2.54	0.22	1.46	0.18	1.26	0.15
Bridgeport_S020	2.54	0.27	2.44	0.22	1.41	0.17	1.21	0.14
West_Fork_S170	2.57	0.27	2.47	0.22	1.42	0.17	1.23	0.14
Dry_Ck_S010	2.69	0.28	2.64	0.23	1.56	0.18	1.38	0.15
West_Fork_S180	2.73	0.28	2.61	0.23	1.5	0.18	1.3	0.15
Amon_G_Carter_S030	2.03	0.24	1.98	0.2	1.87	0.17	1.79	0.14
Amon_G_Carter_S010	2.27	0.25	2.69	0.2	2.92	0.17	3.07	0.14
Amon_G_Carter_S020	2	0.25	1.82	0.2	1.62	0.17	1.48	0.14
Big_Sandy_Ck_S010	1.81	0.25	1.83	0.2	1.81	0.17	1.71	0.14
Big_Sandy_Ck_S020	1.77	0.26	1.57	0.21	1.36	0.18	1.39	0.15
Brushy_Ck_S010	1.76	0.26	1.59	0.21	1.42	0.18	1.42	0.15
Brushy_Ck_S020	1.85	0.26	1.78	0.21	1.69	0.18	1.63	0.15
Brushy_Ck_S030	1.97	0.26	2.18	0.21	2.29	0.18	2.07	0.15

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Big_Sandy_Ck_S030	1.86	0.26	1.79	0.21	1.69	0.18	1.63	0.15
Big_Sandy_Ck_S040	1.81	0.26	1.64	0.21	1.47	0.18	1.46	0.15
Big_Sandy_Ck_S050	2.76	0.28	2.73	0.23	1.62	0.18	1.44	0.15
West_Fork_S190	2.73	0.28	2.7	0.23	1.6	0.18	1.43	0.15
West_Fork_S200	2.69	0.28	2.57	0.23	1.48	0.18	1.28	0.15
Garrett_Ck_S020	2.9	0.27	3	0.22	2.44	0.18	2.48	0.15
Garrett_Ck_S010	2.94	0.28	3	0.23	2.52	0.18	2.57	0.15
Garrett_Ck_S030	2.7	0.28	2.58	0.23	1.48	0.18	1.29	0.15
Salt_Ck_S010	3	0.28	3	0.23	3.54	0.18	3.82	0.15
Salt_Ck_S020	2.99	0.28	3	0.23	2.44	0.18	2.45	0.15
West_Fork_S210	2.72	0.28	2.6	0.23	1.49	0.18	1.29	0.15
West_Fork_S220	2.93	0.28	2.82	0.23	2.76	0.2	1.75	0.15
Eagle_Mountain_S010	2.81	0.27	2.53	0.22	2.34	0.19	1.25	0.15
Eagle_Mountain_S020	2.63	0.25	2.38	0.21	2.23	0.18	1.14	0.14
Walnut_Ck_S020	1.98	0.26	2.08	0.21	2.08	0.18	1.29	0.15
Walnut_Ck_S010	1.97	0.26	2.07	0.21	2.07	0.18	1.28	0.15
Walnut_Ck_S030	2.89	0.28	2.69	0.23	2.39	0.2	1.29	0.15
Eagle_Mountain_S040	2.66	0.26	2.5	0.21	2.25	0.18	1.16	0.14
Eagle_Mountain_S030	2.83	0.27	2.64	0.22	2.35	0.2	1.26	0.15
Silver_Ck_S020	2.81	0.27	2.73	0.22	2.53	0.19	1.48	0.14
Silver_Ck_S010	2.91	0.28	2.81	0.23	2.59	0.2	1.54	0.15
Lake_Worth_S010	2.78	0.27	2.6	0.22	2.32	0.19	1.23	0.14
Lake_Worth_S020	2.7	0.26	2.53	0.21	2.27	0.19	1.18	0.14
West_Fork_S230	2.6	0.26	2.55	0.21	2.28	0.18	1.32	0.15
Lk_Weatherford_S010	2.11	0.26	2.64	0.21	2.78	0.18	1.69	0.22
Lk_Weatherford_S020	1.86	0.24	2.09	0.2	2.03	0.17	1.71	0.22
Clear_Fork_S010	2.25	0.25	2.53	0.2	2.64	0.17	2.73	0.15
Clear_Fork_S020	1.97	0.25	1.7	0.2	1.42	0.17	1.23	0.14
Bear_Ck_S010	2.03	0.25	1.83	0.2	1.61	0.17	1.46	0.14
Bear_Ck_S020	1.92	0.24	1.65	0.19	1.38	0.17	1.19	0.14
Benbrook_S010	1.87	0.24	1.61	0.19	1.36	0.16	1.17	0.14
Benbrook_S020	1.81	0.23	1.56	0.19	1.32	0.16	1.13	0.14
Benbrook_S030	1.79	0.23	1.54	0.18	1.3	0.16	1.12	0.13
Clear_Fork_S030	1.92	0.24	1.91	0.19	1.83	0.17	1.19	0.14
Marys_Ck_S010	2.4	0.25	2.4	0.24	2.36	0.21	1.21	0.14
Clear_Fork_S040	2.21	0.26	2.2	0.21	2.17	0.18	2	0.15
Clear_Fork_S050	2.66	0.27	2.6	0.22	2.33	0.19	1.35	0.15
West_Fork_S240	2.64	0.26	2.44	0.2	2.19	0.18	1.26	0.15
Marine_Ck_S020	2.91	0.26	2.98	0.2	2.98	0.18	2.52	0.15
Marine_Ck_S010	1.76	0.23	1.51	0.18	1.28	0.16	1.1	0.13
West_Fork_S250	2.7	0.27	2.49	0.21	2.24	0.18	1.29	0.15

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
West_Fork_S260	2.46	0.25	2.38	0.19	2.25	0.16	1.35	0.14
West_Fork_S270	3	0.28	3	0.22	2.98	0.19	1.76	0.15
Big_Fossil_Ck_S010	1.99	0.22	2.46	0.18	2.74	0.15	2.91	0.13
LittleFossil_Ck_S010	2.95	0.25	2.28	0.2	2.18	0.17	1.07	0.13
West_Fork_S280	3	0.27	2.53	0.21	2.48	0.19	1.18	0.14
Village_Ck_S010	1.67	0.23	1.65	0.19	1.45	0.16	1.29	0.14
Village_Ck_S020	1.81	0.23	1.56	0.19	1.31	0.16	1.13	0.14
Lake_Arlington_S010	1.78	0.23	1.53	0.18	1.3	0.16	1.11	0.13
Village_Ck_S030	3	0.28	2.64	0.22	2.58	0.19	1.23	0.14
West_Fork_S290	3	0.28	2.64	0.22	2.58	0.19	1.23	0.14
West_Fork_S300	3	0.26	2.46	0.21	2.38	0.18	1.15	0.14
West_Fork_S310	3	0.26	2.36	0.2	2.32	0.18	1.11	0.13
West_Fork_S320	2.03	0.25	1.75	0.2	1.46	0.18	1.26	0.15
Big_Bear_Ck_S010	1.94	0.24	1.77	0.19	1.58	0.17	1.43	0.14
Big_Bear_Ck_S020	2	0.25	1.72	0.2	1.44	0.17	1.24	0.15
West_Fork_S330	2	0.25	1.71	0.2	1.43	0.17	1.24	0.14
Joe_Pool_S020	1.7	0.21	1.7	0.17	1.66	0.15	1.6	0.13
Joe_Pool_S030	1.8	0.23	1.78	0.23	1.76	0.19	1.13	0.14
Joe_Pool_S040	1.75	0.23	1.51	0.18	1.28	0.16	1.1	0.13
Joe_Pool_S010	1.52	0.2	1.31	0.16	1.13	0.14	0.96	0.12
Joe_Pool_S050	1.59	0.21	1.38	0.17	1.18	0.15	1	0.12
Mountain_Ck_S010	1.63	0.21	1.42	0.17	1.22	0.15	1.04	0.13
Mountain_Ck_S020	1.65	0.21	1.42	0.17	1.21	0.15	1.04	0.13
Mountain_Ck_S030	1.7	0.22	1.68	0.21	1.5	0.18	1.07	0.13
West_Fork_S340	1.83	0.23	1.58	0.19	1.33	0.16	1.14	0.14
Elm_Fork_S020	1.99	0.22	2.33	0.18	2.51	0.16	2.62	0.13
Elm_Fork_S010	2.27	0.23	3.12	0.19	3.66	0.16	4.03	0.14
Brushy_Elm_Ck_S010	1.85	0.22	2.01	0.18	2.07	0.15	2.09	0.13
Brushy_Elm_Ck_S020	1.75	0.22	1.66	0.18	1.55	0.15	1.44	0.13
Elm_Fork_S030	1.88	0.22	2.11	0.18	2.22	0.15	2.27	0.13
Elm_Fork_S040	1.76	0.22	1.74	0.17	1.68	0.15	1.6	0.13
Elm_Fork_S050	1.91	0.23	1.87	0.19	1.77	0.16	1.69	0.14
Elm_Fork_S070	1.84	0.23	1.7	0.18	1.53	0.16	1.4	0.13
Elm_Fork_S060	1.61	0.21	1.39	0.17	1.19	0.15	1.02	0.13
Spring_Ck_S010	1.69	0.22	1.46	0.18	1.24	0.15	1.06	0.13
Spring_Ck_S020	1.69	0.22	1.46	0.18	1.24	0.15	1.06	0.13
Ray_Roberts_S010	1.95	0.22	2.23	0.18	2.37	0.16	2.45	0.13
Timber_Ck_S010	2.03	0.25	1.74	0.2	1.46	0.18	1.26	0.15
Timber_Ck_S030	1.85	0.23	1.59	0.19	1.34	0.16	1.15	0.14
Timber_Ck_S020	2.01	0.25	1.73	0.2	1.44	0.17	1.25	0.15
Ray_Roberts_S030	1.88	0.24	1.62	0.19	1.37	0.17	1.19	0.14

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Range_Ck_S010	2.35	0.29	2.35	0.28	2.25	0.26	1	0.12
Range_Ck_S020	1.56	0.21	1.35	0.16	1.16	0.14	0.98	0.12
Lake_Kiowa_S020	1.99	0.25	1.7	0.2	1.43	0.17	1.23	0.14
Lake_Kiowa_S010	2.08	0.26	1.78	0.21	1.49	0.18	1.29	0.15
Ray_Roberts_S020	1.58	0.21	1.37	0.17	1.17	0.15	1	0.12
Range_Ck_S030	1.66	0.22	1.43	0.17	1.22	0.15	1.04	0.13
Buck_Ck_S010	1.57	0.21	1.36	0.17	1.16	0.14	0.99	0.12
Ray_Roberts_S050	1.59	0.21	1.37	0.17	1.17	0.15	1	0.12
Ray_Roberts_S040	1.77	0.22	1.67	0.18	1.54	0.15	1.42	0.13
Ray_Roberts_S060	1.76	0.23	1.51	0.18	1.28	0.16	1.1	0.13
Timber_Ck_S040	1.82	0.23	1.56	0.19	1.32	0.16	1.13	0.14
Elm_Fork_S080	2.35	0.3	2.19	0.26	1.36	0.17	1.17	0.14
Clear_Ck_S010	2.12	0.23	2.84	0.2	3.11	0.17	3.31	0.15
Clear_Ck_S020	2.06	0.23	2.57	0.21	2.69	0.18	2.78	0.15
Clear_Ck_S030	2.12	0.23	2.86	0.2	3.14	0.18	3.34	0.15
Clear_Ck_S040	2.02	0.22	2.87	0.19	3.25	0.16	3.5	0.14
Clear_Ck_S050	1.85	0.21	2.4	0.19	2.57	0.16	2.68	0.14
Clear_Ck_S070	1.67	0.21	1.87	0.18	1.82	0.16	1.76	0.13
Clear_Ck_S060	1.72	0.22	1.64	0.19	1.38	0.17	1.19	0.14
Clear_Ck_S080	1.85	0.21	2.41	0.19	2.6	0.16	2.72	0.14
Clear_Ck_S090	1.67	0.2	2.03	0.18	2.1	0.15	2.13	0.13
Clear_Ck_S110	1.66	0.22	1.43	0.17	1.22	0.15	1.04	0.13
Clear_Ck_S100	1.78	0.22	1.8	0.17	1.76	0.15	1.7	0.13
Clear_Ck_S120	1.75	0.22	1.55	0.18	1.36	0.16	1.2	0.13
Little_Elm_Ck_S010	2.02	0.23	2.26	0.17	2.52	0.14	2.66	0.12
Little_Elm_Ck_S020	1.87	0.22	1.86	0.16	1.93	0.14	1.94	0.12
Little_Elm_Ck_S030	1.53	0.2	1.33	0.16	1.14	0.14	0.97	0.12
Pecan_Ck_S010	1.85	0.24	1.59	0.19	1.34	0.16	1.15	0.14
Doe_Branch_S010	1.57	0.21	1.37	0.17	1.19	0.14	1.02	0.12
Doe_Branch_S020	1.6	0.21	1.38	0.17	1.18	0.15	1.01	0.12
Lewisville_S030	1.78	0.23	1.54	0.18	1.3	0.16	1.12	0.13
Hickory_Ck_S020	1.74	0.22	1.65	0.17	1.53	0.15	1.42	0.13
Hickory_Ck_S010	1.73	0.22	1.64	0.17	1.53	0.15	1.42	0.13
Hickory_Ck_S030	1.66	0.21	1.47	0.17	1.28	0.15	1.12	0.13
Hickory_Ck_S040	2	0.22	2.35	0.18	2.54	0.16	2.66	0.13
Hickory_Ck_S050	2.09	0.25	1.98	0.2	1.82	0.17	1.71	0.15
Lewisville_S010	1.89	0.24	1.68	0.19	1.47	0.16	1.3	0.14
Lewisville_S040	1.54	0.2	1.34	0.16	1.15	0.14	0.97	0.12
Lewisville_S050	1.59	0.21	1.37	0.17	1.17	0.15	1	0.12
Lewisville_S020	1.89	0.24	1.68	0.19	1.46	0.16	1.3	0.14
Elm_Fork_S090	3	0.29	2.75	0.26	2.6	0.21	1.08	0.13

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Elm_Fork_S110	3	0.27	2.75	0.25	2.6	0.21	1.03	0.13
Elm_Fork_S100	3	0.31	2.75	0.28	2.6	0.24	1.26	0.14
Elm_Fork_S120	3	0.27	2.75	0.25	2.6	0.21	1.83	0.13
Denton_Ck_S010	1.9	0.26	2.22	0.21	2.33	0.18	2.64	0.15
Denton_Ck_S020	1.88	0.25	2.2	0.2	2.32	0.17	2.62	0.15
Denton_Ck_S030	1.83	0.25	2.12	0.2	2.21	0.17	2.48	0.14
Denton_Ck_S040	1.85	0.23	1.82	0.18	1.75	0.16	1.68	0.13
Denton_Ck_S050	1.89	0.22	2.02	0.18	2.05	0.16	2.05	0.13
Denton_Ck_S060	1.7	0.22	1.47	0.18	1.25	0.15	1.07	0.13
Denton_Ck_S070	1.72	0.22	1.5	0.18	1.29	0.15	1.12	0.13
Grapevine_S010	1.96	0.24	1.89	0.19	1.77	0.17	1.68	0.14
Denton_Ck_S080	3	0.3	2.98	0.28	2.96	0.22	1.13	0.14
Elm_Fork_S130	1.76	0.22	1.75	0.17	1.69	0.15	1.61	0.13
Hackberry_Ck_S010	1.71	0.2	1.93	0.16	2.06	0.14	2.1	0.12
Hackberry_Ck_S020	1.53	0.2	1.32	0.16	1.14	0.14	0.97	0.12
Hackberry_Ck_S030	1.57	0.21	1.36	0.17	1.16	0.14	0.99	0.12
Elm_Fork_S140	1.78	0.23	1.53	0.18	1.3	0.16	1.11	0.13
Elm_Fork_S150	1.79	0.23	1.54	0.18	1.3	0.16	1.12	0.13
Bachman_Branch_S010	1.9	0.24	1.63	0.19	1.37	0.17	1.18	0.14
Bachman_Branch_S020	1.8	0.23	1.55	0.19	1.31	0.16	1.13	0.14
Elm_Fork_S160	1.81	0.23	1.56	0.19	1.32	0.16	1.13	0.14
Trinity_River_S010	1.78	0.22	1.62	0.18	1.44	0.16	1.3	0.13
Trinity_River_S020	2.03	0.24	1.99	0.2	1.89	0.17	1.81	0.14
White_Rock_Ck_S010	1.92	0.22	2.12	0.18	2.21	0.16	2.24	0.13
White_Rock_Ck_S020	1.9	0.24	1.63	0.19	1.37	0.17	1.18	0.14
White_Rock_Ck_S030	1.87	0.24	1.61	0.19	1.35	0.16	1.16	0.14
White_Rock_Ck_S040	1.84	0.23	1.58	0.19	1.33	0.16	1.15	0.14
Trinity_River_S030	1.97	0.25	1.7	0.2	1.42	0.17	1.23	0.14
Fivemile_Ck_S010	2.04	0.25	1.87	0.2	1.66	0.17	1.52	0.14
Trinity_River_S040	1.84	0.23	1.59	0.19	1.34	0.16	1.15	0.14
Trinity_River_S050	1.79	0.23	1.54	0.18	1.3	0.16	1.12	0.13
Tenmile_Ck_S010	1.86	0.23	1.64	0.19	1.42	0.16	1.25	0.14
Tenmile_Ck_S020	1.66	0.22	1.43	0.17	1.22	0.15	1.04	0.13
Trinity_River_S060	1.89	0.24	1.71	0.19	1.51	0.16	1.35	0.14
Indian_Ck_S010	1.81	0.21	2.17	0.17	2.39	0.14	2.5	0.12
Indian_Ck_S030	1.83	0.22	1.82	0.18	1.76	0.16	1.69	0.13
Indian_Ck_S020	1.54	0.2	1.34	0.16	1.15	0.14	0.97	0.12
Indian_Ck_S040	1.75	0.21	1.95	0.17	2.05	0.15	2.08	0.12
Sister_Grove_S010	2.03	0.23	2.41	0.18	2.63	0.16	2.76	0.13
Sister_Grove_S020	1.82	0.22	1.97	0.17	2.03	0.15	2.04	0.13
East_Fork_S020	1.93	0.22	2.26	0.18	2.45	0.15	2.56	0.13

Subbasin Name	2-yr	2-yr	5-yr	5-yr	10-yr	10-yr	25-yr	25-yr
	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
East_Fork_S010	2.11	0.22	2.78	0.18	3.22	0.15	3.49	0.13
East_Fork_S030	1.77	0.22	1.7	0.18	1.59	0.15	1.49	0.13
East_Fork_S040	1.69	0.22	1.45	0.18	1.24	0.15	1.06	0.13
Wilson_Ck_S010	1.93	0.22	2.18	0.18	2.3	0.15	2.36	0.13
Lavon_S010	1.57	0.2	1.46	0.16	1.34	0.14	1.21	0.12
Lavon_S020	1.58	0.21	1.37	0.17	1.17	0.15	1	0.12
Rowlett_Ck_S010	2.3	0.25	2.16	0.2	1.8	0.17	1.18	0.13
Ray_Hubbard_S010	2.16	0.12	2.16	0.12	2.16	0.12	2.16	0.12
Ray_Hubbard_S020	1	0.12	1	0.12	1	0.12	1	0.12
East_Fork_S050	1.04	0.13	1.04	0.13	1.04	0.13	1.04	0.13
East_Fork_S070	1.15	0.14	1.04	0.14	2.48	0.12	0.98	0.12
East_Fork_S060	1.47	0.14	2.08	0.14	1.03	0.12	3.12	0.12
East_Fork_S080	1.14	0.14	1.04	0.14	1.03	0.12	0.98	0.12
East_Fork_S090	1.15	0.14	1.06	0.14	1.05	0.12	1.03	0.12
East_Fork_S110	1.21	0.15	1.26	0.15	1.11	0.13	1.17	0.12
East_Fork_S100	1.52	0.14	2.23	0.14	2.71	0.12	3.4	0.12
Trinity_River_S070	1.69	0.22	1.5	0.17	1.32	0.15	1.16	0.13
East_Fork_S120	1.75	0.21	1.96	0.17	2.06	0.15	2.1	0.12
Kings_Ck_S020	1.66	0.2	1.72	0.16	1.73	0.14	1.69	0.12
Kings_Ck_S010	1.81	0.21	1.99	0.17	2.07	0.15	2.1	0.13
Kings_Ck_S030	1.86	0.21	2.29	0.17	2.55	0.15	2.7	0.12
Cedar_Ck_S040	2.06	0.24	2.13	0.19	2.11	0.17	2.08	0.14
Cedar_Ck_S010	1.16	0.13	1.16	0.13	1.19	0.13	1.31	0.13
New_Terrell_City_Lake_S010	0.99	0.22	0.86	0.16	0.73	0.15	0.62	0.13
Cedar_Ck_S020	1.74	0.22	1.58	0.18	1.41	0.15	1.26	0.13
Cedar_Ck_S030	2.12	0.24	2.38	0.19	2.51	0.17	2.58	0.14
Trinity_River_S080	1.74	0.21	1.74	0.17	1.69	0.15	1.62	0.13
Trinity_River_S090	1.87	0.23	1.82	0.18	1.72	0.16	1.64	0.13
Chambers_Ck_S010	1.56	0.22	1.74	0.18	1.82	0.15	2.15	0.13
Chambers_Ck_S020	1.63	0.22	2.07	0.17	2.33	0.15	2.78	0.13
Chambers_Ck_S040	1.65	0.22	2.05	0.18	2.28	0.15	2.72	0.13
Chambers_Ck_S030	1.71	0.23	2.02	0.18	2.17	0.16	2.56	0.13
Waxahachie_Ck_S010	2.75	0.27	3.2	0.27	3.31	0.22	3.55	0.14
Waxahachie_Ck_S020	2.06	0.24	2.12	0.2	2.1	0.17	2.07	0.14
Waxahachie_Ck_S030	1.67	0.21	1.56	0.17	1.43	0.15	1.31	0.13
Mustang_Ck_S010	1.58	0.2	1.5	0.16	1.4	0.14	1.29	0.12
Bardwell_S010	1.63	0.2	1.62	0.16	1.57	0.14	1.49	0.12
Chambers_Ck_S050	1.51	0.2	1.92	0.16	2.18	0.14	2.61	0.12
Chambers_Ck_S060	1.47	0.21	1.6	0.17	1.64	0.15	1.93	0.13
Chambers_Ck_S070	1.51	0.21	1.91	0.16	2.16	0.14	2.59	0.12
Chambers_Ck_S080	1.73	0.21	1.82	0.17	1.83	0.15	1.81	0.13

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Post_Oak_Ck_S010	1.77	0.21	1.91	0.17	1.97	0.15	1.98	0.13
Lake_Halbert_S010	1.66	0.2	1.72	0.16	1.72	0.14	1.68	0.12
Navarro_Mills_S020	1.7	0.21	1.75	0.17	1.74	0.15	1.7	0.12
Navarro_Mills_S030	2.09	0.22	2.74	0.18	3.15	0.15	3.41	0.13
Navarro_Mills_S010	2.07	0.23	2.44	0.19	2.65	0.16	2.77	0.14
Navarro_Mills_S040	1.61	0.21	1.39	0.17	1.19	0.15	1.01	0.13
Richland_Ck_S010	1.8	0.21	2	0.17	2.1	0.15	2.14	0.13
Richland_Ck_S020	1.85	0.21	2.26	0.17	2.51	0.15	2.65	0.12
Richland-Chambers_S010	1.62	0.21	1.4	0.17	1.2	0.15	1.02	0.13
Richland-Chambers_S020	1.58	0.21	1.37	0.17	1.17	0.15	1	0.12
Tehuacana_Ck_S020	2.29	0.24	2.81	0.2	3.11	0.17	3.31	0.14
Tehuacana_Ck_S010	1.2	0.22	1.6	0.18	2.11	0.16	2.13	0.13
Trinity_River_S100	1.81	0.23	1.55	0.19	1.31	0.16	1.13	0.14
Fairfield_Lake_S010	2.48	0.24	3.53	0.2	4.21	0.17	4.67	0.14
Trinity_River_S110	2.29	0.28	2	0.22	1.69	0.19	1.5	0.16
Big_Brown_Ck_S010	2.69	0.27	3.59	0.22	4.13	0.19	4.53	0.15
Trinity_River_S120	2.22	0.26	2.25	0.21	2.18	0.18	2.14	0.15
Trinity_River_S130	2.07	0.25	1.85	0.2	1.61	0.18	1.44	0.15
Upper_Keechi_Ck_S030	2.26	0.27	2.01	0.22	1.74	0.19	1.57	0.16
Upper_Keechi_Ck_S010	2.26	0.26	2.24	0.23	2.01	0.2	1.44	0.15
Upper_Keechi_Ck_S020	2.43	0.28	2.3	0.23	2.1	0.2	2	0.16
Upper_Keechi_Ck_S040	2.12	0.26	1.81	0.21	1.51	0.18	1.31	0.15
Trinity_River_S140	1.56	0.21	1.35	0.17	1.16	0.14	0.99	0.12
Little_Elkhart_S010	2.22	0.27	1.9	0.22	1.58	0.19	1.37	0.16
Houston_County_Lake_S010	2.84	0.28	3.79	0.23	4.37	0.19	4.8	0.16
Trinity_River_S150	1.95	0.24	1.69	0.2	1.43	0.17	1.24	0.14
Trinity_River_S160	1.96	0.25	1.68	0.2	1.41	0.17	1.22	0.14
Trinity_River_S170	2.23	0.27	1.93	0.22	1.61	0.19	1.41	0.16
Trinity_River_S180	1.95	0.25	1.68	0.2	1.41	0.17	1.22	0.14
Bedias_Ck_S010	1.85	0.24	2.24	0.19	2.47	0.16	2.62	0.14
Bedias_Ck_S020	1.93	0.24	1.66	0.2	1.39	0.17	1.2	0.14
Trinity_River_S190	1.9	0.24	1.64	0.19	1.39	0.17	1.2	0.14
Livingston_S010	1.95	0.24	1.68	0.2	1.42	0.17	1.23	0.14
Livingston_S030	1.86	0.24	1.6	0.19	1.35	0.16	1.16	0.14
Livingston_S020	1.83	0.23	1.57	0.19	1.33	0.16	1.14	0.14
Trinity_River_S200	1.65	0.2	1.64	0.19	1.38	0.17	1.18	0.14
Long_King_Ck_S010	1.93	0.24	1.66	0.2	1.39	0.17	1.2	0.14
Long_King_Ck_S020	1.82	0.2	1.82	0.2	1.62	0.17	1.48	0.14
Trinity_River_S210	1.87	0.2	1.85	0.2	1.61	0.18	1.45	0.15
Menard_Ck_S010	2.2	0.26	2.2	0.21	2.12	0.18	2.06	0.15

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Trinity_River_S220	1.7	0.2	1.7	0.2	1.43	0.17	1.23	0.14
Trinity_River_S230	1.47	0.2	1.47	0.18	1.25	0.15	1.07	0.13
Trinity_River_S240	1.5	0.2	1.5	0.18	1.27	0.16	1.09	0.13
Trinity_River_S250	1.9	0.21	2.31	0.17	2.55	0.15	2.69	0.13

Table 29: Final Initial and Constant Losses for the 50-yr through 500-yr Frequency Storms

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
West_Fork_S020	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S010	1.21	0.12	1.05	0.09	0.89	0.08	0.57	0.07
West_Fork_S030	1.02	0.12	0.86	0.09	0.69	0.08	0.57	0.07
West_Fork_S040	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S050	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S060	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S070	1.03	0.12	0.86	0.09	0.7	0.08	0.57	0.07
West_Fork_S080	1.01	0.12	0.85	0.09	0.69	0.08	0.56	0.07
West_Fork_S090	1.03	0.12	0.86	0.09	0.7	0.08	0.57	0.07
West_Fork_S100	1	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S120	2.58	0.12	2.41	0.09	2.25	0.08	0.57	0.07
West_Fork_S110	1.04	0.12	0.87	0.09	0.7	0.08	0.58	0.07
Big_Cleveland_S010	3.66	0.12	3.49	0.09	3.33	0.08	0.57	0.07
Big_Cleveland_S020	2.46	0.12	2.29	0.09	2.13	0.08	0.57	0.07
West_Fork_S130	1	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Lost_Ck_S010	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Lost_Ck_S020	1	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S140	1.97	0.12	1.81	0.09	1.65	0.08	0.56	0.07
West_Fork_S150	1.01	0.12	0.85	0.09	0.69	0.08	0.56	0.07
West_Fork_S160	1.02	0.12	0.86	0.09	0.69	0.08	0.57	0.07
Beans_Ck_S010	1.05	0.12	0.89	0.09	0.73	0.08	0.57	0.07
Beans_Ck_S020	1.03	0.12	0.86	0.09	0.69	0.08	0.57	0.07
Big_Ck_S010	1.08	0.12	0.9	0.09	0.74	0.08	0.58	0.07
Big_Ck_S030	1.07	0.13	0.88	0.1	0.71	0.08	0.59	0.08
Big_Ck_S020	1.04	0.12	0.87	0.09	0.7	0.08	0.58	0.07
Bridgeport_S030	1.08	0.13	0.89	0.1	0.72	0.09	0.59	0.08
Bridgeport_S010	0.93	0.11	0.8	0.08	0.65	0.07	0.53	0.06
Bridgeport_S040	1.07	0.13	0.88	0.1	0.72	0.09	0.59	0.08
Bridgeport_S020	1.04	0.12	0.86	0.09	0.7	0.08	0.58	0.07
West_Fork_S170	1.05	0.12	0.87	0.09	0.7	0.08	0.58	0.07
Dry_Ck_S010	1.2	0.13	1.01	0.1	0.84	0.09	0.59	0.08
West_Fork_S180	1.1	0.13	0.9	0.1	0.73	0.09	0.6	0.08

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Amon_G_Carter_S030	1.67	0.12	1.5	0.09	1.34	0.08	0.57	0.07
Amon_G_Carter_S010	3.04	0.12	2.87	0.09	2.7	0.08	0.58	0.07
Amon_G_Carter_S020	1.32	0.12	1.15	0.09	0.98	0.08	0.58	0.07
Big_Sandy_Ck_S010	1.56	0.12	1.37	0.09	1.21	0.08	0.58	0.07
Big_Sandy_Ck_S020	1.19	0.13	1	0.1	0.83	0.09	0.6	0.08
Brushy_Ck_S010	1.24	0.13	1.05	0.1	0.88	0.09	0.59	0.08
Brushy_Ck_S020	1.46	0.13	1.26	0.1	1.09	0.09	0.6	0.08
Brushy_Ck_S030	1.94	0.13	1.74	0.1	1.57	0.09	0.6	0.08
Big_Sandy_Ck_S030	1.46	0.13	1.26	0.1	1.09	0.09	0.6	0.08
Big_Sandy_Ck_S040	1.28	0.13	1.08	0.1	0.91	0.09	0.6	0.08
Big_Sandy_Ck_S050	1.26	0.13	1.06	0.1	0.89	0.09	0.6	0.08
West_Fork_S190	1.25	0.13	1.05	0.1	0.88	0.09	0.6	0.08
West_Fork_S200	1.09	0.13	0.89	0.1	0.72	0.09	0.59	0.08
Garrett_Ck_S020	2.39	0.13	2.2	0.1	2.03	0.09	0.59	0.08
Garrett_Ck_S010	2.48	0.13	2.29	0.1	2.12	0.09	0.59	0.08
Garrett_Ck_S030	1.09	0.13	0.89	0.1	0.72	0.09	0.6	0.08
Salt_Ck_S010	3.82	0.13	3.62	0.1	3.45	0.09	0.6	0.08
Salt_Ck_S020	2.35	0.13	2.14	0.1	1.97	0.09	0.6	0.08
West_Fork_S210	1.09	0.13	0.9	0.1	0.73	0.09	0.6	0.08
West_Fork_S220	1.6	0.13	1.41	0.1	1.24	0.09	0.59	0.08
Eagle_Mountain_S010	1.06	0.13	0.88	0.1	0.71	0.08	0.59	0.08
Eagle_Mountain_S020	0.98	0.12	0.83	0.09	0.67	0.08	0.56	0.07
Walnut_Ck_S020	1.09	0.13	0.9	0.1	0.73	0.09	0.6	0.08
Walnut_Ck_S010	1.09	0.13	0.89	0.1	0.72	0.09	0.6	0.08
Walnut_Ck_S030	1.09	0.13	0.9	0.1	0.73	0.09	0.6	0.08
Eagle_Mountain_S040	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Eagle_Mountain_S030	1.07	0.13	0.88	0.1	0.71	0.09	0.59	0.08
Silver_Ck_S020	1.32	0.12	1.15	0.09	0.98	0.08	0.58	0.07
Silver_Ck_S010	1.37	0.13	1.17	0.1	1	0.09	0.59	0.08
Lake_Worth_S010	1.05	0.12	0.87	0.09	0.7	0.08	0.58	0.07
Lake_Worth_S020	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S230	1.11	0.13	0.91	0.1	0.74	0.09	0.6	0.08
Lk_Weatherford_S010	2.81	0.13	2.61	0.1	2.44	0.09	0.6	0.08
Lk_Weatherford_S020	1.87	0.12	1.7	0.09	1.54	0.08	0.57	0.07
Clear_Fork_S010	2.66	0.13	2.48	0.1	2.31	0.08	0.59	0.08
Clear_Fork_S020	1.05	0.12	0.87	0.09	0.7	0.08	0.58	0.07
Bear_Ck_S010	1.29	0.12	1.11	0.09	0.95	0.08	0.58	0.07
Bear_Ck_S020	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Benbrook_S010	1	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Benbrook_S020	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Benbrook_S030	0.96	0.11	0.82	0.08	0.67	0.07	0.55	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Clear_Fork_S030	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Marys_Ck_S010	1.04	0.12	0.86	0.09	0.7	0.08	0.58	0.07
Clear_Fork_S040	1.86	0.13	1.66	0.1	1.49	0.09	0.6	0.08
Clear_Fork_S050	1.13	0.13	0.92	0.1	0.74	0.09	0.61	0.08
West_Fork_S240	1.07	0.13	0.88	0.1	0.71	0.09	0.59	0.08
Marine_Ck_S020	2.43	0.13	2.24	0.1	2.08	0.09	0.59	0.08
Marine_Ck_S010	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
West_Fork_S250	1.09	0.13	0.89	0.1	0.72	0.09	0.6	0.08
West_Fork_S260	1.2	0.12	1.04	0.09	0.88	0.08	0.56	0.07
West_Fork_S270	1.62	0.13	1.44	0.1	1.27	0.08	0.58	0.08
Big_Fossil_Ck_S010	2.92	0.11	2.8	0.08	2.65	0.07	0.53	0.06
LittleFossil_Ck_S010	0.93	0.11	0.8	0.08	0.65	0.07	0.53	0.06
West_Fork_S280	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Village_Ck_S010	1.14	0.12	0.99	0.09	0.83	0.08	0.55	0.07
Village_Ck_S020	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Lake_Arlington_S010	0.96	0.11	0.82	0.08	0.66	0.07	0.55	0.06
Village_Ck_S030	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
West_Fork_S290	1.05	0.12	0.87	0.09	0.7	0.08	0.58	0.07
West_Fork_S300	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S310	0.96	0.11	0.82	0.08	0.66	0.07	0.54	0.06
West_Fork_S320	1.07	0.13	0.88	0.1	0.72	0.09	0.59	0.08
Big_Bear_Ck_S010	1.28	0.12	1.12	0.09	0.96	0.08	0.84	0.07
Big_Bear_Ck_S020	1.06	0.13	0.88	0.1	0.71	0.08	0.58	0.08
West_Fork_S330	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
Joe_Pool_S020	1.52	0.11	1.41	0.08	1.26	0.06	1.15	0.06
Joe_Pool_S030	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Joe_Pool_S040	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
Joe_Pool_S010	0.85	0.1	0.75	0.07	0.61	0.06	0.5	0.05
Joe_Pool_S050	0.88	0.1	0.77	0.07	0.63	0.06	0.52	0.05
Mountain_Ck_S010	0.92	0.11	0.8	0.08	0.66	0.06	0.54	0.06
Mountain_Ck_S020	0.9	0.11	0.79	0.08	0.64	0.07	0.52	0.06
Mountain_Ck_S030	0.93	0.11	0.8	0.08	0.65	0.07	0.53	0.06
West_Fork_S340	0.98	0.12	0.83	0.09	0.67	0.08	0.56	0.07
Elm_Fork_S020	2.59	0.11	2.46	0.08	2.3	0.07	2.19	0.06
Elm_Fork_S010	4.11	0.12	3.96	0.09	3.8	0.07	3.68	0.07
Brushy_Elm_Ck_S010	2.04	0.11	1.91	0.08	1.76	0.07	1.65	0.06
Brushy_Elm_Ck_S020	1.33	0.11	1.21	0.08	1.06	0.07	0.95	0.06
Elm_Fork_S030	2.23	0.11	2.11	0.08	1.96	0.07	1.84	0.06
Elm_Fork_S040	1.51	0.11	1.39	0.08	1.24	0.07	1.13	0.06
Elm_Fork_S050	1.58	0.12	1.43	0.09	1.27	0.07	1.15	0.07
Elm_Fork_S070	1.27	0.11	1.12	0.08	0.97	0.07	0.85	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Elm_Fork_S060	0.89	0.11	0.78	0.08	0.63	0.06	0.52	0.06
Spring_Ck_S010	0.92	0.11	0.8	0.08	0.65	0.07	0.53	0.06
Spring_Ck_S020	0.92	0.11	0.8	0.08	0.65	0.07	0.53	0.06
Ray_Roberts_S010	2.41	0.11	2.28	0.08	2.13	0.07	2.01	0.06
Timber_Ck_S010	1.07	0.13	0.88	0.1	0.72	0.09	0.59	0.08
Timber_Ck_S030	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Timber_Ck_S020	1.06	0.13	0.88	0.1	0.71	0.08	0.59	0.08
Ray_Roberts_S030	1.02	0.12	0.86	0.09	0.7	0.08	0.58	0.07
Range_Ck_S010	0.88	0.1	0.77	0.07	0.63	0.06	0.51	0.05
Range_Ck_S020	0.86	0.1	0.76	0.07	0.62	0.06	0.51	0.05
Lake_Kiowa_S020	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
Lake_Kiowa_S010	1.09	0.13	0.9	0.1	0.73	0.09	0.6	0.08
Ray_Roberts_S020	0.88	0.1	0.77	0.07	0.62	0.06	0.51	0.05
Range_Ck_S030	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06
Buck_Ck_S010	0.87	0.1	0.77	0.07	0.62	0.06	0.51	0.05
Ray_Roberts_S050	0.88	0.1	0.77	0.07	0.62	0.06	0.51	0.05
Ray_Roberts_S040	1.31	0.11	1.18	0.08	1.02	0.07	0.91	0.06
Ray_Roberts_S060	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
Timber_Ck_S040	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S080	1	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Clear_Ck_S010	3.29	0.13	3.1	0.1	2.94	0.08	2.81	0.08
Clear_Ck_S020	2.71	0.13	2.52	0.1	2.35	0.09	2.22	0.08
Clear_Ck_S030	3.32	0.13	3.13	0.1	2.96	0.08	2.84	0.08
Clear_Ck_S040	3.53	0.12	3.37	0.09	3.21	0.08	3.09	0.07
Clear_Ck_S050	2.65	0.12	2.5	0.09	2.34	0.07	2.22	0.07
Clear_Ck_S070	1.67	0.11	1.53	0.08	1.38	0.07	1.26	0.06
Clear_Ck_S060	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Clear_Ck_S080	2.69	0.12	2.55	0.09	2.39	0.07	2.27	0.07
Clear_Ck_S090	2.08	0.11	1.95	0.08	1.8	0.07	1.69	0.06
Clear_Ck_S110	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06
Clear_Ck_S100	1.62	0.11	1.5	0.08	1.35	0.07	1.23	0.06
Clear_Ck_S120	1.06	0.11	0.93	0.08	0.78	0.07	0.66	0.06
Little_Elm_Ck_S010	2.68	0.1	2.57	0.07	2.43	0.06	2.32	0.05
Little_Elm_Ck_S020	1.9	0.1	1.8	0.07	1.66	0.06	1.55	0.05
Little_Elm_Ck_S030	0.85	0.1	0.76	0.07	0.61	0.06	0.51	0.05
Pecan_Ck_S010	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Doe_Branch_S010	0.91	0.1	0.8	0.07	0.66	0.06	0.55	0.05
Doe_Branch_S020	0.88	0.1	0.77	0.07	0.63	0.06	0.52	0.05
Lewisville_S030	0.96	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Hickory_Ck_S020	1.31	0.11	1.19	0.08	1.04	0.07	0.93	0.06
Hickory_Ck_S010	1.31	0.11	1.19	0.08	1.04	0.07	0.93	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Hickory_Ck_S030	0.99	0.11	0.88	0.08	0.73	0.07	0.61	0.06
Hickory_Ck_S040	2.64	0.11	2.5	0.08	2.35	0.07	2.23	0.06
Hickory_Ck_S050	1.56	0.13	1.38	0.1	1.21	0.08	1.09	0.08
Lewisville_S010	1.15	0.12	0.99	0.09	0.83	0.08	0.71	0.07
Lewisville_S040	0.86	0.1	0.76	0.07	0.62	0.06	0.51	0.05
Lewisville_S050	0.88	0.1	0.77	0.07	0.62	0.06	0.51	0.05
Lewisville_S020	1.15	0.12	0.99	0.09	0.83	0.08	0.71	0.07
Elm_Fork_S090	0.93	0.11	0.8	0.08	0.65	0.07	0.54	0.06
Elm_Fork_S110	0.9	0.11	0.78	0.08	0.63	0.07	0.52	0.06
Elm_Fork_S100	1.11	0.12	0.95	0.09	0.79	0.08	0.67	0.07
Elm_Fork_S120	1.77	0.11	1.65	0.08	1.5	0.07	1.39	0.06
Denton_Ck_S010	2.78	0.13	3.08	0.1	2.91	0.09	2.78	0.08
Denton_Ck_S020	2.76	0.13	3.07	0.1	2.9	0.08	2.77	0.08
Denton_Ck_S030	2.61	0.12	2.89	0.09	2.72	0.08	2.6	0.07
Denton_Ck_S040	1.58	0.11	1.44	0.08	1.29	0.07	1.17	0.06
Denton_Ck_S050	1.99	0.11	1.85	0.08	1.7	0.07	1.58	0.06
Denton_Ck_S060	0.93	0.11	0.8	0.08	0.65	0.07	0.53	0.06
Denton_Ck_S070	0.98	0.11	0.85	0.08	0.7	0.07	0.58	0.06
Grapevine_S010	1.55	0.12	1.4	0.09	1.24	0.08	1.11	0.07
Denton_Ck_S080	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S130	1.52	0.11	1.4	0.08	1.25	0.07	1.14	0.06
Hackberry_Ck_S010	2.08	0.1	1.98	0.07	1.84	0.06	1.73	0.05
Hackberry_Ck_S020	0.85	0.1	0.76	0.07	0.61	0.06	0.5	0.05
Hackberry_Ck_S030	0.87	0.1	0.77	0.07	0.62	0.06	0.51	0.05
Elm_Fork_S140	0.96	0.11	0.82	0.08	0.66	0.07	0.55	0.06
Elm_Fork_S150	0.97	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Bachman_Branch_S010	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Bachman_Branch_S020	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S160	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Trinity_River_S010	1.17	0.11	1.03	0.08	0.88	0.07	0.76	0.06
Trinity_River_S020	1.68	0.12	1.51	0.09	1.35	0.08	1.23	0.07
White_Rock_Ck_S010	2.19	0.11	2.06	0.08	1.91	0.07	1.79	0.06
White_Rock_Ck_S020	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
White_Rock_Ck_S030	1	0.12	0.84	0.09	0.68	0.08	0.56	0.07
White_Rock_Ck_S040	0.99	0.12	0.83	0.09	0.68	0.08	0.56	0.07
Trinity_River_S030	1.05	0.12	0.87	0.09	0.7	0.08	0.58	0.07
Fivemile_Ck_S010	1.36	0.12	1.18	0.09	1.02	0.08	0.89	0.07
Trinity_River_S040	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Trinity_River_S050	0.97	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Tenmile_Ck_S010	1.09	0.12	0.94	0.09	0.78	0.08	0.66	0.07
Tenmile_Ck_S020	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Trinity_River_S060	1.2	0.12	1.05	0.09	0.89	0.08	0.77	0.07
Indian_Ck_S010	2.51	0.1	2.41	0.07	2.26	0.06	2.15	0.05
Indian_Ck_S030	1.6	0.11	1.47	0.08	1.31	0.07	1.2	0.06
Indian_Ck_S020	0.86	0.1	0.76	0.07	0.62	0.06	0.51	0.05
Indian_Ck_S040	2.05	0.1	1.94	0.07	1.8	0.06	1.69	0.05
Sister_Grove_S010	2.75	0.11	2.61	0.08	2.46	0.07	2.34	0.06
Sister_Grove_S020	1.98	0.11	1.86	0.08	1.71	0.07	1.6	0.06
East_Fork_S020	2.54	0.11	2.42	0.08	2.27	0.07	2.15	0.06
East_Fork_S010	3.55	0.11	3.42	0.08	3.26	0.07	3.15	0.06
East_Fork_S030	1.39	0.11	1.26	0.08	1.11	0.07	0.99	0.06
East_Fork_S040	0.92	0.11	0.8	0.08	0.65	0.07	0.53	0.06
Wilson_Ck_S010	2.32	0.11	2.19	0.08	2.04	0.07	1.92	0.06
Lavon_S010	1.12	0.1	1.02	0.07	0.88	0.06	0.77	0.05
Lavon_S020	0.87	0.1	0.77	0.07	0.62	0.06	0.51	0.05
Rowlett_Ck_S010	1.05	0.11	0.93	0.08	0.78	0.07	0.66	0.06
Ray_Hubbard_S010	2.14	0.1	2.04	0.07	1.9	0.06	1.79	0.05
Ray_Hubbard_S020	0.88	0.1	0.77	0.07	0.62	0.06	0.51	0.05
East_Fork_S050	0.91	0.11	0.8	0.08	0.65	0.06	0.54	0.06
East_Fork_S070	0.86	0.1	0.76	0.07	0.62	0.06	0.51	0.05
East_Fork_S060	3.18	0.1	3.09	0.07	2.94	0.06	2.83	0.05
East_Fork_S080	0.86	0.1	0.76	0.07	0.62	0.06	0.51	0.05
East_Fork_S090	0.91	0.1	0.82	0.07	0.67	0.06	0.56	0.05
East_Fork_S110	1.06	0.1	0.96	0.07	0.81	0.06	0.7	0.05
East_Fork_S100	3.48	0.1	3.39	0.07	3.24	0.06	3.13	0.05
Trinity_River_S070	1.03	0.11	0.91	0.08	0.76	0.07	0.65	0.06
East_Fork_S120	2.07	0.1	1.96	0.07	1.82	0.06	1.71	0.05
Kings_Ck_S020	1.63	0.1	1.53	0.07	1.38	0.06	1.28	0.05
Kings_Ck_S010	2.05	0.11	1.94	0.08	1.79	0.07	1.68	0.06
Kings_Ck_S030	2.71	0.1	2.6	0.07	2.46	0.06	2.35	0.05
Cedar_Ck_S040	1.98	0.12	1.82	0.09	1.66	0.08	1.53	0.07
Cedar_Ck_S010	2.13	0.11	1.99	0.08	1.84	0.07	1.72	0.06
New_Terrell_City_Lake_S010	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06
Cedar_Ck_S020	1.14	0.11	1.01	0.08	0.86	0.07	0.74	0.06
Cedar_Ck_S030	2.53	0.12	2.37	0.09	2.21	0.08	2.09	0.07
Trinity_River_S080	1.54	0.11	1.42	0.08	1.27	0.07	1.16	0.06
Trinity_River_S090	1.53	0.11	1.38	0.08	1.23	0.07	1.11	0.06
Chambers_Ck_S010	2.1	0.11	1.97	0.08	1.82	0.07	1.71	0.06
Chambers_Ck_S020	2.79	0.11	2.67	0.08	2.51	0.07	2.41	0.06
Chambers_Ck_S040	2.71	0.11	2.59	0.08	2.43	0.07	2.32	0.06
Chambers_Ck_S030	2.53	0.11	2.39	0.08	2.23	0.08	2.12	0.06
Waxahachie_Ck_S010	3.56	0.12	3.39	0.09	3.22	0.09	3.1	0.07

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Waxahachie_Ck_S020	1.97	0.12	1.8	0.09	1.64	0.08	1.52	0.07
Waxahachie_Ck_S030	1.2	0.11	1.09	0.08	0.94	0.07	0.83	0.06
Mustang_Ck_S010	1.2	0.1	1.11	0.07	0.96	0.06	0.86	0.05
Bardwell_S010	1.42	0.1	1.32	0.07	1.17	0.06	1.07	0.05
Chambers_Ck_S050	2.63	0.1	2.53	0.07	2.38	0.06	2.27	0.05
Chambers_Ck_S060	1.88	0.11	1.76	0.08	1.61	0.07	1.5	0.06
Chambers_Ck_S070	2.6	0.1	2.5	0.07	2.35	0.06	2.25	0.05
Chambers_Ck_S080	1.75	0.11	1.64	0.08	1.49	0.07	1.38	0.06
Post_Oak_Ck_S010	1.94	0.11	1.83	0.08	1.67	0.07	1.57	0.06
Lake_Halbert_S010	1.62	0.1	1.52	0.07	1.37	0.06	1.27	0.05
Navarro_Mills_S020	1.64	0.1	1.53	0.07	1.38	0.07	1.27	0.05
Navarro_Mills_S030	3.46	0.11	3.33	0.08	3.16	0.07	3.06	0.06
Navarro_Mills_S010	2.75	0.12	2.6	0.09	2.44	0.08	2.33	0.07
Navarro_Mills_S040	0.89	0.11	0.78	0.08	0.62	0.07	0.52	0.06
Richland_Ck_S010	2.1	0.11	1.99	0.08	1.84	0.07	1.73	0.06
Richland_Ck_S020	2.66	0.1	2.56	0.07	2.41	0.07	2.3	0.05
Richland-Chambers_S010	0.89	0.11	0.78	0.08	0.63	0.07	0.52	0.06
Richland-Chambers_S020	0.88	0.1	0.77	0.07	0.62	0.07	0.51	0.05
Tehuacana_Ck_S020	3.3	0.12	3.13	0.09	2.97	0.08	2.85	0.07
Tehuacana_Ck_S010	2.07	0.11	1.94	0.08	1.79	0.07	1.67	0.06
Trinity_River_S100	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Fairfield_Lake_S010	4.78	0.12	4.62	0.09	4.45	0.08	4.33	0.07
Trinity_River_S110	1.28	0.14	1.05	0.11	0.87	0.1	0.74	0.09
Big_Brown_Ck_S010	4.58	0.13	4.37	0.1	4.19	0.09	4.06	0.08
Trinity_River_S120	2.01	0.13	1.81	0.1	1.64	0.09	1.51	0.08
Trinity_River_S130	1.27	0.13	1.08	0.1	0.91	0.09	0.78	0.08
Upper_Keechi_Ck_S030	1.37	0.14	1.14	0.11	0.97	0.09	0.83	0.09
Upper_Keechi_Ck_S010	1.26	0.13	1.07	0.1	0.9	0.09	0.77	0.08
Upper_Keechi_Ck_S020	1.81	0.14	1.56	0.11	1.38	0.1	1.24	0.09
Upper_Keechi_Ck_S040	1.11	0.13	0.9	0.1	0.73	0.09	0.6	0.08
Trinity_River_S140	0.87	0.1	0.77	0.07	0.62	0.06	0.51	0.05
Little_Elkhart_S010	1.15	0.14	0.93	0.11	0.75	0.09	0.62	0.09
Houston_County_Lake_S010	4.85	0.14	4.62	0.11	4.44	0.1	4.3	0.09
Trinity_River_S150	1.07	0.12	0.9	0.09	0.73	0.08	0.61	0.07
Trinity_River_S160	1.04	0.12	0.86	0.09	0.7	0.08	0.58	0.07
Trinity_River_S170	1.19	0.14	0.97	0.11	0.79	0.1	0.66	0.09
Trinity_River_S180	1.04	0.12	0.87	0.09	0.7	0.08	0.58	0.07
Bedias_Ck_S010	3.07	0.12	2.91	0.09	2.75	0.08	2.63	0.07
Bedias_Ck_S020	1.03	0.12	0.86	0.09	0.69	0.08	0.57	0.07

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Trinity_River_S190	1.03	0.12	0.87	0.09	0.71	0.08	0.59	0.07
Livingston_S010	1.05	0.12	0.88	0.09	0.72	0.08	0.59	0.07
Livingston_S030	1	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Livingston_S020	0.98	0.12	0.83	0.09	0.67	0.08	0.55	0.07
Trinity_River_S200	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Long_King_Ck_S010	1.03	0.12	0.86	0.09	0.7	0.08	0.57	0.07
Long_King_Ck_S020	1.32	0.12	1.15	0.09	0.99	0.08	0.86	0.07
Trinity_River_S210	1.28	0.13	1.09	0.1	0.92	0.09	0.79	0.08
Menard_Ck_S010	1.93	0.13	1.74	0.1	1.57	0.09	1.44	0.08
Trinity_River_S220	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
Trinity_River_S230	0.93	0.11	0.8	0.08	0.65	0.07	0.53	0.06
Trinity_River_S240	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
Trinity_River_S250	2.7	0.11	2.59	0.08	2.44	0.06	2.33	0.06

1.6 POINT RAINFALL DEPTHS FOR THE FREQUENCY STORMS

Frequency point rainfall depths of various durations and recurrence intervals were collected for the Trinity River basin from NOAA Atlas 14 Volume 11: Precipitation Frequency Atlas of the United States, Texas, published in 2018 (NOAA, 2018). The point rainfall depths varied by county throughout the watershed. A precipitation depth was asssigned to each county located within the Trinity River watershed. The depth was approximately taken from the center of each county. Watershed subbasins were assigned the point rainfall depth for the particular county containing the majority of that subbasins drainage area. Tables 30 through 59 show the point rainfall depths assigned to each county.

Table 30: Frequency Point Rainfall Depths (inches) for Archer County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.82	1.07	1.26	1.51	1.69	1.89	2.1	2.4
1hr	1.44	1.87	2.2	2.64	2.98	3.35	3.75	4.33
2hr	1.75	2.32	2.77	3.39	3.88	4.41	4.98	5.81
3hr	1.93	2.6	3.13	3.88	4.48	5.13	5.83	6.83
6hr	2.26	3.1	3.77	4.71	5.47	6.31	7.21	8.49
12hr	2.64	3.61	4.38	5.47	6.35	7.31	8.37	9.89
24hr	3.06	4.16	5.04	6.26	7.24	8.31	9.5	11.24
48hr	3.55	4.78	5.75	7.11	8.18	9.35	10.66	12.58

Table 31: Frequency Point Rainfall Depths (inches) for Young County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.81	1.07	1.26	1.52	1.71	1.9	2.11	2.4
1hr	1.42	1.88	2.22	2.67	3.01	3.35	3.73	4.26
2hr	1.73	2.32	2.77	3.37	3.84	4.32	4.83	5.54
3hr	1.92	2.59	3.11	3.82	4.38	4.97	5.58	6.41
6hr	2.26	3.07	3.71	4.61	5.34	6.11	6.89	7.96
12hr	2.63	3.58	4.34	5.42	6.29	7.23	8.23	9.64
24hr	3.04	4.14	5.02	6.27	7.28	8.38	9.6	11.36
48hr	3.53	4.78	5.77	7.17	8.29	9.52	10.9	12.92

Table 32: Frequency Point Rainfall Depths (inches) for Jack County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.83	1.09	1.28	1.53	1.72	1.91	2.11	2.38
1hr	1.48	1.93	2.27	2.73	3.06	3.41	3.77	4.27
2hr	1.81	2.38	2.81	3.41	3.89	4.38	4.88	5.55
3hr	2.02	2.65	3.15	3.85	4.42	5.02	5.62	6.41
6hr	2.39	3.16	3.78	4.66	5.41	6.19	6.97	8.02
12hr	2.81	3.76	4.53	5.62	6.53	7.5	8.5	9.88
24hr	3.27	4.43	5.35	6.65	7.71	8.86	10.09	11.82
48hr	3.78	5.12	6.17	7.65	8.82	10.1	11.5	13.53

Table 33: Frequency Point Rainfall Depths (inches) for Clay County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.85	1.1	1.29	1.54	1.73	1.93	2.14	2.44
1hr	1.48	1.93	2.26	2.71	3.04	3.4	3.79	4.35
2hr	1.79	2.36	2.81	3.42	3.9	4.41	4.97	5.79
3hr	1.97	2.63	3.15	3.87	4.45	5.09	5.78	6.77
6hr	2.31	3.11	3.75	4.66	5.41	6.23	7.12	8.39
12hr	2.69	3.63	4.38	5.45	6.32	7.27	8.31	9.81
24hr	3.13	4.21	5.07	6.28	7.26	8.32	9.49	11.19
48hr	3.63	4.86	5.83	7.17	8.24	9.39	10.68	12.56

Table 34: Frequency Point Rainfall Depths (inches) for Wise County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.87	1.13	1.33	1.58	1.76	1.95	2.13	2.38
1hr	1.56	2.03	2.38	2.83	3.17	3.5	3.85	4.33
2hr	1.92	2.51	2.96	3.56	4.02	4.49	4.97	5.64
3hr	2.13	2.81	3.33	4.03	4.57	5.14	5.72	6.51
6hr	2.53	3.35	4	4.88	5.59	6.33	7.1	8.13
12hr	2.96	3.97	4.76	5.87	6.76	7.7	8.66	9.97
24hr	3.44	4.65	5.61	6.94	8.02	9.15	10.33	11.95
48hr	3.98	5.38	6.49	8.02	9.24	10.53	11.91	13.85

Table 35: Frequency Point Rainfall Depths (inches) for Montague County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.87	1.13	1.32	1.56	1.73	1.91	2.1	2.37
1hr	1.55	2.02	2.37	2.81	3.12	3.44	3.81	4.34
2hr	1.9	2.51	2.97	3.58	4.03	4.51	5.04	5.81
3hr	2.11	2.81	3.35	4.08	4.63	5.23	5.88	6.82
6hr	2.49	3.35	4.03	4.96	5.7	6.49	7.36	8.59
12hr	2.93	3.95	4.76	5.9	6.8	7.77	8.83	10.35
24hr	3.41	4.61	5.56	6.88	7.93	9.07	10.32	12.12
48hr	3.94	5.29	6.36	7.84	9	10.27	11.68	13.73

Table 36: Frequency Point Rainfall Depths (inches) for Tarrant County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.88	1.14	1.34	1.6	1.8	2.01	2.21	2.5
1hr	1.57	2.05	2.41	2.89	3.25	3.62	4.02	4.56
2hr	1.94	2.56	3.03	3.67	4.16	4.67	5.22	5.99
3hr	2.15	2.87	3.43	4.18	4.76	5.37	6.02	6.94
6hr	2.56	3.45	4.14	5.08	5.82	6.59	7.43	8.6
12hr	3.02	4.09	4.92	6.05	6.93	7.86	8.85	10.23
24hr	3.52	4.78	5.75	7.07	8.1	9.18	10.33	11.93
48hr	4.07	5.46	6.54	8.04	9.23	10.5	11.83	13.68

Table 37: Frequency Point Rainfall Depths (inches) for Parker County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.85	1.12	1.32	1.6	1.8	2.02	2.23	2.51
1hr	1.52	2	2.37	2.85	3.23	3.6	3.99	4.52
2hr	1.88	2.48	2.94	3.57	4.06	4.57	5.09	5.79
3hr	2.09	2.77	3.29	4.02	4.6	5.2	5.8	6.62
6hr	2.49	3.31	3.96	4.86	5.59	6.36	7.13	8.17
12hr	2.94	3.95	4.75	5.86	6.75	7.7	8.66	9.98
24hr	3.45	4.67	5.63	6.96	8.01	9.12	10.29	11.91
48hr	4.03	5.44	6.54	8.04	9.21	10.46	11.8	13.7

Table 38: Frequency Point Rainfall Depths (inches) for Johnson County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.88	1.16	1.38	1.66	1.88	2.11	2.35	2.67
1hr	1.6	2.11	2.5	3.02	3.42	3.84	4.29	4.91
2hr	1.98	2.63	3.14	3.83	4.36	4.93	5.53	6.39
3hr	2.21	2.95	3.54	4.33	4.96	5.63	6.35	7.36
6hr	2.63	3.54	4.26	5.25	6.03	6.87	7.78	9.06
12hr	3.09	4.18	5.04	6.22	7.14	8.14	9.22	10.77
24hr	3.6	4.88	5.88	7.25	8.32	9.47	10.72	12.53
48hr	4.17	5.64	6.79	8.35	9.55	10.84	12.25	14.29

Table 39: Frequency Point Rainfall Depths (inches) for Dallas County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.92	1.19	1.39	1.64	1.83	2.01	2.2	2.46
1hr	1.68	2.17	2.53	3	3.35	3.7	4.06	4.57
2hr	2.07	2.7	3.19	3.83	4.31	4.81	5.34	6.07
3hr	2.29	3.03	3.59	4.35	4.93	5.54	6.19	7.1
6hr	2.71	3.61	4.32	5.29	6.04	6.85	7.71	8.91
12hr	3.15	4.24	5.09	6.26	7.19	8.18	9.26	10.78
24hr	3.66	4.93	5.93	7.31	8.4	9.58	10.86	12.71
48hr	4.25	5.71	6.86	8.43	9.66	10.98	12.46	14.61

Table 40: Frequency Point Rainfall Depths (inches) for Ellis County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.93	1.22	1.43	1.71	1.92	2.13	2.35	2.65
1hr	1.69	2.21	2.6	3.11	3.5	3.9	4.33	4.94
2hr	2.06	2.74	3.26	3.97	4.52	5.11	5.74	6.65
3hr	2.28	3.06	3.67	4.52	5.19	5.92	6.7	7.82
6hr	2.68	3.64	4.41	5.49	6.36	7.31	8.35	9.85
12hr	3.12	4.26	5.18	6.47	7.52	8.67	9.95	11.82
24hr	3.62	4.96	6.02	7.52	8.72	10.04	11.54	13.75
48hr	4.24	5.77	6.97	8.64	9.94	11.37	13.03	15.53

Table 41: Frequency Point Rainfall Depths (inches) for Cooke County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.89	1.15	1.35	1.61	1.8	1.99	2.19	2.45
1hr	1.63	2.07	2.42	2.9	3.27	3.66	4.06	4.59
2hr	2	2.6	3.08	3.74	4.27	4.84	5.42	6.23
3hr	2.22	2.93	3.5	4.29	4.94	5.63	6.35	7.37
6hr	2.62	3.52	4.24	5.26	6.08	6.98	7.94	9.29
12hr	3.08	4.16	5.02	6.23	7.2	8.26	9.39	11.02
24hr	3.58	4.86	5.86	7.25	8.37	9.57	10.88	12.76
48hr	4.15	5.59	6.73	8.32	9.57	10.93	12.42	14.57

Table 42: Frequency Point Rainfall Depths (inches) for Grayson County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.92	1.17	1.36	1.61	1.8	1.99	2.17	2.42
1hr	1.66	2.12	2.46	2.92	3.27	3.62	3.98	4.48
2hr	2.04	2.65	3.12	3.76	4.27	4.79	5.34	6.09
3hr	2.26	2.98	3.54	4.32	4.93	5.59	6.27	7.22
6hr	2.69	3.59	4.3	5.3	6.11	6.97	7.88	9.14
12hr	3.2	4.29	5.15	6.35	7.3	8.31	9.39	10.91
24hr	3.77	5.06	6.07	7.45	8.54	9.7	10.94	12.7
48hr	4.38	5.85	6.99	8.57	9.8	11.11	12.53	14.54

Table 43: Frequency Point Rainfall Depths (inches) for Denton County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.9	1.16	1.36	1.61	1.79	1.97	2.15	2.39
1hr	1.63	2.1	2.45	2.91	3.24	3.57	3.92	4.39
2hr	2	2.61	3.08	3.69	4.15	4.62	5.12	5.81
3hr	2.22	2.93	3.46	4.19	4.74	5.32	5.93	6.78
6hr	2.63	3.5	4.17	5.08	5.79	6.54	7.33	8.46
12hr	3.11	4.14	4.94	6.03	6.87	7.76	8.72	10.09
24hr	3.63	4.85	5.79	7.06	8.03	9.06	10.19	11.8
48hr	4.21	5.61	6.68	8.14	9.26	10.44	11.73	13.57

Table 44: Frequency Point Rainfall Depths (inches) for Collin County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.92	1.17	1.36	1.6	1.78	1.96	2.13	2.37
1hr	1.67	2.13	2.47	2.92	3.24	3.57	3.92	4.39
2hr	2.06	2.67	3.13	3.75	4.21	4.7	5.21	5.92
3hr	2.29	3	3.55	4.29	4.86	5.46	6.09	6.97
6hr	2.72	3.62	4.31	5.26	6	6.79	7.62	8.79
12hr	3.22	4.3	5.14	6.28	7.17	8.11	9.12	10.54
24hr	3.79	5.05	6.03	7.36	8.39	9.49	10.67	12.33
48hr	4.41	5.86	6.97	8.48	9.63	10.86	12.21	14.13

Table 45: Frequency Point Rainfall Depths (inches) for Rockwall County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.94	1.19	1.37	1.61	1.79	1.96	2.14	2.37
1hr	1.71	2.17	2.51	2.95	3.27	3.59	3.94	4.42
2hr	2.11	2.72	3.19	3.8	4.26	4.74	5.24	5.95
3hr	2.35	3.07	3.62	4.36	4.92	5.51	6.14	7.01
6hr	2.79	3.69	4.39	5.35	6.09	6.87	7.71	8.89
12hr	3.27	4.36	5.21	6.38	7.28	8.25	9.31	10.81
24hr	3.82	5.1	6.1	7.46	8.53	9.67	10.93	12.75
48hr	4.44	5.9	7.04	8.58	9.75	11.02	12.44	14.53

Table 46: Frequency Point Rainfall Depths (inches) for Kaufman County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.94	1.2	1.4	1.65	1.83	2.02	2.21	2.46
1hr	1.73	2.21	2.57	3.04	3.38	3.73	4.1	4.62
2hr	2.12	2.77	3.27	3.93	4.43	4.96	5.53	6.33
3hr	2.36	3.12	3.7	4.51	5.13	5.8	6.52	7.55
6hr	2.79	3.74	4.49	5.54	6.37	7.28	8.26	9.67
12hr	3.25	4.39	5.31	6.59	7.63	8.77	10.02	11.83
24hr	3.77	5.12	6.19	7.7	8.92	10.26	11.74	13.9
48hr	4.42	5.96	7.17	8.84	10.15	11.58	13.18	15.53

Table 47: Frequency Point Rainfall Depths (inches) for Henderson County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.95	1.24	1.46	1.75	1.97	2.2	2.45	2.79
1hr	1.75	2.28	2.69	3.23	3.65	4.08	4.57	5.28
2hr	2.15	2.85	3.4	4.17	4.77	5.43	6.16	7.22
3hr	2.38	3.19	3.85	4.77	5.51	6.33	7.24	8.56
6hr	2.81	3.81	4.63	5.8	6.77	7.86	9.05	10.8
12hr	3.27	4.46	5.42	6.81	7.96	9.25	10.7	12.83
24hr	3.79	5.16	6.27	7.85	9.15	10.6	12.26	14.72
48hr	4.42	5.98	7.22	8.95	10.33	11.86	13.65	16.35

Table 48: Frequency Point Rainfall Depths (inches) for Vanzandt County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.95	1.21	1.41	1.67	1.87	2.07	2.27	2.55
1hr	1.73	2.22	2.59	3.08	3.44	3.81	4.22	4.79
2hr	2.13	2.8	3.31	4.01	4.55	5.12	5.73	6.59
3hr	2.37	3.16	3.77	4.62	5.29	6.01	6.77	7.85
6hr	2.81	3.79	4.57	5.66	6.54	7.48	8.49	9.93
12hr	3.29	4.45	5.36	6.64	7.66	8.77	9.98	11.71
24hr	3.83	5.15	6.19	7.64	8.79	10.03	11.41	13.42
48hr	4.46	5.96	7.12	8.71	9.92	11.25	12.77	15.01

Table 49: Frequency Point Rainfall Depths (inches) for Navarro County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.94	1.22	1.43	1.72	1.94	2.16	2.39	2.7
1hr	1.71	2.23	2.63	3.16	3.56	3.98	4.44	5.09
2hr	2.08	2.78	3.34	4.09	4.69	5.33	6.05	7.1
3hr	2.29	3.12	3.78	4.71	5.44	6.24	7.16	8.53
6hr	2.68	3.72	4.56	5.75	6.71	7.78	9.01	10.86
12hr	3.12	4.34	5.33	6.75	7.89	9.19	10.66	12.88
24hr	3.63	5.03	6.16	7.78	9.09	10.56	12.23	14.72
48hr	4.27	5.87	7.14	8.92	10.33	11.89	13.66	16.29

Table 50: Frequency Point Rainfall Depths (inches) for Hill County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.92	1.21	1.43	1.72	1.94	2.16	2.4	2.72
1hr	1.68	2.21	2.62	3.15	3.56	3.97	4.42	5.06
2hr	2.05	2.72	3.25	3.97	4.53	5.13	5.79	6.71
3hr	2.26	3.02	3.63	4.47	5.15	5.89	6.68	7.82
6hr	2.65	3.58	4.32	5.38	6.24	7.2	8.23	9.71
12hr	3.09	4.2	5.09	6.34	7.36	8.48	9.71	11.51
24hr	3.58	4.9	5.94	7.4	8.55	9.81	11.23	13.32
48hr	4.16	5.71	6.92	8.58	9.87	11.27	12.86	15.2

Table 51: Frequency Point Rainfall Depths (inches) for Freestone County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.94	1.25	1.49	1.79	2.02	2.25	2.5	2.86
1hr	1.71	2.29	2.72	3.29	3.7	4.14	4.63	5.34
2hr	2.1	2.84	3.42	4.2	4.8	5.45	6.17	7.23
3hr	2.33	3.18	3.85	4.78	5.51	6.31	7.21	8.53
6hr	2.74	3.76	4.59	5.75	6.7	7.75	8.92	10.64
12hr	3.18	4.35	5.3	6.66	7.77	9.02	10.43	12.52
24hr	3.67	5	6.08	7.61	8.86	10.26	11.86	14.24
48hr	4.27	5.81	7.02	8.71	10.06	11.54	13.22	15.7

Table 52: Frequency Point Rainfall Depths (inches) for Anderson County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.94	1.23	1.45	1.77	2.03	2.31	2.59	2.96
1hr	1.74	2.27	2.7	3.29	3.78	4.29	4.84	5.59
2hr	2.15	2.87	3.45	4.26	4.91	5.63	6.39	7.48
3hr	2.4	3.24	3.92	4.87	5.65	6.5	7.42	8.75
6hr	2.84	3.88	4.72	5.9	6.87	7.93	9.11	10.84
12hr	3.31	4.5	5.46	6.83	7.95	9.19	10.6	12.68
24hr	3.82	5.17	6.25	7.8	9.05	10.45	12.04	14.4
48hr	4.44	5.98	7.21	8.93	10.29	11.8	13.5	16.01

Table 53: Frequency Point Rainfall Depths (inches) for Leon County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.97	1.28	1.51	1.83	2.08	2.34	2.6	2.97
1hr	1.76	2.33	2.77	3.36	3.81	4.29	4.81	5.54
2hr	2.15	2.88	3.46	4.27	4.91	5.61	6.36	7.42
3hr	2.37	3.21	3.88	4.84	5.62	6.47	7.38	8.68
6hr	2.78	3.78	4.61	5.79	6.78	7.88	9.06	10.75
12hr	3.21	4.36	5.3	6.66	7.81	9.1	10.52	12.59
24hr	3.71	5	6.05	7.59	8.87	10.3	11.91	14.26
48hr	4.31	5.82	7.02	8.72	10.08	11.58	13.25	15.69

Table 54: Frequency Point Rainfall Depths (inches) for Houston County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.98	1.3	1.55	1.9	2.18	2.47	2.77	3.17
1hr	1.82	2.4	2.87	3.52	4.06	4.62	5.2	5.99
2hr	2.25	2.99	3.6	4.47	5.19	5.97	6.78	7.91
3hr	2.49	3.35	4.04	5.05	5.9	6.83	7.8	9.16
6hr	2.94	3.98	4.83	6.06	7.1	8.24	9.46	11.2
12hr	3.42	4.63	5.62	7.02	8.17	9.45	10.87	12.94
24hr	3.95	5.35	6.47	8.04	9.3	10.7	12.28	14.62
48hr	4.54	6.17	7.46	9.28	10.73	12.3	14.02	16.47

Table 55: Frequency Point Rainfall Depths (inches) for Madison County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	0.98	1.27	1.5	1.81	2.05	2.29	2.54	2.87
1hr	1.8	2.35	2.78	3.35	3.79	4.25	4.74	5.44
2hr	2.2	2.94	3.53	4.34	4.98	5.67	6.42	7.47
3hr	2.44	3.3	3.99	4.97	5.77	6.64	7.57	8.9
6hr	2.86	3.93	4.81	6.06	7.1	8.26	9.51	11.3
12hr	3.31	4.57	5.6	7.09	8.32	9.7	11.24	13.49
24hr	3.82	5.27	6.46	8.17	9.57	11.16	12.96	15.62
48hr	4.41	6.1	7.47	9.44	11.04	12.82	14.81	17.74

Table 56: Frequency Point Rainfall Depths (inches) for Sanjacinto County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	1.05	1.38	1.63	1.97	2.22	2.49	2.76	3.14
1hr	1.97	2.6	3.09	3.73	4.22	4.73	5.33	6.22
2hr	2.41	3.31	4.03	5.03	5.82	6.69	7.71	9.22
3hr	2.66	3.75	4.63	5.91	6.95	8.12	9.46	11.48
6hr	3.12	4.53	5.7	7.42	8.88	10.54	12.44	15.28
12hr	3.63	5.32	6.74	8.84	10.64	12.71	15.06	18.6
24hr	4.19	6.18	7.86	10.35	12.5	14.97	17.77	21.97
48hr	4.77	7.14	9.15	12.16	14.78	17.78	21.07	25.89

Table 57: Frequency Point Rainfall Depths (inches) for Walker County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	1	1.32	1.55	1.87	2.1	2.34	2.58	2.91
1hr	1.87	2.45	2.9	3.49	3.93	4.39	4.89	5.6
2hr	2.29	3.09	3.72	4.59	5.27	6	6.8	7.95
3hr	2.53	3.48	4.24	5.31	6.18	7.13	8.16	9.66
6hr	2.96	4.17	5.15	6.56	7.73	9.04	10.47	12.56
12hr	3.44	4.87	6.04	7.74	9.16	10.76	12.55	15.19
24hr	3.96	5.63	7	8.99	10.67	12.56	14.69	17.84
48hr	4.56	6.52	8.14	10.51	12.53	14.79	17.23	20.75

Table 58: Frequency Point Rainfall Depths (inches) for Polk County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	1.05	1.37	1.61	1.94	2.19	2.45	2.73	3.12
1hr	1.98	2.58	3.04	3.67	4.15	4.65	5.22	6.04
2hr	2.42	3.26	3.91	4.82	5.53	6.31	7.17	8.45
3hr	2.68	3.67	4.46	5.57	6.46	7.45	8.55	10.17
6hr	3.15	4.41	5.43	6.9	8.1	9.45	10.95	13.17
12hr	3.66	5.18	6.42	8.21	9.7	11.37	13.26	16.05
24hr	4.21	6.01	7.48	9.63	11.42	13.45	15.71	19.06
48hr	4.78	6.91	8.68	11.29	13.52	16.01	18.68	22.49

Table 59: Frequency Point Rainfall Depths (inches) for Liberty County Subbasins

Duration	Recurrence Interval							
	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	200-yr	500-yr
15min	1.11	1.47	1.73	2.08	2.35	2.62	2.9	3.29
1hr	2.13	2.81	3.33	4.03	4.54	5.08	5.71	6.63
2hr	2.62	3.6	4.38	5.49	6.38	7.37	8.48	10.12
3hr	2.89	4.09	5.07	6.51	7.72	9.09	10.61	12.85
6hr	3.4	4.97	6.31	8.32	10.06	12.09	14.34	17.7
12hr	3.97	5.93	7.61	10.13	12.32	14.91	17.93	22.56
24hr	4.6	6.99	9.03	12.1	14.75	17.91	21.66	27.53
48hr	5.27	8.19	10.67	14.38	17.57	21.33	25.74	32.56

All of the above sets of frequency precipitation depths were utilized as point rainfall depths in the frequency storms for the final HEC-HMS rainfall-runoff model. The appropriate point rainfall depth table was assigned to each subbasin within the HEC-HMS frequency storm editor. The final frequency results were then computed in HEC-HMS through the depth-area analysis of the applied frequency storms.

1.7 FREQUENCY STORM RESULTS – UNIFORM RAINFALL METHOD

The frequency flow values were then calculated in HEC-HMS by applying the frequency rainfall depths to the final watershed model through a depth-area analysis. This rainfall pattern is known as the uniform rainfall method because the same rainfall depths are applied uniformly over the entire watershed. The final HEC-HMS frequency flows for significant locations throughout the watershed model can be seen in Table 60. These results will later be compared, in the main report, to elliptical shaped storm results from HEC-HMS along with other methods from this study.

In some cases, one may observe that the simulated discharge decreases in the downstream direction. It is not an uncommon phenomenon to see decreasing frequency peak discharges for some river reaches as flood waters spread out into the floodplain and the hydrograph becomes dampened as it moves downstream. This can be due to a combination of peak attenuation due to river routing as well as the difference in timing between the peak of the main stem river versus the runoff from the local tributaries and subbasins.

Table 60: Summary of Discharges (cfs) from the HEC-HMS Uniform Rainfall Method

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River below Brushy Creek	West_Fork_J010	191.1	3,600	10,200	16,700	24,700	31,400	39,500	46,900	57,300
West Fork Trinity River at Hwy 281 (TRWB's Antelope Gage)	West_Fork_J020	231.5	3,200	10,200	17,900	27,900	36,500	46,900	56,300	69,000
West Fork Trinity River above Cameron Creek	West_Fork_abv_CameronCk	263.3	1,600	5,600	11,200	19,600	28,100	40,100	51,300	66,200
West Fork Trinity River below Cameron Creek	West_Fork_J030	332.4	3,600	8,800	14,000	25,400	37,100	53,300	68,100	87,700
West Fork Trinity River above Turkey Creek	West_Fork_abv_TurkeyCk	403.1	2,300	7,600	14,200	25,200	36,800	53,600	69,200	91,700
West Fork Trinity River below Turkey Creek	West_Fork_J050	439.2	2,600	8,100	15,000	26,500	39,000	57,200	73,900	98,300
West Fork Trinity River above Big Cleveland Creek	WestFork_abv_Big_Cleveland	549.4	2,100	6,400	11,800	20,800	30,900	47,400	63,100	86,400
West Fork Trinity River below Big Cleveland Creek	West_Fork_J070	648.1	3,600	7,100	12,400	21,200	32,000	50,700	68,400	95,400
West Fork Trinity River near Jacksboro, TX USGS gage	West_Fork_J080	668.7	2,100	6,100	11,400	20,300	30,600	48,200	65,100	91,500
Lost Creek Reservoir Outflow (Lost Creek Res nr Jacksboro USGS gage)	Lost Creek Reservoir	28.8	240	890	1,600	4,500	7,200	10,200	12,700	15,900
Lost Creek above the West Fork	Lost_Ck_abv_WestFork	42.5	220	1,600	3,600	4,800	5,900	7,200	9,600	13,000
West Fork Trinity River below Lost Creek	West Fork + Lost Ck	711.2	2,200	6,400	12,000	21,300	31,600	49,600	67,100	94,500
West Fork Trinity River above Carroll Creek	West_Fork_abv_CarrollCk	750.8	2,200	6,500	12,300	21,500	31,900	49,900	67,400	94,800
West Fork Trinity River below Carroll Creek	West_Fork_J090	792.1	2,200	7,200	18,700	27,700	35,300	50,300	67,800	95,400
West Fork Trinity River above Beans Creek	WestFork_abv_Beans_Ck	827.7	2,200	7,600	20,700	31,000	39,900	50,700	68,200	95,800
West Fork Trinity River below Beans Creek	West Fork + Beans Ck	874.6	2,200	9,000	25,400	38,100	49,300	62,800	74,000	96,800
Bridgeport Reservoir Inflow	Bridgeport Inflow	1095.7	3,900	22,200	59,200	86,200	109,300	136,800	161,200	194,600
Bridgeport Reservoir Outflow	Bridgeport Reservoir	1095.7	2,700	5,500	11,700	12,700	20,400	28,800	37,700	69,200

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River above Dry Creek	West_Fork_abv_DryCk	1136.2	2,500	5,500	11,700	12,800	16,600	28,900	37,900	69,400
West Fork Trinity River below Dry Creek	West_Fork_J100	1162.9	2,500	5,500	12,200	17,200	21,200	29,000	38,000	69,500
West Fork Trinity River above Big Sandy Creek	WestFork_abv_Big_Sandy_Ck	1169.5	2,500	5,500	11,800	16,900	21,700	29,000	38,000	69,600
Amon G Carter Lake Outflow	Amon G Carter Lake	109.5	170	620	1,200	1,500	4,600	10,300	14,800	24,800
Big Sandy Creek at Route 101 bridge near Sunset	Big_Sandy_Ck_J010	151.5	1,900	4,600	7,000	10,200	12,800	15,700	18,400	31,000
Big Sandy Creek above Brushy Creek	Big_Sandy_Ck_abv_Brushy_Ck	192.2	1,400	3,700	5,900	10,100	14,200	19,400	23,800	33,600
Big Sandy Creek below Brushy Creek	Big Sandy Ck + Brushy Ck	262.8	2,400	6,500	10,300	17,300	24,200	33,400	41,500	53,100
Big Sandy Creek about 2 miles upstream of FM 1810	Big_Sandy_Ck_J020	287.7	2,300	6,300	10,300	17,300	24,600	34,600	43,700	56,600
Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114 bridge	Big_Sandy_Ck_J030	334.3	2,700	7,100	11,600	19,100	26,600	37,800	48,100	65,000
Big Sandy Creek above the West Fork Trinity River	Big_Sandy_Ck_abv_WestFork	353.9	2,500	7,000	11,200	19,000	26,700	37,900	48,400	65,400
West Fork Trinity River below Big Sandy Creek	West Fork + Big Sandy Ck	1523.5	4,100	10,400	19,300	28,700	37,400	50,400	62,400	82,200
West Fork Trinity River at FM 3259 near Paradise, TX	West_Fork_J110	1551.8	4,000	10,200	17,100	27,300	37,400	51,100	63,700	82,600
West Fork Trinity River above Salt Creek	WestFork_abv_Salt_Ck	1573.7	3,800	9,700	15,200	24,300	33,600	47,300	59,700	78,500
West Fork Trinity River below Salt Creek	West Fork + Salt Ck	1680.4	3,800	10,000	17,100	28,500	40,700	58,900	75,700	98,800
West Fork Trinity River near Boyd, TX - USGS Gage at FM 730 bridge	West_Fork_J120	1710.8	3,600	10,000	17,000	28,500	40,600	58,700	76,400	101,100
West Fork Trinity River about 0.8 miles upstream of FM 4757 in Wise County	West_Fork_J130	1751.9	3,600	9,900	16,900	28,200	40,000	57,700	74,200	98,800
Walnut Creek at Reno, TX USGS gage at FM1542 bridge in Parker County	Walnut_Ck_J010	62.7	5,000	13,000	19,800	29,100	34,900	41,400	47,200	54,900
Walnut Creek above Eagle Mountain Lake in Tarrant County	Walnut_Ck_abv_Eagle Mountain	81.4	2,600	8,300	14,300	25,000	32,000	40,100	46,800	55,400
Eagle Mountain Reservoir Inflow	Eagle Mountain Inflow	1956.6	5,100	20,100	38,600	67,900	85,400	106,600	125,300	149,700

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Eagle Mountain Reservoir Outflow	Eagle Mountain Reservoir	1956.6	3,700	7,300	14,100	19,000	23,300	30,400	38,900	56,000
Lake Worth Inflow	Lake Worth Inflow	2050.8	3,800	9,200	14,400	25,100	31,000	38,000	44,300	56,500
Lake Worth Outflow	Lake Worth	2050.8	3,500	7,400	14,300	19,300	23,400	30,700	39,200	56,400
West Fork Trinity River above the Clear Fork	WestFork_abv_Clear_Fork	2078.7	3,600	7,500	14,600	19,600	23,800	31,100	39,600	56,800
Lake Weatherford Outflow	Lake Weatherford	108.7	820	2,100	3,000	5,100	8,600	18,500	26,300	38,800
Clear Fork at Kelly Rd nr Aledo USGS gage	Clear_Fork_J010	245.1	2,100	6,200	11,000	17,600	23,100	34,800	49,700	72,100
Clear Fork above Bear Creek	Clear_Fork_abv_Bear_Ck	263.8	2,100	6,400	11,200	17,900	23,400	35,000	49,900	72,300
Benbrook Lake Inflow	Benbrook Inflow	429.2	16,300	43,700	61,600	82,500	99,100	118,000	135,900	163,700
Benbrook Lake Outflow (Clear Fork nr Benbrook)	Benbrook Lake	429.2	0	0	0	1,800	4,200	7,600	12,300	22,600
Clear Fork above Marys Creek	Clear_Fork_abv_Marys_Ck	9.4	4,300	7,800	10,000	12,500	14,300	16,200	18,100	20,800
Marys Creek at Benbrook USGS gage	Marys_Ck_S010	54.2	2,500	12,400	25,100	43,500	52,700	63,100	77,000	92,500
Clear Fork below Marys Creek	Clear Fork + Marys Creek	63.6	4,000	13,200	26,700	46,800	56,700	68,700	83,500	100,800
Clear Fork Trinity River at Fort Worth USGS gage	Clear_Fork_J020	89.0	5,700	17,000	31,500	53,200	62,600	72,100	83,800	99,400
Clear Fork Trinity River above the West Fork	Clear_Fork_abv_WestFork	93.9	6,200	17,100	30,800	50,200	59,700	69,500	80,000	93,900
West Fork Trinity River below the Clear Fork (West Fork at Fort Worth USGS gage)	West Fork + Clear Fork	2172.5	7,300	19,900	35,600	57,400	68,600	80,500	92,900	113,400
West Fork Trinity River above Marine Creek	WestFork_abv_MarineCk	2173.7	7,200	19,800	35,400	57,100	67,900	79,800	92,800	113,100
West Fork Trinity River below Marine Creek	West Fork + Marine Ck	2195.4	8,000	20,600	36,400	58,700	70,000	82,200	95,600	116,300
West Fork Trinity River above Sycamore Creek	West_Fork_J140	2204.6	8,300	19,800	36,100	56,900	66,300	80,600	95,700	115,800
West Fork Trinity River below Sycamore Creek (West Fork Trinity River at Beach	West_Fork_J150	2243.8	8,600	19,700	34,500	58,200	69,400	82,300	97,500	119,400

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork above Big Fossil	WestFork_abv_BigFossil	2256.8	7,700	17,700	31,900	55,400	67,400	80,800	95,500	117,000
West Fork Trinity River and Big Fossil Creek Confluence	West_Fork_J160	2333.4	12,900	23,800	38,000	66,200	81,300	98,300	116,800	143,600
Village Creek at Everman USGS gage	Village_Ck_S010	90.4	7,400	14,300	20,200	27,200	33,000	39,700	46,100	54,800
Lake Arlington Inflow	Lake Arlington Inflow	143.1	13,000	24,600	31,700	40,900	48,500	56,400	64,300	75,100
Lake Arlington Outflow	Lake Arlington	143.1	2,300	3,500	3,600	4,900	10,500	18,700	26,800	37,500
Village Creek above West Fork	Village_Ck_abv_WestFork	191.7	3,300	7,200	11,000	17,300	20,400	23,900	27,200	38,700
West Fork Trinity River below Village Creek	West Fork + Village Ck	2554.0	11,900	21,300	35,600	60,400	77,400	100,300	124,600	161,100
West Fork Trinity River below Johnson Creek	West_Fork_J170	2618.6	9,000	17,700	26,500	49,100	65,600	88,400	115,000	147,600
West Fork Trinity River at Grand Prairie USGS gage	West_Fork_J180	2623.4	9,000	17,700	26,500	49,300	65,700	88,200	113,800	146,400
West Fork Trinity River above Big Bear Creek	West_Fork_abv_Big_Bear_Ck	2625.5	8,900	17,000	25,900	47,700	62,900	84,000	108,000	141,800
West Fork Trinity River below Big Bear Creek	West Fork + Bear Ck	2718.8	10,300	18,300	29,200	56,300	74,300	96,800	125,600	163,000
West Fork Trinity River above Mountain Creek	West_Fork_abv_Mountain_Ck	2727.4	10,300	18,300	28,700	52,400	70,200	92,500	117,300	154,000
Walnut Creek near Mansfield, TX USGS gage	Joe_Pool_S030	62.9	4,100	8,100	11,600	17,100	20,900	25,300	29,800	35,100
Walnut Creek above Joe Pool Lake	Walnut Ck + Joe Pool	67.2	4,000	7,900	11,300	16,700	20,500	25,000	29,400	34,700
Mountain Ck near Venus, TX USGS Gage	Joe_Pool_S010	26.0	3,600	6,700	8,800	11,600	13,900	16,500	18,900	22,300
Joe Pool Lake Inflow	Joe Pool Inflow	224.2	14,100	27,500	38,500	54,600	67,300	82,500	97,400	116,200
Joe Pool Lake Outflow	Joe Pool Lake	224.2	0	0	0	0	0	0	0	0
Mountain Creek Lake Inflow	Mountain Creek Inflow	70.6	20,600	32,800	40,400	50,200	57,800	66,000	74,300	85,300
Mountain Creek Lake Outflow	Mountain Creek Reservoir	70.6	11,900	21,700	29,700	40,500	48,000	56,600	63,800	69,400

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Mountain Creek above the West Fork Trinity River	Mountain_Ck_abv_West_Fork	80.2	8,800	15,500	20,400	26,700	31,900	38,300	44,600	52,600
West Fork Trinity River below Mountain Creek	West Fork + Mountain Ck	2807.6	14,400	24,800	32,500	54,100	72,000	94,400	119,600	157,500
West Fork Trinity River above the Elm Fork Trinity River	West_Fork_abv_Elm_Fork	2820.9	14,700	24,700	32,000	53,600	71,600	94,000	119,000	156,700
Elm Fork Trinity River above Brushy Elm Creek	Elm_Fork_abv_Brushy_Elm_Ck	67.4	2,600	5,200	7,900	12,800	17,700	24,100	30,500	38,900
Muenster Lake Outflow	Muenster Lake	14.0	200	330	340	360	370	510	790	1,200
Brushy Elm Creek above the Elm Fork Trinity River	Brushy_Elm_Ck_abv_Elm_Fork	25.5	1,800	3,600	4,900	6,500	7,700	9,100	10,500	12,400
Elm Fork Trinity River below Brushy Elm Creek	Elm_Fork_J010	92.9	3,300	6,800	10,000	15,600	20,800	27,500	34,500	43,800
Elm Fork Trinity River below Dry Elm Creek	Elm_Fork_J020	137.0	6,200	13,200	19,500	28,500	36,400	45,600	54,800	67,300
Elm Fk Trinity Rv at Gainesville, TX USGS gage	Elm_Fork_J030	177.2	8,300	18,100	26,500	38,300	48,400	60,400	71,900	87,500
Elm Fork Trinity River below Pecan Creek	Elm Fork + Pecan Ck	216.8	8,100	18,100	27,000	39,700	50,800	64,200	77,200	94,200
Elm Fork Trinity River above Ray Roberts Lake	Elm_Fork_abv_Ray_Roberts	265.0	7,600	17,200	25,800	38,400	49,700	64,100	77,800	95,600
Lake Kiowa Inflow	Lake_Kiowa_S010	16.8	1,900	5,000	6,900	9,200	11,000	13,000	15,000	17,600
Lake Kiowa Outflow	Kiowa Lake	16.8	450	1,500	2,300	3,600	4,700	5,900	7,200	8,900
Timber Ck nr Collinsville, TX USGS gage	Timber_Ck_S010	39.0	2,600	7,500	10,800	14,900	18,200	22,000	25,600	30,500
Timber Creek above Ray Roberts Lake	Timber_Ck_abv_Ray_Roberts	64.2	4,000	10,300	15,000	20,800	25,500	31,100	36,200	43,100
Range Creek nr Collinsville, TX USGS gage	Range_Ck_S010	29.3	2,700	8,300	12,900	20,400	24,000	28,000	31,700	36,700
Range Creek above Ray Roberts Lake	Range_Ck_abv_Ray_Roberts	50.6	2,800	6,900	10,400	17,400	21,200	25,600	29,400	34,700
Ray Roberts Lake Inflow	Ray Roberts Inflow	692.6	48,000	90,200	118,800	157,300	189,000	226,700	262,400	310,800
Ray Roberts Lake Outflow (Elm Fork at Greenbelt nr Pilot Point USGS gage)	Ray Roberts Lake	692.6	0	0	0	0	210	1,100	2,000	3,200

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Elm Fork Trinity River above Clear Creek	Elm_Fork_abv_Clear_Ck	36.9	1,200	4,800	9,000	12,000	14,400	17,200	19,700	23,200
Clear Creek above Bingham Creek	Clear_Ck_abv_Bingham_Ck	83.9	2,500	4,700	8,800	15,200	21,100	28,400	35,500	44,200
Clear Creek below Bingham Creek	Clear_Ck_J010	99.9	2,600	5,100	9,700	17,200	24,000	32,500	40,700	50,800
Clear Creek above Williams Creek	Clear_Ck_abv_Williams_Ck	151.6	3,200	5,300	10,100	18,600	26,800	37,300	47,300	60,000
Clear Creek below Williams Creek	Clear_Ck_J020	187.2	4,400	7,400	13,500	24,000	34,000	46,800	59,200	74,700
Clear Creek below Flat Creek	Clear_Ck_J030	214.5	4,600	8,700	16,300	28,300	39,300	53,400	67,100	84,400
Clear Creek above Duck Creek	Clear_Ck_abv_Duck_Ck	259.5	5,100	9,200	17,000	29,700	41,500	56,900	71,900	90,400
Clear Ck nr Sanger, TX USGS gage	Clear_Ck_J040	294.6	6,000	10,400	19,000	32,800	45,700	62,600	78,900	99,300
Clear Creek above Moores Branch	Clear_Ck_abv_Moores_Br	309.9	5,600	9,500	16,500	29,500	42,500	59,700	76,300	97,200
Clear Creek below Moores Branch	Clear_Ck_J050	322.8	5,700	9,600	16,700	29,800	43,000	60,400	77,400	98,600
Clear Creek above the Elm Fork Trinity River	Clear_Ck_abv_Elm_Fork	351.2	5,300	9,100	15,800	28,900	42,500	60,600	78,300	100,600
Elm Fork Trinity River below Clear Creek	Elm Fork + Clear Ck	388.1	5,300	9,300	16,100	29,400	43,300	62,100	80,500	104,000
Little Elm Ck nr Aubrey, TX USGS gage	Little_Elm_Ck_J010	72.9	3,400	7,400	10,400	15,200	19,500	24,700	29,500	35,700
Little Elm Creek below Mustang Creek	Little_Elm_Ck_J020	95.8	4,100	8,700	12,300	18,000	23,100	29,300	35,100	42,500
Doe Br at Hwy 380 nr Prosper, TX USGS gage	Doe_Branch_S010	38.4	4,200	7,200	9,500	12,500	14,900	17,700	20,300	23,800
Doe Branch above Little Elm Creek	Doe_Branch_abv_Lewisville	71.0	6,500	11,600	15,400	20,700	24,800	29,600	34,000	40,100
Little Elm below Doe Branch	Doe Branch + Lewisville	231.3	8,900	17,900	24,800	34,100	41,800	51,200	60,000	72,500
Hickory Creek below North & South Hickory Creek confluence	Hickory_Ck_J010	80.7	7,700	16,400	22,600	30,000	36,000	42,700	48,800	57,200
Hickory Creek at Denton, TX USGS gage	Hickory_Ck_J030	128.9	6,200	13,600	19,100	26,400	32,700	40,300	46,900	55,800

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Hickory Creek at Old Alton Rd above Lewisville Lake	Hickory_Ck_abv_Lewisville	148.9	5,900	12,500	18,000	25,200	31,700	39,400	46,600	55,900
Lewisville Lake Inflow	Lewisville Inflow	968.2	38,700	69,000	91,400	119,300	143,100	169,500	193,800	227,400
Lewisville Lake Outflow (Elm Fork nr Lewisville USGS gage)	Lewisville Lake	968.2	0	0	0	0	1,500	5,500	10,100	17,400
Elm Fork Trinity River above Indian Creek	Elm_Fork_abv_Indian_Ck	21.4	1,200	2,900	4,400	7,200	8,500	10,000	11,300	13,300
Elm Fort Trinity River below Indian Creek	Elm Fork + Indian Ck	37.5	3,000	6,200	9,200	14,400	16,900	19,700	22,300	26,000
Elm Fork Trinity River below Timber Creek	Elm Fork + Timber Ck	61.5	3,700	6,900	9,700	14,800	17,500	21,200	24,700	29,400
Elm Fork Trinity River above Denton Creek	Elm_Fork_abv_Denton_Ck	79.9	5,200	9,100	12,900	19,300	22,900	27,500	31,900	37,900
Denton Creek above FM 1655	Denton_Ck_S010	116.0	3,700	8,700	14,000	20,700	26,800	32,900	41,500	52,600
Denton Creek above Sweetwater Creek	Denton_Ck_J010	285.1	5,400	12,600	20,200	29,500	38,300	46,800	58,800	71,800
Denton Creek below Sweetwater Creek	Denton_Ck_J020	346.6	6,200	14,200	22,900	34,200	44,900	55,600	70,000	86,500
Denton Creek nr Justin, TX USGS gage	Denton_Ck_J030	400.0	4,100	9,700	16,000	26,000	35,900	47,300	62,900	81,700
Denton Creek below Oliver Creek	Denton_Ck_J040	475.3	6,100	15,500	24,100	35,400	44,600	54,800	70,100	92,700
Denton Creek above Elizabeth Creek	Denton_Ck_abv_Elizabeth_Ck	506.1	6,800	15,500	23,300	35,200	45,600	57,200	70,400	94,200
Denton Creek below Elizaveth Creek	Denton_Ck_J050	599.7	12,200	26,600	38,500	55,900	71,200	88,600	105,500	127,600
Grapevine Lake Inflow	Grapevine_Inflow	694.4	14,800	29,100	38,900	55,000	70,300	89,500	107,300	131,300
Grapevine Lake Outflow (Denton Creek nr Grapevine USGS gage)	Grapevine Lake	694.4	0	0	0	0	0	3,900	9,500	19,500
Denton Creek above the Elm Fork Trinity River	Denton_Ck_abv_Elm_Fork	24.3	2,100	4,100	6,100	10,400	12,200	14,300	16,400	19,000
Elm Fork Trinity River near Carrollton USGS gage	Elm Fork + Denton Ck	104.2	6,700	11,700	17,100	26,700	31,500	37,200	43,200	51,200
Elm Fork Trinity River at Interstate 635	Elm_Fork_J060	143.4	11,400	17,500	21,900	30,500	36,600	43,300	50,100	59,600

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Elm Fork Trinity River above Hackleberry Creek	Elm_Fork_abv_Hackberry_Ck	143.4	8,300	13,300	18,300	29,100	35,200	42,100	49,000	57,200
Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage	Elm_Fork_J070	180.4	10,000	15,000	19,100	30,300	37,100	45,100	52,800	62,400
Elm Fork Trinity River above Bachman Branch	Elm_Fork_abv_Bachman_Branch	202.6	9,100	14,100	17,900	27,100	33,700	41,700	48,500	57,700
Bachman Lake Outflow	Bachman Lake	12.7	3,100	6,000	8,100	11,200	13,400	16,000	18,600	21,600
Bachman Branch above the Elm Fork Trinity River	Bachman_Branch_abv_Elm_Fork	14.1	1,600	3,000	4,000	5,300	6,400	7,800	9,200	11,200
Elm Fork Trinity River below Bachman Branch (at Frasier Dam USGS gage)	Elm Fork + Bachman Branch	216.7	10,000	15,600	19,200	27,500	34,400	42,600	49,600	58,900
Elm Fork Trinity River above the West Fork Trinity River	Elm_Fork_abv_West_Fork	222.8	8,100	13,400	18,100	26,800	33,700	41,800	48,800	58,700
Trinity River below the West Fork and Elm Fork confluence	West Fork + Elm Fork	3043.7	20,700	33,700	43,700	77,900	100,900	129,200	163,700	210,600
Trinity River at Dallas, TX USGS gage	Trinity_River_J010	3056.1	18,800	31,600	42,800	76,800	100,200	128,500	162,400	209,500
Trinity River at the Corinth Street bridge in Dallas, TX	Trinity_River_J020	3099.0	19,200	32,200	43,300	77,000	100,600	129,000	163,000	210,400
White Rock Creek at Greenville Ave USGS gage	White_Rock_Ck_S010	66.7	16,300	24,400	30,800	39,500	45,900	52,900	59,600	68,700
White Rock Lake Inflow	White Rock Inflow	95.0	13,200	20,400	25,300	33,300	39,600	46,600	53,200	62,200
White Rock Lake Outflow	White Rock Lake	95.0	9,800	15,300	19,800	26,400	31,900	38,000	43,800	51,900
White Rock Creek above the Trinity River	White_Rock_Ck_abv_Trinity_Rv	134.9	9,100	16,300	20,800	26,100	30,400	35,000	39,600	46,100
Trinity River below White Rock Creek	Trinity River + White Rock	3233.9	23,400	38,200	51,300	78,800	103,500	134,300	167,800	218,800
Trinity River below Honey Springs Branch (Trinity River below Dallas, TX USGS gage)	Trinity_Rv + Honey_Springs	3256.5	23,400	38,300	51,400	78,900	103,500	134,300	167,800	219,000
Trinity River below Five Mile Ceek	Trinity_River + Five_Mile_Ck	3328.8	22,200	36,900	49,800	78,200	102,100	132,400	164,300	213,200
Trinity River above Ten Mile Creek	Trinity_River_abv_Tenmile_Ck	3367.7	20,600	31,500	43,300	70,800	95,100	120,500	148,800	189,900
Trinity River below Ten Mile Creek	Trinity River + Tenmile Ck	3469.8	20,800	32,100	44,000	71,700	96,200	121,900	150,400	191,900

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River above the East Fork Trinity River	Trinity_River_abv_East_Fork	3529.4	20,300	30,200	40,200	68,200	91,200	119,700	145,700	185,300
East Fork Trinity River below Honey Creek	East_Fork+Honey_Ck	167.9	4,100	7,600	11,300	17,700	23,600	31,000	38,000	47,200
East Fork Trinity River near McKinney, TX USGS gage	East_Fork_nr_McKinney	190.1	4,600	8,500	12,500	19,300	25,600	33,800	41,400	51,400
East Fork Trinity River above Wilson Creek	East_Fork_abv_Wilson_Ck	214.8	4,600	8,600	12,500	19,100	25,300	33,500	41,200	51,400
East Fork Trinity River below Wilson Creek	East_Fork + Wilson_Ck	292.3	7,100	12,600	18,000	26,700	34,800	45,500	55,500	68,900
Sister Grove Creek near Blue Ridge USGS gage	Sister_Grove_S010	83.2	1,400	2,800	4,100	6,400	8,400	11,000	13,400	16,500
Sister Grove Creek above Indian Creek	Sister_Grove_abv_Indian_Ck	121.2	2,400	4,600	6,400	8,900	11,000	13,500	15,900	19,600
Indian Creek at SH 78 nr Farmersville, TX USGS gage	Indian_Ck_S010	104.6	2,400	4,200	6,000	8,800	11,200	14,300	17,300	21,200
Indian Creek below Pilot Grove Creek	Indian_Ck + Pilot_Grove_Ck	205.8	4,400	8,800	12,600	18,400	23,400	29,800	35,800	43,800
Indian Creek above Sister Grove Creek	Indian_Ck_abv_Sister_Grove	235.9	4,700	9,300	13,300	19,500	24,900	32,100	38,600	47,300
Indian Creek below Sister Grove Creek	Sister Grove + Indian Ck	357.1	6,200	12,300	17,600	26,200	33,800	44,100	53,500	66,100
Lavon Lake Inflow	Lavon Inflow	768.2	20,300	35,200	47,100	64,200	78,700	100,800	121,900	150,500
Lake Lavon Outflow	Lavon Lake	768.2	0	0	0	0	6,200	14,600	24,800	51,800
Rowlett Creek near Sachse, TX USGS gage	Rowlett_Ck_S010	119.9	13,500	25,400	35,200	46,600	54,600	63,600	72,100	83,800
Ray Hubbard Lake Inflow	Ray Hubbard Inflow	301.8	24,600	42,200	56,900	75,600	90,300	107,300	123,300	145,100
Ray Hubbard Lake Outflow (East Frk blw Ray Hubbard Data)	Ray Hubbard Reservoir	301.8	8,900	16,500	26,000	38,000	47,400	59,800	83,300	101,300
East Fork Trinity River near Forney USGS gage	East_Fork_nr_Forney	349.9	10,500	19,500	30,300	44,100	55,000	69,300	95,500	117,100
East Fork Trinity River above Buffalo Creek	East_Fork_abv_Buffalo_Ck	359.5	9,300	17,800	26,500	40,800	52,700	67,400	91,700	115,500
East Fork Trinity River below Buffalo Creek	East_Fork + Buffalo_Ck	393.9	9,900	18,900	28,300	42,900	55,800	71,900	97,900	123,600

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
East Fork Trinity River above South Mesquite Creek	East_Fork_abv_S_Mesquite_Ck	416.9	7,700	15,500	24,000	36,000	48,100	64,000	82,200	111,600
East Fork Trinity River below South Mesquite Creek	East_Fork+South_Mesquite_Ck	446.4	8,100	16,300	25,200	37,500	50,300	67,000	86,800	117,600
East Fork Trinity River above Mustang Creek	East_Fork_abv_Mustang_Ck	465.5	8,000	15,100	23,000	32,600	43,400	57,200	72,200	96,100
East Fork Trinity River near Crandall, TX USGS gage	East_Fork_nr_Crandall	484.8	8,200	15,500	23,500	33,200	44,300	58,400	73,900	98,300
East Fork Trinity River above the Trinity River	East_Fork_abv_Trinity_River	484.8	8,000	14,100	20,600	28,700	37,100	48,600	59,700	75,100
Trinity River below the East Fork Trinity River	Trinity River + East Fork	4014.2	28,300	43,400	58,200	95,900	126,700	166,200	202,000	254,900
Trinity River below Red Oak Creek	Trinity_River + Red_Oak_Ck	4245.5	30,100	53,800	70,600	97,300	128,500	168,600	205,000	258,700
Trinity River near Rosser, TX USGS gage	Trinity_River_nr_Rosser	4349.6	27,200	40,600	54,900	91,600	126,100	166,200	200,800	253,900
Trinity River above Cedar Creek	Trinity_River_abv_Cedar_Ck	4349.6	26,100	39,600	53,900	72,500	101,900	154,800	190,400	246,400
Kings Creek at SH34 near Kaufman, TX USGS gage	Kings_Ck_nr_Kaufman	222.6	3,800	7,400	10,500	15,300	19,900	25,900	31,500	39,500
Kings Creek above Cedar Creek Reservoir	Kings_Ck_abv_Cedar_Ck_Inflow	343.1	6,000	10,600	15,000	22,600	29,200	37,200	45,200	56,200
Cedar Creek near Kemp, TX USGS gage	Cedar_Ck_nr_Kemp	190.1	5,400	8,400	10,900	14,600	17,100	22,200	27,100	34,100
Cedar Creek above Cedar Creek Reservoir	Cedar_Ck_abv_Cedar_Ck_Inflow	283.5	5,900	11,600	16,300	22,400	27,500	33,800	39,700	48,000
Cedar Creek Reservoir Inflow	Cedar Creek Inflow	1010.8	30,300	61,600	88,900	129,700	163,900	204,900	245,300	301,600
Cedar Creek Reservoir Outflow	Cedar Creek Reservoir	1010.8	21,700	42,300	57,900	81,700	106,500	126,600	133,800	145,600
Trinity River below Cedar Creek	Trinity River + Cedar Creek	5360.4	28,200	43,200	60,200	78,600	114,600	174,100	220,200	295,100
Trinity River at Trinidad, TX USGS gage	Trinity_River_at_Trinidad	5759.3	28,000	43,300	59,800	86,700	112,400	168,400	209,900	286,400
Trinity River above Richland Creek	Trinity_Rv_abv_Richland_Ck	6042.8	28,100	43,800	60,200	82,600	107,600	167,700	211,800	286,800
Waxahachie Creek at Waxahachie	Waxahachie_Ck_S010	60.4	1,500	4,400	8,900	15,500	20,900	27,500	34,000	42,800

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Lake Waxahachie Outflow	Lake Waxahachie	30.6	1,700	3,900	5,900	8,700	12,000	15,600	17,400	26,400
Waxahachie Creek below Lake Waxahachie	Waxahachie Ck+Lk Waxahachie	91.0	2,600	6,400	11,700	19,400	25,500	33,500	42,000	52,000
Mustang Creek above Bardwell Lake	Mustang_Ck_S010	29.9	3,600	6,600	8,700	11,600	14,000	16,700	19,400	23,200
Bardwell Lake Inflow	Bardwell Inflow	174.4	9,200	16,700	22,000	29,200	35,200	42,300	49,400	62,400
Bardwell Lake Outflow	Bardwell Lake	174.4	0	0	1,100	3,500	5,400	8,000	10,600	14,300
Chambers Creek below North Fork and South Fork Chambers Creek	Chambers_Ck_J010	308.4	11,000	20,600	29,700	41,200	53,900	69,700	84,700	104,400
Chambers Creek below Mill Creek	Chambers_Ck_J020	511.9	11,600	21,700	31,700	47,100	66,400	93,100	118,200	153,600
Chambers Creek below Waxahachie Creek	Chambers Ck + Waxahachie Ck	621.0	11,300	21,400	31,400	46,300	65,900	94,400	122,600	162,500
Chambers Creek near Rice, TX USGS gage	Chambers_Ck_J030	650.1	11,200	21,300	29,900	46,200	65,600	90,900	119,500	159,000
White Rock Creek at FM 308 near Irene, TX USGS gage	Navarro_Mills_S010	65.8	3,600	8,100	12,400	19,000	24,600	31,300	37,800	46,300
Navarro Mille Lake Inflow	Navarro Mills Inflow	319.9	11,600	23,900	34,200	49,900	63,200	79,900	96,100	121,700
Navarro Mills Lake Outflow	Navarro Mills Lake	319.9	0	0	0	0	1,400	4,800	8,200	15,000
Richland Creek below Pin Oak Creek	Richland_Ck_J010	395.0	12,700	26,700	39,700	60,700	78,700	100,800	123,100	155,900
Richland Chambers Reservoir Inflow	Richland-Chambers Inflow	1465.5	27,000	52,500	74,900	111,000	143,000	183,400	223,200	281,800
Richland Chambers Reservoir Outflow	Richland-Chambers Reservoir	1465.5	10,200	21,600	34,300	63,700	93,800	136,200	177,300	234,700
Trinity River below Richland Creek	Trinity River + Richland Ck	7508.3	35,500	61,900	86,500	133,000	178,600	247,900	303,700	380,800
Trinity River above Tehuacana Creek	Trinity_Rv_abv_Tehuacana_Ck	7508.3	35,200	61,200	85,800	131,200	176,500	243,400	301,300	377,400
Tehuacana Creek near Streetman, TX USGS gage	Tehuacana_Ck_nr_Streetman	141.3	7,100	15,000	20,400	34,100	43,700	55,100	66,200	81,900
Tehuacana Creek above the Trinity River	Tehuacana_Ck_abv_Trinity_Rv	386.4	7,900	15,100	22,400	38,200	52,900	72,500	91,900	118,800

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River below Tehuacana Creek	Trinity River + Tehuacana Ck	7894.7	35,600	62,500	87,900	135,300	183,600	256,200	332,100	436,300
Trinity River above Big Brown Creek	Trinity_Rv_abv_Big_Brown_Ck	7965.3	35,600	62,400	87,900	134,900	182,000	253,300	326,700	431,700
Trinity River below Big Brown Creek	Trinity River + Big Brown Ck	8001.5	35,700	62,600	88,200	135,500	183,800	254,600	330,900	437,500
Trinity River above Catfish Creek	Trinity_River_abv_Catfish_Ck	8306.6	35,900	63,600	89,700	136,500	186,400	265,000	350,100	467,800
Trinity River below Catfish Creek	Trinity_River + Catfish_Ck	8353.0	35,900	63,700	89,800	136,800	187,000	266,800	352,900	472,100
Trinity River near Oakwood, TX USGS gage	Trinity_River_nr_Oakwood	8593.0	35,700	62,700	86,400	126,100	164,600	261,200	327,200	438,500
Trinity River above Upper Keechi Creek	TrinityRv_abv_UpperKeechi_Ck	8849.7	33,700	57,500	80,300	122,100	153,600	201,400	269,200	359,700
Upper Keechi Creek near Oakwood, TX USGS gage	Upper_Keechi_Ck_nr_Oakwood	150.3	3,400	11,400	19,500	31,100	39,200	48,900	58,300	72,000
Upper Keechie Creek above Buffalo Creek	UpperKeechi_Ck_abv_BuffaloCk	186.8	3,000	10,500	18,000	29,100	37,200	47,100	56,800	70,900
Upper Keechie Creek below Buffalo Creek	Upper_Keechi_Ck+Buffalo_Ck	459.5	5,800	21,000	35,000	54,400	69,900	89,300	109,400	135,700
Upper Keechie Creek above the Trinity River	UpperKeechi_Ck_abv_TrinityRv	509.2	5,700	20,100	33,400	51,900	66,900	86,100	106,000	132,200
Trinity River below Upper Keechi Creek	Trinity River + Upper Keechi	9358.9	33,900	58,100	81,500	124,000	156,500	208,600	279,100	373,400
Trinity River above Big Elkhart Creek	Trinity_Rv_abv_Big_Elkhart	9359.5	33,900	57,900	81,300	124,000	156,400	208,100	278,300	372,500
Houston County Lake Ouflow	Houston County Lake	48.0	110	220	420	900	1,600	4,700	7,900	12,700
Big Elkhart Creek above the Trinity River	Big_Elkhart_abv_Trinity_Rv	143.0	2,000	6,500	10,000	14,700	18,900	25,300	33,100	43,500
Trinity River below Big Elkhart Creek	Trinity River+ Big Elkhart	9502.5	33,900	58,000	81,700	124,500	157,300	209,800	280,500	375,100
Trinity River near Crockett, TX USGS gage	Trinity_River_nr_Crockett	9615.0	34,000	58,100	81,900	124,900	157,800	210,600	281,500	376,400
Trinity River above Lower Keechi Creek	Trinity_Rv_abv_LowerKeech_Ck	9791.7	34,000	53,700	71,100	116,900	149,600	189,200	252,500	342,700
Trinity River below Lower Keechi Creek	Trinity_River+LowerKeechi_Ck	9979.3	34,000	53,700	71,200	117,100	149,900	190,000	253,700	344,400

Location Description	HEC-HMS Element Name	Drainage Area	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River above Bedias Creek	Trinity_River_abv_Bedias_Ck	10374.3	36,400	52,700	70,200	114,800	147,400	186,200	246,300	336,500
Bedias Creek near Madisonville, TX USGS gage	Bedias_Ck_S010	330.6	8,200	16,200	24,400	38,000	47,500	65,100	82,300	105,800
Bedias Creek above the Trinity River	Bedias_Ck_abv_Trinity_River	604.3	11,900	25,800	38,600	59,000	74,700	100,900	126,500	162,400
Trinity River below Bedias Creek	Trinity River + Bedias Ck	10978.5	38,000	71,100	98,700	136,000	161,300	200,700	250,000	341,400
Trinity River at Riverside, TX USGS gage	Trinity River_at_Riverside	11306.7	34,000	63,500	81,400	128,400	157,500	202,600	251,500	341,000
Lake Livingston Inflow	Lake Livingston Inflow	12301.1	67,800	119,800	161,500	221,900	276,400	346,400	418,100	523,500
Lake Livingston Outflow	Lake Livingston	12301.1	35,400	74,000	94,600	130,100	179,200	248,200	316,400	415,400
Trinity River above Long King Creek	Trinity_Rv_abv_Long_King_Ck	12340.5	35,300	73,500	94,200	126,500	171,000	235,800	301,400	396,700
Long King Creek at Livingston, TX USGS gage	Long_King_Ck_S010	141.1	5,700	13,600	19,700	28,700	36,500	46,300	55,800	69,400
Long King Creek above the Trinity River	Long_King_Ck_abv_Trinity_Rv	226.4	7,500	17,000	25,000	37,300	48,200	62,000	75,200	94,300
Trinity River at Goodrich, TX USGS gage	Trinity River + Long King Ck	12566.9	36,100	75,700	96,500	129,300	176,300	245,800	315,500	416,000
Trinity River above Menard Creek	Trinity_River_abv_Menard_Ck	12628.0	36,100	69,100	85,900	107,800	137,000	184,600	244,400	337,600
Menard Creek near Rye, TX USGS gage	Menard_Ck_S010	148.1	2,300	6,300	10,000	15,600	20,800	27,900	34,700	44,400
Trinity River below Menard Creek	Trinity River + Menard Ck	12776.2	37,000	69,900	86,600	108,900	137,300	186,900	246,900	338,900
Trinity River at Romayor, TX USGS gage	Trinity_River_at_Romayor	12873.7	37,500	69,200	85,700	108,000	136,900	185,000	245,100	338,400
Trinity River near Moss Hill, TX	Trinity_River_nr_MossHill_TX	12945.7	36,800	67,200	84,200	105,900	136,400	184,700	244,700	337,600
Trinity River at Liberty, TX USGS gage	Trinity_River_at_Liberty	13176.5	33,000	66,000	84,100	106,300	136,500	185,200	245,500	338,600
Trinity River at Wallisville, TX USGS gage	Trinity Bay	13618.4	32,300	61,800	80,900	104,800	135,000	185,700	246,400	339,700

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3 Terms of Reference

AEP	Annual Exceedance Probability
BLE	Base Level Engineering
cfs	cubic feet per second
CWMS	Corps Water Management System
DEM	Digital Elevation Model
DSMMX	Dam Safety Modification Mandatory Center of Expertise
EM	Engineering Manual
FEMA	Federal Emergency Management Agency
GeoHMS	Geospatial Hydrologic Model System extension
HEC	Hydrologic Engineering Center
HMS	Hydrologic Modeling System
InFRM	Interagency Flood Risk Management
LiDAR	Light Detection and Ranging
NA14	NOAA Atlas 14
NED	National Elevation Dataset
NEXRAD	Next-Generation Radar
NFIP	National Flood Insurance Program
NLCD	National Landcover Database
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PFDS	Precipitation Frequency Data Server
RAS	River Analysis System
RMC	Risk Management Center
sq mi	square miles
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WGRFC	West Gulf River Forecasting Center

Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin

Appendix C - Elliptical Frequency Storms in HEC-HMS

July 2021

InFRM

INTERAGENCY FLOOD RISK MANAGEMENT

Table of Contents

1. Elliptical Frequency Storms in HEC-HMS

1.1 INTRODUCTION TO ELLIPTICAL STORMS

Observations of actual storm events show that average precipitation intensity decreases as the area of a storm increases. The uniform rainfall method results (documented in a separate Appendix) use the depth-area analysis in HEC-HMS to produce frequency peak flow estimates (Version 4.2.1; USACE, 2014). The depth-area analysis in HEC-HMS applies the appropriate depth-area reduction factor to the given point rainfall depths based on the drainage area at a given evaluation point, which are derived from the published depth-area reduction factors from Figure 15 of the National Weather Service TP-40 publication (Hershfield, 1961), as shown in the figure below.

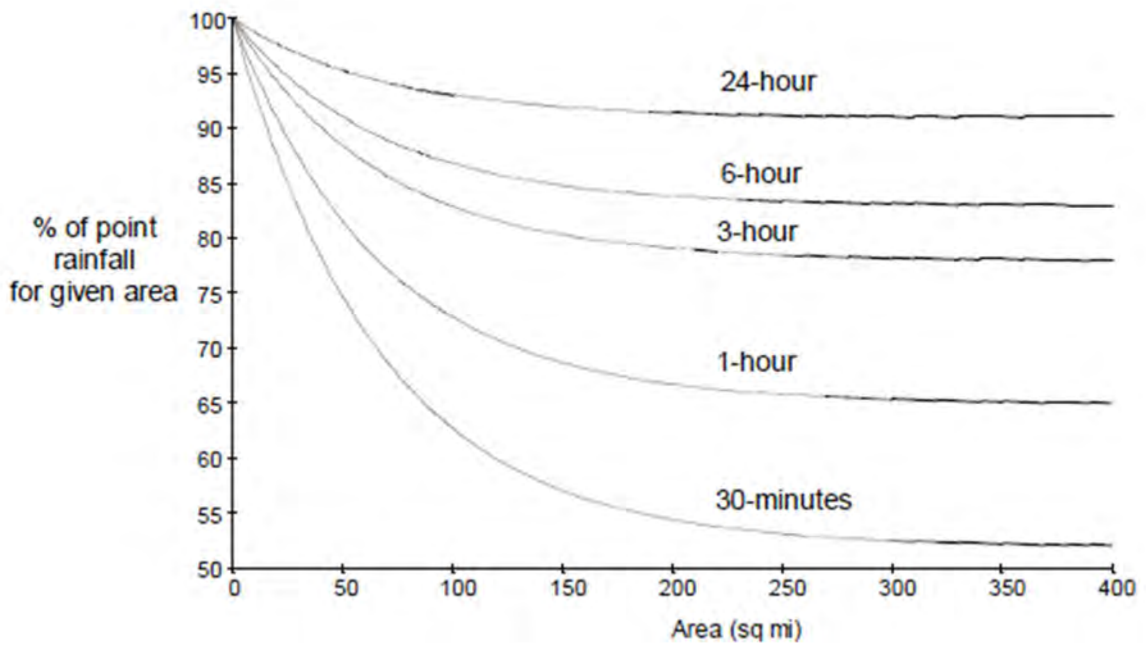


Figure 1: Published Depth-Area Reduction Curves from TP-40

When evaluating a point with a drainage area greater than 400 square miles, the HEC-HMS software issues a warning that the NWS depth-area reduction factors do not support storms beyond 400 square miles, as seen in the figure above. The program will still calculate the peak discharge, but the warning implies that the calculated volume of the storm may not be appropriate for larger drainage areas.

Since the Trinity hydrology study involves calculating frequency discharges for points with up to several thousand square miles of drainage area, the InFRM team developed elliptical frequency storms for points with drainage areas greater than 400 square miles. In these elliptical frequency storms, the same point rainfall depths and durations were applied as in the uniform rainfall method of Chapter 6, but the spatial distribution of the rainfall varied in an elliptical shaped pattern with higher rainfall amounts in the center of the ellipse and lesser amounts towards the outer fringes.

Elliptical shaped storms have been used in a variety of hypothetical design applications, including the Probable Maximum Precipitation (PMP) storms from Hydrometeorlogical Report No 52 (HMR 52) (Hansen, 1982). The elliptical frequency storms constructed for this study are similar to those of HMR 52 in that concentric ellipses are used to construct the storm's spatial pattern, and the storm's location is optimized over the watershed by identifying the storm center location and the angle of its major axis that lead to a maximum peak flow at a downstream junction of interest. Figure 2 shows an example of an elliptical 1% annual exceedance probability (100-yr) storm that was centered over the watershed above the Trinity River at Dallas junction.

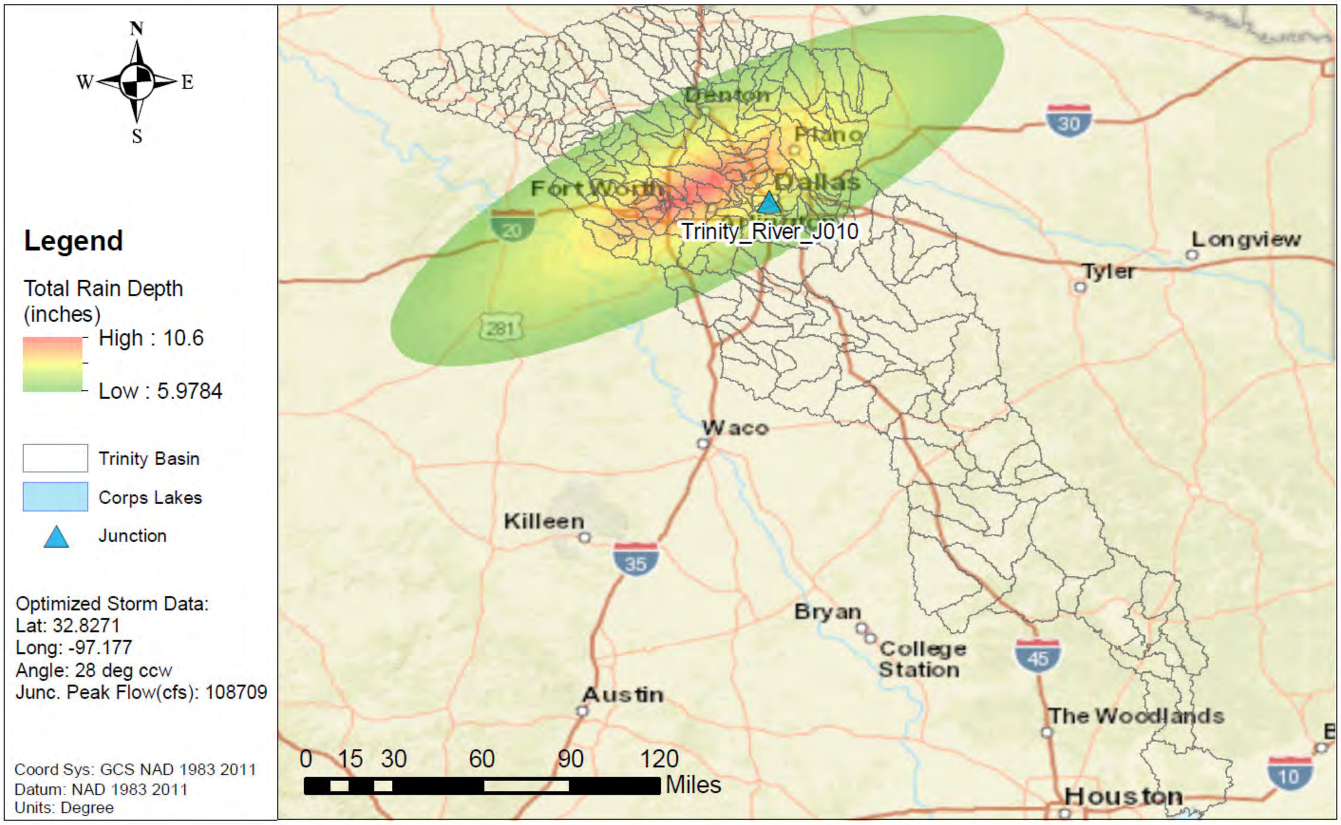


Figure 2: Example 1% AEP (100-yr) Elliptical Frequency Storm

1.2 ELLIPTICAL STORM PARAMETERS AND METHODOLOGY

The following elliptical storm parameters in sections 1.2.1 through 1.2.5 are relevant for the majority of the Trinity Basin. From the upper reaches of the Trinity Basin all the way downstream to the Trinity River near Crockett, TX USGS gage (128 junctions of interest), the orography and the meteorology remain relatively constant and these storm parameters worked well. However, for the 15 junctions of interest below the Crockett USGS gage, the meteorology rapidly changes and a few adjustments to the elliptical storm parameters and methodology were needed. The slightly different approach for the lower Trinity Basin is discussed in section 1.2.6.

Figure 3 below, summarizes the general approach used to create elliptical storms for the majority of the basin. The magnitude of the total storm is based off of one NOAA Atlas 14 point frequency depth queried from the storm center which is multipled by depth area reduction (DAR) factors.

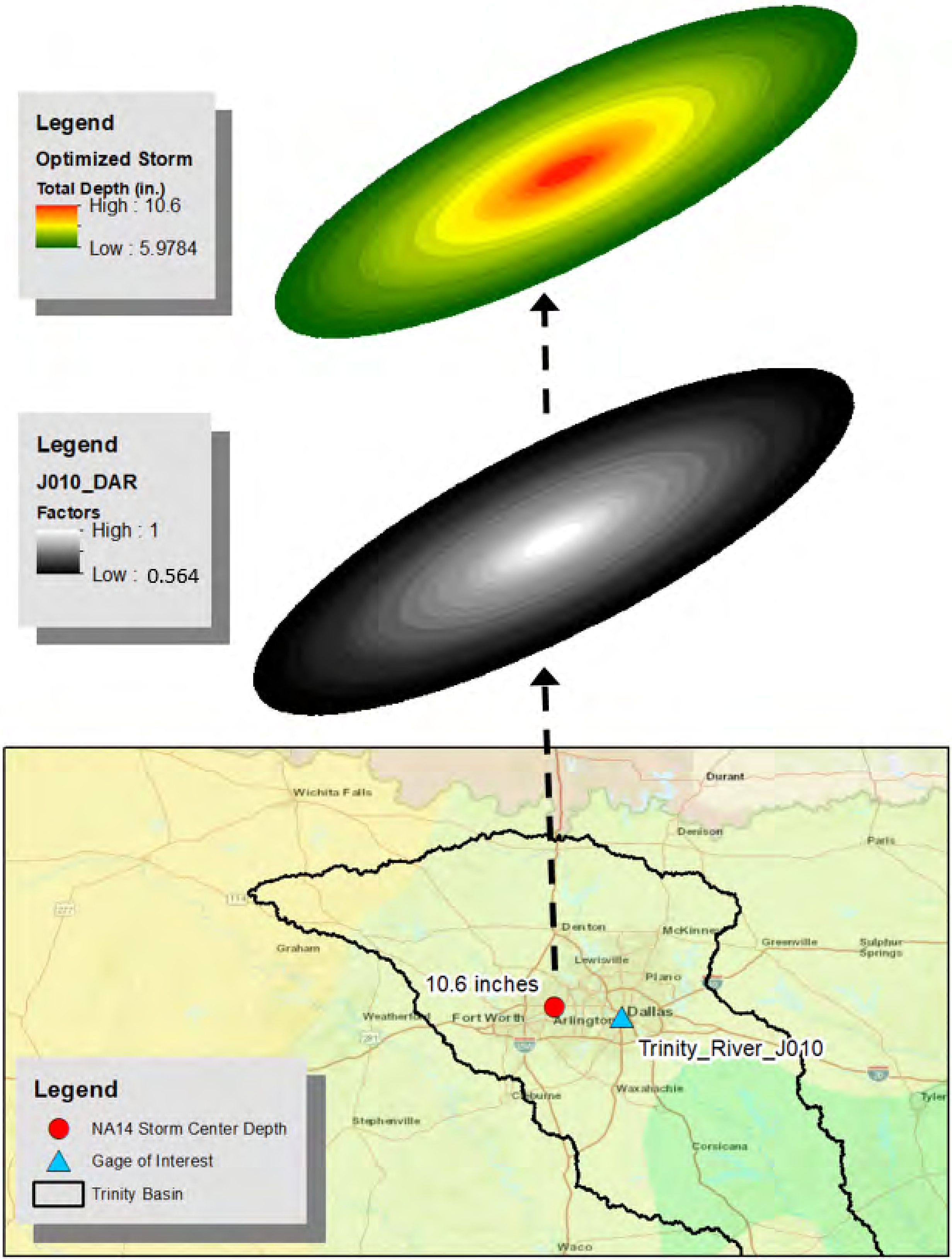


Figure 3: 100yr 48hr Elliptical Storm Generation – Upper Trinity Basin – Trinity River at Dallas

1.2.1 Elliptical Storm Area

This study uses a storm extent of 10,000 square miles. This is due to the historical rainfall studies rarely including data beyond 10,000 square miles (USACE, 1945). While this extent is somewhat arbitrary, testing was done to limit the storm extent to 3,000 square miles and the resulting peak discharges were slightly reduced. However the reduction in peak discharge was not significant because some of the rainfall beyond 3,000 square miles was falling outside the watershed and therefore not contributing to the runoff. Since there is no guidance or research on the subject, the storm extent of 10,000 square miles was used in this study.

1.2.2 Elliptical Storm Rainfall Depths

Elliptical storms were designed for each of the following annual exceedance probabilities (AEP): 1 in 2 years, 1 in 5 years, 1 in 10 years, 1 in 25 years, 1 in 50 years, 1 in 100 years, 1 in 200 years and 1 in 500 years. Point rainfall depths and durations were applied directly from NOAA Atlas 14 Volume 11 which contains depth duration frequency estimates of precipitation for Texas (NOAA, 2018). The point precipitation values that were applied to each elliptical storm were based on the storm center's location, not the location of the outlet of interest. For example, in Figure 3 above, the point precipitation values directly at the storm center (in red) were used to build the magnitude of the elliptical storm rather than the precipitation depths at the junction of interest (blue triangle).

1.2.3 Storm Ellipse Ratio

The HMR-52 study presents the option to design a storm with an ellipse ratio ranging from 2:1 to 3:1. For the Trinity basin, a 3:1 ellipse was used, as it better matched the long, narrow shape of the basin. A 2:1 ellipse was tested in several sections within the Trinity basin, and the optimized storm centerings, storm orientations, and resulting peak flows were generally similar to the results obtained from using a 3:1 ellipse.

1.2.4 Storm Temporal Pattern / Hyetograph

Historically, storms have varying intensities and temporal distributions and many studies have been done to document storm patterns. The six storm temporal distributions that were tested for a previous InFRM study on the Guadalupe Basin are shown in Figure 4. The Soil Conservation Service (1986) documented different distributions for the United States, and Type II is the distribution applicable to Texas and was included in the testing. Other distributions were also tested, including the Frequency Rainfall Distributions from HEC-HMS with the storm centroid occurring at the 25%, 33%, 50%, 67% and 75% of the total distribution. The HEC-HMS Frequency Rainfall Distributions maintain the appropriate storm intensity throughout the storm. In other words, the 100 year, 1 hour rainfall is maintained with the 100 year, 3 hour rainfall and so on all the way through the 100 year, 48 hour rainfall.

While varying the temporal pattern distribution of the storm did have a small effect on the peak discharge, the difference was generally less than 5%. As with the Guadalupe study, the 50% storm distribution was also selected for the Trinity study due to its simplicity and maintaining the proper intensity throughout the storm period. This is also consistent with the temporal distribution used for the uniform rainfall method.

The magnitude of the Frequency Rainfall Distributions in HEC-HMS are created with point rainfall input. The relative magnitude of each 1-hr alternating block within our base temporal pattern was determined with the NOAA Atlas 14 point rainfall frequency data pertinent to the centroid of Tarrant County (1-hr, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr, and 48-hr rainfall data for Tarrant County was used as input). Tarrant County was chosen to establish a base temporal pattern because it is part of the Dallas – Fort Worth metropolitan region which is the primary economic hub within the Trinity Basin. Furthermore, it is meteorologically similar to the majority of the Trinity Basin. As the storm is translated over the basin during the optimization process, the temporal pattern is scaled up or down from the base temporal pattern depending only on the NOAA Atlas 14 point rainfall data at the storm's current centering.

Testing on the Trinity River basin was done for shorter and longer design storm durations (24hr, 48hr, 96hr, and 240hr). In general, it was found that the longer storm durations produced slightly larger peak discharges due to small increases in volume being added at the beginning (and end) of the storm hyetograph. These small volume increases eat away at the initial losses causing more runoff when the intense, central portion of the storm arrives. For this study, the 48 hour storm duration was used throughout the watershed. This storm duration more closely coincides with the duration of the storm events used to calibrate the HMS model, and it also coincides with the storm duration used for the uniform rainfall HMS runs.

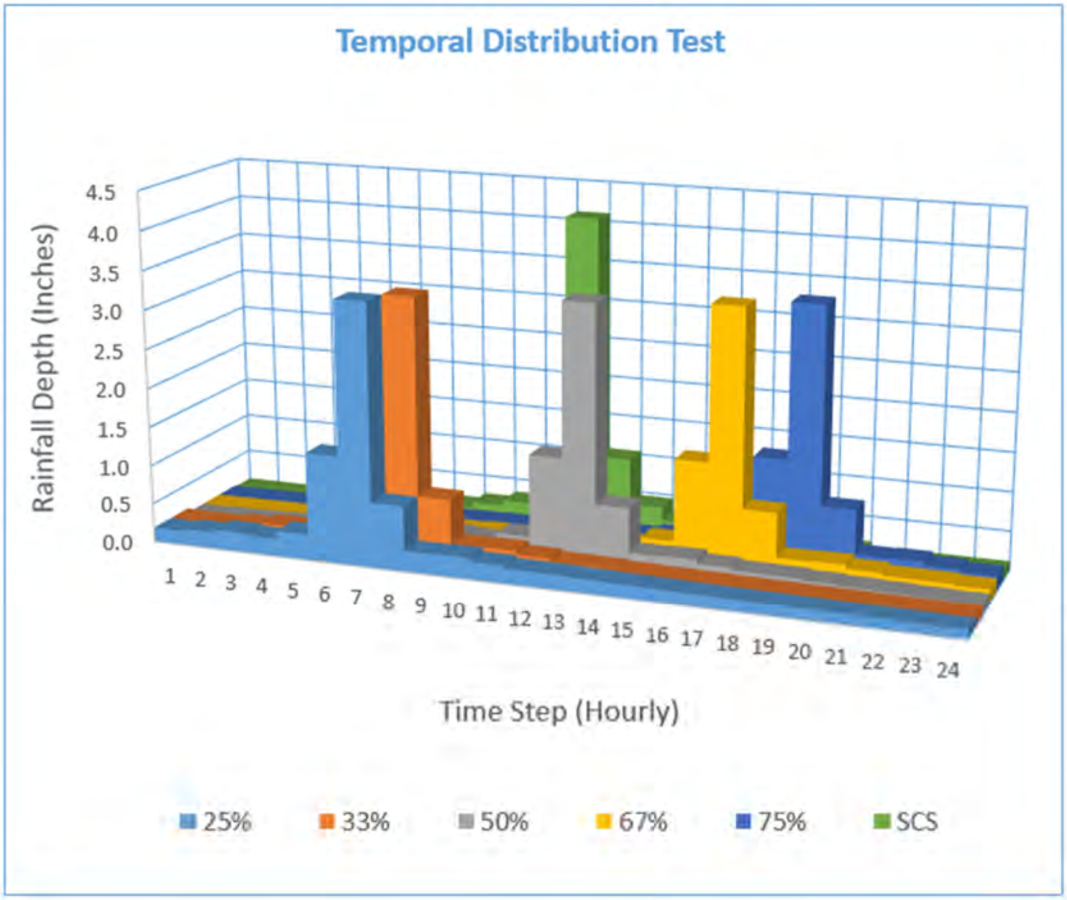


Figure 4: Tested Storm Temporal Distributions for the Guadalupe InFRM Study

1.2.5 Storm Depth Area Reduction Factors

The term depth area reduction factor refers to a storm that has been spatially normalized to a unit depth at the storm center. Thus the remainder of the storm is a percentage of the storm center. A depth area duration table is a way to track the volume of the storm. All storms have varying spatial and temporal patterns and this affects the depth area duration table of the storm.

For the elliptical frequency storms, the storm, shape, temporal pattern, duration, and rainfall depth at the center have all been accounted for. All that remains is to apply a depth area reduction curve to the storm to find the depths at each concentric ellipse. An example of a depth area reduction curve applied to an elliptical storm is shown in Figure 5.

A large amount of research and analysis went into the determination of the appropriate depth area reduction curve for this study. A previous study of elliptical storms had been done by USACE in 2012 for the Dallas Floodway Extension project. This effort analyzed over 100 storms across Texas, Oklahoma, Arkansas and Louisiana. For this study, 35 historical storms more local to the Trinity watershed with total precipitation depths ranging from 5 to 11 inches were analyzed. In the end, a DAR curve for the Upper Trinity was implemented that roughly equated to the median of the 35 observed storms. The DAR curve used for the Lower Trinity is slightly different as it was created predominantly from tropical storm observations. Both curves are presented in Figure 6 and Table 1 below.

Rainfall Depth	Area of Ellipse	Depth Area Reduction Factor
10.0"	0 Sq. Mi.	100%
9.6"	10 Sq. Mi.	96%
9.2"	50 Sq. Mi.	92%
8.4"	100 Sq. Mi.	84%
7.5"	400 Sq. Mi.	75%
6.3"	800 Sq. Mi.	63%
5.0"	1,200 Sq. Mi.	50%

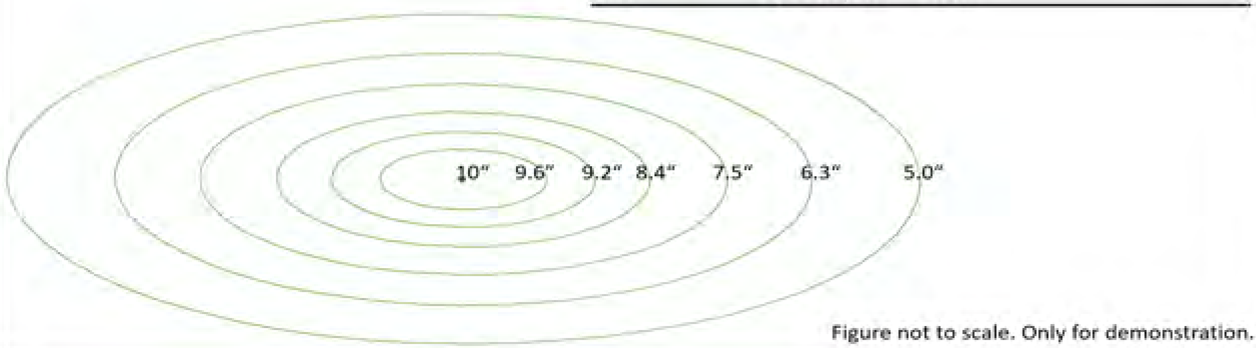


Figure 5: Example of a Depth Area Reduction Curve Applied to an Elliptical Storm

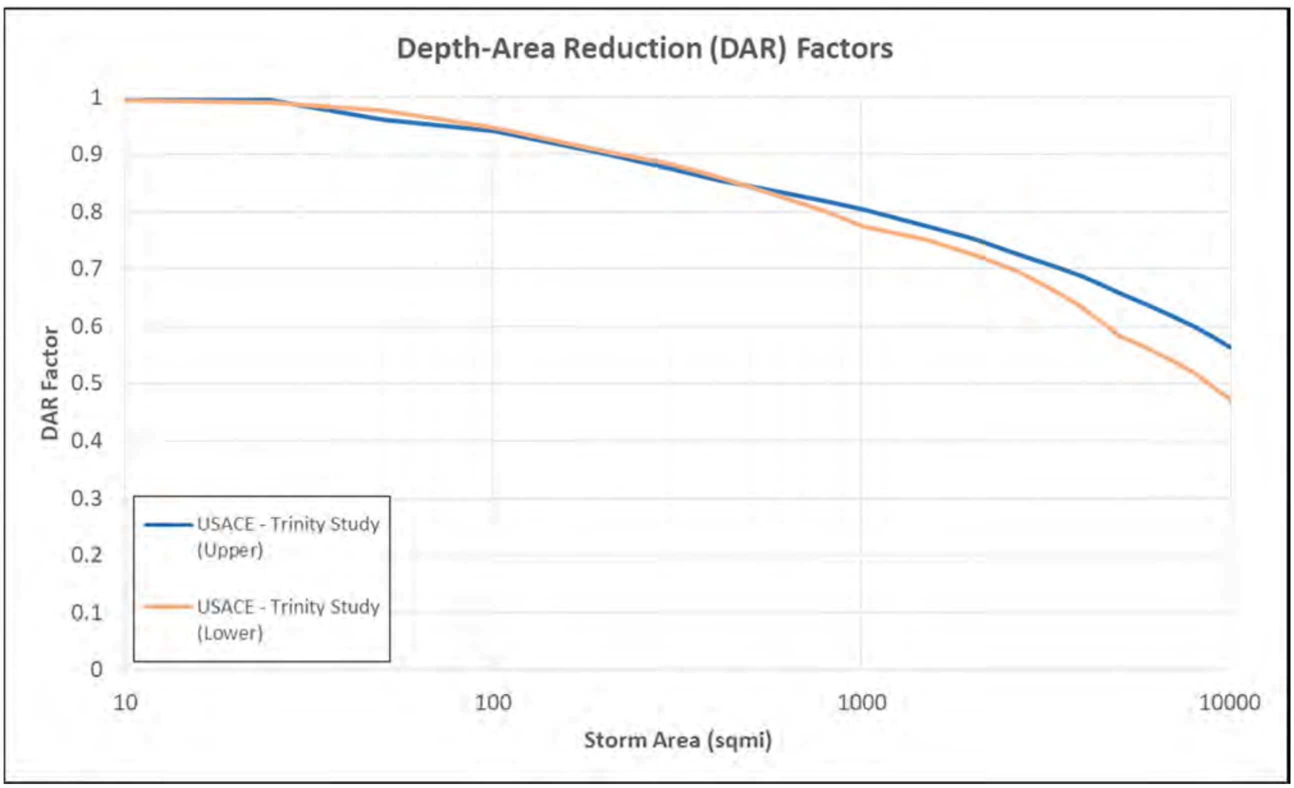


Figure 6: Adopted Depth Area Reduction Curves

Table 1: Adopted Depth Area Reduction Factors

Storm Area in Square Miles	DAR Factors – Trinity (Upper)	DAR Factors– Trinity (Lower)
1	1	1
10	1	1
25	0.997	0.991
50	0.96	0.976
100	0.94	0.946
200	0.902	0.906
300	0.875	0.884
400	0.855	0.862
600	0.834	0.827
800	0.818	0.801
1000	0.804	0.774
1500	0.775	0.75
2000	0.752	0.726
2667	0.726	0.695
3500	0.699	0.655
4000	0.685	0.631
4500	0.672	0.607
5000	0.658	0.583
6000	0.637	0.561
6500	0.626	0.55
7000	0.617	0.539
8000	0.599	0.517
9000	0.581	0.494
10000	0.564	0.472

1.2.6 Elliptical Storm Methodology - Lower Trinity Basin

The parameters listed above work well for the Upper Trinity Basin where the NOAA Atlas 14 precipitation gradient is, in general, spatially uniform and where the storms are largely convective. However, in the Lower Trinity Basin below the Trinity River near Crockett, TX USGS gage, the NOAA Atlas 14 precipitation gradient increases drastically as the basin approaches the Gulf of Mexico where tropical storms tend to drive larger precipitation events (Figure 7).

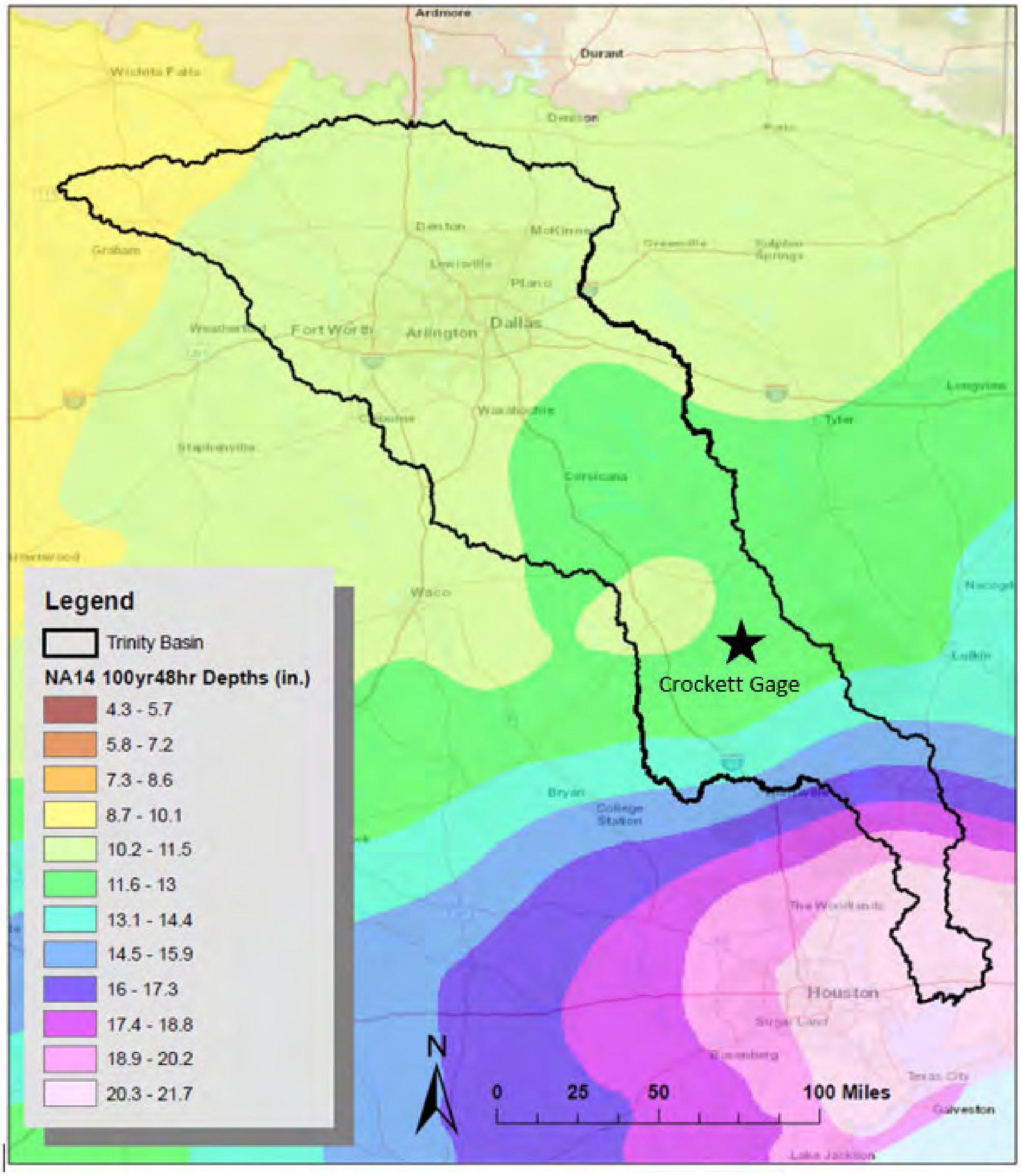


Figure 7: NOAA Atlas 14 100yr48hr Precipitation Gradient – Trinity Basin

The main change in methodology that was employed in the Lower Trinity Basin involves how the NOAA Atlas 14 precipitation data and the DAR curve were used to create the elliptical storm. In the Upper Trinity, only one precipitation depth coinciding with the storm center was used to determine the volume of the storm at the innermost, center ellipse. The DAR curve was then applied to the queried storm center precipitation depth to determine the reduced volumes in the outer ellipses up to 10,000 sqmi (Figure 3 above). Due to the rapidly varying precipitation gradient near the Gulf, determining the outer elliptical volume based off of one center precipitation depth led to volume overestimation in latitudes above the storm center. These upper latitude regions of the storm were not being reduced enough. To compensate for this, a new methodology was applied in which all of the precipitation depths that fell under the 10,000 sqmi elliptical storm positioning were queried instead of just the one depth at the storm center. Then all of the queried precipitation depths were reduced based off of which of the concentric, DAR ellipses they overlapped with (Figure 8 below). In regions where the precipitation depths vary greatly over a short distance, this method performs better since the precipitation gradient is reflected in the makeup of the elliptical storm.

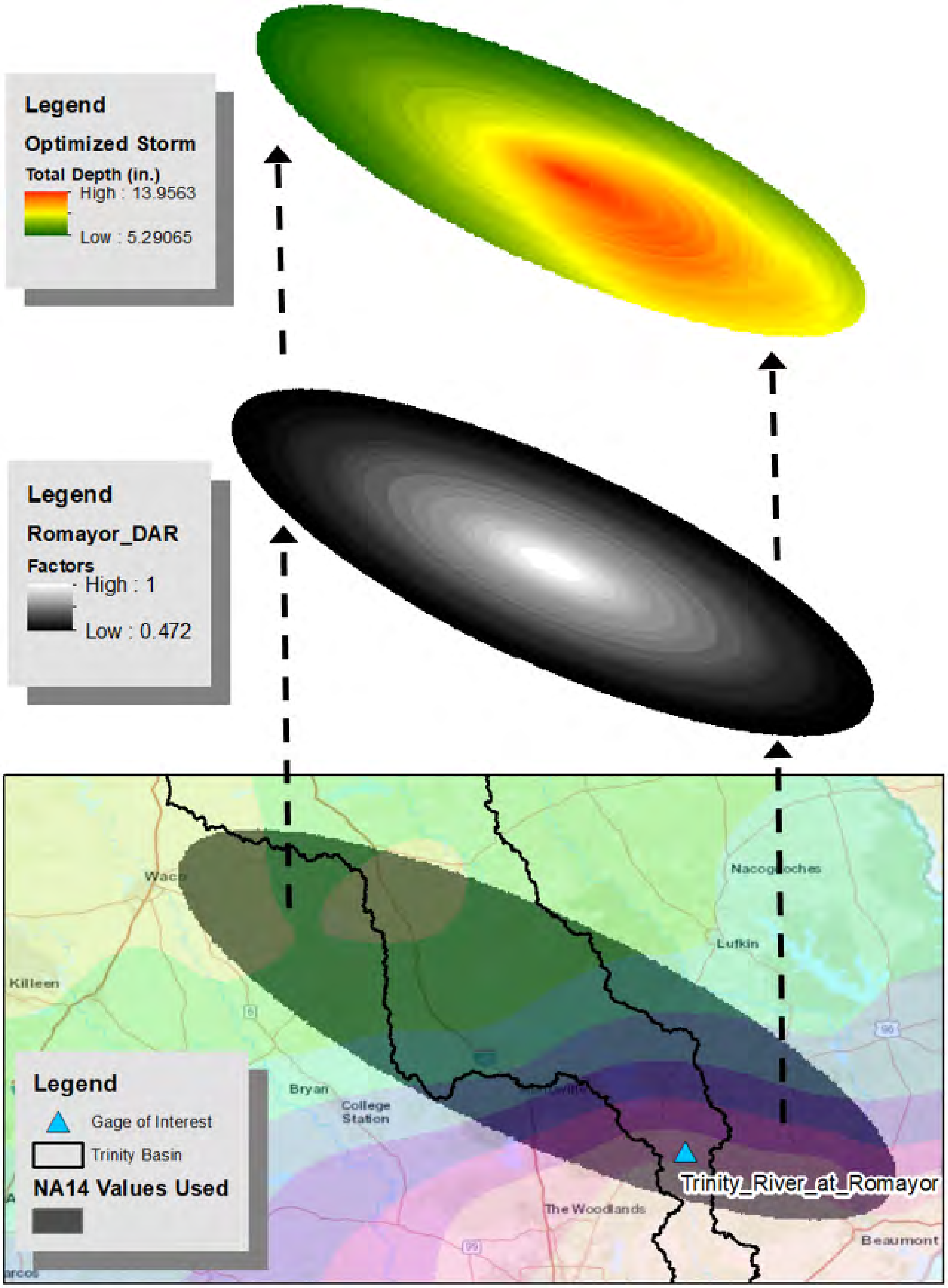


Figure 8: 100yr48hr Elliptical Storm Generation – Lower Trinity Basin – Trinity River at Romayor

A second, small deviation from the prior methodology involved changing the temporal pattern parameter. For the Upper Trinity Basin, a base temporal pattern derived from precipitation depth input specific to Tarrant County was used. For the Lower Trinity Basin, an improvement was made in the methodology that better accounts for potential differences in meteorology. Instead of manipulating a base temporal pattern, a customized temporal pattern unique to each storm centering was built. At each storm centering, the 1-hr, 2-hr, 3-hr, 6-hr, 12-hr, 24-hr, and 48-hr duration precipitation depths were queried and the alternating block method was applied to create a temporal pattern.

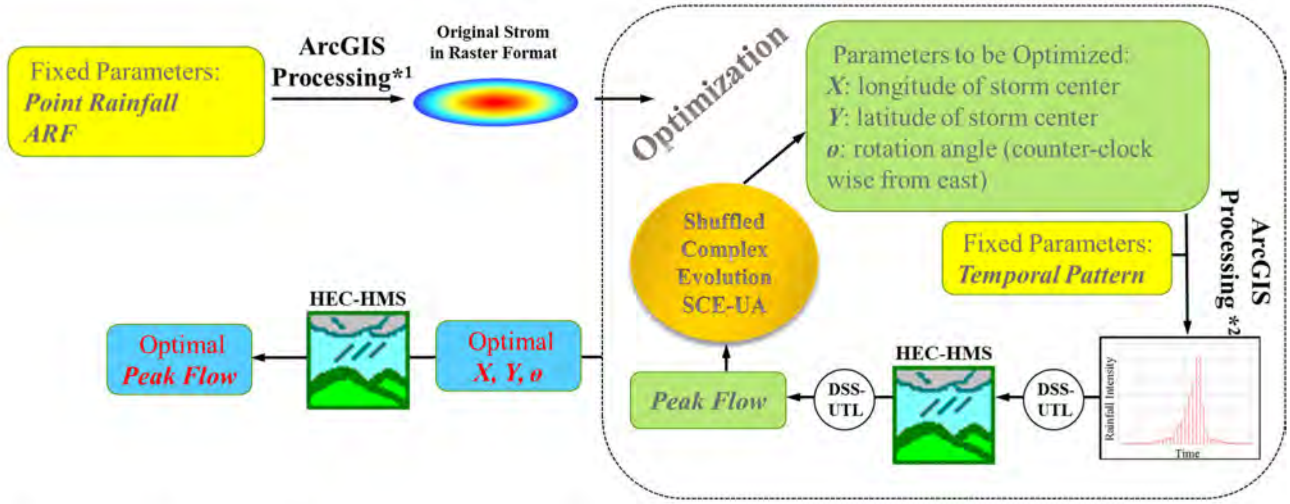
A third and final change involved the DAR curve that was used for the Lower Trinity Basin. A smaller, subset of observed storms that occurred in the Lower Trinity Basin were analyzed in an effort to better account for the potential meteorological differences near the Gulf. In the end, a slightly different DAR curve was adopted for this region (Lower) of the Trinity basin. Both the Upper and Lower Trinity Curves are shown in Figure 6.

1.3 OPTIMIZATION OF THE STORM CENTER LOCATION

For this study, a script was developed for the InFRM team that automatically locates optimal centering locations (x and y) and rotations (ɵ) of (spatially varied) elliptical frequency storms for a list of receiving junctions in a watershed. The script was expected to obtain the combination of the three parameters (x, y, and ɵ) that maximized peak flow at desired junctions while achieving the following objectives:

- To complete the task efficiently.
- To allow users to customize the scripts easily based on their needs.
- To generate reasonable results that can be validated manually.
- To outperform the manual grid search method in terms of precision, accuracy and efficiency.
- To function normally on any machine at USACE with the available software and hardware.

Figure 9 illustrates the schematic flow of the storm optimization. The scheme begins with creating a spatially varied design storm in raster format using ArcGIS. Given the point rainfall (total rainfall at the storm centroid) and the areal reduction factor (ARF), a peak hour storm raster is digitized by creating a series of concentric ellipses and then converting them to raster format. An optimization stage is followed including two major components: 1) parameter update/optimization and 2) automatic simulation of the HEC-HMS hydrologic model. In each iteration of the optimization process, the peak hour storm raster is first shifted and rotated due to updated parameters (x, y, and ɵ); and then allocated into each subbasin as mean areal precipitation (MAP). Since the MAP value for each subbasin only represents the amount of rain during the peak hour (hour 25 of a 48 hour storm), the remaining 47 values are ratioed to create a time series. The time series MAP values, i.e. the hyetographs, are stored in DSS format and transmitted to the HMS model for simulations. After each simulation, the corresponding peak flow value at a desired junction is extracted from the output DSS file. Based on the extracted peak flow value, an optimization algorithm will update the parameters (x, y and ɵ) and then optimization proceeds into the next iteration. After all optimization iterations for a junction are complete, an optimized storm center (x and y) and orientation (ɵ) that leads to a peak flow at a given junction is determined. The optimization process can then be repeated for the next junction of interest.



*1. involves creating ellipse polygons and converting polygon to raster.
*2. involves shifting raster, rotating raster and calculating zonal statistics (for MAP).

Figure 9: Schematic Flowchart for the Storm Opimization Script

Originally, the scripts were designed to automate a grid search, where all possible combinations of parameters (i.e. the ‘grids’) are exhaustively tested and the optimal combination of the three parameters (x, y, and ɵ) can then be obtained. Although the approach of grid search seems straightforward, it does suffer from high computational cost because the computational run time depends on the number of grids, which is further constrained by the range and the interval of each parameter. Given the need of maintaining a certain level of precision or keeping constant intervals of the parameters, the UTA team found that the grid search approach might not be appropriate for this project since the computational run time was excessively lengthy – it increases exponentially with greater drainage area (more possible x and y values).

In order to overcome this issue, the UTA team selected a global optimization (GO) algorithm entitled shuffled complex evolution (SCE) (Duan et al., 1993) - a random sampling approach. Instead of exhausting all possible grids, the random sampling approach tests the objective function around some sampled grids in an iteration while learning about the structure of the objective function for improving the sampling of grids in the next iteration. More details about GO and SCE are included in the following sections.

1.3.1 Global Optimization

The objective of global optimization (GO) is to find the best solution of (possibly nonlinear) models globally, in the (possible or known) presence of multiple local optima. As an example, Figure 10 shows a 3-D plot of a continuous objective function of two bounded parameters x and y. Suppose the goal is to locate the minimal value globally instead of just locally (Note there are many local minimal values but with only one global minimum value in the chart), a global search in the two-dimensional box region is needed. The theory of GO has been applied to many engineering problems like model calibrations and optimal operations of “black-box” system. The storm optimization here is essentially a constrained GO problem, where the objective is to seek the combination of storm centering locations and rotations yielding the maximal peak flow within the constraints of the possible parameter values.

The level of difficulty in solving a GO problem depends on several major characteristics of the objective function. First, there may be multiple local minima in the parameter space. As illustrated in Figure 10, the search of global minimum can be easily “trapped” in the “valleys” of the objective function, depending on the starting point of the search. Second, the objective function in the parameter space may not be smooth or even continuous. In addition, the parameters may exhibit varying degrees of highly nonlinear interaction. In order to deal with these difficulties, the UTA team employed the shuffled complex evolution algorithm (see the following section), which promises to be effective and efficient for the storm optimization task.

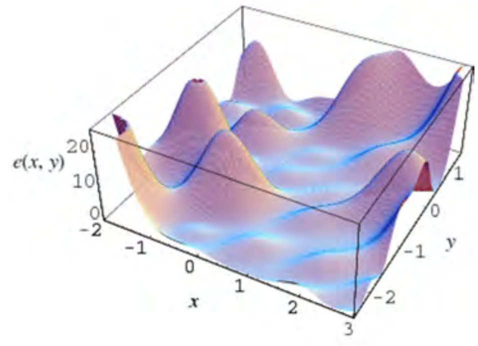


Figure 10: Example of a Global Optimization Problem

1.3.2 **Shuffled Complex Evolution**

The shuffled complex evolution works on the basis of four concepts: (1) combination of deterministic and probabilistic approaches; (2) systematic evolution of a complex of grids; (3) competitive evolution; and (4) complex shuffling. The algorithm begins with a randomly selected population of grids from the parameter space. The grids are sorted ascendingly so that the first point represents the smallest value of the objective function and the last point represents the largest. The initial population generated randomly is first partitioned into several complexes. Each complex is allowed to evolve independently to search the parameter space in different dimensions; and each individual grid in a complex has the potential to participate in the process of reproducing new grids. From each complex, some grids are selected to form a sub-complex, where the modified Nelder and Mead Simplex Method (NMSM) (Nelder and Mead, 1965) is applied for global improvement. The grids of higher fitness values have higher chance of getting selected to generate offspring. The NMSM performs reflection and inside contraction steps to get a better fit grid. This new offspring then replaces the grid with the worst performance in the complex. The grids in the evolved complexes are then pooled together and sorted again, shuffled, and finally reassigned to new complexes to enable information sharing. This process is repeated until some convergence criteria are satisfied.

1.4 ELLIPTICAL FREQUENCY STORM LOCATIONS

The final optimized storm center locations (x, y) and rotations (ɵ) for every node of interest in the Trinity watershed are listed in Table 2. Rotation angles are measured counter-clockwise from the positive x-axis. These location and rotation parameters were determined from 100yr frequency optimizations, and are assumed to be the same for all other frequency events (2yr – 500yr). Testing showed that, in general, optimized locations and orientations did not significantly change between frequency events. Once the optimum storm center location and rotation were determined for each location of interest, the elliptical frequency storms for the standard eight frequency events were constructed using the appropriate NOAA Atlas 14 point rainfall depths.

Table 2: Optimized Elliptical Storm Center Locations and Rotations for Each Model Junction

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
West Fork Trinity River below Lost Creek	West Fork + Lost Ck	711.2	-98.2502	33.3773	3.1
West Fork Trinity River above Carroll Creek	West_Fork_abv_CarrollCk	750.8	-98.3463	33.3507	35.4
West Fork Trinity River below Carroll Creek	West_Fork_J090	792.1	-98.0781	33.2112	79.1
West Fork Trinity River above Beans Creek	WestFork_abv_Beans_Ck	827.7	-98.0621	33.2117	80.8
West Fork Trinity River below Beans Creek	WestFork_+_Beans_Ck	874.6	-98.0350	33.2125	85.1
Bridgeport Reservoir Inflow	Bridgeport Inflow	1095.7	-97.9452	33.1724	101.1
West Fork Trinity River above Dry Creek	West_Fork_abv_DryCk	1136.2	-98.0395	33.2249	157.5
West Fork Trinity River below Dry Creek	West_Fork_J100	1162.9	-97.7770	33.2180	95.2
West Fork Trinity River above Big Sandy Creek	WestFork_abv_Big_Sandy_Ck	1169.5	-97.7709	33.2139	113.9
Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114 bridge	Big_Sandy_Ck_J030	334.3	-97.7448	33.4022	123.0
Big Sandy Creek above the West Fork Trinity River	Big_Sandy_Ck_abv_WestFork	353.9	-97.7170	33.3769	132.4
West Fork Trinity River below Big Sandy Creek	West Fork + Big Sandy Ck	1523.5	-97.7120	33.3202	69.2
West Fork Trinity River at FM 3259 near Paradise, TX	West_Fork_J110	1551.8	-97.7189	33.3196	75.8
West Fork Trinity River above Salt Creek	WestFork_abv_Salt_Ck	1573.7	-97.7191	33.3092	114.2
West Fork Trinity River below Salt Creek	West Fork + Salt Ck	1680.4	-97.7200	33.2084	71.8
West Fork Trinity River near Boyd, TX - USGS Gage at FM 730 bridge	West_Fork_J120	1710.8	-97.7184	33.2097	71.9
West Fork Trinity River about 0.8 miles upstream of FM 4757 in Wise County	West_Fork_J130	1751.9	-97.7291	33.2405	84.9
Eagle Mountain Reservoir Inflow	Eagle Mountain Inflow	1956.6	-97.5604	32.9617	26.3
Lake Worth Inflow	Lake Worth Inflow	2050.8	-97.5349	32.8183	166.7
West Fork Trinity River above the Clear Fork	WestFork_abv_Clear_Fork	2078.7	-97.5260	32.8308	176.4
Clear Fork above Marys Creek	Clear_Fork_abv_Marys_Ck	9.4	-97.4439	32.6760	127.6
Clear Fork below Marys Creek	Clear Fork + Marys Creek	63.6	-97.5399	32.7173	1.3
Clear Fork Trinity River at Fort Worth USGS gage	Clear_Fork_J020	89.0	-97.4252	32.7060	2.0
Clear Fork Trinity River above the West Fork	Clear_Fork_abv_WestFork	93.9	-97.4958	32.7139	162.3
West Fork Trinity River below the Clear Fork (West Fork at Fort Worth USGS gage)	West Fork + Clear Fork	2172.5	-97.3973	32.6971	165.2
West Fork Trinity River above Marine Creek	WestFork_abv_MarineCk	2173.7	-97.4590	32.7200	169.3
West Fork Trinity River below Marine Creek	West Fork + Marine Ck	2195.4	-97.4780	32.7187	169.4
West Fork Trinity River above Sycamore Creek	West_Fork_J140	2204.6	-97.4294	32.7200	178.2
West Fork Trinity River below Sycamore Creek (West Fork Trinity River at Beach Street USGS Gage)	West_Fork_J150	2243.8	-97.4221	32.7224	2.8
West Fork above Big Fossil	WestFork_abv_BigFossil	2256.8	-97.4350	32.7265	174.3

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
West Fork Trinity River and Big Fossil Creek Confluence	West_Fork_J160	2333.4	-97.3372	32.7992	64.1
West Fork Trinity River below Village Creek	West Fork + Village Ck	2554.0	-97.3433	32.7642	19.3
West Fork Trinity River below Johnson Creek	West_Fork_J170	2618.6	-97.2700	32.7444	179.4
West Fork Trinity River at Grand Prairie USGS gage	West_Fork_J180	2623.4	-97.2783	32.7487	178.9
West Fork Trinity River above Big Bear Creek	West_Fork_abv_Big_Bear_Ck	2625.5	-97.2342	32.7375	178.2
West Fork Trinity River below Big Bear Creek	West Fork + Bear Ck	2718.8	-97.2794	32.7519	12.4
West Fork Trinity River above Mountain Creek	West_Fork_abv_Mountain_Ck	2727.4	-97.2575	32.7788	14.5
West Fork Trinity River below Mountain Creek	West Fork + Mountain Ck	2807.6	-97.1953	32.7685	179.9
West Fork Trinity River above the Elm Fork Trinity River	West_Fork_abv_Elm_Fork	2820.9	-97.2542	32.7774	11.6
Ray Roberts Lake Inflow	Ray Roberts Inflow	692.6	-97.0306	33.4809	21.5
Elm Fork Trinity River above Clear Creek	Elm_Fork_abv_Clear_Ck	36.9	-96.9954	33.3300	8.2
Elm Fork Trinity River below Clear Creek	Elm Fork + Clear Ck	388.1	-97.4056	33.4824	144.0
Lewisville Lake Inflow	Lewisville Inflow	968.2	-96.9318	33.2147	162.2
Elm Fork Trinity River above Indian Creek	Elm_Fork_abv_Indian_Ck	21.4	-96.9291	33.0539	8.0
Elm Fort Trinity River below Indian Creek	Elm Fork + Indian Ck	37.5	-96.8899	33.0543	23.0
Elm Fork Trinity River below Timber Creek	Elm Fork + Timber Ck	61.5	-96.8908	33.0101	173.1
Elm Fork Trinity River above Denton Creek	Elm_Fork_abv_Denton_Ck	79.9	-96.8993	33.0495	178.1
Denton Creek nr Justin, TX USGS gage	Denton_Ck_J030	400.0	-97.5137	33.3604	125.2
Denton Creek below Oliver Creek	Denton_Ck_J040	475.3	-97.4056	33.1625	167.0
Denton Creek above Elizabeth Creek	Denton_Ck_abv_Elizabeth_Ck	506.1	-97.4140	33.1664	157.5
Denton Creek below Elizaveth Creek	Denton_Ck_J050	599.7	-97.3828	33.1226	136.9
Grapevine Lake Inflow	Grapevine_Inflow	694.4	-97.3848	33.1218	149.9
Denton Creek above the Elm Fork Trinity River	Denton_Ck_abv_Elm_Fork	24.3	-97.0202	32.9735	19.5
Elm Fork Trinity River near Carrollton USGS gage	Elm Fork + Denton Ck	104.2	-96.8865	33.0146	175.2
Elm Fork Trinity River at Interstate 635	Elm_Fork_J060	143.4	-96.9106	32.9740	170.9
Elm Fork Trinity River above Hackleberry Creek	Elm_Fork_abv_Hackberry_Ck	143.4	-96.8948	33.0067	8.4
Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage	Elm_Fork_J070	180.4	-96.8960	32.9943	20.3
Elm Fork Trinity River above Bachman Branch	Elm_Fork_abv_Bachman_Bra nch	202.6	-96.9488	32.9583	149.7
Elm Fork Trinity River below Bachman Branch (at Frasier Dam USGS gage)	Elm Fork + Bachman Branch	216.7	-96.9375	32.9720	159.5
Elm Fork Trinity River above the West Fork Trinity River	Elm_Fork_abv_West_Fork	222.8	-96.9183	32.9509	159.3
Trinity River below the West Fork and Elm Fork confluence	West Fork + Elm Fork	3043.7	-97.1951	32.8285	31.5

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
Trinity River at Dallas, TX USGS gage	Trinity_River_J010	3056.1	-97.1770	32.8271	27.5
Trinity River at the Corinth Street bridge in Dallas, TX	Trinity_River_J020	3099.0	-97.1870	32.8280	29.2
Trinity River below White Rock Creek	Trinity River + White Rock	3233.9	-97.1262	32.8435	25.1
Trinity River below Honey Springs Branch (Trinity River below Dallas, TX USGS gage)	Trinity_Rv + Honey_Springs	3256.5	-97.1111	32.8539	26.3
Trinity River below Five Mile Ceek	Trinity_River + Five_Mile_Ck	3328.8	-97.1120	32.8517	23.4
Trinity River above Ten Mile Creek	Trinity_River_abv_Tenmile_Ck	3367.7	-97.0693	32.8368	18.3
Trinity River below Ten Mile Creek	Trinity River + Tenmile Ck	3469.8	-97.0427	32.8035	179.9
Trinity River above the East Fork Trinity River	Trinity_River_abv_East_Fork	3529.4	-97.0807	32.8068	10.9
Lavon Lake Inflow	Lavon Inflow	768.2	-96.4704	33.2165	75.3
Ray Hubbard Lake Inflow	Ray Hubbard Inflow	301.8	-96.5955	32.9947	138.4
East Fork Trinity River near Forney USGS gage	East_Fork_nr_Forney	349.9	-96.5877	32.9532	135.4
East Fork Trinity River above Buffalo Creek	East_Fork_abv_Buffalo_Ck	359.5	-96.5869	32.9530	132.5
East Fork Trinity River below Buffalo Creek	East_Fork + Buffalo_Ck	393.9	-96.5702	32.9448	134.1
East Fork Trinity River above South Mesquite Creek	East_Fork_abv_S_Mesquite_C k	416.9	-96.5774	32.9445	130.8
East Fork Trinity River below South Mesquite Creek	East_Fork+South_Mesquite_C k	446.4	-96.5561	32.9125	129.0
East Fork Trinity River above Mustang Creek	East_Fork_abv_Mustang_Ck	465.5	-96.5624	32.8935	124.0
East Fork Trinity River near Crandall, TX USGS gage	East_Fork_nr_Crandall	484.8	-96.5643	32.8874	123.4
East Fork Trinity River above the Trinity River	East_Fork_abv_Trinity_River	484.8	-96.5467	32.8542	120.4
Trinity River below the East Fork Trinity River	Trinity River + East Fork	4014.2	-96.9273	32.8541	11.8
Trinity River below Red Oak Creek	Trinity_River + Red_Oak_Ck	4245.5	-96.9348	32.8373	13.0
Trinity River near Rosser, TX USGS gage	Trinity_River_nr_Rosser	4349.6	-96.7872	32.8364	179.8
Trinity River above Cedar Creek	Trinity_River_abv_Cedar_Ck	4349.6	-96.6807	32.7993	6.0
Cedar Creek Reservoir Inflow	Cedar Creek Inflow	1010.8	-96.0991	32.3864	140.0
Trinity River below Cedar Creek	Trinity River + Cedar Creek	5360.4	-96.4942	32.6132	162.6
Trinity River at Trinidad, TX USGS gage	Trinity_River_at_Trinidad	5759.3	-96.1679	32.3623	166.3
Trinity River above Richland Creek	Trinity_Rv_abv_Richland_Ck	6042.8	-96.1413	32.3654	160.6
Bardwell Lake Inflow	Bardwell Inflow	174.4	-96.7069	32.3280	149.5
Chambers Creek below Mill Creek	Chambers_Ck_J020	511.9	-97.0574	32.2593	156.2
Chambers Creek below Waxahachie Creek	Chambers Ck + Waxahachie Ck	621.0	-97.0213	32.2515	161.0
Chambers Creek near Rice, TX USGS gage	Chambers_Ck_J030	650.1	-96.9728	32.2298	161.4
Richland Creek below Pin Oak Creek	Richland_Ck_J010	395.0	-96.5777	31.9717	58.6
Richland Chambers Reservoir Inflow	Richland-Chambers Inflow	1465.5	-96.4405	32.0129	28.0
Trinity River below Richland Creek	Trinity River + Richland Ck	7508.3	-96.2412	32.3753	15.6
Trinity River above Tehuacana Creek	Trinity_Rv_abv_Tehuacana_C k	7508.3	-96.3369	32.3122	12.9
Trinity River below Tehuacana Creek	Trinity River + Tehuacana Ck	7894.7	-96.3620	32.0049	18.8

Location Description	HEC-HMS Element Name	Drainage Area (sq mi)	Longitude (X)	Latitude (Y)	Rotation of Major Axis (Theta)
Trinity River above Big Brown Creek	Trinity_Rv_abv_Big_Brown_Ck	7965.3	-96.3488	32.0055	14.4
Trinity River below Big Brown Creek	Trinity River + Big Brown Ck	8001.5	-96.3338	32.0086	14.3
Trinity River above Catfish Creek	Trinity_River_abv_Catfish_Ck	8306.6	-96.3441	32.0072	179.9
Trinity River below Catfish Creek	Trinity_River + Catfish_Ck	8353.0	-96.3206	31.9924	9.9
Trinity River near Oakwood, TX USGS gage	Trinity_River_nr_Oakwood	8593.0	-96.3193	32.1500	0.4
Trinity River above Upper Keechi Creek	TrinityRv_abv_UpperKeechi_Ck	8849.7	-96.3095	32.1515	0.6
Trinity River below Upper Keechi Creek	Trinity River + Upper Keechi	9358.9	-96.2930	32.1243	168.4
Trinity River above Big Elkhart Creek	Trinity_Rv_abv_Big_Elkhart	9359.5	-96.3196	32.1218	169.2
Trinity River below Big Elkhart Creek	Trinity River+ Big Elkhart	9502.5	-96.3748	32.1181	1.1
Trinity River near Crockett, TX USGS gage	Trinity_River_nr_Crockett	9615.0	-96.3470	32.1418	0.1
Trinity River above Lower Keechi Creek	Trinity_Rv_abv_LowerKeech_Ck	9791.7	-96.2470	32.0366	151.9
Trinity River below Lower Keechi Creek	Trinity_River+LowerKeechi_Ck	9979.3	-96.2909	32.0508	155.7
Trinity River above Bedias Creek	Trinity_River_abv_Bedias_Ck	10374.29	-96.2231	31.9926	145.9
Bedias Creek above the Trinity River	Bedias_Ck_abv_Trinity_River	604.3	-95.9526	30.9658	124.7
Trinity River below Bedias Creek	Trinity River + Bedias Ck	10978.5	-95.8797	30.9709	52.3
Trinity River at Riverside, TX USGS gage	Trinity River_at_Riverside	11306.7	-95.8826	31.0549	145.8
Lake Livingston Inflow	Lake Livingston Inflow	12301.1	-95.2801	30.8714	157.6
Trinity River above Long King Creek	Trinity_Rv_abv_Long_King_Ck	12340.5	-95.6283	31.0182	169.6
Trinity River at Goodrich, TX USGS gage	Trinity River + Long King Ck	12566.9	-95.6940	31.0571	173.2
Trinity River above Menard Creek	Trinity_River_abv_Menard_Ck	12628.0	-95.5939	30.9433	1.5
Trinity River below Menard Creek	Trinity River + Menard Ck	12776.2	-95.4685	30.9862	159.4
Trinity River at Romayor, TX USGS gage	Trinity_River_at_Romayor	12873.7	-95.4894	30.9636	155.9
Trinity River near Moss Hill, TX	Trinity_River_nr_MossHill_TX	12945.7	-95.4670	30.9793	154.9
Trinity River at Liberty, TX USGS gage	Trinity_River_at_Liberty	13176.5	-95.4456	30.9401	153.7
Trinity River at Wallisville, TX USGS gage	Trinity Bay	13618.4	-95.4915	30.9648	150.6

1.5 ELLIPTICAL FREQUENCY STORM LOSS RATES

The elliptical frequency storms were then applied to the final HEC-HMS basin model with the same frequency loss rates that were used for the uniform rainfall method which is discussed in a separate appendix. In some cases, the 2-yr through 10-yr losses had to be re-adjusted in order to maintain consistency with the frequent end of the statistical frequency curves at the USGS gages. This final adjustment was performed because of the increased level of confidence in the statistical frequency curve for the 2 through 10-yr recurrence intervals. The final 2-yr through 25-yr loss rates used for the elliptical frequency storm events are given in Table 3. The final 50-yr through 500-yr loss rates are the same as those used for the uniform rainfall method and are shown again in Table 4.

Table 3: Final Initial and Constant Losses for the 2-yr through 25-yr Elliptical Frequency Storms

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
West_Fork_S020	1.53	0.22	1.50	0.17	1.27	0.16	1.18	0.14
West_Fork_S010	1.55	0.22	1.59	0.17	1.41	0.16	1.37	0.14
West_Fork_S030	1.54	0.22	1.52	0.18	1.29	0.16	1.20	0.14
West_Fork_S040	1.53	0.22	1.51	0.17	1.28	0.16	1.19	0.14
West_Fork_S050	1.54	0.22	1.51	0.17	1.28	0.16	1.19	0.14
West_Fork_S060	1.53	0.22	1.50	0.17	1.27	0.16	1.18	0.14
West_Fork_S070	1.55	0.22	1.53	0.18	1.29	0.16	1.20	0.14
West_Fork_S080	1.52	0.22	1.49	0.17	1.26	0.16	1.17	0.14
West_Fork_S090	1.56	0.22	1.54	0.18	1.30	0.16	1.21	0.14
West_Fork_S100	1.50	0.22	1.47	0.17	1.25	0.15	1.16	0.14
West_Fork_S120	1.73	0.22	2.24	0.17	2.37	0.16	2.64	0.14
West_Fork_S110	1.58	0.23	1.55	0.18	1.31	0.16	1.22	0.14
Big_Cleveland_S010	1.86	0.22	2.73	0.17	3.12	0.16	3.63	0.14
Big_Cleveland_S020	1.71	0.22	2.18	0.17	2.28	0.16	2.52	0.14
West_Fork_S130	1.51	0.22	1.48	0.17	1.26	0.15	1.17	0.14
Lost_Ck_S010	1.78	0.22	1.50	0.17	1.27	0.16	1.18	0.14
Lost_Ck_S020	2.27	0.24	2.13	0.19	1.25	0.15	1.16	0.14
West_Fork_S140	2.47	0.24	2.76	0.19	1.94	0.16	2.06	0.14
West_Fork_S150	2.28	0.24	2.16	0.19	1.26	0.16	1.17	0.14
West_Fork_S160	2.34	0.24	2.20	0.20	1.29	0.16	1.20	0.14
Beans_Ck_S010	2.32	0.24	2.22	0.19	1.30	0.16	1.22	0.14
Beans_Ck_S020	2.35	0.24	2.22	0.20	1.29	0.16	1.20	0.14
Big_Ck_S010	2.39	0.25	2.27	0.20	1.34	0.16	1.25	0.14
Big_Ck_S030	2.46	0.25	2.31	0.20	1.35	0.16	1.25	0.15
Big_Ck_S020	2.40	0.25	2.25	0.20	1.32	0.16	1.23	0.14
Bridgeport_S030	2.51	0.26	2.35	0.21	1.37	0.17	1.27	0.15
Bridgeport_S010	2.08	0.22	1.96	0.17	1.16	0.14	1.07	0.13
Bridgeport_S040	2.48	0.25	2.34	0.20	1.36	0.17	1.26	0.15
Bridgeport_S020	2.38	0.25	2.24	0.20	1.31	0.16	1.21	0.14
West_Fork_S170	2.41	0.25	2.27	0.20	1.32	0.16	1.23	0.14
Dry_Ck_S010	2.52	0.26	2.43	0.21	1.45	0.17	1.38	0.15
West_Fork_S180	2.56	0.26	2.40	0.21	1.39	0.17	1.30	0.15
Amon_G_Carter_S030	1.71	0.20	1.68	0.17	1.66	0.15	1.79	0.14
Amon_G_Carter_S010	1.91	0.21	2.28	0.17	2.59	0.15	3.07	0.14
Amon_G_Carter_S020	1.68	0.21	1.54	0.17	1.43	0.15	1.48	0.14
Big_Sandy_Ck_S010	1.52	0.21	1.55	0.17	1.60	0.15	1.71	0.14
Big_Sandy_Ck_S020	1.49	0.22	1.33	0.18	1.20	0.16	1.39	0.15

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Brushy_Ck_S010	1.48	0.22	1.35	0.18	1.26	0.16	1.42	0.15
Brushy_Ck_S020	1.56	0.22	1.51	0.18	1.50	0.16	1.63	0.15
Brushy_Ck_S030	1.66	0.22	1.85	0.18	2.03	0.16	2.07	0.15
Big_Sandy_Ck_S030	1.57	0.22	1.52	0.18	1.50	0.16	1.63	0.15
Big_Sandy_Ck_S040	1.52	0.22	1.39	0.18	1.30	0.16	1.46	0.15
Big_Sandy_Ck_S050	2.58	0.26	2.51	0.21	1.50	0.17	1.44	0.15
West_Fork_S190	2.56	0.26	2.48	0.21	1.49	0.17	1.43	0.15
West_Fork_S200	2.52	0.26	2.36	0.21	1.37	0.17	1.28	0.15
Garrett_Ck_S020	2.71	0.25	2.76	0.20	2.27	0.17	2.48	0.15
Garrett_Ck_S010	2.75	0.26	2.76	0.21	2.34	0.17	2.57	0.15
Garrett_Ck_S030	2.53	0.26	2.37	0.21	1.37	0.17	1.29	0.15
Salt_Ck_S010	2.81	0.26	2.76	0.21	3.29	0.17	3.82	0.15
Salt_Ck_S020	2.80	0.26	2.76	0.21	2.27	0.17	2.45	0.15
West_Fork_S210	2.55	0.26	2.39	0.21	1.38	0.17	1.29	0.15
West_Fork_S220	2.29	0.22	2.26	0.18	2.37	0.17	1.75	0.15
Eagle_Mountain_S010	2.19	0.21	2.02	0.18	2.01	0.16	1.25	0.15
Eagle_Mountain_S020	2.05	0.20	1.90	0.17	1.92	0.15	1.14	0.14
Walnut_Ck_S020	1.54	0.20	1.66	0.17	1.79	0.15	1.29	0.15
Walnut_Ck_S010	1.54	0.20	1.66	0.17	1.78	0.15	1.28	0.15
Walnut_Ck_S030	2.25	0.22	2.15	0.18	2.06	0.17	1.29	0.15
Eagle_Mountain_S040	2.07	0.20	2.00	0.17	1.94	0.15	1.16	0.14
Eagle_Mountain_S030	2.21	0.21	2.11	0.18	2.02	0.17	1.26	0.15
Silver_Ck_S020	2.19	0.21	2.18	0.18	2.18	0.16	1.48	0.14
Silver_Ck_S010	2.27	0.22	2.25	0.18	2.23	0.17	1.54	0.15
Lake_Worth_S010	2.17	0.21	2.08	0.18	2.00	0.16	1.23	0.14
Lake_Worth_S020	2.11	0.20	2.02	0.17	1.95	0.16	1.18	0.14
West_Fork_S230	2.03	0.20	2.04	0.17	1.96	0.15	1.32	0.15
Lk_Weatherford_S010	1.69	0.21	2.64	0.17	2.39	0.16	1.69	0.14
Lk_Weatherford_S020	1.49	0.20	2.09	0.17	1.75	0.15	1.71	0.15
Clear_Fork_S010	1.76	0.20	2.02	0.16	2.27	0.15	2.73	0.15
Clear_Fork_S020	1.54	0.20	1.36	0.16	1.22	0.15	1.23	0.14
Bear_Ck_S010	1.58	0.20	1.46	0.16	1.38	0.15	1.46	0.14
Bear_Ck_S020	1.50	0.19	1.32	0.15	1.19	0.15	1.19	0.14
Benbrook_S010	1.46	0.19	1.29	0.15	1.17	0.14	1.17	0.14
Benbrook_S020	1.41	0.18	1.25	0.15	1.14	0.14	1.13	0.14
Benbrook_S030	1.40	0.18	1.23	0.14	1.12	0.14	1.12	0.13
Clear_Fork_S030	1.50	0.19	1.53	0.15	1.57	0.15	1.19	0.14
Marys_Ck_S010	1.87	0.20	1.92	0.19	2.03	0.18	1.21	0.14
Clear_Fork_S040	1.72	0.20	1.76	0.17	1.87	0.15	2.00	0.15

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Clear_Fork_S050	2.07	0.21	2.08	0.18	2.00	0.16	1.35	0.15
West_Fork_S240	2.06	0.20	1.95	0.16	1.88	0.15	1.26	0.15
Marine_Ck_S020	2.27	0.20	2.38	0.16	2.56	0.15	2.52	0.15
Marine_Ck_S010	1.37	0.18	1.21	0.14	1.10	0.14	1.10	0.13
West_Fork_S250	2.11	0.21	1.99	0.17	1.93	0.15	1.29	0.15
West_Fork_S260	1.92	0.20	1.90	0.15	1.94	0.14	1.35	0.14
West_Fork_S270	3.28	0.31	3.00	0.22	2.36	0.15	1.76	0.15
Big_Fossil_Ck_S010	2.17	0.24	2.46	0.18	2.17	0.12	2.91	0.13
LittleFossil_Ck_S010	3.22	0.27	2.28	0.20	1.72	0.13	1.07	0.13
West_Fork_S280	3.28	0.29	2.53	0.21	1.96	0.15	1.18	0.14
Village_Ck_S010	1.82	0.25	1.65	0.19	1.15	0.13	1.29	0.14
Village_Ck_S020	1.98	0.25	1.56	0.19	1.04	0.13	1.13	0.14
Lake_Arlington_S010	1.94	0.25	1.53	0.18	1.03	0.13	1.11	0.13
Village_Ck_S030	3.28	0.31	2.64	0.22	2.04	0.15	1.23	0.14
West_Fork_S290	3.28	0.31	2.64	0.22	2.04	0.15	1.23	0.14
West_Fork_S300	3.28	0.28	2.46	0.21	1.88	0.14	1.15	0.14
West_Fork_S310	3.28	0.28	2.36	0.20	1.84	0.14	1.11	0.13
West_Fork_S320	1.27	0.16	1.12	0.13	1.00	0.12	1.26	0.15
Big_Bear_Ck_S010	1.21	0.15	1.13	0.12	1.09	0.12	1.43	0.14
Big_Bear_Ck_S020	1.25	0.16	1.10	0.13	0.99	0.12	1.24	0.15
West_Fork_S330	1.25	0.16	1.09	0.13	0.98	0.12	1.24	0.14
Joe_Pool_S020	1.33	0.16	1.36	0.14	1.43	0.13	1.60	0.13
Joe_Pool_S030	1.40	0.18	1.42	0.18	1.51	0.16	1.13	0.14
Joe_Pool_S040	1.37	0.18	1.21	0.14	1.10	0.14	1.10	0.13
Joe_Pool_S010	1.19	0.16	1.05	0.13	0.97	0.12	0.96	0.12
Joe_Pool_S050	1.24	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Mountain_Ck_S010	1.27	0.16	1.14	0.14	1.05	0.13	1.04	0.13
Mountain_Ck_S020	1.29	0.16	1.14	0.14	1.04	0.13	1.04	0.13
Mountain_Ck_S030	1.33	0.17	1.34	0.17	1.29	0.15	1.07	0.13
West_Fork_S340	1.14	0.14	1.01	0.12	0.92	0.11	1.14	0.14
Elm_Fork_S020	1.55	0.17	1.86	0.14	2.16	0.14	2.62	0.13
Elm_Fork_S010	1.77	0.18	2.50	0.15	3.15	0.14	4.03	0.14
Brushy_Elm_Ck_S010	1.44	0.17	1.61	0.14	1.78	0.13	2.09	0.13
Brushy_Elm_Ck_S020	1.37	0.17	1.33	0.14	1.33	0.13	1.44	0.13
Elm_Fork_S030	1.47	0.17	1.69	0.14	1.91	0.13	2.27	0.13
Elm_Fork_S040	1.37	0.17	1.39	0.14	1.44	0.13	1.60	0.13
Elm_Fork_S050	1.49	0.18	1.50	0.15	1.52	0.14	1.69	0.14
Elm_Fork_S070	1.44	0.18	1.36	0.14	1.32	0.14	1.40	0.13
Elm_Fork_S060	1.26	0.16	1.11	0.14	1.02	0.13	1.02	0.13

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Spring_Ck_S010	1.32	0.17	1.17	0.14	1.07	0.13	1.06	0.13
Spring_Ck_S020	1.32	0.17	1.17	0.14	1.07	0.13	1.06	0.13
Ray_Roberts_S010	1.52	0.17	1.78	0.14	2.04	0.14	2.45	0.13
Timber_Ck_S010	1.58	0.20	1.39	0.16	1.26	0.15	1.26	0.15
Timber_Ck_S030	1.44	0.18	1.27	0.15	1.15	0.14	1.15	0.14
Timber_Ck_S020	1.57	0.20	1.38	0.16	1.24	0.15	1.25	0.15
Ray_Roberts_S030	1.47	0.19	1.30	0.15	1.18	0.15	1.19	0.14
Range_Ck_S010	1.83	0.23	1.88	0.22	1.94	0.22	1.00	0.12
Range_Ck_S020	1.22	0.16	1.08	0.13	1.00	0.12	0.98	0.12
Lake_Kiowa_S020	1.55	0.20	1.36	0.16	1.23	0.15	1.23	0.14
Lake_Kiowa_S010	1.62	0.20	1.42	0.17	1.28	0.15	1.29	0.15
Ray_Roberts_S020	1.23	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Range_Ck_S030	1.29	0.17	1.14	0.14	1.05	0.13	1.04	0.13
Buck_Ck_S010	1.22	0.16	1.09	0.14	1.00	0.12	0.99	0.12
Ray_Roberts_S050	1.24	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Ray_Roberts_S040	1.38	0.17	1.34	0.14	1.32	0.13	1.42	0.13
Ray_Roberts_S060	1.37	0.18	1.21	0.14	1.10	0.14	1.10	0.13
Timber_Ck_S040	1.42	0.18	1.25	0.15	1.14	0.14	1.13	0.14
Elm_Fork_S080	1.83	0.23	1.75	0.21	1.17	0.15	1.17	0.14
Clear_Ck_S010	1.65	0.18	2.27	0.16	2.67	0.15	3.31	0.15
Clear_Ck_S020	1.61	0.18	2.06	0.17	2.31	0.15	2.78	0.15
Clear_Ck_S030	1.65	0.18	2.29	0.16	2.70	0.15	3.34	0.15
Clear_Ck_S040	1.58	0.17	2.30	0.15	2.80	0.14	3.50	0.14
Clear_Ck_S050	1.44	0.16	1.92	0.15	2.21	0.14	2.68	0.14
Clear_Ck_S070	1.30	0.16	1.50	0.14	1.57	0.14	1.76	0.13
Clear_Ck_S060	1.34	0.17	1.31	0.15	1.19	0.15	1.19	0.14
Clear_Ck_S080	1.44	0.16	1.93	0.15	2.24	0.14	2.72	0.14
Clear_Ck_S090	1.30	0.16	1.62	0.14	1.81	0.13	2.13	0.13
Clear_Ck_S110	1.29	0.17	1.14	0.14	1.05	0.13	1.04	0.13
Clear_Ck_S100	1.39	0.17	1.44	0.14	1.51	0.13	1.70	0.13
Clear_Ck_S120	1.37	0.17	1.24	0.14	1.17	0.14	1.20	0.13
Little_Elm_Ck_S010	1.58	0.18	1.81	0.14	2.17	0.12	2.66	0.12
Little_Elm_Ck_S020	1.46	0.17	1.49	0.13	1.66	0.12	1.94	0.12
Little_Elm_Ck_S030	1.19	0.16	1.06	0.13	0.98	0.12	0.97	0.12
Pecan_Ck_S010	1.44	0.19	1.27	0.15	1.15	0.14	1.15	0.14
Doe_Branch_S010	1.22	0.16	1.10	0.14	1.02	0.12	1.02	0.12
Doe_Branch_S020	1.25	0.16	1.10	0.14	1.01	0.13	1.01	0.12
Lewisville_S030	1.39	0.18	1.23	0.14	1.12	0.14	1.12	0.13
Hickory_Ck_S020	1.36	0.17	1.32	0.14	1.32	0.13	1.42	0.13

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Hickory_Ck_S010	1.35	0.17	1.31	0.14	1.32	0.13	1.42	0.13
Hickory_Ck_S030	1.29	0.16	1.18	0.14	1.10	0.13	1.12	0.13
Hickory_Ck_S040	1.56	0.17	1.88	0.14	2.18	0.14	2.66	0.13
Hickory_Ck_S050	1.63	0.20	1.58	0.16	1.57	0.15	1.71	0.15
Lewisville_S010	1.47	0.19	1.34	0.15	1.26	0.14	1.30	0.14
Lewisville_S040	1.20	0.16	1.07	0.13	0.99	0.12	0.97	0.12
Lewisville_S050	1.24	0.16	1.10	0.14	1.01	0.13	1.00	0.12
Lewisville_S020	1.47	0.19	1.34	0.15	1.26	0.14	1.30	0.14
Elm_Fork_S090	2.34	0.23	2.20	0.21	2.24	0.18	1.08	0.13
Elm_Fork_S110	2.34	0.21	2.20	0.20	2.24	0.18	1.03	0.13
Elm_Fork_S100	2.34	0.24	2.20	0.22	2.24	0.21	1.26	0.14
Elm_Fork_S120	2.34	0.21	2.20	0.20	2.24	0.18	1.83	0.13
Denton_Ck_S010	1.81	0.25	2.04	0.19	2.20	0.17	2.64	0.15
Denton_Ck_S020	1.79	0.24	2.02	0.18	2.19	0.16	2.62	0.15
Denton_Ck_S030	1.74	0.24	1.95	0.18	2.09	0.16	2.48	0.14
Denton_Ck_S040	1.76	0.22	1.67	0.17	1.66	0.15	1.68	0.13
Denton_Ck_S050	1.47	0.17	1.62	0.14	1.76	0.14	2.05	0.13
Denton_Ck_S060	1.33	0.17	1.18	0.14	1.08	0.13	1.07	0.13
Denton_Ck_S070	1.34	0.17	1.20	0.14	1.11	0.13	1.12	0.13
Grapevine_S010	1.53	0.19	1.51	0.15	1.52	0.15	1.68	0.14
Denton_Ck_S080	2.34	0.23	2.38	0.22	2.55	0.19	1.13	0.14
Elm_Fork_S130	1.10	0.14	1.12	0.11	1.16	0.10	1.61	0.13
Hackberry_Ck_S010	1.07	0.12	1.24	0.10	1.42	0.10	2.10	0.12
Hackberry_Ck_S020	0.95	0.12	0.84	0.10	0.78	0.10	0.97	0.12
Hackberry_Ck_S030	0.98	0.13	0.87	0.11	0.80	0.10	0.99	0.12
Elm_Fork_S140	1.11	0.14	0.98	0.12	0.89	0.11	1.11	0.13
Elm_Fork_S150	1.12	0.14	0.99	0.12	0.89	0.11	1.12	0.13
Bachman_Branch_S010	1.19	0.15	1.04	0.12	0.94	0.12	1.18	0.14
Bachman_Branch_S020	1.12	0.14	0.99	0.12	0.90	0.11	1.13	0.14
Elm_Fork_S160	1.13	0.14	1.00	0.12	0.91	0.11	1.13	0.14
Trinity_River_S010	1.11	0.14	1.04	0.12	1.18	0.11	1.30	0.13
Trinity_River_S020	1.67	0.20	1.29	0.13	1.11	0.10	1.18	0.09
White_Rock_Ck_S010	1.58	0.18	1.38	0.12	1.30	0.09	1.46	0.08
White_Rock_Ck_S020	1.57	0.20	1.06	0.12	0.81	0.10	0.77	0.09
White_Rock_Ck_S030	1.54	0.20	1.04	0.12	0.80	0.09	0.75	0.09
White_Rock_Ck_S040	1.52	0.19	1.03	0.12	0.78	0.09	0.75	0.09
Trinity_River_S030	1.63	0.21	1.10	0.13	0.84	0.10	0.80	0.09
Fivemile_Ck_S010	1.53	0.19	0.94	0.10	0.87	0.09	0.99	0.09
Trinity_River_S040	1.38	0.17	0.80	0.10	0.71	0.08	0.75	0.09

Subbasin Name	2-yr	2-yr	5-yr	5-yr	10-yr	10-yr	25-yr	25-yr
	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
Trinity_River_S050	1.34	0.17	0.77	0.09	0.69	0.08	0.73	0.08
Tenmile_Ck_S010	1.40	0.17	0.82	0.10	0.75	0.08	0.81	0.09
Tenmile_Ck_S020	1.25	0.17	0.72	0.09	0.64	0.08	0.68	0.08
Trinity_River_S060	1.42	0.18	0.86	0.10	0.80	0.08	0.88	0.09
Indian_Ck_S010	1.36	0.16	1.28	0.10	1.48	0.09	1.63	0.08
Indian_Ck_S030	1.37	0.17	1.07	0.11	1.09	0.10	1.10	0.08
Indian_Ck_S020	1.16	0.15	0.79	0.09	0.71	0.09	0.63	0.08
Indian_Ck_S040	1.31	0.16	1.15	0.10	1.27	0.09	1.35	0.08
Sister_Grove_S010	1.52	0.17	1.42	0.11	1.63	0.10	1.79	0.08
Sister_Grove_S020	1.37	0.17	1.16	0.10	1.26	0.09	1.33	0.08
East_Fork_S020	1.45	0.17	1.33	0.11	1.52	0.09	1.66	0.08
East_Fork_S010	1.58	0.17	1.64	0.11	2.00	0.09	2.27	0.08
East_Fork_S030	1.33	0.17	1.00	0.11	0.99	0.09	0.97	0.08
East_Fork_S040	1.27	0.17	0.86	0.11	0.77	0.09	0.69	0.08
Wilson_Ck_S010	1.45	0.17	1.29	0.11	1.43	0.09	1.53	0.08
Lavon_S010	1.18	0.15	0.86	0.09	0.83	0.09	0.79	0.08
Lavon_S020	1.19	0.16	0.81	0.10	0.73	0.09	0.65	0.08
Rowlett_Ck_S010	1.73	0.19	1.27	0.12	1.12	0.11	0.77	0.08
Ray_Hubbard_S010	1.30	0.07	1.02	0.06	1.21	0.07	1.40	0.08
Ray_Hubbard_S020	0.60	0.07	0.47	0.06	0.56	0.07	0.65	0.08
East_Fork_S050	0.62	0.08	0.49	0.06	0.58	0.07	0.68	0.08
East_Fork_S070	0.86	0.11	0.61	0.08	1.54	0.07	0.64	0.08
East_Fork_S060	1.10	0.11	1.23	0.08	0.64	0.07	2.03	0.08
East_Fork_S080	0.86	0.11	0.61	0.08	0.64	0.07	0.64	0.08
East_Fork_S090	0.86	0.11	0.63	0.08	0.65	0.07	0.67	0.08
East_Fork_S110	0.91	0.11	0.74	0.09	0.69	0.08	0.76	0.08
East_Fork_S100	1.14	0.11	1.32	0.08	1.68	0.07	2.21	0.08
Trinity_River_S070	1.08	0.14	0.75	0.09	0.70	0.08	0.75	0.08
East_Fork_S120	1.12	0.13	0.98	0.09	1.09	0.08	1.37	0.08
Kings_Ck_S020	1.06	0.13	0.86	0.08	0.91	0.07	1.10	0.08
Kings_Ck_S010	1.15	0.13	1.00	0.09	1.09	0.08	1.37	0.08
Kings_Ck_S030	1.19	0.13	1.15	0.09	1.34	0.08	1.76	0.08
Cedar_Ck_S040	1.31	0.15	1.07	0.10	1.11	0.09	1.35	0.09
Cedar_Ck_S010	0.74	0.08	0.58	0.07	0.63	0.07	0.85	0.08
New_Terrell_City_Lake_S010	0.63	0.14	0.43	0.08	0.38	0.08	0.40	0.08
Cedar_Ck_S020	1.11	0.14	0.79	0.09	0.74	0.08	0.82	0.08
Cedar_Ck_S030	1.35	0.15	1.19	0.10	1.32	0.09	1.68	0.09
Trinity_River_S080	1.11	0.13	0.87	0.09	0.89	0.08	1.05	0.08

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Trinity_River_S090	1.21	0.15	0.92	0.09	0.92	0.09	1.07	0.08
Chambers_Ck_S010	1.29	0.18	1.13	0.12	1.24	0.10	1.40	0.08
Chambers_Ck_S020	1.34	0.18	1.34	0.11	1.59	0.10	1.81	0.08
Chambers_Ck_S040	1.36	0.18	1.33	0.12	1.55	0.10	1.77	0.08
Chambers_Ck_S030	1.41	0.19	1.31	0.12	1.48	0.11	1.66	0.08
Waxahachie_Ck_S010	2.27	0.22	2.08	0.18	2.26	0.15	2.31	0.09
Waxahachie_Ck_S020	1.70	0.20	1.38	0.13	1.43	0.12	1.35	0.09
Waxahachie_Ck_S030	1.38	0.17	1.01	0.11	0.98	0.10	0.85	0.08
Mustang_Ck_S010	1.30	0.17	0.97	0.10	0.95	0.10	0.84	0.08
Bardwell_S010	1.34	0.17	1.05	0.10	1.07	0.10	0.97	0.08
Chambers_Ck_S050	1.25	0.17	1.25	0.10	1.49	0.10	1.70	0.08
Chambers_Ck_S060	1.21	0.17	1.04	0.11	1.12	0.10	1.25	0.08
Chambers_Ck_S070	1.25	0.17	1.24	0.10	1.47	0.10	1.68	0.08
Chambers_Ck_S080	1.12	0.14	0.92	0.09	0.98	0.08	1.18	0.08
Post_Oak_Ck_S010	1.14	0.14	0.97	0.09	1.05	0.08	1.29	0.08
Lake_Halbert_S010	1.07	0.13	0.87	0.08	0.92	0.07	1.09	0.08
Navarro_Mills_S020	1.10	0.14	0.89	0.09	0.93	0.08	1.11	0.08
Navarro_Mills_S030	1.35	0.14	1.39	0.09	1.68	0.08	2.22	0.08
Navarro_Mills_S010	1.34	0.15	1.24	0.10	1.41	0.09	1.80	0.09
Navarro_Mills_S040	1.04	0.14	0.71	0.09	0.63	0.08	0.66	0.08
Richland_Ck_S010	1.16	0.14	1.01	0.09	1.12	0.08	1.39	0.08
Richland_Ck_S020	1.19	0.14	1.15	0.09	1.34	0.08	1.72	0.08
Richland-Chambers_S010	1.04	0.14	0.71	0.09	0.64	0.08	0.66	0.08
Richland-Chambers_S020	1.02	0.14	0.70	0.09	0.62	0.08	0.65	0.08
Tehuacana_Ck_S020	1.48	0.15	1.43	0.10	1.66	0.09	2.15	0.09
Tehuacana_Ck_S010	0.77	0.14	0.81	0.09	1.13	0.09	1.38	0.08
Trinity_River_S100	1.17	0.15	0.79	0.10	0.70	0.09	0.73	0.09
Fairfield_Lake_S010	1.60	0.15	1.79	0.10	2.24	0.09	3.04	0.09
Trinity_River_S110	1.48	0.18	1.01	0.11	0.90	0.10	0.98	0.10
Big_Brown_Ck_S010	1.74	0.17	1.82	0.11	2.20	0.10	2.94	0.10
Trinity_River_S120	1.43	0.17	1.14	0.11	1.16	0.10	1.39	0.10
Trinity_River_S130	1.40	0.17	0.98	0.11	0.95	0.11	0.94	0.10
Upper_Keechi_Ck_S030	1.53	0.18	1.07	0.12	1.02	0.11	1.02	0.10
Upper_Keechi_Ck_S010	1.53	0.18	1.19	0.12	1.18	0.12	0.94	0.10
Upper_Keechi_Ck_S020	1.64	0.19	1.22	0.12	1.24	0.12	1.30	0.10
Upper_Keechi_Ck_S040	1.43	0.18	0.96	0.11	0.89	0.11	0.85	0.10
Trinity_River_S140	1.05	0.14	0.72	0.09	0.68	0.08	0.64	0.08
Little_Elkhart_S010	1.50	0.18	1.01	0.12	0.93	0.11	0.89	0.10
Houston_County_Lake_S010	1.92	0.19	2.01	0.12	2.57	0.11	3.12	0.10

Subbasin Name	2-yr Initial (in)	2-yr Constant (in/hr)	5-yr Initial (in)	5-yr Constant (in/hr)	10-yr Initial (in)	10-yr Constant (in/hr)	25-yr Initial (in)	25-yr Constant (in/hr)
Trinity_River_S150	1.32	0.16	0.90	0.11	0.84	0.10	0.81	0.09
Trinity_River_S160	1.54	0.20	0.99	0.12	0.80	0.10	0.79	0.09
Trinity_River_S170	1.76	0.21	1.14	0.13	0.92	0.11	0.92	0.10
Trinity_River_S180	1.54	0.20	0.99	0.12	0.80	0.10	0.79	0.09
Bedias_Ck_S010	1.46	0.19	1.32	0.11	1.41	0.09	1.70	0.09
Bedias_Ck_S020	1.52	0.19	0.98	0.12	0.79	0.10	0.78	0.09
Trinity_River_S190	1.50	0.19	0.97	0.11	0.79	0.10	0.78	0.09
Livingston_S010	1.17	0.14	0.94	0.11	0.88	0.11	0.80	0.09
Livingston_S030	1.12	0.14	0.90	0.11	0.84	0.10	0.75	0.09
Livingston_S020	1.10	0.14	0.88	0.11	0.82	0.10	0.74	0.09
Trinity_River_S200	0.99	0.12	0.92	0.11	0.86	0.11	0.77	0.09
Long_King_Ck_S010	1.16	0.14	0.93	0.11	0.86	0.11	0.78	0.09
Long_King_Ck_S020	1.09	0.12	1.02	0.11	1.00	0.11	0.96	0.09
Trinity_River_S210	1.40	0.15	1.09	0.12	1.00	0.11	0.94	0.10
Menard_Ck_S010	1.65	0.20	1.30	0.12	1.31	0.11	1.34	0.10
Trinity_River_S220	1.28	0.15	1.00	0.12	0.89	0.11	0.80	0.09
Trinity_River_S230	1.10	0.15	0.87	0.11	0.78	0.09	0.70	0.08
Trinity_River_S240	1.13	0.15	0.89	0.11	0.79	0.10	0.71	0.08
Trinity_River_S250	1.43	0.16	1.36	0.10	1.58	0.09	1.75	0.08

Table 4: Final Initial and Constant Losses for the 50-yr through 500-yr Elliptical Frequency Storms

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
West_Fork_S020	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S010	1.21	0.12	1.05	0.09	0.89	0.08	0.57	0.07
West_Fork_S030	1.02	0.12	0.86	0.09	0.69	0.08	0.57	0.07
West_Fork_S040	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S050	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S060	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S070	1.03	0.12	0.86	0.09	0.70	0.08	0.57	0.07
West_Fork_S080	1.01	0.12	0.85	0.09	0.69	0.08	0.56	0.07
West_Fork_S090	1.03	0.12	0.86	0.09	0.70	0.08	0.57	0.07
West_Fork_S100	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S120	2.58	0.12	2.41	0.09	2.25	0.08	0.57	0.07
West_Fork_S110	1.04	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Big_Cleveland_S010	3.66	0.12	3.49	0.09	3.33	0.08	0.57	0.07
Big_Cleveland_S020	2.46	0.12	2.29	0.09	2.13	0.08	0.57	0.07
West_Fork_S130	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Lost_Ck_S010	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Lost_Ck_S020	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S140	1.97	0.12	1.81	0.09	1.65	0.08	0.56	0.07
West_Fork_S150	1.01	0.12	0.85	0.09	0.69	0.08	0.56	0.07
West_Fork_S160	1.02	0.12	0.86	0.09	0.69	0.08	0.57	0.07
Beans_Ck_S010	1.05	0.12	0.89	0.09	0.73	0.08	0.57	0.07
Beans_Ck_S020	1.03	0.12	0.86	0.09	0.69	0.08	0.57	0.07
Big_Ck_S010	1.08	0.12	0.90	0.09	0.74	0.08	0.58	0.07
Big_Ck_S030	1.07	0.13	0.88	0.10	0.71	0.08	0.59	0.08
Big_Ck_S020	1.04	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Bridgeport_S030	1.08	0.13	0.89	0.10	0.72	0.09	0.59	0.08
Bridgeport_S010	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Bridgeport_S040	1.07	0.13	0.88	0.10	0.72	0.09	0.59	0.08
Bridgeport_S020	1.04	0.12	0.86	0.09	0.70	0.08	0.58	0.07
West_Fork_S170	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Dry_Ck_S010	1.20	0.13	1.01	0.10	0.84	0.09	0.59	0.08
West_Fork_S180	1.10	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Amon_G_Carter_S030	1.67	0.12	1.50	0.09	1.34	0.08	0.57	0.07
Amon_G_Carter_S010	3.04	0.12	2.87	0.09	2.70	0.08	0.58	0.07
Amon_G_Carter_S020	1.32	0.12	1.15	0.09	0.98	0.08	0.58	0.07
Big_Sandy_Ck_S010	1.56	0.12	1.37	0.09	1.21	0.08	0.58	0.07
Big_Sandy_Ck_S020	1.19	0.13	1.00	0.10	0.83	0.09	0.60	0.08
Brushy_Ck_S010	1.24	0.13	1.05	0.10	0.88	0.09	0.59	0.08
Brushy_Ck_S020	1.46	0.13	1.26	0.10	1.09	0.09	0.60	0.08

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Brushy_Ck_S030	1.94	0.13	1.74	0.10	1.57	0.09	0.60	0.08
Big_Sandy_Ck_S030	1.46	0.13	1.26	0.10	1.09	0.09	0.60	0.08
Big_Sandy_Ck_S040	1.28	0.13	1.08	0.10	0.91	0.09	0.60	0.08
Big_Sandy_Ck_S050	1.26	0.13	1.06	0.10	0.89	0.09	0.60	0.08
West_Fork_S190	1.25	0.13	1.05	0.10	0.88	0.09	0.60	0.08
West_Fork_S200	1.09	0.13	0.89	0.10	0.72	0.09	0.59	0.08
Garrett_Ck_S020	2.39	0.13	2.20	0.10	2.03	0.09	0.59	0.08
Garrett_Ck_S010	2.48	0.13	2.29	0.10	2.12	0.09	0.59	0.08
Garrett_Ck_S030	1.09	0.13	0.89	0.10	0.72	0.09	0.60	0.08
Salt_Ck_S010	3.82	0.13	3.62	0.10	3.45	0.09	0.60	0.08
Salt_Ck_S020	2.35	0.13	2.14	0.10	1.97	0.09	0.60	0.08
West_Fork_S210	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
West_Fork_S220	1.60	0.13	1.41	0.10	1.24	0.09	0.59	0.08
Eagle_Mountain_S010	1.06	0.13	0.88	0.10	0.71	0.08	0.59	0.08
Eagle_Mountain_S020	0.98	0.12	0.83	0.09	0.67	0.08	0.56	0.07
Walnut_Ck_S020	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Walnut_Ck_S010	1.09	0.13	0.89	0.10	0.72	0.09	0.60	0.08
Walnut_Ck_S030	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Eagle_Mountain_S040	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Eagle_Mountain_S030	1.07	0.13	0.88	0.10	0.71	0.09	0.59	0.08
Silver_Ck_S020	1.32	0.12	1.15	0.09	0.98	0.08	0.58	0.07
Silver_Ck_S010	1.37	0.13	1.17	0.10	1.00	0.09	0.59	0.08
Lake_Worth_S010	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Lake_Worth_S020	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
West_Fork_S230	1.11	0.13	0.91	0.10	0.74	0.09	0.60	0.08
Lk_Weatherford_S010	2.81	0.13	2.61	0.10	2.44	0.09	0.60	0.08
Lk_Weatherford_S020	1.87	0.12	1.70	0.09	1.54	0.08	0.57	0.07
Clear_Fork_S010	2.66	0.13	2.48	0.10	2.31	0.08	0.59	0.08
Clear_Fork_S020	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
Bear_Ck_S010	1.29	0.12	1.11	0.09	0.95	0.08	0.58	0.07
Bear_Ck_S020	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Benbrook_S010	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Benbrook_S020	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Benbrook_S030	0.96	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Clear_Fork_S030	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Marys_Ck_S010	1.04	0.12	0.86	0.09	0.70	0.08	0.58	0.07
Clear_Fork_S040	1.86	0.13	1.66	0.10	1.49	0.09	0.60	0.08
Clear_Fork_S050	1.13	0.13	0.92	0.10	0.74	0.09	0.61	0.08
West_Fork_S240	1.07	0.13	0.88	0.10	0.71	0.09	0.59	0.08
Marine_Ck_S020	2.43	0.13	2.24	0.10	2.08	0.09	0.59	0.08
Marine_Ck_S010	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
West_Fork_S250	1.09	0.13	0.89	0.10	0.72	0.09	0.60	0.08
West_Fork_S260	1.20	0.12	1.04	0.09	0.88	0.08	0.56	0.07
West_Fork_S270	1.62	0.13	1.44	0.10	1.27	0.08	0.58	0.08
Big_Fossil_Ck_S010	2.92	0.11	2.80	0.08	2.65	0.07	0.53	0.06
LittleFossil_Ck_S010	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
West_Fork_S280	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Village_Ck_S010	1.14	0.12	0.99	0.09	0.83	0.08	0.55	0.07
Village_Ck_S020	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Lake_Arlington_S010	0.96	0.11	0.82	0.08	0.66	0.07	0.55	0.06
Village_Ck_S030	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
West_Fork_S290	1.05	0.12	0.87	0.09	0.70	0.08	0.58	0.07
West_Fork_S300	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
West_Fork_S310	0.96	0.11	0.82	0.08	0.66	0.07	0.54	0.06
West_Fork_S320	1.07	0.13	0.88	0.10	0.72	0.09	0.59	0.08
Big_Bear_Ck_S010	1.28	0.12	1.12	0.09	0.96	0.08	0.84	0.07
Big_Bear_Ck_S020	1.06	0.13	0.88	0.10	0.71	0.08	0.58	0.08
West_Fork_S330	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
Joe_Pool_S020	1.52	0.11	1.41	0.08	1.26	0.06	1.15	0.06
Joe_Pool_S030	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Joe_Pool_S040	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
Joe_Pool_S010	0.85	0.10	0.75	0.07	0.61	0.06	0.50	0.05
Joe_Pool_S050	0.88	0.10	0.77	0.07	0.63	0.06	0.52	0.05
Mountain_Ck_S010	0.92	0.11	0.80	0.08	0.66	0.06	0.54	0.06
Mountain_Ck_S020	0.90	0.11	0.79	0.08	0.64	0.07	0.52	0.06
Mountain_Ck_S030	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
West_Fork_S340	0.98	0.12	0.83	0.09	0.67	0.08	0.56	0.07
Elm_Fork_S020	2.59	0.11	2.46	0.08	2.30	0.07	2.19	0.06
Elm_Fork_S010	4.11	0.12	3.96	0.09	3.80	0.07	3.68	0.07
Brushy_Elm_Ck_S010	2.04	0.11	1.91	0.08	1.76	0.07	1.65	0.06
Brushy_Elm_Ck_S020	1.33	0.11	1.21	0.08	1.06	0.07	0.95	0.06
Elm_Fork_S030	2.23	0.11	2.11	0.08	1.96	0.07	1.84	0.06
Elm_Fork_S040	1.51	0.11	1.39	0.08	1.24	0.07	1.13	0.06
Elm_Fork_S050	1.58	0.12	1.43	0.09	1.27	0.07	1.15	0.07
Elm_Fork_S070	1.27	0.11	1.12	0.08	0.97	0.07	0.85	0.06
Elm_Fork_S060	0.89	0.11	0.78	0.08	0.63	0.06	0.52	0.06
Spring_Ck_S010	0.92	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Spring_Ck_S020	0.92	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Ray_Roberts_S010	2.41	0.11	2.28	0.08	2.13	0.07	2.01	0.06
Timber_Ck_S010	1.07	0.13	0.88	0.10	0.72	0.09	0.59	0.08
Timber_Ck_S030	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Timber_Ck_S020	1.06	0.13	0.88	0.10	0.71	0.08	0.59	0.08

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Ray_Roberts_S030	1.02	0.12	0.86	0.09	0.70	0.08	0.58	0.07
Range_Ck_S010	0.88	0.10	0.77	0.07	0.63	0.06	0.51	0.05
Range_Ck_S020	0.86	0.10	0.76	0.07	0.62	0.06	0.51	0.05
Lake_Kiowa_S020	1.05	0.12	0.87	0.09	0.71	0.08	0.58	0.07
Lake_Kiowa_S010	1.09	0.13	0.90	0.10	0.73	0.09	0.60	0.08
Ray_Roberts_S020	0.88	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Range_Ck_S030	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06
Buck_Ck_S010	0.87	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Ray_Roberts_S050	0.88	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Ray_Roberts_S040	1.31	0.11	1.18	0.08	1.02	0.07	0.91	0.06
Ray_Roberts_S060	0.95	0.11	0.81	0.08	0.66	0.07	0.54	0.06
Timber_Ck_S040	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S080	1.00	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Clear_Ck_S010	3.29	0.13	3.10	0.10	2.94	0.08	2.81	0.08
Clear_Ck_S020	2.71	0.13	2.52	0.10	2.35	0.09	2.22	0.08
Clear_Ck_S030	3.32	0.13	3.13	0.10	2.96	0.08	2.84	0.08
Clear_Ck_S040	3.53	0.12	3.37	0.09	3.21	0.08	3.09	0.07
Clear_Ck_S050	2.65	0.12	2.50	0.09	2.34	0.07	2.22	0.07
Clear_Ck_S070	1.67	0.11	1.53	0.08	1.38	0.07	1.26	0.06
Clear_Ck_S060	1.02	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Clear_Ck_S080	2.69	0.12	2.55	0.09	2.39	0.07	2.27	0.07
Clear_Ck_S090	2.08	0.11	1.95	0.08	1.80	0.07	1.69	0.06
Clear_Ck_S110	0.91	0.11	0.79	0.08	0.64	0.07	0.53	0.06
Clear_Ck_S100	1.62	0.11	1.50	0.08	1.35	0.07	1.23	0.06
Clear_Ck_S120	1.06	0.11	0.93	0.08	0.78	0.07	0.66	0.06
Little_Elm_Ck_S010	2.68	0.10	2.57	0.07	2.43	0.06	2.32	0.05
Little_Elm_Ck_S020	1.90	0.10	1.80	0.07	1.66	0.06	1.55	0.05
Little_Elm_Ck_S030	0.85	0.10	0.76	0.07	0.61	0.06	0.51	0.05
Pecan_Ck_S010	0.99	0.12	0.84	0.09	0.68	0.08	0.56	0.07
Doe_Branch_S010	0.91	0.10	0.80	0.07	0.66	0.06	0.55	0.05
Doe_Branch_S020	0.88	0.10	0.77	0.07	0.63	0.06	0.52	0.05
Lewisville_S030	0.96	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Hickory_Ck_S020	1.31	0.11	1.19	0.08	1.04	0.07	0.93	0.06
Hickory_Ck_S010	1.31	0.11	1.19	0.08	1.04	0.07	0.93	0.06
Hickory_Ck_S030	0.99	0.11	0.88	0.08	0.73	0.07	0.61	0.06
Hickory_Ck_S040	2.64	0.11	2.50	0.08	2.35	0.07	2.23	0.06
Hickory_Ck_S050	1.56	0.13	1.38	0.10	1.21	0.08	1.09	0.08
Lewisville_S010	1.15	0.12	0.99	0.09	0.83	0.08	0.71	0.07
Lewisville_S040	0.86	0.10	0.76	0.07	0.62	0.06	0.51	0.05
Lewisville_S050	0.88	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Lewisville_S020	1.15	0.12	0.99	0.09	0.83	0.08	0.71	0.07

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Elm_Fork_S090	0.93	0.11	0.80	0.08	0.65	0.07	0.54	0.06
Elm_Fork_S110	0.90	0.11	0.78	0.08	0.63	0.07	0.52	0.06
Elm_Fork_S100	1.11	0.12	0.95	0.09	0.79	0.08	0.67	0.07
Elm_Fork_S120	1.77	0.11	1.65	0.08	1.50	0.07	1.39	0.06
Denton_Ck_S010	2.78	0.13	3.08	0.10	2.91	0.09	2.78	0.08
Denton_Ck_S020	2.76	0.13	3.07	0.10	2.90	0.08	2.77	0.08
Denton_Ck_S030	2.61	0.12	2.89	0.09	2.72	0.08	2.60	0.07
Denton_Ck_S040	1.58	0.11	1.44	0.08	1.29	0.07	1.17	0.06
Denton_Ck_S050	1.99	0.11	1.85	0.08	1.70	0.07	1.58	0.06
Denton_Ck_S060	0.93	0.11	0.80	0.08	0.65	0.07	0.53	0.06
Denton_Ck_S070	0.98	0.11	0.85	0.08	0.70	0.07	0.58	0.06
Grapevine_S010	1.55	0.12	1.40	0.09	1.24	0.08	1.11	0.07
Denton_Ck_S080	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S130	1.52	0.11	1.40	0.08	1.25	0.07	1.14	0.06
Hackberry_Ck_S010	2.08	0.10	1.98	0.07	1.84	0.06	1.73	0.05
Hackberry_Ck_S020	0.85	0.10	0.76	0.07	0.61	0.06	0.50	0.05
Hackberry_Ck_S030	0.87	0.10	0.77	0.07	0.62	0.06	0.51	0.05
Elm_Fork_S140	0.96	0.11	0.82	0.08	0.66	0.07	0.55	0.06
Elm_Fork_S150	0.97	0.11	0.82	0.08	0.67	0.07	0.55	0.06
Bachman_Branch_S010	1.01	0.12	0.85	0.09	0.69	0.08	0.57	0.07
Bachman_Branch_S020	0.97	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Elm_Fork_S160	0.98	0.12	0.83	0.09	0.67	0.07	0.55	0.07
Trinity_River_S010	1.17	0.11	1.03	0.08	0.88	0.07	0.76	0.06
Trinity_River_S020	1.26	0.09	1.51	0.09	1.35	0.08	1.23	0.07
White_Rock_Ck_S010	1.64	0.08	2.06	0.08	1.91	0.07	1.79	0.06
White_Rock_Ck_S020	0.76	0.09	0.85	0.09	0.69	0.08	0.57	0.07
White_Rock_Ck_S030	0.75	0.09	0.84	0.09	0.68	0.08	0.56	0.07
White_Rock_Ck_S040	0.74	0.09	0.83	0.09	0.68	0.08	0.56	0.07
Trinity_River_S030	0.79	0.09	0.87	0.09	0.70	0.08	0.58	0.07
Fivemile_Ck_S010	1.02	0.09	1.18	0.09	1.02	0.08	0.89	0.07
Trinity_River_S040	0.74	0.09	0.84	0.09	0.68	0.08	0.56	0.07
Trinity_River_S050	0.73	0.08	0.82	0.08	0.67	0.07	0.55	0.06
Tenmile_Ck_S010	0.82	0.09	0.94	0.09	0.78	0.08	0.66	0.07
Tenmile_Ck_S020	0.68	0.08	0.79	0.08	0.64	0.07	0.53	0.06
Trinity_River_S060	0.90	0.09	1.05	0.09	0.89	0.08	0.77	0.07
Indian_Ck_S010	1.88	0.08	2.41	0.07	2.26	0.06	2.15	0.05
Indian_Ck_S030	1.20	0.08	1.47	0.08	1.31	0.07	1.2	0.06
Indian_Ck_S020	0.65	0.08	0.76	0.07	0.62	0.06	0.51	0.05
Indian_Ck_S040	1.54	0.08	1.94	0.07	1.8	0.06	1.69	0.05
Sister_Grove_S010	2.06	0.08	2.61	0.08	2.46	0.07	2.34	0.06
Sister_Grove_S020	1.49	0.08	1.86	0.08	1.71	0.07	1.6	0.06

Subbasin Name	50-yr	50-yr	100-yr	100-yr	250-yr	250-yr	500-yr	500-yr
	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
East_Fork_S020	1.91	0.08	2.42	0.08	2.27	0.07	2.15	0.06
East_Fork_S010	2.66	0.08	3.42	0.08	3.26	0.07	3.15	0.06
East_Fork_S030	1.04	0.08	1.26	0.08	1.11	0.07	0.99	0.06
East_Fork_S040	0.69	0.08	0.8	0.08	0.65	0.07	0.53	0.06
Wilson_Ck_S010	1.74	0.08	2.19	0.08	2.04	0.07	1.92	0.06
Lavon_S010	0.84	0.08	1.02	0.07	0.88	0.06	0.77	0.05
Lavon_S020	0.65	0.08	0.77	0.07	0.62	0.06	0.51	0.05
Rowlett_Ck_S010	0.79	0.08	0.93	0.08	0.78	0.07	0.66	0.06
Ray_Hubbard_S010	1.61	0.08	2.04	0.07	1.9	0.06	1.79	0.05
Ray_Hubbard_S020	0.66	0.08	0.77	0.07	0.62	0.06	0.51	0.05
East_Fork_S050	0.68	0.08	0.8	0.08	0.65	0.06	0.54	0.06
East_Fork_S070	0.65	0.08	0.76	0.07	0.62	0.06	0.51	0.05
East_Fork_S060	2.39	0.08	3.09	0.07	2.94	0.06	2.83	0.05
East_Fork_S080	0.65	0.08	0.76	0.07	0.62	0.06	0.51	0.05
East_Fork_S090	0.68	0.08	0.82	0.07	0.67	0.06	0.56	0.05
East_Fork_S110	0.80	0.08	0.96	0.07	0.81	0.06	0.7	0.05
East_Fork_S100	2.61	0.08	3.39	0.07	3.24	0.06	3.13	0.05
Trinity_River_S070	0.77	0.08	0.91	0.08	0.76	0.07	0.65	0.06
East_Fork_S120	1.55	0.08	1.96	0.07	1.82	0.06	1.71	0.05
Kings_Ck_S020	1.22	0.08	1.53	0.07	1.38	0.06	1.28	0.05
Kings_Ck_S010	1.54	0.08	1.94	0.08	1.79	0.07	1.68	0.06
Kings_Ck_S030	2.03	0.08	2.6	0.07	2.46	0.06	2.35	0.05
Cedar_Ck_S040	1.49	0.09	1.82	0.09	1.66	0.08	1.53	0.07
Cedar_Ck_S010	1.60	0.08	1.99	0.08	1.84	0.07	1.72	0.06
New_Terrell_City_Lake_S010	0.68	0.08	0.79	0.08	0.64	0.07	0.53	0.06
Cedar_Ck_S020	0.86	0.08	1.01	0.08	0.86	0.07	0.74	0.06
Cedar_Ck_S030	1.90	0.09	2.37	0.09	2.21	0.08	2.09	0.07
Trinity_River_S080	1.16	0.08	1.42	0.08	1.27	0.07	1.16	0.06
Trinity_River_S090	1.15	0.08	1.38	0.08	1.23	0.07	1.11	0.06
Chambers_Ck_S010	1.58	0.08	1.97	0.08	1.82	0.07	1.71	0.06
Chambers_Ck_S020	2.09	0.08	2.67	0.08	2.51	0.07	2.41	0.06
Chambers_Ck_S040	2.03	0.08	2.59	0.08	2.43	0.07	2.32	0.06
Chambers_Ck_S030	1.90	0.08	2.39	0.08	2.23	0.08	2.12	0.06
Waxahachie_Ck_S010	2.67	0.09	3.39	0.09	3.22	0.09	3.1	0.07
Waxahachie_Ck_S020	1.48	0.09	1.8	0.09	1.64	0.08	1.52	0.07
Waxahachie_Ck_S030	0.90	0.08	1.09	0.08	0.94	0.07	0.83	0.06
Mustang_Ck_S010	0.90	0.08	1.11	0.07	0.96	0.06	0.86	0.05
Bardwell_S010	1.07	0.08	1.32	0.07	1.17	0.06	1.07	0.05
Chambers_Ck_S050	1.97	0.08	2.53	0.07	2.38	0.06	2.27	0.05
Chambers_Ck_S060	1.41	0.08	1.76	0.08	1.61	0.07	1.5	0.06

Subbasin Name	50-yr Initial (in)	50-yr Constant (in/hr)	100-yr Initial (in)	100-yr Constant (in/hr)	250-yr Initial (in)	250-yr Constant (in/hr)	500-yr Initial (in)	500-yr Constant (in/hr)
Chambers_Ck_S070	1.95	0.08	2.5	0.07	2.35	0.06	2.25	0.05
Chambers_Ck_S080	1.31	0.08	1.64	0.08	1.49	0.07	1.38	0.06
Post_Oak_Ck_S010	1.46	0.08	1.83	0.08	1.67	0.07	1.57	0.06
Lake_Halbert_S010	1.22	0.08	1.52	0.07	1.37	0.06	1.27	0.05
Navarro_Mills_S020	1.23	0.08	1.53	0.07	1.38	0.07	1.27	0.05
Navarro_Mills_S030	2.60	0.08	3.33	0.08	3.16	0.07	3.06	0.06
Navarro_Mills_S010	2.06	0.09	2.6	0.09	2.44	0.08	2.33	0.07
Navarro_Mills_S040	0.67	0.08	0.78	0.08	0.62	0.07	0.52	0.06
Richland_Ck_S010	1.58	0.08	1.99	0.08	1.84	0.07	1.73	0.06
Richland_Ck_S020	2.00	0.08	2.56	0.07	2.41	0.07	2.3	0.05
Richland-Chambers_S010	0.67	0.08	0.78	0.08	0.63	0.07	0.52	0.06
Richland-Chambers_S020	0.66	0.08	0.77	0.07	0.62	0.07	0.51	0.05
Tehuacana_Ck_S020	2.48	0.09	3.13	0.09	2.97	0.08	2.85	0.07
Tehuacana_Ck_S010	1.55	0.08	1.94	0.08	1.79	0.07	1.67	0.06
Trinity_River_S100	0.73	0.09	0.83	0.09	0.67	0.07	0.55	0.07
Fairfield_Lake_S010	3.59	0.09	4.62	0.09	4.45	0.08	4.33	0.07
Trinity_River_S110	0.96	0.11	1.05	0.11	0.87	0.1	0.74	0.09
Big_Brown_Ck_S010	3.44	0.10	4.37	0.1	4.19	0.09	4.06	0.08
Trinity_River_S120	1.51	0.10	1.81	0.1	1.64	0.09	1.51	0.08
Trinity_River_S130	0.95	0.10	1.08	0.1	0.91	0.09	0.78	0.08
Upper_Keechi_Ck_S030	1.03	0.11	1.14	0.11	0.97	0.09	0.83	0.09
Upper_Keechi_Ck_S010	0.95	0.10	1.07	0.1	0.9	0.09	0.77	0.08
Upper_Keechi_Ck_S020	1.36	0.11	1.56	0.11	1.38	0.1	1.24	0.09
Upper_Keechi_Ck_S040	0.83	0.10	0.9	0.1	0.73	0.09	0.6	0.08
Trinity_River_S140	0.65	0.08	0.77	0.07	0.62	0.06	0.51	0.05
Little_Elkhart_S010	0.86	0.11	0.93	0.11	0.75	0.09	0.62	0.09
Houston_County_Lake_S010	3.64	0.11	4.62	0.11	4.44	0.1	4.3	0.09
Trinity_River_S150	0.80	0.09	0.9	0.09	0.73	0.08	0.61	0.07
Trinity_River_S160	0.78	0.09	0.86	0.09	0.7	0.08	0.58	0.07
Trinity_River_S170	0.89	0.11	0.97	0.11	0.79	0.1	0.66	0.09
Trinity_River_S180	0.78	0.09	0.87	0.09	0.7	0.08	0.58	0.07
Bedias_Ck_S010	2.30	0.09	2.91	0.09	2.75	0.08	2.63	0.07
Bedias_Ck_S020	0.77	0.09	0.86	0.09	0.69	0.08	0.57	0.07
Trinity_River_S190	0.77	0.09	0.87	0.09	0.71	0.08	0.59	0.07
Livingston_S010	0.79	0.09	0.88	0.09	0.72	0.08	0.59	0.07
Livingston_S030	0.75	0.09	0.84	0.09	0.68	0.08	0.56	0.07
Livingston_S020	0.74	0.09	0.83	0.09	0.67	0.08	0.55	0.07
Trinity_River_S200	0.76	0.09	0.85	0.09	0.69	0.08	0.57	0.07
Long_King_Ck_S010	0.77	0.09	0.86	0.09	0.7	0.08	0.57	0.07
Long_King_Ck_S020	0.99	0.09	1.15	0.09	0.99	0.08	0.86	0.07
Trinity_River_S210	0.96	0.10	1.09	0.1	0.92	0.09	0.79	0.08

Subbasin Name	50-yr	50-yr	100-yr	100-yr	250-yr	250-yr	500-yr	500-yr
	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
Menard_Ck_S010	1.45	0.10	1.74	0.1	1.57	0.09	1.44	0.08
Trinity_River_S220	0.79	0.09	0.87	0.09	0.71	0.08	0.58	0.07
Trinity_River_S230	0.70	0.08	0.8	0.08	0.65	0.07	0.53	0.06
Trinity_River_S240	0.71	0.08	0.81	0.08	0.66	0.07	0.54	0.06
Trinity_River_S250	2.03	0.08	2.59	0.08	2.44	0.06	2.33	0.06

1.6 ELLIPTICAL FREQUENCY STORM RESULTS FROM HMS

The frequency peak flow values were then calculated in HEC-HMS by applying the appropriate, optimized elliptical frequency storms for each junction of interest in the final HEC-HMS basin model. These results will later be compared to the uniform rain results from HEC-HMS along with other methods from this study.

