Corridor Development Certificate

Trinity River and East Fork Trinity River Hydrologic and Hydraulic Model Extension

October 2024

US Army Corps
of Engineers
Fort Worth District

Executive Summary

General

The 1988 Record of Decision (ROD) and subsequent development of the "Upper Trinity River Feasibility Study" (UTRFS) by the United States Army Corps of Engineers (USACE) established the framework and criteria that became the 1st Edition of the Corridor Development Certificate (CDC) Manual in 1991. Several additional editions have been published since 1991, however the downstream limit of the Regulatory Zone has not been extended. Several communities downstream of the current Regulatory Zone have expressed interest in participating in becoming a participant in the Common Vision Program thus creating a need for an extended set of CDC hydrologic and hydraulic models.

Model Development

Baseline and future (2055) land use coverage was previously obtained from the NCTCOG as part of the 2013 CDC Update. Additionally, Environmental Protection Agency (EPA) Integrated Climate and Land-Use Scenarios (ICLUS) future land use data was obtained as a publicly available dataset that covers the entire nation through the year 2100 (EPA, 2016). The ICLUS data was especially helpful providing future land use estimates for areas that were not included in the NCTCOG land use data. This information was used to update the existing conditions modeling and the results from the FEMA sponsored Interagency Flood Risk Management (InFRM,2017) Trinity River Watershed Hydrology Assessment (WHA) study (InFRM,2017) and FY2017 FEMA East Fork Trinity River and Upper Trinity River Watershed Risk Map Project to future (Year 2055) conditions, which is the same year as the currently effective CDC modeling.

The peak discharges from HEC-HMS were entered into the HEC-RAS model to develop water surface elevations throughout the extended study area which includes approximately 30 miles along the East Fork downstream of Forney Dam (Lake Ray Hubbard) to the confluence with the Trinity River and about 38 additional miles on the Trinity River ending at Henderson County. The CDC discharges are tabulated and included in this report as well as a summarization and comparison of the resultant 100-year and Standard Project Flood water surface elevations at selected locations.

Conclusions

The amount of urbanization is expected to increase from 32% to 50% percent for the Trinity River above Henderson County and from 33% to 51% for the East Fork Trinity River by the year 2055. This is expected to result in an average increase in the 100-year peak discharge of 11% and 13% for the Trinity River above Henderson County and East Fork Trinity River respectively. The expected increases in urbanization and development have the potential to deplete flood storage and increase flood risk if actions are not taken to stabilize added flood risk. The increased discharges along the East Fork and Main Stem of the Trinity River resulted in increases in the calculated water surface elevations, as expected. In some areas the increase was as high as 1.2 feet for the 100-year peak discharge, while the average increase was 0.6 feet and 0.8 feet for the Trinity River and East Fork of the Trinity River respectively.

Urbanization will continue to increase throughout the Dallas-Fort Worth region. The extended CDC hydrologic and hydraulic modeling has opened the door for new opportunities and new communities to significantly stabilize flood risk along the East Fork and Trinity Main Stem through Henderson County.

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1.0 Introduction

The upper Trinity River watershed has experienced significant continual growth since the development boom of the 1980s, which was the basis for the Regional Environmental Impact Statement Trinity River and Tributaries - 1998 and subsequent issuance of the Record of Decision (ROD) by the United States Army Corps of Engineers (USACE) Fort Worth District in 1988. The ROD established criteria for the analysis of permit applications that included no rise in the 100-year or Standard Project Flood (SPF) water surface elevations, 0% and 5% loss of valley storage for the 100- year and SPF respectively, and no increase or creation of erosive velocities.

In response to the ROD, the cities and counties in the upper Trinity River Corridor formed the Trinity River Steering Committee, facilitated by the North Central Texas Council of Governments (NTCOG), which directed the formation of the Flood Management Task Force (FMTF) to develop a process and manual based on the criteria outlined in the ROD. In 1991, the 1st Edition of the Corridor Development Certificate (CDC) Manual was published.

In 1998, the 2nd Edition of the CDC Manual was published which established the review fund and Cost Recovery Fee which provided a funding stream for continual development of the CDC process and models. The 3rd Edition of the CDC manual, published in 2002, incorporated comments and revisions to the 2nd Edition. The 4th Edition was published in 2010 addressing technological advances and outdated items, and also increased the Cost Recovery Fee. The 4th Edition was amended in 2020 with updated Cost Recovery Fees and a new Model Maintenance Fee to keep the consolidated NFIP-CDC Model HEC-RAS model up to date.