In some cases, one may observe that the simulated peak discharge decreases in the downstream direction. It is not an uncommon phenomenon to see decreasing frequency peak discharges for some river reaches as flood waters spread out into the floodplain and the hydrograph becomes dampened as it moves downstream. This can be due to a combination of peak attenuation due to river routing as well as the difference in timing between the peak of the main stem river versus the runoff from the local tributaries and subbasins.

1.6.1 Tabular Results

The final HEC-HMS frequency flows for the locations of interest throughout the watershed model using the NOAA Atlas 14 rainfall depths can be seen below in Table 5.

Table 5: Summary of Discharges (cfs) from the HEC-HMS Elliptical Frequency Storm Method

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River above Turkey Creek	West_Fork_abv_TurkeyCk	403.1	2,000	7,200	13,300	22,500	32,700	47,800	62,500	83,300
West Fork Trinity River below Turkey Creek	West_Fork_J050	439.2	2,100	7,500	13,800	23,300	34,100	50,000	65,400	88,000
West Fork Trinity River above Big Cleveland Creek	WestFork_abv_Big_Cleveland	549.4	1,900	6,200	11,100	18,500	27,200	41,300	55,800	76,800
West Fork Trinity River below Big Cleveland Creek	West_Fork_J070	648.1	2,800	6,200	11,100	18,600	27,500	42,800	59,200	83,100
West Fork Trinity River near Jacksboro, TX USGS gage	West_Fork_J080	668.7	1,900	5,900	10,600	17,800	26,300	40,700	56,200	79,500
West Fork Trinity River below Lost Creek	West Fork + Lost Ck	711.2	2,000	6,100	11,000	18,600	27,300	41,800	57,500	81,700
West Fork Trinity River above Carroll Creek	West_Fork_abv_CarrollCk	750.8	1,900	5,900	10,700	18,300	26,800	41,000	56,500	80,100
West Fork Trinity River below Carroll Creek	West_Fork_J090	792.1	2,100	9,500	20,500	29,000	36,600	45,800	54,500	69,700
West Fork Trinity River above Beans Creek	WestFork_abv_Beans_Ck	827.7	1,900	10,000	22,100	31,700	40,400	51,100	61,100	78,000
West Fork Trinity River below Beans Creek	West Fork + Beans Ck	874.6	1,700	11,600	26,900	38,900	49,700	62,900	74,300	93,300
Bridgeport Reservoir Inflow	Bridgeport Inflow	1095.7	3,700	24,500	58,400	83,000	105,500	132,300	157,200	192,200
Bridgeport Reservoir Outflow	Bridgeport Reservoir	1095.7	2,600	5,400	11,600	12,400	13,200	21,100	29,300	39,000
West Fork Trinity River above Dry Creek	West_Fork_abv_DryCk	1136.2	2,200	5,500	11,500	12,400	13,300	21,100	29,500	39,200
West Fork Trinity River below Dry Creek	West_Fork_J100	1162.9	1,800	5,900	12,600	17,500	21,800	26,700	31,400	37,800
West Fork Trinity River above Big Sandy Creek	WestFork_abv_Big_Sandy_Ck	1169.5	1,800	5,300	11,800	17,200	22,300	27,600	32,500	39,200
Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114 bridge	Big_Sandy_Ck_J030	334.3	3,600	7,900	12,300	18,800	26,200	36,600	47,000	64,600
Big Sandy Creek above the West Fork Trinity River	Big_Sandy_Ck_abv_WestFork	353.9	3,500	7,900	11,900	18,900	26,400	36,700	47,300	64,500

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River below Big Sandy Creek	West Fork + Big Sandy Ck	1523.5	4,400	11,200	19,700	28,200	36,600	49,000	61,100	78,400
West Fork Trinity River at FM 3259 near Paradise, TX	West_Fork_J110	1551.8	4,200	10,500	17,500	26,600	36,400	49,300	61,800	80,000
West Fork Trinity River above Salt Creek	WestFork_abv_Salt_Ck	1573.7	3,600	9,700	15,300	22,800	31,700	44,500	56,600	74,800
West Fork Trinity River below Salt Creek	West Fork + Salt Ck	1680.4	3,300	9,400	17,000	27,000	38,600	55,600	71,700	95,600
West Fork Trinity River near Boyd, TX - USGS Gage at FM 730 bridge	West_Fork_J120	1710.8	3,000	9,300	16,800	26,700	38,200	54,700	71,500	96,400
West Fork Trinity River about 0.8 miles upstream of FM 4757 in Wise County	West_Fork_J130	1751.9	3,200	9,800	16,700	26,300	37,400	53,300	69,000	92,900
Eagle Mountain Reservoir Inflow	Eagle Mountain Inflow	1956.6	9,300	28,800	43,300	66,800	83,600	102,700	120,300	143,600
Eagle Mountain Reservoir Outflow	Eagle Mountain Reservoir	1956.6	3,800	7,300	13,800	17,200	21,500	27,100	33,000	42,500
Lake Worth Inflow	Lake Worth Inflow	2050.8	4,800	11,800	16,500	25,400	31,200	37,800	43,500	51,500
Lake Worth Outflow	Lake Worth	2050.8	3,000	7,300	13,900	17,400	21,600	27,400	33,400	42,800
West Fork Trinity River above the Clear Fork	WestFork_abv_Clear_Fork	2078.7	3,200	8,200	11,700	18,200	21,300	25,000	29,700	36,100
Benbrook Lake Inflow	Benbrook Inflow	429.2	24,900	47,500	61,800	79,500	94,800	111,900	128,800	154,600
Clear Fork above Marys Creek	Clear_Fork_abv_Marys_Ck	9.4	3,200	4,900	5,900	7,300	8,500	9,700	10,900	12,800
Clear Fork below Marys Creek	Clear Fork + Marys Creek	63.6	5,200	14,800	25,800	39,500	47,400	56,700	68,300	79,800
Clear Fork Trinity River at Fort Worth USGS gage	Clear_Fork_J020	89.0	7,600	18,200	29,100	46,900	55,100	64,000	73,000	82,300
Clear Fork Trinity River above the West Fork	Clear_Fork_abv_WestFork	93.9	8,100	19,200	30,600	45,300	53,300	62,100	71,000	80,900
West Fork Trinity River below the Clear Fork (West Fork at Fort Worth USGS gage)	West Fork + Clear Fork	2172.5	10,700	23,600	36,600	54,300	64,300	75,200	86,400	100,000
West Fork Trinity River above Marine Creek	WestFork_abv_MarineCk	2173.7	10,700	24,000	36,900	53,500	63,400	73,700	86,500	100,200

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
West Fork Trinity River below Marine Creek	West Fork + Marine Ck	2195.4	11,000	24,700	37,900	54,900	65,200	76,000	89,000	103,300
West Fork Trinity River above Sycamore Creek	West_Fork_J140	2204.6	11,300	24,000	37,800	53,900	62,600	73,700	88,000	104,400
West Fork Trinity River below Sycamore Creek (West Fork Trinity River at Beach Street USGS Gage)	West_Fork_J150	2243.8	11,500	23,700	36,900	56,100	66,700	77,200	90,400	108,400
West Fork above Big Fossil	WestFork_abv_BigFossil	2256.8	10,200	21,400	34,600	53,200	64,400	76,000	89,000	107,100
West Fork Trinity River and Big Fossil Creek Confluence	West_Fork_J160	2333.4	12,300	23,700	38,000	60,600	76,400	92,700	108,500	130,200
West Fork Trinity River below Village Creek	West Fork + Village Ck	2554.0	11,700	21,100	36,400	55,000	70,200	89,200	108,600	138,800
West Fork Trinity River below Johnson Creek	West_Fork_J170	2618.6	8,600	17,200	27,000	44,000	58,300	78,100	96,800	129,200
West Fork Trinity River at Grand Prairie USGS gage	West_Fork_J180	2623.4	8,500	17,200	27,100	44,200	58,400	78,000	96,500	128,100
West Fork Trinity River above Big Bear Creek	West_Fork_abv_Big_Bear_Ck	2625.5	8,400	16,500	26,400	42,600	56,700	73,200	93,000	124,500
West Fork Trinity River below Big Bear Creek	West Fork + Bear Ck	2718.8	10,000	17,600	29,700	50,000	66,800	85,300	107,200	143,000
West Fork Trinity River above Mountain Creek	West_Fork_abv_Mountain_Ck	2727.4	10,000	17,500	29,100	46,200	62,600	81,600	101,600	134,400
West Fork Trinity River below Mountain Creek	West Fork + Mountain Ck	2807.6	14,100	22,900	30,300	47,300	63,900	82,900	103,100	137,000
West Fork Trinity River above the Elm Fork Trinity River	West_Fork_abv_Elm_Fork	2820.9	13,100	21,700	29,900	46,800	63,600	83,000	103,100	136,100
Ray Roberts Lake Inflow	Ray Roberts Inflow	692.6	59,500	95,900	120,600	153,100	182,400	216,100	249,700	296,000
Elm Fork Trinity River above Clear Creek	Elm_Fork_abv_Clear_Ck	36.9	2,500	5,400	8,300	11,000	13,200	15,900	18,300	21,700
Elm Fork Trinity River below Clear Creek	Elm Fork + Clear Ck	388.1	8,500	14,000	20,000	28,300	41,700	59,900	77,500	100,300
Lewisville Lake Inflow	Lewisville Inflow	968.2	42,500	69,000	88,200	112,500	135,100	159,700	182,700	215,000

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Elm Fork Trinity River above Indian Creek	Elm_Fork_abv_Indian_Ck	21.4	1,600	3,200	4,400	6,500	7,700	9,100	10,400	12,200
Elm Fort Trinity River below Indian Creek	Elm Fork + Indian Ck	37.5	3,600	6,800	9,100	13,200	15,500	18,100	20,600	24,200
Elm Fork Trinity River below Timber Creek	Elm Fork + Timber Ck	61.5	4,200	7,700	9,800	14,000	16,600	20,200	23,600	28,200
Elm Fork Trinity River above Denton Creek	Elm_Fork_abv_Denton_Ck	79.9	5,800	10,400	13,300	18,700	22,200	26,700	31,000	36,900
Denton Creek nr Justin, TX USGS gage	Denton_Ck_J030	400.0	4,500	11,300	17,400	26,000	35,700	46,800	62,700	82,600
Denton Creek below Oliver Creek	Denton_Ck_J040	475.3	9,400	18,900	26,500	36,000	45,200	55,300	64,500	77,600
Denton Creek above Elizabeth Creek	Denton_Ck_abv_Elizabeth_Ck	506.1	9,800	18,600	25,800	35,600	45,800	57,100	69,500	85,200
Denton Creek below Elizaveth Creek	Denton_Ck_J050	599.7	15,800	29,300	39,500	53,400	68,400	85,300	102,000	123,900
Grapevine Lake Inflow	Grapevine_Inflow	694.4	16,000	28,200	38,600	52,200	66,900	84,800	101,600	124,500
Denton Creek above the Elm Fork Trinity River	Denton_Ck_abv_Elm_Fork	24.3	2,300	4,300	5,800	8,800	10,400	12,200	14,000	16,300
Elm Fork Trinity River near Carrollton USGS gage	Elm Fork + Denton Ck	104.2	7,500	13,400	17,700	25,600	30,100	35,600	41,500	49,300
Elm Fork Trinity River at Interstate 635	Elm_Fork_J060	143.4	12,300	17,500	21,400	29,300	34,900	41,300	47,400	56,400
Elm Fork Trinity River above Hackleberry Creek	Elm_Fork_abv_Hackberry_Ck	143.4	8,900	14,700	19,200	28,000	33,700	40,200	46,600	54,800
Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage	Elm_Fork_J070	180.4	10,800	15,400	20,000	28,800	35,000	42,400	49,400	59,100
Elm Fork Trinity River above Bachman Branch	Elm_Fork_abv_Bachman_Branch	202.6	10,000	14,400	18,700	26,100	32,000	39,500	45,900	54,700
Elm Fork Trinity River below Bachman Branch (at Frasier Dam USGS gage)	Elm Fork + Bachman Branch	216.7	10,700	15,000	19,100	26,600	32,700	40,400	46,900	55,900
Elm Fork Trinity River above the West Fork Trinity River	Elm_Fork_abv_West_Fork	222.8	8,800	14,600	19,000	25,900	32,000	40,000	46,400	55,700

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River below the West Fork and Elm Fork confluence	West Fork + Elm Fork	3043.7	19,300	31,100	41,900	67,100	89,600	113,800	140,200	182,800
Trinity River at Dallas, TX USGS gage	Trinity_River_J010	3056.1	19,000	31,000	42,100	66,200	88,500	113,100	138,900	181,500
Trinity River at the Corinth Street bridge in Dallas, TX	Trinity_River_J020	3099.0	19,000	31,000	42,200	66,300	88,500	113,500	139,100	182,300
Trinity River below White Rock Creek	Trinity River + White Rock	3233.9	21,800	35,500	48,000	68,200	90,000	116,800	143,700	185,500
Trinity River below Honey Springs Branch (Trinity River below Dallas, TX USGS gage)	Trinity_Rv + Honey_Springs	3256.5	21,900	35,700	48,300	68,400	90,000	116,700	143,800	185,700
Trinity River below Five Mile Ceek	Trinity_River + Five_Mile_Ck	3328.8	21,100	34,600	47,300	67,600	88,000	114,100	140,200	180,300
Trinity River above Ten Mile Creek	Trinity_River_abv_Tenmile_Ck	3367.7	20,100	29,900	40,700	59,400	78,800	104,000	125,700	161,300
Trinity River below Ten Mile Creek	Trinity River + Tenmile Ck	3469.8	20,200	30,800	40,600	59,300	78,500	103,700	124,800	160,400
Trinity River above the East Fork Trinity River	Trinity_River_abv_East_Fork	3529.4	19,500	28,400	37,700	56,700	74,900	99,500	122,800	156,000
Lavon Lake Inflow	Lavon Inflow	768.2	24,100	42,300	53,600	69,400	79,900	90,700	106,400	128,700
Ray Hubbard Lake Inflow	Ray Hubbard Inflow	301.8	31,100	50,600	62,300	78,800	90,500	103,200	119,000	141,400
East Fork Trinity River near Forney USGS gage	East_Fork_nr_Forney	349.9	14,000	25,700	35,100	47,200	55,900	65,900	89,500	113,800
East Fork Trinity River above Buffalo Creek	East_Fork_abv_Buffalo_Ck	359.5	12,300	23,200	29,700	44,300	53,700	63,800	85,100	111,700
East Fork Trinity River below Buffalo Creek	East_Fork + Buffalo_Ck	393.9	13,000	24,500	31,700	47,000	56,900	67,900	90,600	119,000
East Fork Trinity River above South Mesquite Creek	East_Fork_abv_S_Mesquite_Ck	416.9	9,500	19,700	28,000	39,600	49,100	59,300	76,000	105,300
East Fork Trinity River below South Mesquite Creek	East_Fork+South_Mesquite_Ck	446.4	10,000	20,500	29,000	41,100	51,000	61,700	79,400	110,600
East Fork Trinity River above Mustang Creek	East_Fork_abv_Mustang_Ck	465.5	9,400	19,000	25,900	35,100	43,700	52,900	66,700	88,800
East Fork Trinity River near Crandall, TX USGS gage	East_Fork_nr_Crandall	484.8	9,600	19,400	26,500	35,800	44,600	53,900	68,100	90,700

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
East Fork Trinity River above the Trinity River	East_Fork_abv_Trinity_River	484.8	9,200	17,100	22,800	30,500	37,200	44,700	55,500	70,600
Trinity River below the East Fork Trinity River	Trinity River + East Fork	4014.2	27,000	41,600	54,200	80,400	104,100	134,200	166,200	210,600
Trinity River below Red Oak Creek	Trinity_River + Red_Oak_Ck	4245.5	27,100	43,400	55,300	81,000	105,000	135,200	167,700	212,700
Trinity River near Rosser, TX USGS gage	Trinity_River_nr_Rosser	4349.6	25,600	38,900	51,000	74,000	98,700	131,500	164,600	207,300
Trinity River above Cedar Creek	Trinity_River_abv_Cedar_Ck	4349.6	24,700	38,000	50,000	68,300	76,700	105,600	150,100	196,600
Cedar Creek Reservoir Inflow	Cedar Creek Inflow	1010.8	45,200	82,100	106,000	135,000	158,200	182,100	219,900	274,400
Cedar Creek Reservoir Outflow	Cedar Creek Reservoir	1010.8	32,400	55,600	70,000	88,300	105,900	123,700	129,800	140,500
Trinity River below Cedar Creek	Trinity River + Cedar Creek	5360.4	27,600	41,300	53,400	71,600	79,200	112,300	162,400	220,600
Trinity River at Trinidad, TX USGS gage	Trinity_River_at_Trinidad	5759.3	33,300	51,200	68,000	89,100	106,800	125,100	155,800	188,200
Trinity River above Richland Creek	Trinity_Rv_abv_Richland_Ck	6042.8	31,300	48,100	63,500	83,100	99,900	117,300	149,800	187,500
Bardwell Lake Inflow	Bardwell Inflow	174.4	10,400	18,700	23,400	30,700	35,700	41,300	48,500	59,200
Chambers Creek below Mill Creek	Chambers_Ck_J020	511.9	13,600	29,100	40,900	62,200	75,900	88,300	114,200	148,800
Chambers Creek below Waxahachie Creek	Chambers Ck + Waxahachie Ck	621.0	12,800	28,300	39,500	60,200	74,300	86,700	113,500	152,700
Chambers Creek near Rice, TX USGS gage	Chambers_Ck_J030	650.1	12,500	28,000	39,000	59,200	73,300	88,100	110,500	148,800
Richland Creek below Pin Oak Creek	Richland_Ck_J010	395.0	19,000	37,800	50,100	64,800	76,300	87,600	106,900	135,300
Richland Chambers Reservoir Inflow	Richland-Chambers Inflow	1465.5	33,300	64,300	85,700	112,000	133,000	154,500	188,200	237,200
Richland Chambers Reservoir Outflow	Richland-Chambers Reservoir	1465.5	9,500	26,700	42,700	65,800	86,000	107,400	143,200	193,900
Trinity River below Richland Creek	Trinity River + Richland Ck	7508.3	36,200	64,300	88,100	122,800	150,100	177,200	234,800	304,000
Trinity River above Tehuacana Creek	Trinity_Rv_abv_Tehuacana_Ck	7508.3	35,300	63,300	87,600	122,400	149,500	178,100	234,200	306,200

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River below Tehuacana Creek	Trinity River + Tehuacana Ck	7894.7	38,700	59,000	81,700	124,000	157,800	192,800	259,200	349,800
Trinity River above Big Brown Creek	Trinity_Rv_abv_Big_Brown_Ck	7965.3	37,900	58,600	80,900	120,000	148,400	189,000	254,100	345,000
Trinity River below Big Brown Creek	Trinity River + Big Brown Ck	8001.5	38,200	59,100	81,600	121,000	154,000	190,100	255,900	348,700
Trinity River above Catfish Creek	Trinity_River_abv_Catfish_Ck	8306.6	39,500	60,800	85,300	122,200	153,300	190,100	264,300	367,200
Trinity River below Catfish Creek	Trinity_River + Catfish_Ck	8353.0	39,800	61,400	86,000	123,200	154,200	191,500	266,400	370,700
Trinity River near Oakwood, TX USGS gage	Trinity_River_nr_Oakwood	8593.0	36,300	59,500	81,100	107,400	129,000	152,400	223,500	308,900
Trinity River above Upper Keechi Creek	TrinityRv_abv_UpperKeechi_Ck	8849.7	33,000	54,300	71,800	99,000	121,800	139,500	160,100	235,500
Trinity River below Upper Keechi Creek	Trinity River + Upper Keechi	9358.9	33,700	54,900	72,200	99,700	122,900	140,900	163,700	243,300
Trinity River above Big Elkhart Creek	Trinity_Rv_abv_Big_Elkhart	9359.5	33,600	54,300	72,000	99,500	122,800	140,700	163,600	241,800
Trinity River below Big Elkhart Creek	Trinity River+ Big Elkhart	9502.5	33,100	53,300	70,100	98,000	121,600	139,300	160,600	233,700
Trinity River near Crockett, TX USGS gage	Trinity_River_nr_Crockett	9615.0	33,300	53,900	71,500	98,700	121,900	139,800	160,600	235,000
Trinity River above Lower Keechi Creek	Trinity_Rv_abv_LowerKeech_Ck	9791.7	32,900	48,100	56,600	72,500	96,400	114,900	145,300	181,300
Trinity River below Lower Keechi Creek	Trinity_River+LowerKeechi_Ck	9979.3	32,700	48,200	56,600	72,600	96,700	115,200	145,500	181,500
Trinity River above Bedias Creek	Trinity_River_abv_Bedias_Ck	10374.286	32,600	47,200	54,300	68,600	92,800	110,200	140,400	175,800
Bedias Creek above the Trinity River	Bedias_Ck_abv_Trinity_River	604.3	13,100	32,500	46,800	64,300	76,800	90,800	114,400	147,300
Trinity River below Bedias Creek	Trinity River + Bedias Ck	10978.5	44,300	69,800	96,100	128,000	150,400	172,300	205,200	251,400
Trinity River at Riverside, TX USGS gage	Trinity River_at_Riverside	11306.7	41,000	61,500	71,800	109,300	133,800	158,700	194,300	249,200
Lake Livingston Inflow	Lake Livingston Inflow	12301.1	77,000	111,100	144,000	193,600	233,400	278,700	333,900	413,400
Lake Livingston Outflow	Lake Livingston	12301.1	38,900	65,700	81,100	100,400	120,700	158,200	210,400	281,800

Location Description	HEC-HMS Element Name	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%
		sq mi	2-YR	5-YR	10-YR	25-YR	50-YR	100-YR	200-YR	500-YR
Trinity River above Long King Creek	Trinity_Rv_abv_Long_King_Ck	12340.5	39,600	67,000	82,800	102,100	123,700	159,400	208,300	277,000
Trinity River at Goodrich, TX USGS gage	Trinity River + Long King Ck	12566.9	40,000	69,000	84,400	104,700	126,400	162,200	211,200	282,700
Trinity River above Menard Creek	Trinity_River_abv_Menard_Ck	12628.0	39,400	59,900	73,600	89,400	101,100	118,200	148,200	207,300
Trinity River below Menard Creek	Trinity River + Menard Ck	12776.2	40,700	64,000	77,400	94,100	107,700	127,500	159,500	220,900
Trinity River at Romayor, TX USGS gage	Trinity_River_at_Romayor	12873.7	40,700	62,900	76,500	93,100	107,000	126,200	157,100	218,100
Trinity River near Moss Hill, TX	Trinity_River_nr_MossHill_TX	12945.7	39,600	59,200	73,800	91,300	104,600	122,000	152,200	208,800
Trinity River at Liberty, TX USGS gage	Trinity_River_at_Liberty	13176.5	34,800	54,500	70,800	90,200	103,700	120,900	151,100	205,300
Trinity River at Wallisville, TX USGS gage	Trinity Bay	13618.4	32,300	45,700	62,400	84,000	98,700	115,300	141,800	188,300

*Drainage area is uncontrolled area downstream of USACE dams

1.6.2 **Map Results**

The following 'a' figures represent the 100yr48hr heatmap results for the optimization of each junction of interest in the Elliptical Storm HMS model. For each junction of interest, the optimization script ran 300+ times recording the junction flow rate for various storm centerings and orientations. Each of the recorded storm centerings (x,y) and resulting flow rates (z) at the junction of interest were recorded and used to create a rasterized heat map. The red shading represents storm locations that led to relatively high flow rates at the junction whereas the green shading represents storm locations that led to relatively low flow rates.

The following 'b' figures show the final, total storm depths and optimized storm configurations for each junction. Note that the peak flow values recorded in the 'a' figures may differ slightly from the final peak flow values recorded in the 'b' figures and in Table 5 above. This is due to a couple of small tweaks to the HMS model parameters that were done after the 100yr48hr storm centerings were determined.

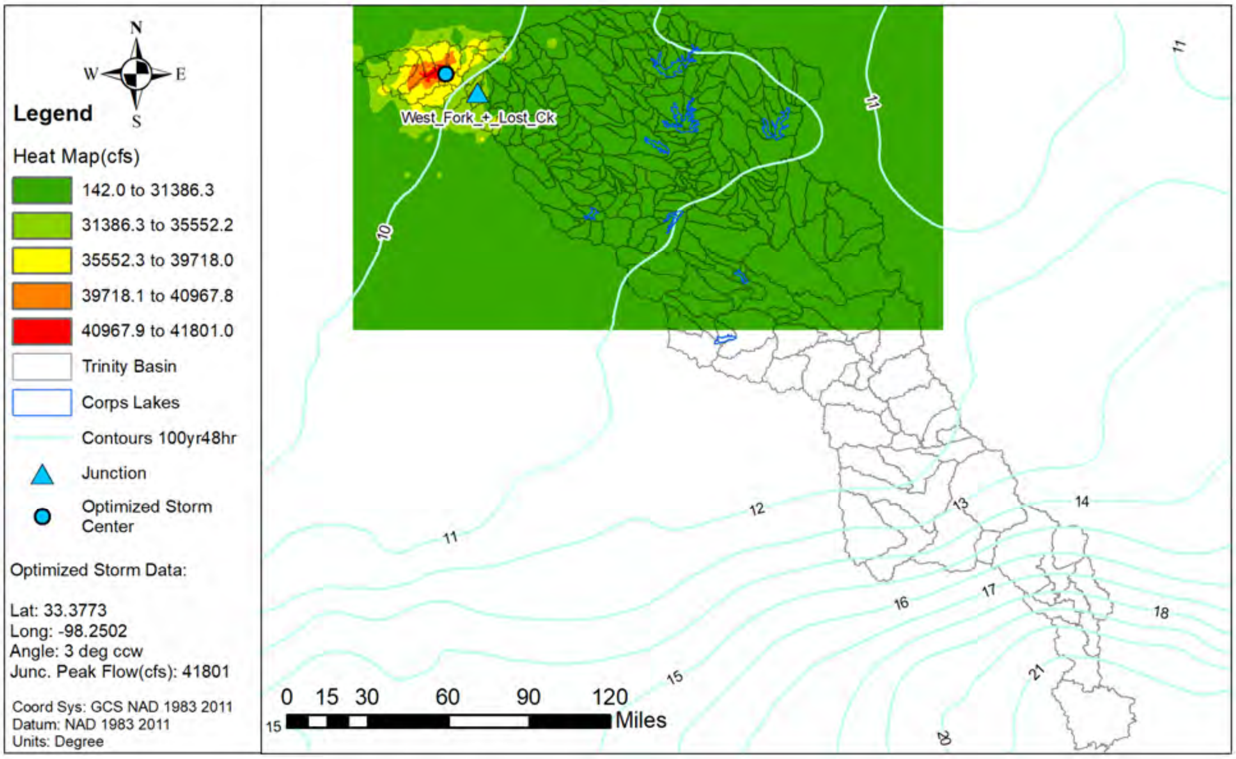


Figure 11a: Elliptical Storm Heat Map for the West Fork Trinity River below Lost Creek

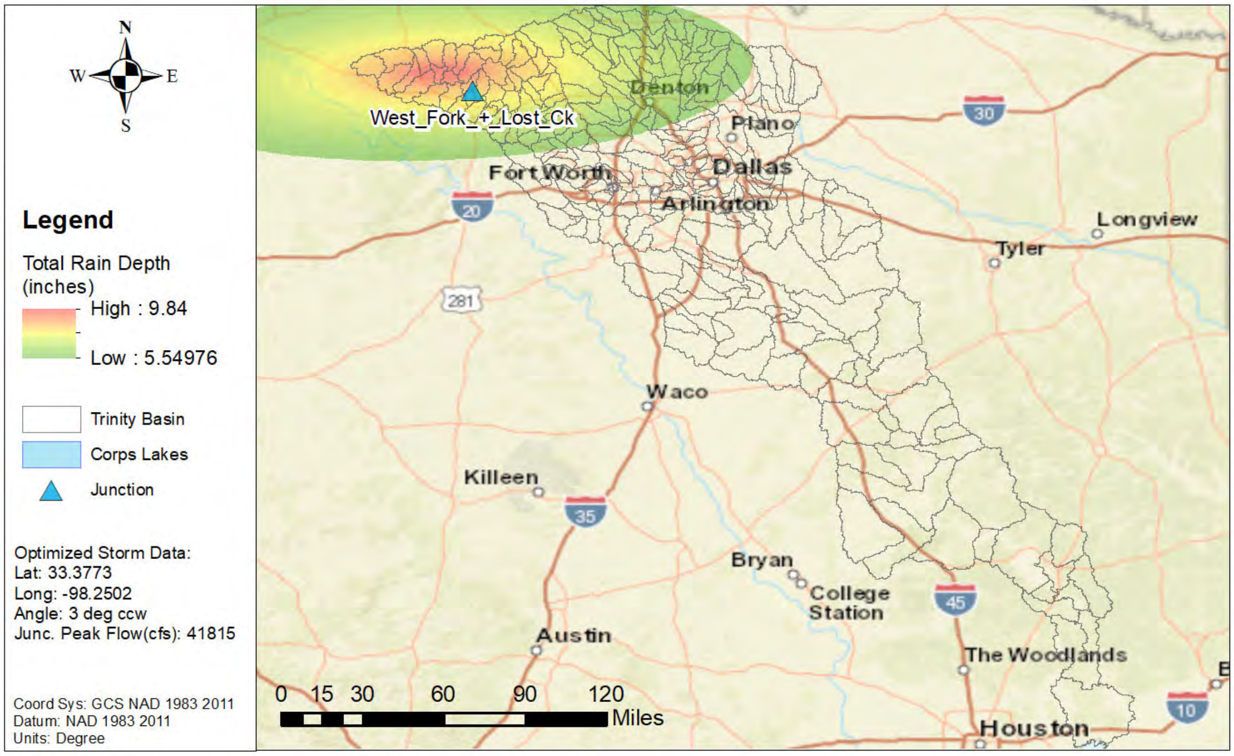


Figure 11b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Lost Creek

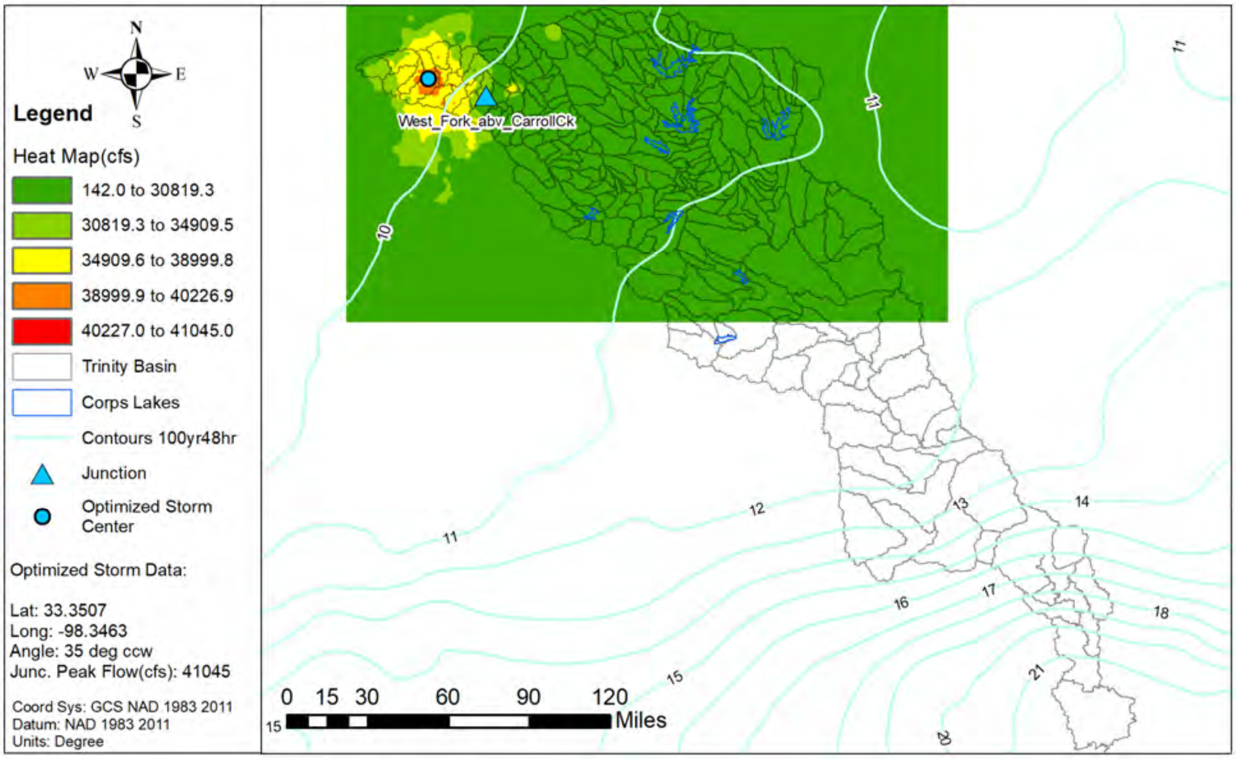


Figure 12a: Elliptical Storm Heat Map for the West Fork Trinity River above Carroll Creek

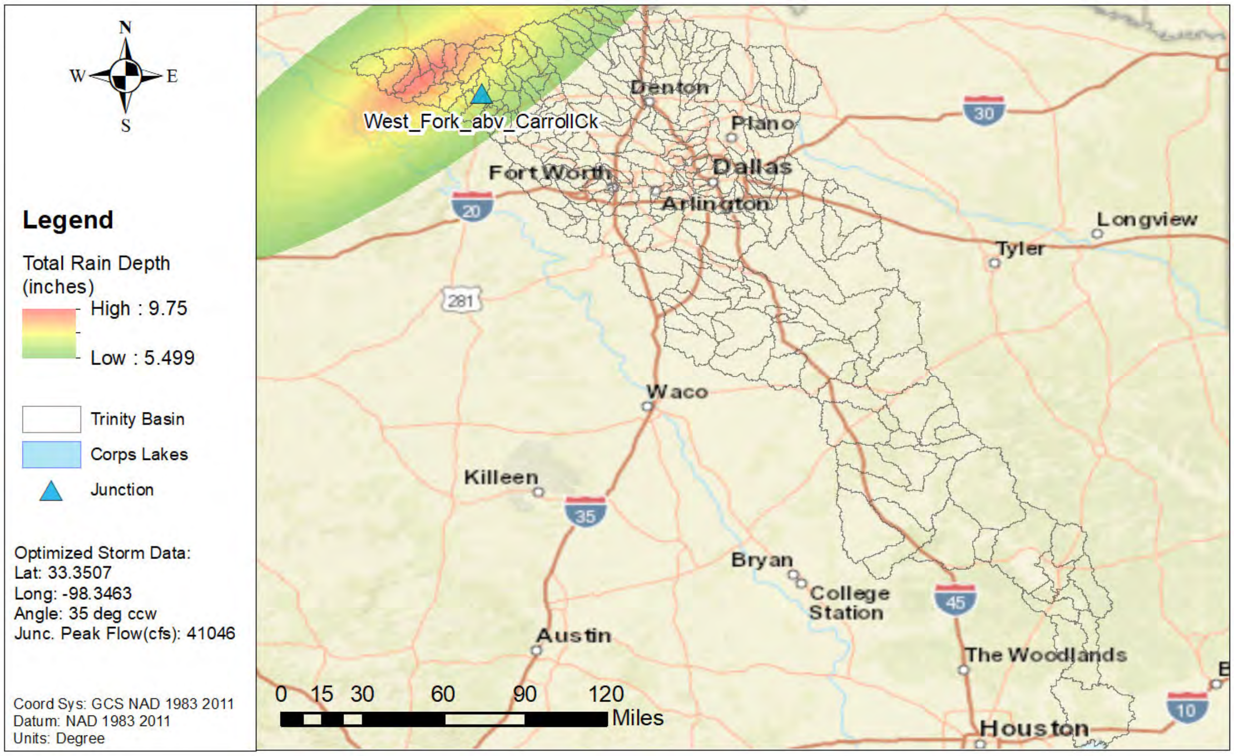


Figure 12b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Carroll Creek

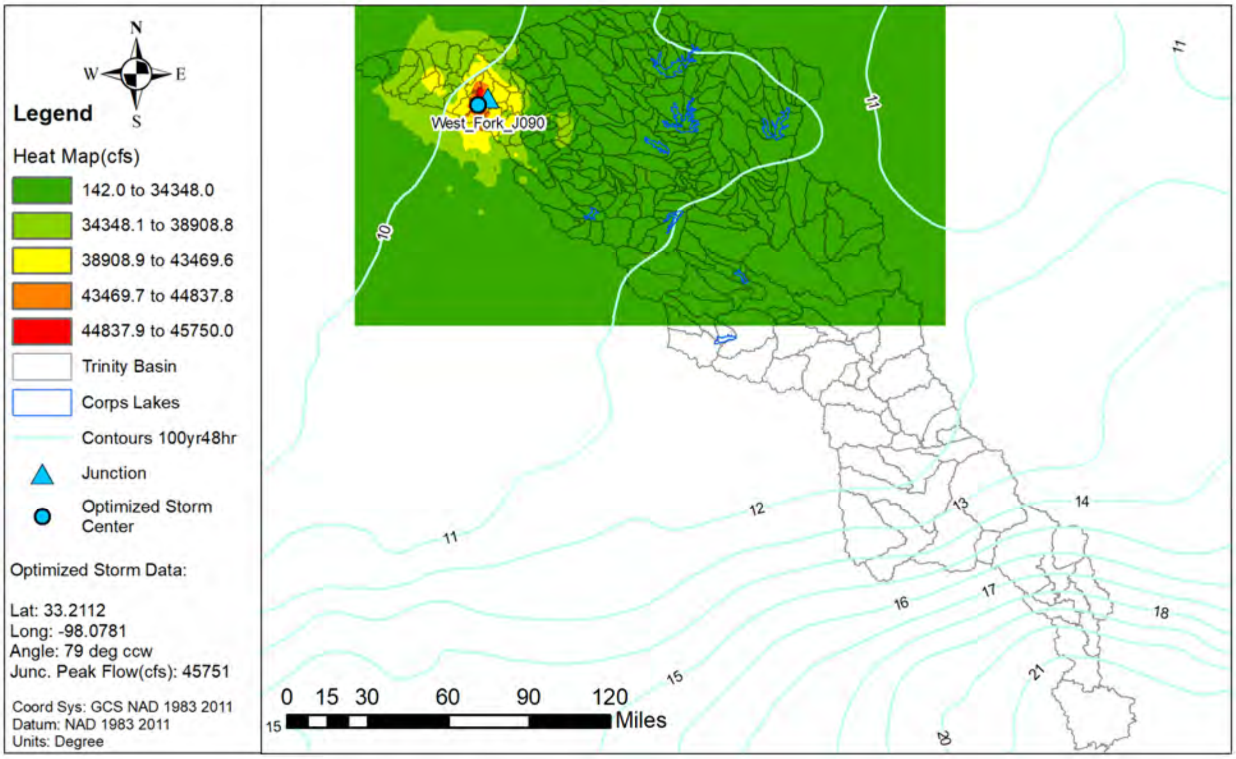


Figure 13a: Elliptical Storm Heat Map for the West Fork Trinity River below Carroll Creek

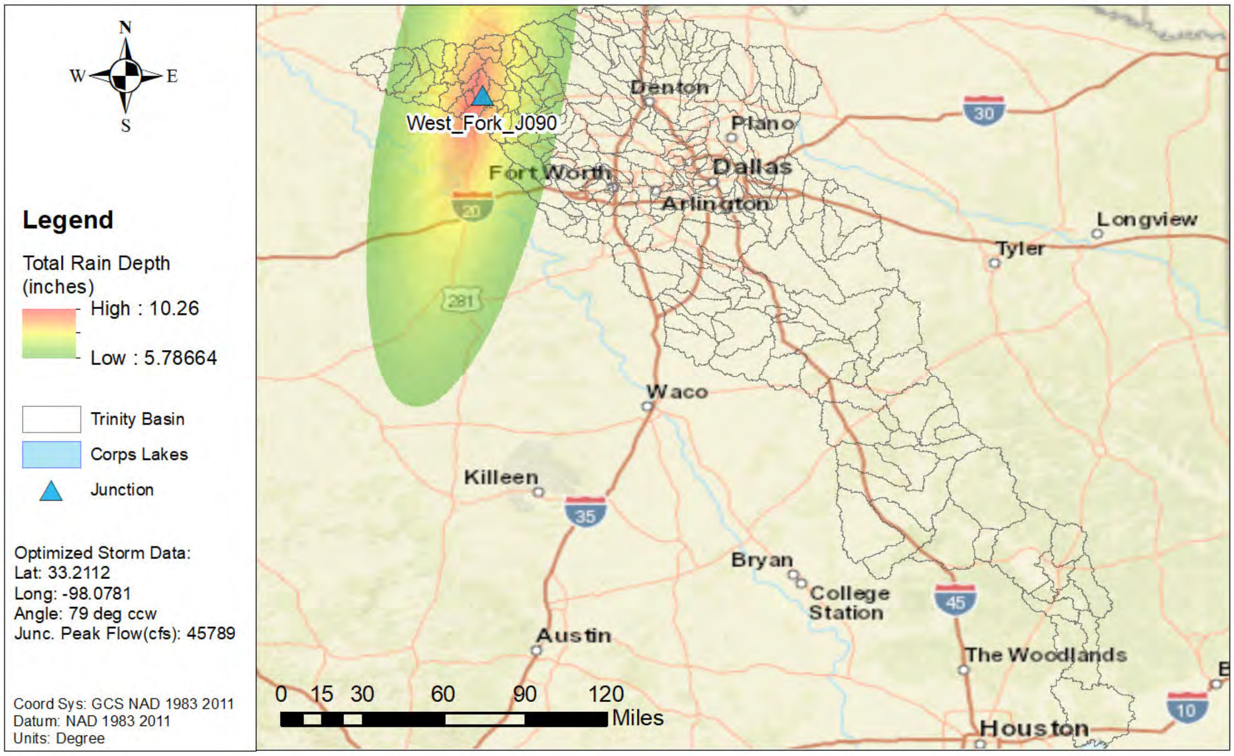


Figure 13b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Carroll Creek

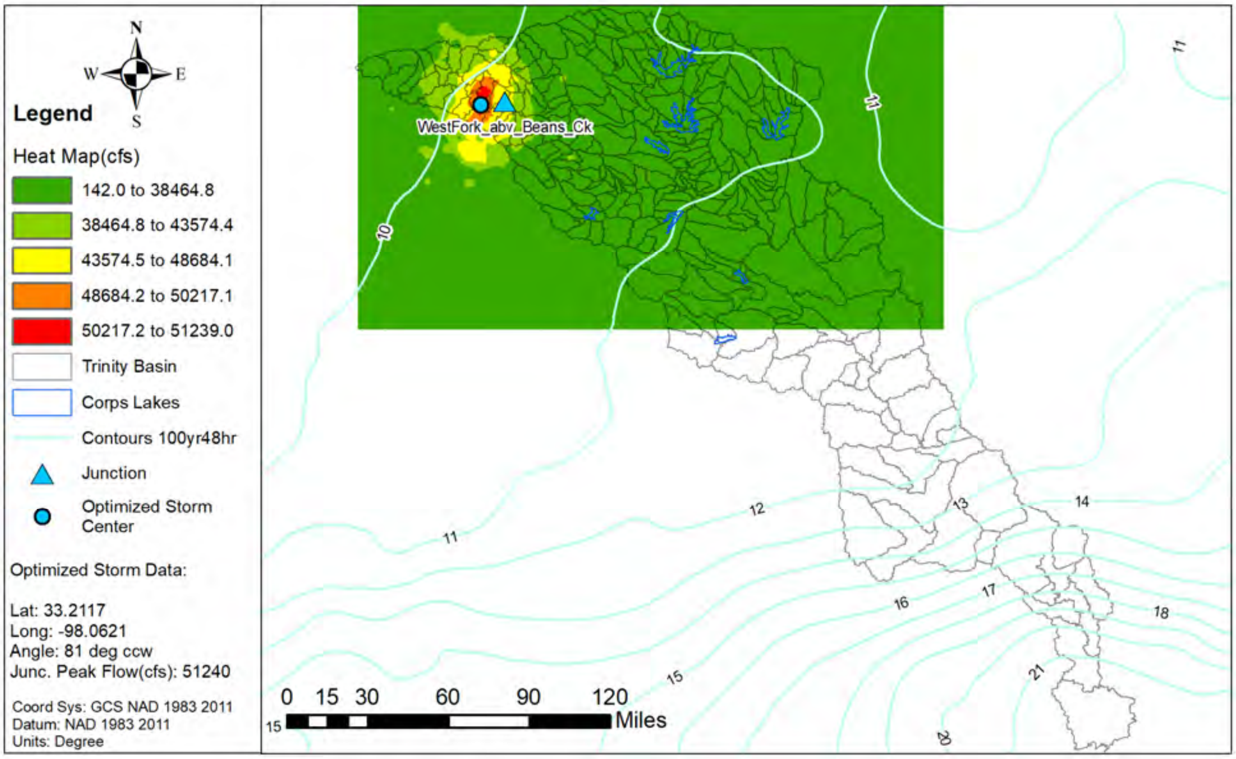


Figure 14a: Elliptical Storm Heat Map for the West Fork Trinity River above Beans Creek

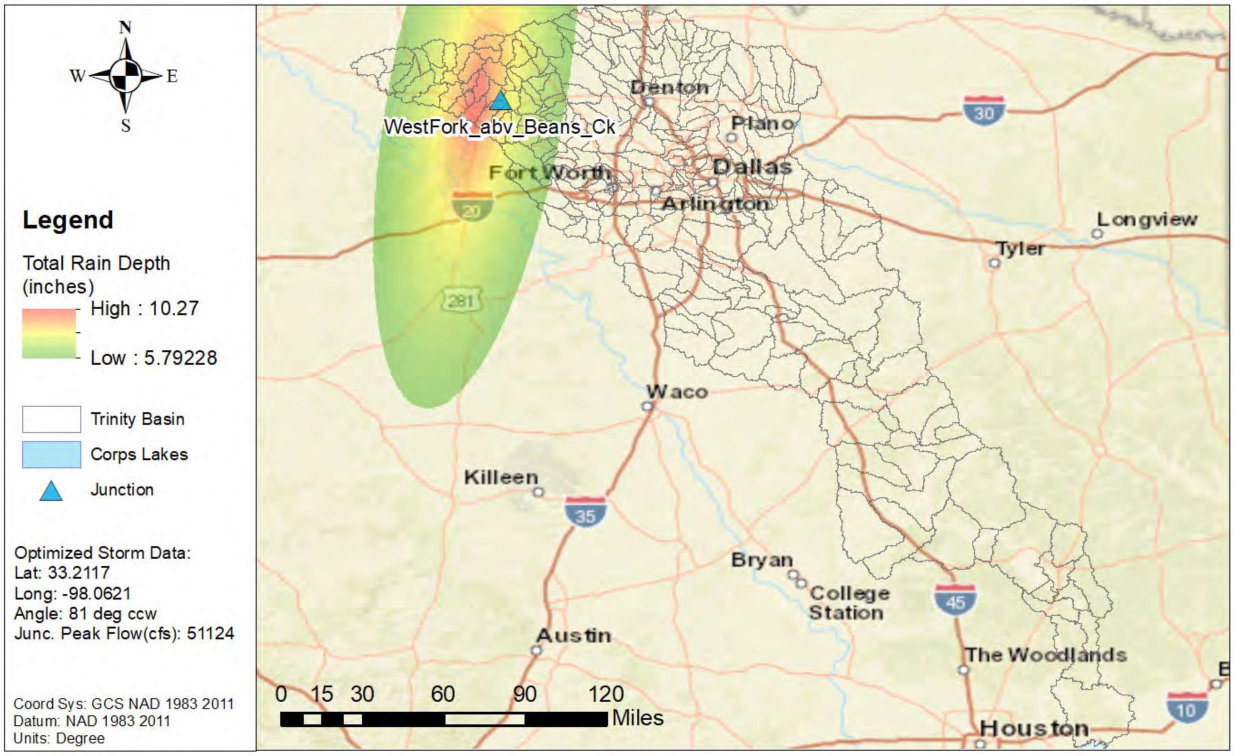


Figure 14b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Beans Creek

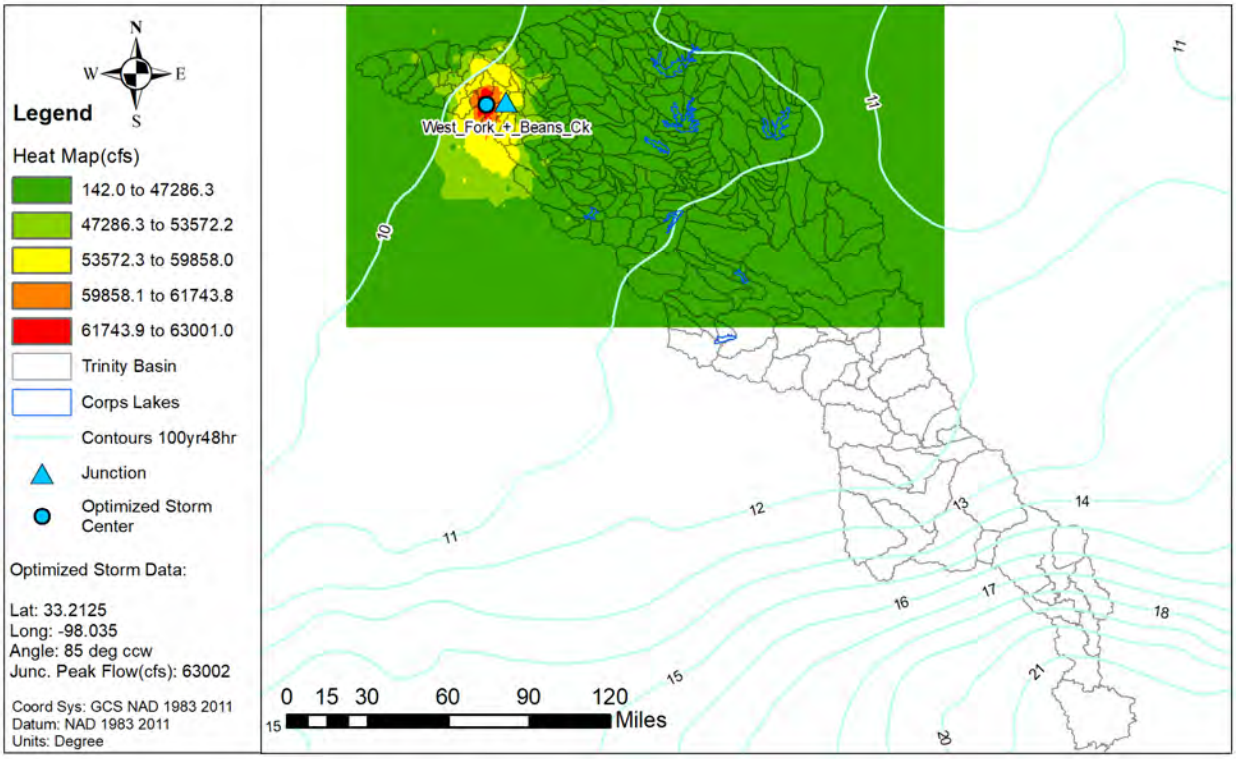


Figure 15a: Elliptical Storm Heat Map for the West Fork Trinity River below Beans Creek

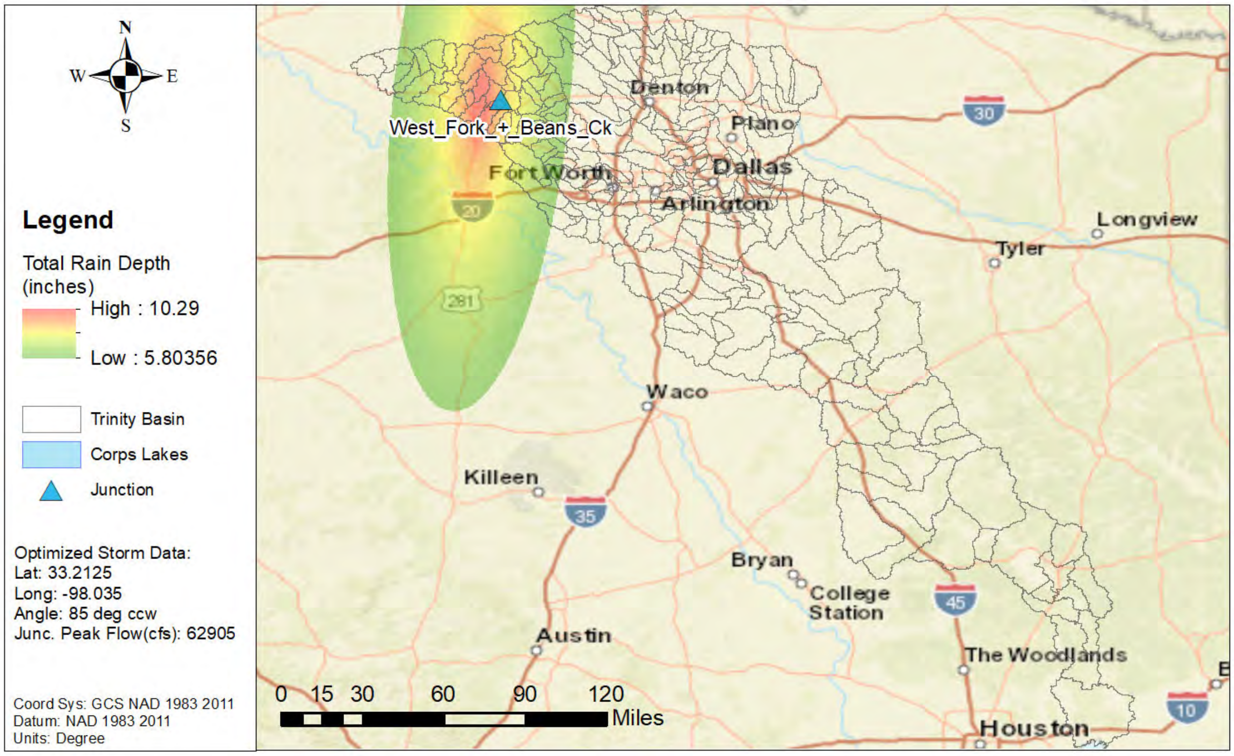


Figure 15b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Beans Creek

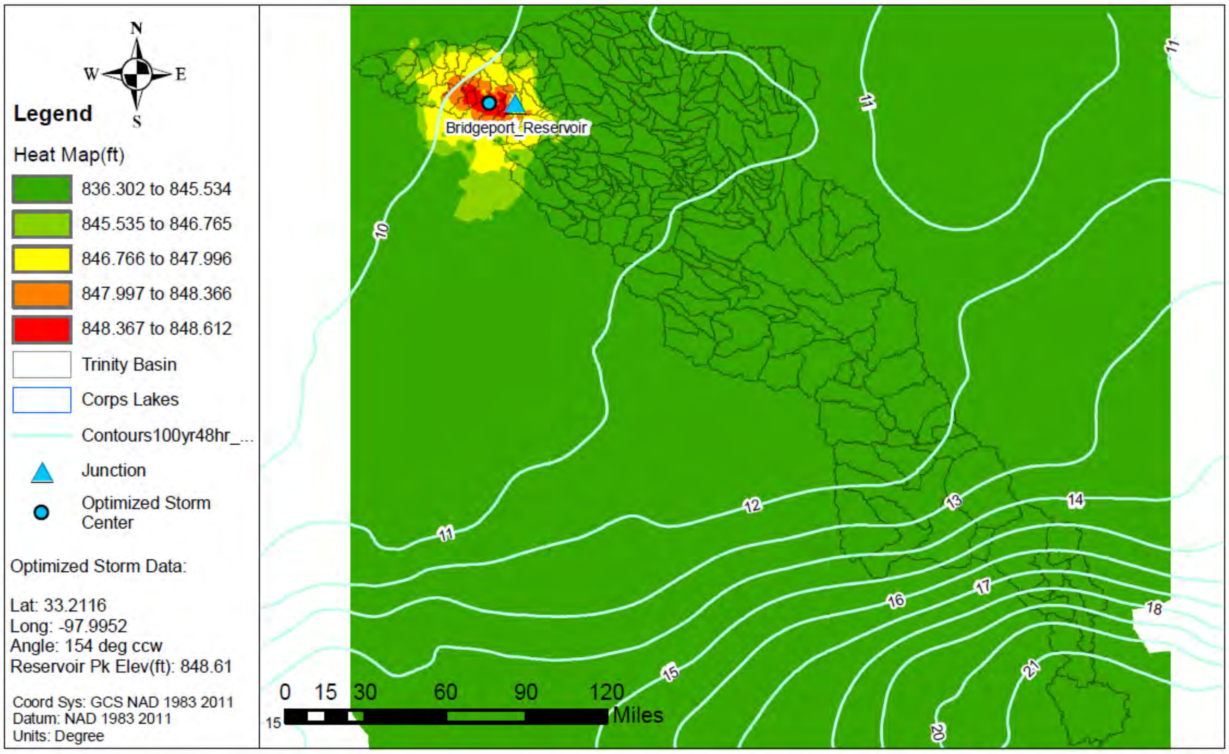


Figure 16a: Elliptical Storm Heat Map for the Bridgeport Reservoir

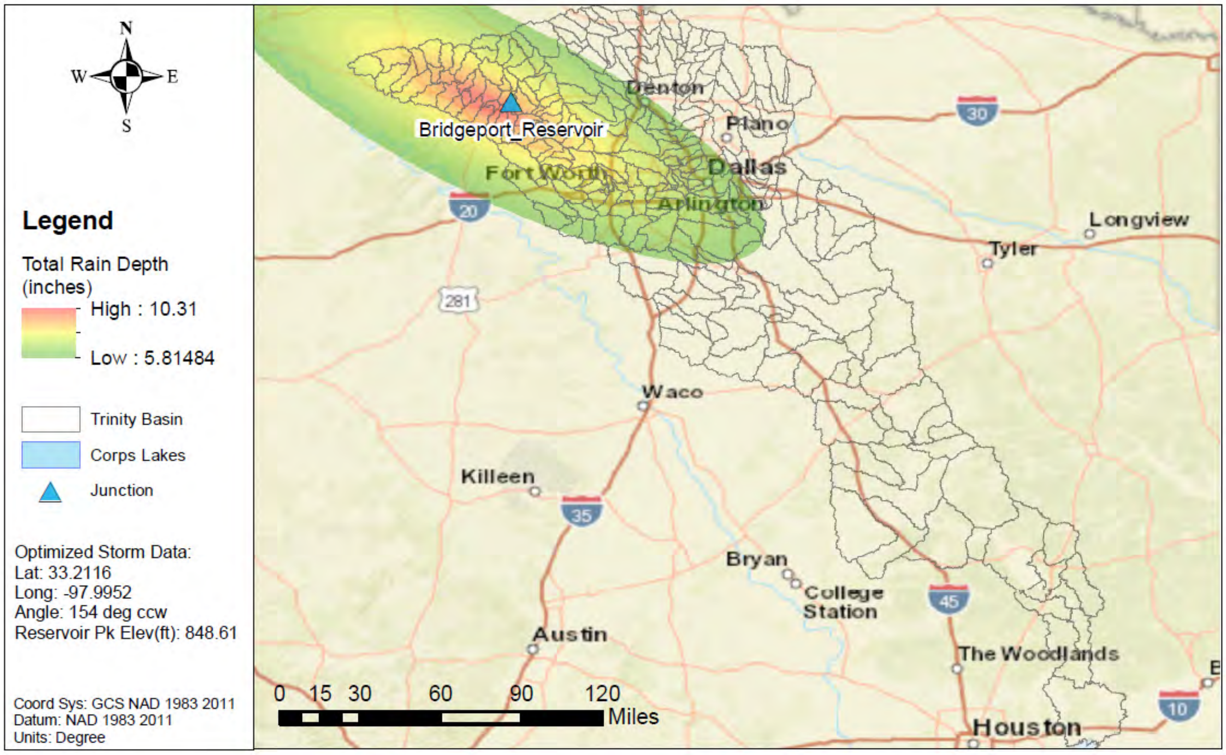


Figure 16b: NA14 1% AEP Elliptical Storm for the Bridgeport Reservoir

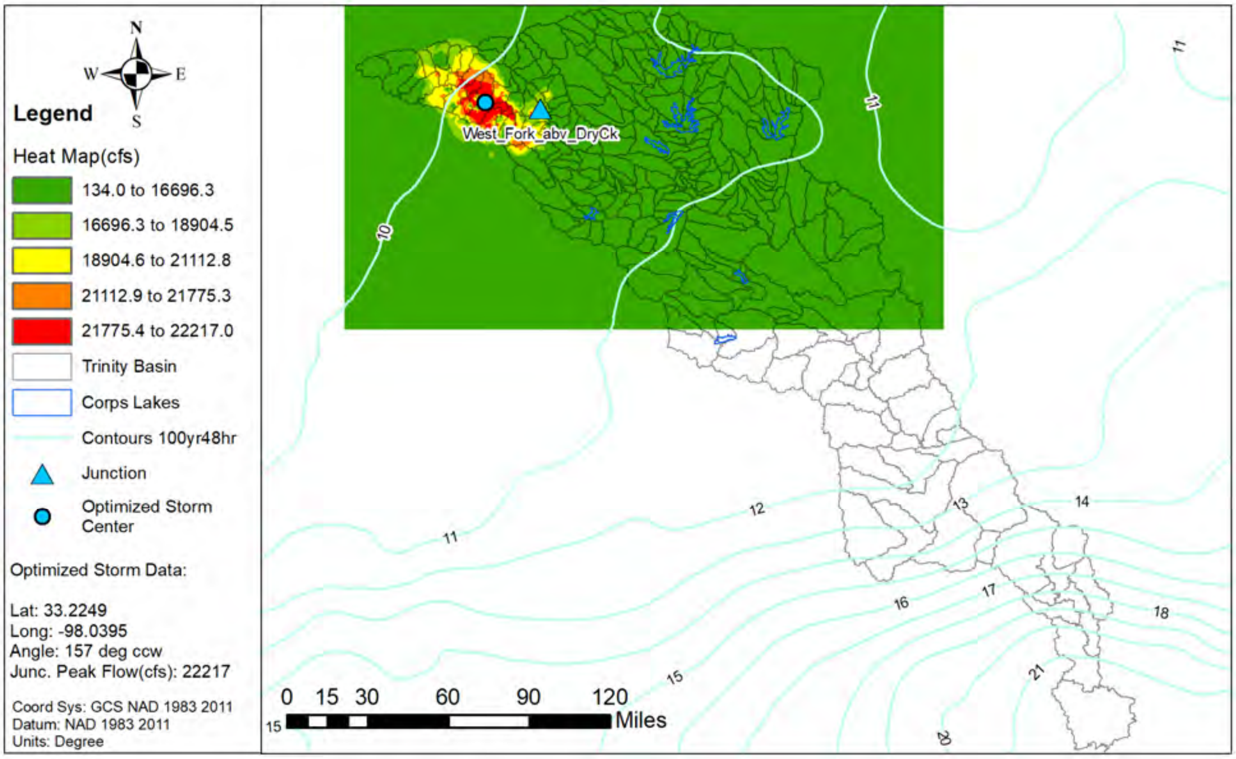


Figure 17a: Elliptical Storm Heat Map for the West Fork Trinity River above Dry Creek

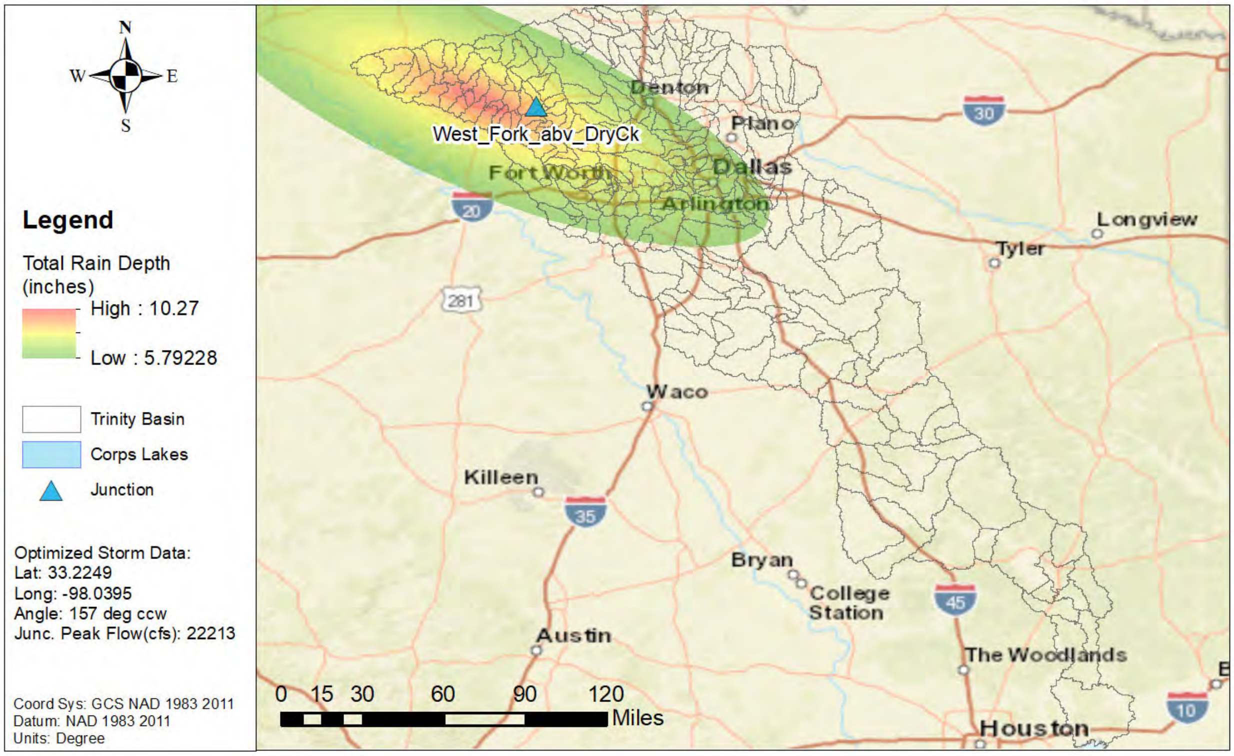


Figure 17b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Dry Creek

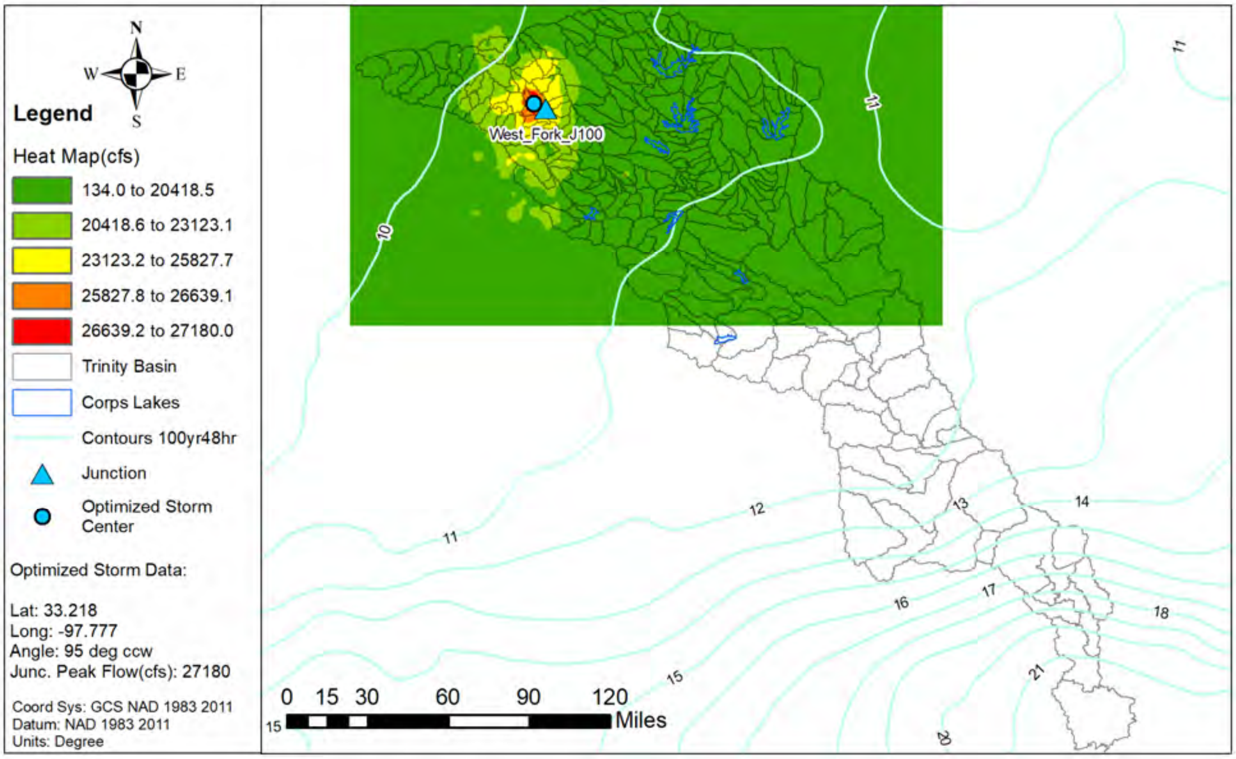


Figure 18a: Elliptical Storm Heat Map for the West Fork Trinity River below Dry Creek

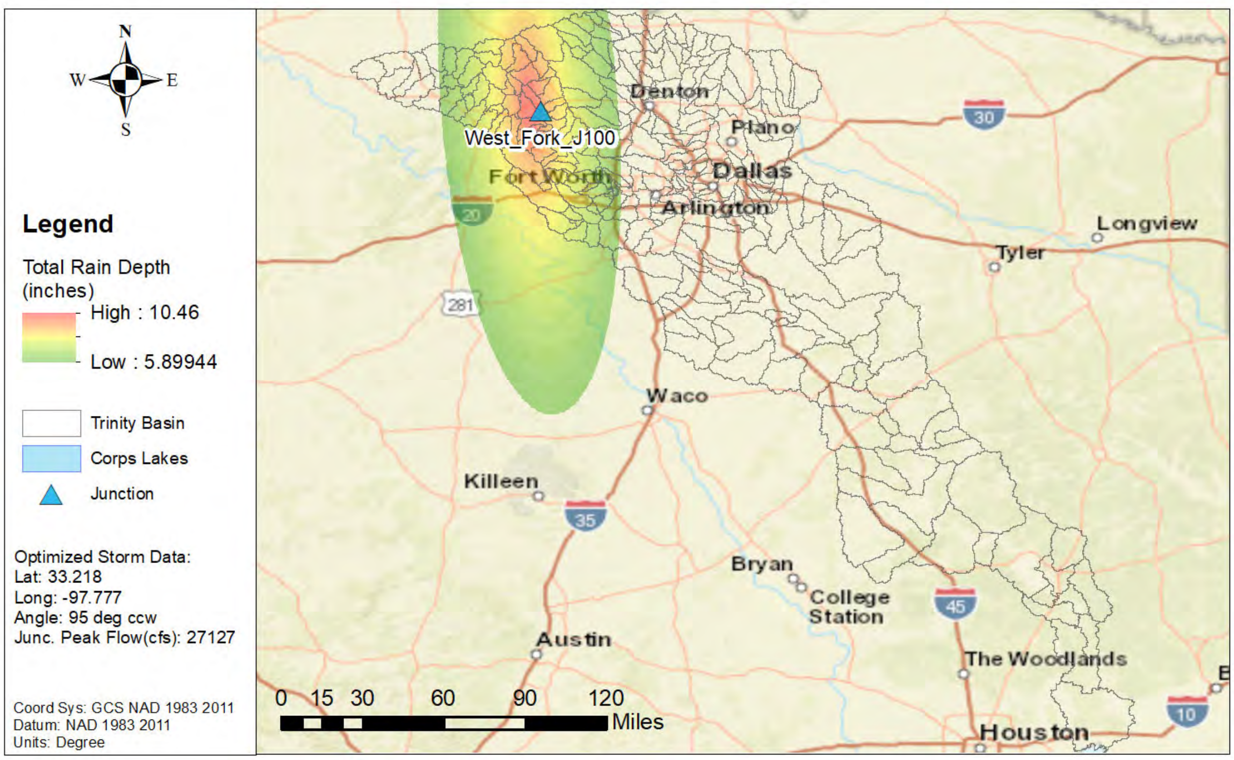


Figure 18b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Dry Creek

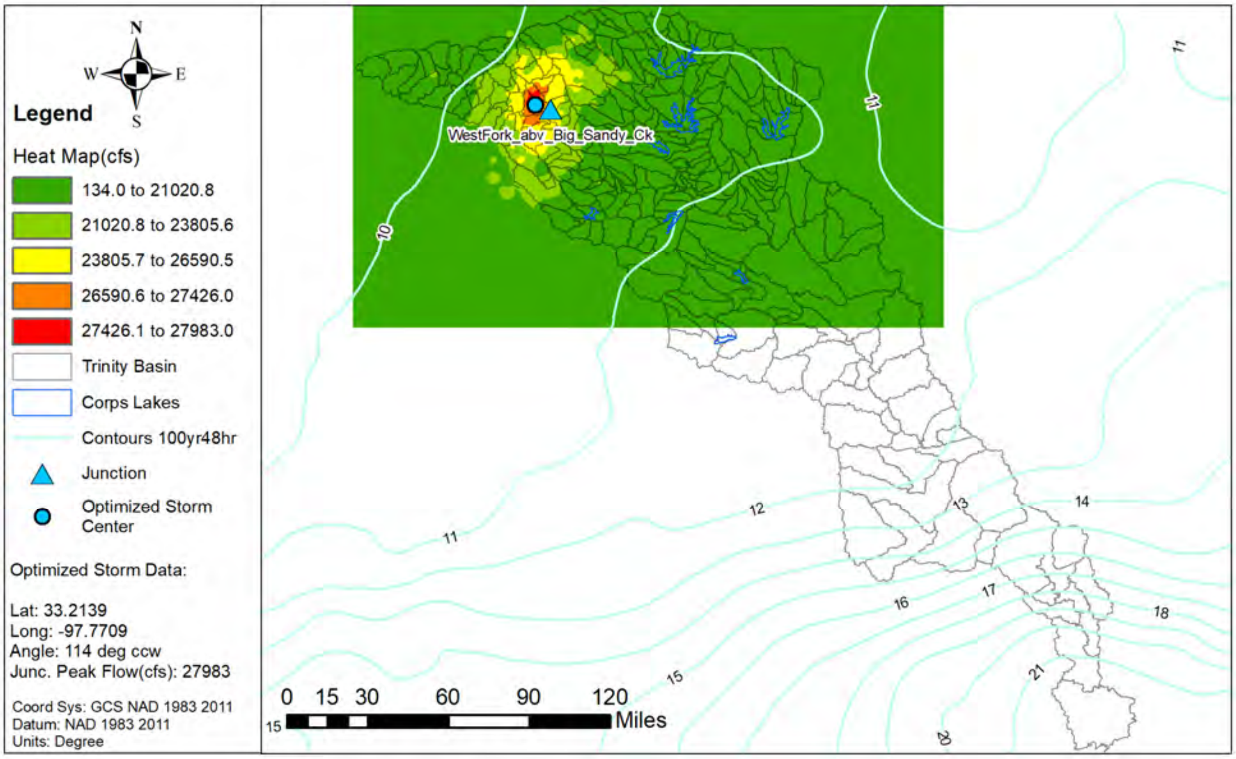


Figure 19a: Elliptical Storm Heat Map for the West Fork Trinity River above Big Sandy Creek

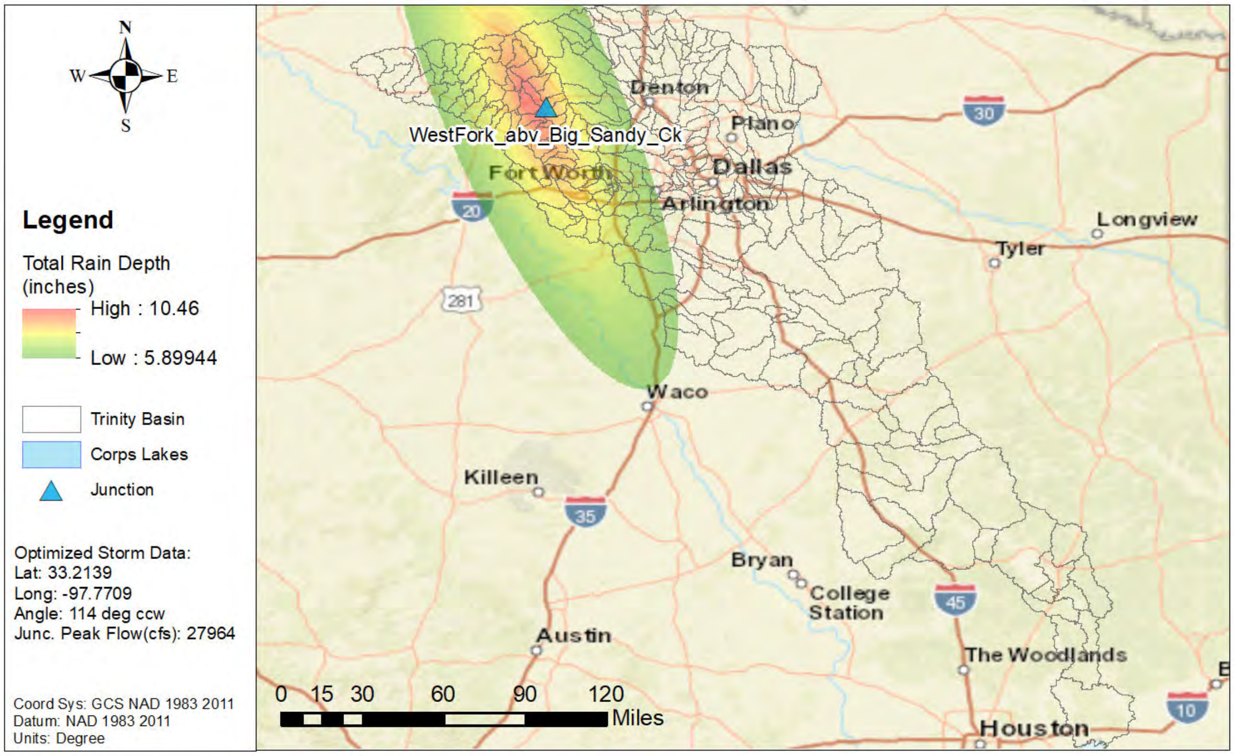


Figure 19b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Big Sandy Creek

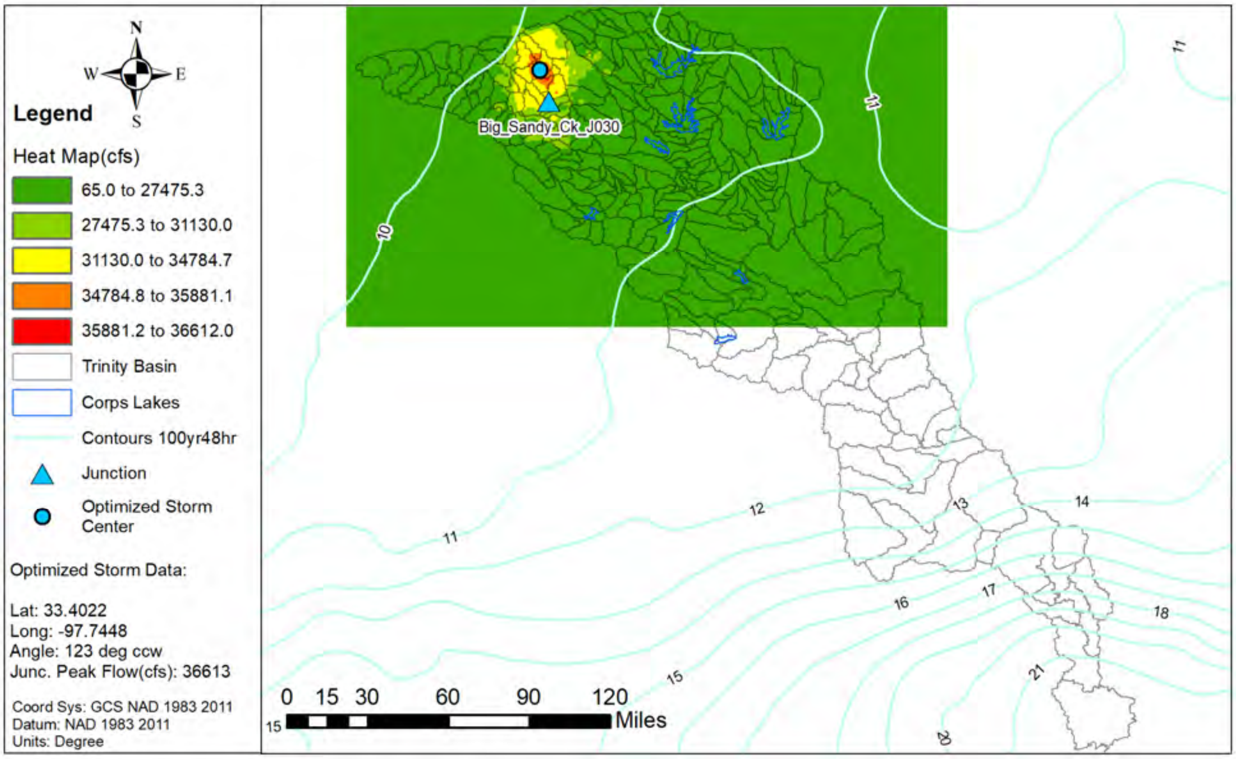


Figure 20a: Elliptical Storm Heat Map for Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114 bridge

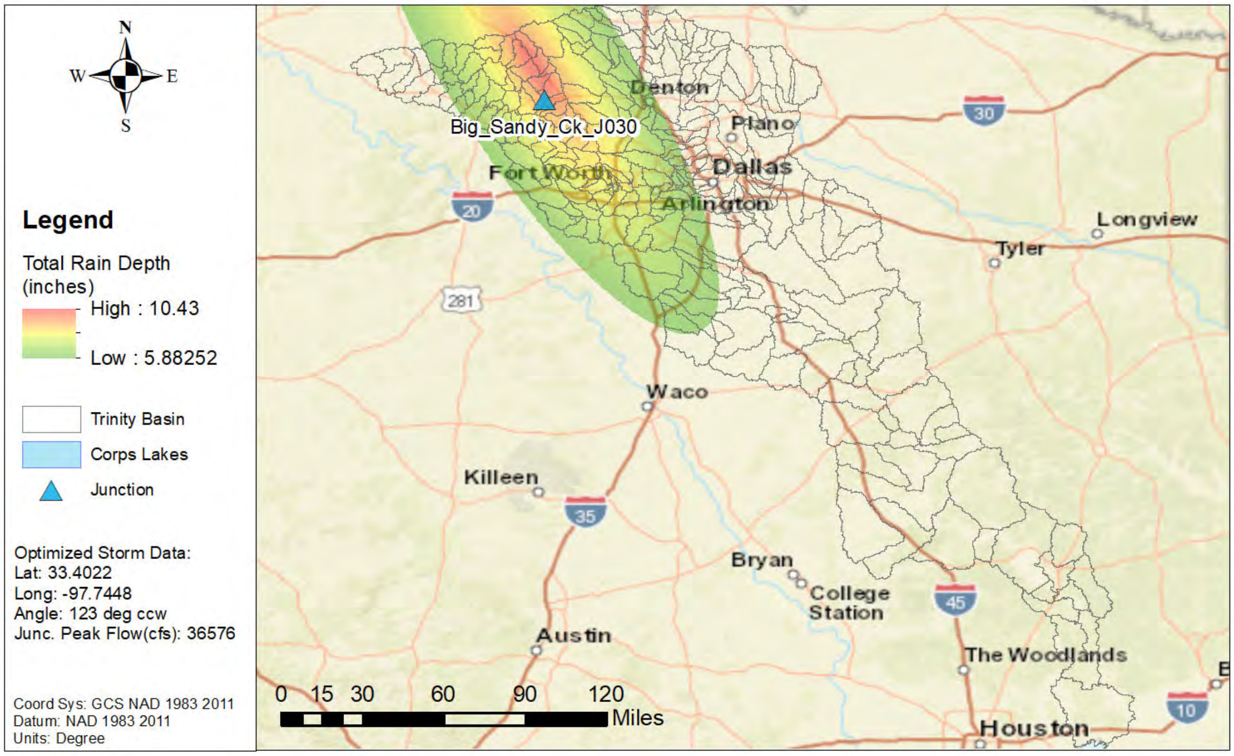


Figure 20b: NA14 1% AEP Elliptical Storm for Big Sandy Creek nr Bridgeport USGS Gage at Hwy 114

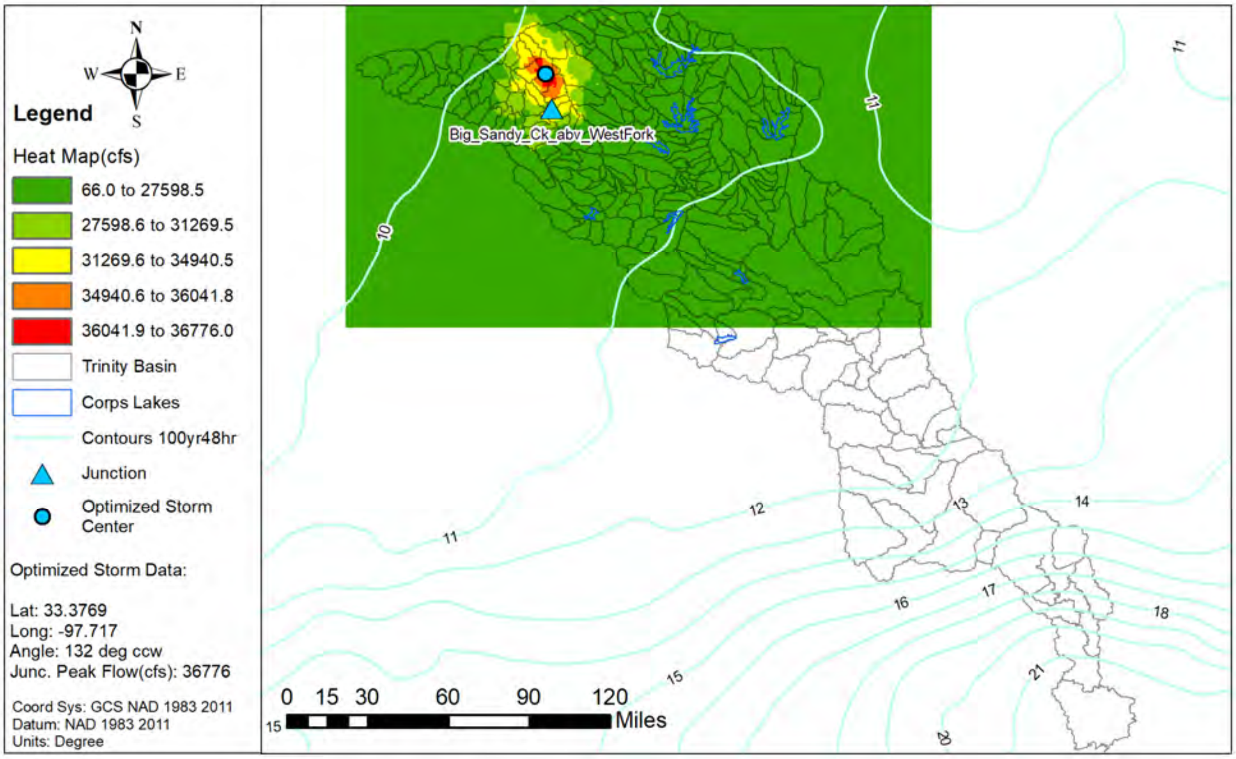


Figure 21a: Elliptical Storm Heat Map for the Big Sandy Creek above the West Fork Trinity River

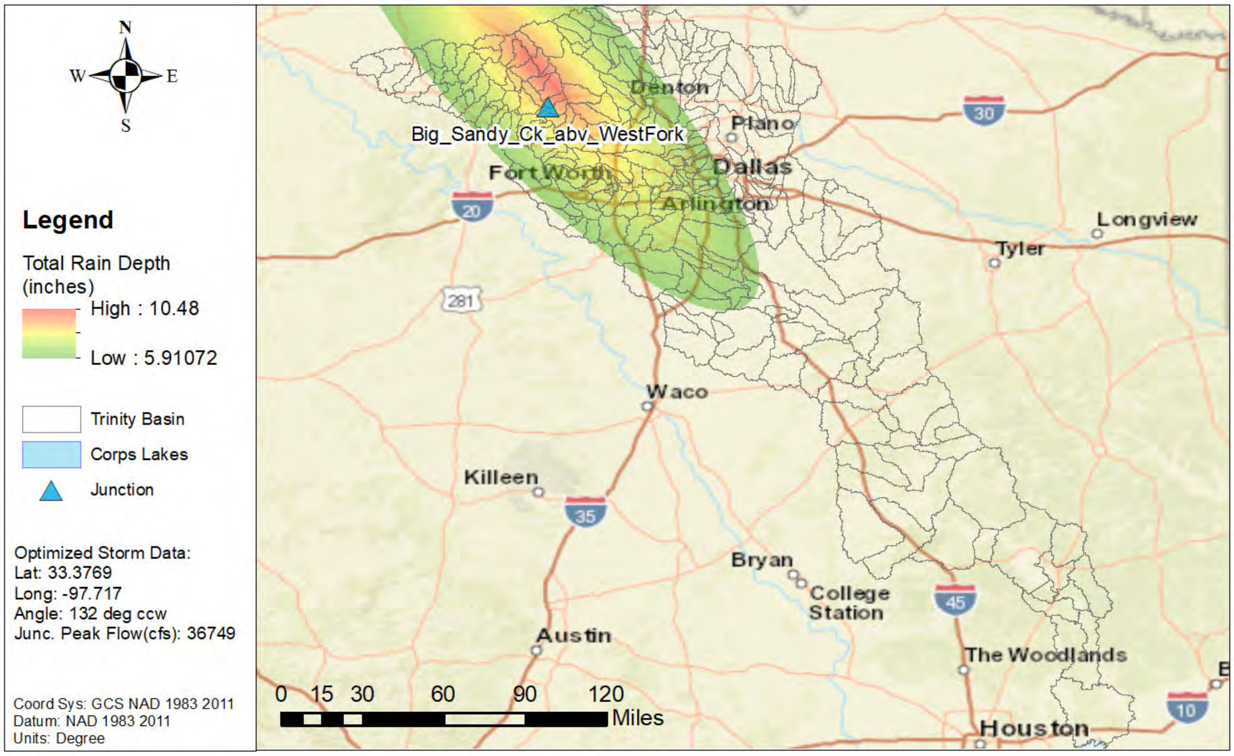


Figure 21b: NA14 1% AEP Elliptical Storm for the Big Sandy Creek above the West Fork Trinity River

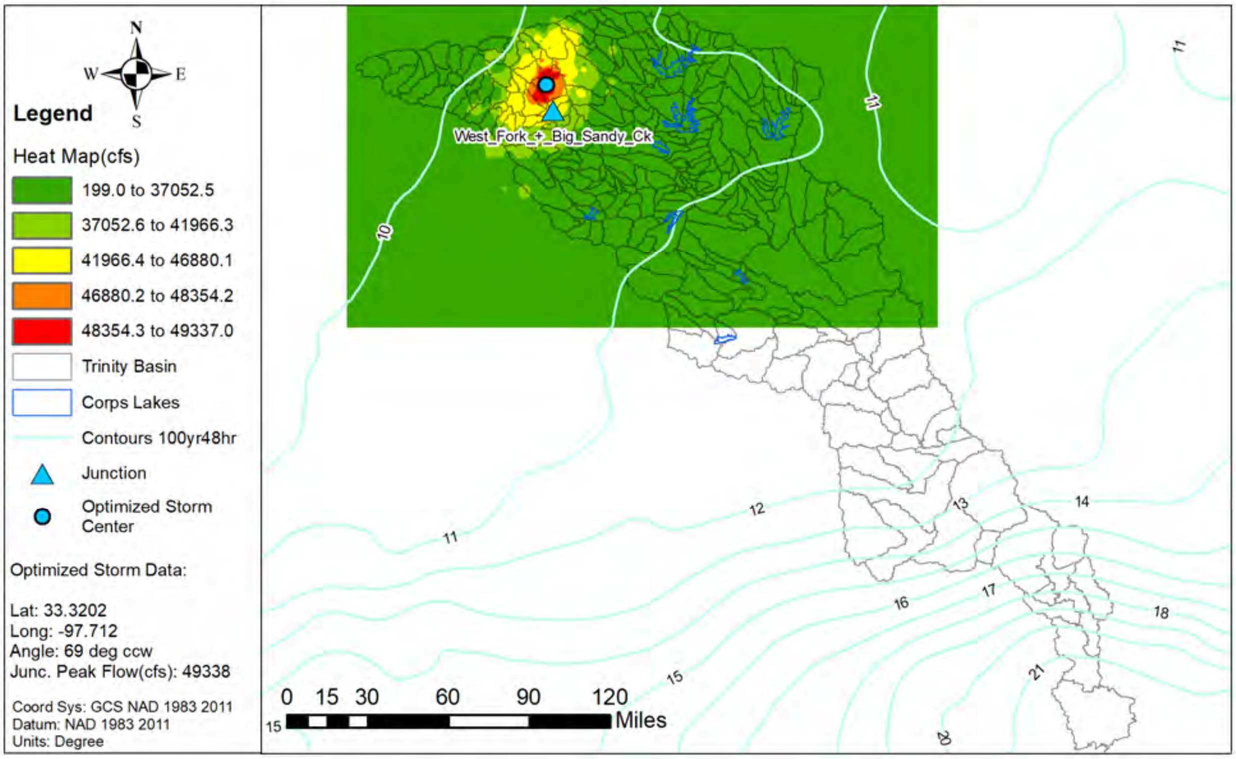


Figure 22a: Elliptical Storm Heat Map for the West Fork Trinity River below Big Sandy Creek

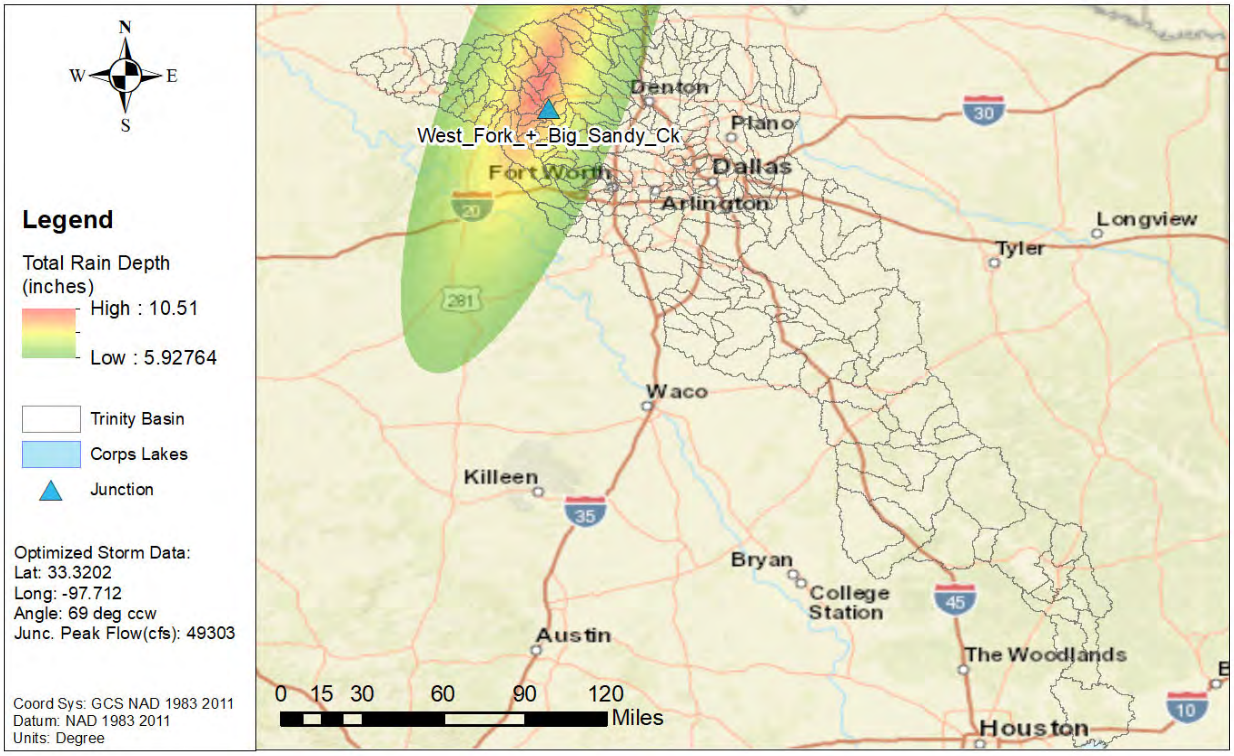


Figure 22b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Big Sandy Creek

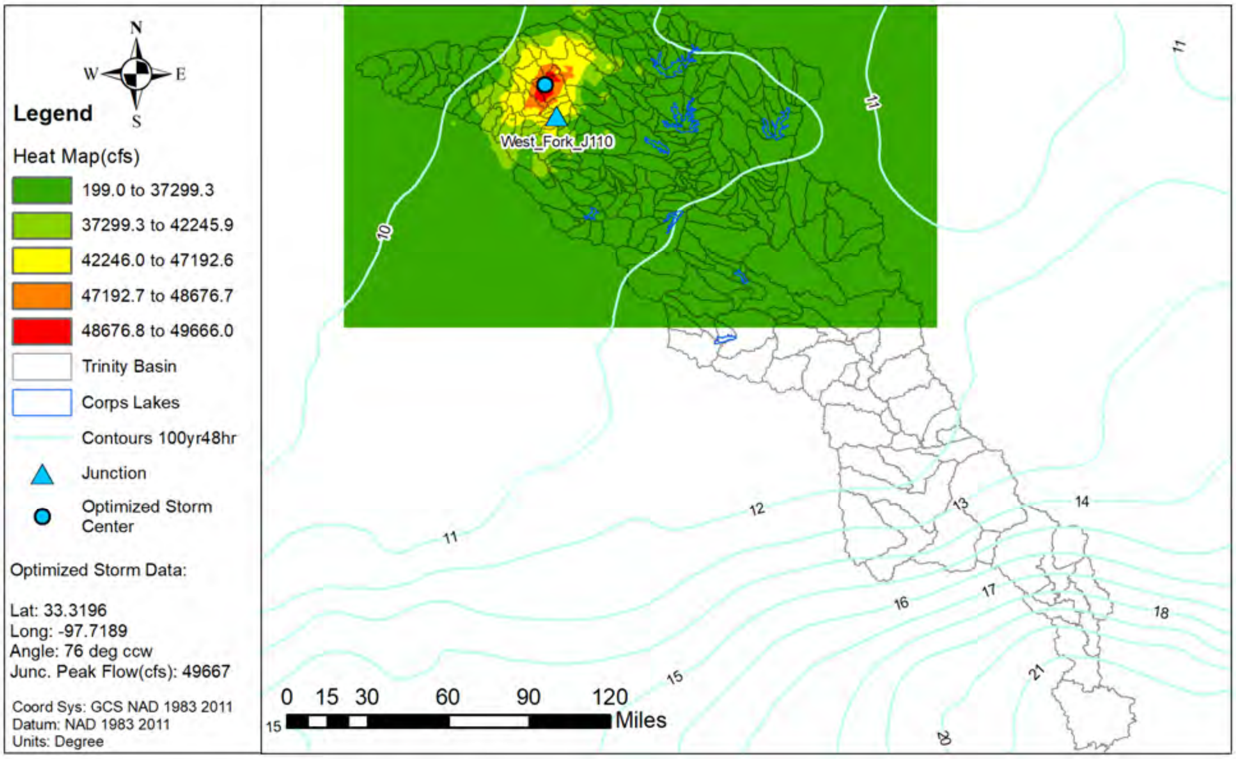


Figure 23a: Elliptical Storm Heat Map for the West Fork Trinity River at FM 3259 near Paradise, TX

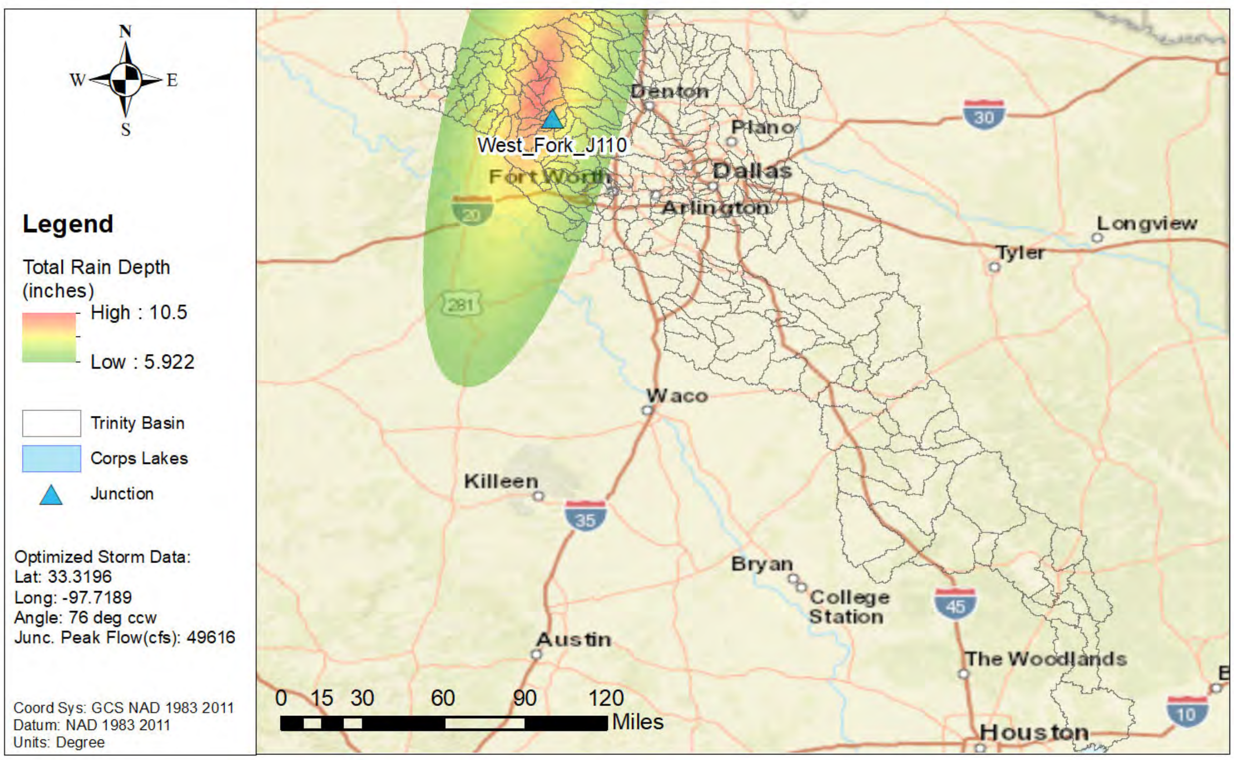


Figure 23b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River at FM 3259 near Paradise, TX

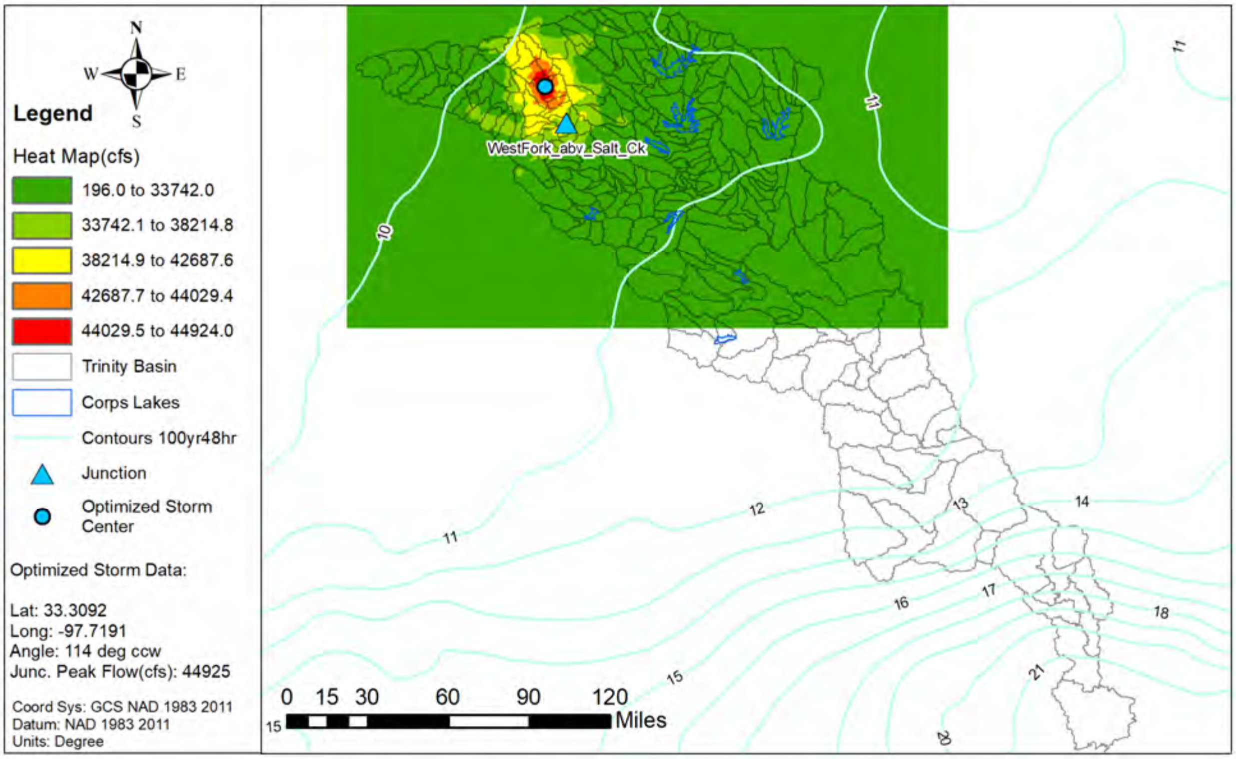


Figure 24a: Elliptical Storm Heat Map for the West Fork Trinity River above Salt Creek

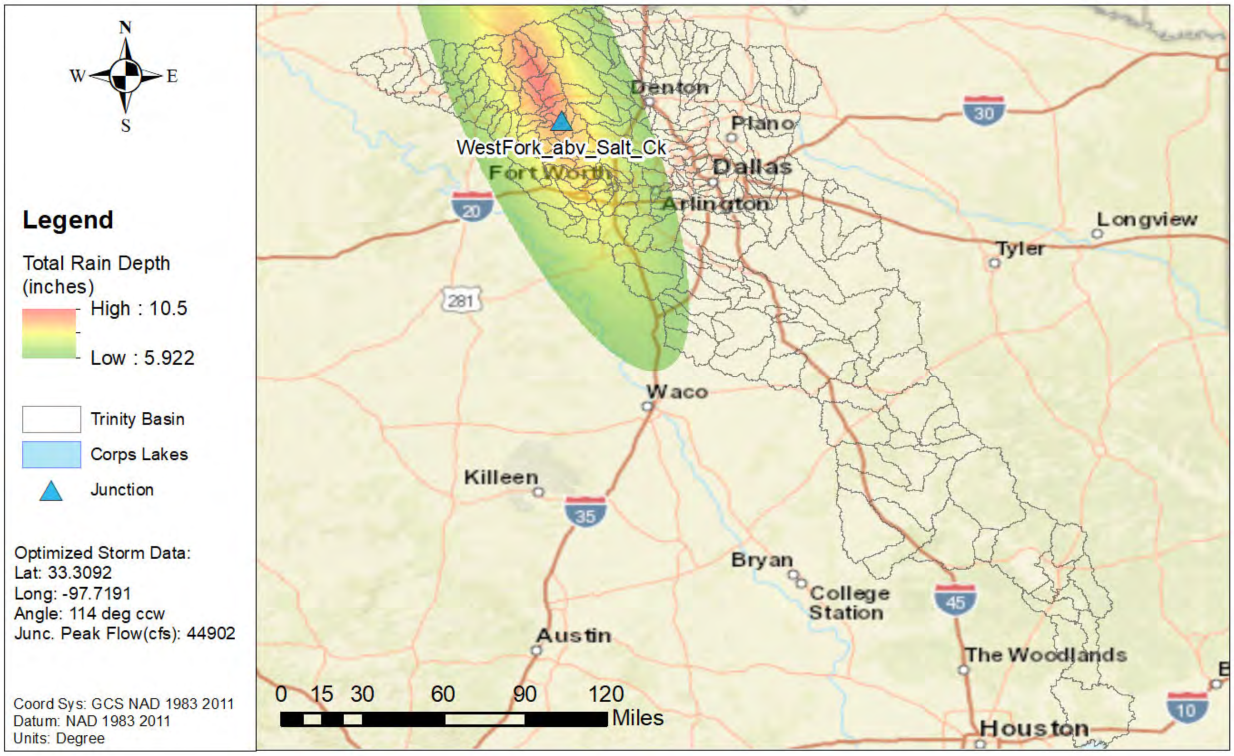


Figure 24b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Salt Creek

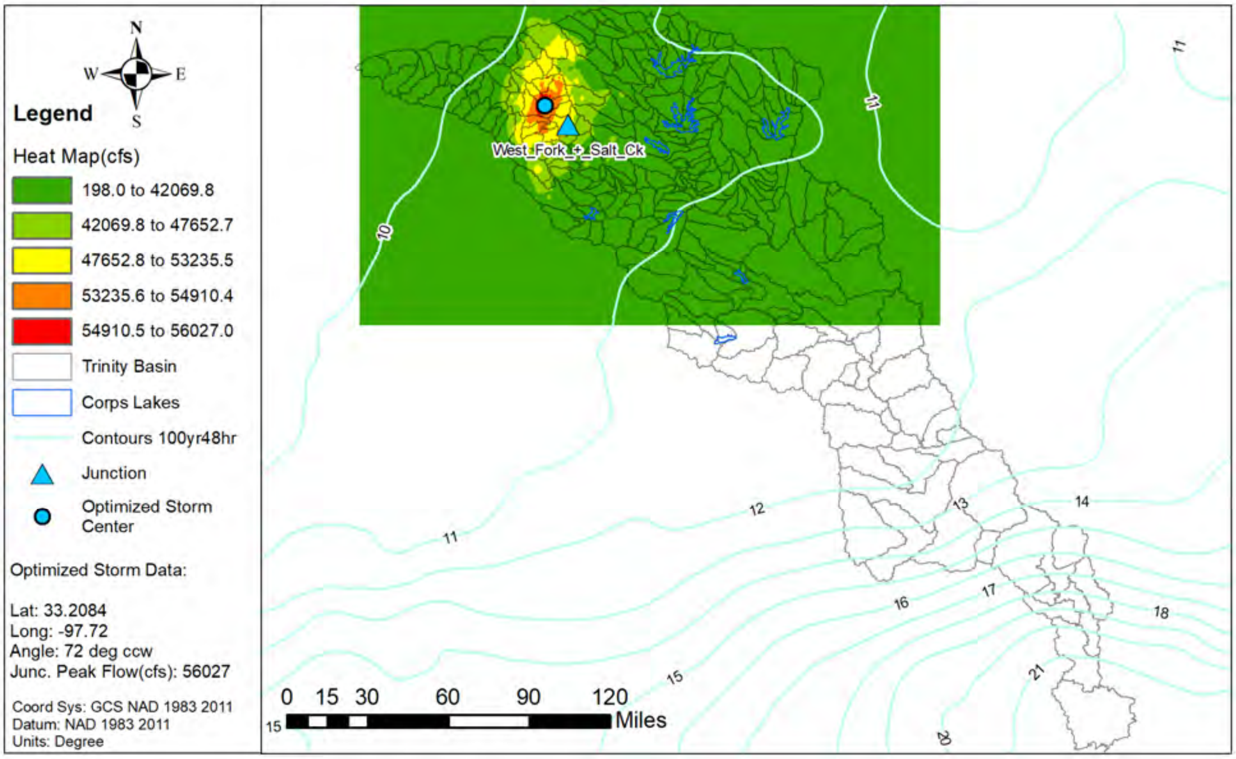


Figure 25a: Elliptical Storm Heat Map for the West Fork Trinity River below Salt Creek

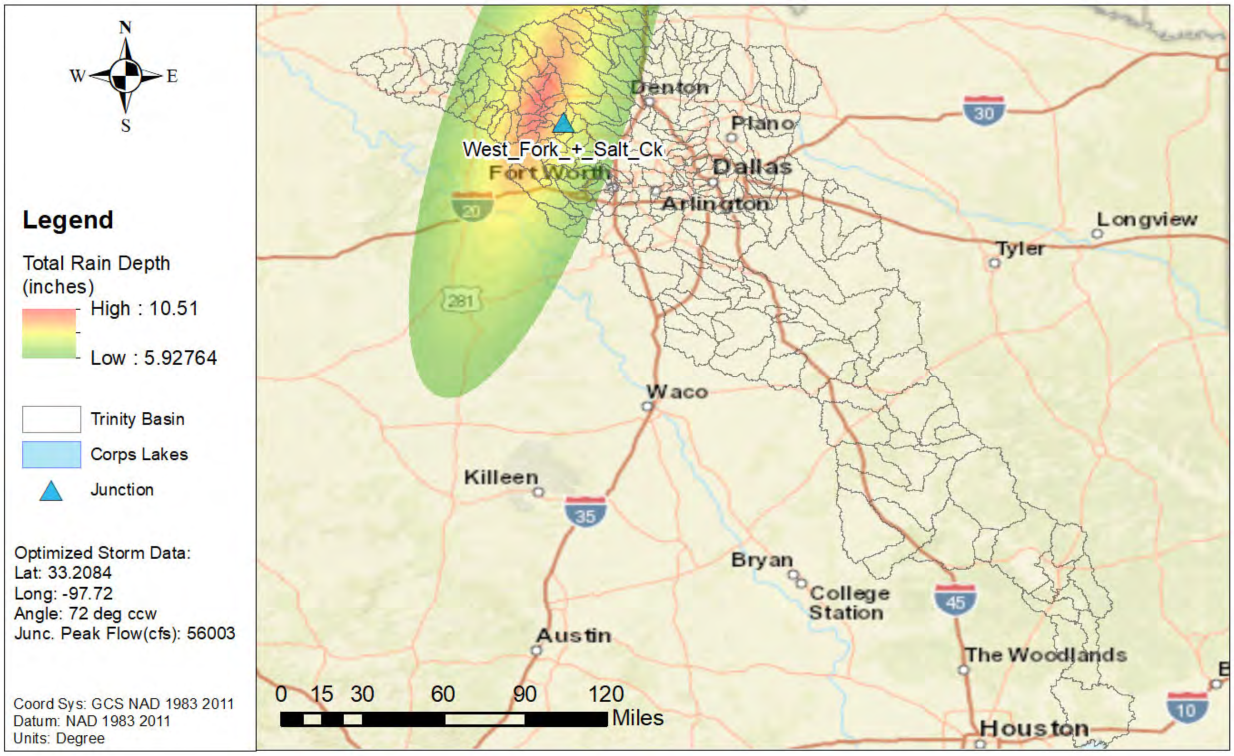


Figure 25b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Salt Creek

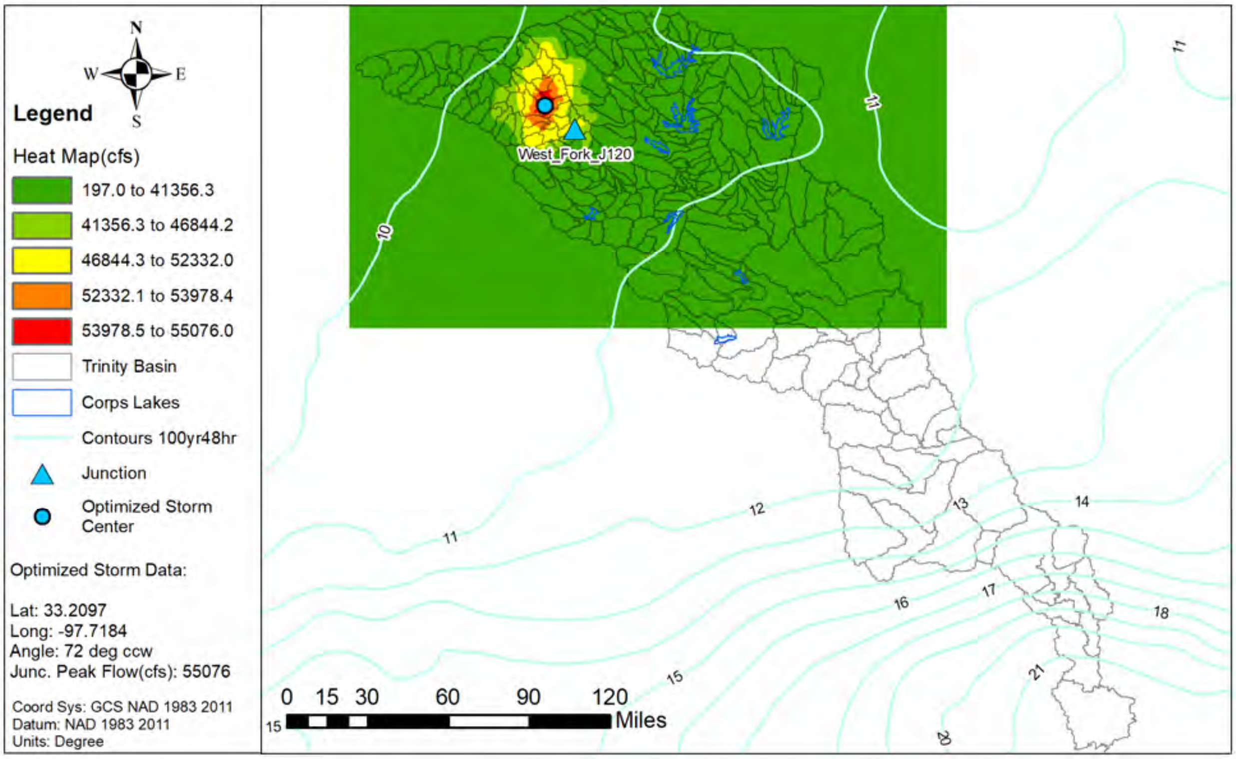


Figure 26a: Ellipt. Storm Heat Map for West Fork Trinity River nr Boyd, TX - USGS Gage at FM 730 bridge

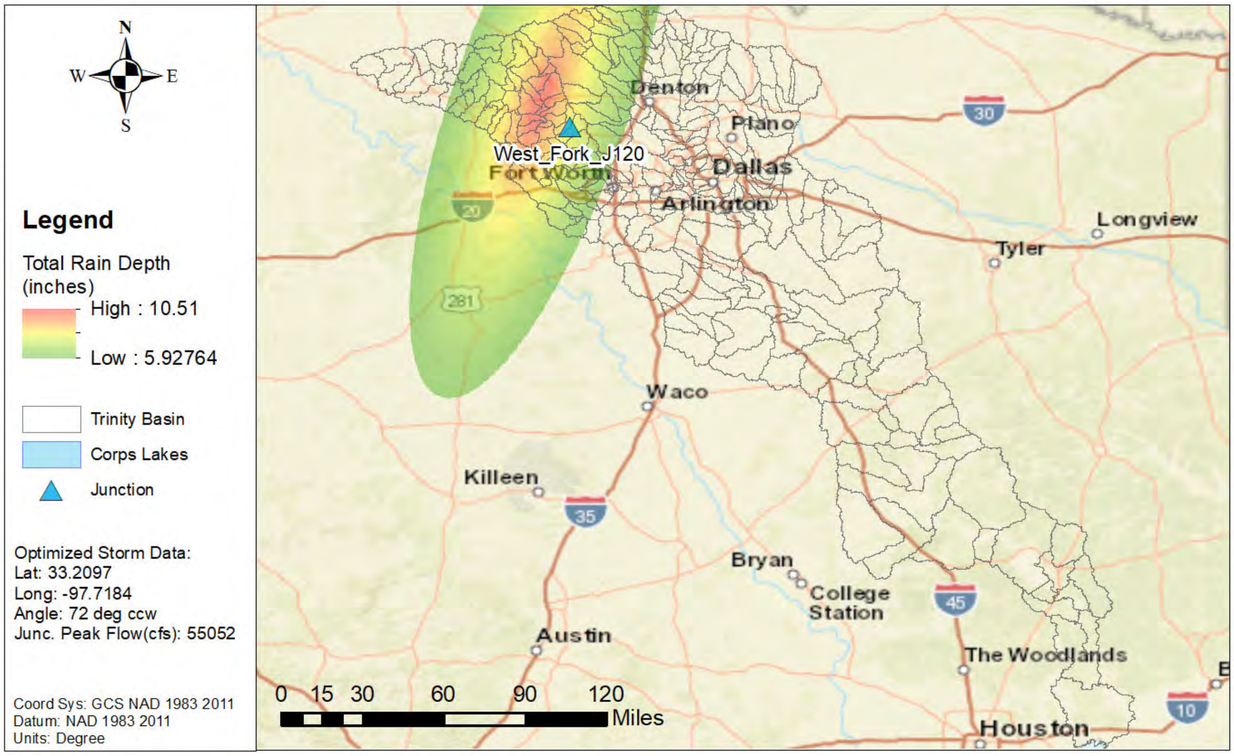


Figure 26b: NA14 1% AEP Ellip. Storm for West Fork Trinity River nr Boyd, TX - USGS Gage at FM 730

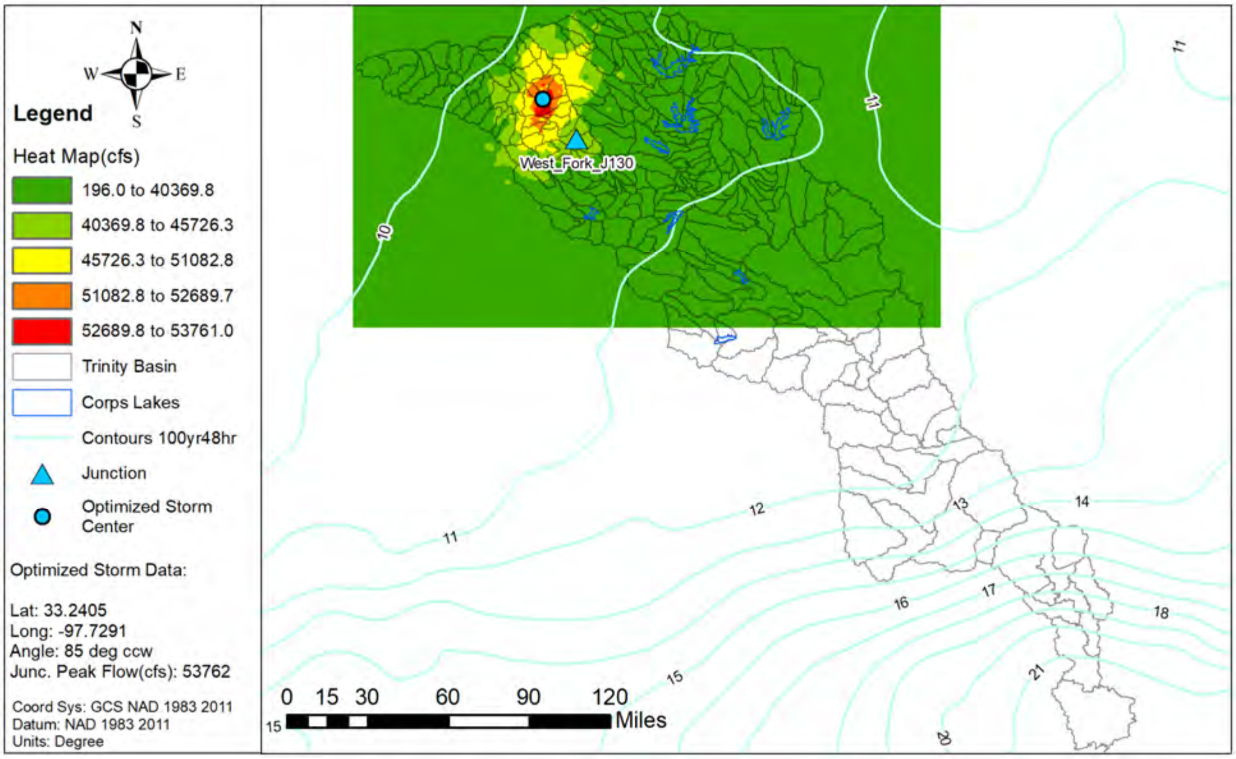


Figure 27a: Ellip. Storm Heat Map for West Fork Trinity River 0.8 miles upstream of FM 4757 in Wise Co.

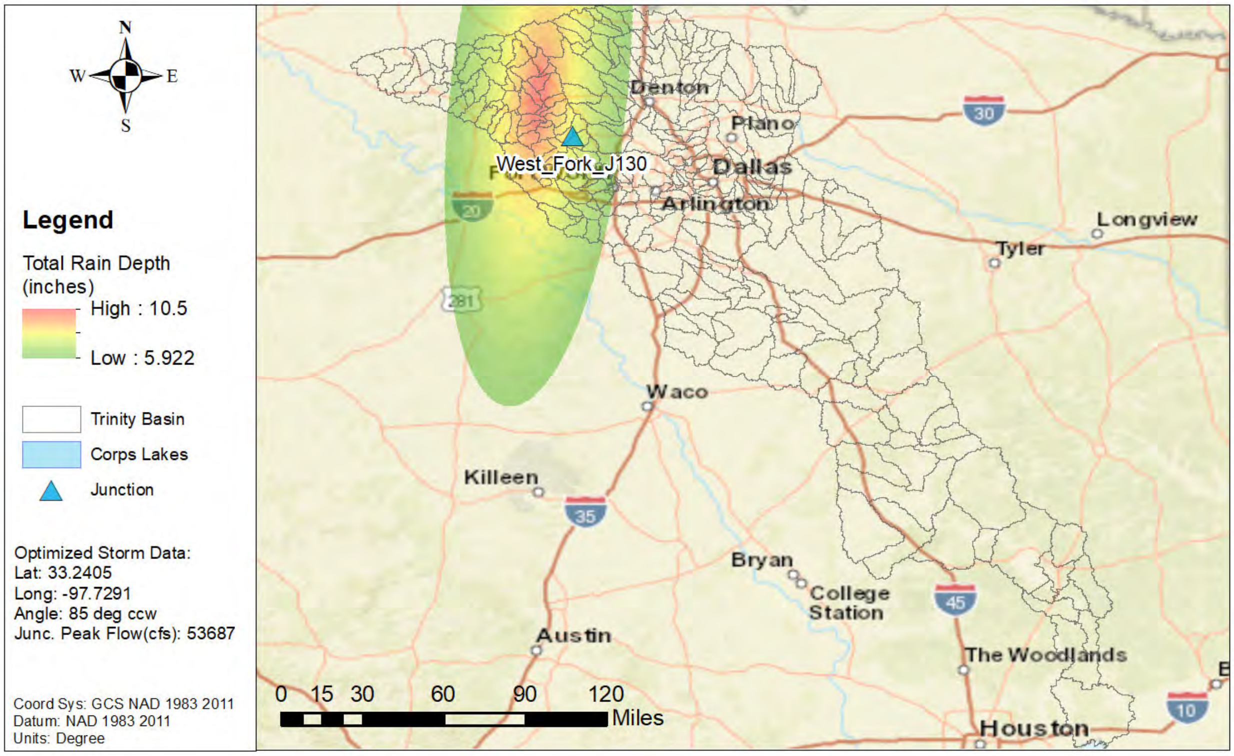


Figure 27b: NA14 1% AEP Ellip. Storm for W. Fork Trinity Riv. 0.8 miles upstream of FM 4757 in Wise Co.

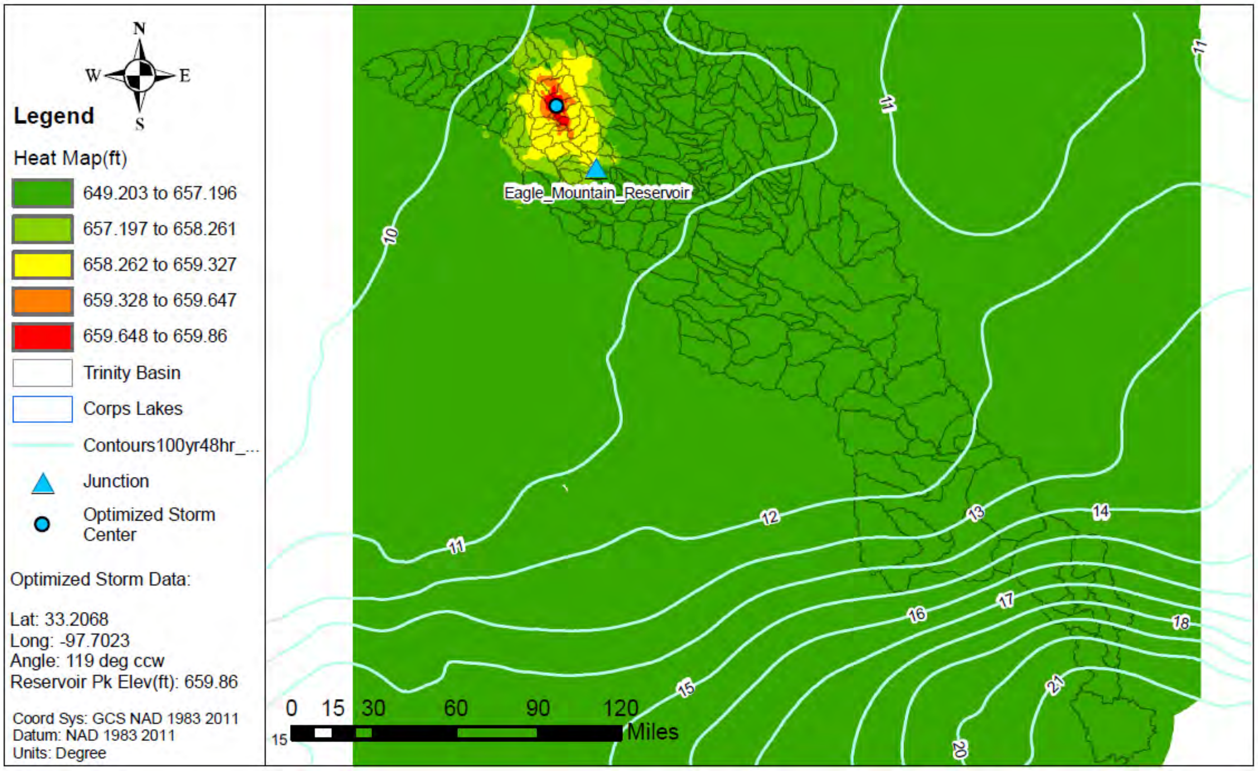


Figure 28a: Elliptical Storm Heat Map for the Eagle Mountain Reservoir

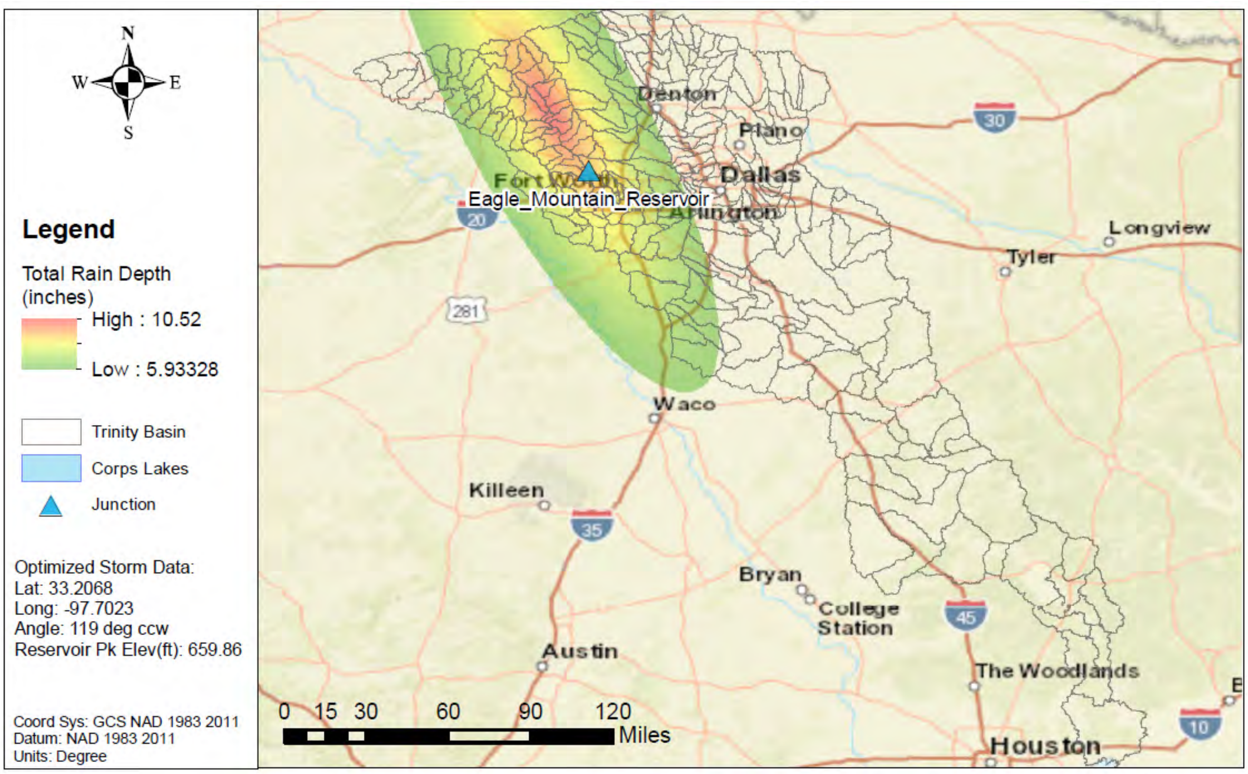


Figure 28b: NA14 1% AEP Elliptical Storm for the Eagle Mountain Reservoir

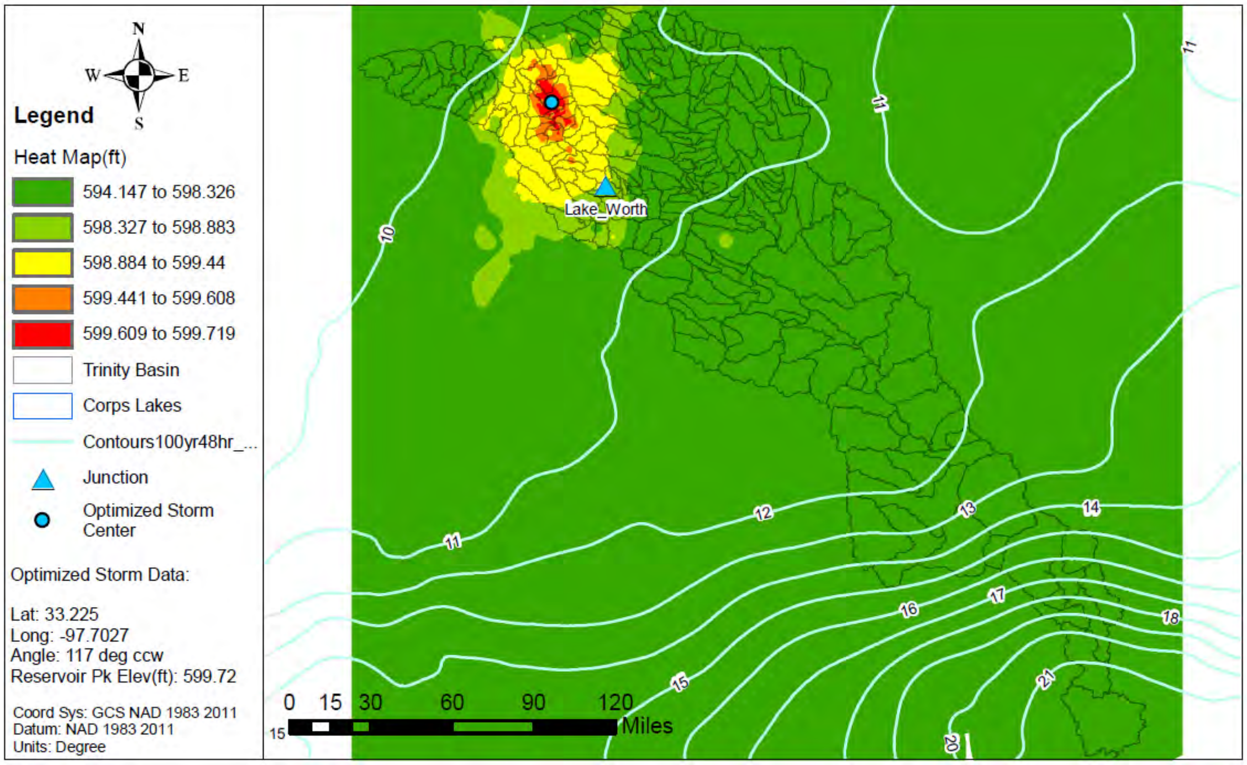


Figure 29a: Elliptical Storm Heat Map for the Lake Worth

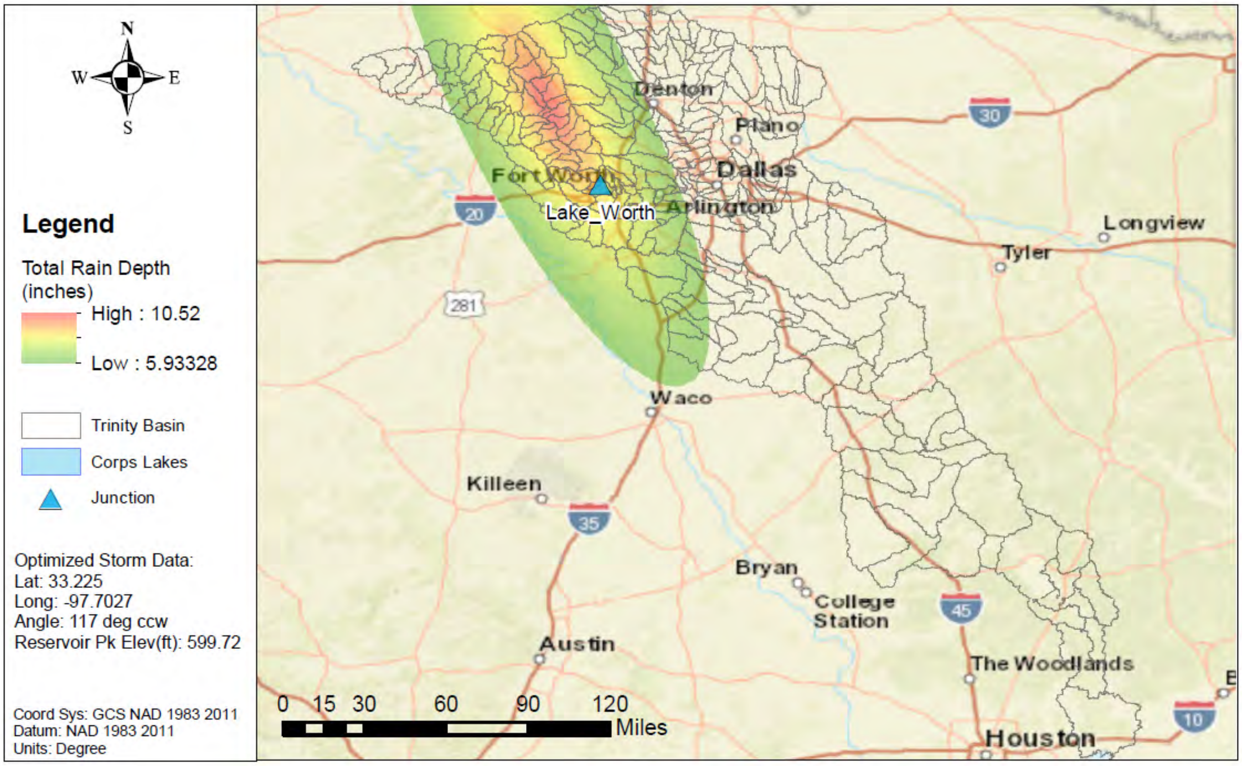


Figure 29b: NA14 1% AEP Elliptical Storm for the Lake Worth

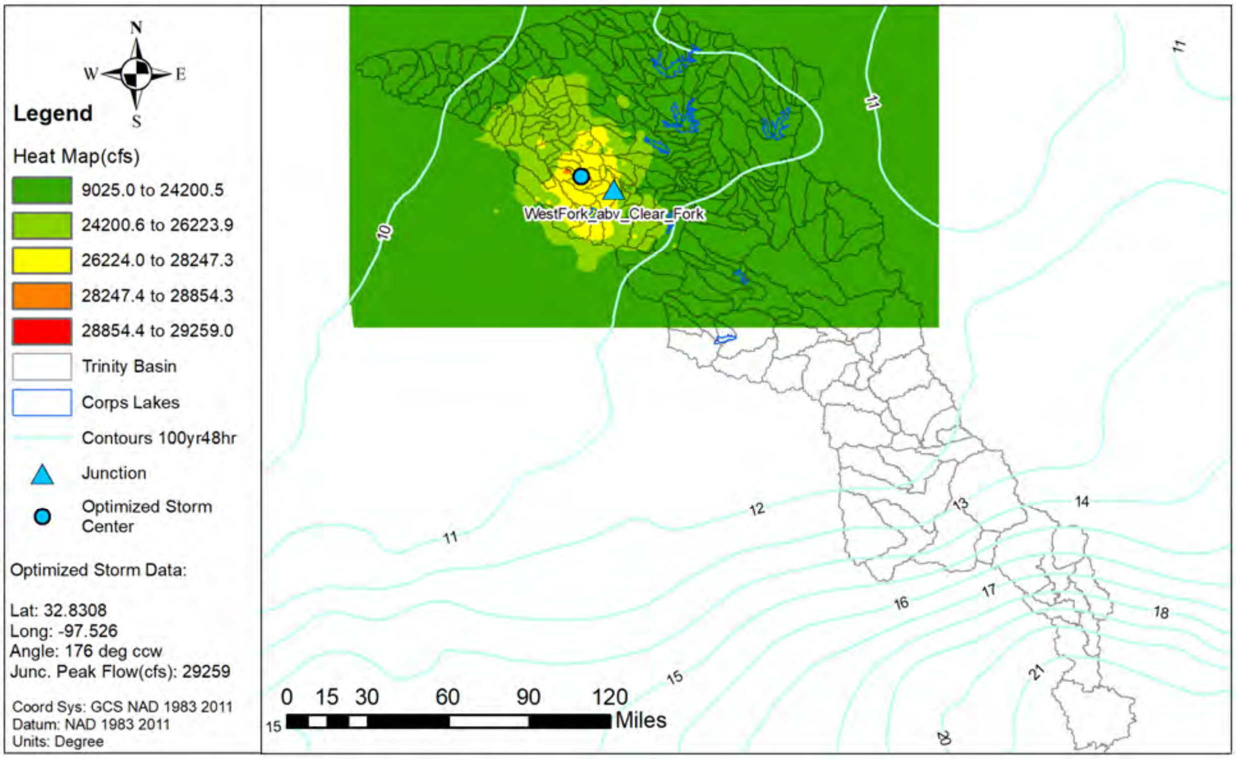


Figure 30a: Elliptical Storm Heat Map for the West Fork Trinity River above the Clear Fork

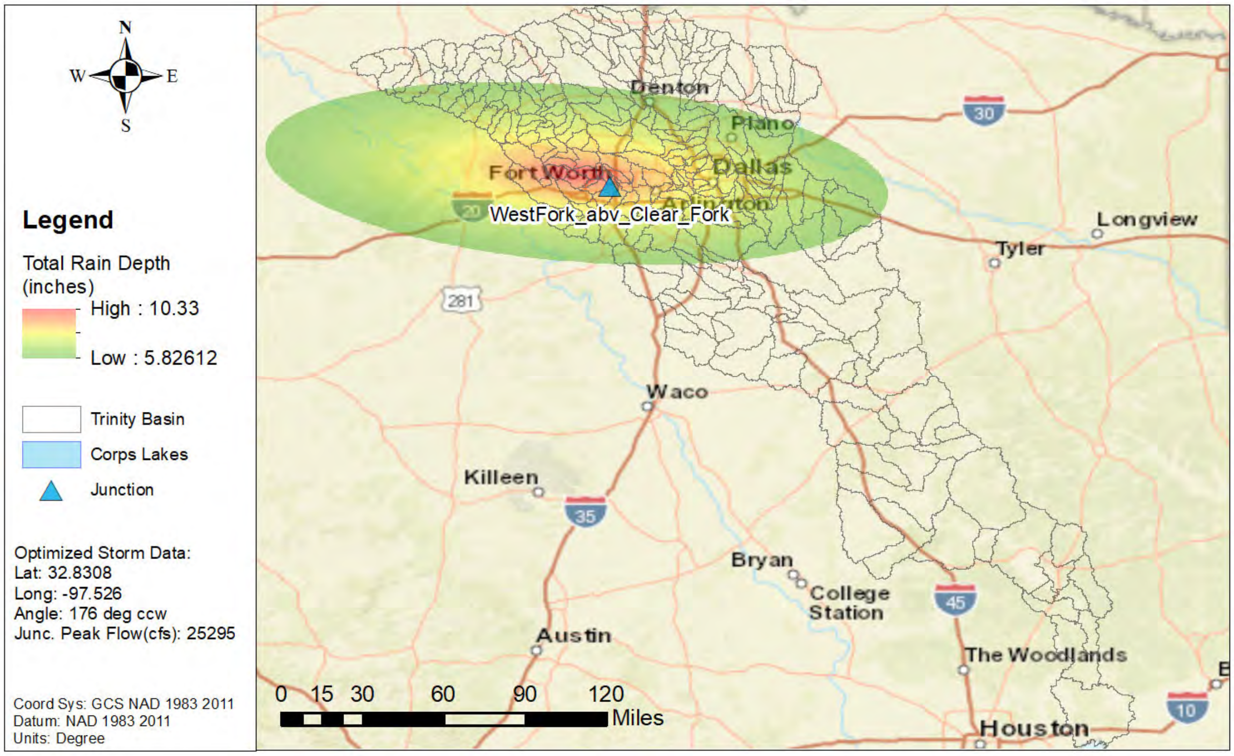


Figure 30b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above the Clear Fork

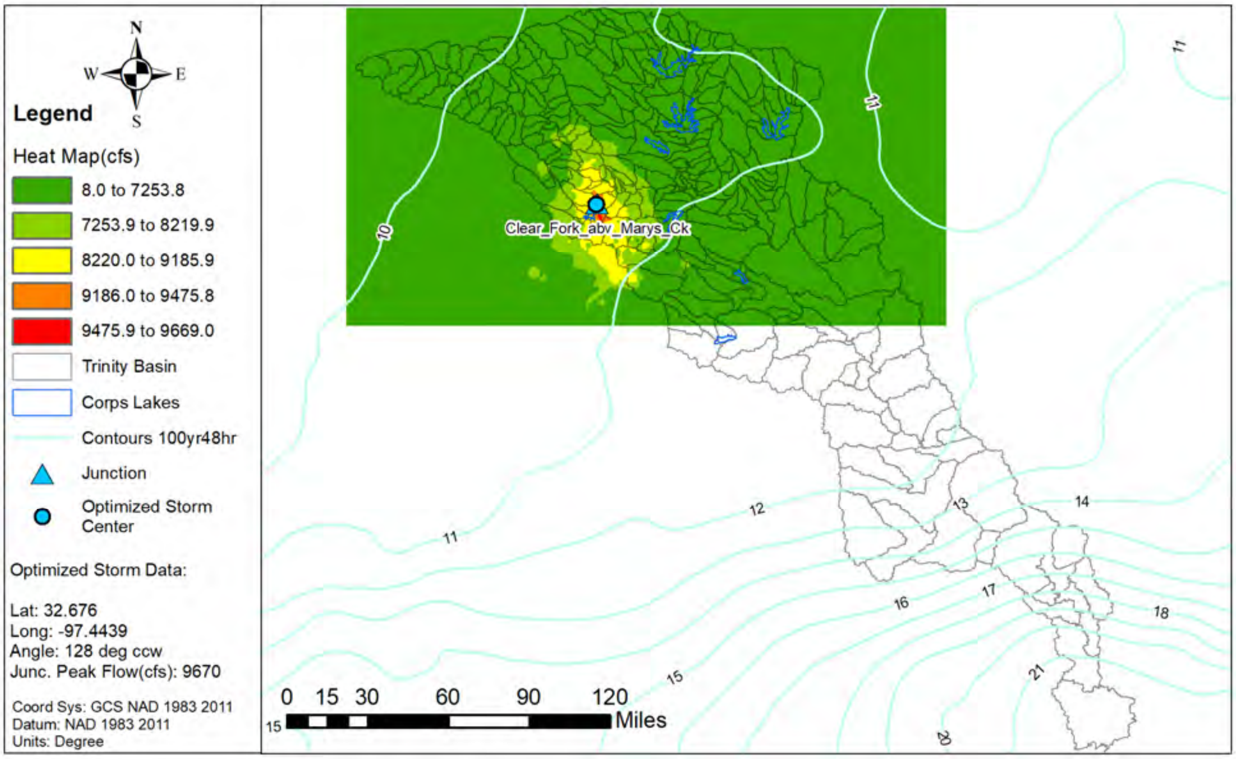


Figure 31a: Elliptical Storm Heat Map for the Clear Fork above Marys Creek

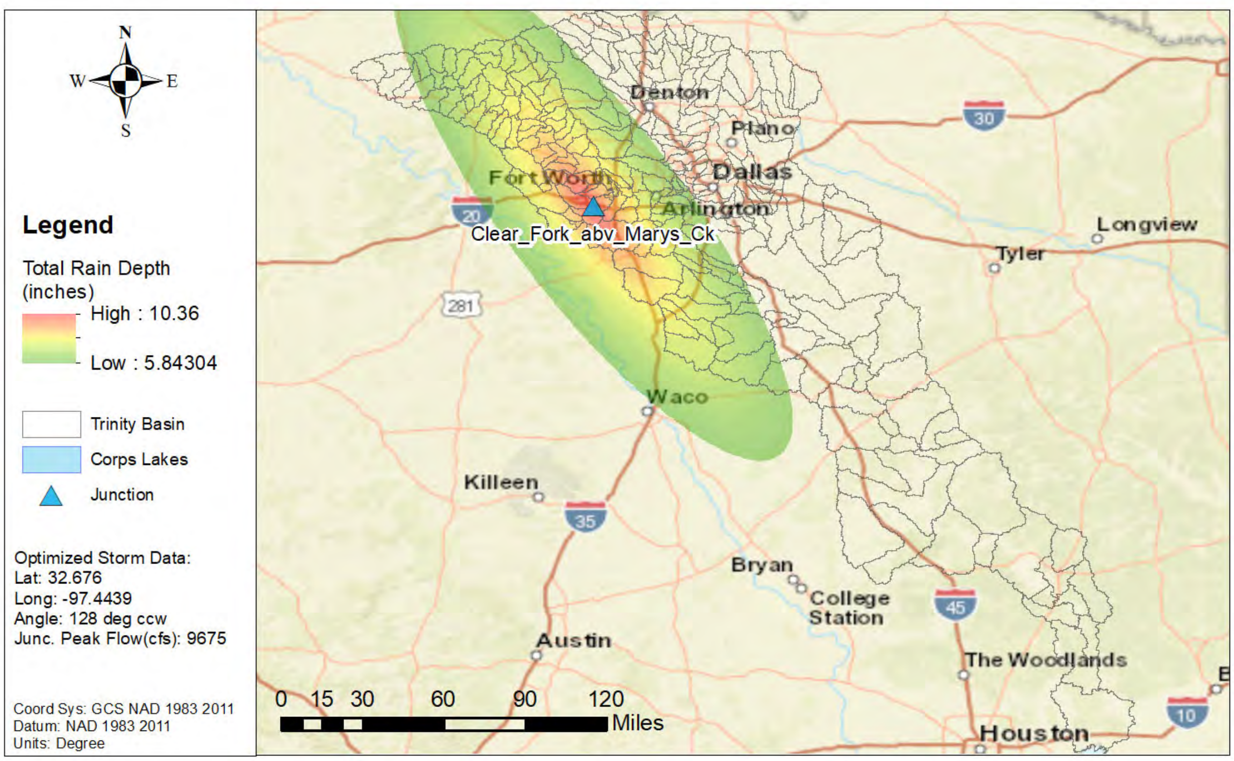


Figure 31b: NA14 1% AEP Elliptical Storm for the Clear Fork above Marys Creek

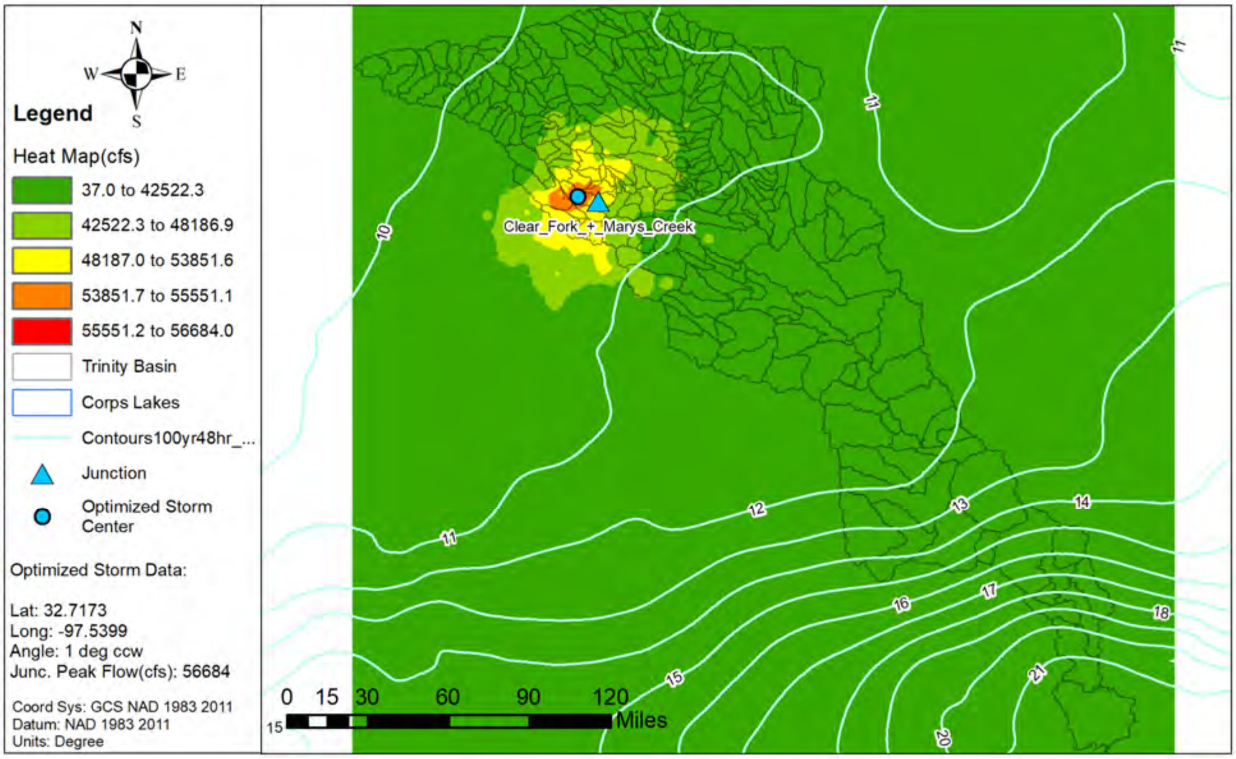


Figure 32a: Elliptical Storm Heat Map for the Clear Fork below Marys Creek

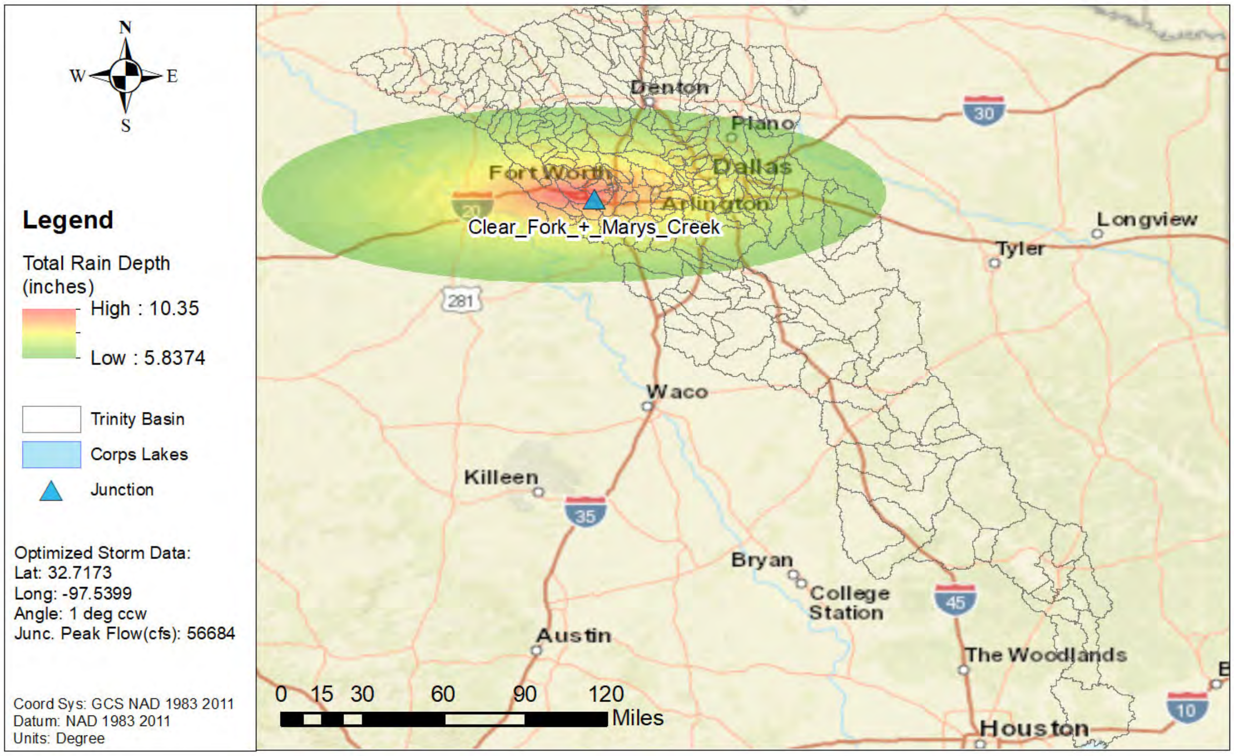


Figure 32b: NA14 1% AEP Elliptical Storm for the Clear Fork below Marys Creek

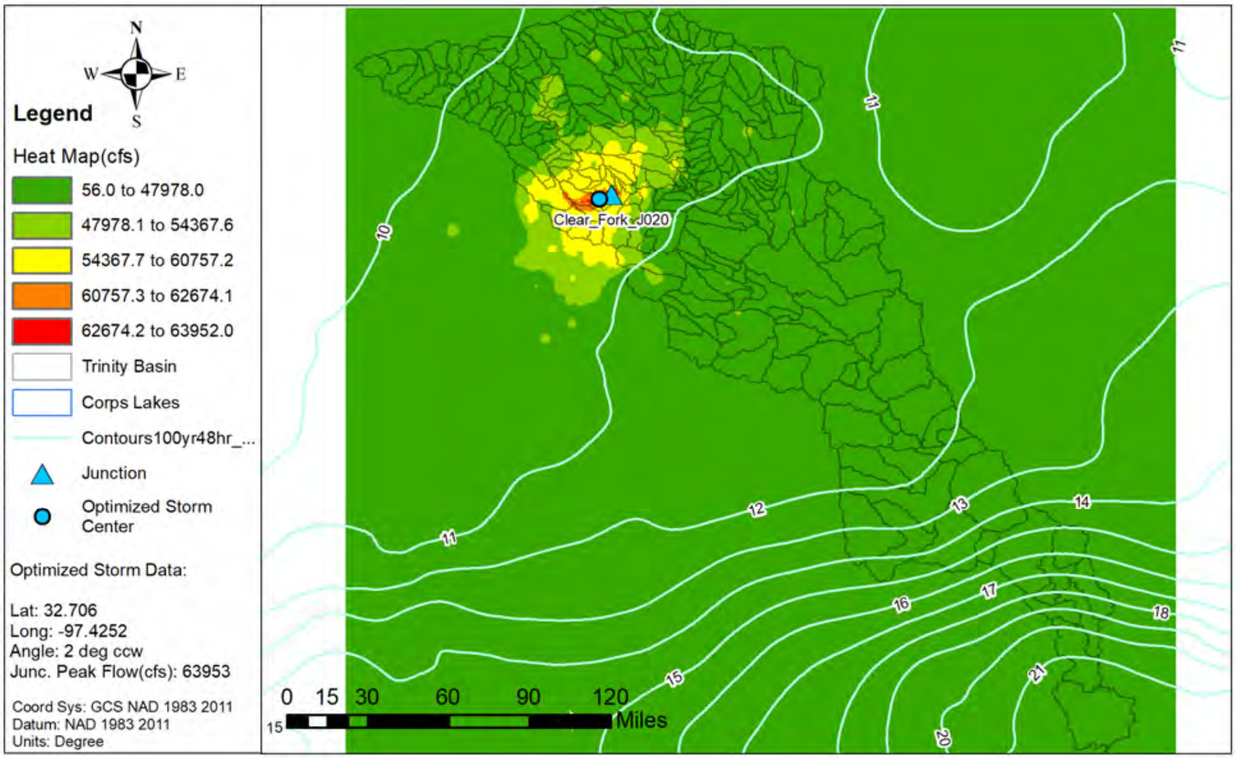


Figure 33a: Elliptical Storm Heat Map for the Clear Fork Trinity River at Fort Worth USGS gage

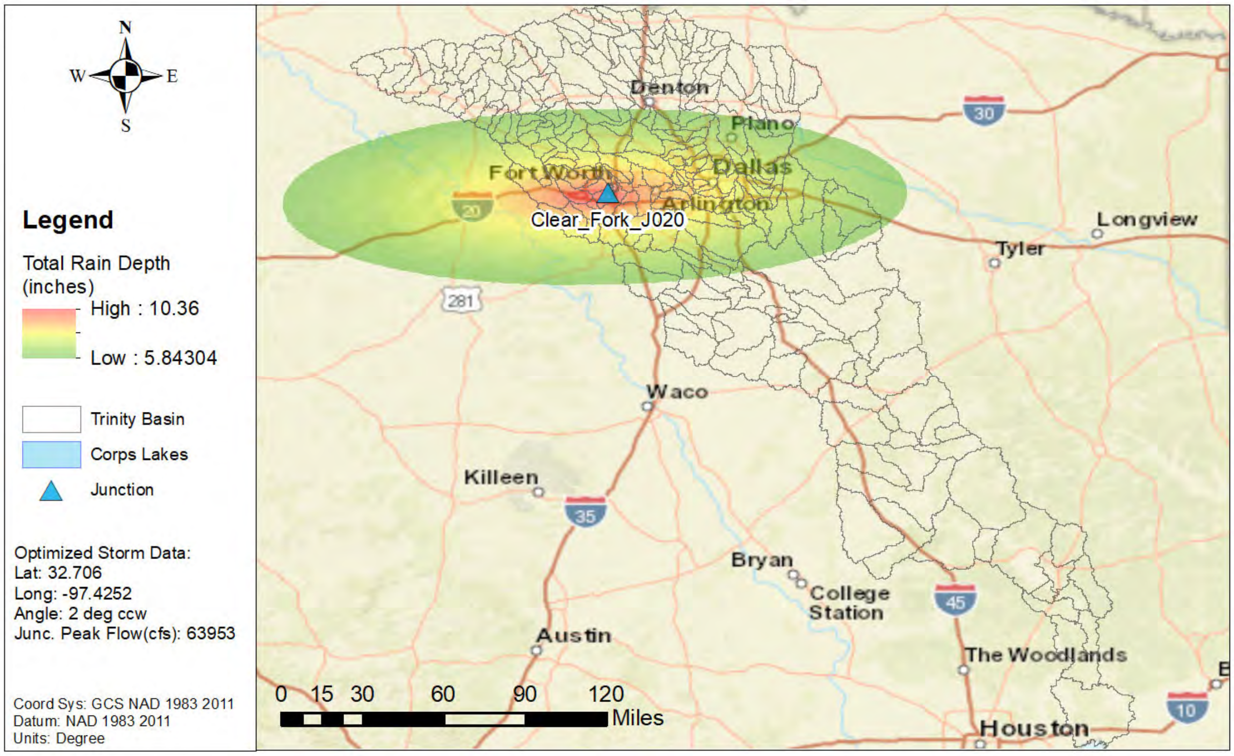


Figure 33b: NA14 1% AEP Elliptical Storm for the Clear Fork Trinity River at Fort Worth USGS gage

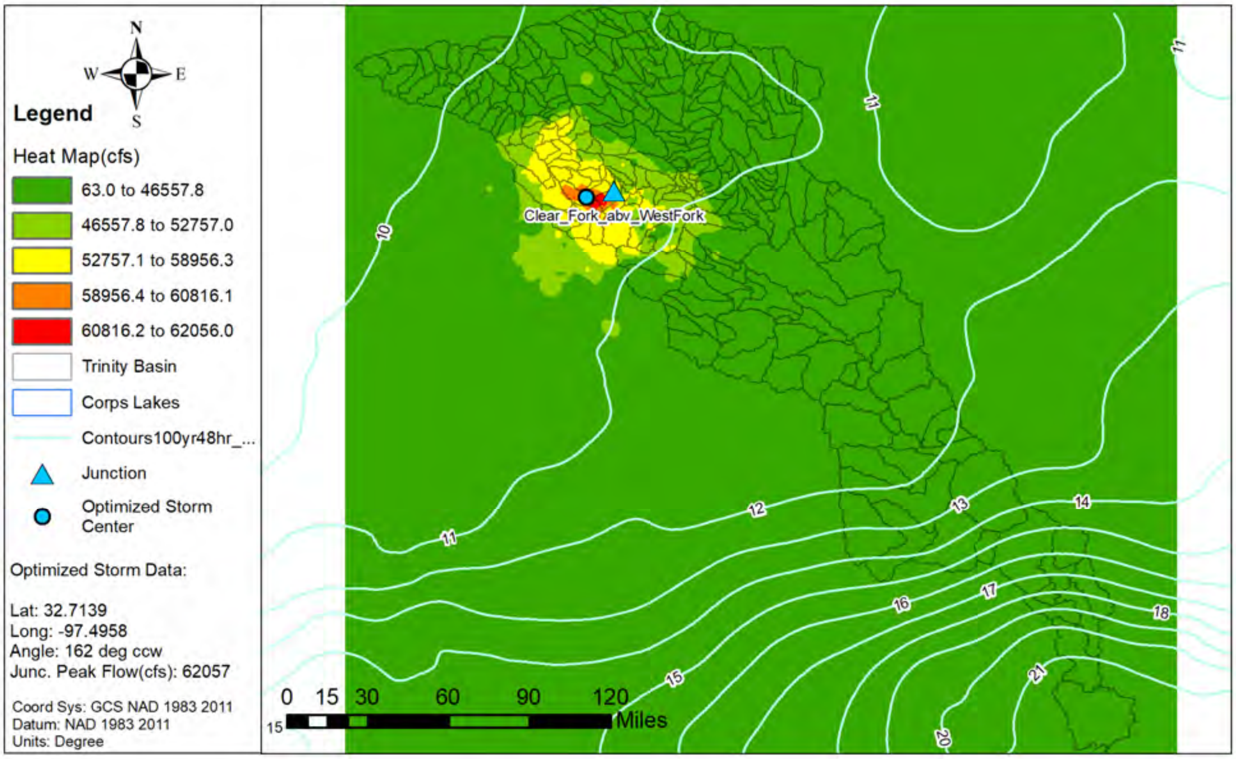


Figure 34a: Elliptical Storm Heat Map for the Clear Fork Trinity River above the West Fork

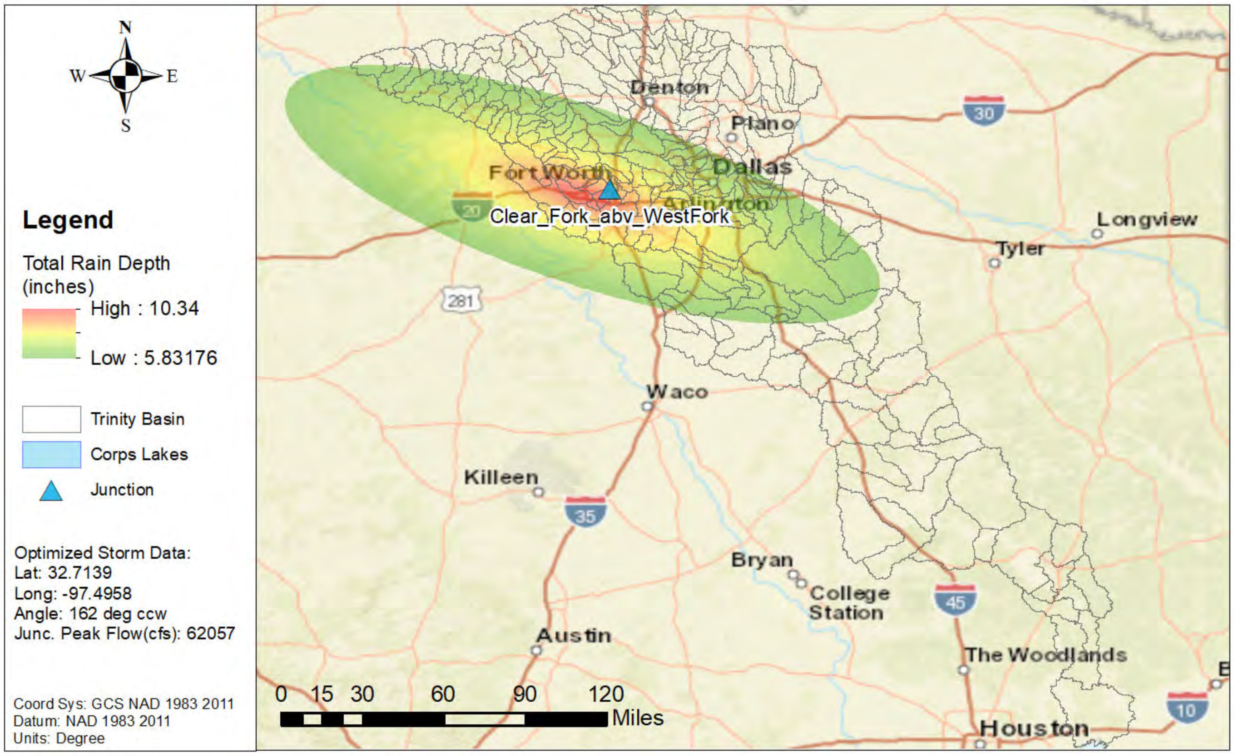


Figure 34b: NA14 1% AEP Elliptical Storm for the Clear Fork Trinity River above the West Fork

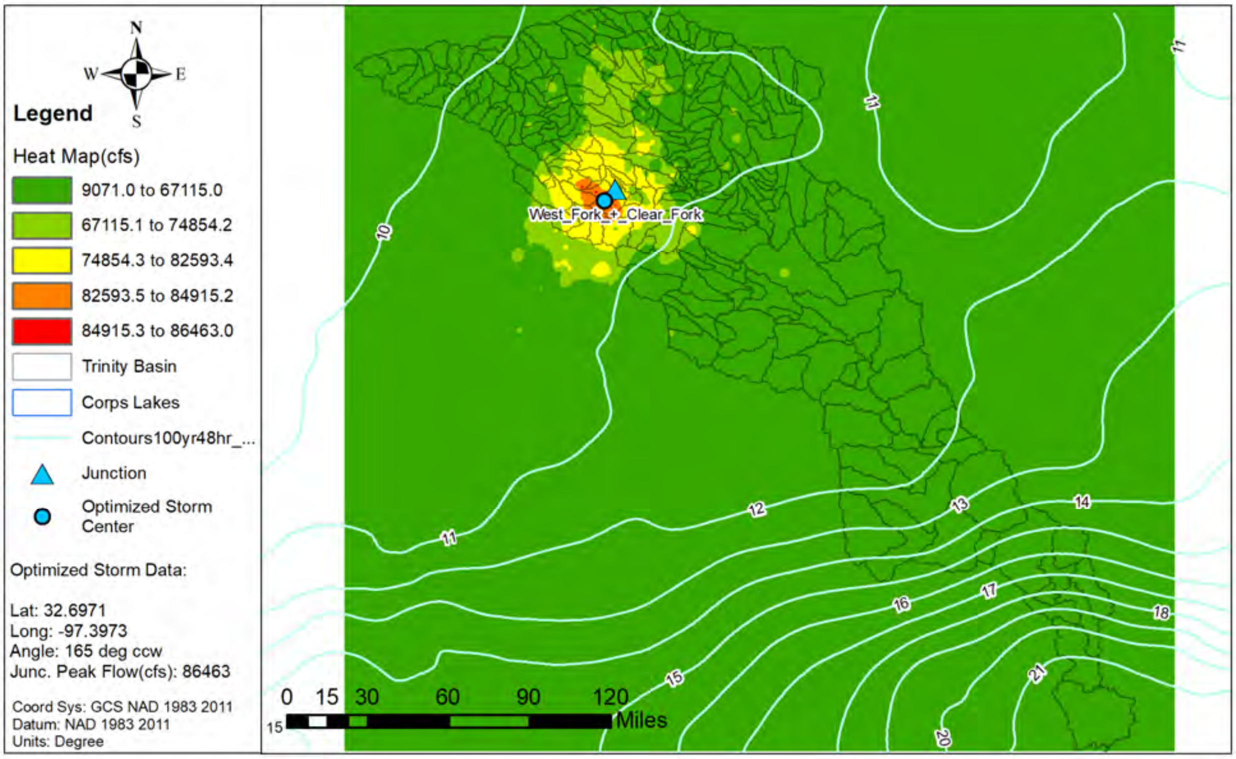


Figure 35a: Elliptical Storm Heat Map for the West Fork Trinity River below the Clear Fork

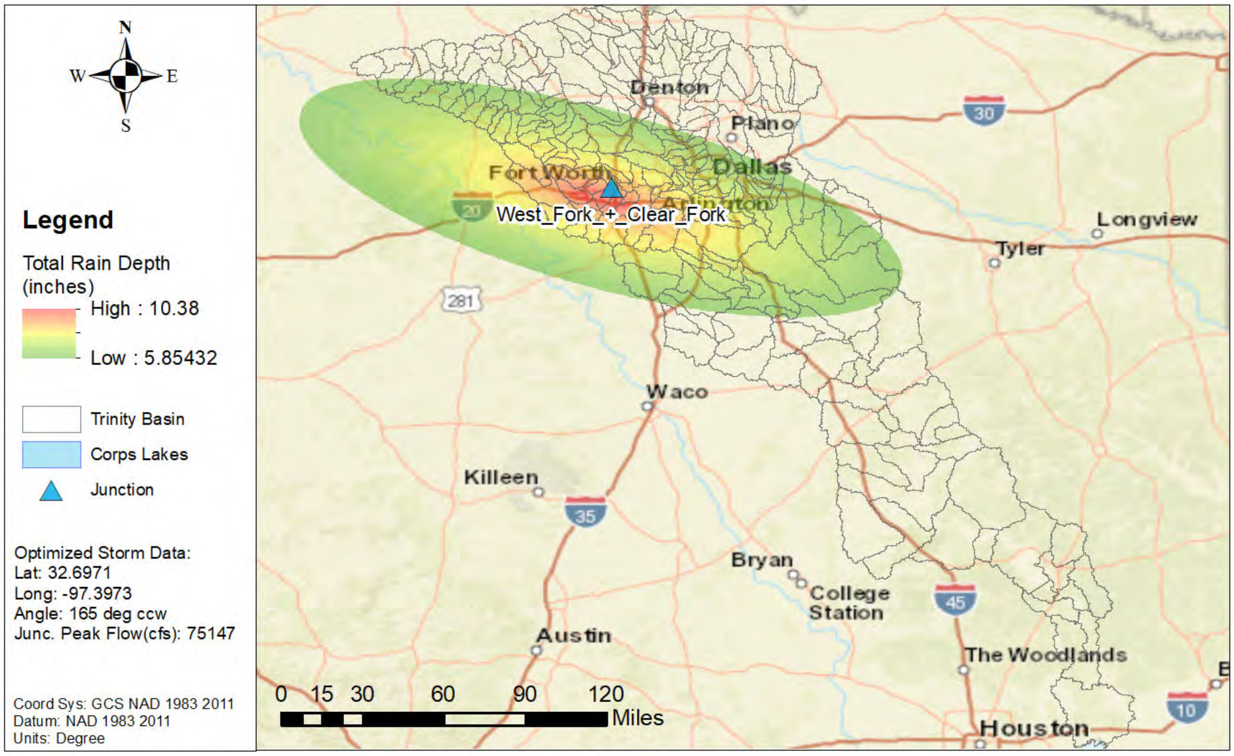


Figure 35b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below the Clear Fork

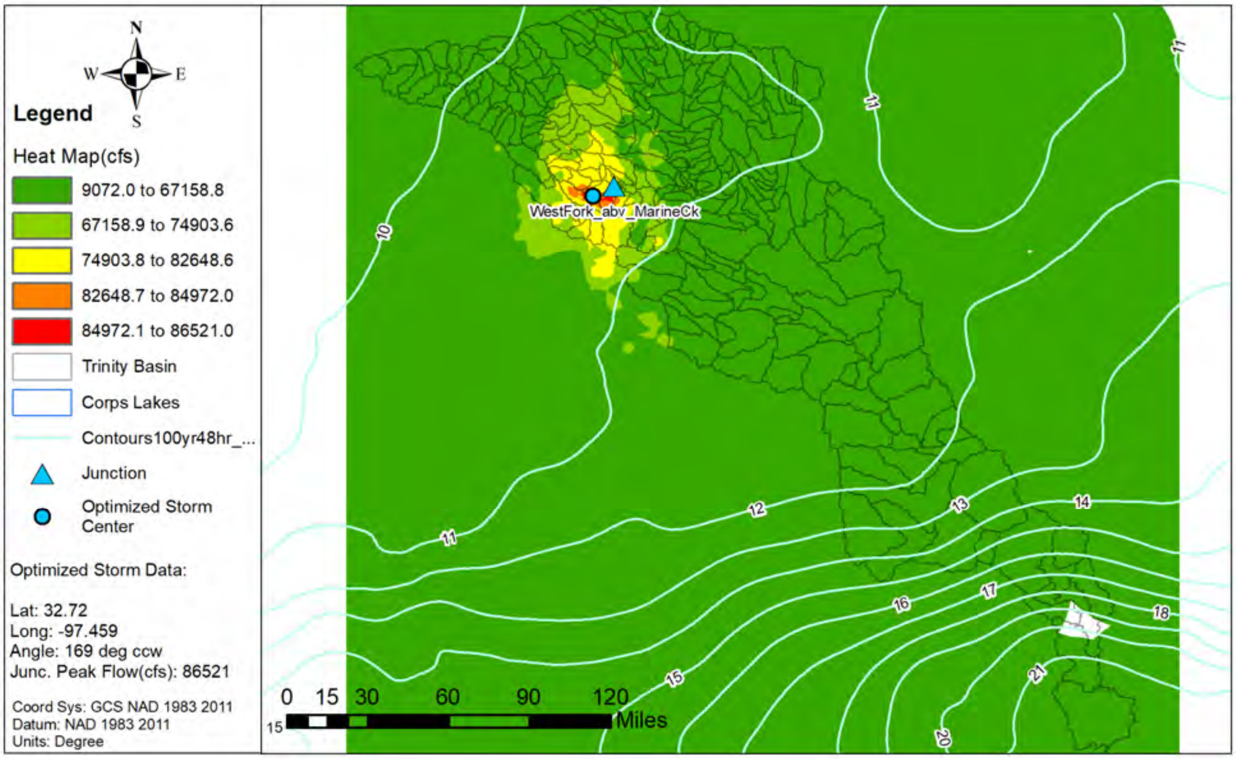


Figure 36a: Elliptical Storm Heat Map for the West Fork Trinity River above Marine Creek

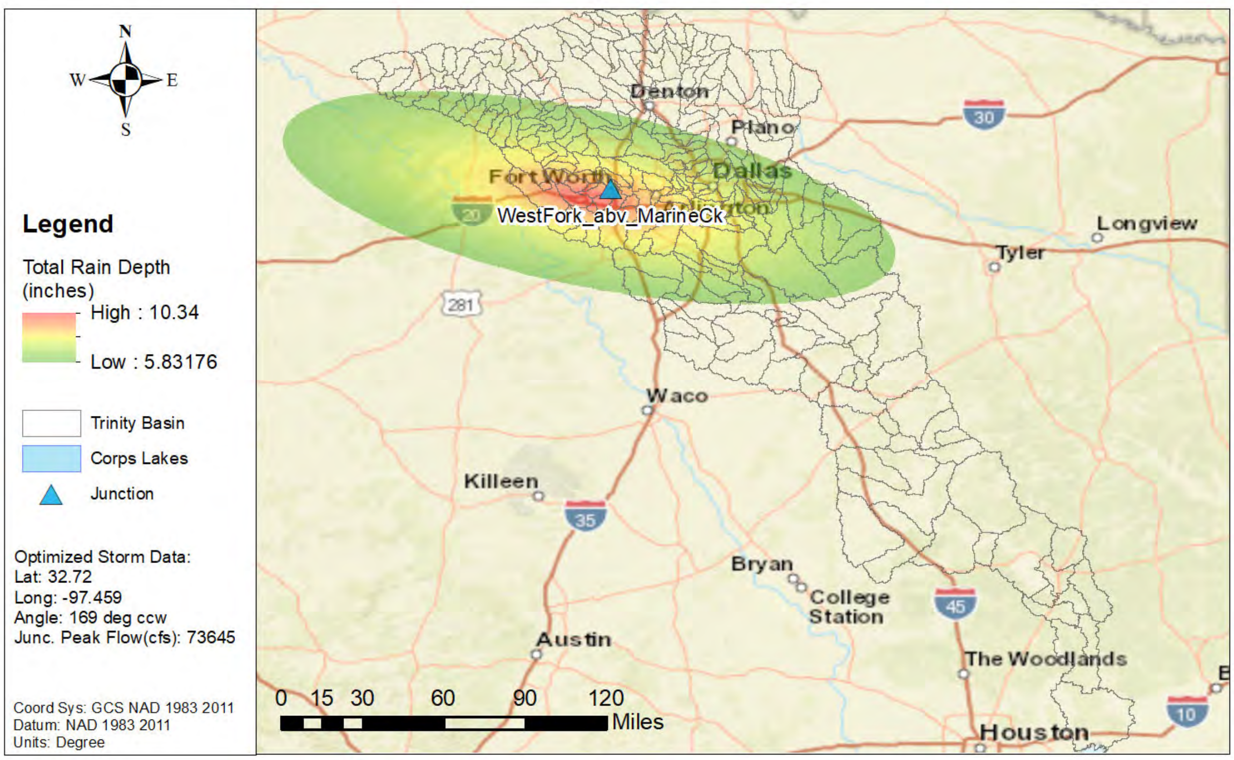


Figure 36b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Marine Creek

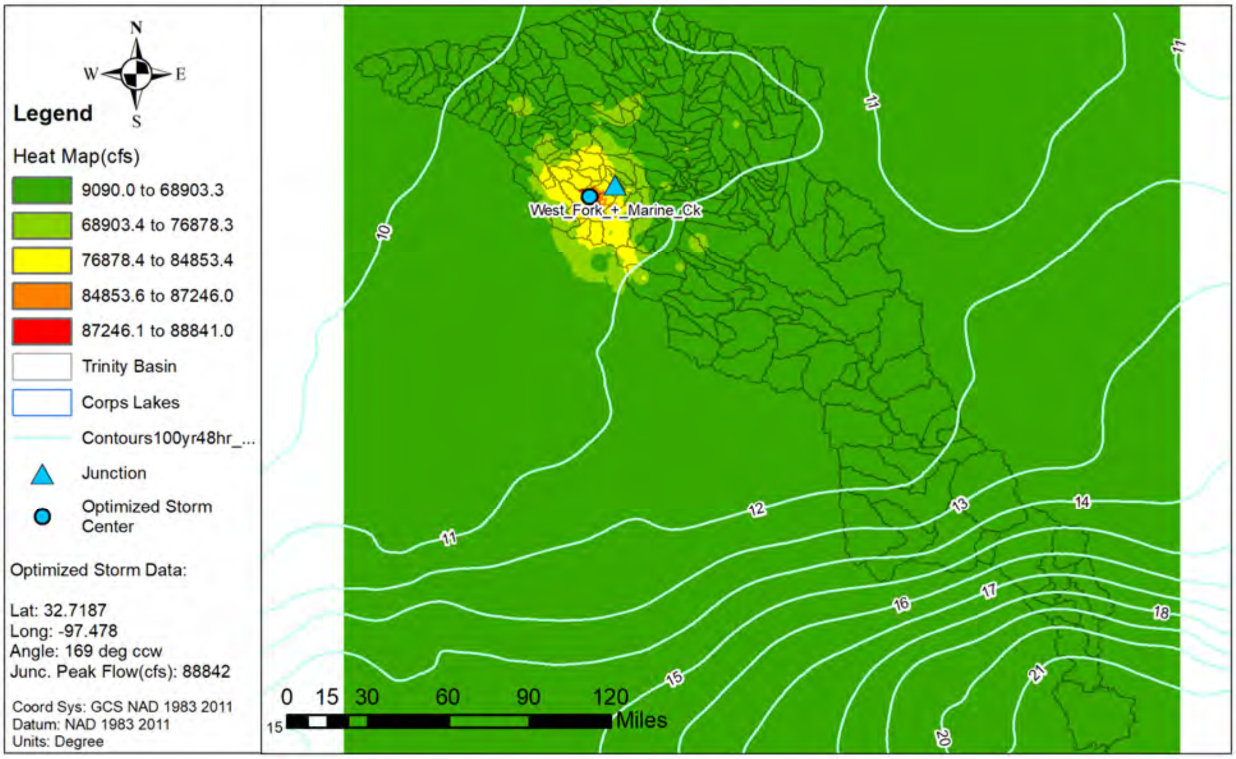


Figure 37a: Elliptical Storm Heat Map for the West Fork Trinity River below Marine Creek

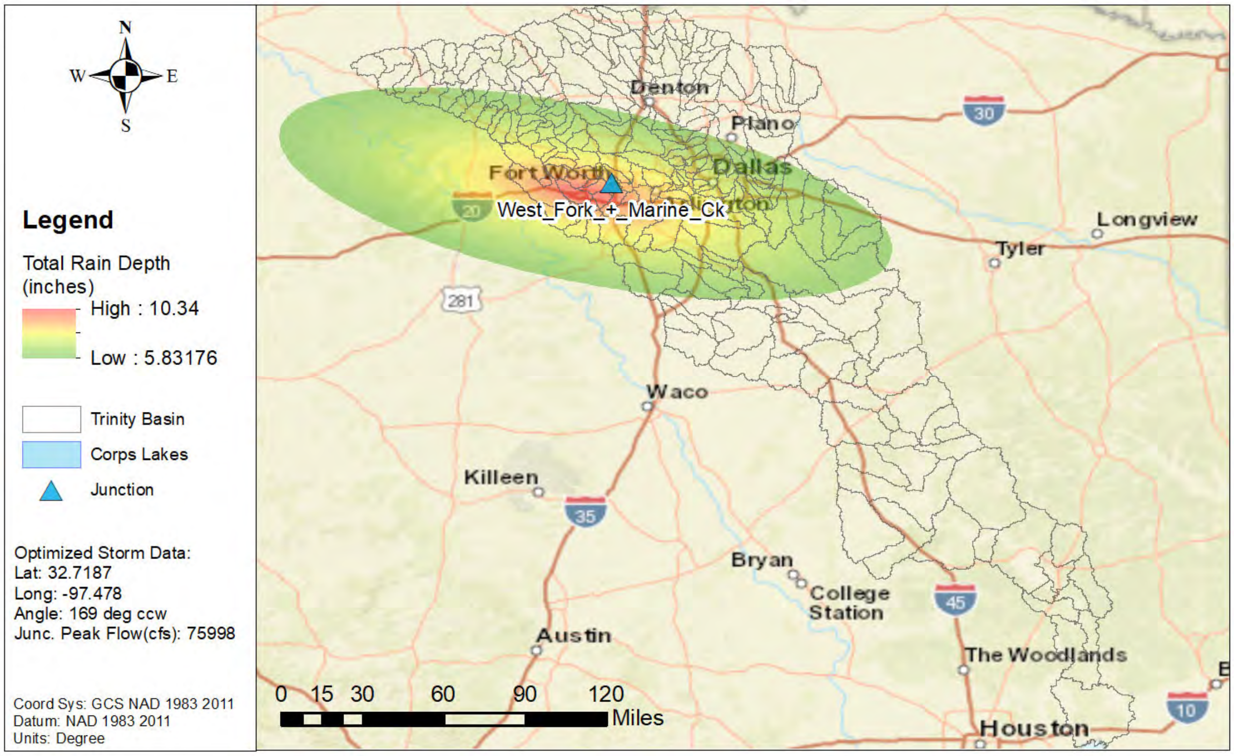


Figure 37b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Marine Creek

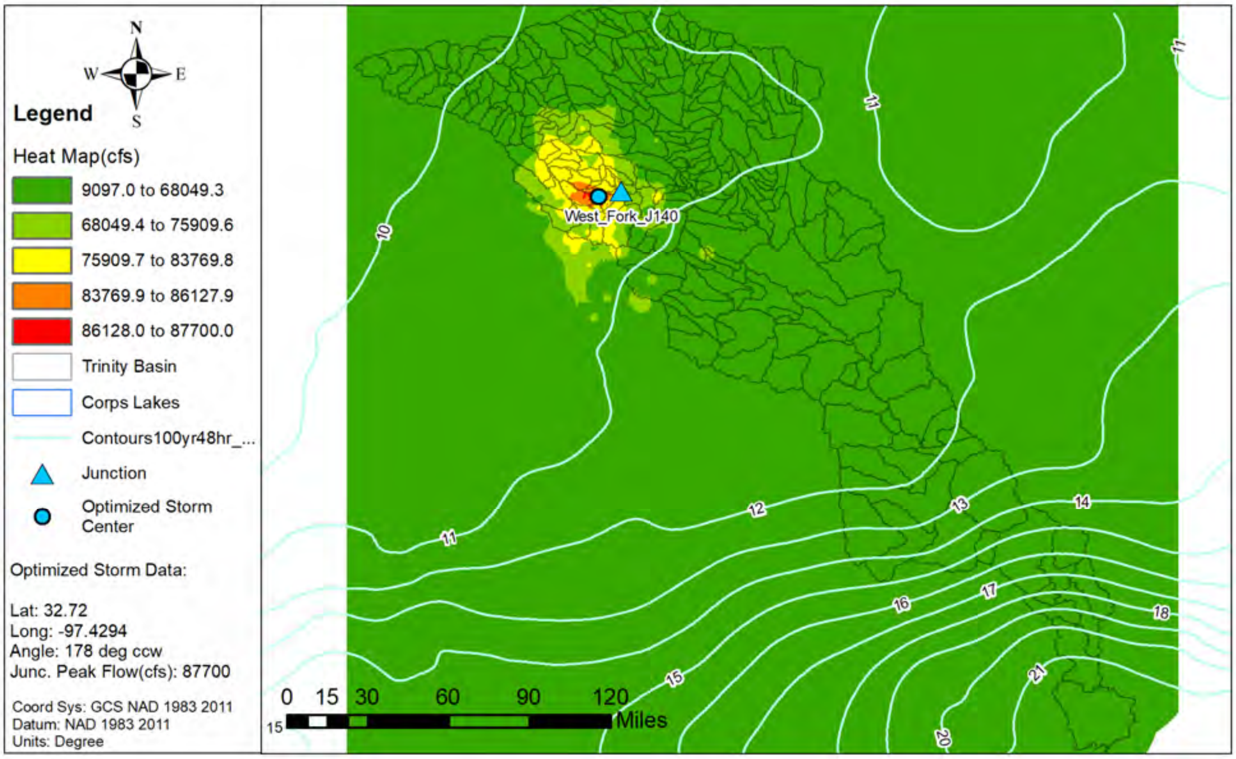


Figure 38a: Elliptical Storm Heat Map for the West Fork Trinity River above Sycamore Creek

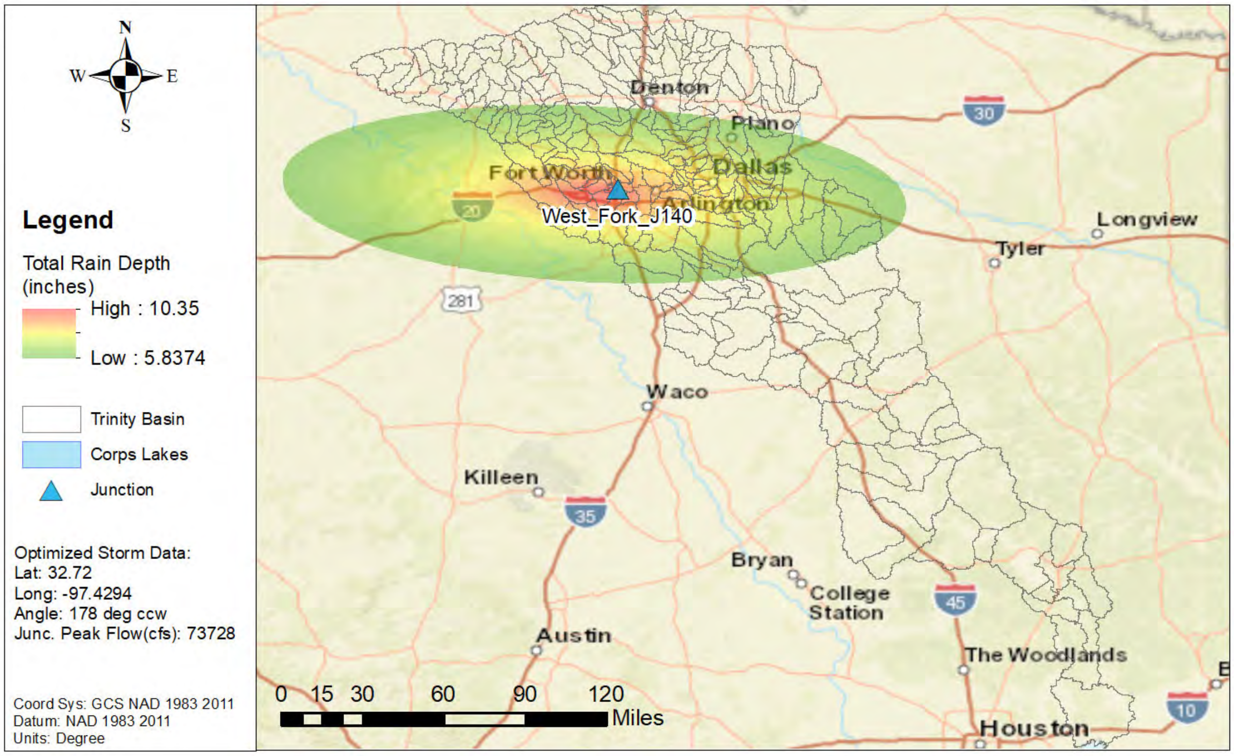


Figure 38b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Sycamore Creek

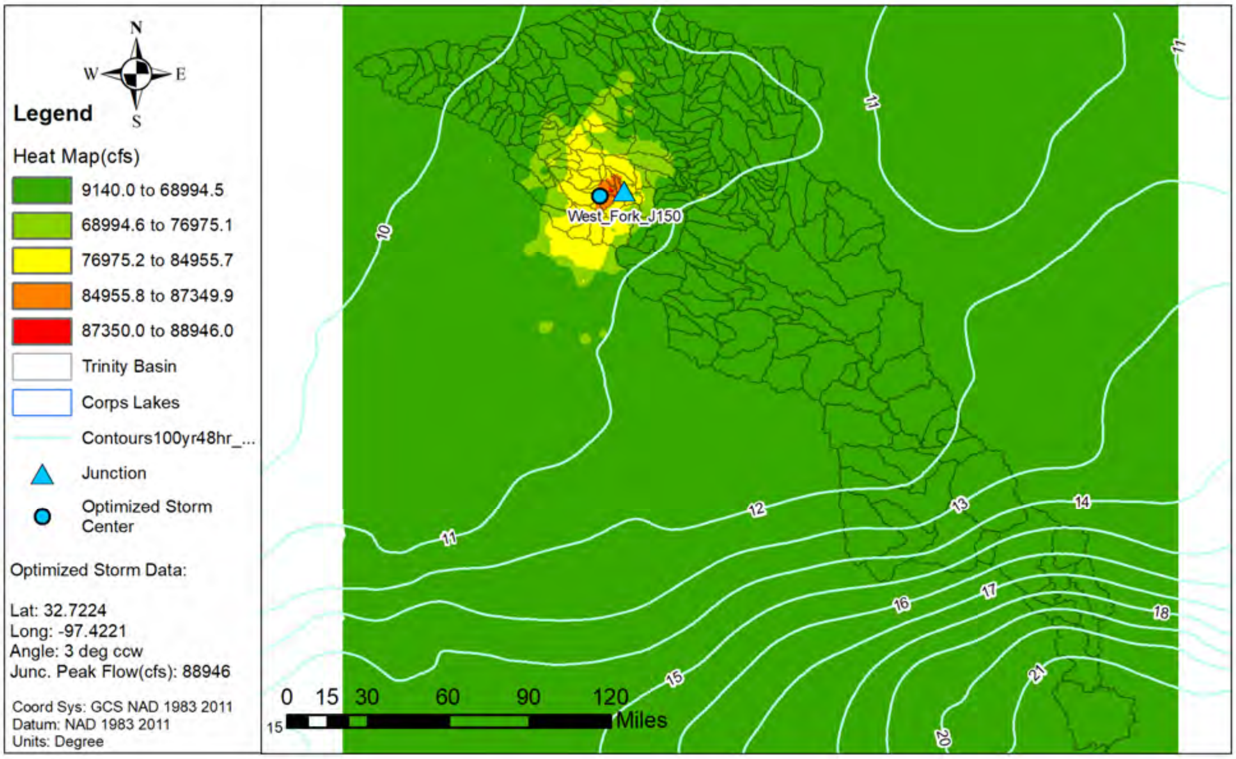


Figure 39a: Elliptical Storm Heat Map for the West Fork Trinity River below Sycamore Creek

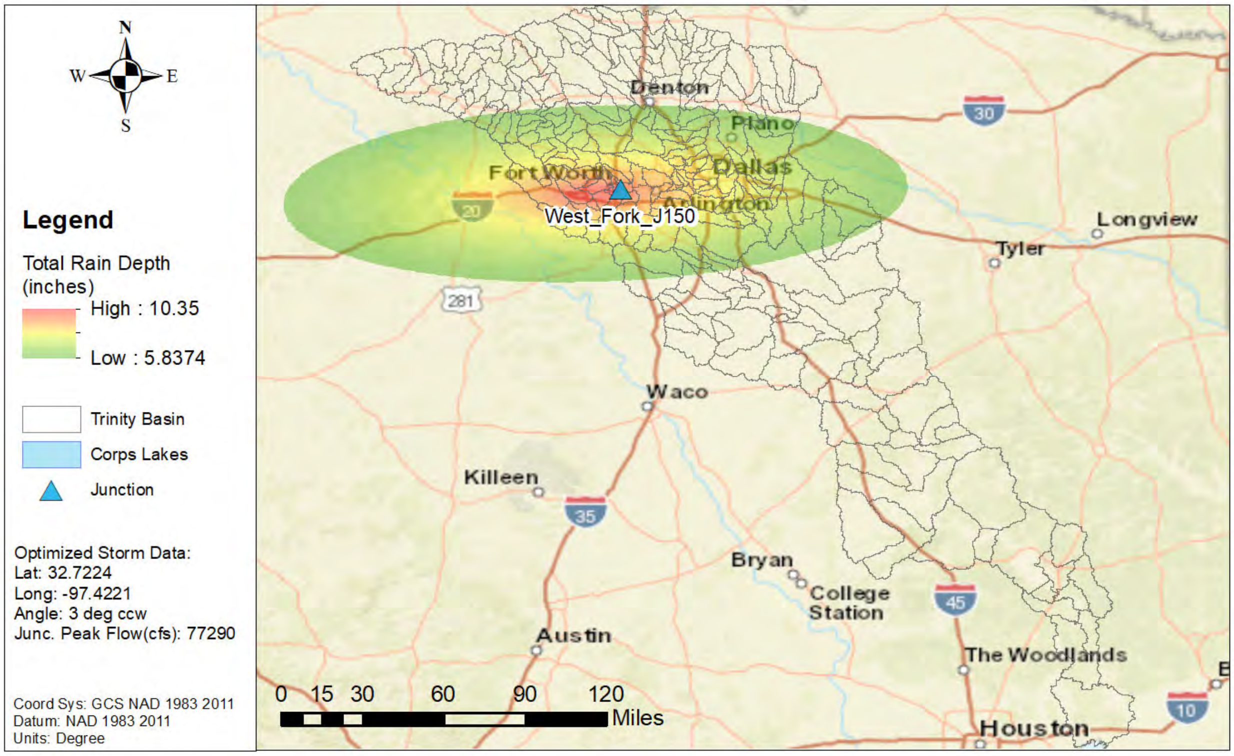


Figure 39b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Sycamore Creek

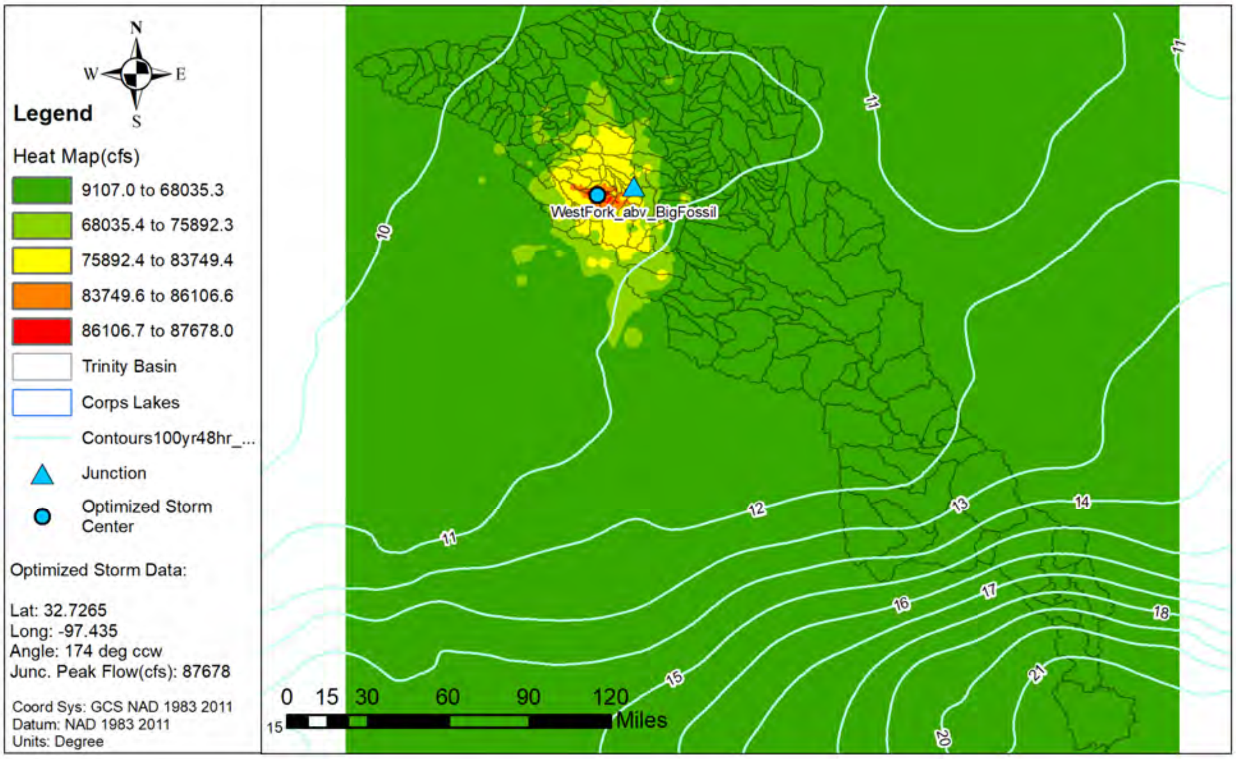


Figure 40a: Elliptical Storm Heat Map for the West Fork above Big Fossil

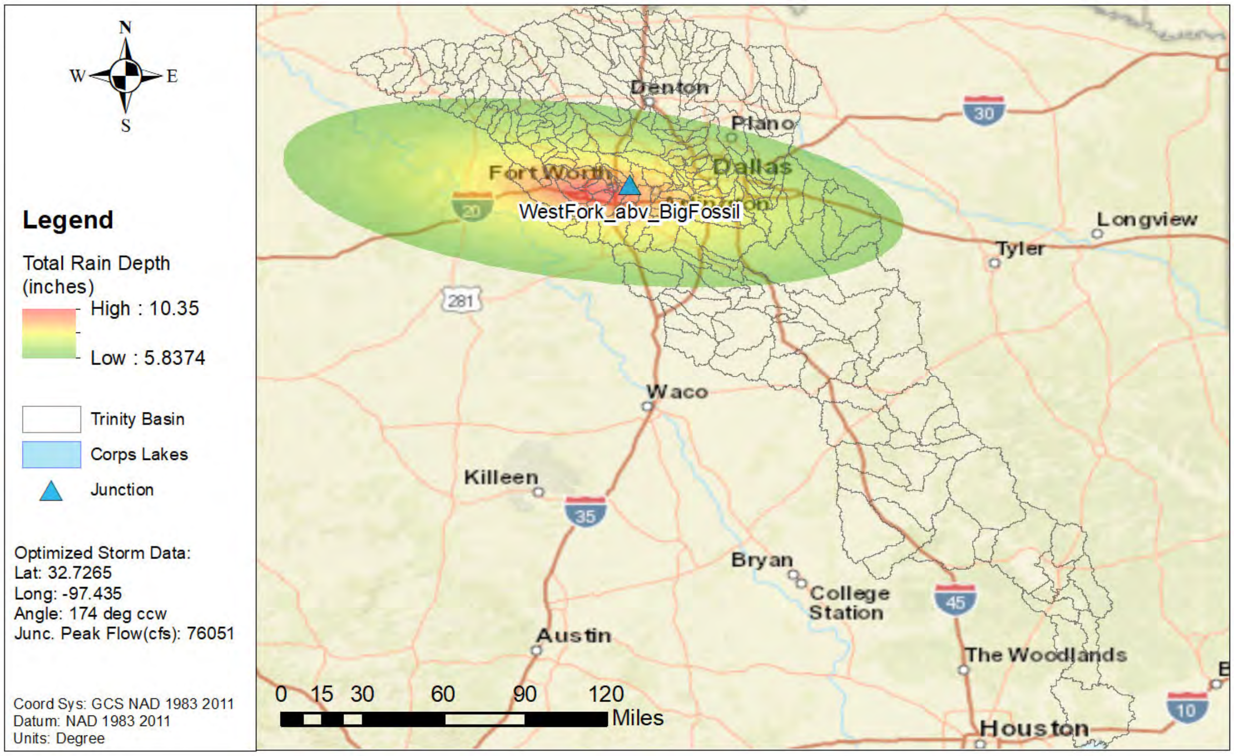


Figure 40b: NA14 1% AEP Elliptical Storm for the West Fork above Big Fossil

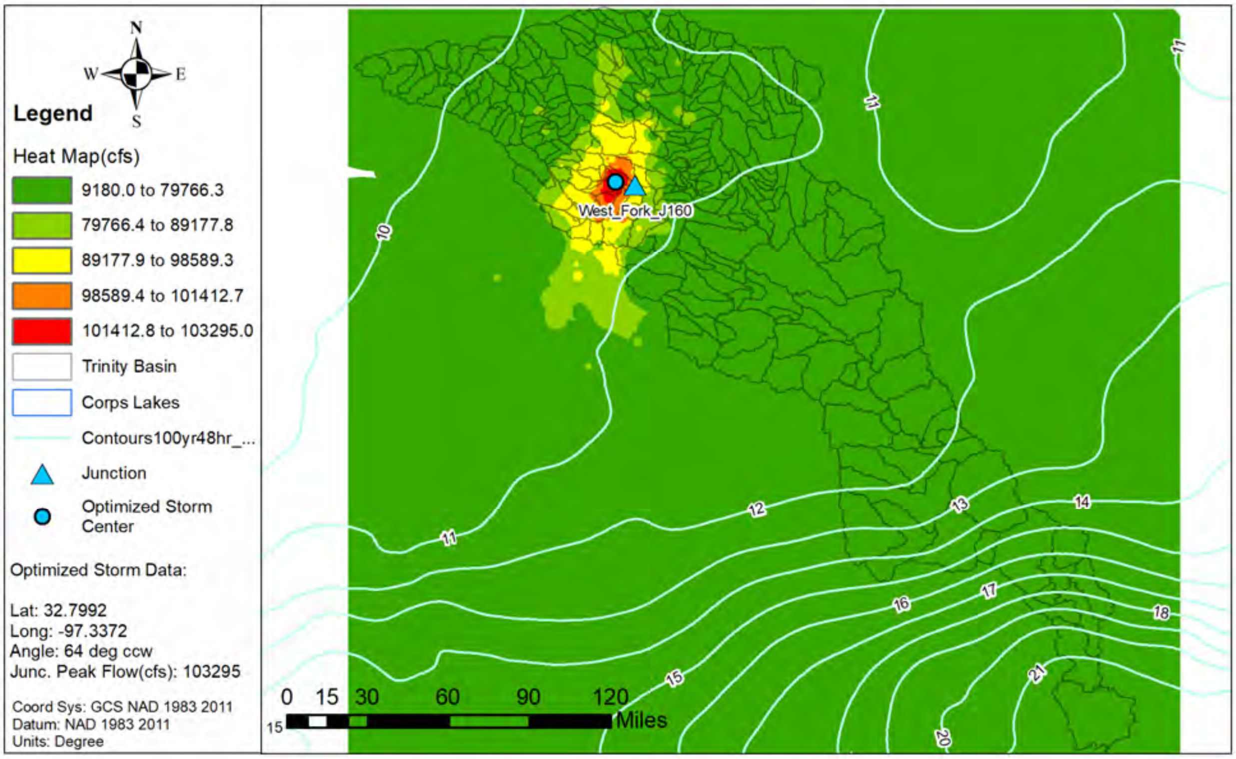


Figure 41a: Elliptical Storm Heat Map for the West Fork Trinity River and Big Fossil Creek Confluence

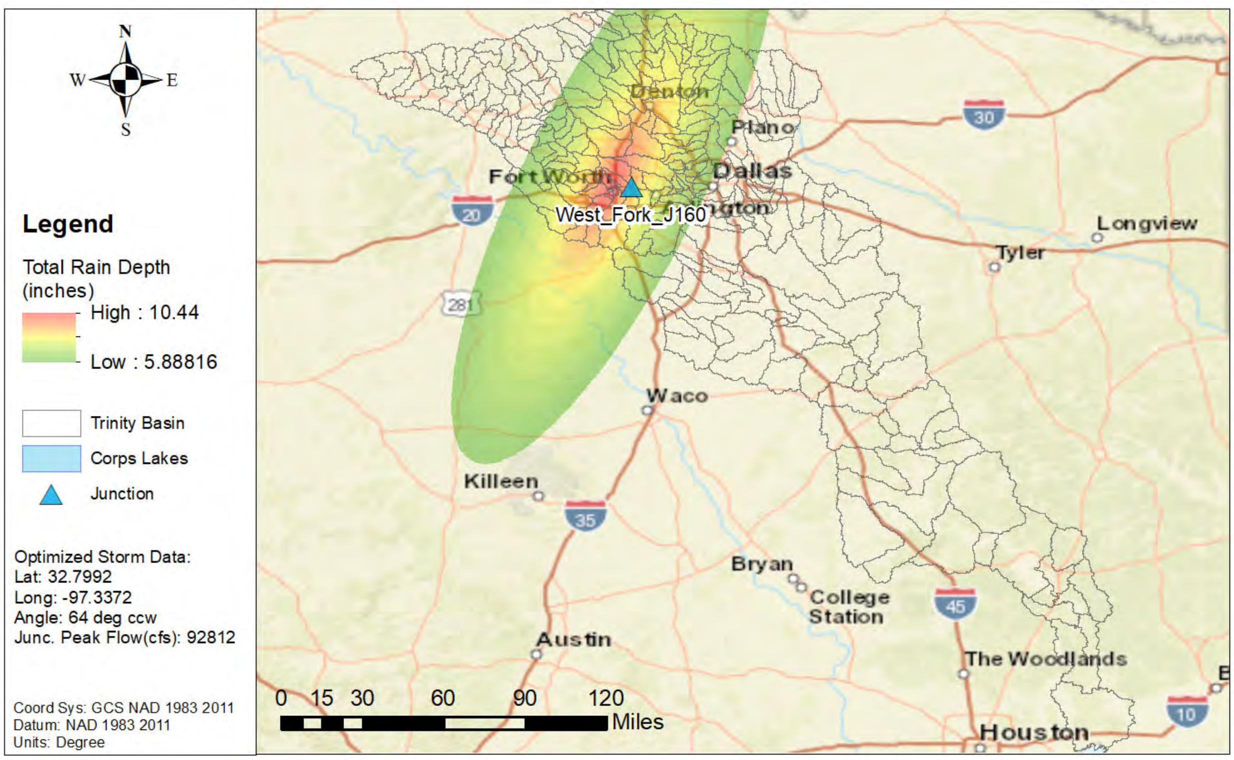


Figure 41b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River and Big Fossil Creek Confluence

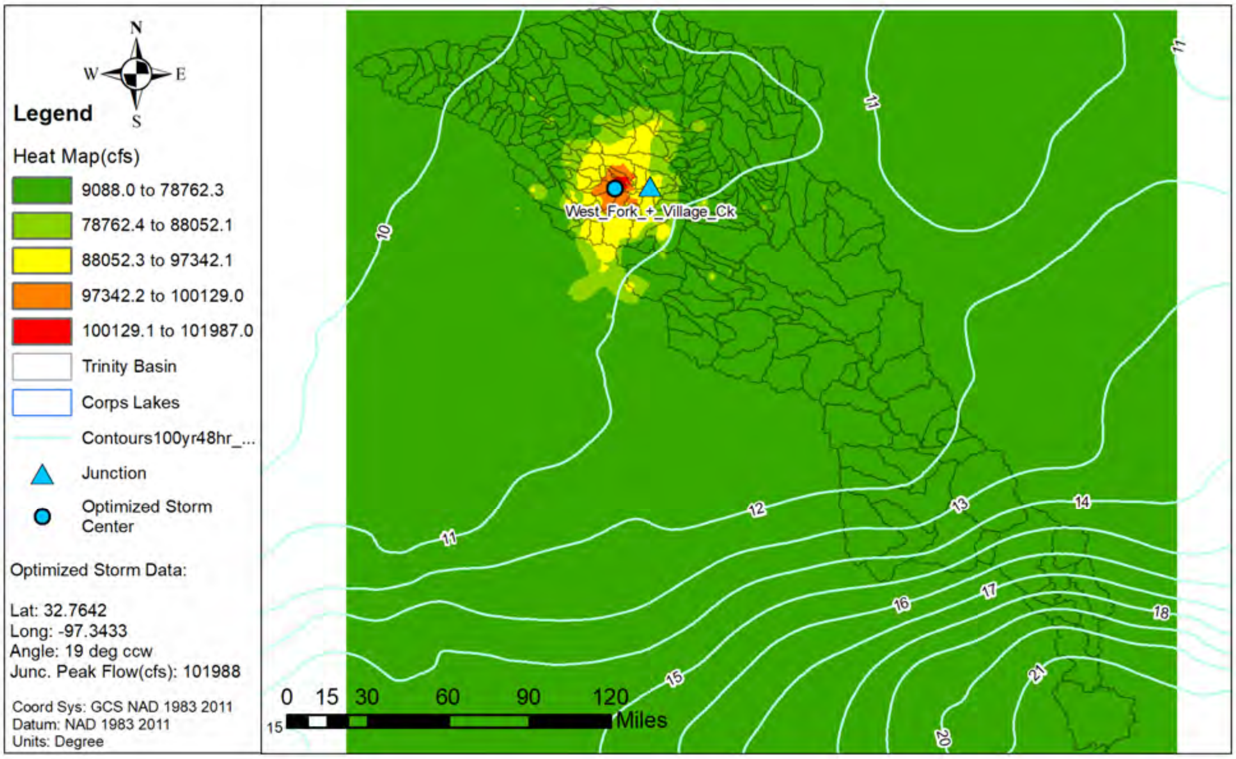


Figure 42a: Elliptical Storm Heat Map for the West Fork Trinity River below Village Creek

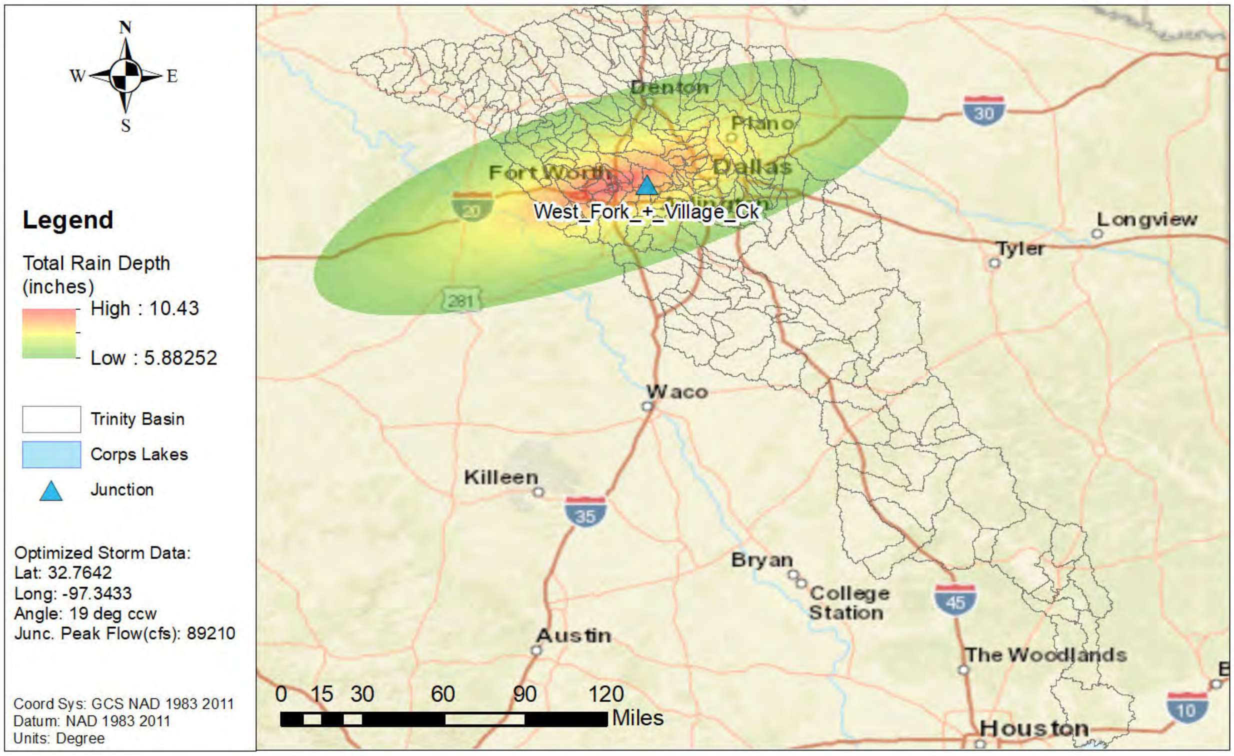


Figure 42b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Village Creek

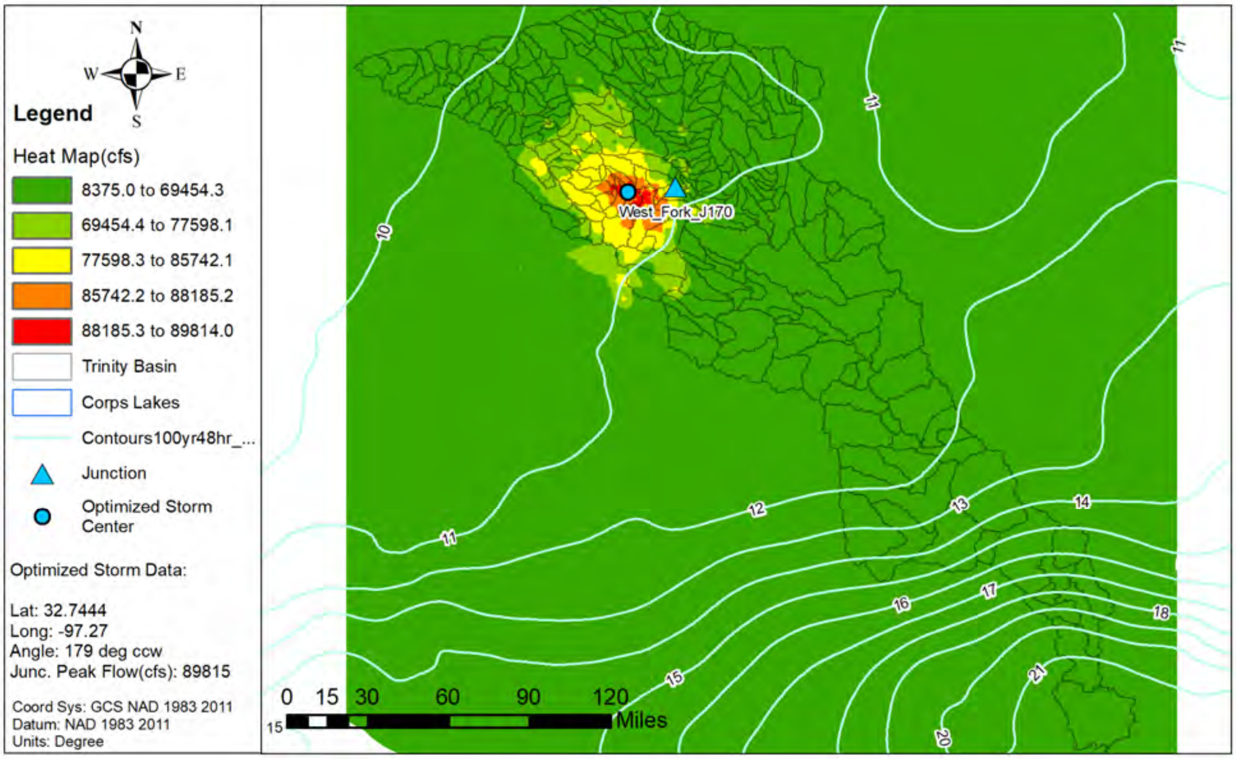


Figure 43a: Elliptical Storm Heat Map for the West Fork Trinity River below Johnson Creek

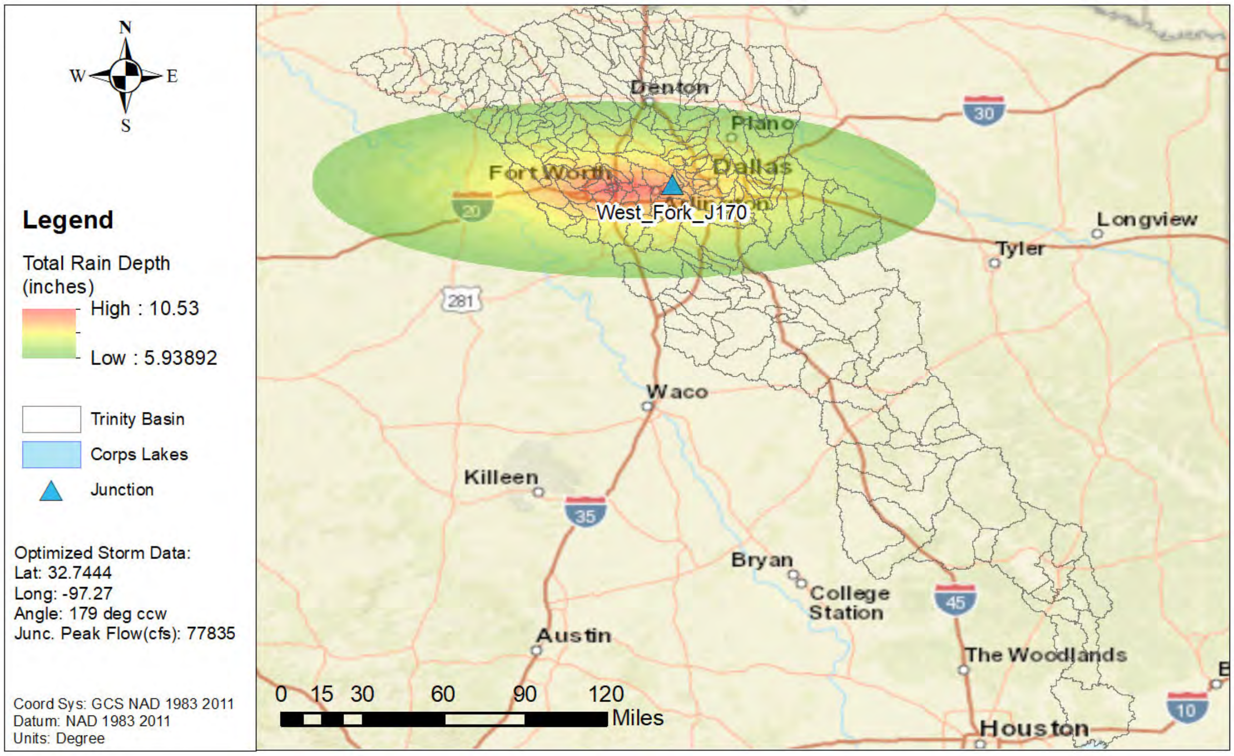


Figure 43b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Johnson Creek

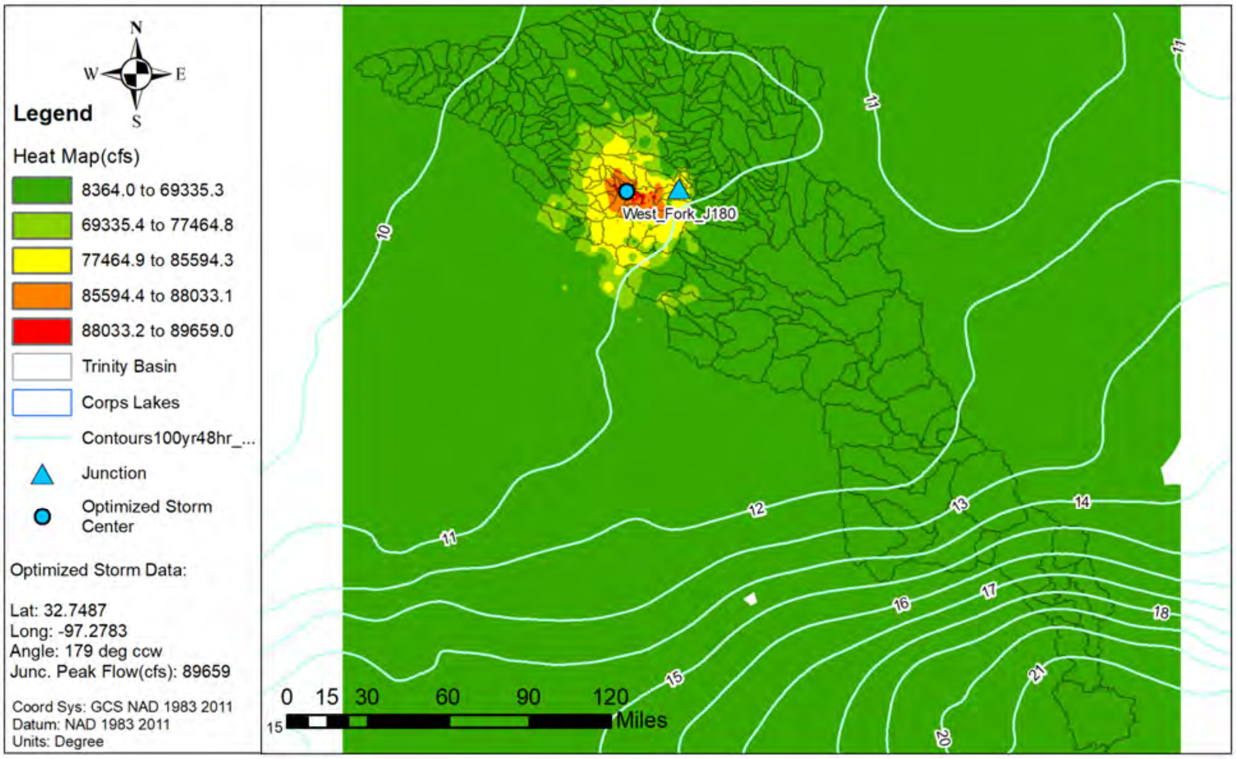


Figure 44a: Elliptical Storm Heat Map for the West Fork Trinity River at Grand Prairie USGS gage

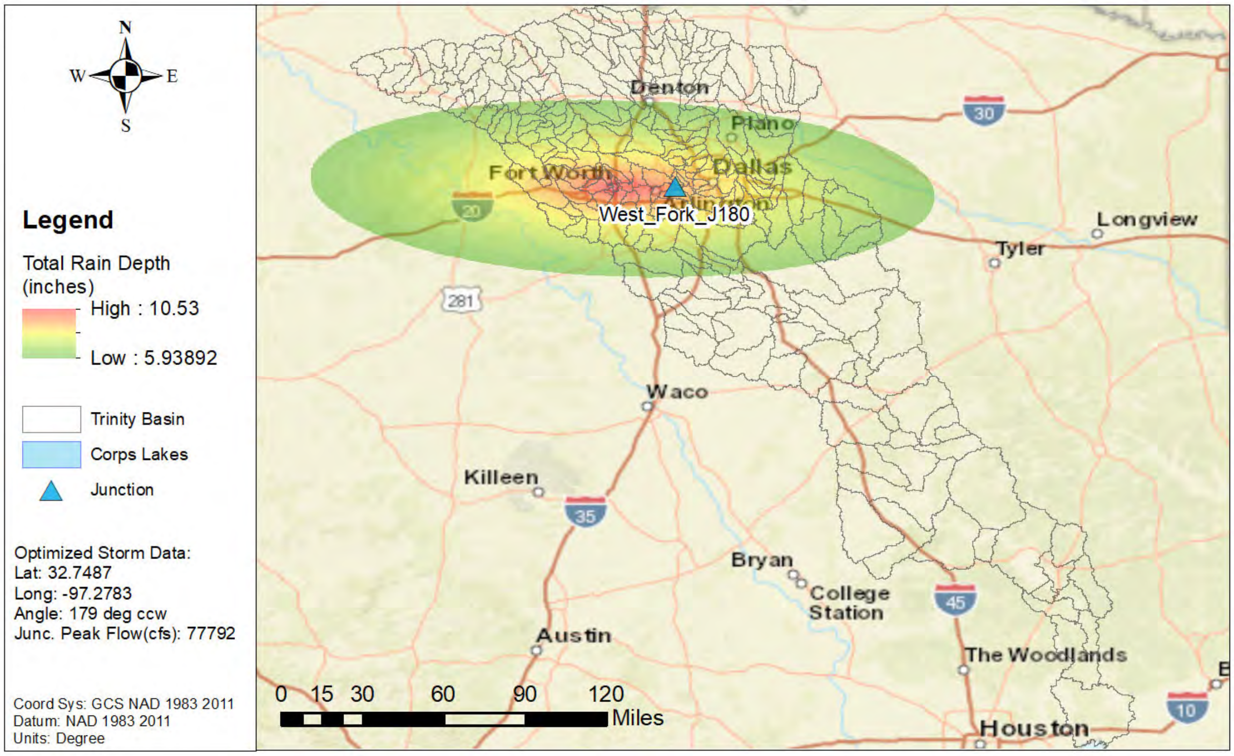


Figure 44b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River at Grand Prairie USGS gage

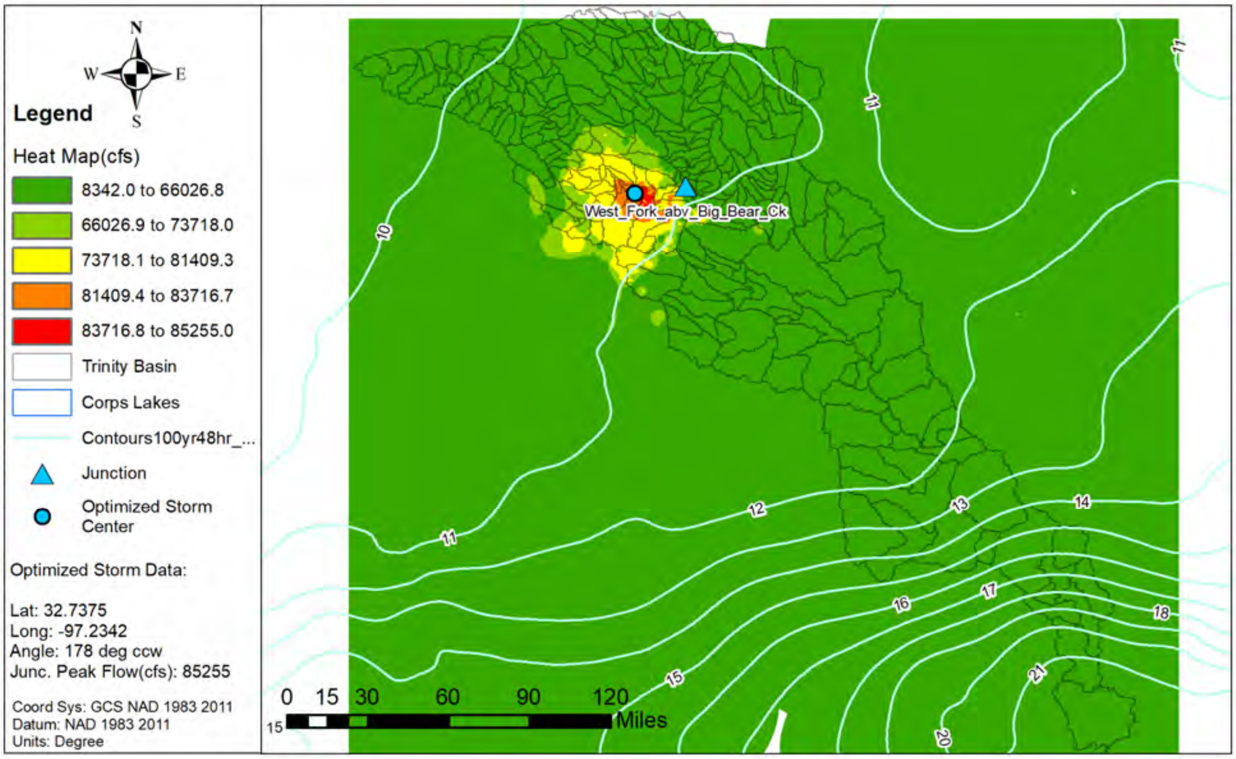


Figure 45a: Elliptical Storm Heat Map for the West Fork Trinity River above Big Bear Creek

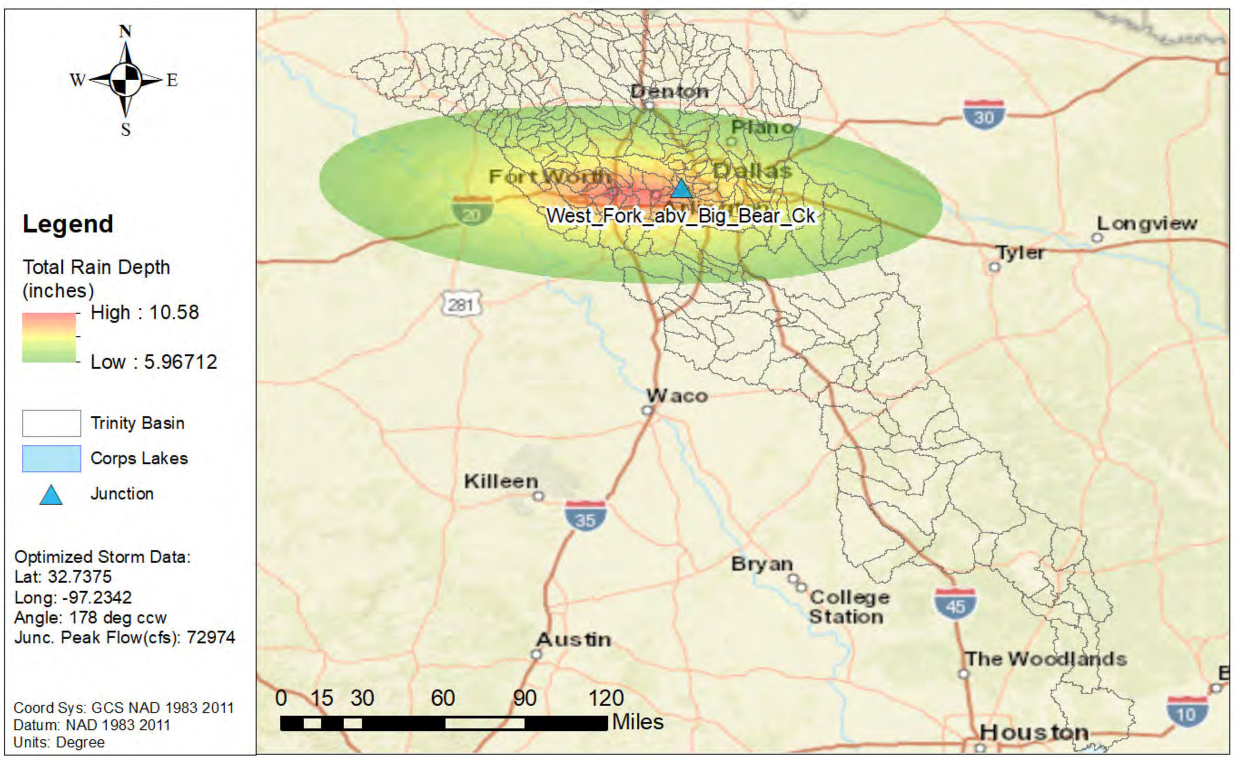


Figure 45b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Big Bear Creek

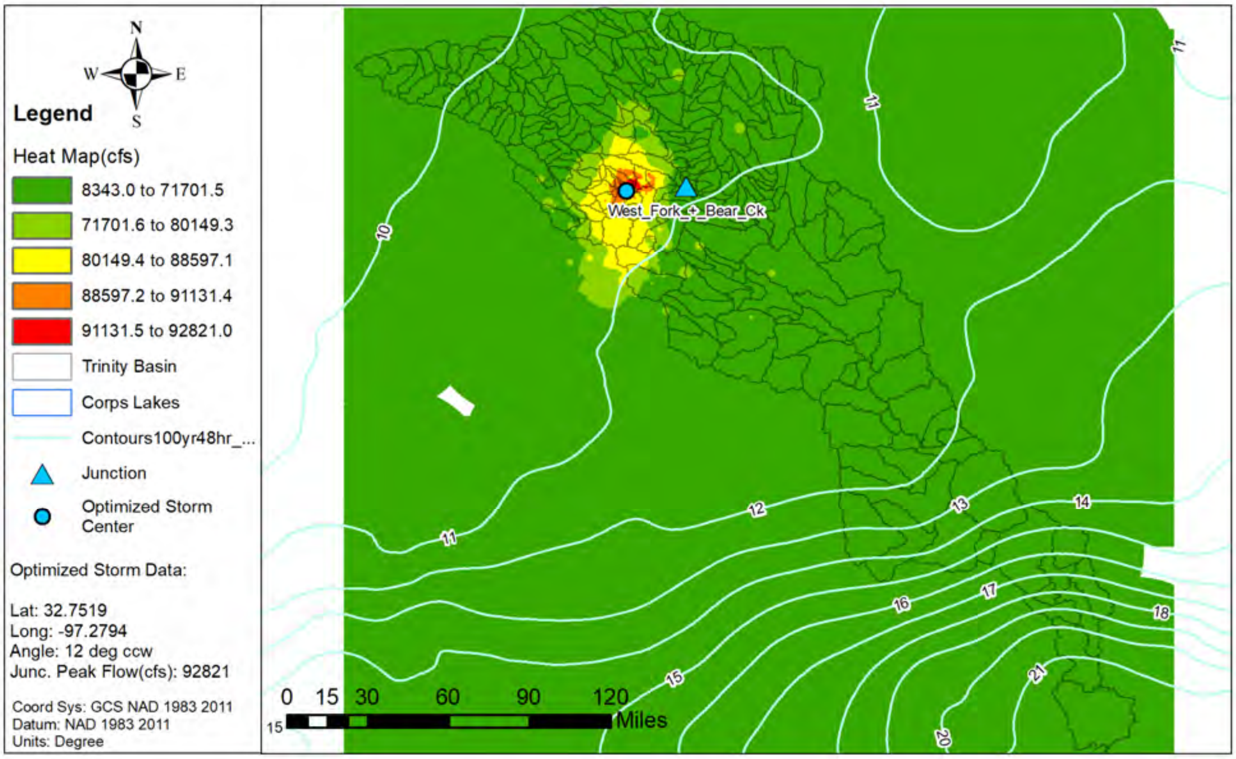


Figure 46a: Elliptical Storm Heat Map for the West Fork Trinity River below Big Bear Creek

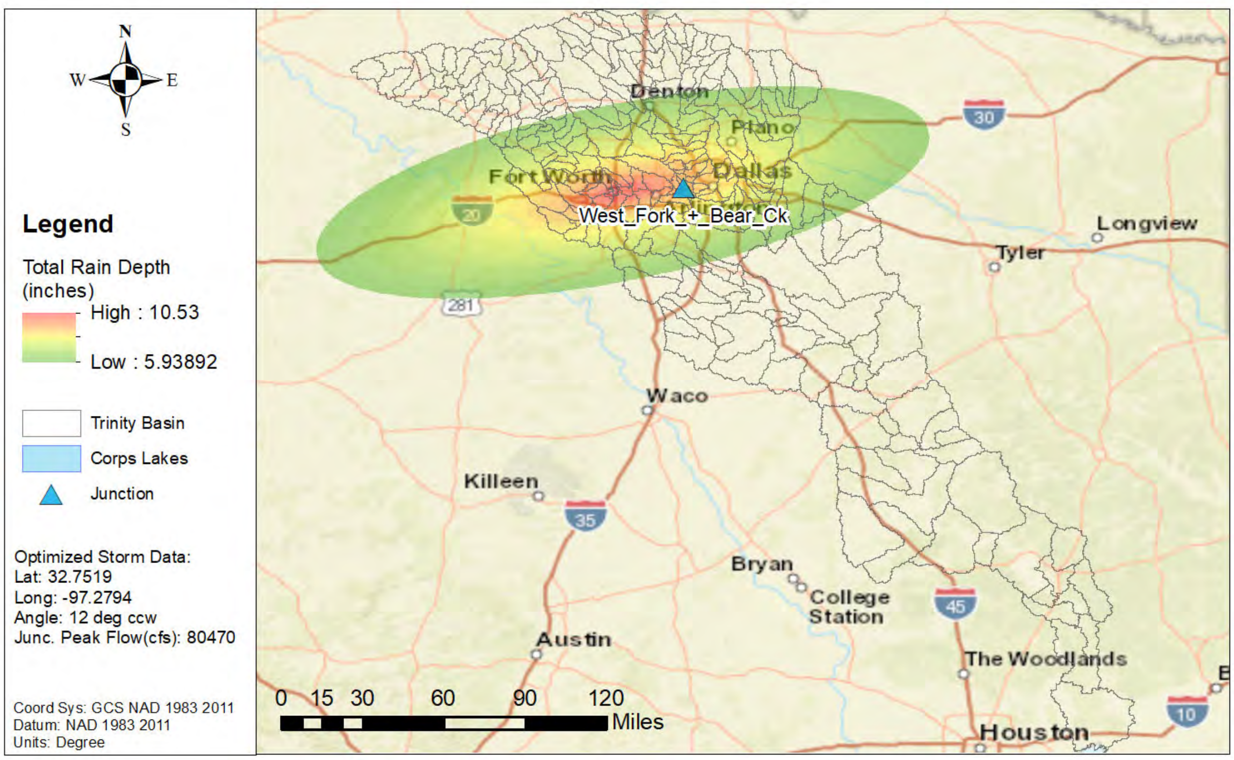


Figure 46b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Big Bear Creek

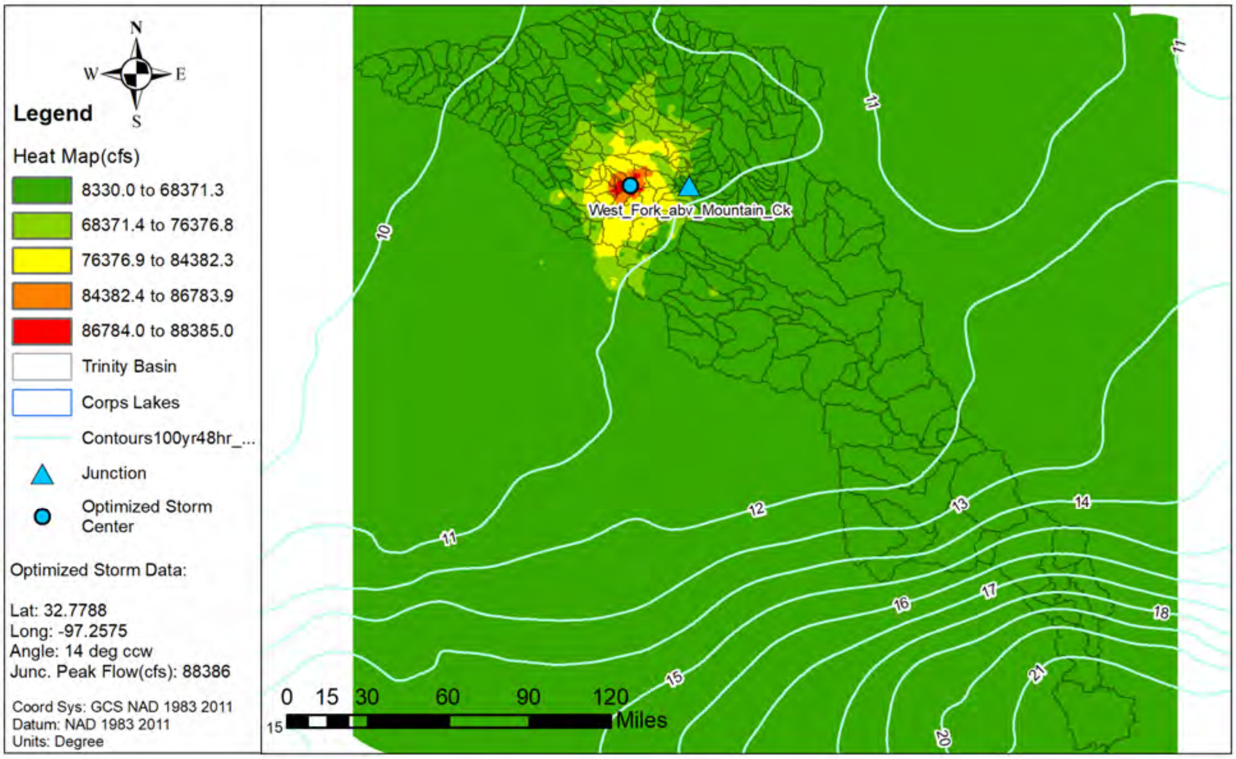


Figure 47a: Elliptical Storm Heat Map for the West Fork Trinity River above Mountain Creek

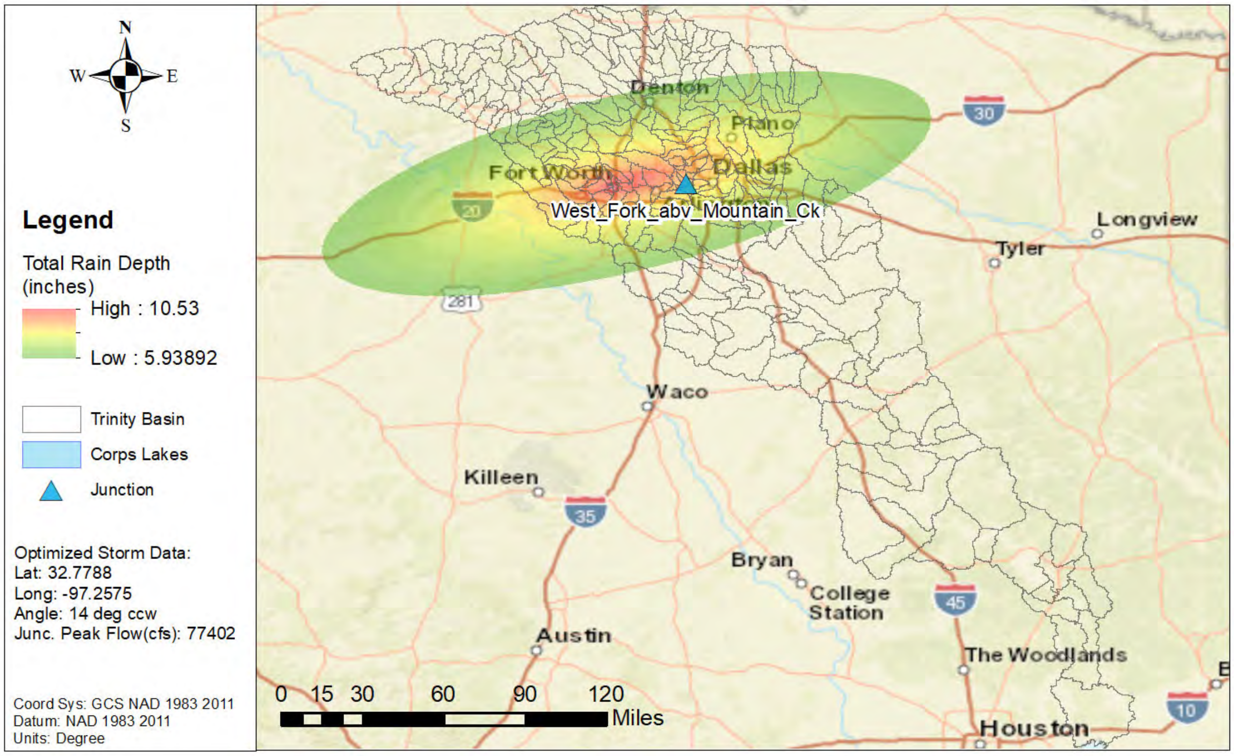


Figure 47b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above Mountain Creek

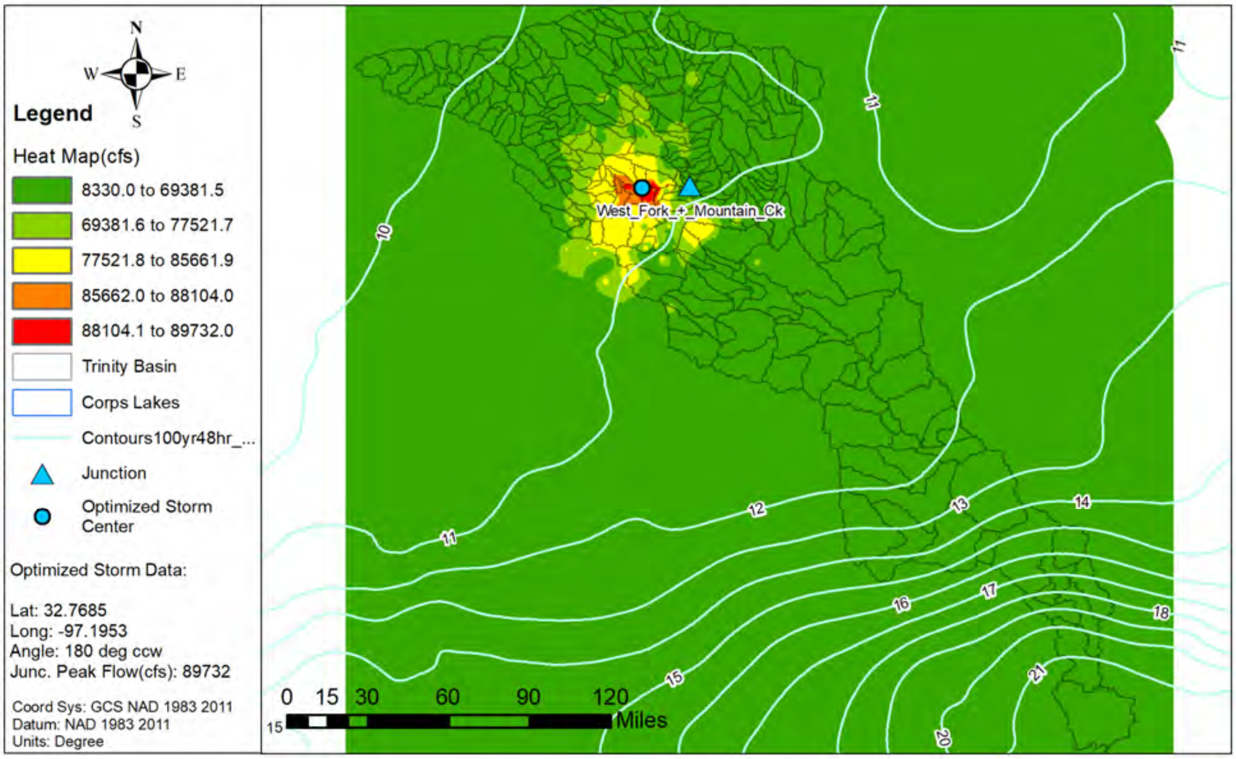


Figure 48a: Elliptical Storm Heat Map for the West Fork Trinity River below Mountain Creek

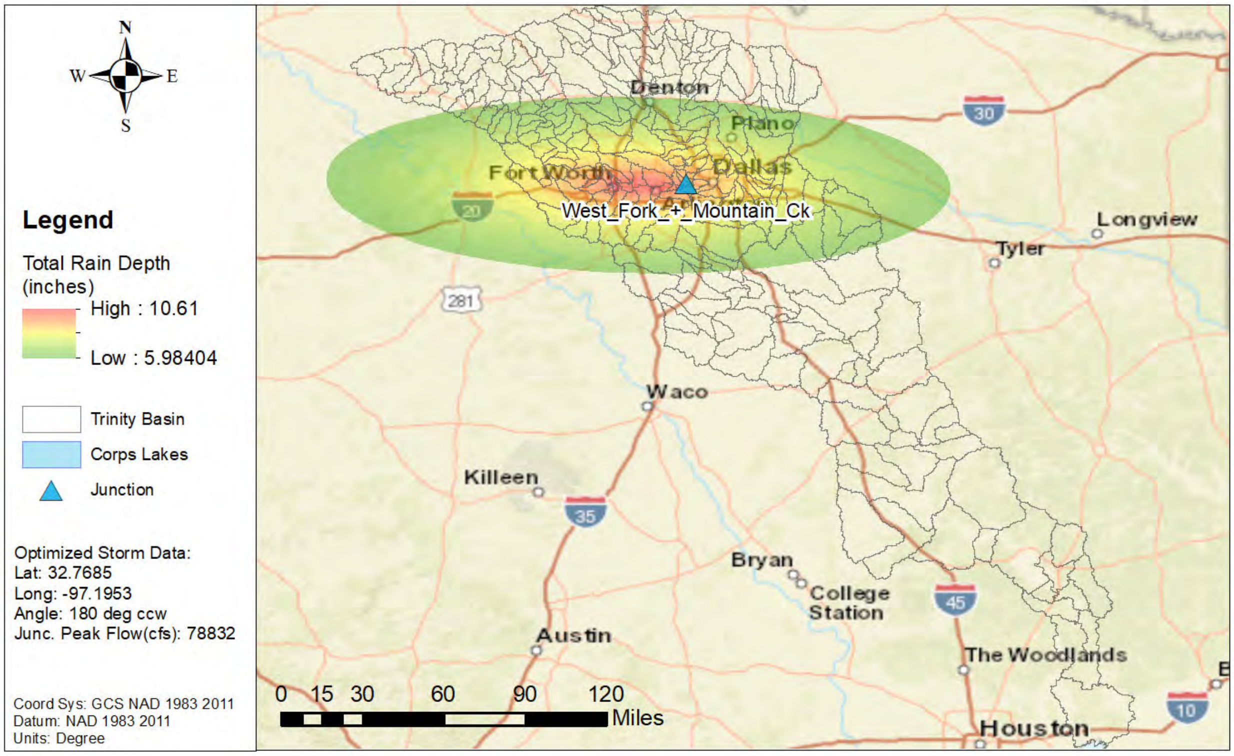


Figure 48b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River below Mountain Creek

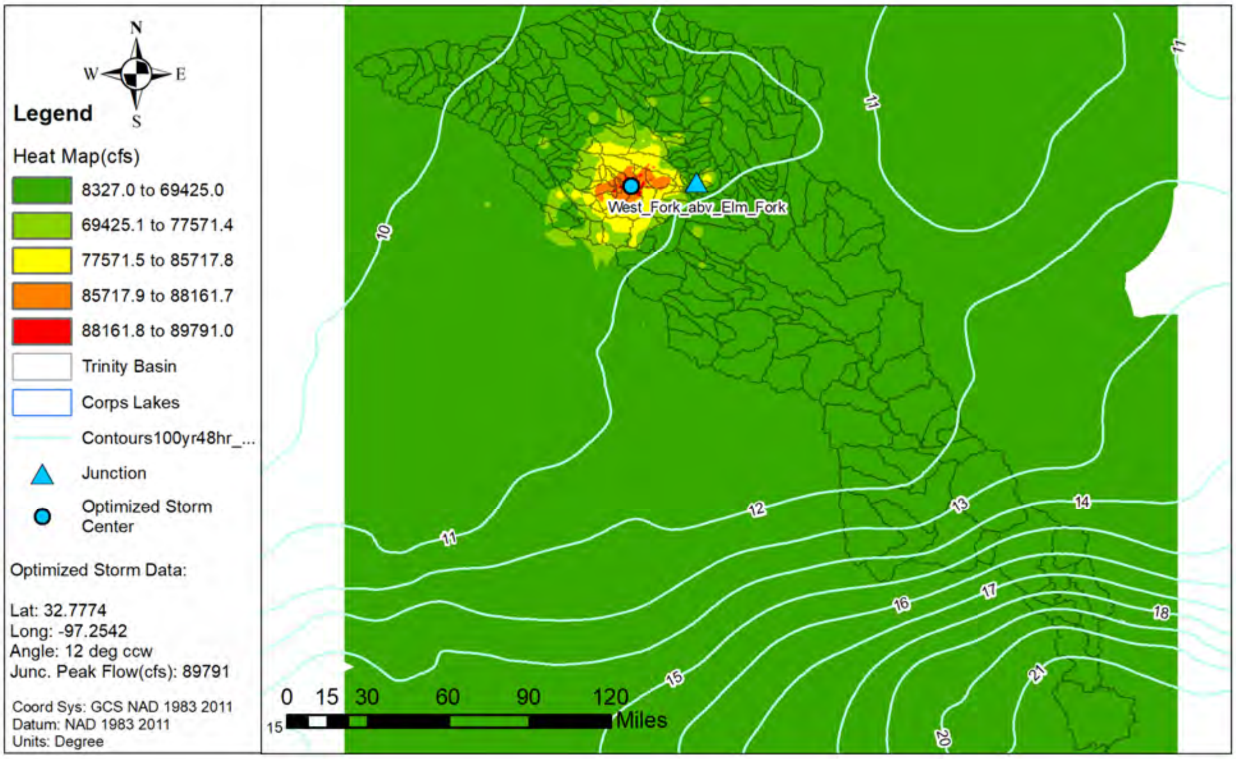


Figure 49a: Elliptical Storm Heat Map for the West Fork Trinity River above the Elm Fork Trinity River

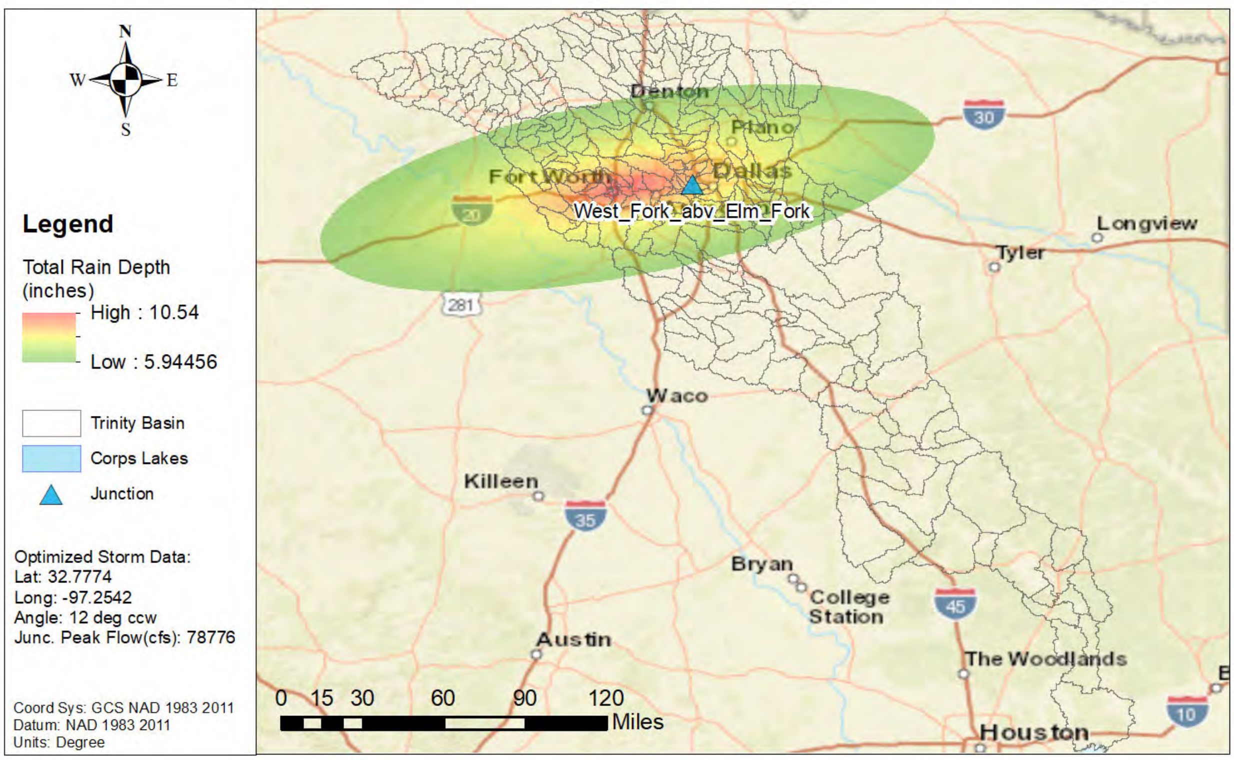


Figure 49b: NA14 1% AEP Elliptical Storm for the West Fork Trinity River above the Elm Fork Trinity River

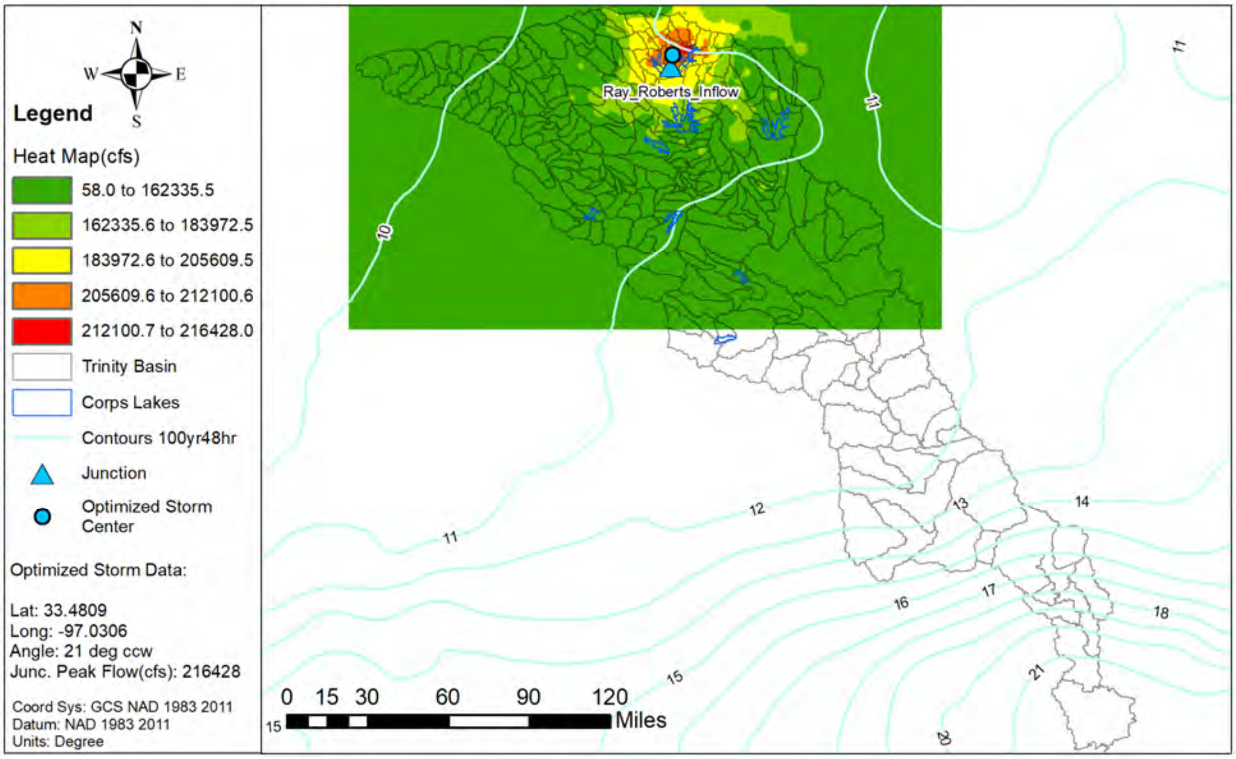


Figure 50a: Elliptical Storm Heat Map for the Ray Roberts Lake Inflow

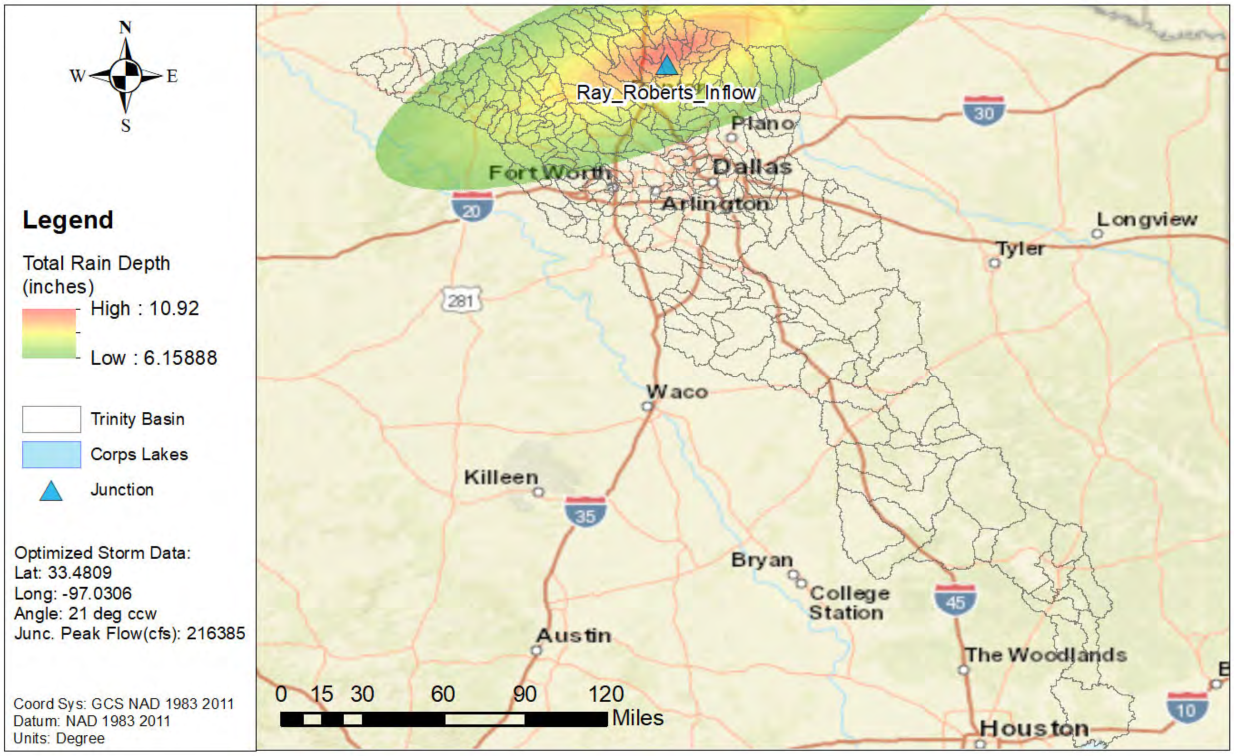


Figure 50b: NA14 1% AEP Elliptical Storm for the Ray Roberts Lake Inflow

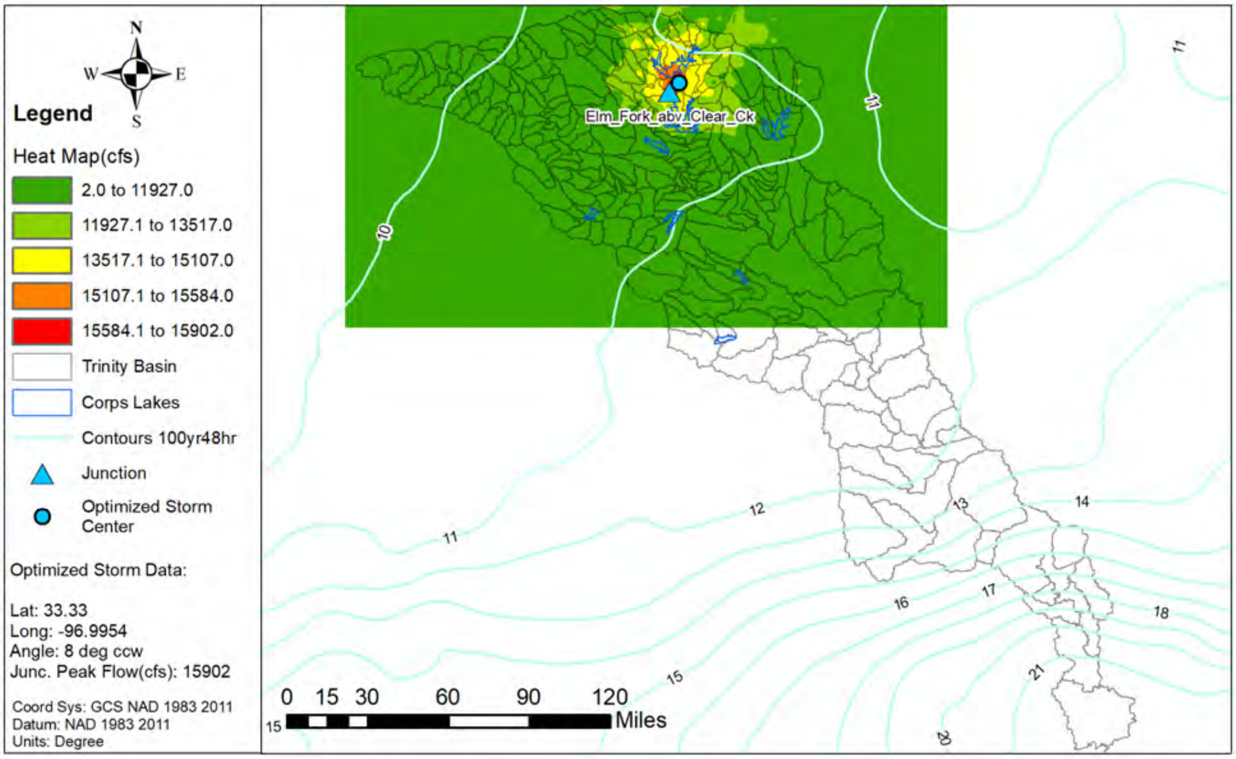


Figure 51a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Clear Creek

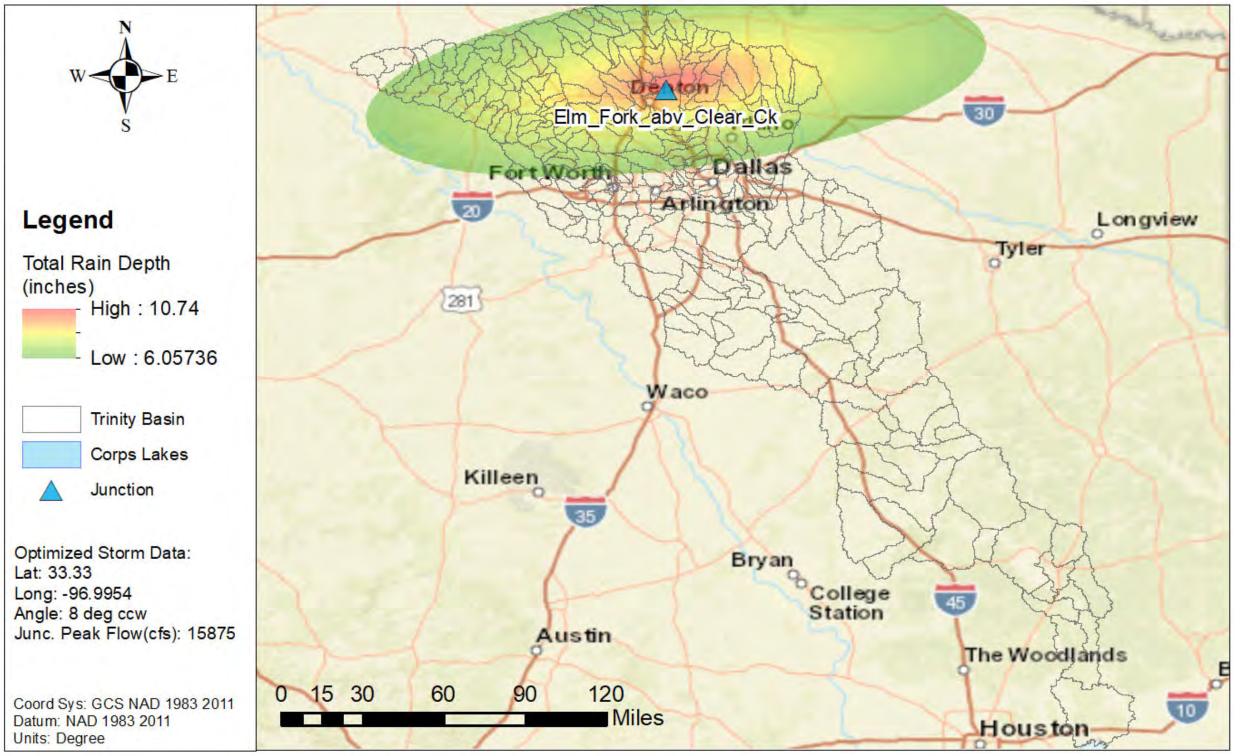


Figure 51b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Clear Creek

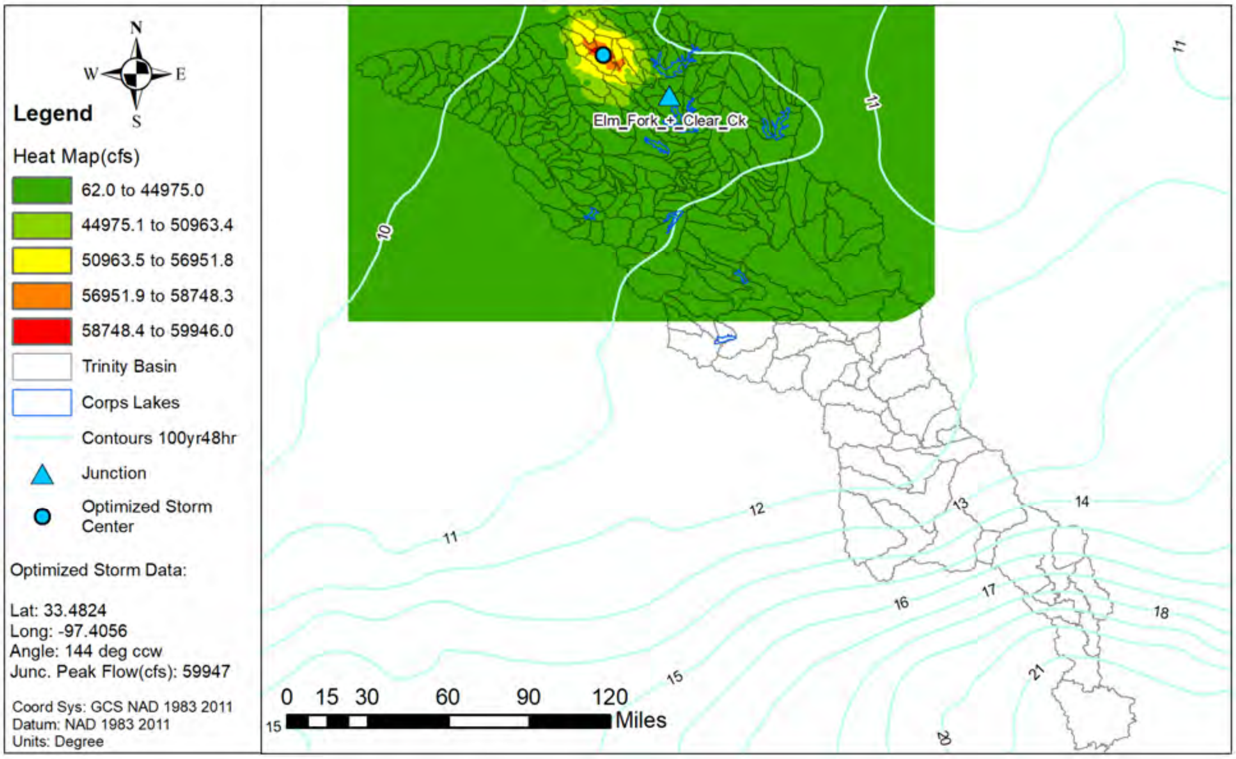


Figure 52a: Elliptical Storm Heat Map for the Elm Fork Trinity River below Clear Creek

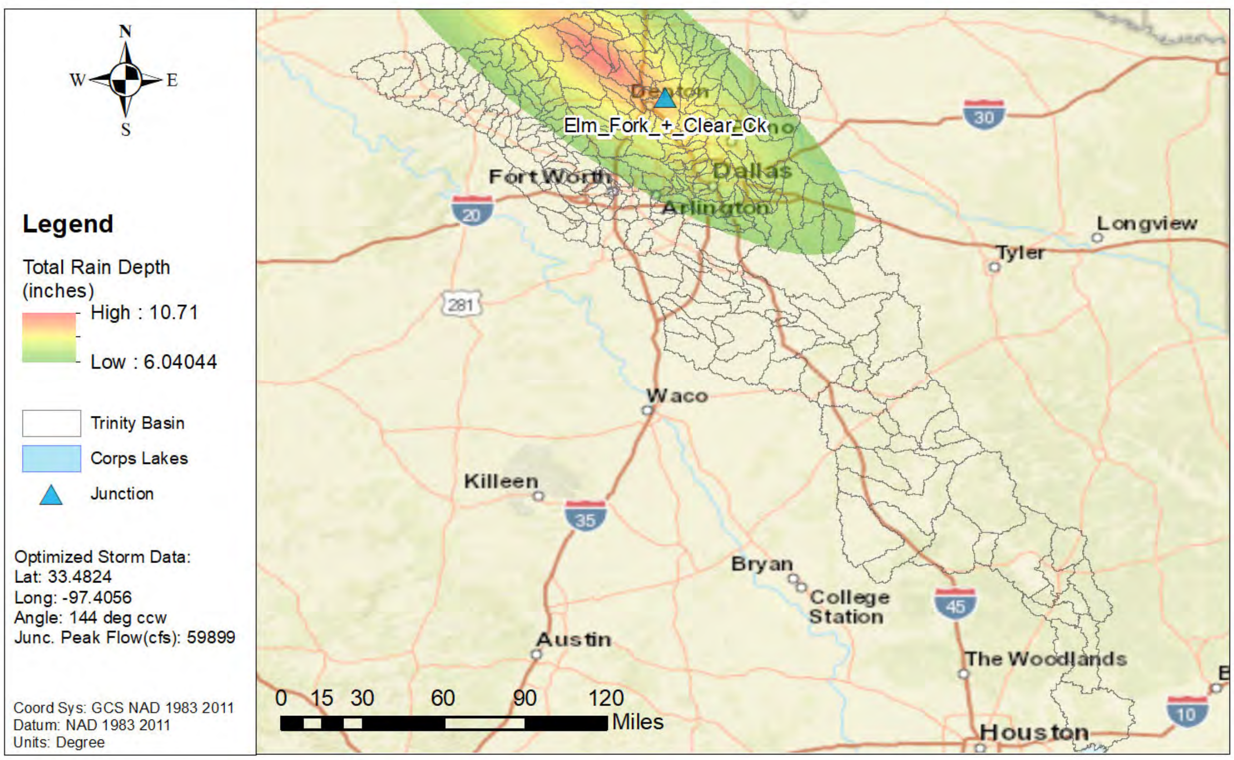


Figure 52b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River below Clear Creek

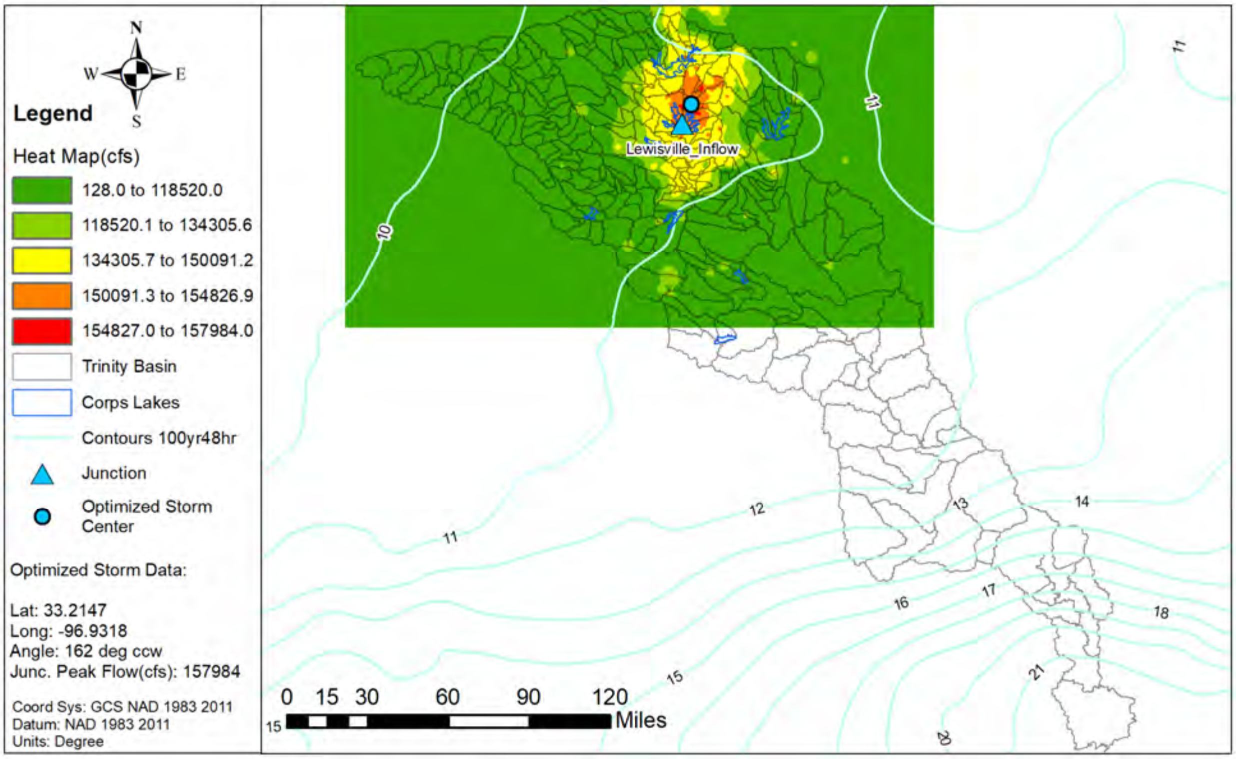


Figure 53a: Elliptical Storm Heat Map for the Lewisville Lake Inflow

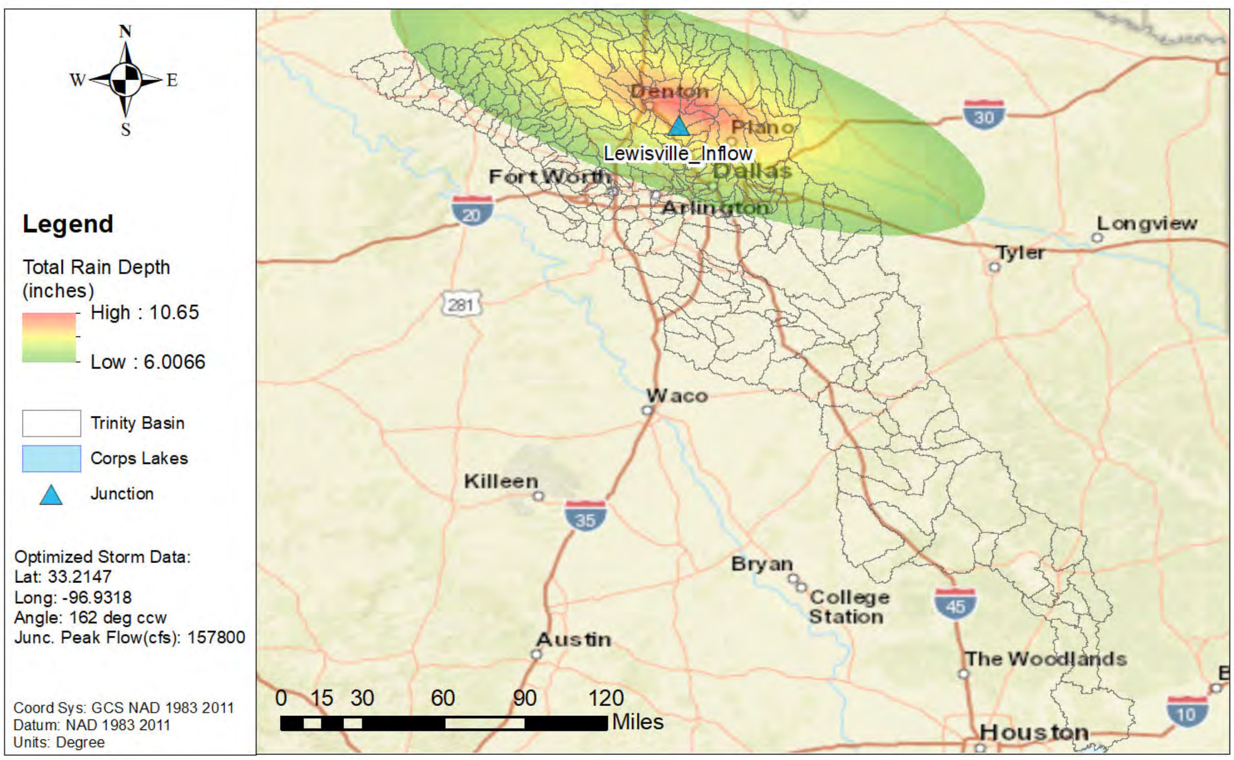


Figure 53b: NA14 1% AEP Elliptical Storm for the Lewisville Lake Inflow

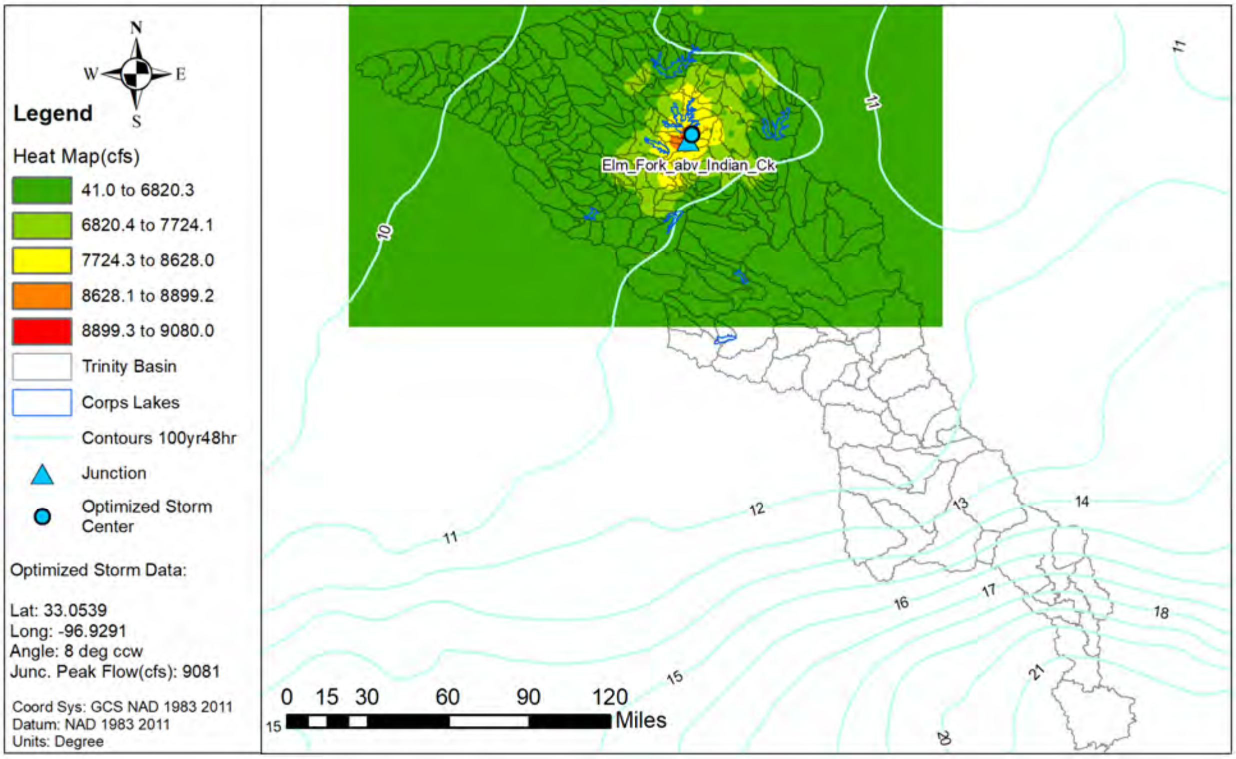


Figure 54a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Indian Creek

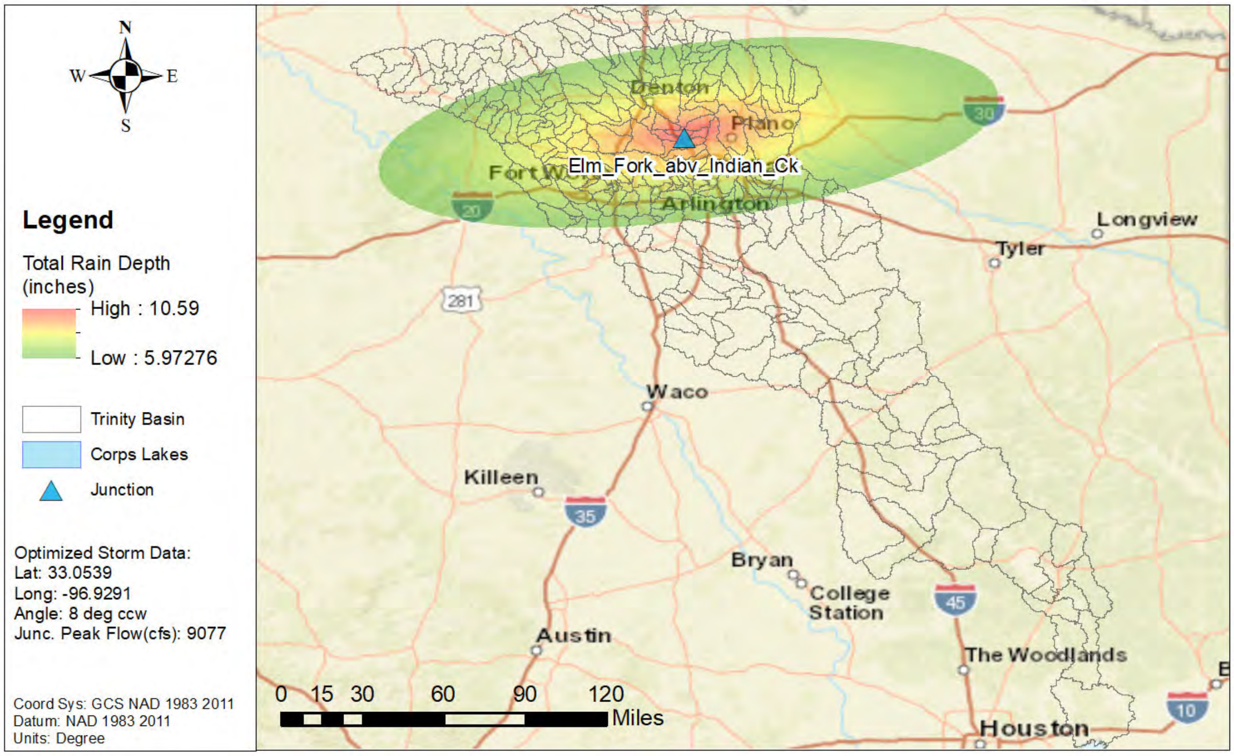


Figure 54b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Indian Creek

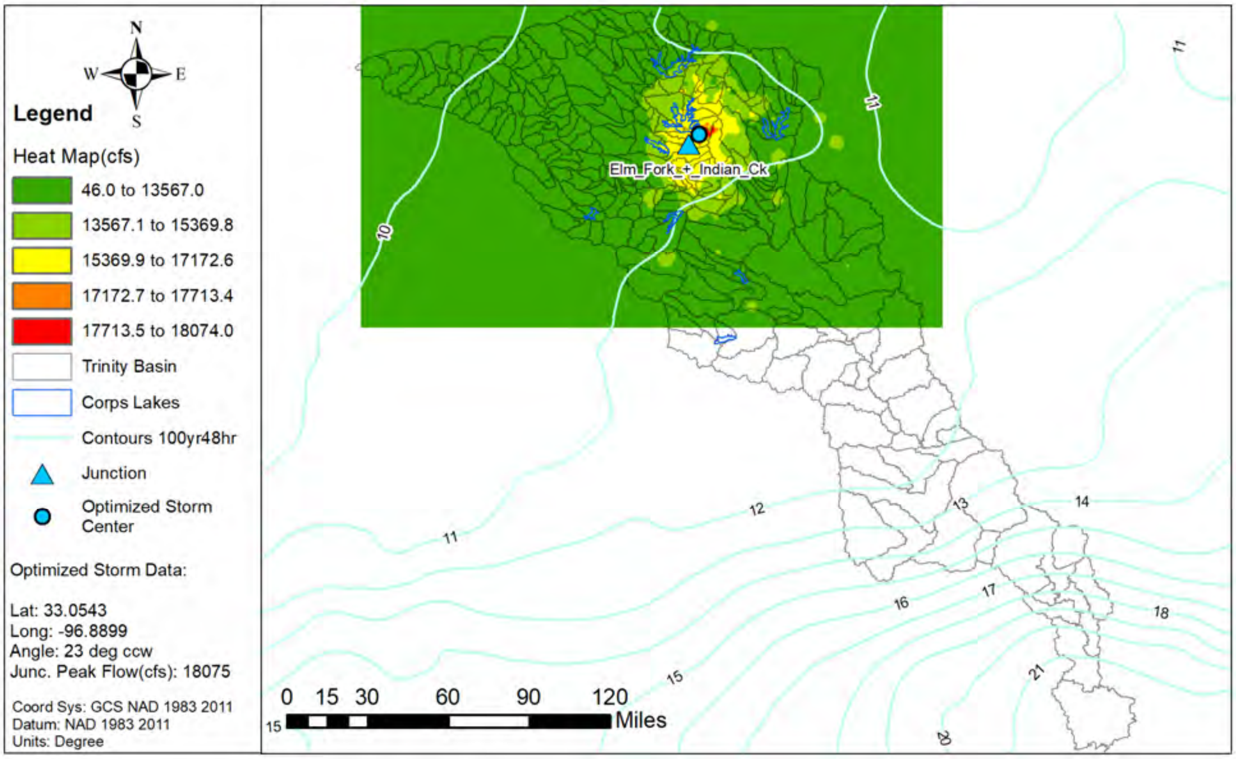


Figure 55a: Elliptical Storm Heat Map for the Elm Fort Trinity River below Indian Creek

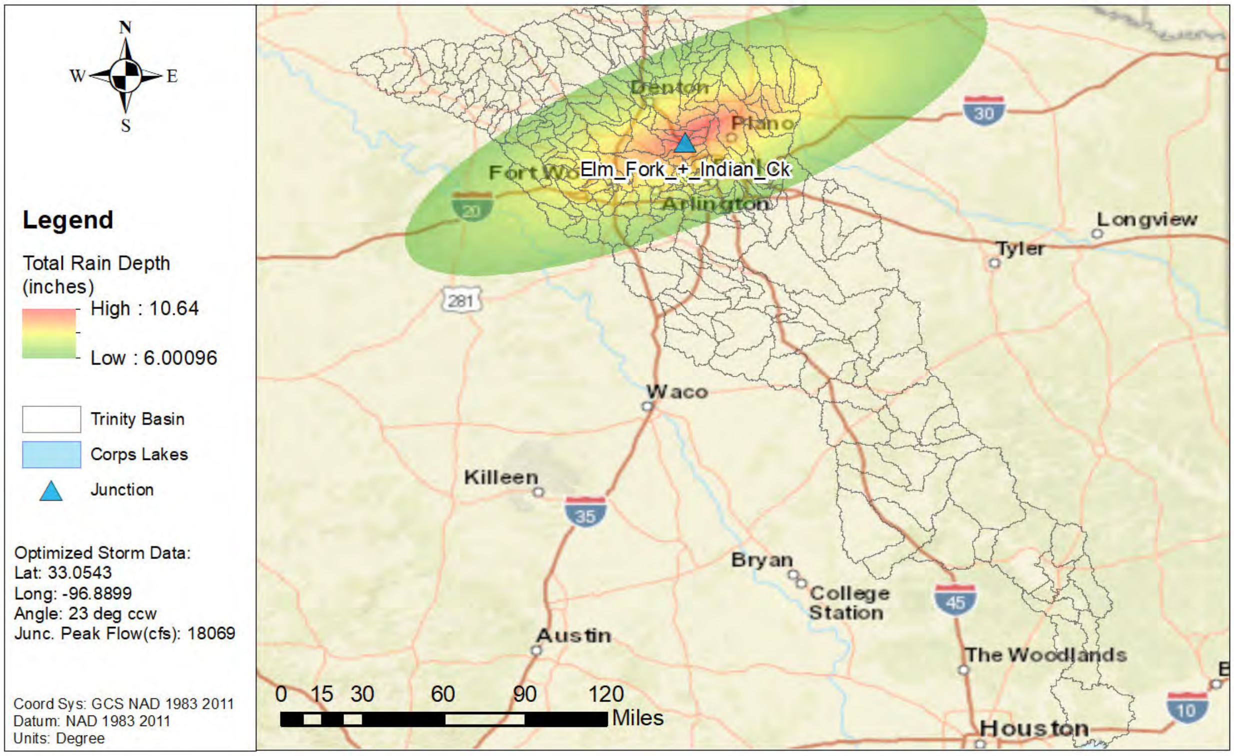


Figure 55b: NA14 1% AEP Elliptical Storm for the Elm Fort Trinity River below Indian Creek

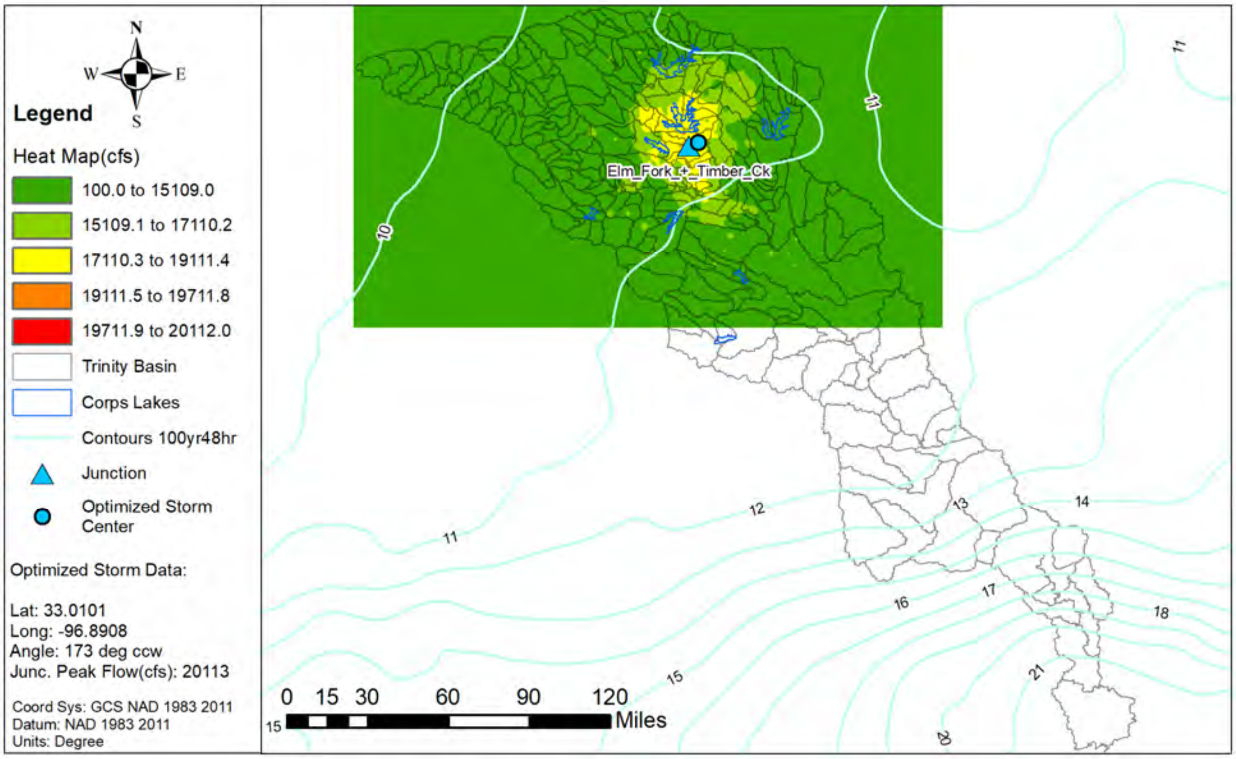


Figure 56a: Elliptical Storm Heat Map for the Elm Fork Trinity River below Timber Creek

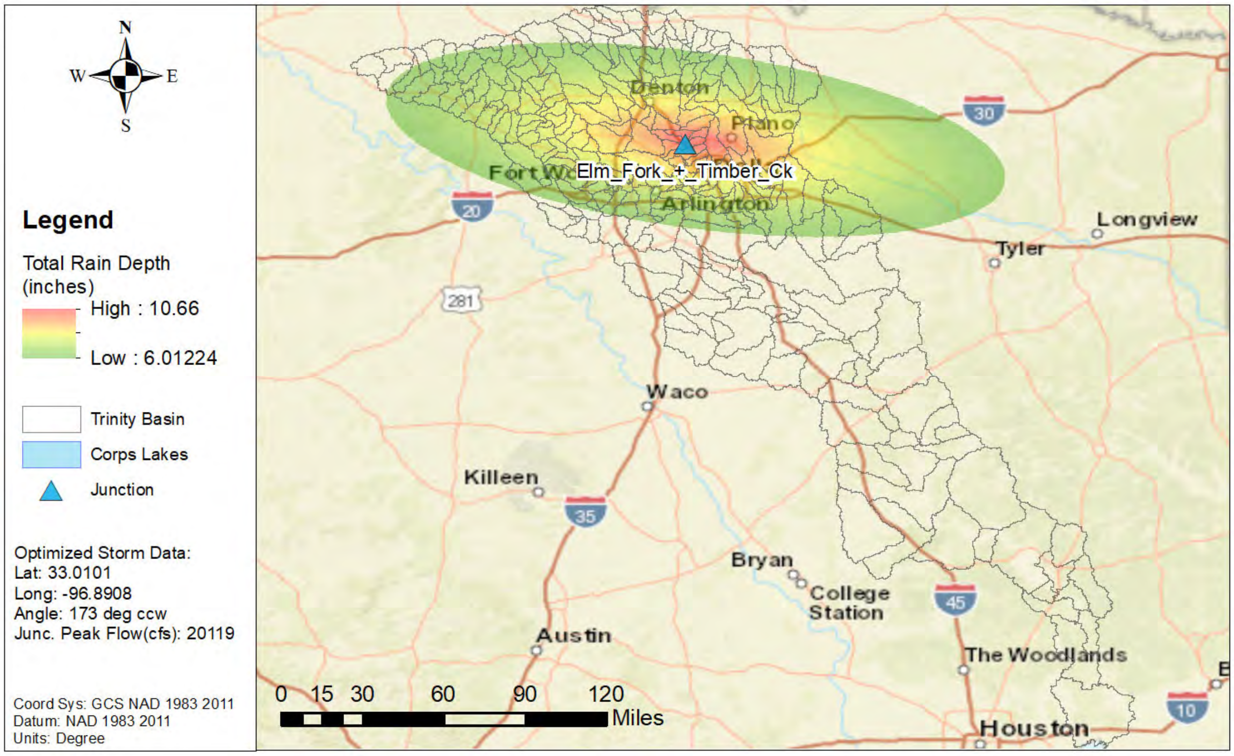


Figure 56b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River below Timber Creek

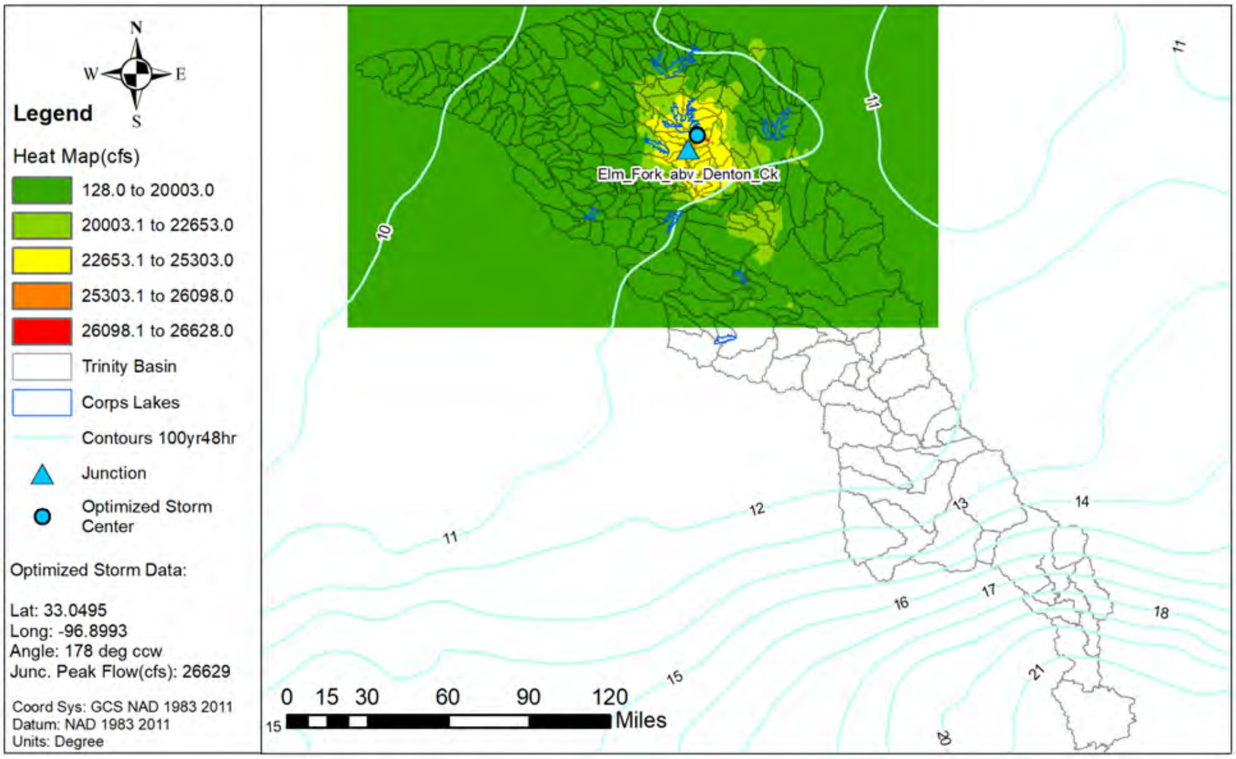


Figure 57a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Denton Creek

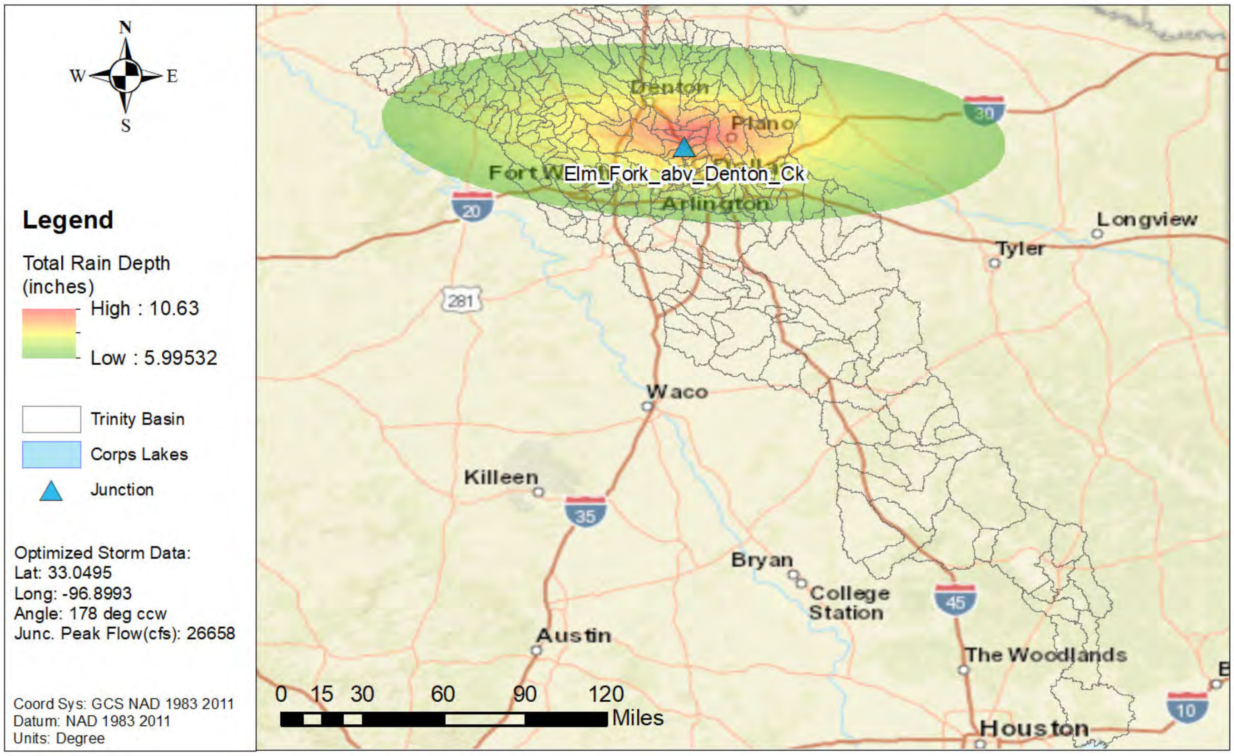


Figure 57b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Denton Creek

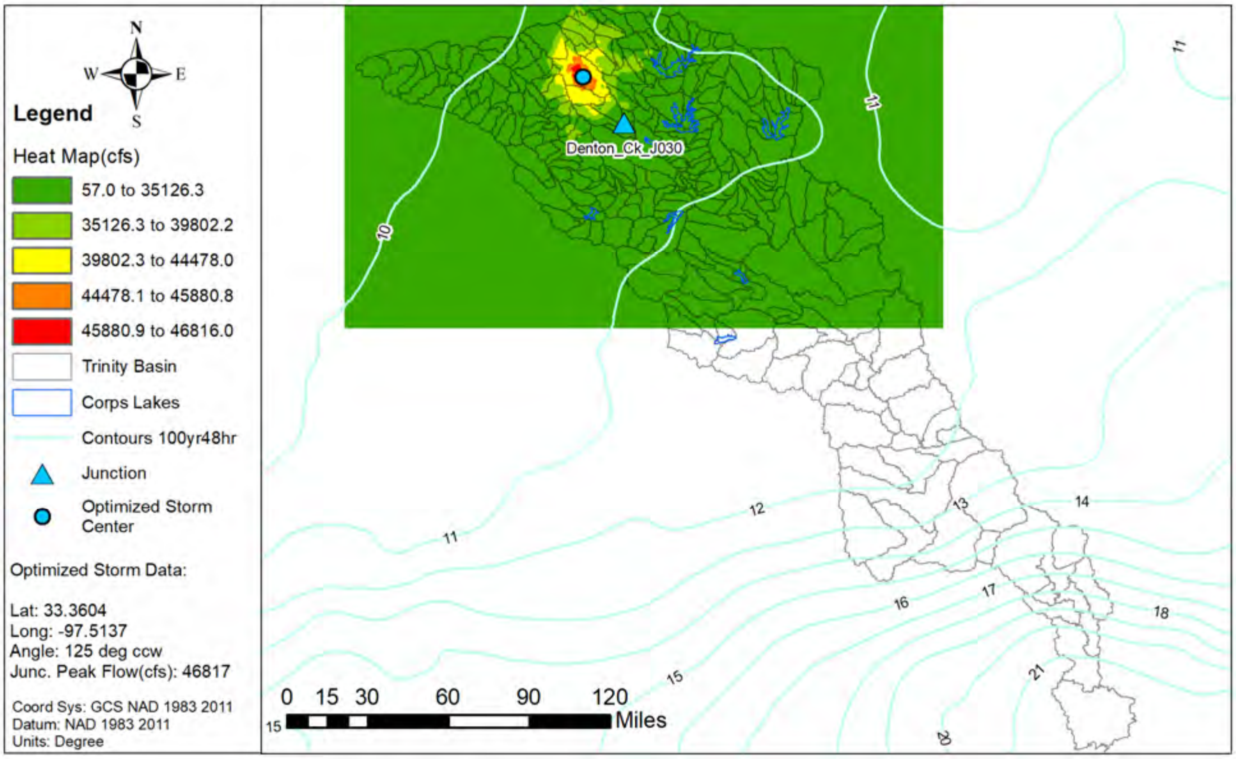


Figure 58a: Elliptical Storm Heat Map for the Denton Creek nr Justin, TX USGS gage

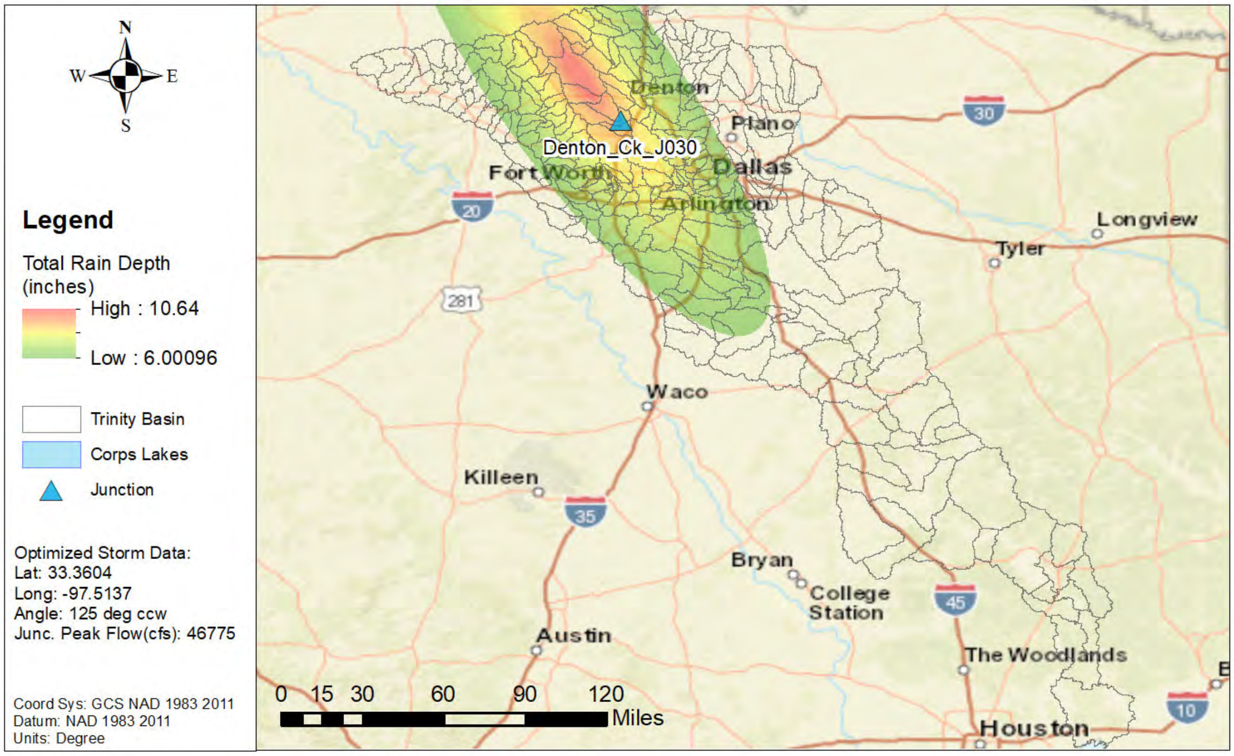


Figure 58b: NA14 1% AEP Elliptical Storm for the Denton Creek nr Justin, TX USGS gage

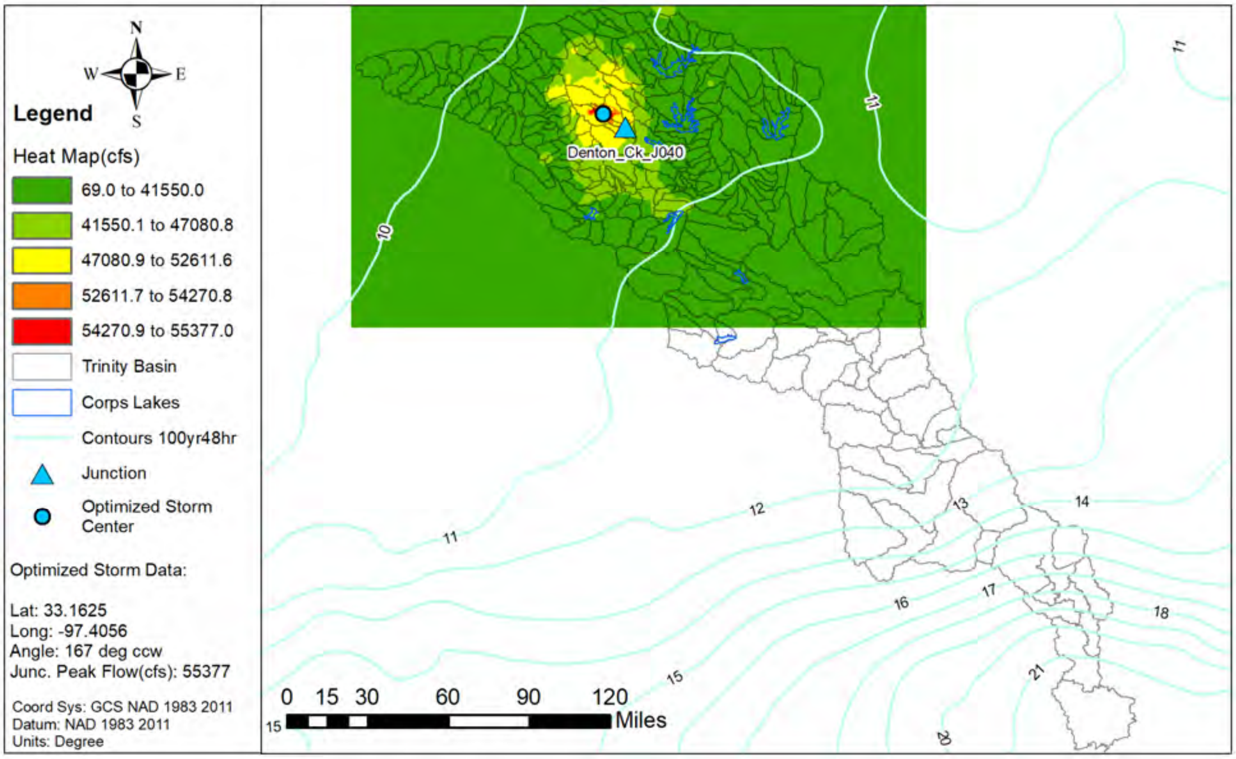


Figure 59a: Elliptical Storm Heat Map for the Denton Creek below Oliver Creek

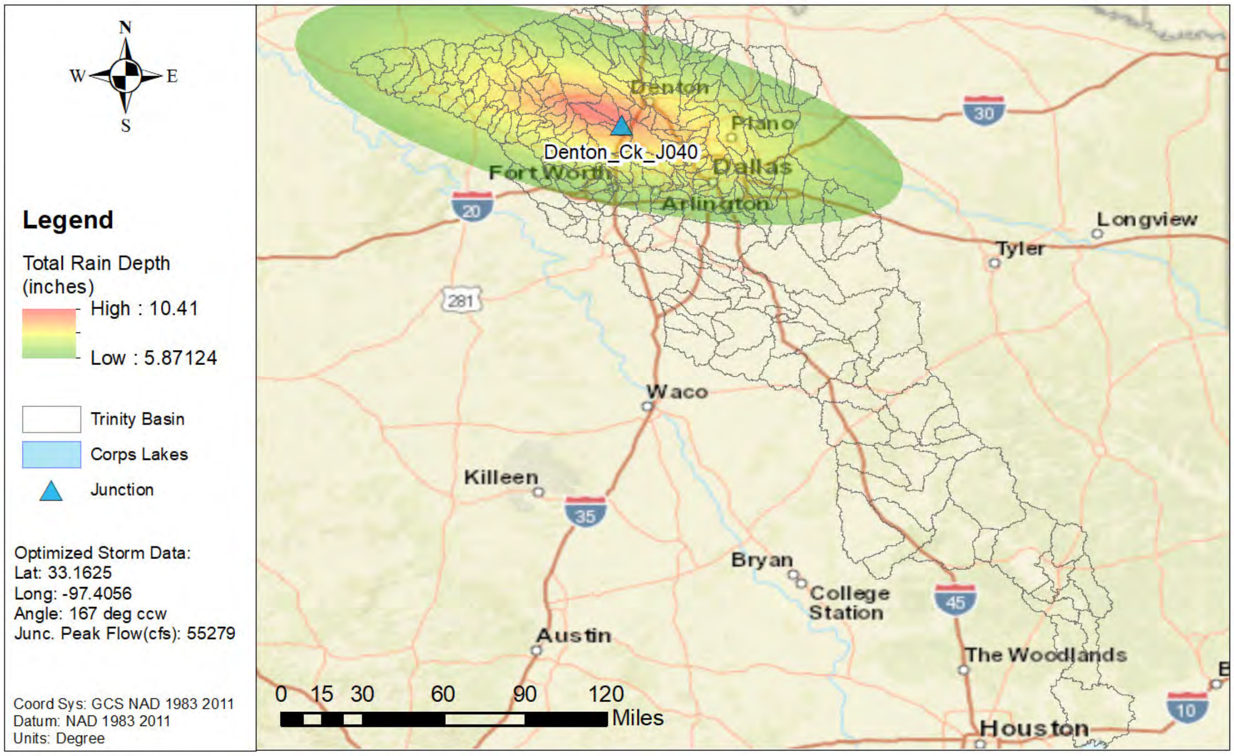


Figure 59b: NA14 1% AEP Elliptical Storm for the Denton Creek below Oliver Creek

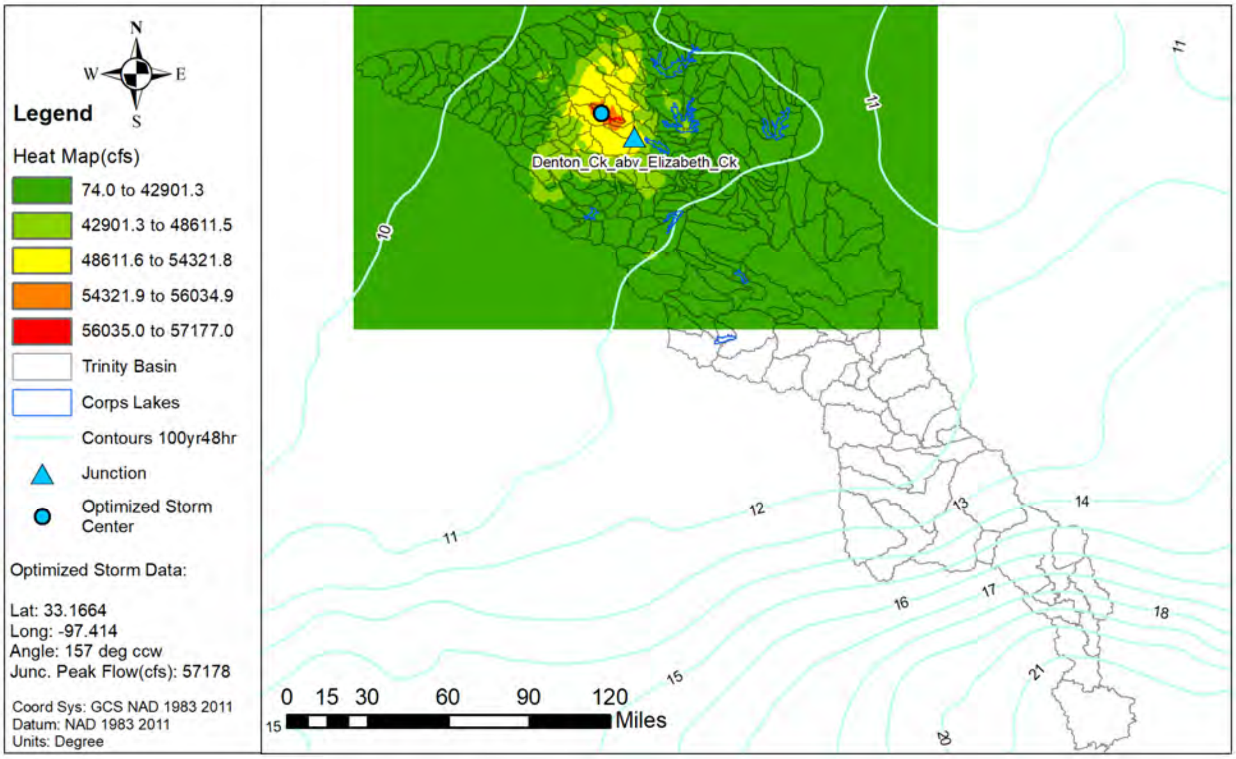


Figure 60a: Elliptical Storm Heat Map for the Denton Creek above Elizabeth Creek

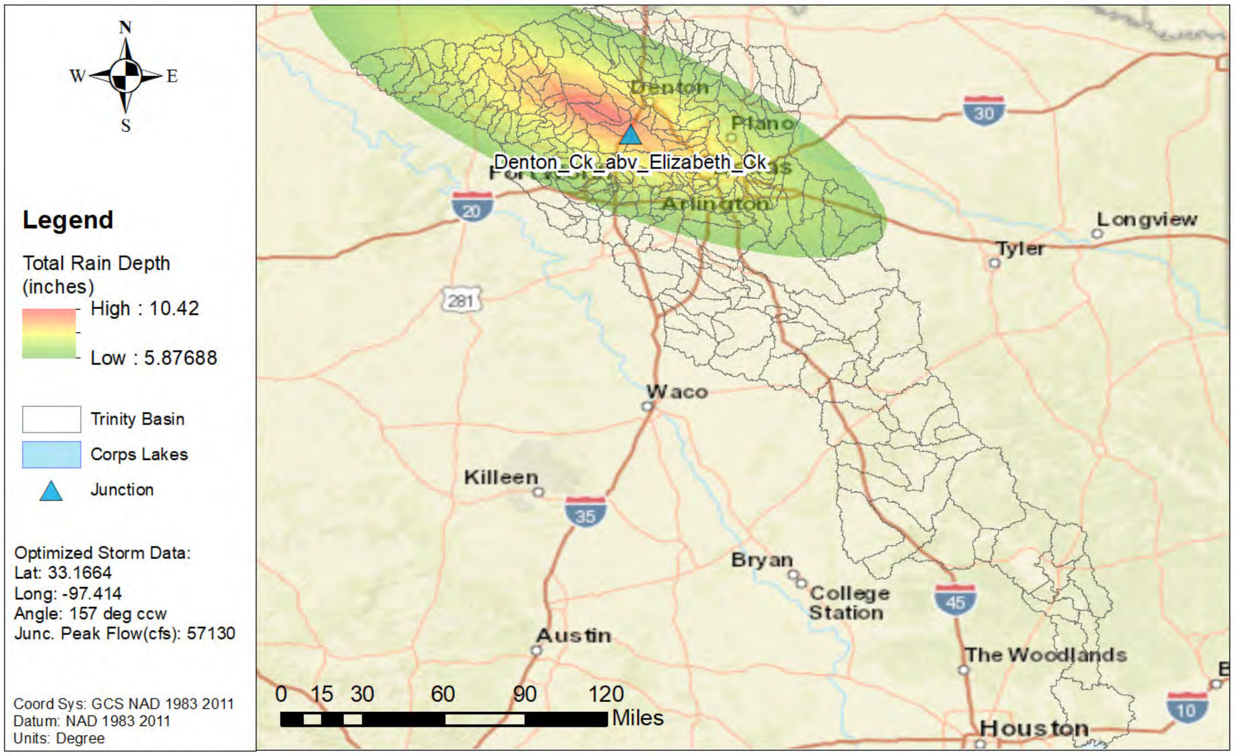


Figure 60b: NA14 1% AEP Elliptical Storm for the Denton Creek above Elizabeth Creek

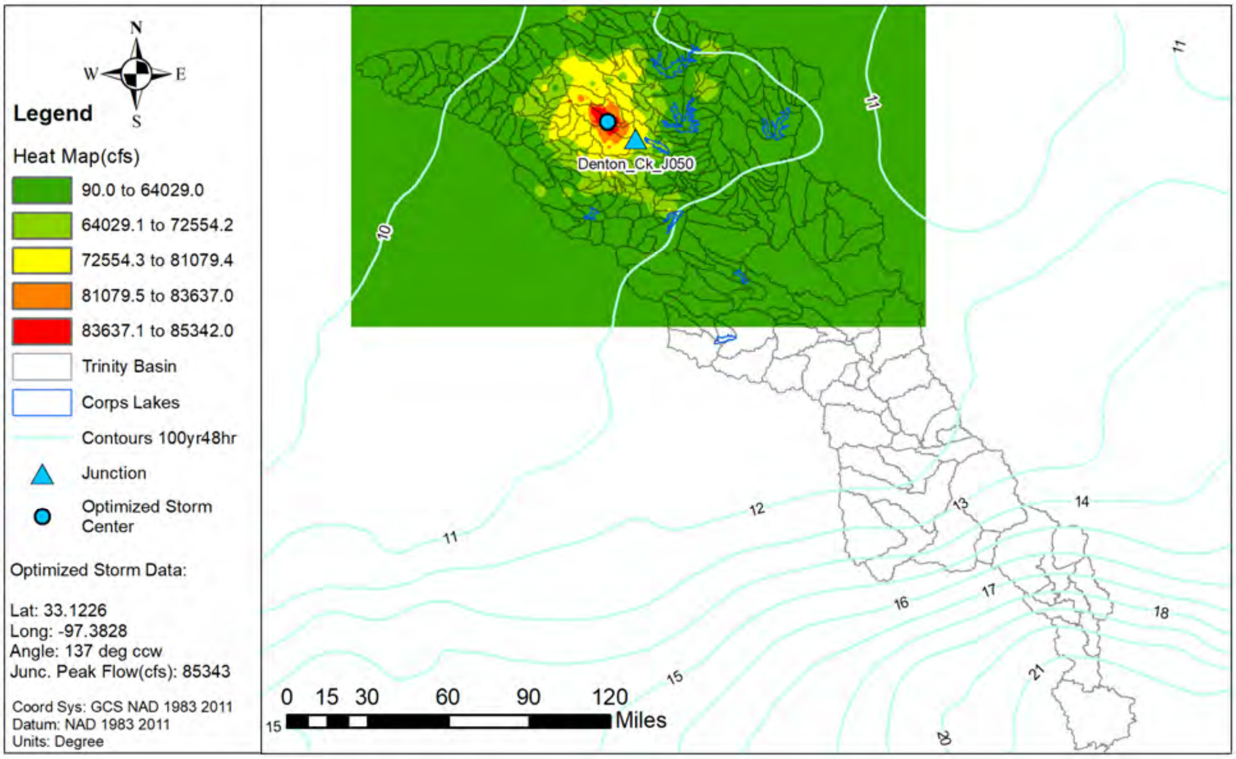


Figure 61a: Elliptical Storm Heat Map for the Denton Creek below Elizaveth Creek

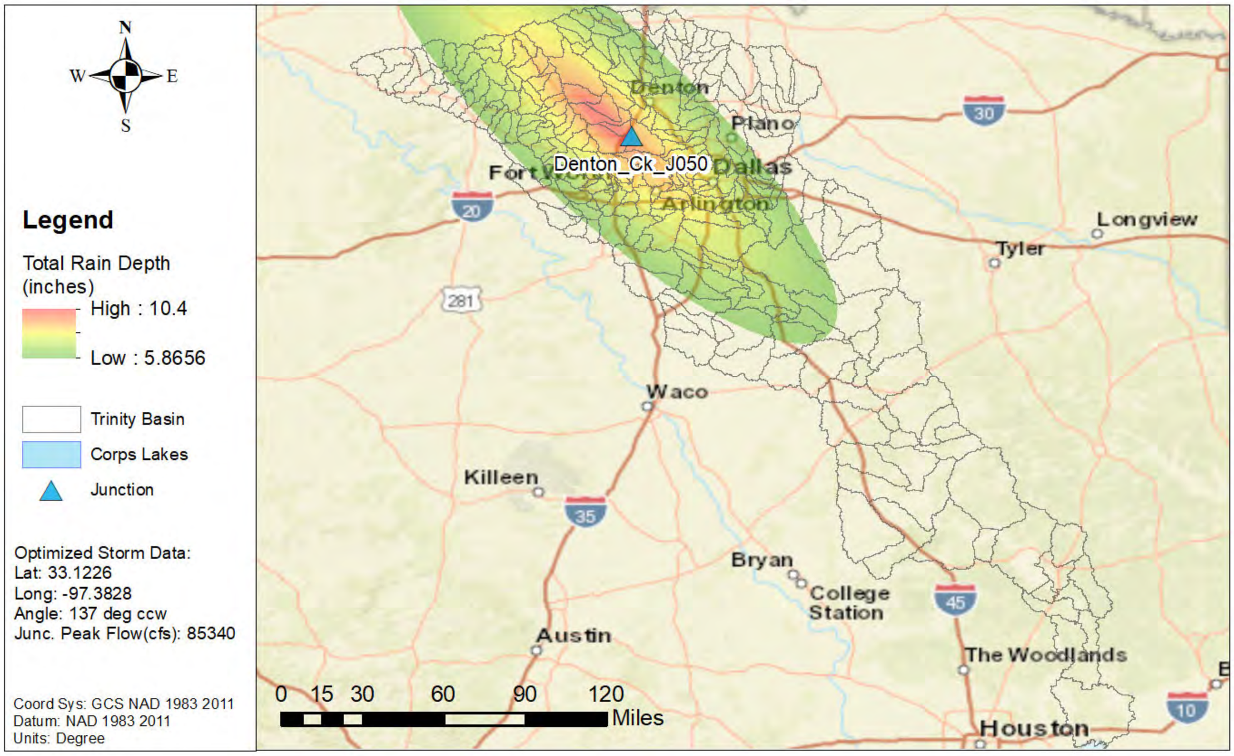


Figure 61b: NA14 1% AEP Elliptical Storm for the Denton Creek below Elizaveth Creek

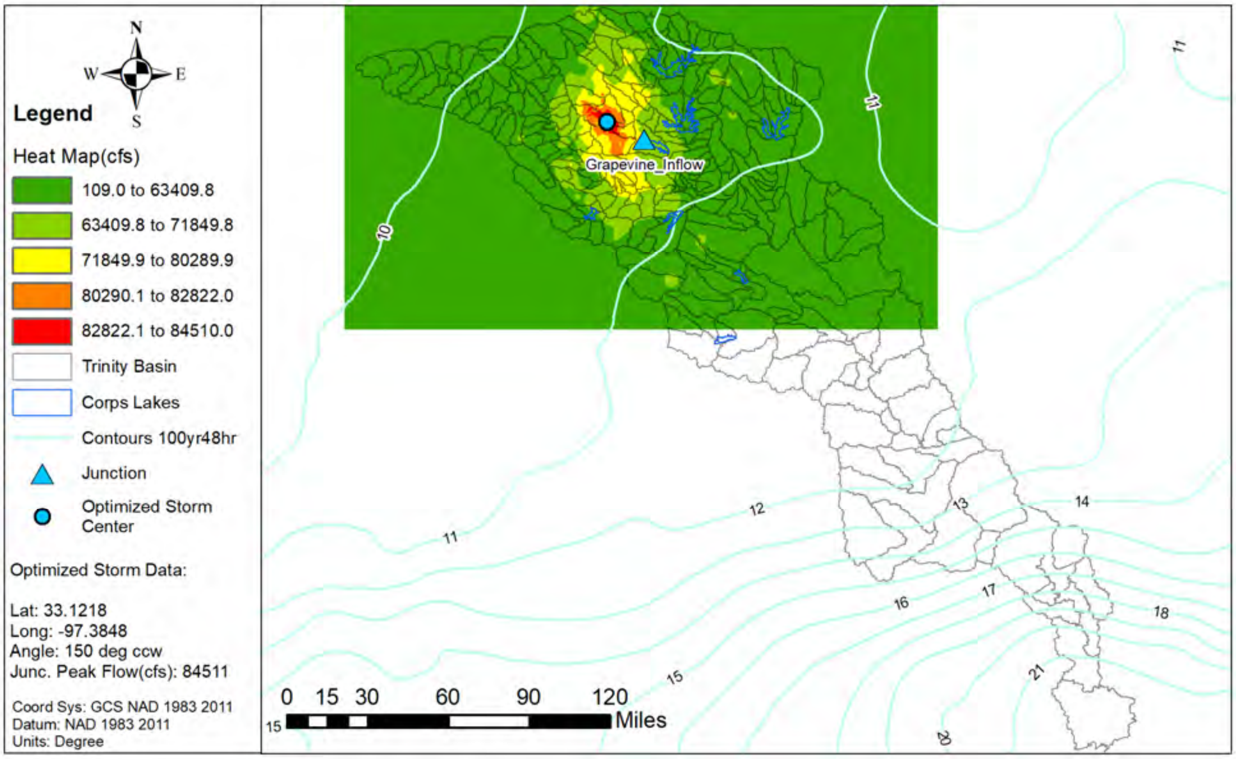


Figure 62a: Elliptical Storm Heat Map for the Grapevine Lake Inflow

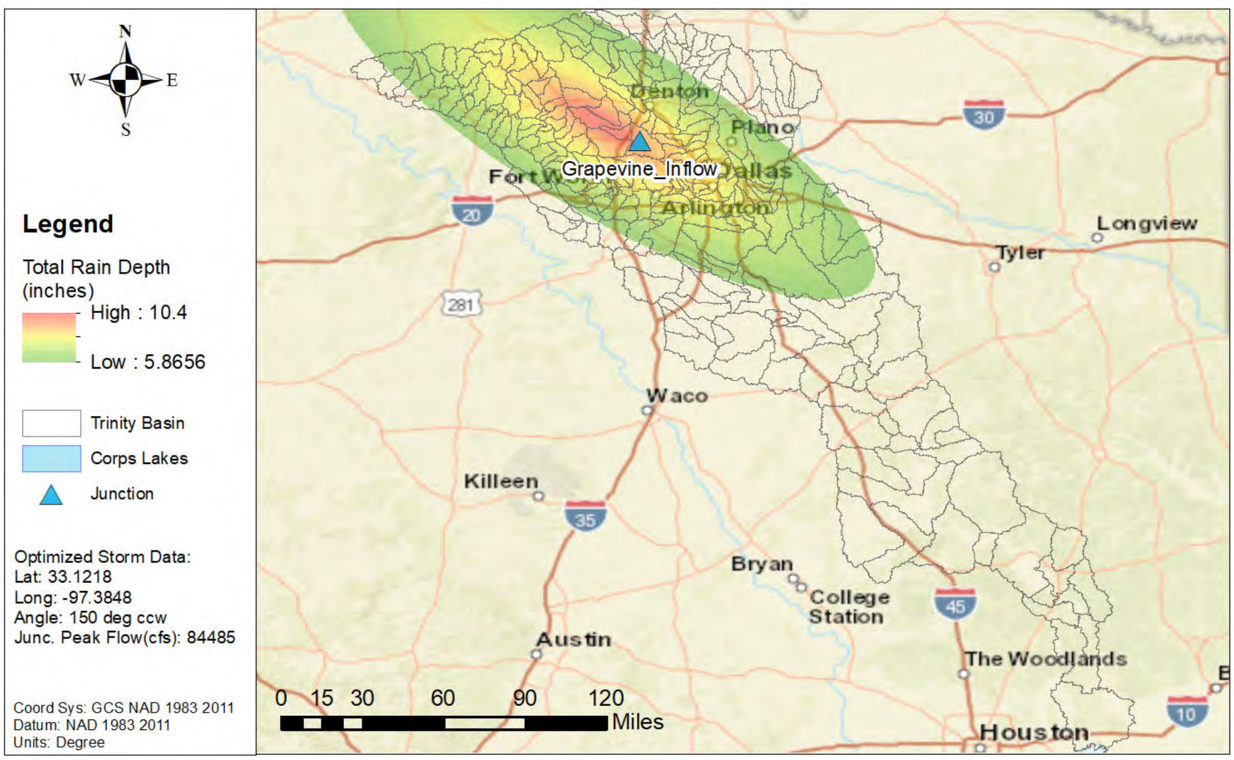


Figure 62b: NA14 1% AEP Elliptical Storm for the Grapevine Lake Inflow

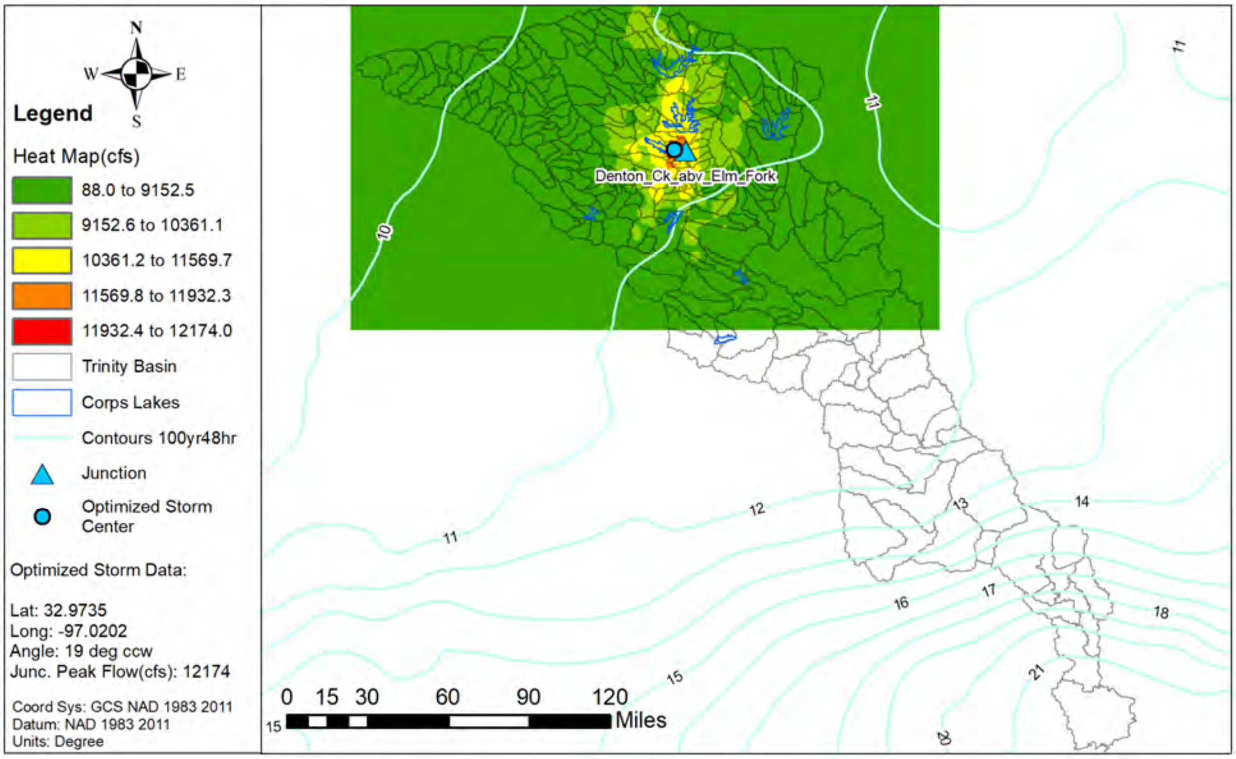


Figure 63a: Elliptical Storm Heat Map for the Denton Creek above the Elm Fork Trinity River

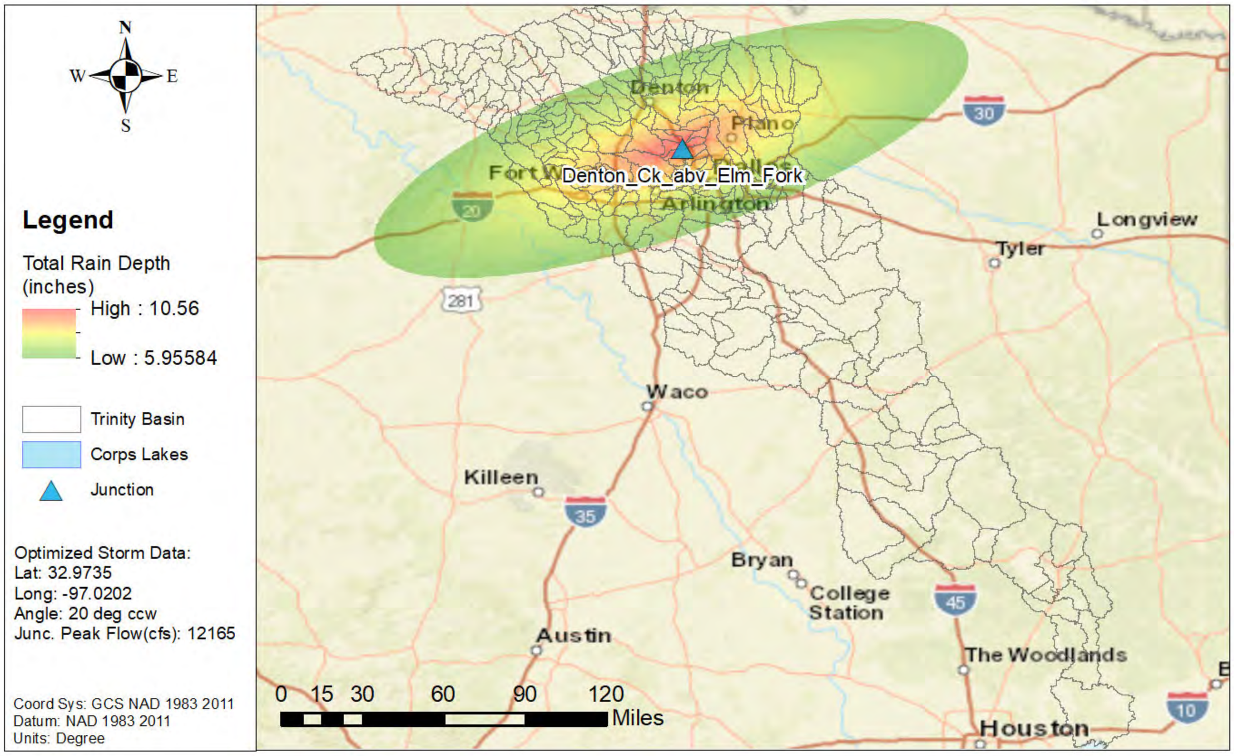


Figure 63b: NA14 1% AEP Elliptical Storm for the Denton Creek above the Elm Fork Trinity River

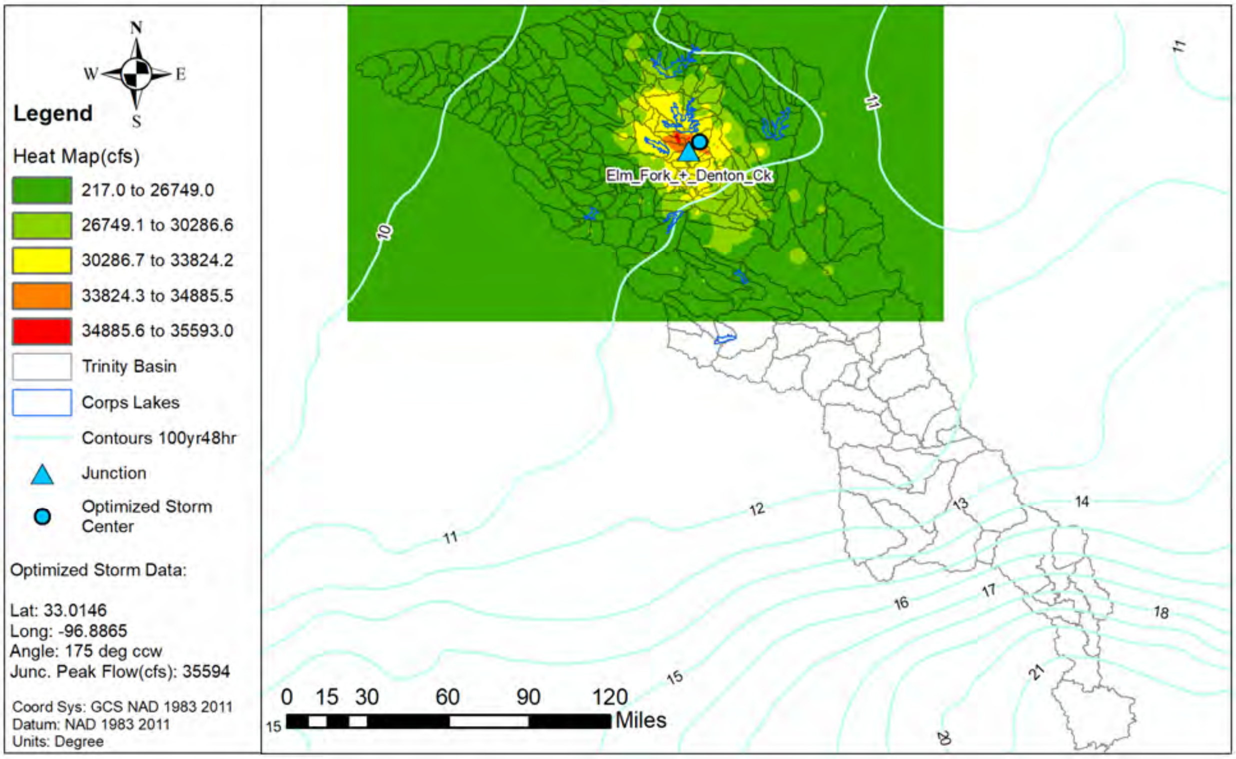


Figure 64a: Elliptical Storm Heat Map for the Elm Fork Trinity River near Carrollton USGS gage

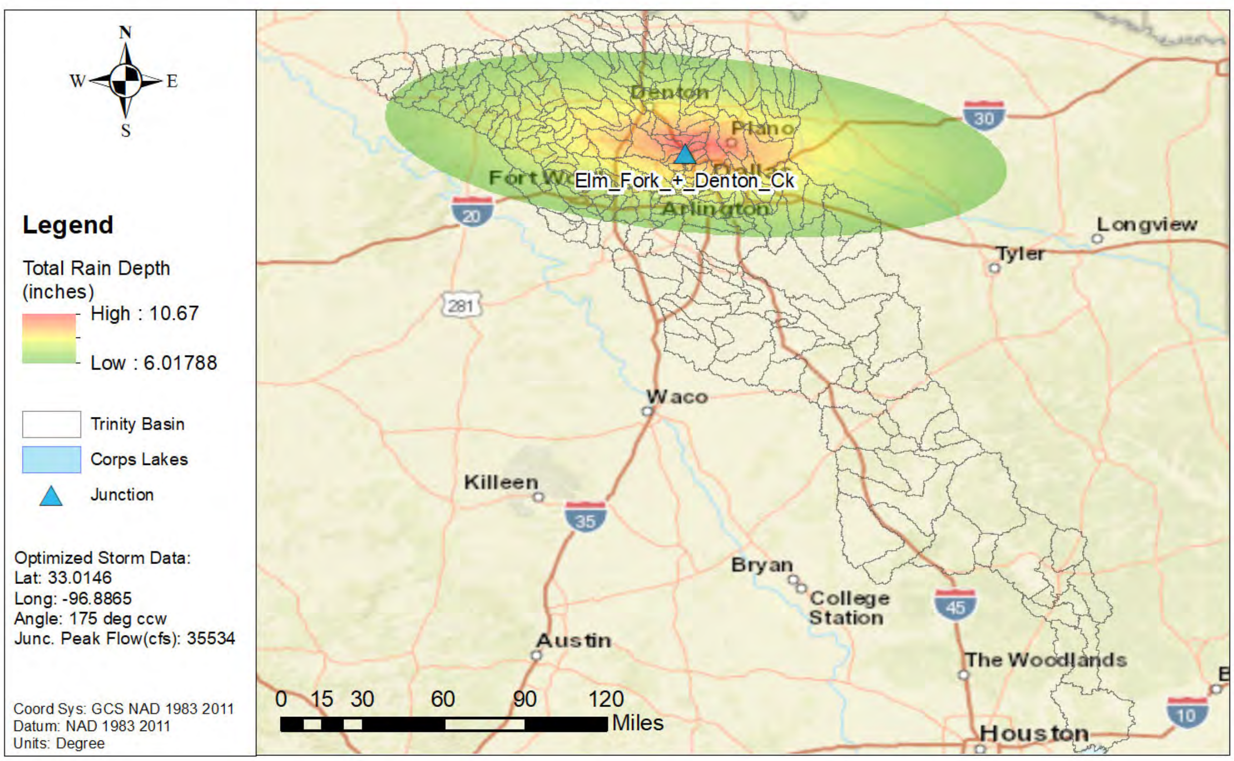


Figure 64b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River near Carrollton USGS gage

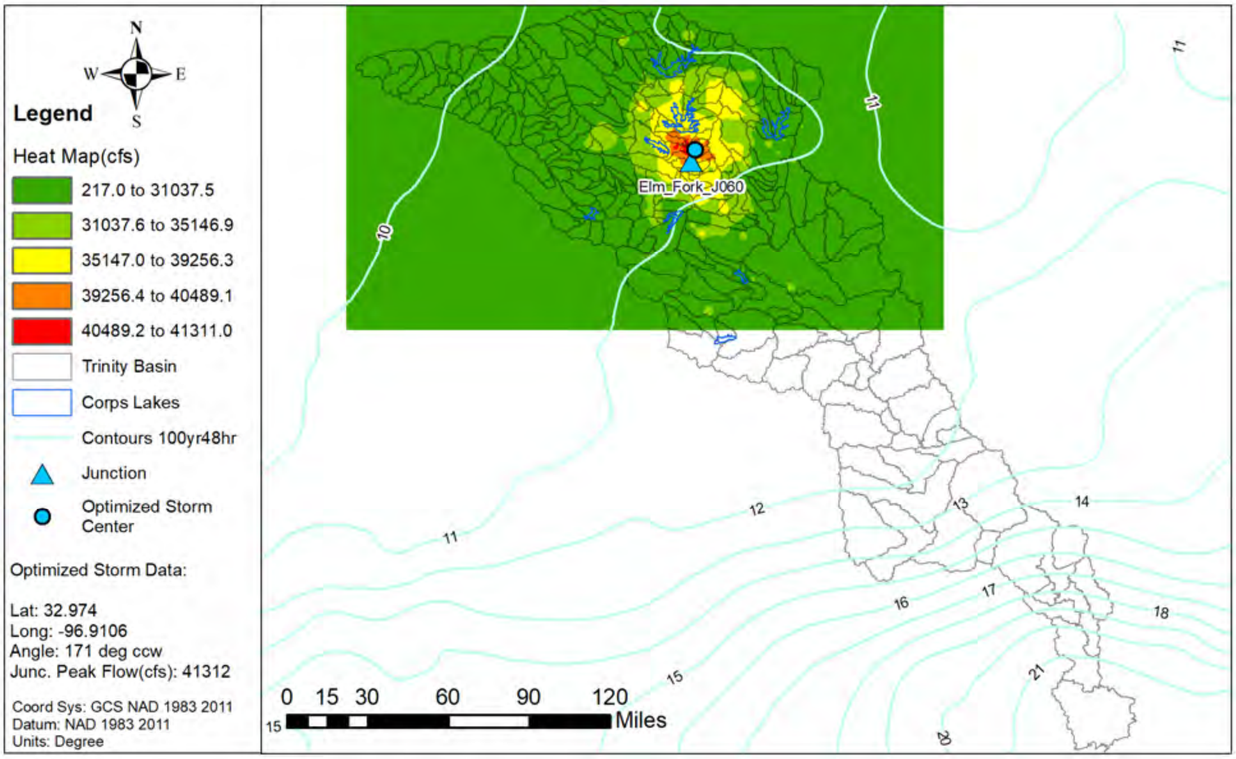


Figure 65a: Elliptical Storm Heat Map for the Elm Fork Trinity River at Interstate 635

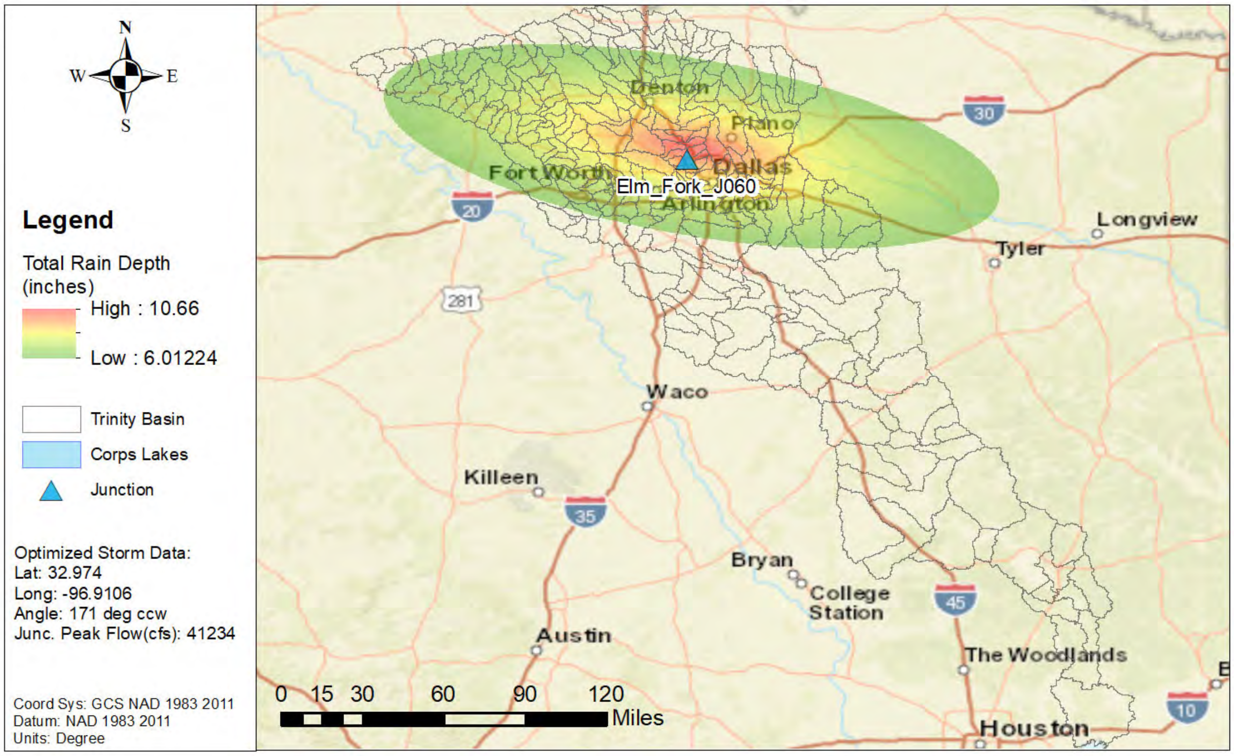


Figure 65b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River at Interstate 635

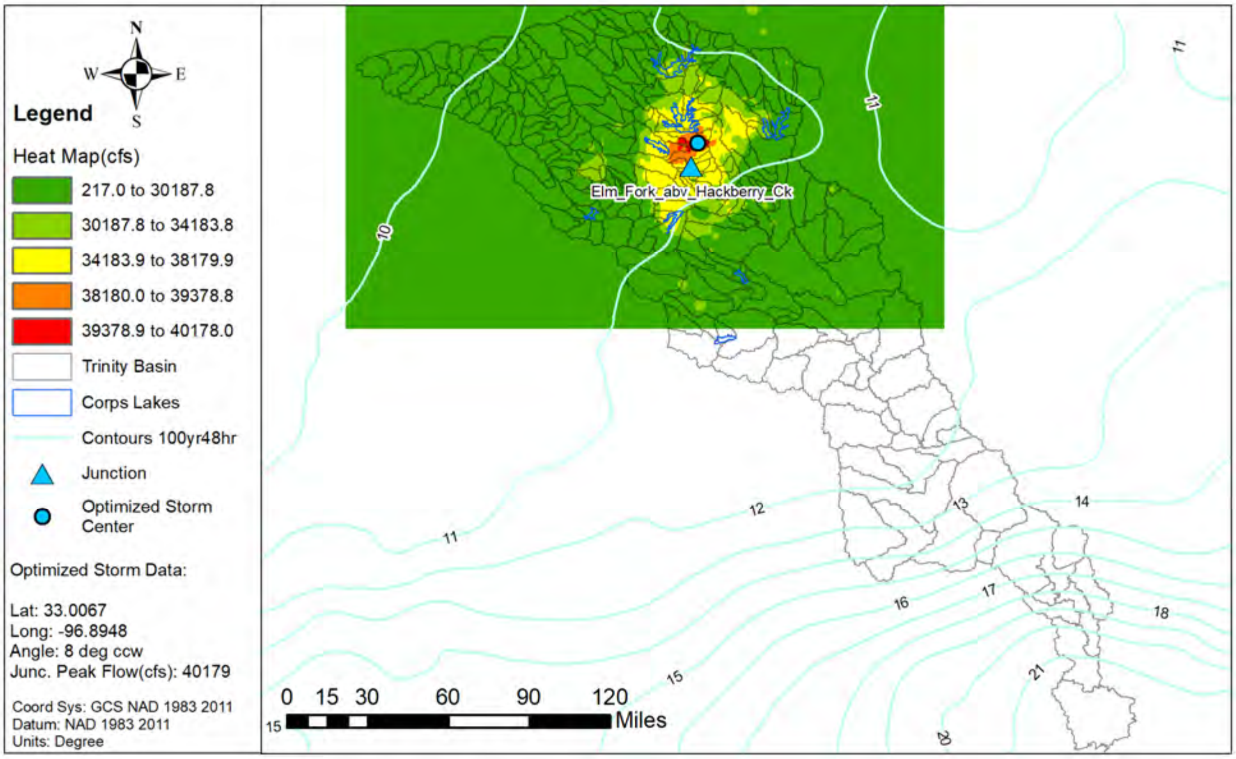


Figure 66a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Hackleberry Creek

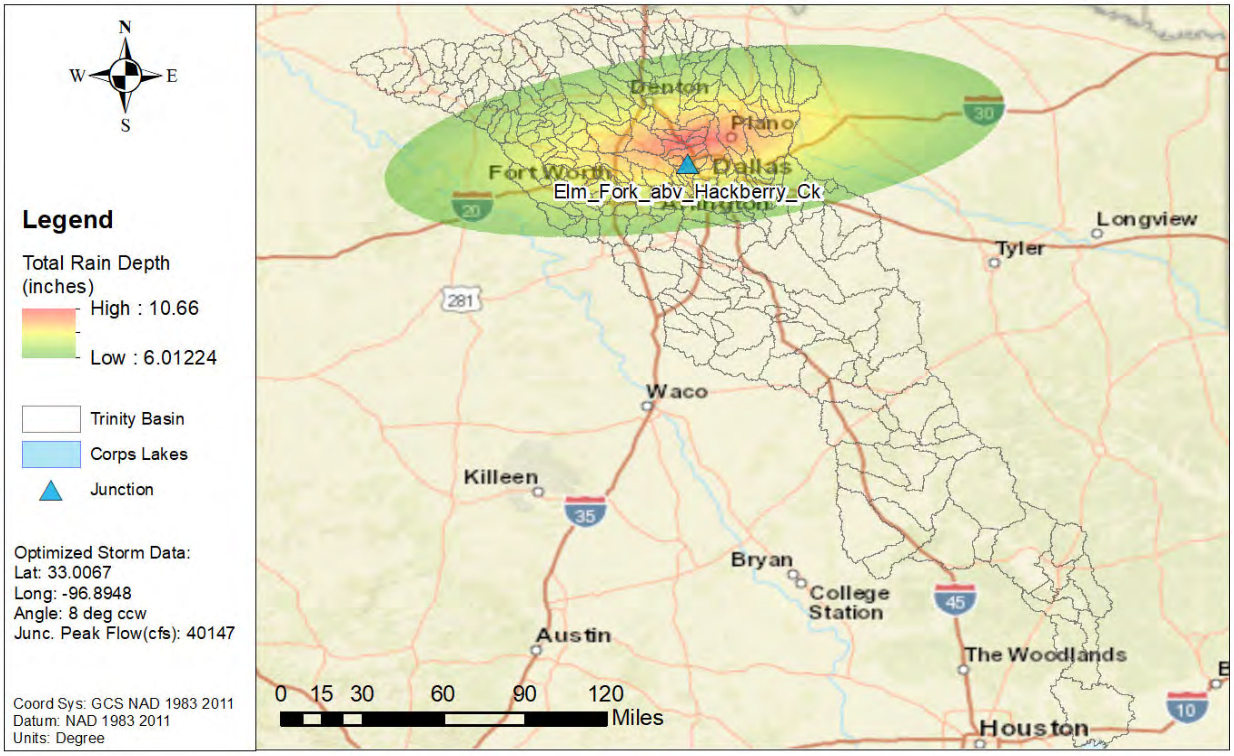


Figure 66b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Hackleberry Creek

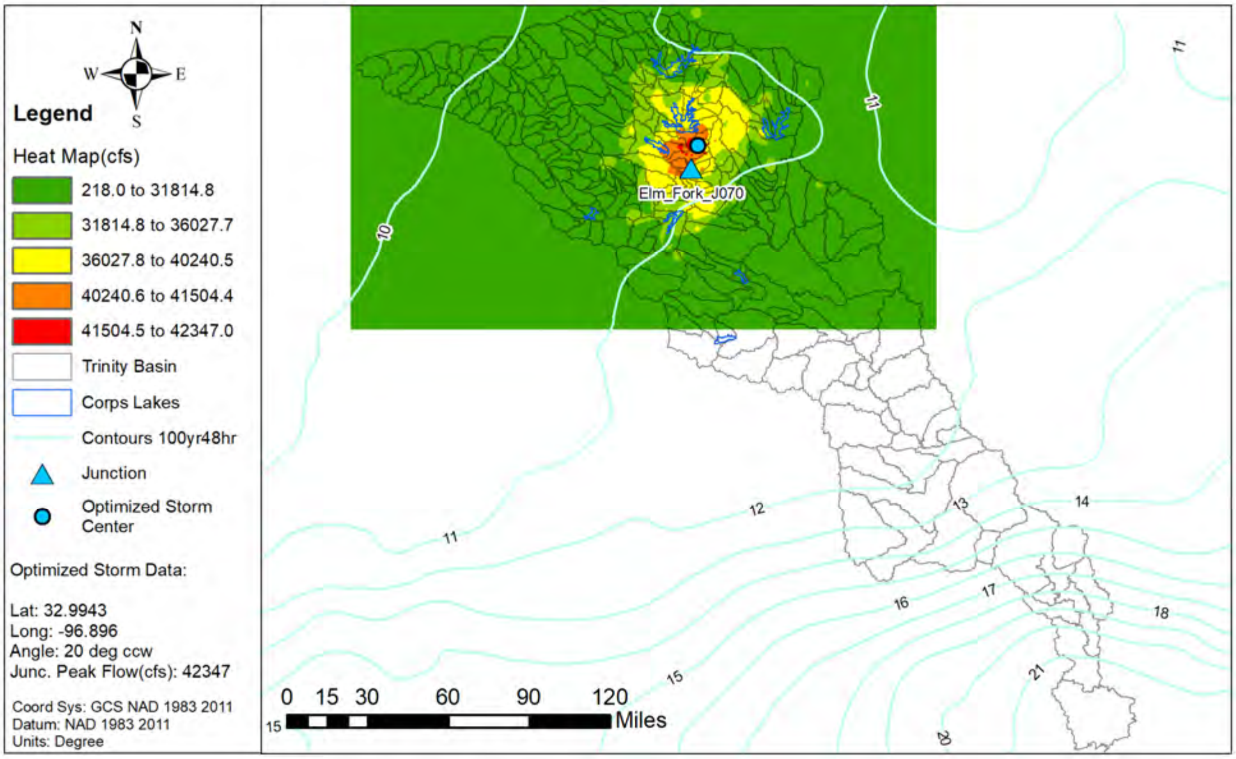


Figure 67a: Elliptical Storm Heat Map for the Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage

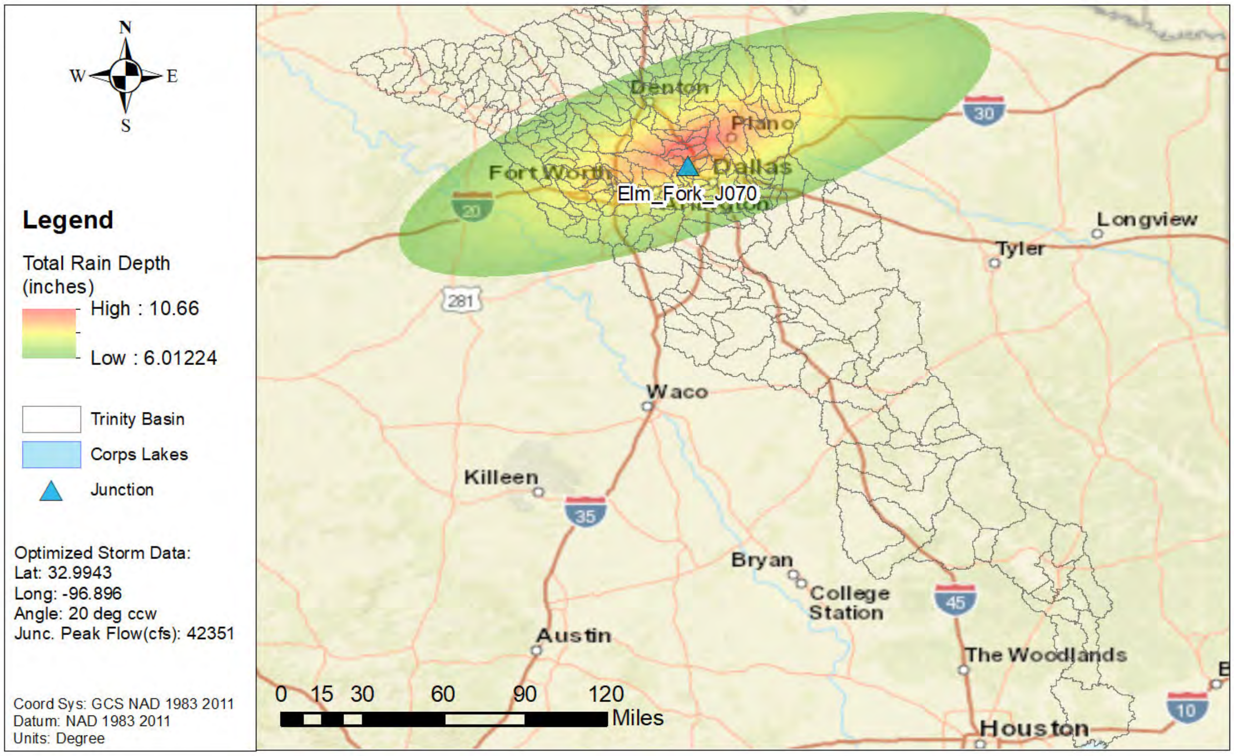


Figure 67b: NA14 1% AEP Elliptical Storm for the Elm Fk Trinity Rv at Spur 348 in Irving; TX USGS gage

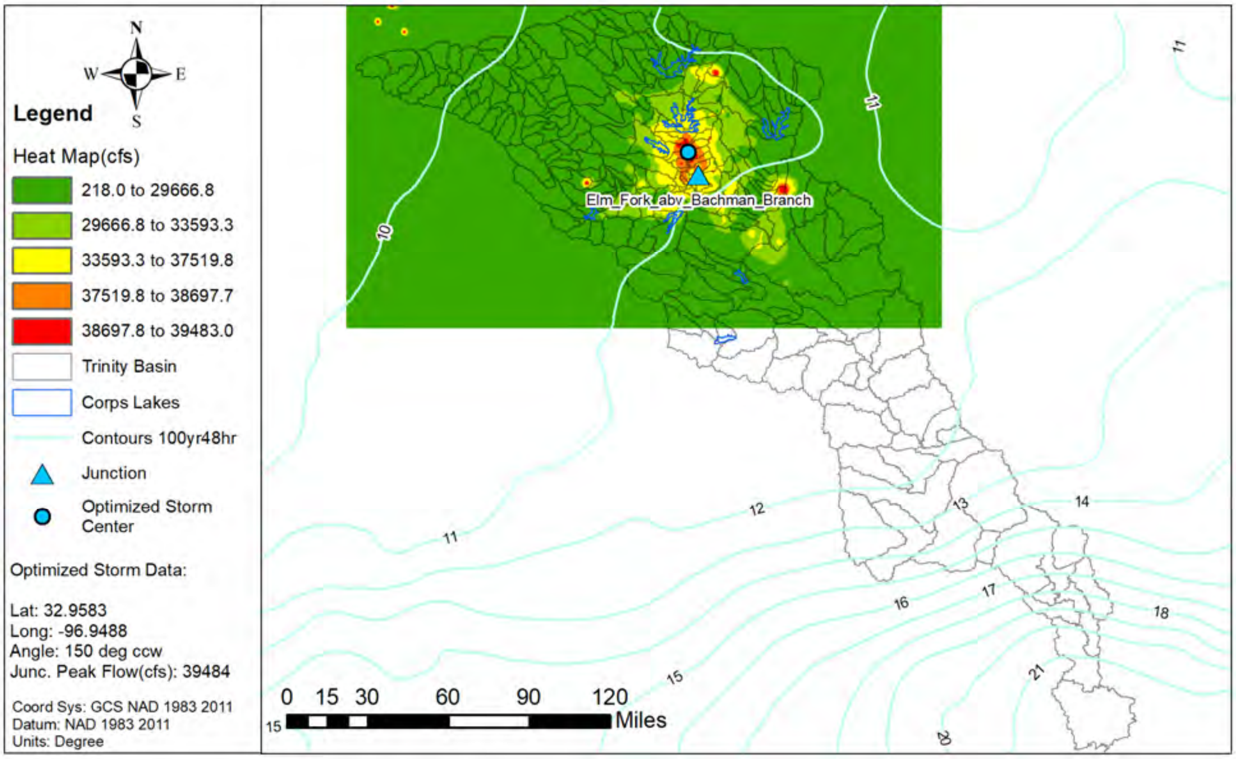


Figure 68a: Elliptical Storm Heat Map for the Elm Fork Trinity River above Bachman Branch

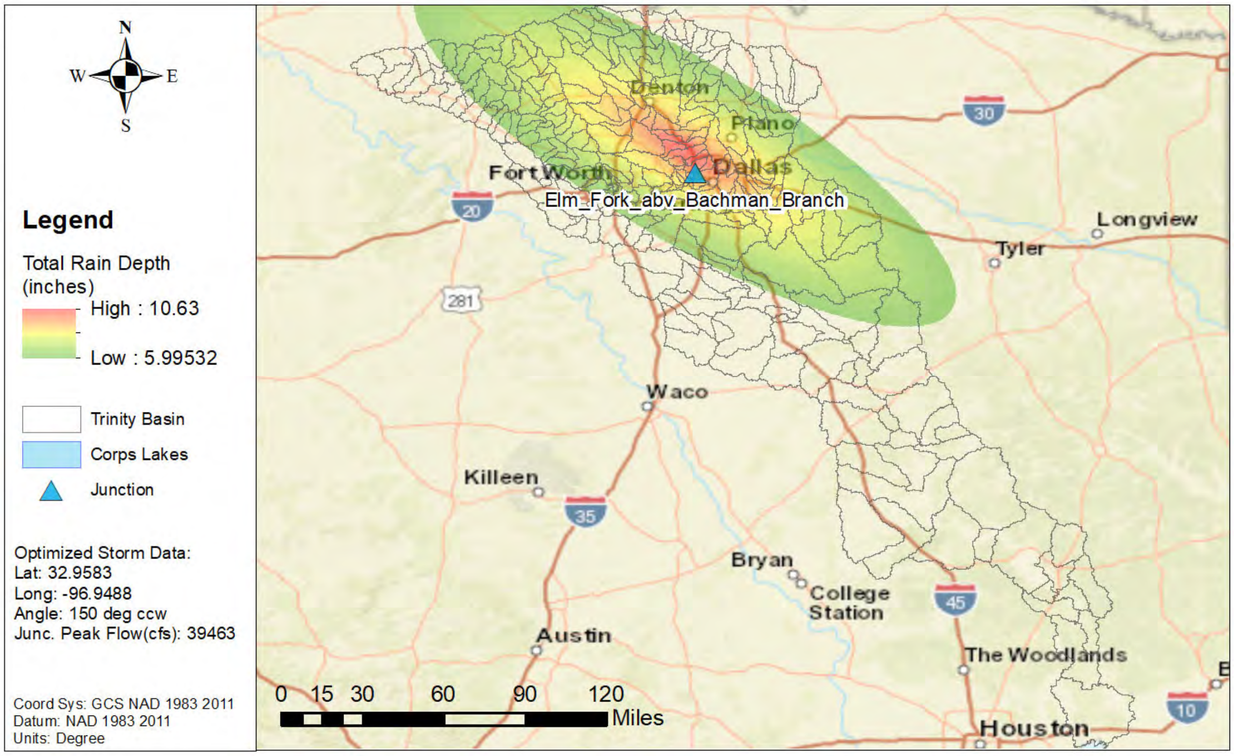


Figure 68b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above Bachman Branch

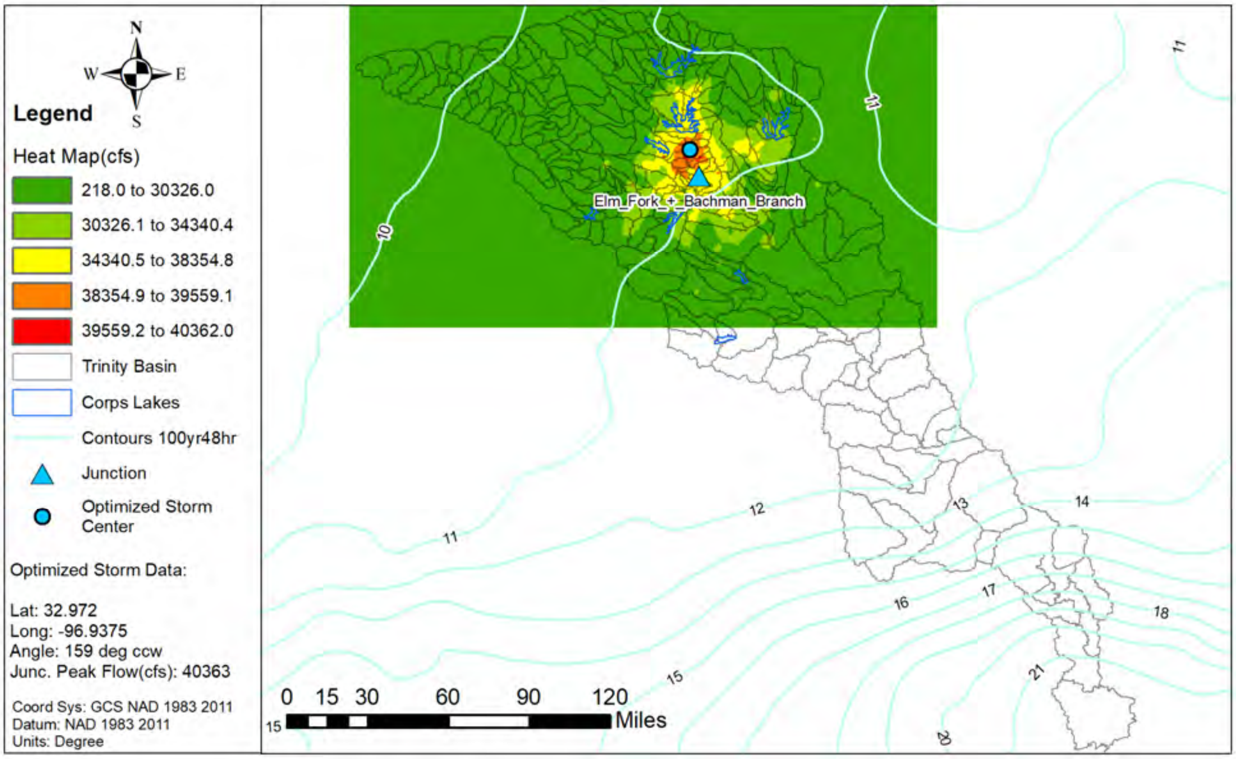


Figure 69a: Elliptical Storm Heat Map for the Elm Fork Trinity River below Bachman Branch

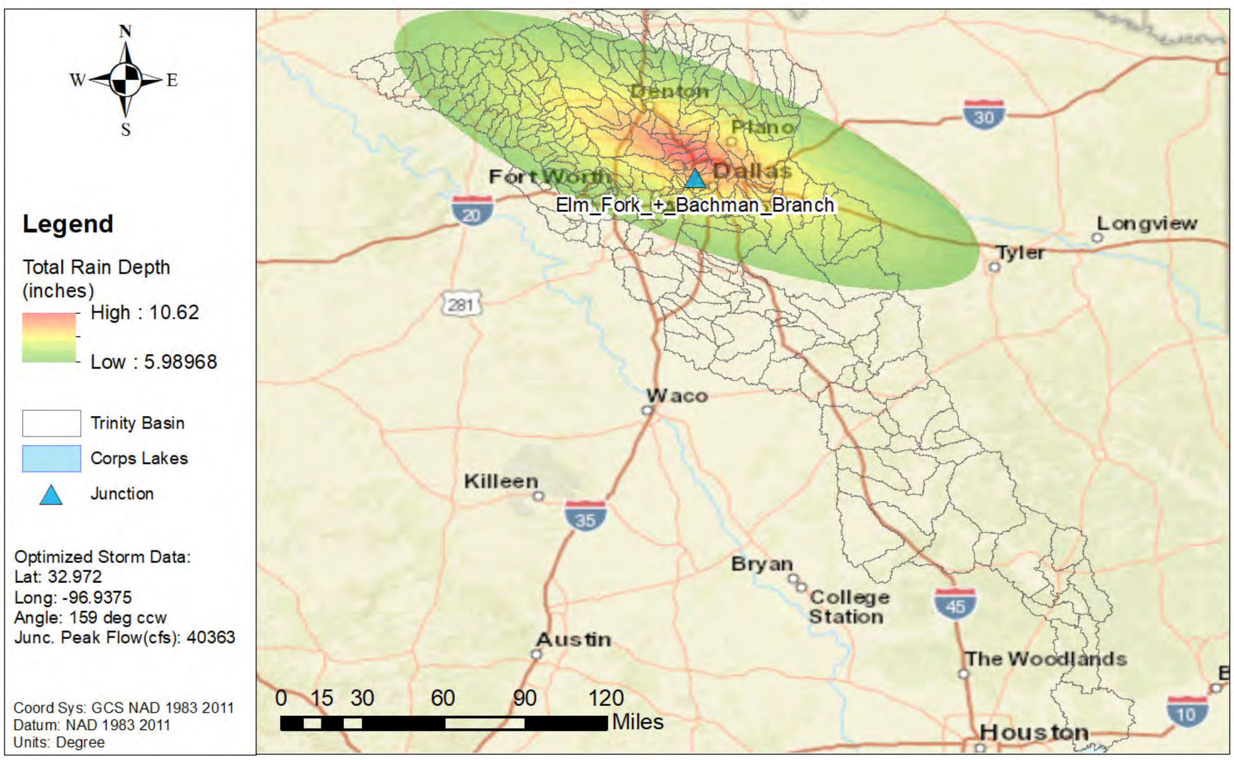


Figure 69b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River below Bachman Branch

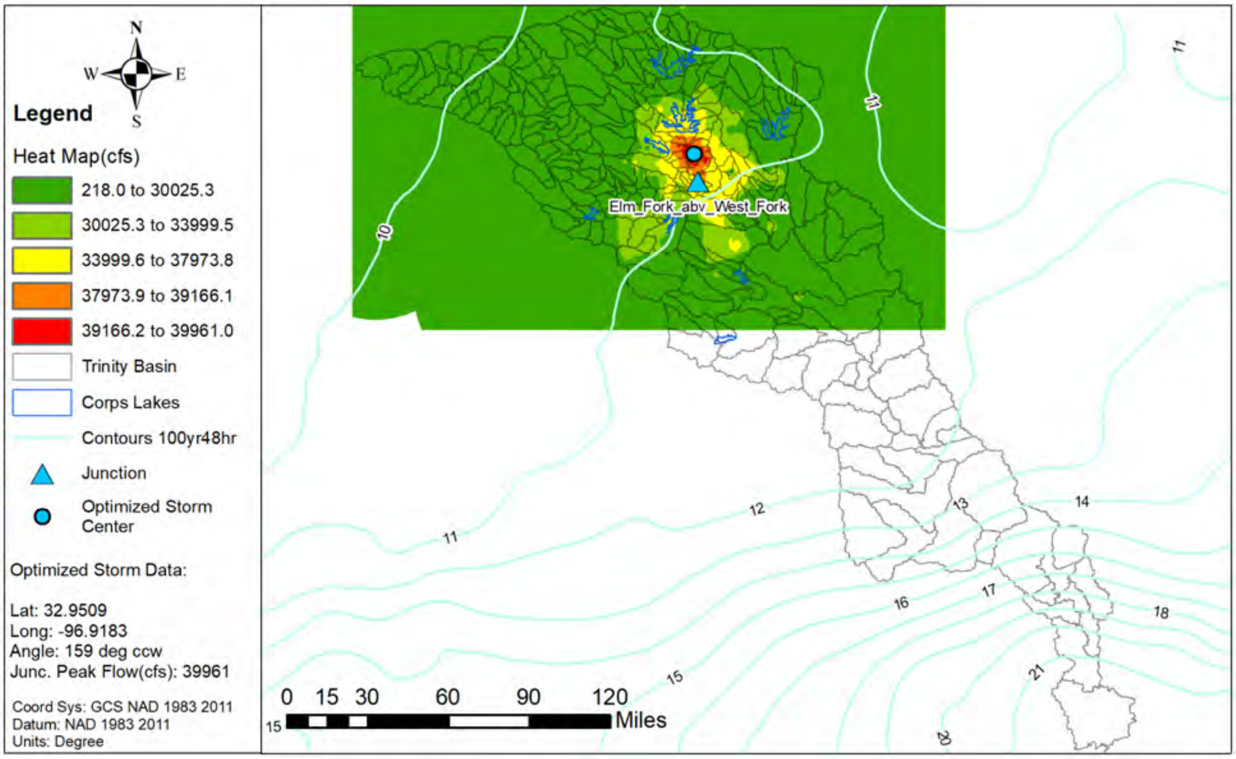


Figure 70a: Elliptical Storm Heat Map for the Elm Fork Trinity River above the West Fork Trinity River

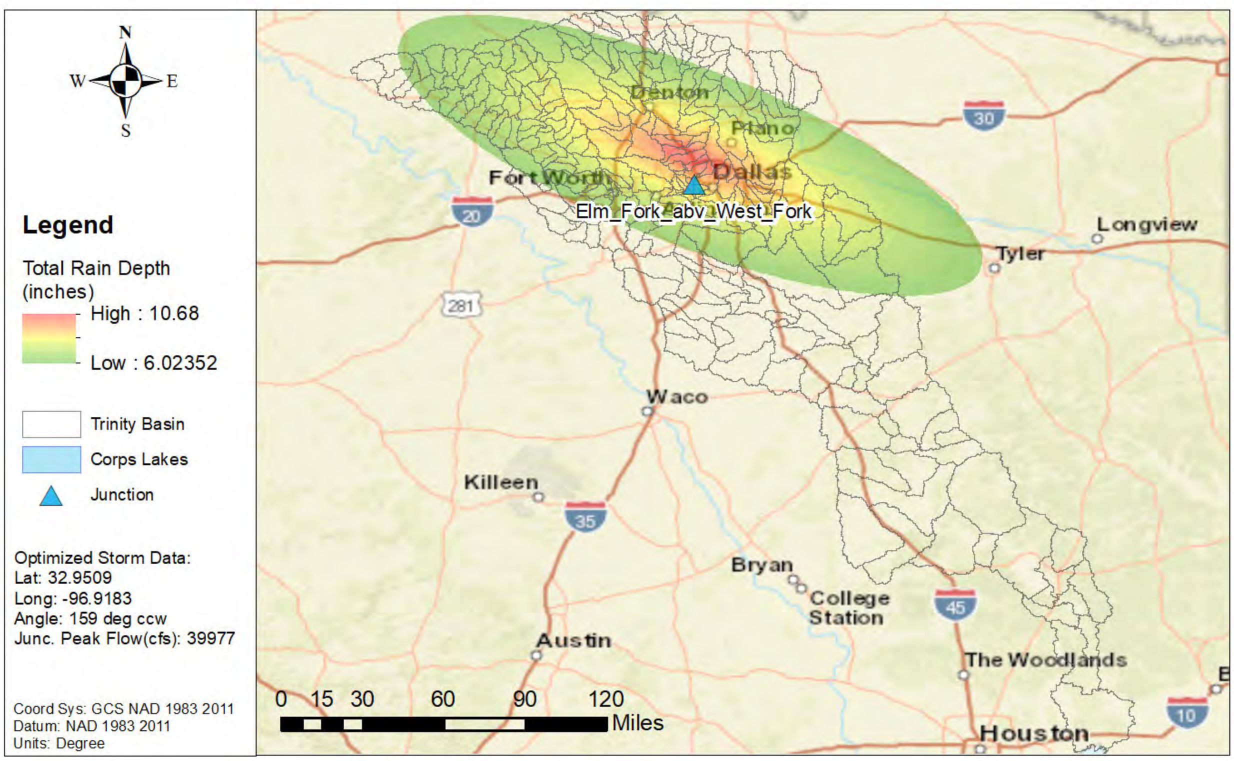


Figure 70b: NA14 1% AEP Elliptical Storm for the Elm Fork Trinity River above the West Fork Trinity River

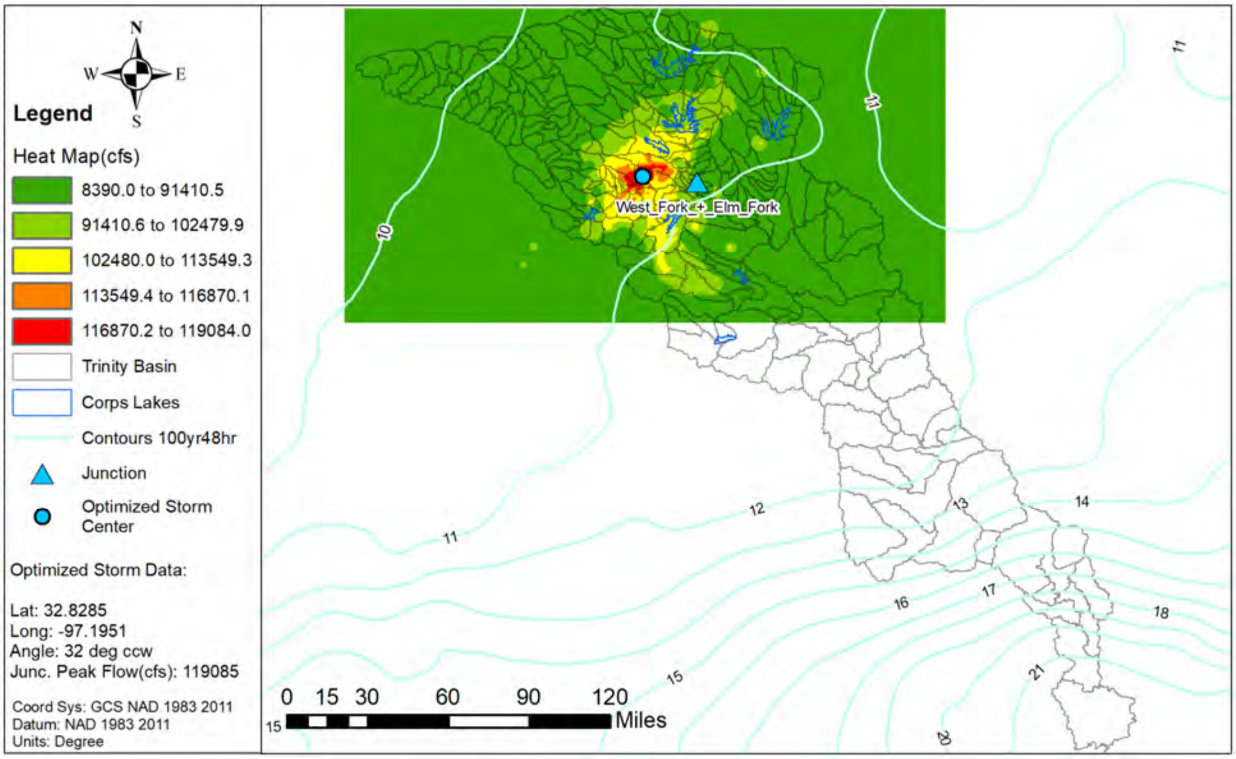


Figure 71a: Elliptical Storm Heat Map for the Trinity River below the West Fork and Elm Fork confluence

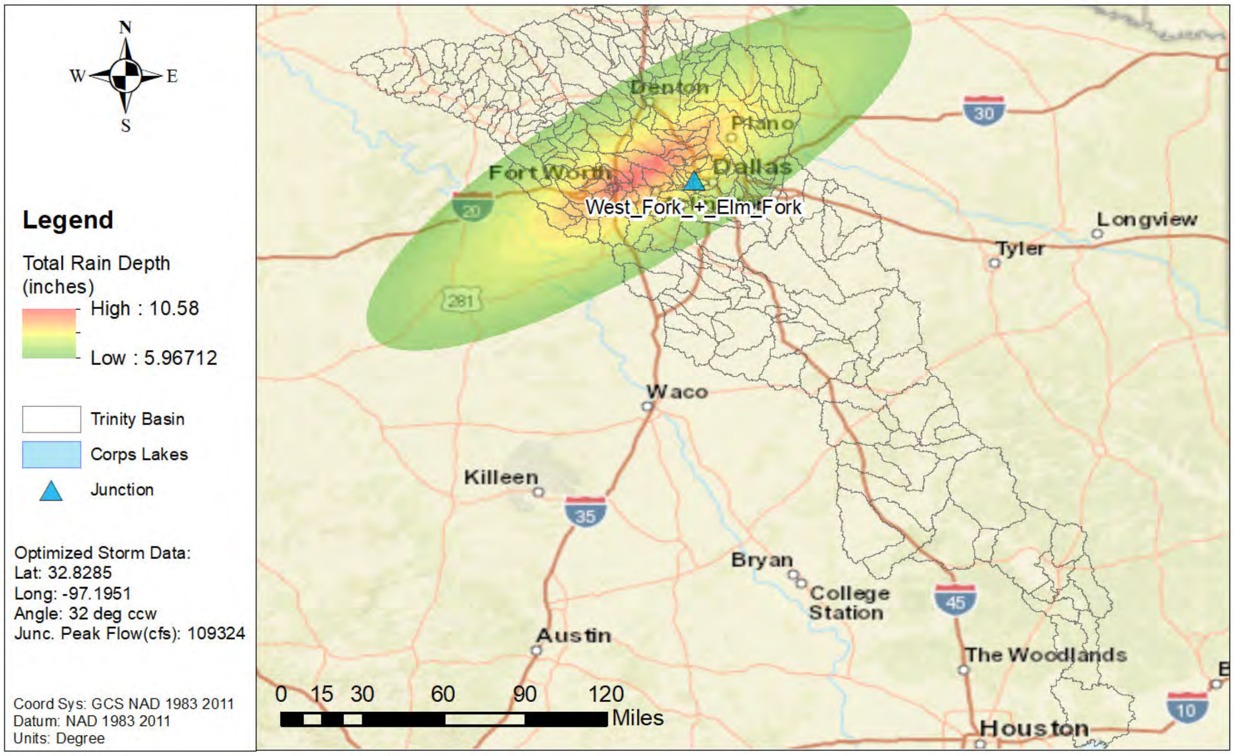


Figure 71b: NA14 1% AEP Elliptical Storm for the Trinity River below the West Fork & Elm Fork confluence

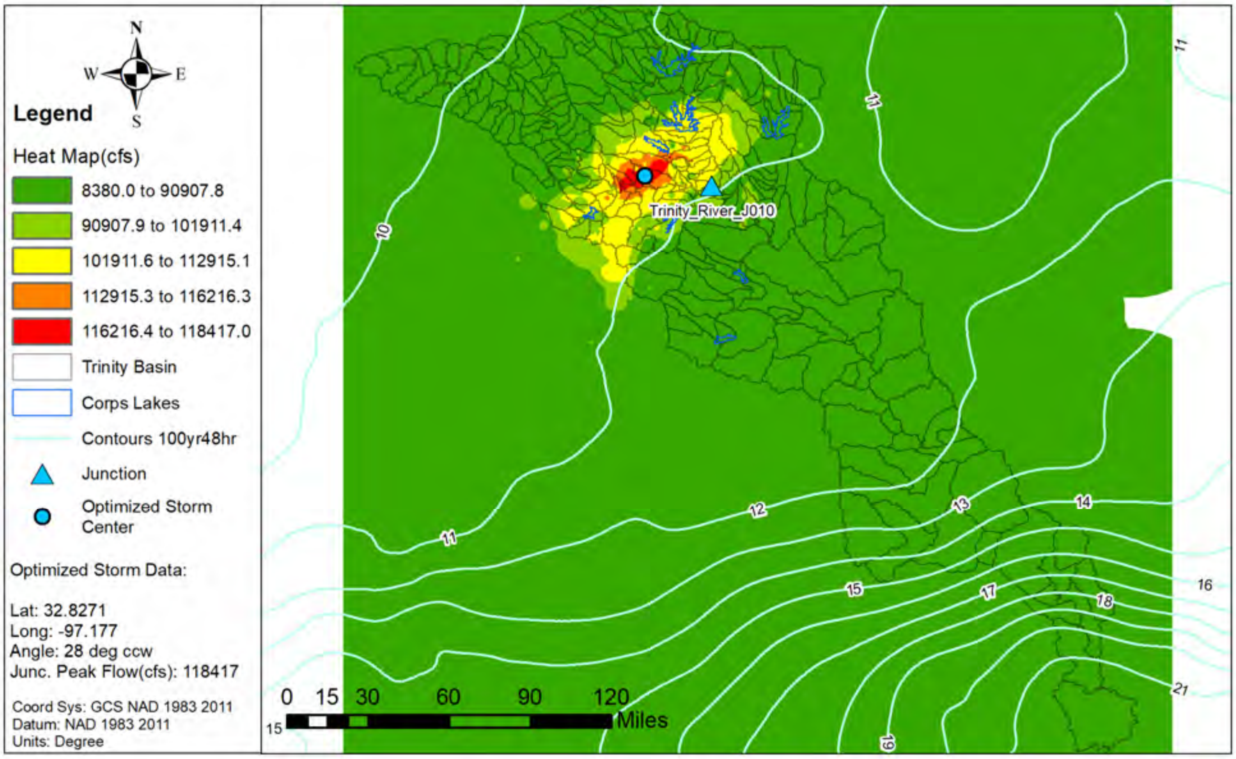


Figure 72a: Elliptical Storm Heat Map for the Trinity River at Dallas, TX USGS gage

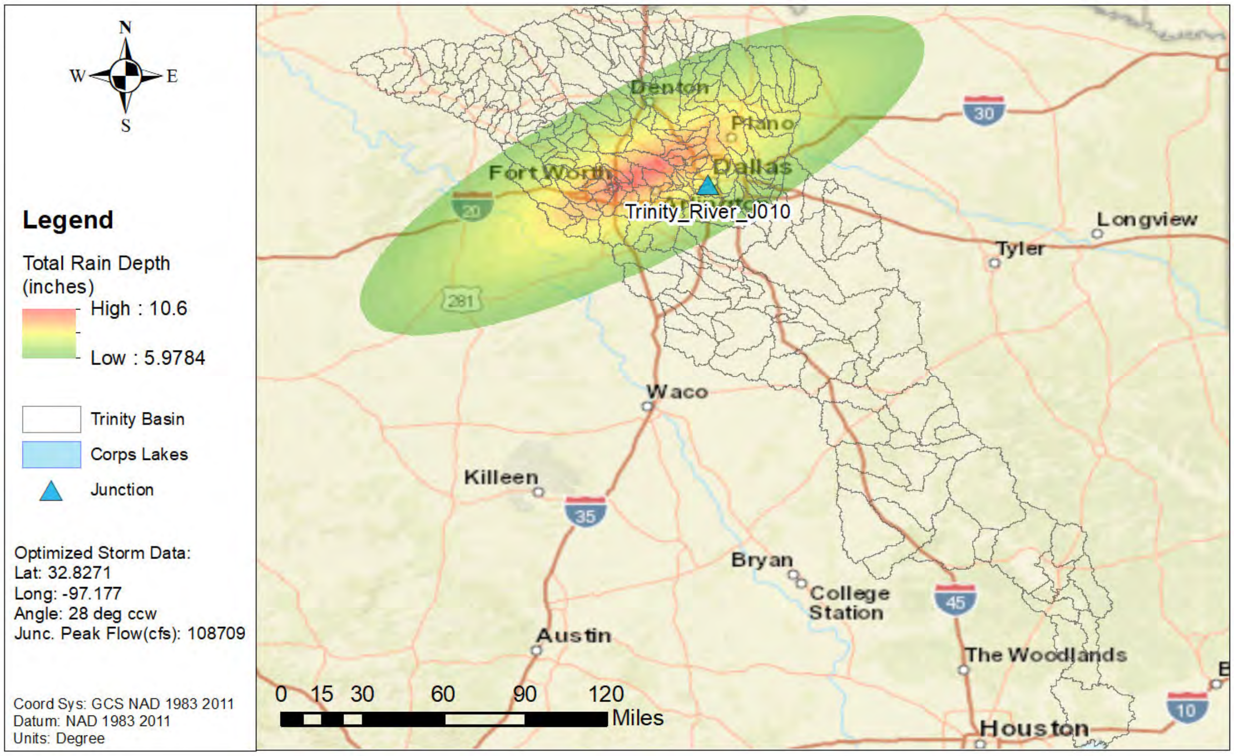


Figure 72b: NA14 1% AEP Elliptical Storm for the Trinity River at Dallas, TX USGS gage

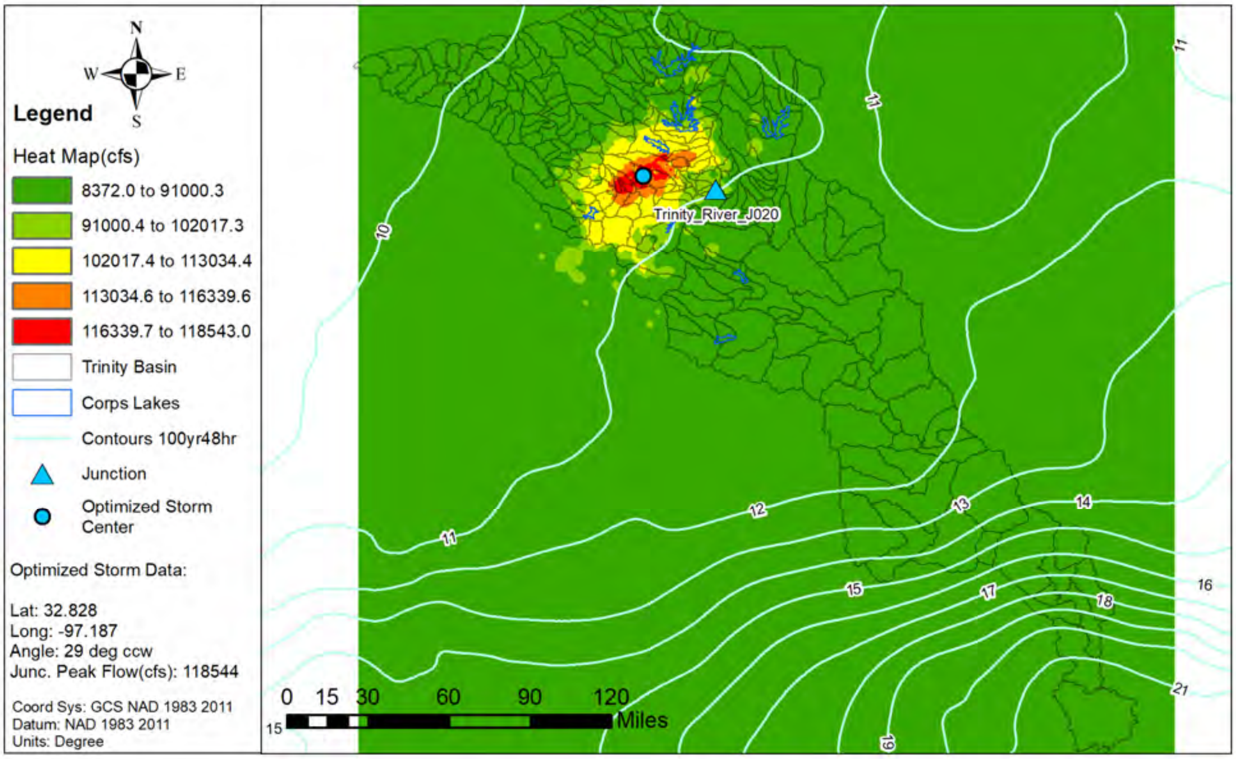


Figure 73a: Elliptical Storm Heat Map for the Trinity River at the Corinth Street bridge in Dallas, TX