In 2013, the upper Trinity River hydrology model was updated using 2005 (baseline) land use and projected 2055 (future) land use. The HEC-RAS hydraulic model was also updated to reflect the CDC permitted and constructed projects. Prior to 2013, the hydraulic model had been updated periodically but never on a comprehensive scale which included all the CDC permitted and constructed projects along the corridor.

While the hydrology and hydraulic models have been updated, the downstream limit of the Regulatory Zone has not been extended since the CDC program was created. Several communities downstream of the current model limits have expressed interest in participating in becoming a participant in the Common Vision Program thus creating a need for an extended set of CDC hydrologic and hydraulic models.

Additional background about Common Vision Program and updates to modeling and manuals can be found at the NCTCOG website: https://www.nctcog.org/envir/watershed-management/corridor-development-certificate-program/trinity-river-corridor-development-certificate.

2.0 Study Purpose

The purpose of this study is the extension of the CDC model downstream on the Trinity River main stem and inclusion of the East Fork of the Trinity River. The CDC model will be extended by updating the existing conditions modeling and results from the FEMA sponsored Interagency Flood Risk Management

(InFRM,2017) Trinity River Watershed Hydrology Assessment (WHA) study (InFRM,2017) and FY2017 FEMA East Fork Trinity River and Upper Trinity River Watershed Risk Map Project. The models will be updated adjusting model parameters to represent future land use (2055) conditions. The Standard Project Flood (SPF) event will also be estimated using the updated models.

3.0 Study Area

The current CDC study hydraulic model limits model extend from the Upper Trinity River headwaters to the confluence of Five Mile Creek near the IH 20 bridge in Dallas. This area covers about 6,275 square miles and includes the majority of the Dallas-Fort Worth Metroplex. The CDC hydraulic model (HEC-RAS) limits are as follows:

- Elm Fork: West Fork/Elm Fork confluence to Lewisville Dam (29.04 miles)
- West Fork: West Fork/Elm Fork confluence to Lake Worth Dam (58.08 miles)
- Clear Fork: West Fork/Clear Fork confluence to Benbrook Dam (12.43 miles)
- Trinity River main stem: West Fork/Elm Fork confluence to downstream of Dowdy Ferry Road in southeast Dallas (23.25 miles).

The extension of the CDC Model consists of:

- East Fork Trinity River from Forney Dam (Lake Ray Hubbard) to the confluence with the East Fork/Trinity River main stem (approximately 29 miles)

- Trinity River main stem from the end of the current CDC Model to the USGS Gage at Rosser in Henderson County (approximately 30 miles)

The extended modeling area is represented by the blue lines in Figure 1.