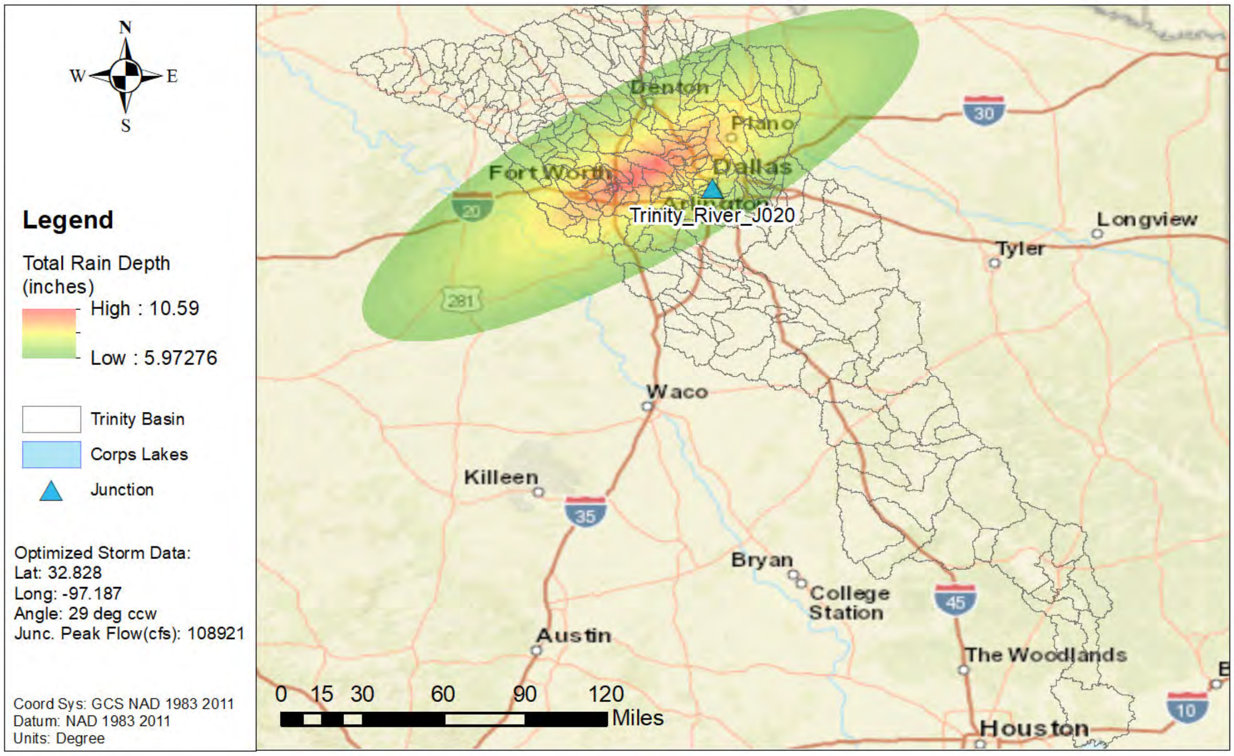


Figure 73b: NA14 1% AEP Elliptical Storm for the Trinity River at the Corinth Street bridge in Dallas, TX

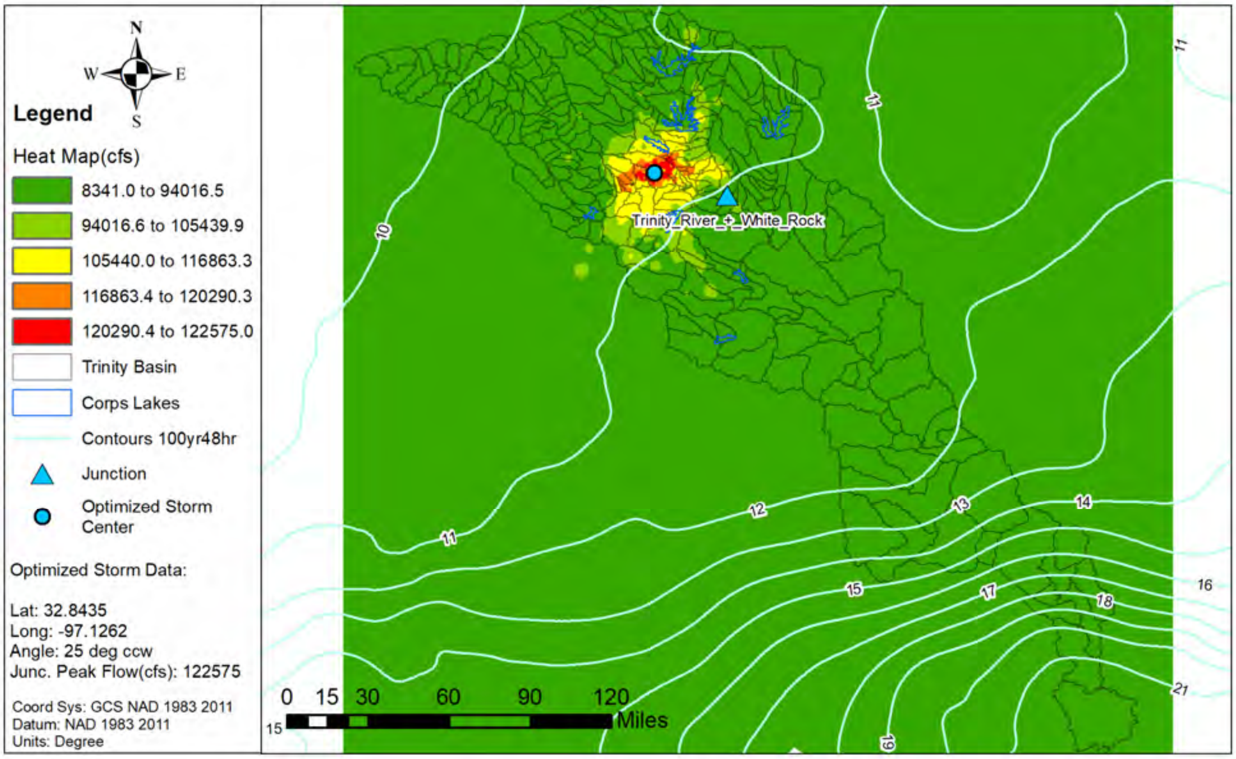


Figure 74a: Elliptical Storm Heat Map for the Trinity River below White Rock Creek

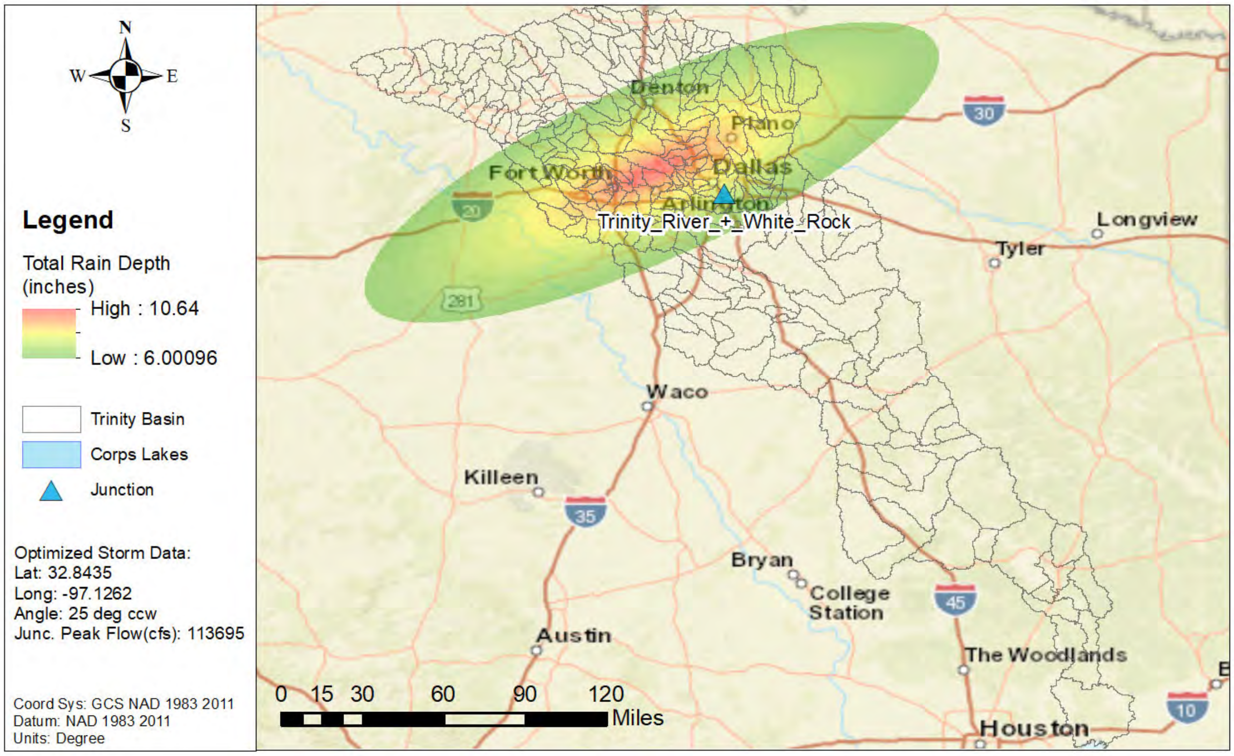


Figure 74b: NA14 1% AEP Elliptical Storm for the Trinity River below White Rock Creek

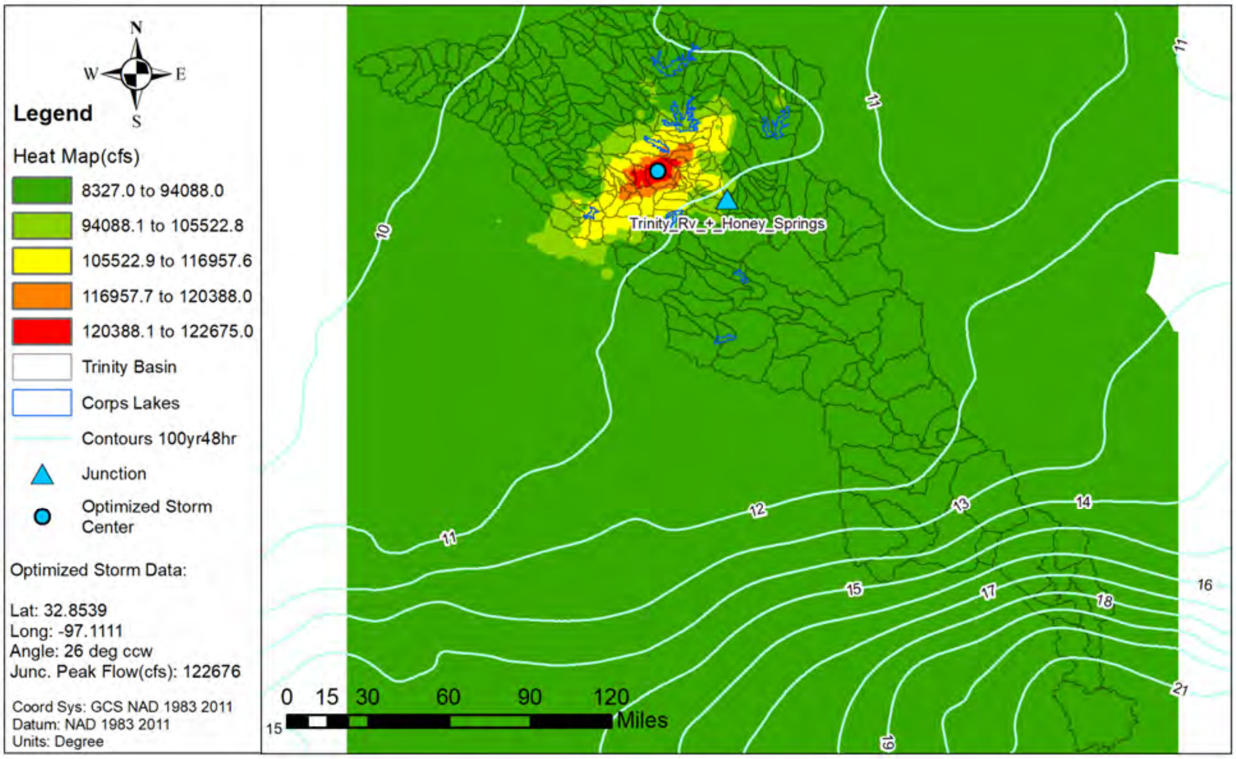


Figure 75a: Elliptical Storm Heat Map for the Trinity River below Honey Springs Branch

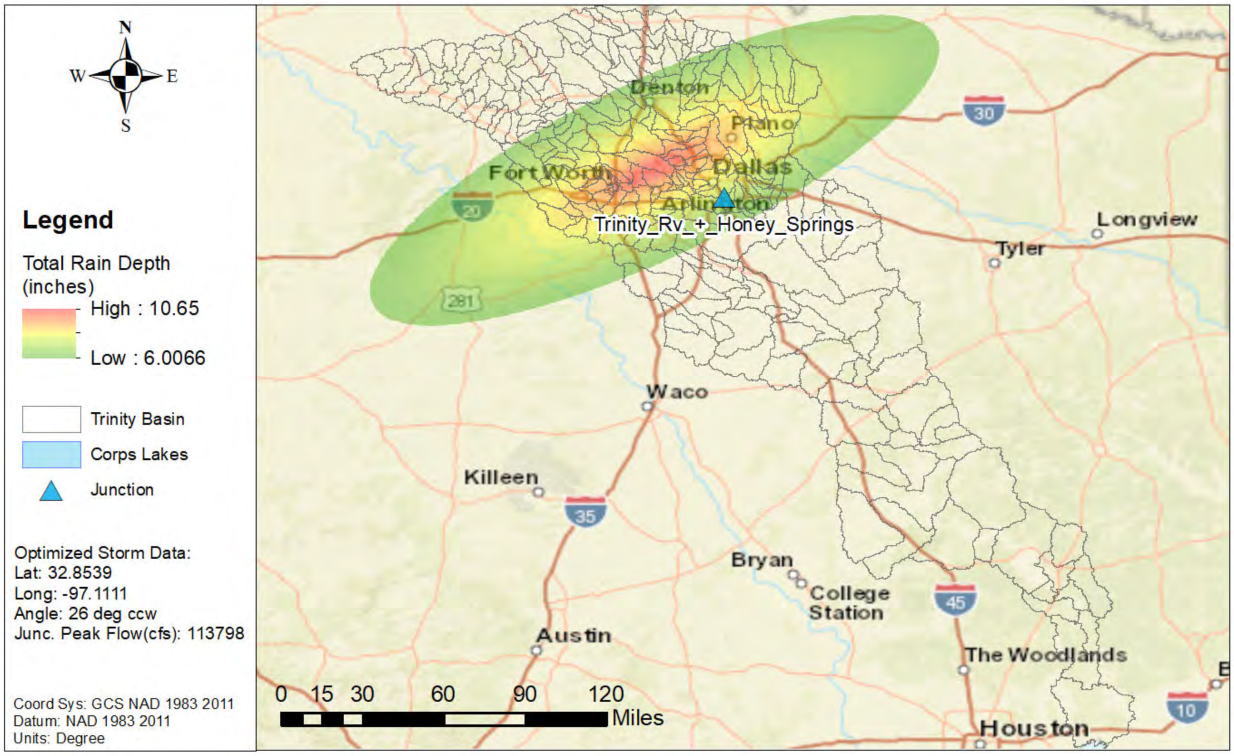


Figure 75b: NA14 1% AEP Elliptical Storm for the Trinity River below Honey Springs Branch

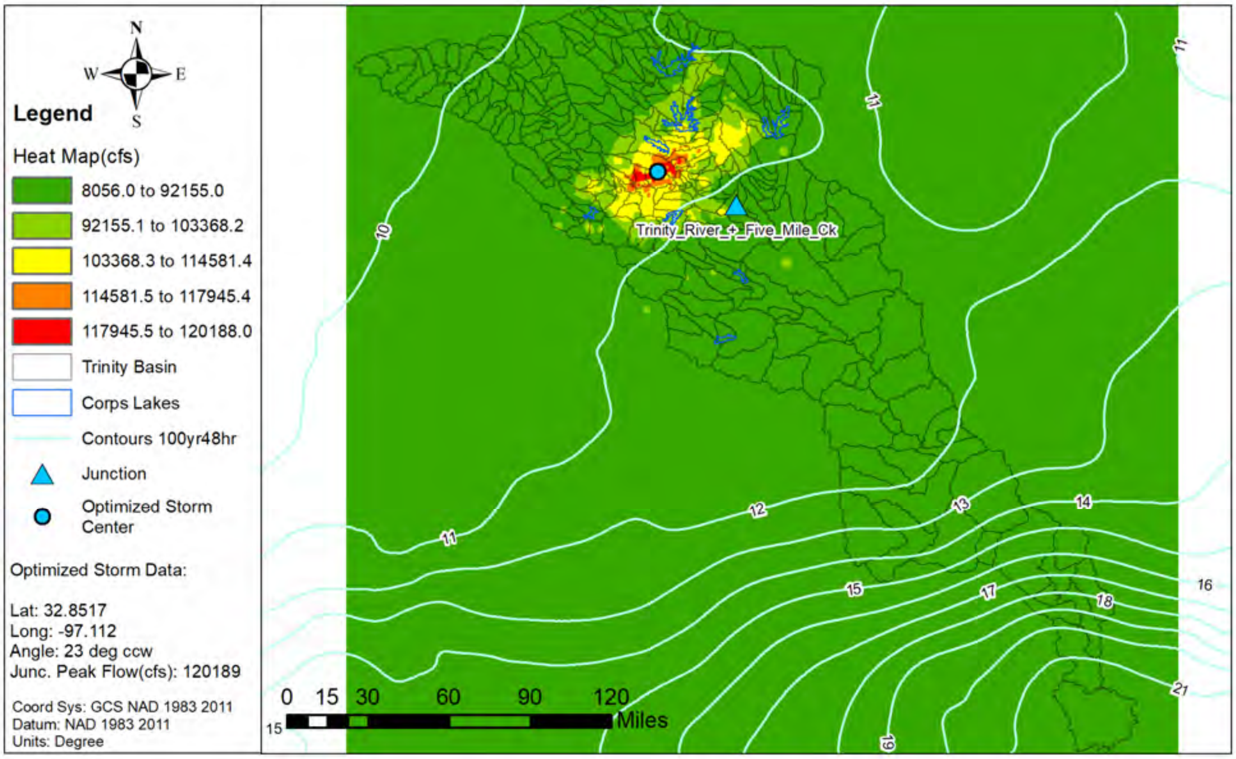


Figure 76a: Elliptical Storm Heat Map for the Trinity River below Five Mile Ceek

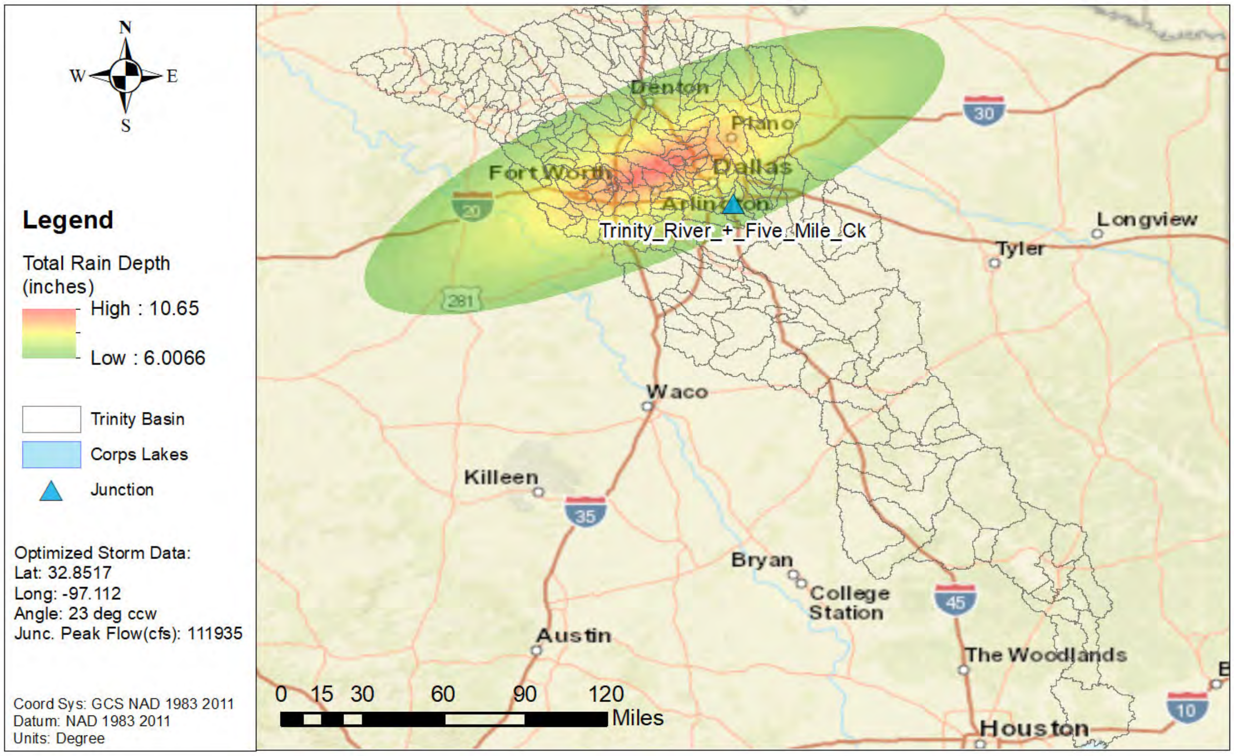


Figure 76b: NA14 1% AEP Elliptical Storm for the Trinity River below Five Mile Ceek

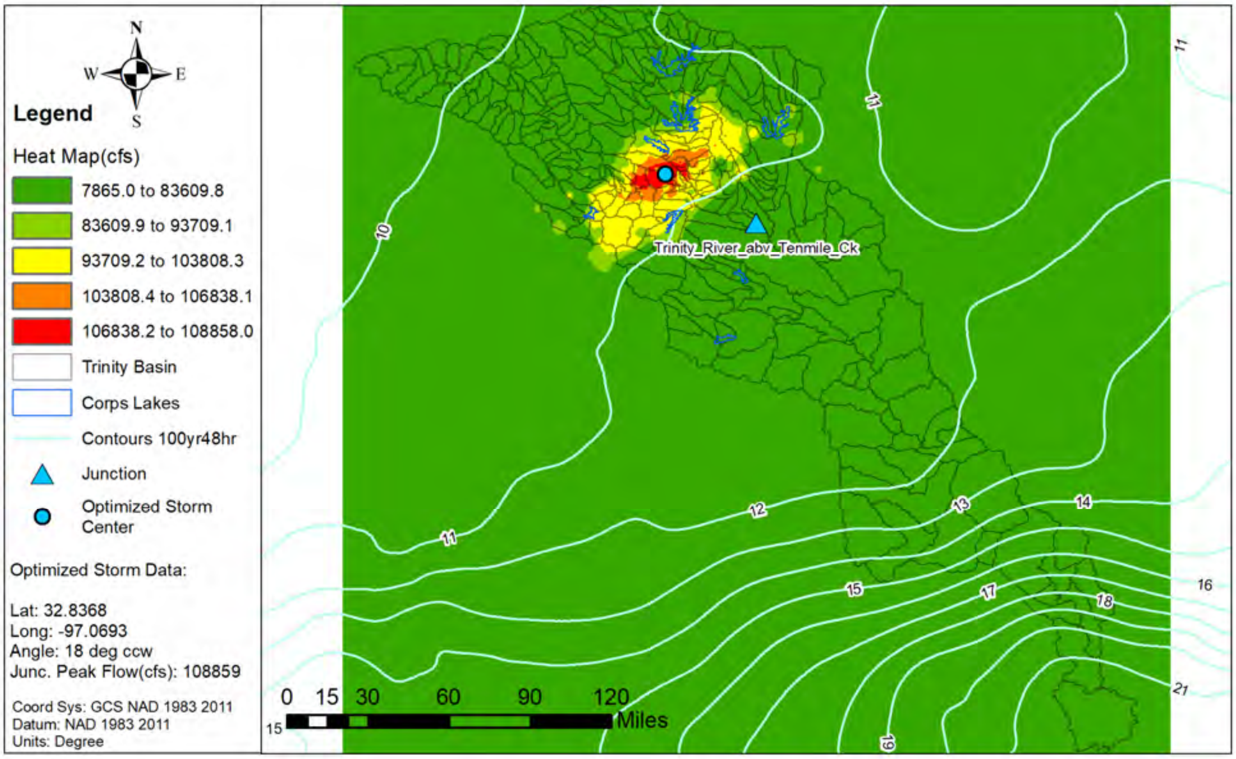


Figure 77a: Elliptical Storm Heat Map for the Trinity River above Ten Mile Creek

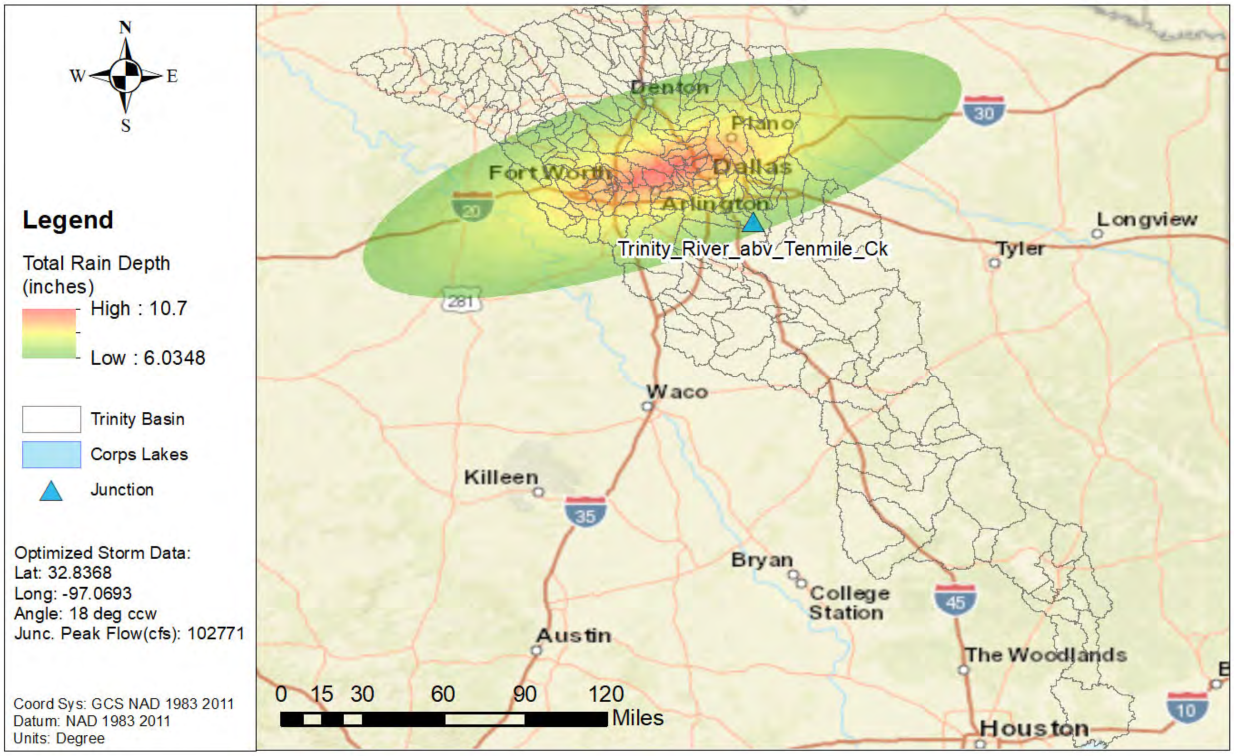


Figure 77b: NA14 1% AEP Elliptical Storm for the Trinity River above Ten Mile Creek

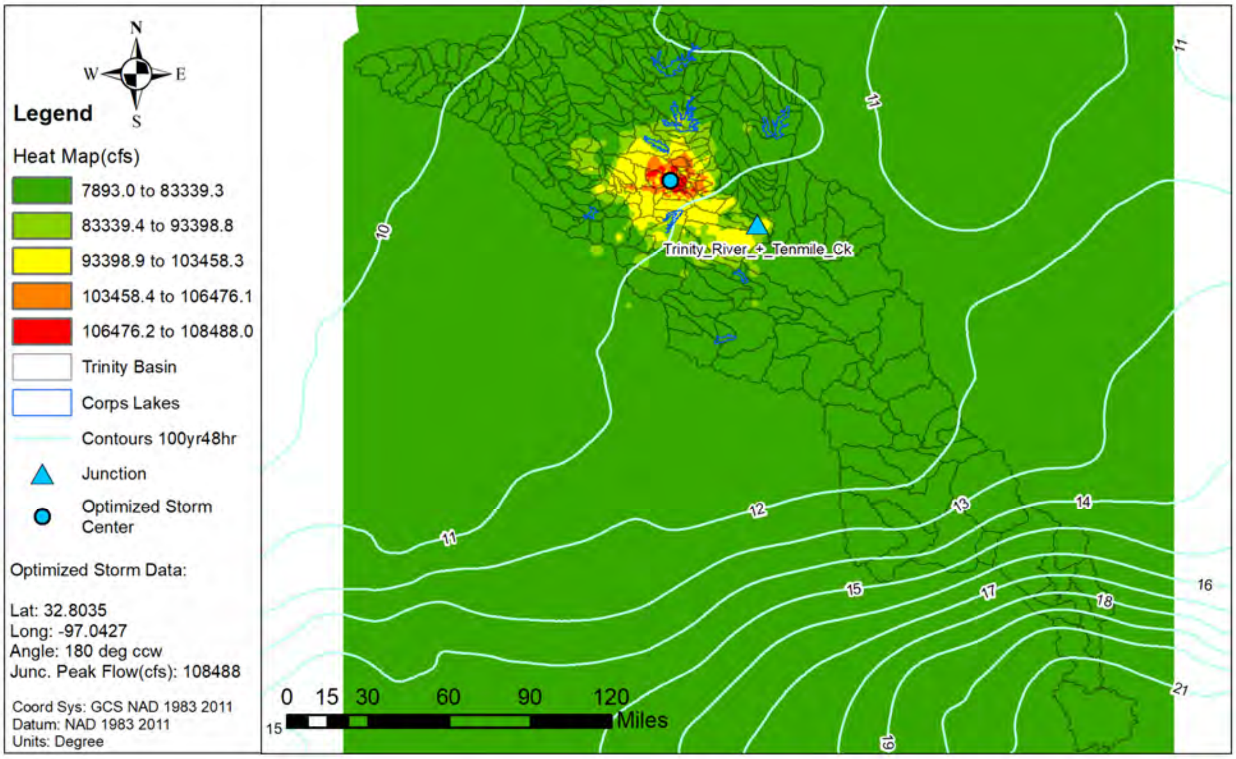


Figure 78a: Elliptical Storm Heat Map for the Trinity River below Ten Mile Creek

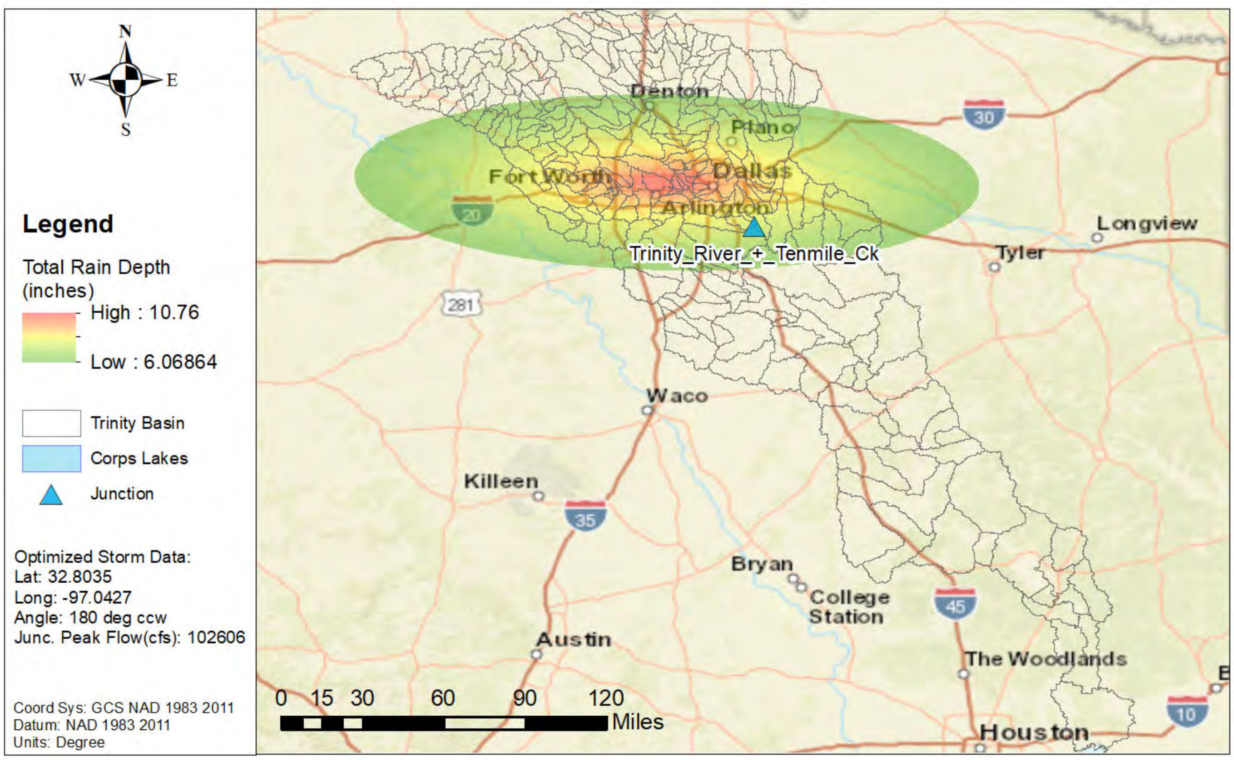


Figure 78b: NA14 1% AEP Elliptical Storm for the Trinity River below Ten Mile Creek

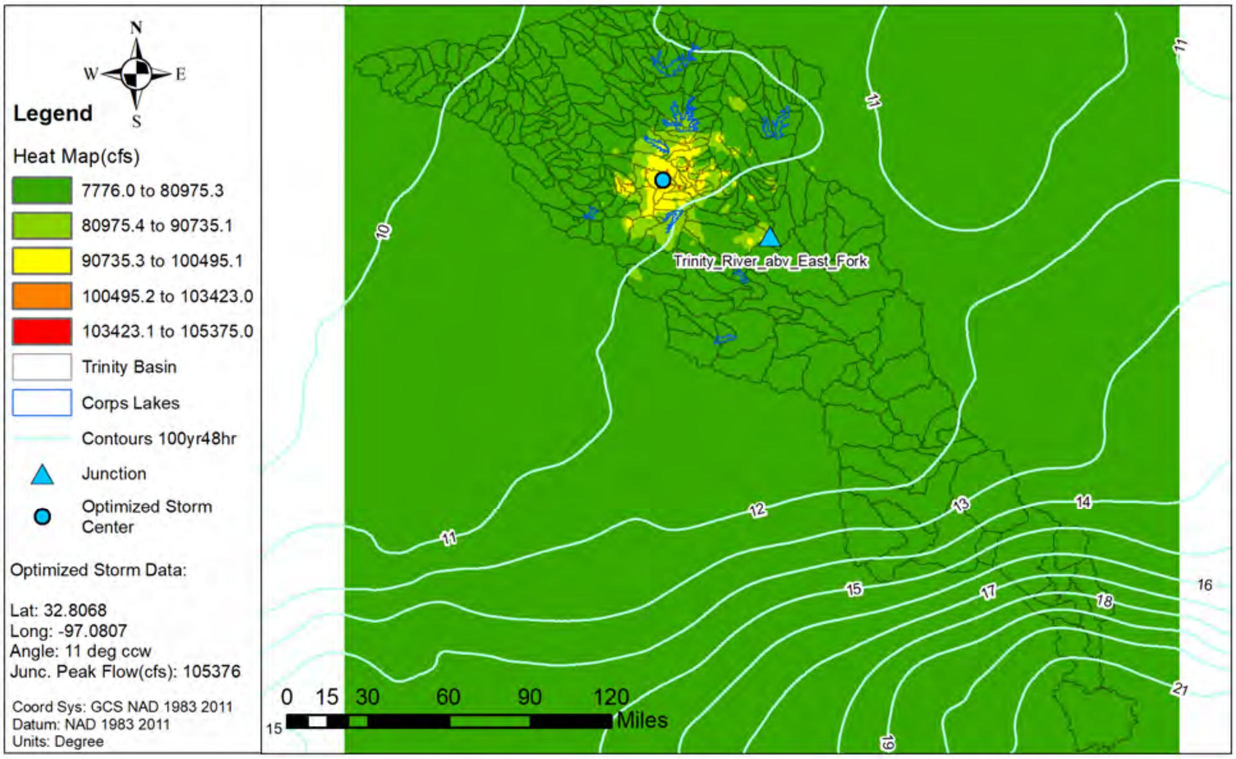


Figure 79a: Elliptical Storm Heat Map for the Trinity River above the East Fork Trinity River

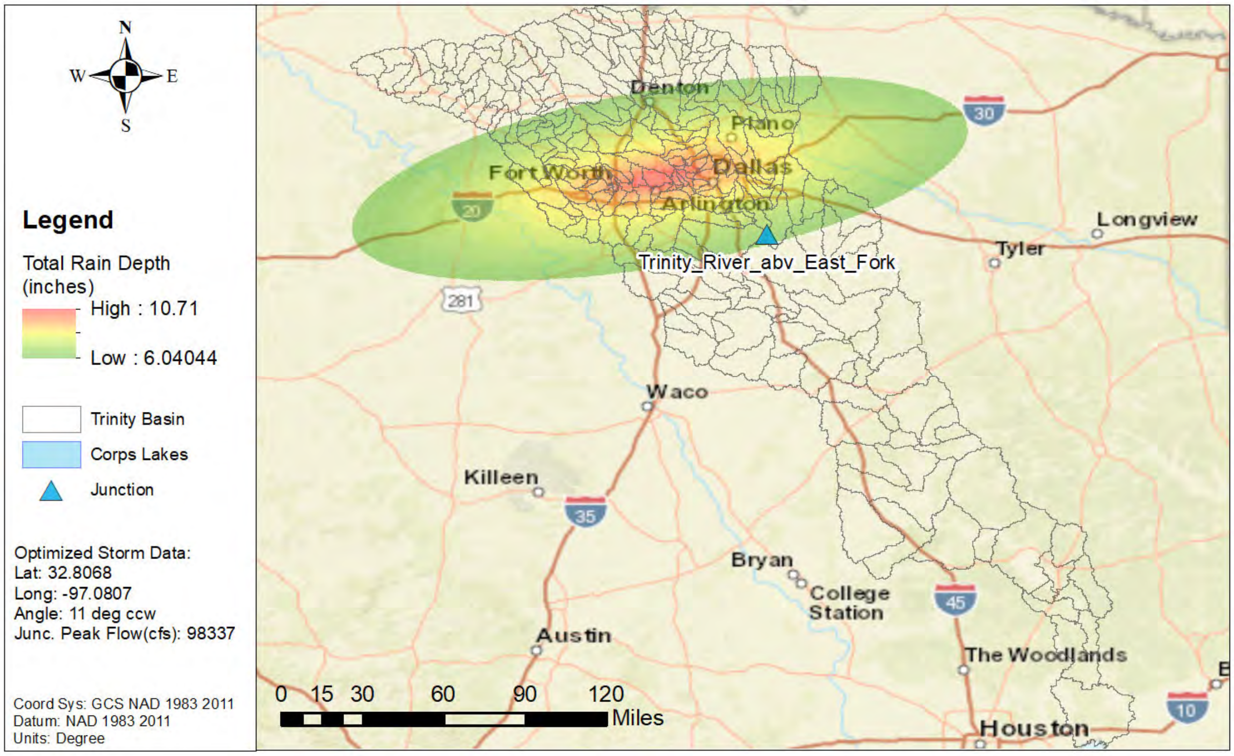


Figure 79b: NA14 1% AEP Elliptical Storm for the Trinity River above the East Fork Trinity River

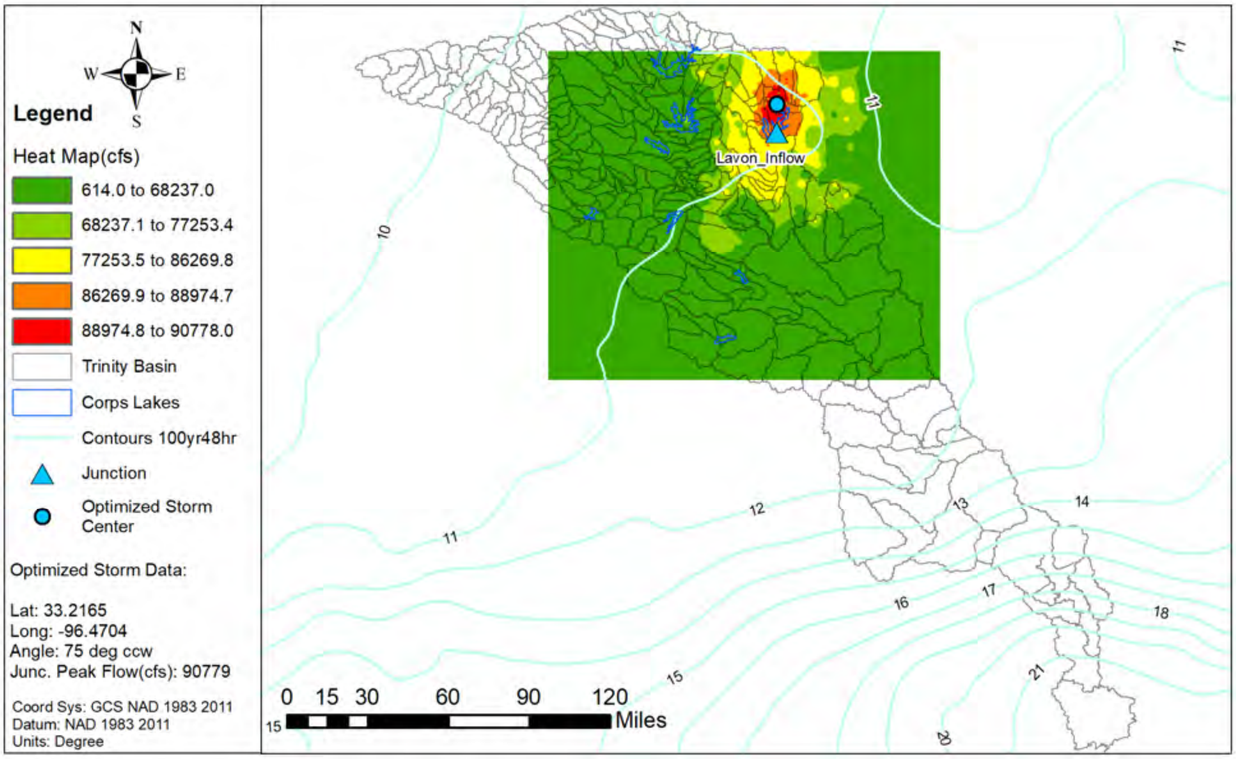


Figure 80a: Elliptical Storm Heat Map for the Lavon Lake Inflow

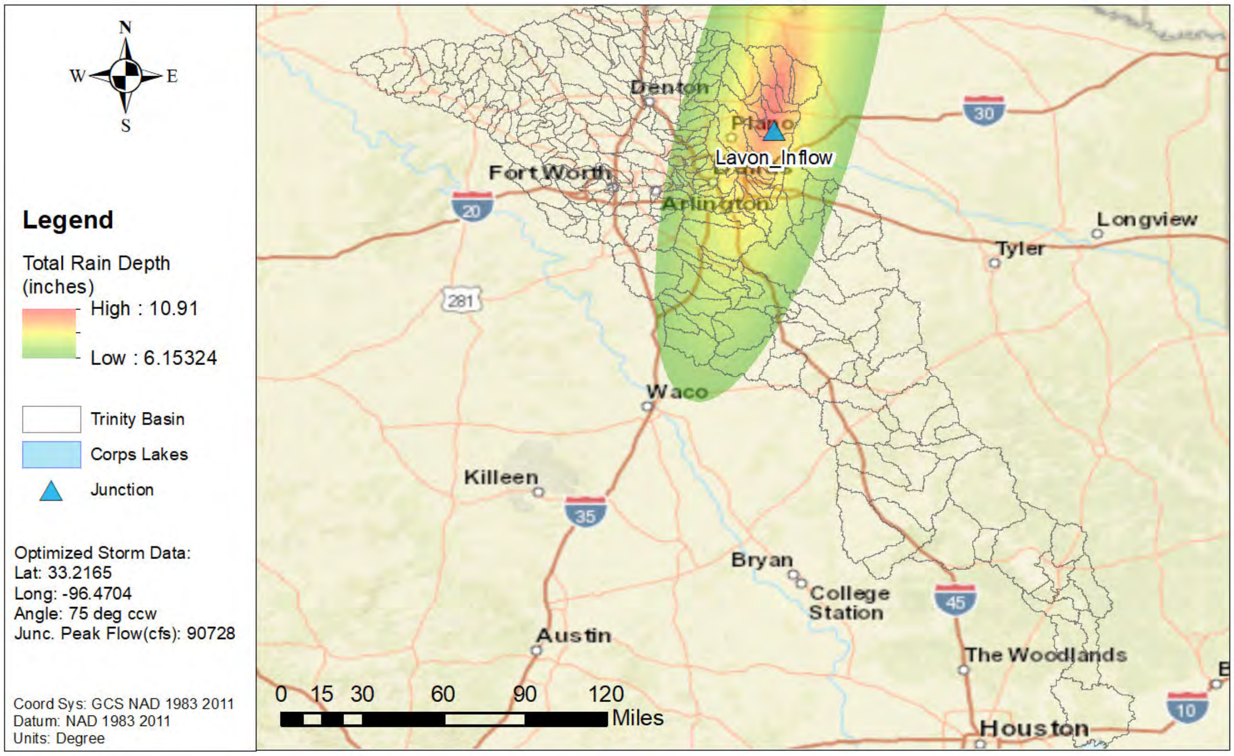


Figure 80b: NA14 1% AEP Elliptical Storm for the Lavon Lake Inflow

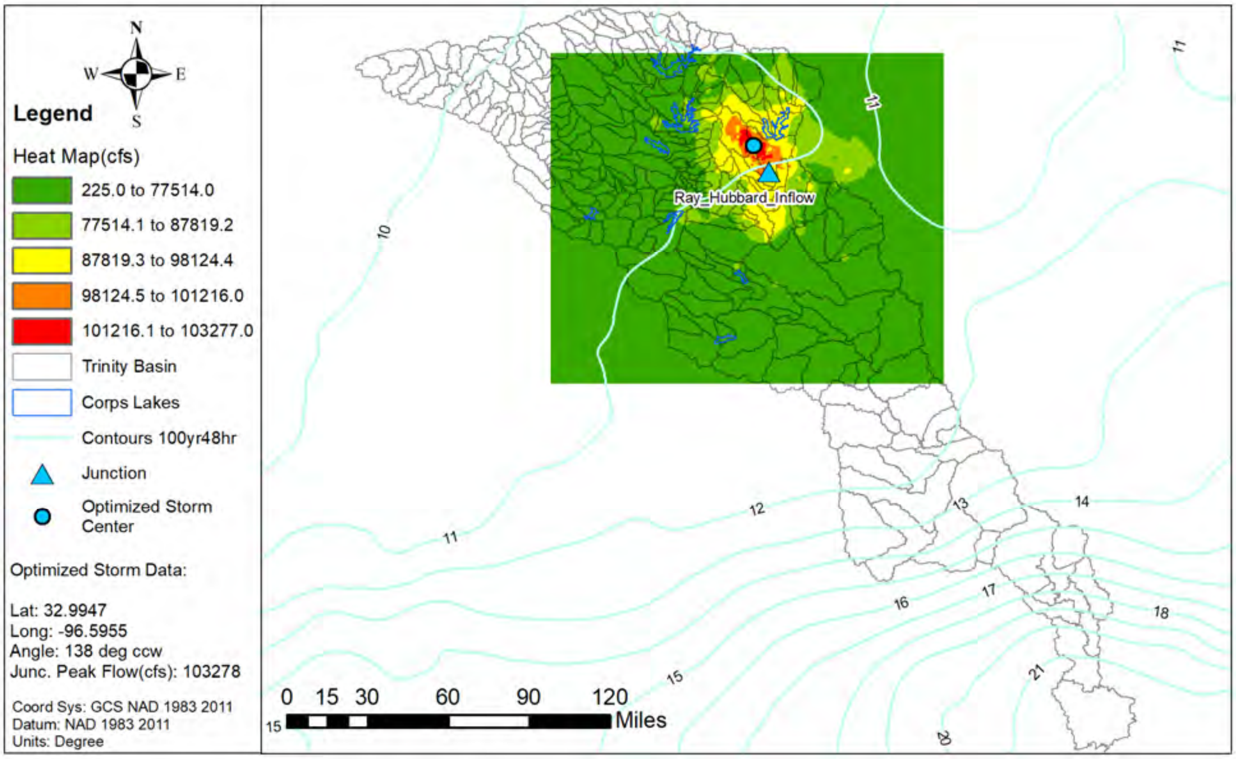


Figure 81a: Elliptical Storm Heat Map for the Ray Hubbard Lake Inflow

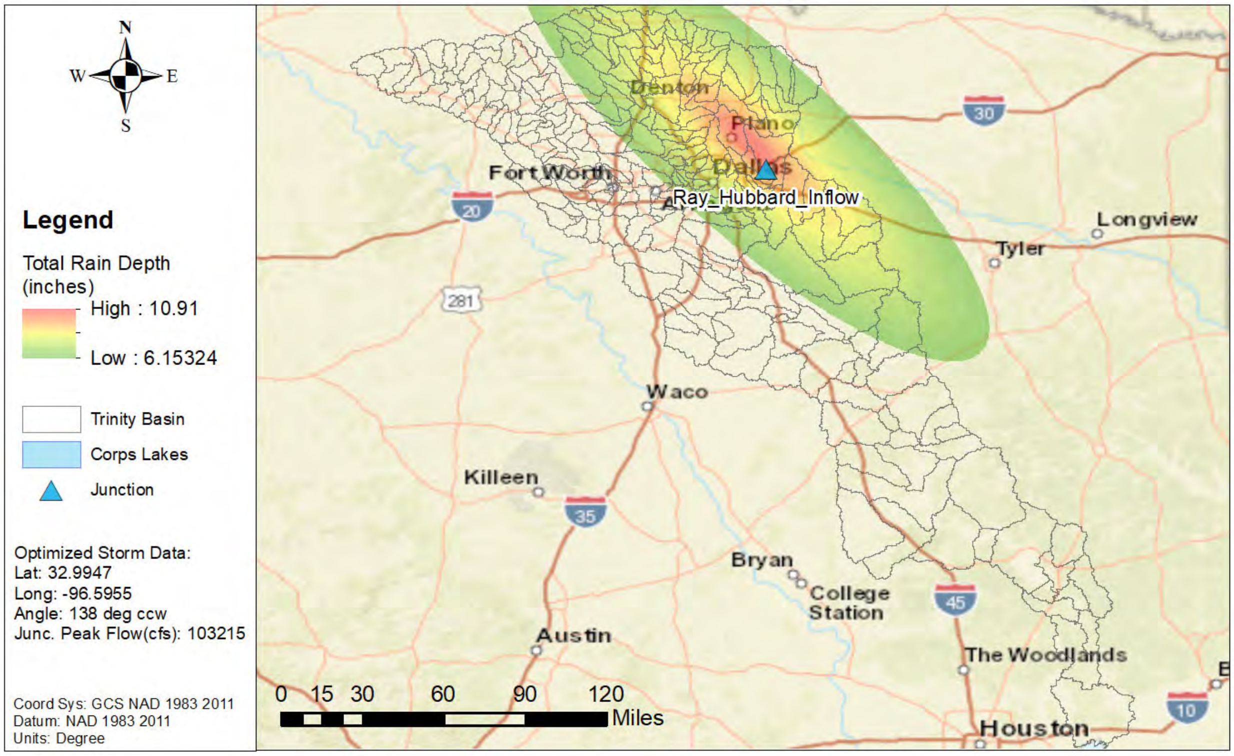


Figure 81b: NA14 1% AEP Elliptical Storm for the Ray Hubbard Lake Inflow

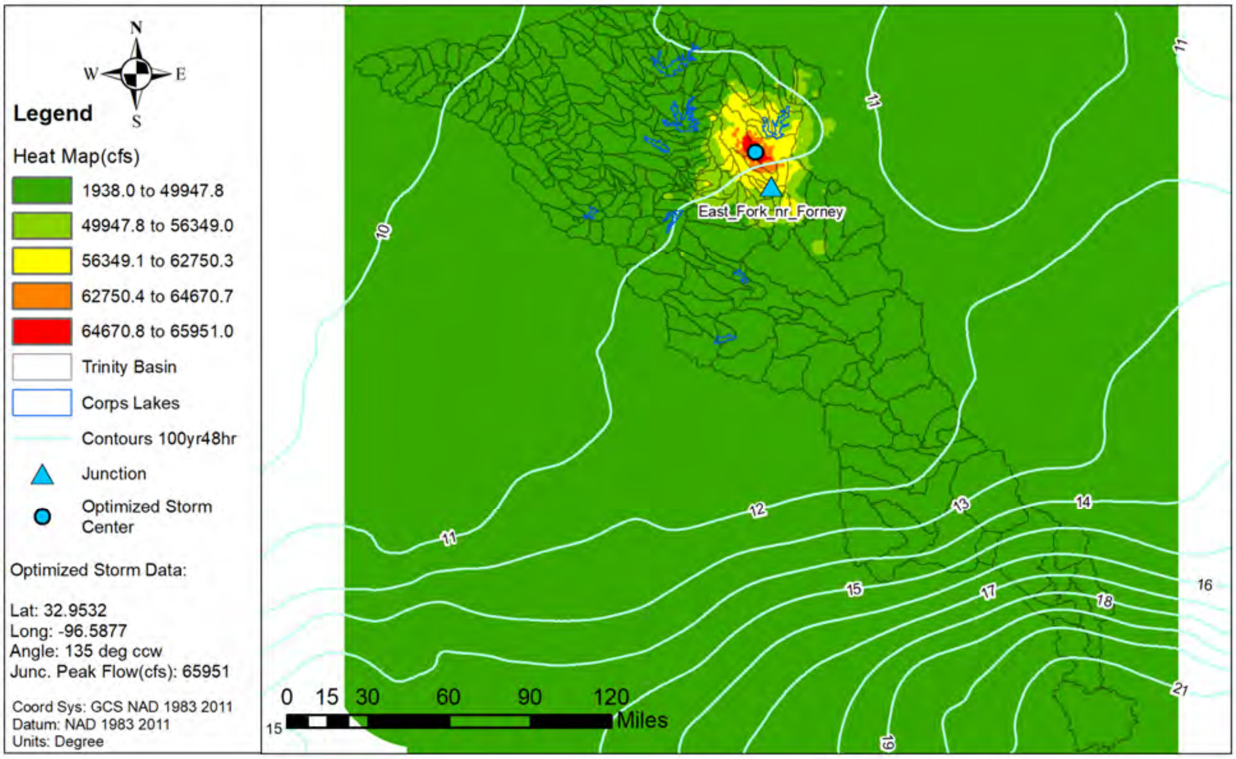


Figure 82a: Elliptical Storm Heat Map for the East Fork Trinity River near Forney USGS gage

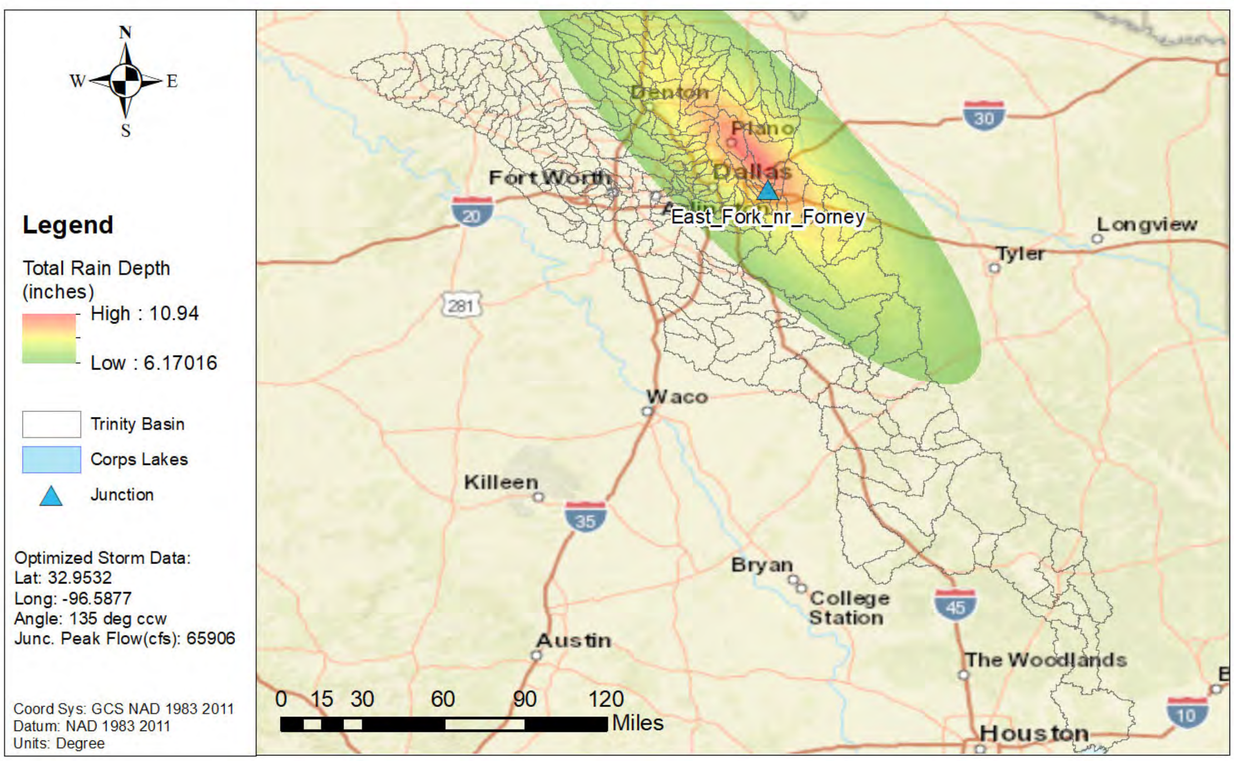


Figure 82b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River near Forney USGS gage

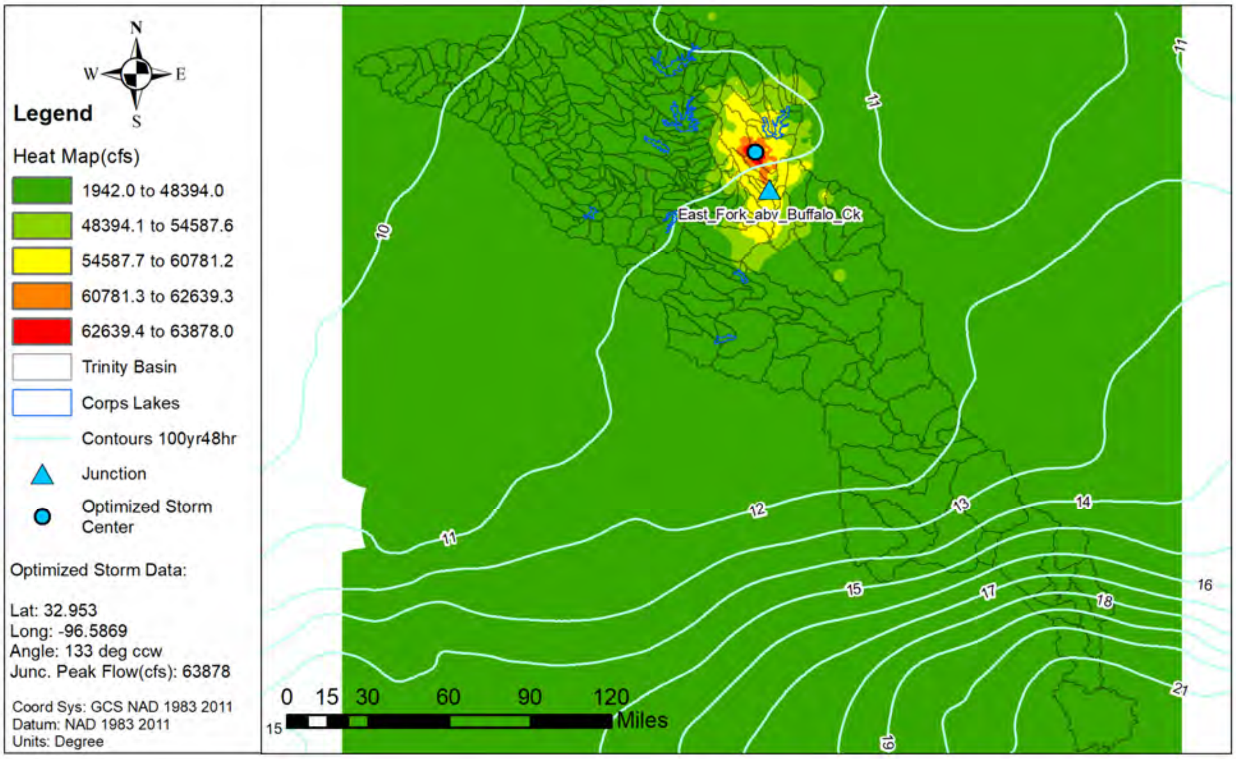


Figure 83a: Elliptical Storm Heat Map for the East Fork Trinity River above Buffalo Creek

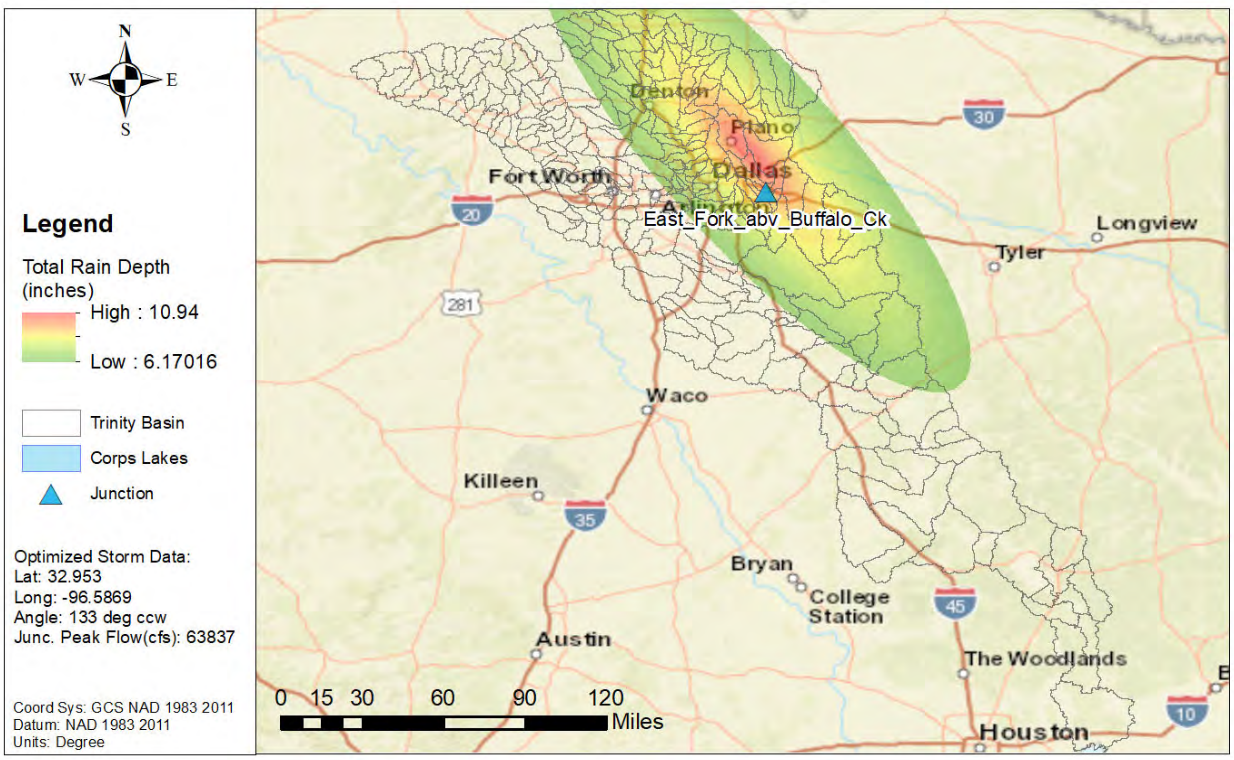


Figure 83b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above Buffalo Creek

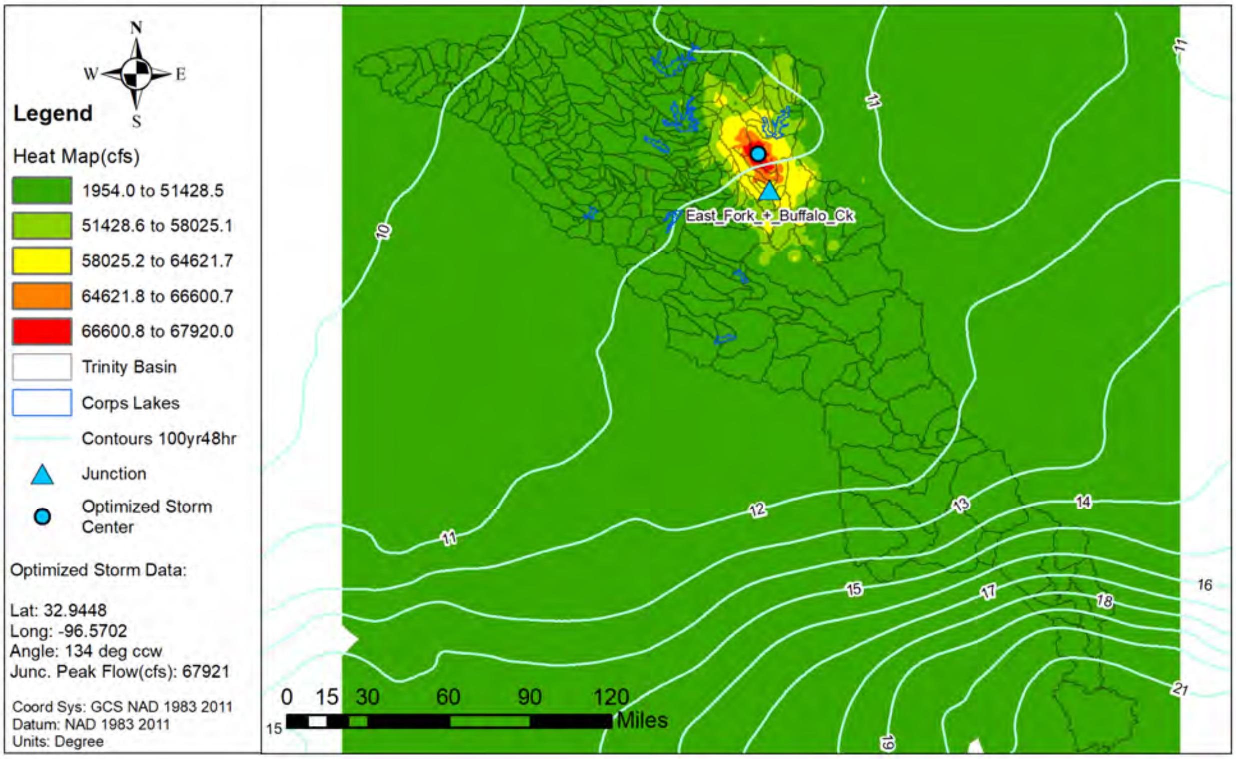


Figure 84a: Elliptical Storm Heat Map for the East Fork Trinity River below Buffalo Creek

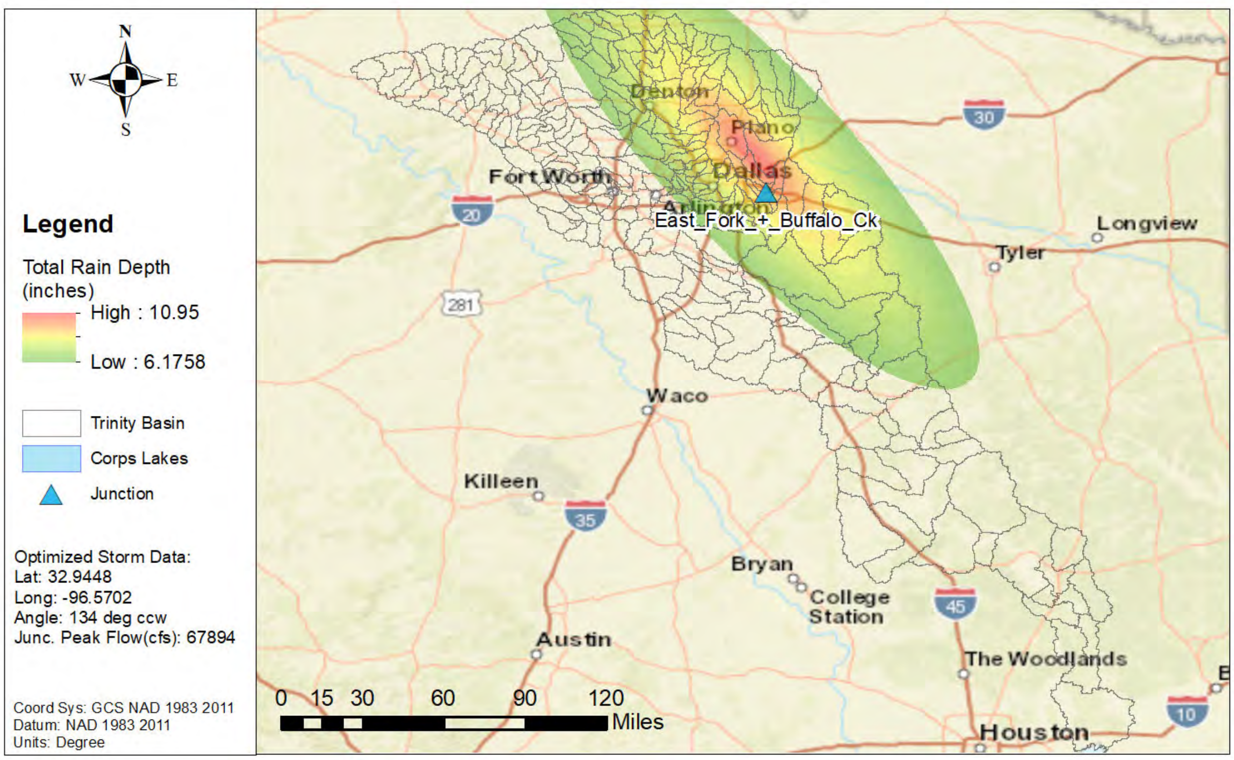


Figure 84b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River below Buffalo Creek

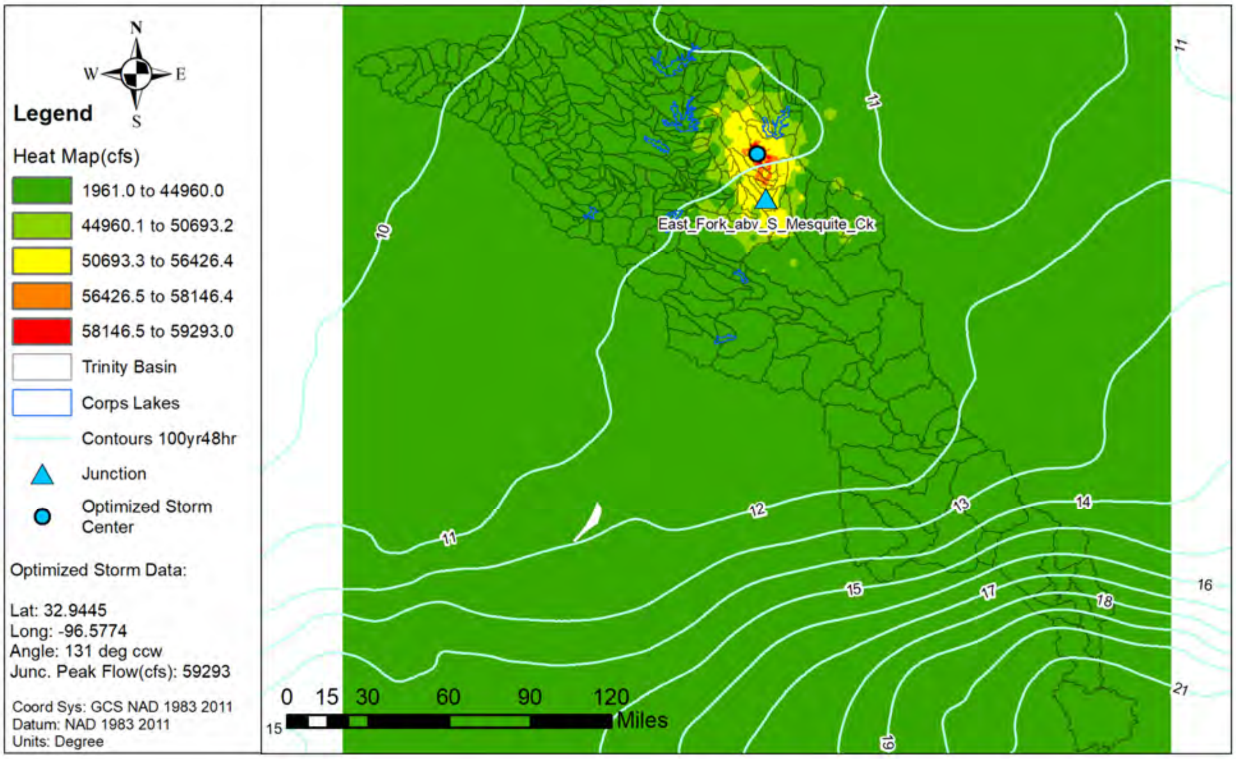


Figure 85a: Elliptical Storm Heat Map for the East Fork Trinity River above South Mesquite Creek

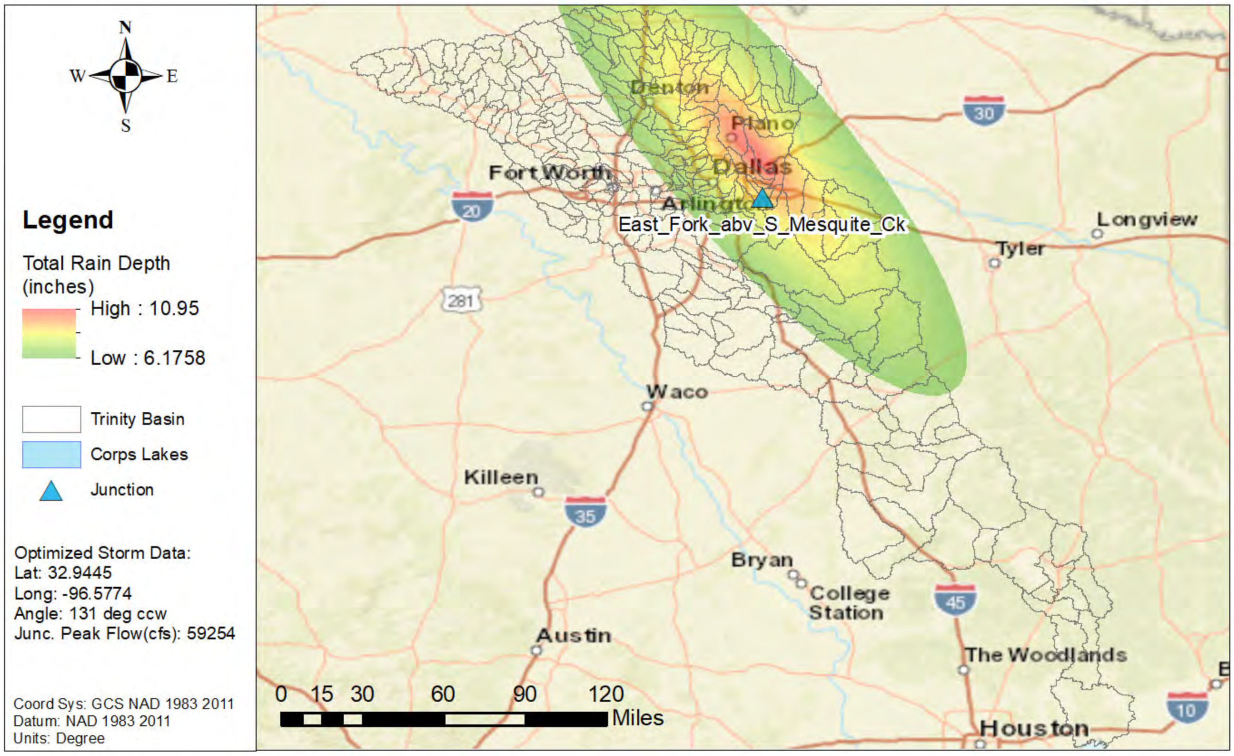


Figure 85b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above South Mesquite Creek

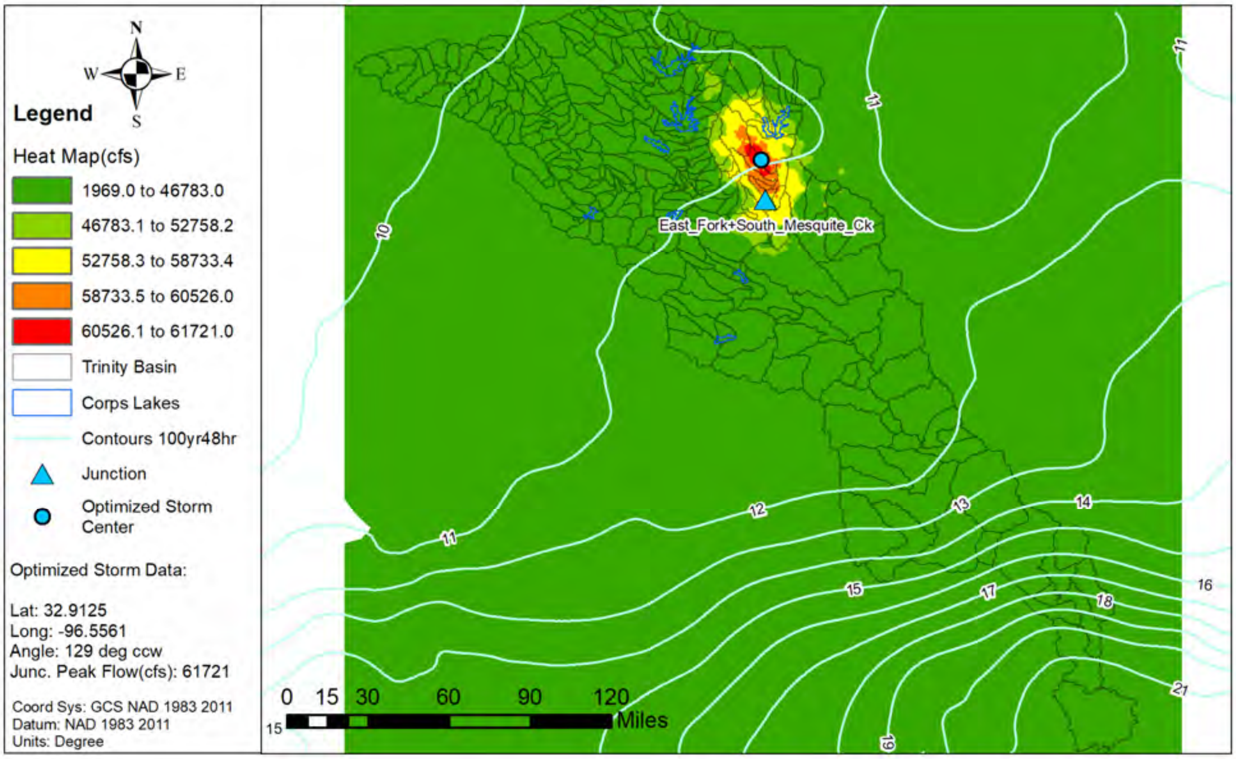


Figure 86a: Elliptical Storm Heat Map for the East Fork Trinity River below South Mesquite Creek

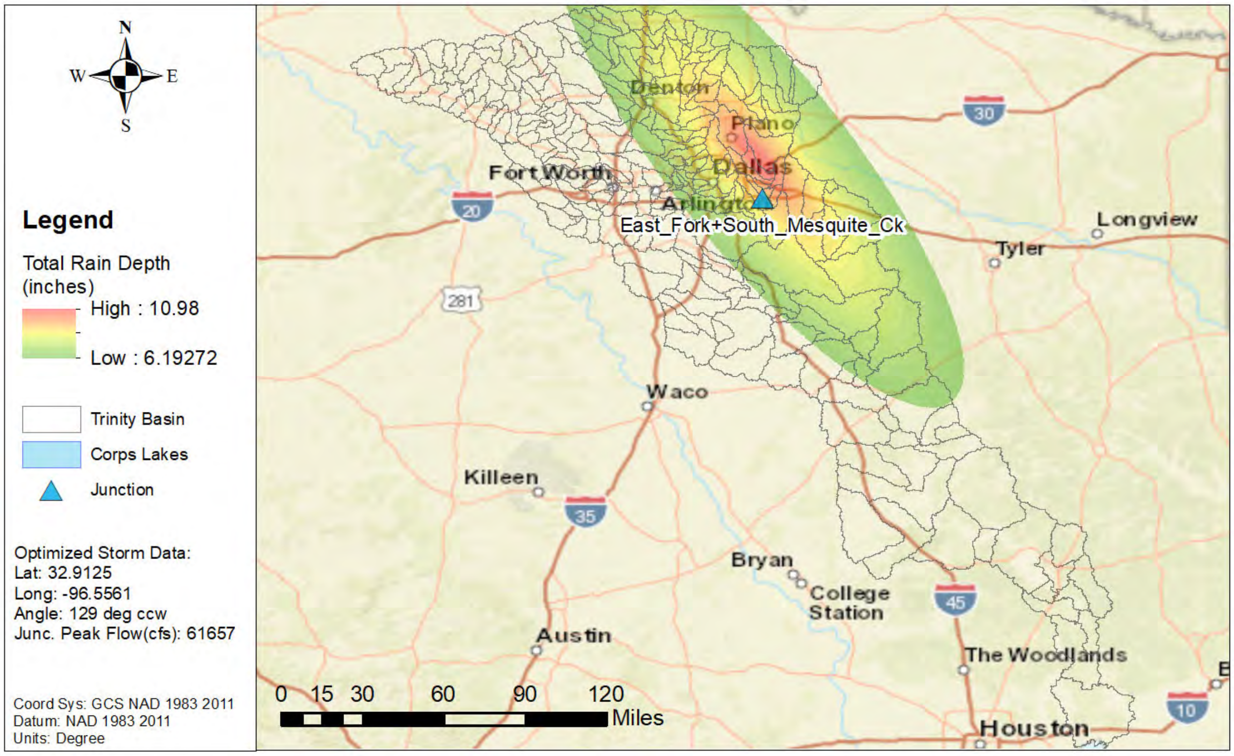


Figure 86b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River below South Mesquite Creek

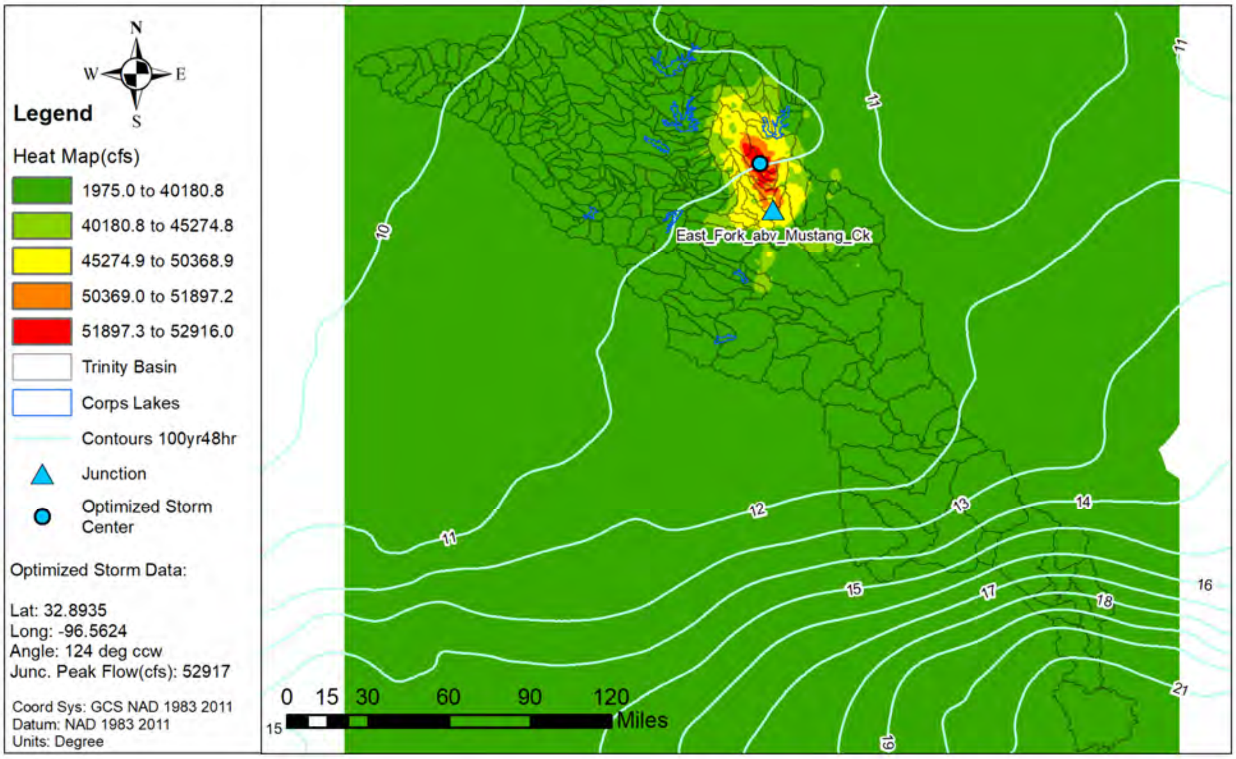


Figure 87a: Elliptical Storm Heat Map for the East Fork Trinity River above Mustang Creek

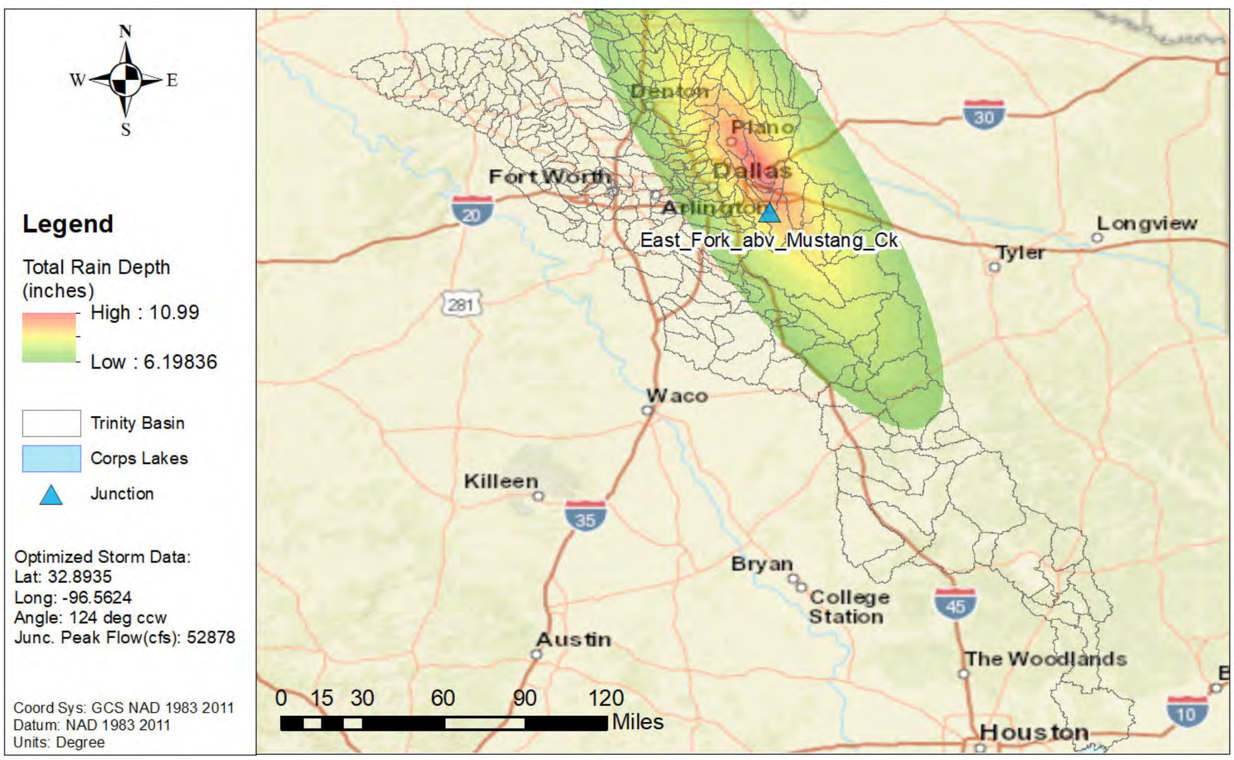


Figure 87b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above Mustang Creek

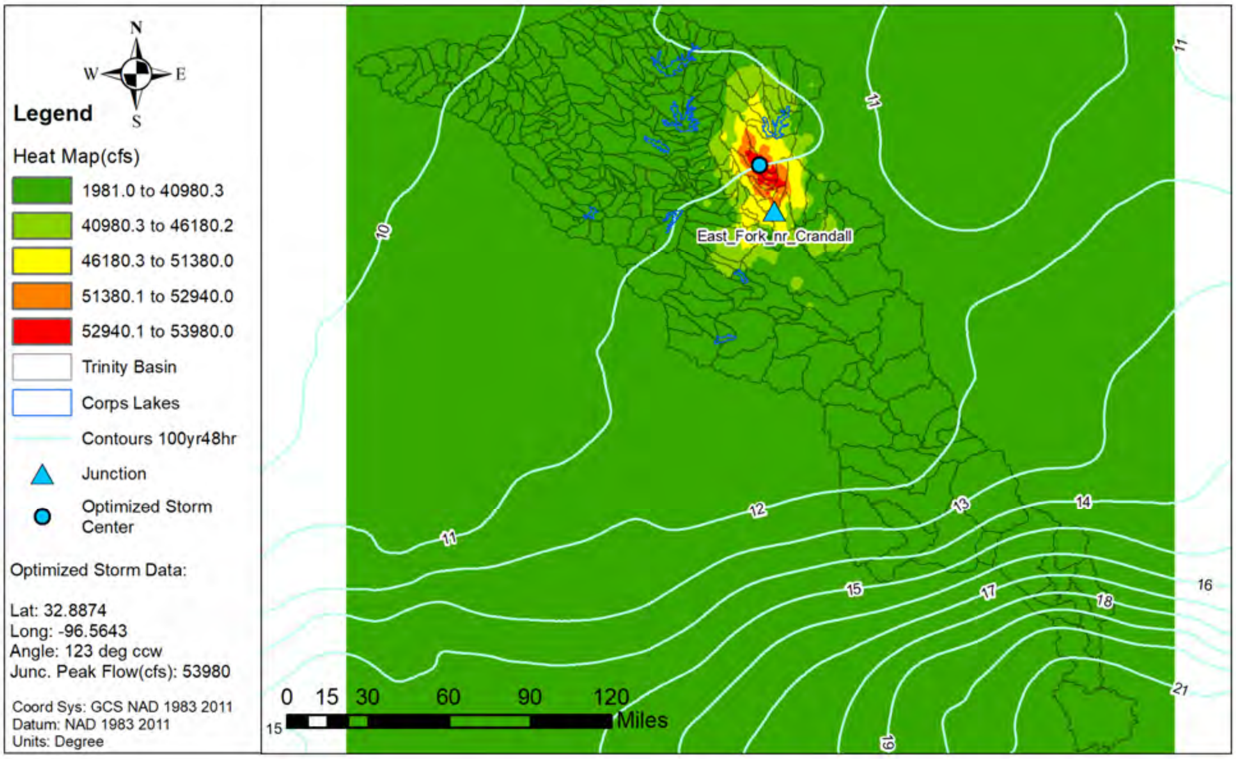


Figure 88a: Elliptical Storm Heat Map for the East Fork Trinity River near Crandall, TX USGS gage

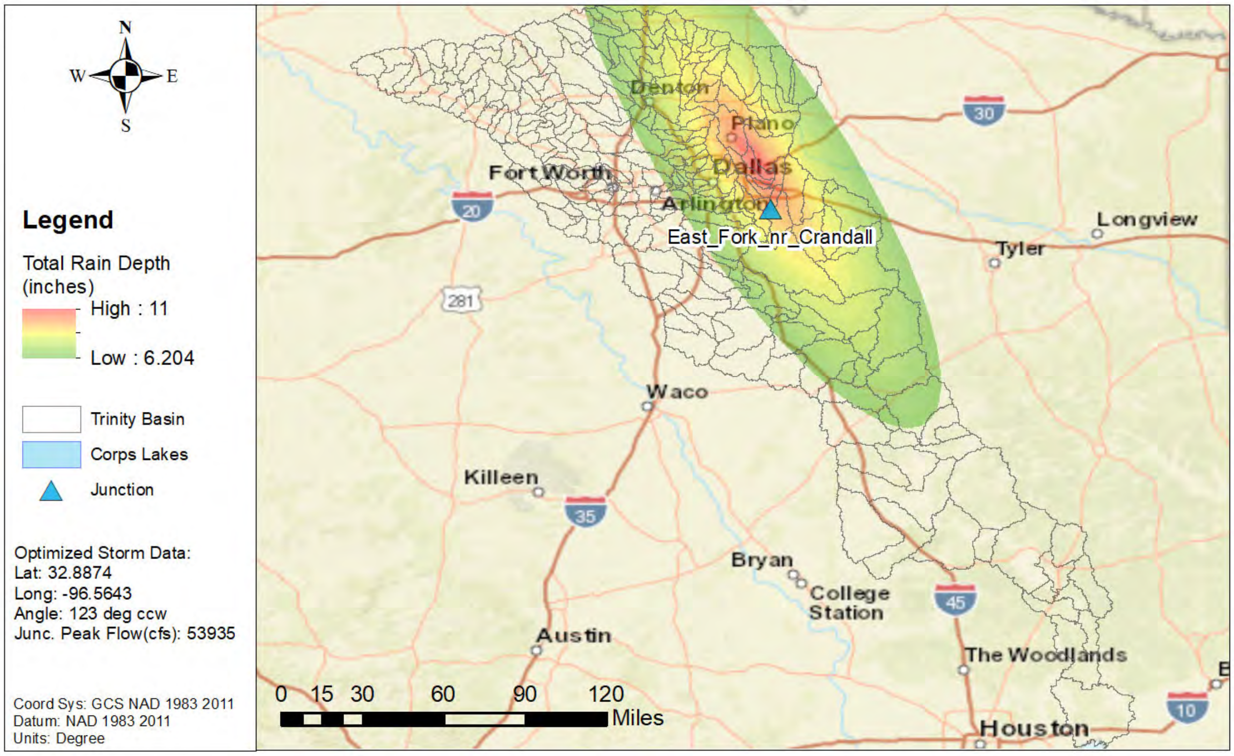


Figure 88b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River near Crandall, TX USGS gage

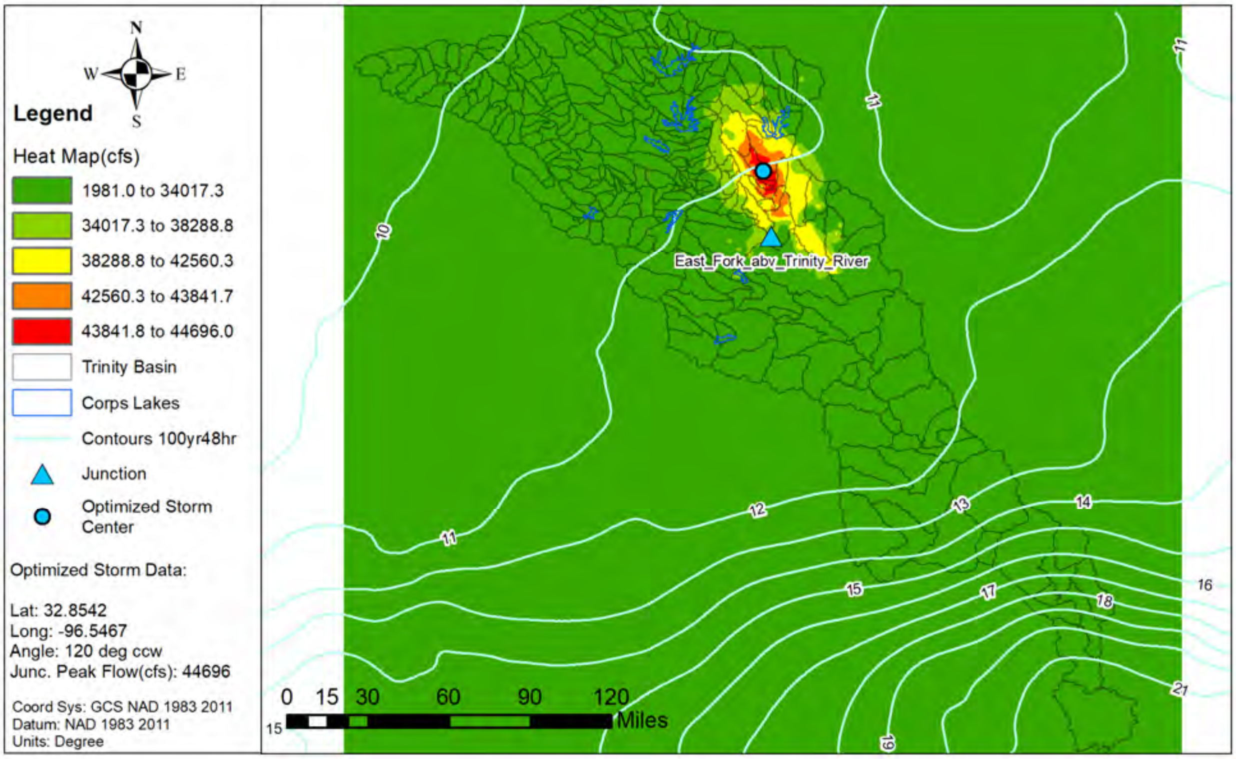


Figure 89a: Elliptical Storm Heat Map for the East Fork Trinity River above the Trinity River

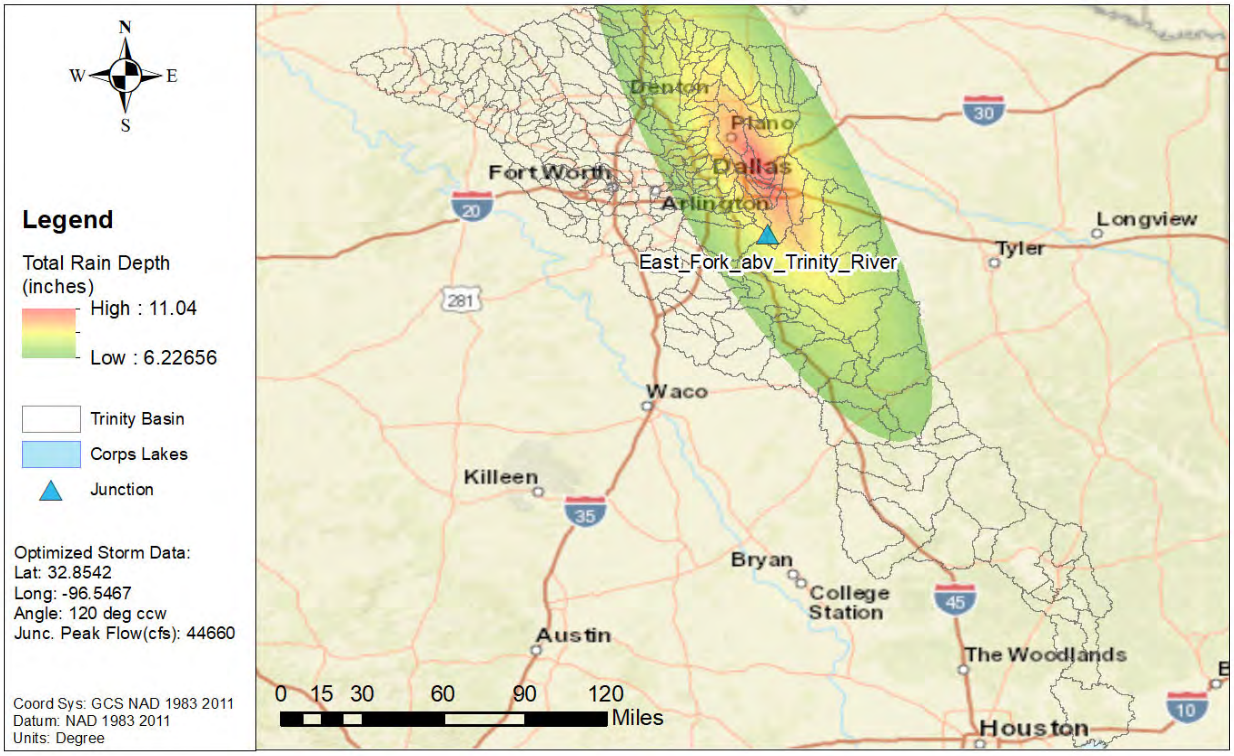


Figure 89b: NA14 1% AEP Elliptical Storm for the East Fork Trinity River above the Trinity River

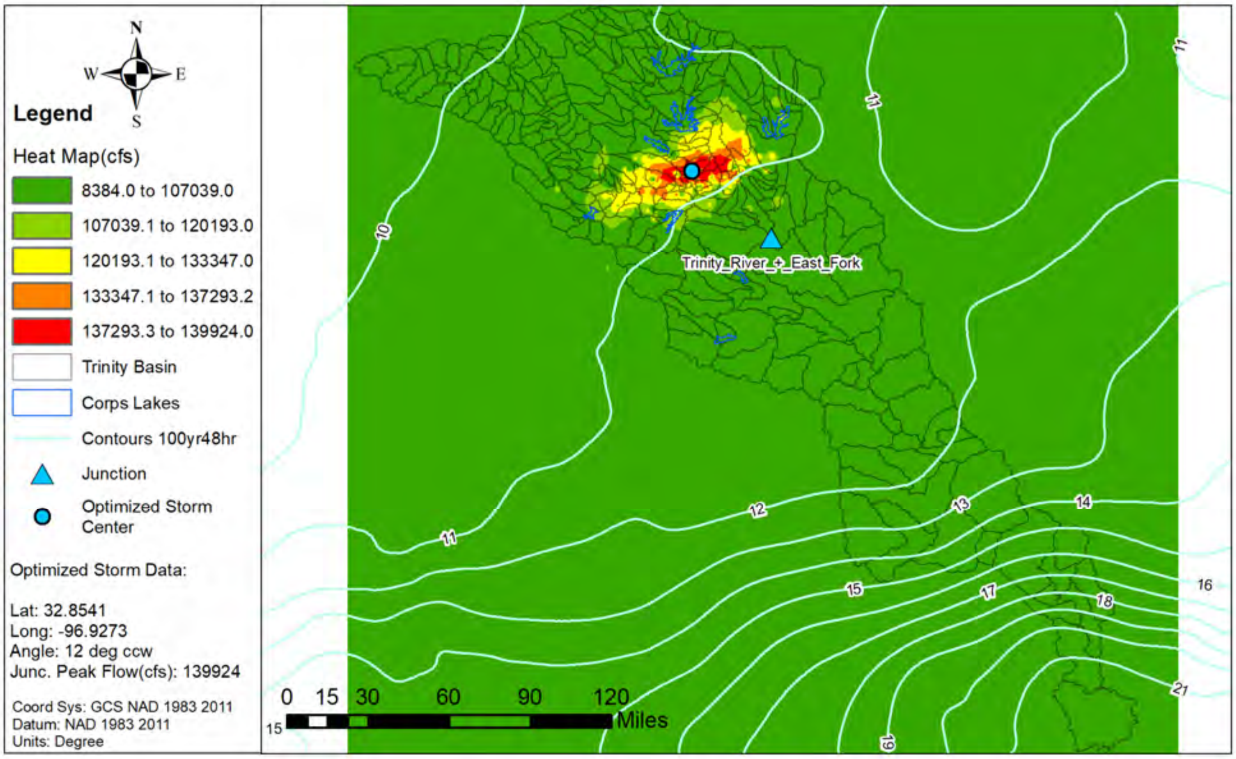


Figure 90a: Elliptical Storm Heat Map for the Trinity River below the East Fork Trinity River

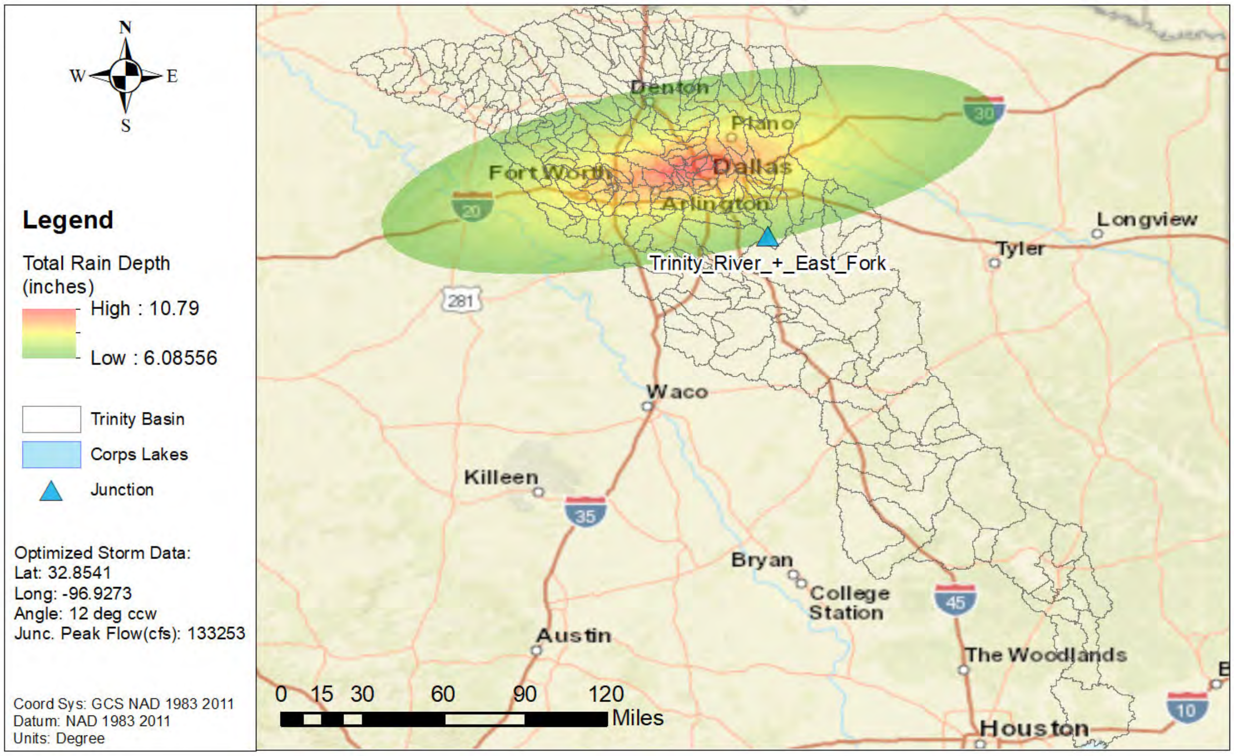


Figure 90b: NA14 1% AEP Elliptical Storm for the Trinity River below the East Fork Trinity River

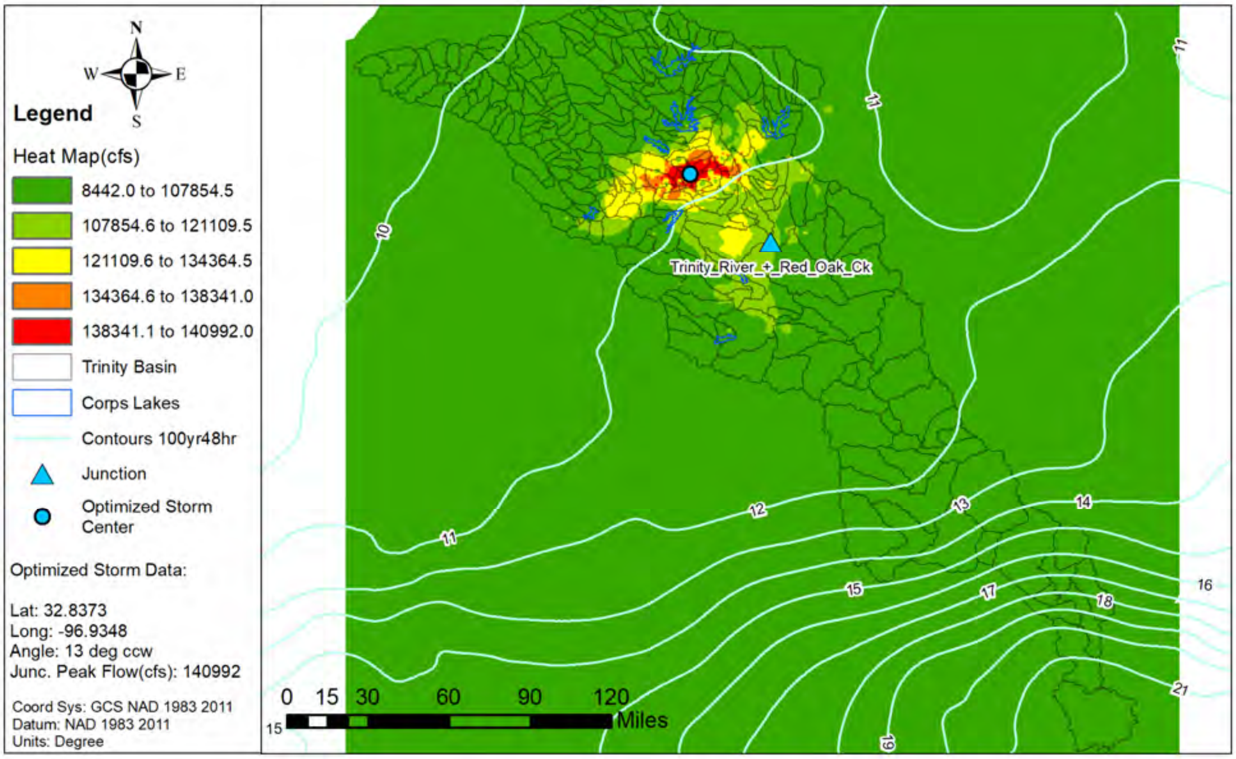


Figure 91a: Elliptical Storm Heat Map for the Trinity River below Red Oak Creek

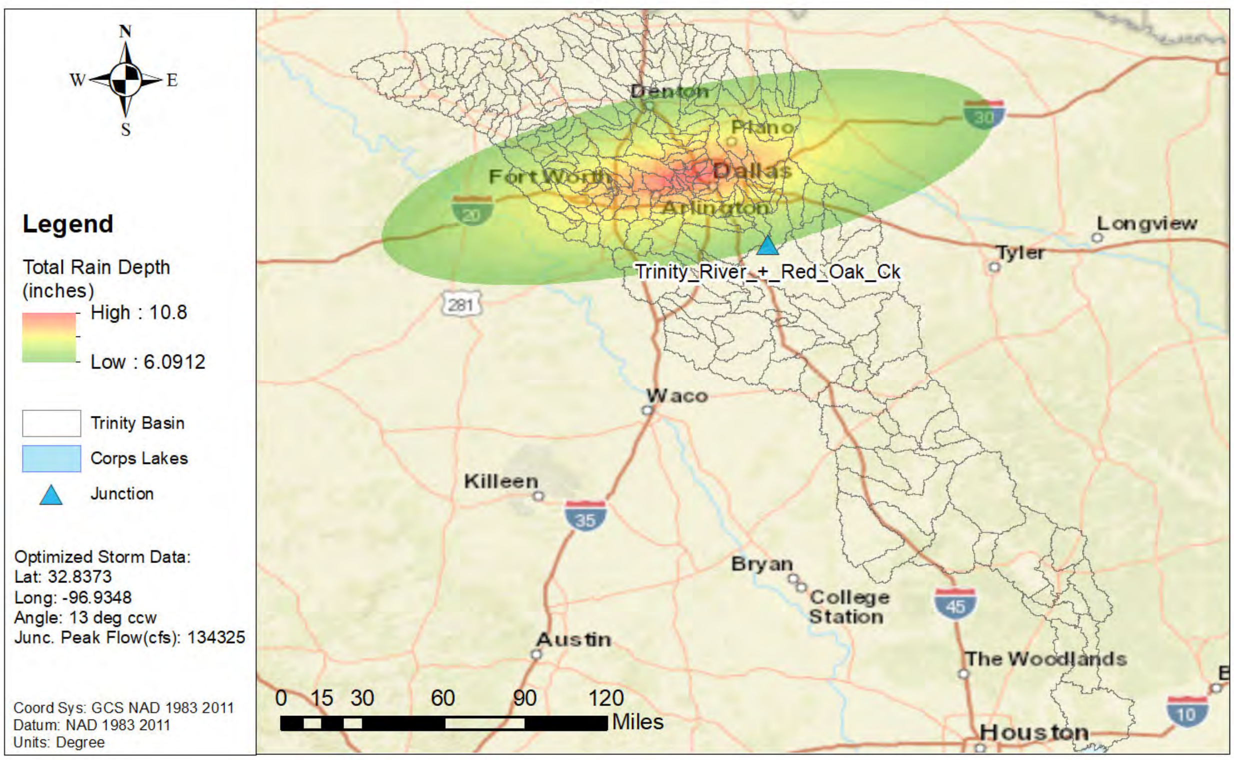


Figure 91b: NA14 1% AEP Elliptical Storm for the Trinity River below Red Oak Creek

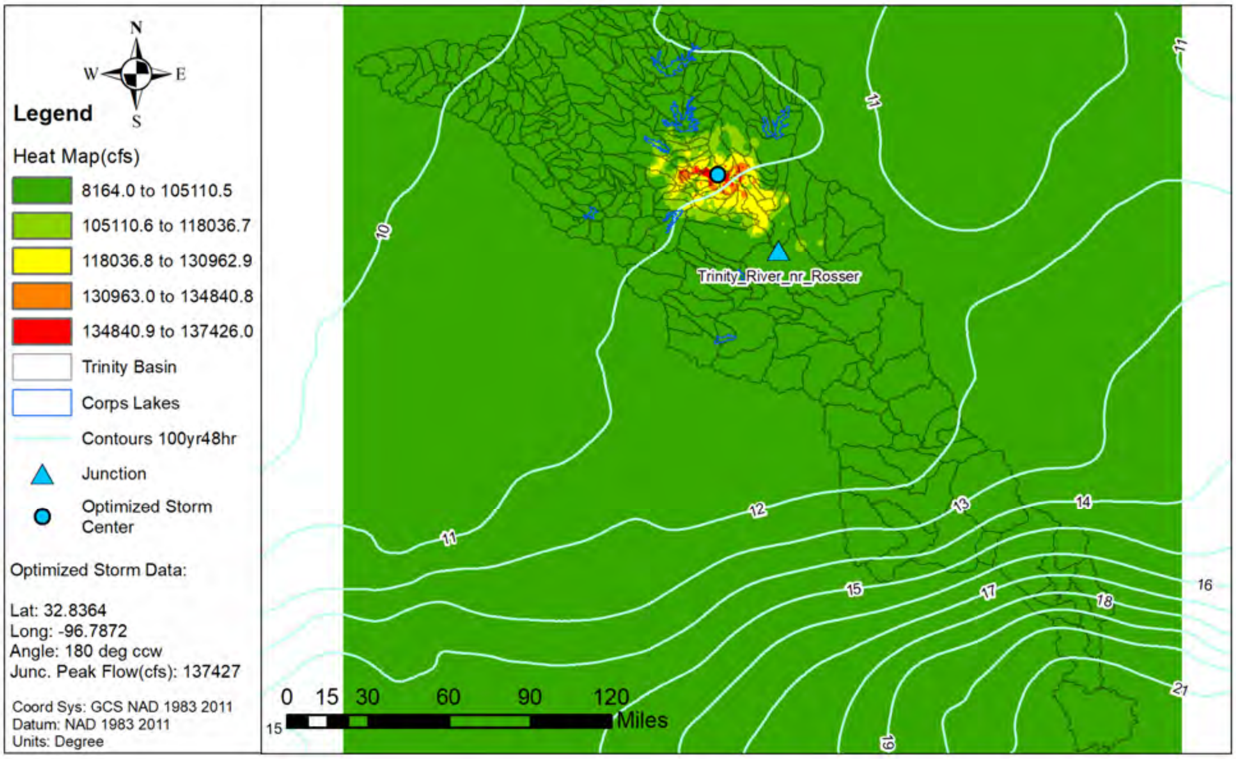


Figure 92a: Elliptical Storm Heat Map for the Trinity River near Rosser, TX USGS gage

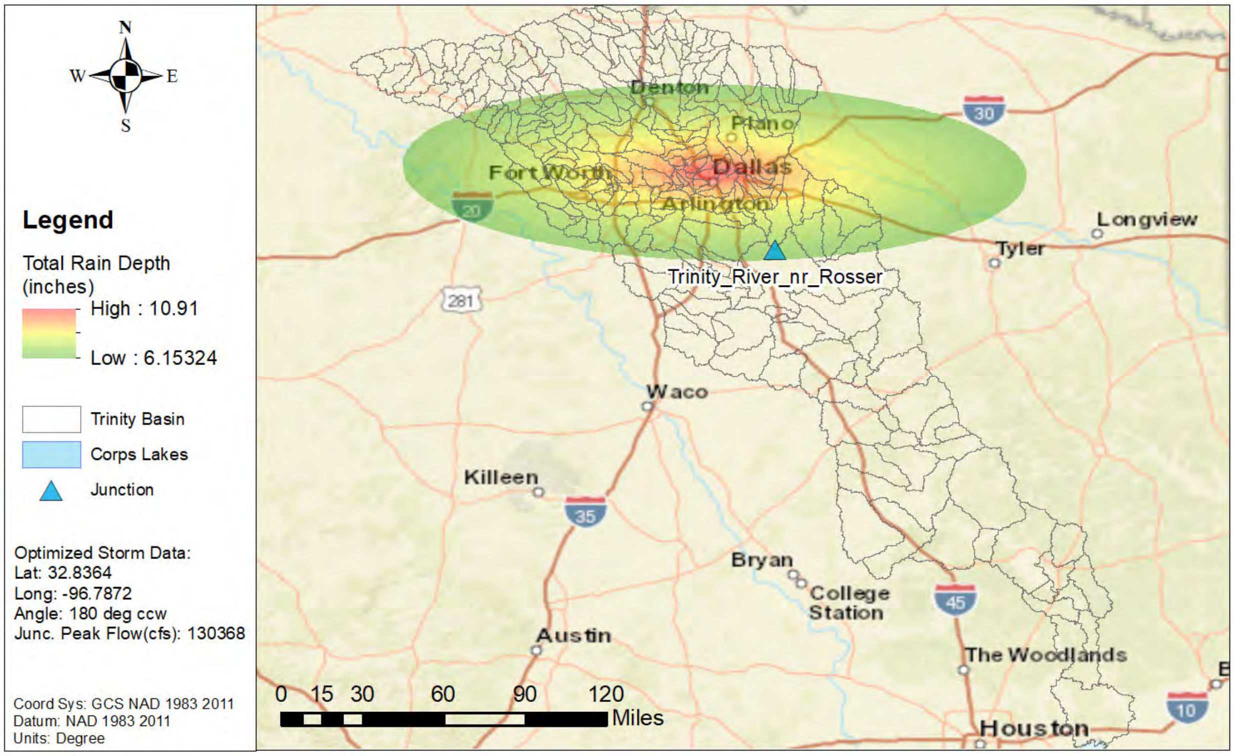


Figure 92b: NA14 1% AEP Elliptical Storm for the Trinity River near Rosser, TX USGS gage

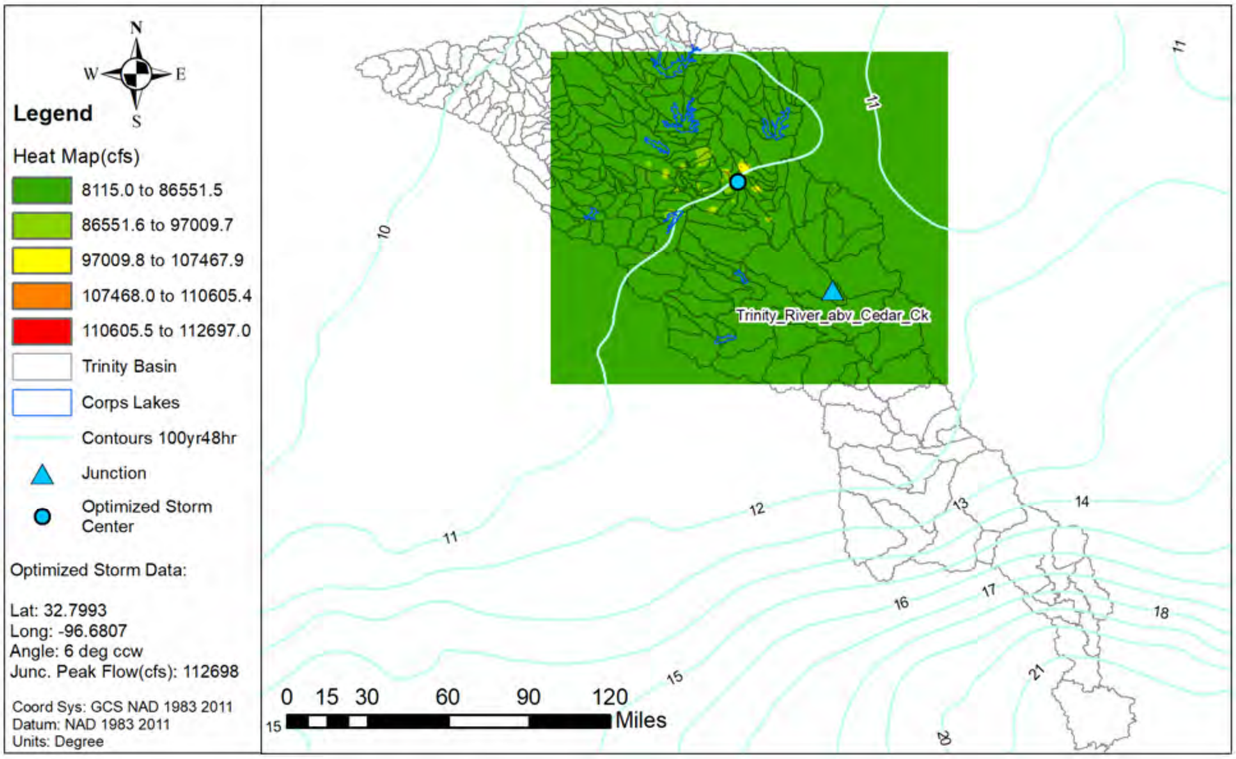


Figure 93a: Elliptical Storm Heat Map for the Trinity River above Cedar Creek

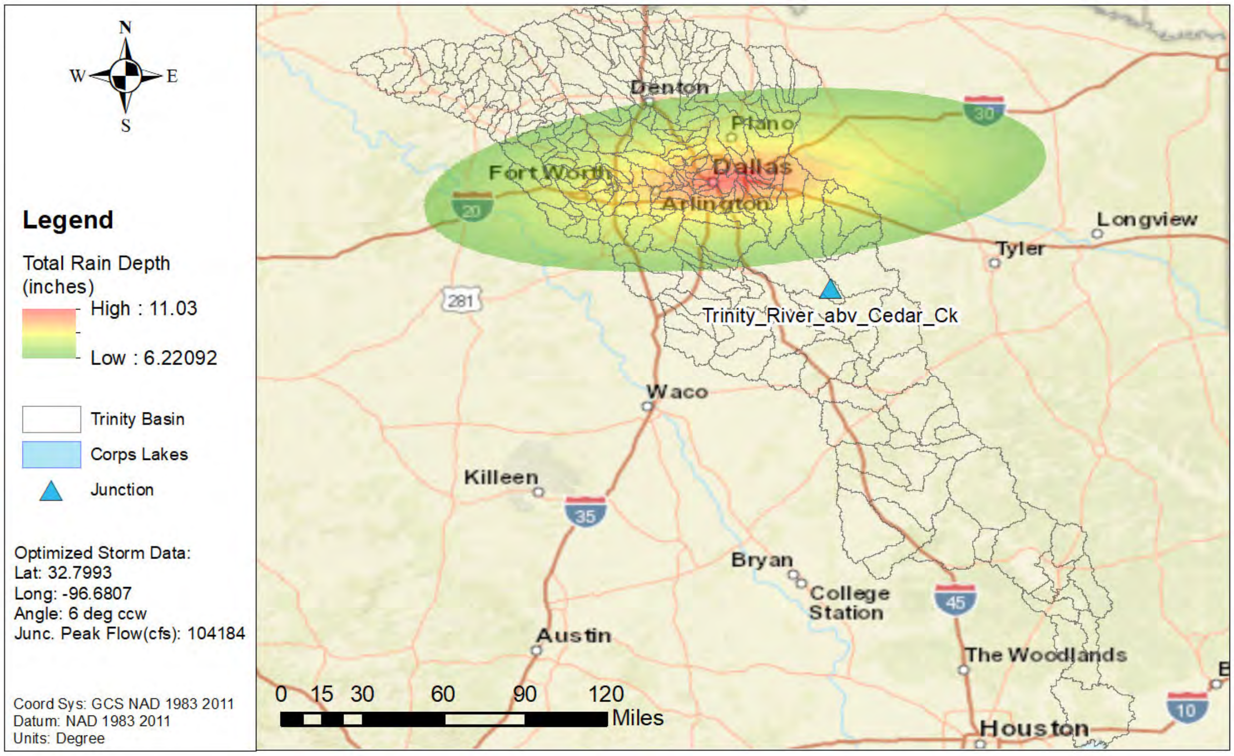


Figure 93b: NA14 1% AEP Elliptical Storm for the Trinity River above Cedar Creek

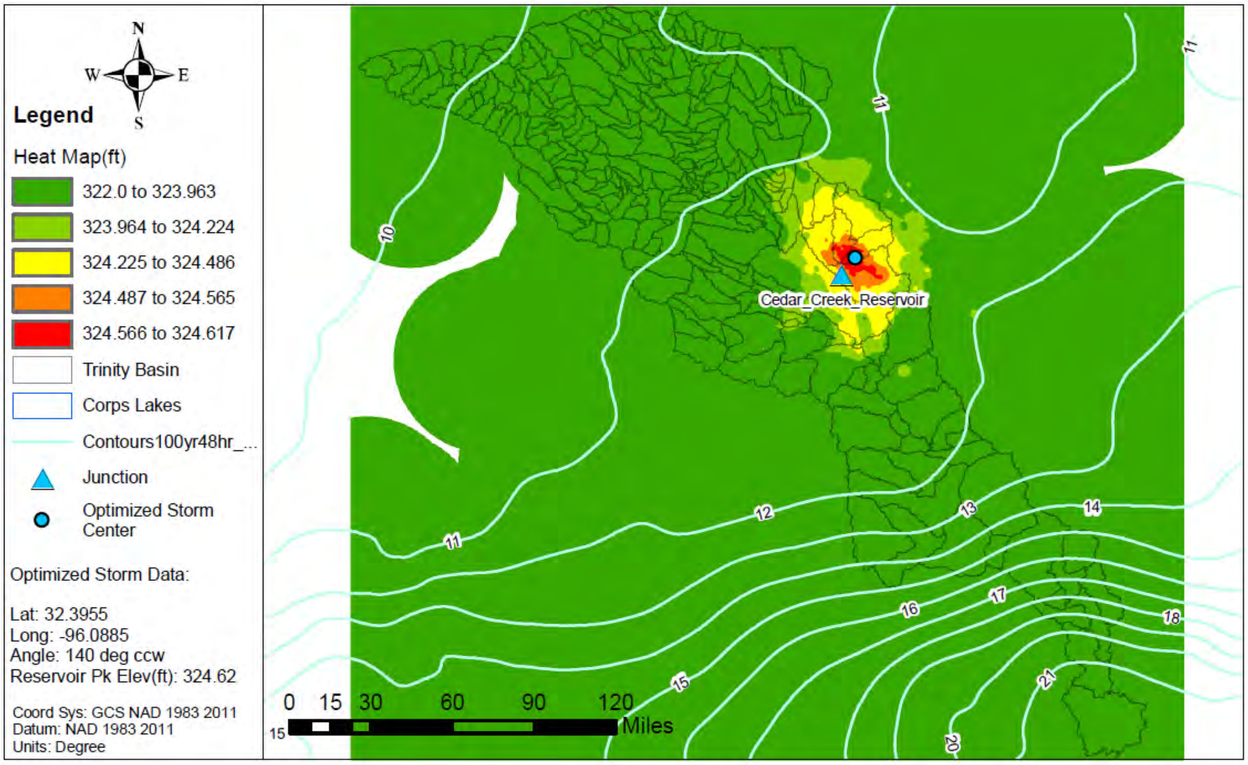


Figure 94a: Elliptical Storm Heat Map for the Cedar Creek Reservoir

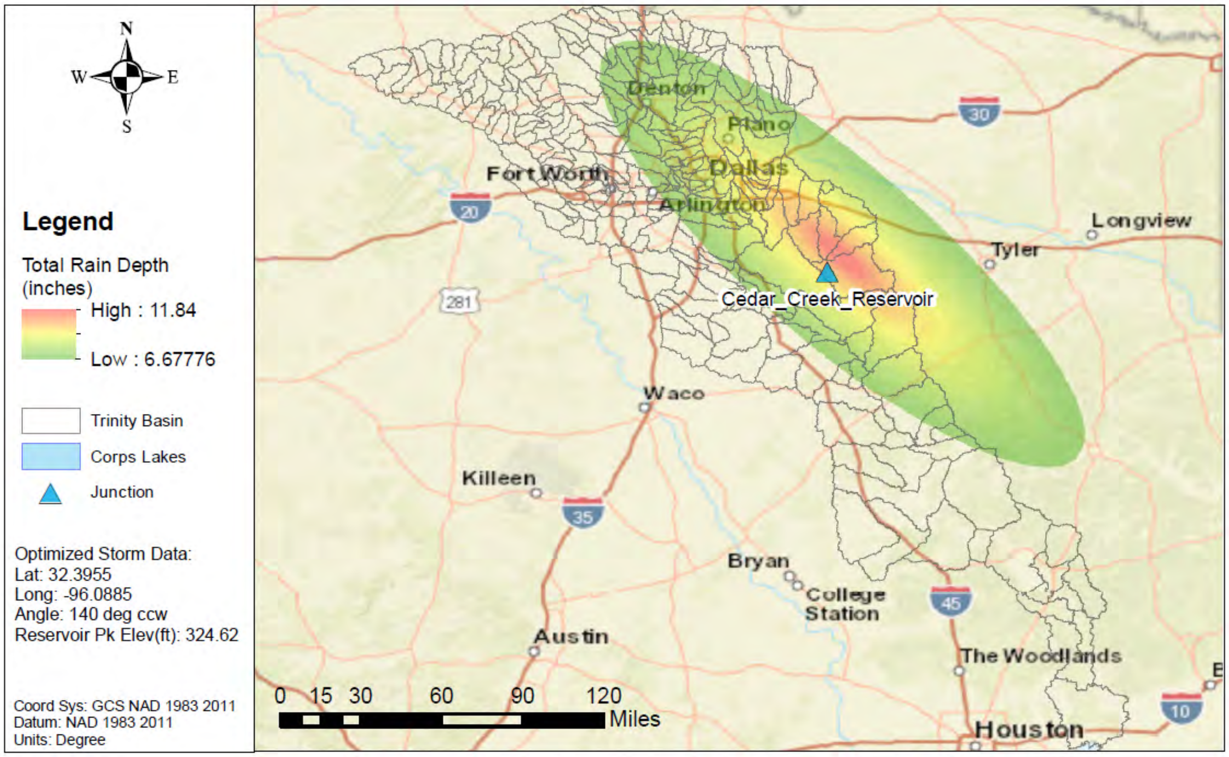


Figure 94b: NA14 1% AEP Elliptical Storm for the Cedar Creek Reservoir

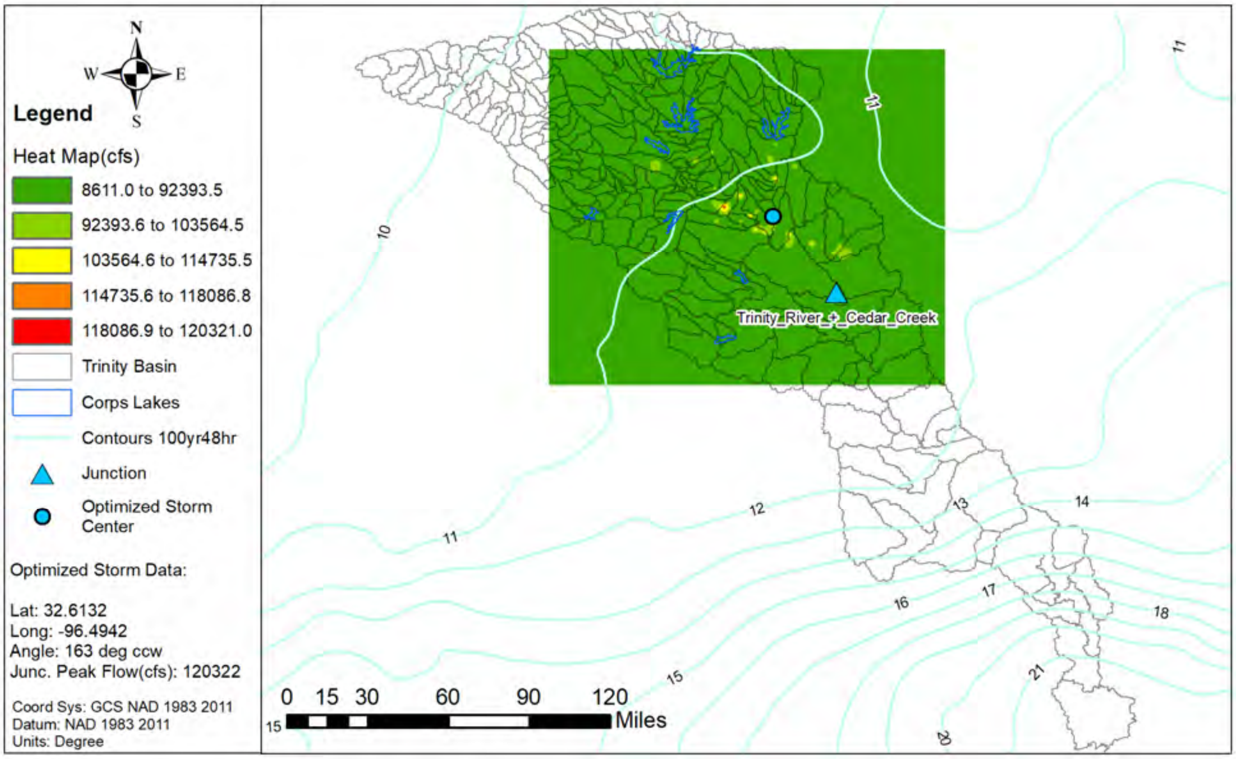


Figure 95a: Elliptical Storm Heat Map for the Trinity River below Cedar Creek

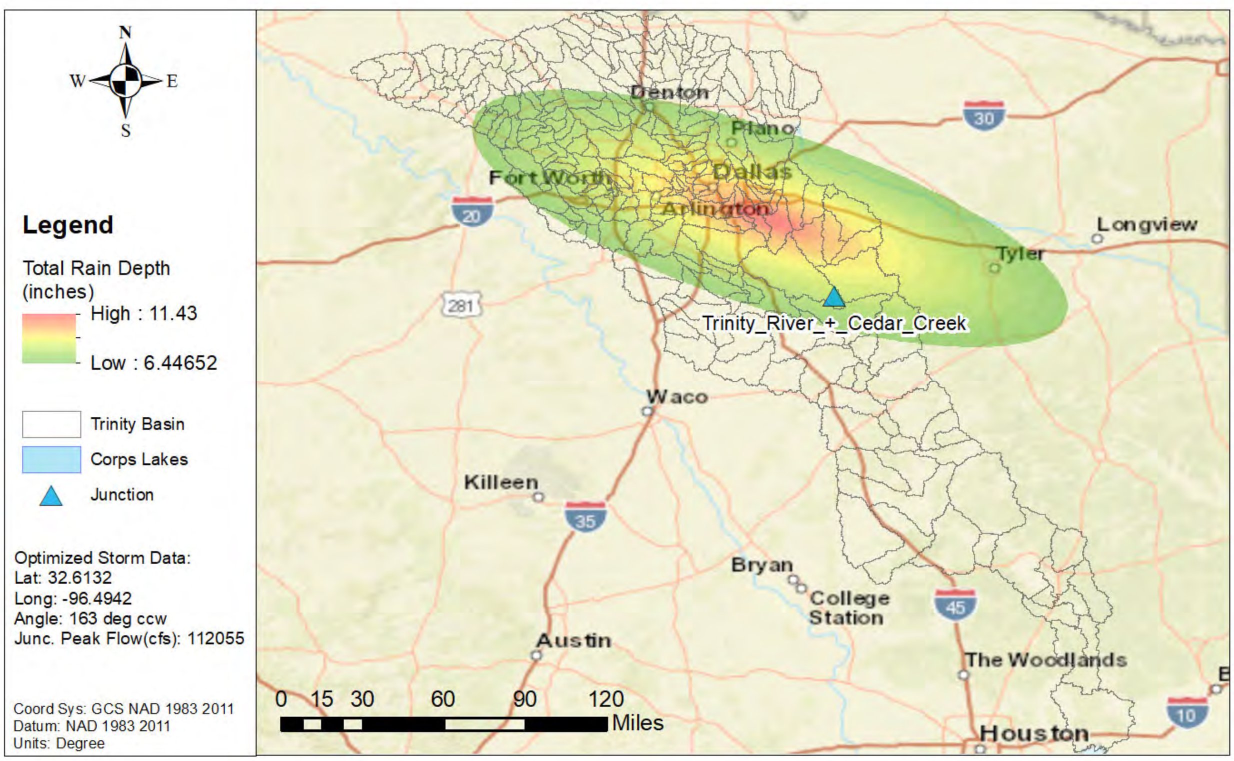


Figure 95b: NA14 1% AEP Elliptical Storm for the Trinity River below Cedar Creek

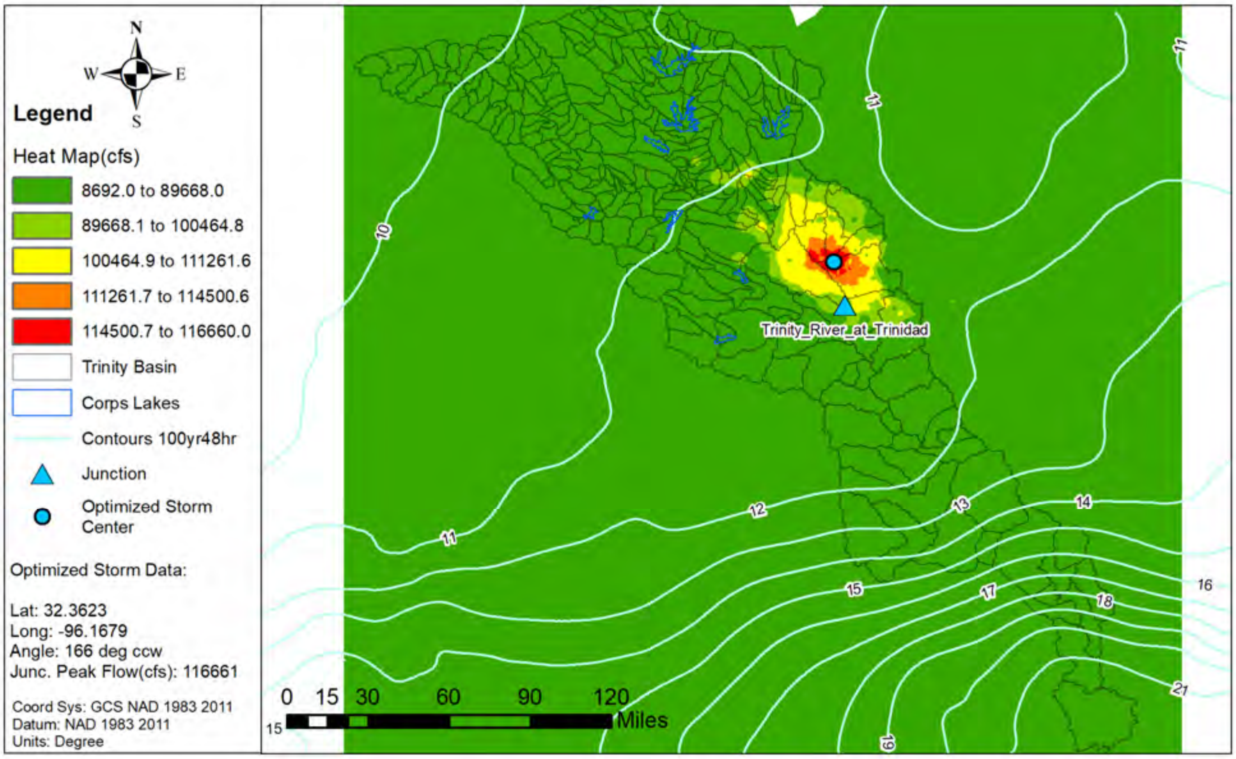


Figure 96a: Elliptical Storm Heat Map for the Trinity River at Trinidad, TX USGS gage

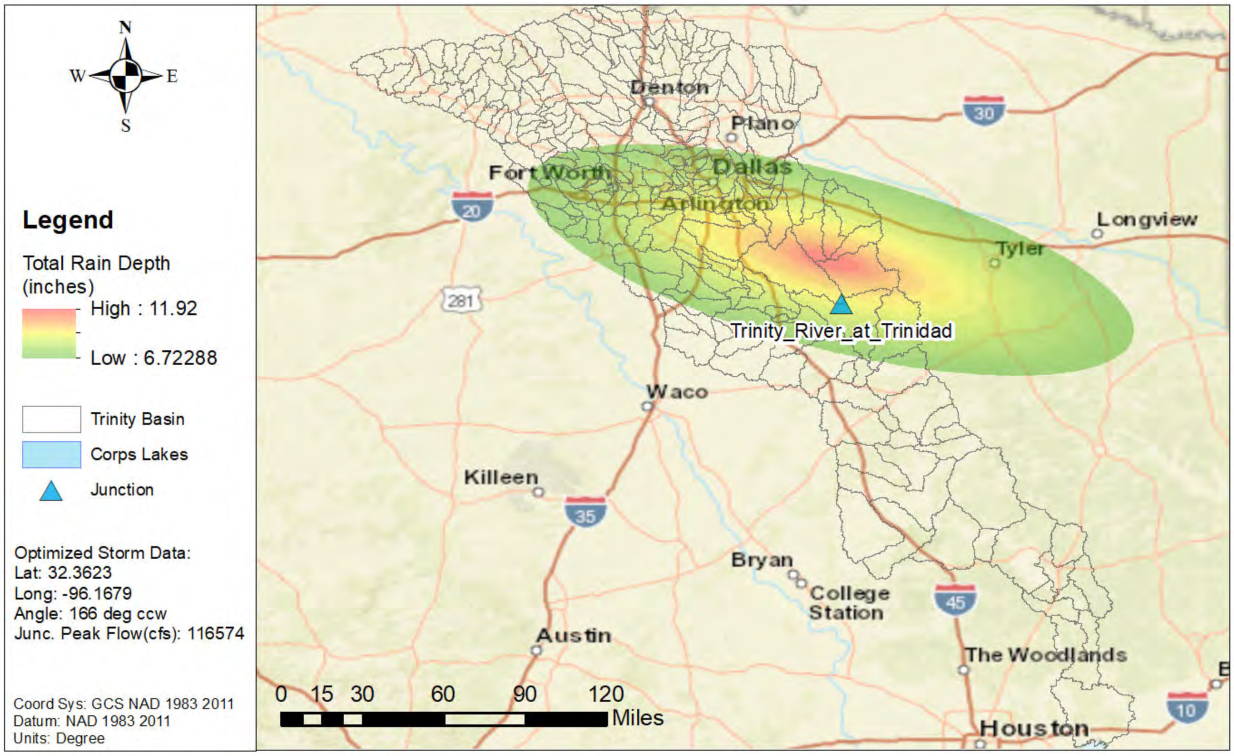


Figure 96b: NA14 1% AEP Elliptical Storm for the Trinity River at Trinidad, TX USGS gage

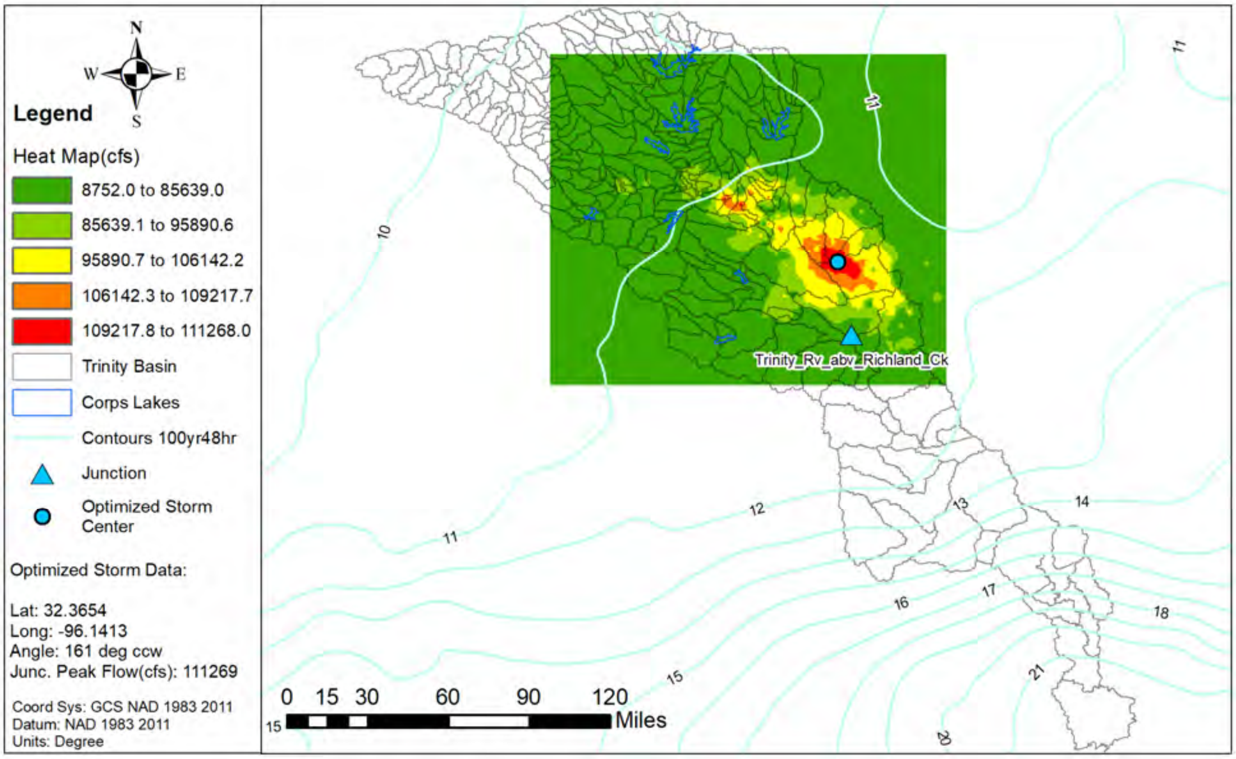


Figure 97a: Elliptical Storm Heat Map for the Trinity River above Richland Creek

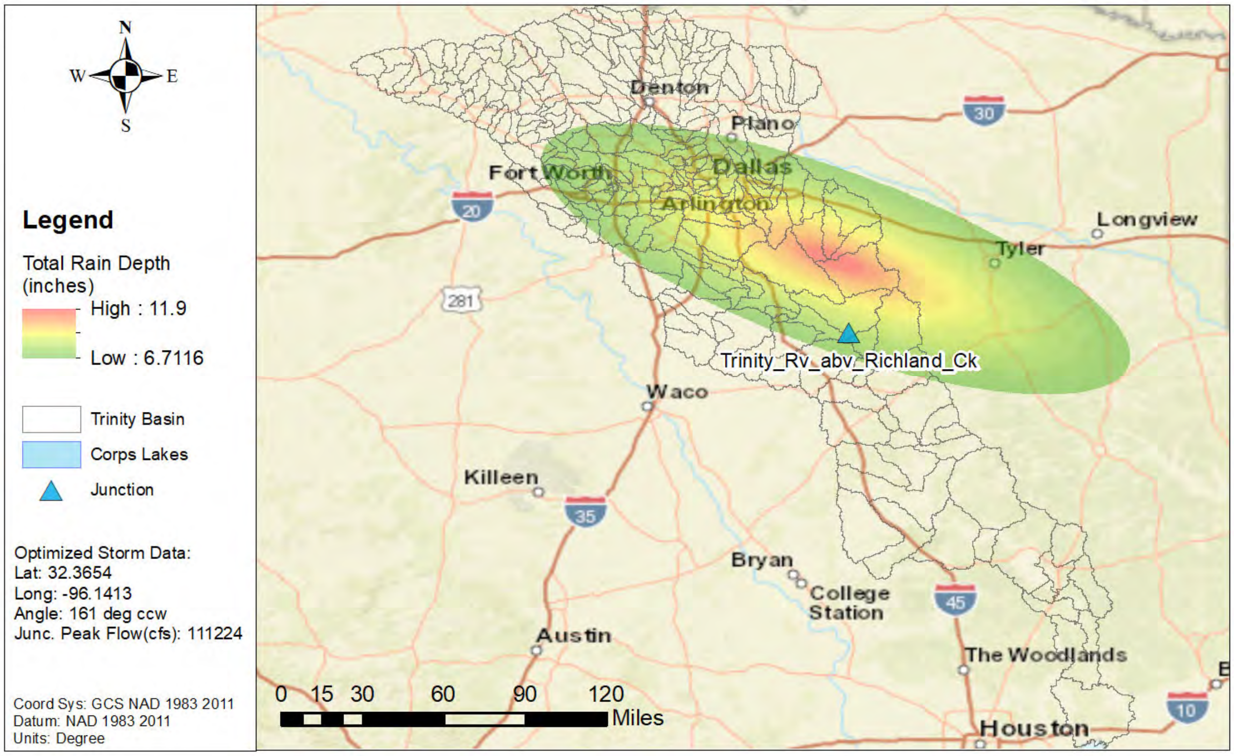


Figure 97b: NA14 1% AEP Elliptical Storm for the Trinity River above Richland Creek

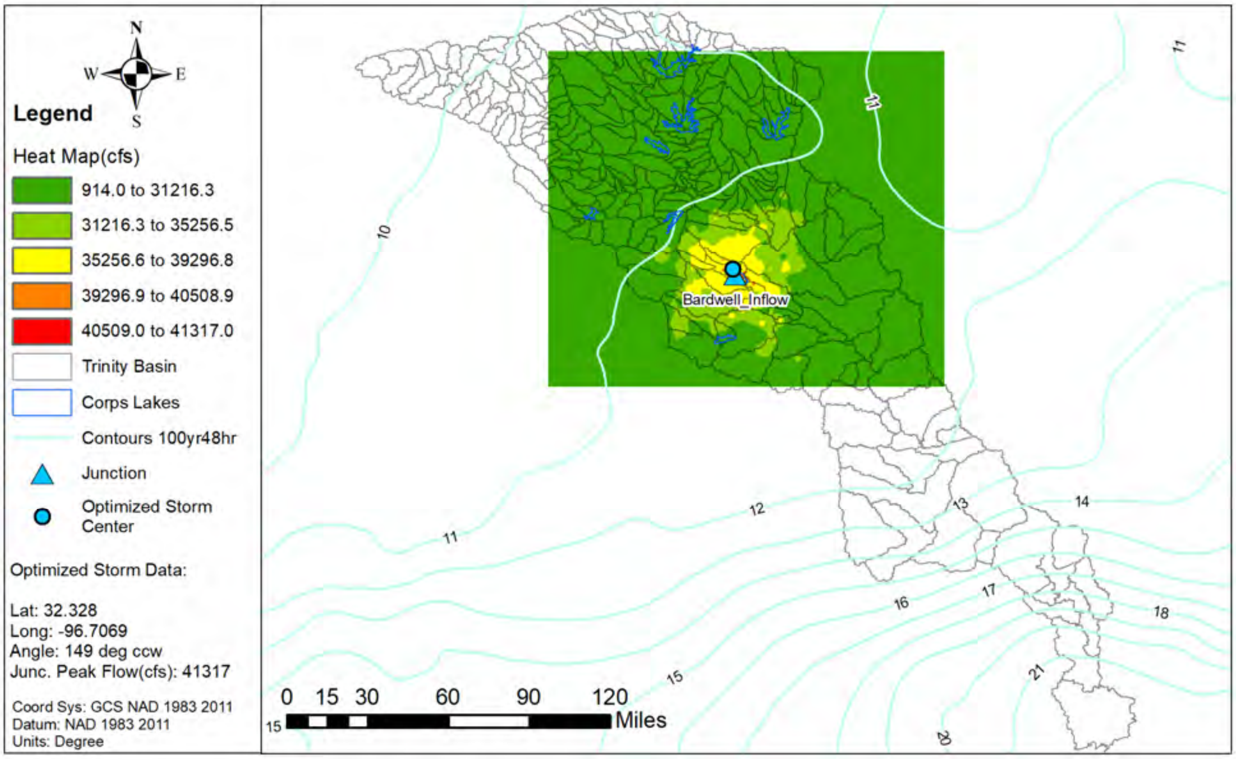


Figure 98a: Elliptical Storm Heat Map for the Bardwell Lake Inflow

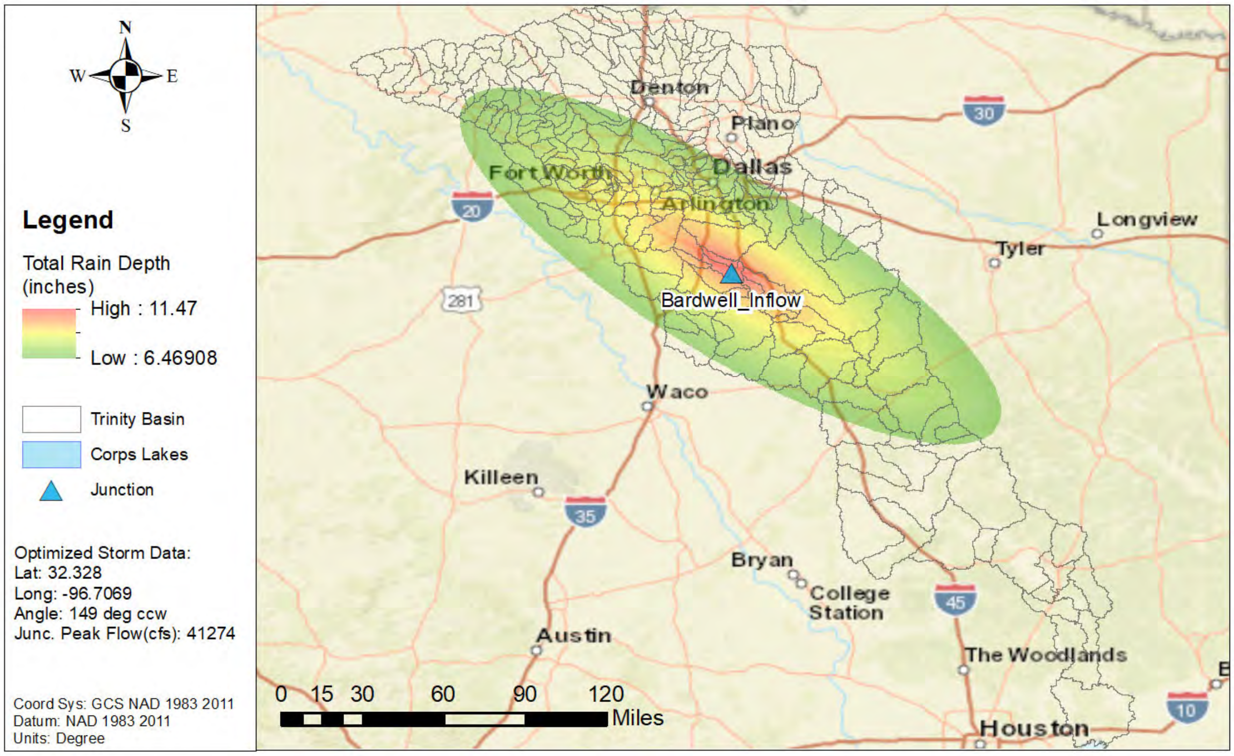


Figure 98b: NA14 1% AEP Elliptical Storm for the Bardwell Lake Inflow

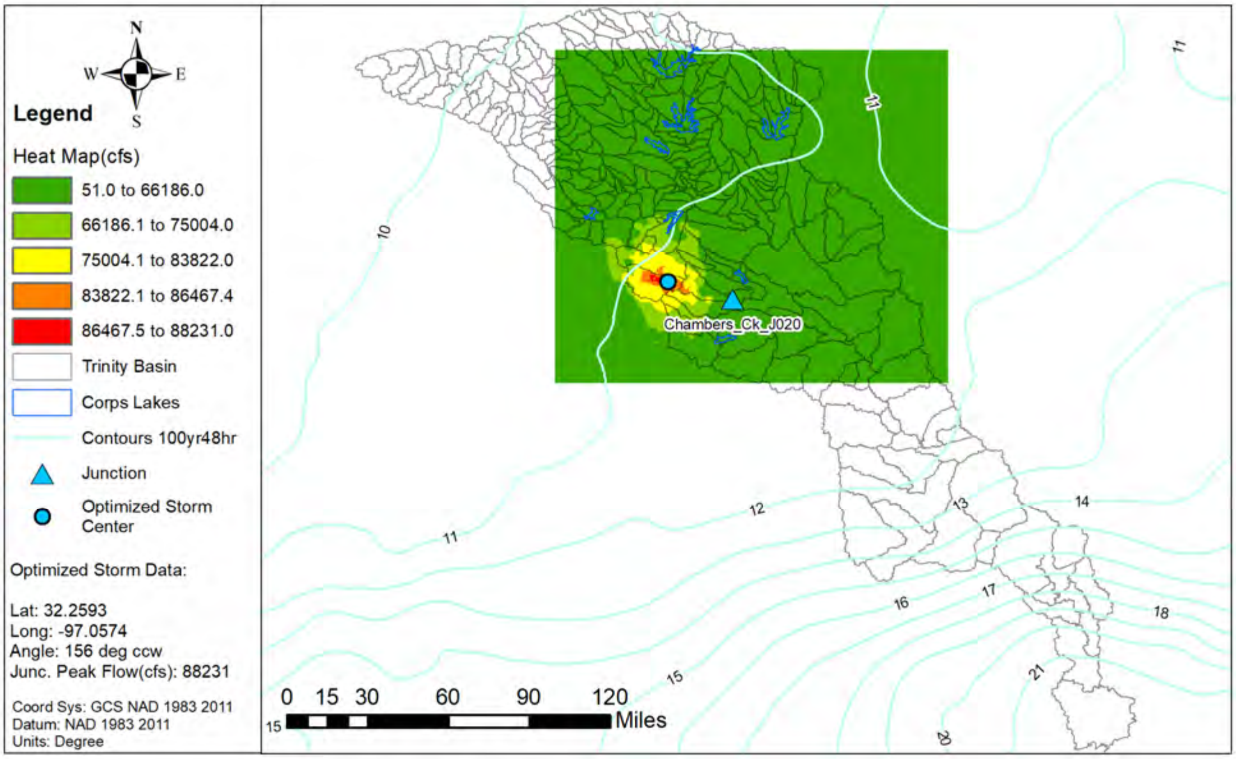


Figure 99a: Elliptical Storm Heat Map for the Chambers Creek below Mill Creek

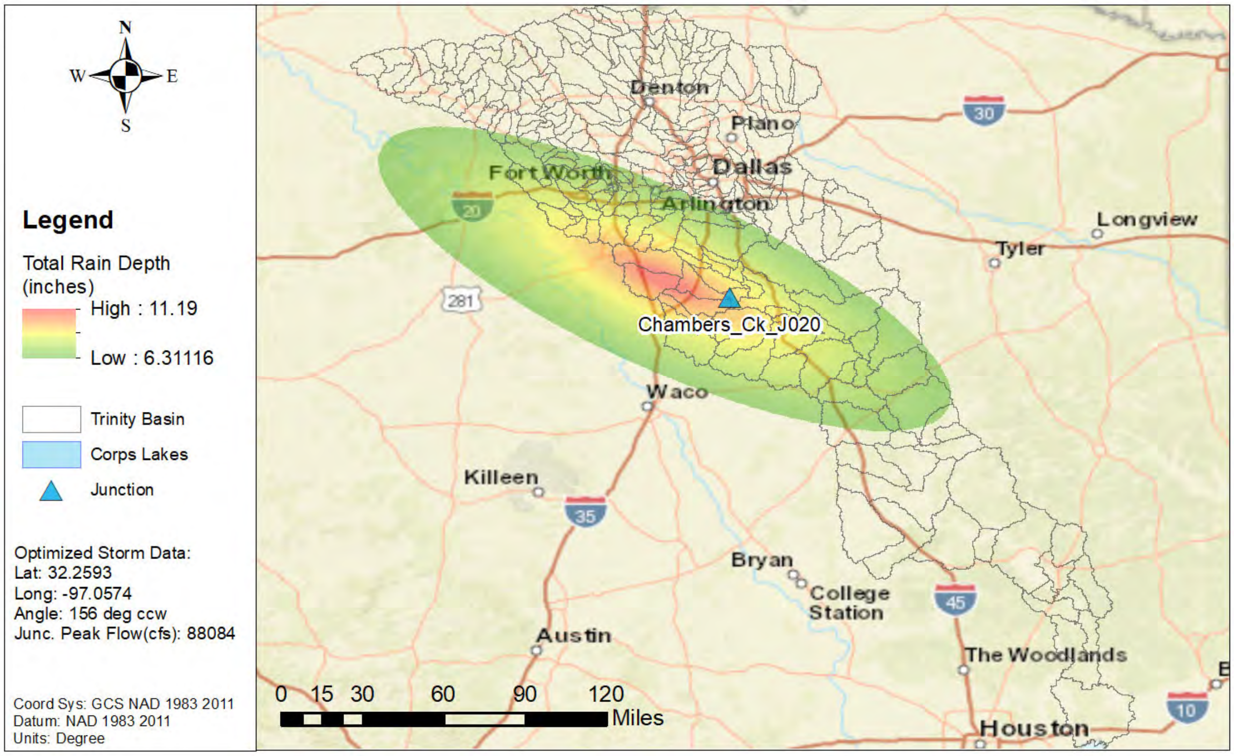


Figure 99b: NA14 1% AEP Elliptical Storm for the Chambers Creek below Mill Creek

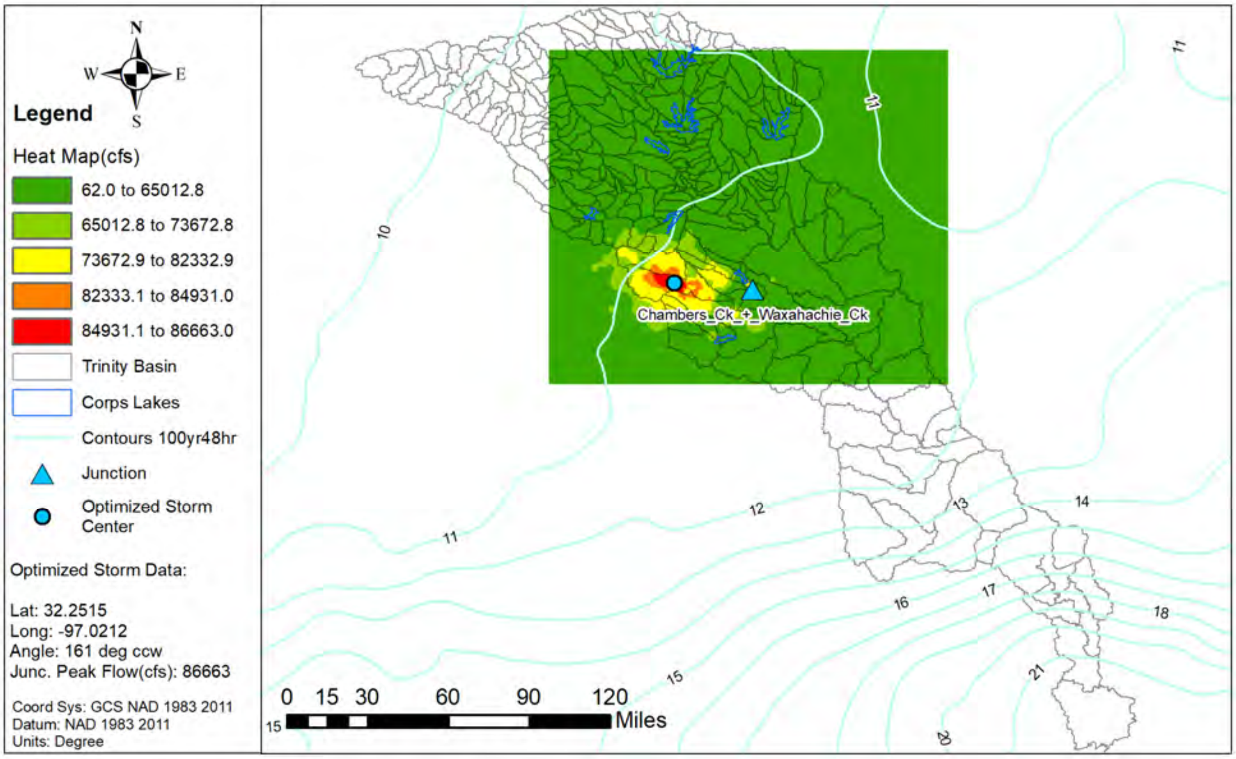


Figure 100a: Elliptical Storm Heat Map for the Chambers Creek below Waxahachie Creek

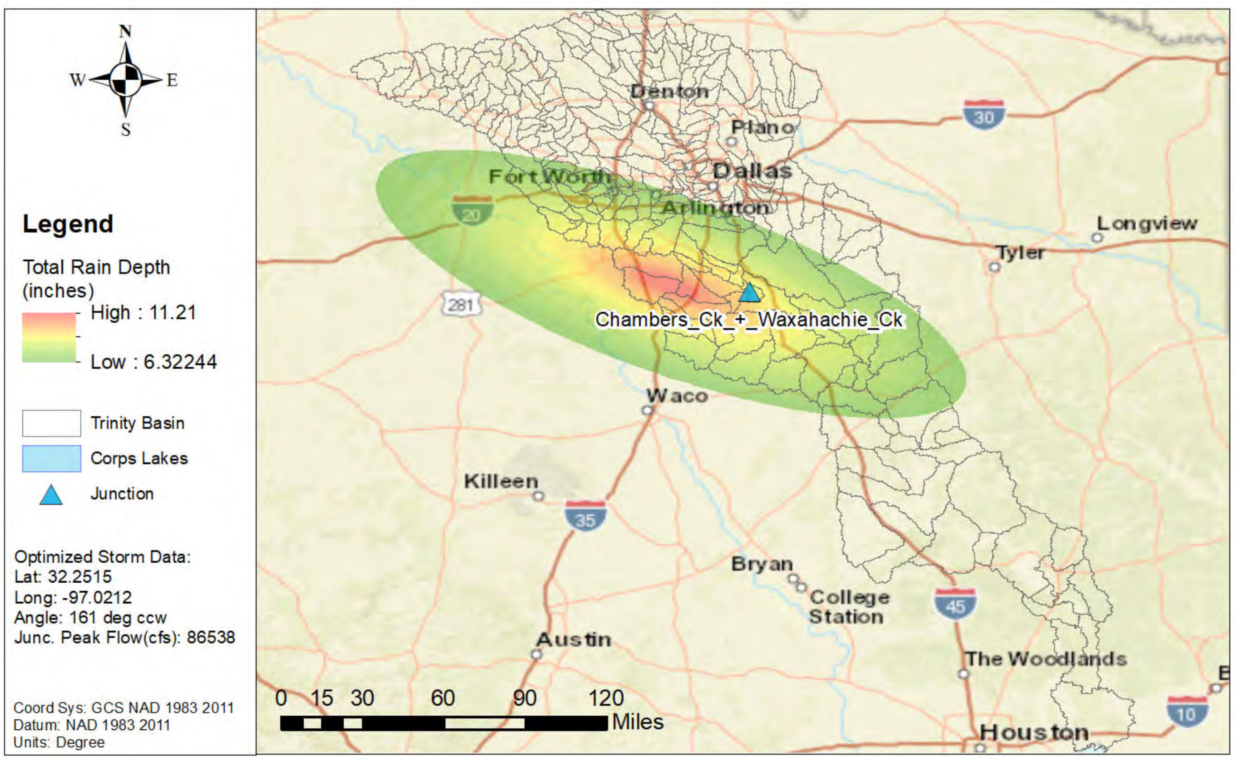


Figure 100b: NA14 1% AEP Elliptical Storm for the Chambers Creek below Waxahachie Creek

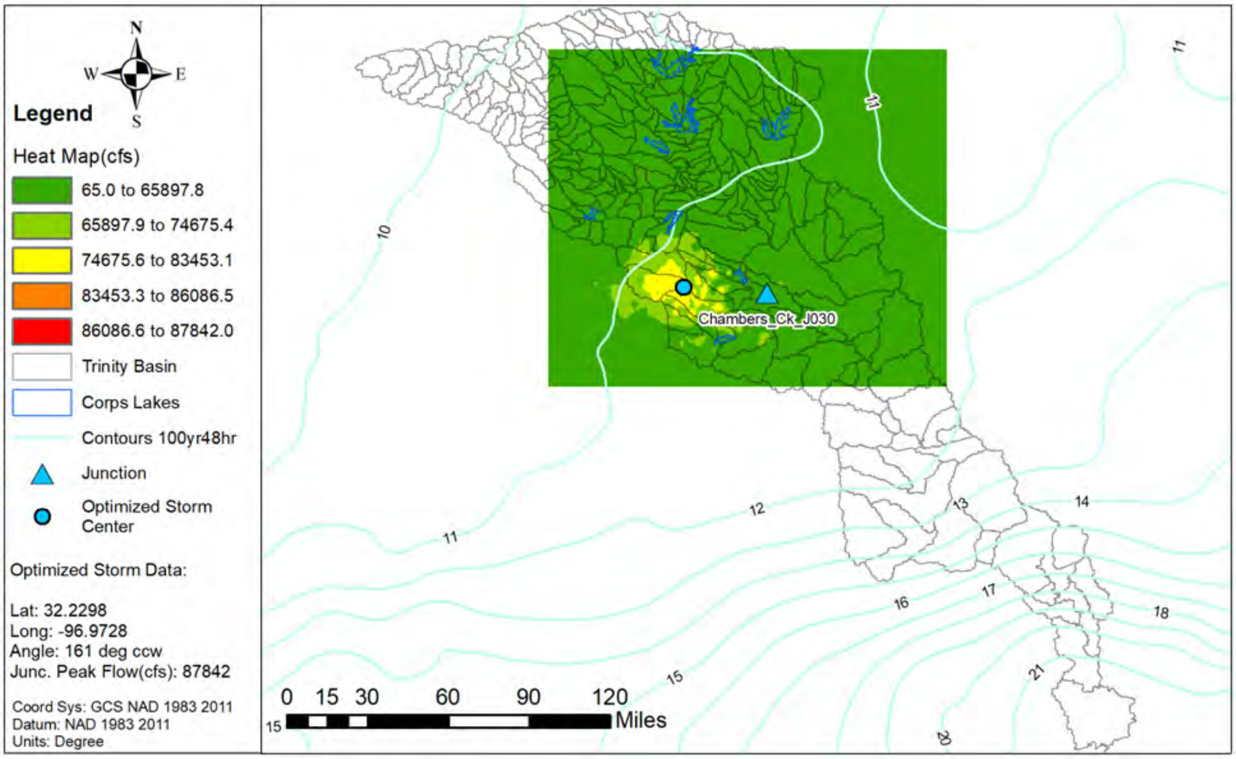


Figure 101a: Elliptical Storm Heat Map for the Chambers Creek near Rice, TX USGS gage

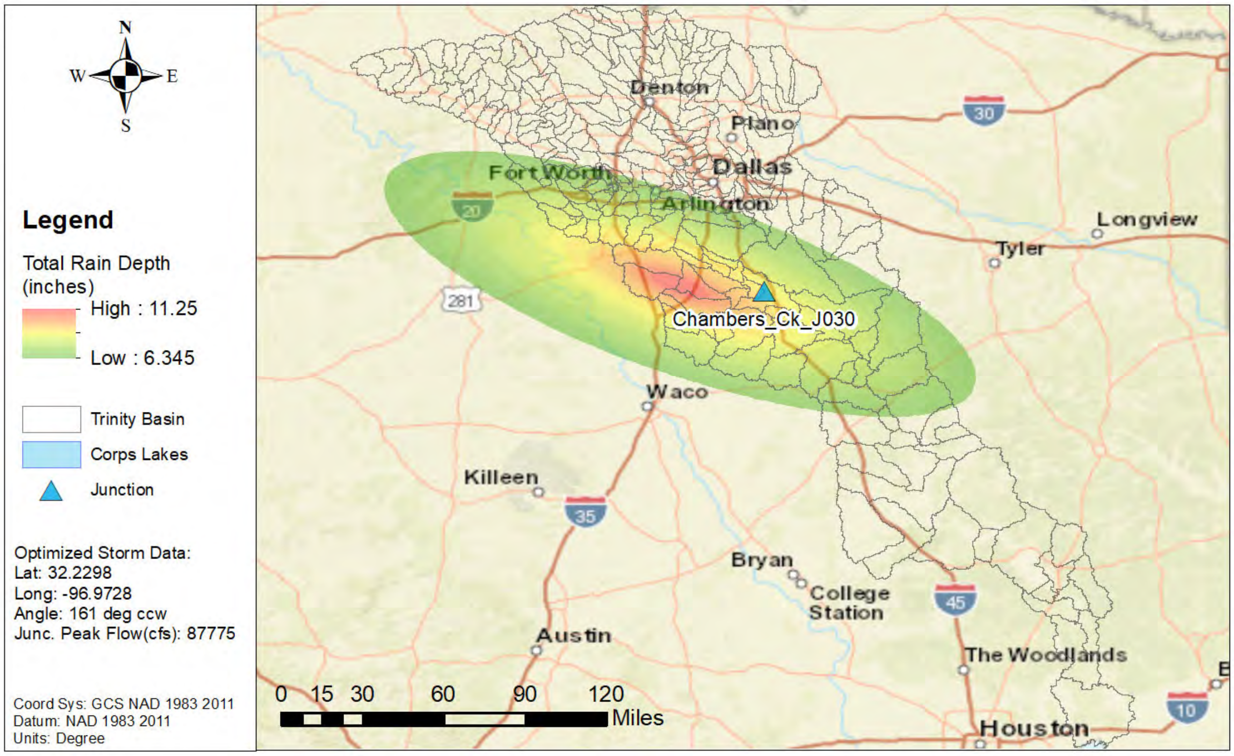


Figure 101b: NA14 1% AEP Elliptical Storm for the Chambers Creek near Rice, TX USGS gage

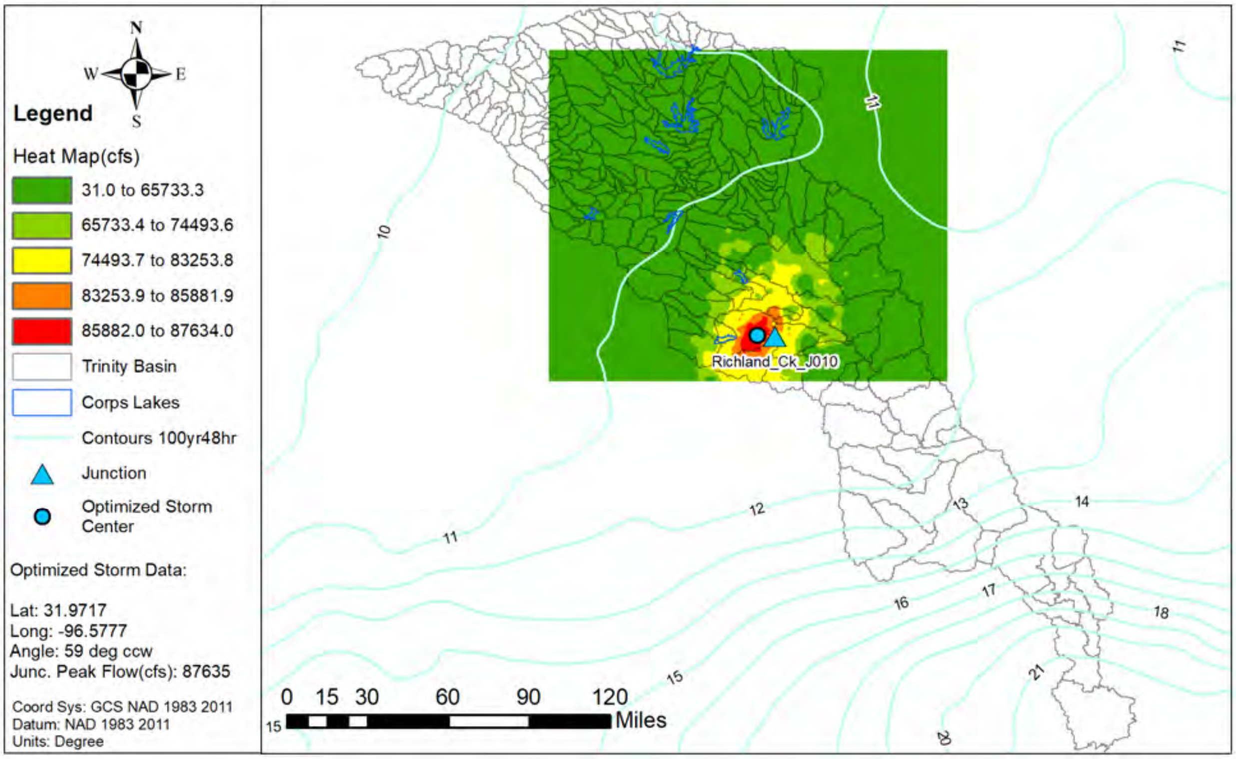


Figure 102a: Elliptical Storm Heat Map for the Richland Creek below Pin Oak Creek

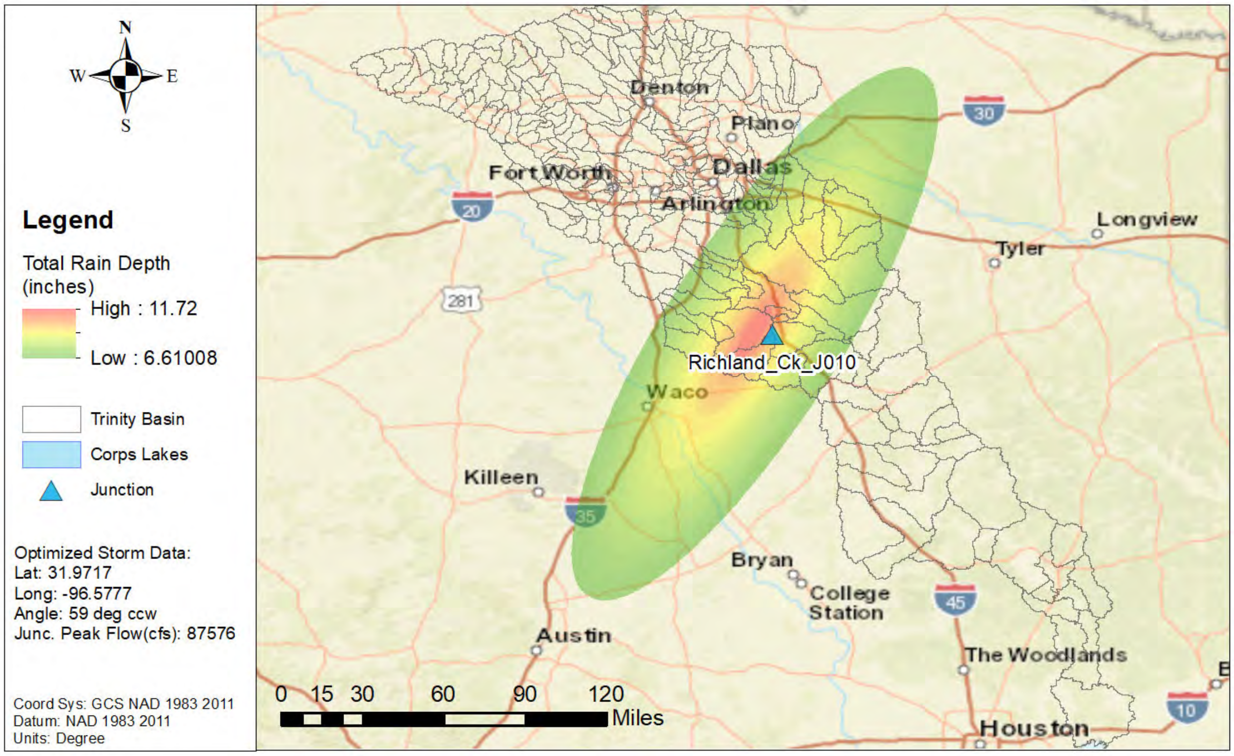


Figure 102b: NA14 1% AEP Elliptical Storm for the Richland Creek below Pin Oak Creek

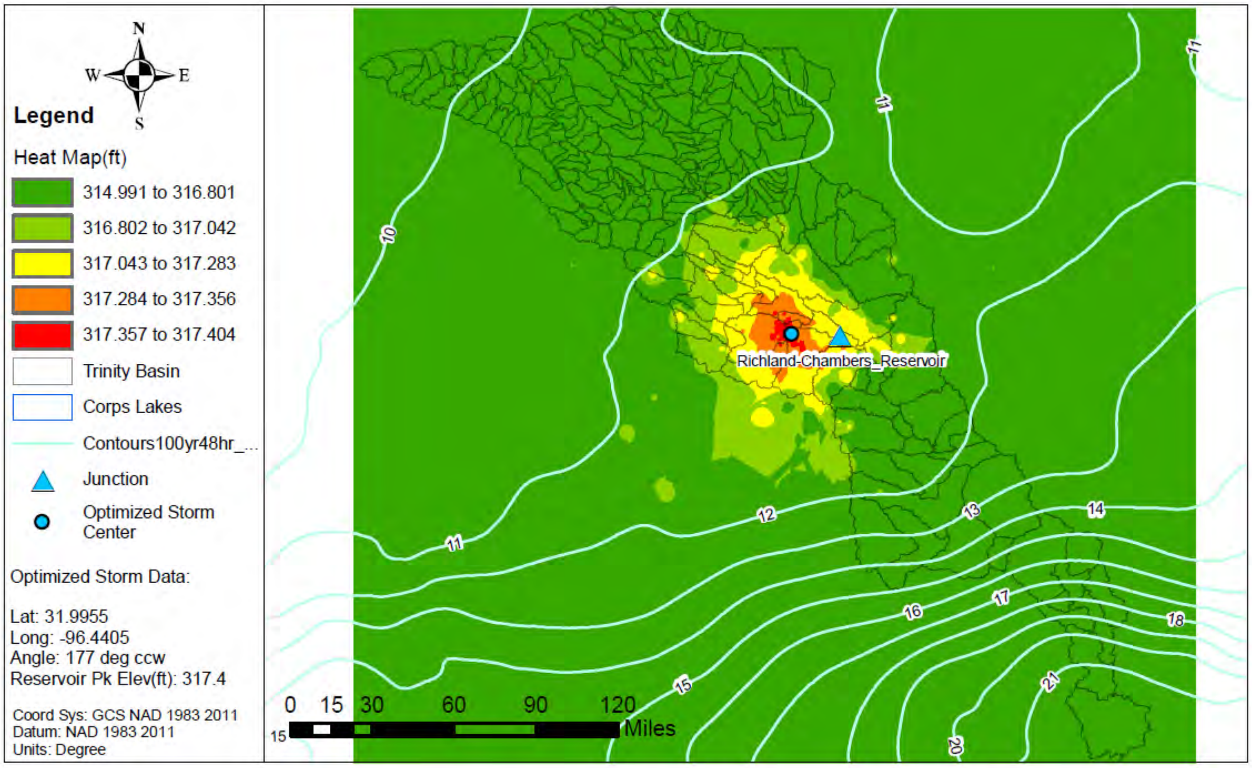


Figure 103a: Elliptical Storm Heat Map for the Richland Chambers Reservoir

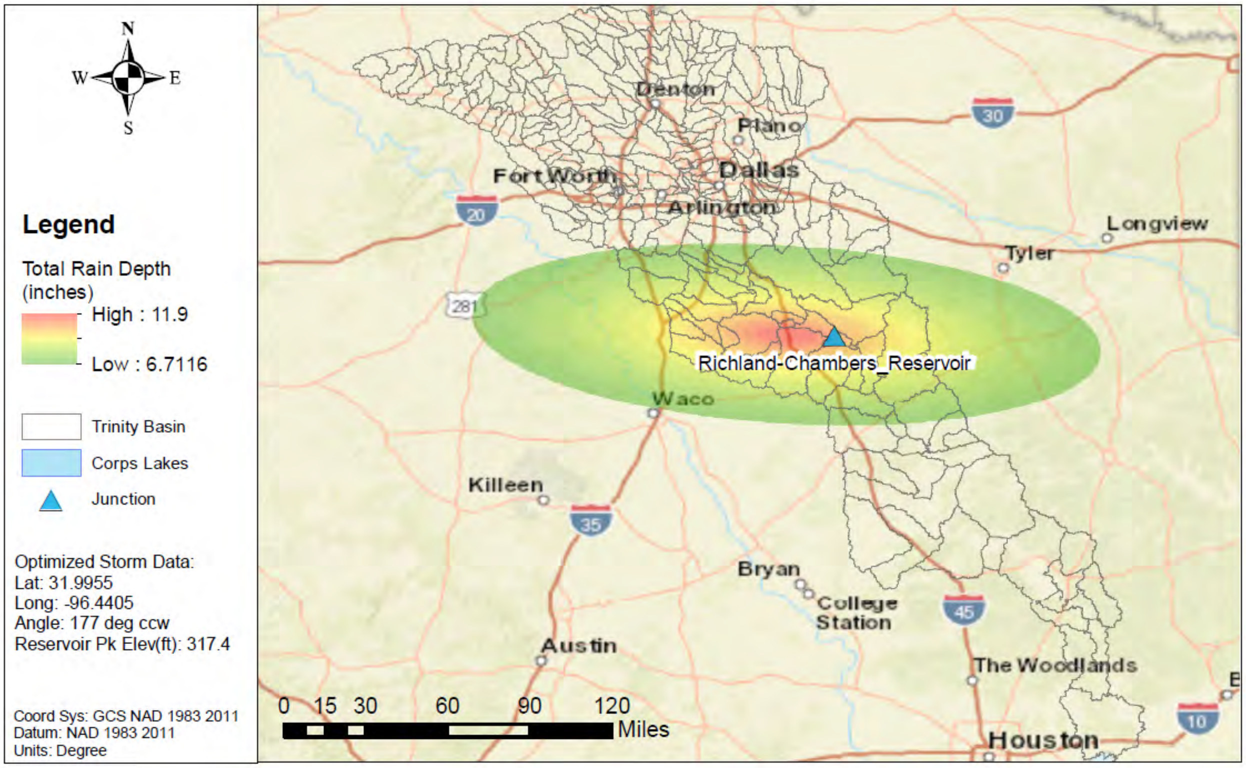


Figure 103b: NA14 1% AEP Elliptical Storm for the Richland Chambers Reservoir

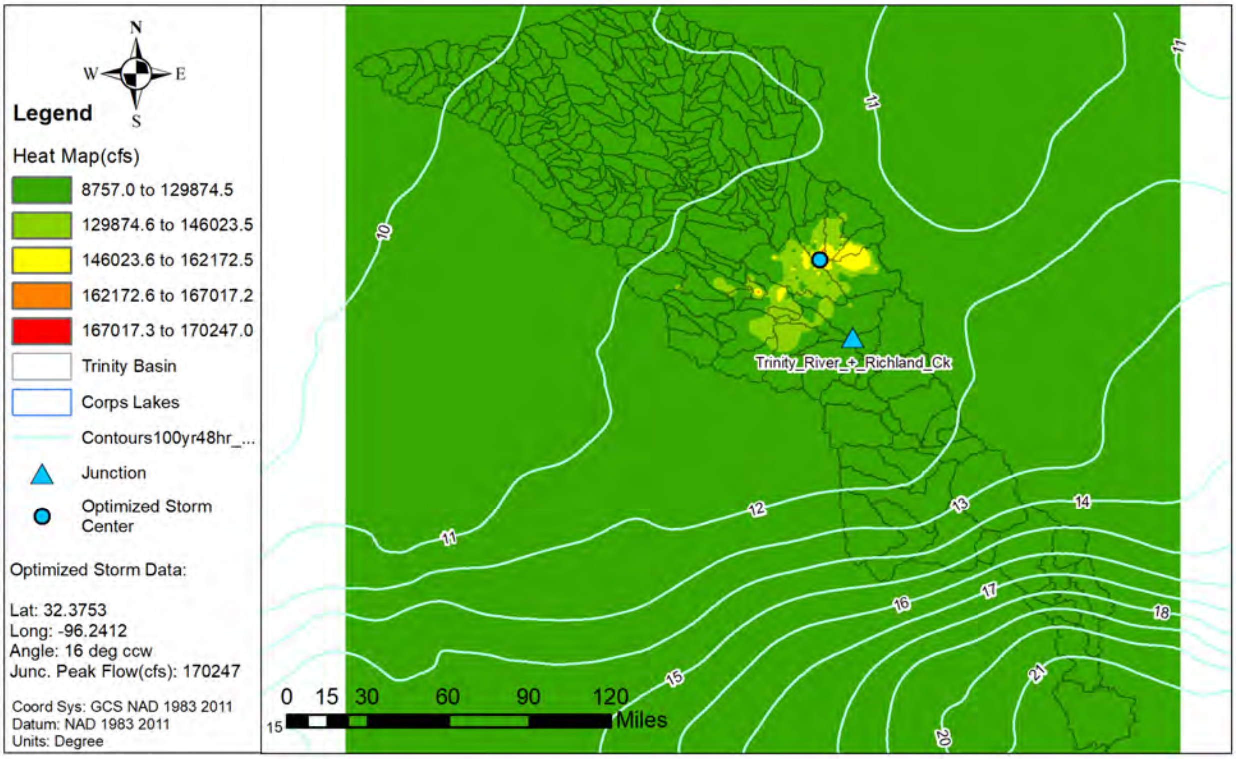


Figure 104a: Elliptical Storm Heat Map for the Trinity River below Richland Creek

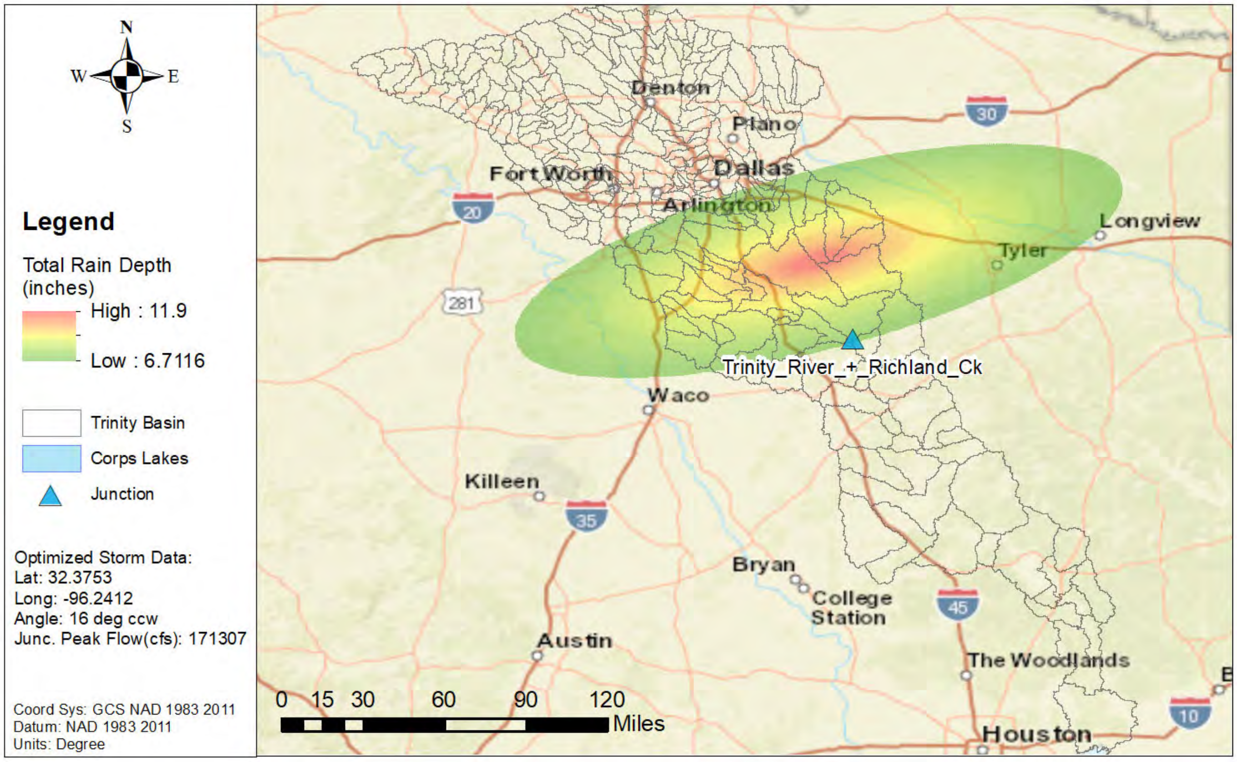


Figure 104b: NA14 1% AEP Elliptical Storm for the Trinity River below Richland Creek

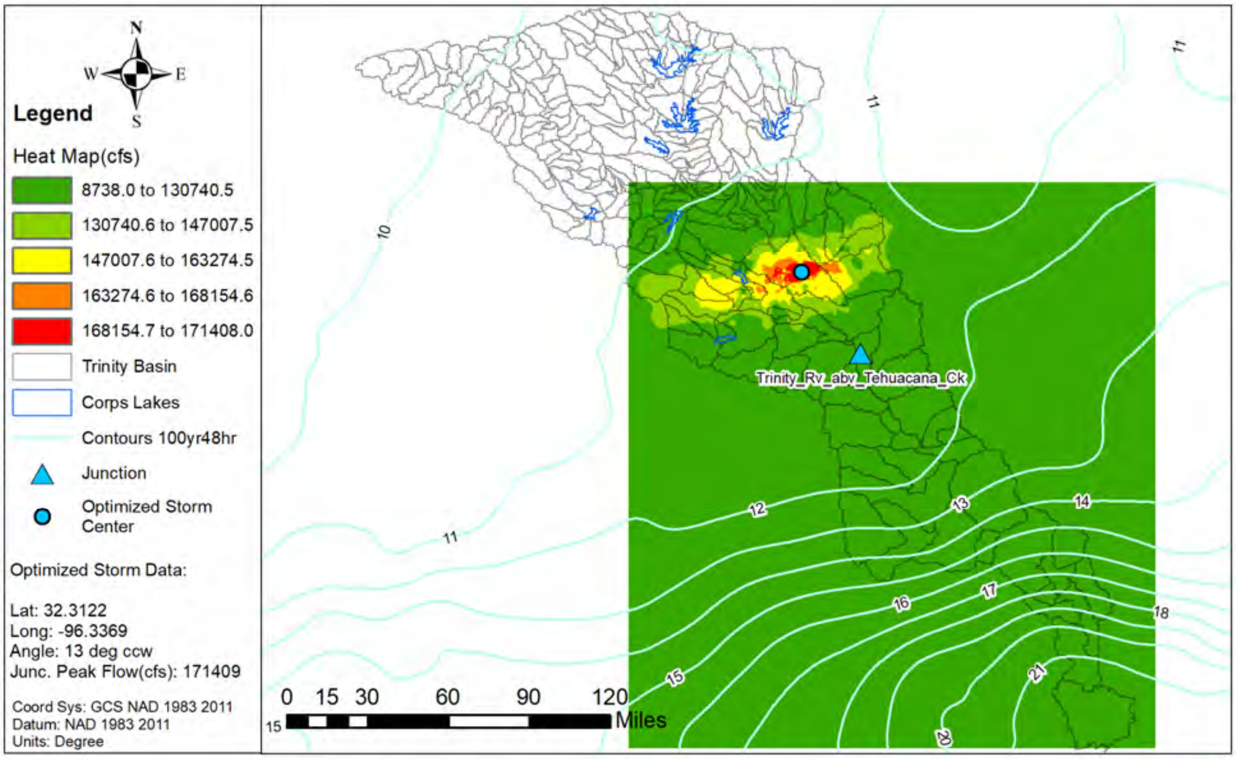


Figure 105a: Elliptical Storm Heat Map for the Trinity River above Tehuacana Creek

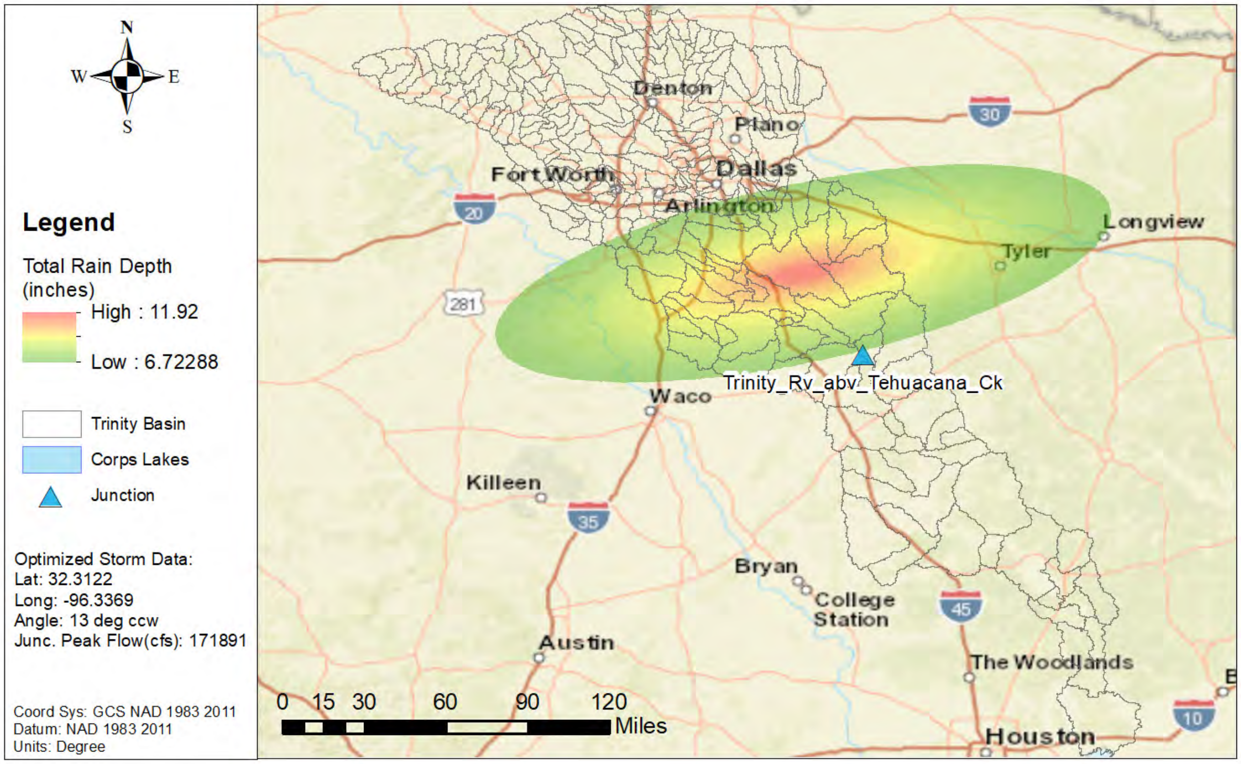


Figure 105b: NA14 1% AEP Elliptical Storm for the Trinity River above Tehuacana Creek

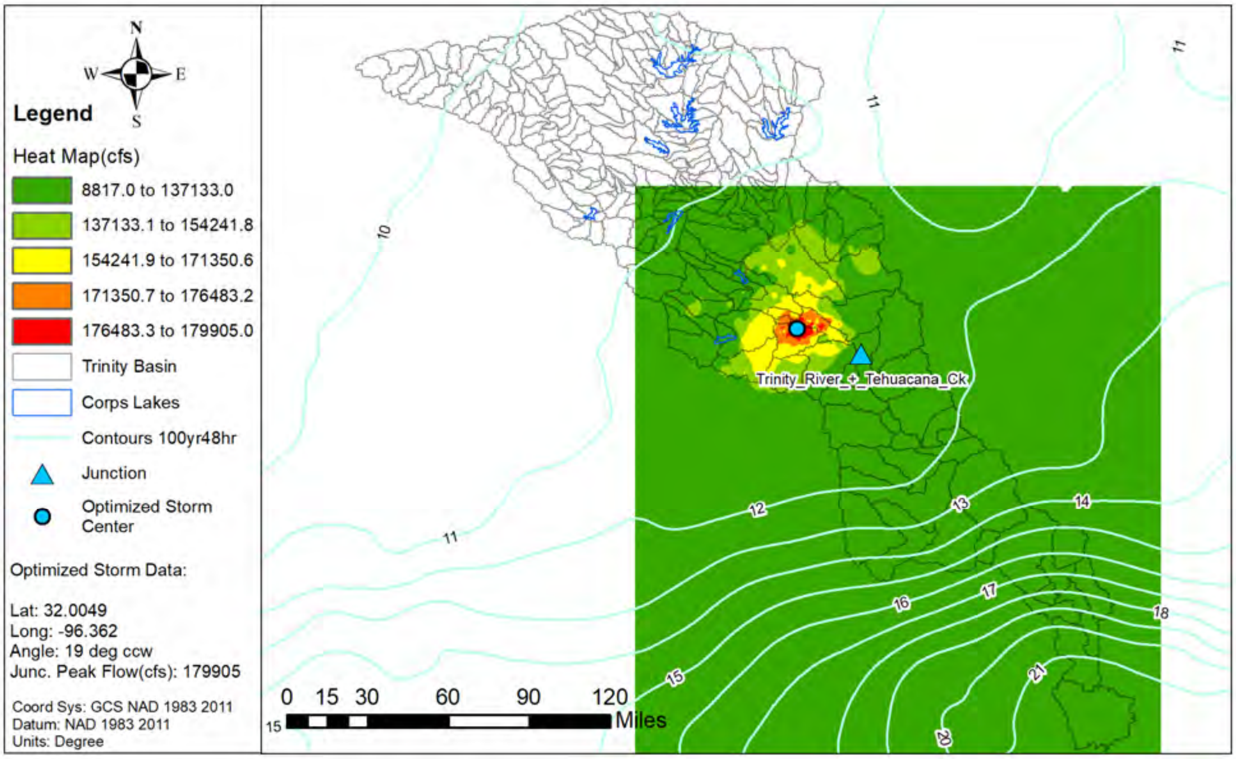


Figure 106a: Elliptical Storm Heat Map for the Trinity River below Tehuacana Creek

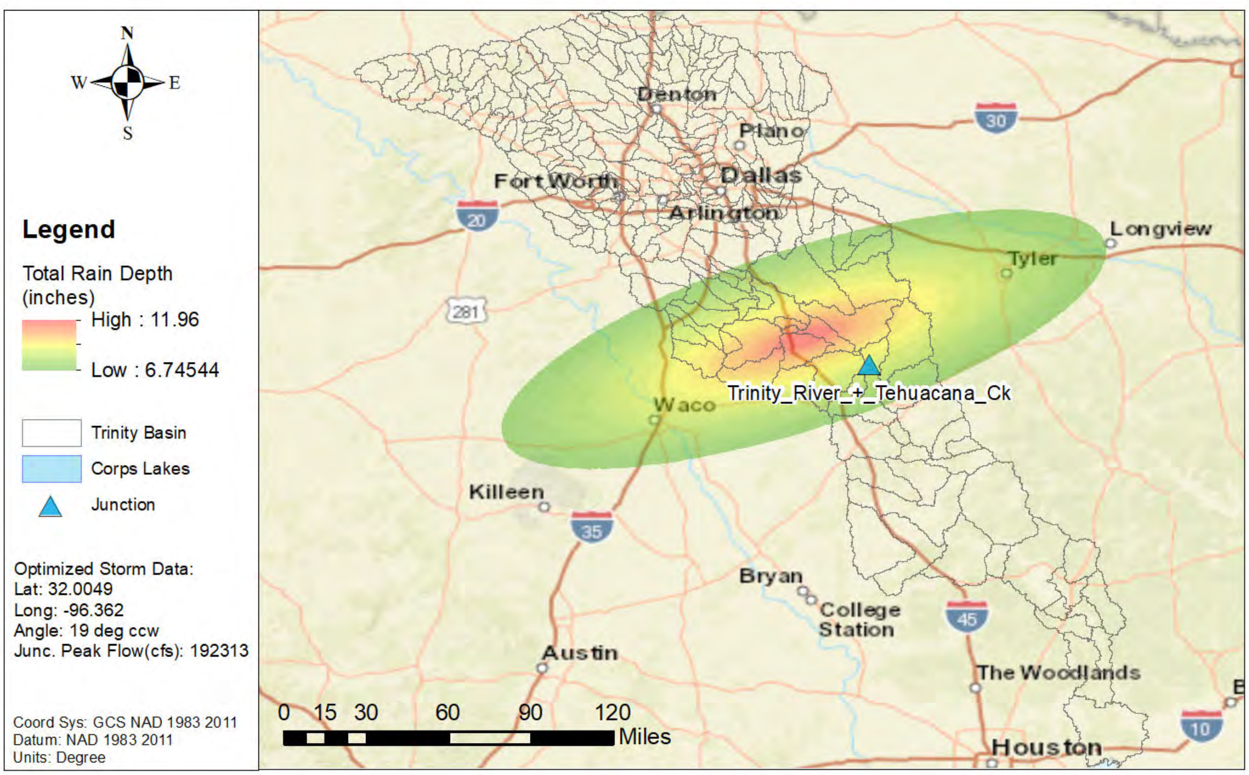


Figure 106b: NA14 1% AEP Elliptical Storm for the Trinity River below Tehuacana Creek

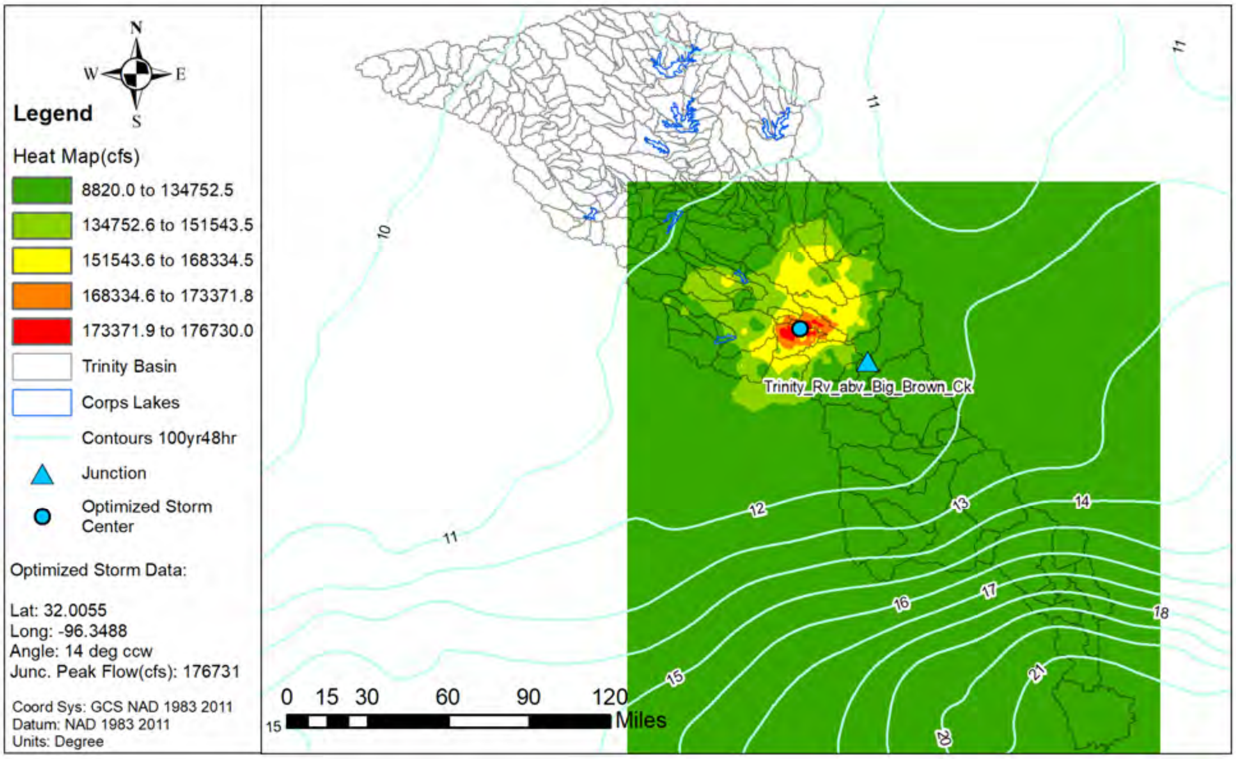


Figure 107a: Elliptical Storm Heat Map for the Trinity River above Big Brown Creek

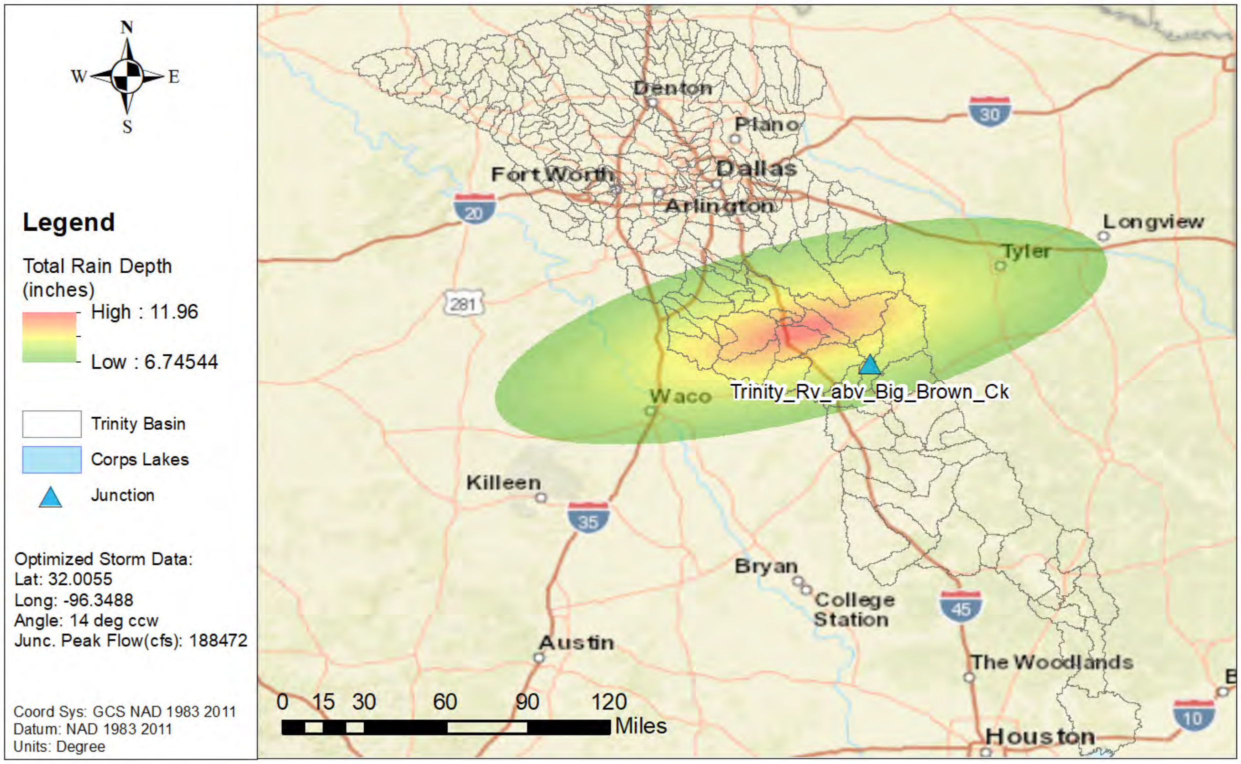


Figure 107b: NA14 1% AEP Elliptical Storm for the Trinity River above Big Brown Creek

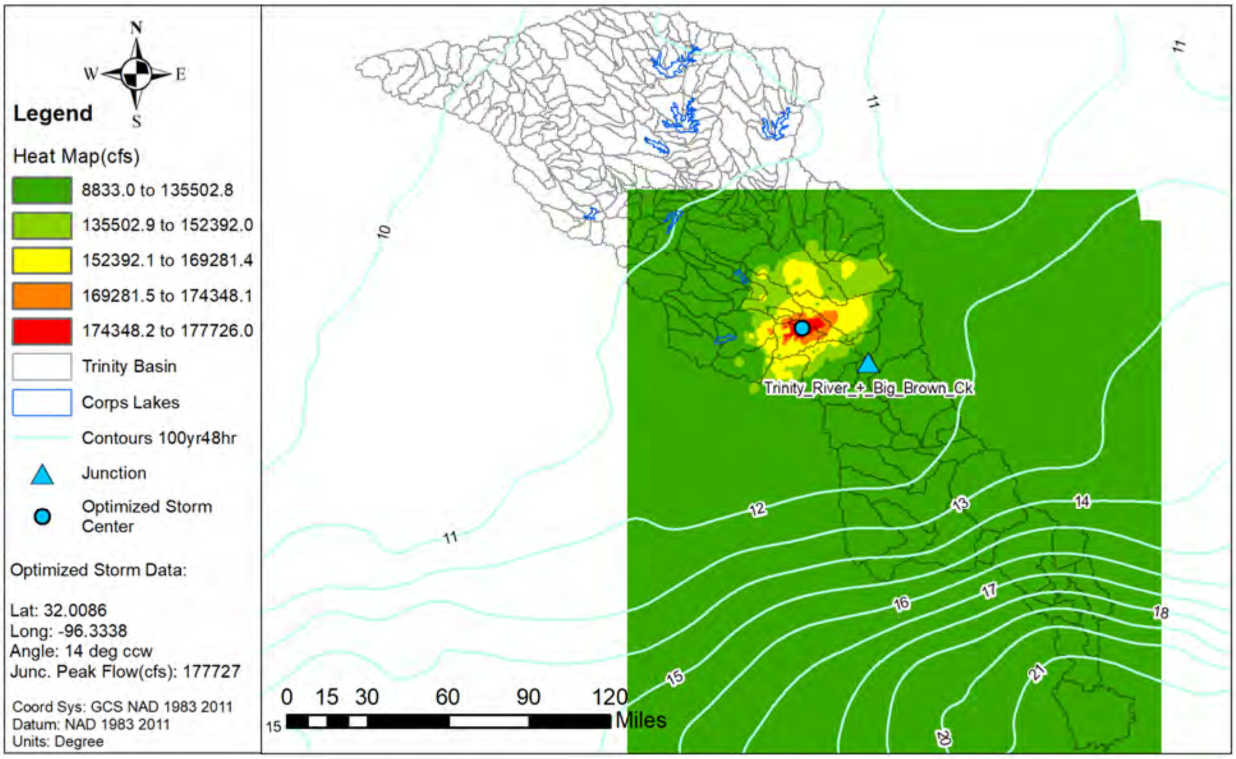


Figure 108a: Elliptical Storm Heat Map for the Trinity River below Big Brown Creek

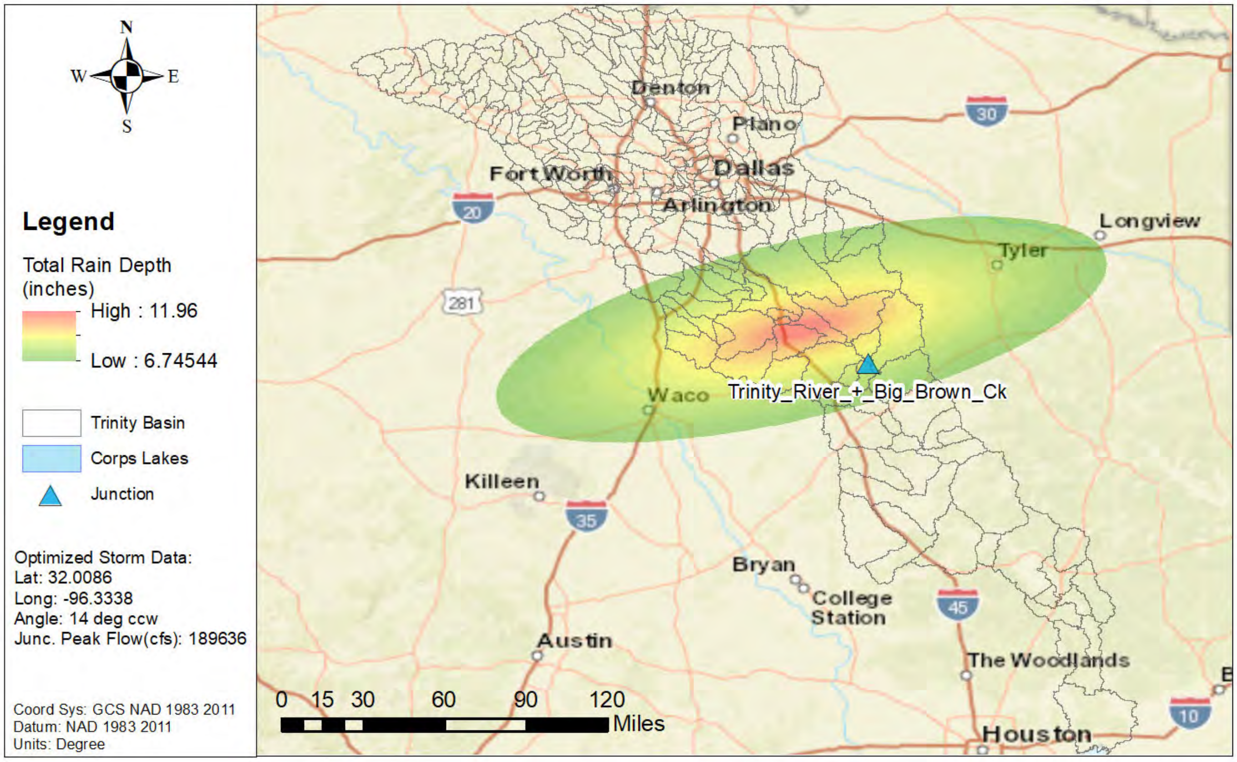


Figure 108b: NA14 1% AEP Elliptical Storm for the Trinity River below Big Brown Creek

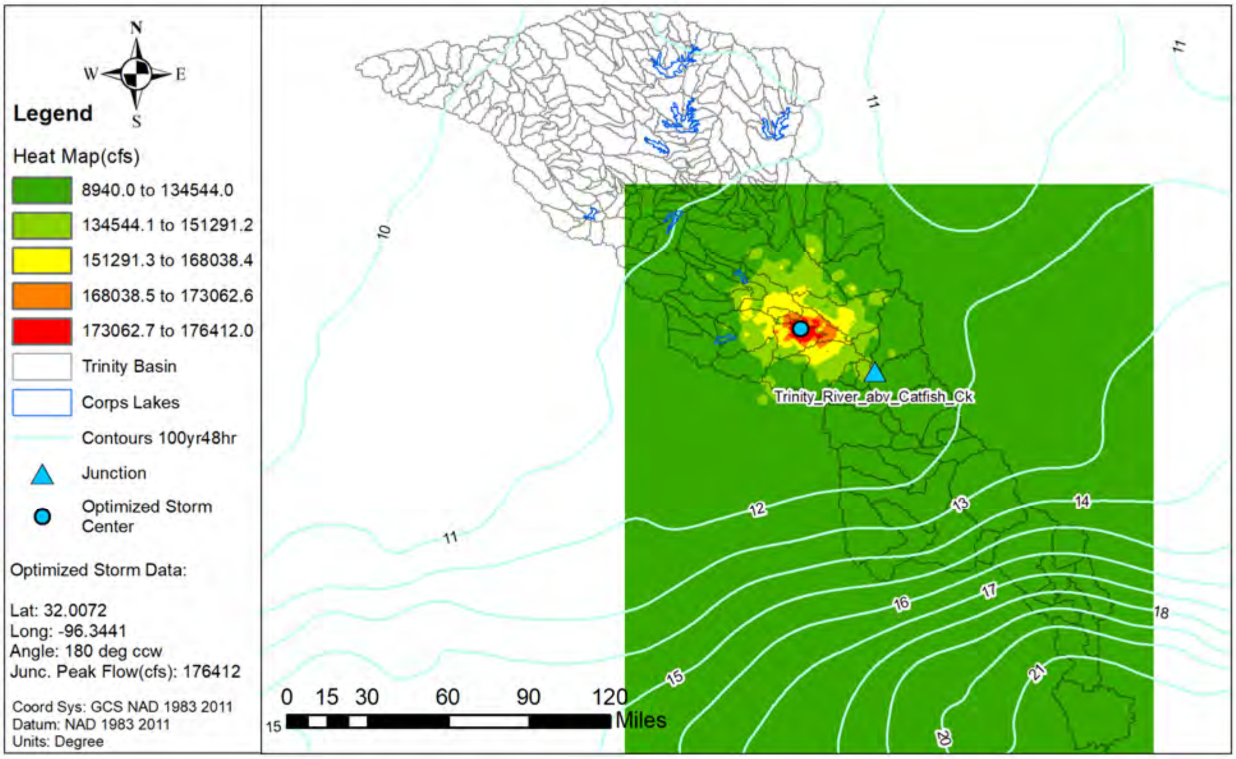


Figure 109a: Elliptical Storm Heat Map for the Trinity River above Catfish Creek

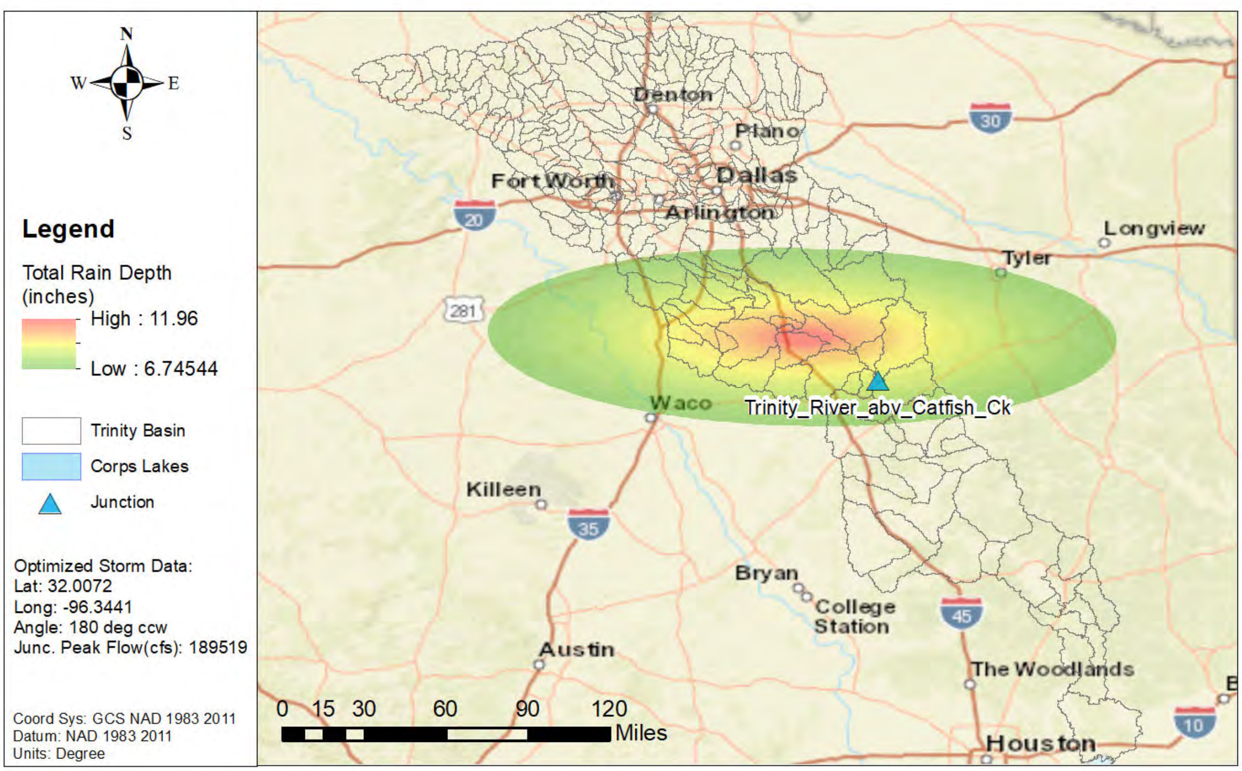


Figure 109b: NA14 1% AEP Elliptical Storm for the Trinity River above Catfish Creek

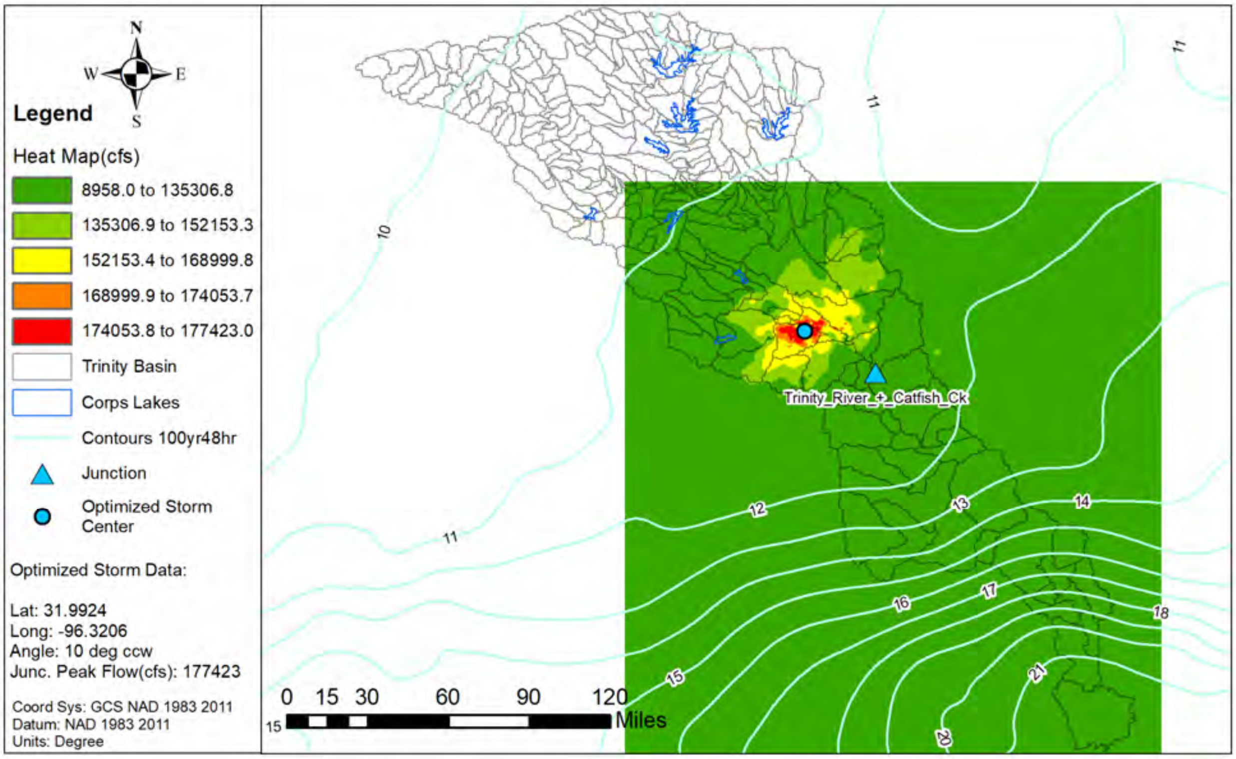


Figure 110a: Elliptical Storm Heat Map for the Trinity River below Catfish Creek

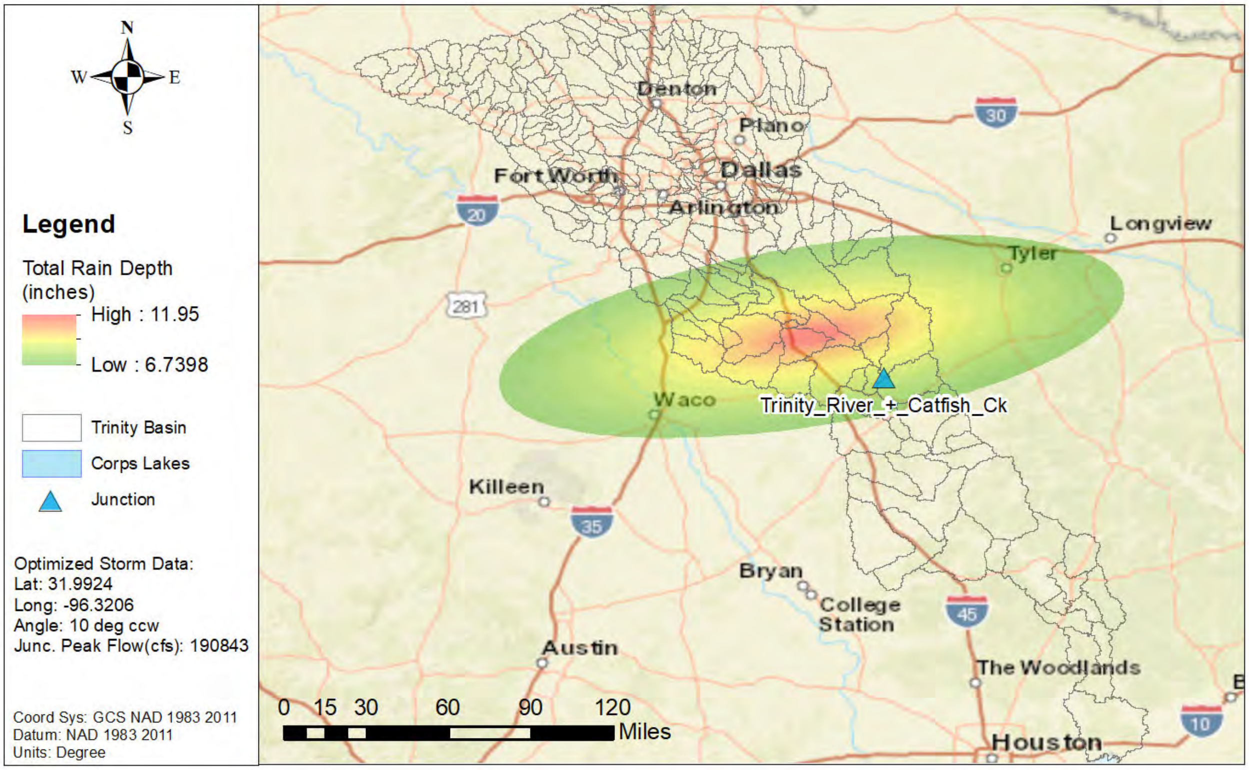


Figure 110b: NA14 1% AEP Elliptical Storm for the Trinity River below Catfish Creek

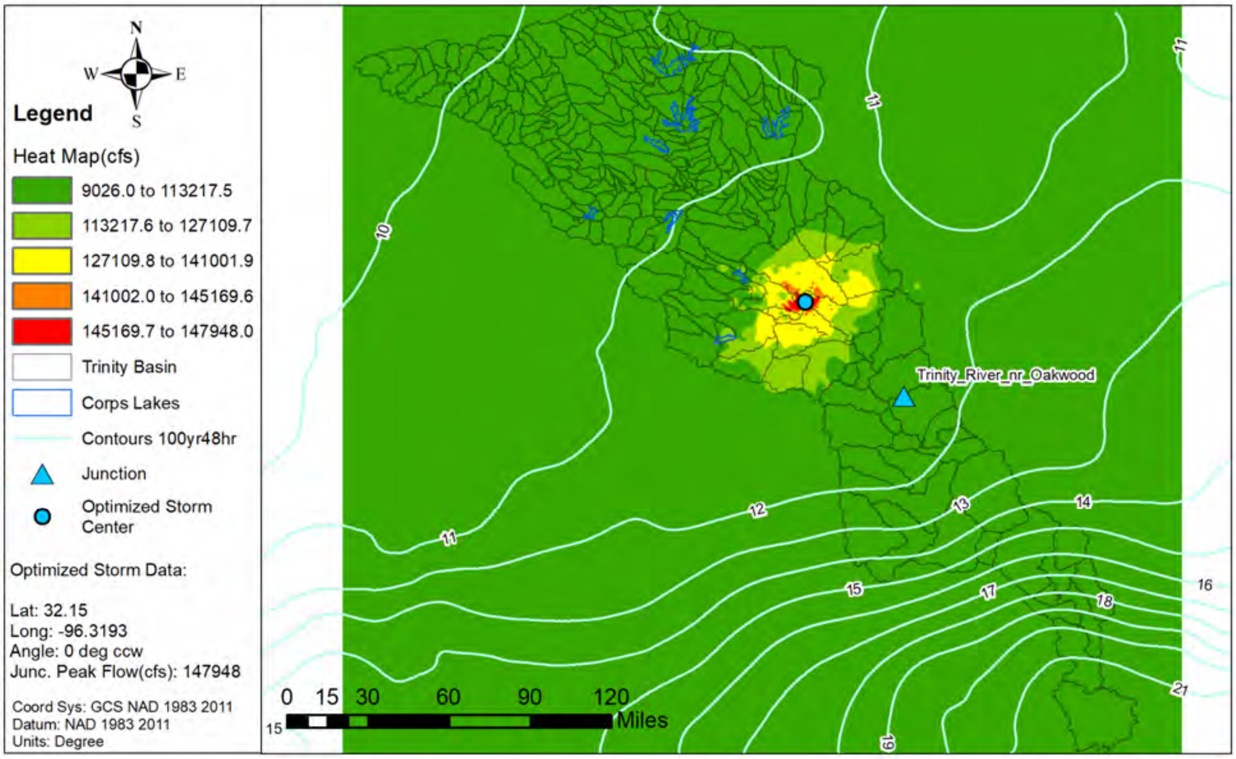


Figure 111a: Elliptical Storm Heat Map for the Trinity River near Oakwood, TX USGS gage

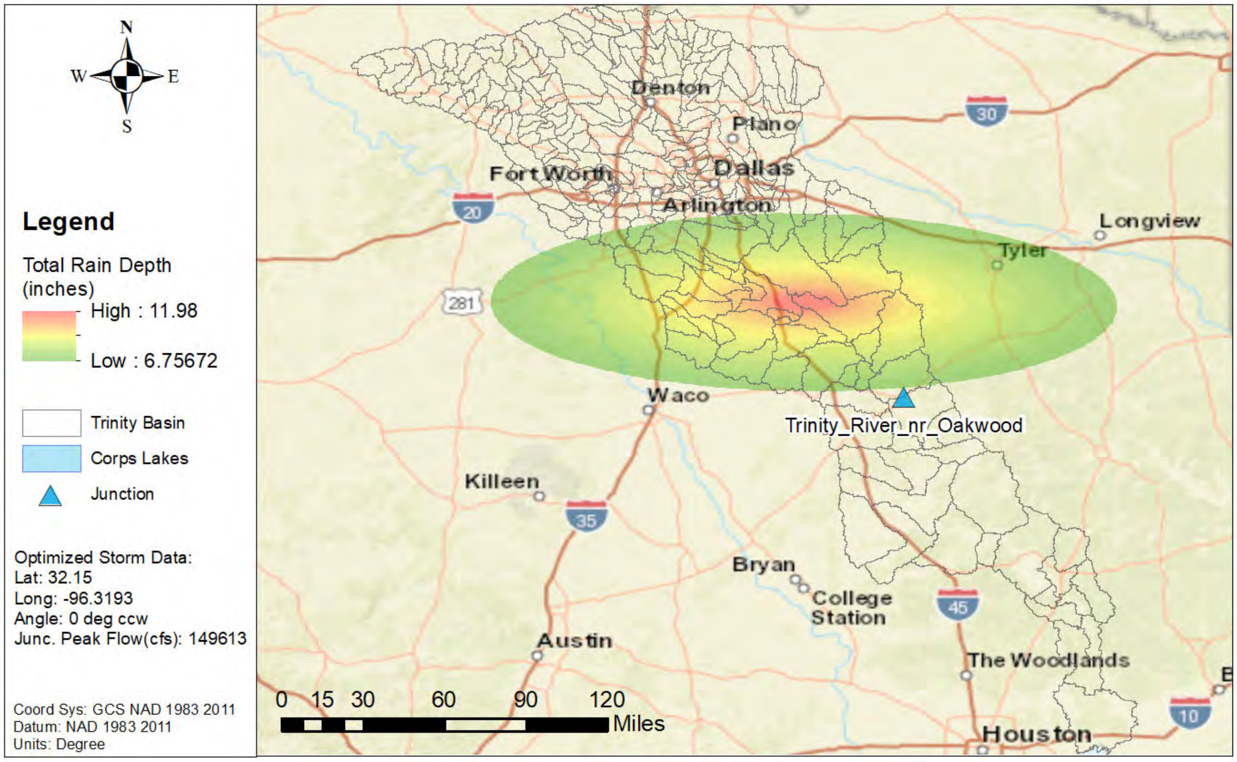


Figure 111b: NA14 1% AEP Elliptical Storm for the Trinity River near Oakwood, TX USGS gage

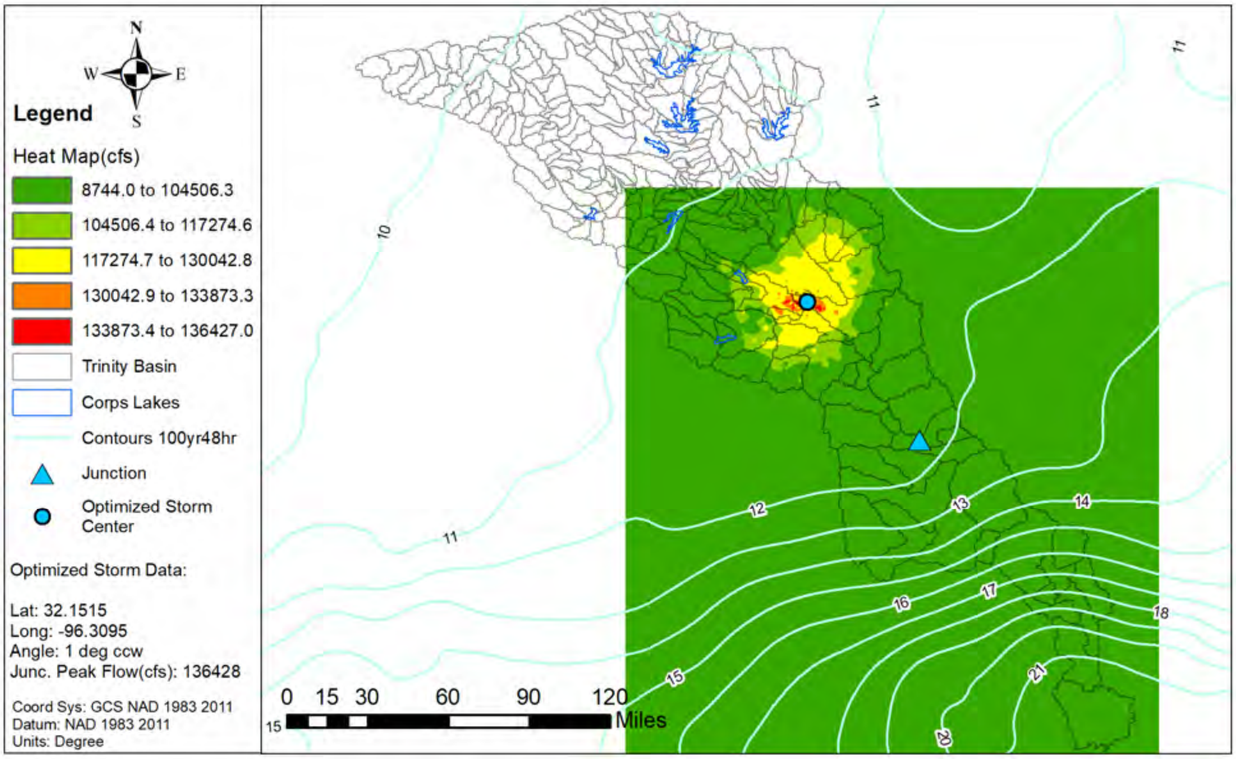


Figure 112a: Elliptical Storm Heat Map for the Trinity River above Upper Keechi Creek

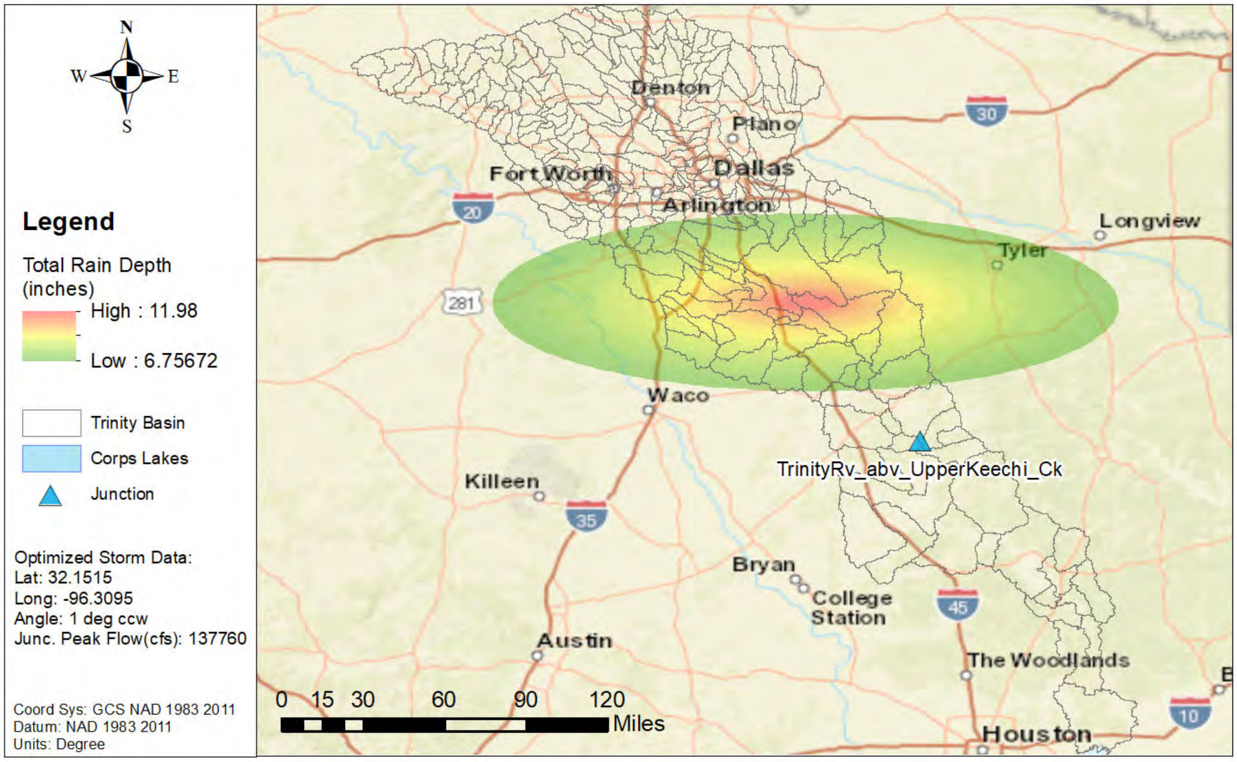


Figure 112b: NA14 1% AEP Elliptical Storm for the Trinity River above Upper Keechi Creek

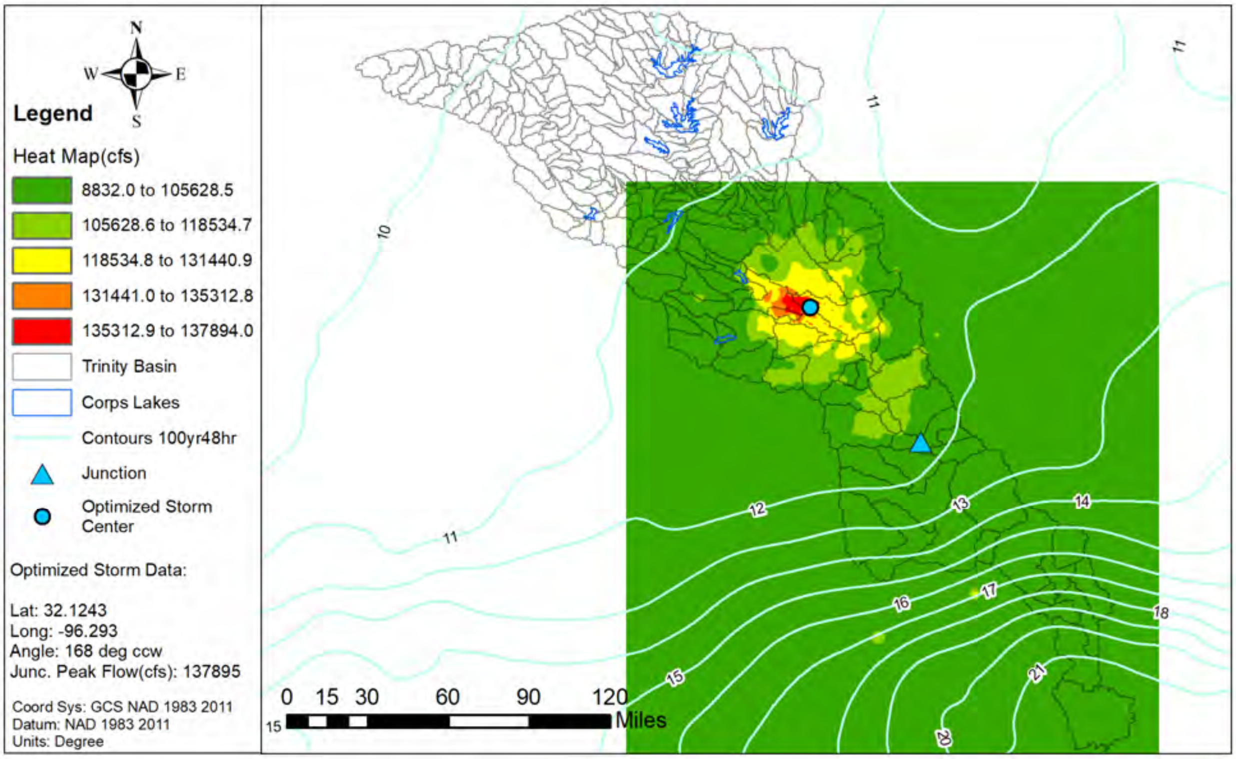


Figure 113a: Elliptical Storm Heat Map for the Trinity River below Upper Keechi Creek

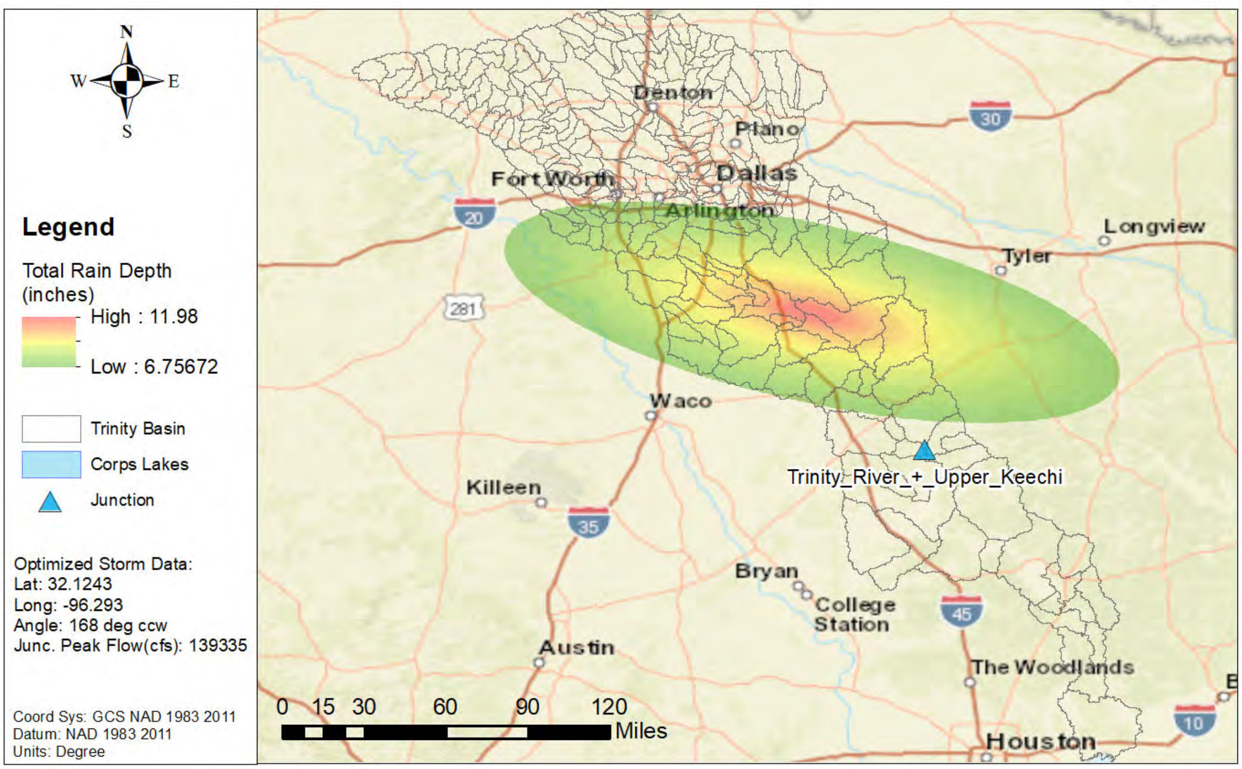


Figure 113b: NA14 1% AEP Elliptical Storm for the Trinity River below Upper Keechi Creek

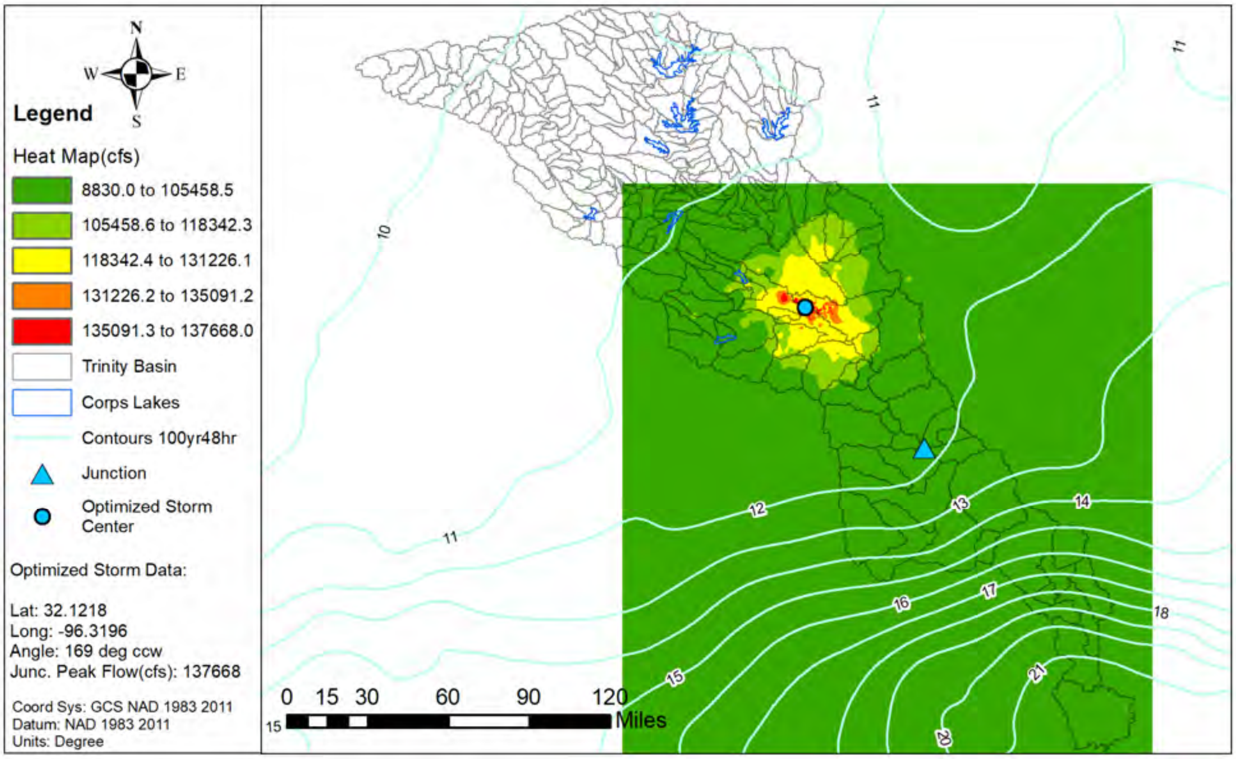


Figure 114a: Elliptical Storm Heat Map for the Trinity River above Big Elkhart Creek

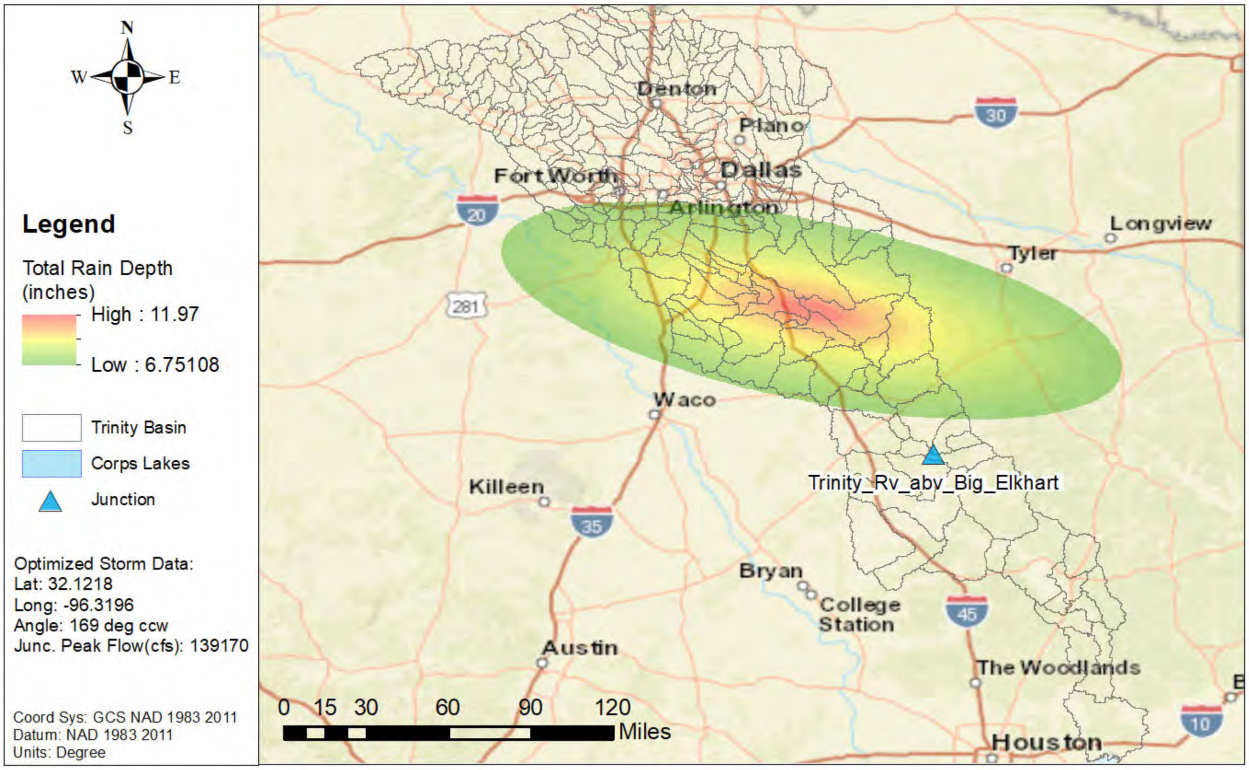


Figure 114b: NA14 1% AEP Elliptical Storm for the Trinity River above Big Elkhart Creek

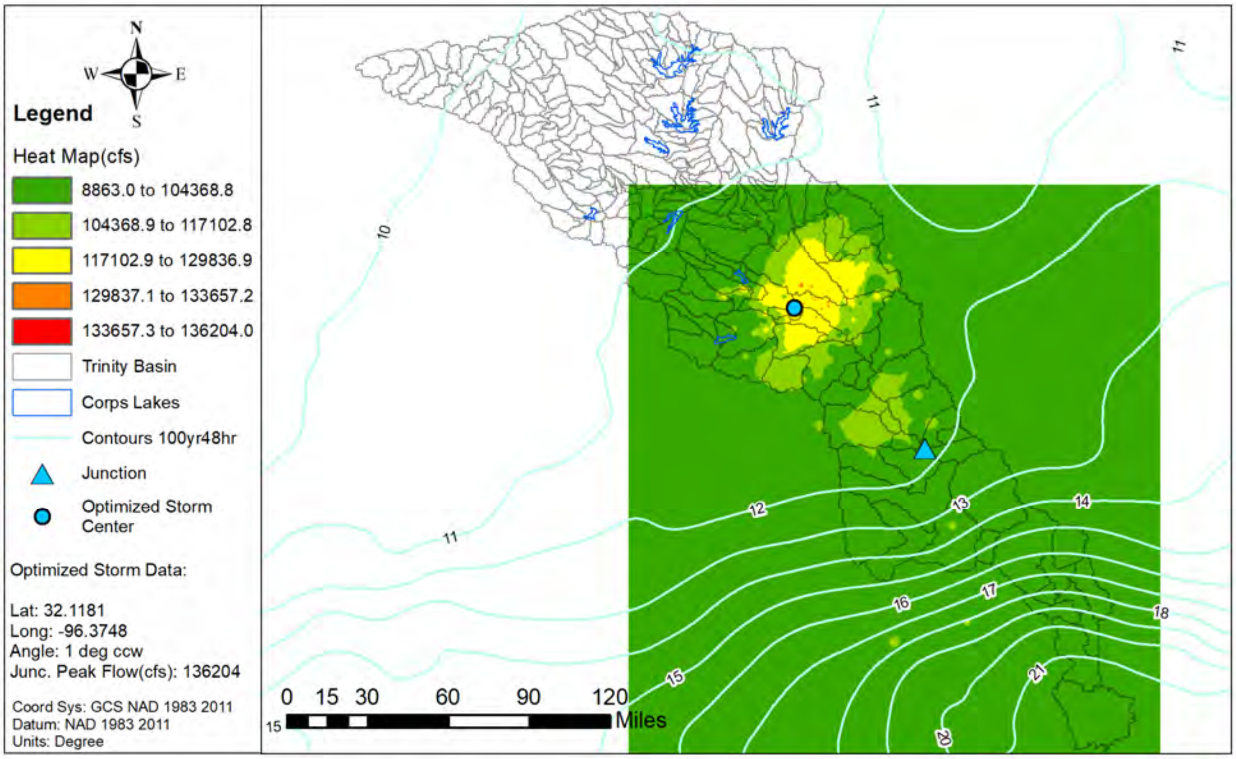


Figure 115a: Elliptical Storm Heat Map for the Trinity River below Big Elkhart Creek

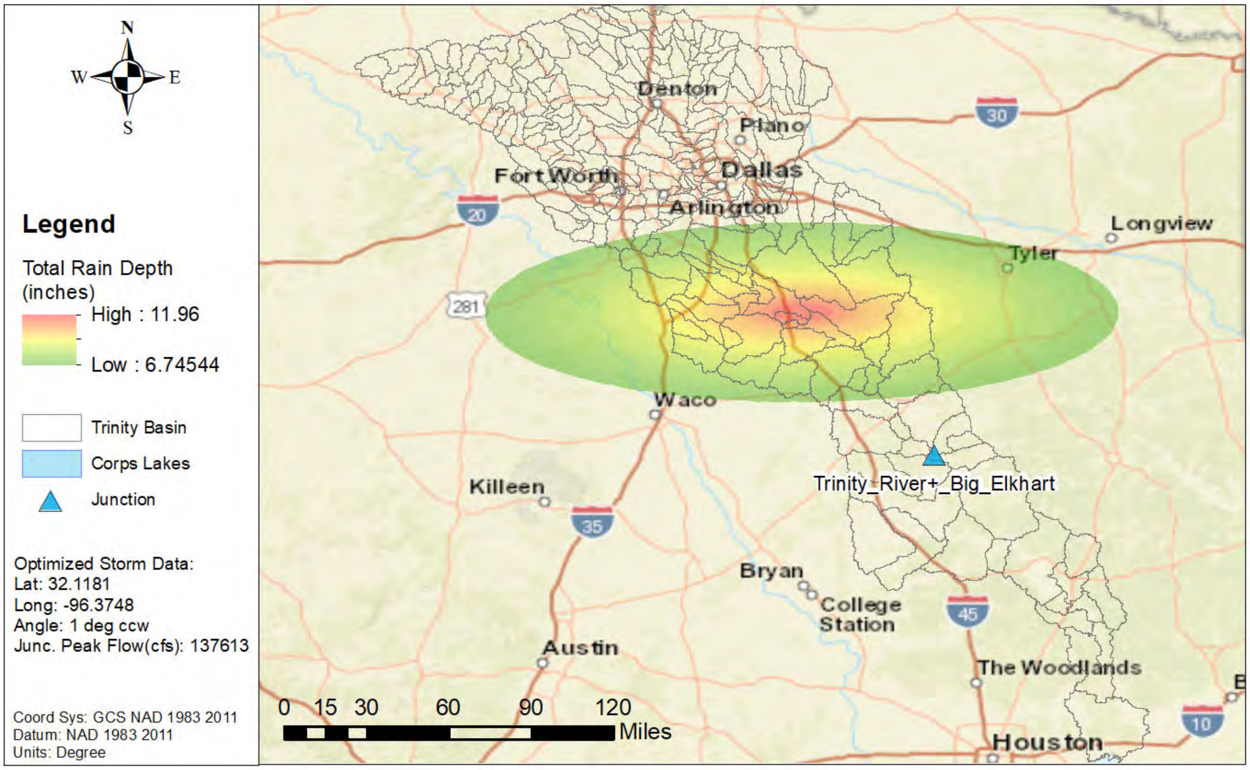


Figure 115b: NA14 1% AEP Elliptical Storm for the Trinity River below Big Elkhart Creek

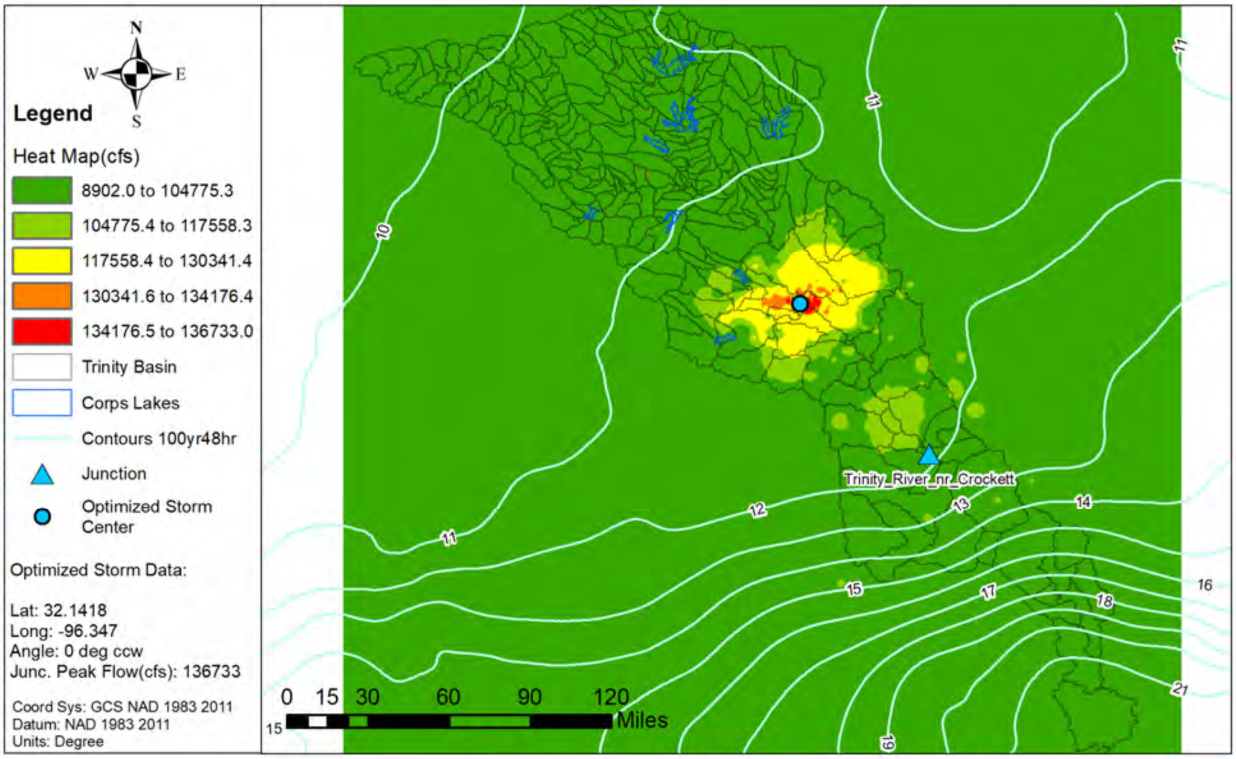


Figure 116a: Elliptical Storm Heat Map for the Trinity River near Crockett, TX USGS gage

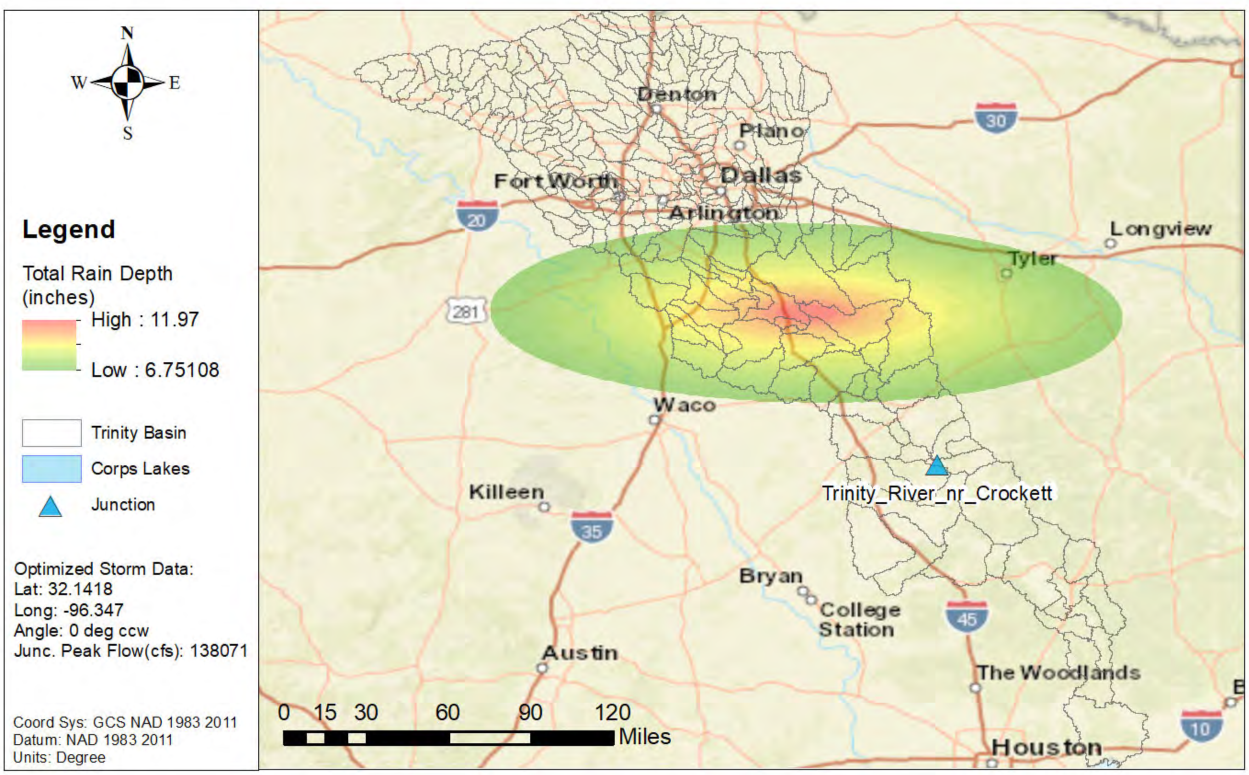


Figure 116b: NA14 1% AEP Elliptical Storm for the Trinity River near Crockett, TX USGS gage

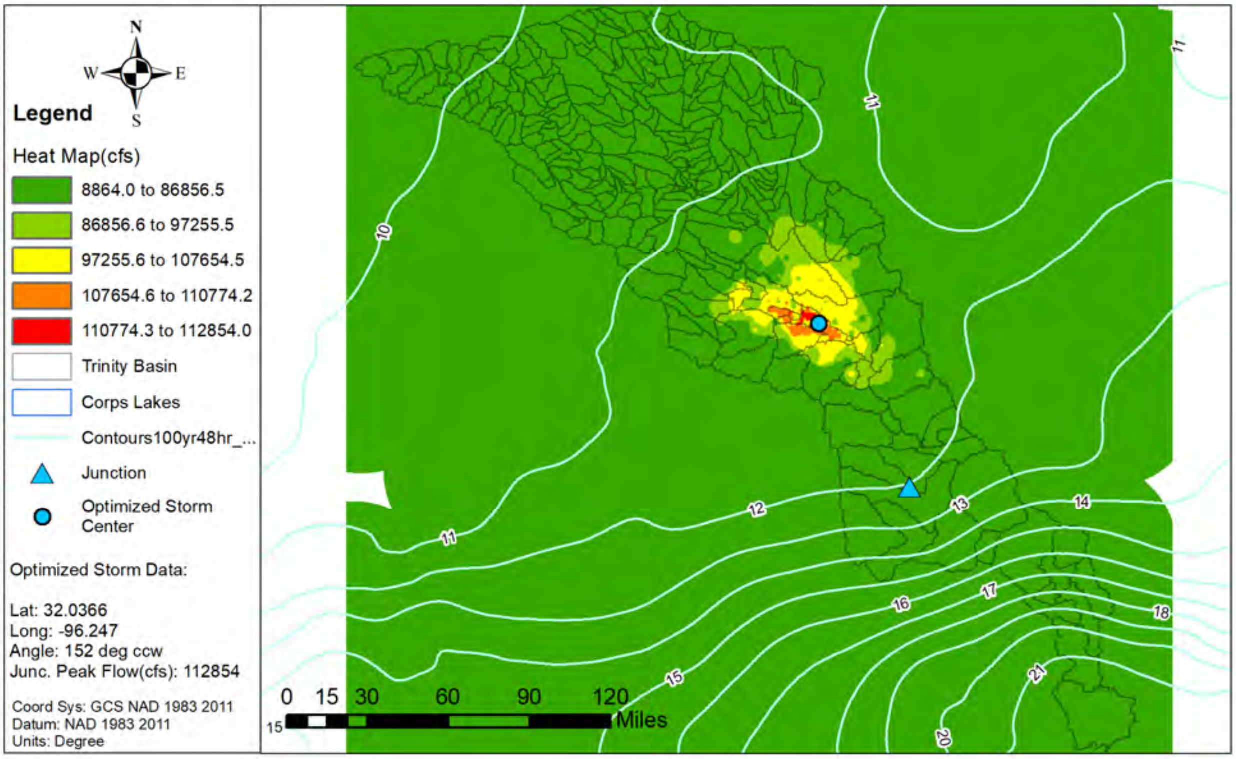


Figure 117a: Elliptical Storm Heat Map for the Trinity River above Lower Keechi Creek

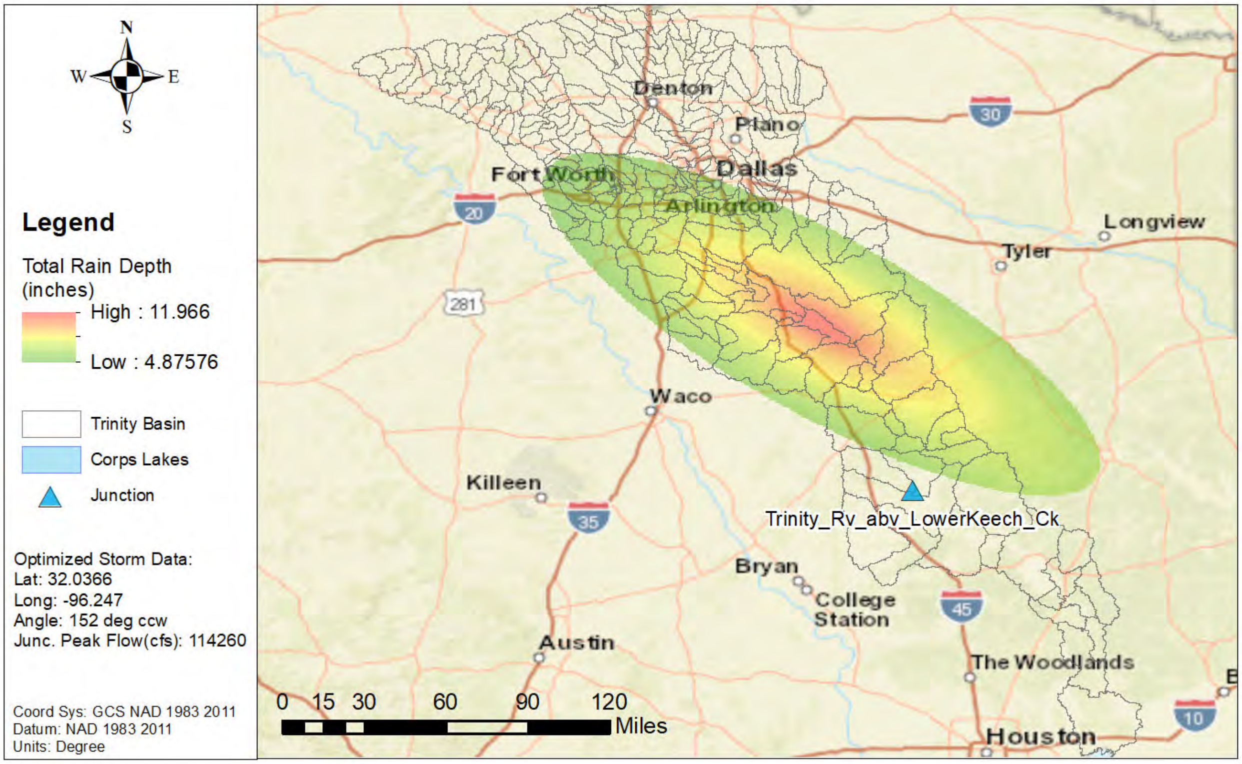


Figure 117b: NA14 1% AEP Elliptical Storm for the Trinity River above Lower Keechi Creek

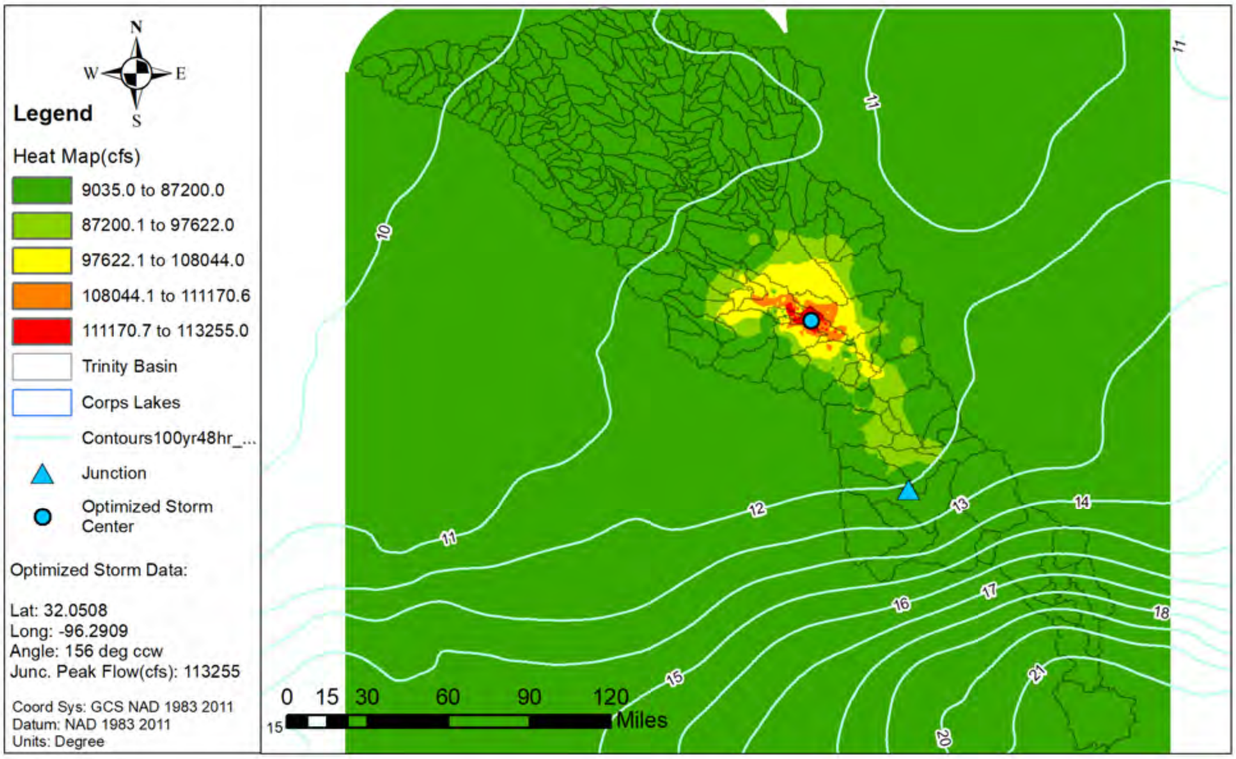


Figure 118a: Elliptical Storm Heat Map for the Trinity River below Lower Keechi Creek

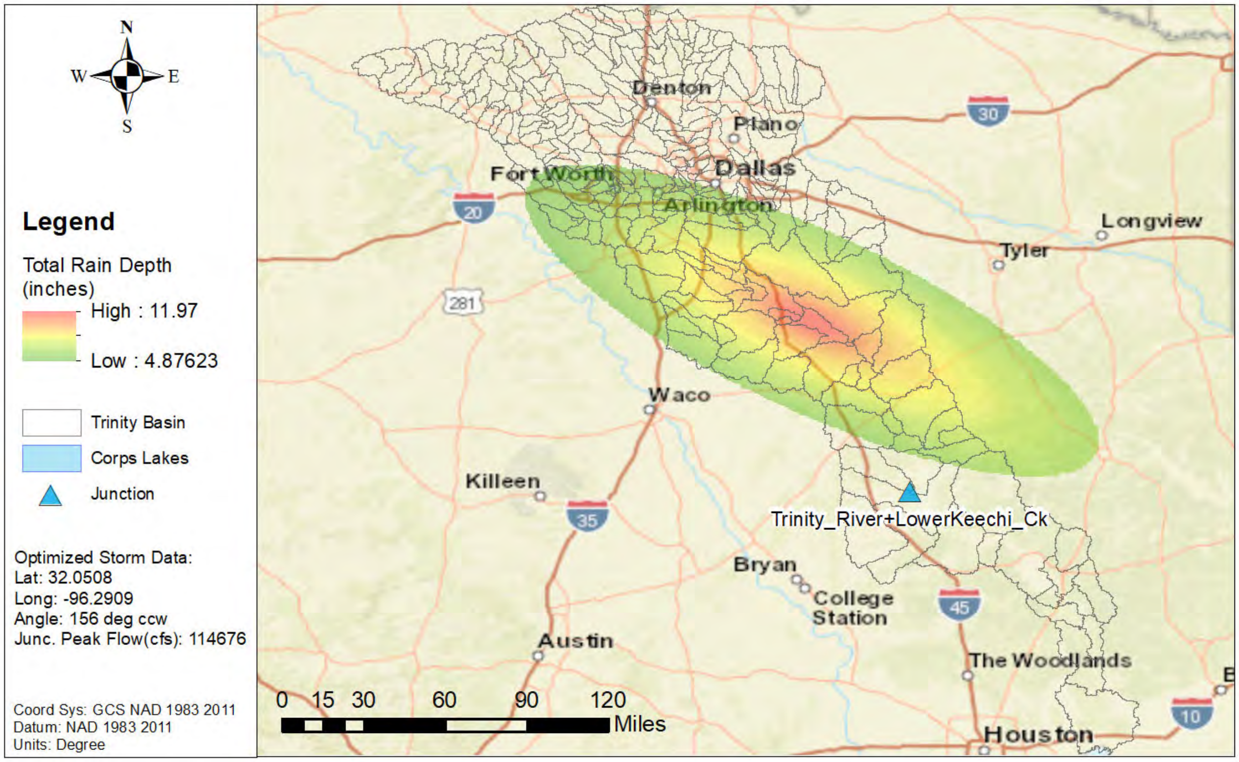


Figure 118b: NA14 1% AEP Elliptical Storm for the Trinity River below Lower Keechi Creek

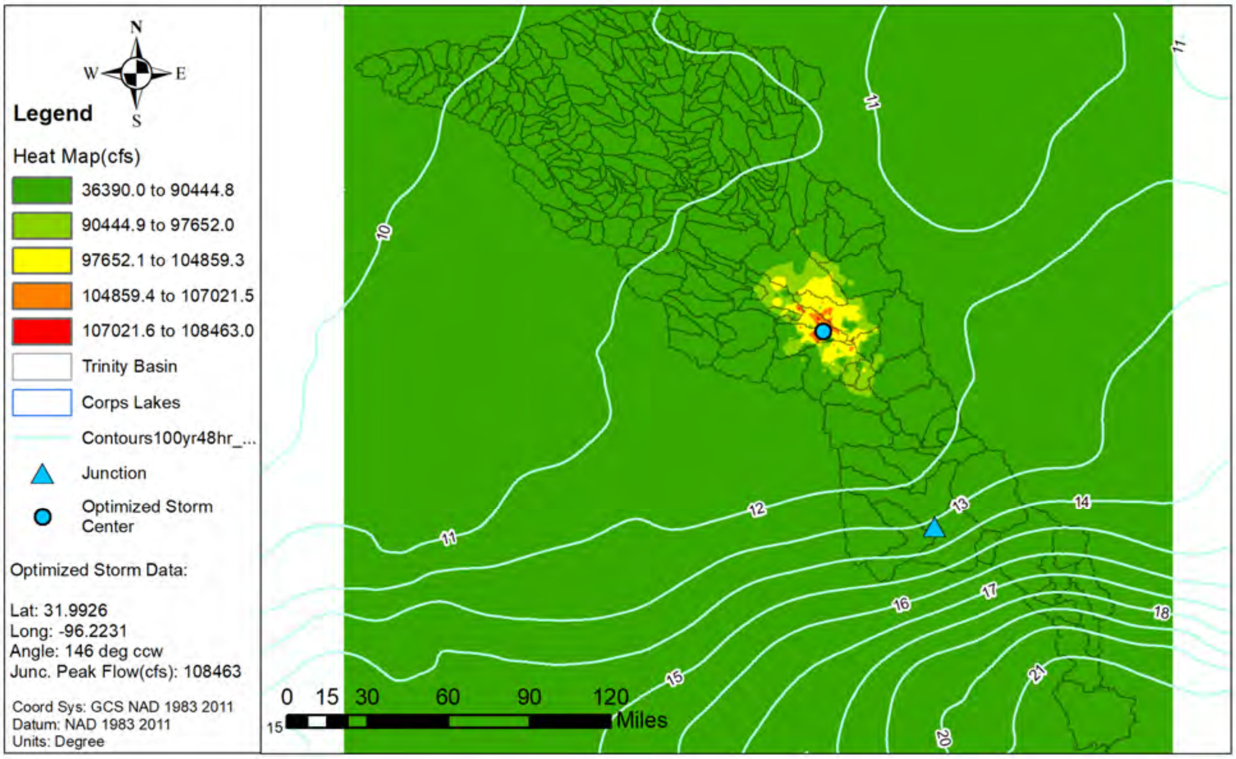


Figure 119a: Elliptical Storm Heat Map for the Trinity River above Bedias Creek

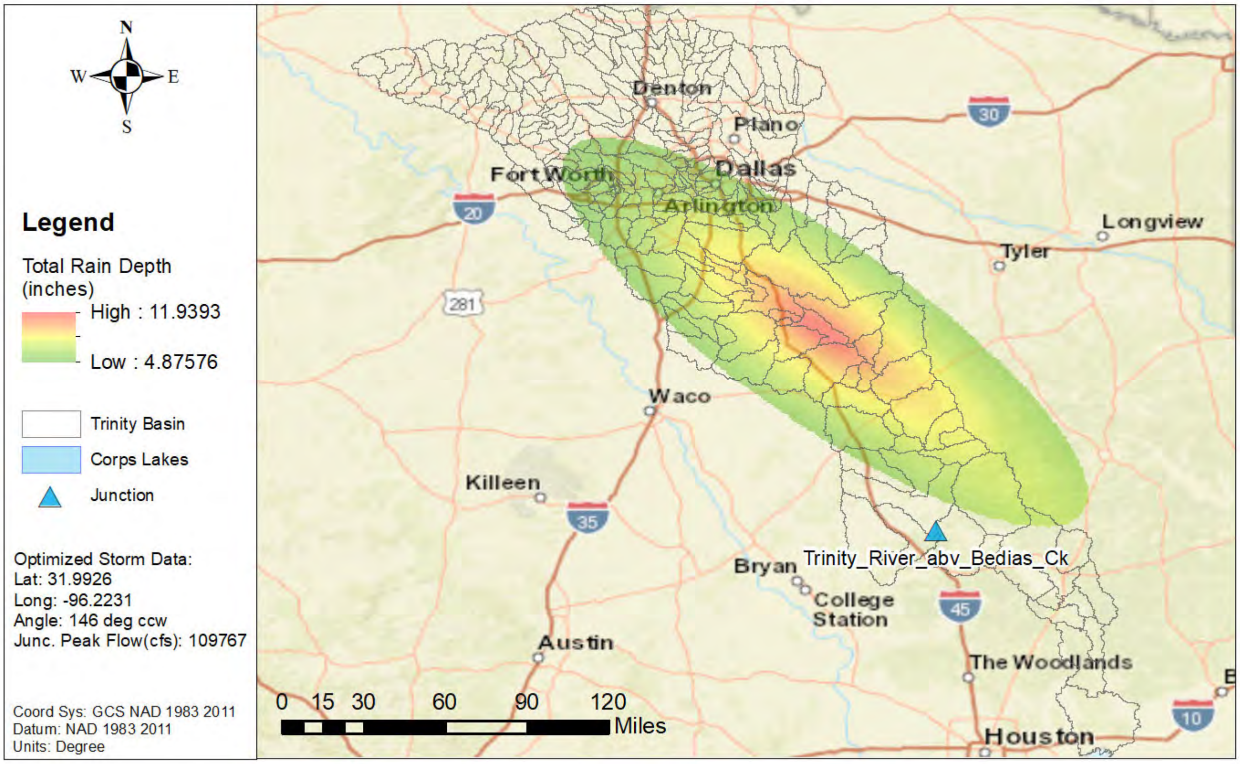


Figure 119b: NA14 1% AEP Elliptical Storm for the Trinity River above Bedias Creek

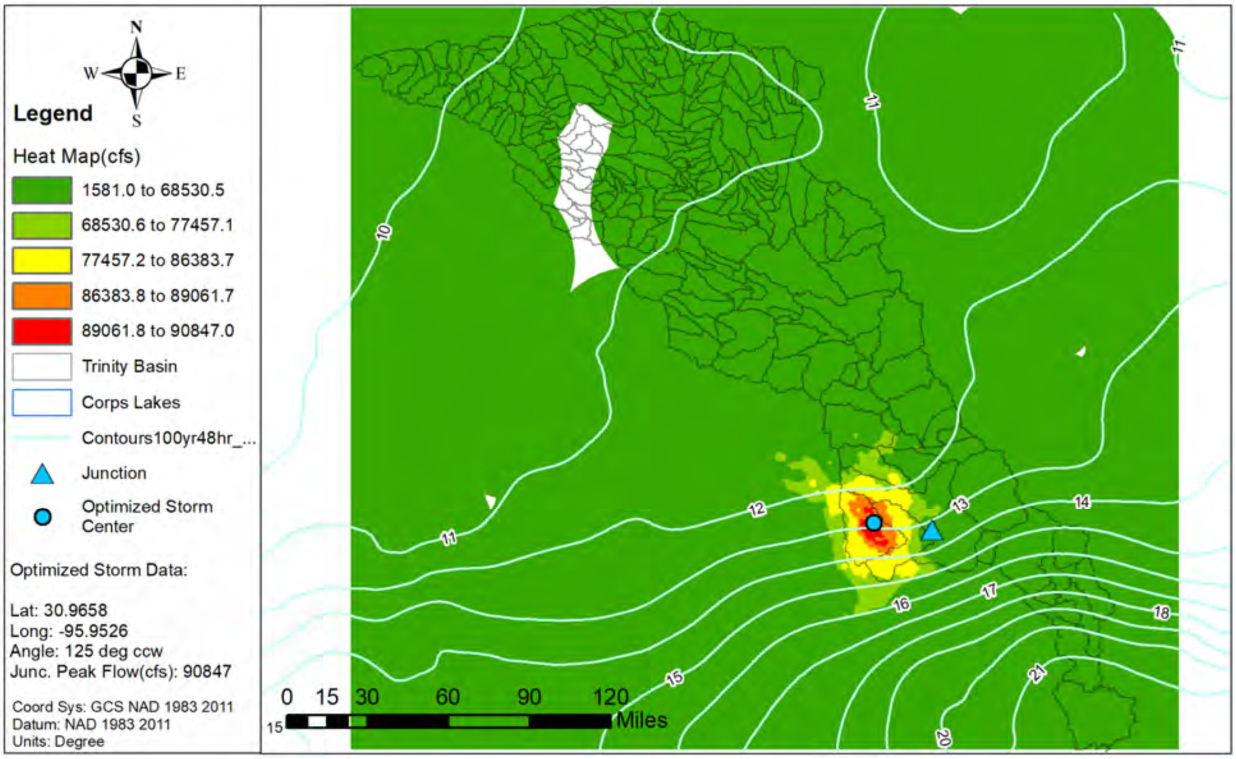


Figure 120a: Elliptical Storm Heat Map for the Bedias Creek above the Trinity River

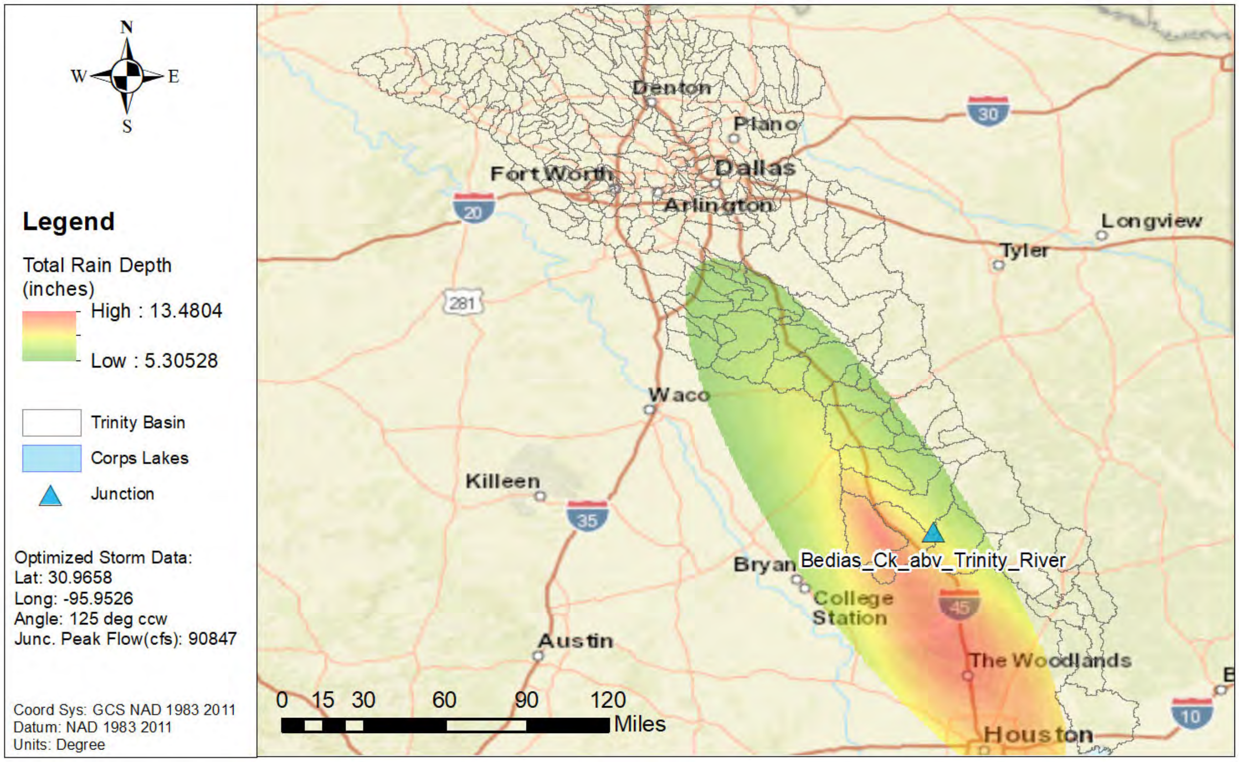


Figure 120b: NA14 1% AEP Elliptical Storm for the Bedias Creek above the Trinity River

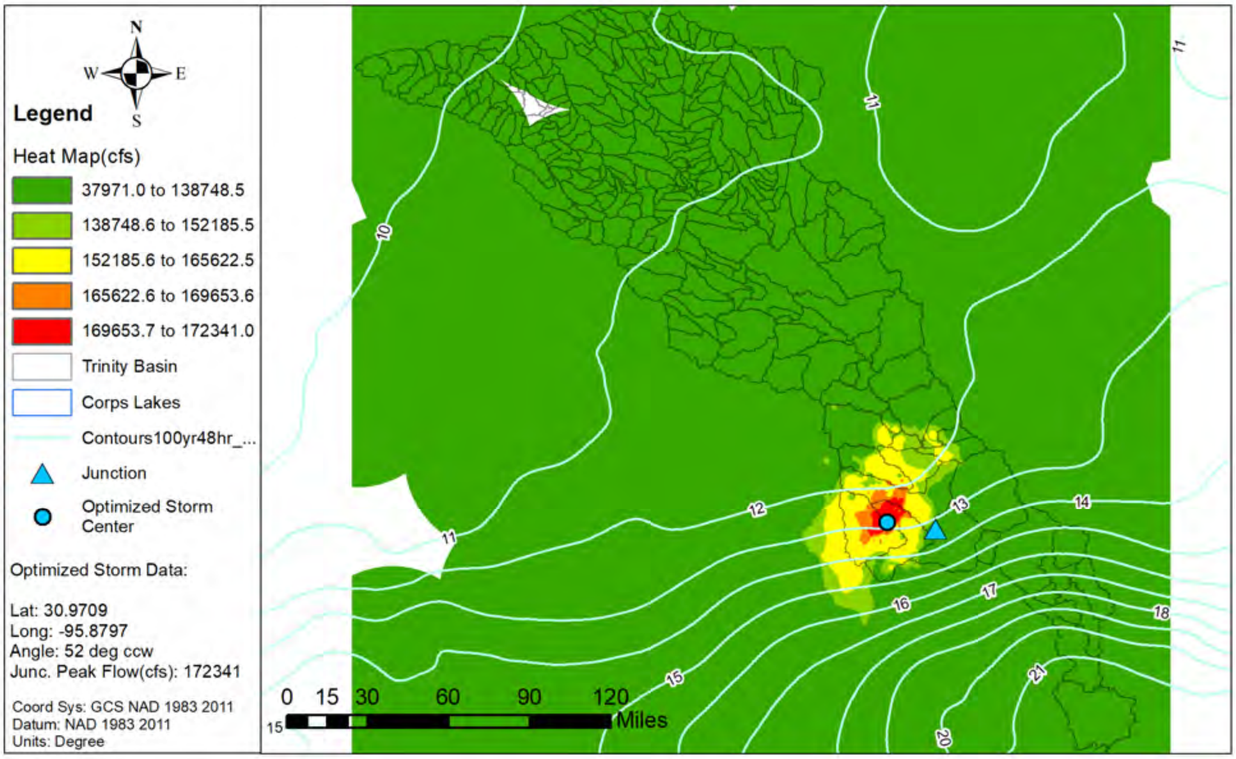


Figure 121a: Elliptical Storm Heat Map for the Trinity River below Bedias Creek

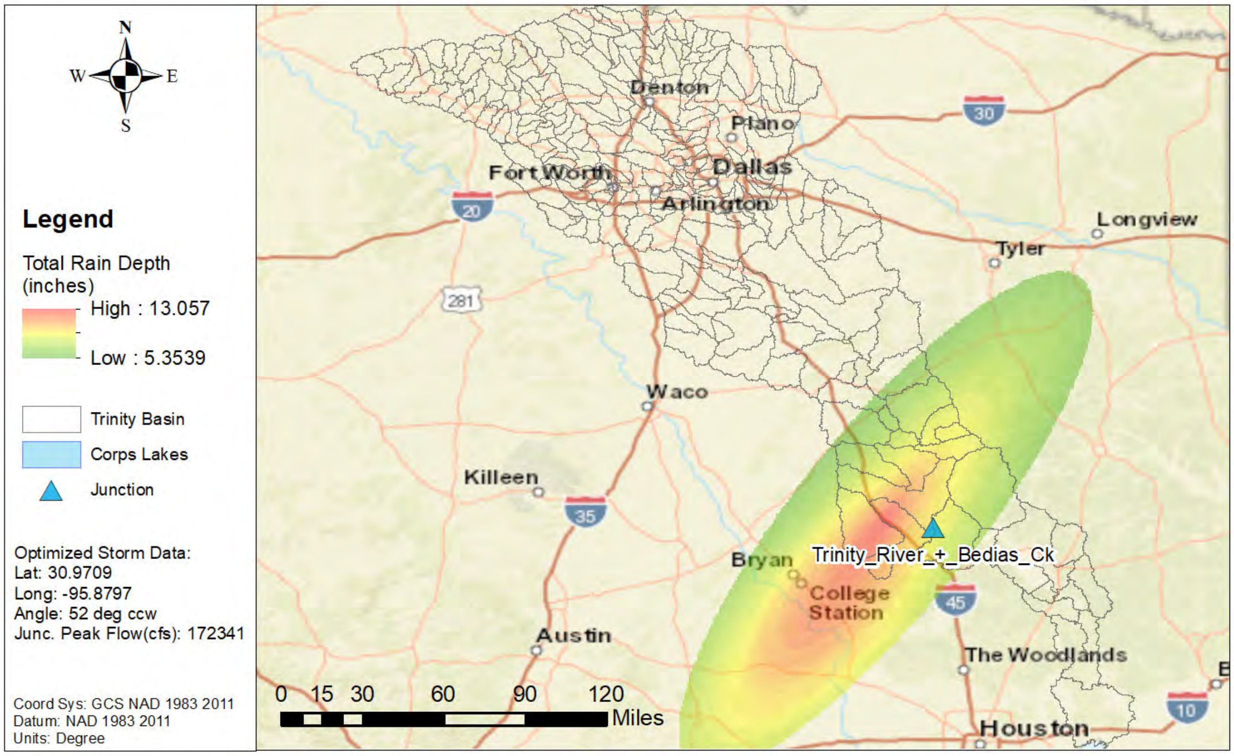


Figure 121b: NA14 1% AEP Elliptical Storm for the Trinity River below Bedias Creek

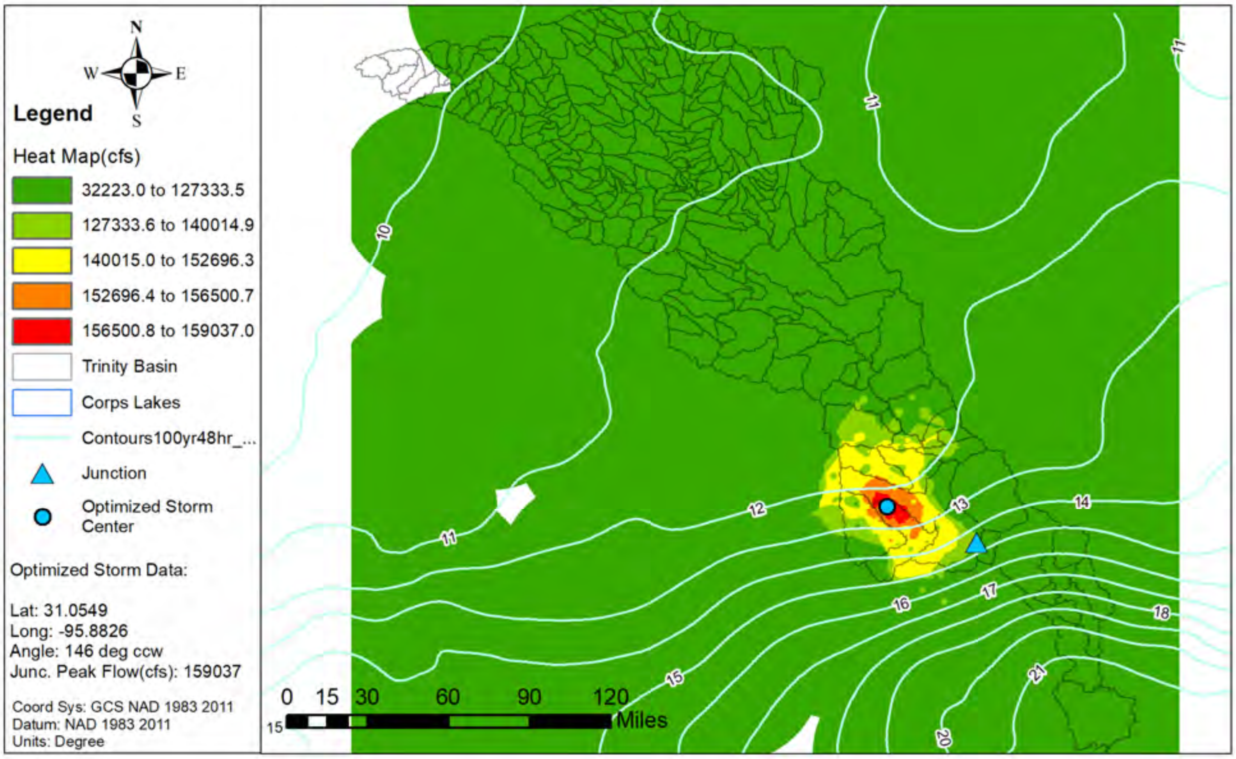


Figure 122a: Elliptical Storm Heat Map for the Trinity River at Riverside, TX USGS gage

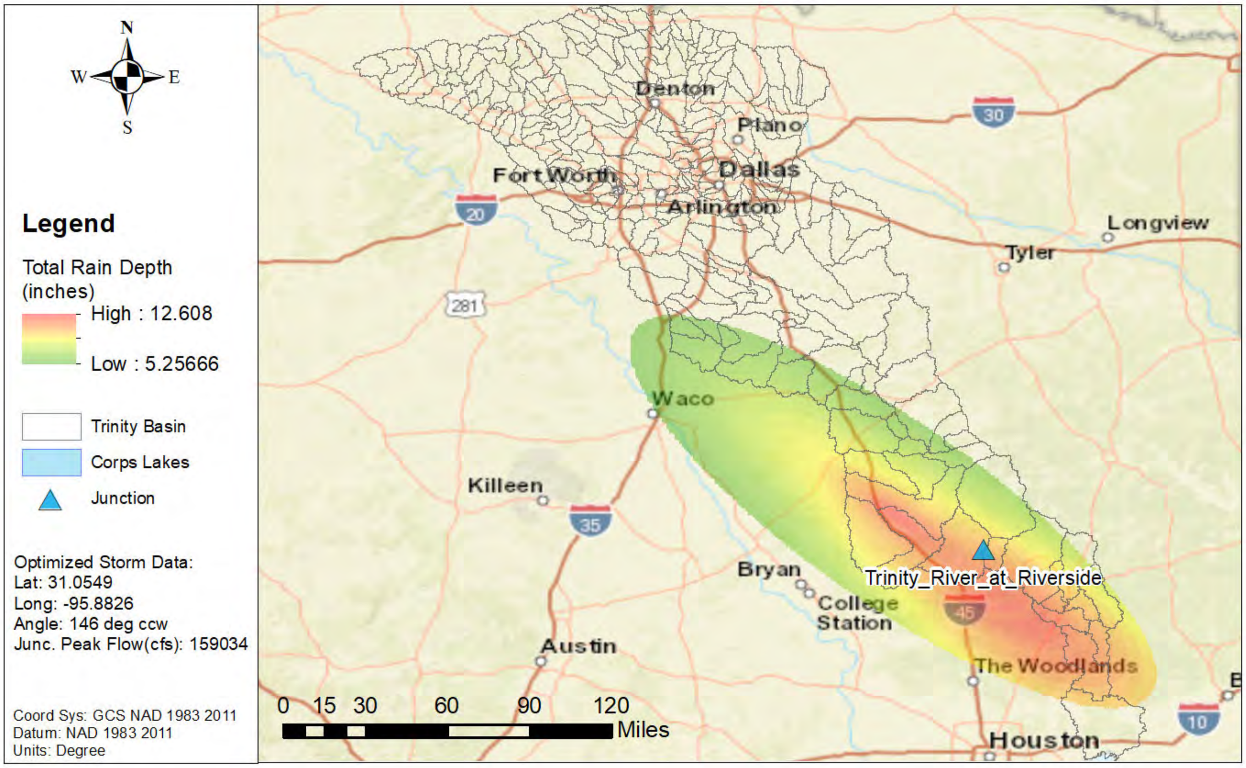


Figure 122b: NA14 1% AEP Elliptical Storm for the Trinity River at Riverside, TX USGS gage

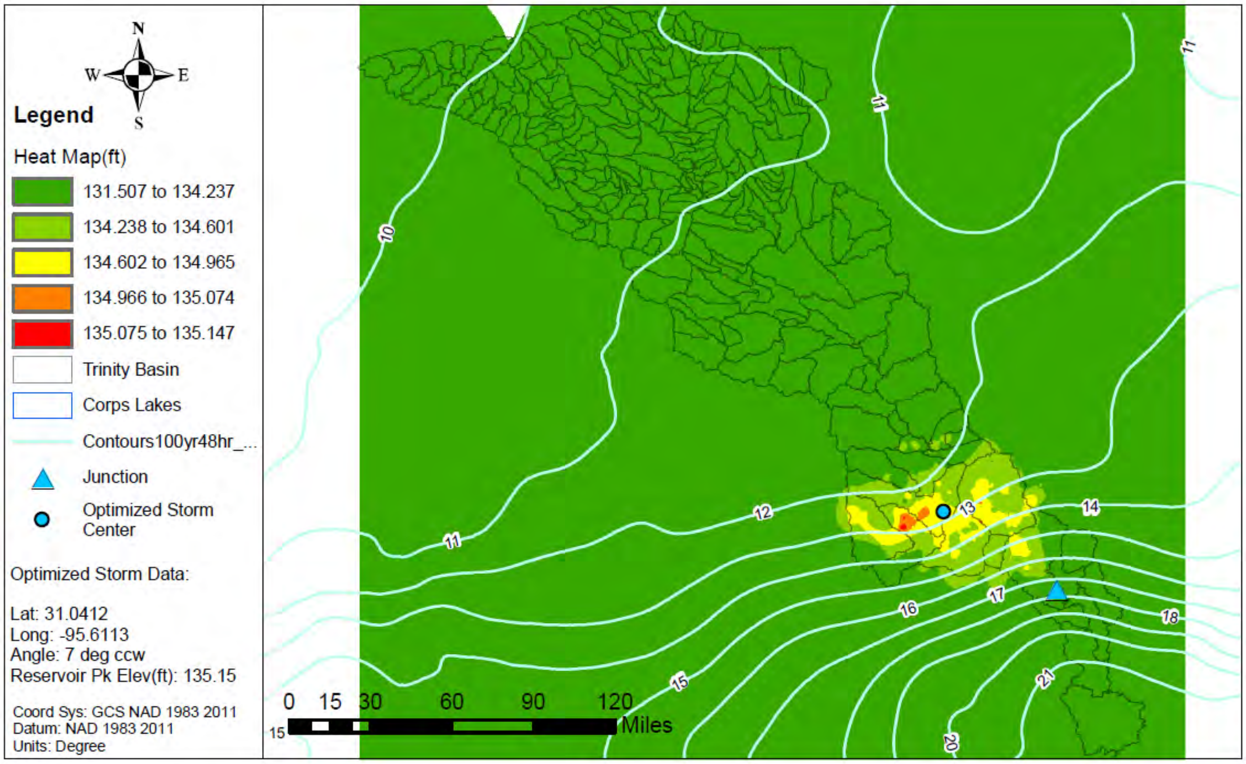


Figure 123a: Elliptical Storm Heat Map for the Lake Livingston

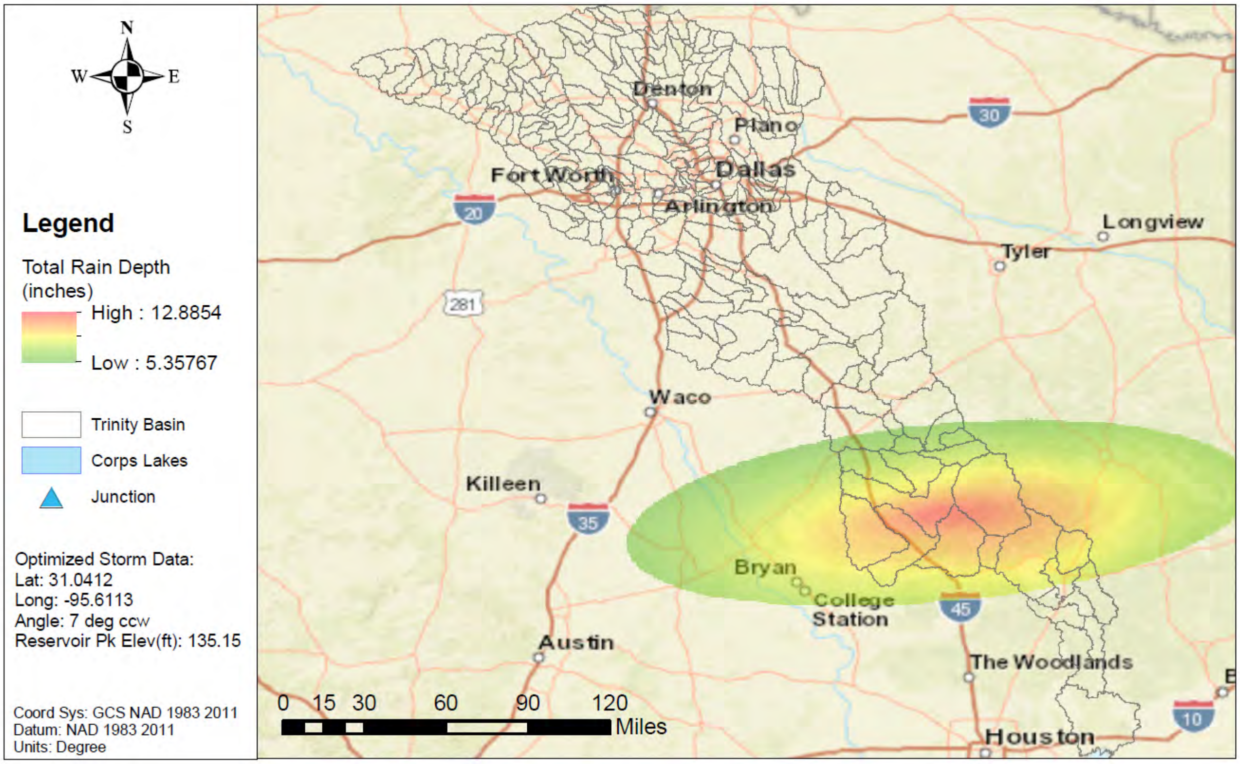


Figure 123b: NA14 1% AEP Elliptical Storm for the Lake Livingston

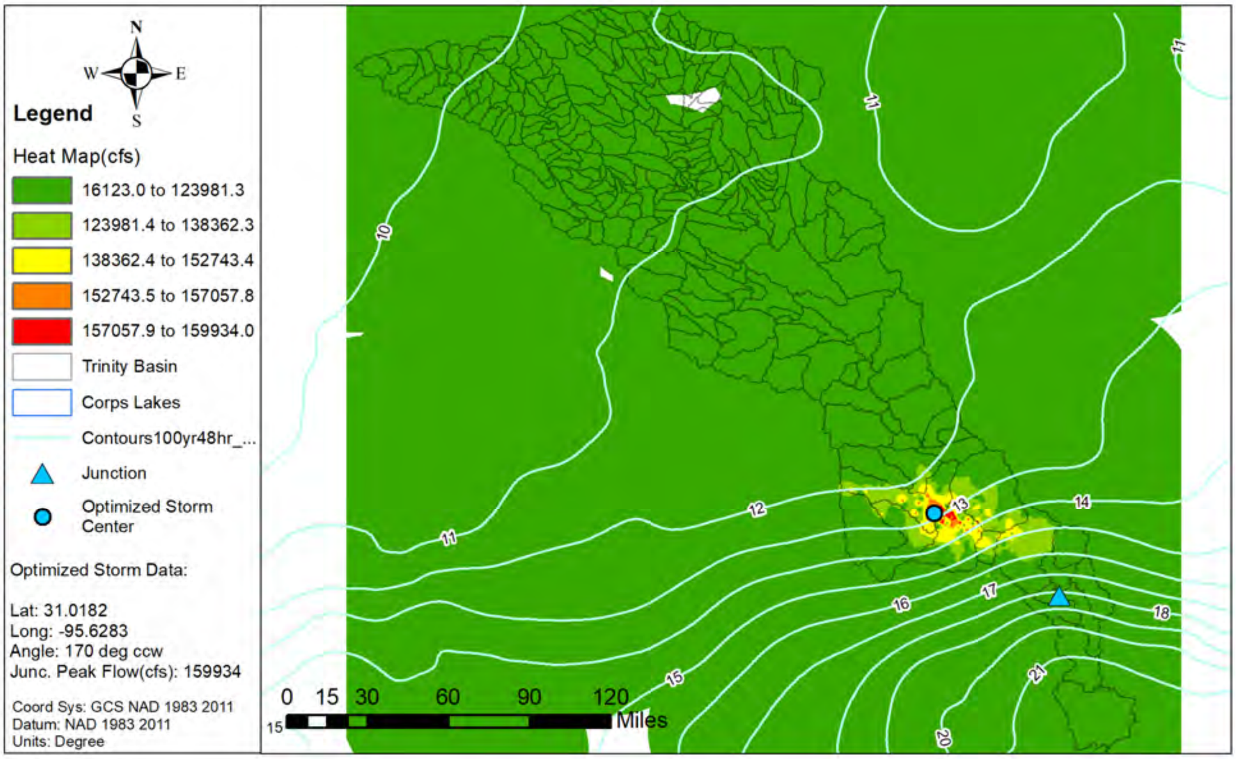


Figure 124a: Elliptical Storm Heat Map for the Trinity River above Long King Creek

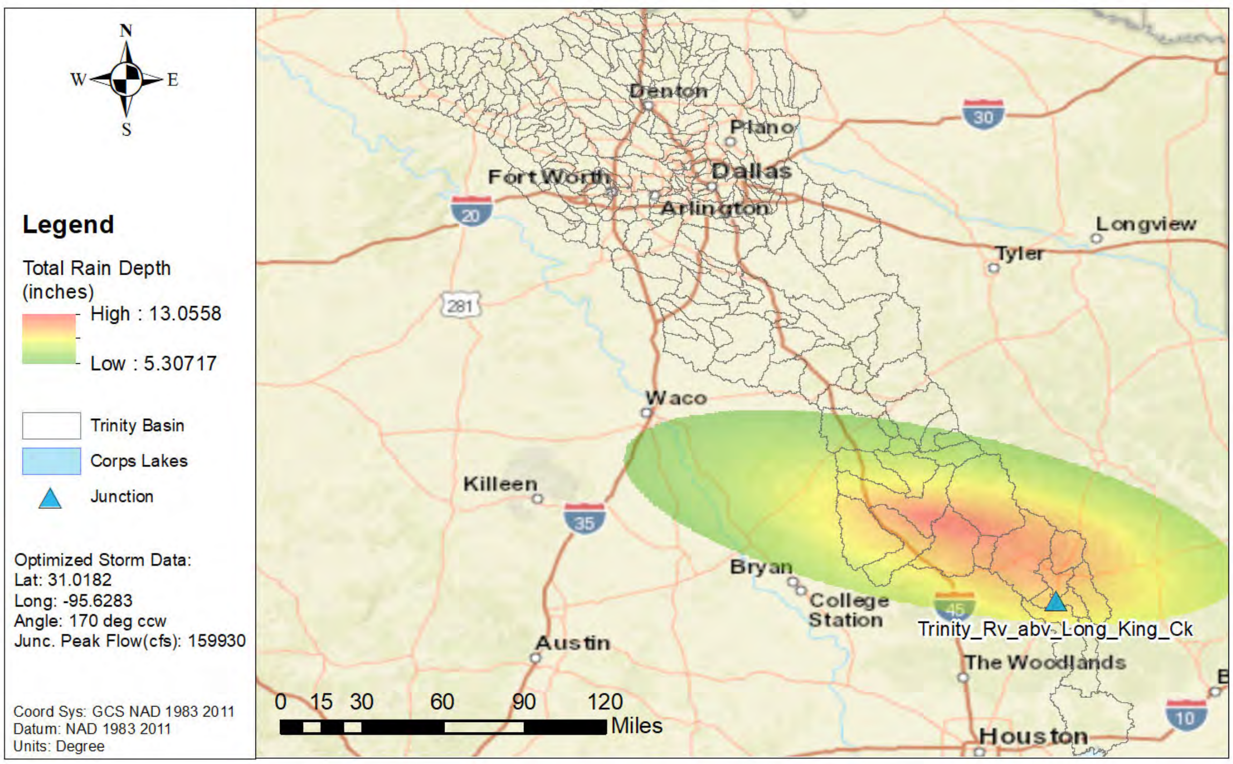


Figure 124b: NA14 1% AEP Elliptical Storm for the Trinity River above Long King Creek

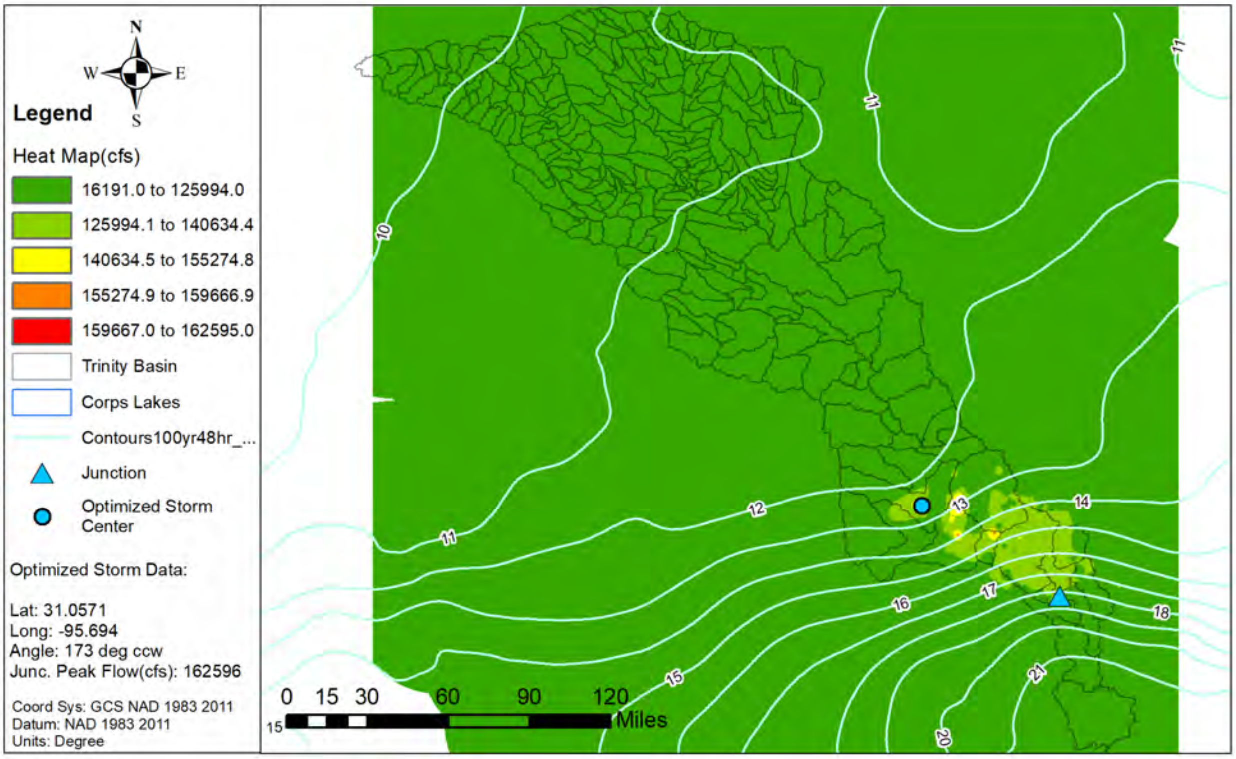


Figure 125a: Elliptical Storm Heat Map for the Trinity River at Goodrich, TX USGS gage

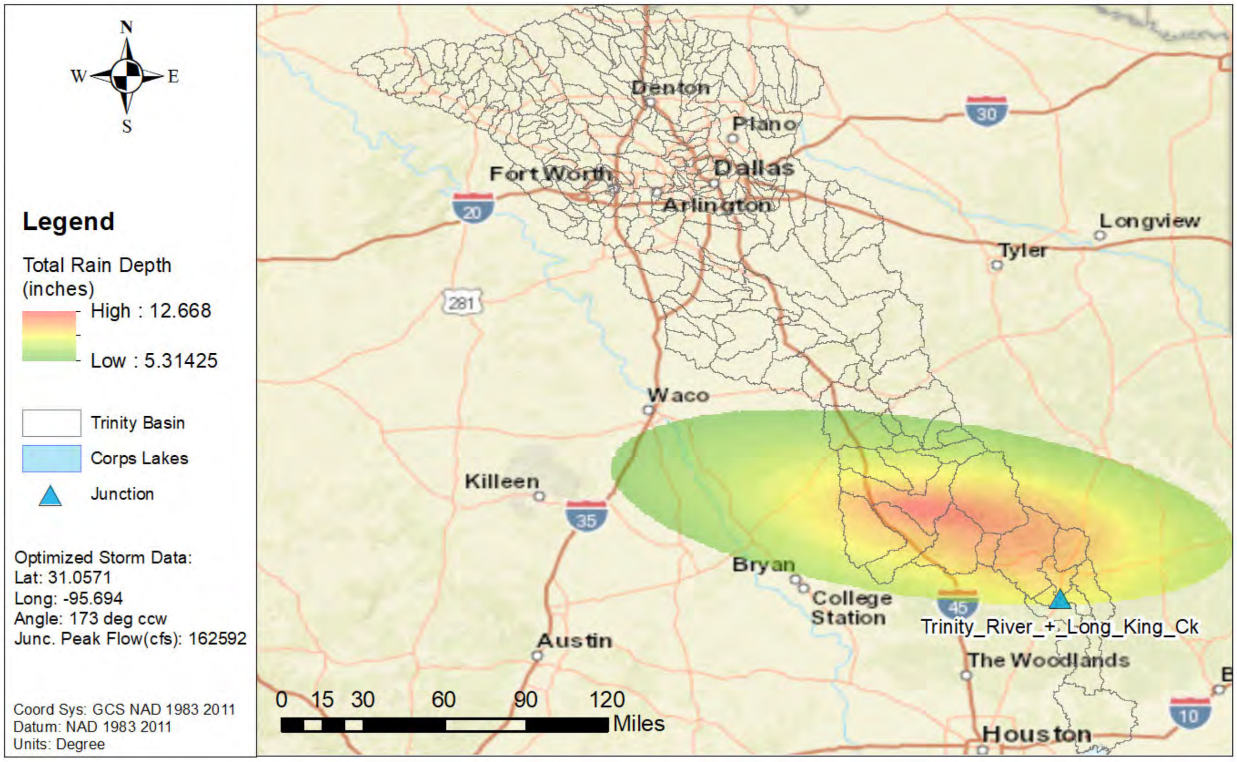


Figure 125b: NA14 1% AEP Elliptical Storm for the Trinity River at Goodrich, TX USGS gage

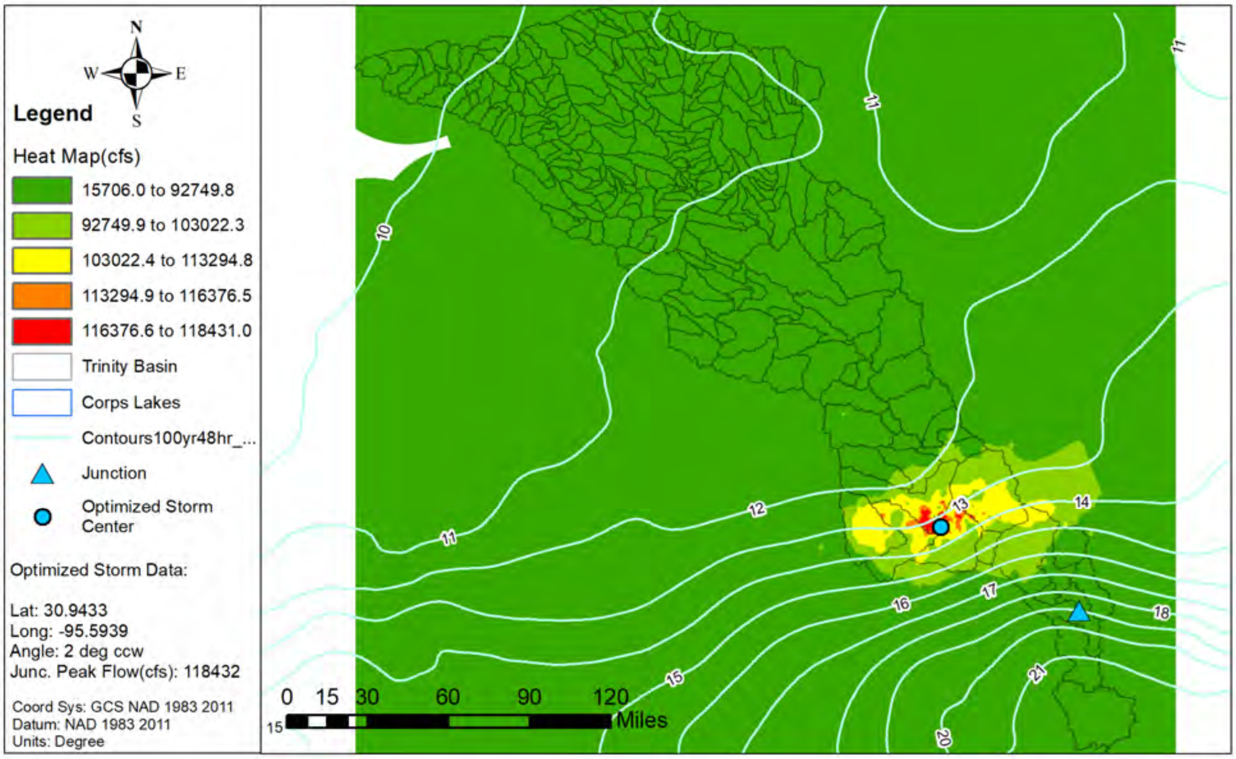


Figure 126a: Elliptical Storm Heat Map for the Trinity River above Menard Creek

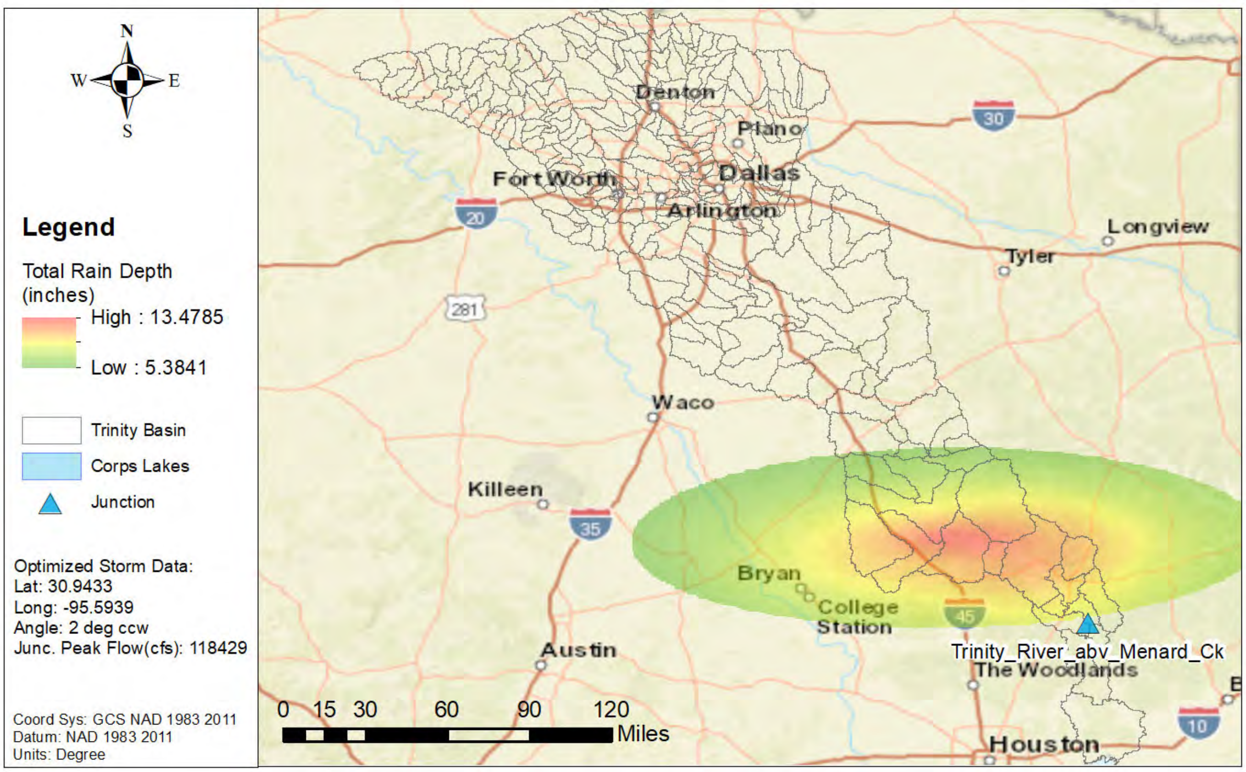


Figure 126b: NA14 1% AEP Elliptical Storm for the Trinity River above Menard Creek

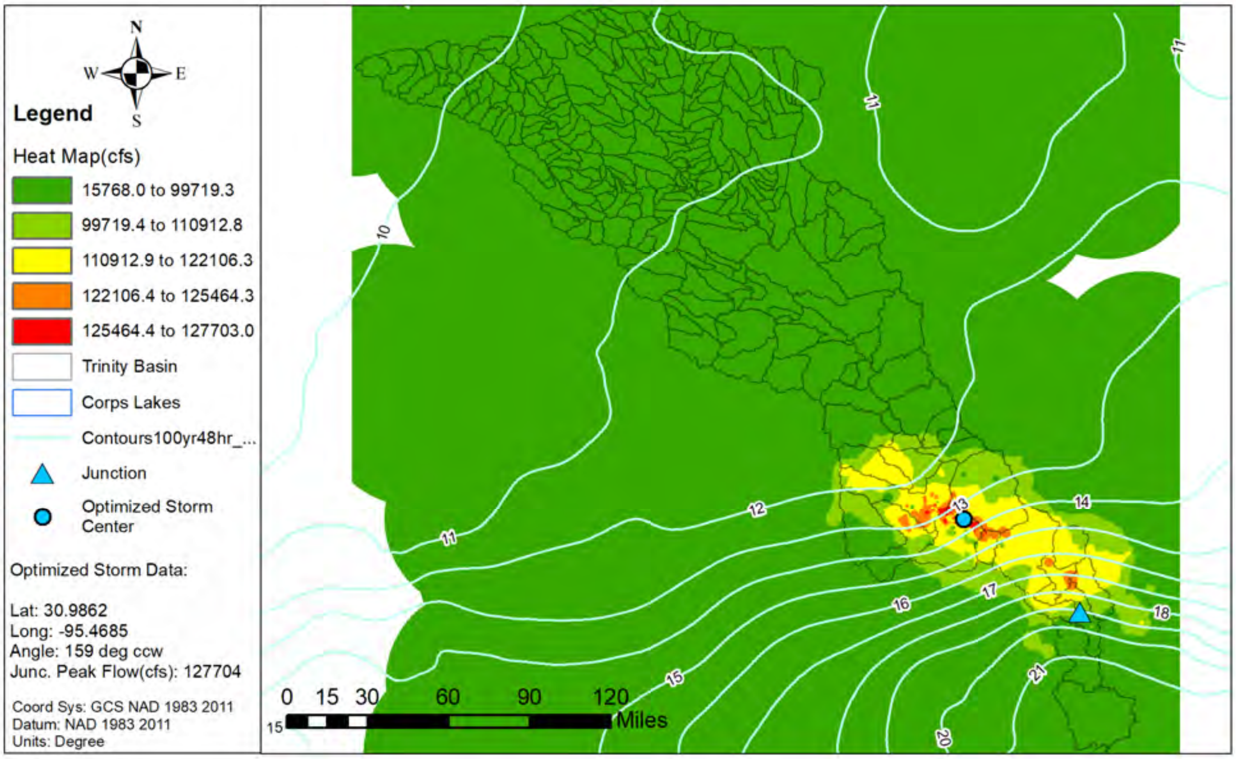


Figure 127a: Elliptical Storm Heat Map for the Trinity River below Menard Creek

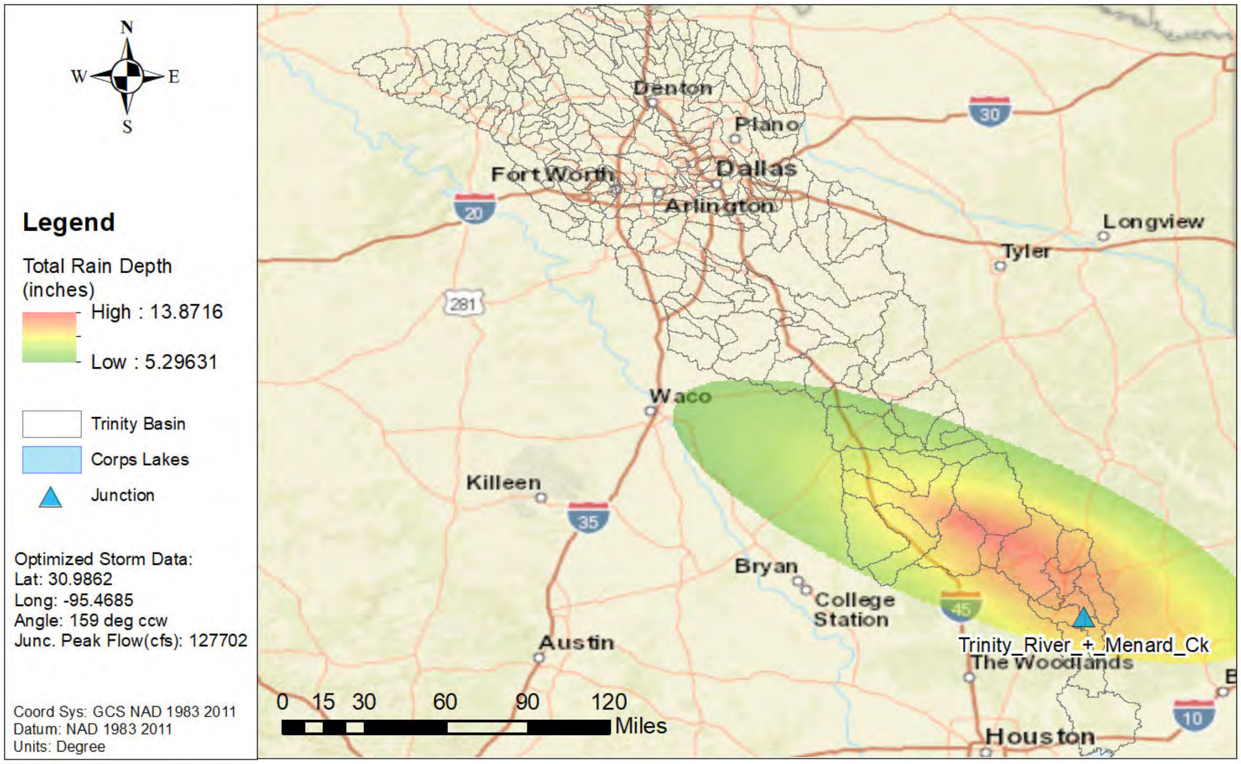


Figure 127b: NA14 1% AEP Elliptical Storm for the Trinity River below Menard Creek

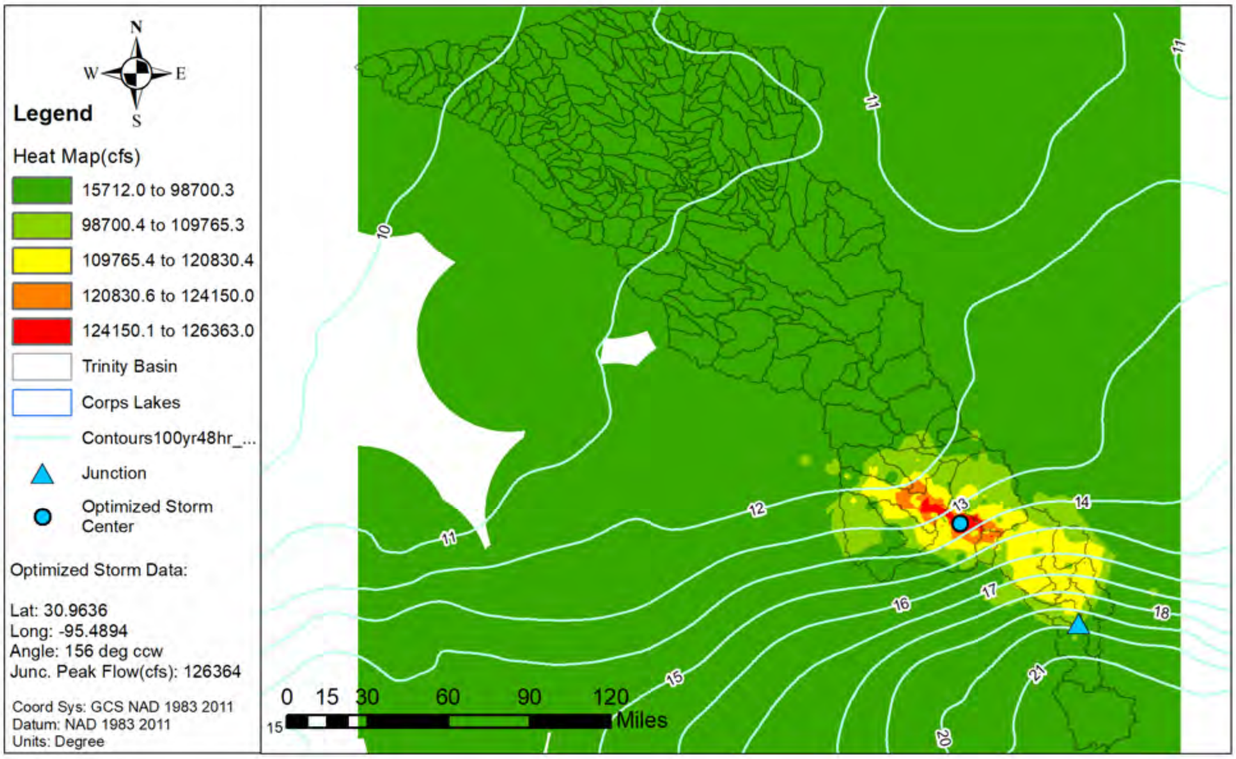


Figure 128a: Elliptical Storm Heat Map for the Trinity River at Romayor, TX USGS gage

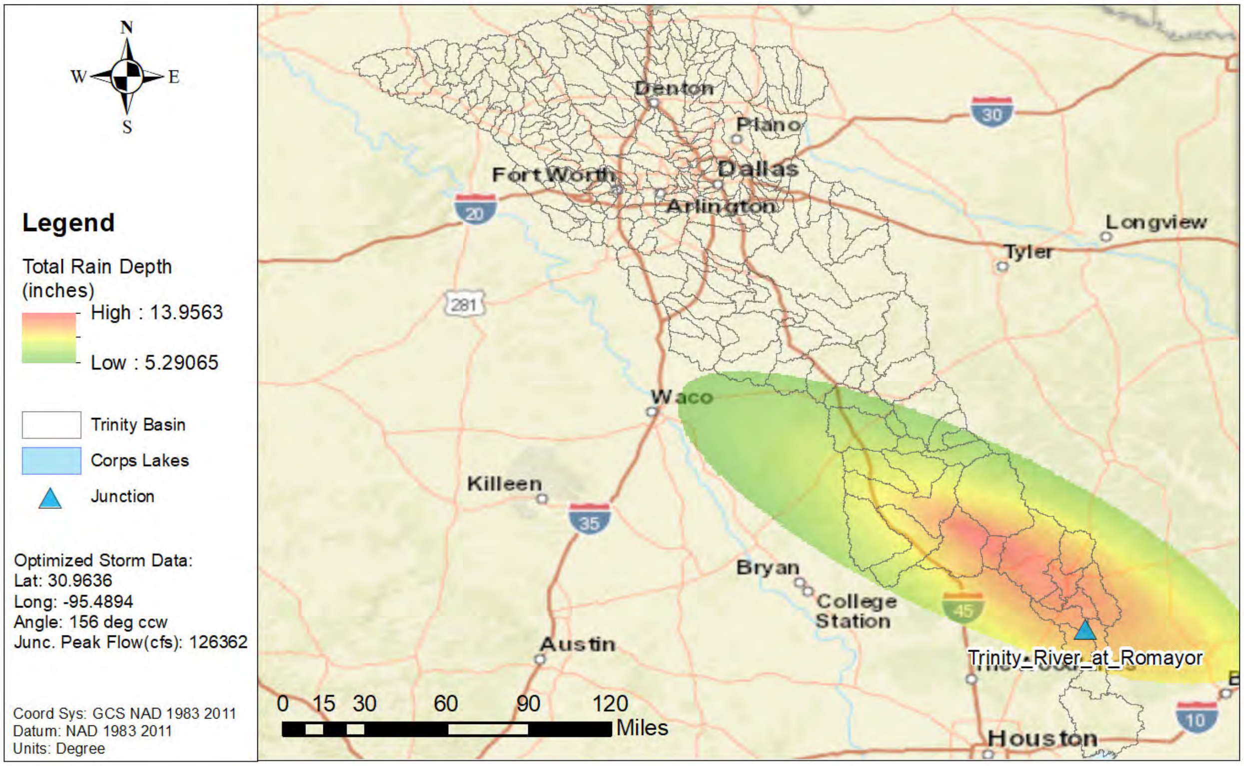


Figure 128b: NA14 1% AEP Elliptical Storm for the Trinity River at Romayor, TX USGS gage

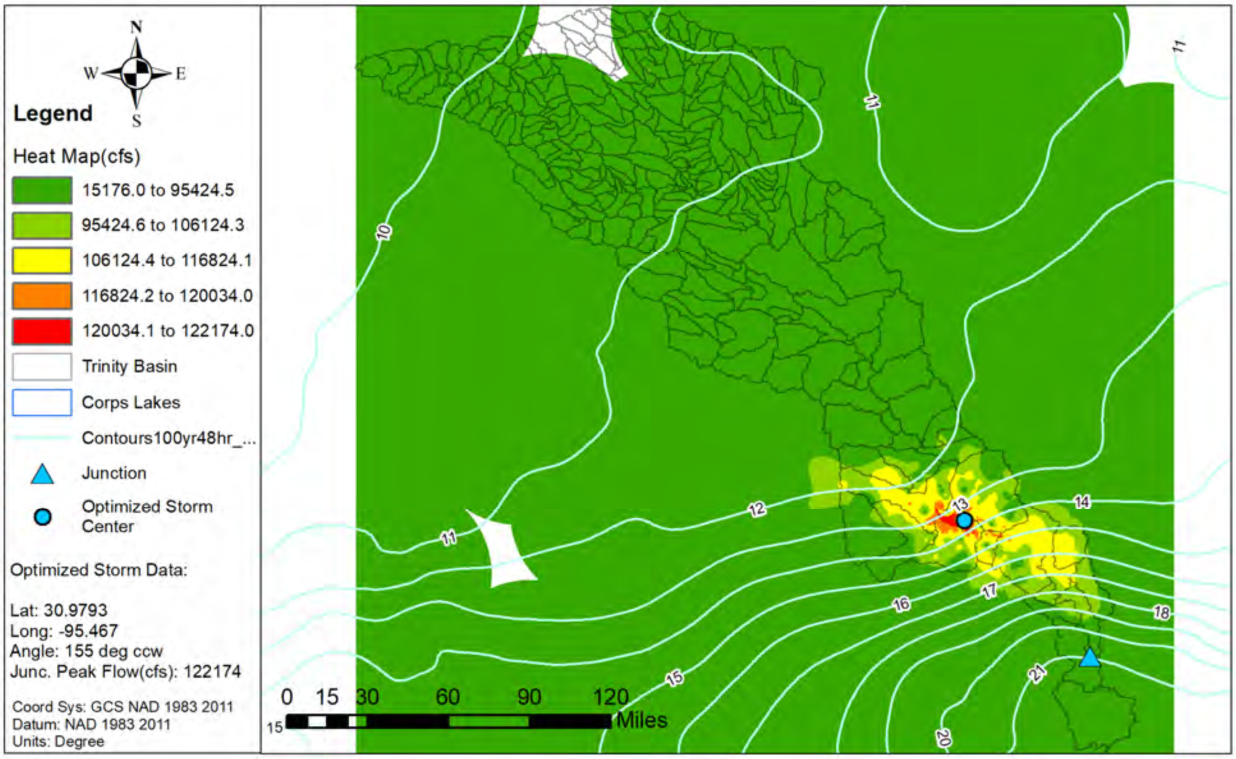


Figure 129a: Elliptical Storm Heat Map for the Trinity River near Moss Hill, TX

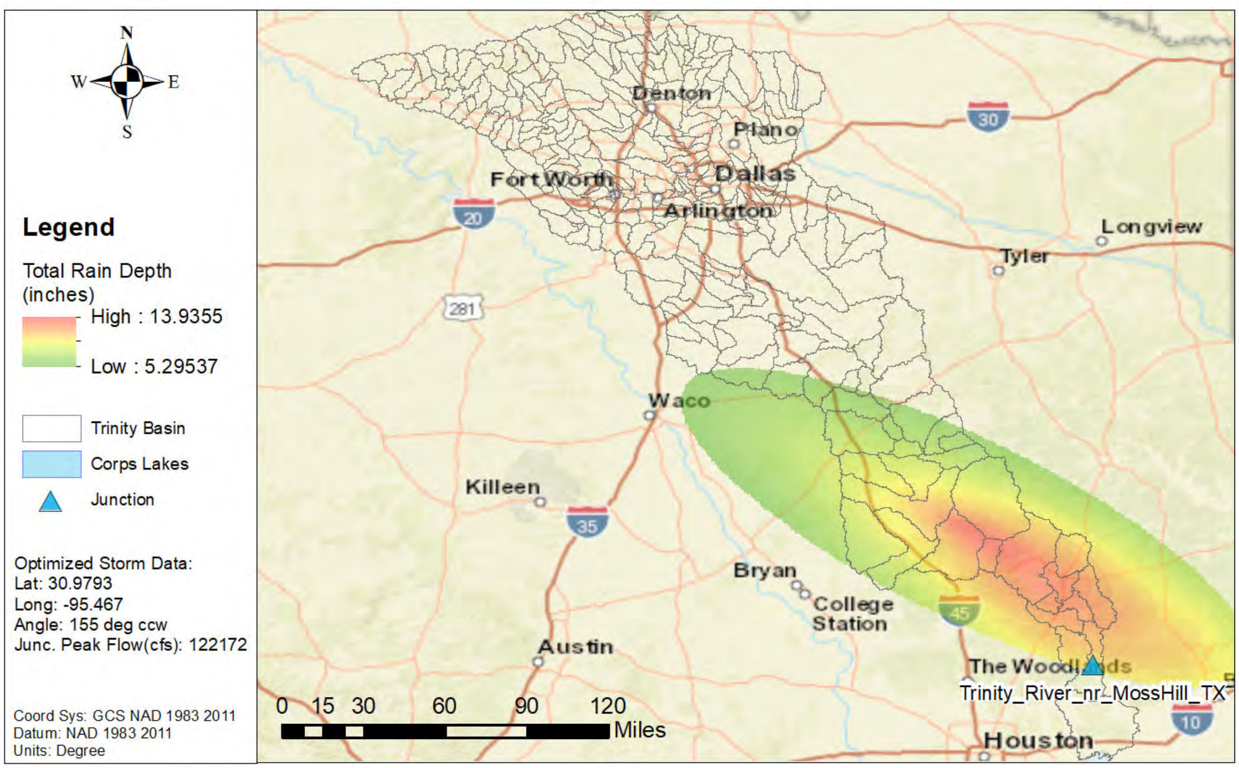


Figure 129b: NA14 1% AEP Elliptical Storm for the Trinity River near Moss Hill, TX

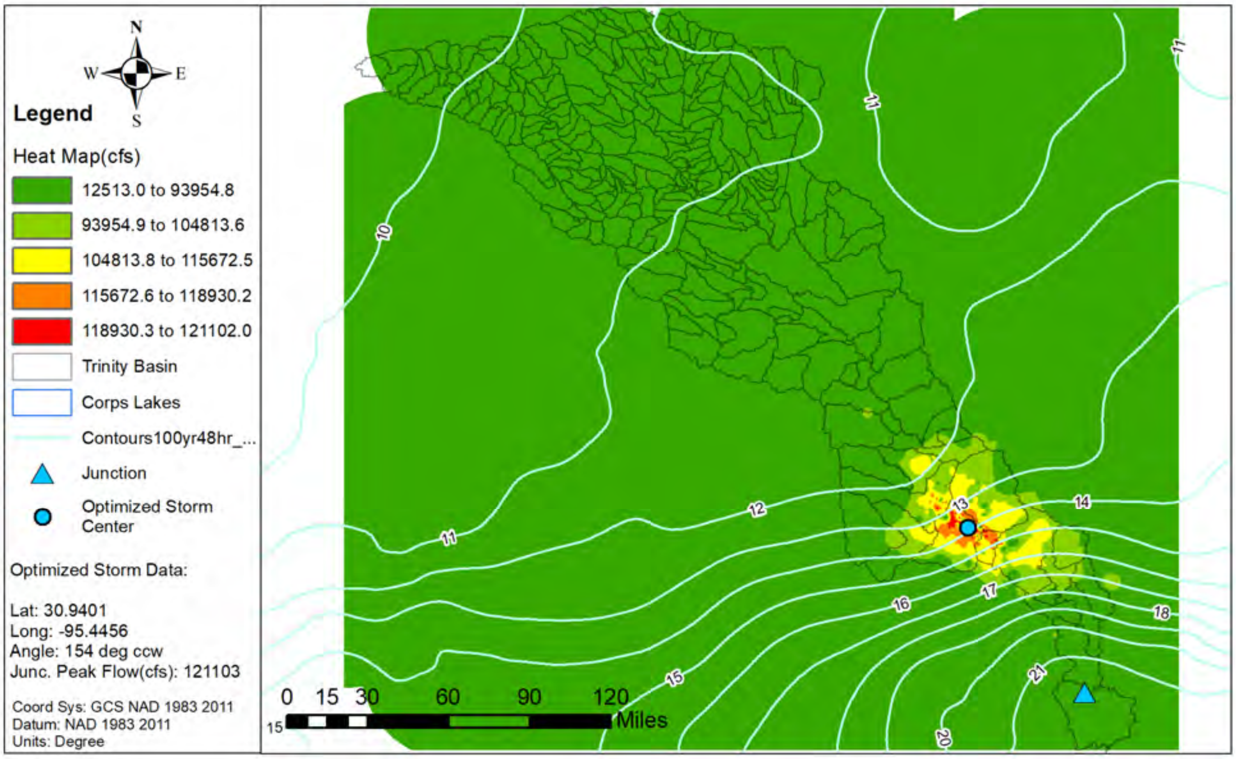


Figure 130a: Elliptical Storm Heat Map for the Trinity River at Liberty, TX USGS gage

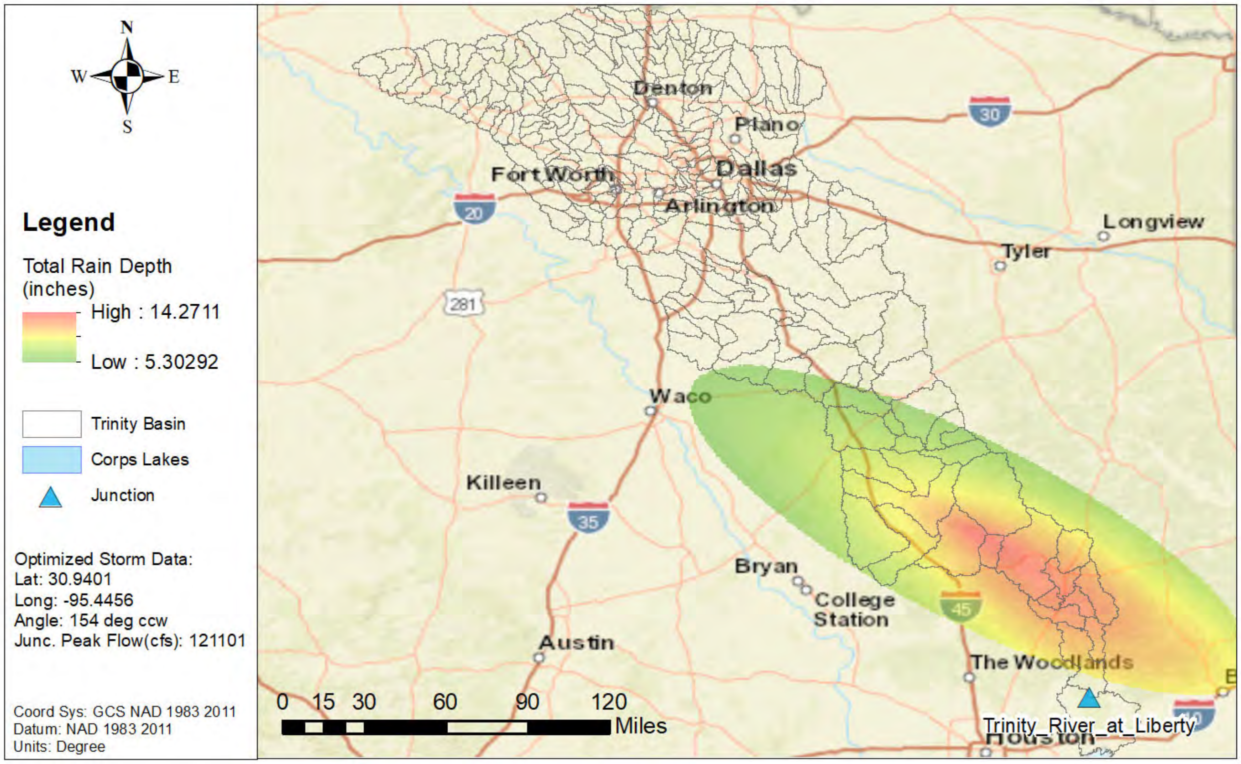


Figure 130b: NA14 1% AEP Elliptical Storm for the Trinity River at Liberty, TX USGS gage

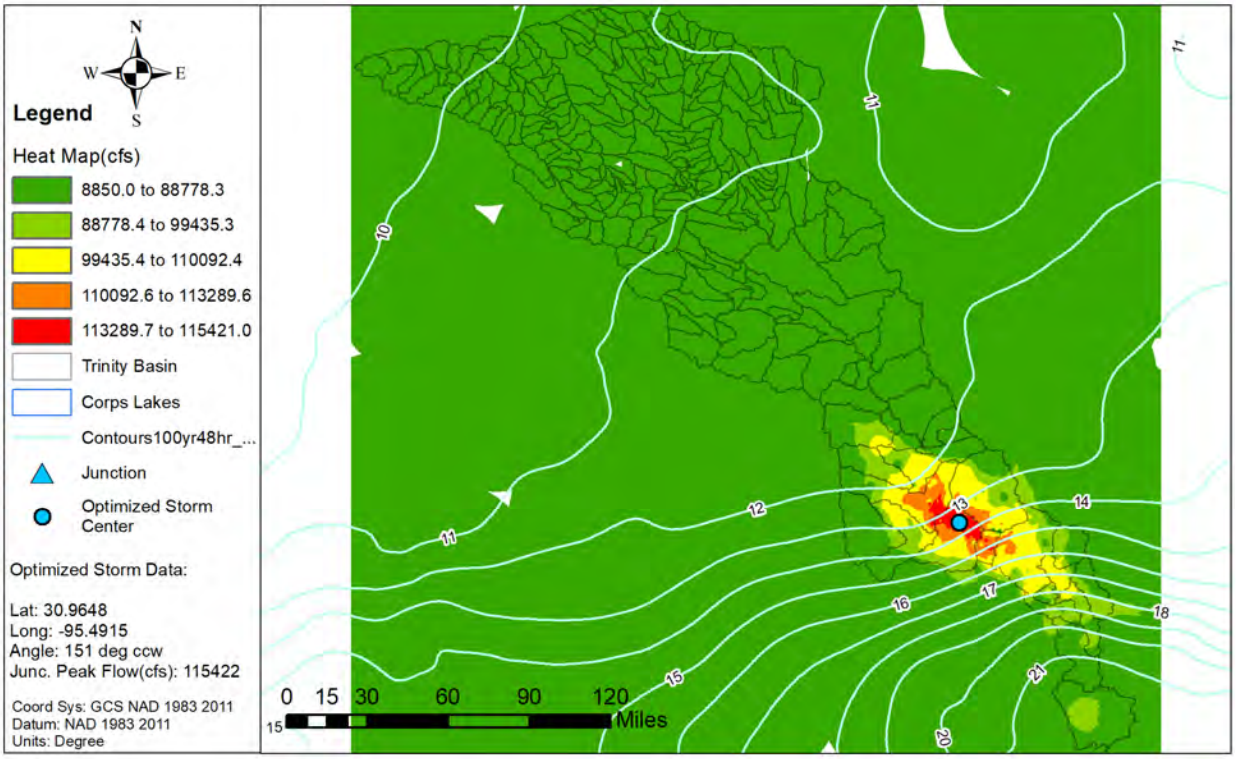


Figure 131a: Elliptical Storm Heat Map for the Trinity River at Wallisville, TX USGS gage

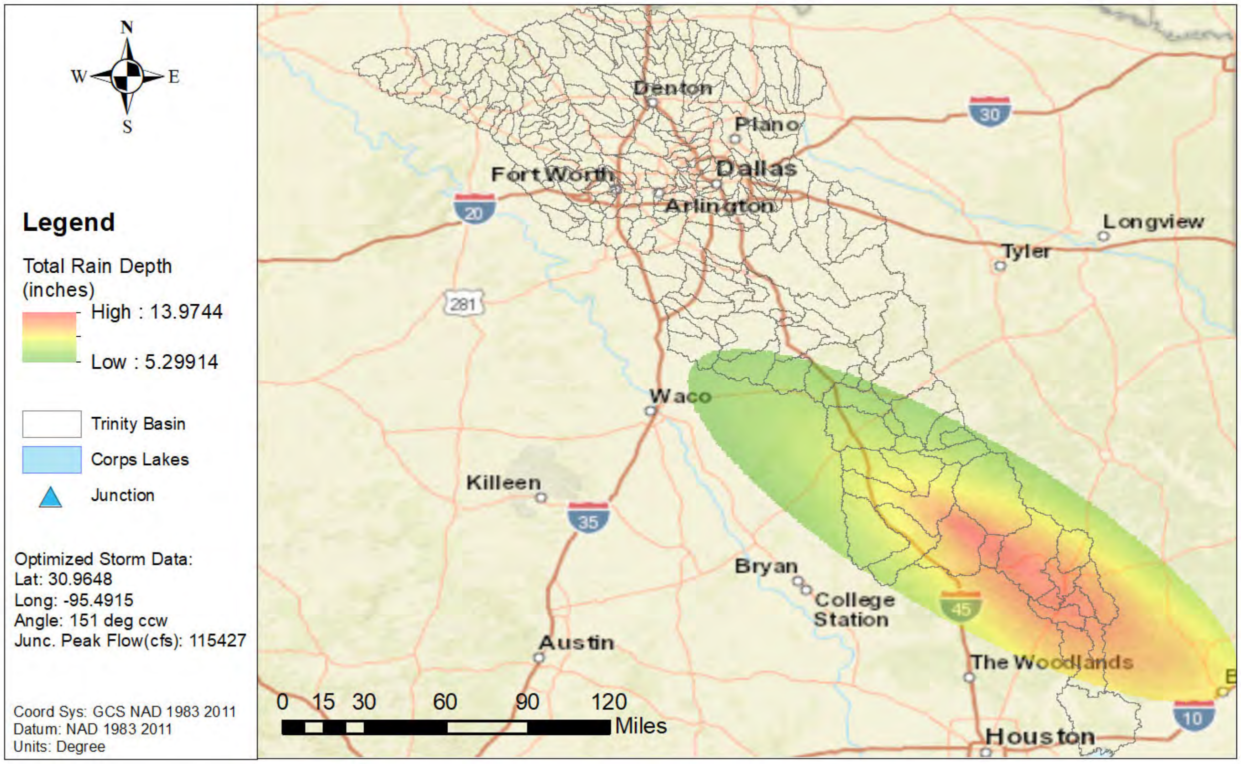


Figure 131b: NA14 1% AEP Elliptical Storm for the Trinity River at Wallisville, TX USGS gage

2 References and Resources

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2.3 DATA SOURCES, GUIDANCE, AND PROCEDURES

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ESRI Streetmap2D Image Service - ESRI basemap data, DeLorme basemap layers, Automotive Navigation Data (AND) road data, U.S. Geological Survey (USGS) elevation data, UNEP-WCMC parks and protected areas for the world, Tele Atlas Dynamap® and Multinet® street data for North America and Europe and First American (CoreLogic) parcel data for the United States.
ESRI World Imagery Service - Imagery from NASA, icubed, U.S. Geological Survey (USGS), U.S. Department of Agriculture Farm Services Agency (USDA FSA), GeoEye, and Aerials Express.
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3 Terms of Reference

AEP	Annual Exceedance Probability
ARF	Areal Reduction Factor
cfs	cubic feet per second
CWMS	Corps Water Management System
DAR	Depth Area Reduction
EM	Engineering Manual
EMA	expected moment algorithm
ERDC	Engineering Research & Development Center of USACE
FEMA	Federal Emergency Management Agency
FIS	flood insurance study
GeoHMS	Geospatial Hydrologic Model System extension
GIS	Geographic Information Systems
GO	Global Optimization
HEC	Hydrologic Engineering Center
HMR	Hydrometeorological Report
HMS	Hydrologic Modeling System
InFRM	Interagency Flood Risk Management
MAP	Mean Areal Precipitation
NA14	NOAA Atlas 14
NMSM	Nelder and Mead Simplex Method
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PFDS	Precipitation Frequency Data Server
PMP	Probable Maximum Precipitation
SCE	Shuffled Complex Evolution
sq mi	square miles
TP40	Technical Paper 40
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin
Appendix D – RiverWare Analysis

July 2021

InFRM
INTERAGENCY FLOOD RISK MANAGEMENT

Table of Contents

1. RiverWare Study

1.1 INTRODUCTION

This report summarizes the RiverWare portion of the hydrologic analysis being completed for the InFRM Hydrology Study of the Trinity River Basin (Version 7.0.4; University of Colorado Boulder, 2017). The report will focus predominately on the calibration, data selection, and operation policies in the simulation-run RiverWare model used to match Trinity River Basin historical flows. A detailed evaluation of the Trinity River Watershed period-of-record (POR) hydrology will be in this report. Ultimately, the results of the RiverWare analysis hinge on the best available datasets being selected, and that the datasets are not overly susceptible to numerical error. These topics will be discussed in greater detail in the following sections.

1.2 UPDATE OF EXISTING POR HYDROLOGY AND OPERATIONS MODELS

Prior to RiverWare, a legacy program called SUPER was used to establish POR hydrology or naturalized local flow datasets. The transition to RiverWare began in 2009. The existing USACE Riverware POR hydrology model had USGS and USACE flow data through 2011. For the InFRM study, gage data was incorporated into the RiverWare operation model through December 31, 2015. A RiverWare POR hydrology model was also created by converting the SUPER POR hydrology model and incorporates gage data from the U.S. Geological Survey (USGS) and U.S. Army Corps of Engineers (USACE) that date back to January 1, 1940.

A decision was made to convert the SUPER POR hydrology model into a RiverWare POR hydrology model at the onset of the InFRM Hydrology Study of the Trinity River Basin. The decision allowed Lake Worth to be incorporated into the RiverWare POR hydrology model and the RiverWare operation model; this was not done previously for SUPER or the RiverWare operation model. RiverWare models particular streams and reservoirs and includes the stream gages found in
Table 1 below and reservoirs found in Table 2 in section 1.3.

Table 1: Key Stream Gages used in RiverWare Models

Stream Gages	USGS Site Number	USGS Site Name
Fort Worth on Clear Fork	08047500	Clear Fk Trinity Rv at Fort Worth, TX
Fort Worth	08048000	W Fk Trinity Rv at Fort Worth, TX
Grand Prairie abv Mountain Creek	08049500	W Fk Trinity Rv at Grand Prairie, TX
Grand Prairie on Mountain Creek	08050100	Mountain Ck at Grand Prairie, TX
Carrolton	08055500	Elm Fk Trinity Rv nr Carrollton, TX
Grapevine Outflow	08055000	Denton Ck nr Grapevine, TX
Benbrook Outflow	08047000	Clear Fk Trinity Rv nr Benbrook, TX
Dallas	08057000	Trinity Rv at Dallas, TX
Crandall	08062000	E Fk Trinity Rv nr Crandall, TX

Stream Gages	USGS Site Number	USGS Site Name
Navarro Mills Outflow	08063100	Richland Ck nr Dawson, TX
Corsicana	08064500	Chambers Ck nr Corsicana, TX
Richland Chambers Outflow	08064600	Richland Ck nr Fairfield
Trinidad	08062700	Trinity Rv at Trinidad, TX
Oakwood	08065000	Trinity Rv nr Oakwood, TX
Riverside	08066000	Trinity Rv at Riverside, TX
Midway	08065500	Trinity Rv nr Midway, TX
Romayor	08066500	Trinity Rv at Romayor, TX
Richland	08063500	Richland Ck nr Richland, TX
Rosser	08062500	Trinity Rv nr Rosser, TX
Ray Hubbard Outflow	08061750	E Fk Trinity Rv nr Forney
Lewisville Outflow	08053000	Elm Fk Trinity Rv nr Lewisville
Bardwell Outflow	08063800	Waxahachie Ck nr Bardwell

The Trinity River Basin is probably one of the most complicated Basins to analyze with a RiverWare model in Texas. The screenshots of the Riverware model diagram are found in Figure 1 and Figure 2. The RiverWare operations model includes legacy gage locations that are no longer active. There are dam site locations specified that do not actually exist. These are artifacts of the original SUPER model and impoundment at these areas are unlikely. Additionally, significant pumpage from and into the Trinity River Basin were accounted for as seen in the screenshots.

For this study, flow data were updated through December 31st, 2015. Both the RiverWare POR hydrology and operations models begin on January 1st, 1940. Rulesets were written for the operations model to mimic conservation releases. As pumpage demands and releases have changed throughout the years due to differing demands, the ruleset attempted to recreate recent pumpage demands and releases and to match approximately the last 10 years of record, from 2005-2015.

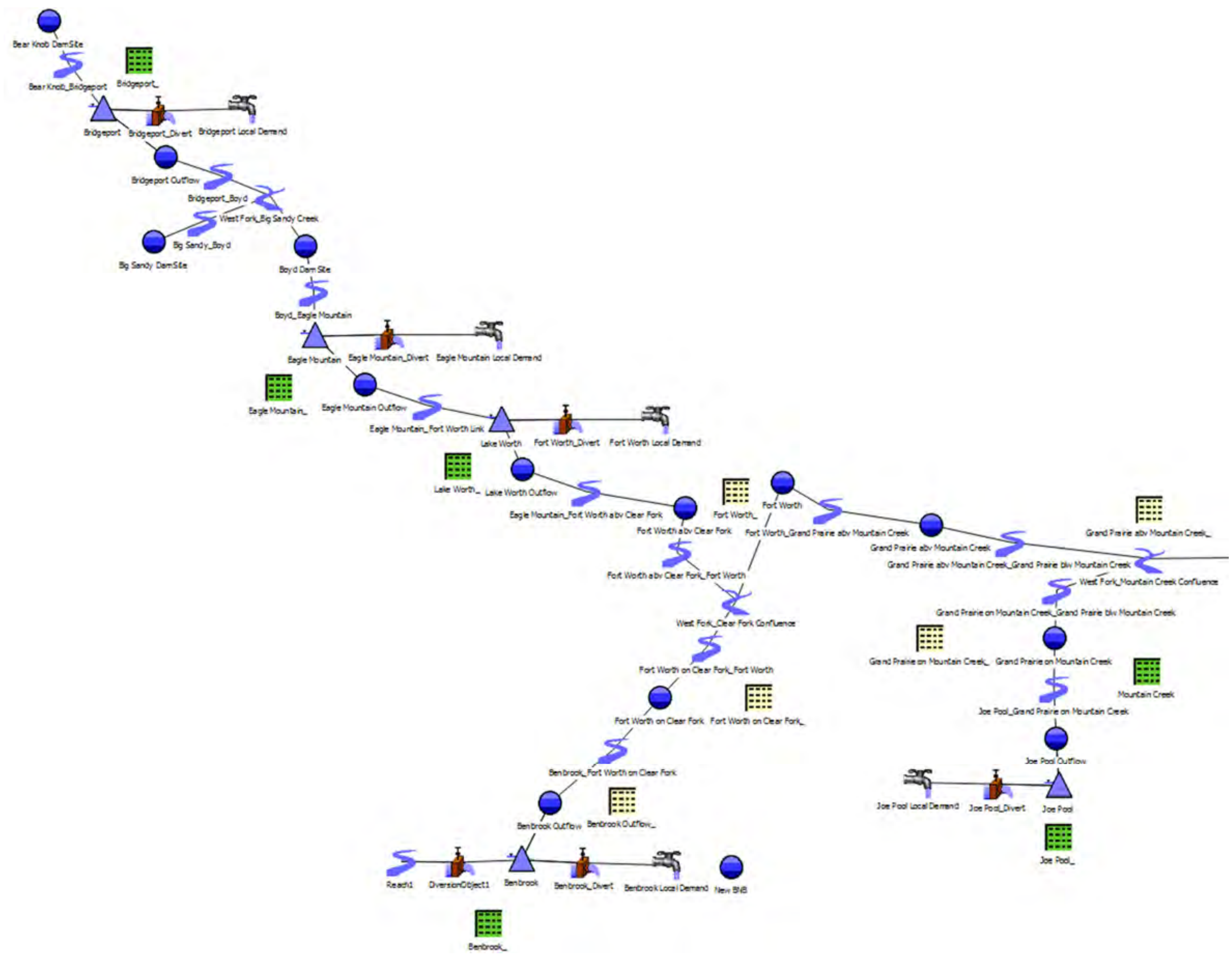

Figure 1: RiverWare Diagram of West Trinity River Basin

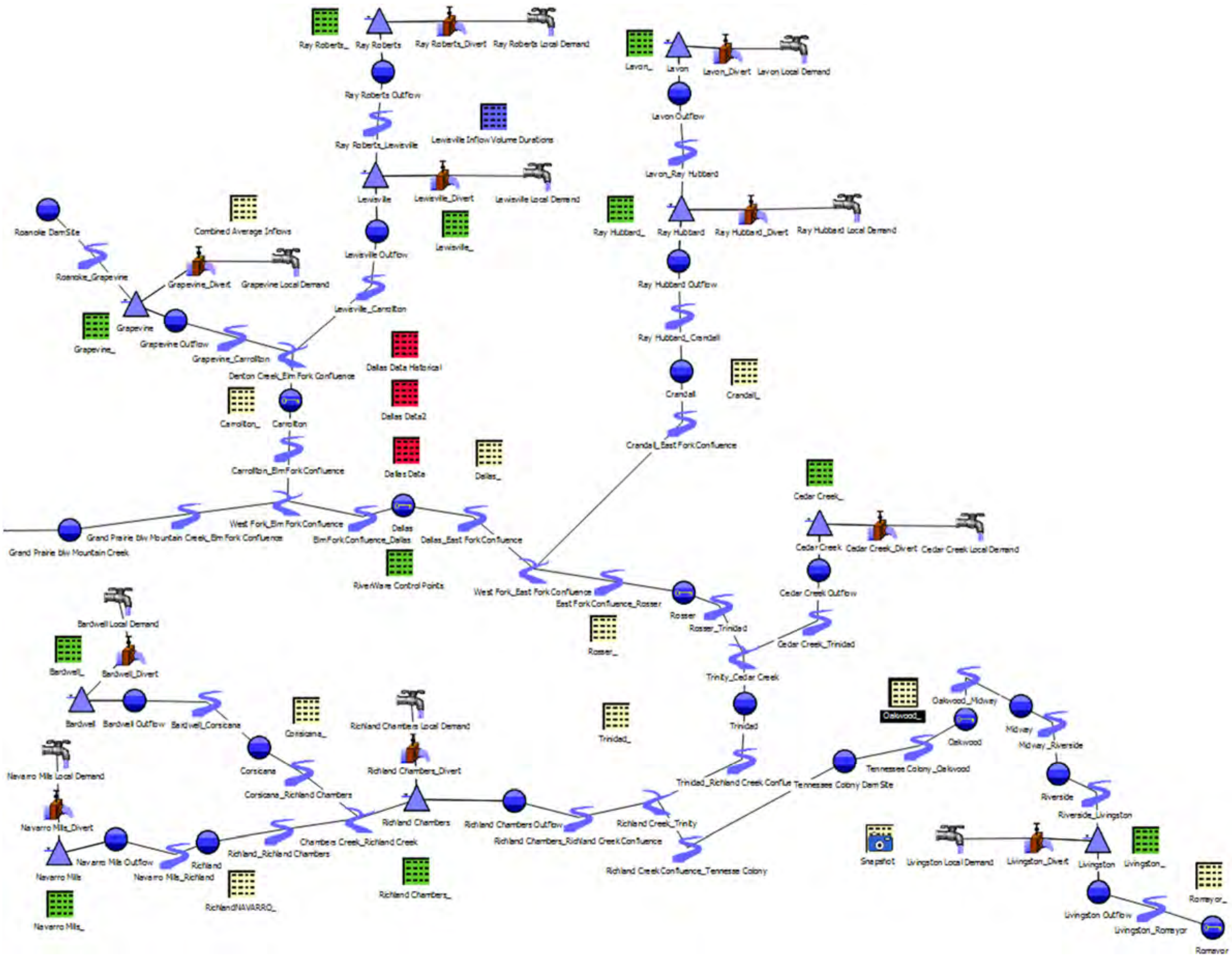

Figure 2: RiverWare Diagram of East Trinity River Basin

1.2.1 DATA SOURCES USED TO DEVELOP RIVERWARE MODEL

The primary data used in the hydrology model is daily USGS flows and USACE reservoir inflows. USGS gage data were often found online, but at times were found within USACE records. Evaporation rates were specified for each reservoir based on USACE calculated evaporation. The pumpage data are assimilated from various stakeholders. Pumpage and releases are implemented using rulesets that reflect the last 10 years of record, as well as evaporation.

1.2.2 METHODOLOGY USED TO DEVELOP POR HYDROLOGY

The important methods used to develop the POR hydrology for the Trinity River Watershed in this report are the drainage-area-ratio method, reservoir inflow calculation, and reservoir inflow smoothing algorithm. The methods will be explained in greater detail in the following paragraphs.

Rarely is there a watershed study where sufficient and consistent gage datasets exist. Incomplete gage datasets for both stream gages and reservoirs gages can be attributed to budget limitations and anthropogenic changes, i.e. installation of reservoirs. To reconcile the inconsistent datasets, drainage area ratios are used to extrapolate and interpolate gage datasets. The drainage-area-ratio method (Gupta, 2008) provides a numerical approximation of the missing gage data, using gage datasets upstream or downstream on the same river (Equation 1).

$$Q_y = \frac{Q_x}{A_x} A_y$$

Equation 1: Drainage-Area-Ratio Method

$Q_y = Flow\ at\ gaged\ site\ Y\ of\ drainage\ area\ A_y\ [L^3/\ T]$

$Q_x = Flow\ at\ gaged\ site\ X\ of\ drainage\ area\ A_x\ [L^3/\ T]$

$A_y = Drainage\ area\ of\ unavailable\ gaging\ station\ record\ Y\ [L^2]$

$A_x = Drainage\ area\ of\ available\ gaging\ station\ record\ X\ \ [L^2]$

The numerous array of reservoir inflow calculations tolerate for thoroughness, as well as disjointedness. All reservoir inflow calculations utilize a mass balance approach. The method selection for the calculation of reservoir inflow is subjective. There are two methods used to calculate reservoir inflow; they will be called the “net evaporation reservoir inflow method” and the “evaporation reservoir inflow method” which is the method applied to USACE datasets. The net evaporation reservoir method incorporates precipitation, whereas, the evaporation reservoir inflow calculation does not incorporate precipitation into the reservoir inflow calculation (Equation 2 and Equation 3).

$$I = \Delta S + E + R + Q_{total} - P$$

Equation 2: Net Evaporation Reservoir Inflow Method

$I = Inflow\ into\ the\ reservoir\ [L^3/\ T]$

$\Delta S = Change\ in\ reservoir\ storage\ [L^3/\ T]$

$E = Evaporation\ from\ the\ reservoir\ [L^3/\ T]$

$R = Releases\ from\ the\ reservoir\ [L^3/\ T]$

$Q_{total} = Total\ pumpage\ out\ of\ the\ reservoir\ [L^3/\ T]$

$P = Precipation\ on\ the\ reservoir\ [L^3/\ T]$

$$I = \Delta S + E + R + Q_{total}$$

Equation 3: Evaporation Reservoir Inflow Method

$I = Inflow\ into\ the\ reservoir\ [L^3/\ T]$

$\Delta S = Change\ in\ reservoir\ storage\ [L^3/\ T]$

$E = Evaporation\ from\ the\ reservoir\ [L^3/\ T]$

$R = Releases\ from\ the\ reservoir\ [L^3/\ T]$

$Q_{total} = Total\ pumpage\ out\ of\ the\ reservoir\ [L^3/\ T]$

The calculated reservoir inflow is subject to measurement error and numerical error. The evaporation parameter is arguably the most difficult parameter to estimate when calculating reservoir inflow. The uncertainty in measurement often leads to negative reservoir inflow values, which violates the conservation of mass principle. The reservoir inflow values are numerically smoothed by scaling positive inflows and rectifying negative inflows to resolve this inconsistency of negatives. The smoothed inflow algorithm is applied over a monthly time period with a daily time step (Equation 4, Equation 5, Equation 6, and Equation 7). There are additional inflow smoothing methods available, but this method is sufficient to resolve negative reservoir inflows in this case.

$$Montly\ Total\ Inflow = \sum_{i}^{i_f} I_i$$

Equation 4: Monthly Total Inflow Method

$$\text{Nonnegative Inflow} = \begin{Bmatrix} if\ I_i < 0 \\ 0 \\ else \\ I_i \end{Bmatrix}$$

Equation 5: Nonnegative Inflow Method

$$Montly\ Total\ Nonnegative\ Inflow = \sum_{i}^{i_f} Nonnegative\ Local$$

Equation 6: Monthly Total Nonnegative Inflow Method

$$Smoothed\ Inflow = \begin{Bmatrix} if\ Monthly\ Total\ Inflow < 0\ OR\ Montly\ Total\ Nonnegative\ Inflow = 0 \\ Nonnegative\ Inflow * 0 \\ else \\ Nonnegative\ Inflow * \dfrac{Monthly\ Total\ Inflow}{Montly\ Total\ Nonnegative\ Inflow} \end{Bmatrix}$$

Equation 7: Smoothed Inflow Method

$I = Inflow\ into\ the\ reservoir\ on\ the\ i^{th}\ day\ [L^3/\ T]$

$i = i^{th}\ day\ of\ the\ month\ []$

$i_f = last\ day\ of\ the\ month\ []$

$Montly\ Total\ Nonnegative\ Inflow = Summation\ of\ the\ monthly\ nonnegative\ inflows\ [L^3/\ T]$

$Montly\ Total\ Inflow = Summation\ of\ the\ monthly\ reservoir\ inflows\ [L^3/\ T]$

Nonnegative Inflow = A nonnegative dataset of the reservoir inflows $[[L^3/\ T]: [L^3/\ T]]$

Smoothed Inflow = A smoothed dataset of the reservoir inflows $[[L^3/\ T]: [L^3/\ T]]$

The methods presented above along with the RiverWare modeling software have permitted for the development of POR hydrology for the Trinity River Basin Watershed. The following section will describe how these methods were implemented within the framework of the RiverWare modeling software and the precursor to the RiverWare modeling software.

1.3 RIVERWARE OPERATIONAL MODEL APPLICATION

The POR hydrology needed to evaluate the Trinity River Watershed requires the use of numerical models.. RiverWare 7.0.4 was used to analyze the hydrologic processes of reservoirs within the Trinity River Watershed. The hydrologic analysis includes the use of a multiple-run and simulation-run RiverWare model. The multiple-run

RiverWare model produced the POR hydrology from January 1940 to December 2015 for all stream and reservoir gage sites. The POR hydrology is the naturalized local flows, where major anthropogenic impacts have been removed, including effects of reservoir regulation. The RiverWare POR hydrology model was compared to the legacy SUPER model and proved successful. The simulation-run RiverWare model used the POR hydrology datasets to simulate flow within the Trinity River Watershed with reservoir regulation policies incorporated for the entire POR, which will be used in the statistical frequency analysis portion of this study.

The process for developing POR hydrology, for the reservoirs and control points or stream gages of interest, is to assimilate historical reservoir inflow and stream flow datasets, then implement drainage-area-ratio methods and reservoir inflow smoothing algorithms in a multiple-run RiverWare model to numerically solve for the POR hydrology. Analyzing regulated flows at gages or control points, pool elevations and operational release over the POR requires the POR hydrology and reservoir operational policies and rule sets incorporated into a simulation-run RiverWare operation model. The reservoir operational policies and rule sets applied to reservoirs can be compared to historical pool elevations, releases, and local inflows to verify consistency with historical datasets. Ultimately the policies and rule sets can be applied to the POR hydrology to establish synthetic pool elevation and reservoir operation before the reservoirs existed.

When developing the RiverWare POR Hydrology, the impoundment dates of major reservoirs are important to incorporate. A list of key impoundments in the Trinity River Basin are found in Table 2. The dates are incorporated into the rule-based simulation logic of RiverWare to ensure appropriate estimation of local naturalized flows. In addition to the impoundment dates, stream gage installation and removal dates are important for estimation.

Table 2: Date of Impoundment for Dams in the Trinity Basin

Dam Name	Impoundment Date
Bardwell	December 1965
Benbrook	October 1952
Bridgeport	April 1932
Cedar Creek	July 1965
Eagle Mountain	February 1934
Worth	June 1914
Grapevine	May 1952
Joe Pool	January 1986
Lavon	October 1953
Lewisville	November 1954
Livingston	October 1968
Mountain Creek	January 1937
Navarro Mills	October 1962
Ray Hubbard	January 1968

Dam Name	Impoundment Date
Ray Roberts	October 1987
Richland-Chambers	July 1987

1.4 RIVERWARE OPERATIONAL MODEL OUTPUT RESULTS

The final product of this analysis, is the POR pool elevations for the reservoirs and POR stream flows from Jan 1940 to Dec 2015. The datasets and numerical methods were vetted and the results were crosschecked thoroughly with the historical datasets. The stream flow results were given to the USGS for additional statistical analysis.

The RiverWare simulated POR stream flow results (depicted in blue) were compared to measured USGS gaged flow (depicted in red) are show in Figure 3 to Figure 24. All stream gage locations shown have good correspondence between RiverWare and UGSG flow values. The subtle deviations can be attributed to the way RiverWare operations are unrealistically exact and how USACE reservoir regulators make decisions with additional insight. The large deviations and missing data can be attributed to downstream gaging prior to impoundment and lack of a recording gage.

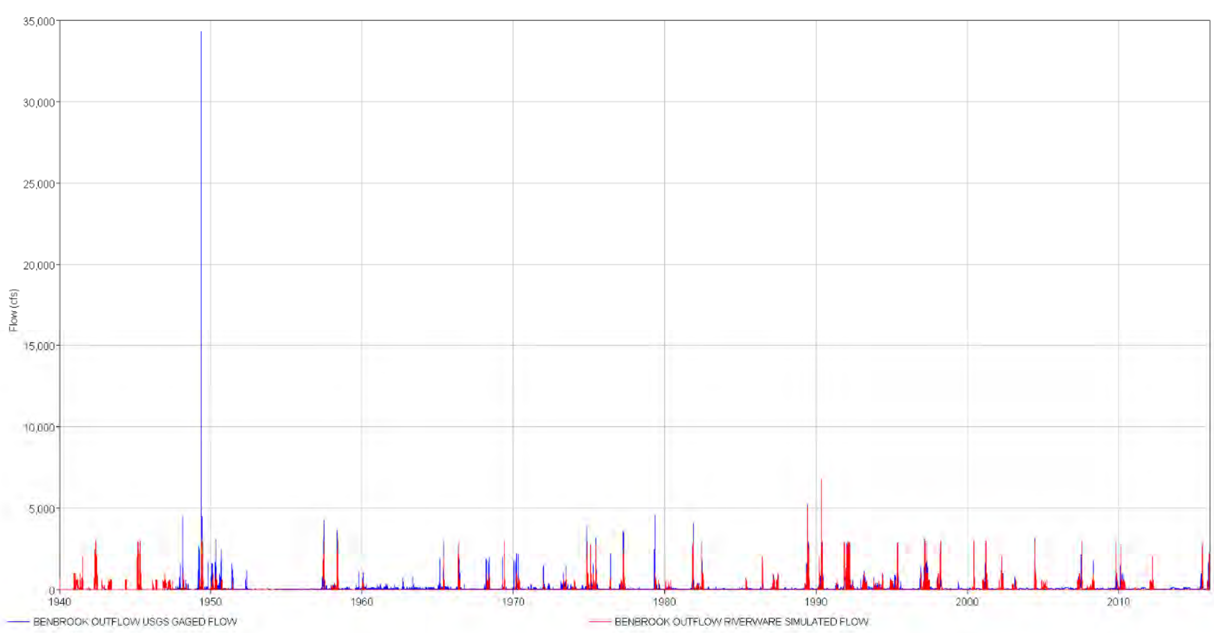

Figure 3: The Benbrook Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

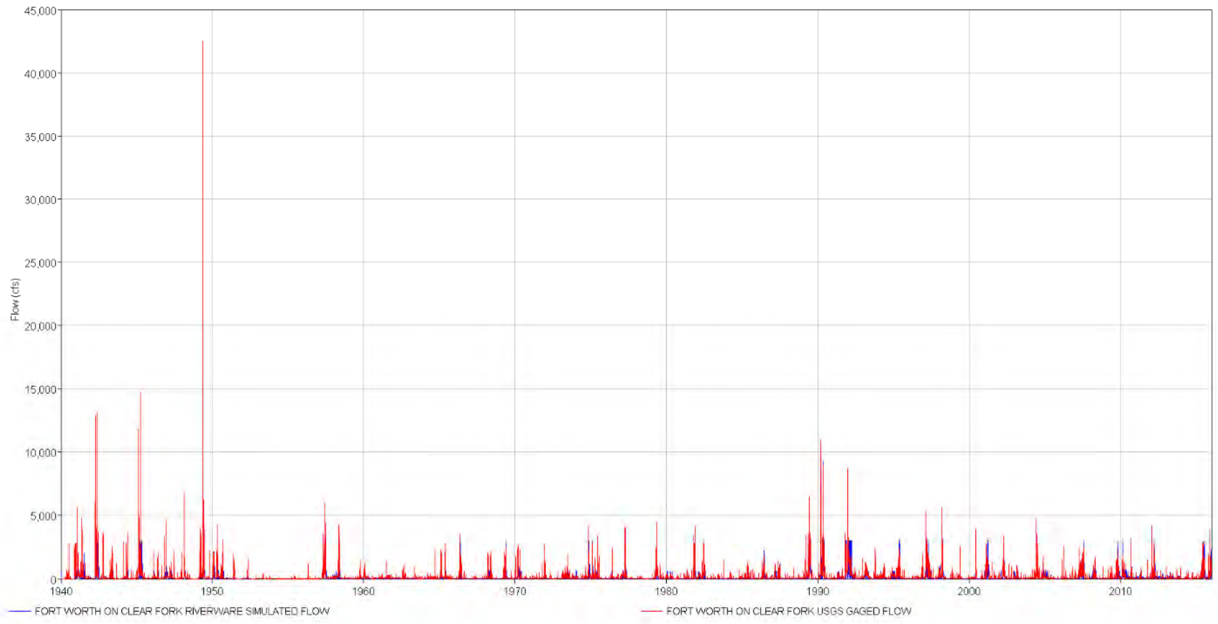

Figure 4: The Fort Worth on Clear Fork Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

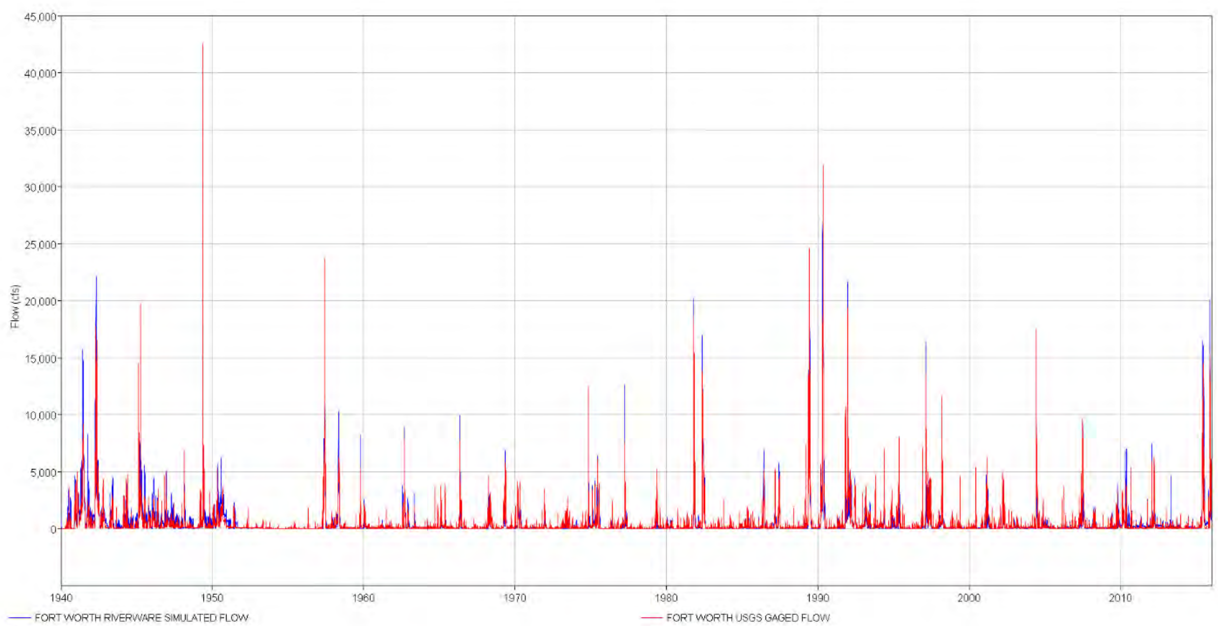

Figure 5: The Forth Worth on West Fork Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

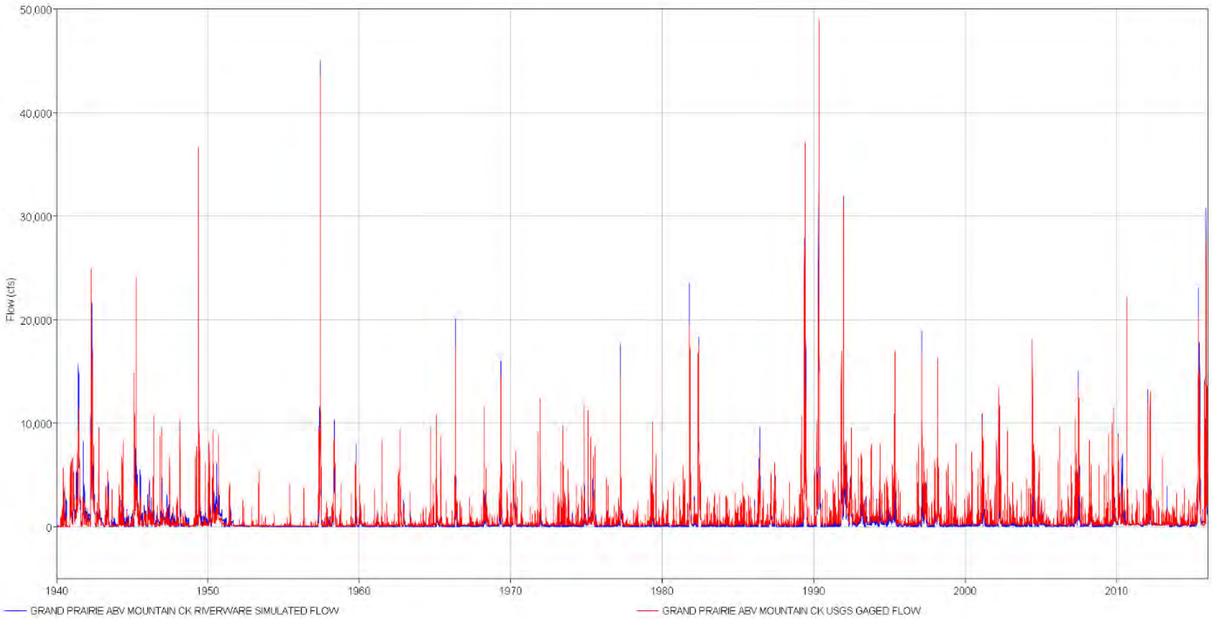

Figure 6: The Grand Prairie Abv Mountain Creek Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

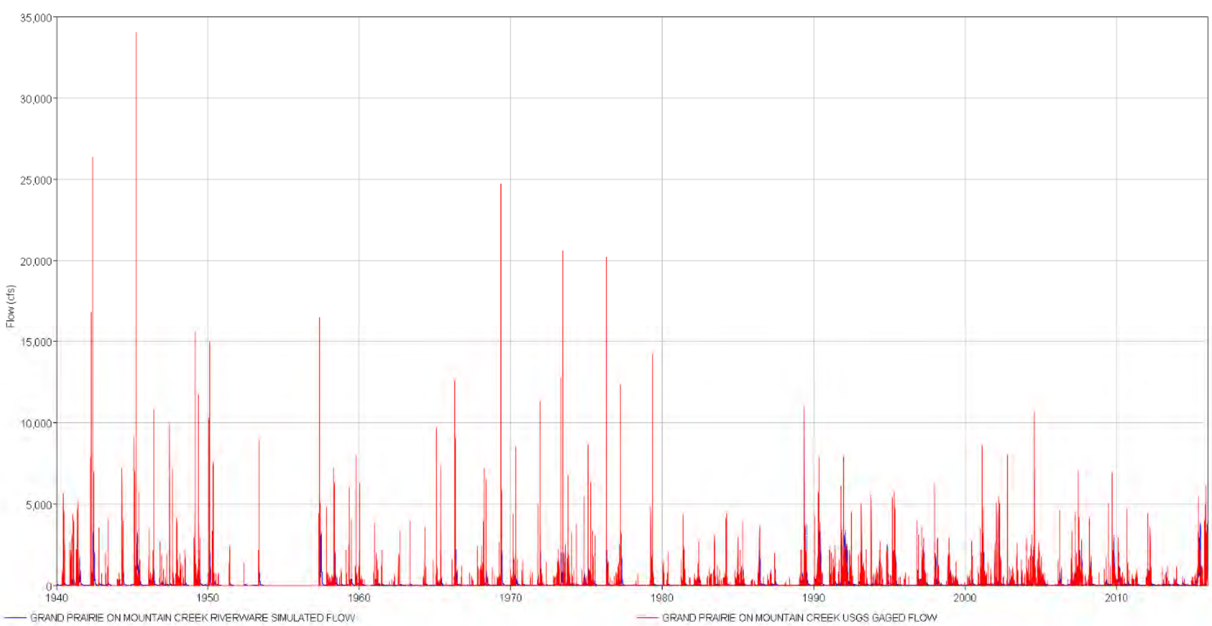

Figure 7: The Grand Prairie on Mountain Creek Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

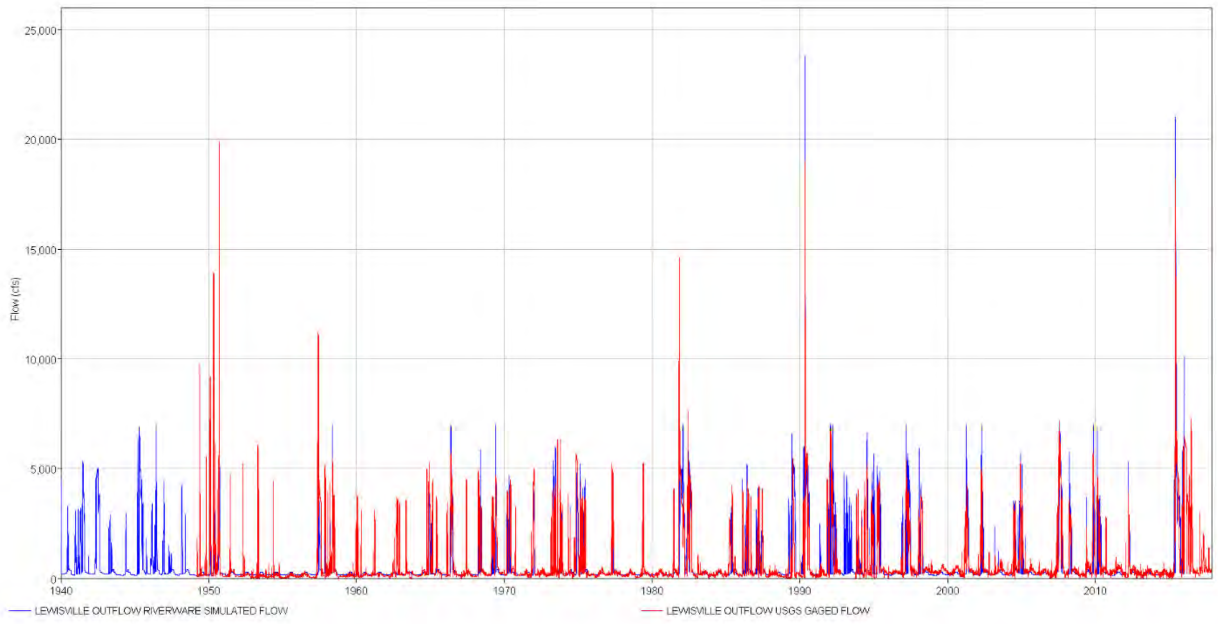

Figure 8: The Lewisville Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

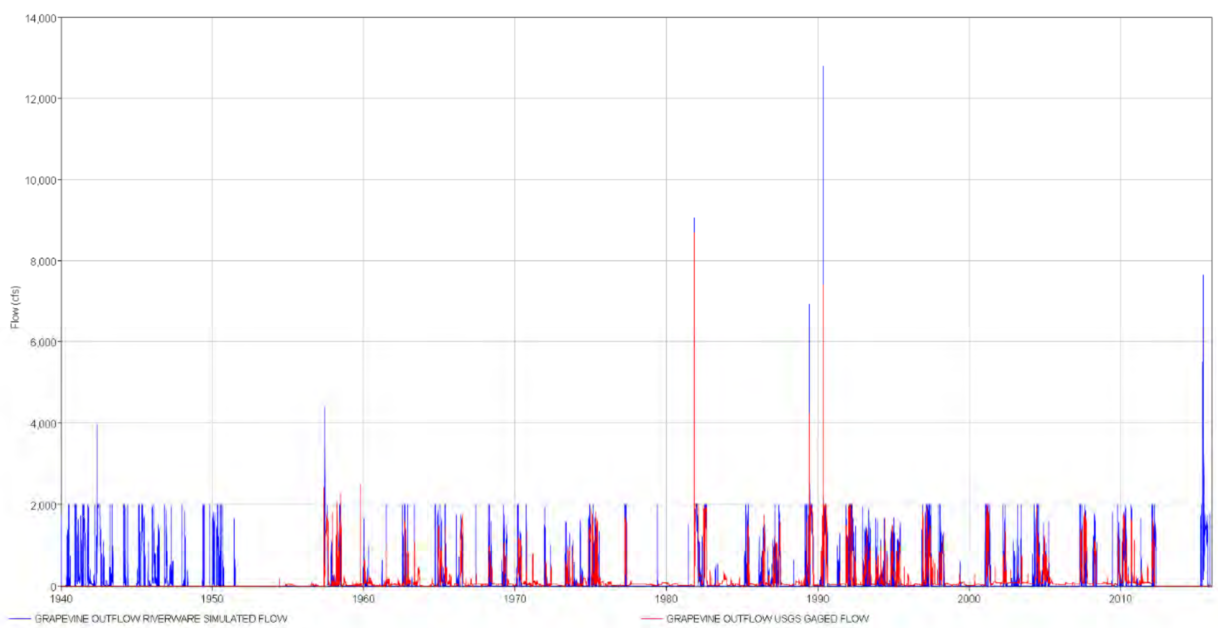

Figure 9: The Grapevine Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

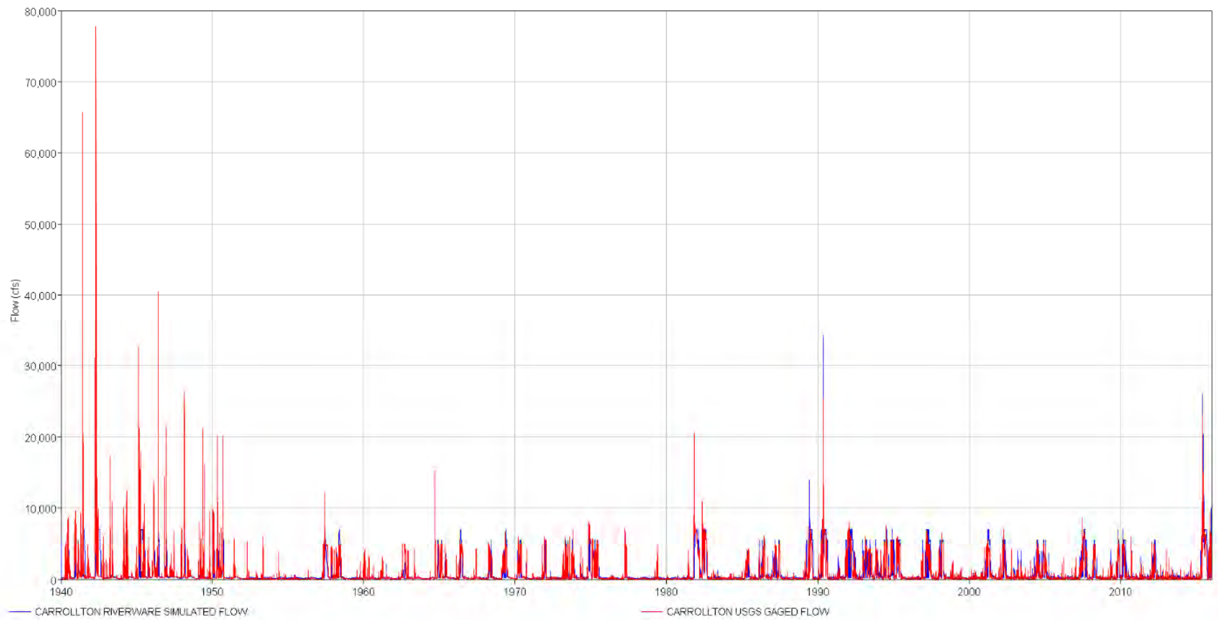

Figure 10: The Carrollton Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

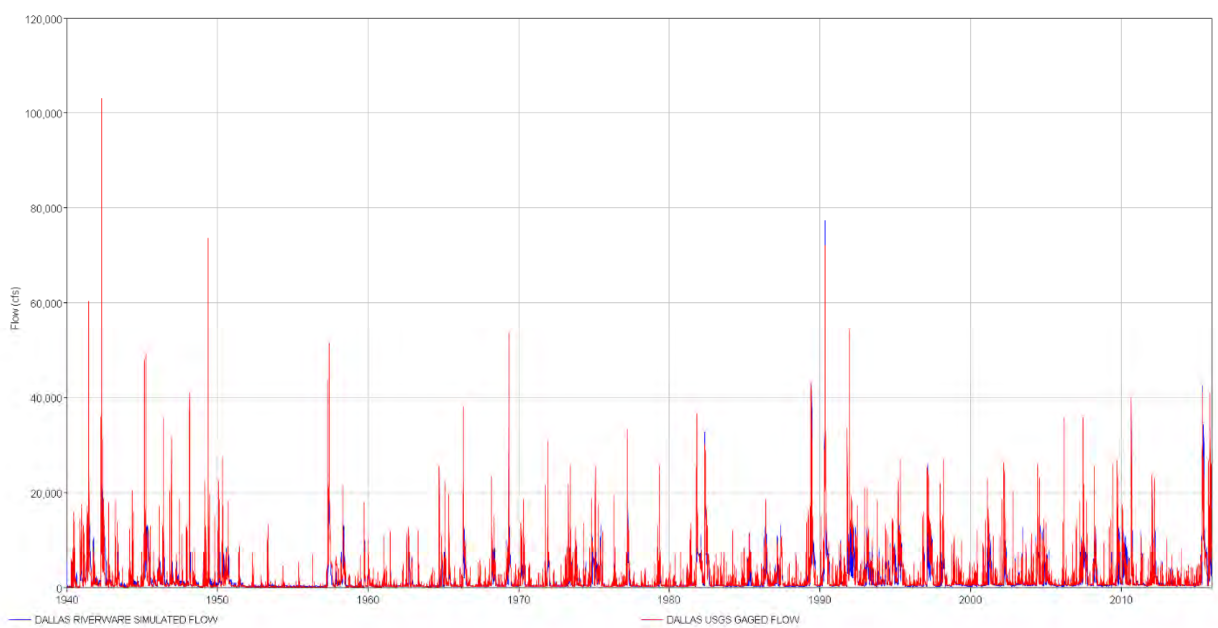

Figure 11: The Dallas Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

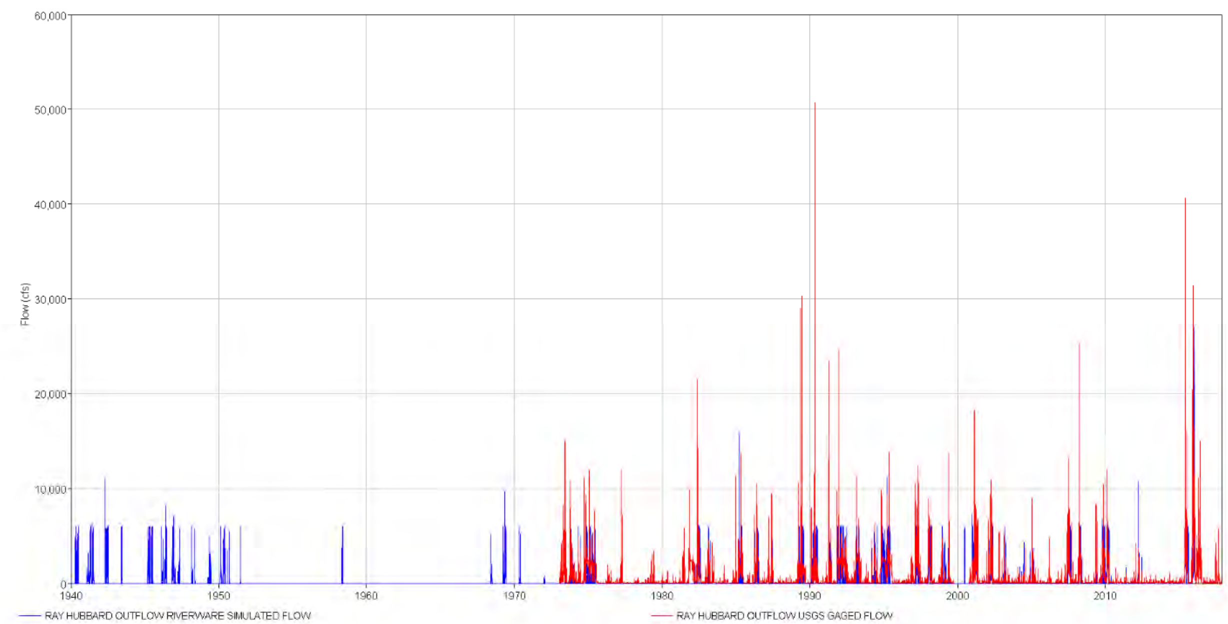

Figure 12: The Ray Hubbard Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

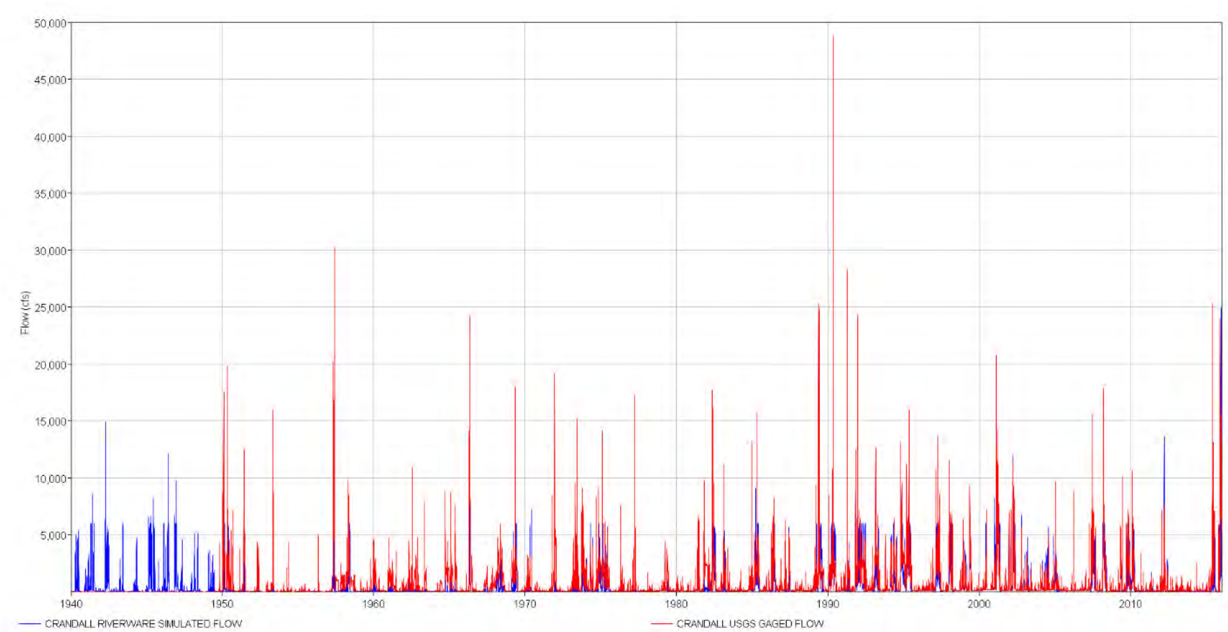

Figure 13: The Crandall Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

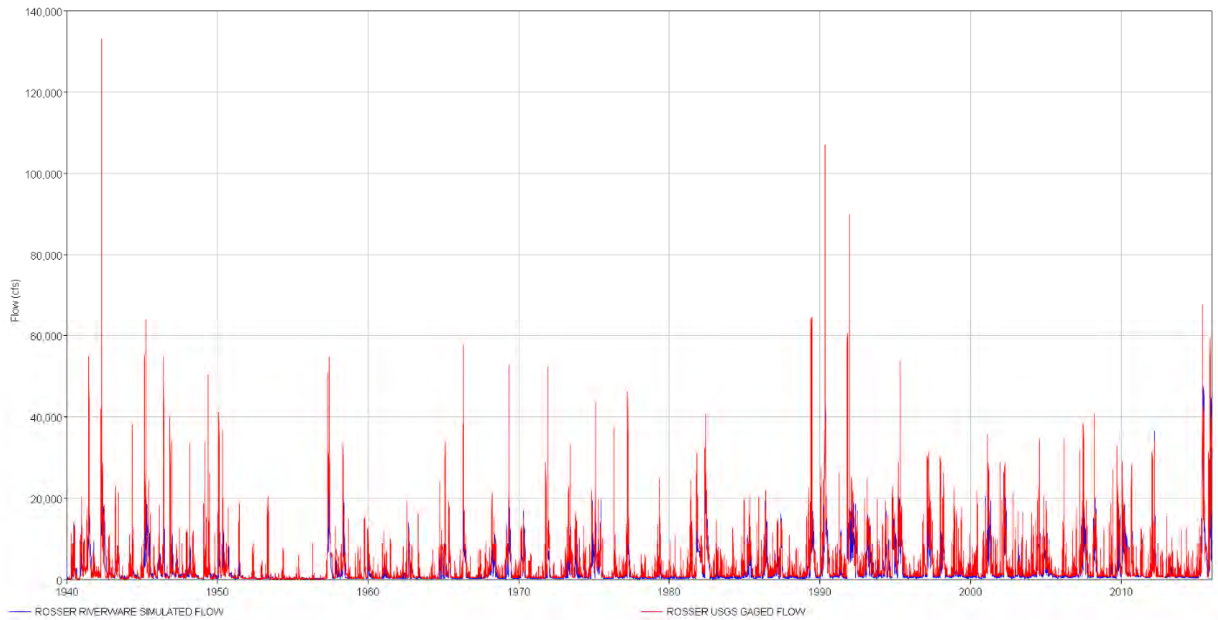

Figure 14: The Rosser Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

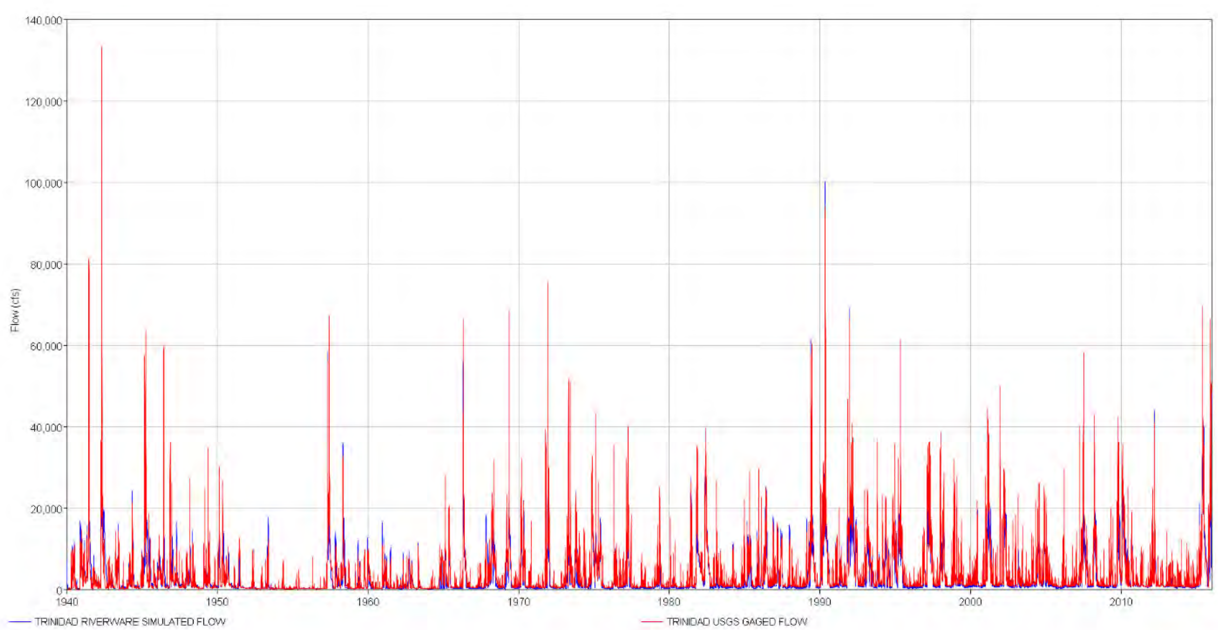

Figure 15: The Trinidad Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

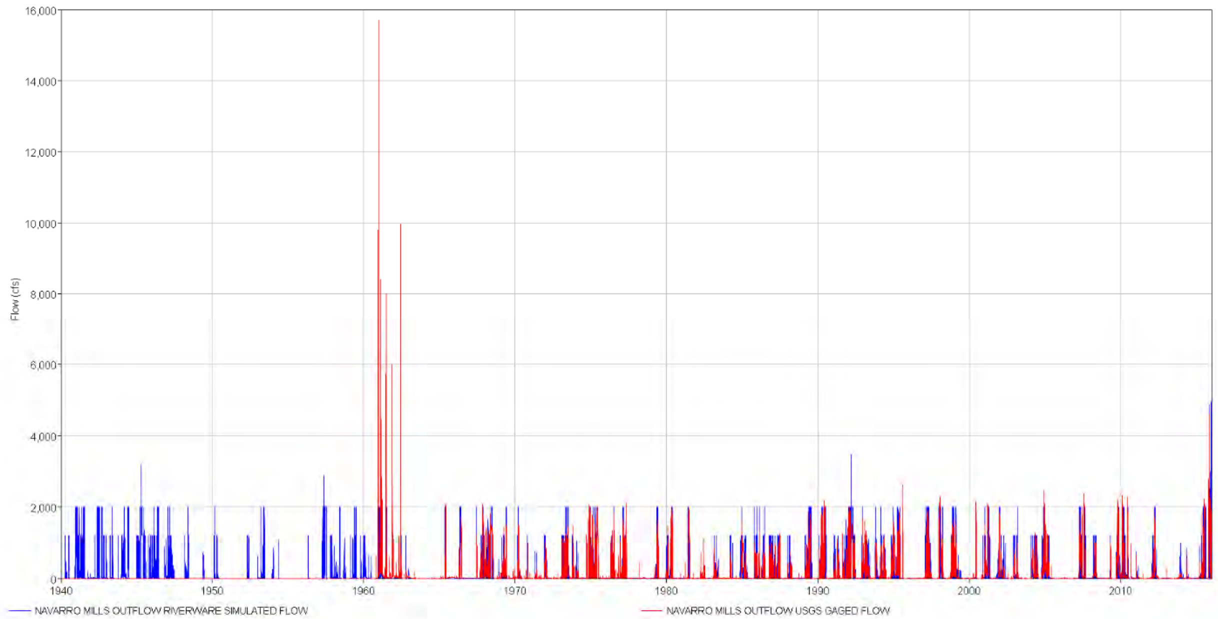

Figure 16: The Navarro Mills Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red)

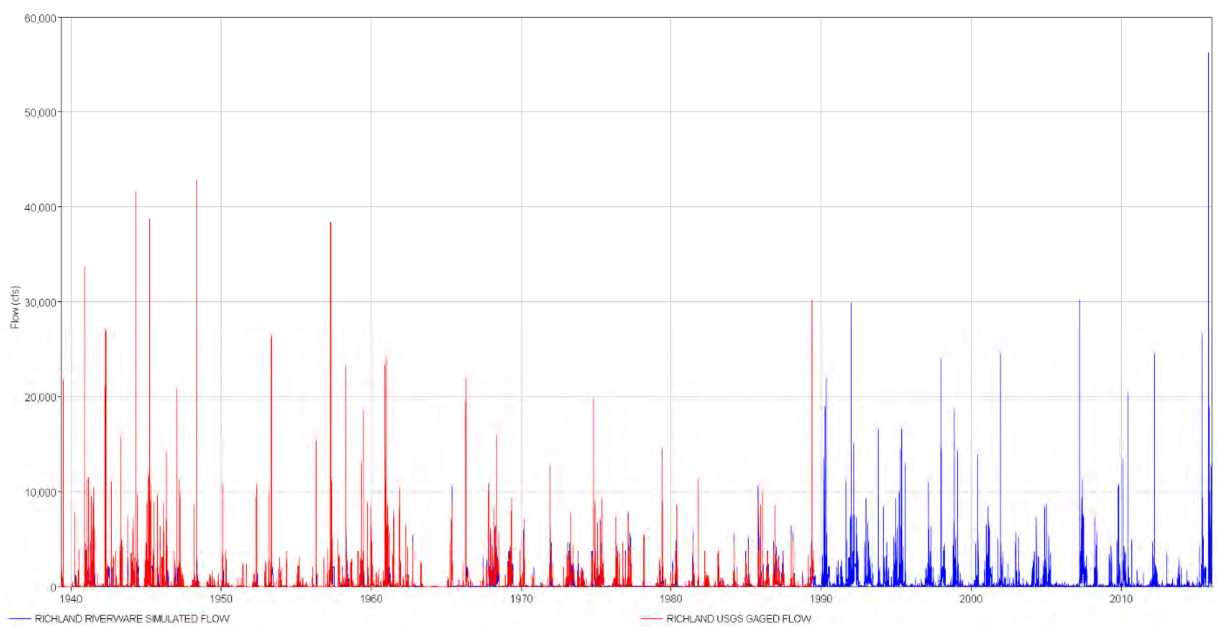

Figure 17: The Richland Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

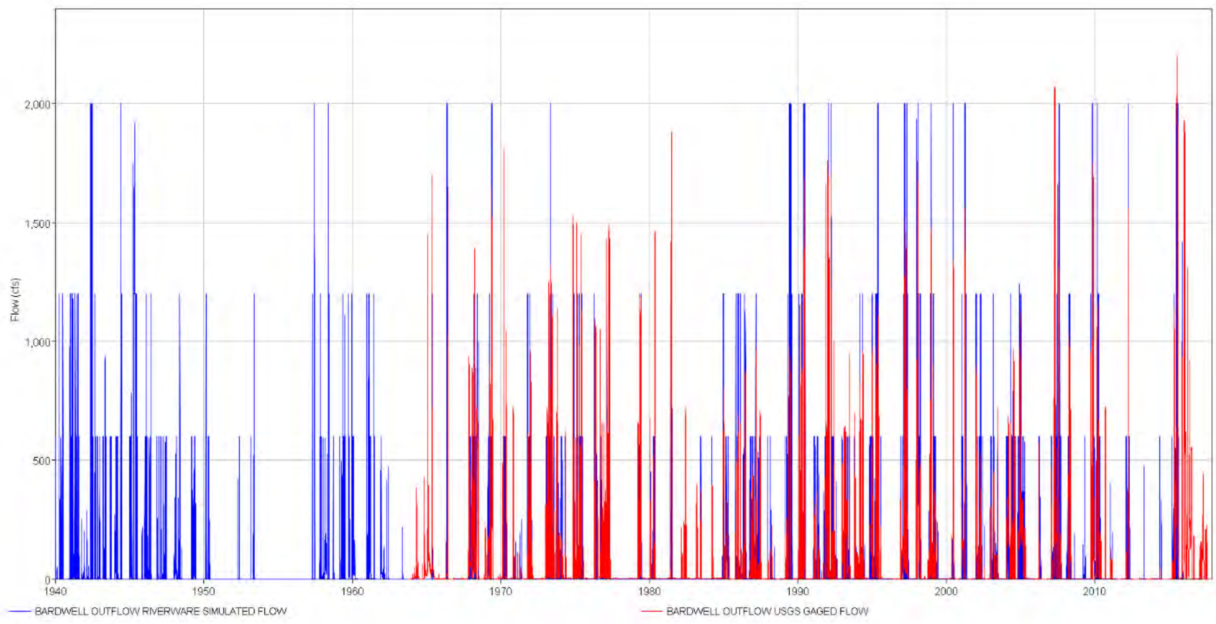

Figure 18: The Bardwell Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

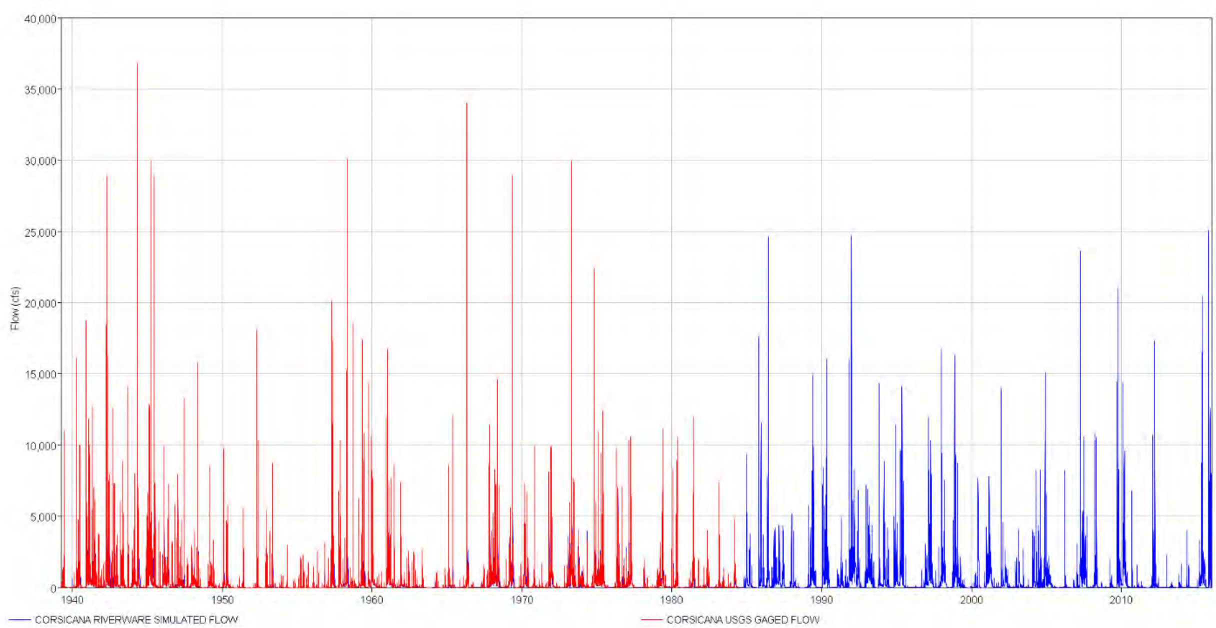

Figure 19: The Corsicana Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

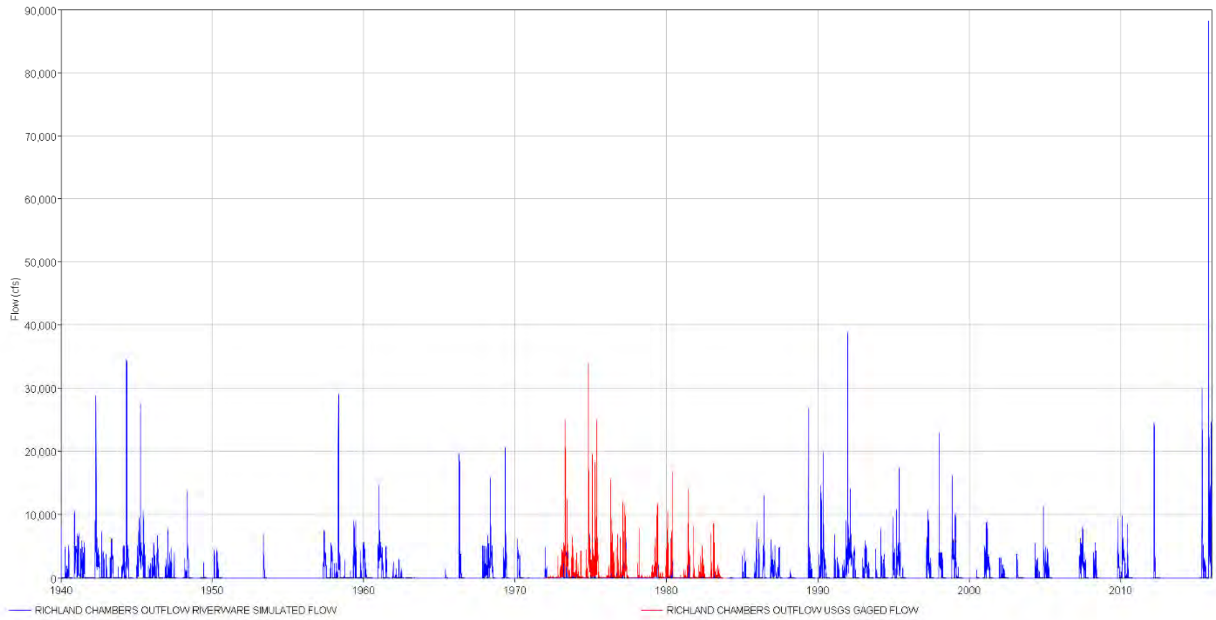

Figure 20: The Richland Chambers Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

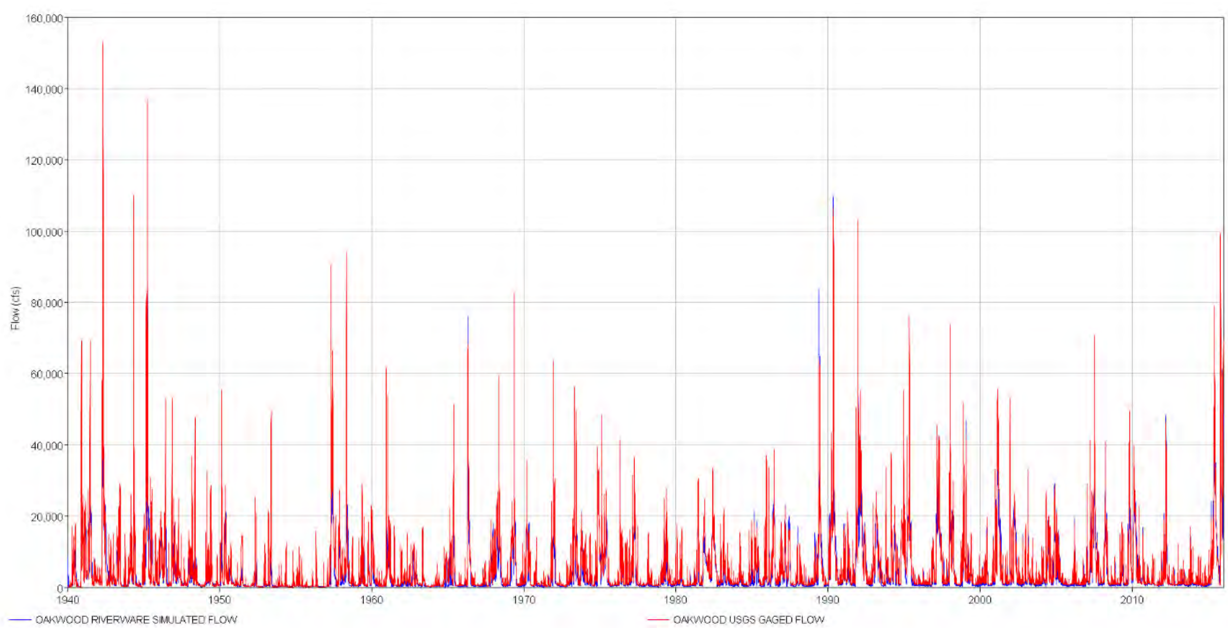

Figure 21: The Oakwood Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

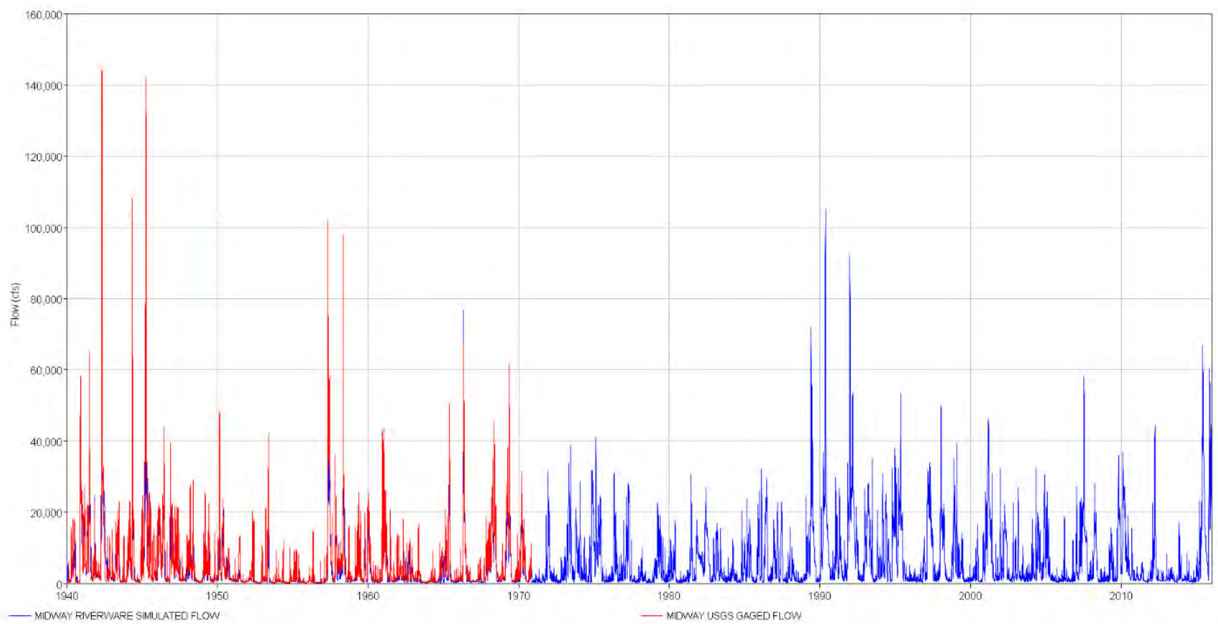

Figure 22: The Midway Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

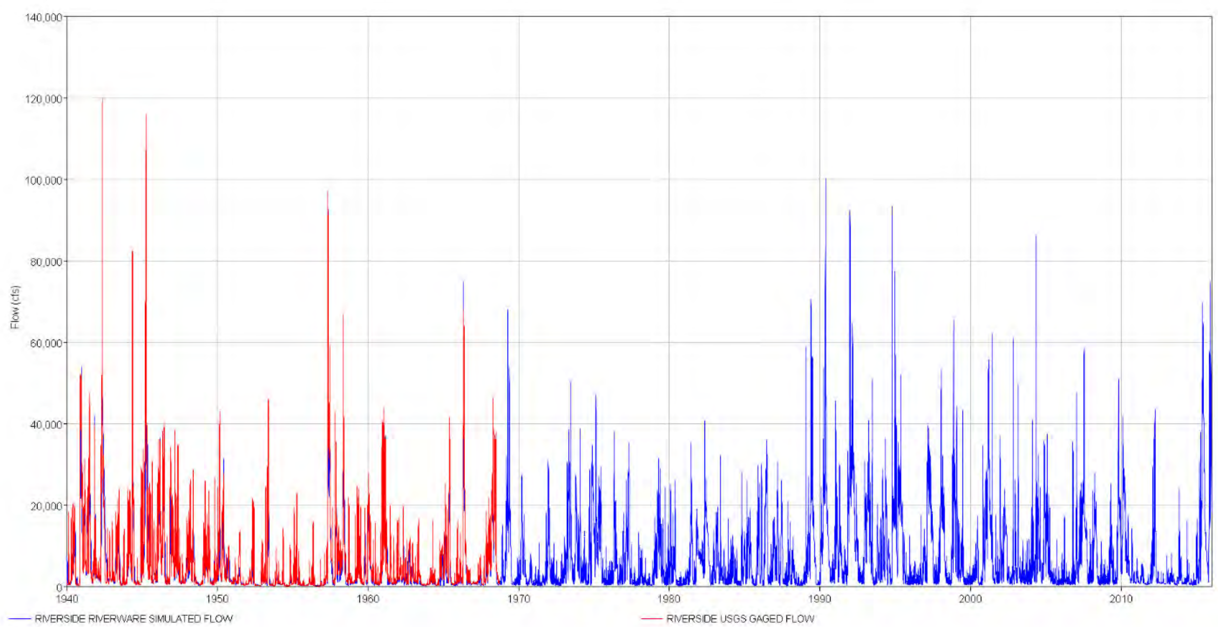

Figure 23: The Riverside Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

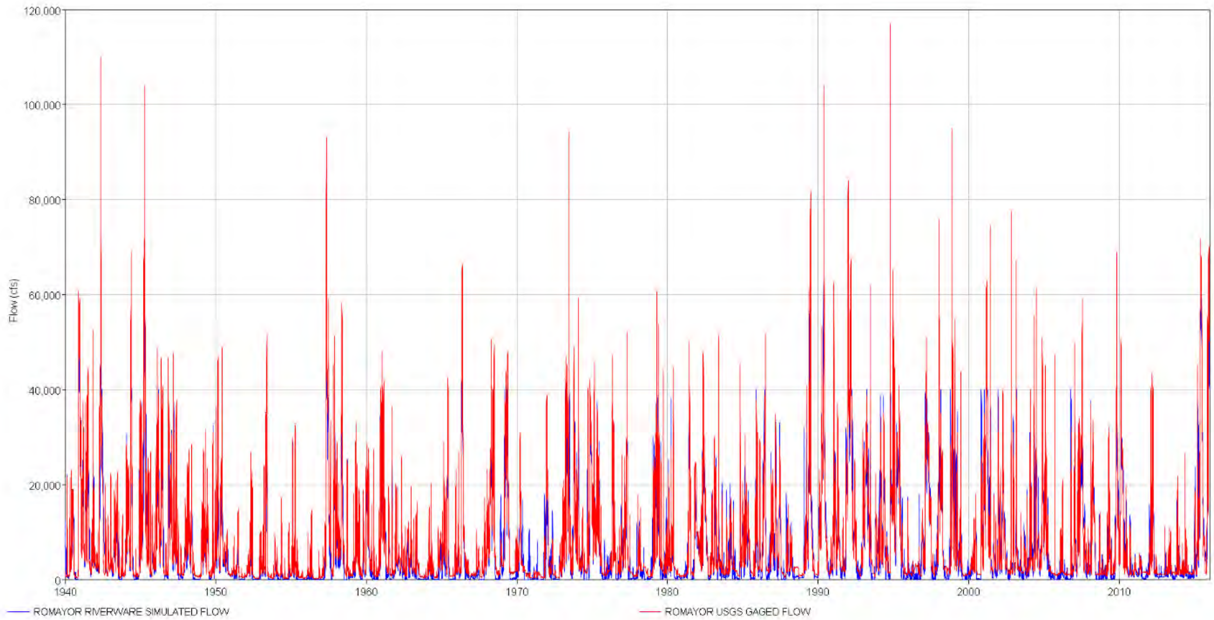

Figure 24: The Romayor Outflow for RiverWare Simulated Flow (Blue) compared to USGS Historic Flow (Red).