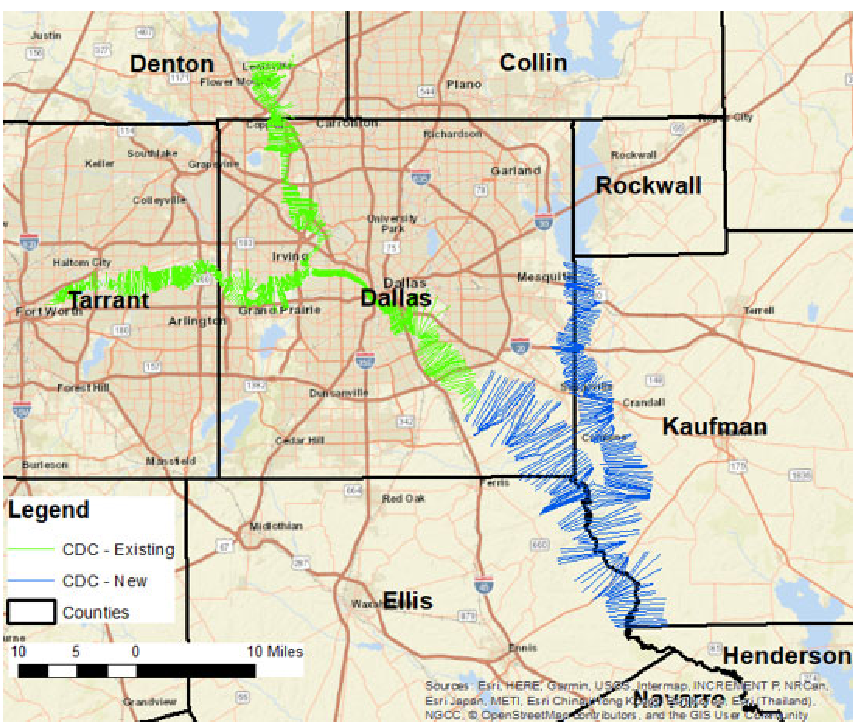


Figure 1: Effective (Green) and Extended (Blue) CDC RAS Model Extents

4.0 Hydrology

4.1 Overview

The existing conditions FEMA sponsored InFRM Trinity River WHA study (InFRM,2017) was completed in 2021 and extends from the headwaters of the Trinity River Basin to the Gulf of Mexico which has a total drainage area of nearly 17,969 square miles. The Trinity River Basin drains all or part of 37 counties which includes the Dallas/Fort Worth Metropolitan area that is comprised of 7.5 million people. The West Fork Trinity River begins in Archer County and flow in a southeasterly direction for approximately 715 miles to empty into the Gulf of Mexico through the Trinity Bay and Galveston Bay. There are also approximately 2,000 miles of major tributaries that drain into the Trinity River.

The InFRM Trinity River WHA model was updated to reflect 2055 land use conditions, which is the same conditions being modeled in the current CDC hydrology model.

4.2 Methodology

The CDC hydrology model was revised to reflect updated land uses through the Clear Fork, West Fork, Elm Fork, and Main Stem of the Trinity River. The sub-area areas remained the same, but the Snyder's time to peak (T_p), and percent imperviousness were revised to reflect the increase in development through the corridor. The updated InFRM Trinity River WHA HEC-HMS model was used to develop future discharges for the 2-yr thru 500-yr events. The 2013 CDC model was used in combination with the InFRM Trinity River WHA HEC-HMS model to produce the future SPF discharges for the extended study area due to differences in peak discharges (10% for SPF) at the shared boundary (Trinity River below Five Mile Creek) between effective CDC model and extended CDC model . Specific updates and model uses are discussed in additional detail in the following sections.

4.2.1 Land Use Processing

The existing conditions WHA HEC-HMS model was updated using the 2055 land use, which is the same future land use year being used in the currently effective CDC modeling. The percent urbanization and percent imperviousness of each sub-area was determined from the land use type within the sub-area and assigned a corresponding value. A combination of NCTCOG data and EPA ICLUS data (ICLUS, 2017) was used on the study. The EPA ICLUS Shared Socioeconomic Pathways (SSP) 5 and Representative Concentration Pathways (RCP) 8.5 scenario was used where future land used estimates were not available and where ICLUS data produced higher estimates of urbanization. This specific ICLUS scenario assumes higher population growth and higher emissions than other ICLUS scenarios. Table 1 is a list of the land use relationships that were used with the NCTCOG land use data. Table 2 is a list of land use relationships that were used with the ICLUS data. These relationships were used to estimate average values for each subbasin in the HEC-HMS model. The percent urbanization within the Trinity River watershed above Henderson County is expected to increase from around 18% to 32% by the year 2055. Figure 2 illustrates how urbanization is expected to spread through the year 2055. Existing and Future percent urban estimates for each subbasin are in Appendix 1.