1.5 STREAMGAGE DATA AND STATISTICAL FLOOD FLOW FREQUENCY RESULTS

For the statistical analysis of the RiverWare modeling results, USGS staff analyzed the simulated hourly peak streamflows for 22 USGS streamflow-gaging stations (streamgages) that were included in the RiverWare model. The analyzed streamgages are listed in Table 3. A peaking factor was applied to the RiverWare daily time-step data. A peaking factor is needed to convert the daily peak flows to hourly (instantaneous) peak flows. A peaking factor of 'N/A' signifies that no peaking factor was applied to that dataset. It was determined that the difference between daily and instantaneous annual peak discharge was negligible in regard to the present analysis. If two peaking factors were applied to the gage, they are both listed as well as the inflection point in log10 scale. Peak streamflow frequency analyses were conducted at the gages using the simulated hourly annual peak flow data for the entire period of record provided by RiverWare output. In addition to the analyses performed on the simulated hourly peaks, the same analyses were repeated for the simulated daily peaks and then compared to the flood flow frequency results, which were based on observed instantaneous peak streamflows for the USGS historic analyses discussed in the Statistical Hydrology Appendix.

Table 3: USGS NWIS station number and name, abbreviated name in report, stream name, latitude, longitude, and start (and end if applicable) date of historic peak record for the 22 gages analyzed in this section of the report.

Station number and name	Name in report	Stream name	Latitude	Longitude	Historic peak record begins (ends)	Peaking Factor
08047000 Clear Fork Trinity River near Benbrook, Tex.	Benbrook gage	Clear Fork Trinity River	32.6651	-97.4420	1948	y=1.022x
08047500 Clear Fork Trinity River at Fort Worth, Tex.	Fort Worth Clear Fork gage	Clear Fork Trinity River	32.7324	-97.3589	1922	log10(daily) > 3.25: y=0.683x+1.650 log10(daily) < 3.25: y=0.834x+1.209
08048000 West Fork Trinity River at Fort Worth, Tex.	Fort Worth West Fork gage	West Fork Trinity River	32.7610	-97.3325	1921	y=0.627x+1.713
08049500 West Fork Trinity River at Grand Prairie, Tex.	Grand Prairie gage	West Fork Trinity River	32.7625	-96.9944	1925	log10(daily) > 4: y=1.153x-0.593 log10(daily) < 4: y=0.782x+0.914
08050100 Mountain Creek at Grand Prairie, Tex.	Mountain Creek gage	Mountain Creek	32.7499	-96.9261	1961	y=1.065x
08053000 Elm Fork Trinity River near Lewisville, Tex.	Lewisville gage	Elm Fork Trinity River	33.0457	-96.9611	1950	N/A
08055000 Denton Creek near Grapevine, Tex.	Denton Creek gage	Denton Creek	32.9871	-97.0128	1948	y=0.635x+1.35
08055500 Elm Fork Trinity River near Carrollton, Tex.	Carrollton gage	Elm Fork Trinity River	32.9660	-96.9445	1908	log10(daily) > 3.5: y=0.987x+0.141 log10(daily) < 3.5: y=0.829x+0.813
08057000 Trinity River at Dallas, Tex.	Dallas gage	Trinity River	32.7749	-96.8219	1904	y=1.006x+0.032
08061750 East Fork Trinity River near Forney, Tex.	Forney gage	East Fork Trinity River	32.7743	-96.5036	1973	y=0.796x+0.998
08062000 East Fork Trinity River near Crandall, Tex.	Crandall gage	East Fork Trinity River	32.6387	-96.4853	1950	log10(daily) > 4: y=1.088x-0.323 log10(daily) < 4: y=0.955x+0.231
08062500 Trinity River near Rosser, Tex.	Rosser gage	Trinity River	32.4265	-96.4630	1908	y=1.006x
08062700 Trinity River at Trinidad, Tex.	Trinidad gage	Trinity River	32.1477	-96.1025	1965	N/A
08063100 Richland Creek near Dawson, Tex.	Dawson gage	Richland Creek	31.9385	-96.6814	1961	y=1.026x
08063500 Richland Creek near Richland, Tex.	Richland gage	Richland Creek	31.9507	-96.4214	1939	y=1.024x
08063800 Waxahachie Creek near Bardwell, Tex.	Bardwell gage	Waxahachie Creek	32.2435	-96.6403	1964	N/A
08064100 Chambers Creek near Rice, Tex.	Rice gage	Chambers Creek	32.1985	-96.5203	1984	log10(daily) > 4: y=1.230x-0.856 log10(daily) < 4: y=0.926x+0.380
08064600 Richland Creek near Fairfield, Tex.	Fairfield gage	Richland Creek	31.9524	-96.0975	1973 (1981)	N/A
08065000 Trinity River near Oakwood, Tex.	Oakwood gage	Trinity River	31.6485	-95.7894	1890	N/A
08065500 Trinity River near Midway, Tex.	Midway gage	Trinity River	31.0746	-95.6994	1940 (1970)	N/A
08066000 Trinity River at Riverside, Tex.	Riverside gage	Trinity River	30.8594	-95.3988	1903 (1968)	N/A
08066500 Trinity River at Romayor, Tex.	Romayor gage	Trinity River	30.4252	-94.8508	1924	N/A

The peaking factor used for this study was developed using a log-log regression between USGS hourly and daily peak flows (Figure 25). The period of record analyzed for the peaking factor formulation was truncated to the period of record applicable to the regulated conditions present in the RiverWare model. For example, Figure 25 shows the peaking factor formulation for the Fort Worth West Fork streamgage. The analysis of hourly data as a function of the daily data was restricted to peaks after the impoundment of Benbrook Lake in 1952. In addition to filtering for regulated conditions, additional analysis ensured that USGS observed daily and hourly peaks occurred on the same date.

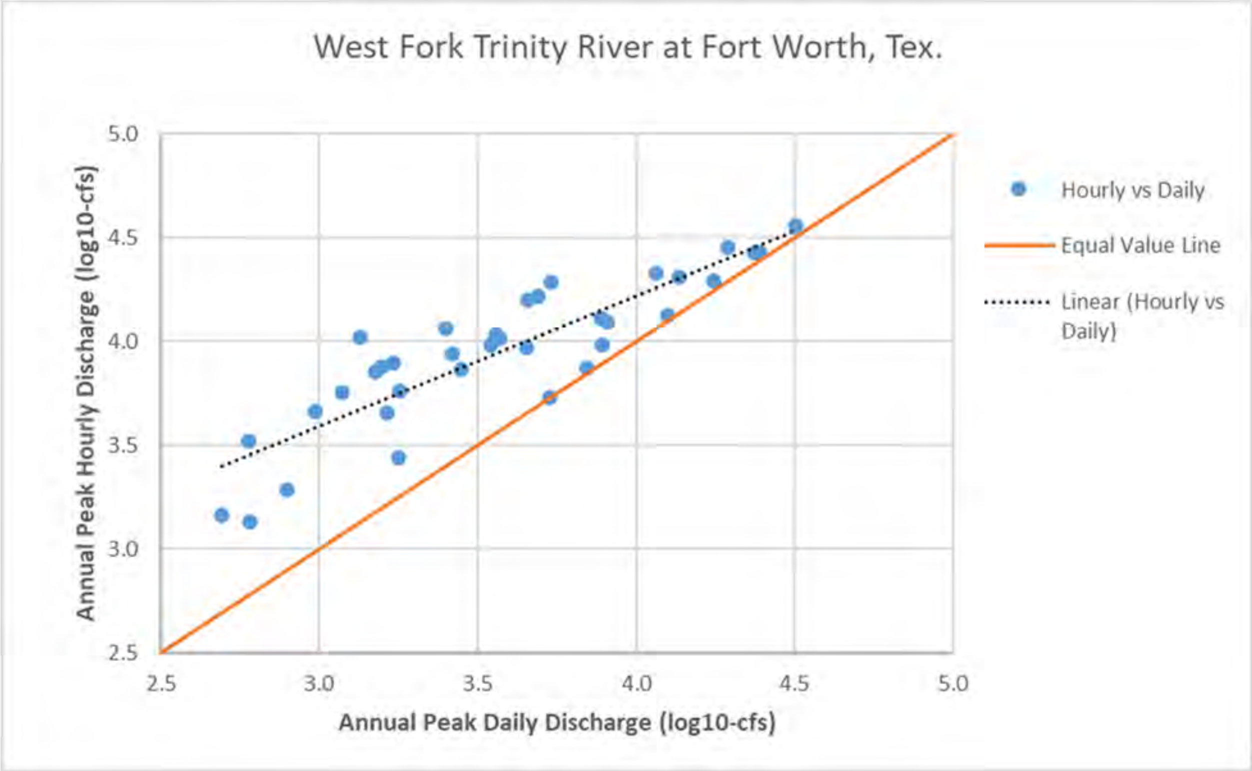

Figure 25: Plot of USGS hourly historic annual peak streamflow vs. daily historic annual peak streamflow for West Fork Trinity River at Fort Worth, Tex. The linear fit is plotted along with its formula, and an equal value line is plotted for reference.

At five of the analyzed gage locations (Fort Worth Clear Fork, Grand Prairie, Carrollton, Crandall, and Rice gages), a separate flow regime was observed in the upper end of the hourly vs. daily peak flow relationship, and two peaking factors were developed for lower and upper daily peak flows. For example, Figure 26 shows the two separate relationships observed for the Grand Prairie gage, and the two peaking factors derived from these separate relationships. The first peaking factor was applied to simulated daily peak flows less than 10,000 ft^3/s, whereas the second peaking factor was applied to simulated daily peak flows greater than 10,000 ft^3/s. The inflection point between these two peaking factors is unique to each gage. Please refer to Table 3 for the inflection point at each gage.The need for two peaking factors at several gage locations highlights a change in streamflow characteristics for the greatest magnitude events.

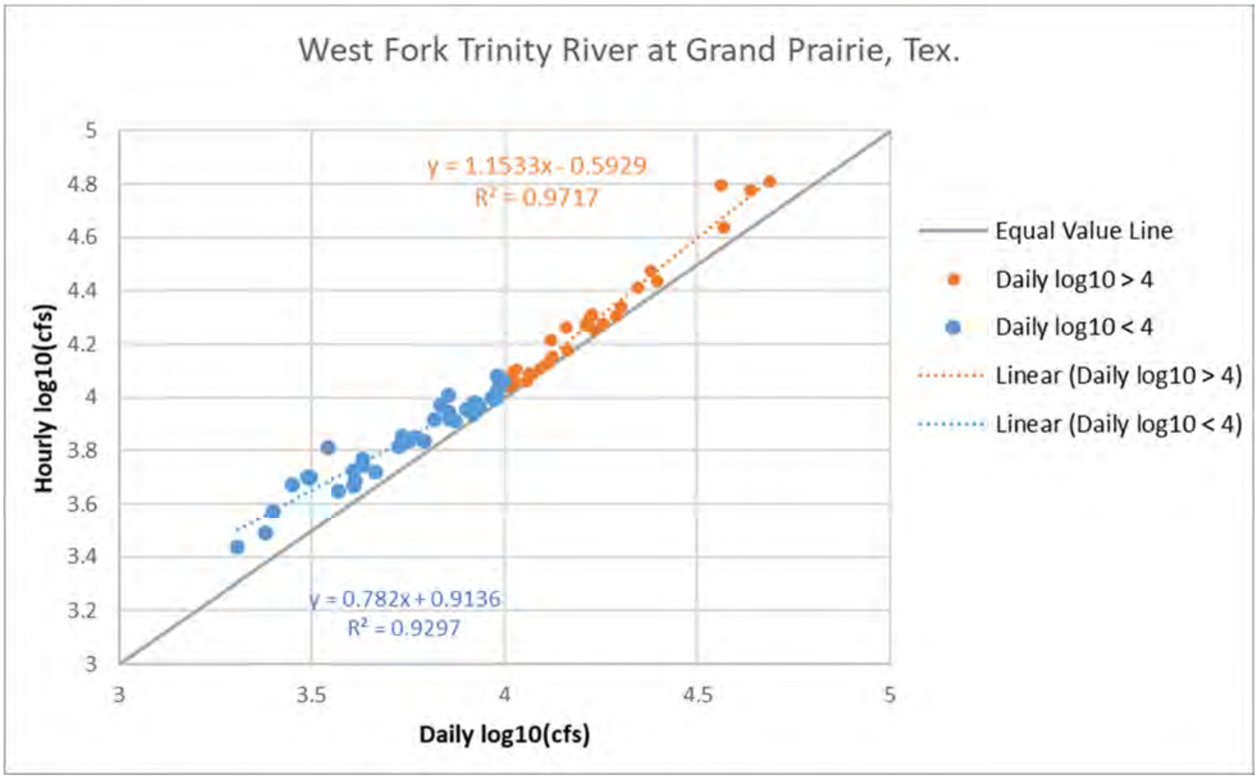

Figure 26: Plot of USGS hourly historic annual peak streamflow vs. daily historic annual peak streamflow for West Fork Trinity River at Grand Prairie, Tex. The two linear fit lines are plotted along with their formulae, and an equal value line is plotted for reference.

For four of the analyzed gages (Denton Creek, Forney, Dawson, and Bardwell gages), regulation rulesets in RiverWare were deemed too strict for real-world conditions. Peak streamflow output from the model was highly regulated, resulting in several “steps” of regulated peaks, which did not provide adequate information for a comparison to the historic frequency analysis. Because RiverWare was designed as a reservoir operations model and not a hydraulic model, it is designed to follow a strict set of rules for reservoir operations that may not reflect the more nuanced and complex approach reservoir operators follow for releases. As a result, streamflows, and consequently peak stream flows, downstream of reservoir or control point objects in RiverWare will be more uniform than in reality and more optimistic in a control structure’s ability to regulate extreme events. Therefore, RiverWare simulated peak streamflow frequency curves can be expected to provide lower estimates than the historic analysis presented in the Statistical Hydrology Appendix in general. Though this may be perceived as a failure of the model, and in fact it has been deemed so in several gage locations, the simulated results may still provide valuable information for frequency analyses in the Trinity basin. Not all the gages show these increased effects of regulation and provide peak streamflow estimates similar to those observed in the historic record. In addition, the RiverWare results may be seen as lower bounds to exceedance probabilities in the basin because they represent the best-case, ideally regulated scenario for peak streamflows in the basin.

The USGS (England et al., 2018) (Bulletin 17C) provides guidance for computation of peak streamflow frequency. The Bulletin 17C methodology is already implemented in USACE HEC-SSP software (Version 2.1.1; USACE, 2017). Bulletin 17C incorporates the expected moments algorithm (EMA), which allows for the incorporation of more complicated or subjective measurements such as paleo-hydrology, interval peaks, and sophisticated gap-infill for years of missing annual peak streamflow records. EMA also include mathematically rigorous computation of uncertainty bounds based on implicit recognition that the skew coefficient is itself uncertain. This was not a feature of Bulletin 17B.

The 17C analysis also advised on use of the multiple Grubbs-Beck low outlier test, which is capable of identifying many potentially influencing low floods (PILFs). The multiple Grubbs-Beck test is a substantial improvement on the single Grubbs-Beck test used in Bulletin 17B (Grubbs & Beck, 1972). The presence of low outliers is endemic in Texas flood hydrology (Asquith et al., 1995). Low outliers within a time series of peak streamflow are anticipated to be too small to be representative of large rainfall and runoff events. The multiple Grubbs-Beck test (MGBT), which is available in the aforementioned USACE software package, is suitable for Texas hydrology. In the statistical computations, low outliers are conditionally truncated, but not removed, from the sample. Overall improved fit of the LPIII distribution in the right or high magnitude tail of the fitted distribution is achieved by low outlier detection.

Peak streamflow analyses for this study were made using the HEC-SSP software (USACE, 2016). The HEC-SSP software uses the three-parameter, log-Pearson type III (LPIII) probability distribution, and the use of this distribution represents a type of standard of practice in the United States and is consistent between Bulletins 17B and 17C. The first and second parameters of the LPIII are the arithmetic mean and standard deviation, and the third parameter of the LPIII is skew. For the estimate of skew, the sample skew computed for the data at each streamgage location was used by HEC-SSP using the “station skew” option. This skew option was selected because there exists no definitive replacement for the generalized skew for the circumstances of analyses described in this chapter. With select exceptions, the station skew option was used throughout the analyses. Unless otherwise noted in Table 4, the period of record available for the streamgages was deemed sufficient enough not to raise concerns on general reliability of the statistical computations themselves.

Table 4: USGS NWIS station number and name, abbreviated name in report, regional skew (unitless), regional skew mean square error (MSE – unitless), and HEC-SSP adopted skew for the gages not using the station skew option.

Station number and name	Name in report	Regional Skew	Regional Skew MSE	HEC-SSP Adopted Skew
08047000 Clear Fork Trinity River near Benbrook, Tex.	Benbrook gage	0.100	0.40	-0.201
08062000 East Fork Trinity River near Crandall, Tex.	Crandall gage	0.000	0.40	-0.363

After an analysis of the data listed in Table 4, it was determined that the station skew did not adequately fit the greatest simulated peak streamflow events on record. Highly truncated periods of record because of higher low-outlier thresholds (such as that seen in the Crandall streamgage data) or data heavily influenced by regulation (such as that seen in the Benbrook streamgage data) required the station skew value calculated by HEC-SSP to be weighted by a regional skew to account for this limited information on natural peak flows at the gages. Regional skew values shown by Judd et al. (1996) were used to fit the simulated data, although these values should be taken with some uncertainty because of the use of simulated instead of historic peak streamflow data for most of the streamgages listed in Table 4. The weighted regional skew option was applied to both the simulated hourly and daily peak flow data at each of the RiverWare gages listed in Table 4.

08047000 Clear Fork Trinity River near Benbrook, Tex.

The simulated streamgage record for the Benbrook streamgage is 1940–2015. The 1990 simulated hourly peak streamflow was 8,209 cubic feet per second (ft^3/s), which is the simulated peak of record. Figure 27a shows the peak streamflow data for the simulated and historic data as well as the impoundment of Benbrook Lake. The Benbrook streamgage is located several miles downstream of Benbrook Lake, a flood control and water conservation reservoir. Construction on the lake began in 1947 and impoundment began in 1952, which had a noticeable influence on historic flows at the Benbrook streamgage (Figure 27a). The RiverWare model simulates the operations of Benbrook Lake throughout the entire simulated period of record, so pre-regulation flows are not observed in the simulated data.

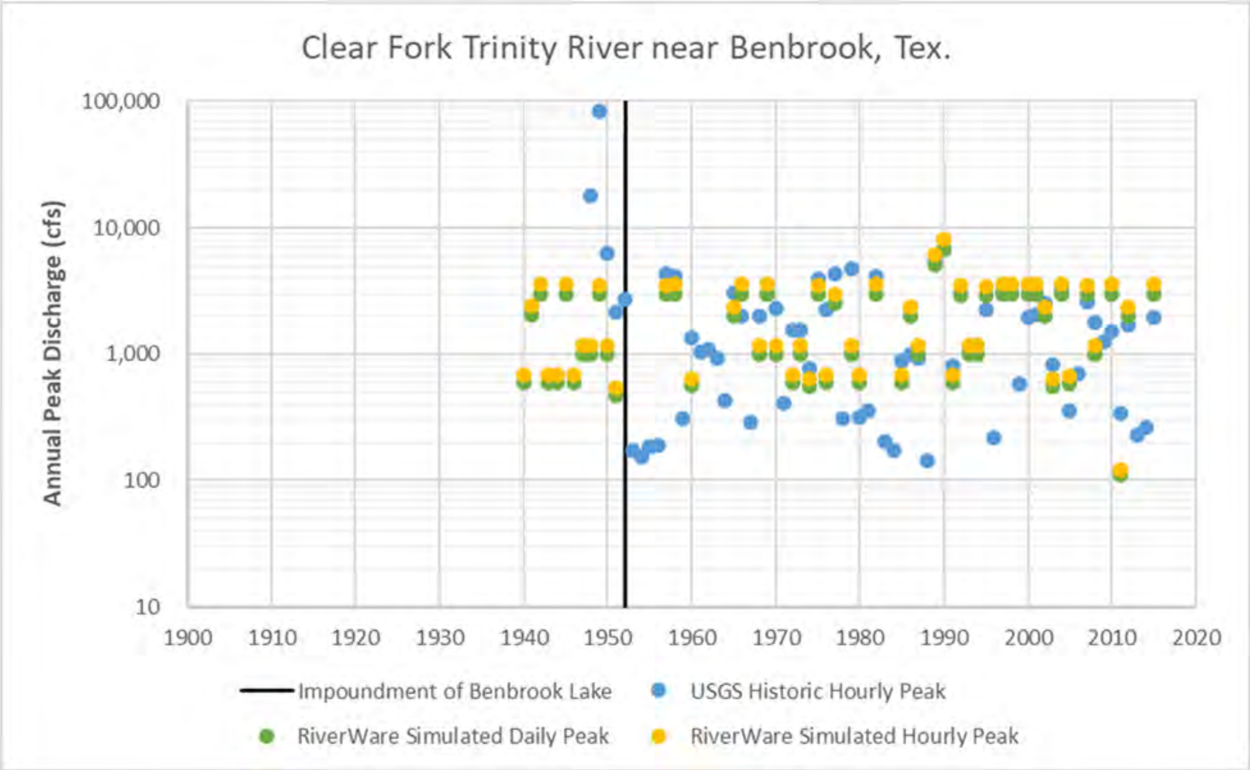

Figure 27a: USGS historic hourly peak streamflows, RiverWare simulated daily peak streamflows, and RiverWare simulated hourly peak streamflow data for the streamgage 08047000 Clear Fork Trinity River near Benbrook, Tex. The impoundment of Benbrook Lake is also demarcated on the plot.

The LPIII computed peak streamflow frequency curve for the Benbrook streamgage simulated hourly data is shown in Figure 27b. The MGBT-computed low-outlier threshold for the Benbrook gage is 1,059 ft^3/s. The evidence of simulated RiverWare regulation is apparent in the data, with four distinct “steps” in the ordered peaks. After removing low-outliers, only three peaks exist outside of these “steps.” Despite the influence of self-evident regulation on the peak streamflow data, the LPIII computed distribution provides a relatively close fit to the data, matching the trend of the regulation “steps" and the two highest peak streamflow events.

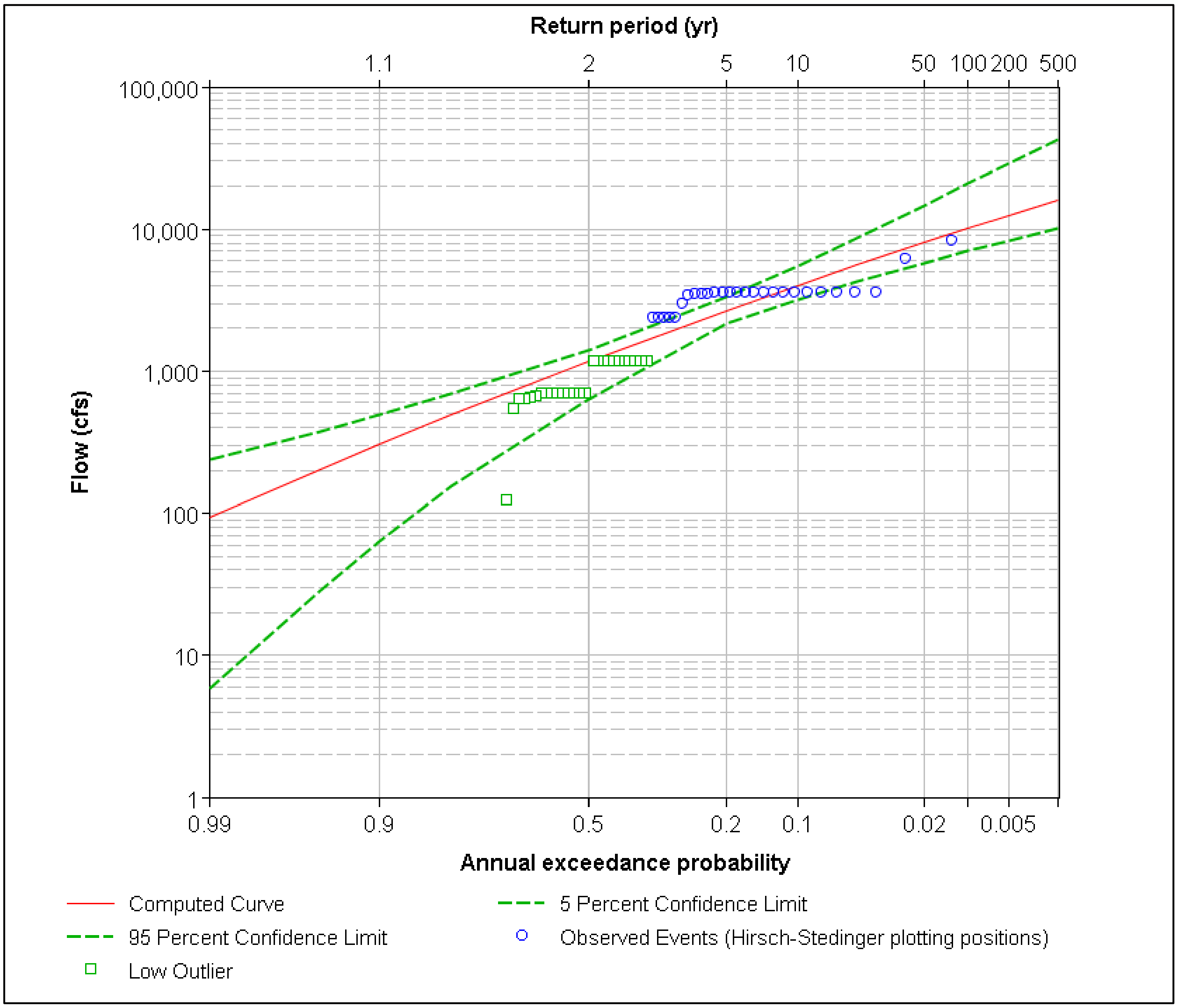

Figure 27b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08047000 Clear Fork Trinity River near Benbrook, Tex. hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 27c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Benbrook streamgage. Because the peaking factor adjustment to the daily data was minor, the difference between the hourly and daily simulated fitted frequency curves are deemed minor as well. The historic fitted frequency curve shows a slightly greater negative skew, providing lower peak flow estimates for the lowest AEP range than the simulated fitted frequency curve.

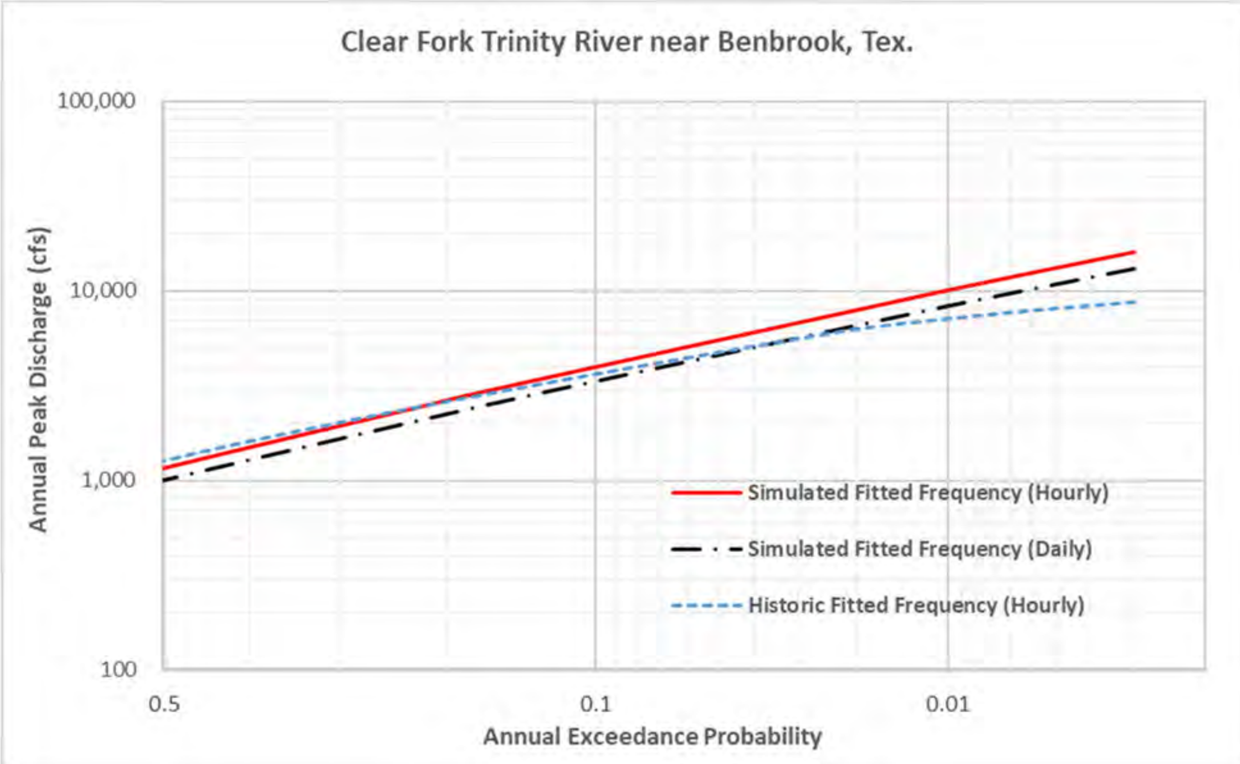

Figure 27c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08047000 Clear Fork Trinity River near Benbrook, Tex.

08047500 Clear Fork Trinity River at Fort Worth, Tex.

The simulated streamgage record for the Fort Worth Clear Fork streamgage is 1940–2015. The 1990 hourly peak streamflow for the regulated data was 25,376 ft^3/s, which is the simulated peak of record. Figure 28a shows the peak streamflow data for the simulated and historic data as well as the impoundment of Benbrook Lake. The effects of Benbrook Lake on the data for the Fort Worth Clear Fork streamgage is not as self-evident as for the Benbrook streamgage. Logic dictates that this is because of other tributaries such as Marys Creek joining the Clear Fork with unregulated, intervening drainages.

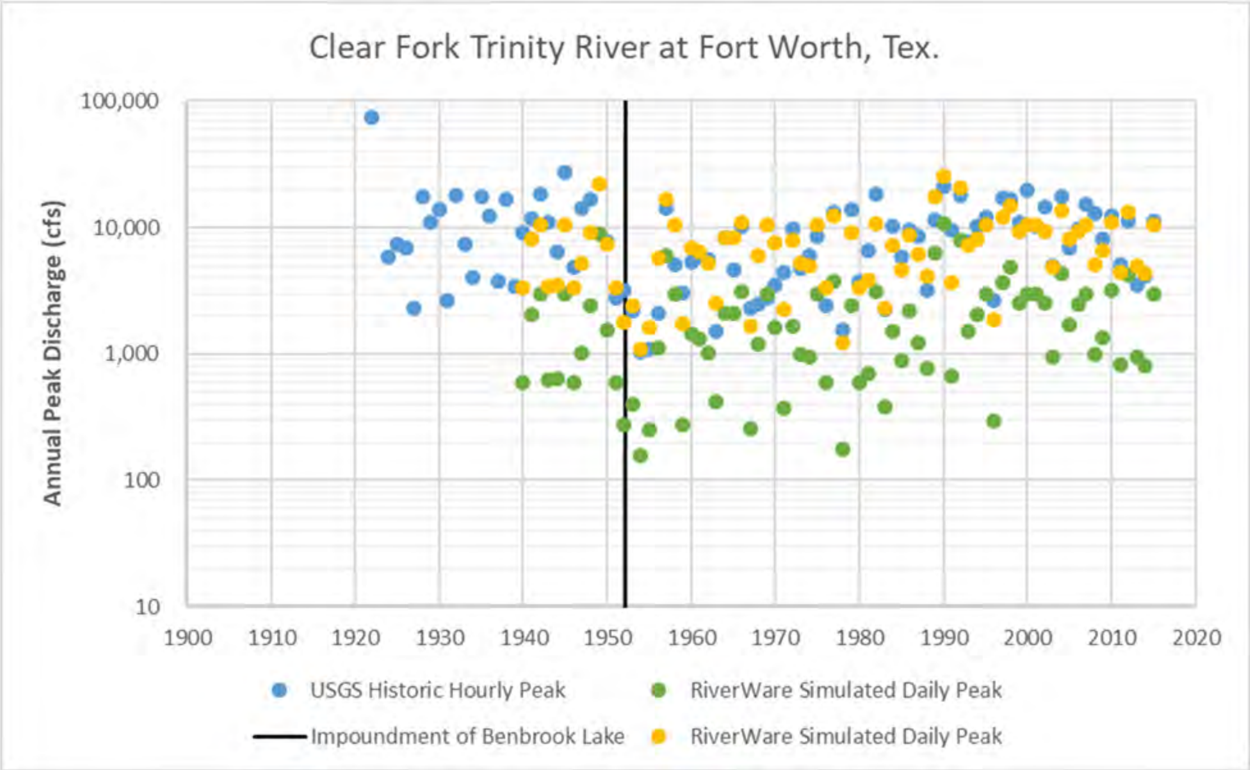

Figure 28a: USGS historic hourly peak streamflows, RiverWare simulated daily peak streamflows, and RiverWare simulated hourly peak streamflow data for streamgage 08047500 Clear Fork Trinity River at Fort Worth, Tex. The impoundment of Benbrook Lake is also demarcated on the plot.

The LPIII computed peak streamflow frequency curve for the Fort Worth Clear Fork streamgage simulated hourly data is shown in Figure 28b. The MGBT-computed low-outlier threshold was 3,367 ft^3/s. Some evidence of regulated reservoir releases in RiverWare is seen in a “step” of identical peak streamflow at approximately 10,000 ft^3/s. However, regulation is not clearly seen as for the Benbrook streamgage upstream, most likely attributable to the reasons mentioned in the previous paragraph.

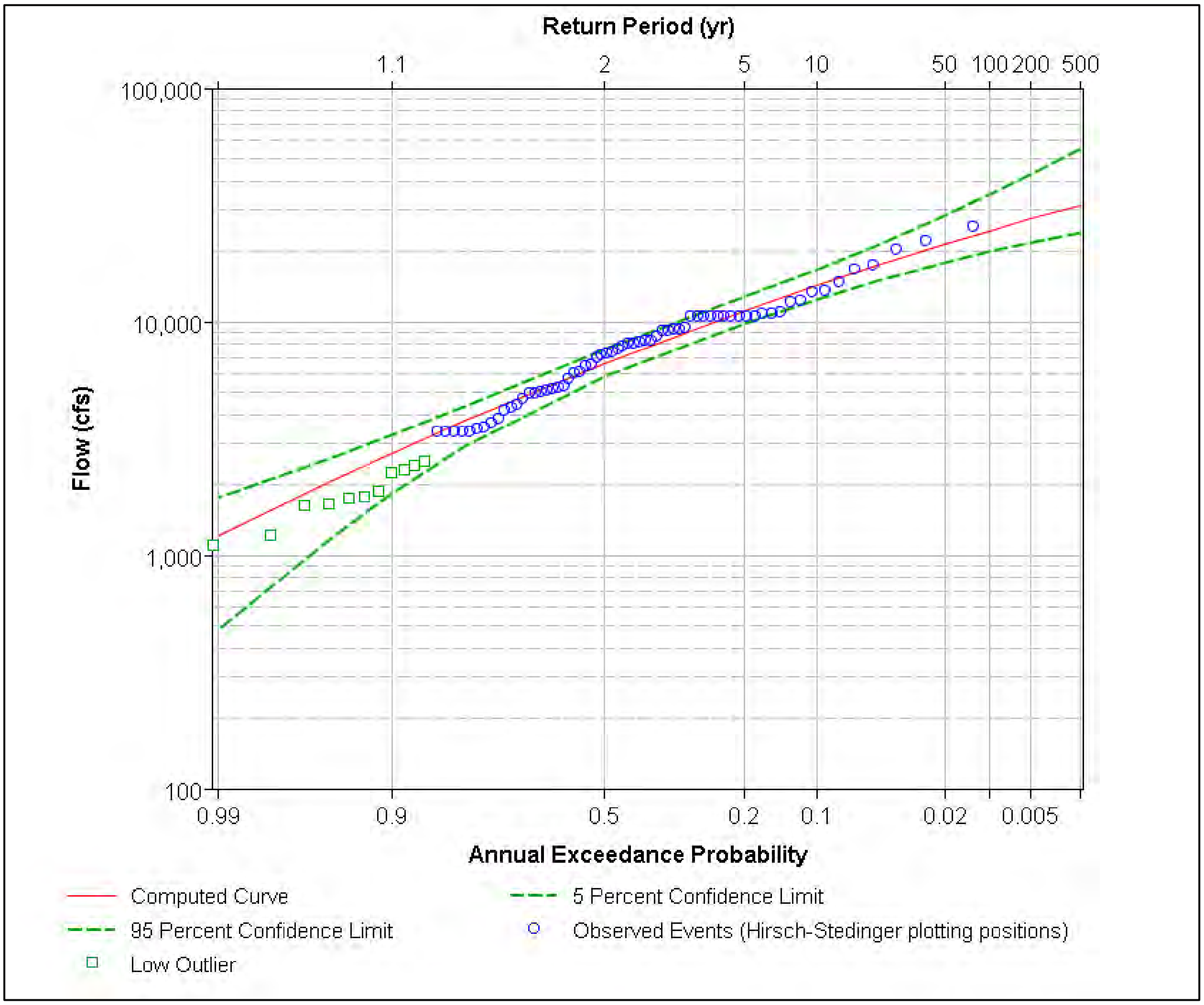

Figure 28b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08047500 Clear Fork Trinity River at Fort Worth, Tex. hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 28c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Fort Worth Clear Fork streamgage. The figure shows a marked difference between the daily and hourly simulated fitted frequency curves, which is a result of the flashy nature of this stretch of the Clear Fork of the Trinity River. The historic fitted frequency curve shows a slightly greater negative skew, providing lower peak flow estimates for the lowest AEP range than the simulated fitted frequency curve.

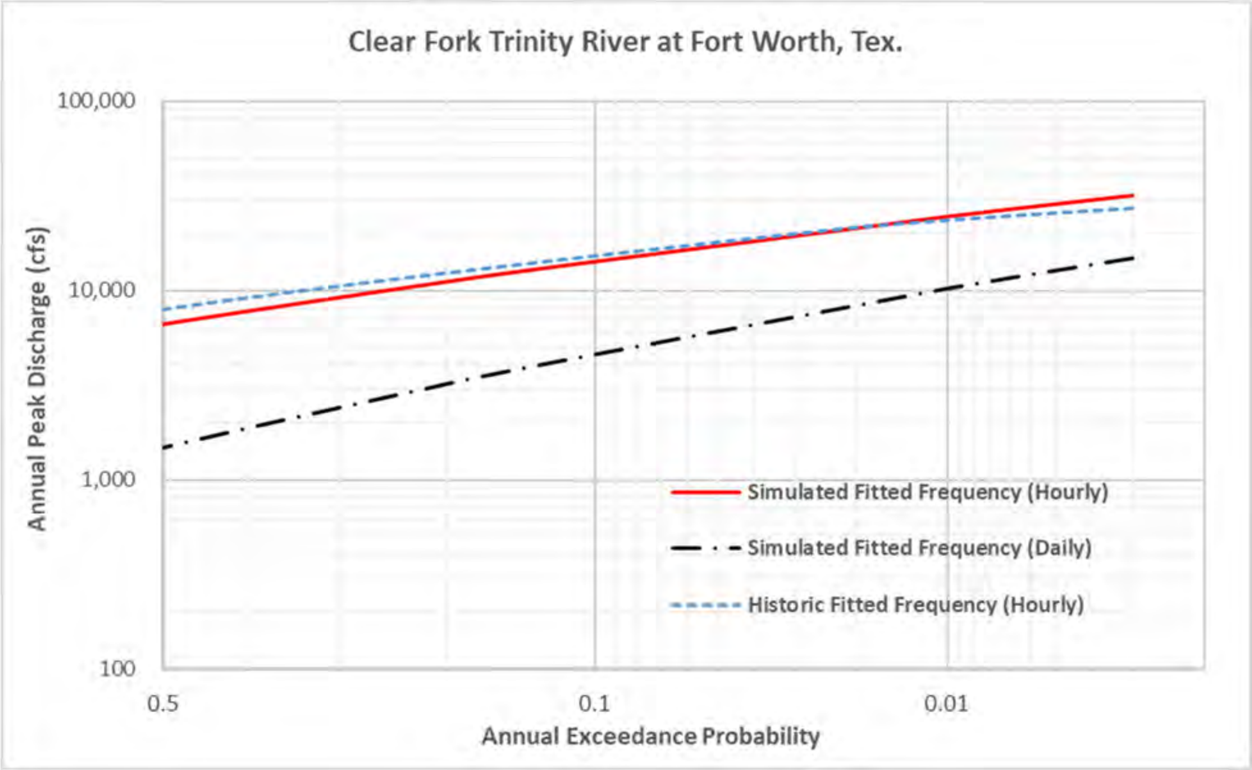

Figure 28c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08047500 Clear Fork Trinity River at Fort Worth, Tex.

08048000 West Fork Trinity River at Fort Worth, Tex.

The simulated streamflow record for the Fort Worth West Fork streamgage is 1940–2015. The 1999 peak streamflow for the simulated hourly data was 30,740 ft³/s, which is the simulated peak of record. Figure 29a shows the peak streamflow data for the simulated and historic data as well as the impoundment of Benbrook Lake, which appears to have a mitigating effect on the historic data by restricting flows to below 40,000 ft³/s.

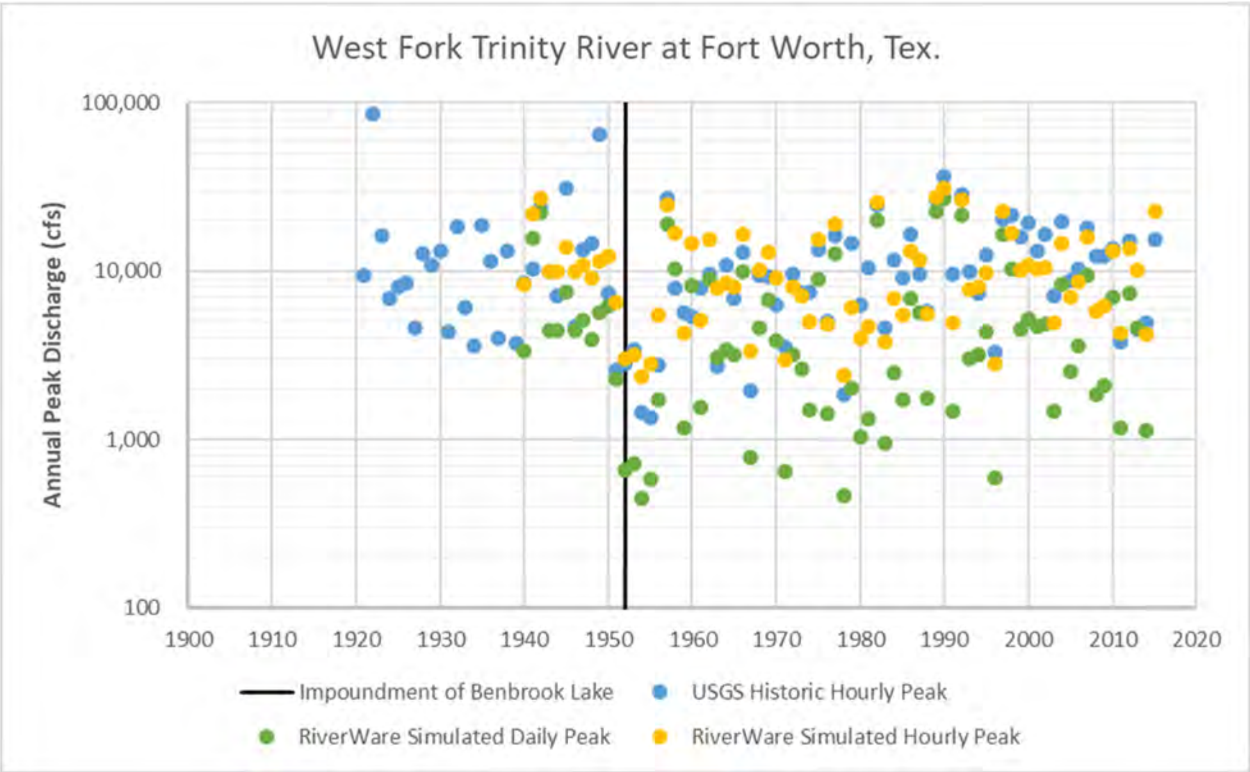

Figure 29a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08048000 West Fork Trinity River at Fort Worth, Tex. The impoundment of Benbrook Lake is also demarcated on the plot.

The LPIII computed peak streamflow frequency curve for the Fort Worth West Fork streamgage simulated hourly data is shown in Figure 29b. No low-outlier threshold was set because of the gradual decline in peak streamflow in the higher AEP range. There is a shift in the ordered peaks near 11,000 ft³/s, and the peaks also appear to plateau around 13,000 ft³/s. However, the fitted curve is nearly linear with only a slight negative skew.

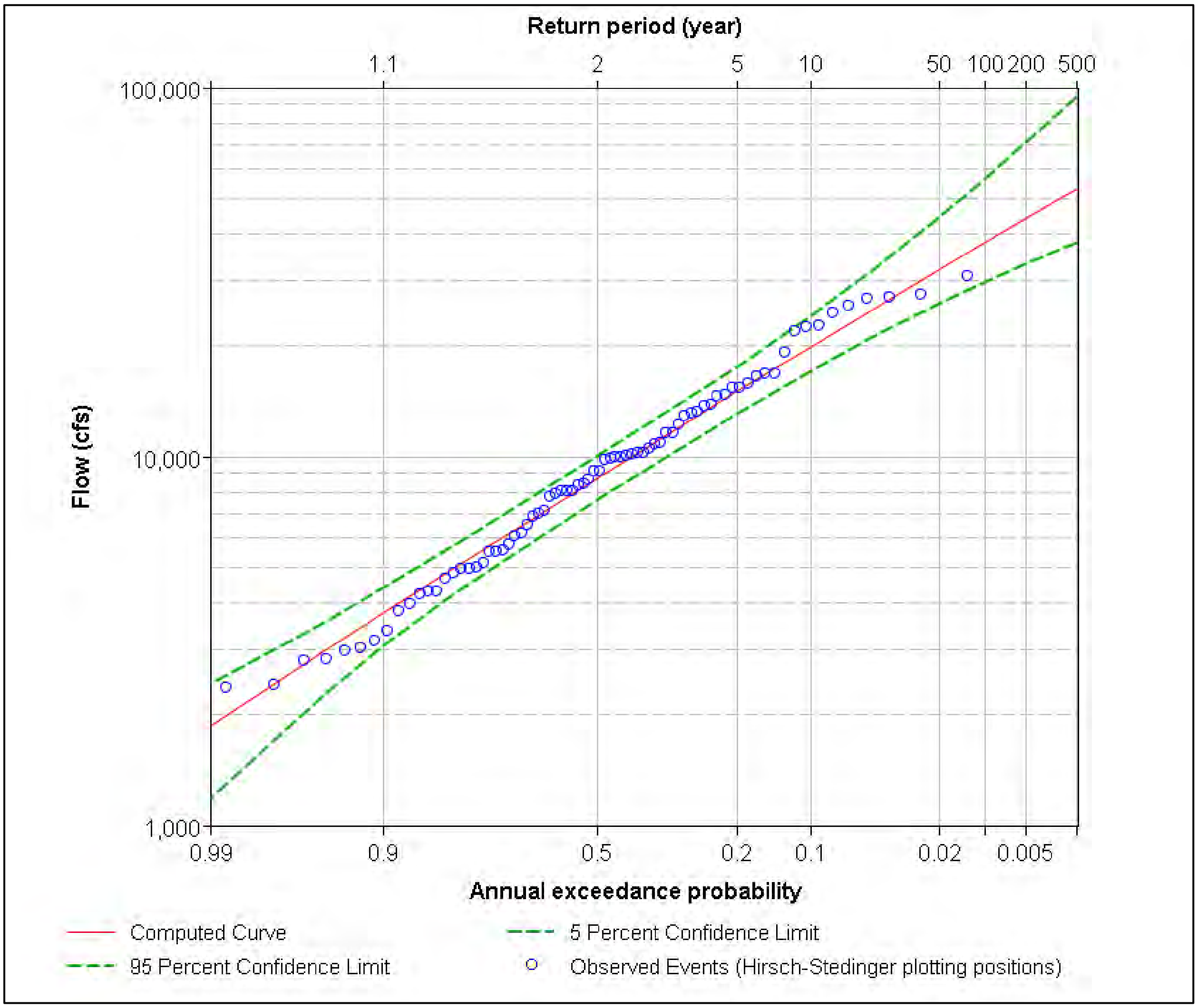

Figure 29b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08048000 West Fork Trinity River at Fort Worth, Tex. hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 29c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Fort Worth West Fork streamgage. The peaking factor has a measured impact on peak flows at the gage, creating a curve much flatter than the simulated daily and historic hourly fitted frequency curves. However, in the probability range of increased importance above 0.1 AEP (10-year event), the difference between the fitted frequency curves lessens.

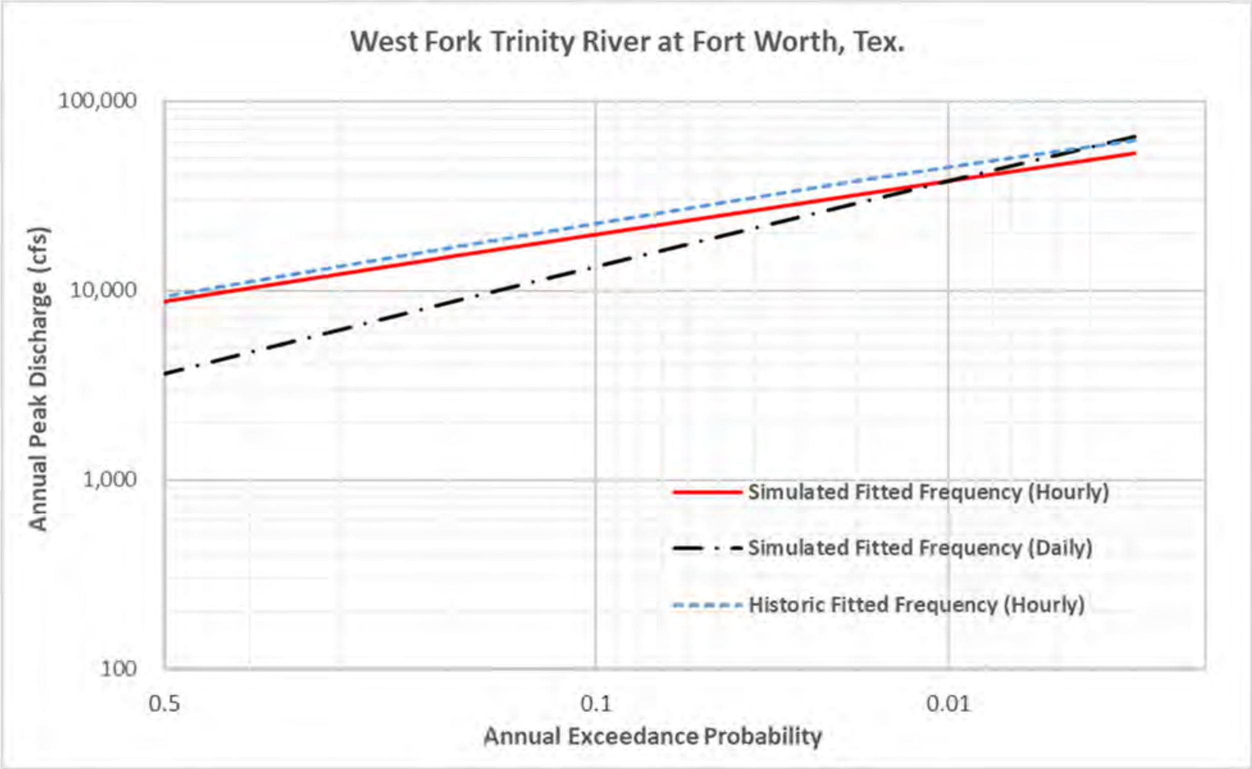

Figure 29c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08048000 West Fork Trinity River at Fort Worth, Tex.

08049500 West Fork Trinity River at Grand Prairie, Tex.

The simulated streamflow record for the Grand Prairie streamgage is 1940–2015. The 1957 peak streamflow for the simulated hourly data was 59,097 ft^3/s, which is the simulated peak of record. Figure 30a shows the peak streamflow data for the simulated and historic data. The Grand Prairie streamgage is not proximal to any major flood control reservoirs, and peak flows occasionally surpass 50,000 ft^3/s. However, as a result of regulation in RiverWare, simulated peak flows fail to match the greatest events observed in the historic data, which may cause a decrease in the simulated fitted frequency curve from the historic curve.

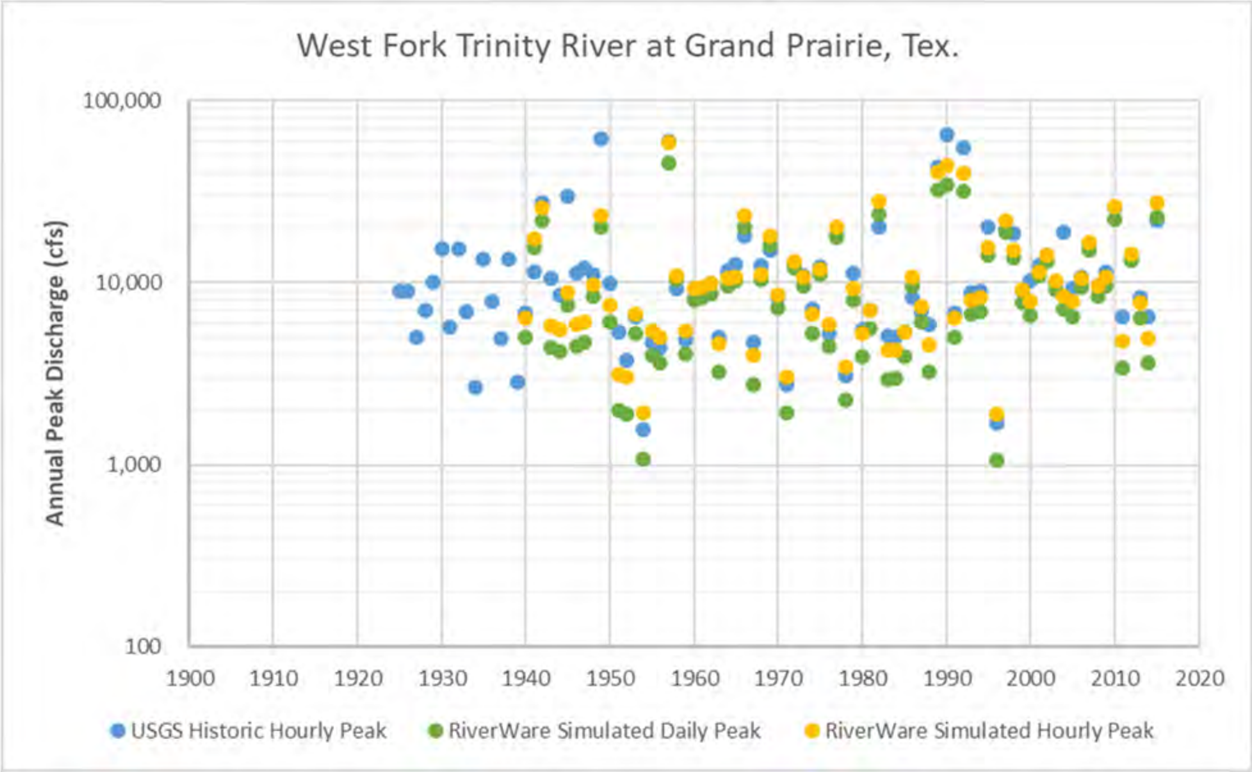

Figure 30a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08049500 West Fork Trinity River at Grand Prairie, Tex.

The LPIII computed peak streamflow frequency curve for the Grand Prairie streamgage simulated hourly data is shown in Figure 30b. A low-outlier threshold of 3,000 ft^3/s was manually set. The ordered events for the Grand Prairie streamgage form a generally smooth ordered trend, with no major shifts or skew in the data.

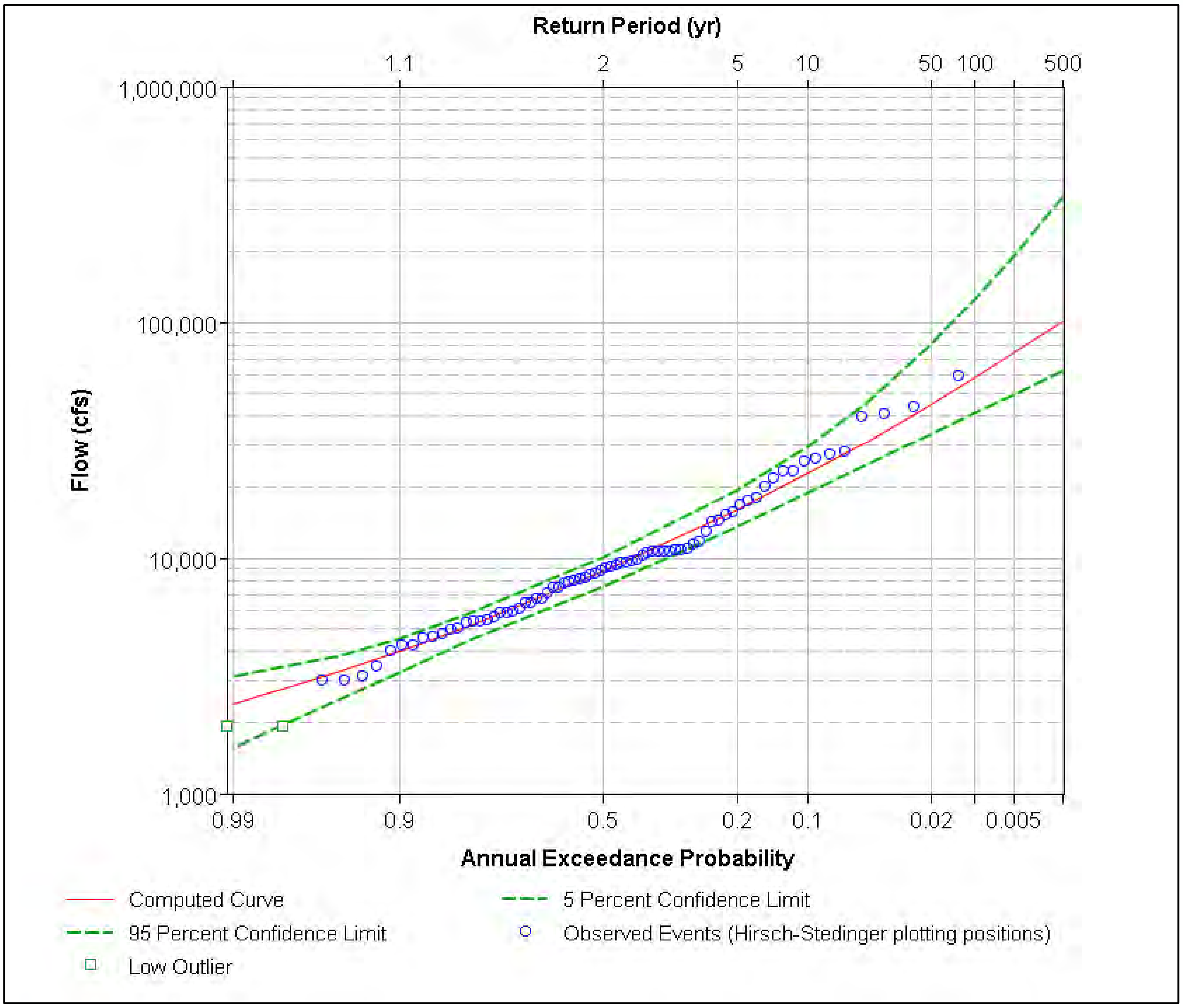

Figure 30b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08049500 West Fork Trinity River at Grand Prairie, Tex. streamgage hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 30c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Grand Prairie streamgage. The differences between the three fitted frequency distributions are nearly identical, with the historic fitted frequency curve plotting only slightly above the hourly simulated fitted curve.

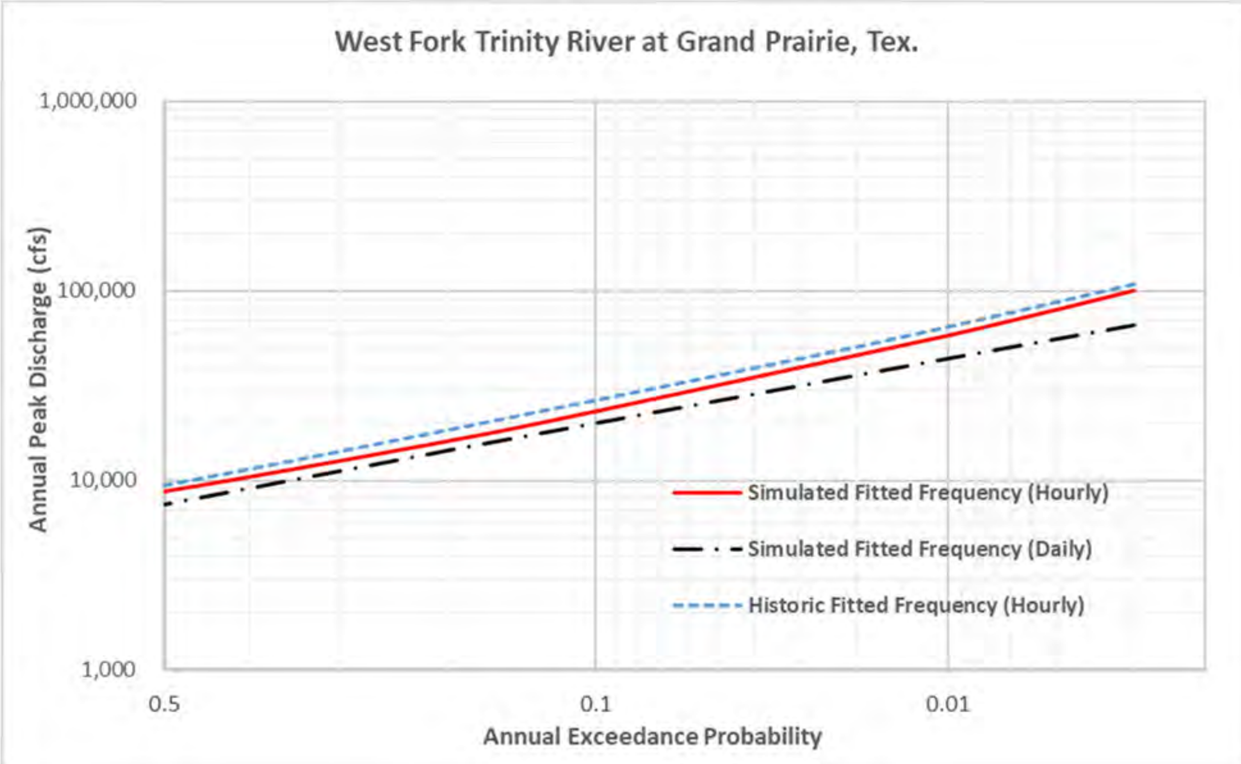

Figure 30c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08049500 West Fork Trinity River at Grand Prairie, Tex.

08050100 Mountain Creek at Grand Prairie, Tex.

The simulated streamflow record for the Mountain Creek streamgage is 1940–2015. The 1989 peak streamflow for the simulated hourly data was 16,388 ft³/s, which is the simulated peak of record. Figure 31a shows the peak streamflow data for the simulated and historic data along with the impoundment of Joe Pool (1986) and Mountain Creek (1937) Reservoirs. The USGS streamgage was constructed after the impoundment of Mountain Creek Reservoir, but the influence of Joe Pool Reservoir is seen in the capping of flows at 20,000 ft³/s.

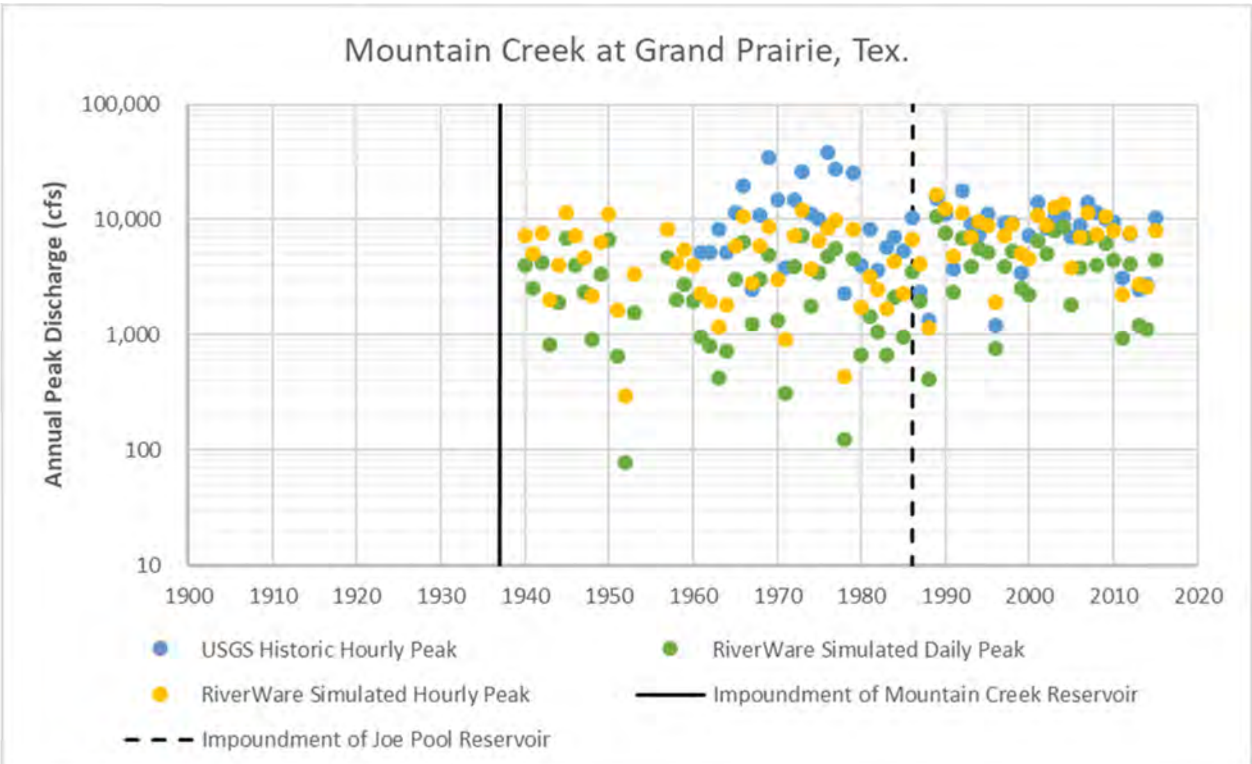

Figure 31a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08050100 Mountain Creek at Grand Prairie, Tex.

The LPIII computed peak streamflow frequency curve for the Mountain Creek streamgage simulated hourly data is shown in Figure 31b. A low-outlier threshold of 1,500 ft³/s was manually set. The peak streamflow frequency curve for the Mountain Creek streamgage has a very high negative skew nearly approaching a horizontal asymptote, possibly the result of Mountain Creek Lake effectively mitigating floods on Mountain Creek.

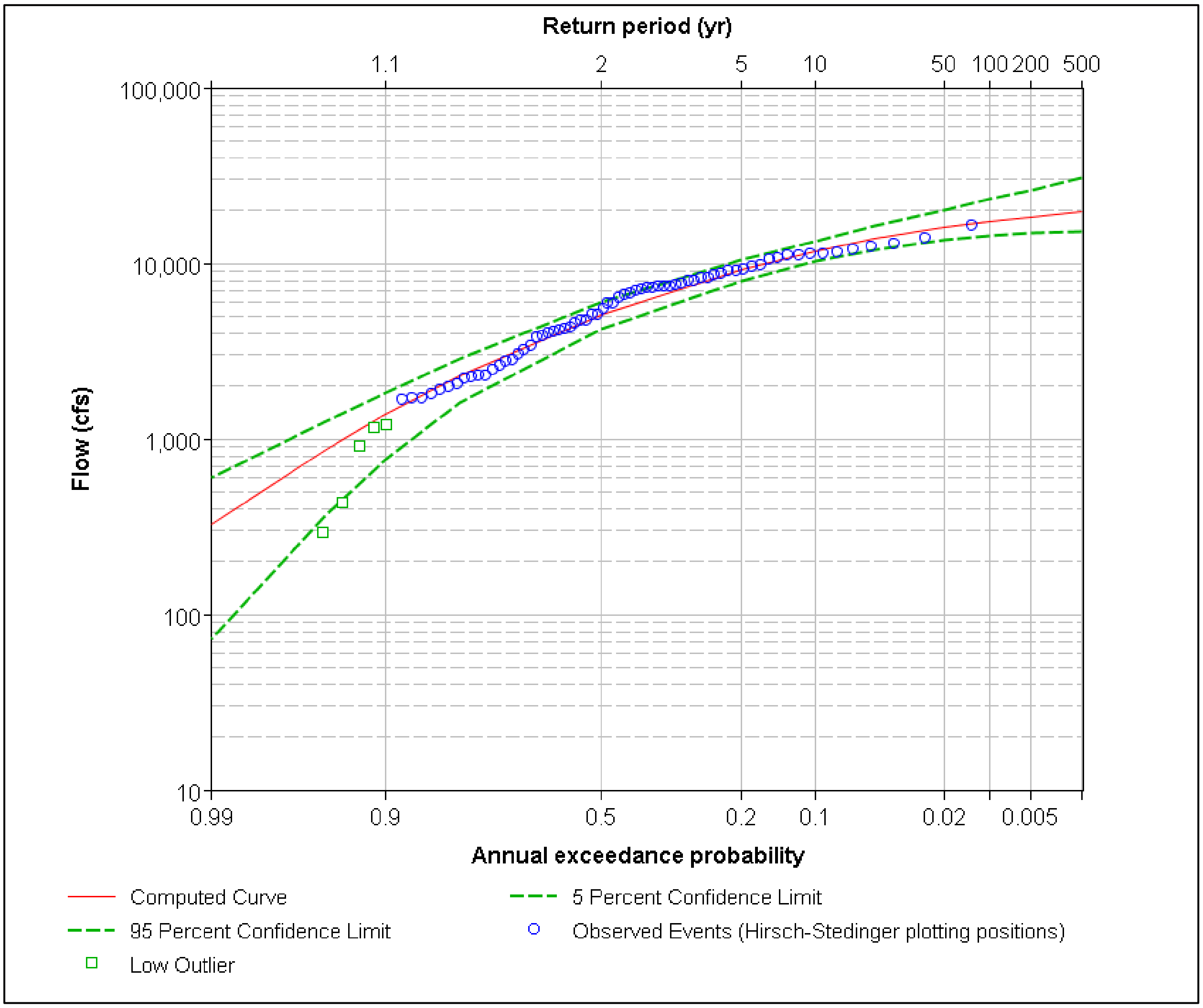

Figure 31b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08050100 Mountain Creek at Grand Prairie, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 30c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Mountain Creek streamgage. Mountain Creek is a tributary of the Trinity River, which means that it is a smaller stream more susceptible to flash flooding. The flashy nature of Mountain Creek is observed in the difference between the simulated daily and hourly fitted frequency curves. The historic fitted frequency curve shows a smaller negative skew, and the simulated and historic fitted frequency curves reach their closest point near 0.01 AEP (100-year return interval) but then begin to diverge slightly in the right-hand tail of the distribution.

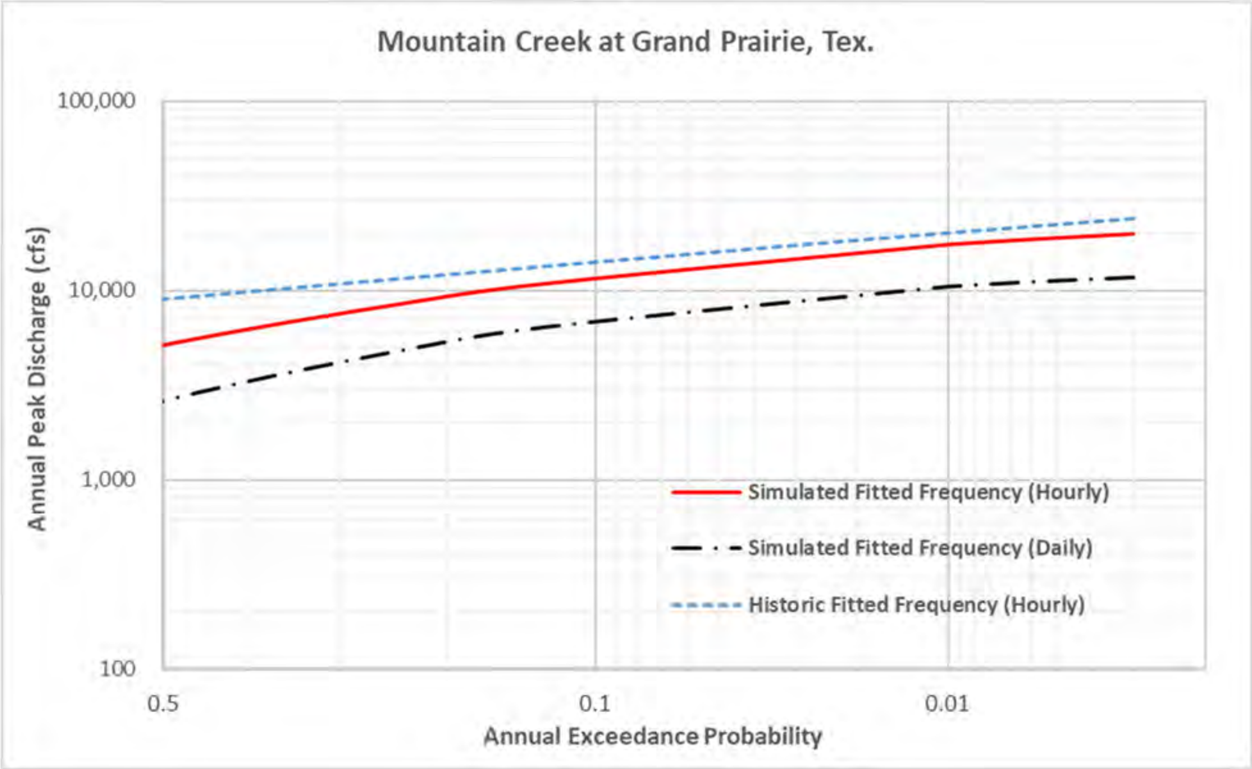

Figure 30c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08050100 Mountain Creek at Grand Prairie, Tex.

08053000 Elm Fork Trinity River near Lewisville, Tex.

The simulated streamflow record for the Lewisville streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 23,774 ft^3/s, which is the simulated peak of record. No peaking factor was applied to the Lewisville streamgage data, so daily peak flows are equated to hourly, or instantaneous, peak flows. This means that peak flows at the Lewisville streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. Figure 31a shows the peak streamflow data for the simulated and historic data along with the impoundment of Lewisville Lake in 1955. Only five years of historic data exist before the construction of Lewisville Lake, so it is unclear what impact it has had on flows at the Lewisville streamgage. Even though the simulated data plots close to the historic data, it misses a couple of the historic peaks and has a much smaller spread than the historic dataset, which is indicative of a simple ruleset in RiverWare not matching more complex operations in reality.

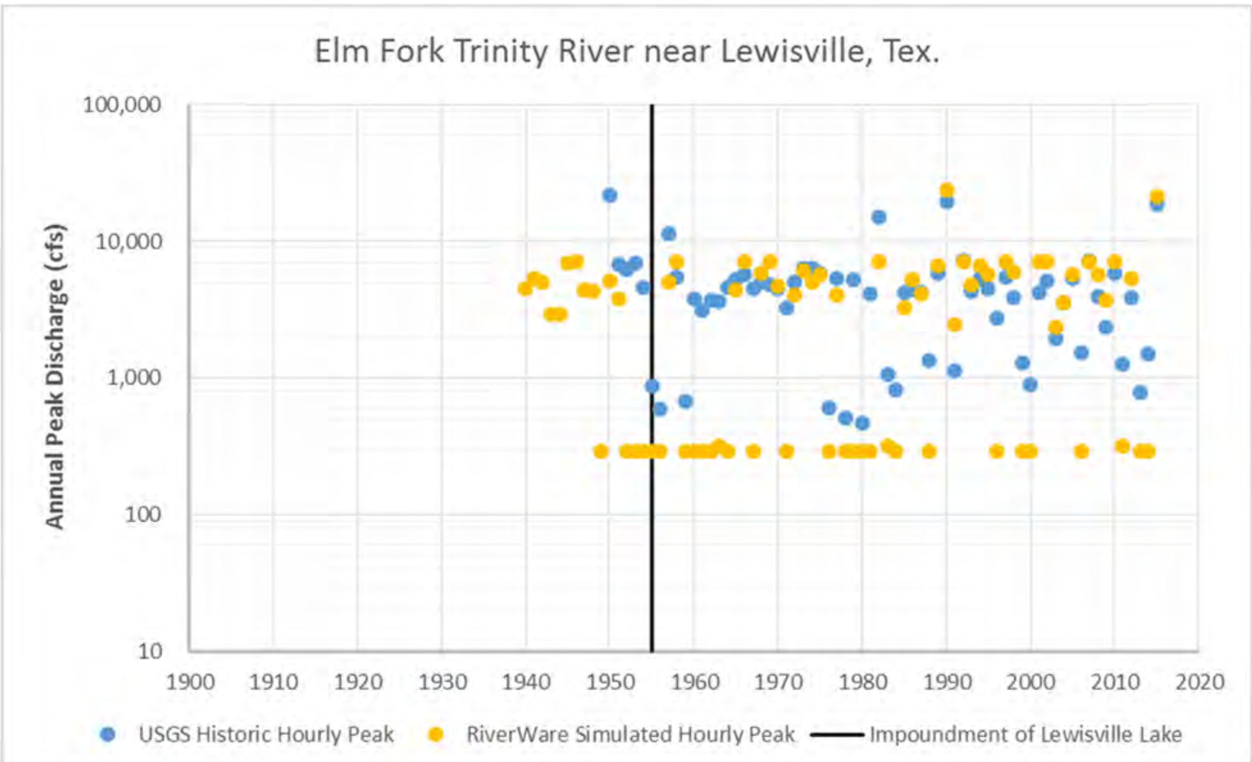

Figure 31a: USGS historic hourly peak streamflows and RiverWare hourly streamflow flow data for streamgage 08053000 Elm Fork Trinity River near Lewisville, Tex.

The LPIII computed peak streamflow frequency curve for the Lewisville streamgage simulated hourly data is shown in Figure 31b. The MGBT-computed low-outlier threshold for the Lewisville gage is 2,910 ft^3/s. Fitting a curve to the Lewisville streamgage ordered events proves difficult, with a data heavily influenced by regulation and the two greatest events incongruous with the remainder of the data.

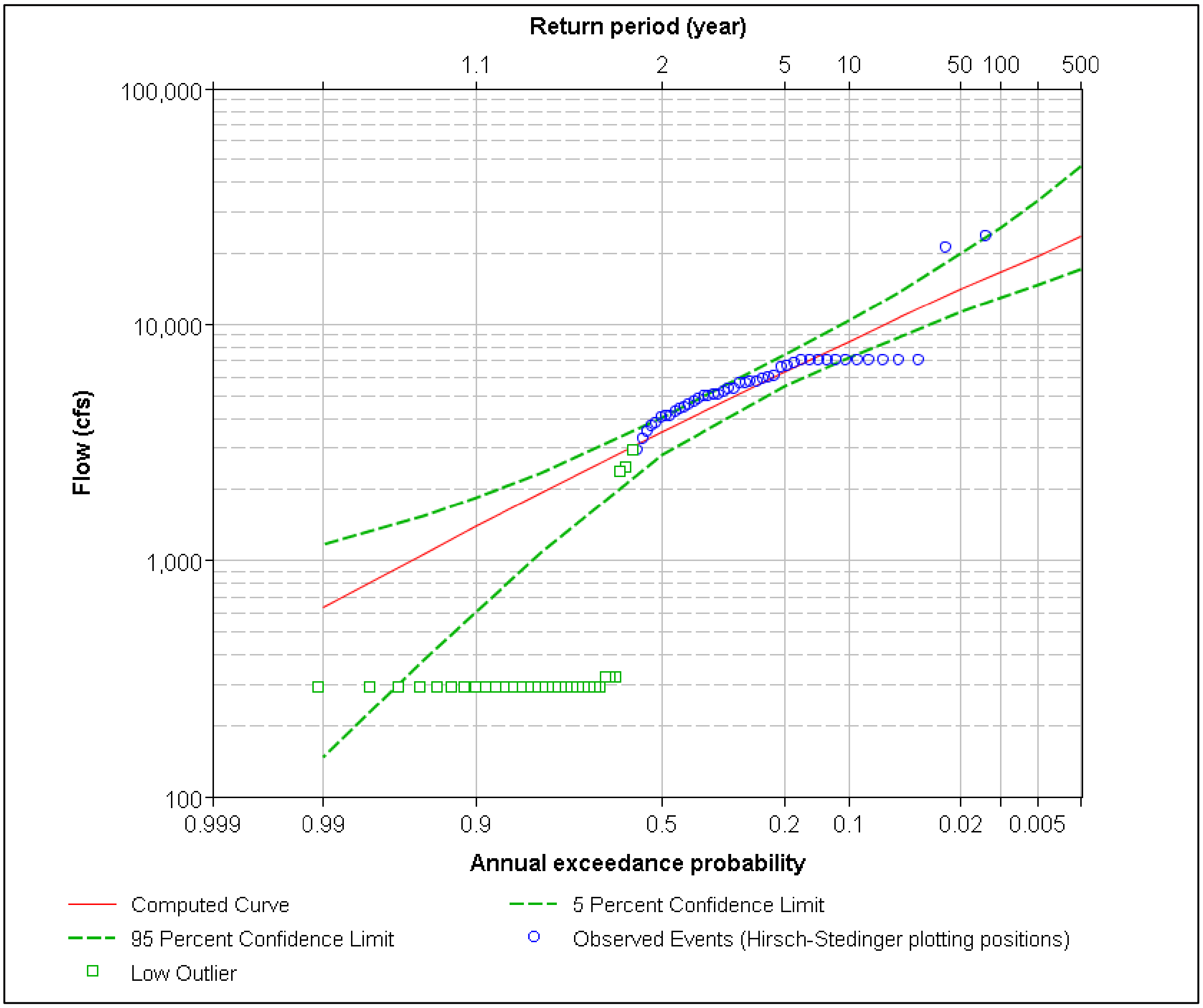

Figure 31b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08053000 Elm Fork Trinity River near Lewisville, Tex. streamgage hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 31c compares the LPIII computed peak streamflow frequency curves for the simulated hourly and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Lewisville streamgage. No daily simulated fitted frequency curve is plotted for the Lewisville streamgage because a peaking factor was not applied to the simulated data. Both the historic and simulated data are comprised almost entirely of regulated peak streamflow data and the differences between the two resulting fitted frequency curves are small, despite the poor fit to the simulated data.

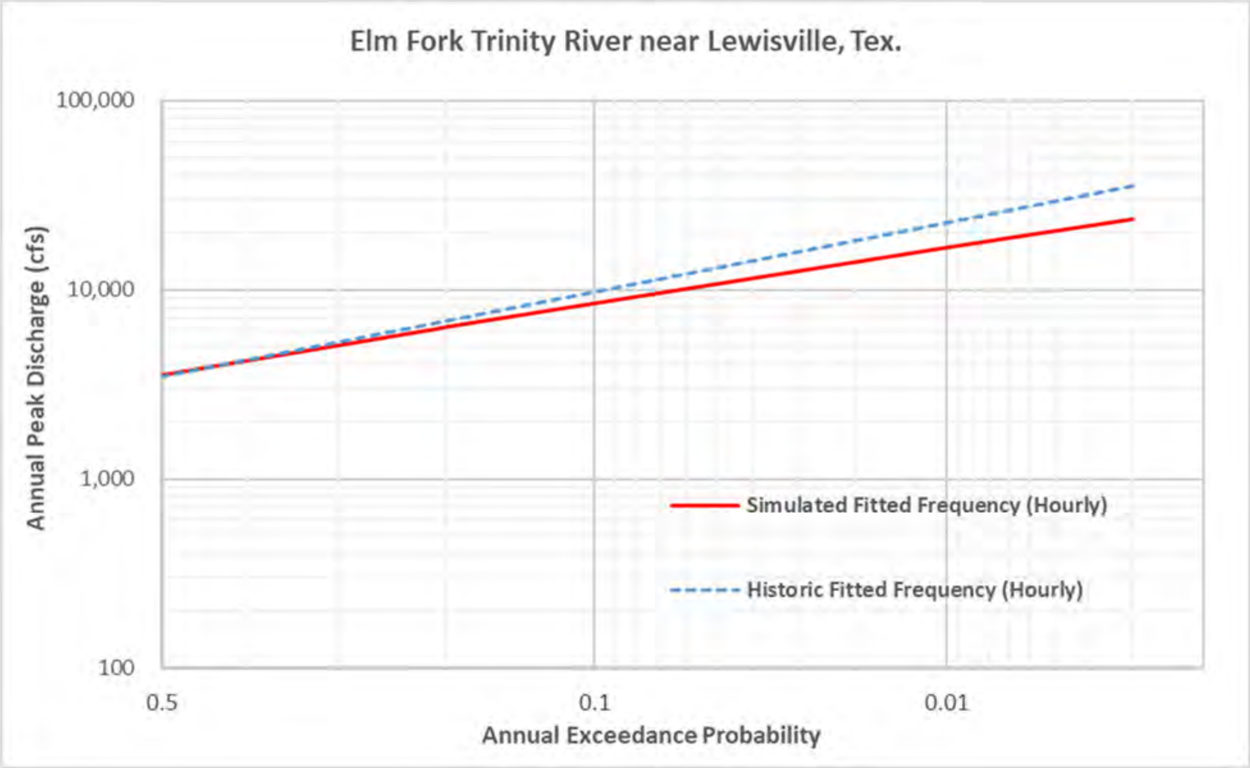

Figure 31c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily and historic hourly data for streamgage 08053000 Elm Fork Trinity River near Lewisville, Tex.

08055000 Denton Creek near Grapevine, Tex.

The simulated streamflow record for the Denton Creek streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 9,074 ft^3/s, which is the simulated peak of record. Figure 32a shows the peak streamflow data for the simulated and historic data along with the impoundment of Grapevine Lake. Only four years of historic data exist before the construction of Grapevine Lake, so it is difficult to determine using observational data what impact the lake had on flows at the Grapevine streamgage. However, no historic peaks exceeded 10,000 ft^3/s after impoundment of the lake in 1952, even though three of the four years of record prior to 1952 had peaks exceeding this threshold. Analysis at this gage was discarded because of the lack of correlation between the historic and simulated peak streamflow data. The ruleset in RiverWare clearly did not match the complex and nuanced approach to releases the operators at Grapevine Lake followed.

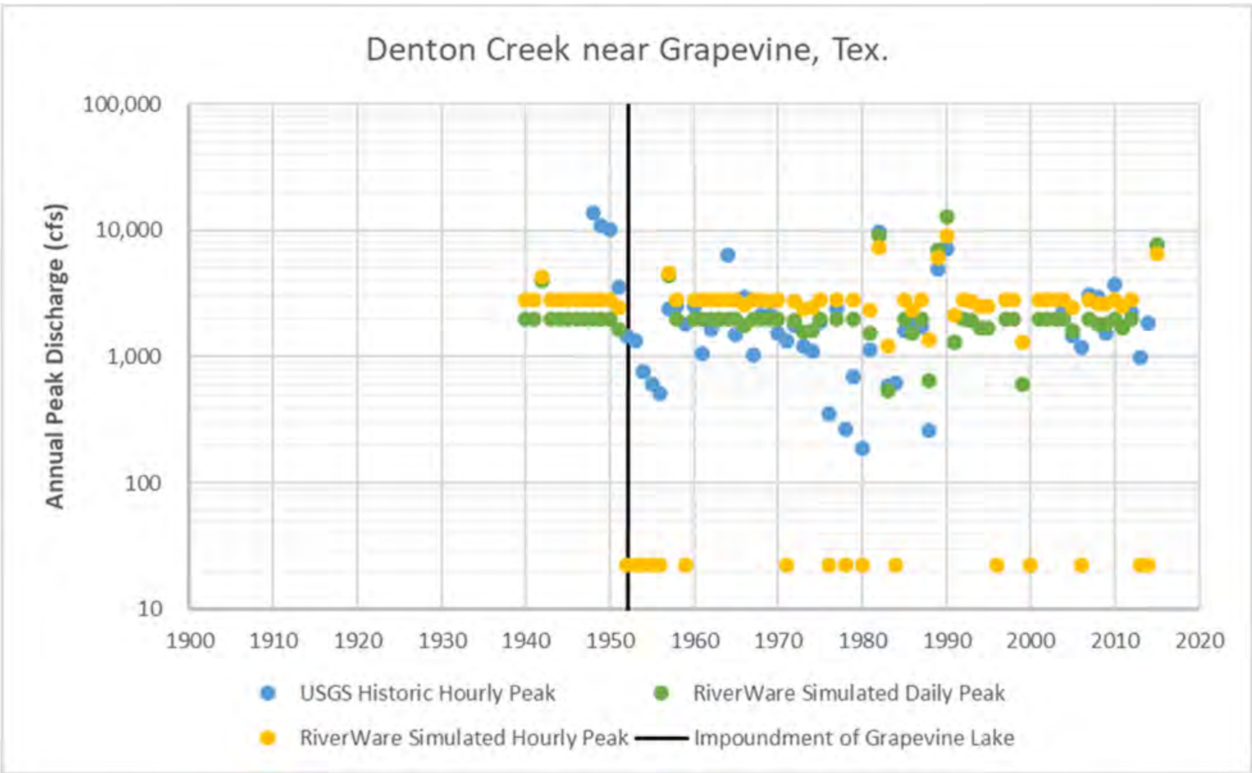

Figure 32a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08055000 Denton Creek near Grapevine, Tex.

08055500 Elm Fork Trinity River near Carrollton, Tex.

The simulated streamflow record for the Carrollton streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 41,113 ft³/s, which is the simulated peak of record. Figure 33a shows the peak streamflow data for the simulated and historic data along with the impoundment of Lewisville Lake in 1955. The historic period begins well before the construction of Lewisville Lake, and the impact the reservoir has on flows can clearly be seen in the figure. One historic peak is available for the historic period of record in 1908.

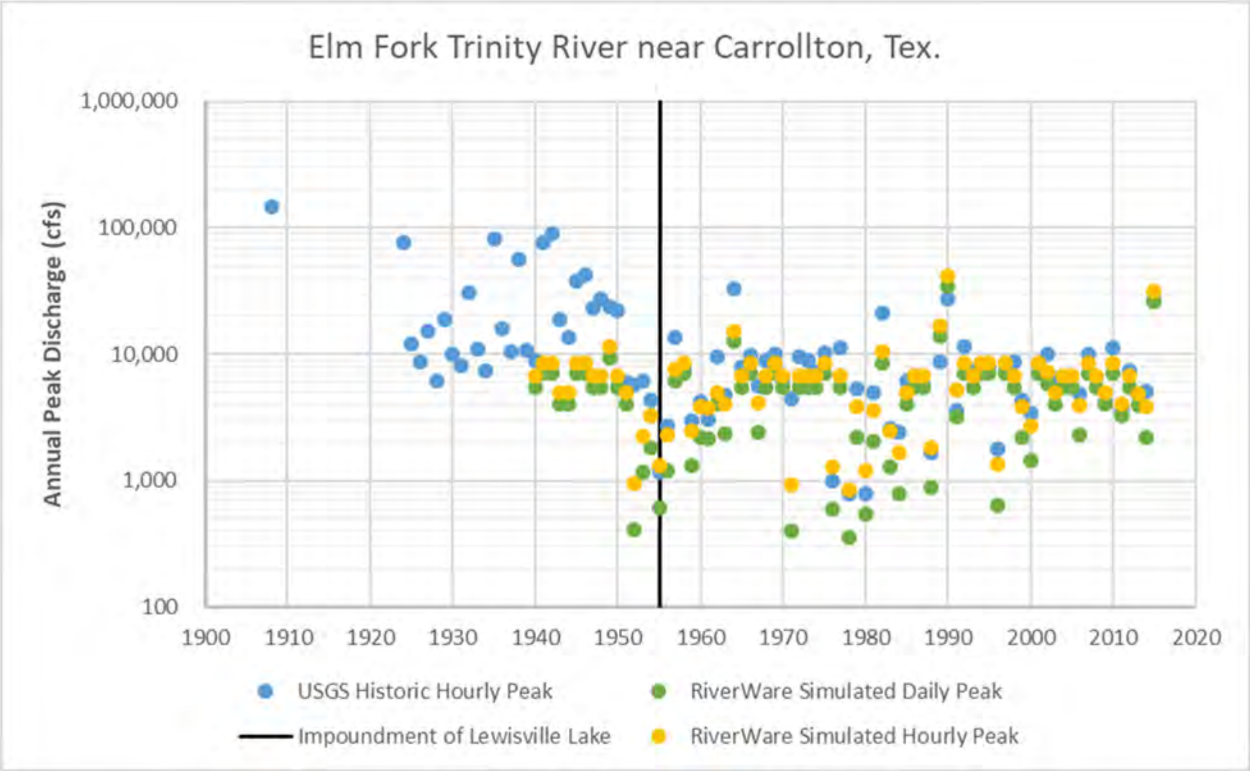

Figure 33a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08055500 Elm Fork Trinity River near Carrollton, Tex.

The LPIII computed peak streamflow frequency curve for the Carrollton streamgage simulated hourly data is shown in Figure 33b. The low-outlier threshold for the Carrollton gage was manually set to 4,000 ft³/s. The simulated data is greatly influenced by simulated regulated releases from Lewisville Lake in RiverWare, and the resultant fitted frequency distribution provides a fit to the data that trends lower than the greatest ordered events.

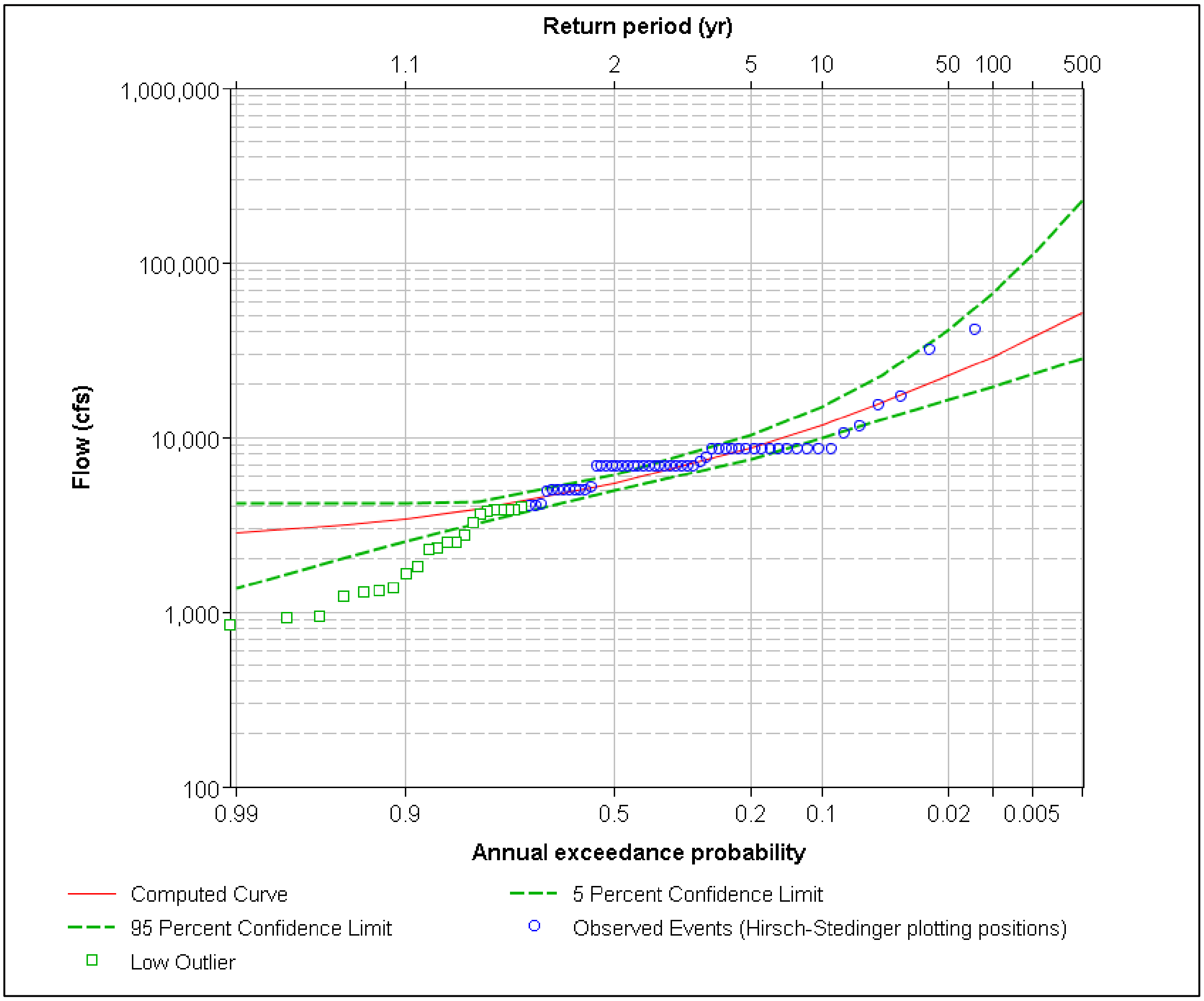

Figure 33b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08055500 Elm Fork Trinity River near Carrollton, Tex. streamgage hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 33c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Carrollton streamgage. The daily and hourly fitted frequency curves plot close to one another, which is expected from a larger river not as susceptible to flash floods. There is a slight increase in the historic fitted frequency curve over the simulated, but overall the curves plot close to one another.

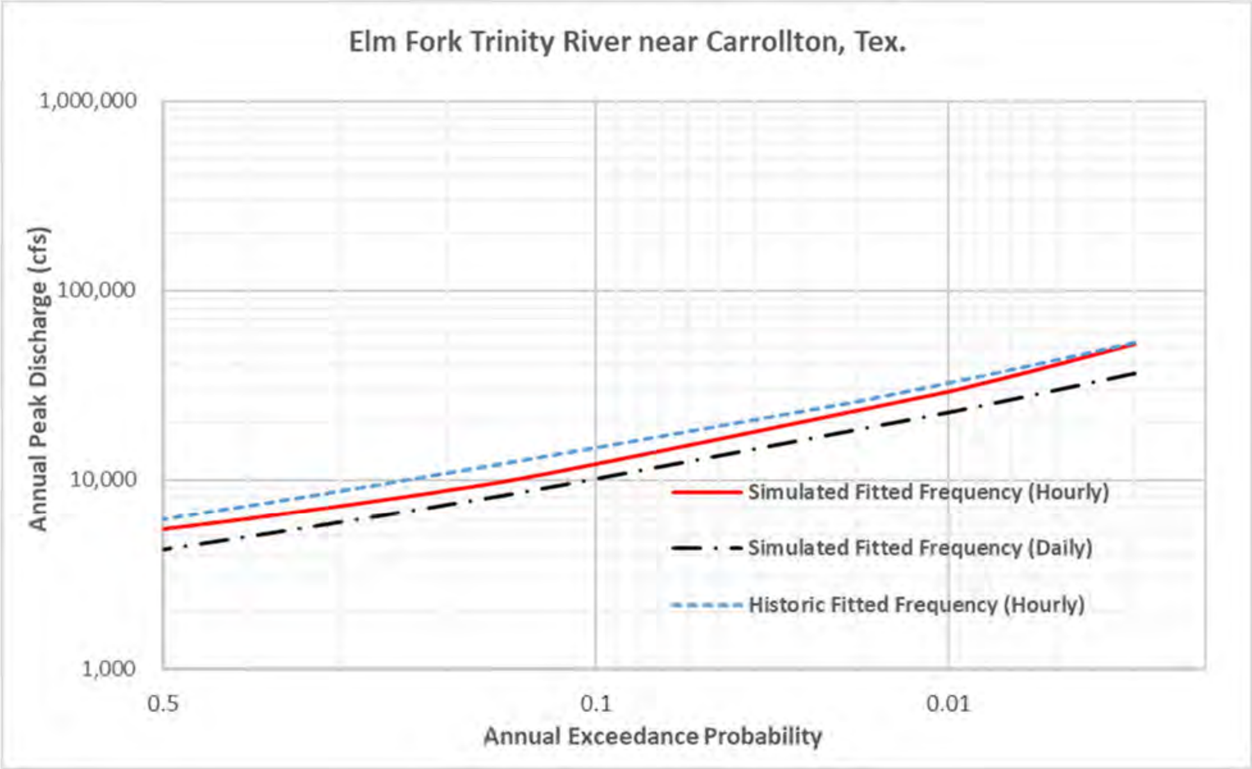

Figure 33c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08055500 Elm Fork Trinity River near Carrollton, Tex.

08057000 Trinity River at Dallas, Tex.

The simulated streamflow record for the Dallas streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 89,058 ft^3/s, which is the simulated peak of record. The historic data extends back to 1904, which means that the historic data contains a mix of flow regimes, with various upstream reservoirs constructed over the past century and continual development in the metro area increasing urban runoff. Figure 34a shows the peak streamflow data for the simulated and historic data.

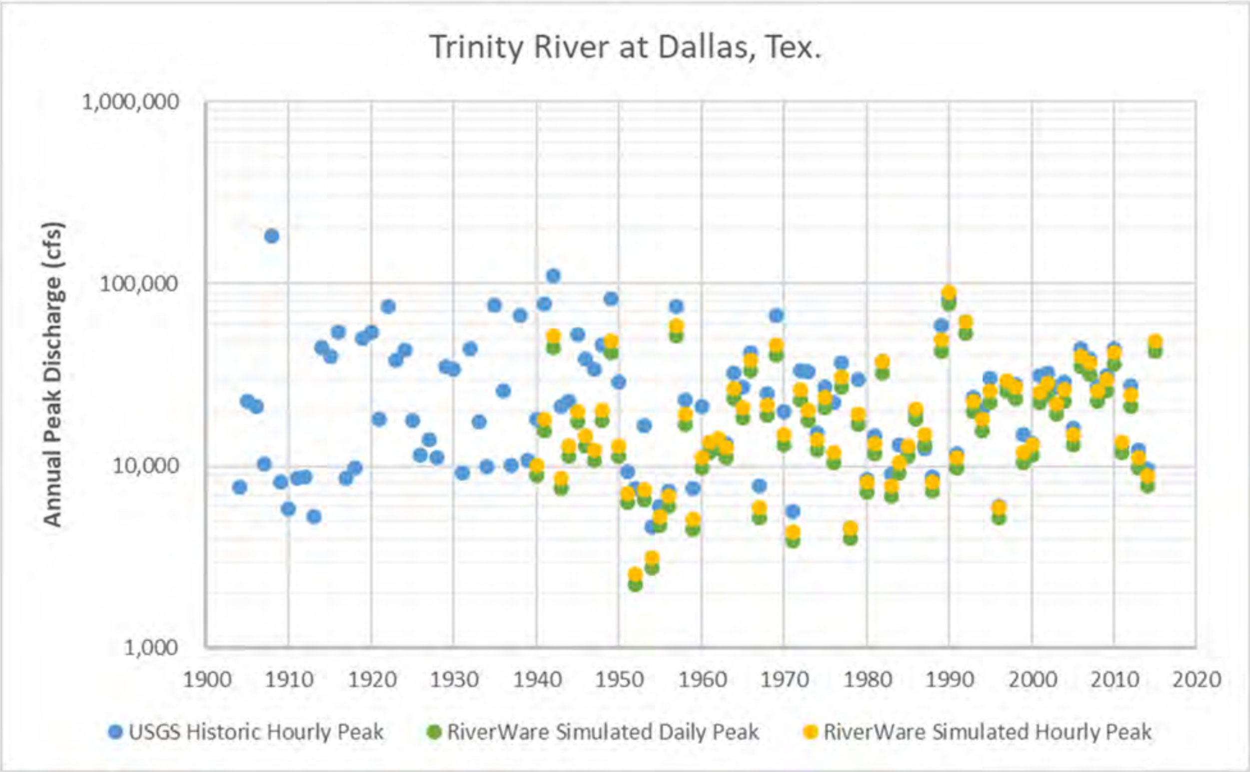

Figure 34a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08057000 Trinity River at Dallas, Tex.

The LPIII computed peak streamflow frequency curve for the Dallas streamgage simulated hourly data is shown in Figure 34b: For the Dallas gage, the MGBT did not compute a low-outlier threshold. Apart from a few “shifts” in the data at about 10,000, 15,000, and 35,000 ft^3/s, the ordered events show a consistent upward trend, resulting in a more linear fitted frequency curve with a relatively small skew.

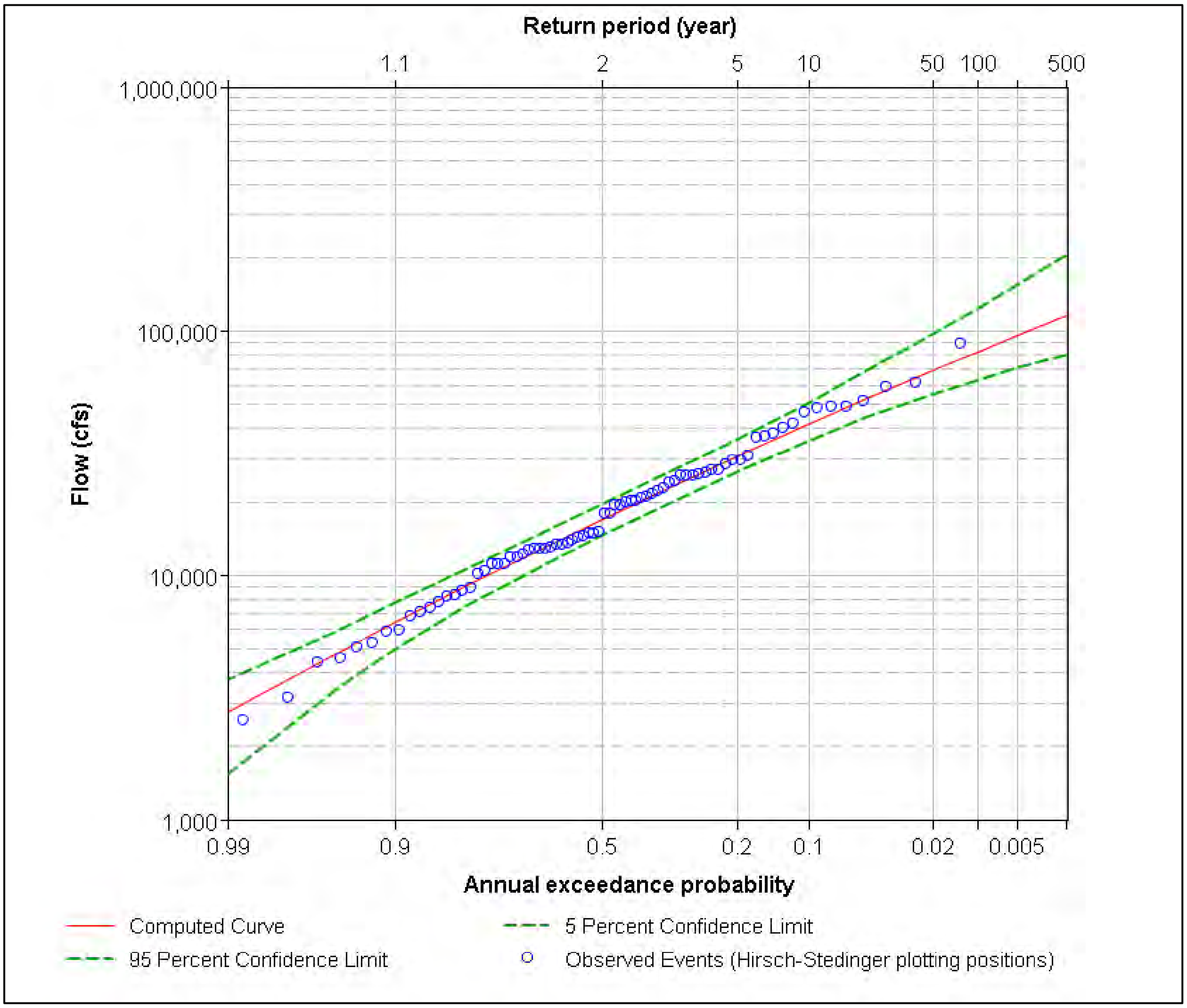

Figure 34b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08057000 Trinity River at Dallas, Tex. streamgage hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 34c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Dallas streamgage. Because the Trinity River at Dallas is a much larger stream not as susceptible to flash floods, there is little difference between the simulated hourly and simulated daily fitted frequency curves. At 0.1 AEP (10-year return interval) and below, the historic and simulated fitted frequency curves trend closer together until they are nearly identical. However, the two curves diverge near the 0.5 AEP because of a greater negative skew in the simulated curve. This could be caused by simulated regulation in RiverWare successfully capturing and regulating lower peak flows in the model's simplified ruleset.

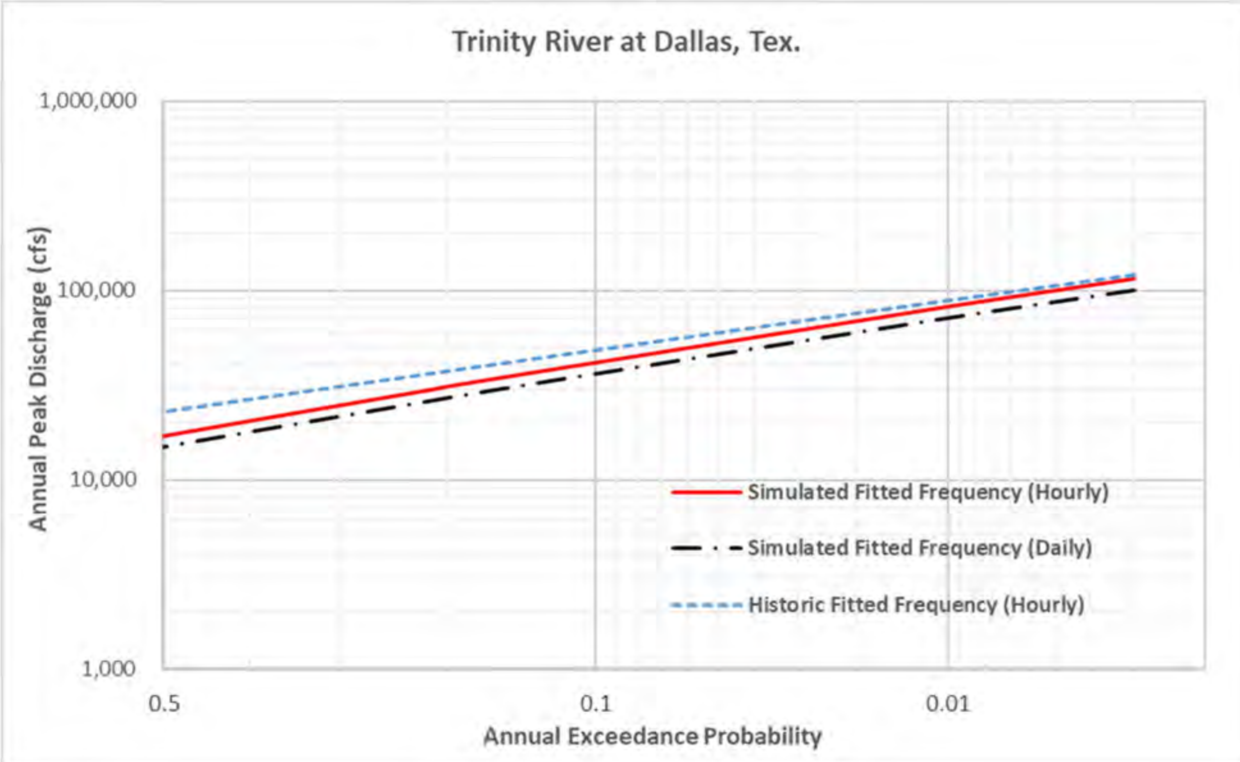

Figure 34c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08057000 Trinity River at Dallas, Tex.

08061750 East Fork Trinity River near Forney, Tex.

The simulated streamflow record for the Forney streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 48,431 ft^3/s, which is the simulated peak of record. Figure 35a shows the peak streamflow data for the simulated and historic data along with the impoundment of Ray Hubbard Lake in 1968. The Forney streamgage was constructed after the impoundment of Ray Hubbard Lake, so it is unclear what impact it has had on flows at the streamgage. Analysis at this gage was discarded because of the lack of correlation between the historic and simulated peak streamflow data. The ruleset in RiverWare clearly did not match the complex and nuanced approach to releases the operators at Ray Hubbard Lake followed. The simulated data fail to match multiple historic peaks of notable magnitude and do not have the spread in data exhibited in the historic dataset.

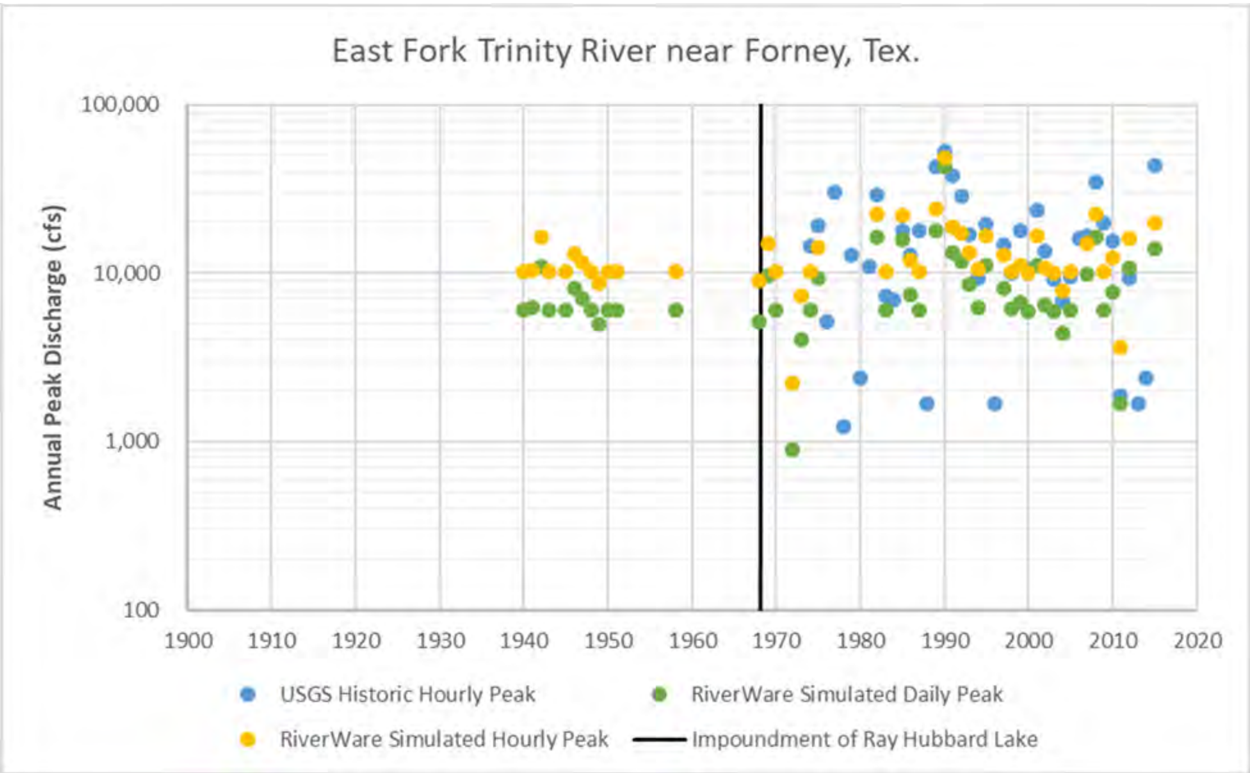

Figure 35a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08061750 East Fork Trinity River near Forney, Tex.

08062000 East Fork Trinity River near Crandall, Tex.

The simulated streamflow record for the Crandall streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 43,562 ft^3/s, which is the simulated peak of record. Figure 36a shows the peak streamflow data for the simulated and historic data along with the impoundment of Ray Hubbard Lake in 1968. Though the Crandall streamgage was constructed before the impoundment of Ray Hubbard Lake, the reservoir does not appear to have much of an impact on peak streamflow at the streamgage.

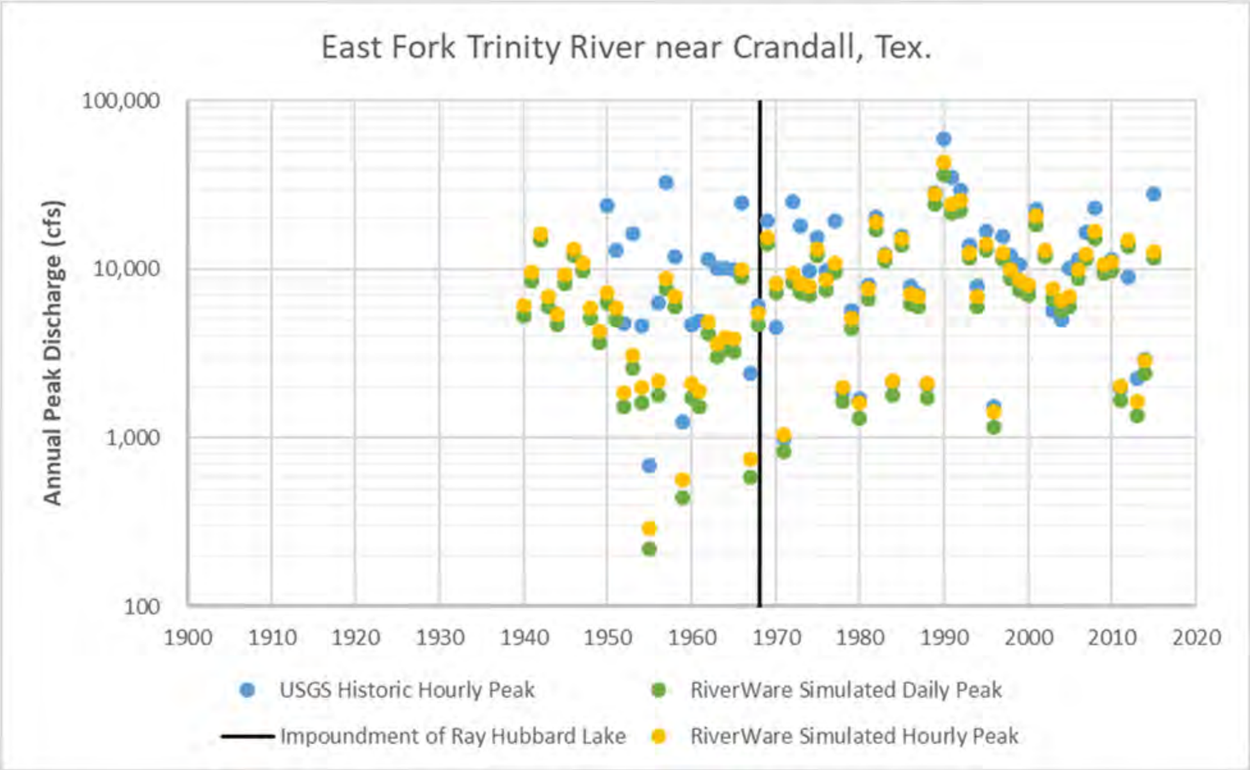

Figure 36a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08062000 East Fork Trinity River near Crandall, Tex.

The LPIII computed peak streamflow frequency curve for the Crandall streamgage simulated hourly data is shown in Figure 36b. The MGBT-computed low-outlier threshold for the Crandall gage is 4,283 ft^3/s. The effects of regulation seen at the Crandall streamgage are greatly diminished further downstream from Ray Hubbard Lake at the Forney streamgage. No regulated release “steps” are apparent in the data and the trend in the ordered events is relatively smooth and consistent except for a shift in the data around 12,000 ft^3/s and a distinctively high peak event.

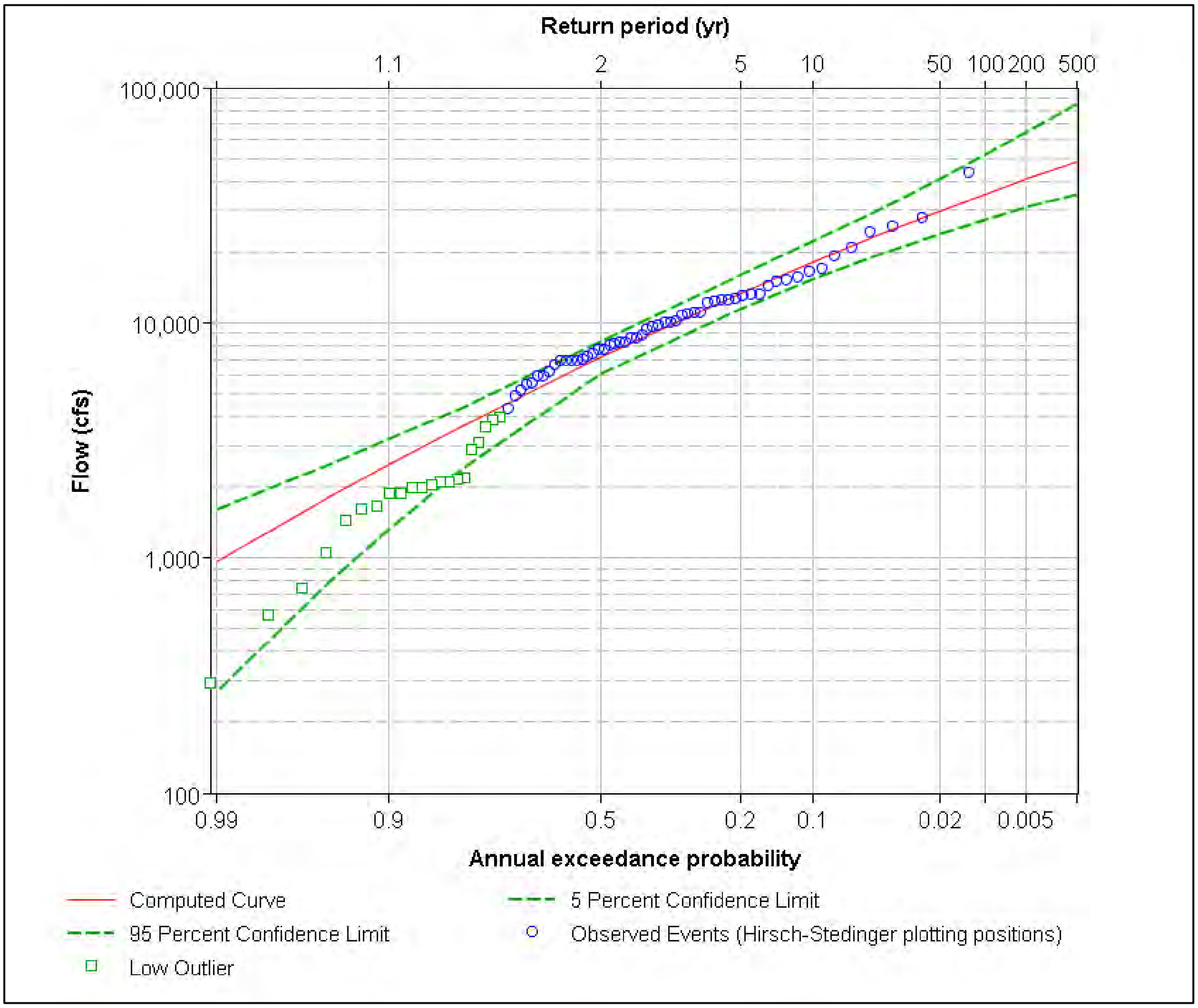

Figure 36b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08062000 East Fork Trinity River near Crandall, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 36c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Crandall streamgage. The three curves are very similar, with only a slight increase in the simulated hourly fitted frequency curve over the simulated daily, indicating a larger stream not susceptible to flash floods. Furthermore, the simulated hourly fitted frequency curve is lower than the historic hourly curve, highlighting the increased effects of regulation in RiverWare, even though that regulation was not immediately apparent in the raw data.

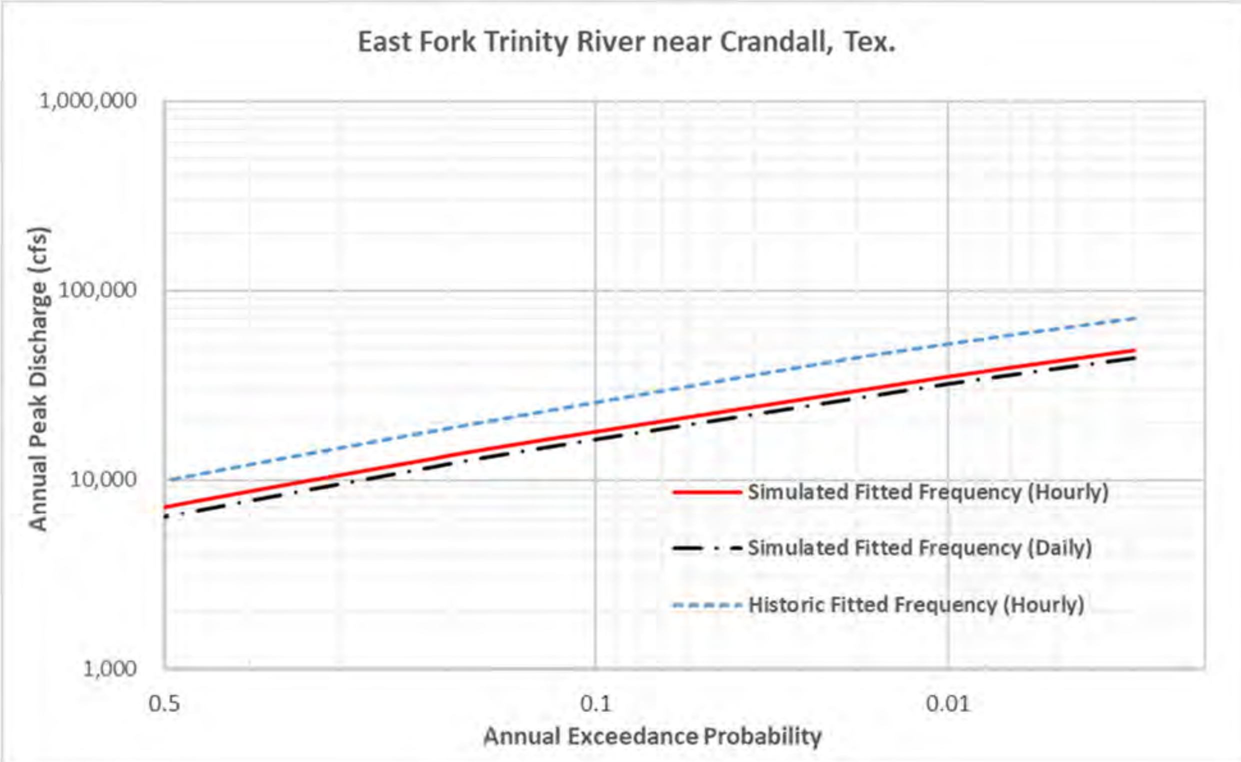

Figure 36c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08062000 East Fork Trinity River near Crandall, Tex.

08062500 Trinity River near Rosser, Tex.

The simulated streamflow record for the Rosser streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 107,985 ft^3/s, which is the simulated peak of record. Figure 37a shows the peak streamflow data for the simulated and historic data. One historic peak is available for the historic period of record in 1908.

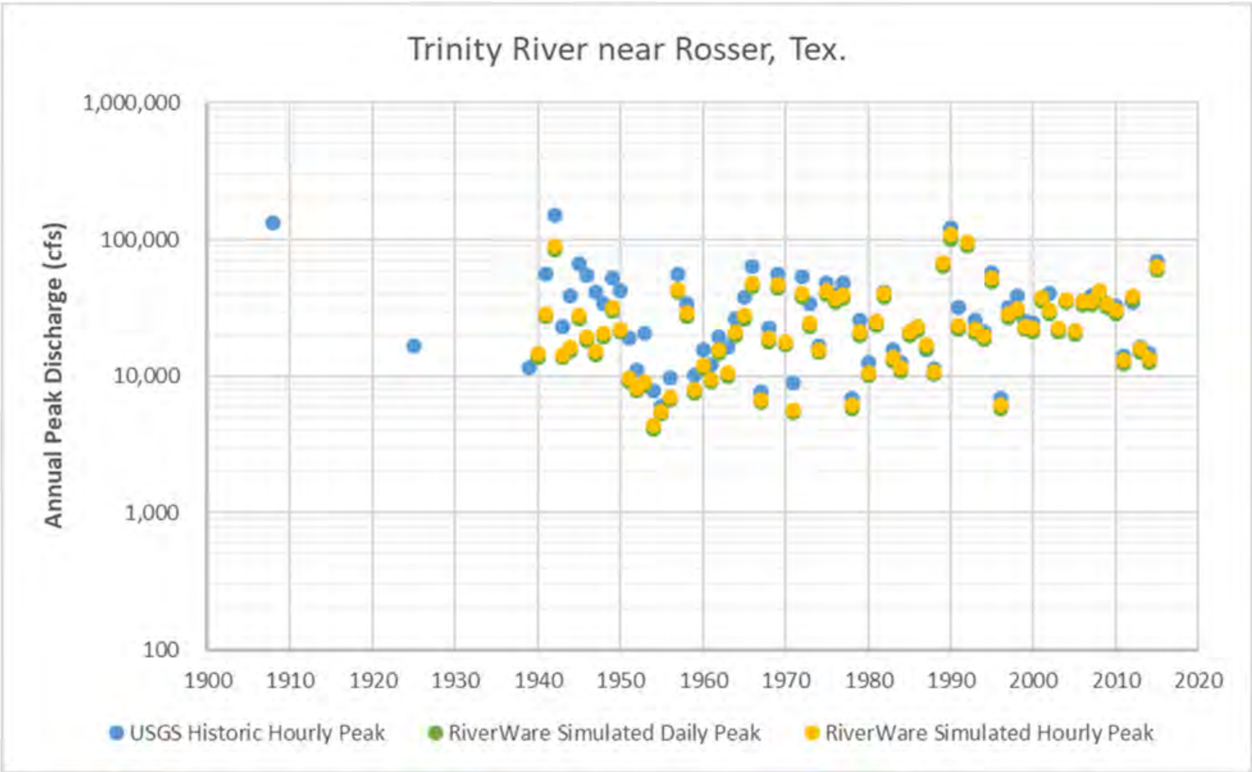

Figure 37a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08062500 Trinity River near Rosser, Tex.

The LPIII computed peak streamflow frequency curve for the Rosser streamgage simulated hourly data is shown in Figure 37b. For the Rosser gage, the MGBT did not compute a low-outlier threshold. The ordered events show a consistent trend, resulting in a more linear fitted frequency curve with a relatively small skew. The data do show a slight increase in the greatest peak events that appear to break slightly with the otherwise generally smooth trend.

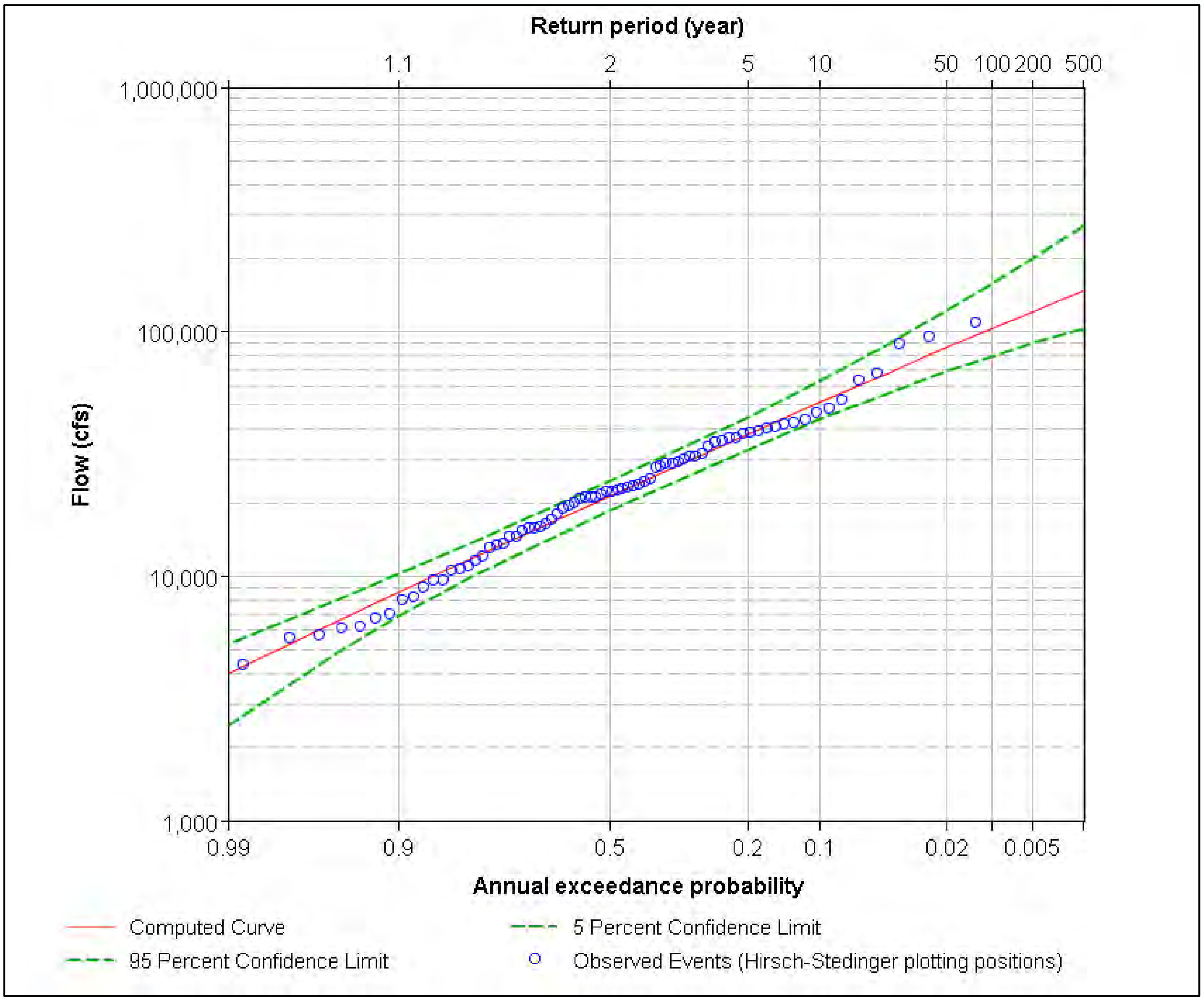

Figure 37b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08062500 Trinity River near Rosser, Tex. streamgage hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 37c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Rosser streamgage. The difference between the simulated daily and simulated hourly fitted frequency curves are small, which means that peak flows at the Rosser streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. The small difference between the historic and simulated fitted frequency curves also show that extending the regulated period of record with RiverWare has a limited effect on flows on this stretch of the Trinity River.

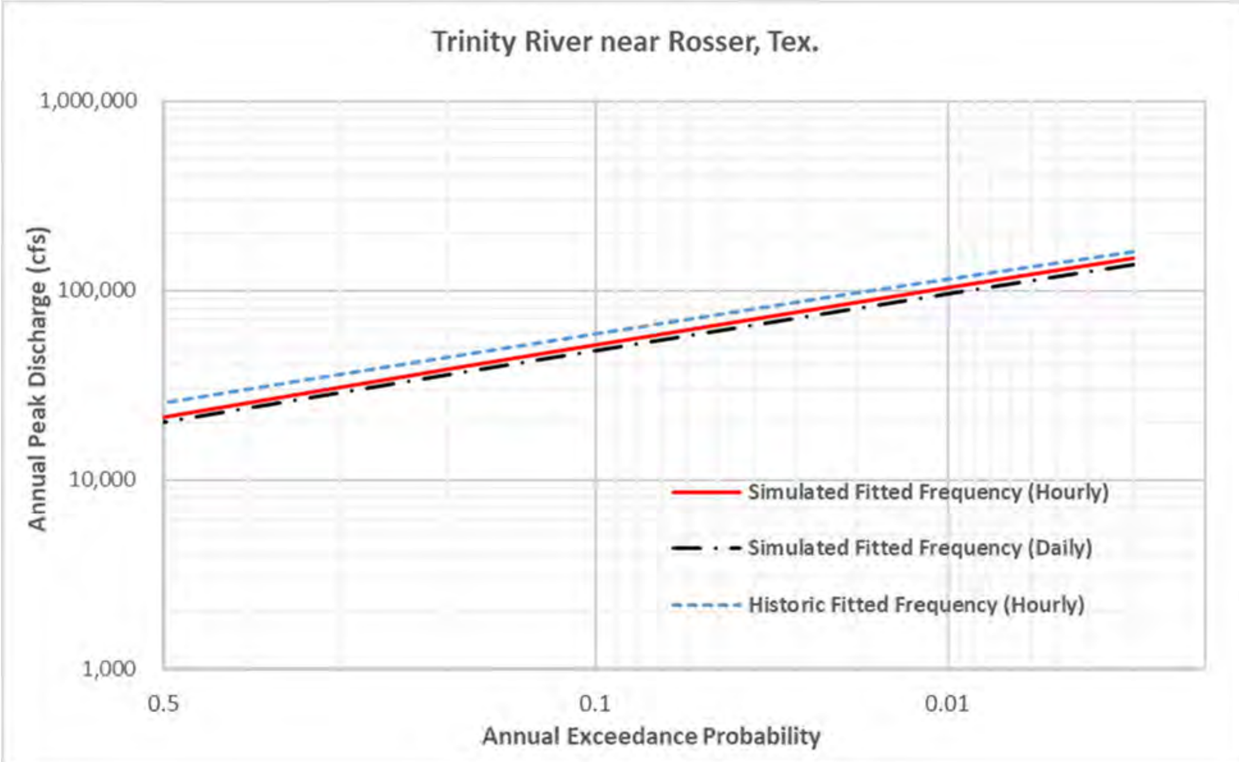

Figure 37c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08062500 Trinity River near Rosser, Tex.

08062700 Trinity River at Trinidad, Tex.

The simulated streamflow record for the Trinidad streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 100,109 ft^3/s, which is the simulated peak of record. No peaking factor was applied to the Trinidad streamgage data, so daily peak flows are equated to hourly, or instantaneous, peak flows. This means that peak flows at the Trinidad streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. Figure 38a shows the peak streamflow data for the simulated and historic data.

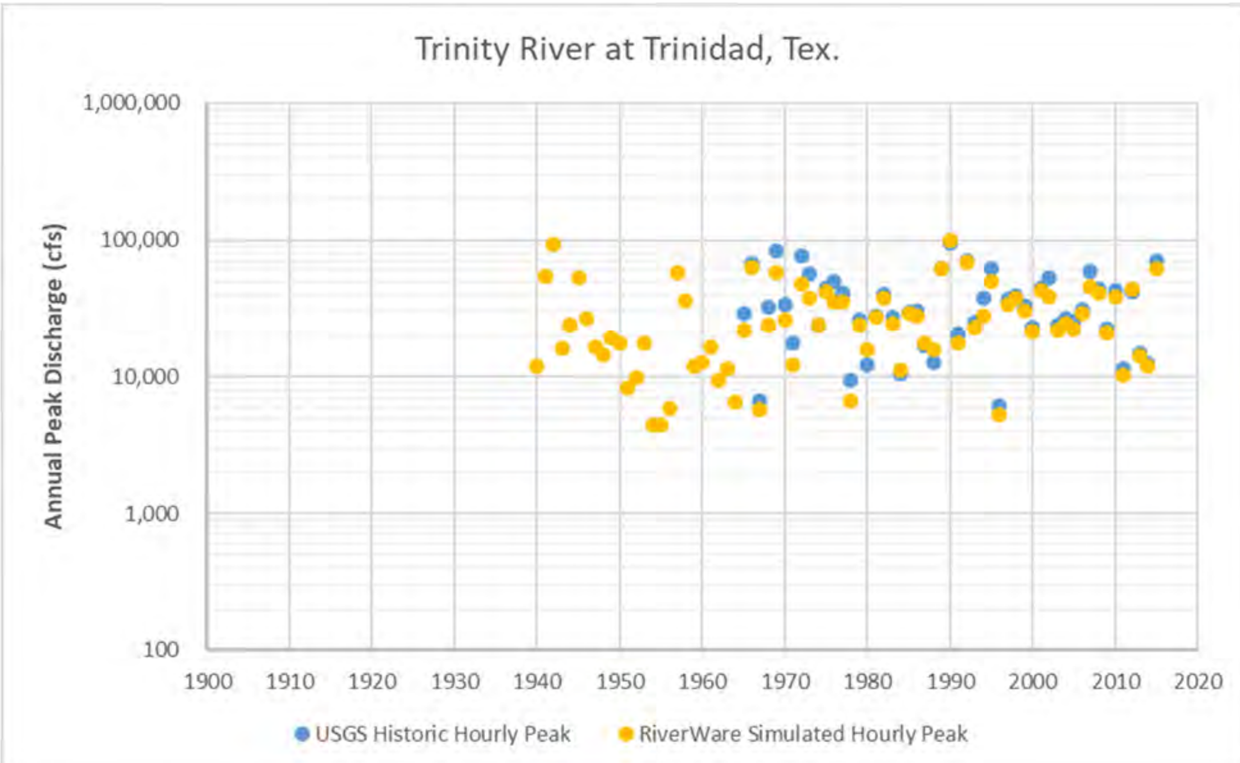

Figure 38a: USGS historic hourly peak streamflows and RiverWare hourly peak streamflow data for streamgage 08062700 Trinity River at Trinidad, Tex.

The LPIII computed peak streamflow frequency curve for the Trinidad streamgage simulated hourly data is shown in Figure 38b. For the Trinidad gage, the MGBT did not compute a low-outlier threshold. The ordered events show a consistent trend, resulting in a more linear fitted frequency curve with a relatively small skew. The data do show a slight increase in the two greatest peak events that appear to break slightly with the otherwise generally smooth trend.

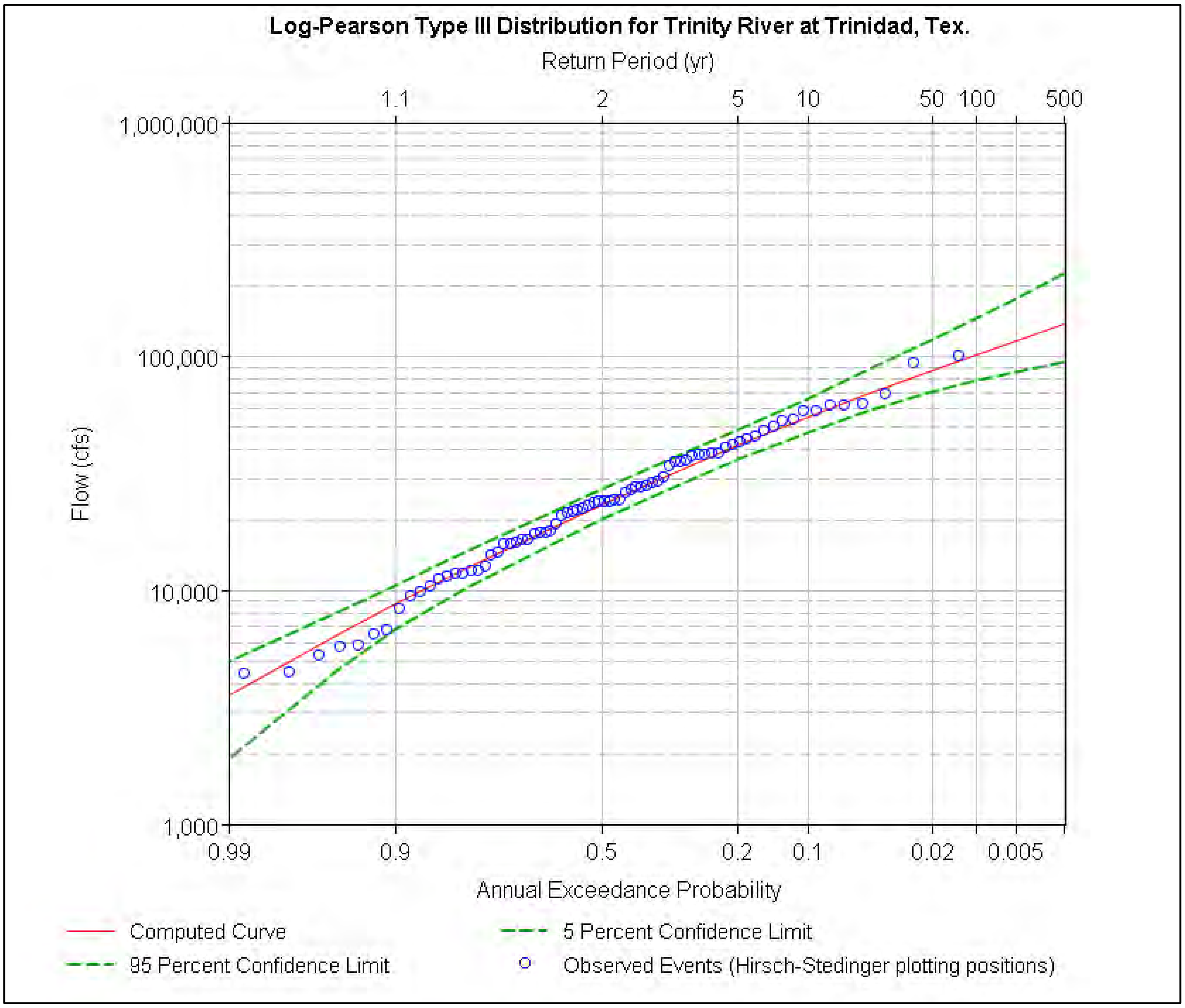

Figure 38b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08062700 Trinity River at Trinidad, Tex. streamgage hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 38c compares the LPIII computed peak streamflow frequency curves for the simulated hourly and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Trinidad streamgage. The small difference between the historic and simulated fitted frequency curves also show that extending the regulated period of record with RiverWare has a limited effect on flows on this stretch of the Trinity River. The curves do, however, diverge at the left tail of the distribution, possibly because of RiverWare regulating smaller peak flows more than what is in the historic data.

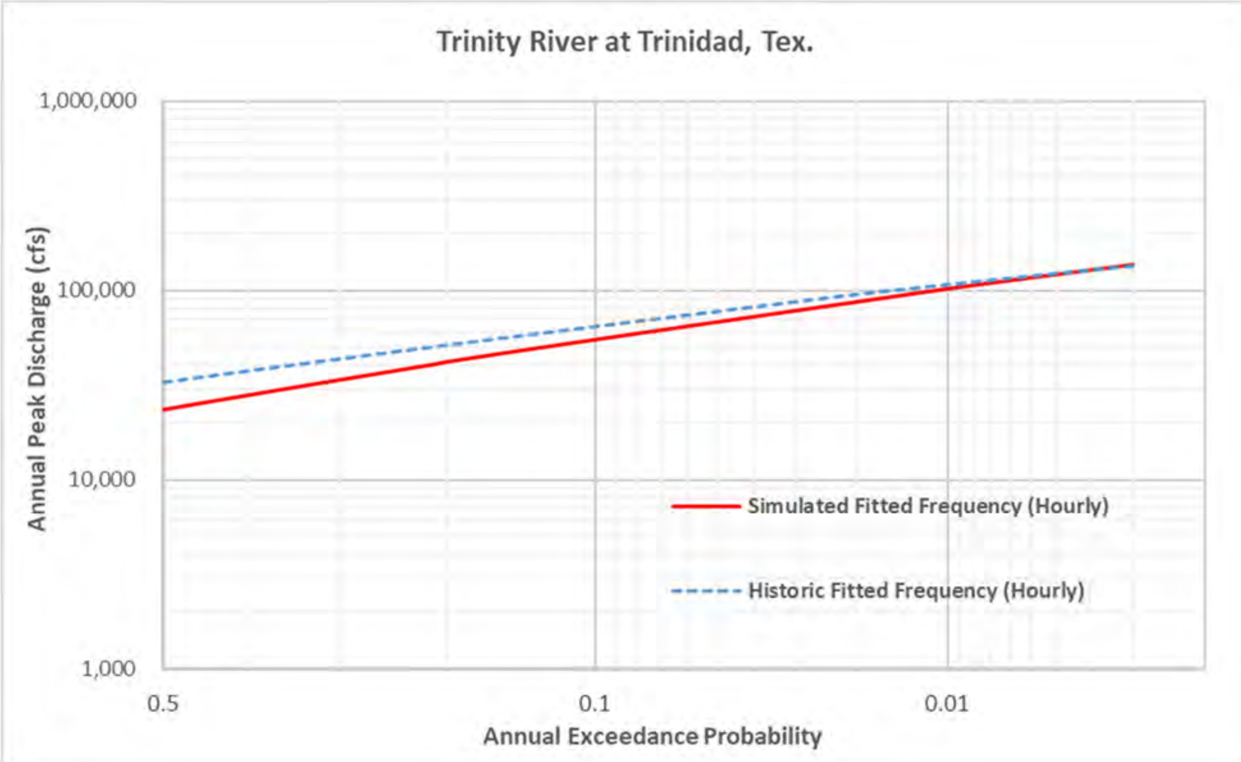

Figure 38c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated hourly and historic hourly data for streamgage 08062700 Trinity River at Trinidad, Tex.

08063100 Richland Creek near Dawson, Tex.

The simulated streamflow record for the Dawson streamgage is 1940–2015. The 1992 peak streamflow for the simulated hourly data was 4,276 ft^3/s, which is the simulated peak of record. Only two years of historic data exist before the construction of Navarro Mills Lake in 1963, so it is unclear what impact it has had on flows at the Dawson streamgage. However, the two peaks prior to the construction of the reservoir both exceed 10,000 ft^3/s, but with the reservoir in place, peak flow has not exceeded 5,000 ft^3/s. Analysis at this gage was discarded because of the lack of correlation between the historic and simulated peak streamflow data The ruleset in RiverWare clearly did not match the releases that occurred in reality. The simulated data fail to match multiple historic peaks of notable magnitude and do not have the spread in data exhibited in the historic dataset. . Because of this, a frequency curve was not computed and associated figure was not developed for this location.

08063500 Richland Creek near Richland, Tex.

The simulated streamflow record for the Richland streamgage is 1940–2015. The 2007 peak streamflow for the simulated hourly data was 38,682 ft^3/s, which is the simulated peak of record. Figure 39a shows the peak streamflow data for the simulated and historic data along with the impoundment of Navarro Mills Lake in 1963. The impact of the upstream reservoir is seen in the reduction of the number of peak flows above 30,000 ft^3/s. The USGS streamgage was removed in 1989, most likely because of the backwater effects of nearby Richland Chambers Reservoir.

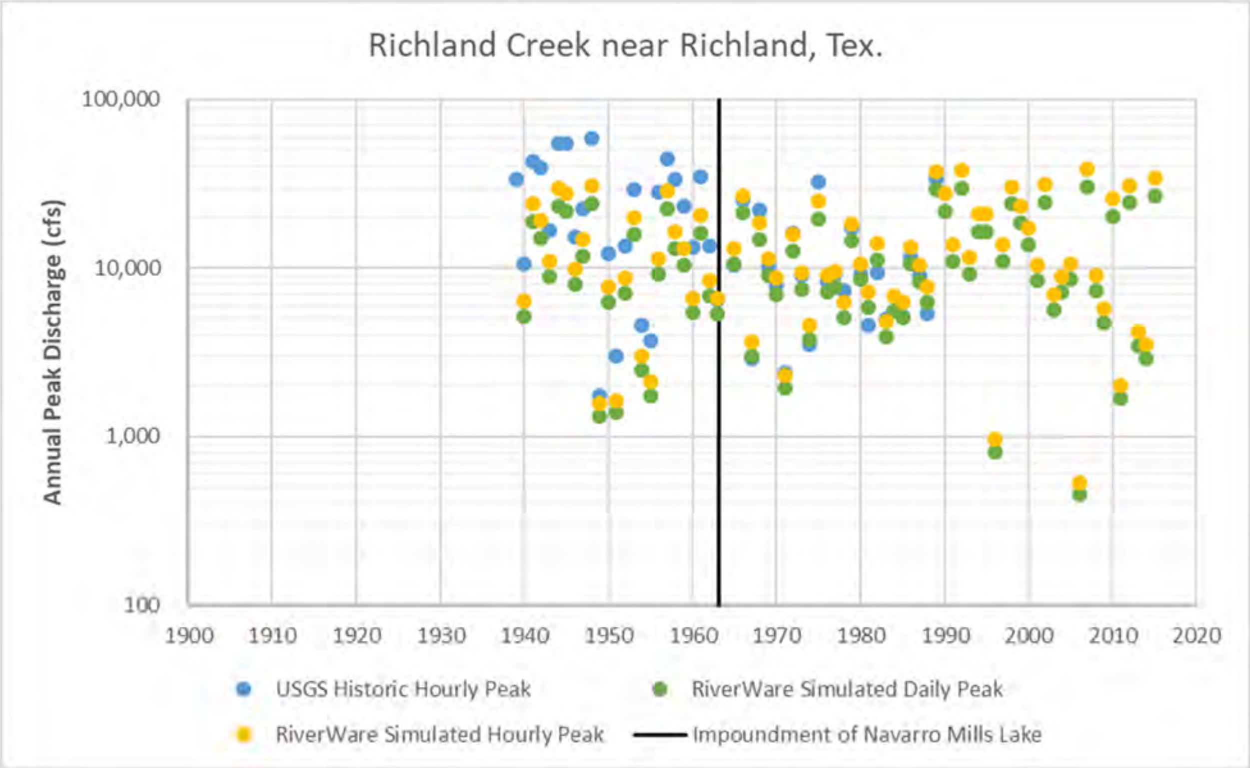

Figure 39a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08063500 Richland Creek near Richland, Tex.

The LPIII computed peak streamflow frequency curve for the Richland streamgage simulated hourly data is shown in Figure 39b. The MGBT-computed low-outlier threshold for the Richland gage is 5,792 ft^3/s. The ordered events show a consistent upward trend, resulting in a more linear fitted frequency curve with a relatively small skew. The greatest peak events do appear to plateau around 40,000 ft^3/s, breaking with the otherwise generally smooth trend.

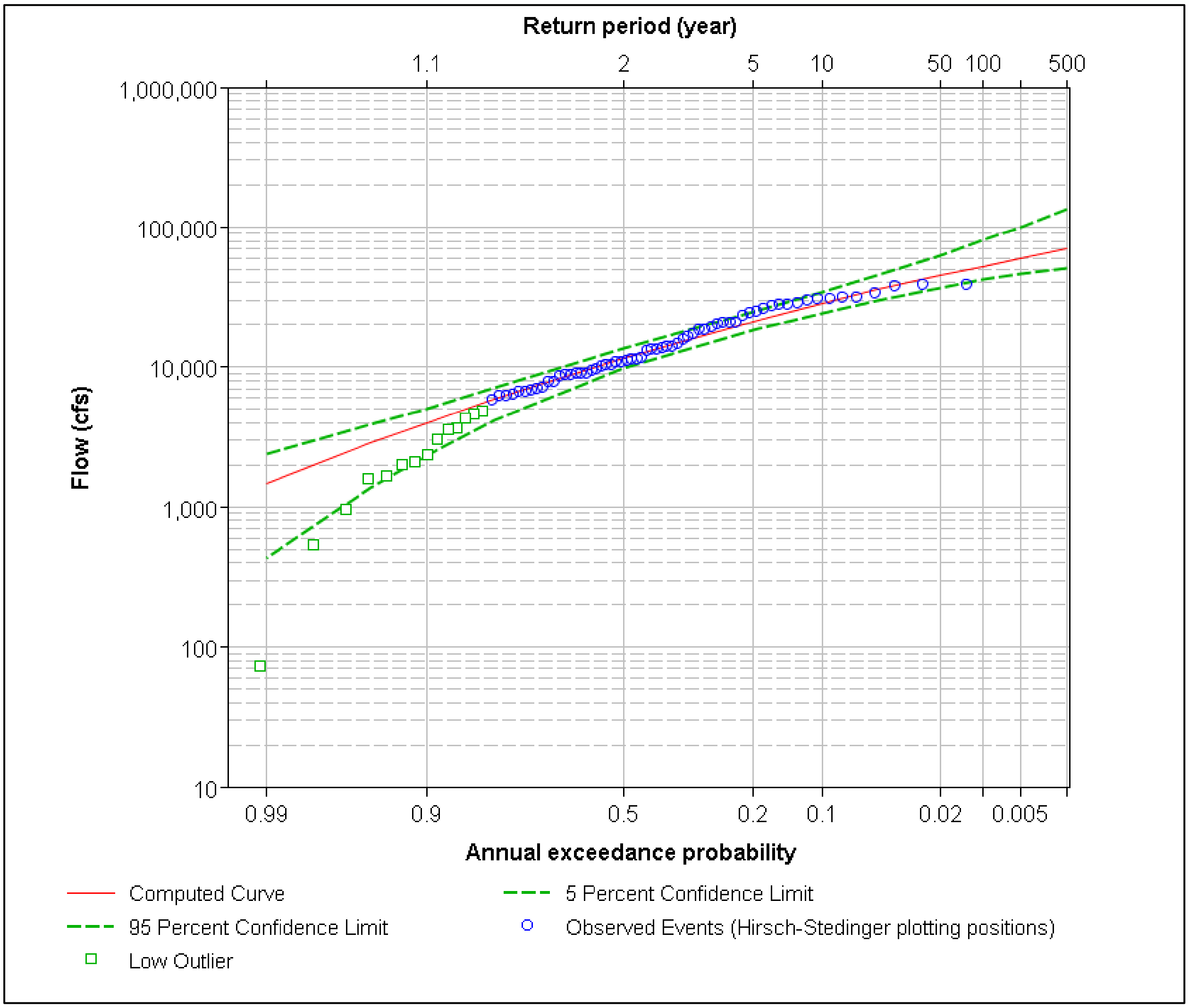

Figure 39b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08063500 Richland Creek near Richland, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 39c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Richland streamgage. The fitted frequency curves show a moderate increase in hourly peak flows over daily peak flows, and a decrease in simulated peaks from historic, highlighting the effect of extending the period of regulated record with RiverWare at the Richland streamgage.

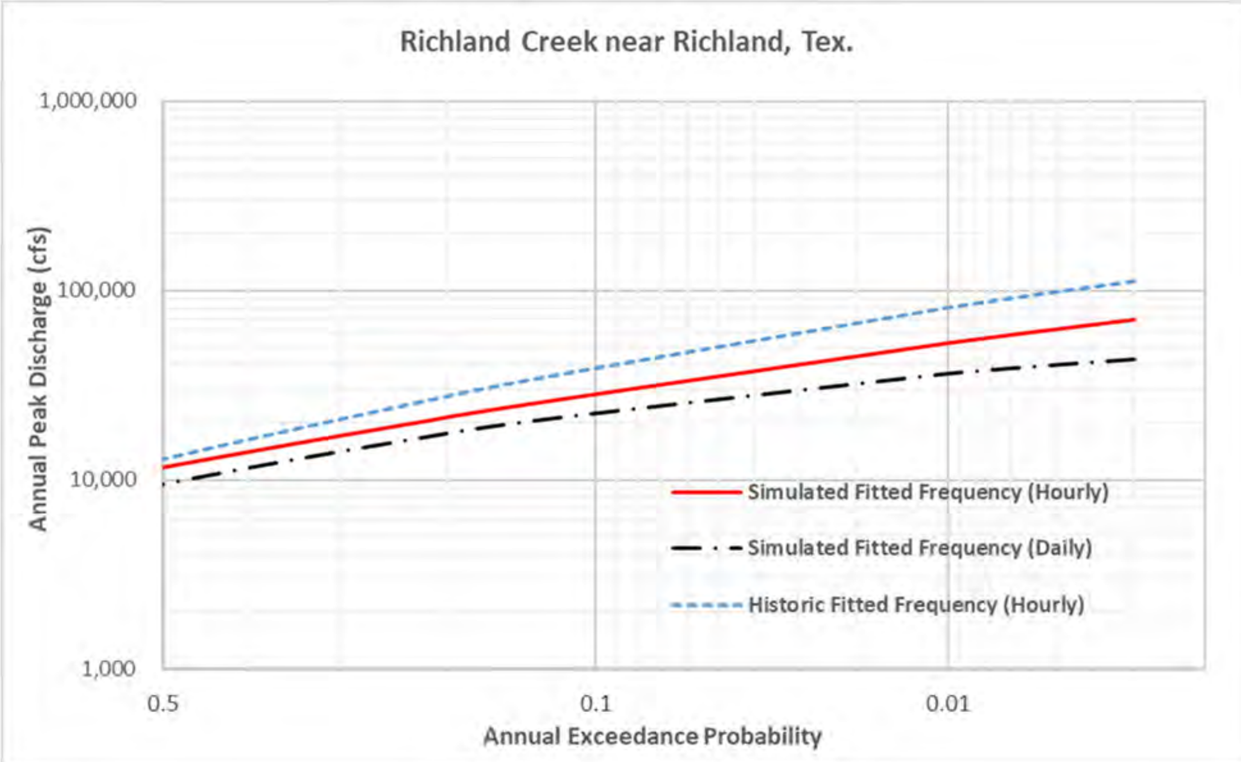

Figure 39c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08063500 Richland Creek near Richland, Tex.

08063800 Waxahachie Creek near Bardwell, Tex.

The simulated streamflow record for the Bardwell streamgage is 1940–2015. Because the data is heavily regulated in RiverWare, the peak streamflow never exceeded the regulated release of 2,000 ft^3/s, which occurred 20 times during the 76 years of simulated record. Because of its historic proximity to Bardwell Lake, the simulated Bardwell streamgage data is the same as the RiverWare simulated Bardwell Lake outflow. Because reservoir releases are engineered and generally sustained, a peaking factor was not needed for the Bardwell streamgage data. Therefore, the daily RiverWare data are equated to hourly (instantaneous) peak flow data. This means that peak flows at the Bardwell streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. Figure 40a shows the peak streamflow data for the simulated and historic data along with the impoundment of Bardwell Lake in 1965. Only one year of historic data exists before the construction of Bardwell Lake, so it is unclear what impact it has had on flows at the Bardwell streamgage. Analysis at this gage was discarded because of the lack of correlation between the historic and simulated peak streamflow data. The ruleset in RiverWare clearly did not match the releases that occurred in reality. The simulated data fail to match multiple historic peaks of notable magnitude and do not have the spread in data exhibited in the historic dataset.

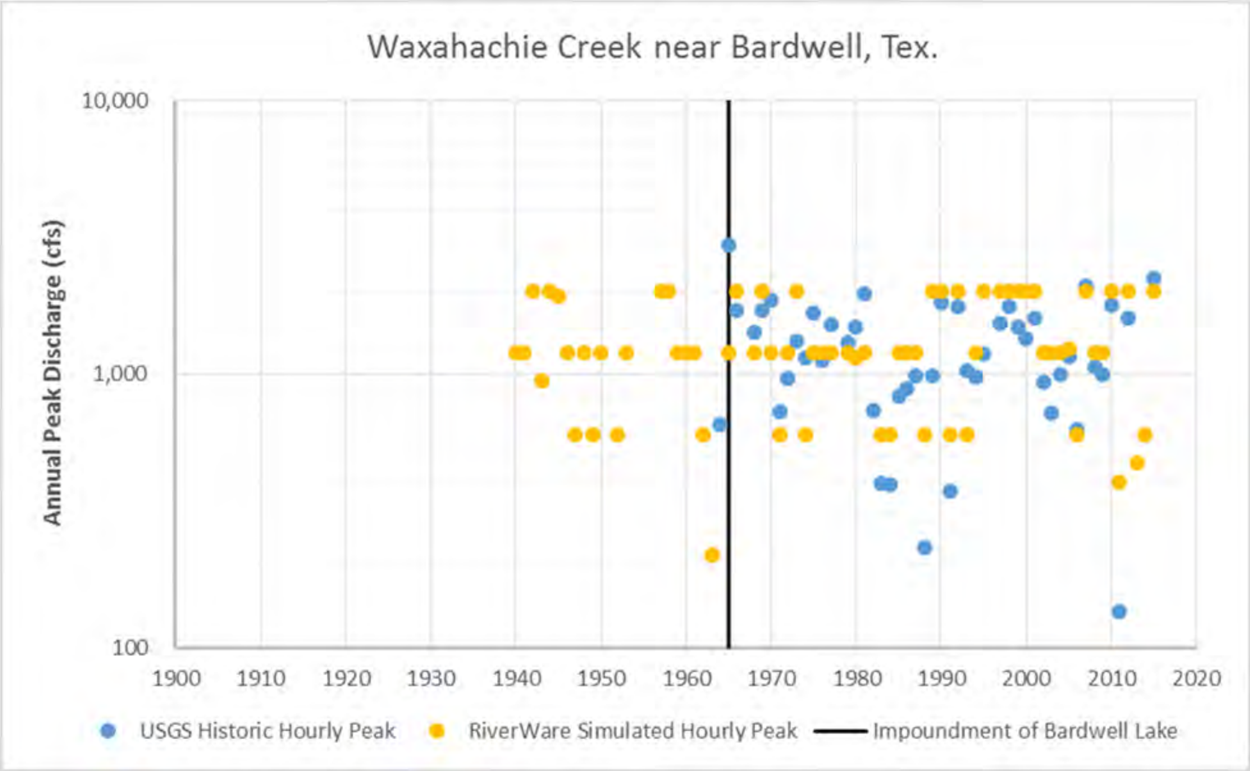

Figure 40a: USGS historic hourly peak streamflows and RiverWare hourly peak streamflow data for streamgage 08063800 Waxahachie Creek near Bardwell, Tex.

08064100 Chambers Creek near Rice, Tex.

The simulated streamflow record for the Rice streamgage is 1940–2015. The 1966 peak streamflow for the simulated hourly data was 43,320 ft³/s, which is the simulated peak of record. Figure 41a shows the peak streamflow data for the simulated and historic data. The RiverWare data was extracted from the USGS Chambers Creek near Corsicana, Tex. gage location, but historic data ended in 1984 when the streamgage was discontinued. A drainage-area ratio was applied to the RiverWare data so that it could be directly compared to the currently active streamgage near Rice, Tex. The RiverWare simulated data appear to be underestimating the greatest peaks in the historic record. Simplistic reservoir rulesets upstream and overly confident simulated regulation could have caused this dampening in larger peak streamflows.

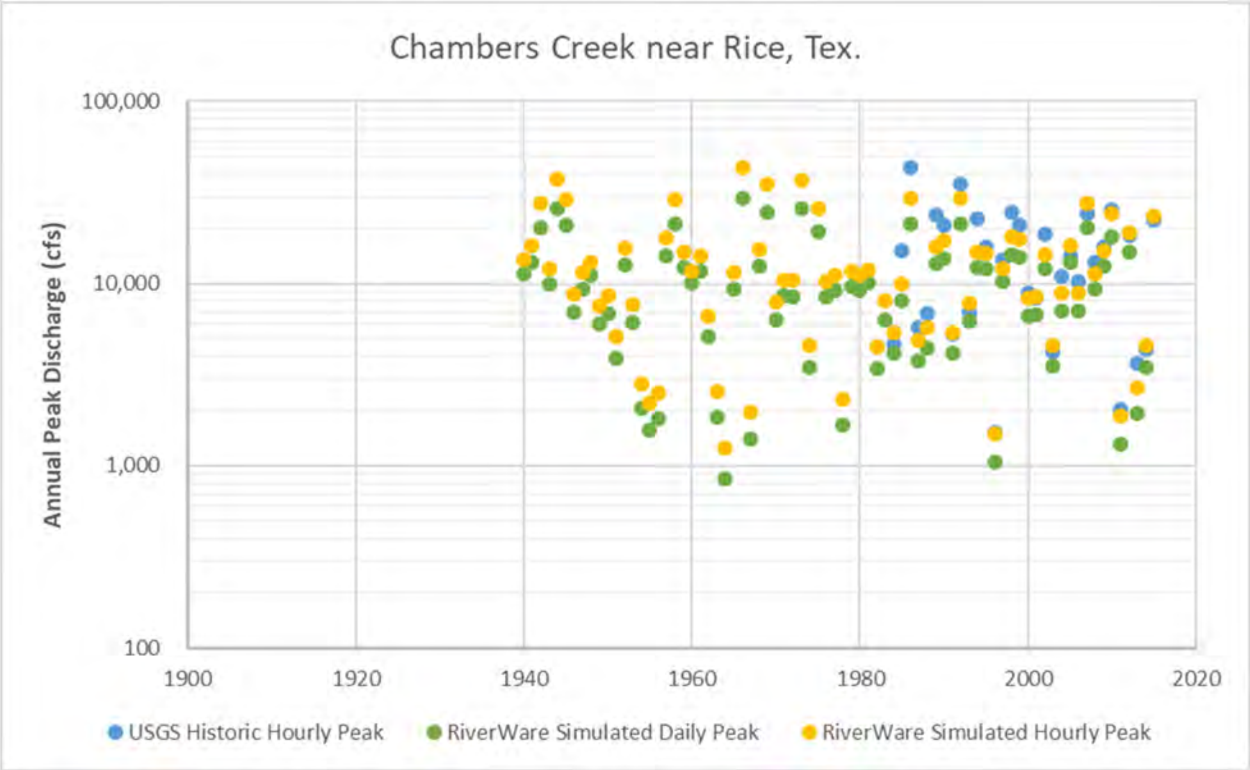

Figure 41a: USGS historic hourly peak streamflows, RiverWare daily peak streamflows, and RiverWare hourly peak streamflow data for streamgage 08064100 Chambers Creek near Rice, Tex.

The LPIII computed peak streamflow frequency curve for the Rice streamgage simulated hourly data is shown in Figure 41b. The MGBT-computed low-outlier threshold for the Rice gage is 4,472 ft³/s. Multiple shifts appear throughout the ordered events, and the peaks appear to begin to plateau at the upper end of the ordered events, resulting in a fitted frequency curve with a relatively large negative skew.

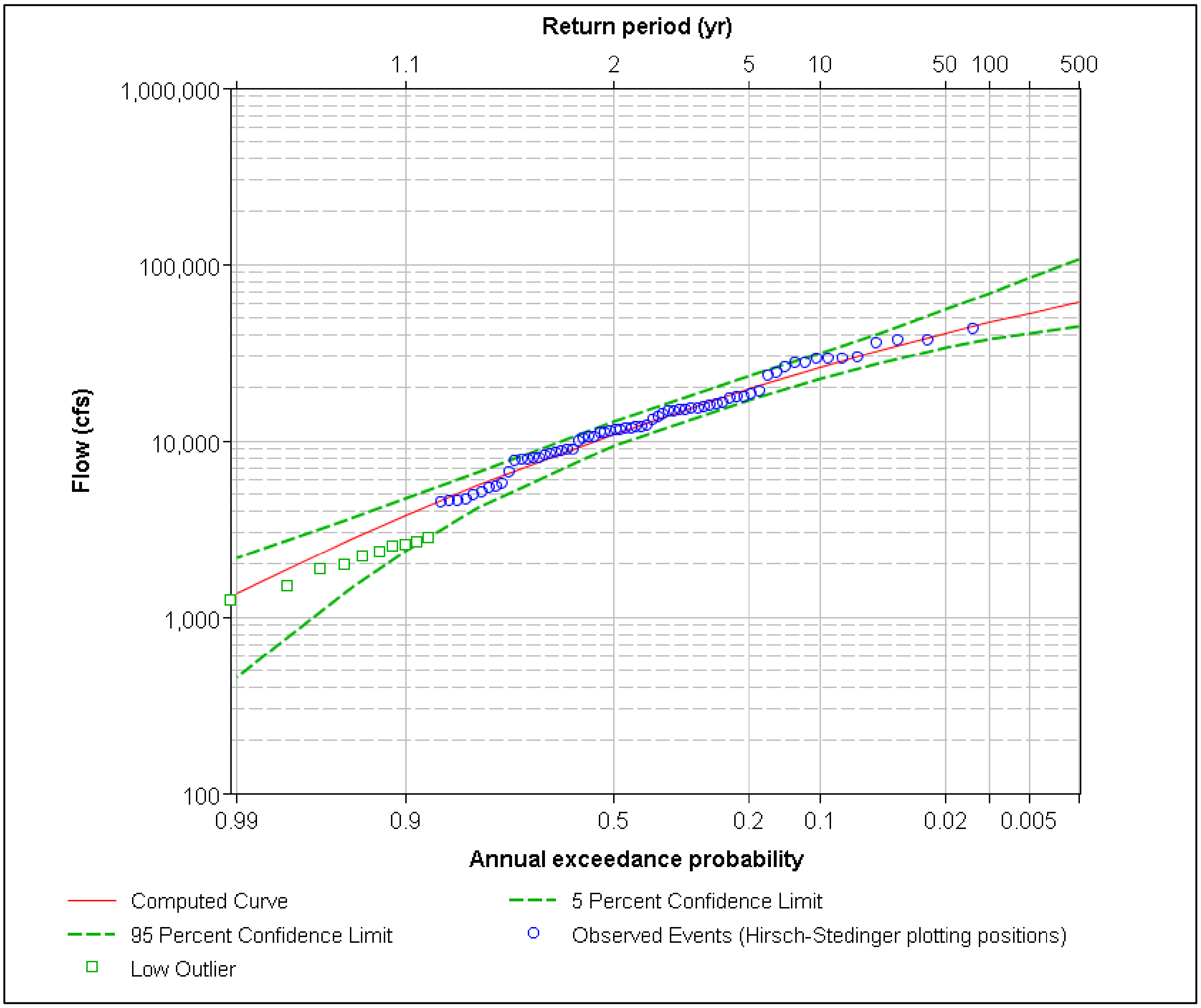

Figure 41b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08064100 Chambers Creek near Rice, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 41c compares the LPIII computed peak streamflow frequency curves for the simulated hourly, simulated daily, and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Rice streamgage. The fitted frequency curves show a large increase in hourly peak flows over daily peak flows, and only a slight deviation in simulated peaks from historic, especially in the right-hand tail of the distribution. While the modeled results align well with the historic results overall, the deviation in larger AEP symbolizes RiverWare's lower bounding estimates of peak annual streamflow.

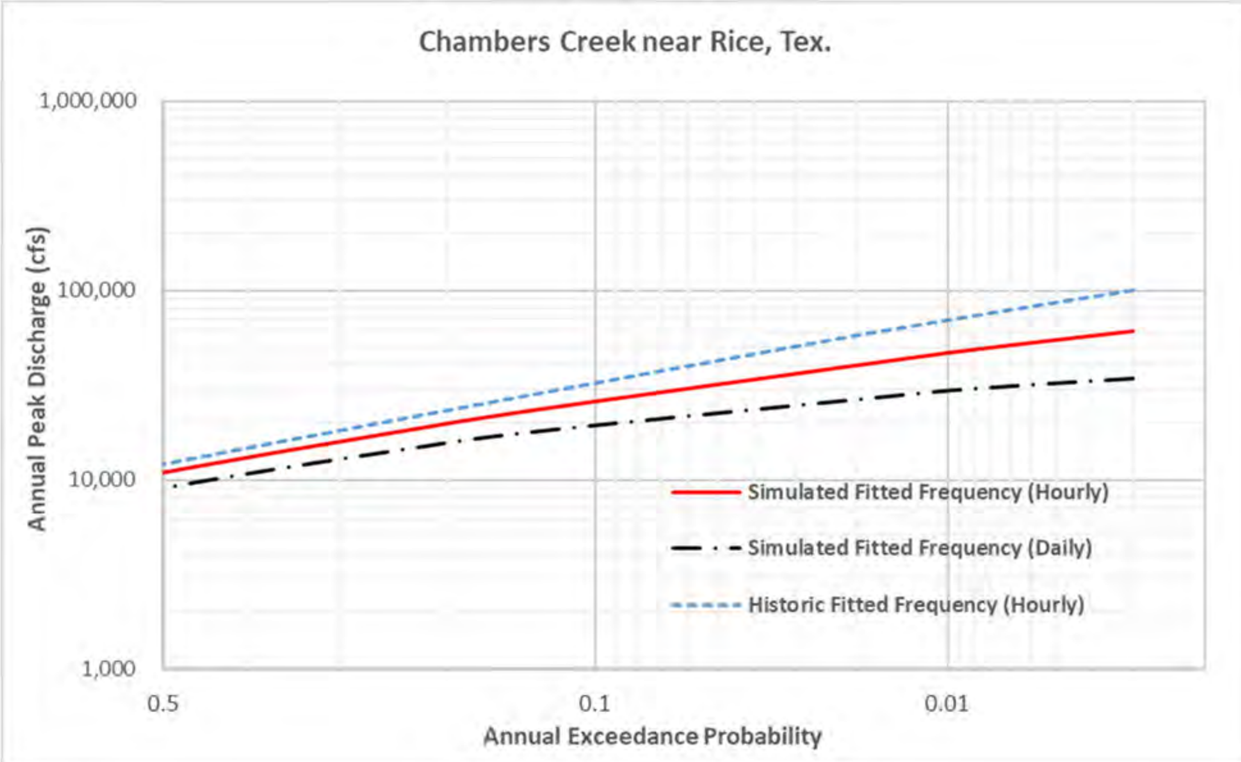

Figure 41c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08064100 Chambers Creek near Rice, Tex.

08064600 Richland Creek near Fairfield, Tex.

The simulated streamflow record for the Fairfield streamgage is 1940–2015. The 1992 peak streamflow for the simulated hourly data was 38,664 ft^3/s, which is the simulated peak of record. Figure 42a shows the peak streamflow data for the simulated and historic data, as well as the impoundment of Richland Chambers Reservoir in 1984. Historic data for the location lasted for just over 10 years, so its usefulness in comparison to simulated data is limited. Because of its historic proximity to Richland Chambers Reservoir, the simulated Fairfield streamgage data is the same as the RiverWare simulated Richland Chambers Reservoir outflow. Because reservoir releases are engineered and generally sustained, a peaking factor was not needed for the Fairfield streamgage data. Therefore, the daily RiverWare data are equated to hourly (instantaneous) peak flow data. This means that peak flows at the Fairfield streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time.

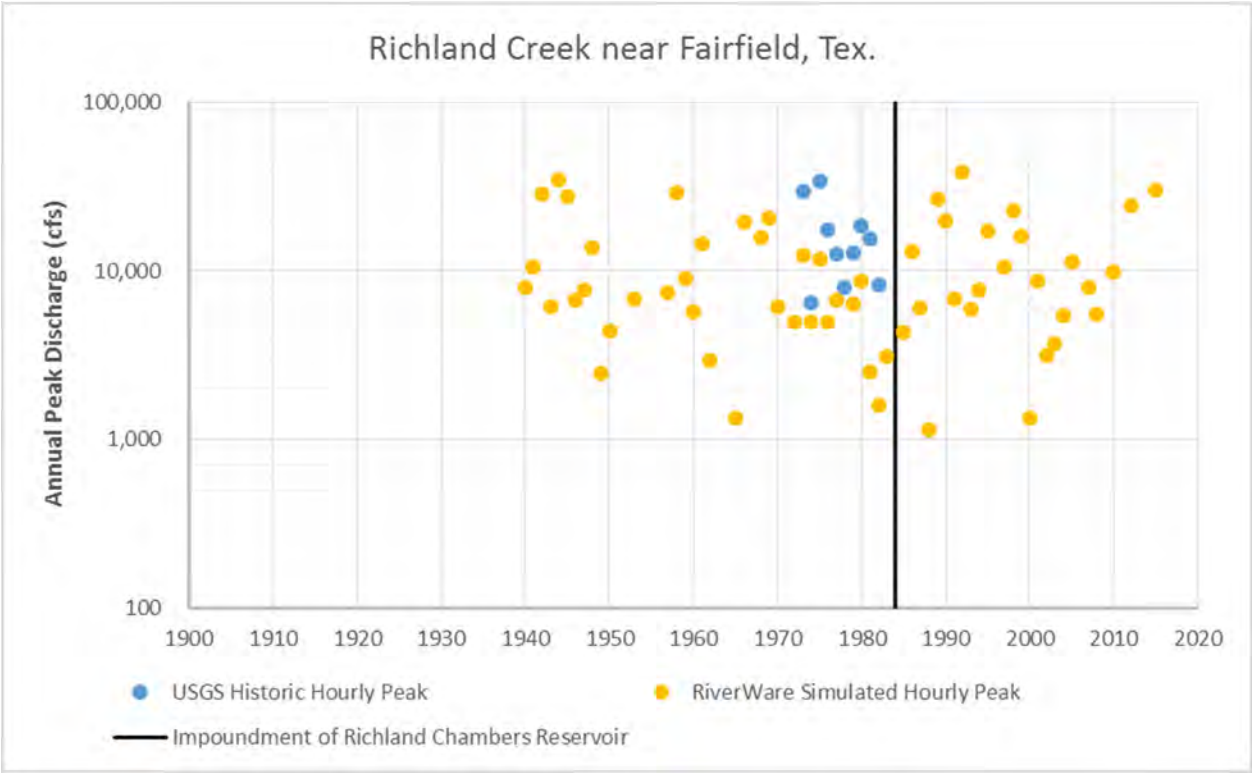

Figure 42a: USGS historic hourly peak streamflows and RiverWare hourly peak streamflow data for streamgage 08064600 Richland Creek near Fairfield, Tex.

The LPIII computed peak streamflow frequency curve for the Fairfield streamgage simulated hourly data is shown in Figure 42b. The MGBT-computed low-outlier threshold for the Fairfield gage is 2,398 ft^3/s. The ordered events show a consistent upward trend with a negative skew, indicating a trend towards plateauing peak events.

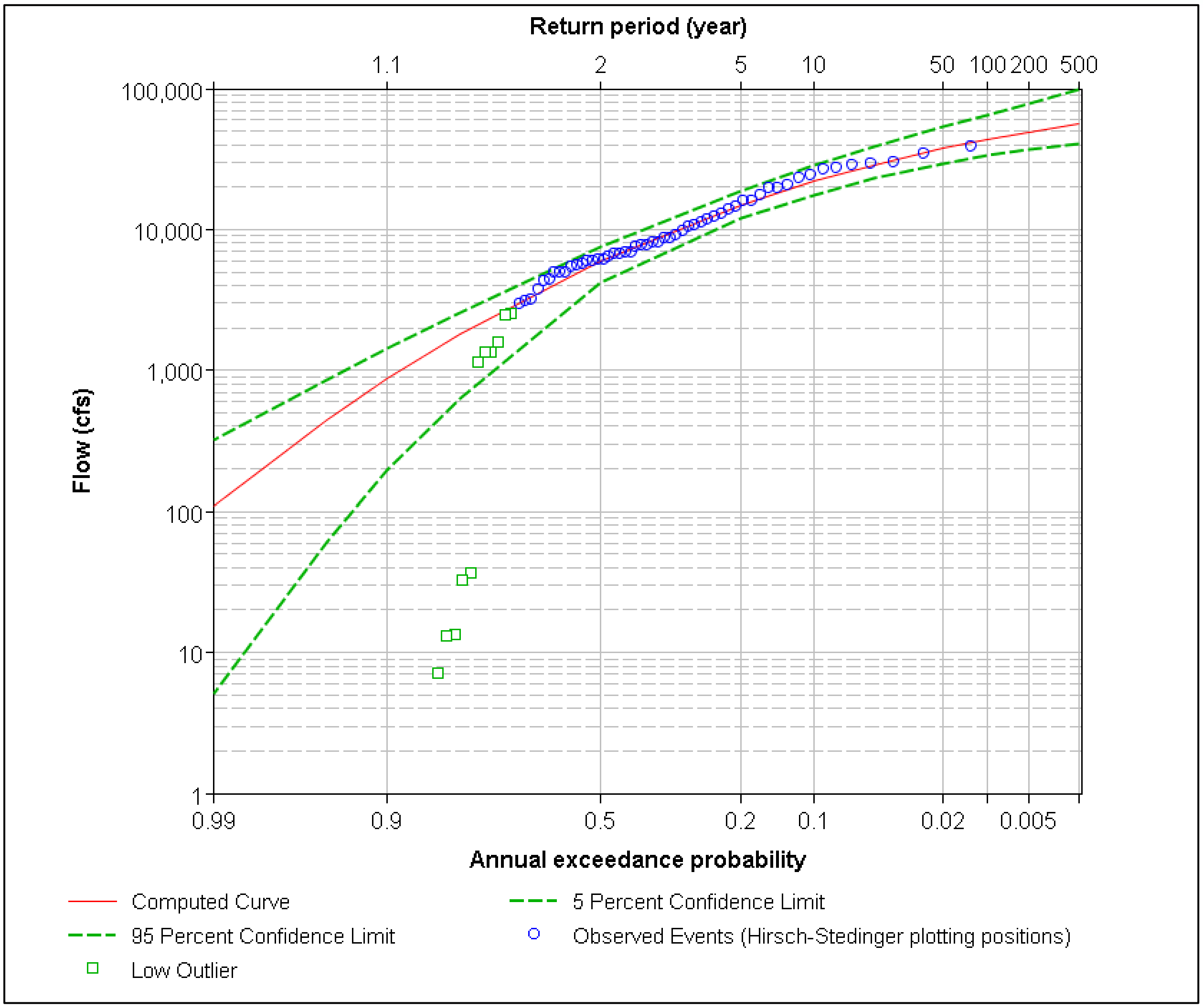

Figure 42b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08064600 Richland Creek near Fairfield, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

USGS peak flow data is only available for ten years at the Fairfield gage, as it was removed for the construction of Richland Chambers reservoir. No historic analysis is performed at the Fairfield gage, so there is no LPIII computed peak streamflow frequency curve comparison for this streamgage location.

08065000 Trinity River near Oakwood, Tex.

The simulated streamflow record for the Oakwood streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 109,612 ft^3/s, which is the simulated peak of record. No peaking factor was applied to the Oakwood streamgage data, so daily peak flows are equated to hourly, or instantaneous, peak flows. This means that peak flows at the Oakwood streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. Figure 43a shows the peak streamflow data for the simulated and historic data. Two historic peaks are available for the historic period of record in 1890 and 1908. The simulated dataset misses several of the greatest historic peaks, but follows the same range in magnitude overall.

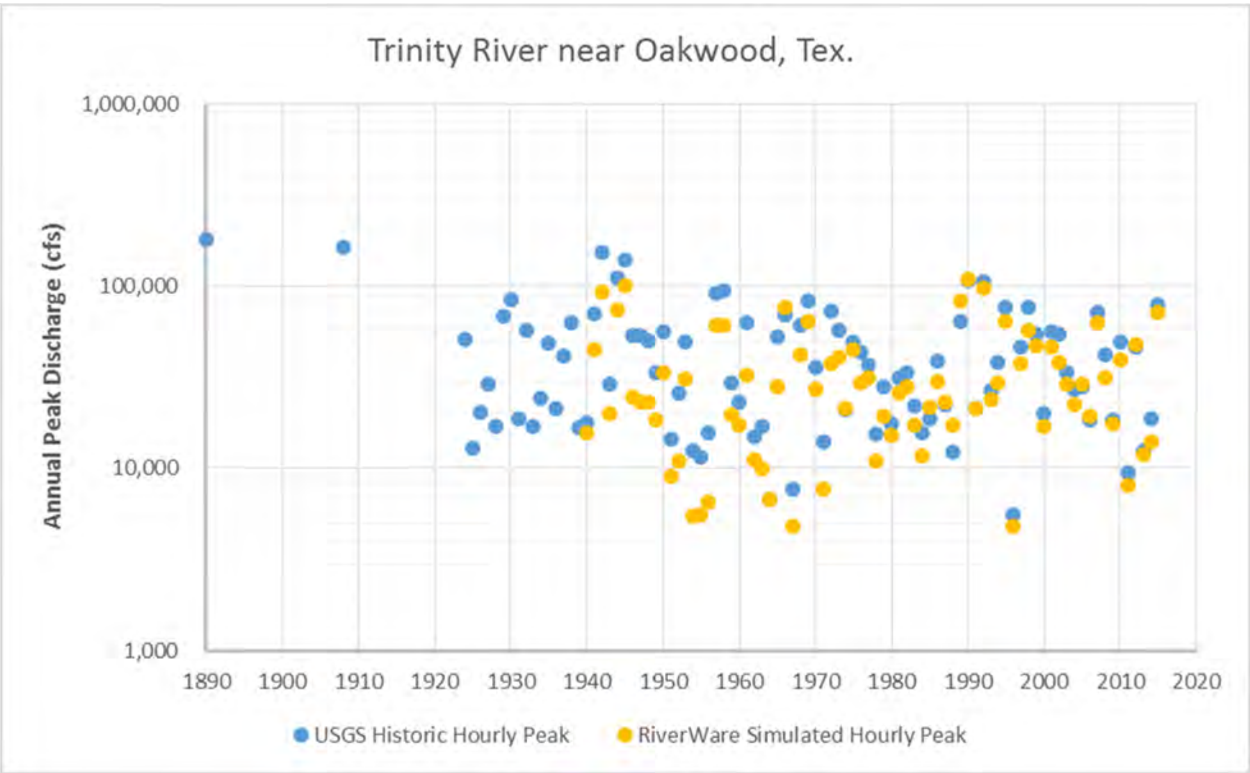

Figure 43a: USGS historic hourly peak streamflows and RiverWare hourly peak streamflow data for streamgage 08065000 Trinity River near Oakwood, Tex.

The LPIII computed peak streamflow frequency curve for the Oakwood streamgage simulated hourly data is shown in Figure 43b. For the Oakwood gage, the MGBT did not compute a low-outlier threshold. The ordered events show a consistent and smooth trend, resulting in a fitted frequency curve with a relatively small skew. There are a few shifts in the data, most notably at about 12,000 and 50,000 ft^3/s.

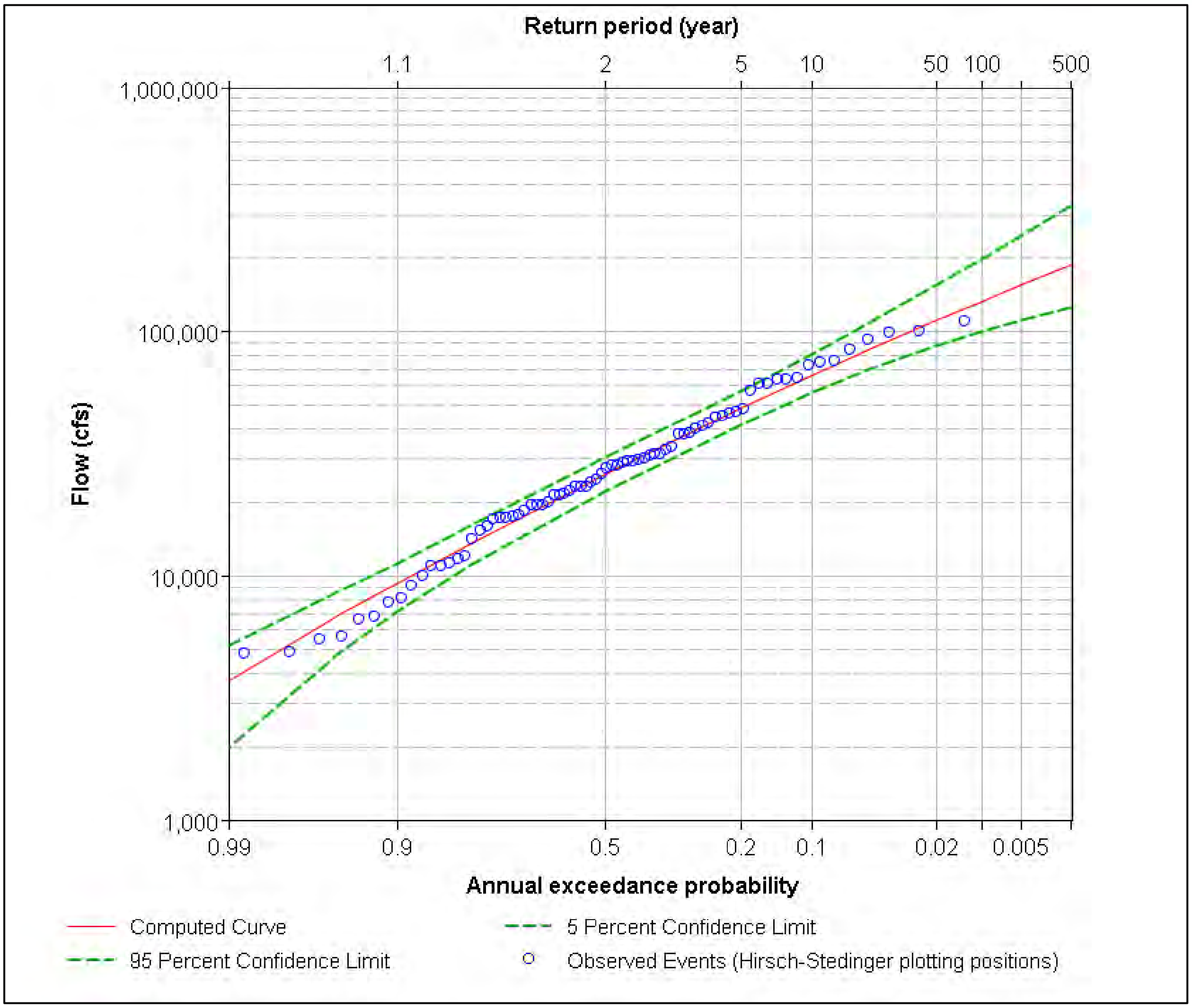

Figure 43b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08065000 Trinity River near Oakwood, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 43c compares the LPIII computed peak streamflow frequency curves for the simulated hourly and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Oakwood streamgage. A small but noticeable increase in the historic fitted frequency curve over the simulated curve is seen in the right tail of the distribution, where the more negative skew of the historic curve causes the historic curve to cross underneath the simulated curve. This skewness also contributes to the gap between the historic and simulated curves in the greater AEP range, where RiverWare is possibly over-regulating flows in the basin.

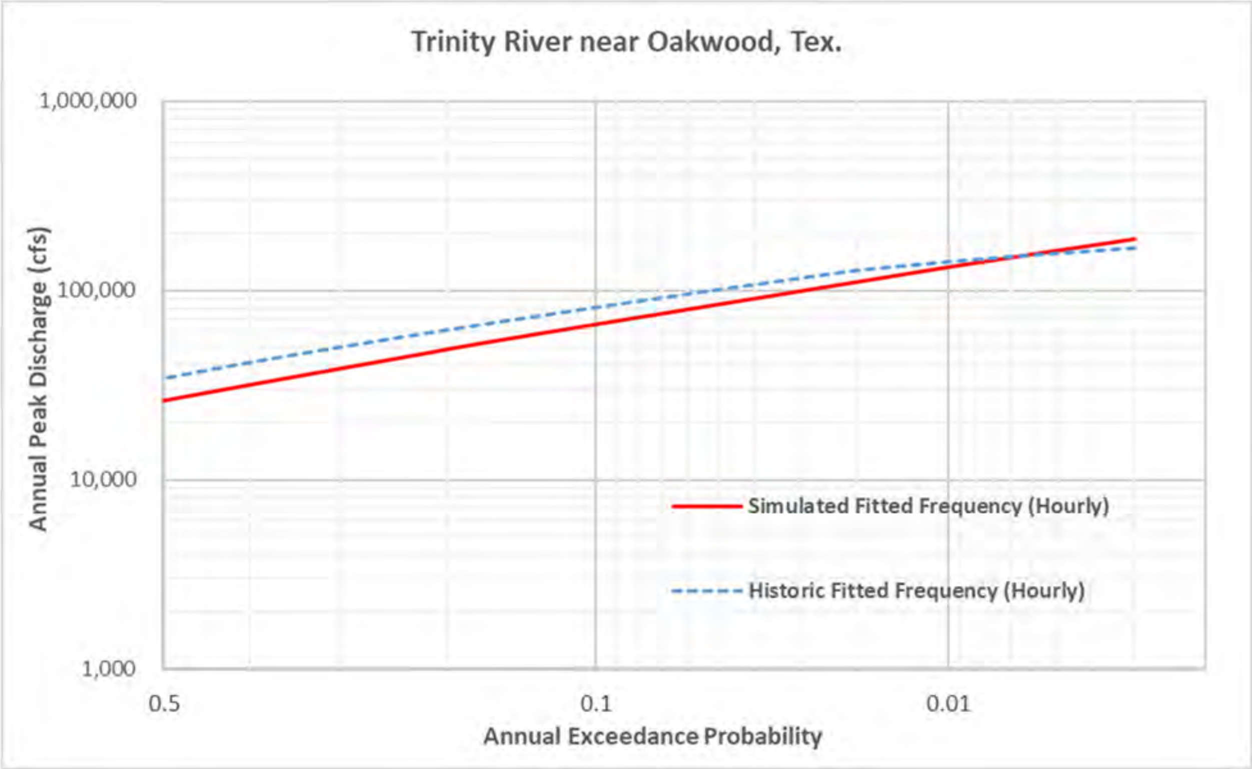

Figure 43c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08065000 Trinity River near Oakwood, Tex.

08065500 Trinity River near Midway, Tex.

The simulated streamflow record for the Midway streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 105,175 ft^3/s, which is the simulated peak of record. No peaking factor was applied to the Midway streamgage data, so daily peak flows are equated to hourly, or instantaneous, peak flows. This means that peak flows at the Midway streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. Figure 44a shows the peak streamflow data for the simulated and historic data. The Midway USGS streamgage was discontinued after 1970.

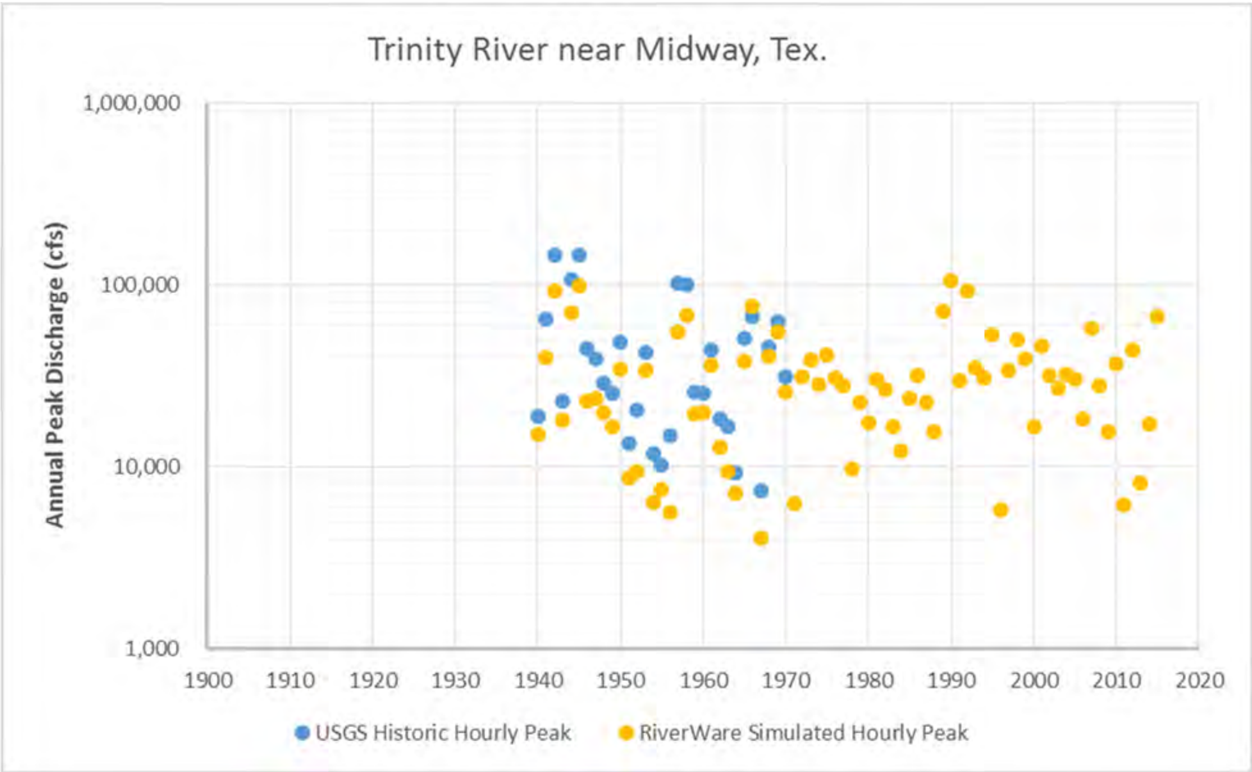

Figure 44a: USGS historic hourly peak streamflows and RiverWare hourly peak streamflow data for streamgage 08065500 Trinity River near Midway, Tex.

The LPIII computed peak streamflow frequency curve for the Midway streamgage simulated hourly data is shown in Figure 44b. A low-outlier threshold was manually set at 5,000 ft^3/s. The ordered events show a consistent and smooth trend, resulting in a fitted frequency curve with a relatively small skew. There are a few shifts in the data, most notably at about 1,000 and 80,000 ft^3/s. Also, peak events appear to begin to plateau at approximately 100,000 ft^3/s.

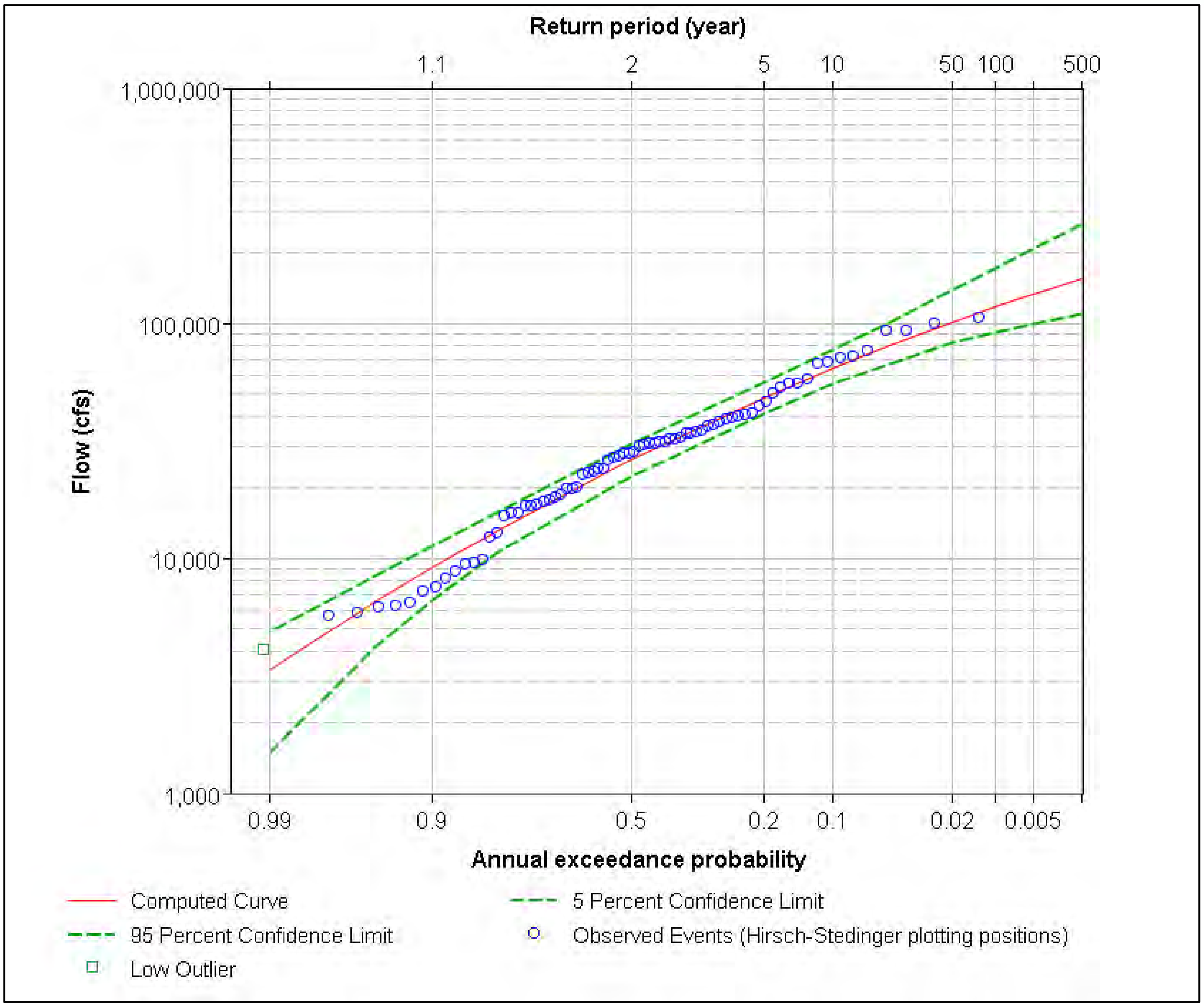

Figure 44b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08065500 Trinity River near Midway, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

USGS historic peak flow data for the Midway streamgage was only available for 1940–1970, and no historic frequency analysis was performed at the streamgage location. Therefore, there is no comparison of the LPIII computed peak streamflow frequency simulated and historic fitted frequency curves.

08066000 Trinity River at Riverside, Tex.

The simulated streamflow record for the Riverside streamgage is 1940–2015. The 1990 peak streamflow for the simulated hourly data was 100,308 ft³/s, which is the simulated peak of record. No peaking factor was applied to the Riverside streamgage data, so daily peak flows are equated to hourly, or instantaneous, peak flows. This means that peak flows at the Riverside streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. Figure 45a shows the peak streamflow data for the simulated and historic data. The Riverside USGS streamgage was discontinued after 1968, most likely because of the backwater effects of Livingston Lake downstream.