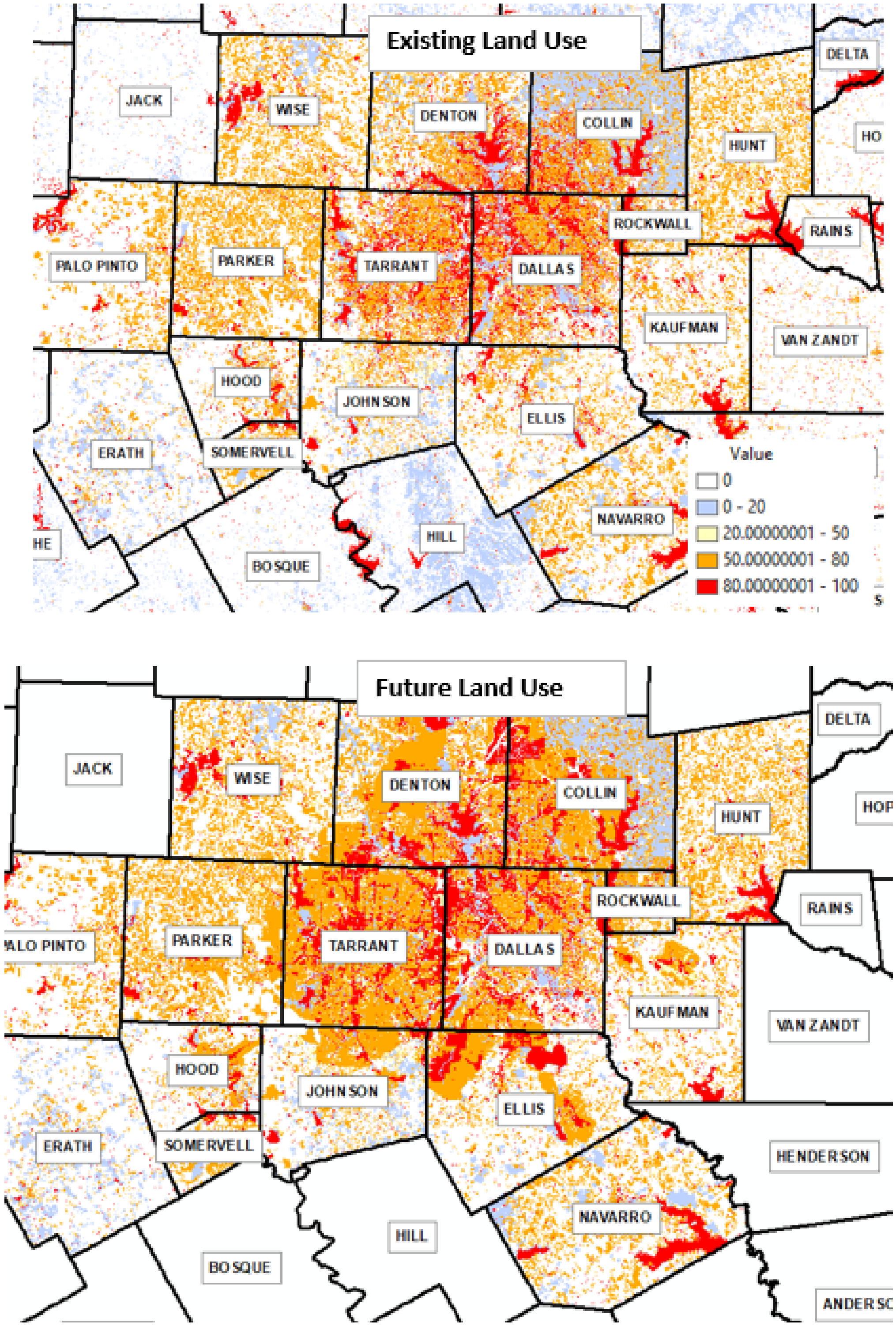


Figure 2: Percent Urban Estimates for Existing and Future Land Use

Table 1: Percent Urbanization and Impervious Assignments for NCTCOG Land Use

Land Use Code	Description	Examples of Use	Assigned Percent Urbanized	Assigned Percent Impervious
111	Single family	Single family detached units and duplexes	80	41
112	Multi-family	Apartments, condominiums, residential hotels, converted apartments and townhouses (single family attached)	95	70
113	Mobile home	Mobile homes inside mobile home parks and free-standing units outside parks	40	20
114	Group quarters	Nursing homes, group homes, college dormitories, jails, military base personnel quarters	70	60
120	Commercial	Commercial (office and retail)	90	90
121	Office	Generally include and administration functions including corporate and government offices, banks	90	90
122	Retail	Retail trade and services, such as department stores, repair shops, supermarkets, restaurants	95	95
123	Institutional	Churches, governmental facilities, museum, education, hospitals, medical clinics, libraries and military bases	50	40
124	Hotel/motel	Hotels and motels	95	95
125	Institutional/semi-public	School, churches	50	40
126	Education	Schools	50	40
131	Industrial	Manufacturing plants, warehouses, office showrooms	95	90
141	Transportation	Railroads, radio and television communication stations, truck terminals	30	15
142	Roadway	Roadway and right-of-ways	80	35
143	Utilities	Sewage treatment and power plants, power line easements, pump stations, water treatment plants and water systems	70	60
144	Airport	Airport terminals	40	20
146	Runway	Airport runways	100	100
147	Large stadium	Large stadium	95	95
148	Railroad	Railroad	30	15
149	Communication	Communication	50	35
151	Transit	Transit	30	15

Land Use Code	Description	Examples of Use	Assigned Percent Urbanized	Assigned Percent Impervious
160	Mixed use	Areas that contain both commercial (office and retail) and residential uses either in the same facility or in very close proximity	95	90
170	Parks/recreation	Public and private parks, golf courses, cemeteries, public and private tennis courts and swimming pools, amusement parks	10	6
171	Parks/recreation	Public and private parks, golf courses, cemeteries, public and private tennis courts and swimming pools, amusement parks	10	6
172	Landfill	Sanitary landfills, land applications, and similar waste management facilities	10	5
173	Under construction	Land that has undergone site preparation and construction has begun	20	15
174	Cemeteries	Cemeteries	10	6
181	Flood control	Major flood control structures including levies and flood channels	0	0
300	Vacant	Vacant land	0	0
301	Vacant	Vacant land	0	0
302	Residential acreage	Residential homes on acreage	80	41
303	Ranch land	Ranch land	0	0
304	Timberland	Timberland	0	0
305	Farmland	Farmland	5	3
309	Improved acreage	Improved acreage	10	6
401	Parking	Parking	100	100
500	Water	Water	100	100
501	Water	Water	100	100
502	Small water bodies	Small water bodies	100	100

Table 2: Percent Urbanization and Impervious Assignments for ICLUS Land Use

EPA Code	EPA Class Name	Assigned Percent Urbanized	Assigned Percent Impervious
0	Natural Water	100	100
1	Reservoirs, canals	100	100
2	Wetlands	0	0
3	Recreation, conservation	0	0
4	Timber	0	0
5	Grazing	0	0
6	Pasture	0	0
7	Cropland	0	0
8	Mining, barren land	0	0
9	Parks, golf courses	10	6
10	Exurban, low density	40	20
11	Exurban, high density	80	41
12	Suburban	80	41
13	Urban, low density	80	41
14	Urban, high density	95	70
15	Commercial	95	95
16	Industrial	95	90
17	Institutional	50	40
18	Transportation	30	15

4.2.2 Initial Abstraction and Constant Loss Rates

The initial and constant losses from the InFRM Trinity River WHA were used for this study. 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 initially developed using the regional USACE Fort Worth District Method for determining losses based on soil type (percent sand) (Rodman, 1977; USACE, 1986). After calculating the default frequency loss rates based on soil type, two additional adjustments were made to the loss rate parameters. First, an adjustment was made to the initial deficits to account for the presence of NRCS flood control structures in the watershed that have not been modeled in detail. Second and finally, a Bulletin 17C adjustment was made to the loss rates of the frequent storm events (50% to 4% AEP) to better align the HEC-HMS results with the statistical results at the gages.

The USACE Fort Worth District Method for determining losses method produces a default set of loss rates for each frequency event, based on the soil type in each subbasin (Rodman, 1977). The method assumes that the antecedent moisture conditions become wetter, and the losses decrease as the rarity of the flood event increases, which is consistent with other research (McEnroe, 2003). In general, the 50% AEP loss rates are intended to correspond to an "average" or "normal" antecedent soil moisture condition, and the 0.2% AEP loss rates should correspond to a "wet" soil moisture condition. Table 3 summarizes the range of default loss rates of the Fort Worth District method by frequency and soil type. A geospatial grid of percent sand for the State of Texas developed by the USACE Fort Worth District was used to spatially calculate the percent sand for each subbasin. That percent sand value was then used to interpolate between the 0% and 100% sand loss rate values in Table 3 to assign the default initial and constant loss rates to each subbasin.