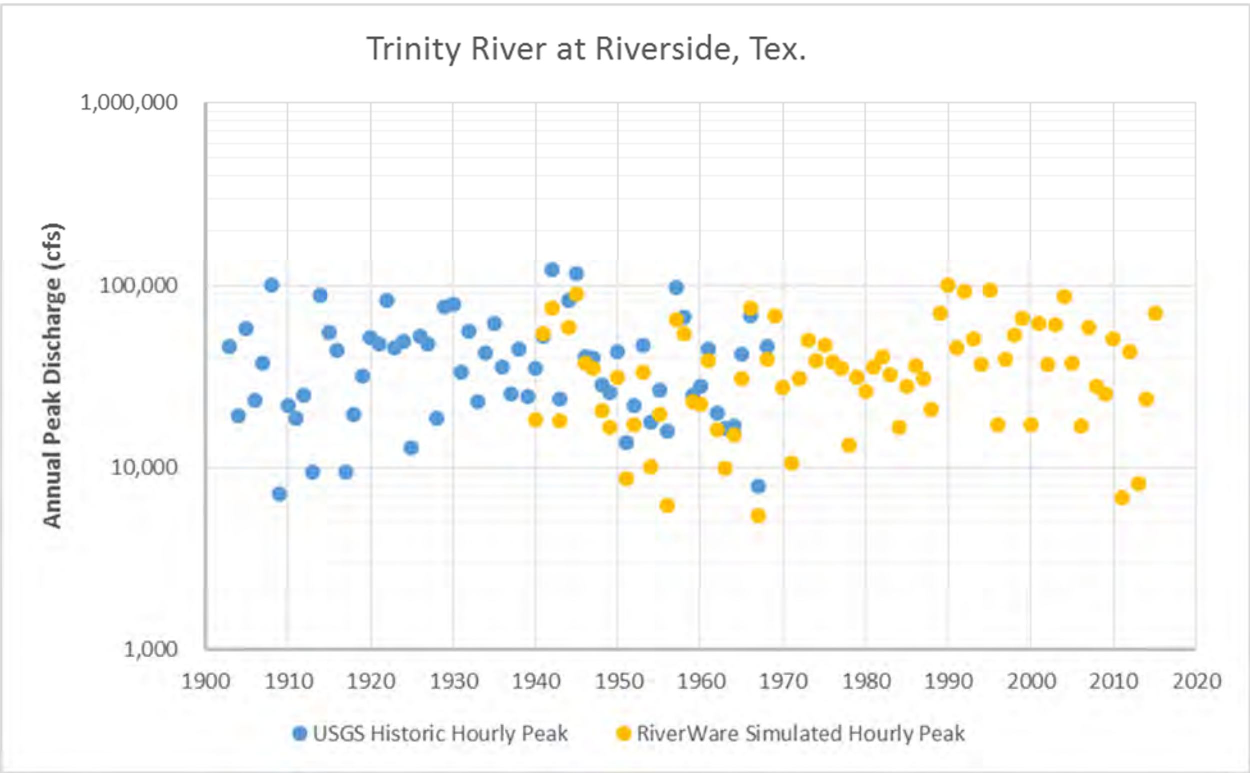

Figure 45a: USGS historic hourly peak streamflows and RiverWare hourly peak streamflow data for streamgage 08066000 Trinity River at Riverside, Tex.

The LPIII computed peak streamflow frequency curve for the Riverside streamgage simulated hourly data is shown in Figure 45b. The MGBT-computed low-outlier threshold for the Riverside gage is 13,254 ft³/s. The ordered events show a consistent and smooth trend, beginning to plateau around 100,000 ft³/s, which results in a fitted frequency curve with a negative skew.

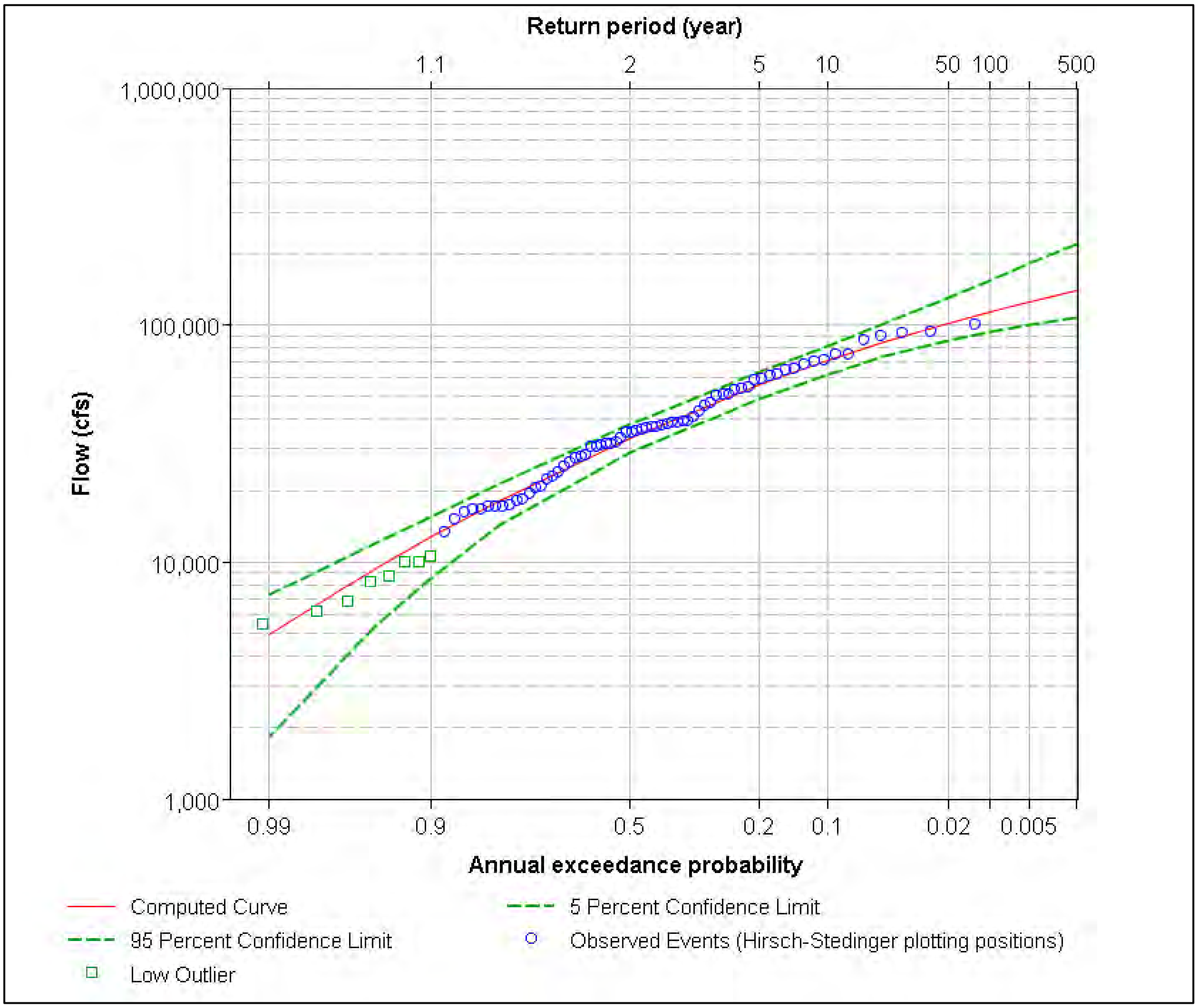

Figure 45b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08066000 Trinity River at Riverside, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 45c compares the LPIII computed peak streamflow frequency curves for the simulated hourly and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Riverside streamgage. The historic and simulated fitted frequency curves are nearly identical, showing that extending the regulated period of record with RiverWare has a limited effect on flows on this stretch of the Trinity River. However, there is a slight but noticeable decrease in the simulated fitted frequency curve in the lower AEP range, beginning at around 0.1 AEP.

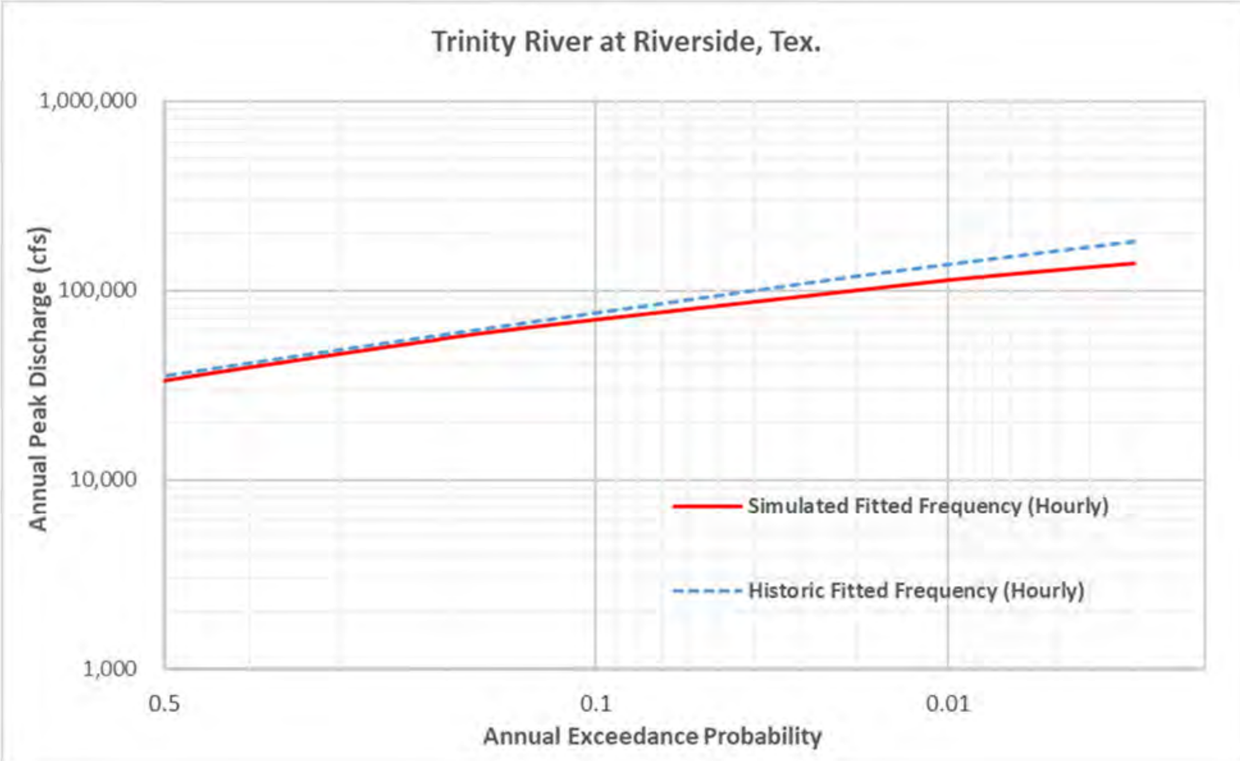

Figure 45c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08066000 Trinity River at Riverside, Tex.

08066500 Trinity River at Romayor, Tex.

The simulated streamflow record for the Romayor streamgage is 1940–2015. The 1995 peak streamflow for the simulated hourly data was 98,463 ft³/s, which is the simulated peak of record. No peaking factor was applied to the Romayor streamgage data, so daily peak flows are equated to hourly, or instantaneous, peak flows. This means that peak flows at the Romayor streamgage are typically sustained over the course of the entire day and do not peak sharply over a short period of time. Figure 46a shows the peak streamflow data for the simulated and historic data, as well as the impoundment of Livingston Lake in 1966, though the lake is not a flood control reservoir and is expected to have a limited effect on peak streamflow. The underestimating of peak flows in RiverWare can be observed again in the Romayor gage dataset, even though the gage is not proximal to any major flood control structures. The simulated data appears to be underestimating several of the greatest historic events.

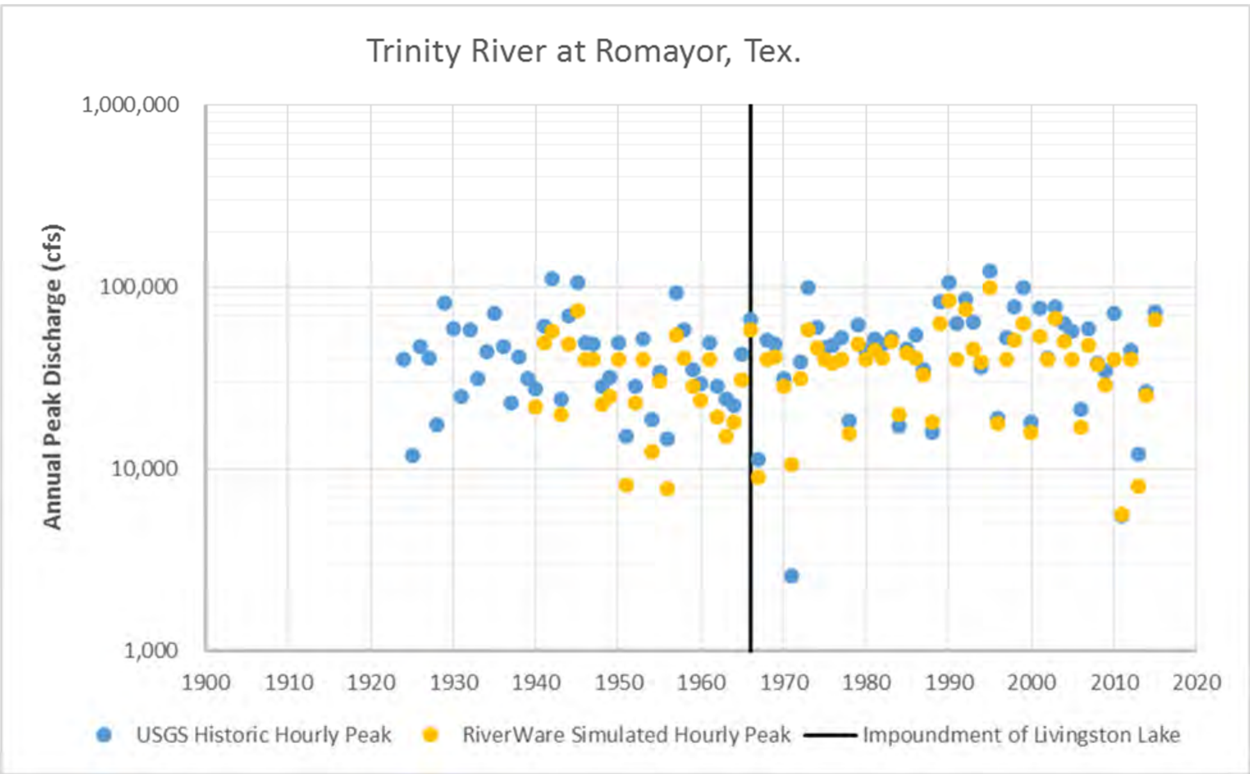

Figure 46a: USGS historic hourly peak streamflows and RiverWare hourly peak streamflow data for streamgage 08066500 Trinity River at Romayor, Tex.

The LPIII computed peak streamflow frequency curve for the Romayor streamgage simulated hourly data is shown in Figure 46b. The MGBT-computed low-outlier threshold for the Riverside gage is 33,063 ft³/s. The ordered events show a consistent and smooth trend, resulting in a more linear fitted frequency curve with a relatively small skew. A small step appears in the data at approximately 40,000 ft³/s, possibly the result of regulated releases from nearby Livingston Lake upstream.

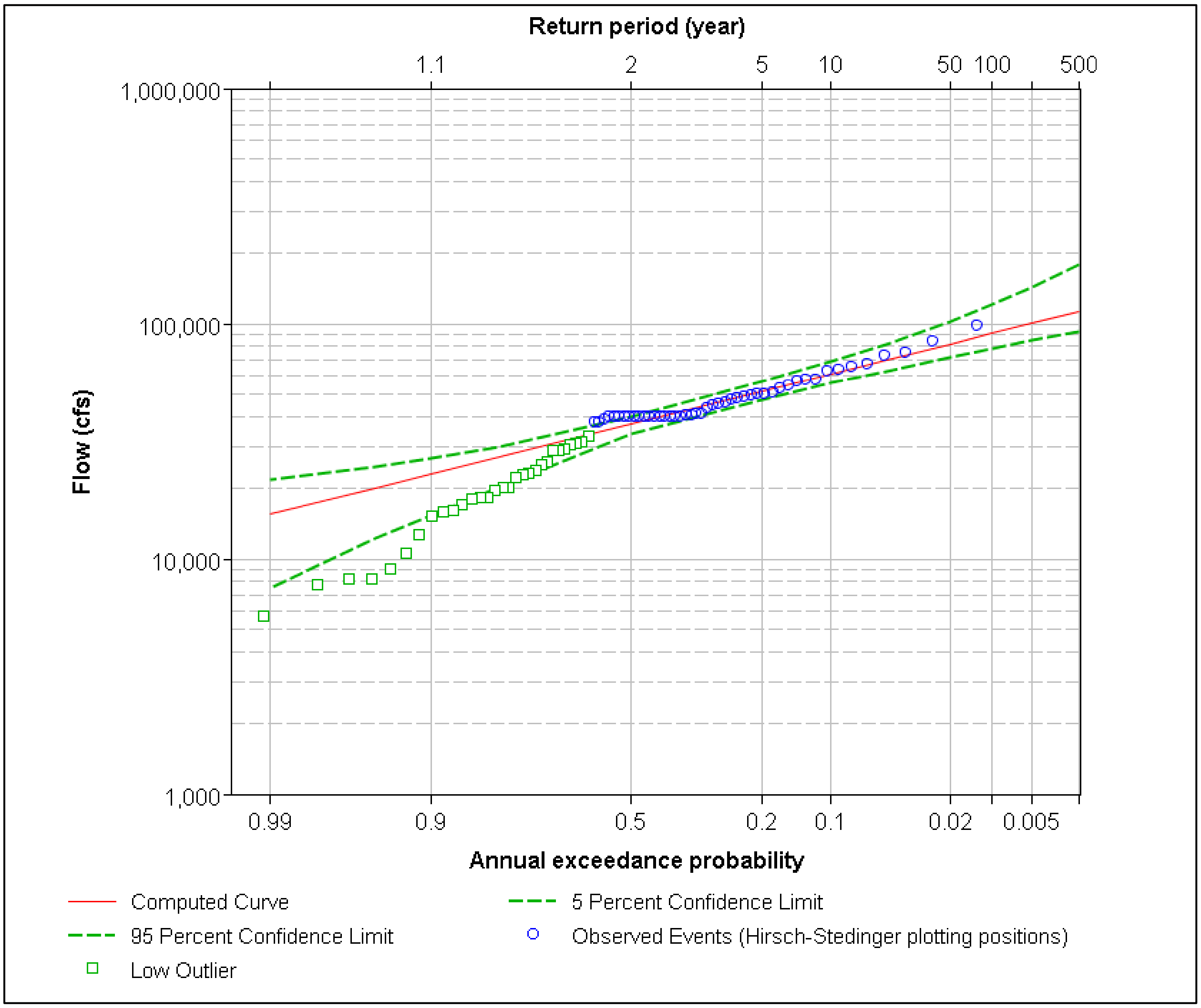

Figure 46b: Peak streamflow frequency using log-Pearson type III distribution for streamgage 08066500 Trinity River at Romayor, Tex. and hourly RiverWare output from screenshot of USACE HEC-SSP software.

Figure 46c compares the LPIII computed peak streamflow frequency curves for the simulated hourly and USGS historic peak streamflow data computed in the Statistical Hydrology Appendix at the Romayor streamgage. The historic and simulated fitted frequency curves are nearly identical in the upper range of AEP, showing that extending the regulated period of record with RiverWare has a limited effect on flows on this stretch of the Trinity River, even though the Romayor streamgage is downstream from Livingston Lake.

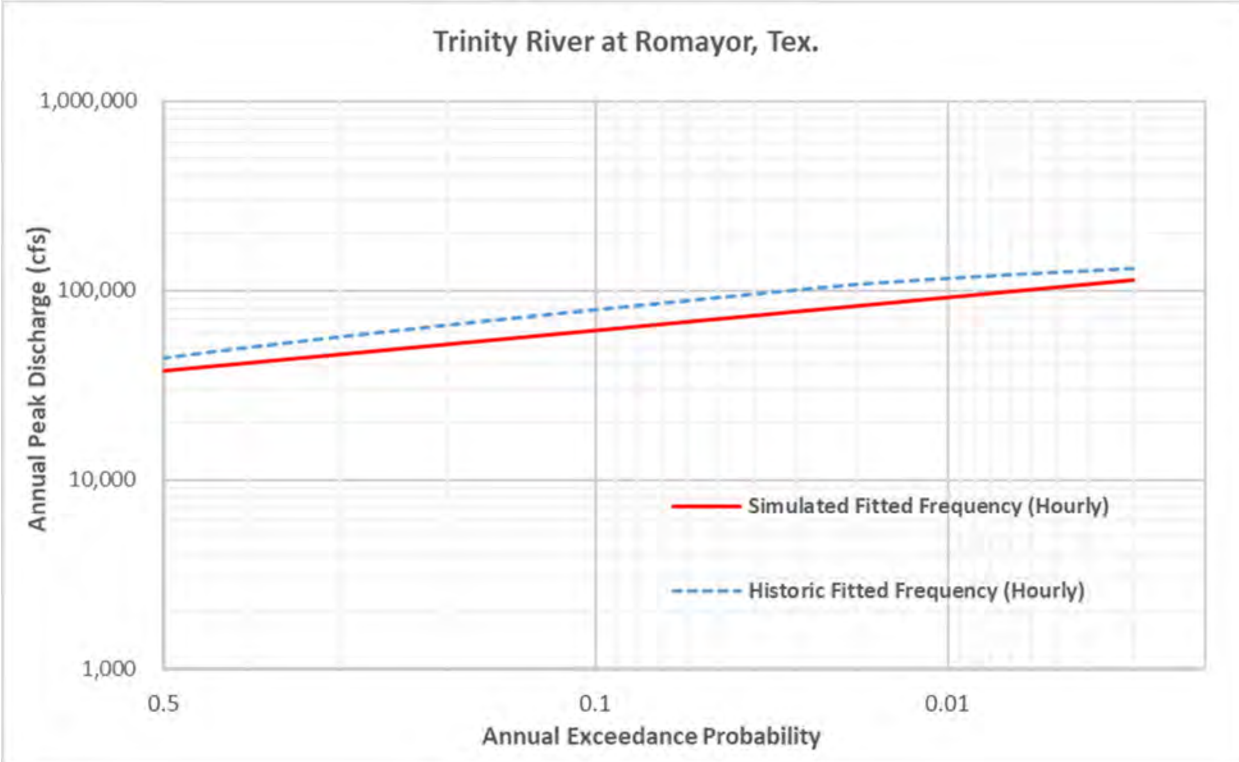

Figure 46c: Comparison of log-Pearson type III computed peak streamflow frequency curves for the simulated daily, simulated hourly, and historic hourly data for streamgage 08066500 Trinity River at Romayor, Tex.

Table 5 summarizes the results of the frequency analysis for the hourly peak streamflows for the 18 streamgages in the Trinity River watershed analyzed for this study. Four were not included because of the influence of regulation in RiverWare failing to match historic data. This issue arose quite frequently in the Trinity watershed, where there are many flood control structures and regulated sections of river. RiverWare was designed as a reservoir operations modeling software, so it will attempt to find a regulated solution to any given inflow based on a set of rules. Despite a modeler's best efforts, these rules can never be as complex or nuanced as the daily decisions being made by reservoir operators in response to a storm event or flooding. Additionally, RiverWare was not specifically designed to model rainfall, runoff, tributary inflow, or other hydrologic processes that contribute to flooding. Instead it routes a user-specified input through a system of regulation objects that simulate a watershed. Therefore, RiverWare modeling results can be expected to be optimistic about capturing peak streamflow events with regulation rulesets, producing lower peak streamflow estimates. This does not necessarily mean that it fails as an analytical tool, but rather should be compared to the other peak streamflow frequency analyses in this report with caveats. The RiverWare model does not produce unrealistic or unreliable results, but rather provides lower bounds to the peak streamflow frequency analysis, based on ideally regulated flows in the Trinity basin.

Differences between the simulated hourly and simulated daily fitted frequency curves diminish downstream, a signal of changing stream characteristics. As the Trinity River increases in size, it is less susceptible to flash floods, and peak streamflow events are typically sustained over the course of the entire day and do not peak sharply over a short period of time.

The effects of regulation on the watershed also diminish downstream on the Trinity River. Regulation has a more nuanced effect on the Trinity further downstream where it is not susceptible to flash floods, but most of the flood control reservoirs in the basin are upstream in the Dallas-Fort Worth metropolitan (metroplex) area.

The fitted frequency results for gages on the Trinity River increase markedly throughout the metroplex. This is most likely because of two factors. First, increased urbanization in the metroplex has led to a large percentage of impermeable surfaces, increasing runoff in the area. Second, the Trinity River coalesces from multiple tributaries in the metroplex (Clear Fork, West Fork, Elm Fork, and East Fork), each contributing a measurable amount of flow to the main stem. Past the Rosser gage, the incremental increase in the fitted frequency curve slows, and even decreases in some cases as the river leaves the heavily urbanized metroplex and the tributaries entering the Trinity have a lower proportional discharge than that of the main stem, so their effects are not as evident. Another reason for the stabilization of the frequency curve could be the attenuation of the flood wave based on the shape of the basin. Beyond the Richland-Chambers watershed, tributaries to the Trinity River appear to have a negligible effect on peak flows, and the Trinity becomes a transport corridor with a declining flood wave.

The Richland-Chambers watershed is the largest subbasin of the Trinity downstream of the Dallas-Fort Worth metroplex. Five gages in this subbasin were analyzed for this report. The Richland-Chambers watershed is a much smaller watershed than the Trinity, which means that its creeks are more susceptible to flash floods and peak flows are not typically sustained outside of a timeframe of many hours. Evidence of this is seen in Table 1, which shows larger peaking factors for the Richland-Chambers gages used to convert the daily peak streamflows to hourly peaks, except for those immediately downstream of flood control reservoirs. Reservoirs in the watershed help mitigate the effects of flooding, and evidence of this is seen in the step-wise ordered peak events and difference in the historic and simulated hourly fitted frequency curves such as that of the Richland gage.

Table: 5 Statistically estimated annual peak streamflow frequency results for the twenty-two U.S. Geological Survey streamflow-gaging stations in the Trinity River basin based on USACE HEC-SSP B17C computations.

Station number and name and stramflow estimate type	Flood flow frequency by annual exceedence probability (AEP)							
	AEP 0.500 (ft^3/s)	AEP 0.200 (ft^3/s)	AEP 0.100 (ft^3/s)	AEP 0.050 (ft^3/s)	AEP 0.020 (ft^3/s)	AEP 0.010 (ft^3/s)	AEP 0.005 (ft^3/s)	AEP 0.002 (ft^3/s)
Clear Fork Trinity River near Benbrook, Tex.								
Lower 95%-CI	628	2,171	3,204	4,265	5,781	7,008	8,294	10,069
Estimate	**1,165**	**2,654**	**4,007**	**5,576**	**8,007**	**10,132**	**12,514**	**16,081**
Upper 95%-CI	1,398	3,363	5,525	8,648	14,750	21,134	29,262	43,086
Clear Fork Trinity River at Fort Worth, Tex.								
Lower 95%-CI	5,791	9,730	12,409	14,920	17,931	19,955	21,777	23,920
Estimate	**6,626**	**11,093**	**14,236**	**17,318**	**21,365**	**24,425**	**27,493**	**31,563**
Upper 95%-CI	7,559	12,741	16,725	21,284	28,548	35,103	42,722	54,759
West Fork Trinity River at Fort Worth, Tex.								
Lower 95%-CI	7,669	13,119	17,103	21,033	26,093	29,801	33,411	38,046
Estimate	**8,759**	**15,028**	**19,848**	**24,924**	**32,133**	**38,014**	**44,295**	**53,252**
Upper 95%-CI	10,002	17,463	23,969	31,843	44,780	56,814	71,163	94,402
West Fork Trinity River at Grand Prairie, Tex.								
Lower 95%-CI	7,550	13,682	18,956	24,829	33,637	41,174	49,539	61,996
Estimate	**8,734**	**16,099**	**22,900**	**31,174**	**44,969**	**58,073**	**73,988**	**100,281**
Upper 95%-CI	10,102	19,518	29,903	45,760	80,903	124,749	192,276	340,051
Mountain Creek at Grand Prairie, Tex.								
Lower 95%-CI	4,239	7,941	10,219	12,022	13,577	14,313	14,817	15,256
Estimate	**5,094**	**9,201**	**11,660**	**13,712**	**15,927**	**17,295**	**18,444**	**19,689**
Upper 95%-CI	6,054	10,556	13,412	16,266	20,093	23,092	26,224	30,615
Elm Fork Trinity River near Lewisville, Tex.								
Lower 95%-CI	2,811	5,479	7,208	8,947	11,272	13,035	14,789	17,083
Estimate	**3,532**	**6,314**	**8,482**	**10,776**	**14,043**	**16,709**	**19,553**	**23,598**
Upper 95%-CI	4,032	7,476	10,425	13,943	19,886	25,765	33,281	46,621
Elm Fork Trinity River near Carrollton, Tex.								
Lower 95%-CI	4,971	7,535	9,974	12,590	16,362	19,532	23,018	28,175
Estimate	**5,437**	**8,695**	**11,794**	**15,673**	**22,384**	**29,018**	**37,381**	**51,854**
Upper 95%-CI	6,136	10,309	15,011	22,499	40,856	66,619	111,159	224,406
Trinity River at Dallas, Tex.								
Lower 95%-CI	14,617	26,604	35,543	44,368	55,473	63,347	70,779	79,984
Estimate	**16,993**	**30,901**	**41,707**	**53,082**	**69,154**	**82,157**	**95,918**	**115,307**
Upper 95%-CI	19,746	36,345	51,007	68,816	97,782	124,412	155,879	206,351
East Fork Trinity River near Crandall, Tex.								
Lower 95%-CI	6,030	11,463	15,334	19,145	24,008	27,507	30,836	34,975
Estimate	**7,188**	**13,393**	**18,144**	**23,060**	**29,855**	**35,226**	**40,795**	**48,452**
Upper 95%-CI	8,378	15,921	22,239	29,497	41,086	51,788	64,561	85,353
Trinity River near Rosser, Tex.								
Lower 95%-CI	18,529	33,019	43,889	54,770	68,928	79,379	89,599	102,771
Estimate	**21,383**	**38,210**	**51,483**	**65,678**	**86,136**	**103,028**	**121,230**	**147,424**
Upper 95%-CI	24,672	44,881	62,984	85,300	122,635	157,927	200,554	270,595
Trinity River at Trinidad, Tex.								
Lower 95%-CI	20,191	36,137	47,526	58,266	70,819	79,059	86,374	94,866
Estimate	**23,446**	**41,775**	**55,349**	**69,107**	**87,750**	**102,242**	**117,078**	**137,208**
Upper 95%-CI	27,215	48,602	66,407	86,975	118,533	146,186	177,673	226,156

Station number and name and stramflow estimate type	Flood flow frequency by annual exceedence probability (AEP)							
	AEP 0.500 (ft^3/s)	AEP 0.200 (ft^3/s)	AEP 0.100 (ft^3/s)	AEP 0.050 (ft^3/s)	AEP 0.020 (ft^3/s)	AEP 0.010 (ft^3/s)	AEP 0.005 (ft^3/s)	AEP 0.002 (ft^3/s)
Richland Creek near Richland, Tex.								
Lower 95%-CI	9,914	18,328	24,300	30,064	37,152	41,990	46,373	51,534
Estimate	**11,664**	**21,369**	**28,519**	**35,695**	**45,283**	**52,620**	**60,024**	**69,896**
Upper 95%-CI	13,624	25,122	34,342	45,223	63,329	80,320	100,668	133,903
Chambers Creek near Rice, Tex.								
Lower 95%-CI	9,322	17,033	22,451	27,559	33,559	37,462	40,875	44,757
Estimate	**10,929**	**19,786**	**26,158**	**32,434**	**40,649**	**46,815**	**52,936**	**60,951**
Upper 95%-CI	12,756	23,119	31,230	40,544	55,208	68,281	83,369	107,038
Richland Creek near Fairfield, Tex.								
Lower 95%-CI	4,169	11,921	17,607	23,102	29,515	33,519	36,814	40,253
Estimate	**5,943**	**14,951**	**21,995**	**28,907**	**37,565**	**43,636**	**49,249**	**55,947**
Upper 95%-CI	7,584	18,883	28,315	38,571	53,285	65,387	78,668	98,569
Trinity River near Oakwood, Tex.								
Lower 95%-CI	22,280	41,710	56,274	70,550	88,243	100,574	112,048	126,037
Estimate	**26,113**	**48,764**	**66,501**	**85,210**	**111,642**	**132,991**	**155,534**	**187,185**
Upper 95%-CI	30,588	57,624	81,386	109,958	156,099	198,391	248,269	328,070
Trinity River near Midway, Tex.								
Lower 95%-CI	22,458	41,385	54,936	67,652	82,295	91,693	99,868	109,136
Estimate	**26,345**	**48,112**	**64,062**	**80,000**	**101,198**	**117,350**	**133,589**	**155,156**
Upper 95%-CI	30,838	56,248	77,027	101,114	138,190	170,687	207,744	264,984
Trinity River at Riverside, Tex.								
Lower 95%-CI	28,953	49,094	62,152	73,757	86,361	93,935	100,174	106,848
Estimate	**33,370**	**55,929**	**70,789**	**84,555**	**101,480**	**113,474**	**124,849**	**139,016**
Upper 95%-CI	38,296	63,762	81,934	101,614	130,317	154,186	180,309	218,974
Trinity River at Romayor, Tex.								
Lower 95%-CI	33,745	47,707	55,696	63,077	72,196	78,692	84,889	92,680
Estimate	**37,473**	**51,637**	**61,074**	**70,164**	**82,035**	**91,054**	**100,180**	**112,482**
Upper 95%-CI	40,344	56,799	68,707	81,628	101,764	120,289	142,448	178,655

2 References and Resources

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3 Terms of Reference

AEP	Annual Exceedance Probability
CADSWES	Center for Advanced Decision Support for Water and Environmental Systems
cfs	cubic feet per second
EMA	expected moments algorithm
FEMA	Federal Emergency Management Agency
ft	feet
HEC	Hydrologic Engineering Center
LPIII	Log-Pearson Type III
InFRM	Interagency Flood Risk Management
MGBT	Multiple Grubbs-Beck Test
MSE	Mean Square Error
PILF	Potentially Influencing Low Floods
POR	Period of Record
SSP	Statistical Software Package
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey

Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin
Appendix E - Reservoir Studies

July 2021

InFRM
INTERAGENCY FLOOD RISK MANAGEMENT

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1. Reservoir Studies

1.1 INTRODUCTION TO STAGE FREQUENCY ANALYSIS

This appendix describes the methods used to update the pool frequency curves for the Trinity River Basin Reservoir projects. The reservoir projects that have been analyzed for this report are Bardwell, Benbrook, Grapevine, Joe Pool, Lavon, Lewisville, Navarro Mills, Ray Roberts, and Richland-Chambers. Richland-Chambers is operated by the Tarrant Regional Water District (TRWD) while the other projects are operated by the United States Army Corps of Engineers (USACE). The frequency curves were developed to represent the current reservoir control plan and watershed conditions (as of 2016). A frequency analysis is a statistical method of prediction that consists of studying past events that are characteristic of a particular hydrology process in order to determine the probabilities of occurrence of these events in the future. A Stage-Frequency curve estimates the annual exceedance probability (AEP) for reservoir pool elevations. For example, if a reservoir pool at the spillway crest has an AEP of 1/50 (1 in 50 years on average), then the reservoir has a 2% chance of the reservoir pool elevation equaling or exceeding the spillway crest elevation in any given year. The stage-frequency curve can be determined using empirical (observed or measured) data; however, the reservoir pool elevations associated with 1% AEP (100-year) or 0.2% AEP (500-year) occurrences are typically beyond the observed reservoir pool elevation period of record (POR). Models serve the purpose of extrapolating reservoir pool elevation frequencies beyond the observed record.

For the presented study, the stage frequency curves representing current conditions were developed to evaluate the Trinity River Basin projects' pools elevations resulting from the 50% AEP (2-year) to the 0.2% AEP (500-year) events. This study incorporates available reservoir inflow and pool data (from historical peaks to the year 2016) into statistical software, and applies statistical methods to estimate the n-day critical inflow duration and simulate inflow and elevation period of record for each reservoir project. The historical peaks may be observed and recorded by local residents or seen as water marks on bridge piers or tree trunks; those water elevation marks can be translated into peak discharge values via the use of models or by extrapolating rating curves or extrapolation of observed data points. For each project, the Hydrologic Engineering Center-Statistical Software Package (HEC-SSP) was used to compute volume duration frequency curves from the annual maximum peak reservoir inflows (Version 2.1.1; USACE, 2017). An empirical stage frequency curve was developed from the available reservoir pool Annual Maximum Series (AMS). An event based stochastic Monte Carlo simulation model, Risk Management Center-Reservoir Frequency Analysis (RMC-RFA), was used to extrapolate the stage frequency curve beyond the limits of the empirical stage frequency curve (Version 1.0.0; USACE, 2017). RiverWare was used to develop a current condition POR for reservoir inflows and elevations (Version 7.1; University of Colorado Boulder, 2017). The AMS results derived from RiverWare were used to create the empirical stage frequency curve. The empirical stage-frequency curve was used to validate RFA model simulation results. The results showed adequate validation to the upper end of the empirical stage frequency curves and it is believed to be a reasonable extrapolation for frequency of rare pool events.

Pool frequencies for the Trinity River Basin projects can be found in the following referenced report-years: Bardwell (USACE Fort Worth District, 2009), Benbrook (FEMA, 2009), Grapevine (FEMA Tarrant Co., 2009; FEMA Denton Co., 2011), Joe Pool (USACE Fort Worth District, 1974; FEMA Ellis Co., 2013), Lavon (USACE Fort Worth District, 2009), Lewisville (FEMA Denton Co, 1983), Navarro Mills (USACE Fort Worth District, 2009), and Ray Roberts (FEMA Denton Co, 1983). No previous records or stage frequency elevation estimates were made to compare to the results documented in this report for Richland-Chambers. The pool frequencies from these reports were used in the effective Federal Emergency Management Agency (FEMA) Flood Insurance Study (FIS) reports. The FEMA pool frequencies for the aforementioned projects are listed in Table 1 in the National Geodetic Vertical Datum of 1929 (NGVD29). Additional USACE pool frequencies were added to Table 1 when no FEMA pool frequencies were available. In this report, main emphasis is placed on comparing the updated 1% AEP (100-year) and 0.2% AEP (500-year) events computed via the RMC-RFA program through WY 2016 to the FEMA adopted pool frequencies of each project.

Table 1. Trinity River Basin Projects Effective FEMA FIS Pool Elevation Frequencies and the USACE 2009 Pool Elevation Frequency Recording

Project	FEMA's Pool Annual Chance of Exceedance (ACE%) /Return Interval (N-Year)				USACE 2009 Pool Annual Chance of Exceedance (ACE%) /Return Interval (N-Year)			
	10% (10-yr)	2% (50-yr)	1% (100-yr)	0.2% (500-yr)	10% (10-yr)	2% (50-yr)	1% (100-yr)	0.2% (500-yr)
	Elevation (Feet) NGVD				Elevation (Feet) NGVD			
Bardwell	N/A	N/A	N/A	N/A	N/A	439	440	N/A
Benbrook	704.8	712.2	715	727	N/A	N/A	N/A	N/A
Grapevine	554	562.3	564	568.4	N/A	N/A	N/A	N/A
Joe Pool	527.5	536	537.5	543.5	N/A	N/A	N/A	N/A
Lavon	N/A	N/A	N/A	N/A	N/A	503.8	504.3	N/A
Lewisville	529.5	535	537	541	N/A	N/A	N/A	N/A
Navaro Mills	N/A	N/A	N/A	N/A	N/A	443	444	N/A
Ray Roberts	639.5	644	645.5	649	N/A	N/A	N/A	N/A

1.2 WATERSHED DESCRIPTION

The Trinity River flows for a total of 550 river miles with the headwaters of the basin located in Northern Central Texas, beginning near the Texas-Oklahoma border, and ending in the Trinity Bay which drains to the Gulf of Mexico near Houston (Figure 1). There are roughly 1,980 miles of major tributaries that drain to the river. The watershed drains 17,969 square miles. Table 2, lists the corresponding drainage area for the reservoir projects and their closest United State Geological Survey (USGS) gages. In many instances, project inflow reads recording gage data from the nearest USGS gage upstream of the dam, especially if the project drainage area does not vary significantly from the nearest USGS gage. The nearest USGS gage rating curve can also be used to estimate the historical peak discharges for the projects.

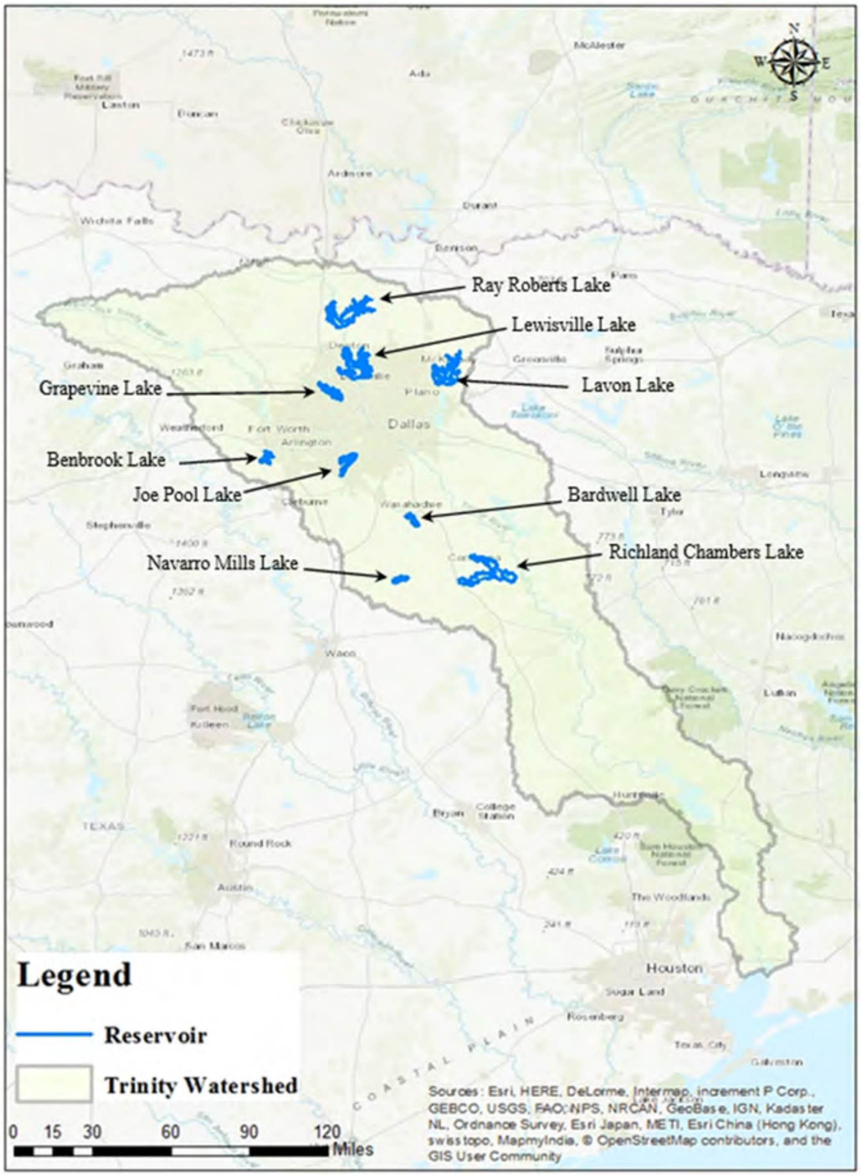


Figure 1: Map of the Trinity River Watershed

A brief site specific watershed description follows for each reservoir, presented alphabetically:

<u>Bardwell Lake</u>: Bardwell Lake is located on Waxahachie Creek, and it flows in a generally southeasterly direction to its confluence with Chambers Creek, which is a left bank tributary of Richland Creek. Richland Creek flows east to its confluence with the Trinity River at river mile 372.4. Waxahachie Creek has a streambed slope of 4.4 feet/mile, 60 to 100 feet wide with banks 15 to 20 feet high. The basin is rectangular in shape being about 31 miles long and averaging about six miles in width.

<u>Benbrook Lake</u>: Benbrook Lake is located on the Clear Fork of the Trinity River at river mile 15. The Clear Fork of the Trinity River originates in north central Texas and is approximately 65 miles long. It flows in a generally southeasterly direction through Parker County and then northeasterly to its junction with the West Fork of the Trinity River at Fort Worth, Texas. The watershed area upstream of the dam is approximately 55 miles long and 11

miles wide. The watershed is relatively narrow in the headwater area but several small tributary streams entering the Clear Fork give the lower portion a definite fan shape. The streambed slope is 11.5 feet/mile.

Grapevine Lake: Grapevine Lake is located on Denton Creek at river mile 11.7. The Denton Creek of the Trinity River flows 98 miles in a southeasterly direction until it joins the Elm Fork of the Trinity River at river mile 18.6. On average the watershed is about 66 miles long and 11 miles wide. The streambed slope is 2.3 feet/mile. The topography of the Denton Creek Watershed consists of gently rolling hills, with increasingly rugged topography in the basin's upper reaches. The gentler terrain is generally farmed, while the rougher parts of the watershed are used for rangeland.

Joe Pool: Joe Pool Lake is located on Mountain Creek. It originates in the northern part of Johnson County, Texas and flows in a north and northeasterly direction for approximately 37 miles until it joins the West Fork of the Trinity River at river mile 507.8. The Mountain Creek watershed is about 37 miles long, with a maximum width of about 16 miles. The average stream slope is 10.0 feet/mile. The topography of the watershed consists of gently rolling hills and broad pastures on the western part of the watershed. The topography of the eastern part of the watershed consists of a high Austin Chalk limestone bluff that protrudes a couple hundred feet above the Mountain Creek river channel. The highest parts of the bluff range in elevation from 740 to 890 feet, which is the highest ridge for many miles in any direction.

Lavon Lake: Lavon Lake is located on the East Fork of the Trinity River originating in north central Texas. The East Fork flows about 110 miles in a southerly direction until it merges with the Trinity River upstream of Rosser, TX. The East Fork joins the main stem at approximately river mile 460 of the Trinity River. The stream average slope is 4.6 feet/mile. The watershed has a length of about 78 miles and a maximum width of about 30 miles. The watershed topography varies from gently rolling hills and valleys in the upper portion to gentle, flat lands in the lower portion.

Lewisville Lake: Lewisville Lake is located on the Elm Fork of the Trinity River at river mile 30. The Elm Fork originates in north central Texas and flows southeasterly for approximately 110 miles to its confluence with the West Fork of the Trinity. The watershed is about 80 miles long and has a maximum width of 60 miles. The river streambed average slope is about 7.5 feet/mile. The topography throughout the basin is predominantly gently rolling. Basin topography varies from level or gently rolling in the lower reaches to broken prairie in the north and northwestern reaches.

Navarro Mills: Navarro Mills Lake is located on Richland Creek, a tributary of the Trinity River. From its source, Richland Creek flows in a generally southeasterly and easterly direction for about 97 miles to its confluence with the Trinity River, 372 miles above its mouth. The watershed lies within the central portion of the Trinity River Basin. The watershed has an overall length of 83 miles and a maximum width of about 40 miles. The streambed slope is about 14.3 feet/mile. In the upper portion of the watershed the soils are thin and the slopes are steep. Matured streams and valleys with broad alluvial plains characterize the terrain.

Ray Roberts: Ray Roberts Lake is located on the Elm Fork of the Trinity River at river mile 60. The Elm Fork flows southeast for about 110 miles to its confluence with the West Fork of the Trinity River. The watershed lies in the north central portion of Texas. The watershed is about 80 miles long and has a maximum width of 60 miles. The average slope of the streambed is 7.5 feet/mile. The topography of the Elm Fork Watershed consists of gently rolling hills and broad river valleys. The basin topography is steeper and rougher in the upper reaches. The terrain is more gently rolling and flatter in the lower reaches. Some rough land occurs along the streams in the lower reaches.

Richland-Chambers: Richland-Chambers Lake is located on Richland Creek, which is a tributary of the Trinity River approximately 20 miles southeast of Corsicana in north central Texas. Agriculture was the predominant land use in the region beginning in the late 1800's, and by the early 1940's the area suffered from soil depletion and erosion due to non-conservation farming practices and climatic events of the 1930's.

Table 2: Trinity River Basin Projects and USGS Gages Drainage Area

Project	Drainage Area (mi²)	USGS ID	USGS Site Name	Drainage Area (mi²)	USGGS Gage Location
Bardwell	178	8064500	Chambers Cr nr Corsicana, TX	963	Downstream of Bardwell
Benbrook	429	8046000	Clear Fk Trinity R nr Aledo, TX	251	Upstream of Benbrook
Grapevine	695	8054000	Denton Cr nr Roanoke, TX	621	Upstream of Grapevine
Joe Pool	232	8050100	Mountain Cr Grand Prairie, TX	298	Downstream of Joe Pool
Lavon	770	8061500	East Fk Trinity R nr Rockwall, TX	840	Downstream of Lavon
Lewisville	1,660	8053000	Elm Fk Trinity R. nr Lewisville, TX	1,673	Downstream of Lewisville
Navarro Mills	320	8063100	Richland Ck nr Dawson, TX	333	Downstream of Navarro Mills
Ray Roberts	692	8050500	Elm Fk Trinity R. nr Sanger, TX	381	At Ray Roberts
Richland-Chambers	1,957	None	None	None	None

Note: The listed drainage area in the table above refers to the contributing drainage area.
Due to regulations upstream, Richland Chambers inflow was supplied via RiverWare.

1.3 CLIMATE

The climate over the Trinity River Basin is generally mild. In summers, the days are hot and the nights cool. Normally, the winter periods are short and comparatively mild, but occasional cold periods of short duration result from the rapid movement of cold, high-pressure air masses from the northwestern polar regions and the continental western highlands. Freezing temperatures occur yearly over a large portion of the headwater area, and snowfall is experienced occasionally. Wind movements during December, January, and February are usually northerly, being influenced by continental high-pressure areas. During the remainder of the year, southerly or southeasterly winds from the Gulf of Mexico are dominant. The mean annual temperature is fairly uniform throughout the basin, ranging from about 69 degrees Fahrenheit in the southern watershed area to about 65 degrees in the northwest. The coldest months, have average minimum daily temperatures in the lower 40's; the warmest months have average maximum daily temperatures in the mid 90's. The mean annual precipitation is 32.7 inches, and varies from about 36 inches near the mouth to about 29 inches in the headwaters. Hydrologic conditions in the Trinity River Basin are best characterized by precipitation and streamflow.

1.4 RUNOFF

Warm seasonal rainfall is largely the result of thunderstorm activity, with amounts varying considerably in both intensity and location. Because of the preponderance of tropical maritime air, heavy showers of short duration may occur at any time during the year. Streamflow generally is proportional to precipitation and the size of the watershed, except downstream from reservoirs and point sources such as wastewater-treatment plants. The topography, soils and intense rainfalls over a short period of time on the watershed lead to rapid runoff and sharp-crested flood hydrographs. Floods can occur at any time of the year with damaging results. Overall, the steep gradients of the streams, the thin layer of topsoil with frequent outcroppings of rock, and the well-defined valleys in the watershed above projects produce rapid runoff during storm periods. In general, streams have low normal flow. The highest average monthly flows usually occur in April-June, and September-November. Flood flows, however, may occur during any month.

1.5 METHODS

1.5.1 EMPIRICAL STAGE-FREQUENCY

For the evaluation of hydrologic loading, an extreme-value series of annual maximum stages needs to be generated from the observed and/or simulated period of record. An empirical stage-frequency curve will then be constructed by ranking the annual maximum data, assigning the data a plotting position, and then plotting the data on probability paper using a plotting position formula. Many plotting position formulas can be used for the orientation of an empirical frequency curve, but a plotting position formula that is flexible and makes the fewest assumptions is preferred (USACE, 2017). Gumbel (1958) summarizes five conditions that a plotting position formula should satisfy:

1. The plotting position must be such that all observations can be plotted
2. The plotting position should lie between the observed frequencies of $(m-1)/n$ and m/n where m is the rank of the observations beginning with $m = 1$ for the largest value and n is the number of years of record or the number of observations
3. The return period of a value equal to or larger than the largest observation and the return period of a value equal to or smaller than the smallest observation should converge toward n
4. The observations should be equally spaced on the frequency scale
5. The plotting position should have an intuitive meaning, be analytically simple, and easy to use.

The most practical plotting position formula which satisfies all five of Gumble's conditions is the Weibull plotting position. A rank-order method is used to plot the annual maxima. This involves ordering the data from the largest event to the smallest event, assigning a rank of 1 to the largest event and a rank of n to the smallest event, and using rank (i) of the event to obtain a probability plotting position. The Weibull plotting position formula is an unbiased estimator of exceedance probability for all distributions, and is used to plot the stage data for constructing an empirical stage-frequency curve: $P_i = i / (n + 1)$; where, i is the rank of the event, n is the sample size in years, and P_i is the exceedance probability for an event with rank i.

1.5.2 VOLUME-SAMPLING APPROACH

A common method for estimating a hydrologic loading curve for a dam is by volume-based sampling. In this method, a large number of flood events is generated using random sampling of flood volumes, the associated flood hydrographs are routed through the reservoir, and the peak reservoir elevation for each event is recorded.

The general workflow for a volume-based hydrologic loading analysis is as follows:

1. Choose a stage for the reservoir to begin the flood event
2. Choose an inflow flood hydrograph to scale
3. Sample a flood volume from the reservoir inflow frequency curve
4. Scale the selected flood hydrograph to match the sampled flood volume
5. Route the scaled flood hydrograph through the reservoir using an operations model
6. Record the peak stage that occurred during the event.

For the stochastic model, RMC-RFA, choices made in steps 1-3 are made using random selection from a probability distribution. The choice is random in the sense that it occurs without pattern, but the relative frequency of the outcomes in the long term is defined by a probability distribution. Reservoir stages for starting the simulation come from a *pool duration curve*, which is a probability distribution for the elevation of the reservoir pool. They may be seasonally-based, in which case first the season of the flood event occurrence is selected at random, and then a starting stage is selected at random from the pool duration curve for that particular season. Sampled flood volumes come from the familiar flow frequency curve produced by fitting an analytical probability distribution to an AMS of river discharges. In the volume-based approach, instead of analyzing instantaneous peak discharge (as is typically the case in a Bulletin 17B/C-type analysis), the analysis is performed on a longer-duration volume (such as three or four day average discharge.)

When steps 1-6 are performed a large number of times (for example, 10,000 *samples*), the resulting peak stages are ranked and plotted, producing a stage-frequency curve for the reservoir. However, substantial uncertainty exists in several of the inputs to the model, especially the inflow frequency curve. To account for these uncertainties, steps 1-6 are performed a large number of times with different parameters for the inputs. The input parameters are varied across *realizations*, and for each realization, steps 1-6 are repeated over a large number of *samples.* Thus, the full simulation with uncertainty will contain a number of events equal to the number of realizations times the number of samples. By varying parameters across realizations, the uncertainty in the probability of an event, for example reaching spillway crest elevation, can be better assessed. Each realization will produce an estimate of the probability of reaching this elevation based on the parameters used to drive the realization. Percentiles (for example the 5th and 95th percentiles) of these probabilities produce a confidence interval for the probability of reaching the spillway. If the mean probability of exceeding any stage is taken, then the result is the *expected frequency curve*, which is the single best estimate for the probability of exceeding a particular stage.

1.5.3 RISK MANAGEMENT CENTER – RESERVOIR FREQUENCY ANALYSIS (RMC-RFA)

RMC-RFA software was developed by the USACE Risk Management Center for use in dam safety risk assessments. It can produce a stage-frequency curve with confidence bounds using a stochastic model with the volume-sampling approach. The model functions best in situations where dam operations are relatively simple, especially when the spillway is not regulated using gates. A simplification of the operational rules is assumed through the use of an elevation-discharge table which is based on a combination of dam discharge structures and calibration to historical releases. Development of model inputs is aided by tools within the program that allow the user to estimate inputs, such as flood seasonality or pool duration curves, in a consistent and automated manner. Other inputs, such as the volume frequency curve or reservoir operations, are developed by the user independently.

1.6 DATA ANALYSIS AND MODEL INPUT

1.6.1 INFLOW HYDROGRAPH AND POOL STAGE

Estimates of daily average flows and pool elevations for the Trinity River Basin projects were retrieved from the USACE water management database system for water year (WY) 1925 through WY 2016 for Joe Pool and Lavon Lakes; and for WY 1941 through WY 2016 for Bardwell, Benbrook, Grapevine, Lewisville, Navarro Mills, Ray Roberts, and Richland-Chambers Lakes. Records prior to project construction were simulated using RiverWare. Joe Pool and Lavon Lakes were extended further than the rest of the projects due to available USGS discharge data, which covers longer periods. The Trinity River Basin project impoundment dates are shown in Table 3. RiverWare software mimics a watershed by modeling its features as linked objects, including storage or power reservoir objects, stream reach objects, groundwater storage objects, or diversion objects. In a simple model, these objects simulate basic hydrologic processes through mass balance calculations and can be linked to one another through inflow-outflow calculations. More advanced modeling is achieved by selecting object-specific methods that further define the hydrologic processes associated with each object. Additionally, RiverWare may operate under a rule-based simulation, which creates logic-based interdependency of objects through user-defined rules. These rules may look forwards and backwards in time, and given priorities in one rule may supersede others depending on the importance defined by the user. These detailed yet simple modeling techniques allow RiverWare to simulate reservoir pool elevations and inflows efficiently.

Table 3: Trinity River Basin Dams Deliberate Impoundment Dates

Project	Impoundment Date
Bardwell	Nov. 20, 1965
Benbrook	Sept.. 29, 1952
Grapevine	Jul. 3, 1952
Joe Pool	Jan. 7, 1986
Lavon	Sept. 14, 1953
Lewisville	Nov. 01, 1954
Navarro Mills	Mar. 15, 1963
Ray Roberts	Jun. 30, 1987
Richland-Chambers	Jul. 14, 1987

The USACE Water Management section inspected the dataset for quality before being used in the analyses. The instantaneous (hourly) lake inflows were gathered. One example is Bardwell Lake hourly inflow shown in Figure 2. The hourly records may contain many gaps. The gaps are for times when real time recording was missing. Data with missing records were not used in the analyses. In this report, Grapevine Lake was used to illustrate the simulated pre-dam construction daily average inflow and post dam construction pool elevation records; see Figure 3. All project inflows and pool elevations can be presented in a similar manner.

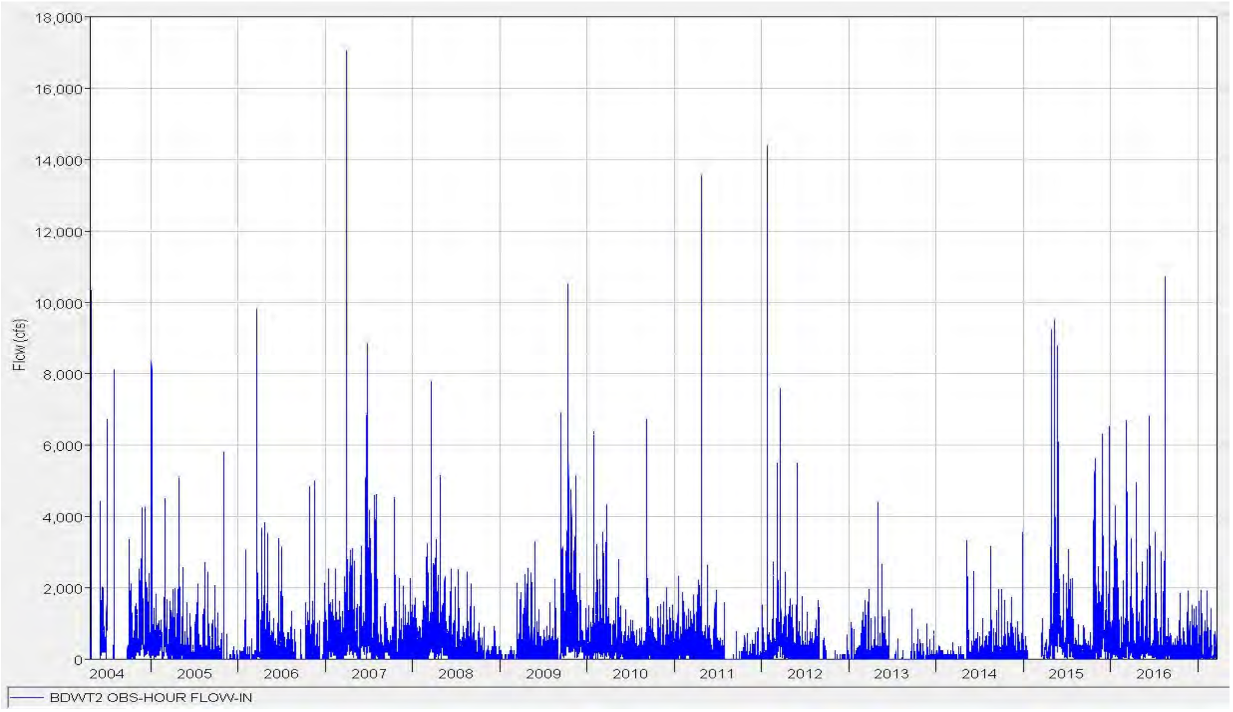


Figure 2: Bardwell Lake Hourly Inflow

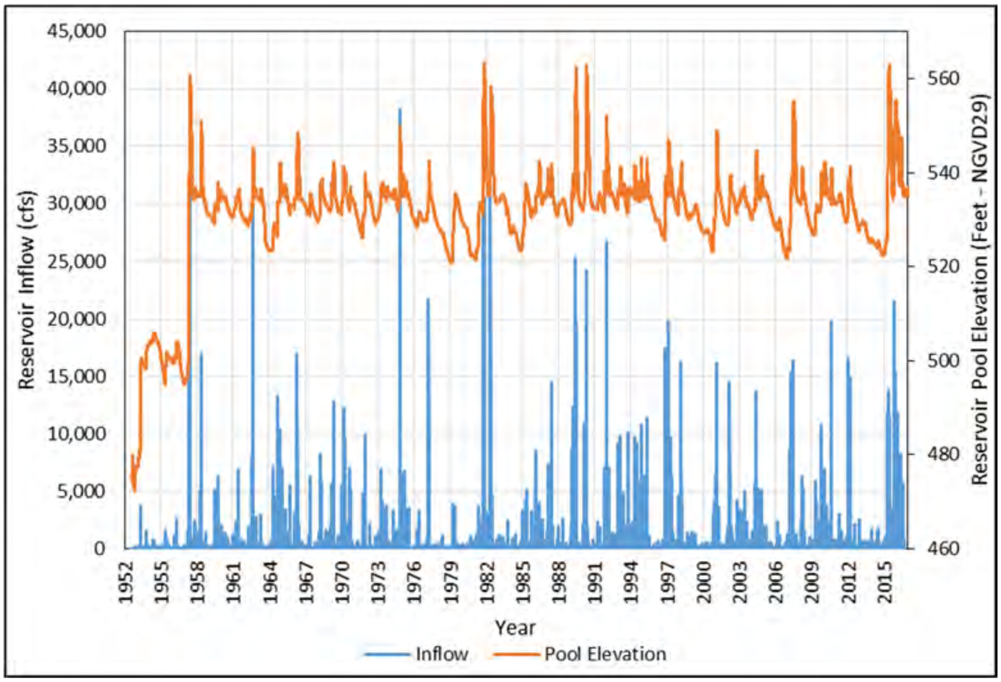


Figure 3: Grapevine Lake Daily Average Inflow and Elevation

1.6.2 INSTANTANEOUS PEAK ESTIMATES

An extract of the 1-day average maximum annual peaks for each project was made available for the analysis. The lake inflow systematic record contains a mixed population of observed (recorded) post-dam construction flows and pre-dam construction synthetic flow years generated using RiverWare. The unrecorded historical n-day peaks at the lakes were developed by establishing a discharge peak correlation with the nearest USGS gage when available. The USGS gages used for correlation are listed in Table 4. The criteria of selection was based on each gage location, its proximity to the corresponding lake, and its drainage area size in relation to the reservoir contributing drainage area. In addition, the observed hydrographs entering the reservoir must mimic similar patterns of those observed at the gage location to be considered. Historical peaks at the selected USGS gages were generated by establishing a relationship between stage where historical high water marks were captured and discharge peaks. Once a strong trendline correlation was maintained with a high R^2 value, the corresponding regression equation was used to estimate the peak. A stage-peak relationship example is illustrated in Figure 4. Table 4 lists the historical peaks estimated from the rating curves at each USGS gage. No USGS gage or historical peaks are associated with Richland Chambers Lake.

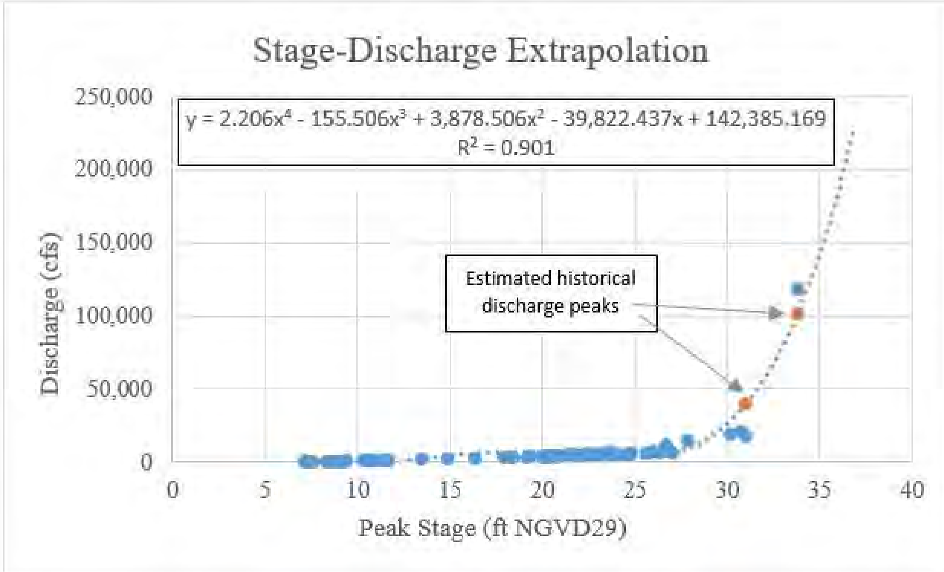


Figure 4: Stage-Discharge corresponding Relationship for USGS 08053000 Elm Fk Trinity River nr Lewisville, TX

Table 4: Trinity River Basin USGS Estimated Historical Peaks

Project	Nearby USGS Gage ID	Peak Flow (cfs), Year			
Bardwell	8064500	68,500, 1887	41,200, 1913	24,200, 1936	
Benbrook	8046000	68,000, 1922			
Grapevine	8054000	55,700, 1908			
Joe Pool	8050100	67,200, 1922			
Lavon	8061500	67,300, 1924	65,600, 1922	33,000, 1913	13,400, 1908
Lewisville	8053000	118,600, 1908			
Navarro Mills	8063100	52,400, 1929			
Ray Roberts	8050500	103,000, 1908			

1.6.3 DAILY AVERAGE ANNUAL PEAK (AMS) ESTIMATES

The reservoir projects' historical n-day inflows were generated from the USGS gages historical peaks. Several attempts were made to better justify the best predictable peaks. The drainage area to peak ratio method was applied to calculate the projects' inflow peaks. The method was found applicable for the Trinity River Watershed streams. The predicted peaks follow a general straight line trend which is used to estimate the peaks. The trendline interpolates between peaks. It produces the best formula used for prediction. The 5% and 95% confidence bounds can be generated using the formula:

$X = Y \pm t_{\alpha} * SE^{(1/n + [(X-Xm)2]/SSxx)}$; where X is the instantaneous AMS peak, Y is the predicted n-day daily average AMS, t_{α} represents the two-tailed inverse distribution for the 5% and 95% probabilities (confidence bounds), SE is the standard error, n is the number of years, X_m is the average instantaneous peak value, and SS_{xx} is the sum of squares of deviations of data from their sample mean ($\sum(X-X')^2$). An example of a correlation between the instantaneous peaks and the 1-Day AMS peaks with the predicted value for Lavon Lake is illustrated in Figure 5.

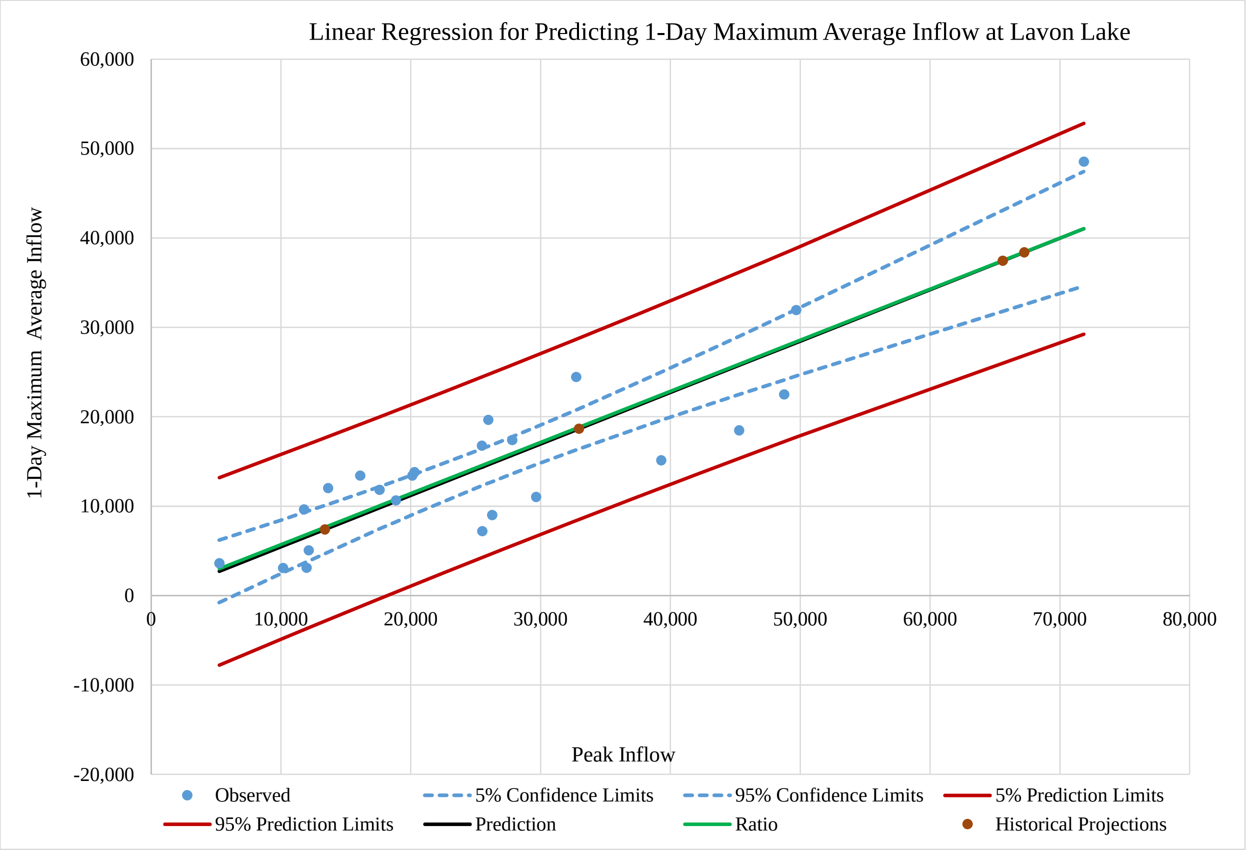


Figure 5: Lavon Lake's 1-Day AMS Best Estimate

Furthermore, peak results obtained from the drainage area to peak ratio method were validated by analyzing the peaks and applying best fitting curves through the instantaneous- n-day AMS data points. The n-day AMS historical peaks can be estimated by utilizing the best corresponding relationship (formula) with the strongest R^2 value among all fitting curves. Figure 6 illustrates the corresponding correlation that best depicts the missing historical peaks for Joe Pool. The 1-day AMS best estimated peak was 15,980cfs, which compares closely to the best estimated peak from applying the drainage area to peak ratio method at 15,350cfs. In this report, peaks estimated from the drainage area to peak ratio method with 5% and 95% confidence bounds were adopted in the study and used for further analyses for all USACE projects.

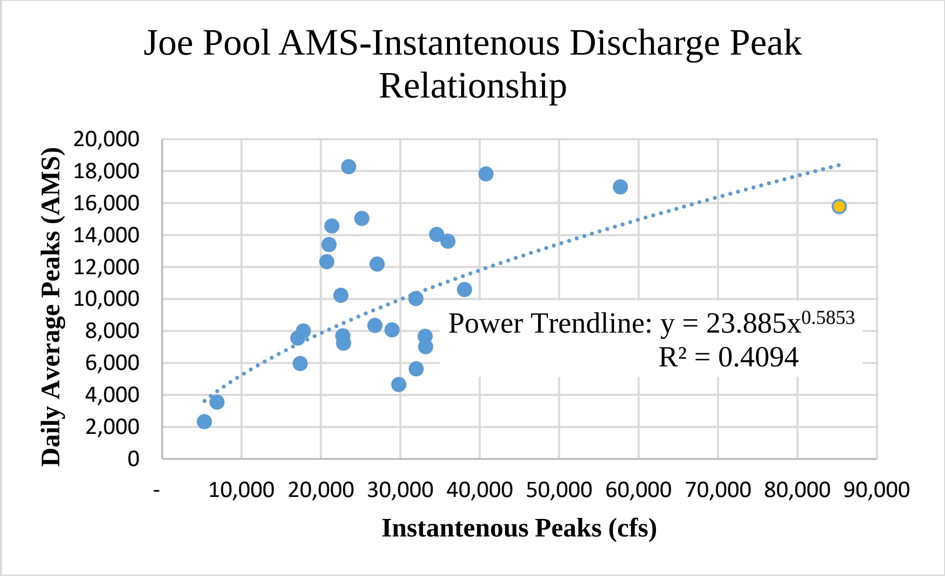


Figure 6: Joe Pool Inflow Discharge Relationship

Table 5 is a summary of each project's instantaneous peak and the developed 2, 3, 4, and 5-day AMS historical peaks, which can be generated similarly to the 1-day AMS peaks shown in Figure 5.

Table 5: Trinity River Basin N-Day AMS Estimated Historical Peaks

Project	N-Day Duration AMS Peak (cfs) (Historical)						Instantenous Peak (cfs)
	Year	1-Day	2-Day	3-Day	4-Day	5-Day	
Bardwell	1887	12,504	11,040	8,067	6,479	5,348	29,659
	1913	6,477	5,446	4,075	3,313	2,771	14,350
	1936	3,894	3,048	2,364	1,956	1,667	7,789
Benbrook	1922	49,570	30,921	22,706	19,266	13,847	67,970
Grapevine	1908	24,082	21,161	18,127	15,299	13,214	55,700
Joe Pool	1922	15,347	12,582	10,034	8,674	7,730	67,186
Lavon	1908	7,390	6,633	5,677	5,000	4,477	13,386
	1913	18,651	15,982	13,638	11,829	10,342	32,957
	1922	37,436	31,577	26,917	23,221	20,124	65,601
	1924	38,390	32,368	27,591	23,799	20,620	67,257
Lewisville	1908	96,998	72,608	54,507	43,060	35,462	118,615
Navaro Mills	1929	30,322	19,047	13,680	10,584	8,724	52,400
Ray Roberts	1908	51,939	33,518	25,654	21,105	18,153	103,014
Richland Chambers	None	N/A	N/A	N/A	N/A	N/A	N/A

1.7 CRITICAL INFLOW DURATION ANALYSIS

The critical inflow duration can be defined as the inflow duration that tends to produce most consistently the highest water surface elevation for the reservoir. Although projects located on the Trinity River Basin are impacted by similar weather patterns and storms usually occur in similar seasons, it is very likely projects will have different critical durations due to the fact that each project's sub-watershed is featured by a unique contributing drainage area and topography. Steep slopes result in rapid runoff (short critical duration), and flatter slopes result in a longer critical duration. The storm duration can also impact critical durations; longer storms result in longer critical durations. For these nine dams in the Trinity River Basin, the most critical flood season was determined to occur during the spring, between March and June. In order to determine critical inflow duration of the observed rainfall-runoff events, extreme rainfall runoff (inflow) events are examined. All large inflow events are independent, meaning that different year hydrographs can be presented in one figure to determine the proper critical duration. The duration peak inflow was used to determine a reasonable value for critical inflow duration. Although this method was found accurate to produce good estimates, the critical duration can be adjusted later on during the analysis to reflect the most appropriate frequency curve. Best engineering judgment remains necessary in the final selection of the most appropriate value. For each project, a set of historical inflow events (hydrographs) with daily peak inflows greater than a certain threshold were extracted from the RiverWare simulated daily average inflow period of record (*i.e.* examine the top 20% largest independent inflow events for each project inflow). The best estimate inflow duration for the reservoir is estimated by taking the average hydrograph of the major events specified. Bardwell Lake was selected to demonstrate the lake inflow critical duration best estimate (Figure 7).

Best estimates of the n-day critical durations for all projects are listed in Table 6. These results were finalized after making several sensitivity analyses while running the RMC-RFA program. The best critical duration estimate produced the most conservative frequency elevation in the lake. The purpose of this analysis is to have a better understanding of the runoff response from large single rain events that helps establish what volume discharge frequency curves need to be examined.

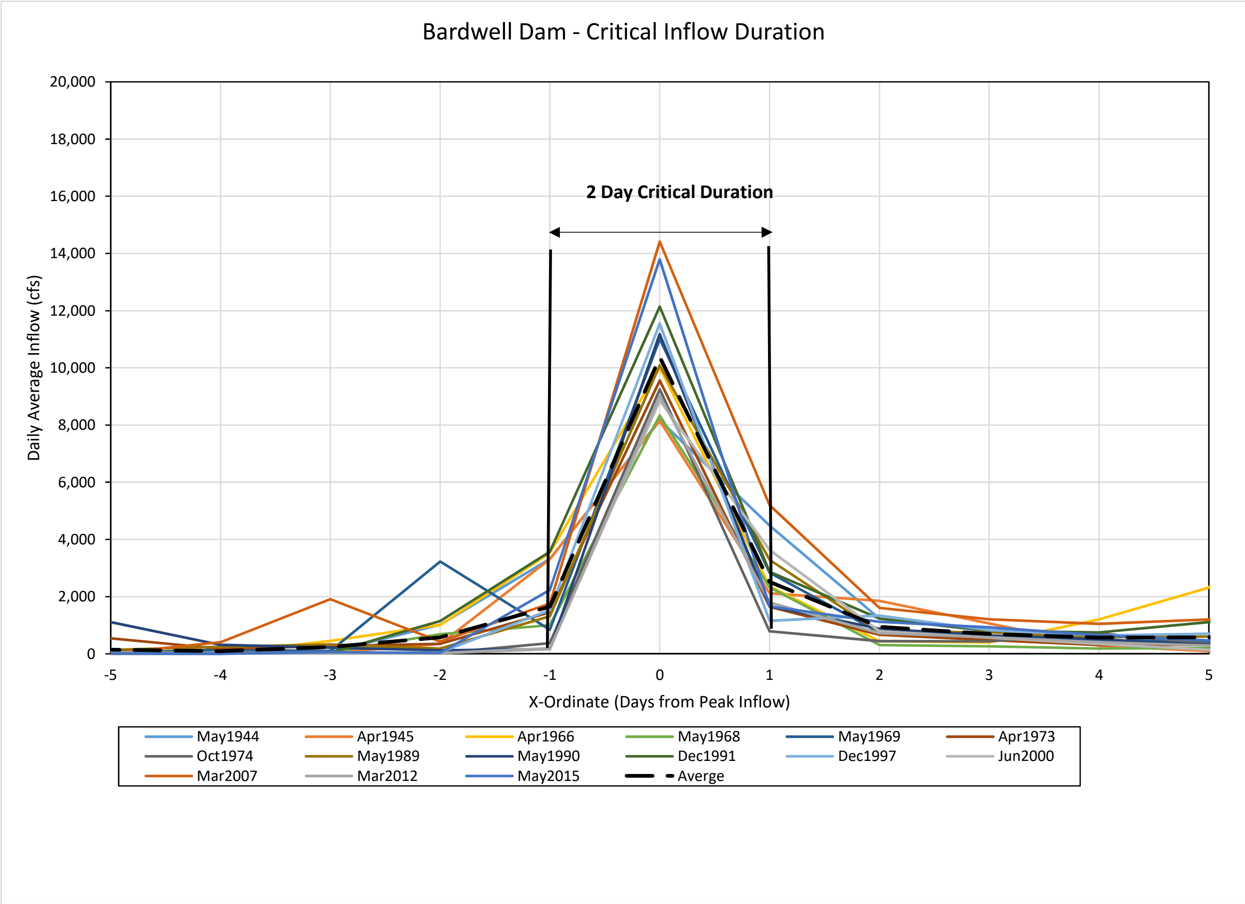


Figure 7: Bardwell Lake Critical Duration Inflow Analysis

Table 6: Trinity River Basin Inflow Duration Analysis

Project	Minimum Threshold Peak (cfs)	Number of Analyzed Inflow Events	Critical Duration (Days)
Bardwell	8,000	15	2
Benbrook	11,000	13	2
Grapevine	19,500	13	3
Joe Pool	3,200	16	2
Lavon	30,400	12	3
Lewisville	43,000	14	3
Navarro Mills	18,000	12	2
Ray Roberts	34,800	12	2
Richland Chambers	40,000	10	3

1.7.1 VOLUME/FLOW FREQUENCY STATISTICAL ANALYSIS

The volume/flow frequency analyses for the Trinity River Basin lakes were estimated by following Bulletin 17C guidelines and procedures (statistical techniques) to determine exceedance probabilities associated with specific flow rates utilizing HEC-SSP (Version 2.1.1; USACE, 2017). The observed and developed daily average annual maximum peaks were used to establish a relationship between flow magnitude and frequency. In this report, the term volume/flow frequency refers to the frequency with which a flow over a given duration, such as 1-, 2-, 3-, 4-, and 5-day, is expected to be equaled or exceeded. The duration range selection was based on inspecting the shape of the hydrographs such as those shown in Figure 7 and the critical durations listed in Table 6. To adequately assess the risk associated with the Trinity River Basin Dams' structures in question, the 2-Day critical duration was used to construct hypothetical inflow frequency events for Bardwell, Benbrook, and Joe Pool; the 3-Day critical duration was used to construct inflow frequency events for Grapevine, Lavon, Lewisville, and Richland Chambers dams. The events were routed through the projects to estimate the reservoirs' stage-frequency curves.

1.7.2 BULLETIN 17C

The use of Bulletin 17C guidance allows for computations of the annual exceedance probability of the instantaneous and daily average peaks, using the Expected Moments Algorithm (EMA). It estimates distribution parameters based on sample moment in a more integrated manner that incorporates non-standard, censored, or historical data at once, rather than as a series of adjustment procedures (Cohn et al., 1997). In this report, and when applicable, each project was assigned the associated historical peaks shown in Table 5 (*i.e.* Ray Roberts, for a 2-day critical duration would be assigned one (1) historical peak of 33,518 cfs for the year of 1908). Values of perception thresholds from the historical peak events were set for the historical peak years for each project (*i.e.* 1908 was set for Ray Roberts). The set of threshold peaks define the range of stream flow for which a flood event could have been observed; consequently, years for which an event was not observed and recorded must have had a peak flow rate outside of the perception threshold. The use of Bulletin 17C procedures provide confidence intervals for the resulting frequency curve that incorporate diverse information appropriately, as historical data and censored values impact the uncertainty in the estimated frequency curve (Cohn et al., 2001). Within the Bulletin 17C EMA methodology, every annual peak flow in the analysis period, whether observed or not, is represented by a flow range that might simply be limited to the gaged value when one exists. However, it could also reflect an uncertain flow estimate which is the case for the Trinity River Basin projects.

1.7.3 HEC-SSP CALCULATIONS

A series of n-day volume duration frequency curves was developed for each of the Trinity River Basin projects. The volume duration frequency results from this analysis were developed using HEC-SSP. The Multiple Grubbs-Beck Test (MGBT) algorithm was used for the low outlier test. Plotting position of the censored data is adopted from the Hirsch-Stedinger plotting position algorithm (Hirsch, 1982). Except for assigning only a station skew value to Richland Chambers, a regional skew value was made available and incorporated to the study as part of the analysis to calculate the generalized skew in addition to computations made using the systematic (observed) station skew value. More details about the regional skew development and Mean Squared Error (MSE) value can be found in the “Model Comparison for Regional Skew Analysis for Trinity River Basin USACE Reservoirs in Texas” report (USACE Fort Worth District, 2017). HEC-SSP gives the option to analyze data with different skew values to best estimate the stage frequency curve. Each developed frequency curve underwent different analysis techniques before adoption. The MSE value of 0.141 was used. Table 7 contains skews and record lengths for each project input into the HEC-SSP program.

Table 7: Summary of HEC-SSP Input Parameters

Project	Systematic Record (years)	Historic Record (years)	Regional Skew	MSE
Bardwell	77	137	-0.52	0.141
Benbrook	77	159	-0.52	0.141
Grapevine	76	109	-0.52	0.141
Joe Pool	92	95	-0.52	0.141
Lavon	92	109	-0.52	0.141
Lewisville	76	109	-0.52	0.141
Navarro Mills	78	122	-0.52	0.141
Ray Roberts	76	117	-0.52	0.141
			Station Skew	
Richland Chambers	76	76	-0.282	N/A

Note: The actual systematic record length is less than the systematic record length shown in the Table. The actual systematic record length was extended utilizing RiverWare.

The computed frequency flows from HEC-SSP for the different Trinity Basin reservoirs are listed in Table 8. The statistical parameters generated based on applying the Bulletin17C EMA method, regional skews and MSE, and low outlier tests for Multiple Grubbs-Beck are listed in Table 9. Only pertinent critical durations were listed for each project (*i.e.* 2-Day and 3-Day).

Table 8: Trinity River Basin Lakes Bulletin 17C Computed Median Inflows

N	ACE	Bulletin 17C EMA Computed Average (Median) Peaks (cfs)								
Yrs	%	Bardwell	Benbrook	Joe Pool	Navarro Mills	Ray Roberts	Grapevine	Lavon	Lewisville	Richland Chambers
		2-Day					3-Day			
500	0.2	10,972	32,421	27,639	28,854	75,364	37,167	50,344	111,664	104,115
200	0.5	9,626	26,362	23,650	25,428	62,457	31,610	44,026	96,437	86,850
100	1	8,586	21,977	20,606	22,720	53,095	27,362	39,122	84,584	74,437
50	2	7,528	17,802	17,553	19,911	44,118	23,103	34,112	72,493	62,588
20	5	6,098	12,670	13,529	16,040	32,899	17,510	27,332	56,249	47,795
10	10	4,987	9,135	10,515	12,987	24,946	13,356	22,073	43,857	37,245
5	20	3,839	5,949	7,542	9,808	17,476	9,317	16,672	31,459	27,191
2	50	2,198	2,360	3,662	5,288	8,286	4,218	9,089	15,082	14,322

Table 9: Trinity River Basin Lakes Bulletin 17C Computed Median Inflow Statistics

Statistics	2-Day Computed Statistics					3-Day Computed Statistics			
	Bardwell	Benbrook	Joe Pool	Navarro Mills	Ray Roberts	Grapevine	Lavon	Lewisville	Richland Chambers
Mean	3.32	3.33	3.53	3.69	3.89	3.58	3.93	4.14	4.14
Standard Deviation	0.31	0.52	0.41	0.35	0.41	0.45	0.34	0.42	0.35
Station Skew	-0.29	-0.47	-0.65	-0.94	-0.33	-0.73	-0.5	-1.01	-0.28
Historical Events	3	1	1	1	1	1	4	1	0
Low outliers	29	40	45	28	1	21	14	27	1
Missing Flows	57	66	2	43	40	32	13	32	0
Systematic Events	77	92	92	78	76	76	92	76	76
Effective Recod Length	108	119	50	94	116	88	95	82	76

Note: The number of missing flows capture gaps between historical event peak years and the earliest systematic peak event in the POR

1.8 RMC-RFA DATA INPUT

1.8.1 INFLOW HYDROGRAPHS

Several inflow hydrographs were selected to route through RMC-RFA. The particular years of which hourly reservoir inflow hydrographs were routed are:

Bardwell: March 2017, May 2015 (2 events), and October 2009.
Benbrook: March 2007, April 2008, March 2012, and November 2015.
Grapevine: June 1941, June 1989, September 2010, and November 2015.
Joe Pool: March 2007, September 2009, January 2012, and May 2015.
Lavon: May 1982 and May 2015.
Lewisville: May 1990, April 2007, June 2007, and May 2015.
Navarro Mills: June 2010, March 2012, May 2015, and October 2015.
Ray Roberts: June 2007, April 2009, May 2015, and November 2015.

Richland Chambers: May 2015 and October 2015.

The selected hydrographs' characteristics represent different hydrograph shapes (from peaky to large volume events) experienced at the Trinity River Basin lakes. Samples of the selected hourly hydrographs for Grapevine Lake are shown in Figure 8.

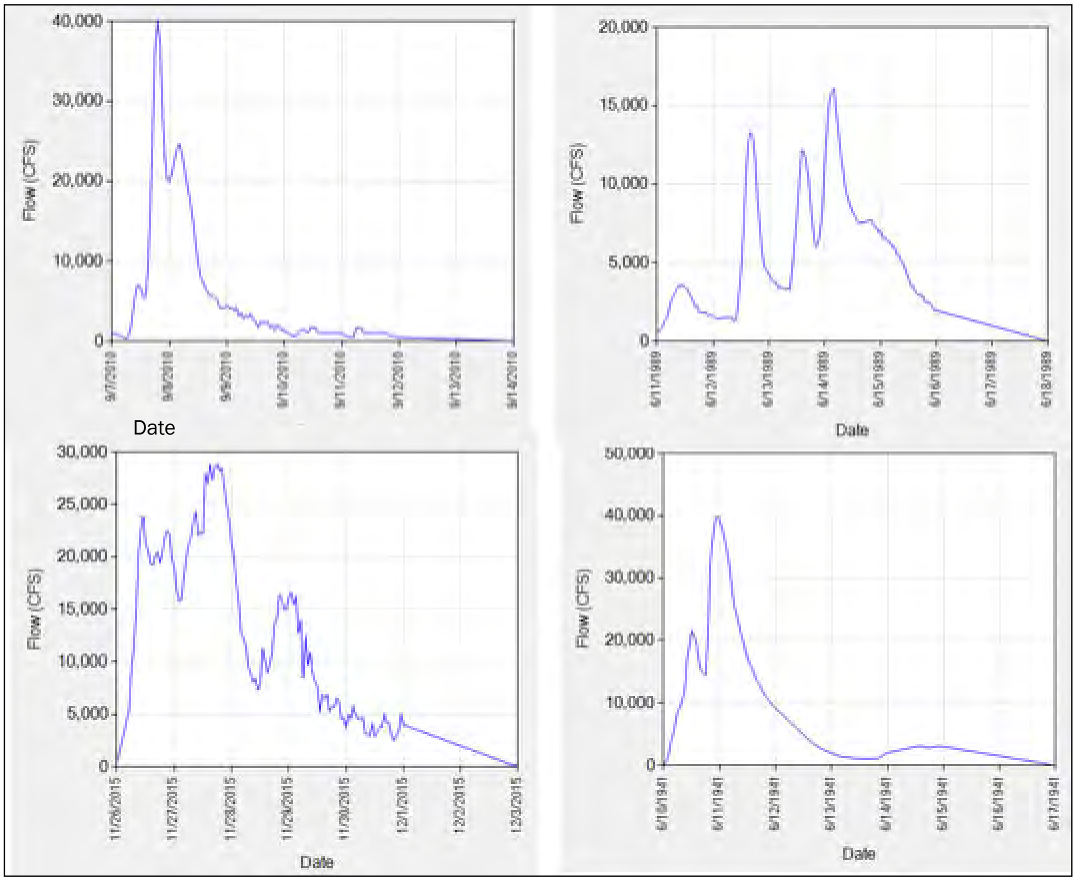


Figure 8: Grapevine Inflow Hydrographs

1.8.2 VOLUME FREQUENCY CURVE COMPUTATION

The computed volume frequency statistical parameters shown in Table 9 were fed into the RMC-RFA program to produce the n-day duration inflows for all projects. As stated in the HEC-SSP computations section, Bulletin 17C procedures and guidelines were followed to produce the volume discharge frequencies. Plots of the different individual 2- and 3-Day discharge frequency curves are shown in Figures 9 through 17.

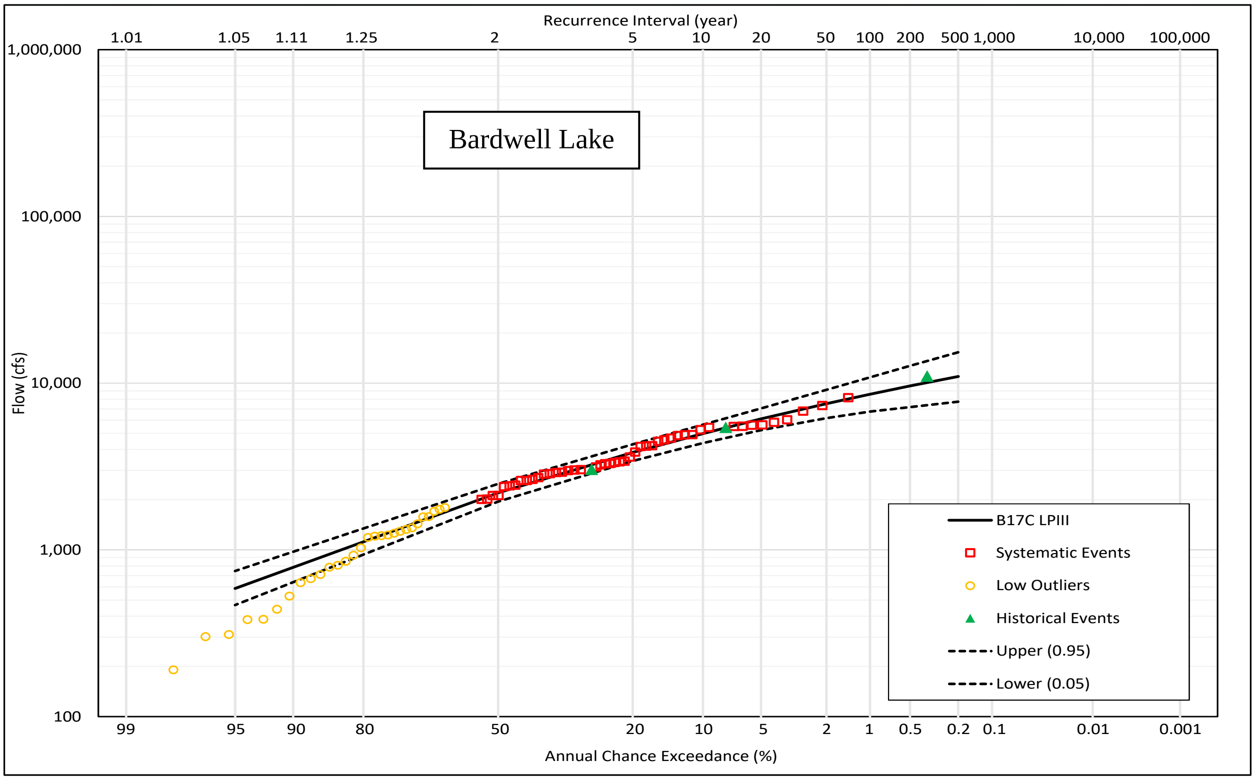


Figure 9: Bardwell Lake Computed 2-Day Volume Frequency Curve

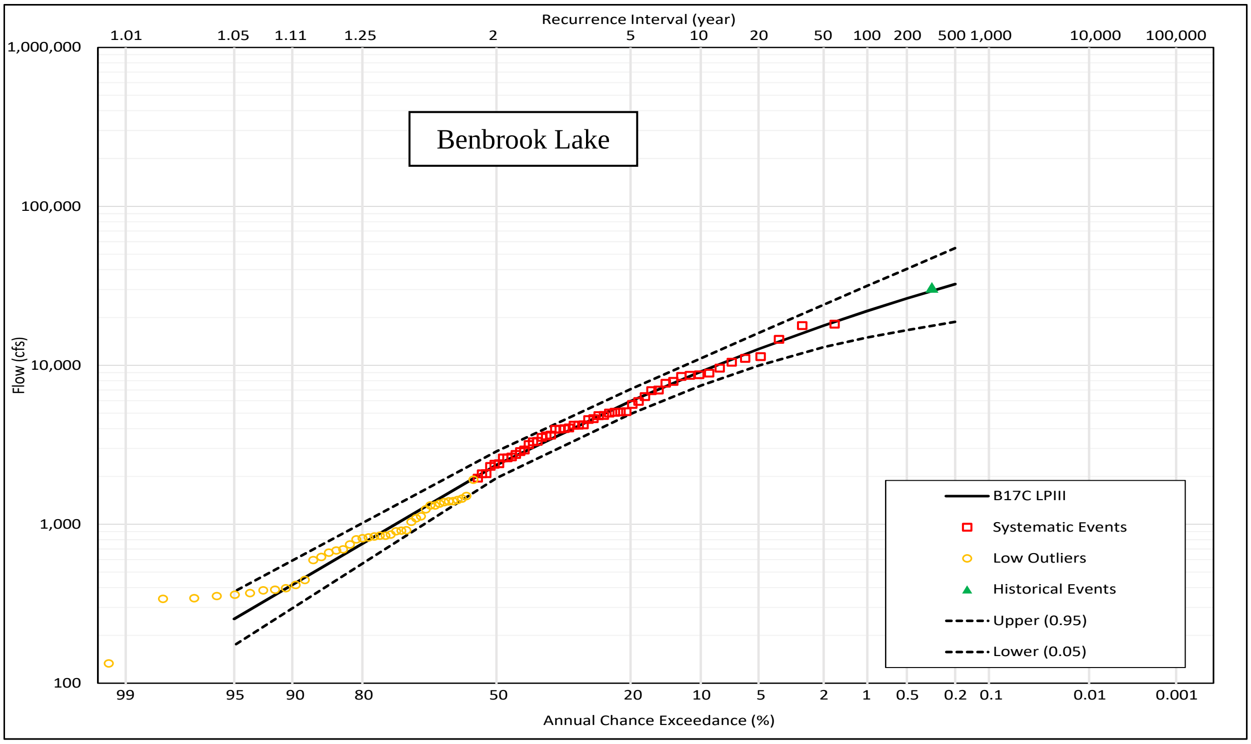


Figure 10: Benbrook Lake Computed 2-Day Volume Frequency Curve

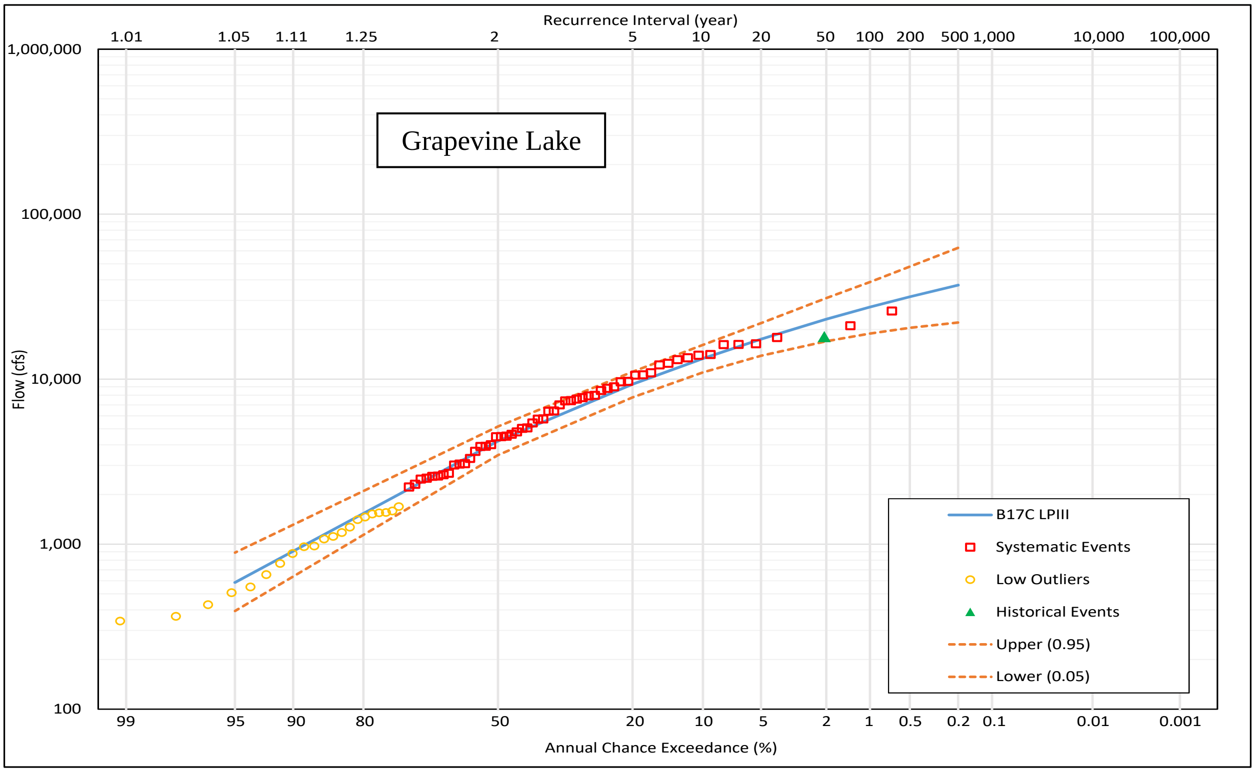


Figure 11: Grapevine Lake Computed 3-Day Volume Frequency Curve

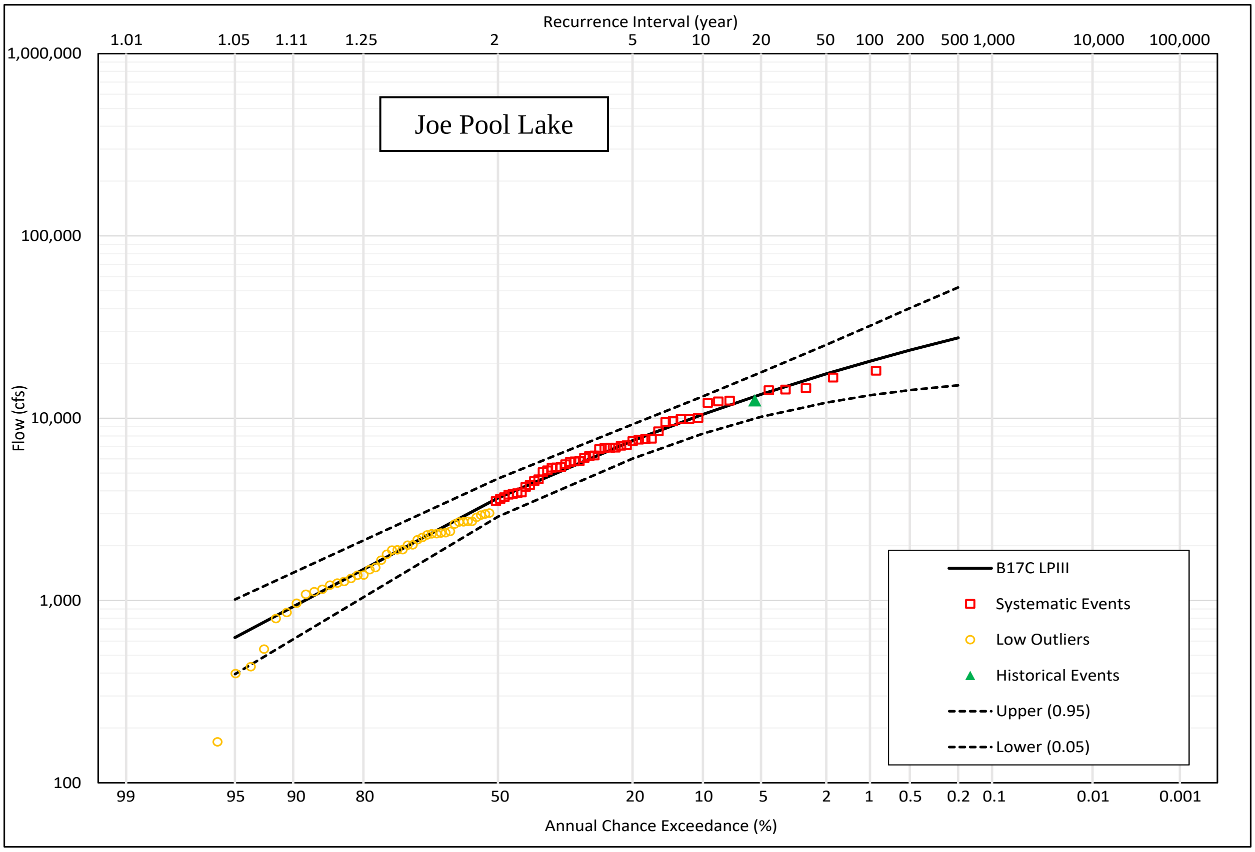


Figure 12: Joe Pool Lake Computed 2-Day Volume Frequency Curve

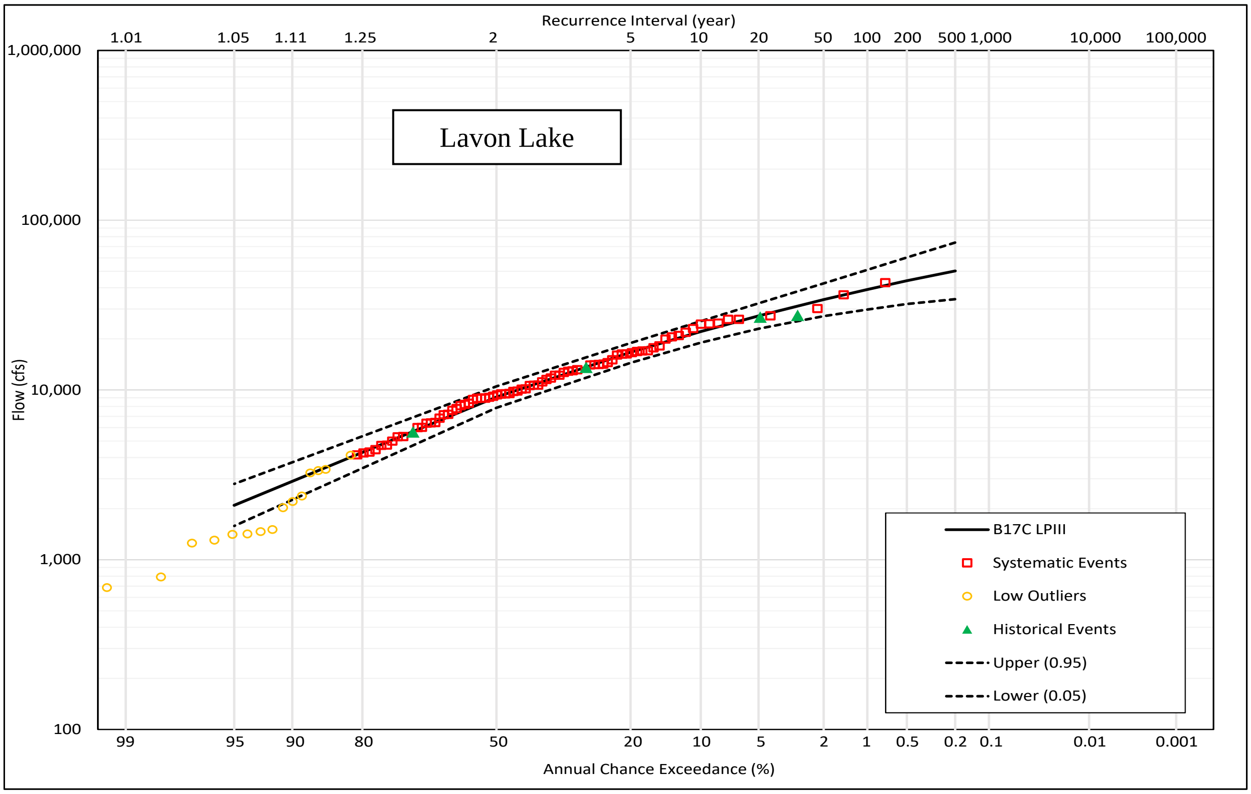


Figure 13: Lavon Lake Computed 3-Day Volume Frequency Curve

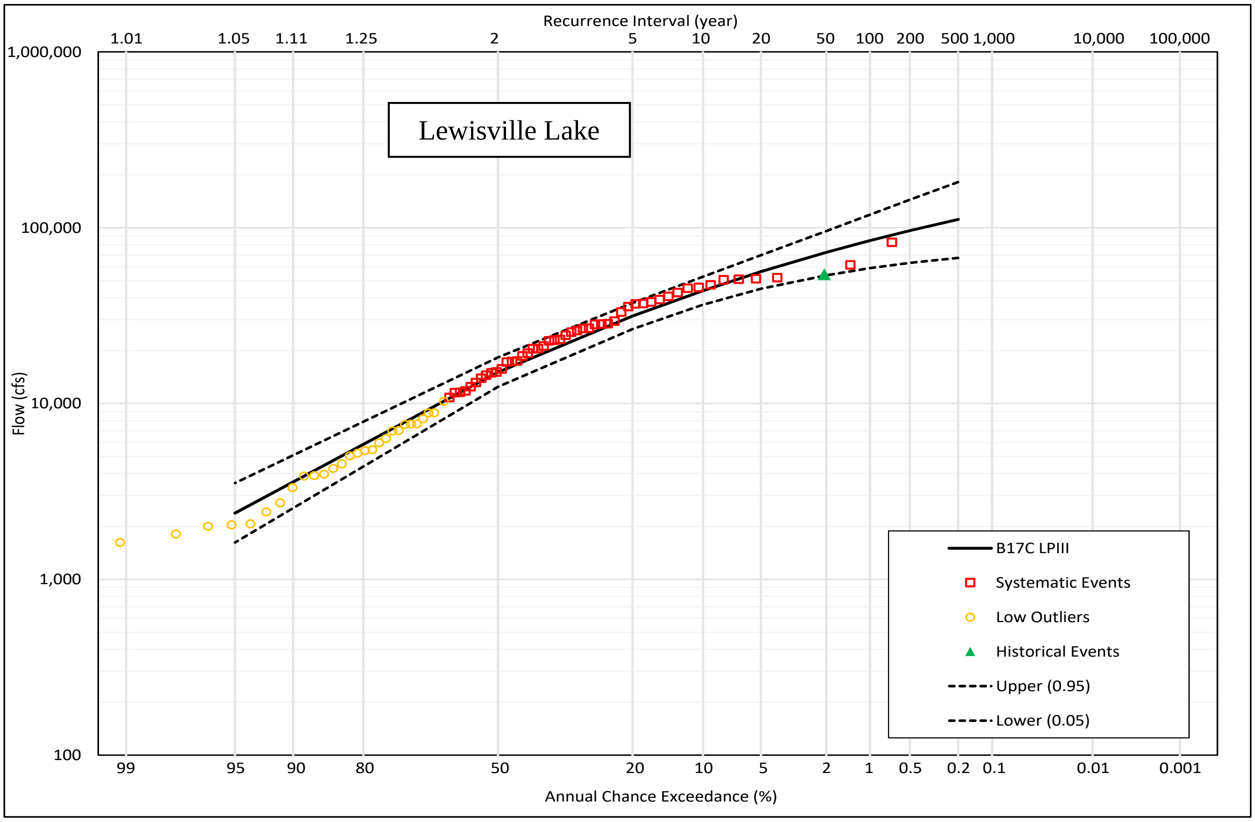


Figure 14: Lewisville Lake Computed 3-Day Volume Frequency Curve

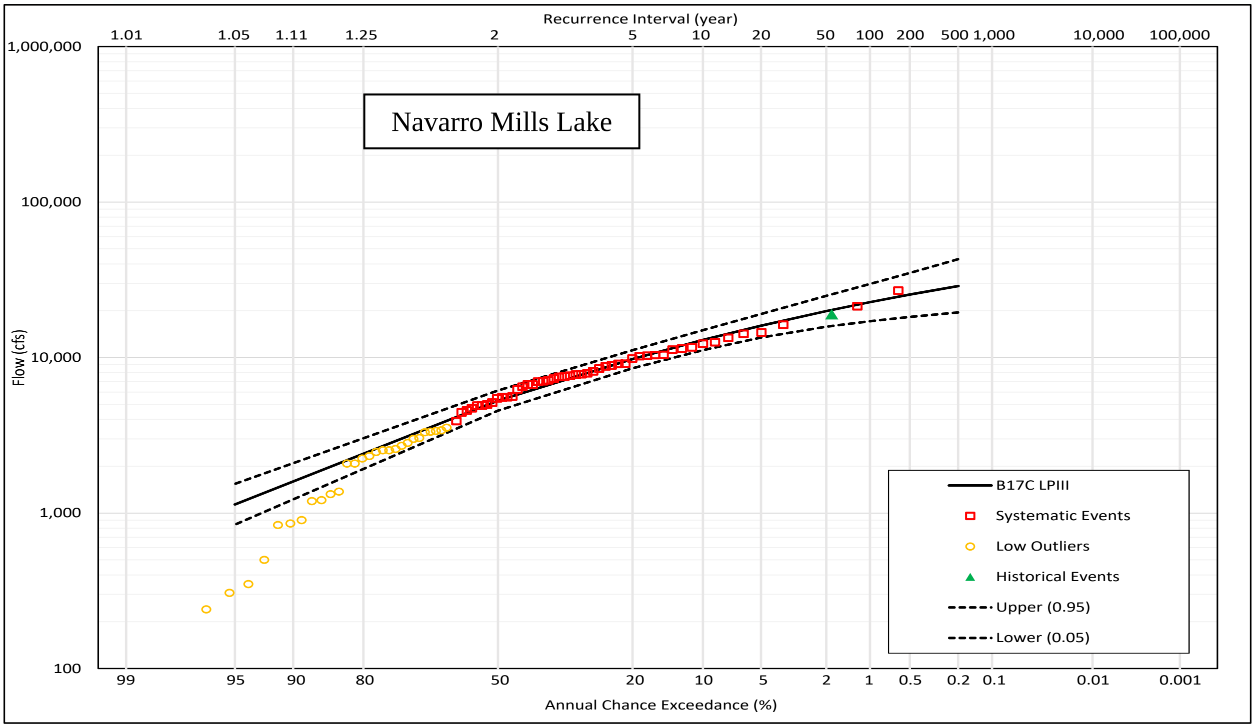


Figure 15: Navarro Mills Lake Computed 2-Day Volume Frequency Curve

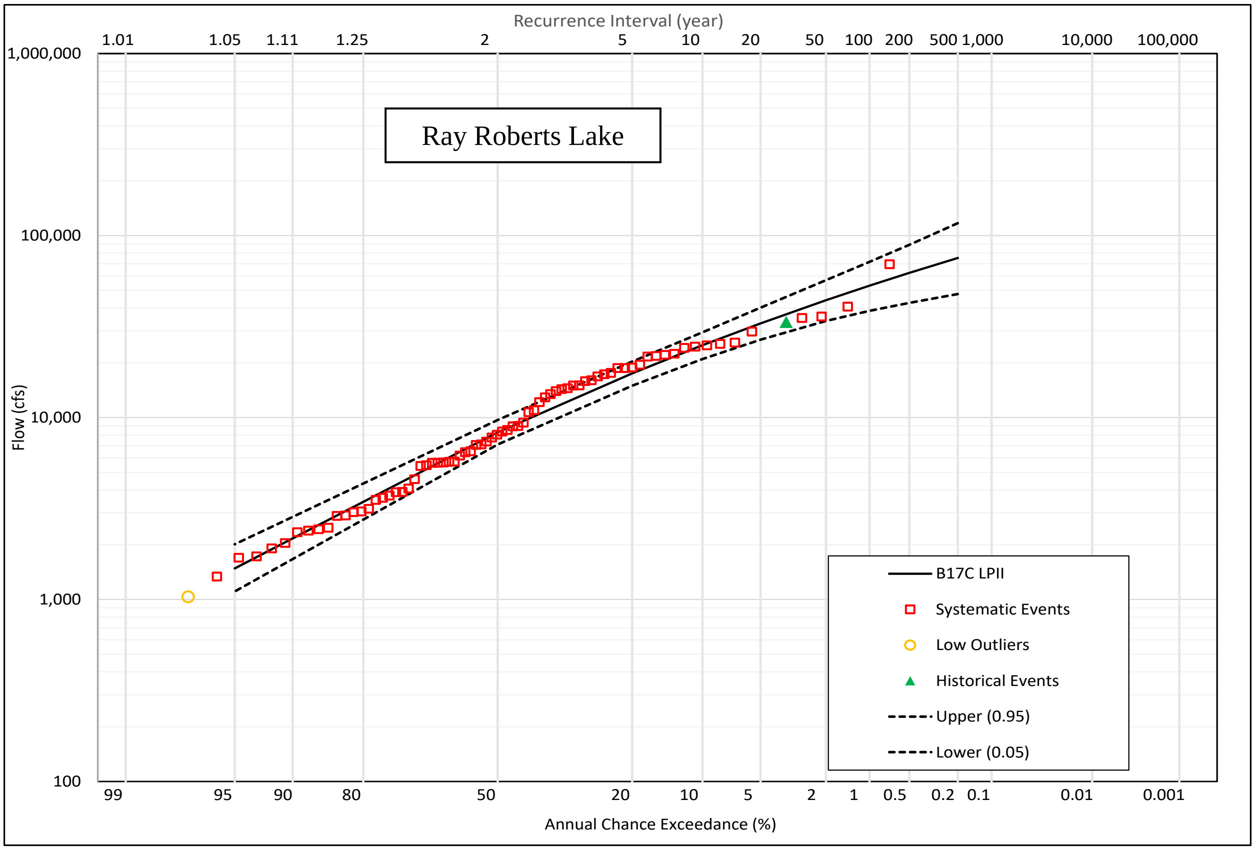


Figure 16: Ray Roberts Lake Computed 2-Day Volume Frequency Curve

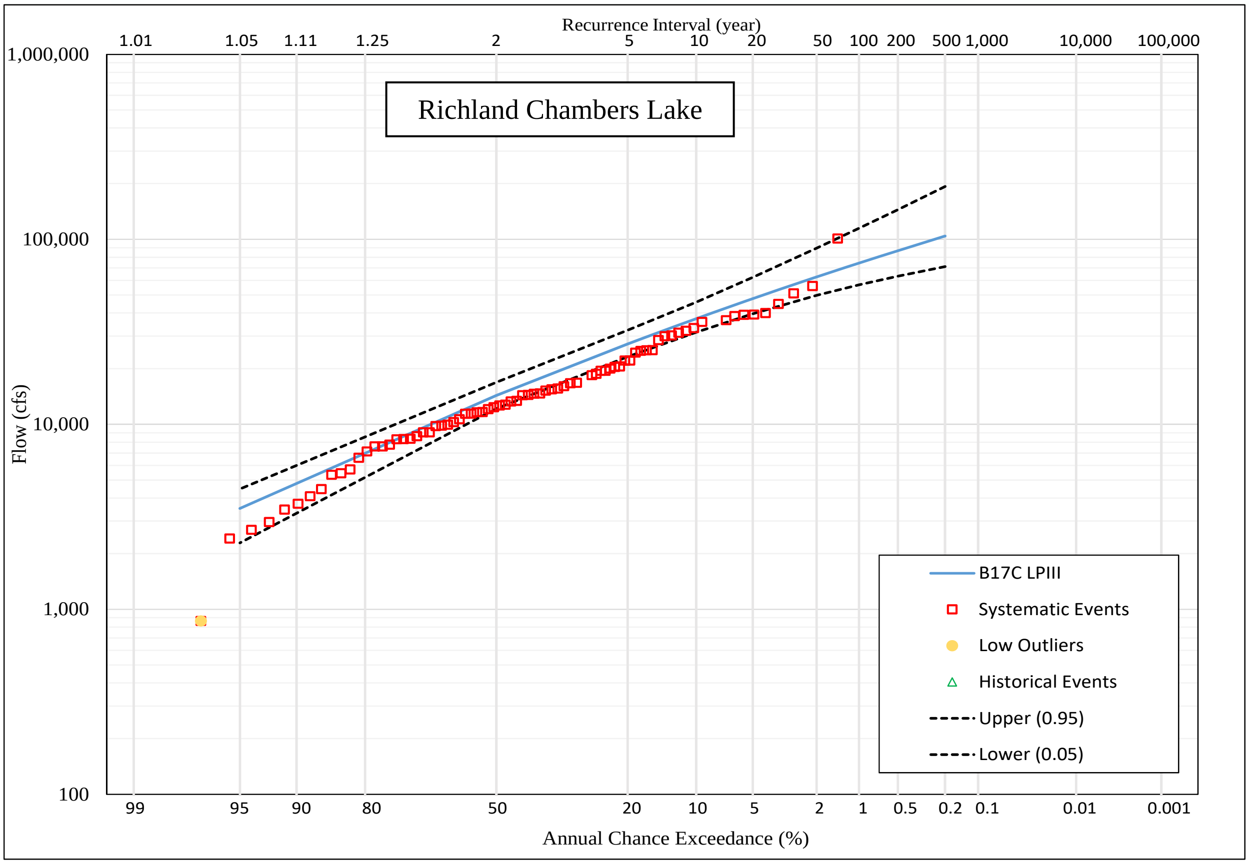


Figure 17: Richland Chambers Lake Computed 3-Day Volume Frequency Curve

1.9 RMC-RFA ANALYSES

1.9.1 FLOOD SEASONALITY

Many reservoirs have operations (pool level) that vary by season in response to the cyclical changes in meteorology and hydrology throughout the year. The inflow pattern at the Trinity River Basin lakes have two distinct mechanisms that raise the pool elevation: thunderstorms and tropical storms. Thunderstorms can occur at any time of the year and tropical storms can happen between June and November. Due to meteorological and hydrologic conditions, most significant floods occur during late spring, summer, and fall months.

The term *flood seasonality* is intended to describe the frequency of occurrence of rare floods on a seasonal basis, where a rare flood is defined as any event where the flow exceeds some user specified threshold for a specified flow duration. In the RMC-RFA model operation, a month of flood occurrence is first selected at random according to the relative frequency. Once the month of flood occurrence is specified, a starting pool elevation for the event can be determined from the reservoir stage-duration curve for that particular month. This approach ensures that seasonal variation in reservoir operations is a part of the peak-stage simulation.

The flood seasonality analysis is performed two ways: 1) Assign critical n-day flood seasonality, threshold flow, maximum events per year, and minimum days between events. With these criteria, a total number of events can be calculated. It should be noted that the critical duration used could be different from the volume frequency curve adopted critical duration. 2) Screen out annual maximum peak reservoir pool elevations for the period of record. Peak reservoir pool elevations are the result of significant inflow events and variation of reservoir pool operations. A sensitivity analysis can be done to determine which method applies better when running RMC-RFA; this is done to obtain the most defensible starting pool elevation corresponding to the most frequent events for each month. Projects for which the flood seasonality input parameters were applied (method 1) are listed in Table

10. Table 11 lists projects where screening for the period of record annual maximum peak performed better (method 2). A list of results obtained by method 1, including Ray Roberts, were also included in Table 11.

Table 10: Flood Seasonality Parameters Input Method

Project	Critical Duration (Days)	Threshold Flow (cfs)	Minimum Days Between Events	Maximum Number of Events
Ray Roberts	3	10,000	7	5
Richland Chambers	3	20,000	14	1

Table 11: Reservoir Stage AMS Peak Analysis and Parameter Input Method Results

Month	Relative Frequency by Stage AMS (Method 2)							
	Bardwell		Benbrook		Grapevine		Joe Pool	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
January	4	0.050	0	0.000	0	0.000	2	0.031
February	4	0.050	2	0.030	4	0.050	5	0.061
March	9	0.120	9	0.120	7	0.090	5	0.061
April	8	0.100	4	0.050	4	0.050	8	0.101
May	16	0.210	20	0.260	18	0.230	19	0.251
June	13	0.170	14	0.180	17	0.220	12	0.161
July	2	0.030	3	0.040	4	0.050	4	0.051
August	0	0.000	0	0.000	0	0.000	0	0.000
September	1	0.010	2	0.030	2	0.030	1	0.011
October	7	0.090	15	0.190	12	0.160	16	0.211
November	3	0.040	5	0.060	6	0.080	1	0.011
December	10	0.130	3	0.040	3	0.040	4	0.050
Month	Relative Frequency by Stage AMS (Method 2)						Applying Method 1	
	Lavon		Lewisville		Navarro Mills		Ray Roberts	
	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency	Frequency	Relative Frequency
January	3	0.040	3	0.041	5	0.061	2	0.030
February	2	0.030	1	0.011	3	0.041	4	0.050
March	7	0.090	8	0.101	8	0.101	8	0.100
April	8	0.100	5	0.061	6	0.081	6	0.080
May	19	0.250	16	0.211	19	0.251	12	0.160
June	14	0.180	9	0.121	14	0.181	11	0.140
July	2	0.030	3	0.041	2	0.031	2	0.030
August	0	0.000	1	0.011	1	0.011	0	0.000
September	2	0.030	3	0.041	0	0.000	2	0.030
October	13	0.170	19	0.250	8	0.101	21	0.270
November	4	0.050	5	0.061	3	0.041	4	0.050
December	3	0.030	4	0.050	8	0.100	5	0.060

The relative frequencies shown in Table 11 can be presented in a plot format (Figure 18 for Grapevine).

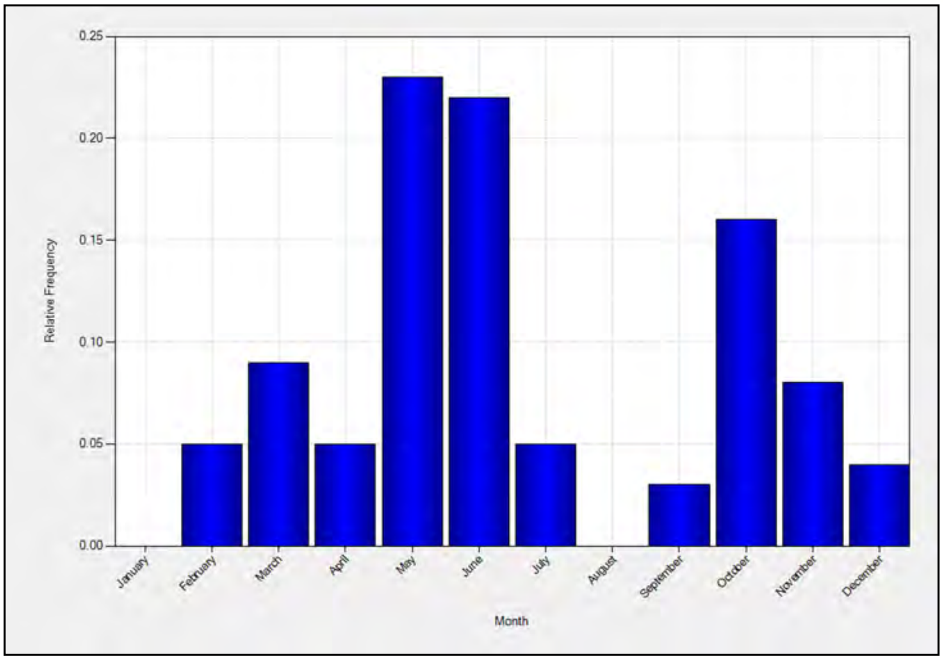


Figure 18: Grapevine Histogram of RMC-RFA Flood Seasonality Model Input

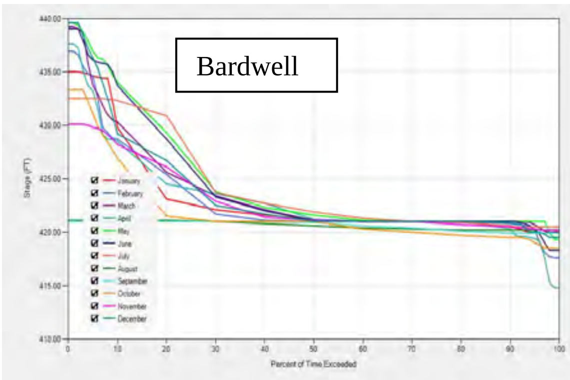
1.9.2 RESERVOIR STARTING STAGE

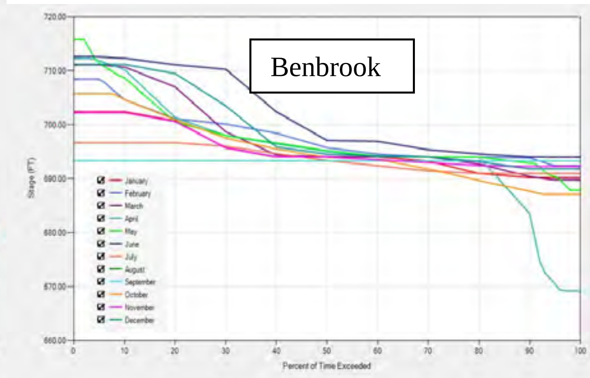
Reservoir starting pool duration curves represent the percent of time during which particular reservoir pools are exceeded. With the exception of Richland-Chambers Lake, an inflow threshold method was used to establish starting pool duration curves based on an inflow threshold value, which is normally selected to meet the value that falls under the estimated n-day critical duration and its most frequent event (volume) value. By doing so, all inflow hydrographs into the lake only consider rising limbs responsible for raising the pool. The projects final duration curves are illustrated in Figure 19. The starting pool duration curves showed consistent patterns of pool changes of when pools were exceeded between (40-50) % and 70% of the time for all months. Several starting pool duration curves were generated based on varying the inflow threshold peak values. The finalized inflow threshold peaks along with the final critical durations are listed in Table 12.

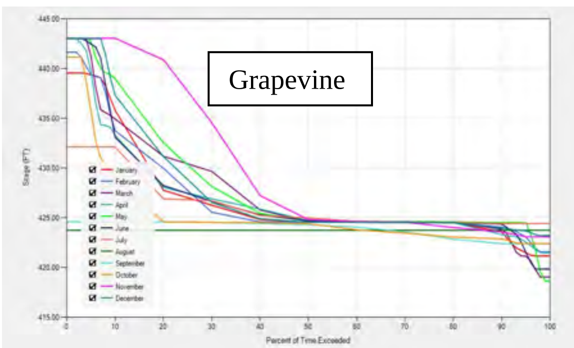
Richland-Chambers reservoir starting stage was estimated by analyzing pool elevations by first filtering observed daily average pools so that they only represent typical starting pools based on a pool change threshold. Then, the filtered data set is sorted by month or season. Because RMC-RFA chooses a starting pool elevation for its simulations based on historic data, the historic data must be filtered so that it is not influenced by flooding events. Starting pool elevations should form the basis for flooding events, not be the result of said events. Therefore, historic pool elevations were filtered with a pool change threshold of 0.5 feet per day and a typical high (flood) pool duration of 12 days. This filtered stage data now forms the basis for the starting pool elevation for the RMC-RFA reservoir simulation. Table 13 lists Richland Chamber’s filtered starting pool elevations by month and probability.

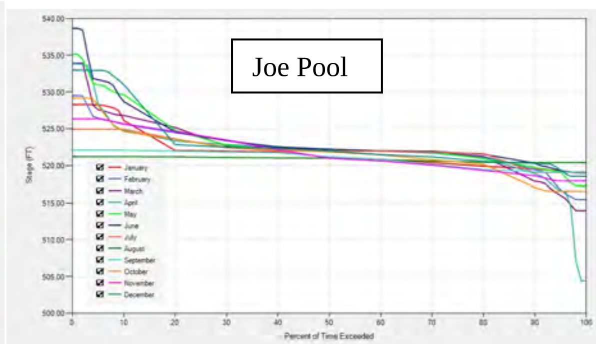
Table 12: Trinity River Basin Threshold Peaks and Critical Durations

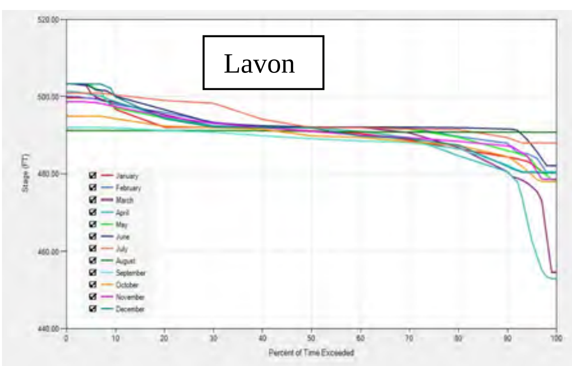
Project	Bardwell	Benbrook	Grapevine	Joe Pool	Lavon	Lewisville	Navarro mills	Ray Roberts
Inflow Threshold (cfs)	483	275	447	570	2,100	2,400	1,100	1,250
critical Duration (Days)	2	2	3	2	3	3	2	2

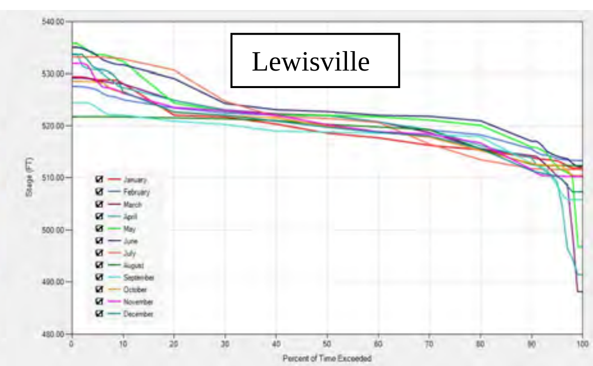












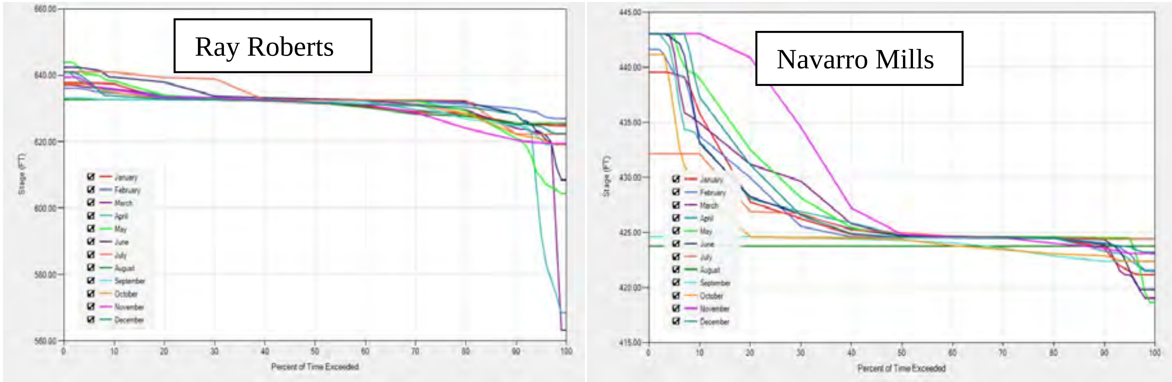


Figure 19: Trinity River Basin Lakes Starting Stage Durations

Table 13: Richland Chambers Starting Pool Elevation for the RMC-RFA Reservoir Simulation Model

Prob.	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov	Dec
0.999	291.86	292.15	291.83	293.12	289.95	298.03	296.58	295.16	293.93	293.00	292.89	292.37
0.99	292.17	292.47	292.25	297.09	302.32	298.79	297.59	296.13	294.76	293.61	293.39	292.80
0.95	303.35	303.37	303.86	304.19	307.71	307.73	306.65	305.37	304.16	303.16	302.70	302.11
0.90	305.87	306.53	306.97	307.83	308.74	308.90	308.24	307.10	306.27	305.78	305.17	305.60
0.85	307.47	307.97	308.22	308.79	309.17	309.59	309.13	308.22	307.36	307.10	307.36	306.98
0.80	308.58	308.63	309.14	309.46	309.92	311.90	311.18	310.14	309.28	308.72	308.91	308.83
0.75	309.41	309.39	310.03	309.87	312.47	312.58	311.79	310.78	310.07	309.79	309.59	309.31
0.70	310.67	310.64	310.41	310.76	313.05	313.50	312.95	311.99	311.28	310.72	310.28	310.10
0.65	311.09	311.15	312.46	313.47	313.93	314.08	313.36	312.42	311.77	311.48	311.30	311.20
0.60	311.49	312.04	313.40	314.01	314.33	314.33	313.71	312.73	312.03	311.71	311.58	311.42
0.55	312.07	312.73	314.41	314.52	314.52	314.53	313.97	313.02	312.29	311.91	311.70	311.68
0.50	312.66	313.51	314.69	314.69	314.69	314.69	314.15	313.31	312.59	312.13	311.98	311.95
0.45	313.70	314.39	314.85	314.83	314.85	314.83	314.29	313.49	312.83	312.38	312.17	312.50
0.40	314.38	314.81	314.95	314.91	314.97	314.90	314.41	313.63	313.01	312.55	312.44	312.93
0.35	314.92	314.96	314.99	314.97	315.02	314.96	314.51	313.75	313.19	312.75	312.90	314.06
0.30	314.98	314.99	315.03	315.01	315.09	315.02	314.61	313.87	313.30	313.04	313.58	314.33
0.25	315.01	315.03	315.09	315.05	315.16	315.09	314.72	314.00	313.48	313.27	314.46	314.93
0.20	315.04	315.08	315.17	315.12	315.26	315.21	314.84	314.17	313.67	313.47	314.81	315.00
0.15	315.11	315.21	315.27	315.23	315.34	315.31	314.96	314.34	313.91	314.29	315.00	315.10
0.10	315.23	315.32	315.35	315.32	315.38	315.36	315.03	314.57	314.18	314.71	315.08	315.27
0.05	315.35	315.40	315.42	315.39	315.45	315.43	315.23	314.85	314.62	314.99	315.33	315.37
0.01	315.52	315.67	315.82	315.68	315.89	315.65	315.39	315.18	315.18	315.22	315.57	315.77
0.001	315.89	315.92	316.10	316.06	316.32	316.06	315.79	315.45	315.50	315.42	316.14	316.53

1.9.3 EMPIRICAL FREQUENCY CURVE

For the evaluation of hydrologic hazards of each project, an extreme-value series of annual maximum stage was generated from the n-year systematic (RiverWare + Observed) period of record shown in Table 7. Each POR annual maximum series was extracted, the AMS was ranked, and it was plotted on log probability paper using the Weibull plotting position formula shown in Section 5.1. Figure 20 is Grapevine Dam's empirical stage frequency relationship when applying the Weibull plotting positions. The systematic frequency peaks for all the projects were plotted against the RMC-RFA pool frequency curves. The plotting position of the highest and lowest points are the most uncertain due to having insufficient record lengths necessary to inform accurate plotting positions at the extremes.

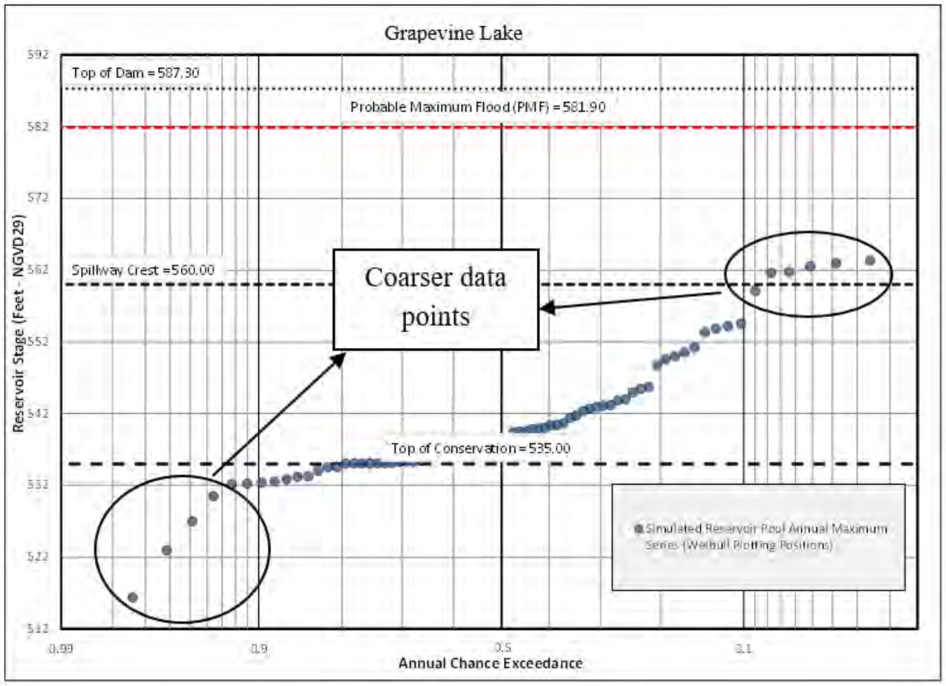
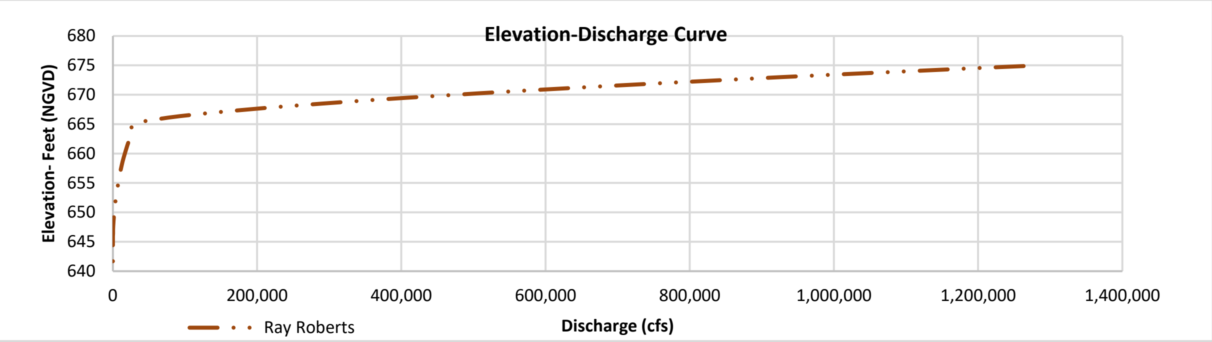
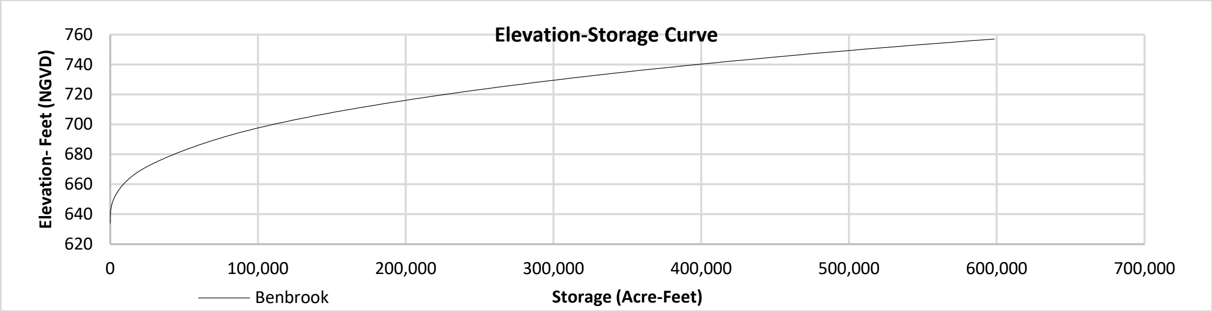


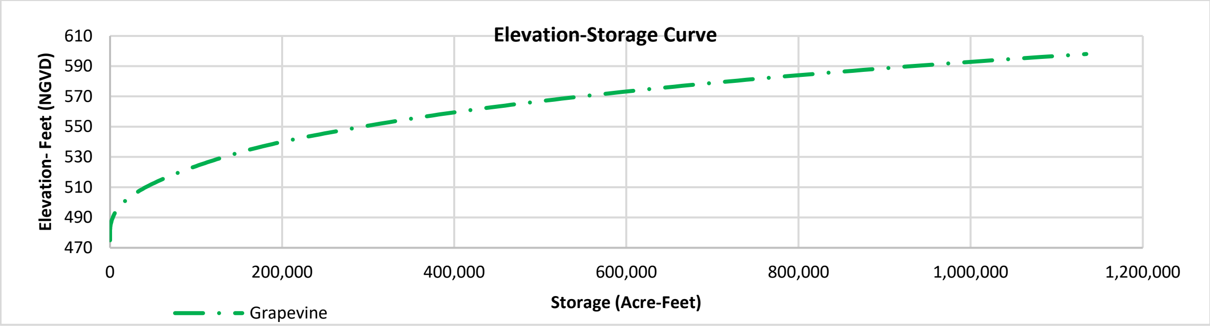
Figure 20: Stage Duration Frequency Example for Grapevine Lake

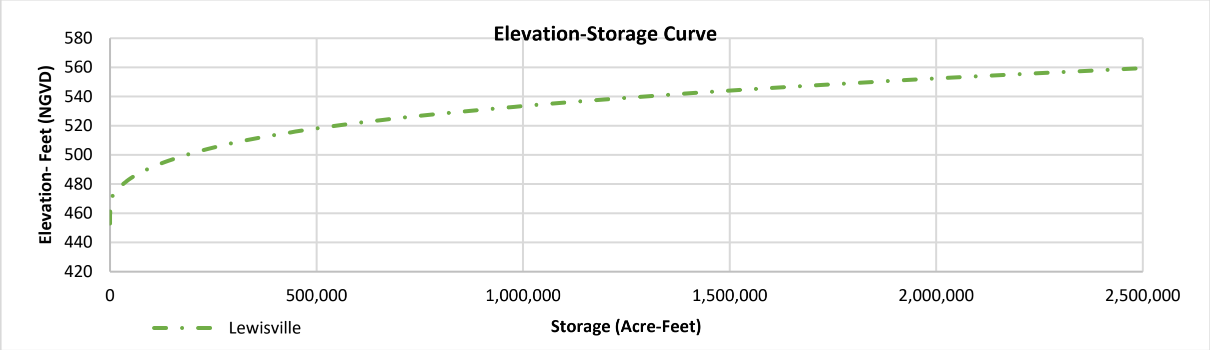
1.9.4 RESERVOIR MODEL

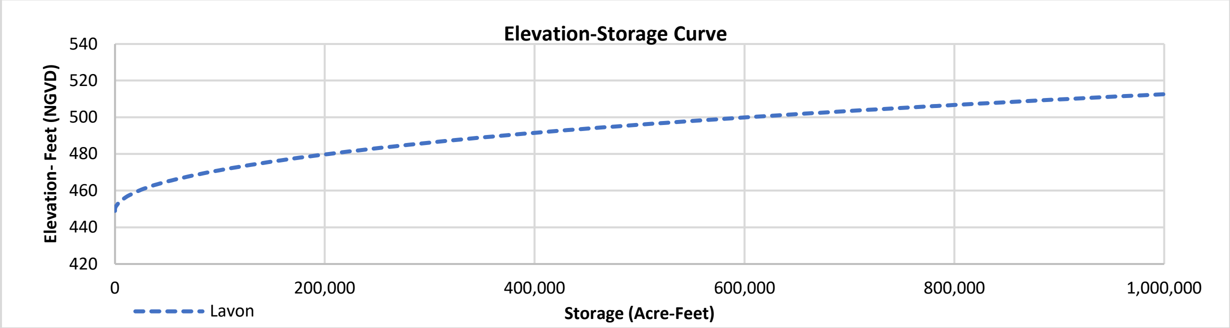
The reservoir details such as the Stage-Storage-Discharge function and top of dam, spillway, and inflow design flood elevations were obtained from the Fort Worth District USACE electronic library archived files. The latest Geographic Information System (GIS)-10 meter Digital Elevation Model (DEM) data layers were used and processed through ArcMap-GIS to obtain up to date stage-storage curves for the reservoirs. The Stage-Storage-Discharge information gathered and developed was entered into the Reservoir Model and used to route the inflow hydrographs. The Discharge-Elevation and Storage-Elevation curves for the projects are shown in Figures 21 and 22, respectively. Pertinenet reservoir stages are listed in Table 14.


Elevation-Discharge Curve
Elevation- Feet (NGVD)
680
675
670
665
660
655
650
645
640
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
1,400,000
Ray Roberts
Discharge (cfs)


Elevation-Storage Curve
Elevation- Feet (NGVD)
760
740
720
700
680
660
640
620
0
100,000
200,000
300,000
400,000
500,000
600,000
700,000
Benbrook
Storage (Acre-Feet)


Elevation-Storage Curve
Elevation- Feet (NGVD)
610
590
570
550
530
510
490
470
0
200,000
400,000
600,000
800,000
1,000,000
1,200,000
Grapevine
Storage (Acre-Feet)


Elevation-Storage Curve
Elevation- Feet (NGVD)
580
560
540
520
500
480
460
440
420
0
500,000
1,000,000
1,500,000
2,000,000
2,500,000
Lewisville
Storage (Acre-Feet)


Elevation-Storage Curve
Elevation- Feet (NGVD)
540
520
500
480
460
440
420
0
200,000
400,000
600,000
800,000
1,000,000
Lavon
Storage (Acre-Feet)

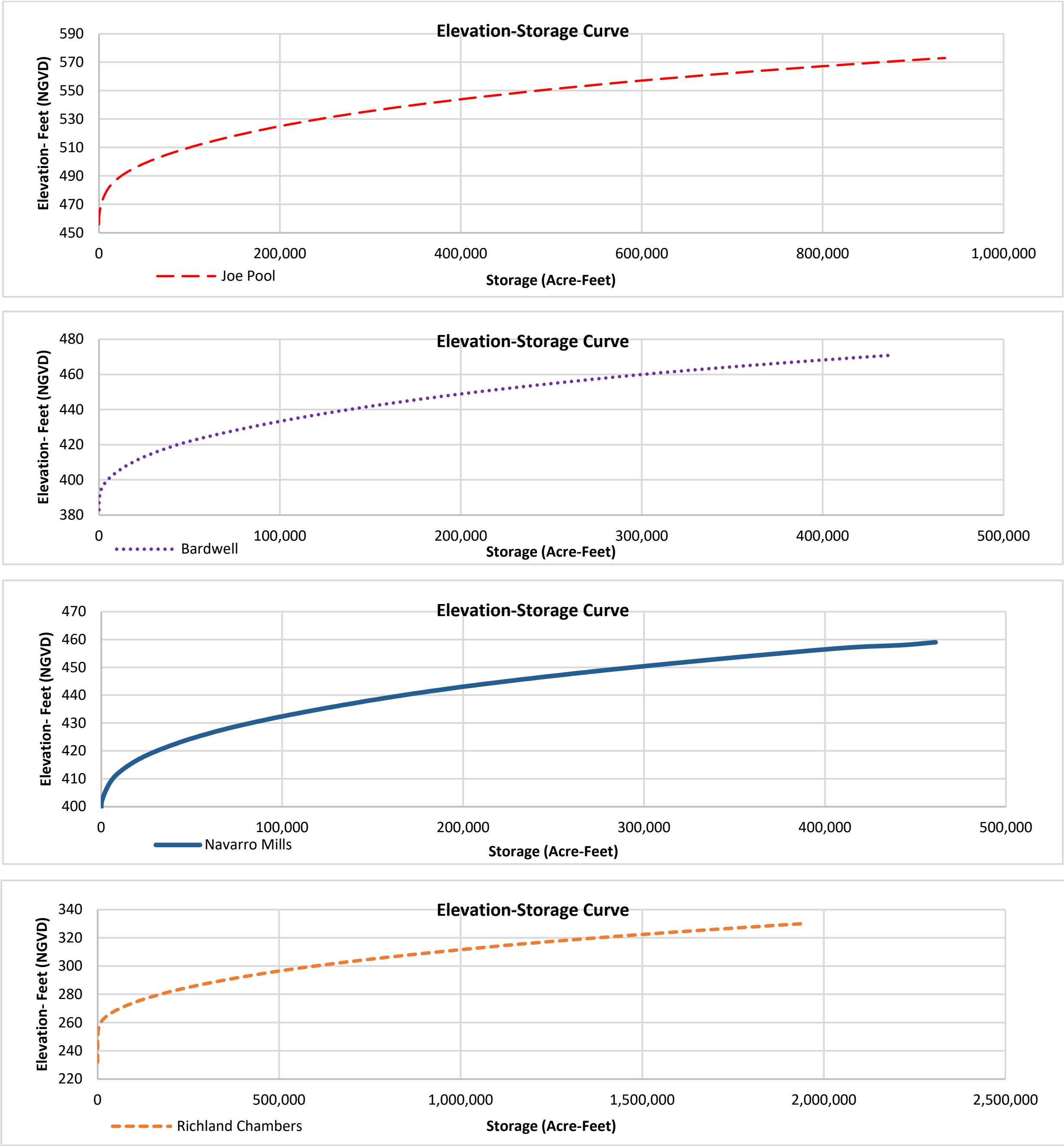


Figure 21: Trinity River Projects Outflow Discharge-Elevation Curves

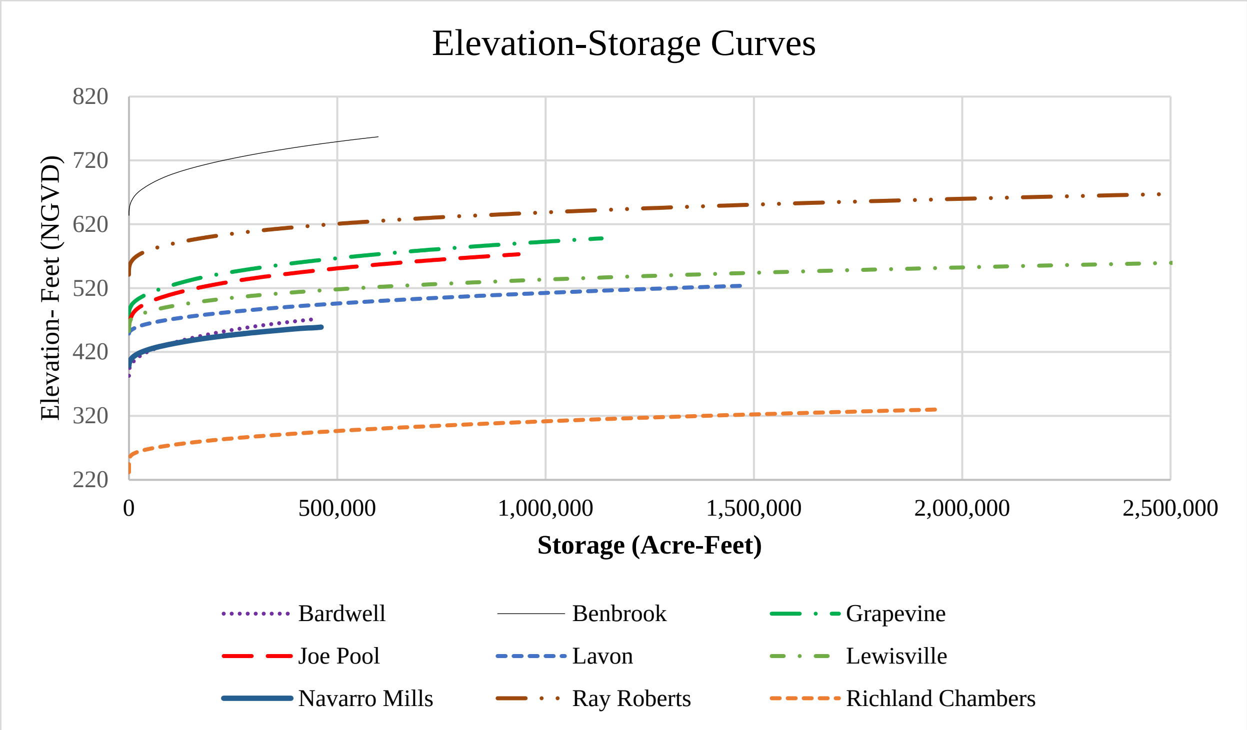


Figure 22: Trinity River Projects Storage-Elevation Curves

Table 14: Trinity River Basin Lakes Features

Project	Bardwell	Benbrook	Grapevine	Joe Pool	Lavon	Lewisville	Navarro Mills	Ray Roberts	Richland Chambers
Pertinent Feature	Elevation (Feet)-NGVD								
Top of Dam	460.0	747.0	588.0	564.5	514.0	560.0	457.0	665.0	330.0
Top of Flood Control Pool	439.0	724.0	560.0	536.0	503.5[1]	532.0	443.0[1]	640.5	315.0
Spillway Crest	439.0	710.0[3]	560.0	541.0[2]	475.5	532.0	414.0	645.5[2]	315.0
Top of Conservation Pool	421.0	694.0	535.0	522.0	492.0	522.0	424.5	632.5	-

[1] at notch in emergency spillway. [2] at crest of perched emergency spillway. [3] at top of closed tainter gates.

The importance of using accurate Storage-Discharge-Elevation (Stage) curves is that it results in more accurate estimates of high extreme peak values associated with high degree of uncertainty (*i.e.* 1% AEP and beyond). Such high peaks are normally observed near or above the spillway crest.

1.10 RESULTS

The RMC-RFA program was used to simulate rainfall-runoff floods using the inflow-frequency curve and the adopted flood seasonality. The specified hourly inflow hydrographs in section 1.8.1 are weighted equally to account for each unique shape (*i.e.* volume and peak) and to have the same probability. A routing time window of 5 days was specified to calculate the full size of floods routed through the reservoir on an hourly basis. The RMC-RFA model was simulated using the expected stage frequency curve only model option. This runs 10,000 realizations with 1,000,000 events per realization. This means RMC-RFA simulates a total of 10 billion events

(10,000 x 1,000,000) to produce its best estimate of the expected curve. The following sections outline detailed results about each project's new simulated expected stage-frequency curve. Each federally owned project has a flowage easement elevation. The flowage easement land is privately owned land on which the Federal government (*i.e.* USACE) has acquired certain perpetual rights. These include the right to flood it in connection with the operation of the reservoir, the right to prohibit construction of any structure for human habitation, the right to approve all other structures constructed on flowage easement land, except fencing. Having imposed properties located above the easement elevation keeps from what would become damageable property out of the flood pool, so that the reservoir can be operated with a full focus upon downstream conditions and the concern for dam safety. To put things in perspective about the flowage easement, figures in the following sections illustrate easement elevation references in relation to the reservoir pool frequencies, spillway crest elevation, and top of dam.

The results shown below were first obtained utilizing the RMC-RFA program. Once ran, a second look at the results was deemed necessary to ensure accurate results are maintained. Accurate results lie in fitting the best estimate pool frequency curves through the observed elevation data points for the more frequent events, generally within the 50% to 2% AEP range, which is highly representative by the observed AMS data. For rare events such as the 1%ACE (100-year) and 0.2%ACE (500-year), a second adjustment was made using best engineering judgment and knowledge of operations during high peak events. The final adopted curves were thus the combined results of modeling and best engineering judgment efforts. Adopted pool frequency curves along with comparison with FEMA's currently-effective pool frequencies and the Fort Worth District USACE reported pool frequencies are shown below.

1.10.1 BARDWELL LAKE

Table 15: Bardwell Lake Stage Frequency Estimate

Bardwell Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	425.69			
5	20	430.94			
10	10	434.50			
25	4	438.10			
50	2	440.00			
100	1	441.50	NA	NA	444.00
250	0.4	443.21			
500	0.2	444.24			

Table 16: Bardwell Lake Computed Frequency Discharge Release

Bardwell Lake		RMC-RFA Best Estimate			
N-Year	ACE%	Elevation-NGVD	Spillway Release (cfs)	Gate Release (cfs)	Total Release (cfs)
2	50	425.69	0	1,200	1,200
5	20	430.94	0	2,000	2,000
10	10	434.50	0	2,000	2,000
25	4	438.10	0	2,000	2,000
50	2	440.00	1,080	920	2,000
100	1	441.50	4,335	0	4,335
250	0.4	443.21	6,060	0	6,060
500	0.2	444.24	9,470	0	9,470

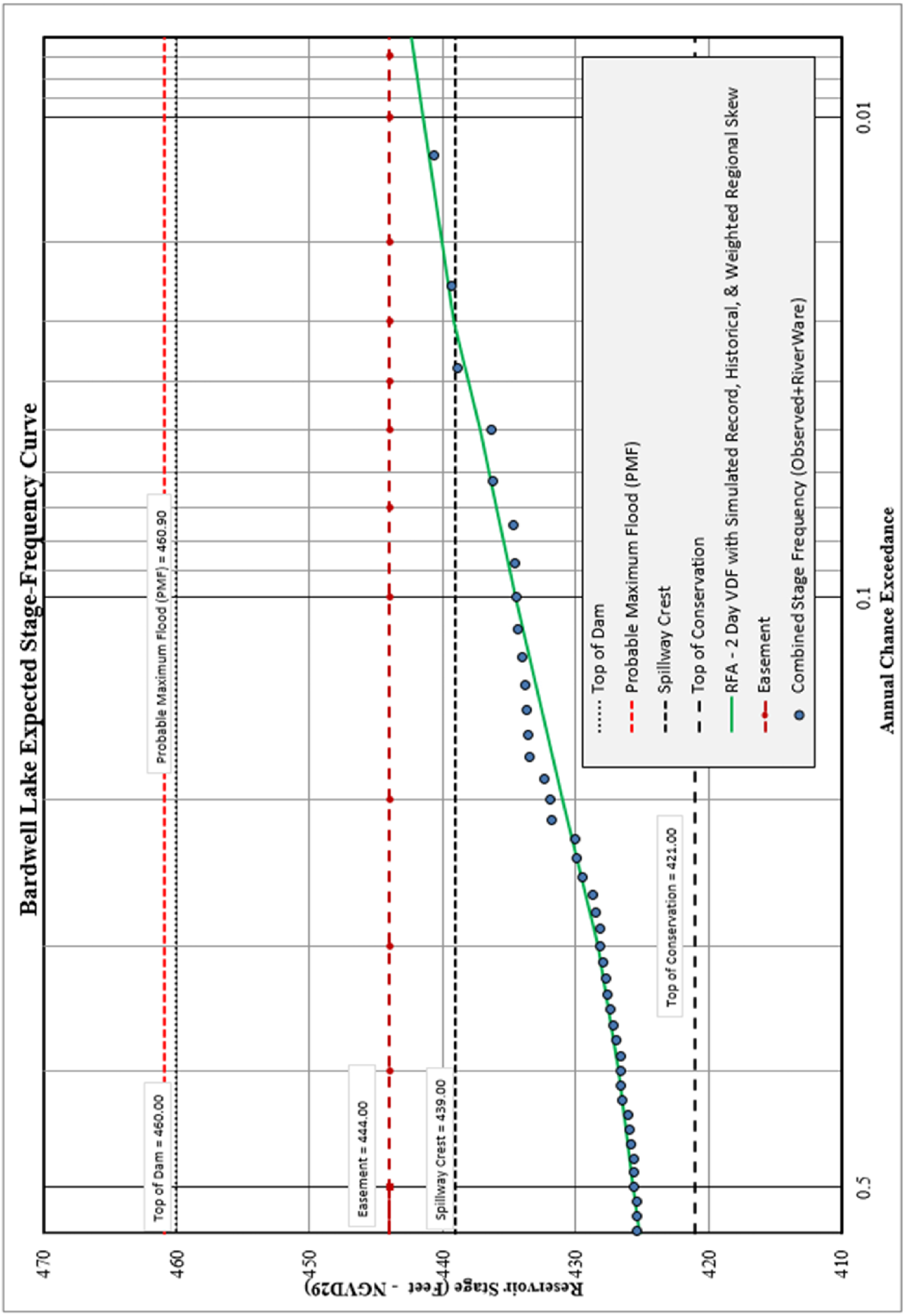


Figure 23: Bardwell Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.2 BENBROOK LAKE

Table 17: Benbrook Lake Stage Frequency Estimate

Benbrook Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	697.20			
5	20	704.00			
10	10	711.00	704.80	6.20	
25	4	713.73			
50	2	715.68	712.20	3.48	
100	1	717.57	715.00	2.57	741.00
250	0.4	720.27			
500	0.2	722.29	727.00	-4.71	

Table 18: Benbrook Lake Computed Frequency Discharge Release

Benbrook Lake		RMC-RFA Best Estimate				FEMA'S Effective Outflow (cfs)
N-Year	ACE%	Elevation-NGVD	Spillway Release (cfs)	Gate Release (cfs)	Release (cfs)	
2	50	697.20	0	3,000	3,000	
5	20	704.00	0	6,000	6,000	
10	10	711.00	400	5,600	6,000	6,000
25	4	713.73	3,800	2,200	6,000	
50	2	715.68	4,300	2,200	6,000	8,400
100	1	717.57	6,700	0	6,700	13,000
250	0.4	720.27	10900	0	10,900	
500	0.2	722.29	14,600	0	14,600	46,000

Note: Benbrook Low Crest Notch Elevation = 710-ft (NGVD) and Spillway Crest Elevation = 724-ft (NGVD)

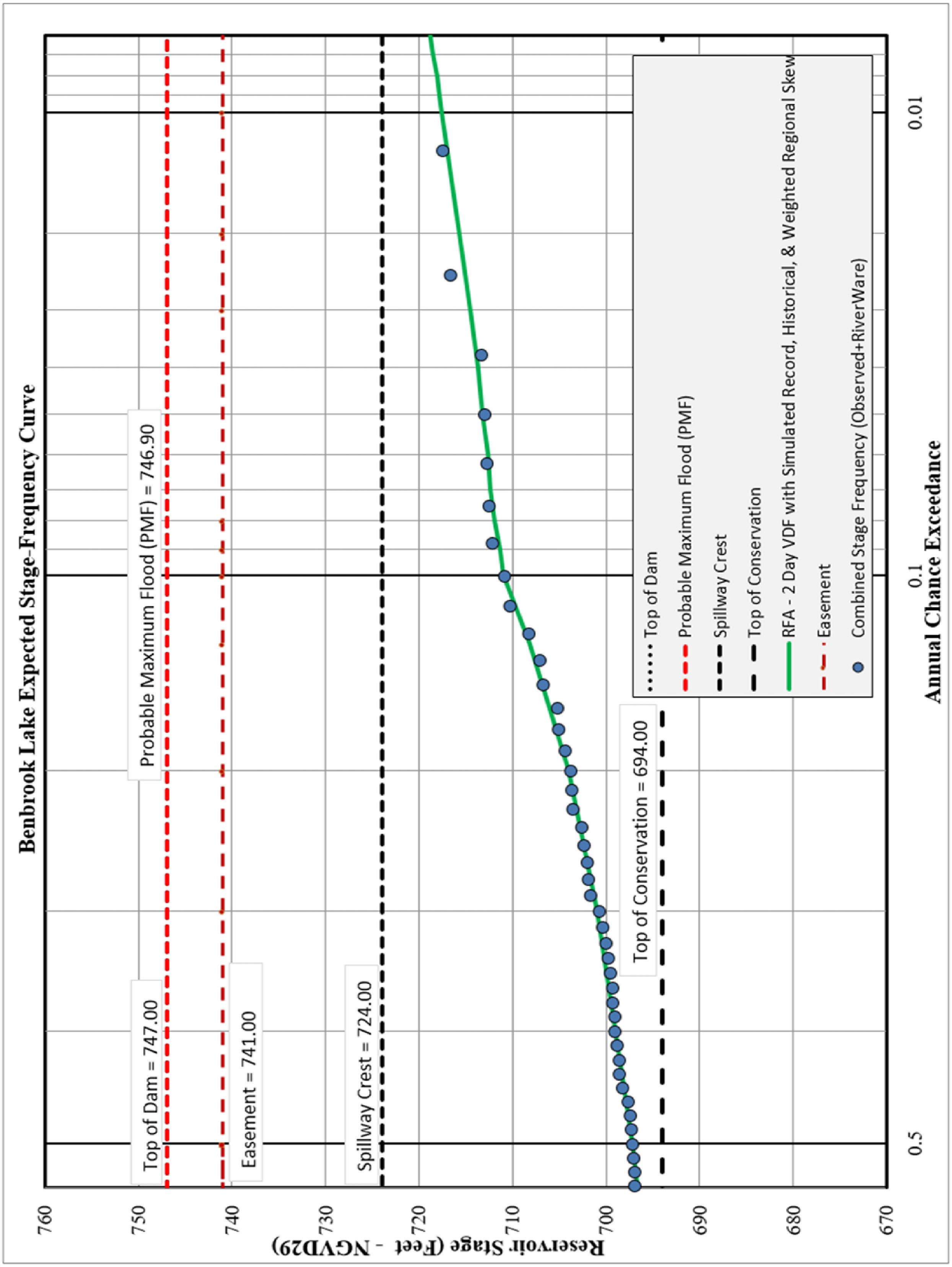


Figure 24: Benbrook Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.3 GRAPEVINE LAKE

Table 19: Grapevine Lake Stage Frequency Estimate

Grapevine Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	538			
5	20	546			
10	10	556	554	2	
25	4	561.54			
50	2	562.83	562.3	0.53	
100	1	564	564	0	572
250	0.4	565.61			
500	0.2	566.91	568.4	-1.49	

Table 20: Grapevine Lake Computed Frequency Discharge Release

Grapevine Lake		RMC-RFA Best Estimate				FEMA's Effective Outflow (cfs)
N-Year	ACE%	Elevation-NGVD	Spillway Release (cfs)	Gate Release (cfs)	Total Release (cfs)	
2	50	538	0	2,000	2,000	
5	20	546	0	2,000	2,000	
10	10	556	0	2,000	2,000	4,000
25	4	561.54	3,100	0	3,100	
50	2	562.83	7,700	0	7,700	7,000
100	1	564	13,100	0	13,100	9,400
250	0.4	565.61	22,200	0	22,200	
500	0.2	566.91	30,800	0	30,800	36,200

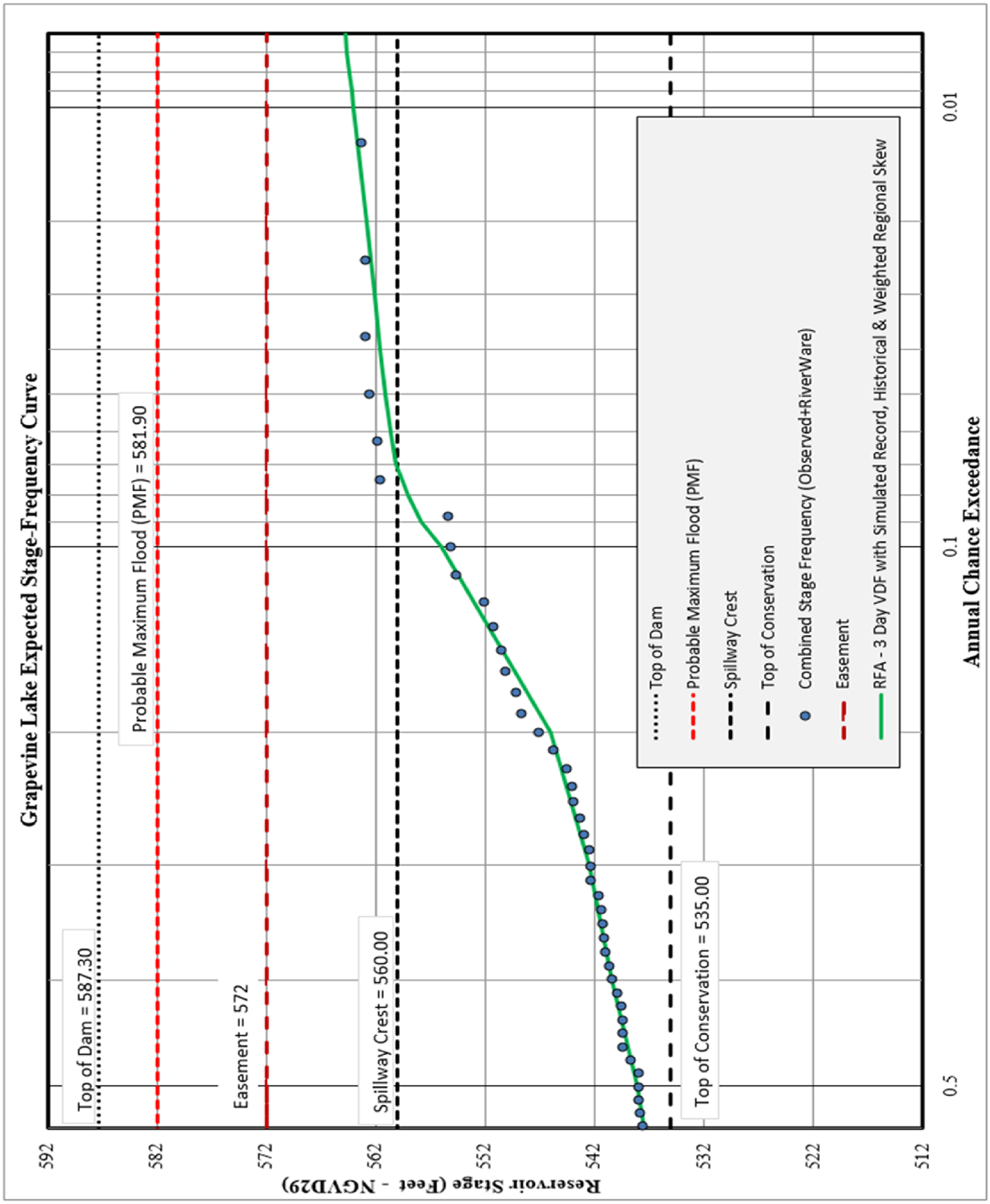


Figure 25: Grapevine Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.4 JOE POOL LAKE

Table 21: Joe Pool Lake Stage Frequency Estimate

Joe Pool Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	524.50			
5	20	527.00			
10	10	531.00	527.50	3.50	
25	4	535.30			
50	2	537.50	536.00	1.50	
100	1	539.00	537.50	1.50	541.00
250	0.4	540.80			
500	0.2	542.17	543.50	-1.33	

Table 22: Joe Pool Lake Computed Frequency Discharge Release

Joe Pool Lake		RMC-RFA Best Estimate			
N-Year	ACE%	Elevation-NGVD	Spillway Release (cfs)	Gate Release(cfs)	Total Release(cfs)
2	50	524.50	0	1,200	1,200
5	20	527.00	0	2,400	2,400
10	10	531.00	0	4,000	4,000
25	4	535.30	0	4,000	4,000
50	2	537.50	0	4,000	4,000
100	1	539.00	0	4,000	4,000
250	0.4	540.80	0	4,000	4,000
500	0.2	542.17	200	3,800	4,000

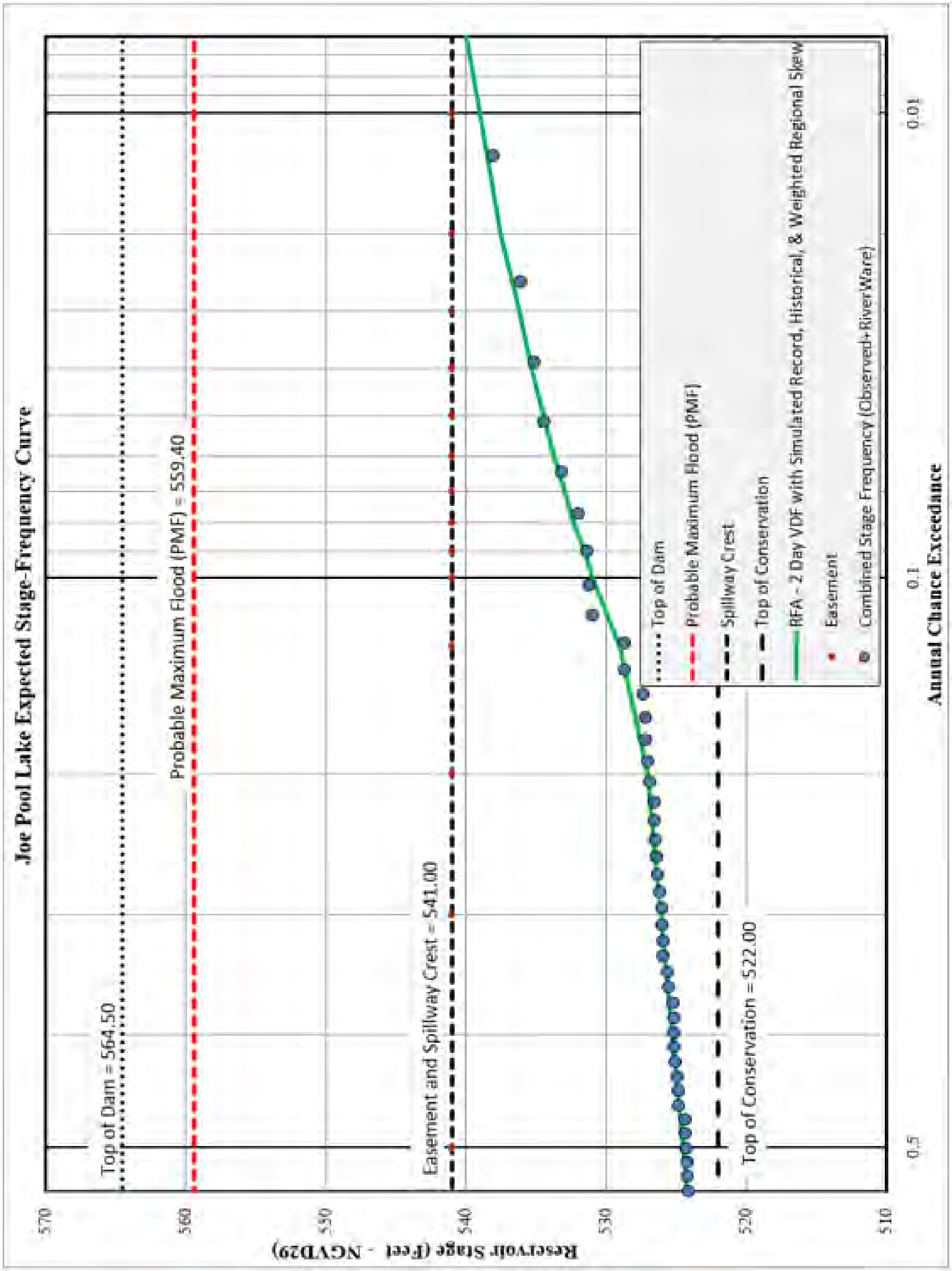


Figure 26: Joe Pol Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.5 LAVON LAKE

Table 23: Lavon Lake Stage Frequency Estimate

Lavon Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	493.90			
5	20	499.50			
10	10	502.80			
25	4	503.70			
50	2	504.00			
100	1	504.30	NA	NA	508.00
250	0.4	504.70			
500	0.2	505.00			

Table 24: Lavon Lake Computed Frequency Discharge Release

Lavon Pool Lake		RMC-RFA Best Estimate			
N-Year	ACE%	Elevation-NGVD	Spillway Release (cfs)	Gate Release(cfs)	*Total Release(cfs)
2	50	493.90	0	4,000	4,000
5	20	499.50	0	8,000	8,000
10	10	502.80	0	8,000	8,000
25	4	503.70	10,665	0	10,665
50	2	504.00	22,000	0	22,000
100	1	504.30	35,200	0	35,200
250	0.4	504.70	53600	0	53600
500	0.2	505.00	66,000	0	66,000

*Total releases provided here were based on observed releases from historical events and induced surcharge envelope curve.

*Tainter gate project release is based on forecast and inflow. See Plate 7-2 in the WCM of this project for more release details. Total release is subject to wide range of changes depending on forecast and inflow. Induced surcharge envelope curve was obtained from Design memorandum No.1, Hydrology-Part A, Vol. 214-H computation for Lavon Reservoir modification. The spillway consists of 12- 40 ft x 28 ft Tainter gates with crest elevation 475.5 ft NGVD and hydraulic head (Hd) = 33.0 ft.

For Lavon Lake, the annual maximum observed releases were plotted against the annual maximum pool elevations. Figure 27 illustrates the actual observed release and peak distribution in relation to operating instructions. Because Lavon Lake operates based upon forecast and inflow, it can be seen that releases are concentrated between different operational curves. However, the induced surcharge envelope curve is tangent to the highest 3 peaks in record with releases of 13,500cfs, 20,453cfs, and 43,700cfs. The rest of the observed annual peaks fall between the other curves. It is recommended to follow the induced surcharge envelope curve as it captures those peaks in a least conservative release manner. Best engineering judgment should not be ruled out during operation.

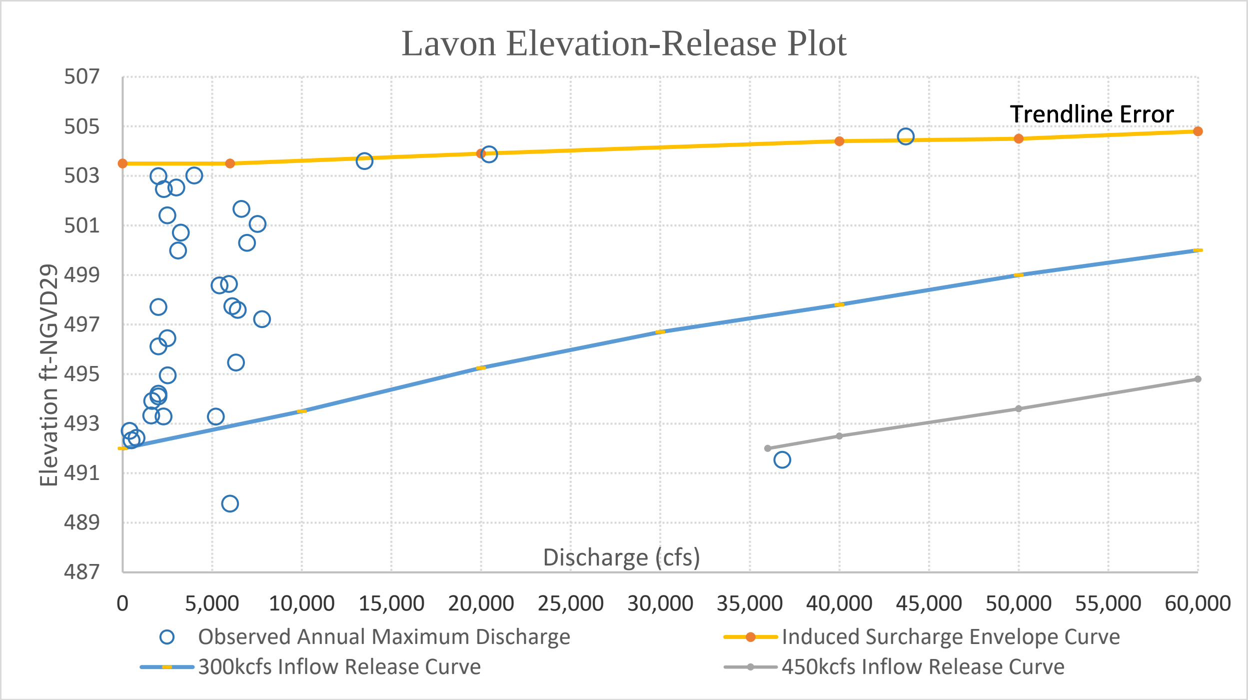


Figure 27: Lavon Lake Discharge vs. Elevation

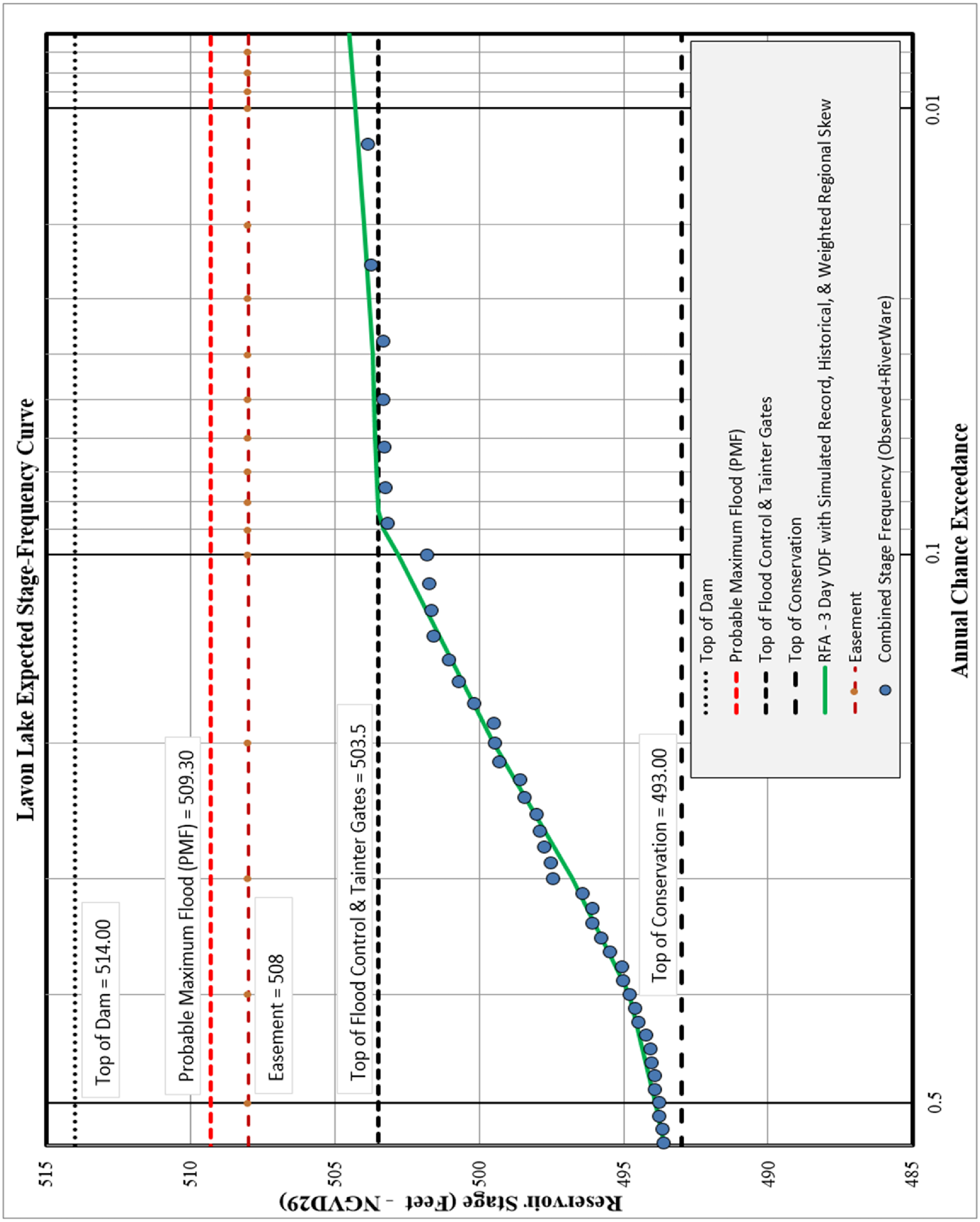


Figure 28: Lavon Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.6 LEWISVILLE LAKE

Table 25: Lewisville Lake Stage Frequency Estimate

Lewisville Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	523.88			
5	20	527.75			
10	10	532.15	529.50	2.65	
25	4	535.02			
50	2	536.50	535.00	1.50	
100	1	537.75	537.00	0.75	537.00
250	0.4	539.26			
500	0.2	540.50	541.00	-0.50	

Table 26: Lewisville Lake Computed Frequency Discharge Release

Lewisville Pool Lake		RMC-RFA Best Estimate				FEMA's Effective Outflow (cfs)
N-Year	ACE%	Elevation-NGVD	Spillway Release (cfs)	Gate release(cfs)	Total Release(cfs)	
2	50	523.88	0	4,000	4,000	
5	20	527.75	0	7,000	7,000	
10	10	532.15	200	6,800	7,000	6,300
25	4	535.02	9,400	0	9,400	
50	2	536.50	17,900	0	17,900	9,000
100	1	537.75	26,500	0	26,500	21,000
250	0.4	539.26	38,900	0	38,900	
500	0.2	540.50	50,000	0	50,000	55,000

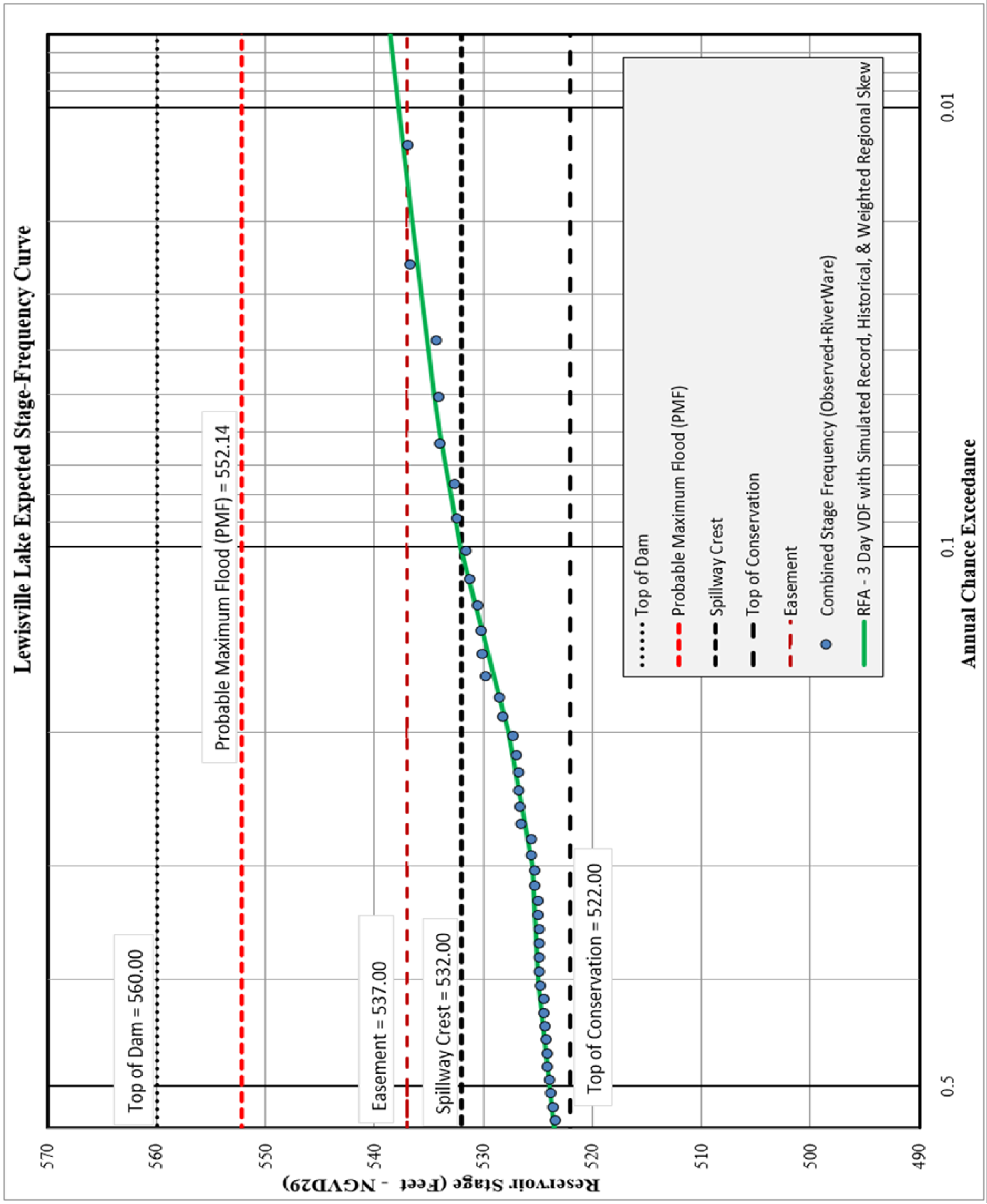


Figure 29: Lewisville Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.7 NAVARRO MILLS

Table 27: Navarro Mills Lake Stage Frequency Estimate

Navarro Mills Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	430.90			
5	20	436.10			
10	10	439.84			
25	4	443.20			
50	2	444.00			
100	1	444.50	NA	NA	446.00
250	0.4	445.23			
500	0.2	445.74			

Table 28: Navarro Mills Lake Computed Frequency Discharge Release

Navarro Mills Pool Lake		RMC-RFA Best Estimate			
N-Year	ACE%	Elevation-NGVD	Spillway Release(cfs)	Gate release(cfs)	*Total Release(cfs)
2	50	430.90	0	1,000	1,000
5	20	436.10	0	2,000	2,000
10	10	439.84	0	2,000	2,000
25	4	443.20	3,000	0	3,000
50	2	444.00	7,000	0	7,000
100	1	444.50	9,900	0	9,900
250	0.4	445.23	15,300	0	15,300
500	0.2	445.74	21,000	0	21,000

* Total releases provided here are based on observed historical releases and readings from the induced surcharge envelop curve.
* Tainter gate project release is based on forecast and inflow. See Plate 10 in the WCM of this project for more release details. Total release is subject to wide range of changes depending on forecast and inflow.
The induced surcharge envelope data was obtained from Hydrology Section file, Volume 320, Navarro Mills. Reservoir, Vol. 1, Design Memorandum No. 1.
The Tainter gate spillway rating curve was obtained from Hydraulics Section file, volume 17-MT, Trinity River Basin, Richland Creek, Navarro Mills Dam, Hydraulics Studies, July 1956.

The spillway consists of 6- 40 Ft x 29 Ft Tainter gates with crest elevation 414.0 Ft NGVD and hydraulic head (Hd) = 28.0 Ft.

The annual maximum observed releases were plotted against the annual maximum pool elevations observed in the reservoir. Figure 30 illustrates the actual observed release and peak distribution in relation to operating instructions. Because Navarro Mills operates based upon forecast and inflow, it can be seen that releases fluctuate between different operational curves. However, the induced storage envelope curve is tangent to the highest peak in record with a release of 4,680cfs. The rest of the observed annual peaks fall between the other curves. It is recommended to follow the induced surcharge envelope curve along with best engineering judgment to control releases.

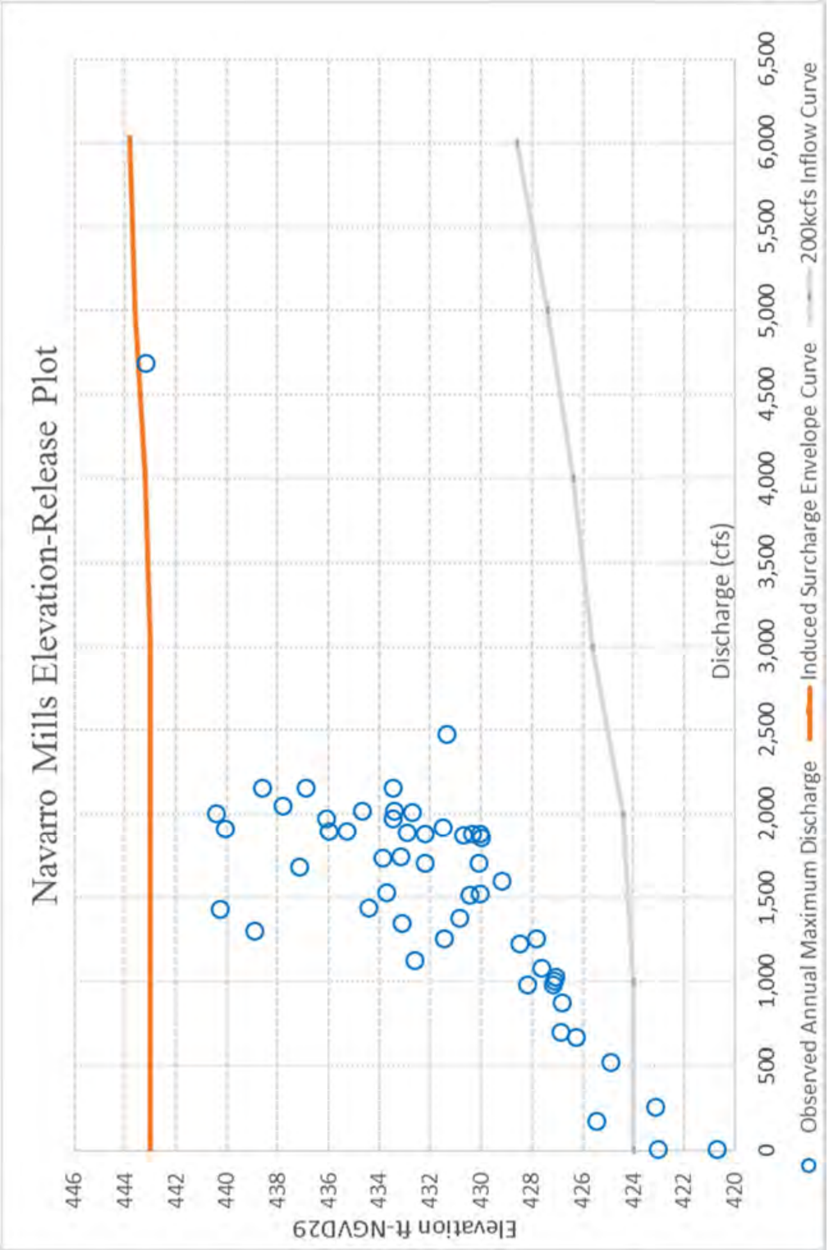


Figure 30: Navarro Mills Discharge vs. Elevation

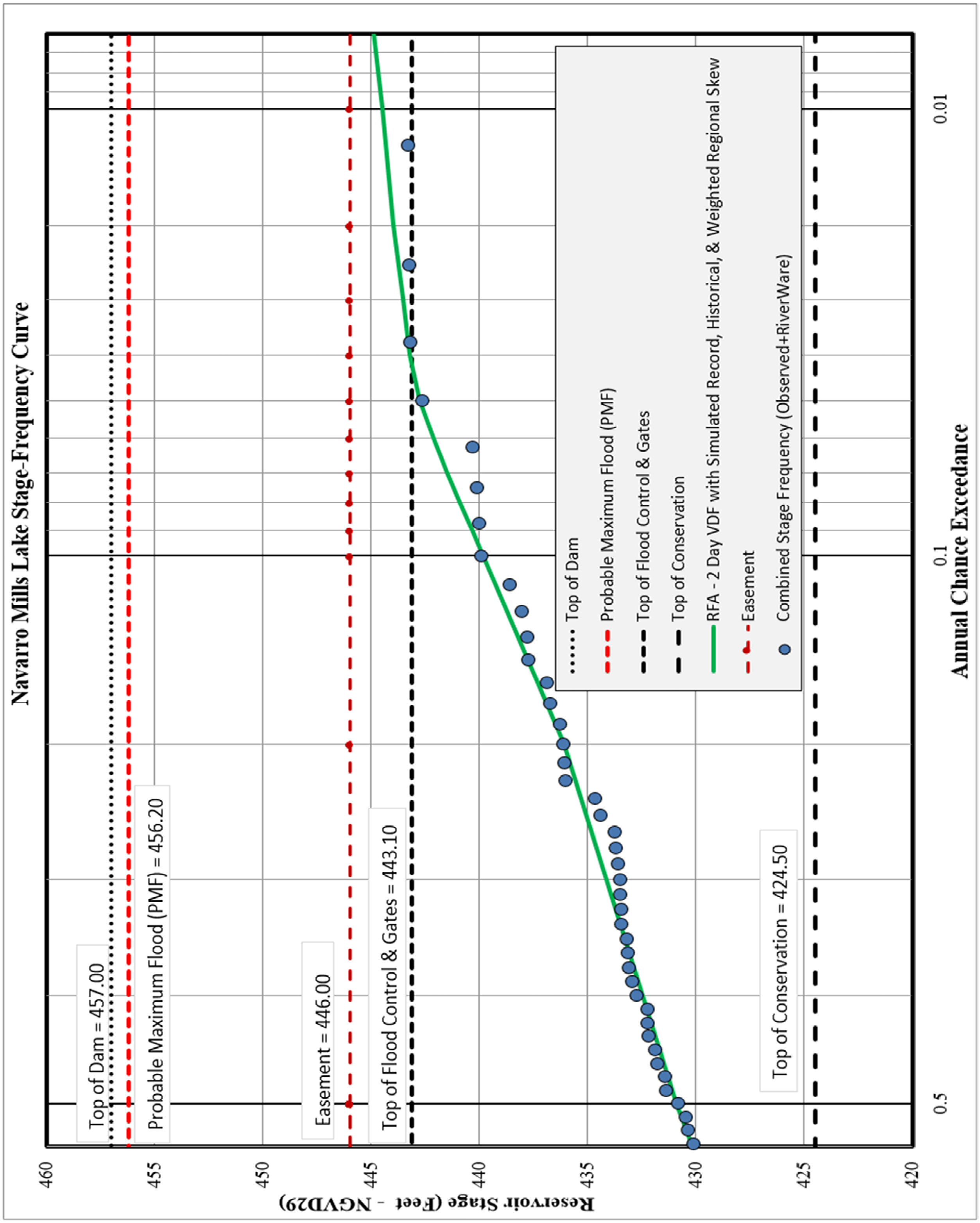


Figure 31: Navarro Mills Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.8 RAY ROBERTS

Table 29: Ray Roberts Lake Stage Frequency Estimate

Ray Roberts Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		Feet	
2	50	633.25			
5	20	635.70			
10	10	639.50	639.50	0.00	
25	4	641.10			
50	2	644.00	644.00	0.00	
100	1	645.50	645.50	0.00	645.50
250	0.4				
500	0.2	648.50	649.00	-0.50	

Table 30: Ray Roberts Lake Computed Frequency Discharge Release

Ray Roberts Pool Lake		RMC-RFA Best Estimate				FEMA's Effective Outflow (cfs)*
N-Year	ACE%	Elevation-NGVD	Spillway Release(cfs)	Gate Release(cfs)	Total Release(cfs)	
2	50	633.25	0	2,000	2,000	
5	20	635.70	0	4,000	4,000	
10	10	639.50	0	7,000	7,000	6,295
25	4	641.10	0	7,000	7,000	
50	2	644.00	0	7,000	7,000	8,996
100	1	645.50	0	7,000	7,000	10,238
250	0.4					
500	0.2	648.50	890	6,110	7,000	12,752

* approximately 100 feet downstream of confluence of Bray Branch (8.10 mi^2), 48121CV001B.

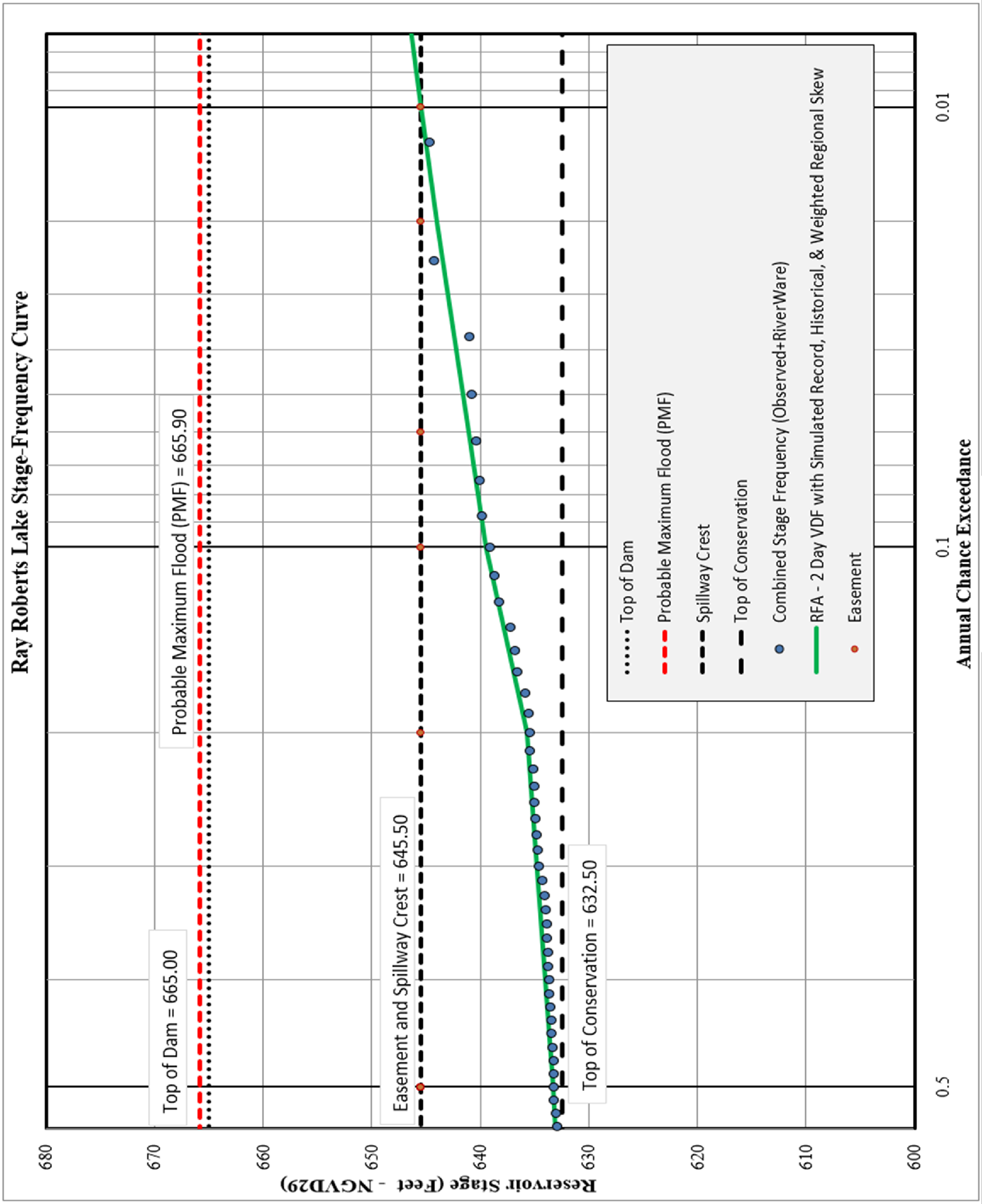


Figure 32: Ray Roberts Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

1.10.9 RICHLAND CHAMBERS

Table 31: Richland Chambers Lake Stage Frequency Estimate

Richland-Chambers Lake		RMC-RFA Best Estimate	FEMA Effective	Change in Pool	Easement Pool
N-Year	ACE%	Feet-NGVD		ft	Feet
2	50	315.90	NA	NA	320.00
5	20	316.30			
10	10	316.60			
25	4	317.10			
50	2	317.40			
100	1	317.60			
250	0.4	318.00			
500	0.2	318.30			

Table 32: Richland Chambers Lake Computed Frequency Discharge Release

Richland Chambers Pool Lake		RMC-RFA Best Estimate			
N-Year	ACE%	Elevation-NGVD	Spillway Release(cfs)	Gate Release(cfs)	Total Release(cfs)
2	50	315.90	13,060	0	13,060
5	20	316.30	25,870	0	25,870
10	10	316.60	37,440	0	37,440
25	4	317.10	62,600	0	62,600
50	2	317.40	91,840	0	91,840
100	1	317.60	111,325	0	111,325
250	0.4	318.00	150,295	0	150,295
500	0.2	318.30	193,000	0	193,000

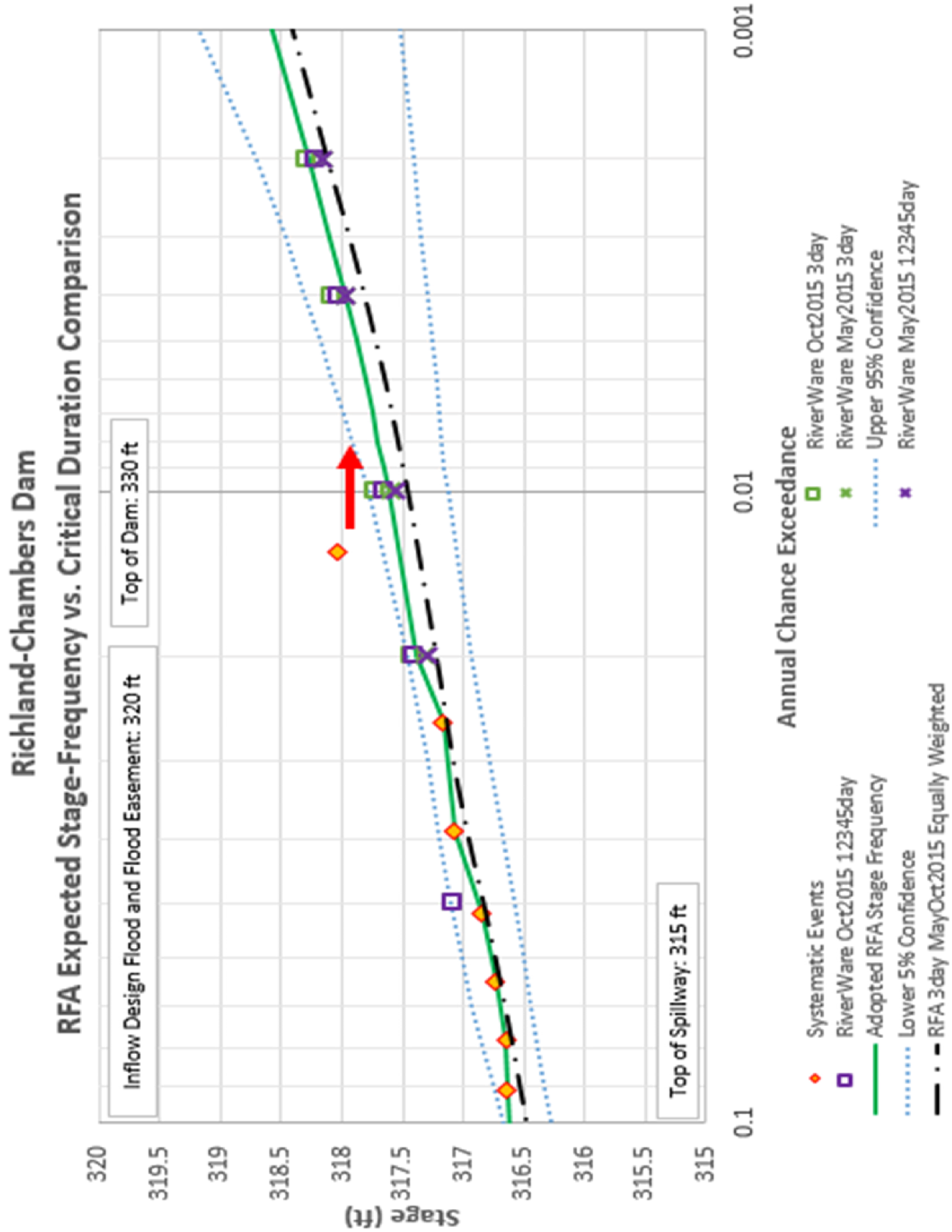


Figure 33: Richland Chambers Dam Current Condition (2016) Stage-Frequency Curve for Rainfall Simulations

2 References and Resources

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2.3 DATA SOURCES, GUIDANCE, AND PROCEDURES

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ESRI Streetmap2D Image Service - ESRI basemap data, DeLorme basemap layers, Automotive Navigation Data (AND) road data, U.S. Geological Survey (USGS) elevation data, UNEP-WCMC parks and protected areas for the world, Tele Atlas Dynamap® and Multinet® street data for North America and Europe and First American (CoreLogic) parcel data for the United States.
ESRI World Imagery Service - Imagery from NASA, icubed, U.S. Geological Survey (USGS), U.S. Department of Agriculture Farm Services Agency (USDA FSA), GeoEye, and Aerials Express.
ESRI. ArcGIS software. Application reference available from: http://www.esri.com/

3 Terms of Reference

AEP	Annual Exceedance Probability
AMS	Annual Maximum Series
B17B	Bulletin 17B
B17C	Bulletin 17C
cfs	cubic feet per second
DEM	Digital Elevation Map
EMA	expected moments algorithm
FEMA	Federal Emergency Management Agency
FIS	Flood Insurance Study
ft	feet
GIS	Geographic Information System
HEC	Hydrologic Engineering Center
in	inches
InFRM	Interagency Flood Risk Management
MGBT	Multiple Grubbs-Beck Test
MSE	Mean Square Error
NGVD29	National Geodetic Vertical Datum of 1929
POR	Period of Record
RFA	Reservoir Frequency Analysis
RMC	Risk Management Center
SSP	Statistical Software Package
TRWD	Tarrant Regional Water District
USACE	U.S. Army Corps of Engineers
USGS	U.S. Geological Survey
WY	Water Year

Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin
Appendix F – 2-Dimensional HEC-RAS Analysis of Mary's Creek

July 2021

INTERAGENCY FLOOD RISK MANAGEMENT

USACE 2-Dimensional HEC-RAS Analysis of Mary's Creek
January 2019

1.0 Introduction

The Mary's Creek watershed is a developing watershed on the West Side of the Dallas-Fort Worth Metroplex. The watershed has approximately 54 square miles of drainage area above the USGS streamflow gage at Vickery Blvd. and drains into the Clear Fork Trinity River below Benbrook Dam. Significant resources have been spent by different entities attempting to estimate flood frequency for this watershed, however short USGS streamflow gage record length, small observed storm events, in addition to uncertainties in the rating curve at the site have presented challenges.

Unit hydrograph theory is a commonly utilized method that transfers excess precipitation into runoff hydrographs. Historically, one of the acknowledged limitations of unit hydrograph theory is the assumption of linearity. This assumption implies that a watershed would have the same lag time receiving a very low intensity rain event as it would when receiving a high intensity event. The concerns with this assumption are reduced when the model can be calibrated moderately rare to truly rare storms. However, this is rarely the case, particularly in dam safety studies, but can also be true for events on the scale of the 1% annual chance exceedance (i.e. 100 year recurrence interval) event.

Mary's Creek is a location that does not have a very long streamflow gage record (installed 1998) and has not experienced a very high intensity rainfall event that would be similar in scale to the 1% annual chance exceedance (ACE) event. As such, there is uncertainty when using calibrated model parameters from storm events much less intense than the 1% ACE event. Literature indicates that the lag time of a unit hydrograph generally tend to decrease as storm intensity increases. To account for the aforementioned shortcomings of unit hydrograph theory, USACE dam safety studies normally apply a 25-50% peaking factor to the unit hydrograph of the contributing area upstream of a dam per ER 1110-8-2(FR) "Inflow Design Floods for Dams and Reservoirs". Due to the use of physically-based routing routines/methods, HEC-RAS 2-D has been utilized by the USACE dam safety community to develop variable unit hydrograph parameters for different rainfall intensities (USACE RMC).

The purpose of this study is to utilize the HEC-RAS 2-Diminsional (2D) model and equations to investigate the variability in unit hydrograph parameters for the purpose of improving flood frequency estimates within the Mary's Creek watershed.

2.0 HEC-HMS Model Development and Calibration

The HEC-RAS 2D model and equations will be used to analyze the unit hydrograph variability for the Mary's Creek watershed, however an HEC-HMS model is required to determine the appropriate excess precipitation that will be applied during calibration of the HEC-RAS model. Although, the USACE HEC (Hydrologic Engineering Center) intends to implement the use of spatially varied rainfall and losses into the HEC-RAS program, these were not available in the official HEC-RAS version (5.0.6) at the time of this study.

2.1 Watershed Delineation

The Mary's Creek watershed above the USGS gage (Marys Creek at Benbrook, TX, 08047050) has a total drainage area of 54 square miles and was subdivided into 10 aubbasins (Table 2.1) to better represent the predominant runoff generation within the Mary's Creek watershed. A 5m DEM developed from 2015 Lidar was used to delineate the subbasins. The subbasins and their drainage areas within HEC-HMS are shown below.