Table 3: Default Frequency Loss Rates by Soil Type for the USACE Fort Worth District Method

Annual Exceedance Probability (AEP) %	Initial Abstraction (inches) for Soil with 0% Sand	Infiltration Rate (inches per hour) for Soil with 0% Sand	Initial Abstraction (inches) for Soil with 100% Sand	Infiltration Rate (inches per hour) for Soil with 100% Sand
50%	1.50	0.20	2.10	0.26
20%	1.30	0.16	1.80	0.21
10%	1.12	0.14	1.50	0.18
4%	0.95	0.12	1.30	0.15
2%	0.84	0.10	1.10	0.13
1%	0.75	0.07	0.90	0.10
0.4%	0.61	0.06	0.73	0.09
0.2%	0.50	0.05	0.60	0.08

After calculating the default frequency loss rates based on soil type, two additional adjustments were made to the loss rate parameters. First, the default initial deficits were increased to account for the presence of NRCS type flood control structures in the watershed that have not been modeled in detail. This adjustment for the NRCS flood control structures was made based on data from the National Inventory of Dams (NID) (USACE, 2016). In this case, the percent of each subbasin area that was controlled by NRCS type structures was multiplied by the inches of runoff that can typically be stored between the riser and spillway of the NRCS structures in that basin (typically up to 4 inches of runoff). For the frequent storm events (50% to 4% AEP), the initial loss due to the NRCS structures was decreased in proportion to the total depth of rain for that event.

Second and finally, a Bulletin 17C adjustment was made to the loss rates to better align the HEC-HMS results with the statistical results for the frequent storm events (50% to 4% AEP) at the gages. A comparison was made between the preliminary HEC-HMS results with the calculated frequency loss rates and the statistical flow frequency curves from the USGS gage records. A final adjustment was then made to the initial deficits and constant losses for the 50% through 10% AEP storms in order to have a better correlation with the statistical frequency curves estimated from the USGS gage records. This step was performed because of the increased confidence level in the gage records' statistical frequency curves for the 50% through 10% AEP range. The 4% AEP losses were also adjusted when needed to create a smoother transition between the 2% and 10% AEP flow values. Loss rates for events with an AEP at or below 2% were not adjusted based on the statistical frequency curves because stream gage records in Texas are not long enough and there is too much variability in the rare AEP statistical flow estimates over time to justify adjusting the rare AEP loss rates. Generally, a stream gage record that is 3 to 4 times the length of the return period being estimated is needed before the statistical results can be considered reliable enough for this type of adjustment. For the 1% AEP event, this would require a stream gage record of 300 to 400 years in length, which is not available anywhere in Texas.

The final loss rates after all of these adjustments that were used for the uniform rainfall frequency storm events are documented in the InFRM Trinity River WHA Appendices B (Rainfall Runoff Modeling in HEC-HMS) and C (Elliptical Frequency Storms in HEC-HMS). These final loss rates line up well with the band of observed losses from the calibration storms. Based on the range of observed initial and constant losses from the calibration storms, the adopted losses for the frequency storms could be characterized to represent "average" to "wet" conditions (the "average" moisture conditions being applied to the 50% AEP storm, and "wet" moisture conditions being applied to the 0.2% AEP and SPF storms), which are appropriate assumptions for modeling hypothetical flood events. However, none of the adopted frequency losses are at the extreme wet or extreme dry ends of the range of calibrated losses during the InFRM Trinity River WHA study (InFRM,2017).

4.2.3 Unit Hydrograph Parameters

The InFRM Trinity River WHA HEC-HMS model was calibrated to verify that 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-year) flood. A total of seventeen recent storm events spanning 1991-2015 were used to fine tune the model. One of the parameters that was calibrated was the Snyder unit hydrograph parameters of lag time and peaking coefficient. While the WHA produced reliable unit hydrograph parameters for existing conditions, estimates were needed for how these parameters would change with future urbanization.

The U.S. Army Corps of Engineers Fort Worth District developed a method in 1977, utilizing observed data within the upper Trinity/Dallas Fort Worth Region to adjust the lag time, accounting for the effects of urbanization (Rodman, 1977) The method recognizes that watersheds with similar shapes and characteristics demonstrate a reduction in flood peak travel time and increase in peak discharges as urbanization increases. Model calibration to observed storm data across basins with varying levels of urbanization was performed to development Urbanization Curves which correlated measurable watershed characteristics to lag time for varying degrees of urbanization. Using the Urbanization Curves watershed lag times reduce by about half (46%) from a watershed without any urbanization to a fully urbanized watershed. For a watershed than increases from 0% to 50% urbanization, the watershed lag times would decrease by 23%. More discussion on the Urbanization Curves can be found in the 1977

USACE Report (Rodman, 1977). The existing and future lag times can be found in Appendix 2.

4.2.4 Storm Duration

The uniform rainfall and elliptical storm simulations utilized a 48-hour storm duration for the 2-year through 500-year events, while the SPF simulations utilized the standard HMR-52 72-hour duration.

4.2.5 Uniform Rainfall Methodology

Frequency point rainfall depths of various durations and recurrence intervals (2-year through 500-year) 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 Trinity River watershed. A precipitation depth was assigned to each county located within the watershed. The depth was approximately taken from the center of each county. Watershed subbasins were assigned the point rainfall depth for the county containing the majority of that subbasin's drainage area. Point rainfall values were reduced based on the contributing drainage area and figure 15 from the National Weather Service TP-40 publication. The final frequency results were then computed in HEC-HMS through the depth-area analysis of the applied frequency storms.

4.2.6 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 use the depth-area analysis in HEC-HMS to produce frequency peak discharge estimates. 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 3 of the National Weather Service TP-40 publication (Hershfield, 1961), as shown in Figure 3.

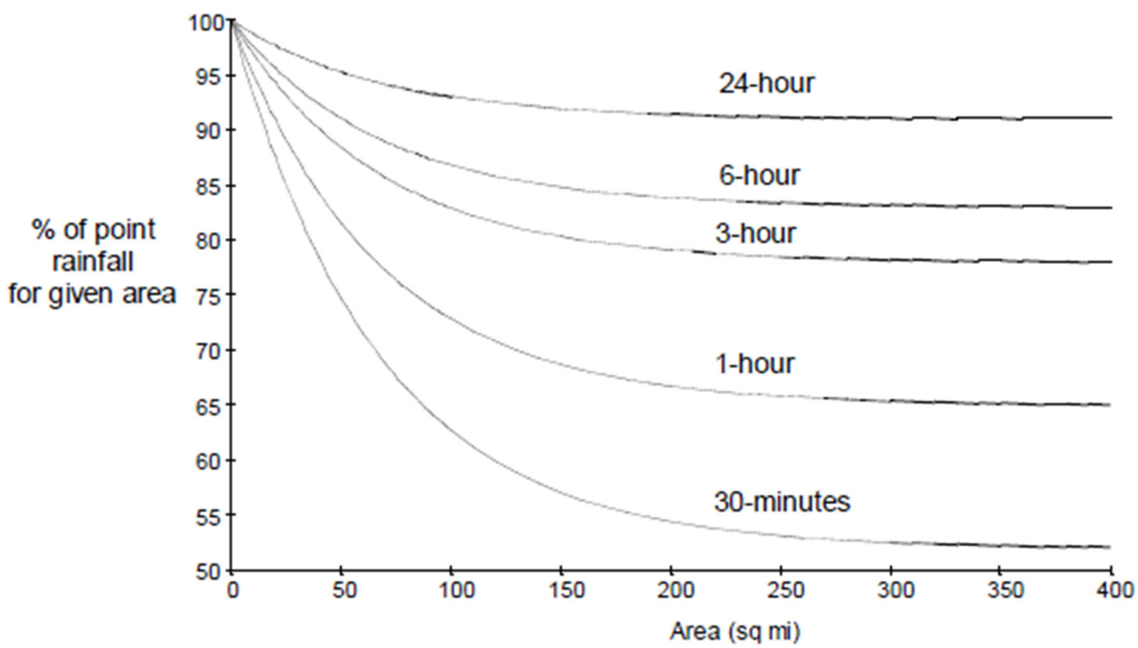


Figure 3: Depth-Area Reduction from Figure 4.1 of TP-40

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 River 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, 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 Hydrometeorological 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 led to the highest peak discharge at a downstream junction of interest. Figure 4 shows an example of an elliptical 1% annual exceedance probability (100-year) storm that was centered over the watershed above the Trinity River at Dallas junction. This storm is located such that the majority of the rain falls below the USACE flood control reservoirs, thus optimizing the peak discharge of the Trinity River at Dallas.