Table 2.1 HEC-HMS Subbasins

Subbasin	Area (mi2)
MarysCk_S10	6.9
MarysCk_Trib_S10	2.0
Little_MarysCk_S10	6.1
MarysCk_S20	2.0
PattersonBr_S10	2.2
MarysCk_S30	1.4
South_MarysCk_S10	9.3
MarysCk_S40	5.4
WalnutCk_S10	10.0
MarysCk_S50	8.9

Maps of the subbasin layout are shown in Figures 2.1 and 2.2 below.

Figure 2.1 – HEC-HMS Subbasin Layout

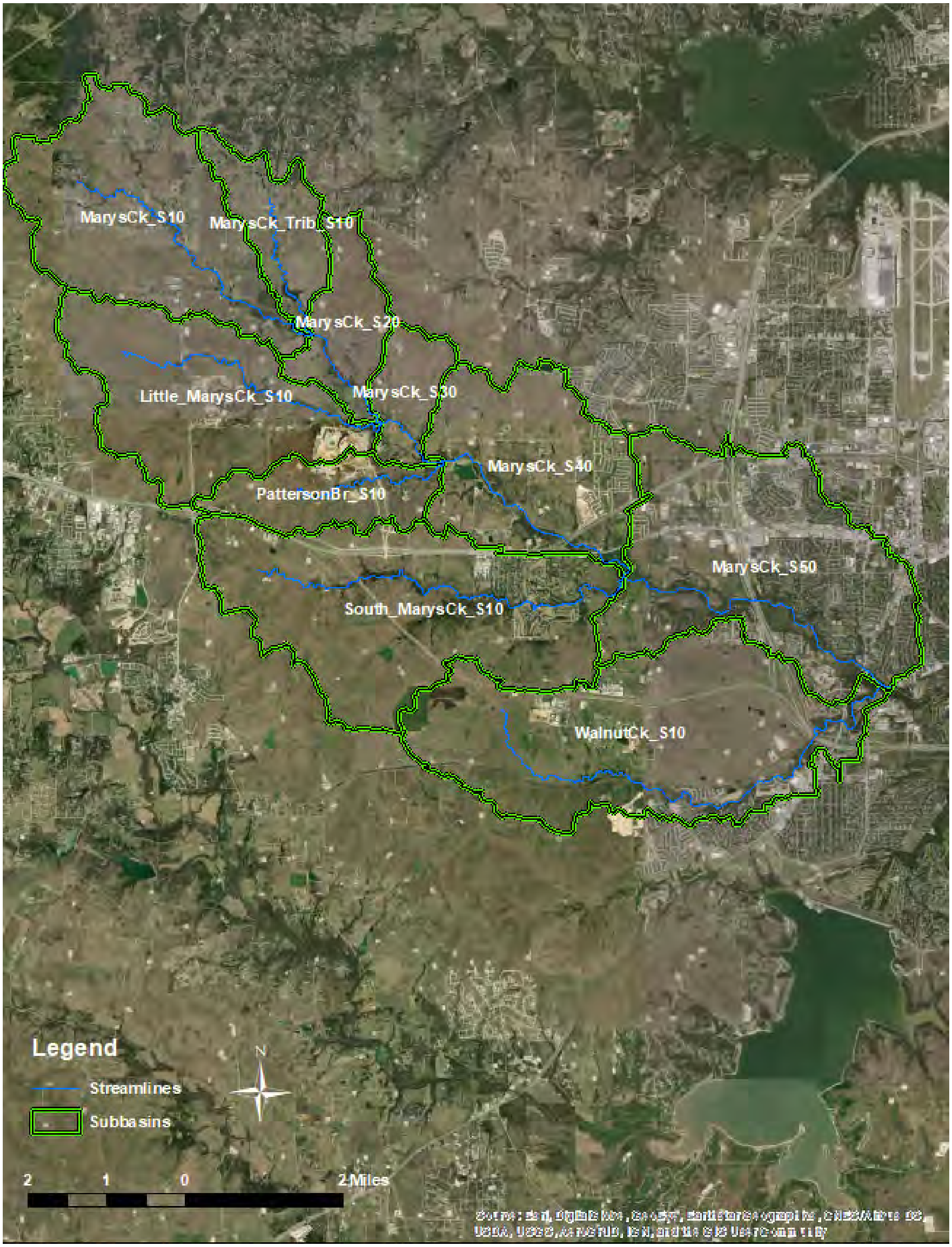


Figure 2.2 – HEC-HMS Subbasin Layout with Aerial Imagery

2.2 Initial Parameter Estimates

2.2.1. Losses

The Initial and Constant Loss method was chosen to convert precipitation hyetographs applied to each subbasin into excess precipitation. The initial estimates for losses used in the calibration runs are shown in Table 2.2 below. Basin average percent impervious values were computed using the 2011 National Land Cover Dataset (NLCD) Percent Impervious Layer. Initial loss volume and constant loss rates were adjusted for each subbasin during HEC-HMS model calibration, but the percent impervious values were held constant.

Table 2.2 – Initial Estimates of Loss and Percent Impervious Values

Subbasin	Initial Loss (in)	Constant Loss (in/hr)	% Impervious
MarysCk_S10	0	0.10	2
MarysCk_Trib_S10	0	0.10	2
Little_MarysCk_S10	0	0.10	1
MarysCk_S20	0	0.10	0
PattersonBr_S10	0	0.10	2
MarysCk_S30	0	0.10	0
South_MarysCk_S10	0	0.10	5
MarysCk_S40	0	0.10	7
WalnutCk_S10	0	0.10	8
MarysCk_S50	0	0.10	26

2.2.2. Unit Hydrograph Parameters

The Snyder’s Unit Hydrograph method was selected to route excess precipitation to the outlet of each subbasin. Initial estimates for unit hydrograph parameters for the 10 subbasins within the watershed were made using the Snyder’s lag time equation which utilizes measured watershed characteristics in addition to a calibrated coefficient (C_T). The below equation 2.1 from the Texas Commission on Environmental Quality (TCEQ), Hydrologic and Hydraulic Guidelines for Dams in Texas, can be used to estimate the Snyder lag time based on measureable watershed characteristics and the coefficient C_T that is assumed to be consistent for a watershed and can thus be used to develop lag times for any additional subbasins within the watershed.

$$T_L = C_T(L \cdot L_{CA}/S^{0.5})^{0.38}$$

T_L = Lag Time (hr)
C_T = coefficient
L = hydraulic length of watershed along the longest flow path (mi)
L_{CA} = hydraulic length along the longest water course from the point under consideration to a point opposite the centroid of the drainage basin (mi)
S = weighted slope of the basin (ft/mi), measured from the 85% to the 10% points along the longest stream path in the basin (EM 1110-2-1405)

Equation 2.1 – Snyder Unit Hydrograph Equation

The calibrated C_T and peaking coefficient for this watershed was obtained from the ongoing Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity River Basin currently scheduled for completion by the end of 2019. The InFRM study simulated the Mary's Creek watershed as a single subbasin (Marys_Ck_S010) above the USGS gage with simulated results that were very similar to the observed results. The calibrated lag times and peaking coefficients were also very similar for the calibration events. The lag times varied between 1.9 and 2.4 hours, while the peaking coefficients varied between 0.78-0.83. The adopted lag time and peaking coefficient were 2.1 hours and 0.78, respectively. This resulted in a calibrated C_T was 0.59, with a measured L of 18.0 miles, L_{CA} of 7.4 miles, and S of 23.4 ft/mi. The InFRM calibration plots are in table Figures 2.3-2.5.

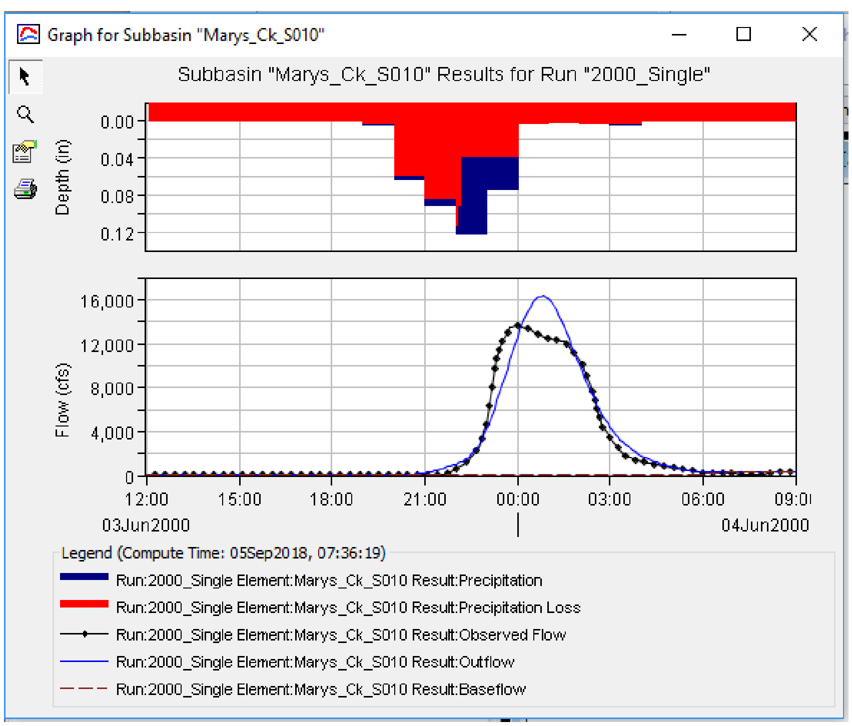


Figure 2.3 – InFRM Calibration Results for June 2000 (Lag Time – 2.1 hrs, Cp – 0.78)

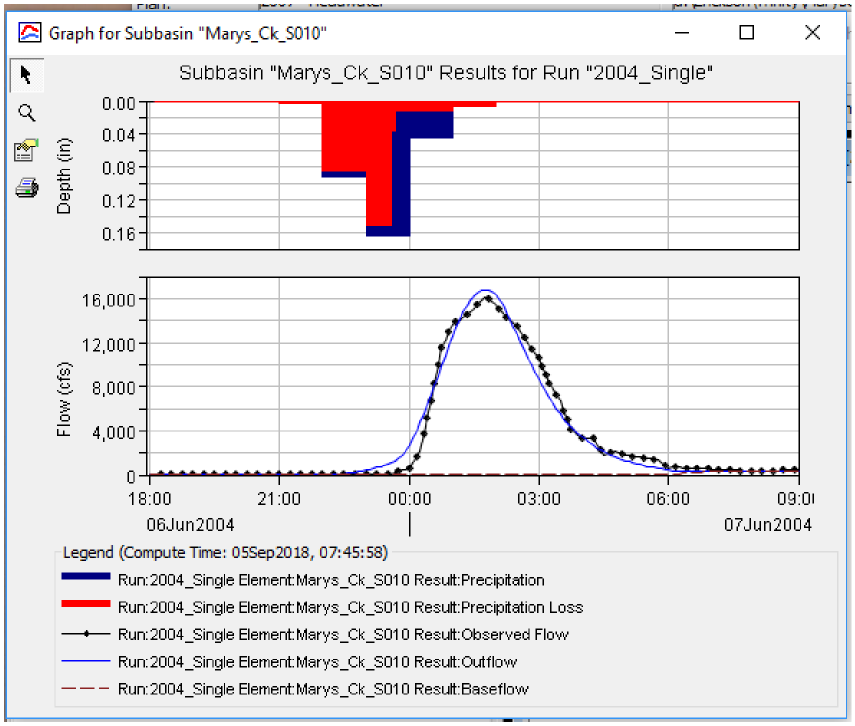


Figure 2.4 – InFRM Calibration Results for June 2004 (Lag Time – 1.9 hrs, Cp – 0.78)

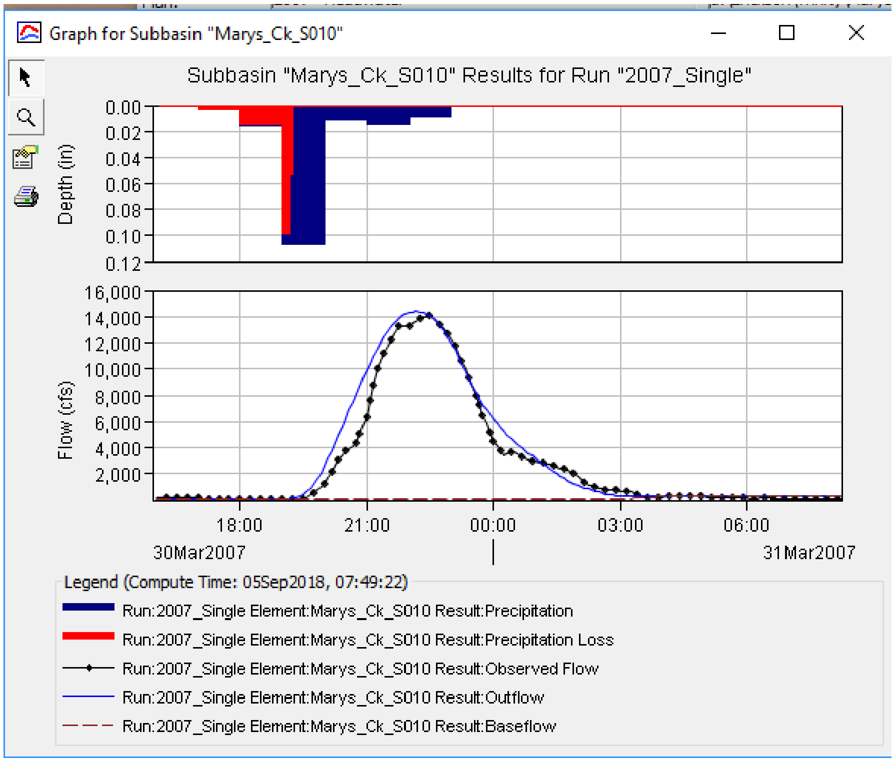


Figure 2.5 – InFRM Calibration Results for March 2007 (Lag Time – 2.4 hrs, Cp – 0.83)

The initial estimates of the unit hydrograph parameters are shown in Table 2.3.

Table 2.3 – Initial Estimates of Unit Hydrograph Parameters

Name	Area HMS	L(mi)	Lca(mi)	S1085(ft/mi)	Lag Time (hr)
MarysCk_S10	6.88	6.5	3.4	33.9	1.0
MarysCk_Trib_S10	1.96	4.4	2.2	41.3	0.7
Little_MarysCk_S10	6.09	6.8	4.1	38	1.0
MarysCk_S20	1.99	4.4	2.2	38.7	0.7
PattersonBr_S10	2.25	5.4	2.5	46.5	0.8
MarysCk_S30	1.36	2.9	1.7	50.2	0.5
South_MarysCk_S10	9.31	8.8	4	35.9	1.2
MarysCk_S40	5.36	5	2.1	34.9	0.7
WalnutCk_S10	10.07	10.6	5.3	34.1	1.4
MarysCk_S50	8.9	6.8	2.4	33.8	0.9

2.2.3. Stream Routing

The Modified Puls method was chosen to route runoff hydrographs once they entered a defined channel. Storage-Discharge relationships were required for the routing reaches throughout the model and were obtained by running a series of steady flow profiles through the available HEC-RAS model that was developed by Freese and Nichols Inc. (FNI) in 2013 in a study for the City of Fort Worth and Benbrook. The model was extended farther upstream to include the extents where new HEC-HMS routing reaches were developed. Travel times through most of the HEC-HMS routing reaches, with velocities of approximately 5 feet per second, were minimal, such that only one subreach per routing reach was initially parameterized. These values were later adjusted during model calibration.

2.3 HEC-HMS Model Calibration

2.3.1. Precipitation

Historic precipitation data for observed storm events were collected from the National Weather Service (NWS) gridded precipitation data files. NEXRAD Stage III grids were used for the basin. The NEXRAD Stage III grids are stored in a binary file format called XMRG. The historical XMRG data were processed into hourly precipitation grids in HEC-DSS format using HEC-METVUE. This data was acquired from the NWS West Gulf River Forecasting Center (WGRFC) and the http://dipper.nws.noaa.gov/hdsb/data/nexrad/nexrad.html website.

2.3.2. Parameter Adjustment

After the HEC-HMS model was constructed and initial parameter estimates were made, the model was calibrated to observed storm events for the purpose of obtaining excess precipitation hyetographs for use in calibration of the HEC-RAS 2D model. Model calibration is the process of adjusting initial estimates of model parameters in order to improve the agreement between computed and observed results. Calibration events chosen for this study included those that occurred in 2000, 2004, 2007, and 2015. For these storms, the NWS hourly rainfall radar data allowed the team to fine tune the HEC-HMS model through detailed calibration. Figures 2.6 thru 2.9 illustrate the storm totals as well as their orientation.

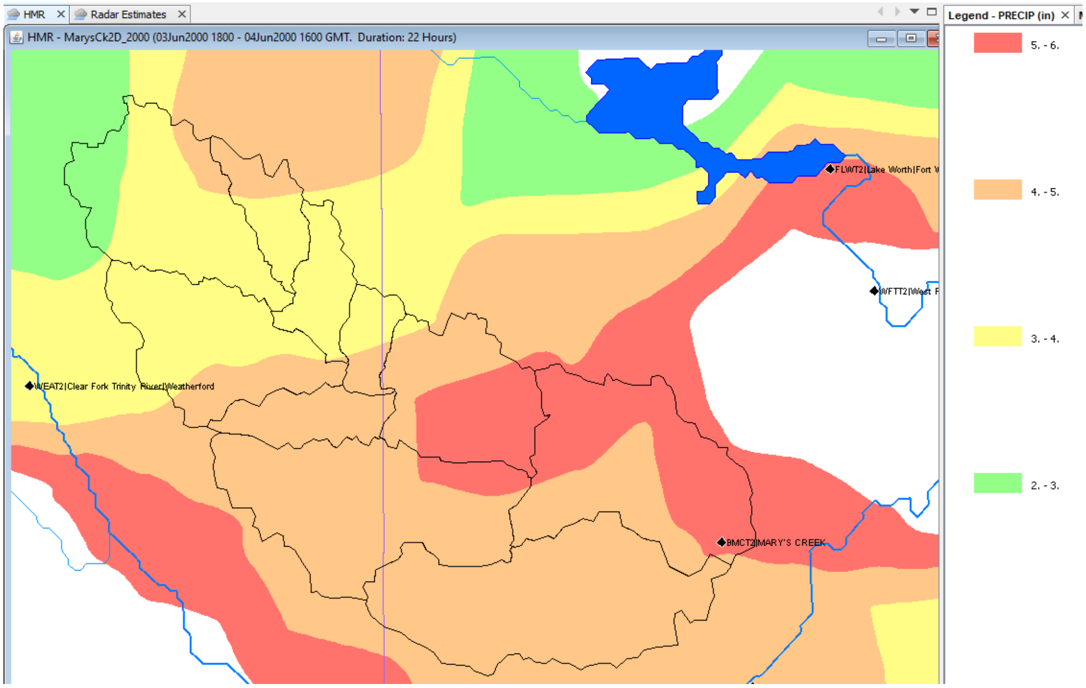


Figure 2.6 – Rainfall totals for June 2000 storm

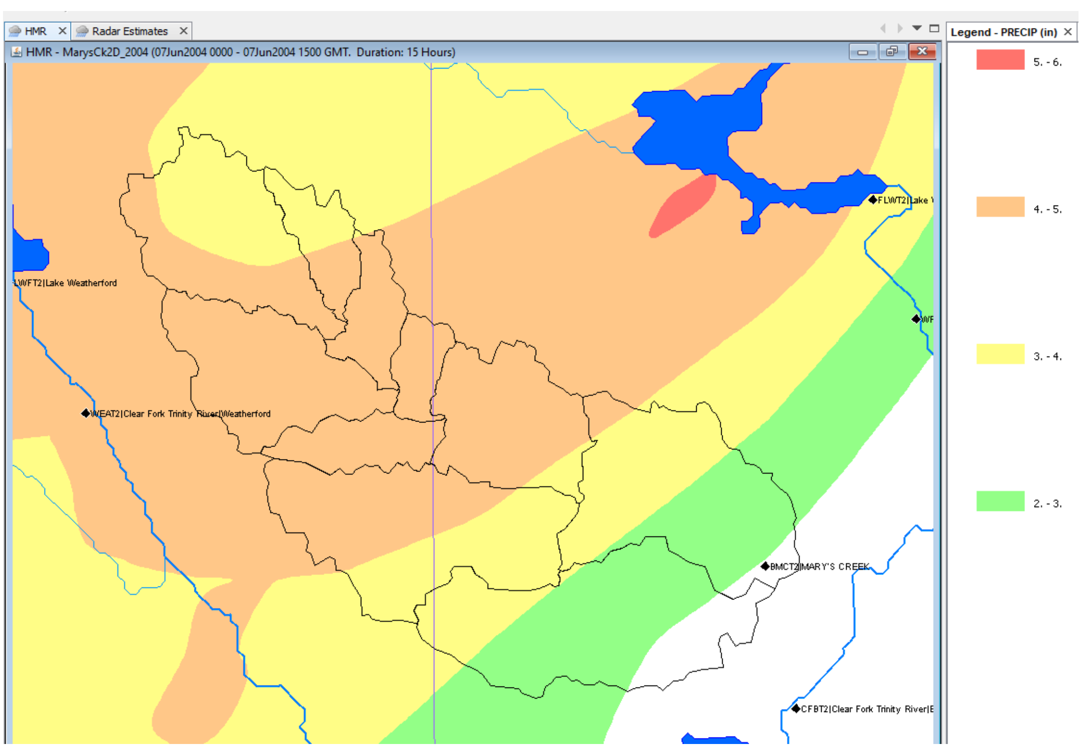


Figure 2.7 – Rainfall totals for June 2004 storm

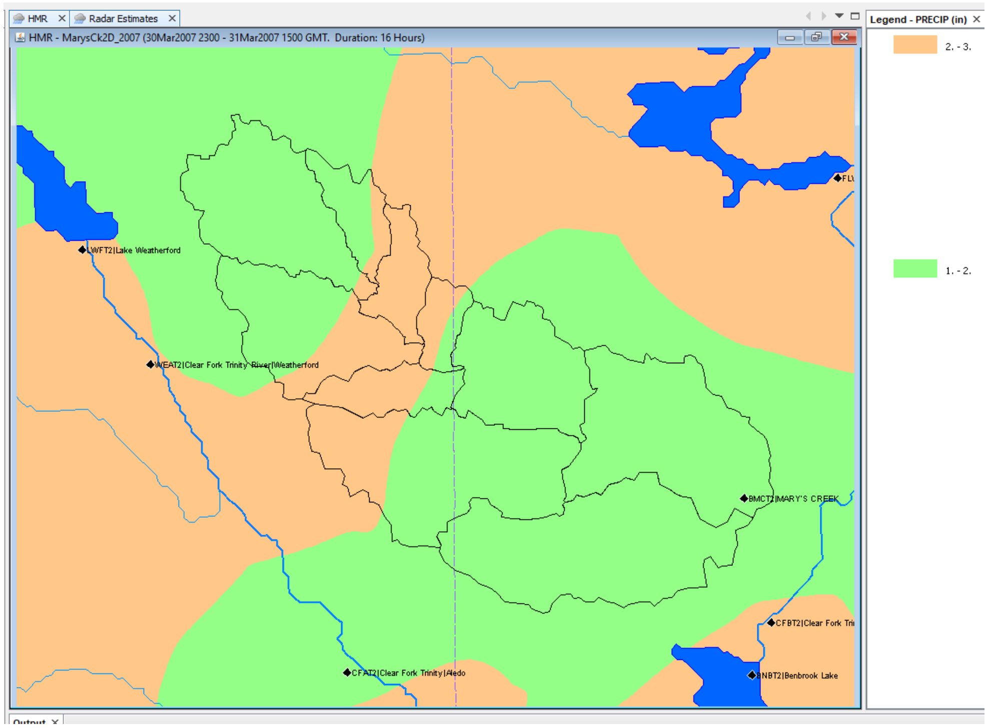


Figure 2.8 – Rainfall totals for March 2007 storm

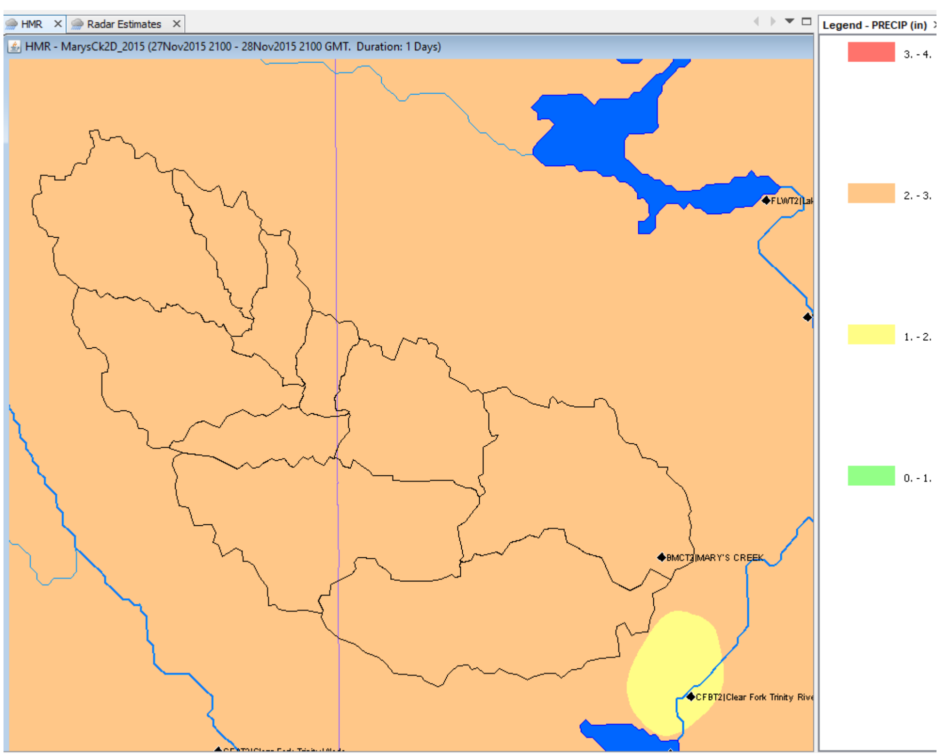


Figure 2.9 – Rainfall totals for November 2015 storm

Model parameters were adjusted so that the volume, timing, and shape of the simulated hydrographs would be more similar to volume, timing, and shape of the observed hydrographs. The methods of adjustment for each parameter are summarized in Table 2.4   Figures 2.10 through 2.13 illustrate the final comparisons between the simulated hydrographs in HMS and the observed hydrographs.

Table 2.4 - HEC-HMS Calibration Approach

Parameter	Calibration Approach
Baseflow Parameters	First, the baseflow parameters were adjusted to match the observed flow rates at the start and end of each calibration event. The initial discharges for the subbasins upstream of a certain gage were adjusted uniformly up or down to match the initial observed discharge at that gage. Similarly, the recession constant was adjusted to match the slope of the recession limb of the observed hydrograph, and the ratio to peak was adjusted to match the observed discharge at the end of the calibration event. All baseflow parameters were adjusted uniformly for all subbasins.
Initial Loss (in)	After adjusting the baseflow parameters, the initial and constant losses were adjusted to calibrate the total volume of the flood hydrograph. The initial loss was adjusted according to the antecedent soil moisture conditions at the beginning of each observed storm event. The initial loss was increased or decreased until the timing and volume of the initial runoff generally matched the observed arrival of the flow hydrograph at the nearest downstream gage. All subbasins that were upstream of each gage were generally adjusted uniformly, unless specific rainfall and observed flow patterns necessitated adjusting the subbasin initial losses on an individual basis.
Constant Loss Rate (in/hr)	After adjusting the initial loss parameters, the constant loss rates were adjusted to calibrate the total volume of the flood hydrograph. The subbasins' constant loss rates were increased or decreased until the volume and magnitude of the simulated hydrographs generally matched the observed volume of the flow hydrograph at the nearest downstream gage. The combination of the adjusted baseflow and loss rate parameters led to the total calibrated volume at the gage.
Lag Time (hours)	After adjusting initial loss volume and constant loss rates, the Snyder's lag times were adjusted upstream of an individual gage. The Snyder's lag times were adjusted to match the timing of the observed peak flow at the gage. Normally, all of the subbasin lag times upstream of an individual gage were adjusted uniformly and proportionally to one another, unless the magnitude or shape of the observed hydrograph necessitated making individual adjustments.
Peaking Coefficient	Peaking coefficients were adjusted to match the general shape of the observed flow hydrograph as higher peaking coefficients produce steeper, narrower flood hydrographs, and lower peaking coefficients produce flatter, wider flood hydrographs. Efforts were also made to ensure that the adjusted peaking coefficients fell within the typical range of 0.4 to 0.8
Modified Puls Routing Subreaches	The number of subreaches in the Modified Puls routing reaches were the final parameters to be adjusted when necessary. Calibration of routing parameters focused on storms that fell near the upstream end of the watershed and were routed downstream with little intervening subbasin flow. Adjustments to the number of subreaches in a given routing reach were made in order to match the

Parameter	Calibration Approach
	amount of attenuation in the peak flow that occurred from the upstream end of a reach to the downstream gage. The reach's storage volume (storage-discharge curve) was not adjusted.

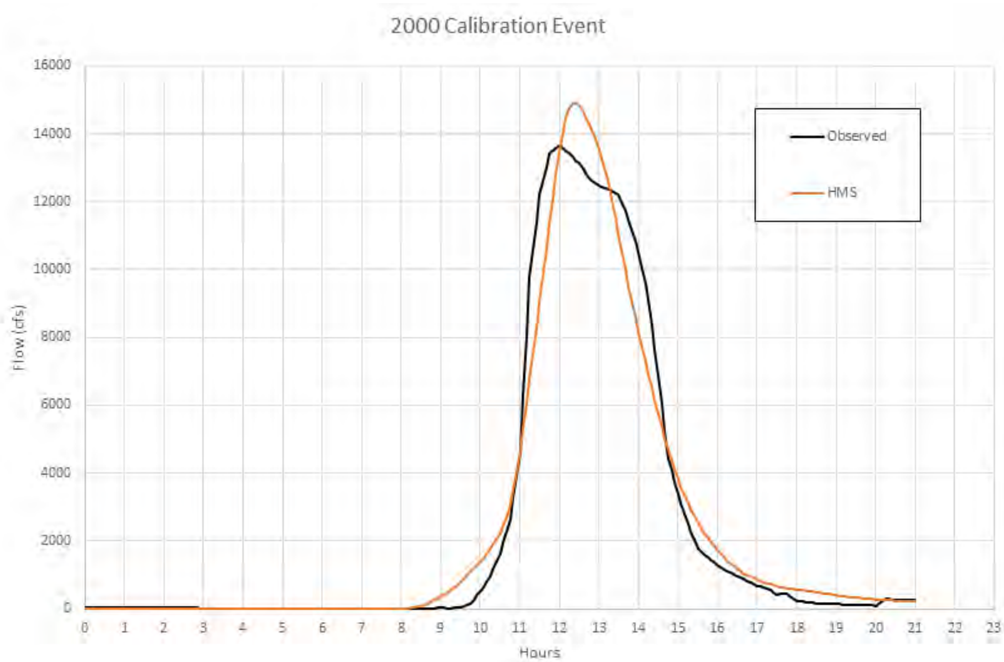


Figure 2.9 – Calibration Results for June 2000 Storm

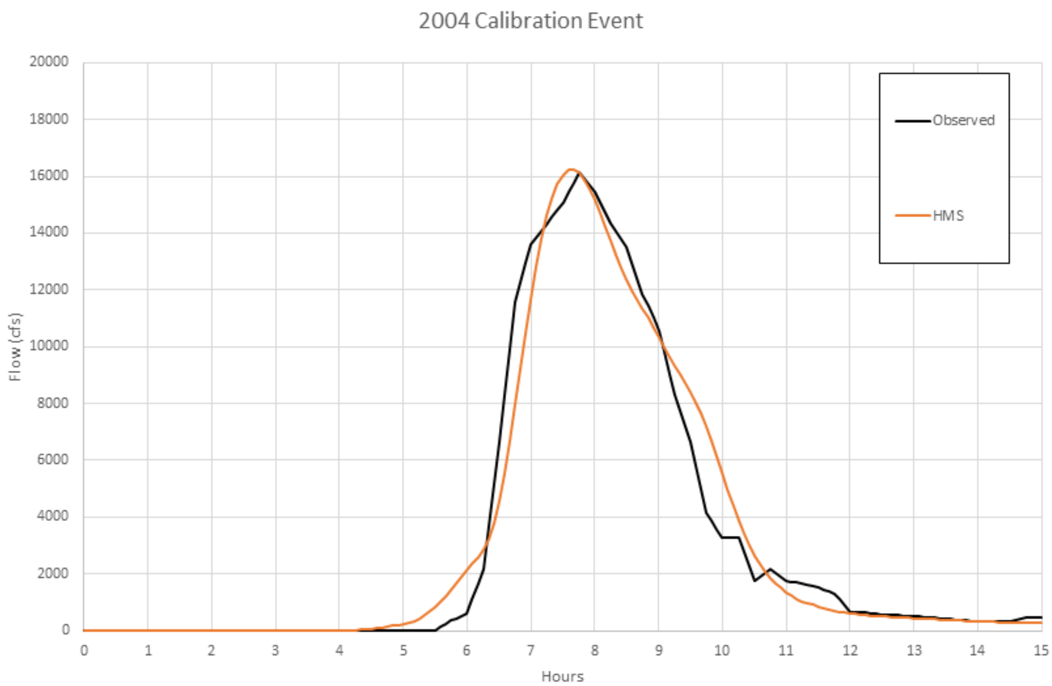


Figure 2.10 – Calibration Results for June 2004 Storm

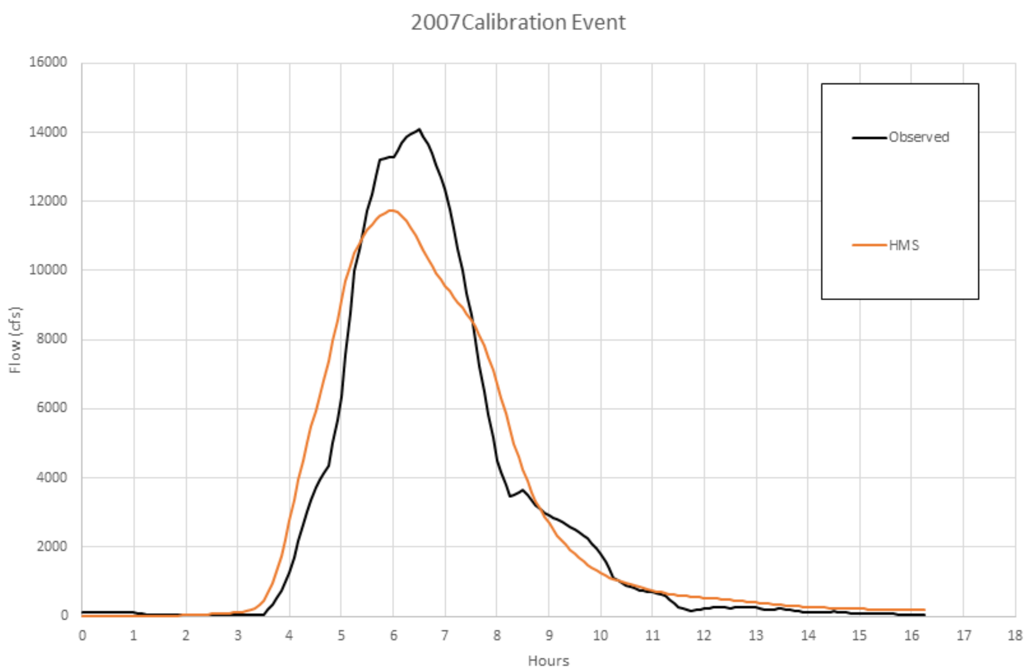


Figure 2.11 – Calibration Results for March 2007 Storm

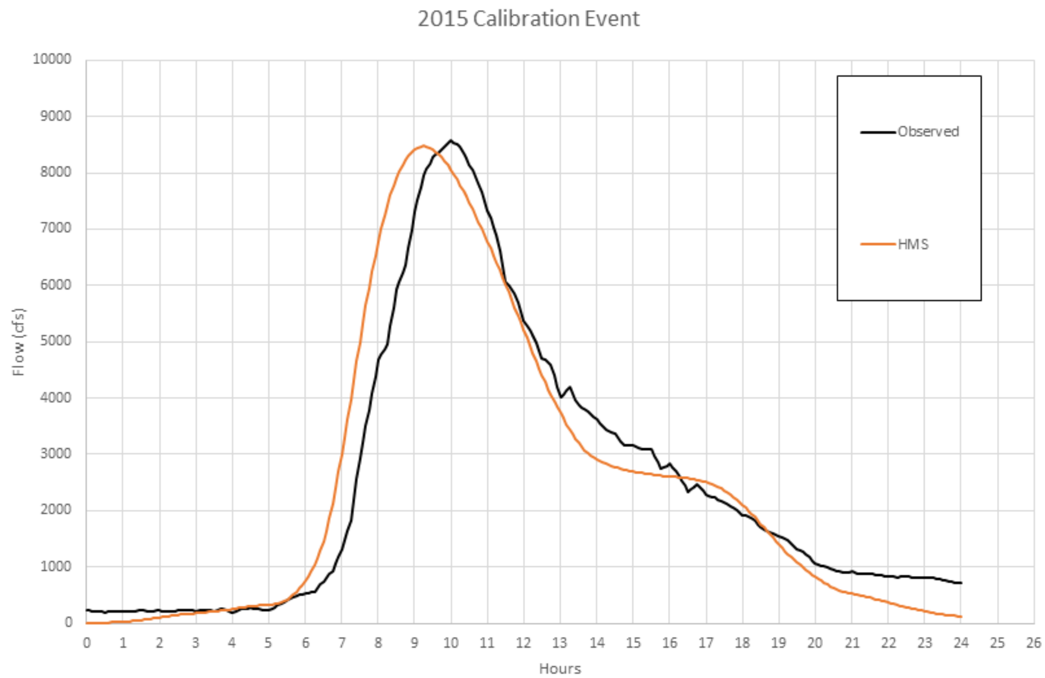


Figure 2.12 – Calibration Results for November 2015 Storm

The final calibration parameters can be found in Table 2.5.

Table 2.5 – Final Calibrated HMS Parameters

Baseflow – Initial Discharge (cfs/sq mi)				
Subbasin	**2000**	**2004**	**2007**	**2015**
MarysCk_S10	0.1	0.1	0.1	0.1
MarysCk_Trib_S10	0.1	0.1	0.1	0.1
Little_MarysCk_S10	0.1	0.1	0.1	0.1
MarysCk_S20	0.1	0.1	0.1	0.1
PattersonBr_S10	0.1	0.1	0.1	0.1
MarysCk_S30	0.1	0.1	0.1	0.1
South_MarysCk_S10	0.1	0.1	0.1	0.1
MarysCk_S40	0.1	0.1	0.1	0.1
WalnutCk_S10	0.1	0.1	0.1	0.1
MarysCk_S50	0.1	0.1	0.1	0.1
Baseflow – Recession Constant				
Subbasin	**2000**	**2004**	**2007**	**2015**
MarysCk_S10	0.3	0.3	0.3	0.3
MarysCk_Trib_S10	0.3	0.3	0.3	0.3

Little_MarysCk_S10	0.3	0.3	0.3	0.3
MarysCk_S20	0.3	0.3	0.3	0.3
PattersonBr_S10	0.3	0.3	0.3	0.3
MarysCk_S30	0.3	0.3	0.3	0.3
South_MarysCk_S10	0.3	0.3	0.3	0.3
MarysCk_S40	0.3	0.3	0.3	0.3
WalnutCk_S10	0.3	0.3	0.3	0.3
MarysCk_S50	0.3	0.3	0.3	0.3
Baseflow – Ratio to Peak				
Subbasin	**2000**	**2004**	**2007**	**2015**
MarysCk_S10	0.01	0.05	0.05	0.05
MarysCk_Trib_S10	0.01	0.05	0.05	0.05
Little_MarysCk_S10	0.01	0.05	0.05	0.05
MarysCk_S20	0.01	0.05	0.05	0.05
PattersonBr_S10	0.01	0.05	0.05	0.05
MarysCk_S30	0.01	0.05	0.05	0.05
South_MarysCk_S10	0.01	0.05	0.05	0.05
MarysCk_S40	0.01	0.05	0.05	0.05
WalnutCk_S10	0.01	0.05	0.05	0.05
MarysCk_S50	0.01	0.05	0.05	0.05
Losses – Initial Loss (in)				
Subbasin	**2000**	**2004**	**2007**	**2015**
MarysCk_S10	2.7	2.1	0.6	0.5
MarysCk_Trib_S10	2.7	2.1	0.6	0.5
Little_MarysCk_S10	2.7	2.1	0.6	0.5
MarysCk_S20	2.7	2.1	0.6	0.5
PattersonBr_S10	2.7	2.1	0.6	0.5
MarysCk_S30	2.7	2.1	0.6	0.5
South_MarysCk_S10	2.7	2.1	0.6	0.5
MarysCk_S40	2.7	2.1	0.6	0.5
WalnutCk_S10	2.7	2.1	0.6	0.5
MarysCk_S50	2.7	2.1	0.6	0.5
Losses – Constant Loss (in/hr)				
Subbasin	**2000**	**2004**	**2007**	**2015**
MarysCk_S10	0.3	0.3	0.02	0.01
MarysCk_Trib_S10	0.3	0.3	0.02	0.01
Little_MarysCk_S10	0.3	0.3	0.02	0.01
MarysCk_S20	0.3	0.3	0.02	0.01
PattersonBr_S10	0.3	0.3	0.02	0.01
MarysCk_S30	0.3	0.3	0.02	0.01

South_MarysCk_S10	0.3	0.3	0.02	0.01
MarysCk_S40	0.3	0.3	0.02	0.01
WalnutCk_S10	0.3	0.3	0.02	0.01
MarysCk_S50	0.3	0.3	0.02	0.01
Transform – Lag Time (hr)				
Subbasin	**2000**	**2004**	**2007**	**2015**
MarysCk_S10	1.2	1.0	1.2	1.7
MarysCk_Trib_S10	0.8	0.7	0.8	1.2
Little_MarysCk_S10	1.3	1.0	1.3	1.8
MarysCk_S20	0.8	0.7	0.8	1.2
PattersonBr_S10	0.9	0.8	0.9	1.3
MarysCk_S30	0.6	0.5	0.6	0.9
South_MarysCk_S10	1.4	1.2	1.4	2.0
MarysCk_S40	0.9	0.7	0.9	1.2
WalnutCk_S10	1.7	1.4	1.7	2.4
MarysCk_S50	1.1	0.9	1.1	1.5
Transform – Peaking Coefficient				
Subbasin	**2000**	**2004**	**2007**	**2015**
MarysCk_S10	0.83	0.83	0.83	0.83
MarysCk_Trib_S10	0.83	0.83	0.83	0.83
Little_MarysCk_S10	0.83	0.83	0.83	0.83
MarysCk_S20	0.83	0.83	0.83	0.83
PattersonBr_S10	0.83	0.83	0.83	0.83
MarysCk_S30	0.83	0.83	0.83	0.83
South_MarysCk_S10	0.83	0.83	0.83	0.83
MarysCk_S40	0.83	0.83	0.83	0.83
WalnutCk_S10	0.83	0.83	0.83	0.83
MarysCk_S50	0.83	0.83	0.83	0.83
Routing – Subreaches				
Subbasin	**2000**	**2004**	**2007**	**2015**
MaryCk_R10	3	3	3	3
MaryCk_R20	2	2	2	2
MaryCk_R30	5	5	5	5
MaryCk_R40	6	6	6	6

3.0 HEC-RAS Model Development and Calibration

3.1 2D Computational Mesh

2015 North Central Texas Council of Governments (NCTCOG) Lidar point data was provided by the City of Fort Worth and was used to create a 1m DEM of the study area. There were small areas on the watershed boundary where Lidar coverage was not complete. In these locations, National Elevation Dataset 10 meter data was used to supplement the Lidar data (USGS). The coordinate system used for the study was NAD 1983 State Plane Texas North Central FIPS 4202 feet.

A total of 10 HEC-RAS 2D areas were created to cover the same extent as the subbasins shown in the HMS Subbasin map (Figure 2.1). This was done so that the excess precipitation developed during HMS model calibration could be used on each of the HEC-RAS 2D areas. The 2D areas were refined near the floodplain to improve conveyance estimates. Generally, a 500 foot grid cell size was used to create the HEC-RAS 2D mesh. Breaklines where added to represent major stream centerlines and were then burned or forced into the mesh with smaller cell sizes between 10 to 30 feet to approximate the different Manning's n value characteristics between the channel and overbanks. This resulted in total channel widths between 20-60 feet. A channel width of 20 feet was common for the tributaries to Mary's Creek, while 60 feet is the channel width used for the main stem of Mary's Creek. A map of the terrain and 2D areas can be seen in Figure 3.1.

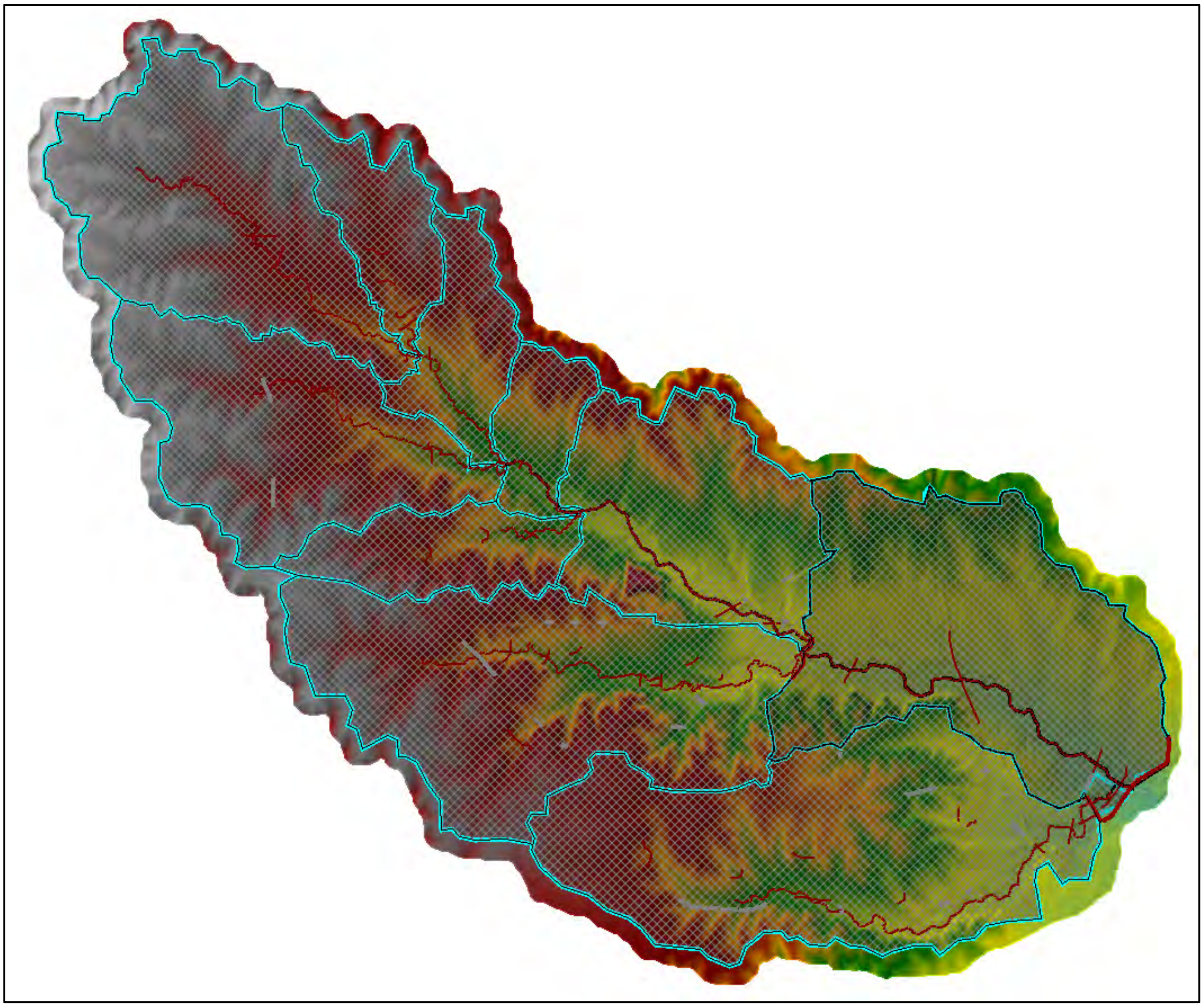


Figure 3.1 – Map of Terrain and 2D Areas

Figure 3.2 is a sample of the 2D mesh with cells and breaklines (shown in red). This location shows the US-377 crossing over Mary's Creek and is near the downstream end of the study area.

Figure 3.2 – Mesh Cells and Breaklines over Terrain

The 2011 National Land Cover Dataset (NLCD) was used to identify predominant land uses within the watershed. Manning's n values were assigned based on values from Table 3-1 of the HEC-RAS Reference Manual (Feb 2016). Channel regions were delineated to distinguish between roughness inside the channel and the roughness of the overbank areas. Channel roughness values were assigned a value of 0.04. The NLCD 2011 dataset for the watershed can be seen in Figure 3.3.

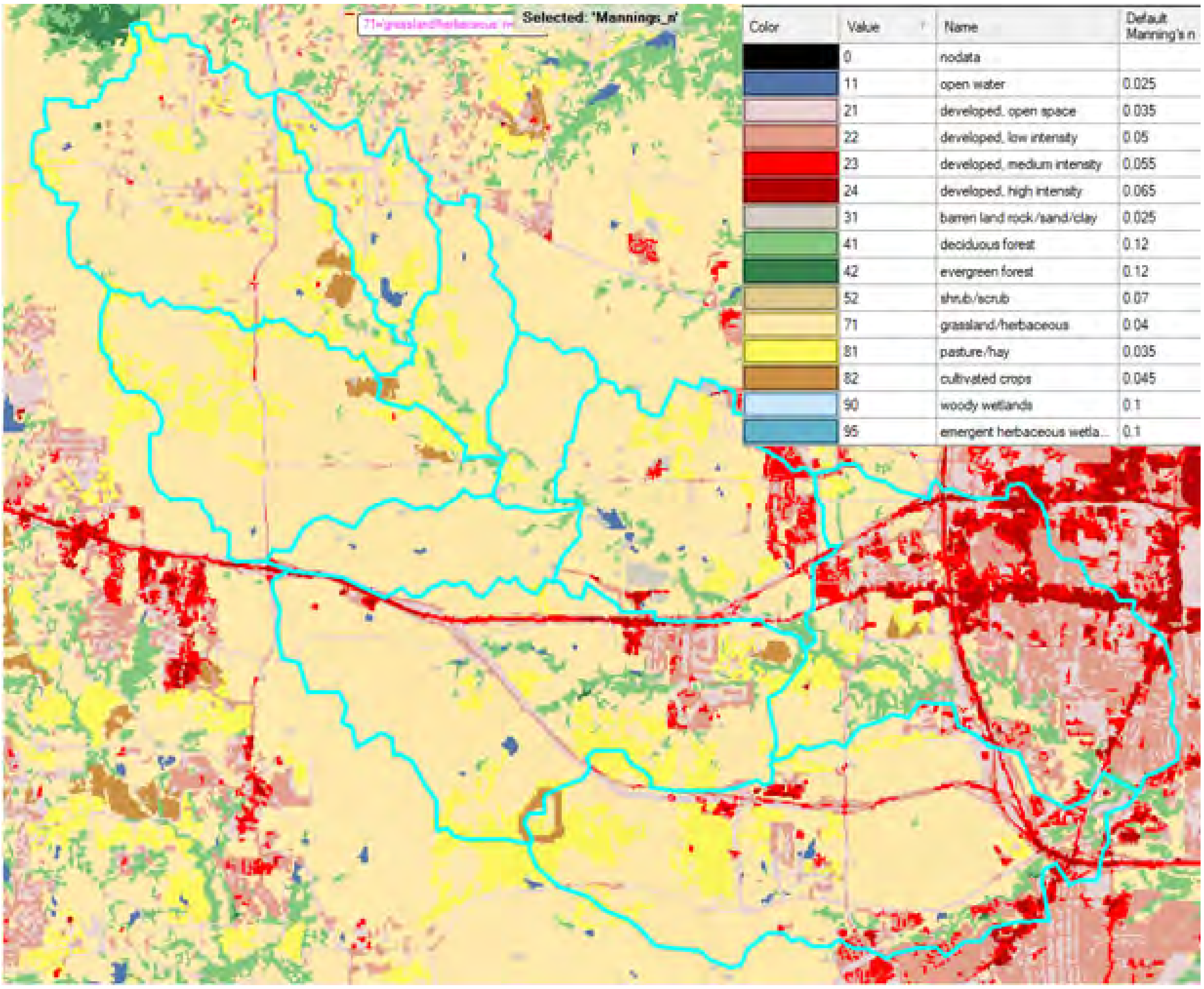


Figure 3.3 – Land Use Data and Initial Manning's n Values

3.2 Boundary Conditions

After the computational mesh was created, boundary conditions were developed for each of the 2D areas. The current version of HEC-RAS limits the user to utilize the weir equation to compute flow across an element connecting one 2D area to another. This can be very challenging to find a stable solution where a high weir coefficient is needed to simulate the rapid transfer of flow from one 2D area to another. Because of this, and in order to shorten the computation times, separate geometries were developed for the headwater 2D areas and also for each of the 2D areas along Mary's Creek. A figure of the geometry containing the headwater areas only is shown below in Figure 3.4.

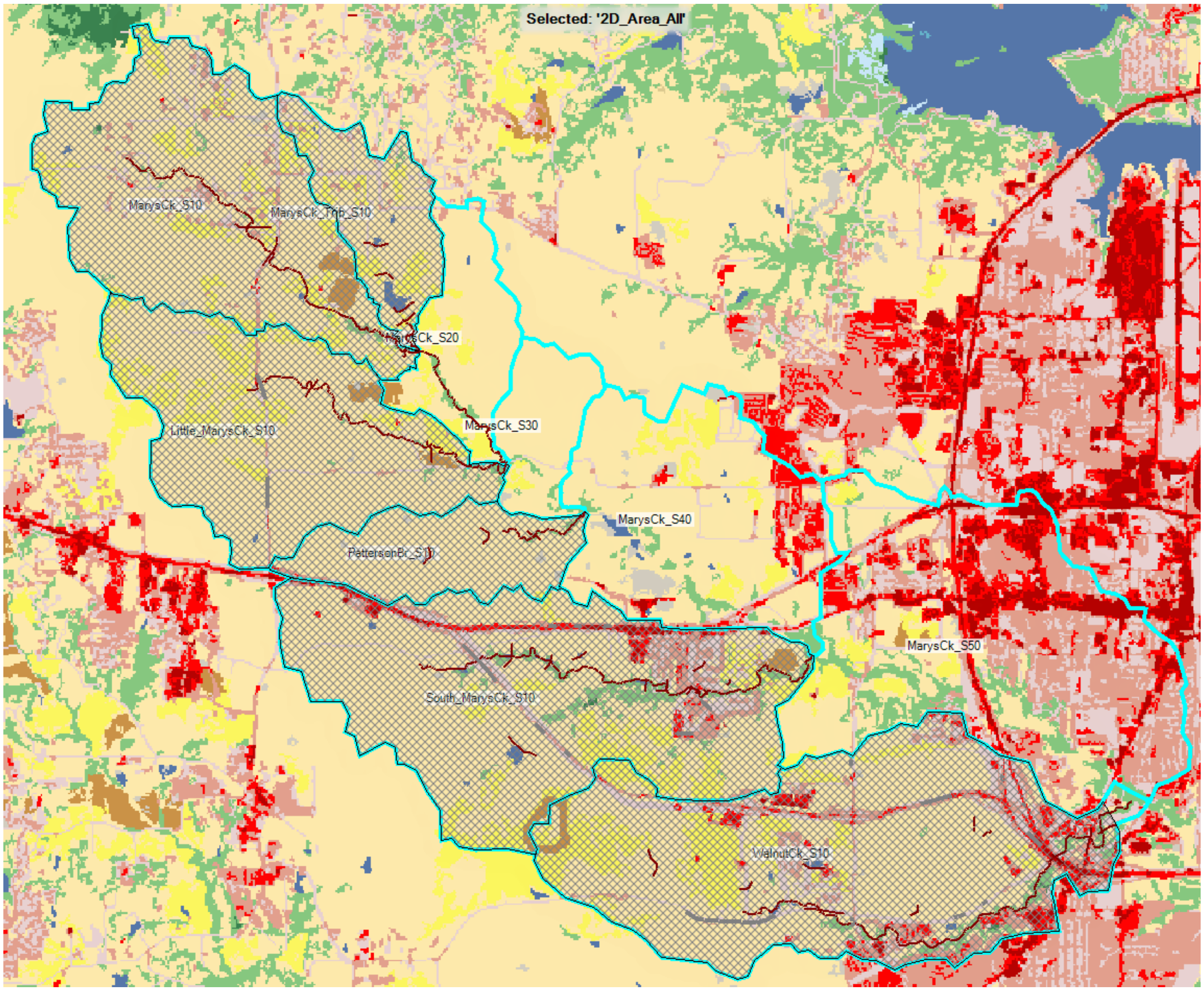


Figure 3.4 – Headwater 2D Areas for Mary's Creek Watershed

In order to get the resulting hydrograph results at the downstream end of the study area, the following process was followed.

1. The headwater 2D area simulations were made using the precipitation information developed during the HMS simulations.
2. The hydrographs at the downstream end of each of the 2D areas were stored in DSS.
3. The hydrographs from step 2 were then applied at the upstream end of the appropriate downstream 2D area. The precipitation for that specific 2D area was then applied. The downstream hydrograph for that 2D area was then stored in DSS.
4. This process is not completed until the final downstream 2D area has been simulated. This process ensures that all of the precipitation is routed to the downstream limit of the study area.

Figure 3.5 is a flow chart illustrating this process. Figure 3.6 also illustrates this process for the MarysCk_S20 2D area.

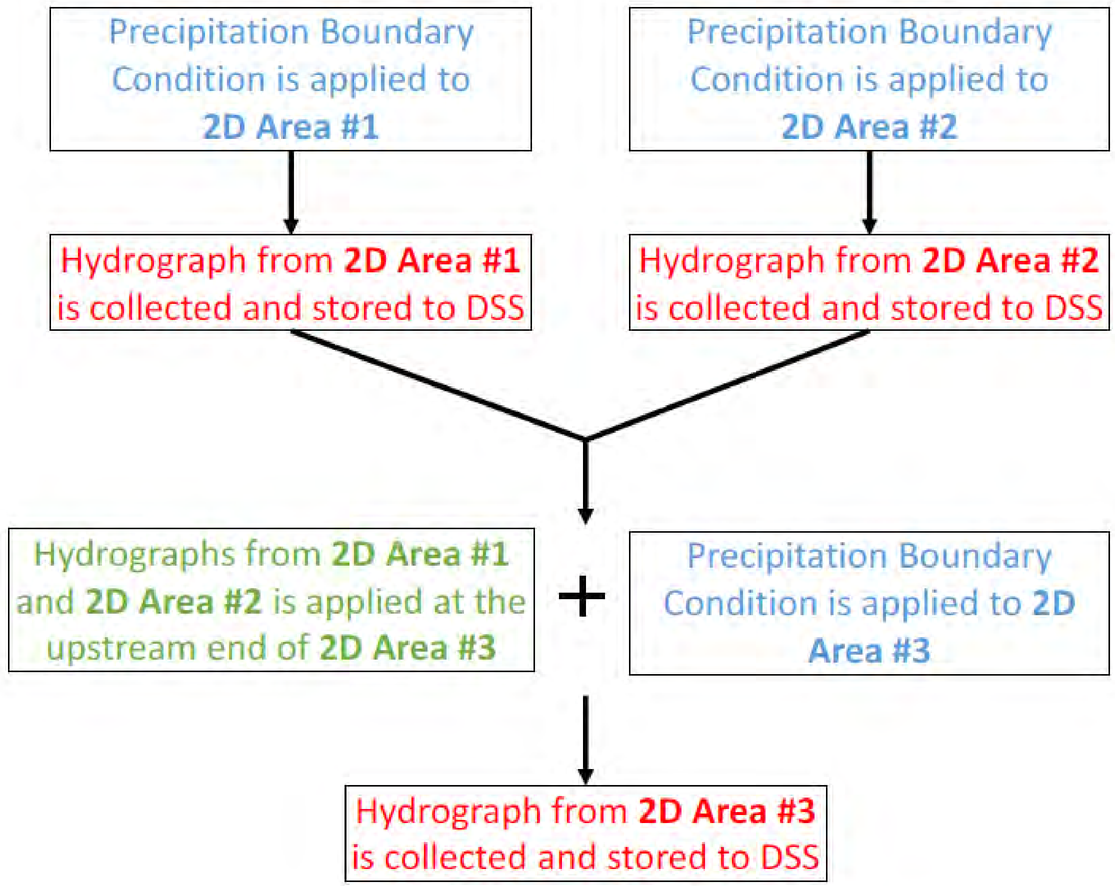


Figure 3.5 – 2D Area Connectivity

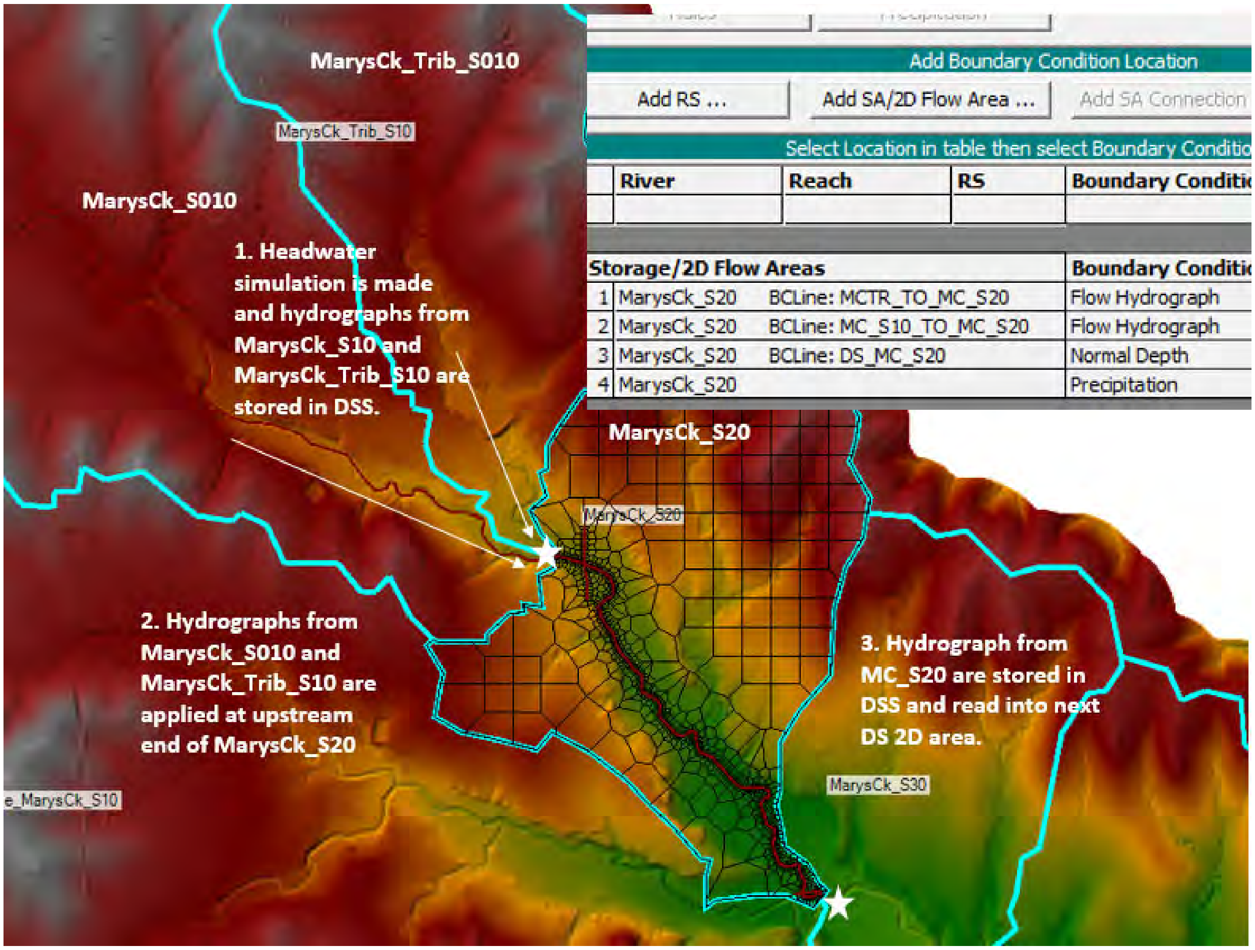


Figure 3.6 – Connectivity Example at MC_S20 2D Area

The downstream boundary for each of the 2D areas was selected as normal depth with the exception of the downstream limit of the study area (2D area MC_S50), which utilized a rating curve as the downstream boundary condition. The rating curve at the downstream end of the study area was taken from the 2013 Marys Creek Open Channel Study performed by Freese and Nichols. The study utilized an unsteady flow 1-D HEC-RAS model to develop the rating curve.

Precipitation was also applied as a Boundary Condition to the 2D area. For the RAS calibration events, this included the excess precipitation hyetographs developed from the HMS calibration simulations. After the model was calibrated, the precipitation hyetographs applied to the basin were 1 hour rainfall values (1 in/hr, 2 in/hr, etc) in order to investigate the resulting lag times and peak flow rates for the different rainfall intensities.

3.3 SA/2D Connections

SA/2D Area connections are model elements that hydraulically connect internal and external model elements. The model contains 23 SA/2D Area connections. Internal SA/2D Area connections were used inside of the same 2D area to define key urban features (e.g., embankments, culverts, and bridges). The internal hydraulic connections requires station-elevation data. Flow over the connections are governed by the 1D weir equation and require station-elevation data and a weir coefficient. Culverts can also be sp External SA/2D area connections were not used in this study.

Area connections were modeled as notched weirs (assumed no pressure flow) in order to improve computational speed and stability. Figure 3.7 shows the plan view of the internal connection representing the IH-20 crossing over South Mary's Creek. Figure 3.8 depicts the weir profile and culvert openings for the same internal connection. The internal structures were used to ensure that the model domain was hydraulically connected and that the complex urban drainage network was accurately modeled.

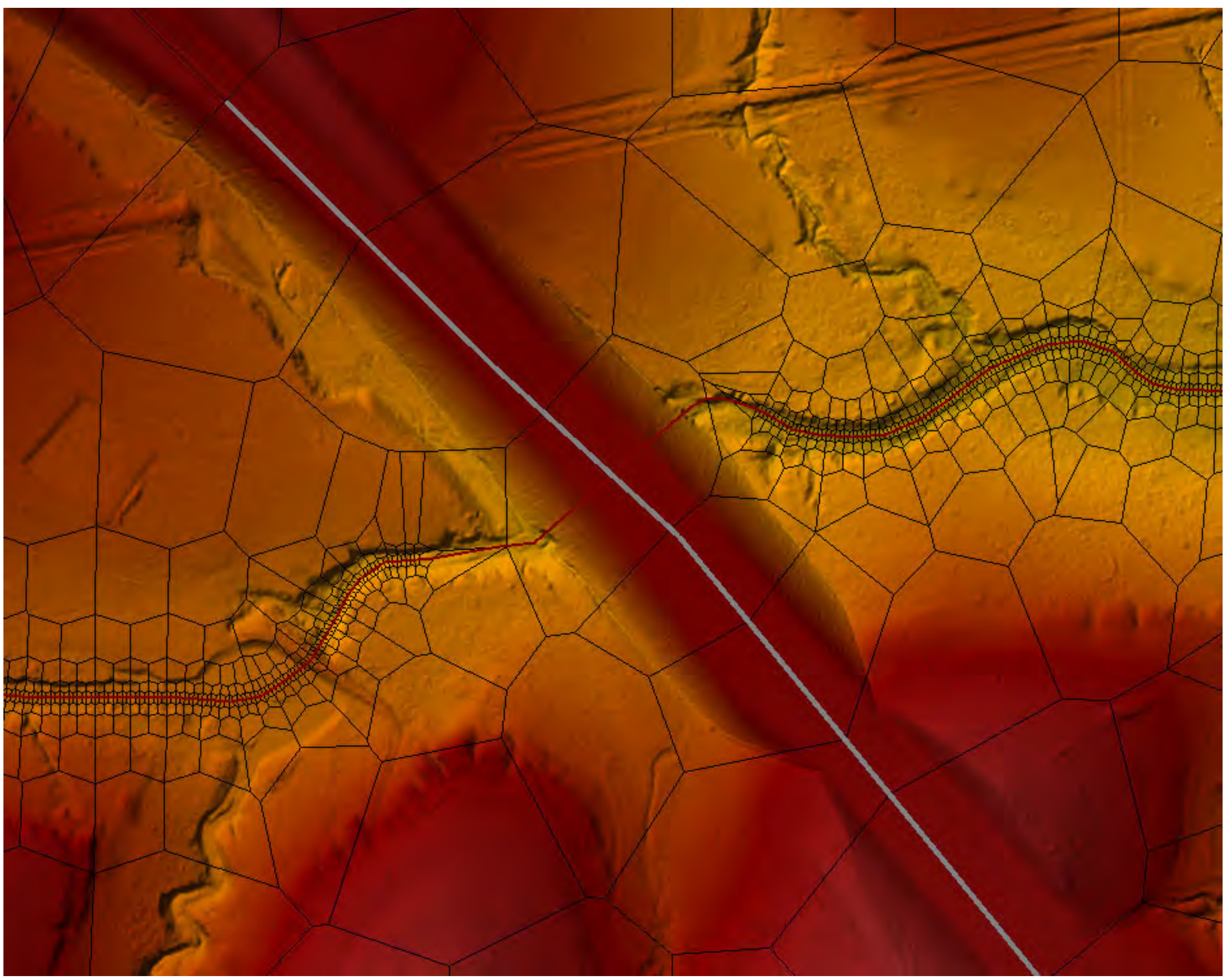


Figure 3.7 – Plan View of Internal Connection Representing IH-20 across South Mary's Creek

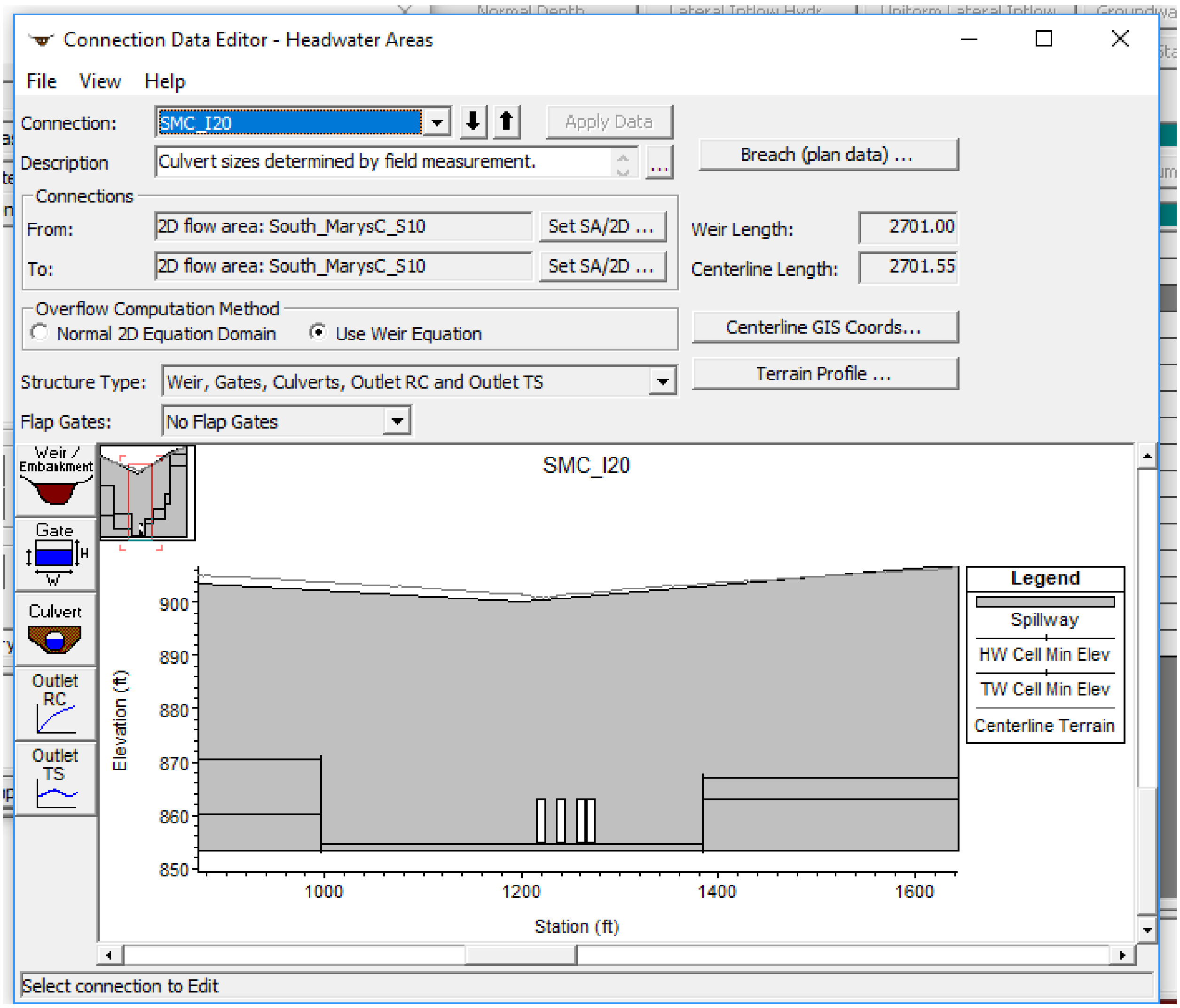


Figure 3.8 – Weir Profile and Culverts (4 – 8ft x 8ft) of IH-20 across South Mary's Creek

Field measurements were made of the culvert sizes for 15 locations that had significant embankments that would likely have a significant effect on the hydraulic routing. The crossings that were field measured are noted in the SA/2D Connection Editor Description window. Google Earth imagery and/or nearby crossing information was used to estimate the culvert information for the other locations.

3.4 Model Evaluation Metrics

In addition to simple graphical comparisons comparing simulated to observed hydrographs, statistical tests were also employed in evaluating model performance. The following subsections describe the model evaluation metrics and the corresponding performance rankings used to evaluate the model calibration and validation in this study.

Statistical Methods

1. Nash-Sutcliffe Efficiency (NSE). The Nash-Sutcliffe Efficiency (NSE) measures the relative magnitude of the residual variance compared to the measured data variance. NSE ranges between - ∞ and 1.0 (1 inclusive), where NSE = 1 is optimal. Values of NSE ≤0.0 indicate the mean observed value is a better predictor than the simulated value, meaning that the performance is unacceptable. NSE is calculated as:

$$NSE = 1 - \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}{\sum_{i=1}^{n}\left(Y_i^{obs} - \bar{Y}^{obs}\right)^2}\right]$$

2. Root Mean Square Error –Observed Standard Deviation Ratio (RSR). The root mean square error (RMSE) is valuable because it indicates the error in the units of the constituent of interest, where the lower the RMSE the better the model performance. The RMSE –Observed Standard Deviation Ratio (RSR) normalizes the root mean square error by using the standard deviation of the observations, incorporating the benefits of error index statistics so that the resulting statistic can be applied to various constituents. RSR is calculated as:

$$RSR = \frac{RSME}{STDEV_{obs}} = \frac{\left[\sqrt{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right)^2}\right]}{\left[\sqrt{\sum_{i=1}^{n}\left(Y_i^{obs} - \bar{Y}^{obs}\right)^2}\right]}$$

3. Percent Bias (PBIAS). Percent bias (PBIAS) measures the average tendency of the simulated data to be larger or smaller than the observed data. The optimal value for PBIAS is 0.0, with low absolute percent bias indicating accurate model simulation. Positive values mean the model underestimation bias when compared to the observed, whereas negative values indicate the model overestimation bias. PBIAS is calculated as:

$$PBIAS = \left[\frac{\sum_{i=1}^{n}\left(Y_i^{obs} - Y_i^{sim}\right) \times 100}{\sum_{i=1}^{n}\left(Y_i^{obs}\right)}\right]$$

Performance Rating for Model Evaluation Metrics

Model performance statistics were evaluated for the model calibration and validation effort. For the purposes of this study, performance statistics are evaluated using the performance ratings as shown in Table 2.1. The selected performance ratings shown below, and they are consistent with standard practice in industry (D. N. Moriasi, 2007). A summary of performance statistics for each of the events being simulated in RAS is also included below in Table 2.2.

Table 2.1 – Model Evaluation Metrics

Performance Rating	NSE	RSR	PBIAS
Very Good	0.65 < NSE ≤ 1.00	0.00 < RSR ≤ 0.60	PBIAS < ± 15
Good	0.55 < NSE ≤ 0.65	0.60 < RSR ≤ 0.70	± 15 ≤ PBIAS < ± 20
Satisfactory	0.40 < NSE ≤ 0.55	0.70 < RSR ≤ 0.80	± 20 ≤ PBIAS < ± 30
Unsatisfactory	NSE ≤ 0.40	RSR > 0.80	PBIAS ≥ ± 30

Table 2.2 – Summary of Performance Statistics for Simulated Events

Event	NSE	RSR	PBIAS	Performance Rating
2000 Calibration	0.93	0.30	-8	Very Good
2004 Calibration	0.90	0.30	-12	Very Good
2007 Validation	0.90	0.30	-9	Very Good
2015 Validation	0.94	0.20	-5	Very Good

3.5 HEC-RAS Calibration

After the SA/2D Connections were added and modified based on field measurements, the model was initialized and calibrated. The model was initialized by simulating a very large rainfall event (2 feet) in order to fill in all of the voids since excess precipitation will be used for the calibration event. The model was simulated long enough for all of the significant runoff to drain from the watershed. A restart file was created at the end of the simulation. Baseflow was not added, as this is not a significant component of runoff hydrographs in this watershed. After the model was initialized, the Manning's n values were adjusted for model calibration. The Manning's n values were decreased from 0.04 to 0.03 for grassland and prairie land use, which covered the large majority of the drainage area. The remainder of the Manning's n values were unchanged from the initial estimates. Figures 2.6 through 2.9 Section 2.3.2 on HMS parameter adjustment show how the rainfall fell across the watershed. Figure 3.9 through Figure 3.12 show how well the simulated hydrographs in RAS match the observed hydrographs. The diffusion wave equations were used for all RAS simulations to improve model stability and reduce simulation times. The "HMS-TR55" and the "HMS-Regional Study" hydrographs resulted from single subbasin models with identical excess precipitation hyetographs. The point of these figures is to compare results from different unit hydrograph methods.

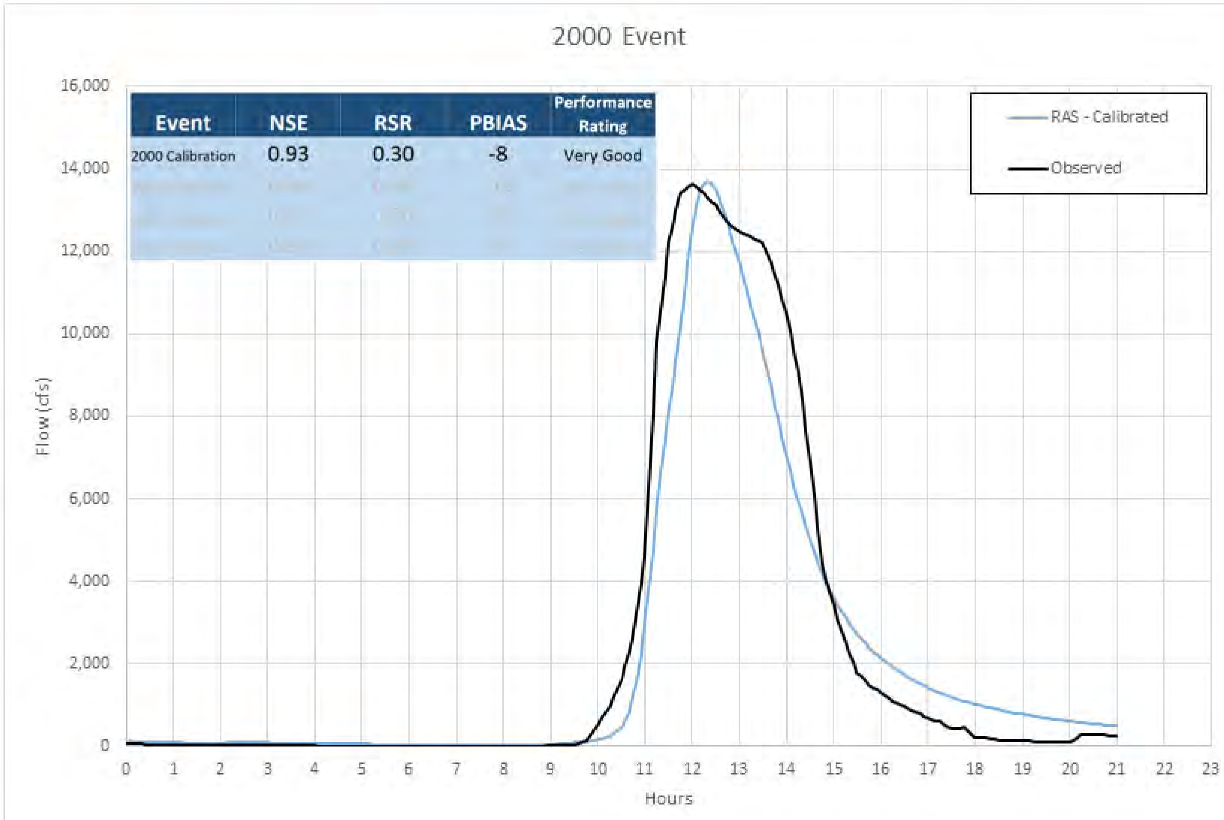


Figure 3.9 – RAS Calibration Results for June 2000 Storm

The June 2000 storm had a basin average rainfall total of about 4.4 inches with most of the rainfall falling in about 4 hours. The storm was centered in the bottom half of the watershed and had a very high percentage of rainfall loss due to dry soil conditions. The watershed experienced a maximum 1-hour basin average rainfall rate of 1.4 in/hr, with an estimated maximum 1-hour basin average excess rainfall rate of 0.9 in/hr.

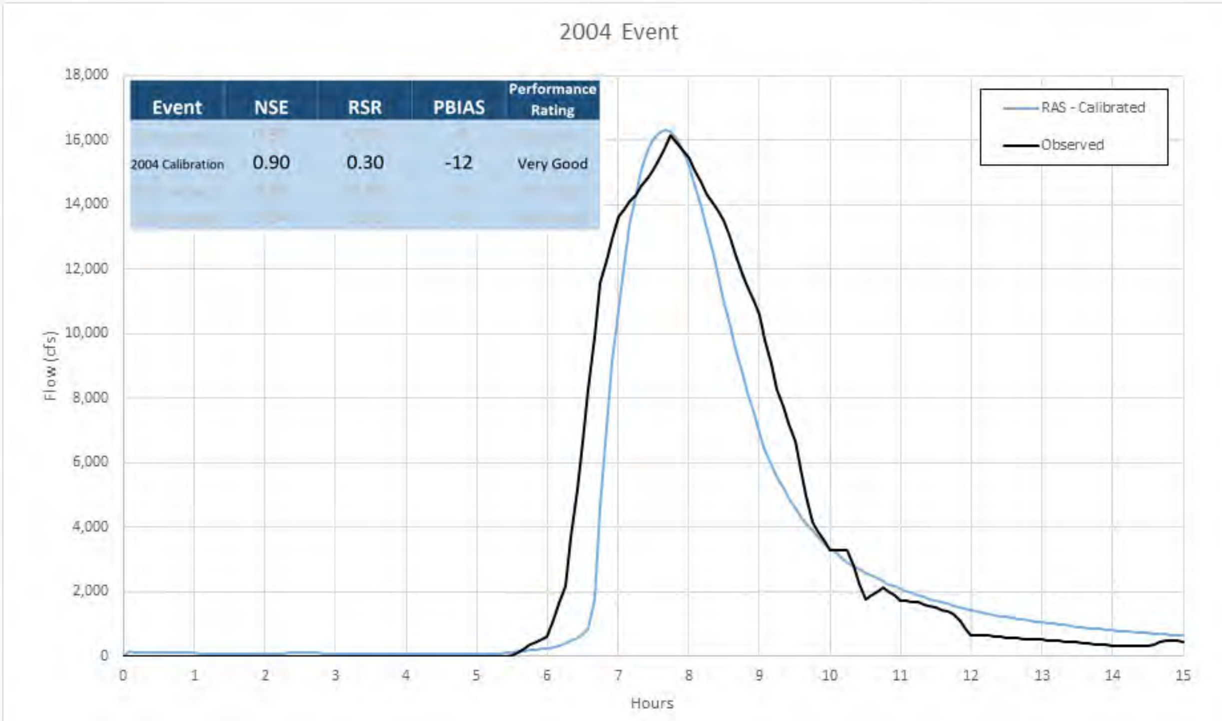


Figure 3.10 – RAS Calibration Results for June 2004 Storm

The June 2004 storm had a basin average rainfall total of about 3.7 inches with most of the rainfall falling in about 3 hours. The storm was centered in the central part to upper half of the watershed and had a very high percentage of rainfall loss due to dry soil conditions. The watershed experienced a maximum 1-hour basin average rainfall rate of 1.9 in/hr, with an estimated maximum 1-hour basin average excess rainfall rate of 0.9 in/hr.

3.5 HEC-RAS Validation

After storms were calibrated a final set of Manning's n values were developed by taking the average of the two storm events. The final Manning's n values were then used to validate the HEC-RAS model and final Manning's roughness coefficients for 2 storm events.

A comparison between the initial, calibrated and final Manning's n values that were used in all of the RAS 2D simulation is shown below in table 3.2. The cells shaded blue were decreased from the initial estimates.

Table 3.1 – Initial, Calibrated, and Final Manning's n Values

Land Use Description	Initial	2000	2004	Final
Channel (Natural, Clean, Winding)	0.04	0.04	0.04	0.04
Barren Land Rock/Sand/Clay	0.025	0.025	0.025	0.025
Cultivated Crops	0.045	0.045	0.045	0.045
Deciduous Forest	0.12	0.12	0.12	0.12
Developed, High Intensity	0.065	0.065	0.065	0.065
Developed, Low Intensity	0.05	0.05	0.05	0.05
Developed, Medium Intensity	0.055	0.055	0.055	0.055
Developed, Open Space	0.035	0.035	0.035	0.035
Emergent Herbaceous Wetlands	0.1	0.1	0.1	0.1
Evergreen Forest	0.12	0.12	0.12	0.12
Grassland/Herbaceous	0.04	0.02	0.04	0.03
Open Water	0.025	0.025	0.025	0.025
Pasture/Hay	0.035	0.035	0.035	0.035
Shrub/Scrub	0.07	0.07	0.07	0.07
Woody Wetlands	0.1	0.1	0.1	0.1

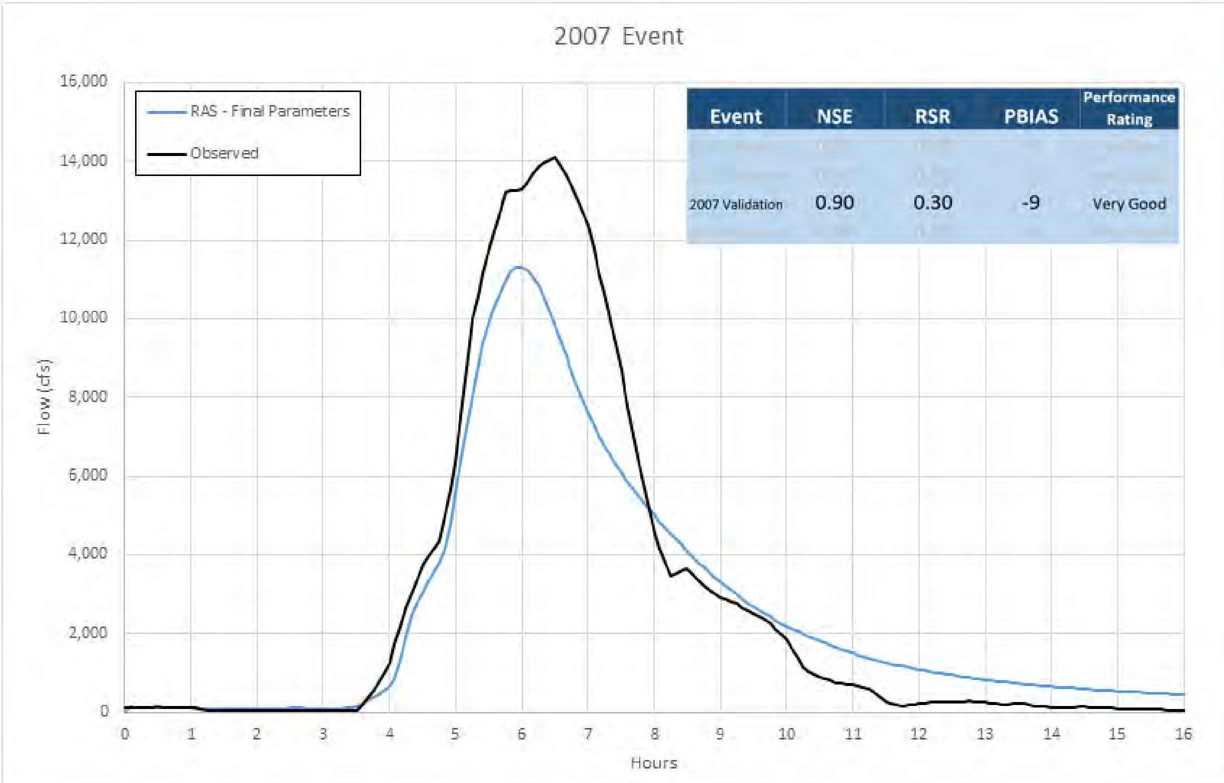


Figure 3.11 – RAS Validation Results for March 2007 Storm

The March 2007 storm had a basin average rainfall total of about 1.9 inches with most of the rainfall falling in about 1 hour. The storm was centered in the central part to upper half of the watershed and had a moderate-low percentage of rainfall loss due to moderate-moist soil conditions. The watershed experienced a maximum 1-hour basin average rainfall rate of 1.3 in/hr, with an estimated maximum 1-hour basin average excess rainfall rate of 1.1 in/hr.

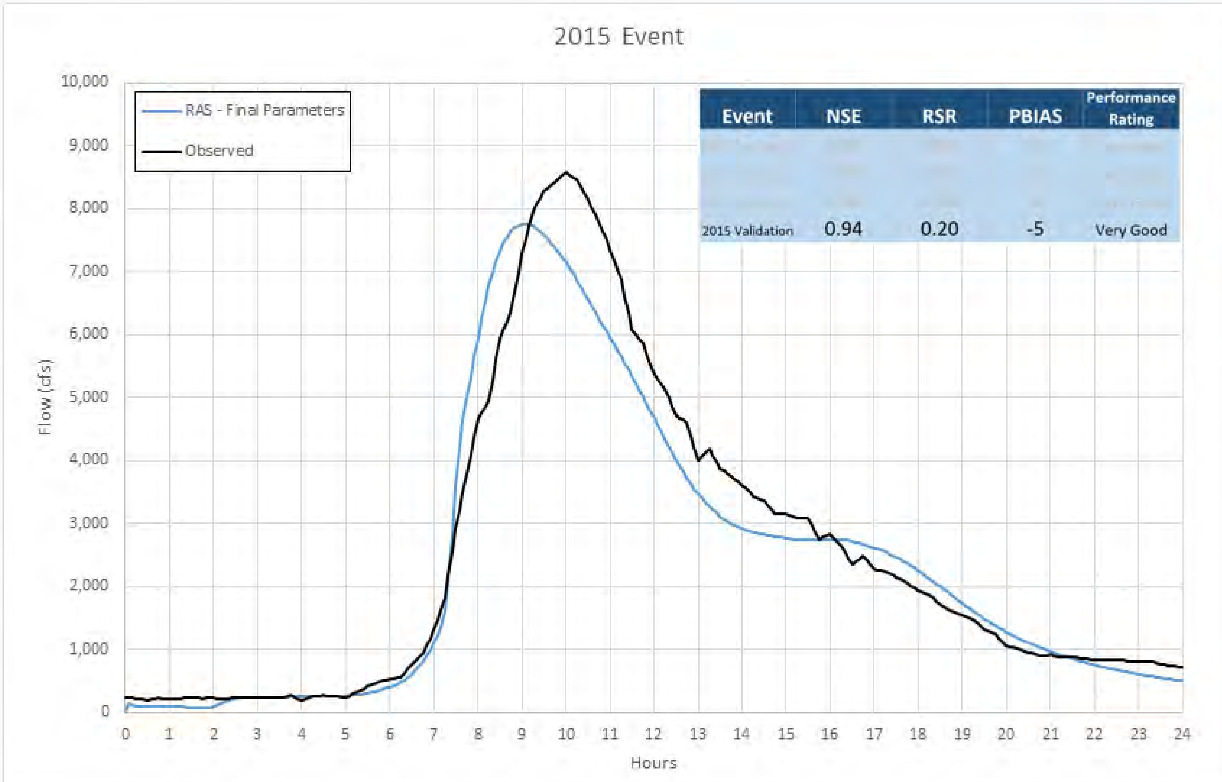


Figure 3.12 – RAS Validation Results for November 2015 Storm

The November 2015 storm had a basin average rainfall total of about 2.3 inches with most of the rainfall falling over about 17 hours. The storm occurred uniformly over the watershed and had a moderate-low percentage of the rainfall loss due to moderate-moist soil conditions. The watershed experienced a maximum 1-hour basin average rainfall and excess precipitation rate of 0.2 in/hr.

4.0 Results

After calibrating the roughness values to improve the model's ability to reproduce observed storm hydrographs, a final set of roughness values was selected and excess rainfall or varying intensities were applied to the 2D area/watershed. Intensities varying between 0.25 in/hr to 5 in/hr were tested as similar in magnitude to the events that are primarily used to estimate flood frequency for the Federal Emergency Management Agency (FEMA) National Flood Insurance Program (NFIP). The excess rainfall was then routed using the diffusion wave equations in the HEC-RAS model to produce a total flow hydrograph at the downstream end of the study area. This is an estimate of what the flow hydrograph would be if there was a certain amount of runoff distributed uniformly across the watershed.

Each of the total flow hydrographs were divided by the total inches of rainfall for that particular simulation so that the resulting hydrograph contained 1-unit (or 1-inch in this case) of runoff. For example, the highest intensity event contained 5 inches in 1 hour and had a peak of 83,000 cfs. Each of the flows in the hydrograph were divided by 5 and so the peak of the unit hydrograph was 16,600 cfs. This example is illustrated in Figure 4.1.

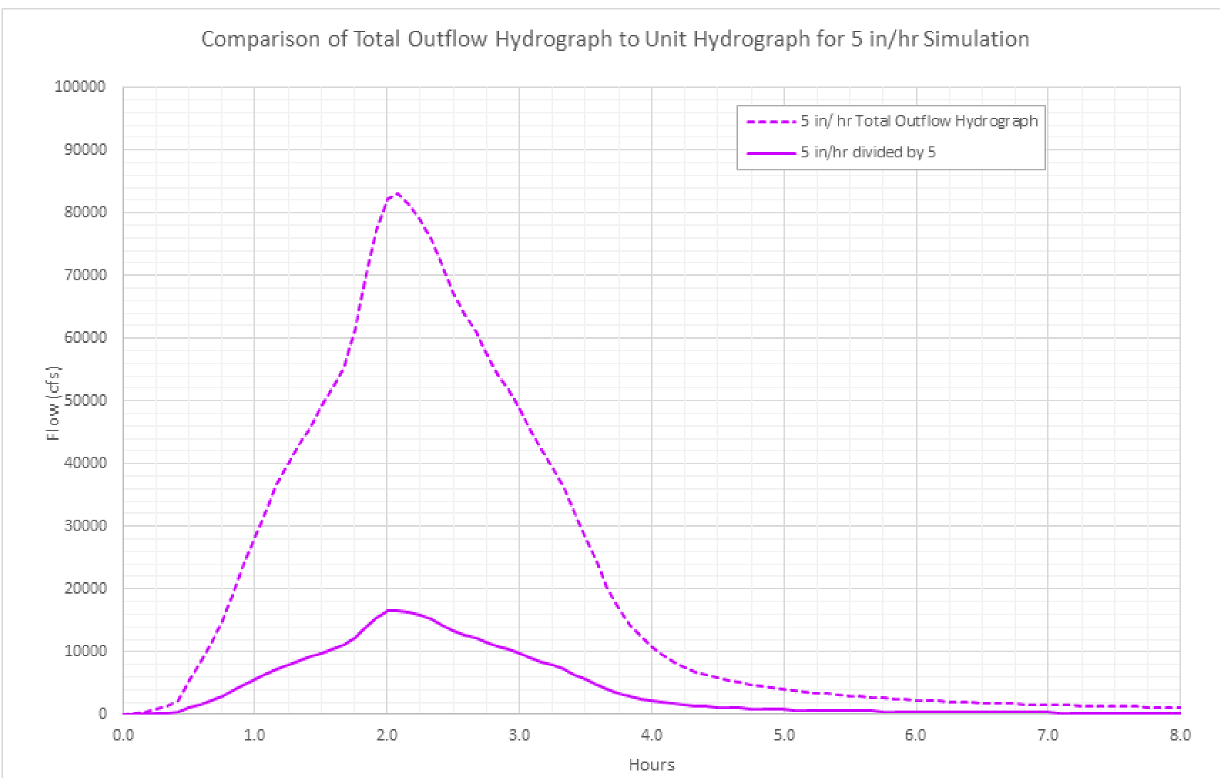
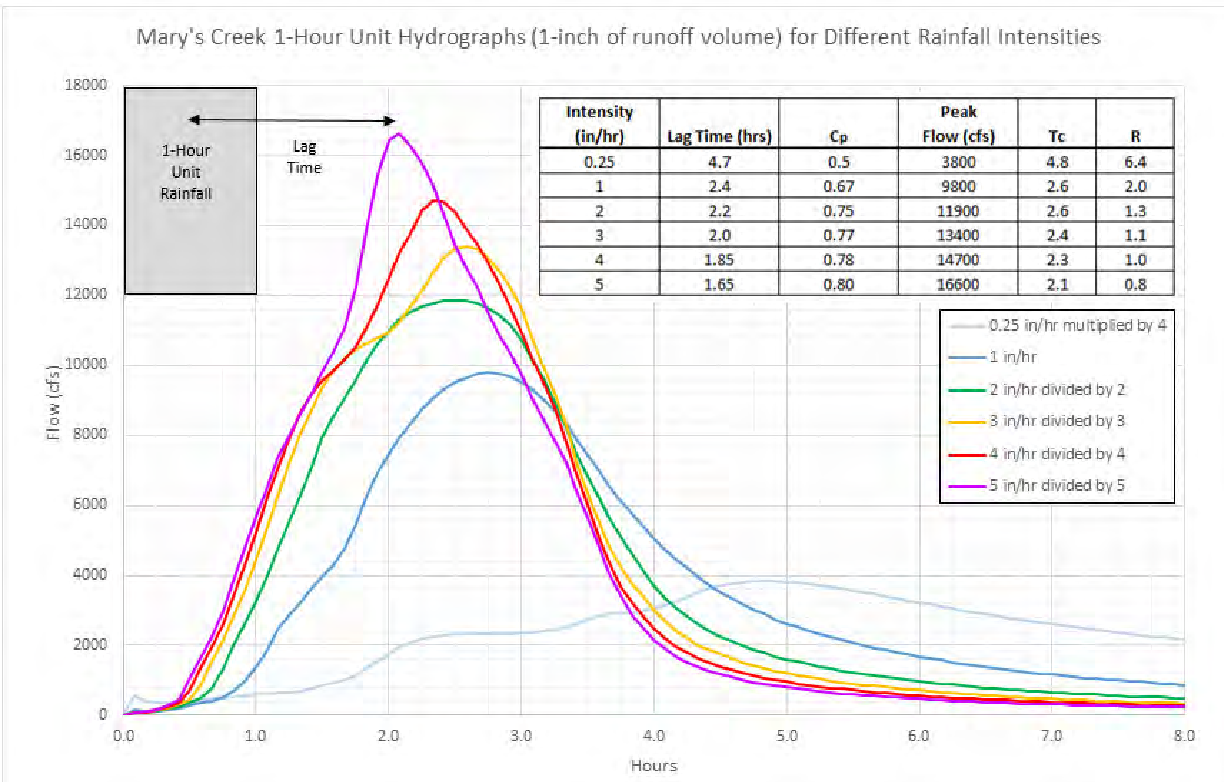


Figure 4.1 – Comparison of Total Outflow Hydrograph to Unit Hydrograph for 5 inches in 1 hour

The findings of this study indicated that with increases in rainfall intensity applied to the HEC-RAS model, the lag times decreased while peak discharges increased for the unit hydrograph of the Mary's Creek watershed. The lag times were 4.7, 2.4, 2.2, 2.0, 1.85, and 1.65 hours for the 0.25 in/hr, 1 in/hr, 2 in/hr, 3 in/hr, 4 in/hr, and 5 in/hr events respectively. Figure 4.2 displays the unit hydrographs for all of the different intensities. The Tc and R values are the corresponding Clark unit hydrograph parameters developed by HMS that best match the Snyder unit hydrograph parameters.



Intensity (in/hr)	Lag Time (hrs)	Cp	Peak Flow (cfs)	Tc	R
0.25	4.7	0.5	3800	4.8	6.4
1	2.4	0.67	9800	2.6	2.0
2	2.2	0.75	11900	2.6	1.3
3	2.0	0.77	13400	2.4	1.1
4	1.85	0.78	14700	2.3	1.0
5	1.65	0.80	16600	2.1	0.8

Figure 4.2 – Unit Hydrographs for Different Intensities

The NFIP was created in 1968 to guide new development (and construction) away from flood hazard areas and to help transfer the costs of flood damages to the property owners through the payment of flood insurance premiums. FEMA administers the NFIP. The standard that is generally used by FEMA in regulating development and in publishing flood insurance rate maps is the 1% ACE flood elevation or Base Flood Elevation (BFE). The 1% ACE flood is defined as a flood which has a 1% chance of being equaled or exceeded in any year. Sensitivity testing was performed to see how the results from this study compare to other common methodologies paying particular attention to the 1% ACE event. Figure 4.3 below shows different 1% ACE event hydrographs for the Mary's Creek watershed based on different methodologies for the Mary's Creek watershed.

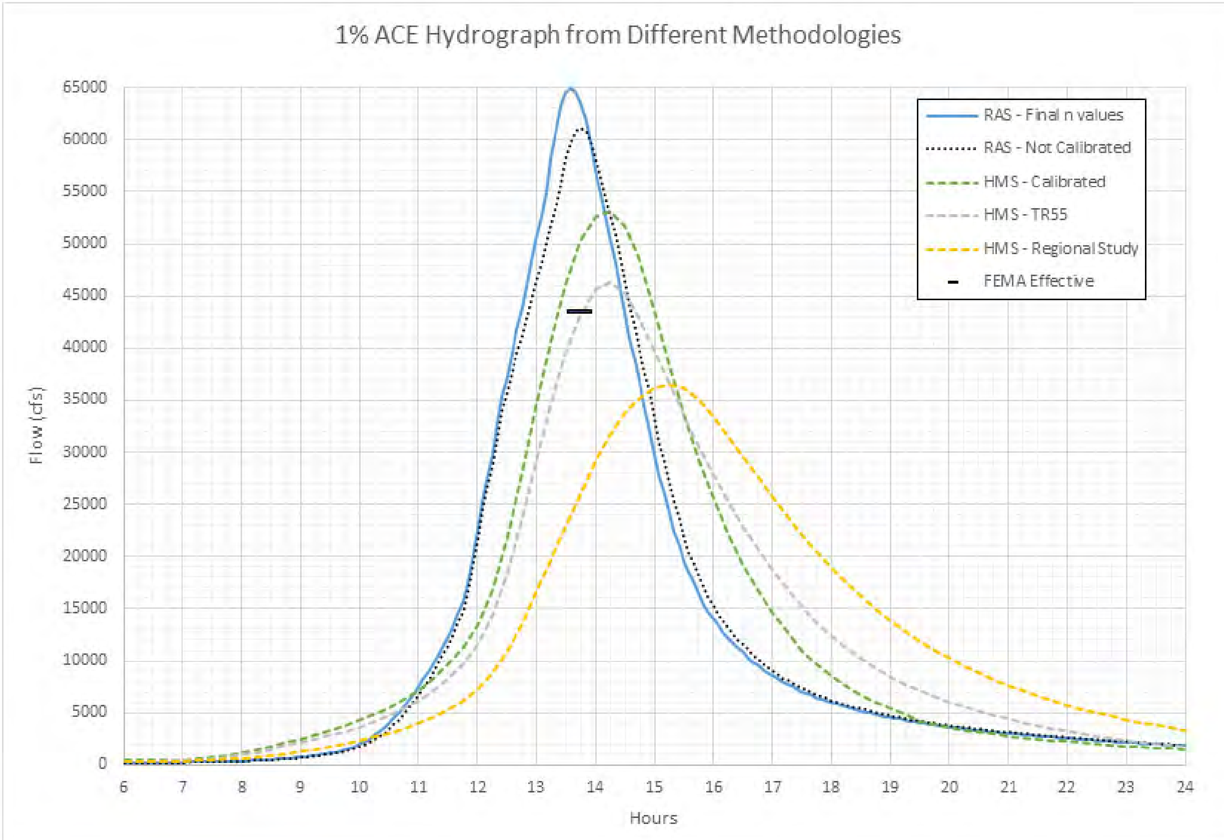


Figure 4.3 – 1% ACE Hydrograph Estimates from Different Methodologies

Each of the methods used the USACE Fort Worth District Losses for the 1% ACE event (Initial Loss = 0.86 in and Constant Loss = 0.09 in/hr) for the Mary's Creek watershed. These losses vary by frequency and are based off of the percent sand value of the watershed. The percent sand varies based on soil permeability rates. The selected losses fall within the range (Initial: 0.5 – 2.7 in and Constant: 0.01 – 0.30 in/hr) observed during the HEC-HMS model calibration of observed events. Even if the losses were changed, the relationship between the hydrographs would be very similar. There is a wide variation in estimates of peak discharge for this event (37-65k cfs) depending on what methodology is selected. All methods utilized the same hyetograph (8.79 inches basin average 9.25 inches point based off of 2004 USGS rainfall atlas for Texas(Asquith)). The "RAS – Final n values" hydrograph was produced by using the HEC-RAS 2D model with final Manning's n values and simulating with unsteady diffusion wave equations. The "HMS – Calibrated" hydrograph was produced by using HEC-HMS and the parameters that were developed during HEC-HMS calibration of observed storm events. The estimated maximum basin-average excess rainfall intensities simulated during HEC-HMS model calibration was approximately 1.0 in/hr). Comparatively, the 1% ACE basin average excess rainfall intensity is approximately 2.9 in/hr, based on the USGS rainfall. The "HMS – Regional Study" hydrograph used a lag time and peaking coefficient that is recommended based on USACE Fort Worth District Urbanization Curves. All of the methods (with the exception of the HEC-RAS results) assume linearity in unit hydrograph parameters or that the lag time and unit discharge is the same for all intensities on the watershed. All of the methods produce peak discharge estimates significantly less than the HEC-RAS 2D results including the calibrated HEC-HMS model.

The calibration simulations in Section 3 illustrate how the rising and falling limbs of the HMS hydrographs are less steep than the observed hydrograph, indicating that the parameters used in the HMS modeling do simulate the watershed response to rainfall as well as the RAS 2D model. Overall, the RAS 2D model emulates the observed hydrograph much better than the other methods and is able to replicate the expected non-linear routing phenomena for higher rainfall intensities. For these reasons, the RAS 2D model can reasonably be expected to provide a better estimate of flood frequency for this specific watershed given all the unique and dynamic flow characteristics during a rare flood event.

The results of this study could be used to develop a composite set of unit hydrograph parameters for use in future flood frequency studies. Though the current version of HEC-HMS allows for variable unit hydrograph parameters, a composite value was found to better approximate the results produced using the RAS 2D simulations.

This was performed for several hypothetical (frequency) events. Each event was simulated using RAS 2D. The resulting hydrographs were then calibrated to in HMS by using the same excess precipitation and by modifying the unit hydrograph parameters to produce a hydrograph that closely resembled the RAS 2D hydrograph. This procedure was performed for the 50% (2-yr), 10%, (10-yr), 2% (50-yr), 1% (100-yr), and 0.2% (500-yr) ACE events. Each of the events resulted in a different set of unit hydrograph parameters with lag time decreasing as excess rainfall from the total storm increased. This is the same trend discovered when analyzing different rainfall intensities. The lag times from each of the hypothetical (frequency) events were then used to solve for C_T from equation 2.1. Since the lag times were different for each of the events, each event resulted in a different C_T and thus different equation. The results of calibrating standard Snyder unit hydrograph parameters in HMS to RAS 2D is included in table 4.1 below.

Table 4.1 – Results of Calibrating HMS Parameters to RAS 2D Results

Event	Lag Time (hr)	C_p	C_T	Total Excess Precip (in)	Initial Loss	Constant Loss
50% ACE	2.8	0.57	0.83	0.53	1.95	0.25
10% ACE	2.0	0.75	0.59	2.7	1.41	0.17
2% ACE	1.6	0.76	0.48	5.1	1.04	0.12
1% ACE	1.5	0.78	0.45	6.6	0.86	0.09
0.2 % ACE	1.2	0.75	0.36	10.1	0.58	0.07

Equations 4.1 through 4.5 can be used on any future studies within the Mary's Creek watershed where additional subbasins are needed to develop flood frequency estimates. The L, L_{CA}, and S values (As defined in Equation 2.1) for the new subbasins can be used to estimate subbasin lag times. A peaking coefficient of 0.76 can be used for events within the 10% to 0.2 % range due to the small variation between the events. The peaking coefficient should be reduced if using events less than the 10% event.

$$T_{L,50\%} = 0.83\left(\frac{L * L_{CA}}{S^{0.5}}\right)^{0.38} \qquad Use\ with\ a\ C_p = 0.57$$

Equation 4.1 – Snyder Lag Time Equation to compute 50% ACE discharges within Mary's Creek Watershed

$$T_{L,10\%} = 0.59\left(\frac{L * L_{CA}}{S^{0.5}}\right)^{0.38} \qquad Use\ with\ a\ C_p = 0.76$$

Equation 4.2 – Snyder Lag Time Equation to compute 10% ACE discharges within Mary's Creek Watershed

$$T_{L,2\%} = 0.48\left(\frac{L * L_{CA}}{S^{0.5}}\right)^{0.38} \qquad Use\ with\ a\ C_p = 0.76$$

Equation 4.3 – Snyder Lag Time Equation to compute 2% ACE discharges within Mary's Creek Watershed

$$T_{L,1\%} = 0.45\left(\frac{L * L_{CA}}{S^{0.5}}\right)^{0.38} \qquad Use\ with\ a\ C_p = 0.76$$

Equation 4.4 – Snyder Lag Time Equation to compute 1% ACE discharges within Mary's Creek Watershed

$$T_{L,0.2\%} = 0.36\left(\frac{L * L_{CA}}{S^{0.5}}\right)^{0.38} \qquad Use\ with\ a\ C_p = 0.76$$

Equation 4.5 – Snyder Lag Time Equation to compute 0.2% ACE discharges within Mary's Creek Watershed

If intermediate events are desired or if different loss rates are used, the below equation can be used to re-solve for a new lag time and thus new C_T value to produce an equation similar to equations 4.1 through 4.5. This equation was developed based off of the observed relationship between total 24-hour excess precipitation and lag times from the RAS 2D results (Figure 4.4).

$$T_{L,new} = -0.54 ln(Total\ 24\ hr\ Excess\ Precipitation) + 2.48$$

Equation 4.6 – Equation for Snyder Lag Time with a Different Total 24-Hour Excess Precipitation Amount

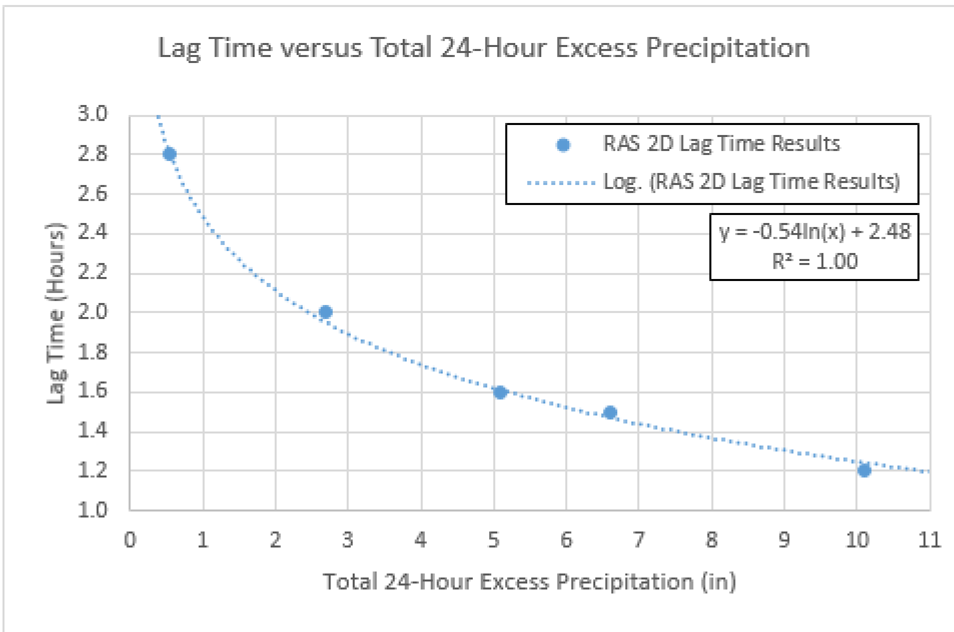


Figure 4.4 – RAS 2D Lag Times versus Total 24-Hour Excess Precipitation

5.0 Limitations and Opportunities for Improvement

The Diffusion Wave equation set was utilized for increased model stability and more efficient simulation run time. Hydrodynamic flow when using the Diffusion Wave equation set is driven by pressure gradients balanced by bottom friction. The advection, turbulence and coriolis terms of the momentum equation are disregarded when using this approximation. Use of the Full Momentum (i.e. Saint Venant) equation set could potentially improve the accuracy and precision in the hydrodynamic runoff estimates; however, using this numerical solution would be computationally burdensome. Therefore, it was deemed that the Diffusion Wave equation set would provide an adequate approximation, resulting in sufficiently accurate modeled inflows and headwater elevations for this study effort, since the

Diffusion Wave equation set accounts for more physical processes than traditional methods such as TR-55 or available regional equations.

Having the 2D areas for the headwater subbasins separated from the downstream Mary's Creek subbasins did not allow the water surfaces of the downstream 2D areas to affect the upstream 2D areas. Each 2D area D/S boundary was set to normal depth and used the downstream channel slope as the friction slope. The 2D areas were modeled separately due to the difficulty of using the weir equation to model flow in a channel (or from one 2D area to another). Attempts were made to include all 2D areas in a single geometry, however significant instability was experienced when using high weir coefficients that were required at the SA/2D connection between connecting 2D areas. Using a low weir coefficient (0.2-0.5) resulted in "walls" at the connections. The "walls" had elevations (or depths) that were much higher upstream of the connection. Figure 4.1 illustrates this affect by showing deep water (dark blue) next to shallow water (light blue) for a given flow, when the depths should be the same.

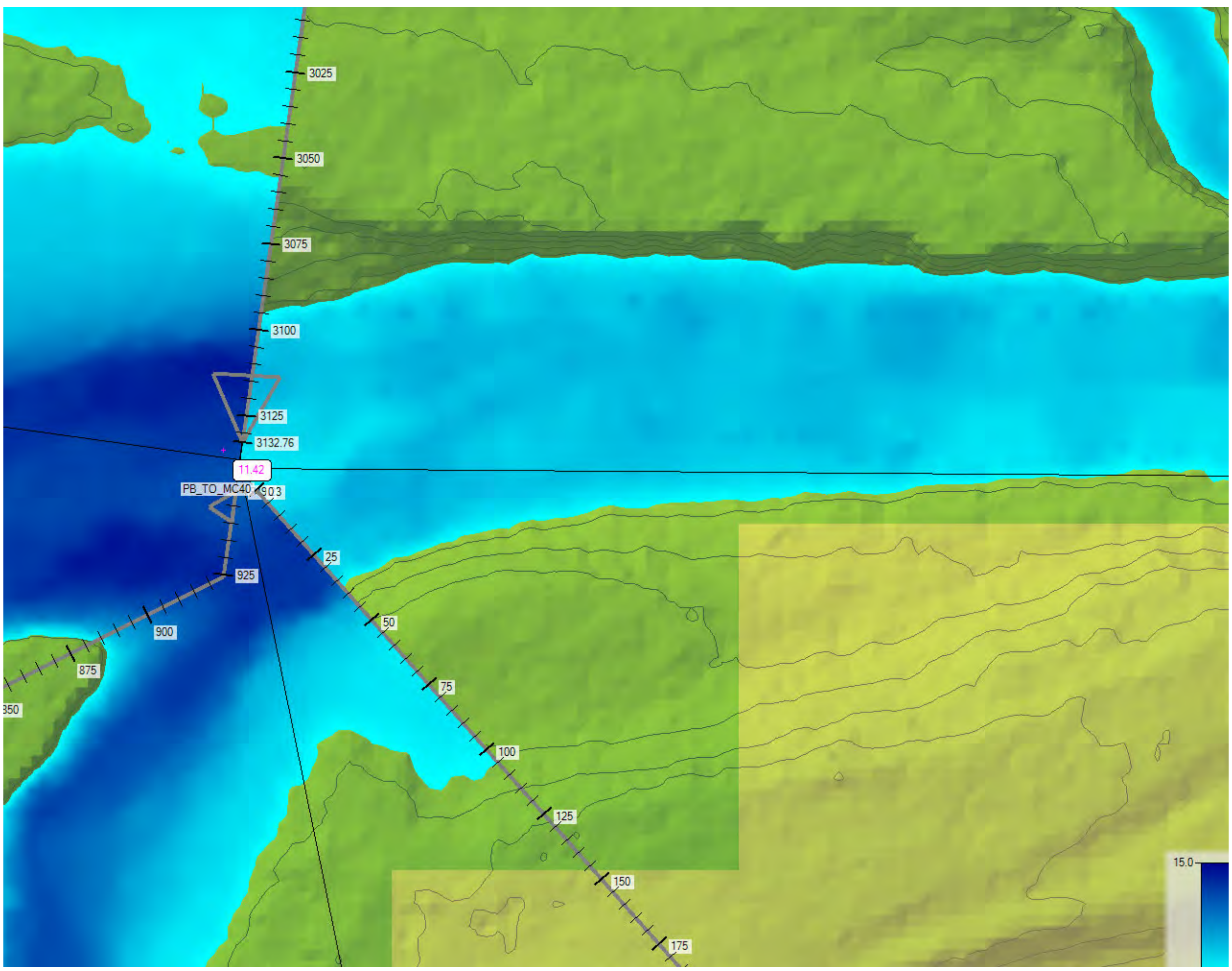


Figure 5.1 – Example of "Wall" at SA/2D Connection

The selected friction slopes resulted in small differences (generally 2 feet or less) in water surfaces between 2-D areas. This was considered reasonable for the purposes of this study. Given the added level of detail over normal methods.

Cell resolution was 500 ft in order to keep the total cell count and resulting simulation times to a manageable amount.

The culvert openings were measured for the largest embankments, however the invert elevations were not surveyed, but were approximated using the terrain model. The elevations could be refined through a field survey and the remaining culvert crossings in the model could also be measured and surveyed.

Opportunities for improvement of the study results include additional sensitivity testing, comparisons with other watershed parameter estimation techniques, HEC-RAS simulation using the full Saint Venant equation set as well as additional recommended equations for parameter estimation.

The ponds and small dams within the watershed were not modeled in detail, most of the ponds have standing water and are assumed to be small enough that any storage effects would not significantly alter the equations developed in this study, but these could be added to increase the detail within the model.

6.0 Conclusion

Unit hydrograph theory is a commonly used method to convert excess precipitation into runoff hydrographs for flood frequency studies. Historically, one of the limitations of this method is the assumption that a watershed would have the same lag time when experiencing a very low intensity rain event as it would when receiving a high intensity event.

Literature indicates that lag times generally tend to decrease as storm intensity increases. USACE dam safety studies normally apply a 25-50% peaking factor to the unit hydrograph for the contributing drainage area upstream of a dam per ER 1110-8-2(FR) “Inflow Design Floods for Dams and Reservoirs”. This is due to the fact that calibrated storm events are commonly less intense than the hypothetical (frequency) events simulated in a flood frequency study. Snyder indicated in his study that “the lag for a particular drainage basin is apt to be slightly greater for small floods than for large floods occurring from a given type and duration of storm.” (Snyder)HEC-RAS 2-D has been utilized by the USACE dam safety community to develop variable unit hydrographs for different rainfall intensities.

The results of this study indicate that as rainfall intensity increases on the Mary’s Creek watershed, the lag time decreases resulting in higher peak discharges than would be produced from using a single static lag time for all rainfall intensities. The results from this study are consistent with those found in literature such as Snyder and Minshall (Snyder and Minshall). Hydraulic characteristics such as wave velocity and roughness vary as discharge varies. This occurs on tributaries as well as the mainstem and the resulting hydrograph at the downstream end is the product of all the physical processes occuring in the watershed. Snyder lag times were reduced by 25% from the 10% ACE event to the 1% ACE event and 37% from the 10% ACE event to the 0.2% ACE event. Overall, the RAS 2D model emulates the observed hydrographs much better than the other methods and is also able to replicate the expected non-linear routing phenomena for higher rainfall intensities. For these reasons, the calibrated RAS 2D model can reasonably be expected to provide a better estimate of flood frequency than traditional methods for this specific watershed given all the unique and dynamic flow characteristics during a large flood event.

The purpose of this study was to utilize the HEC-RAS 2D model and equations to investigate the variability in unit hydrograph parameters for the purpose of improving estimates of flood frequency on the Mary's Creek watershed. Equations 4.1 through 4.6 in Section 4.0 can be used on new studies to estimate unit hydrograph parameters for the Mary's Creek watershed where additional subbasins are needed to estimate flood frequency.

7.0 Conclusion

Asquith, W.H., Roussel, M.C., Atlas of *Depth-Duration Frequency of Precipitation Annual Maxima for Texas*; U.S. Geological Survey Scientific Investigations Report 2004-5041; 2009.

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Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the Trinity River Basin
Appendix G – Peer Review Comments and Responses

July 2021

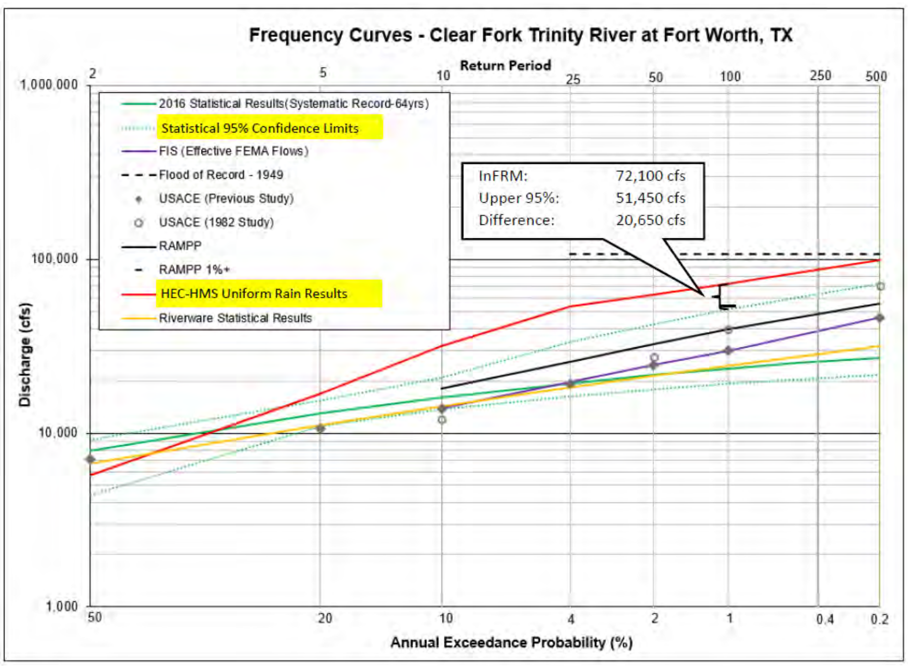
INTERAGENCY FLOOD RISK MANAGEMENT

Responses to Peer Review Comments - Part 1

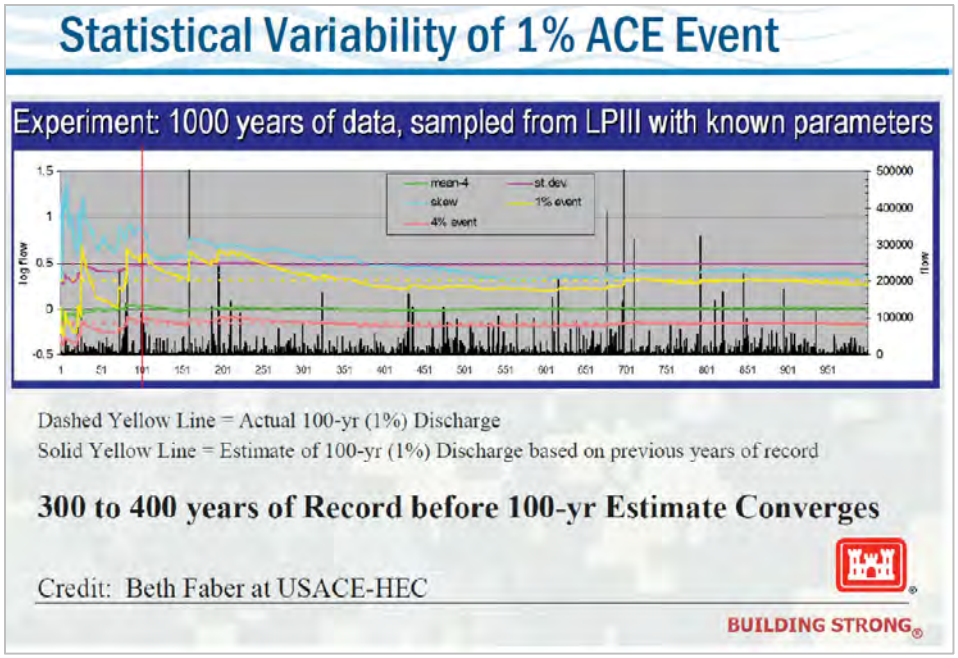
The following comments on the InFRM Trinity WHA report were received on 11-Sep-2020. Responses from USACE are shown in blue.

Peer Review Comments:

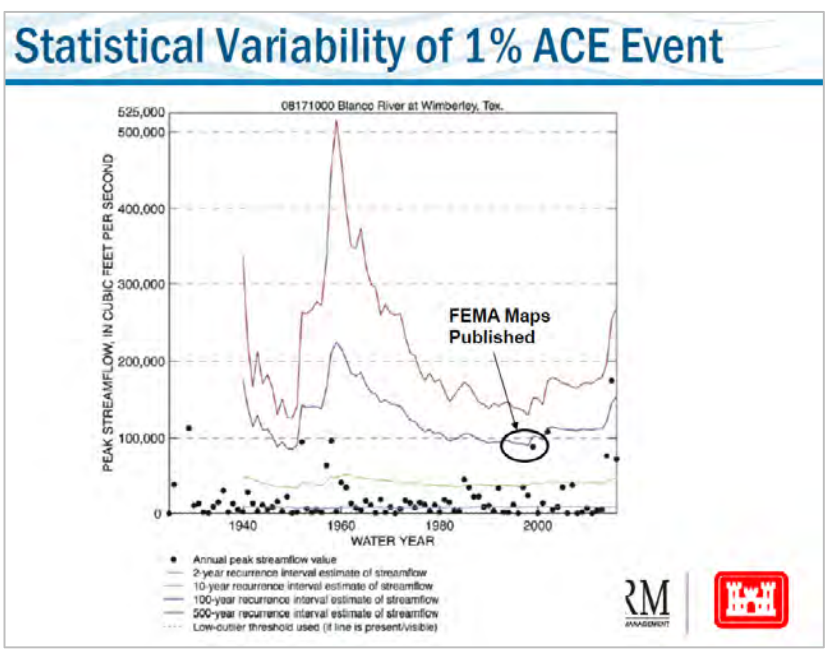
1. **Comparison to Statistical Hydrology** -
   The Mary's Creek frequency flows computed with HEC-HMS have a general agreement with the statistical analysis, at the very least, they plot within the confidence bands. The frequency flows computed with HEC-HMS for the Clear Fork at the IH-30 gauge do not share the same general agreement with their statistical counterpart. The Clear Fork HMS flows plot well above the upper 95% confidence band, see below. The assessment of the validity of the statistical analysis states, "it is suggested that hydrologic and hydraulic modeling would be especially informative to assess the possibility of substantially larger estimates than those provided by the statistical analysis." While in agreement with the possibility that the site has not experienced a large event to date, at what point does the modeling stray too far from the statistics? The proposed 100-year flow is over three times that recommended by the USGS statistical analysis.



Comment 1 Response: As shown in the figures below, flood frequency estimates for the 1% annual chance (100-yr) flood generally do not stabilize until there is 3-4 times the record length of the flood return period being estimated. Because of this, flood frequency estimates have the possibility of being very different in the future than what they are today, even with 60+ years of record as is available for this gage. The USGS has noted in the Statistical Hydrology Appendix A when discussing the change over time figures "A striking feature of the (statistical hydrology) figures is the sensitivity of estimates of the 100- and 500-year return period when large floods are observed (included) in the record."

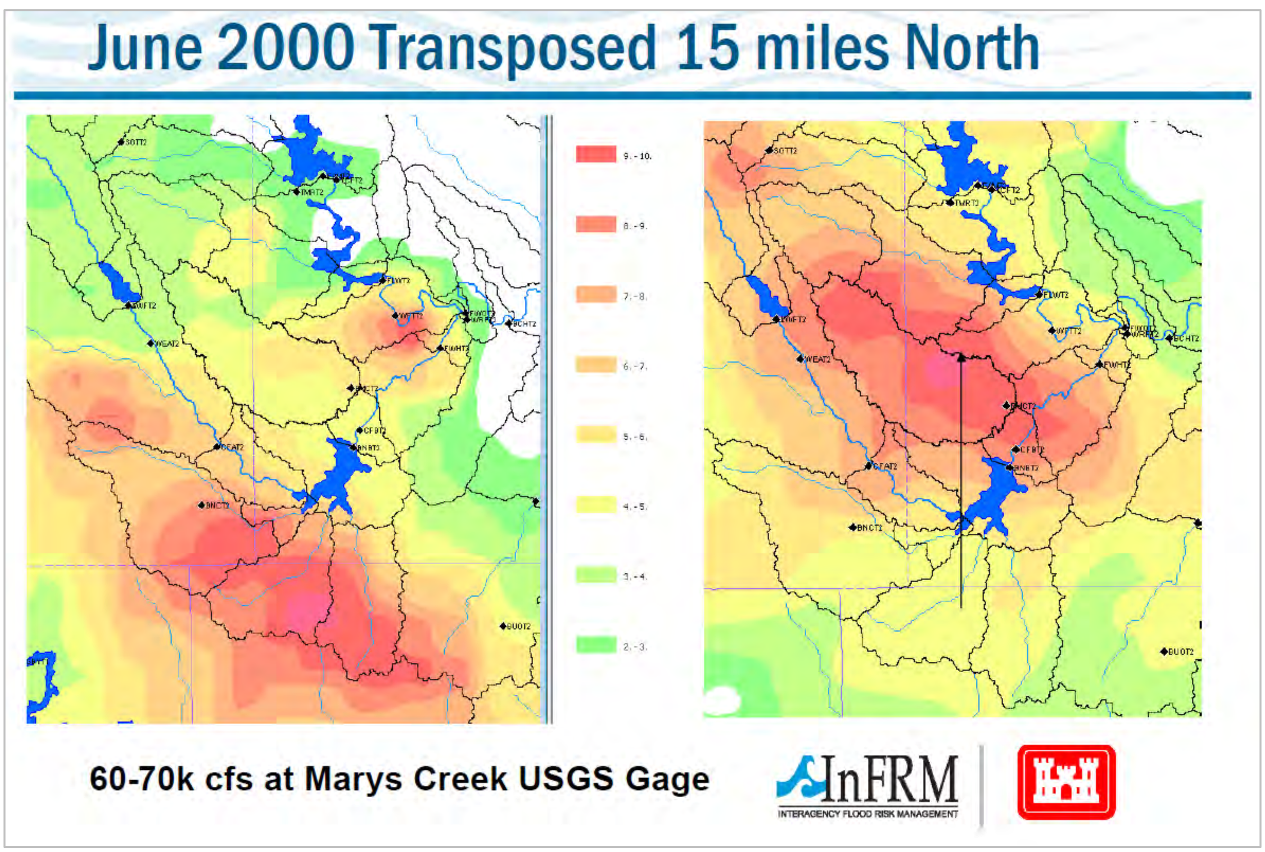


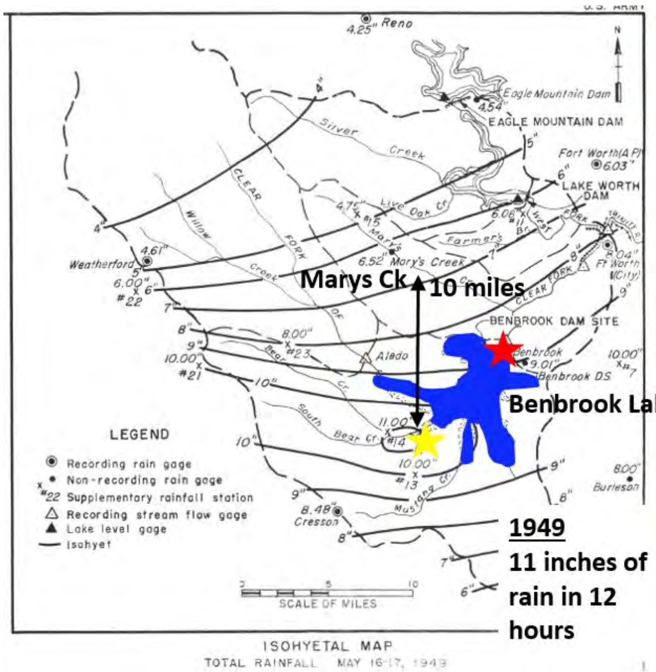
https://www.hec.usace.army.mil/training/materials.aspx#FLOOD_FREQUENCY_ANALYSIS

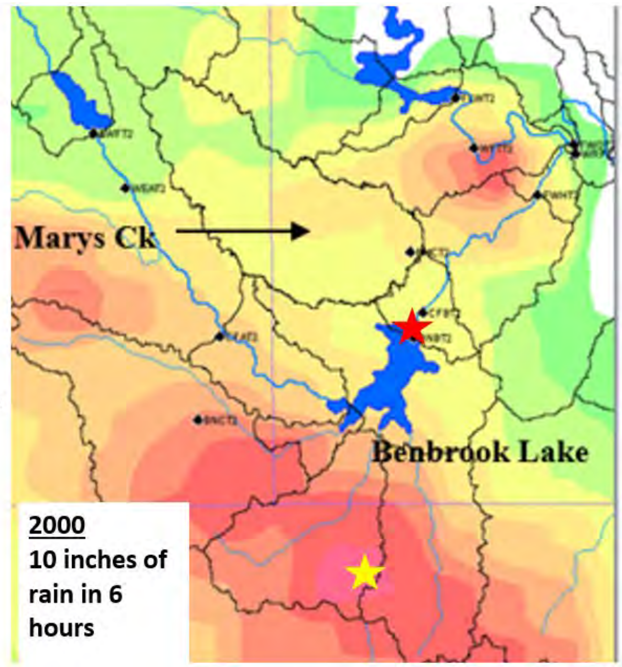


When developing flood hazard estimates, it is important to consider all information available as recommended in the statement "it is suggested that *<u>hydrologic and hydraulic modeling would be especially informative to assess the possibility of substantially larger estimates than those provided by the statistical analysis</u>*." provided by the USGS in the Statistical Analysis Appendix. Watersheds in the vicinity of Benbrook dam, including Mary's Creek have significant runoff potential due to their flashy watershed characteristics, steep slopes, defined drainage networks, and mostly grassland land cover within the watershed.

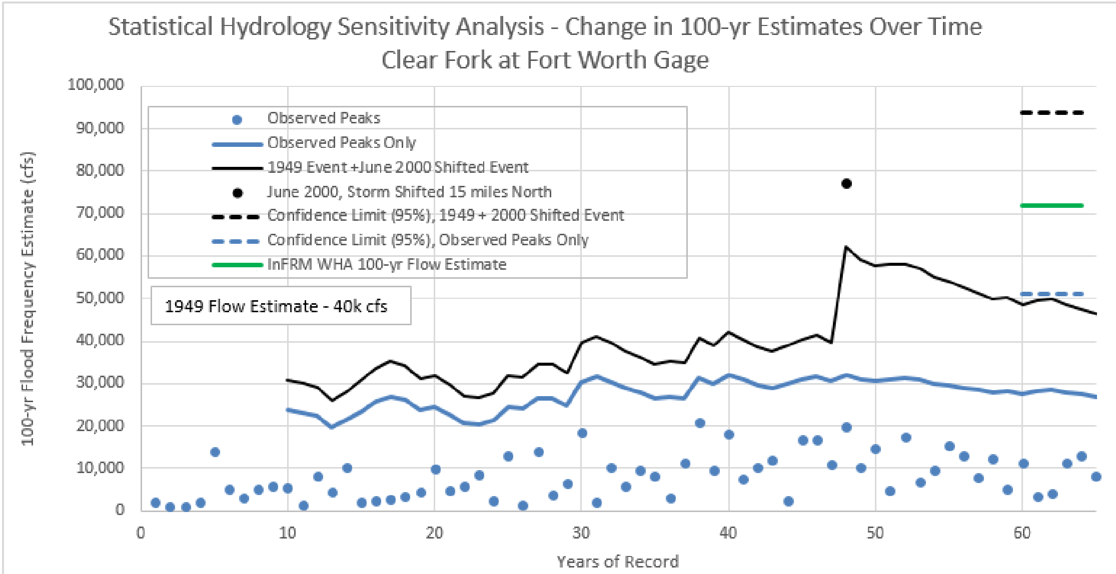
A storm shifting study was performed for the Mary's Creek watershed to get additional information about flood runoff potential. The June 2000 event which occurred directly above Benbrook Dam was shifted 15 miles North over the Mary's Creek watershed. The rainfall was then moved over the Mary's Creek watershed using the same losses from the HEC-HMS calibration run. This resulted in discharges in the range of 60-70k cfs from an actual storm event that fell very close to Mary's Creek. These flows are very similar to what is being proposed as the 1 % annual chance flood for this study. A similar study could be performed with the May 1949 storm, which was also centered just upstream of Benbrook Lake. This storm had a 24 hour point total of around 11 inches and its center was only about 10 miles from the Mary's Creek watershed. Two very large events were centered 10-15 miles from Mary's Creek within a 50-year time period. If one of these nearby events would have been centered over Mary's Creek, it is likely FEMA effective floodplain would have been exceeded significantly.





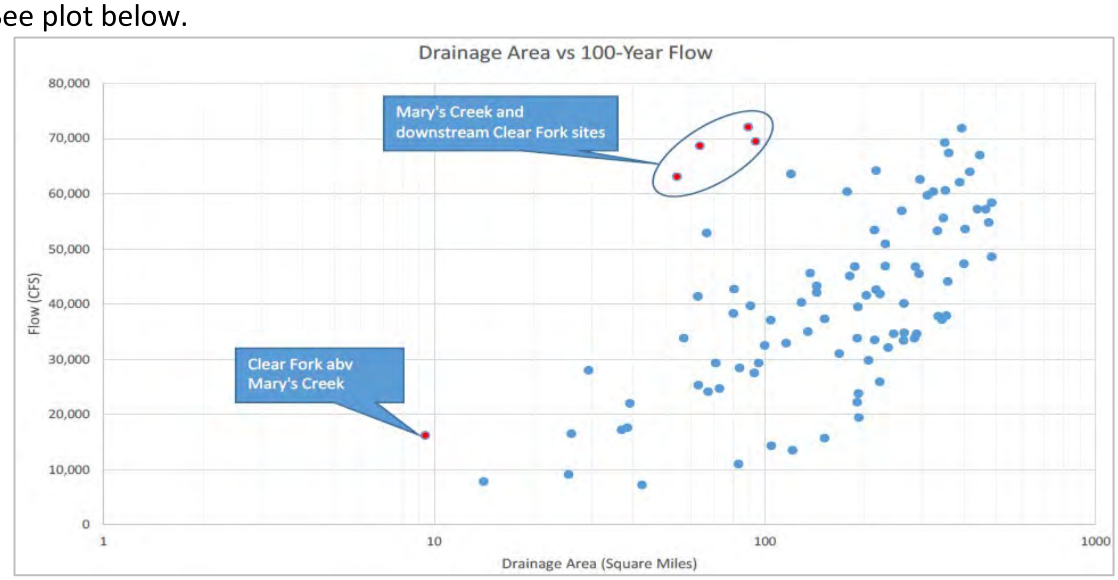


Additional sensitivity analysis of the Clear Fork at Fort Worth statistical hydrology estimates for the 1% annual chance flood was performed. The results of the test indicate that the addition of large storm events could have a very significant affect even on the upper 95% confidence limits. The May 1949 event produced a basin average rainfall amount of about 6.5 inches over Mary's Creek. Using the 1949 estimated losses and rainfall as identified in the USACE Fort Worth Floodway Detailed Project Report (DPR), this resulted in approximately 40k cfs at the Clear Fork at Fort Worth gage with current land use conditions. The shifted June 2000 storm would have produced an estimated flow of about 77k cfs at the gage using June 2000 loss rates. These two events were added to the statistical record and were compared to the original statistical 100-yr change over time analysis. The results show that the upper 95% confidence limit is very sensitive even with 60+ years of record length. For example, by adding in the 1949 and shifted 2000 events, the upper confidence limit would nearly double to between 90-100k cfs. An additional test could have included shifting the 1949 event only 10 miles to the North, which would have produced very large flows off of Mary's Creek and through the Fort Worth Floodway and increased the confidence limits even higher. These test runs indicate that the 100-yr statistical hydrology confidence limits and median estimate for the Clear Fork at Fort Worth gage are very sensitive to large flood events that may occur in the watershed. The 1949 flood and the 2000 flood are 2 events that fell only 10-15 miles away from Mary's Creek within a 50-year period. Either one of these nearby events could have drastically changed the 1% annual chance statistical hydrology estimate at this location and provides support for the likelihood of substantially larger flow estimates than those provided by the statistical analysis. This conclusion is consistent with previous statement that statistical analysis estimates do not tend to stabilize until there is 3-4 times the record length of the flood return period being estimated



Statistical analysis is not being ignored for this study, rather published regional rainfall statistics, which have been very stable within the North Texas region for decades are being relied upon in combination with detailed rainfall-runoff modeling to develop best estimates of long term flood hazard potential with emphasis on the 1% annual chance event. We are also relying on statistical flow estimates to guide the modeling for return intervals that are 3-4 times shorter than the gage record, such as the 2-yr through 10-yr events.

2. **Flow vs Drainage Area Comparison** - When plotting 100-year flow vs. drainage area, Mary's Creek and the subsequent downstream Clear Fork locations plot well outside the scatter produced by other sites in this study. The 9.2 square mile area of the Clear Fork above Mary's Creek also plots as an outlier. See plot below.



Comment 2 Response: The flow values for Mary's Creek were developed using standard loss rates and published precipitation estimates, which have been very stable in this region for several decades. These two model elements in combination with the calibrated watershed parameters developed from observed data produce flow estimates that are higher than other locations with similar drainage areas. It should be noted however that there are many factors that influence how watershed runs off for a given subbasin and estimates for a specific watershed should not be forced to fit results from other watersheds when there are many factors that go into how a watershed will respond to rainfall. Some of these factors can include basin slope, land cover/roughness, channel capacity and shape, tributary characteristics, detention basins, etc. Calibration to observed data as well as detailed 2-dimensional modeling in HEC-RAS approximates many of the physical processes that go into producing the watershed response for this particular watershed. It is impossible to remove all uncertainty from flow estimates but the current estimates are believed to be the best available for this specific watershed and should not be forced to line up with other watersheds in the study area.

3. **Flow vs Drainage Area Comparison (Guadalupe River WHA)** – Four of the top five sites in the entire Trinity River watershed in terms of discharge per square mile are on Mary's Creek or the Clear Fork. For the sake of comparison, discharge per square mile values for some of the top responding sites in Guadalupe River Basin from the 2019 InFRM WHA are also tabulated. The values for Mary's Creek and the Clear Fork are in line with those from the flashy Hill Country watershed. It should also be noted that point rainfall depths used to compute the Guadalupe River basin flows are higher than those from Tarrant or Parker County by about one-inch for a 24-hour, 100-year storm.

Trinity River Flow per Drainage Area

Location	Area (sq mi)	Q100 (cfs)	Q/A
Clear Fork above Marys Creek	9.4	16,200	1,723
Marys Creek at Benbrook USGS gage	54.2	63,100	1,164
Clear Fork below Marys Creek	63.6	68,700	1,080
Range Creek nr Collinsville, TX USGS gage	29.3	28,000	956
Clear Fork Trinity River at Fort Worth USGS gage	89	72,100	810

Guadalupe River Flow per Drainage Area

Location	Area (sq mi)	Q100 (cfs)	Q/A
Bear Creek above Guadalupe River	16.7	24,600	1,473
Guadalupe River above Bear Creek	36	48,600	1,350
Guadalupe River below Bear Creek	52.8	69,400	1,314
Guadalupe River above the Comal River (USGS Gage)	88.3	88,300	1,000
Blanco River below Little Blanco	237.8	187,500	788

Comment 3 Response: The Clear Fork subbasins have high degree of urbanization, which also leads to shorter lag times. The InFRM team performed a sensitivity test of increasing the Clear

Fork lag times, and it showed that increasing the Clear Fork lag times would actually increase the flows through the Fort Worth floodway, because the timing of their runoff would overlap more with the Mary's Creek runoff.

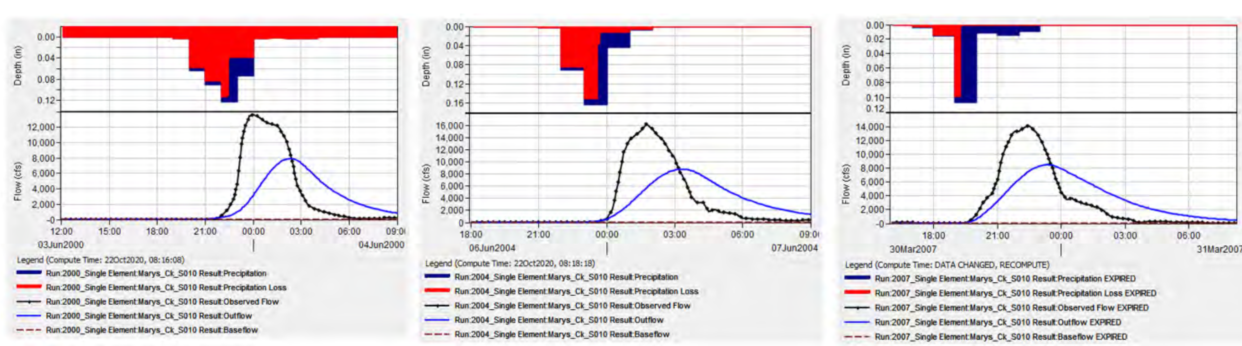
It is not surprising that the Mary's Creek watershed would have some similarities to flashy watersheds in the Hill County. Mary's Creek has significant runoff potential due to flashy watershed characteristics such as steep slopes, defined drainage networks, and mostly grassland land cover which provides very little resistance to flow for a large portion of the watershed's drainage area. This watershed has been described as "very flashy" by the USGS who has expressed challenges in reaching this site with sufficient time to make direct measurements. The flashy watershed parameters appear to be justified based on model calibration to observed watershed responses to rainfall. It is preferable to keep the Mary's Creek watershed parameters that were developed using rigorous and detailed analysis methods rather than revising them to be more consistent with the results from a different watershed that were developed with less detailed methods.

4. **Flow Comparison with other Trinity Locations with Similar Drainage Areas**– The Mary's Creek watershed is compared to a selection of other watersheds in the Trinity Basin below. Basin slopes and urbanization percentages were taken from the 2013 CDC H&H Model Update Report. The Mary's Creek 100-year flow is 2.5 times higher than the neighboring Bear Creek watershed (above Benbrook Lake) despite nearly identical slope and slightly less urbanization. The Mary's Creek 100-year flow is 1.9 times higher than the more urbanized but less steep Big Fossil Creek watershed.

Site	Area (sq mi)	Basin Slope	% Urban	Q100 (cfs)
Mary's Creek	54.2	24.61	13.5	63,100
Big Fossil Creek	56.86	16.22	36.07	33,800
Bear Ck abv Benbrook Lake	58.92	24.76	5	24,900

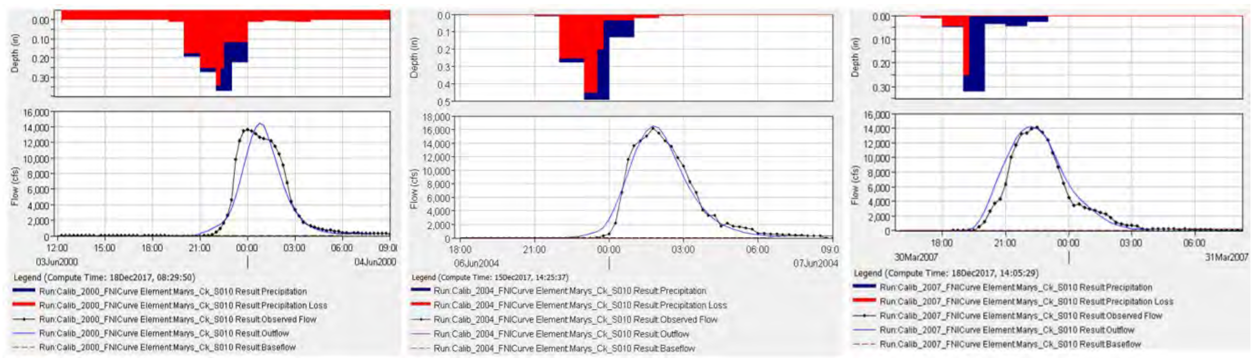
Comment 4 Response: The below figures compare modeling results to observed data using watershed parameters from different sources.

Big Fossil Creek Parameters applied to Mary's Creek



The Big Fossil Creek watershed has a lag time estimate of 3.6 hours. The plots above illustrate that this lag time is too long when compared to observed storm events on the Mary's Creek watershed. The effect of a lag time that is too long is the underestimation of peak discharges

<u>InFRM WHA Calibrated Parameters</u>



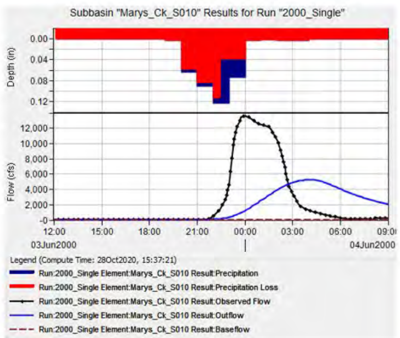
The calibrated HEC-HMS lag times ranged from 1.9 hours to 2.4 hours for the observed storm events on Mary's Creek, which is much faster/peakier than the values being applied to the Big Fossil Creek watershed.

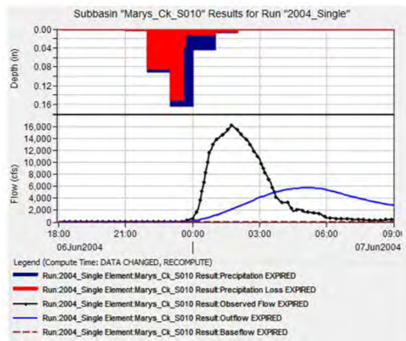
While the differences in drainage area is small between the Mary's Creek watershed and the Big Fossil Creek watershed, the difference in watershed slope is not as small. The Mary's Creek watershed is about 50% steeper than the Big Fossil Creek watershed. While this comparison does not prove the Big Fossil Creek discharges are too low, it does indicate that applying the Bear Creek parameters to Mary's Creek would be inappropriate and result in an underestimation of the flashiness or peak discharge estimates for the watershed.

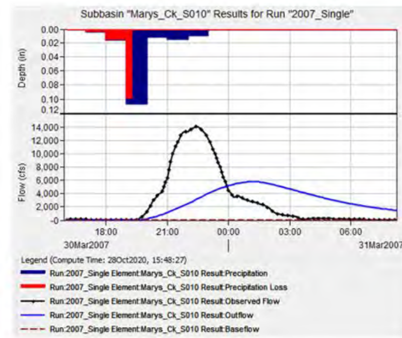
The Bear Creek watershed above Benbrook has a similar drainage area and similar slope to Mary's Creek. The analysis involved in developing the Mary's Creek watershed parameters was very detailed and included site-specific calibration to observed watershed responses while the analysis for the Bear Creek watershed was less detailed. Preliminary results using other methods such NRCS TR-55 as well as HEC-RAS 2D rain-on-grid indicate the Bear Creek watershed could produce 100-yr flows between 50-70k cfs, which are consistent with the results of the detailed analysis performed for Mary's Creek. It is preferable however to keep the Mary's Creek watershed parameters that were developed using rigorous and detailed analysis methods rather than revising them to be more consistent with the results from different watersheds that used less detailed methods.

Bear Creek watershed parameters (lag time and peaking coefficient) were used for Mary's Creek and the compared with observed watershed responses.

<u>Bear Creek Parameters applied to Mary's Creek</u>





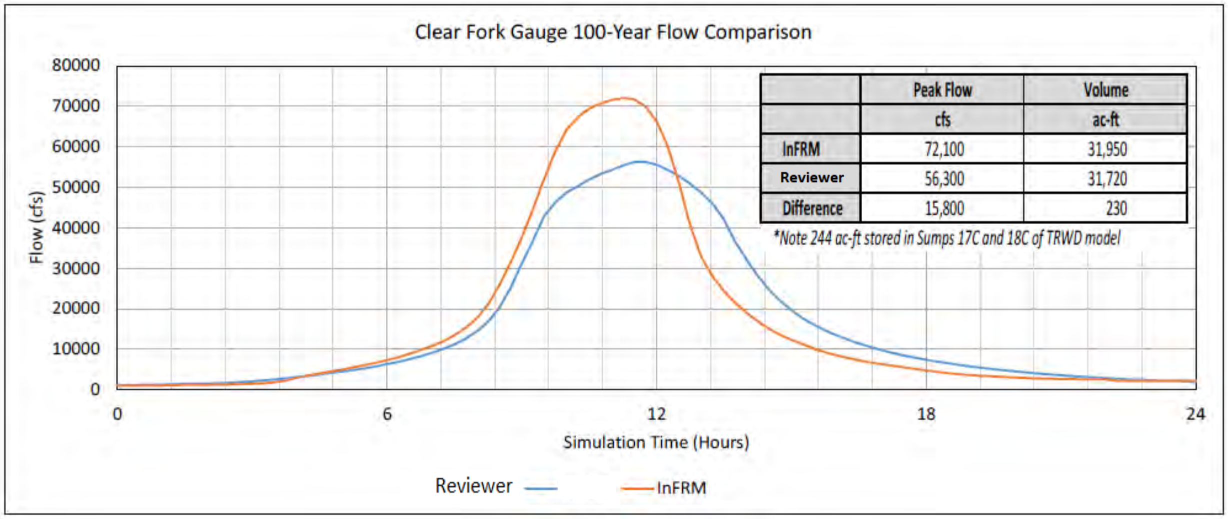


The Bear Creek watershed has a lag time estimate of 5.5 hours. The plots above illustrate that this lag time is too long when compared to observed storm events on the Mary's Creek watershed. The effect of a lag time that is too long is the underestimation of peak discharges

While this comparison does not prove the Bear Creek discharges are too low, it does indicate that applying the Bear Creek parameters to Mary's Creek would be inappropriate and result in an underestimation of the flashiness or peak discharge estimates for the watershed.

Similarities between the Bear Creek and Mary's Creek watershed's led to some additional investigation of the Bear Creek watershed parameters. As mentioned previously, additional methods such as NRCS TR-55, HEC-RAS 2D Rain-on-Grid, as well as additional HMS model calibration consistently pointed to a much shorter lag time (2-3 hours) than was originally estimated (5.5 hours). The lag time for Bear Creek was reduced to 2.75 hours.

5. **Flow Comparison with Reviewer Model**– The Reviewer has an in-house model used for real-time flood forecasting in the Fort Worth Floodway. The model uses HEC-HMS to compute runoff for tributary areas (Mary's Creek), local drainage, and interior sump area drainage. A 1D unsteady HEC-RAS model is used to dynamically route the flows through the Fort Worth floodway and the adjoining sump areas. This model was well calibrated upon development and has been regularly used to produce favorable results during real-time simulations. With all that said, applying the same 100-year rainfall onto the Reviewer's model while using losses recommended by the Trinity WHA produces a flow of 56,300 cfs at the Clear Fork Trinity gage site. This same location has a 100-year flow of 72,100 cfs recommended in the WHA. Both of these models have shown to produce reliable results and are backed up with favorable calibration plots. There is concern, however, that the two models can produce 100-year flow estimates that are nearly 20,000 cfs apart.



It is understood that in hydrologic modeling there can be a wide range of "acceptable outcomes". In this case, the modeling does not agree with the statistics, the modeling results do not agree with the results of other models, and the results showing the area to be by far the most responsive to flooding in the entire Trinity watershed, on par with a Hill Country watershed. With all of that said, it is recommended that additional analysis be performed to determine the reasonableness of the parameters used for the hydrologic modeling. A possible approach would be a HEC-WAT analysis that can sample from a range of meteorological, watershed parameter, and antecedent condition inputs to produce a more robust assessment of the flood risk on this reach.

Based upon our analysis of the results in this report, the Reviewer would request that the InFRM team please review the request to undertake additional work to determine if the results for Mary's Creek and the Clear Fork are reasonable and consistent with other watersheds in the Trinity Basin. The Reviewer will be glad to provide our information, data, models, and staff to help in this effort. Therefore, if it is determined this additional analysis is warranted, the Reviewer asks for said analysis be completed and provided for review prior to any public release of results influenced by Mary's Creek and the Clear Fork.

Comment 5 Response: The current study has resulted in a very thorough understanding of the Mary's Creek watershed response to rainfall. It is acknowledged that there is significant variability in hydrology, particularly in meteorological patterns such as storm duration as well as antecedent conditions (wet, average, dry). The model parameters, such as rainfall and losses, as well as study methods for this reach were consistent with the rest of the watershed, with differences in results being explained by the site specific runoff characteristics or rainfall volume differences. The WHA results are considered the best available estimates for long term flood risk, however there is residual uncertainty and additional analysis is warranted but based upon input from FEMA, this will need to be performed as part of a separate study at a later date. Please see response from FEMA regarding the estimated timing for which the WHA results may be up for consideration by Communities for potential BFE updates.

"We note the concern that accepting the WHA may lead to higher 1% annual chance flood elevations, ie, base flood elevations (BFEs). FEMA has a rigorous and lengthy public acceptance process before any modifications to BFEs incurred due to this WHA data will need to adopted by communities. At this time, that process is a minimum of five years in the future, therefore, there will be ample time for affected communities and stakeholders to demonstrate what, if any, better data exists on this update of hydrology, which incorporates upward of 40 years of additional records from the effective FIS hydrology." – FEMA, November 2020

USACE would welcome the opportunity to partner with the Reviewer in the planning, evaluation, completion and application of any future additional analyses and future studies. At this time, a future study is anticipated through the Mary's Creek watershed as part of the Transportation and Stormwater Infrastructure (TSI) study. While the scope is still in development, the Reviewer is one of the Project Team members for the study.

6. **West Fork at Fort Worth Results Comparison to Statistical Hydrology** - The conditions on the West Fork Trinity River below the confluence with the Clear Fork are heavily influenced by the flows from the Clear Fork. The flows computed using HEC-HMS plot outside the confidence bands of the statistical analysis. This stretch of the West Fork Trinity River is also part of the Federal levee system, and any additional analysis used on the Clear Fork should be extended to this stretch of the West Fork.
   Comment 6 Response: The response from Comment 1 discussing the differences between the statistical analysis results and the recommended results apply to this location as well. While this location includes 20 additional years of record, it is still significantly less record length (300-400 years) than would likely be required for a stable 100-yr flood estimate. It is agreed that additional analysis on the Clear Fork should include this reach which is part of the Federal levee system, but that analysis will likely be performed in a separate future study for the levee system.

7. **Cedar Creek Reservoir Data** - The Reviewer will provide elevation-storage-discharge relationships that more closely mimic Cedar Creek spillway operation policy. The Cedar Creek Spillway Policy can be summed up by the following:

   1. Do not raise the eight tainter gates at rates any faster than 2 feet/hour. (Roughly 12 kcfs to 13 kcfs per hour)
   2. Release 50 percent of all inflow if the lake is at or below elevation 322.7 and 100 percent of all inflow (up to spillway maximum capacity) if the lake is above elevation 322.7. Maximum spillway capacity is approximately 112 kcfs.
   3. Operate the two bascule gates only after all eight tainter gates are fully opened.

   It is understood that this type of operational scheme cannot be entered into HEC-HMS for automatic operation. The Reviewer can provide either a reservoir outflow time series for each event based upon the final reservoir inflow hydrographs or simplified rating curves that roughly mimic the policy. Although, it is possible that these rating curves will be event-specific. Based on internal simulations the 100-year elevation would be lowered by nearly 1-foot and would be more in line with the 1% ACE reservoir elevation published in the Henderson County FIS.

Comment 7 Response: The Elevation-Storage-Discharge information was updated.

8. **Lake Bridgeport Data** - The Reviewer will provide elevation-storage-discharge relationships currently in use. The relationships have been adjusted to the NAVD88 vertical datum. Starting pool elevation should be 836.0 ft-NAVD88, as that is the elevation recognized by the Reviewer as top of conservation pool.
Comment 8 Response: Concur. The modeled top of conservation was originally 836.3 ft-NAVD but was updated to the 836.0 ft-NAVD. Elevation-Storage-Discharge information was also updated.

9. **Eagle Mountain Lake Data** - The Reviewer will provide elevation-storage-discharge relationships currently in use. The relationships have been adjusted to the NAVD88 vertical datum. Starting pool elevation should be 649.1 ft-NAVD88, as that is the elevation recognized by the Reviewer as top of conservation pool.
Comment 9 Response: Concur. The modeled top of conservation matches that identified by the Reviewer. Elevation-Storage-Discharge information was updated.

10. **Marine Creek Lake Data** - The Reviewer will provide elevation-storage-discharge relationships currently in use. The rating used in the model is not restrictive enough. The Reviewer rating has been calibrated to observed pool levels and is regularly used in real-time runoff modeling performed by the Reviewer.
Comment 10 Response: The Elevation-Storage-Discharge information was updated.

Responses to Peer Review Comments - Part 2

The following comments on the InFRM Trinity WHA report were received on 11-Sep-2020. Responses from USACE and the InFRM team are shown in blue.

Peer Review Comments:

1. **Land Use / Percent Impervious Cover** - The Johnson Creek Watershed comprises approximately twenty percent (20%) of the City of Arlington, and is located in the Sub-basin West_Fork_S300. Please review the Land Use Percent Impervious values and Curve Numbers that were calculated in the 2017 Johnson Creek Hydrology Study and incorporated into the 2019 Tarrant County Floodplain Insurance Rate Maps. *A hyperlink to this report and models has been provided in a separate email.* According to the 2017 Johnson Creek HEC-HMS Model that was approved by FEMA, the percent impervious value for Johnson Creek is approximately 90%. However the percent impervious value in Sub-basin West Fork_ S300 = 52%.
The Time to Peak (Tp) for Sub-basin West_Fork_S300 at the confluence with the West Fork Trinity River (WFTR) is approximately 27 hours. The Time to Peak = 14 hours in the Johnson Creek Unsteady HEC-RAS Model that routed the Flood Hydrographs, near the intersection of Matlock Road and I.H. 20, downstream to the confluence with the West Fork Trinity River.
The Rush Creek Unsteady HEC-RAS Model that was adopted by the City of Arlington and was submitted to FEMA in 2017, indicates the Peak Discharges occur at approximately 12 hours at the confluence with Village Creek, located near Division Street, east of Dottie Lynn Parkway. However the Time to Peak for Sub-basin Village_Ck_S030 at the confluence with the West Fork Trinity River (WFTR) is approximately 29 hours.
Based upon the differences of the input and output between the City of Arlington's Rush Creek and Johnson Creek H&H Models, compared to the CWMS Rush Creek and Johnson Creek Sub-basins summary results; we are providing a hyper link to these City of Arlington's H&H Models and requesting their incorporation into the Revised CWMS Uniform and Elliptical Trinity Basin HMS Models.

Comment 1 Response: Please keep in mind that the purpose of the Trinity WHA is to estimate frequency flows for the larger streams and rivers within the 18,000 square mile study area. It would neither be appropriate nor efficient to try to incorporate detailed tributary models into the basin-wide Trinity HEC-HMS model. It is appropriate to develop separate detailed models for these tributaries, as the City of Arlington has done for Rush Creek and Johnson Creek. When requested, USACE can help local governments to update their detailed tributary hydrologic models to be more consistent with the InFRM basin-wide model through its Floodplain Management Services (FPMS) program. USACE is currently engaged in this type of effort with the City of San Marcos within the Guadalupe River basin.

Regarding the percent imperviousness, we could not find a percent impervious value of 90% in the Johnson Creek HEC-HMS model or report. We did find that the average SCS Curve Number was about 90. The 52% Imperviousness for West_Fork_S300 came from the CDC HEC-HMS model with the NCTCOG's 2005 Land Use values for existing conditions, and that value still appears reasonable based on the mixed land uses observed on aerial imagery within that subbasin. While the commercial and industrial areas north of Division Street may be more than 90% impervious, the single family residential areas between Division Street and I-20 would have lower percent impervious values.

Regarding the time to peak, the Trinity WHA HEC-HMS model uses a 48-hour storm duration, so the peak rainfall does not occur until 24 hours into the simulation. Whereas the Johnson Creek and Rush Creek models use a 24-hour storm duration with a peak rainfall that is 12 hours into the simulation. Therefore, most of the difference in timing between these two studies is due to the timing of the peak rainfall. The Snyder's Lag times for West_Fork_S300 and Village_Ck_S030 subbasins are 3.5 and 5.4 hours, respectively. These are the same subbasin lag times that are being used in the current CDC HEC-HMS model for baseline conditions.

2. **Routing** - Please provide the input and output parameters that were utilized to calculate the one (1) hour Lag Time for the Routing Reaches West_Fork_R251 and West_Fork_R264.

Comment 2 Response: These 1-hr lag routing reaches were added during calibration of the HEC-HMS model to better match the observed travel times between the West Fork at Beach Street and the West Fork at Grand Prairie USGS gage. The Modified Puls routing reaches on the West Fork did a good job of matching the observed peak attenuation, but the timing needed a slight adjustment. Please see Appendix B for more information on the calibration of these reaches.

3. **Routing** - There are storage volumes / discharges and land use parameters available from regional watersheds that will have an impact on the peak discharges of the Trinity River and its major Tributaries.
We request that the Current Effective Hydrologic and Hydraulic Model Parameters for Big Fossil Creek, Big Bear Creek, Village Creek upstream of Lake Arlington, and other watersheds similar in size to these sub-basins be incorporated into the CWMS Trinity River Basin Models.

Comment 3 Response: Since the purpose of the Trinity WHA is to estimate frequency flows for the larger streams and rivers within the 18,000 square mile study area, it would not be appropriate to incorporate all of the small, detailed subbasins from tributary models into the basin-wide Trinity HEC-HMS model. The land use parameters came from the CDC HEC-HMS model with the NCTCOG's 2005 land use values for existing conditions and have been approved by the regional governments. We can, however, incorporate the best available storage data into our existing routing reaches.

We received FEMA's effective HEC-RAS and HEC-2 models for Big Fossil Creek, Big Bear Creek, Little Bear Creek, and Village Creek and compared them to our existing model data. Of those, only Big Bear Creek and Village Creek currently have routing reaches in the Trinity WHA model.

We updated the Big_Bear_Ck_R010 and Village_Ck_R010 routing reaches with storages from the effective FEMA models. values for existing conditions and have been approved by the regional governments.

4. **Routing** - Please incorporate the current storage volumes in HEC-RAS from the Viridian Development. This project received a LOMR and also a CDC Permit.

   Comment 4 Response: The Storage Discharge relationship for Routing reach West_Fork_R262 reflects the completed construction of the Viridian Development, as modeled in the current CDC HEC-RAS model.

5. **Routing -** There appear to be similarities between the 1994 Current Effective HEC-2 Village Creek Storage Volumes and the Routing Reach Village_Ck_R020, downstream of Lake Arlington. Based upon the changes in the storage volumes within the Floodplain that have occurred since the early 1990's, we would like to provide either the 2009 TNRIS Lidar or the 2018 NCTCOG lidar for your review and inclusion along Village Creek downstream of Lake Arlington, into the CWMS Models. Please let us know if you do not have these current topography sources.

   Comment 5 Response: The storage volumes for Village_Ck_R020 were taken from the current CDC HEC-HMS model. The InFRM team generally uses the best available routing data from existing HEC-RAS models. If an updated LiDAR-based HEC-RAS model is available for that reach of Village Creek, then we could use it to update the storage volumes in our model. However, it is not within the scope of our study to develop new HEC-RAS models.

6. **Routing -** The TWDB 2007 Volumetric Survey utilized NGVD 1929 Datum indicates Lake Arlington has a total reservoir capacity of 40,188 Acre-Feet at conservation pool. The CWMS Lake Arlington storage at Time 0:00 is 40,329 Acre-Feet.

   Although the beginnings of these storage volumes difference is less than 1%, can you please confirm if there was an adjustment factor applied, since the InFRM Report utilizes the NAVD 1988 Datum?

   Comment 6 Response: The difference between the two datums is negligible at Lake Arlington. The CWMS model utilizes the TWDB 2007 Volumetric Survey with a capacity of 40188 acre-feet at elevation 550.0 ft. For the frequency storms, the initial pool elevation was set at 550.07 feet to allow a small amount of flow (28 cfs) from Lake Arlington at the beginning of the simulation. This small difference in elevation would explain the small difference in storage.

7. **Peak Elevation** - The Uniform Rainfall peak water surface elevation on Lake Arlington = 564.8'; and the peak water surface elevation from the Elliptical Models = 562.4. Since a large portion of the watershed upstream of Lake Arlington is pervious, and will continue to be developed, the Reviewer will most likely continue to utilize the Current summary of reservoir elevations, published in the Tarrant County FIS, for the 1% Annual Chance Event = 563.8'.

   Comment 7 Response: The Trinity WHA is not a regulatory product, and it is up to cities to choose how best to incorporate its results. Since Lake Arlington has less than 150 square miles of drainage area, an elliptical storm was not optimized for the area above the lake. Therefore, the results of the uniform rainfall results would be the best estimate of the frequency pool elevations. According to the depth area analysis for Lake Arlington, the 1% peak pool elevation was 564.0 ft, as shown in Table 11.1 in the InFRM report. This is only a 0.2 ft difference from the current FIS value.

8. **Gage Input** - Please review and incorporate the USGS Lake Arlington Discharge Gage Data.

   Comment 8 Response: Concur. The InFRM team did use the reservoir pool elevation data from USGS gage 08049200 Lk Arlington at Arlington, TX in its calibration of the HEC-HMS model.

9. **Drainage Area / Peak Discharge** - The March 21, 2019 Dallas County Flood Insurance (FIS) Table 4, indicates the Drainage Area of the West Fork of the Trinity River = 2,622 square miles, below the confluence of Johnson Creek.
   However in Table 6.5 on page 94 of the WHA Report, the listed drainage area at West_Fork_J170 = 3,047.8 square miles.
   In the Tarrant County FIS, on the West Fork Trinity River at the confluence with Big Fossil Creek, the drainage area = 2,267 square miles. However at West_Fork_J160 the drainage area = 2,762.5.
   Can you please provide guidance on the differences in drainage areas at these two different Hydrologic Elements?

   Comment 9 Response: It appears that the primary difference at both of these locations was whether or not the area above Benbrook Lake was included in the listed drainage area. Table 6.5 in the InFRM report lists total drainage area, which includes the area above Benbrook Lake. Subtracting the Benbrook Lake area from the drainage area in Table 6.5 results in a difference of only 4 square miles at the West Fork below Johnson Creek (West_Fork_J170). In the Tarrant County table the West Fork "at the confluence of Big Fossil Creek" and "downstream of confluence with Big Fossil Creek" are listed separately. Tarrant County's FIS lists the drainage area of the West Fork downstream of confluence with Big Fossil Creek as 2,340 square miles. When you add Benbrook Lake's drainage area to that number, the difference is only 6 square miles downstream of Big Fossil Creek (West_Fork_J160).

10. **Drainage Area / Peak Discharge** - The Uniform Rainfall HEC-HMS Model calculated a Peak Discharge at West_Fork_J170 = 104,981 CFS below the Johnson Creek confluence. However a Peak Discharge = 98,800 CFS is listed on Table 6.5 at this location, can you please provide confirmation, which discharge was calculated from the HEC-HMS Model?

    Comment 10 Response: The 104,981 cfs peak discharge is from the model's 100-yr simulation run and does not include the area reduction factors for the point rainfall depths. The results in Table 6.5 were taken from the depth area analyses in HEC-HMS, which include the proper area reduction factors.

    However, due to the large drainage areas of these locations on the West Fork, the elliptical storm results are recommended. The 100-yr peak flow at West_Fork_J170 from the elliptical storm is 77,800 cfs.

11. **Report Distribution** - Although these reports are in the Draft Phases, we recommend that the InFRM Reports also be provided to TXDOT and Emergency Planners to ensure they are aware of potential changes to the flood stage elevations within the Trinity River Basin.
Comment 11 Response: Concur. The InFRM team continues to try to engage with as many stakeholders as possible. If you have a good POC at TXDOT, please let us know. Our previous POC has left the organization. We have been coordinating with the NCTCOG's Flood Management Task Force (FMTF) throughout the study and would look to those members to share the study report and results with other pertinent staff within their respective cities. The state agencies of TDEM and TWDB have also been briefed on these studies. Once the report is finalized, it will also be available for public download from InFRM's website.

12. **Other Review Comments** - If review questions from other agencies are available, can you please send us their comments?
Comment 12 Response: The InFRM team is still in the process of addressing comments from various stakeholders. An appendix to the InFRM Trinity report has been added to include all comments and responses.

13. **Trinity Hydraulic Models** - After the input parameters and output data has been reviewed and approved from the CWMS Trinity Basin Hydrology, we request that the Trinity River Hydraulic Models be updated with the most current topography sources available and field surveyed cross sections of as-built projects be incorporated from the Trinity River Main Stem and the major tributaries, such as the West Fork, Elm Fork, East Fork, and Clear Fork.
Comment 13 Response: USACE supports updating the hydraulic models. However, the NCTCOG's FMTF is the governing body over the Trinity River hydraulic models through the CDC program. Therefore, any scope to update the Trinity River hydraulic models would need to be coordinated through that group.

Responses to Peer Review Comments - Part 3

The following comments on the InFRM Trinity WHA report were received from the InFRM Academic Council on 04-Dec-2020. Responses from USACE are shown in blue below each comment.

Review of InFRM Watershed Hydrology Assessment for the Trinity River Basin

Reviewer 1 from the InFRM Academic Council

SUMMARY

The reviewer was tasked by the Interagency Flood Rick Management (InFRM) team to review "*Watershed Hydrology Assessment for the Trinity River Basin*" conducted by the U.S. Army Corps of Engineers (USACE) – Fort Worth District (FWD). This report starts with thorough background information and a compelling motivation of the study followed by a well-documented section of the methodology of estimating the frequency flow values throughout the Trinity River Basin. With the findings from performed statistical analysis, rainfall-runoff watershed modeling, and reservoir modeling, the engineering team at USACE came up with recommended frequency flows for future adoption in the Trinity River Basin based on a combined modeling approach of using NOAA Atlas 14 uniform rainfall, elliptical storms, and reservoir studies. The reviewer thinks that the report is well written with comprehensiveness and clarity using the most updated data and sciences available.

The reviewing process involves checking and verifying technical components in hydrology and hydraulics in terms of storm selection, hydrologic modeling, and rainfall depth. The reviewer found that the selected storms for calibration of the models were consistent with those identified in a prior study conducted the University of Texas at Arlington (UTA) team for the Trinity River Basin. The hydrologic models (HEC-HMS) of the Trinity River Basin mainly use the Standard Snyder Method for the transformation component. Four routing methods like the Modified Puls, Muskingun, Lag, and

Straddle Stagger methods are found in the HEC-HMS models, while the Modified Puls (100+ reaches) and Muskingum (60+ reaches) methods are used more frequently than the others among the four. The reviewer also verified the uniform rainfall depth utilized in the models and found them consistent with the published values from the NOAA Atlas 14 website for corresponding counties in the Trinity River Basin. To the reviewer's perspective, this report is well organized with extensive technical details, but the reviewer believes that it would be further improved by addressing and providing clarifications to the comments generated from this reviewing process, which will help the InFRM and USACE engineering teams maintain the superior quality of their technical products for future engineering applications and adoption.

MAJOR COMMENTS

Comment 1: The Methodology section should be expanded considerably to include a basic list of the methodologies used in the study. The current content of this section seems too abbreviated to the reviewer. Section 4 mentions parameters and data used in the analysis that are not mentioned or explained in the methodology section. For example, Sections 4.2 and 4.5 mention the Trinity CWMS study, but little information of CWMS is not mentioned and/or referred in the document.

Comment 1 Response: Section 3 (Methodology) of the main report is intended to provide a brief description of the different methods utilized in the WHA multi-layered analysis. Additional detail for the methodology and data used (Including the CWMS study) is included in the following sections of the main report, with even more detail in the appendices. Including all the information/detail from the appendices would have increased the main report size from 265 pages to 1,000+ pages. This section was modified to reference the following sections and appendices for more detail.

Comment 2: In Section 6.3 (Page 60), the report describes the sources to estimate the initial parameters for HEC-HMS model. The reviewer thinks that there is a lack of clarity in explaining how the initial loss and constant loss rate values were determined for this part of work. Did the USACE engineering team follow the same method as documented in the Reconnaissance Report (USACE, 1990), which was mainly based on the sand percentage of the sub-basins? The reviewer thinks that an elaboration with detailed procedures is needed for initial loss estimation.

Comment 2 Response: Each section in the main report is intended to provide a brief description of the different methods utilized in the WHA multi-layered analysis. Additional detail for the methodology used in developing rainfall-runoff model parameters is included appendix B. Additional detail was added to the appendix to clarify that the initial estimates for loss rates for model calibration were established using the HEC-HMS Technical Reference manual recommending loss rates that vary based on soil type/group. Loss estimates were adjusted significantly during model calibration due to different soil moisture conditions leading up to each storm event. The WHA frequency storm simulations used loss rates based on the sand percentage and varied for each frequency event.

Comment 3: In Section 6.4 (Page 62), the calibration was performed based on historical storms occurring over a 25-year span (1991-2016). Normally, a watershed of such size might have experienced noticeable changes in land cover/land type that really need to be reflected in hydrologic models. However, the reviewer noticed that the developed HEC-HMS models only utilize the land cover information based on the 2011 condition to represent the recent/current watershed situation. The reviewer thinks that it is necessary to provide explicit explanations/justifications on why the same imperviousness values were used to represent the watershed conditions over the period of 25 years.

Comment 3 Response: Most of the calibration events occurred between 2000 and 2015, with 2011 falling within a few years of most of the events. Recomputing specific percent loss values for each calibration event may slightly adjust the calibrated losses but would not likely change the final frequency runs significantly since the final frequency loss rates are determined using the standard Fort Worth District method based on sand percentage and the final percent impervious values were updated using the latest percent impervious information (2016).

Comment 4: In Section 6.5 (Pages 90-91), the report summarizes the decision-making process for selecting parameters for the final model based on calibrated parameters. Due to the past experiences with HMS model calibration, the reviewer envisions that the calibrated loss parameters (IA and CL) would exhibit large variations. The report also confirms the reviewer's speculation as "*These losses (initial IA and CL values of various frequencies) also fall well within the band of observed losses from the calibration storms*". The reviewer thinks that including the range or variation of calibrated loss parameters into the section will better demonstrate the comparisons between the calibrated and final loss parameters. A comparative analysis will reveal how "*conservative*" the HMS model is set up and the level of uncertainties associated with the rainfall-runoff modeling approach.

Comment 4 Response: Calibrated loss rates do exhibit large variations from one storm event to the next. This phenomenon has been observed across several watersheds across Texas, including the InFRM Guadalupe River WHA. Some areas within the Trinity WHA model exhibit more variation than others but the variation is present across the different soil types. For example, there are soils with high runoff potential (Group D, Clay) that have both high and low losses for each of the different events. See subbasins above Richland-Chambers reservoir as an example for soil group D. It should also be noted that while the calibration events do provide some information about observed losses, the limited number of calibration events that were used are not necessarily a complete picture of what loss rates are possible across the watershed. This Section 6.5 was modified to refer to Appendix B for the full range of calibrated loss rates.

Comment 5: In Section 6.4.3 (Page 88), the report describes the investigation for Mary's Creek. For HEC-RAS 2D model, it says "*The model was calibrated and validated, with there being a very small difference between* <u>*the calibrated model and the uncalibrated model*</u>". This statement sounds vague to the reviewer. Is there any figure/table/result that can support this statement? In Appendix F, the reviewer did see several comparisons of the observed and calibrated hydrographs but could notfind the comparisons as described between the uncalibrated and calibrated hydrographs.

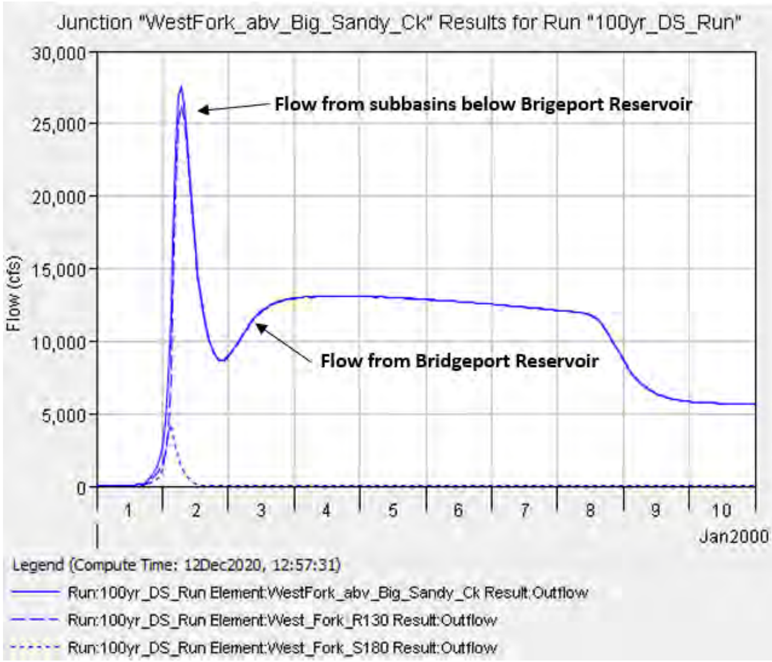
Comment 5 Response: Figure 4.3 of Appendix F illustrates the difference between the calibrated and uncalibrated RAS 2D model 1% annual chance hydrographs. The uncalibrated model produced a peak discharge 6% lower than the calibrated model. The results from the two models are identified in the figure as "RAS – Final n values" and "RAS Not Calibrated". A note was added to the main report mentioning the 6% difference refers to the figure.

Comment 6: In Section 7.2 (Page 104), the report describes the elliptical storm parameters and methodology with a lack of clarity in explaining how the ellipticals storm parameters were determined for this study. It will provide tremendous benefits for future references if detailed procedures could be incorporated in addition to just showing Figure 7.3 alone.

Comment 6 Response: The information in this section of the main report is intended to provide a brief description of the elliptical design storm methodology. Additional methodology details may be found in the appendices. Including all the information/detail from the appendices would have increased the main report size from 265 pages to 1,000+ pages. This section was modified to reference the following sections and appendices for more detail. A note was added to section 7.2 referring to Appendix C – Elliptical Frequency Storms in HEC-HMS for additional detail.

Comment 7: In Section 7.7 (Page 124), the report compares the results from using elliptical storms and uniform rain scenarios. From Figure 7.14, the reviewer noticed that the differences larger than 10% in peak discharge are mainly for the nodes with drainage areas between 300 to 800 square miles. The report acknowledges the differences between the two approach (See "*Though there is some scatter in the difference between methods around the 400 square mile node*"). The reviewer wonders if there is any explanation for these scatters with large differences. The reviewer also noticed in Figure 7.14 that there are five data points showing positive differences, meaning the peak discharge values generated from the elliptical storms are larger than those from the uniform rain scenarios. Given that elliptical storms in general carry less rainfall depth than that of uniform rain, the elliptical storms tend to generate lower peak flow than that of uniform rainfall. Is there any explanation for the nodes with positive differences?

Comment 7 Response: The differences are very small (+2%) where the elliptical design storms are producing higher peak discharge estimates than the uniform rainfall method. The West Fork above Big Sandy Creek location was investigated. In this case the total drainage area for this gage is approximately 1,170 square miles and includes Bridgeport Reservoir (TRWD) which has a drainage area of 1,111 square miles. The model simulation indicates that Bridgeport Reservoir attenuates upstream flood peaks such that the peak discharge at the West Fork above Big Sandy Creek is primarily driven by the drainage area downstream of the reservoir. Because of the differences in how rainfall is reduced based on storm location and drainage area, the subbasins downstream of Bridgeport Reservoir received slightly more rainfall volume for the elliptical design storm than they did for the uniform rainfall storm. This caused the subbasins downstream of Bridgeport Reservoir to have higher peak discharges for the elliptical design storms than the uniform rainfall storms. This was just one example and there could be other factors contributing to the small differences between the two storm types.



Comment 8: In Section 8, the report includes the methodology and results of the POR hydrologic analysis and results comparison between RiverWare simulated and statistical analysis. On Page 133, it says "*RiverWare 7.0.4 was used to analyze the hydrology and hydraulic processes of reservoirs within the Trinity River Watershed. The hydrology and hydraulic analysis includes the use of a multiple-run and simulation-run RiverWare model*". Based on the reviewer's knowledge, RiverWare model does not have the capability of hydraulic analysis. To avoid confusion, please change the "*hydrology and hydraulic analysis*" to "*hydrologic analysis*".

Comment 8 Response: Concur. The description was modified.

Comment 9: On Page 136 (Section 8.7), Table 8.3 shows the analyzed stream gages with peaking factors. Since the peaking factors of some gages show as N/A, the reviewer thinks that it will be more beneficial to add explanations/clarifications for these N/A values.

Comment 9 Response: Concur. The following explanation was added to the report. "A Peaking Factor of 'N/A' signifies that no peaking factor was applied to that dataset. It was determined that the difference between daily and instantaneous annual peak discharge was negligible regarding the present analysis. If two peaking factors were applied to the gage, they are both listed as well as the inflection point in log10 scale."

Comment 10: On Page 137 (Section 8.7), the report mentions that 10,000 ft^3/s is used as a separating threshold to apply different peaking factor for the Grand Prairie gage. Is this separation value (10,000 ft^3/s) selected as the universal threshold for other gages? If yes, please explain the rationale behind this number. If not, more details are needed for readers to better understand the rationale of determining separation values for different gages.

Comment 10 Response: Concur. The following text was clarified in the report. *"At five of the analyzed gage locations (Fort Worth Clear Fork, Grand Prairie, Carrollton, Crandall, and Rice gages), a separate flow regime was observed in the upper end of the hourly vs. daily peak flow relationship, and two peaking factors were developed for lower and upper daily peak flows. For example, Figure 8.5 shows the two separate relationships observed for the Grand Prairie gage, and the two peaking factors derived from these separate relationships. The two linear fit lines are plotted along with their formulae, and an equal value line is plotted for reference. The first peaking factor was applied to simulated daily peak flows less than 10,000 ft^3/s, whereas the second peaking factor was applied to simulated daily peak flows greater than 10,000 ft^3/s.* The inflection point between these two peaking factors is unique to each gage. Please refer to Table 8.3 for the inflection point at each gage. *The need for two peaking factors at several gage locations highlights a change in streamflow characteristics for the greatest magnitude events."*

Comment 11: In Section 11, the report provides the final recommendations of the frequency discharges for future adoption. The reviewer compared the 100-yr peak discharge values from the WHA report with those from the 2013 and 2020 CDC manuals for the 26 gages in the Upper Trinity Basin as shown in Table 1 below. Figure 1 is made to better illustrate the discrepancies between the WHA report and CDC manuals (2013 and 2020). Though the CDC reports are for the future 2055 scenarios, the inconsistent trend of differences (while some are higher, some are lower than WHA report) is found as a concern to the reviewer. The reviewer thinks that it is necessary to provide explicit explanations/justifications for the inconsistencies to facilitate future adoption. Forexample:

(1) For some gages (Eagle Mountain Reservoir, Lake Worth Outflow, West Fork Trinity River above the Clear Fork, Trinity River below White Rock Creek, Trinity River below Honey Springs Branch, and Trinity River below Five Mile Creek), the 100-yr peak discharge values from 2013 CDC

and 2020 CDC are close (difference within 3%), while they all show 10-40% larger values than those in the WHA report.

(2) For some gages (West Fork Trinity River below the Clear Fork, West Fork Trinity River above Marine Creek, West Fork Trinity River below Marine Creek, West Fork Trinity River above Sycamore Creek, West Fork Trinity River below Sycamore Creek, and West Fork above Big Fossil), the 100-yr peak discharge values from the 2013 CDC is close to those from WHA (difference within 8%), while the discharge values from the 2020 CDC are 17%-30% lower than those in the WHA report.

(3) For gages (West Fork Trinity River below Village Creek, West Fork Trinity River below Johnson Creek, West Fork Trinity River at Grand Prairie USGS gage, West Fork Trinity River above Big Bear Creek, West Fork Trinity River below Big Bear Creek, West Fork Trinity River above Mountain Creek, and West Fork Trinity River above the Elm Fork Trinity River), both 2013 and 2020 CDC reports show higher discharge values than those in the WHA report (the 2013 CDC report shows 14-40% higher and the 2020 CDC report shows 10-34% higher than those of the WHA report).

Table 1. Comparisons of 100-Yr Peak Discharge among Trinity WHA report, 2013 CDC Manual, and 2020 CDC Manual.

No.	Location Description		Trinity WHA Report	CDC_2013		CDC_2020		
		Contributing Area (mi^2)	100-YR (cfs)	100-YR (cfs)	Difference between WHA and CDC_2013	100-YR (cfs)	Difference between WHA and CDC_2020	Difference between CDC_2020 and CDC_2013
1	Eagle Mountain Reservoir Outflow	1,956.6	29,000	35,500	22%	35,800	23%	1%
2	Lake Worth Outflow	2,050.8	29,200	35,100	20%	35,400	21%	1%
3	West Fork Trinity River above the Clear Fork	2,078.7	25,300	35,100	39%	35,400	40%	1%
4	Clear Fork above Marys Creek	438.6	16,200	11,600	-28%	13,000	-20%	12%
5	Clear Fork below Marys Creek	492.8	68,700	48,500	-29%	27,600	-60%	-43%
6	West Fork Trinity River below the Clear Fork	2,601.7	75,100	69,400	-8%	48,700	-35%	-30%
7	West Fork Trinity River above Marine Creek	2,602.9	73,600	69,200	-6%	48,400	-34%	-30%
8	West Fork Trinity River below Marine Creek	2,624.6	76,000	71,500	-6%	50,500	-34%	-29%

9	West Fork Trinity River above Sycamore Creek	2,633.8	73,700	68,200	-7%	51,700	-30%	-24%
10	West Fork Trinity River below Sycamore Creek	2,673	77,300	83,500	8%	75,300	-3%	-10%
11	West Fork above Big Fossil	2,686	76,100	77,800	2%	64,700	-15%	-17%
12	West Fork Trinity River below Village Creek	2,983.1	89,200	110,400	24%	97,800	10%	-11%
13	West Fork Trinity River below Johnson Creek	3,047.8	77,800	109,000	40%	87,700	13%	-20%
14	West Fork Trinity River at Grand Prairie USGS gage	3,052.5	77,800	106,300	37%	87,500	12%	-18%
15	West Fork Trinity River above Big Bear Creek	3,054.7	73,000	99,200	36%	84,200	15%	-15%
16	West Fork Trinity River below Big Bear Creek	3,148	80,500	105,500	31%	95,300	18%	-10%
17	West Fork Trinity River above Mountain Creek	3,156.6	77,400	102,500	32%	91,400	18%	-11%
18	West Fork Trinity River above the Elm Fork Trinity River	3,474.2	78,800	103,100	31%	92,200	17%	-11%
19	Elm Fork Trinity River above Indian Creek	1,682.2	26,500	21,000	-21%	21,000	-21%	0%
20	Elm Fort Trinity River below Indian Creek	1,698.2	26,500	21,000	-21%	24,600	-7%	17%
21	Elm Fork Trinity River below Timber Creek	1,722.3	26,500	30,300	14%	35,600	34%	17%
22	Trinity River at Dallas, TX USGS gage	6,064.7	108,700	128,600	18%	119,800	10%	-7%
23	Trinity River below White Rock Creek	6,242.4	113,700	123,900	9%	127,500	12%	3%
24	Trinity River below Honey Springs Branch	6,265	113,800	130,200	14%	127,400	12%	-2%
25	Trinity River below Five Mile Creek	6,337.3	111,900	129,000	15%	126,900	13%	-2%
26	Clear Fork Trinity River above the West Fork	523	69,500	48,300	-31%	32,600	-53%	-33%

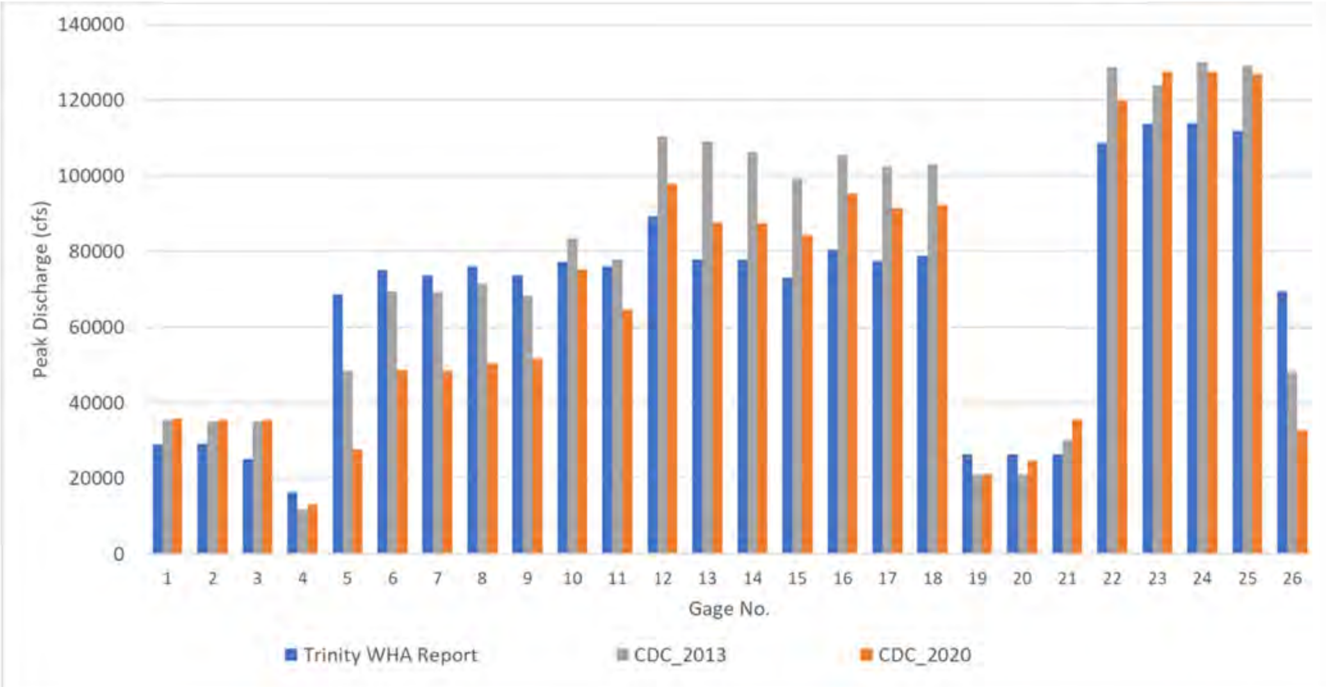


Figure 1. Comparisons of 100-Yr Peak Discharge among Trinity WHA report, 2013 CDC Manual, and 2020 CDC Manual.

Comment 11 Response: In general, the Trinity WHA is a multi-layered analysis where flood frequency estimates are investigated using several different methods. While some of the methods have been used previously but include additional detail, such as additional rainfall-runoff model calibration to observed streamflow data, some of the methods are new methods that have not been used in the area to produce flood frequency estimates, such as reservoir simulation using the USACE Risk Management Center Reservoir Frequency Analysis (RMC-RFA) software. The intent of the WHA study is to develop existing land use condition estimates of flood frequency based on best available science, data, and techniques. The CDC modeling has the same goal, with the main difference being that future land use conditions are used to develop flood frequency estimates. It is not surprising that there would be many locations where the CDC model has higher flood frequency estimates since the CDC modeling utilizes future (Increased urbanization) land use, where there is a higher amount of rainfall that runs off into the creeks and rivers. Where the WHA results are higher, additional explanation is helpful. One of the most significant areas where the WHA flood estimates are higher originates at Mary's Creek near Benbrook and continues downstream through the Clear Fork and West Fork until just downstream of the confluence with Sycamore Creek where the CDC flows become higher. The primary cause for the increases through this reach are changes to the watershed parameters of the Mary's Creek watershed. In 1998, a USGS streamflow gage was installed on the Mary's Creek watershed, One of the benefits of this gage being installed was for the ability to see how rapidly water travels through this watershed. During the Trinity WHA rainfall-runoff model calibration to observed streamflow data, the results consistently pointed to a much more flashy/peaky watershed response than has been used in previous models, including the CDC model. One additional difference between the two models were the losses used for Mary's Creek. The CDC model used an initial loss of about 2.5 inches for the Mary's Creek watershed while the WHA used an initial loss of about 0.9 inches. The losses used in the WHA study for Mary's Creek were consistent with other losses in the model, while the CDC model used losses that were much higher than other subbasins within the model. Of the 102 subbasins within the Trinity River CDC model, 93 subbasins had an initial loss of less than 1 inch for the 100-yr event. Though specific documentation within the CDC model was not found explaining the reason for using the 2+ inches of initial loss, it is believed that these losses were used to force the model to compute results that were more similar to the statistical hydrology results for the West Fork and Clear Fork USGS streamflow gages near Fort Worth. This same process was not followed for the Trinity WHA as the results from each method were computed separately and compared to one another.

WHA results are also higher on the Elm Fork below Lake Lewisville. The results that are recommended are based on the results developed using the USACE RMC-RFA program. This is a stochastic modeling technique which allows factors such as inflow volume frequency estimates, starting reservoir elevations, and observed inflow hydrograph shapes to all be considered and varied through many simulations to produce a reliable stage-frequency estimate for a reservoir. This is a very detailed analysis technique that is currently in use for USACE dam safety studies although it has not been used previously to provide flood frequency estimates in the CDC program. Reservoir study results using RMC-RFA were used below the USACE reservoirs until a higher flood frequency estimate was computed using the rainfall-runoff modeling results. Additional detail regarding the methodology used to compute the discharges below the USACE reservoirs can be found in Appendix E – Reservoir Studies.

The difference between the 2013 and 2020 values is a misprint within the CDC manual (2020 version). The 2020 version published flood frequency estimate tables from an older version of the CDC model. The discharges have not been updated since those identified in the 2013 CDC model version.

MINOR COMMENTS

Comment 1: On Pages 13-14, please place a space between the numbers and “cfs” to keep consistency throughout the report. Please change “sq-miles” to “sq mi” per the Terms of Reference.

Comment 1 Response: Recommendation incorporated.

Comment 2: On Page 22, it will be more beneficial if the USGS gage numbers can be added for the corresponding locations in Table 2.1. Also, can Table 2.1 be presented before Section 2.2.1 since it is mentioned in Section 2.2? It currently does not appear until Page 22, when only mentioned on Page 18.

Comment 2 Response: Recommendation incorporated.

Comment 3: On Page 24, some division lines of the Table 2.3 are missing. The same problem for Table 4.1 on Page 27. Please double check the format of the tables throughout the report.

Comment 3 Response: Recommendation incorporated.

Comment 4: In Page 34, Table 5.1 mentions three columns that are not addressed in the text before the table: “Low-outlier threshold used”, “Kendall’s Tau of analyzed annual peak streamflows”, and “Kendall’s Tau p-value of analyzed annual peak streamflows”. The low outlier threshold and the

Kendall's tau test are explained in Section 5.1. Consider moving the table to be located after these are explained for clarity.

Comment 4 Response: Recommendation incorporated.

Comment 5: On Pages 51-57 (Section 5.3 and Section 5.4), the figure numbers in the main content do not correctly correspond to the Figures.

Comment 5 Response: Figure numbers updated.

Comment 6: On Page 85, Table 6.4 mentions that the "*The initial loss was adjusted according to the antecedent soil moisture conditions at the beginning of each observed storm event*." but antecedent soil moisture conditions or data had not yet been discussed. Please address this.

Comment 6 Response: Description updated to clarify how losses were adjusted.

Comment 7: On Pages 87-88, Figure 6.19 and Figure 6.20 are not mentioned in the main text.

Comment 7 Response: Text updated to reference figures.

Comment 8: On Page 104. Section numbers are not correct. Should be "7.2.1XXX".

Comment 8 Response: Section numbers updated.

Comment 9: On Page 115 (Section 7.6), it seems the figure numbers are not correct. It should be "Figure 7.10 and Figure 7.12 are examples of the 100yr 48hr heatmap results ....." instead of "Figure 7.11 and Figure 7.13". "Figure 7.12 and Figure 7.14 are examples of the final, total storm depths ...." should be referred as Figure 7.11 and Figure 7.13. Please double check.

Comment 9 Response: Figure numbers were updated.

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Reviewer 2 from the InFRM Academic Council

SUMMARY

This study updates the frequency flows and pool elevations for various stream reaches in the Trinity River Basin. Several methods were conducted to analyze the frequency flows and pool elevations: (1) statistical analyses (e.g., LP III) of historical stream gage data, (2) uniform rainfall-runoff modeling in HEC-HMS, (3) elliptical storm rainfall-runoff modeling in HEC-HMS, (4) extended period-of-record reservoir modeling using the RiverWare software, and (5) reservoir studies using the RMC-RFA program. Ultimately, the recommended frequency flows are based on the results of both uniform and elliptical storm HMS modeling, as well as the RMC-RFA reservoir analysis. The statistical hydrology and RiverWare analysis results were only used as reference or points of comparison, and were not adopted directly.

GENERAL COMMENTS

The authors ought to be congratulated on completing an excellent and comprehensive analysis on a major river basin in Texas. The report utilized the best available data for the study, and provided a detailed discussion on the various tools / methods used. The results of the study showed that the updated flow and pool elevation values for the various return frequencies differ from those published in the effective FIS. This was to be expected since this new study included additional gage records, improved validation / calibration of watershed models based on updated information (e.g., NOAA Atlas 14 2018 rainfall, high resolution spatial datasets), and the consideration / inclusion of new hydrologic methods (e.g., elliptical storm modeling). The report, however, could benefit from providing additional information or clarifications in certain sections as listed below.

SPECIFIC COMMENTS (COMMENTS / QUESTIONS SHOWN IN ITALICS)

- Section 4. Data collection
  - Elevation Data: USGS NED (2013) – 10m and 30m DEM – *Are DEM data from different years used to simulate / calibrate the historical storms (e.g., 1991 vs 2015 events), or did the study only used the most recent DEM for all calibration events?*

    Comment 9 Response: Separate DEM data was not obtained for each calibration event, The DEMs referenced were obtained from the USGS NED in 2013.

-
    - Landuse data: NLCD (2016) – *Same 2016 LULC data used for all historical storms? (Impervious cover for 1991 could be substantially different from impervious data for 2015)*

      Comment Response: The calibration events utilized percent impervious estimates from 2011 data. Most of the calibration events occurred between 2000 and 2015, with 2011 falling within a few years of most of the events. Recomputing specific percent loss values for each calibration event may slightly adjust the calibrated losses but would not likely change the final frequency runs significantly since the final frequency loss rates are determined using the standard Fort Worth District method based on sand percentage and the final percent impervious values were updated using the latest percent impervious information (2016).
    - Precipitation data: Hourly NWS NEXRAD Stage III grids for historical storms – *Are these data post-processed or QC'ed with available rain gages?*

      Comment Response: Yes. The precipitation is QC'ed and adjusted using hourly ground observations from various precipitation networks.
    - Section 4.9. *Add RiverWare to the list of programs used in this study (Table 4.3). Might want to also add HEC-RAS 2D to the list since it was used to develop a 2D model for Mary's Creek.*

      Comment Response: Concur. The table was updated to include these programs/versions.
- Section 5. Statistical hydrology
    - Section 5.1. Statistical analysis was done using the Log-Pearson III (LP3) distribution. *What is the basis for selecting LP3 as the main probability distribution method? Were other types of probability distribution considered for this study (e.g., Gamma, Kappa, Generalized Pareto)?*

      Comment Response: Federal agencies have been following set guidelines for flood frequency analysis beginning in 1967 with Bulletin 15 "A Uniform Technique for Determining Flood Flow Frequencies" published by the U.S. Water Resources Council (USWRC, 1967). Since then, the documentation and guidelines have undergone several revisions culminating in the present Bulletin 17C used for this report. Throughout these revisions, however, the LPIII distribution has remained the recommended distribution.

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- The authors acknowledged issues regarding the role of reservoirs in conducting statistical analysis for the stream gages. *Since the reservoirs differ in construction time, period of record, and rules of operation, how are the impacts of reservoirs being incorporated or addressed in the statistical analysis?*

  Comment Response: The influence of reservoirs is determined on a site-by-site basis. A streamgage record containing data from before and after reservoir construction must be adjusted to represent only current conditions in the flood frequency analysis. In some cases, modeled data may be substituted for this prior record by simulating the impact of reservoirs from the start of the gaged record (see chapter 8, RiverWare). In this case, that means removing the data from prior to the construction of the reservoir which most recently influences the dataset.

  In this case, the analyst must consider several factors. First, when does the USGS record begin to indicate peak code '6' (discharge affected by regulation or diversion)? However, multiple upstream reservoirs may have been completed over time, and each one's impact on the gaged location must be considered, not just the first or last to be completed. Next, how far downstream is the gaged location from the reservoir? Does flow primarily originate from the reservoir's releases? Or does more flow originate from the drainage area between the gage and the reservoir? Finally, a visual inspection of the gaged record (typically in log-transform) may reveal a shift in annual peak discharge attributable to a specific reservoir's construction.

  Each of these factors must be considered when evaluating a gage's record for FFQ analysis, which makes this decision a site-by-site determination.

- It was also mentioned that PeakFQ does not distinguish between USGS Code 6 (substantial regulated effects anticipated) and Code C (substantial urban effects anticipated). *Is this limitation important, and how does it affect the overall statistical analysis?*

  Comment Response: Because PeakFQ does not make this determination, it is up to the analyst to determine the effects of either of these values. Code '6' (discharge affected by regulation or diversion) tends to signify a shift in the data due to regulation (see response to above comment), whereas code 'C' (discharge affected by urbanization, agricultural changes, channelization, etc.) might signify a gradual change in peaks over time, such as an increasing trend due to increased impervious surfaces in the drainage basin as a result of development. The PeakFQ software makes no distinction between these two codes, but neither does it make a distinction between systematic record and urbanized/regulated record in the LPIII analysis. Therefore, it is up to the analyst to modify the input data as they see fit.

- Section 6. Uniform Rainfall-runoff modeling in HEC-HMS
  - Percent impervious (2011 NLCD) pg. 60 – *Not 2016 NLCD as stated in the Data Collection section (pg. 26)?*

    Comment Response: This section was clarified. 2011 percent impervious was available at study initiation and was used during model calibration. The final frequency runs used the updated 2016 percent impervious data.
  - Model validation / calibration – *Are all calibration events simulated using hourly NEXRAD rainfall data? Hourly data might not have sufficient temporal resolution to accurately represent the storms, especially for shorter events. For these cases, the authors might want to consider using hyetographs from available rain gages (e.g., Thiessen Polygon method) to further calibrate / validate their models.*

    Comment Response: Rain gage data is an additional option available for development of precipitation data over the study area. The trade off between using rain gages over NEXRAD products is that the potential gain with shorter time intervals available at the rain gages is potentially offset by the loss of information between rainfall gages where there is not a dense network of rainfall gages to accurately capture the spatial resolution of the storm. In addition, the cost of using the Thiessen Polygon method to develop rainfall across the watershed or 18k square miles would be very significant. This additional testing would need to be accomplished as part of a separate study at a later date.
  - Uniform rainfall frequency runs utilized 1-hr alternating blocks hyetographs – *Why not use 15-min alternating blocks, since the report stated that the latest simulations used 15-min time steps?*

    Comment Response: Smaller drainage areas which utilized the uniform rainfall method did use 15-min rainfall data and timesteps while the larger drainage areas elliptical design storm method used 1-hr rainfall and timesteps. Use of 15-min rainfall data over 1-hour data for such large drainage areas do not significantly change results.

- Frequency point rainfall depths (NOAA Atlas 14 2018) were approximately taken from the center of each county. *What does "approximately" mean? Does it refer to the centroid of each county based on a GIS analysis? Also, since the areal extent of each county ranges from tens of square miles to thousands of square miles, shouldn't the point rainfall be area-weighted (in particular for the larger counties)?*

  Comment Response: The center of each county refers to the centroid as determined by GIS analysis. Counties in Texas are much larger than the subbains in the rainfall runoff model. In general, a single county encompasses several subbasins and each county centroid was generally between 20-30 miles apart with small changes over that distance making the assumption reasonable for the purposes of this study.

- Section 7. Elliptical frequency storms
  - Uniform rainfall scenarios (Section 6) used depth-area analysis (not applicable for storm areas >400 mi^2) Solution: elliptical storms (example: PMP storms from HMR 52) to calculate depth area reduction (DAR) factors for drainage areas exceeding 400 mi^2 – *What is the basis for the 400 mi^2 cutoff, and not, e.g., 100-200 mi^2?*

    Comment Response: Since the 1960s, the standard practice for utilizing rainfall-runoff modeling to compute peak discharge frequencies has been to utilize the depth area reduction relationships contained in Figure 15 of the National Weather Service Technical Paper 40 (TP-40). The 400 square miles is based off of the depth area relationships not extending beyond that storm area. Sensitivity testing between the uniform rainfall assumption and elliptical design storm assumption indicate similar results (within 10%) for drainage areas up to 2,000 square miles.
  - Section 7.2.4. The authors stated that SCS Type II is the most applicable rainfall distribution for Texas. *For southeastern (SE) Texas that covers the downstream section of the Trinity River Basin, the most applicable SCS storm is type III. Please check /revise statement.* Comment Response: The statement was revised.
  - Section 7.4. Elliptical storm location and orientation. The report stated that storm center locations and rotations were optimized. *What does "optimize" mean? Does it mean choosing a location and angle that resulted in the highest rainfall magnitude for the area of coverage?*

Comment Response: Yes. The final optimized location and orientation leads to the maximum peak flow for a given location. The report was revised to clarify.

- Section 8. RiverWare analysis
  - *What is the difference between RiverWare and the more commonly used HEC-ResSim, and why was it used in this study instead of ResSim? Can it be integrated into the Trinity Basin CWMS?*

    Comment Response: Both RiverWare and HEC-ResSim are sufficient for reservoir POR analysis. RiverWare was utilized for this study primarily because of its availability as an existing model. CWMS does have the ability to integrate RiverWare..
  - Section 8.5. The report stated that the RiverWare model produced POR hydrology (naturalized local flows where major anthropogenic impacts have been removed). *Aside from reservoir regulation, are the impacts of urbanization (e.g., decreases in infiltration loss and increases in runoff) addressed in RiverWare?*

    Comment Response: Adjustments were not made to account for changes infiltration amounts. While it may provide some additional detail of how urbanization has impacted runoff volumes/peak discharges, this level of analysis detail is not typically performed for POR simulations.
- Section 9. Reservoir Studies.
  - *Elaborate on the reasons behind the discrepancies found between the RMC-RFA vs effective FIS results (pg. 170) – it was briefly discussed in Conclusions (Section 12)*

    Comment Response: The use of additional hydrologic methods such as the USACE reservoir study stochastic modeling techniques using RMC-RFA resulted in improved stage and flow frequency estimates when compared to methods used to produce estimates from several decades in the past. In other words, the FEMA FIS estimates utilized methods that relied upon statistical analysis of observed reservoir elevations or simulated reservoir elevations based on POR simulations, while the RMC-RFA estimates were based off of a more thorough analysis procedure which varied reservoir starting elevation, inflow hydrograph shapes, as well as inflow volumes. More detailed description of the techniques used to produce the RMC-RFA estimates can be found in Appendix E – Reservoir Studies.
- Section 10. Comparison of Frequency Flow estimates.
  - It was stated that the results of each method were considered and the recommended method

▪ is highlighted in blue – *not seeing any blue highlights in any of the table or figures.*

Comment Response: Concur. The tables were not highlighted and this statement was removed.

- *In the tables, the authors might want to consider putting "Not applicable" or "NA" in the blank cells, assuming that no data is available.*

  Comment Response: A note was added in the introduction to clarify the blank cells are where data was not available for this study..

- Section 11. Frequency flow and pool elevation recommendations
  - Results vary based on uniform rain HMS, elliptical rain HMS, and reservoir study (Tables 11.1 and 11.2). *Why are frequency flows from some relatively large rivers / subbasins (> 400mi^2) based on uniform rain HMS instead of elliptical HMS?*

    Comment Response: Based on comparison between uniform rainfall results and elliptical design storm results from Section 7, it was determined that use of uniform rainfall methodology was reasonable up to at least 1000 square miles. For drainage areas of about 2000 square miles, the difference between the two methods was about 10 percent. The decision was made to switch from the uniform rainfall to elliptical design storm results at a major confluence to avoid any small jumps or dips along the river due to a change in the rainfall method. The maximum drainage area where the uniform results are recommended is 828 square miles at the West Fork Trinity River above Beans Creek location.
- Section 12. References and Resources
  - *Fix typos on section headers – should be 12.1, 12.2, 12.3, … instead of 14.1, 14.2, etc. Also applied to the next section: 13. Terms of Reference (instead of Section 15), as well as the Table of Contents.*

    Comment Response: Concur. Typos were corrected.