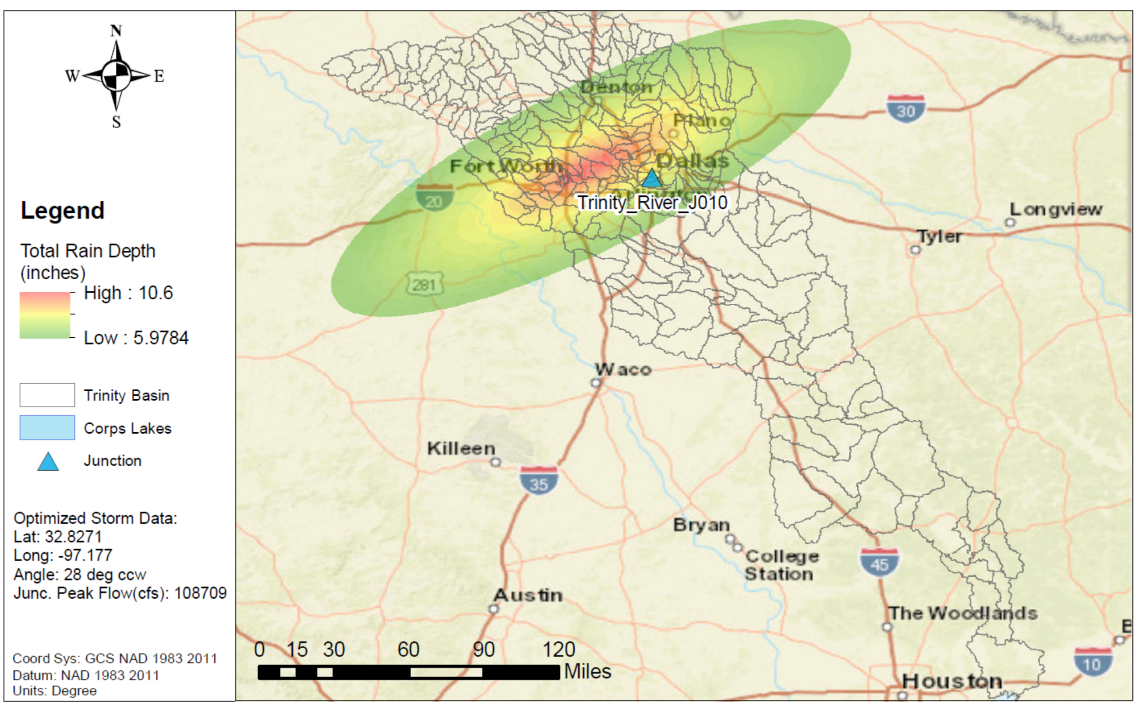


Figure 4: InFRM Trinity River WHA Elliptical Storm Example

4.2.7 Elliptical Storm Parameters

The elliptical design storm, and storm center locations (x, y) and rotations (ɵ) of the InFRM Trinity WHA was used for this study. Storm depth-area relationships were developed through analysis of depth-area relationships of observed storm events in the region. These location and rotation parameters were determined from 100year frequency optimizations and are assumed to be the same for all other frequency events (2year – 500year).

The elliptical frequency storms were applied to the final HEC-HMS basin model with the same future conditions frequency hydrologic parameters.

For additional information about elliptical design storms for the Trinity River Basin, see the InFRM Trinity River WHA Appendix C – Elliptical Frequency Storms in HEC-HMS.

4.2.8. Standard Project Flood (SPF) Computation Procedure

The currently effective CDC SPF peak discharges end at the Trinity River and Five Mile Creek confluence. This required the development of new SPF peak discharges for the Trinity River from Five Mile Creek to Henderson County and for the East Fork Trinity River below Forney Dam (Lake Ray Hubbard. The process for developing SPF discharges for the CDC extension is similar to the methodology used in the 2013 CDC Update (USACE,2013). For SPF storm centering, and orientation angle, the InFRM Trinity River WHA elliptical storms were used since these storms were optimized for the peak discharge at a given location. The process of developing the SPF 72-hour storm and discharges using HEC-MetVue and HEC-HMS was as follows:

1. Determine InFRM Trinity River WHA elliptical storm centering, angle and drainage area below USACE dams.
2. Compute Probable Maximum Precipitation (PMP) storm (gridded DSS file) in HEC-MetVue.
3. Reduce PMP storm by 50% in HEC-MetVue to create SPF storm (gridded DSS file)
4. Utilize SPF storm (gridded DSS file) to create subbasin average precipitation for use in 2013 CDC HEC-HMS model, which was used in this study to produce the SPF flow hydrograph at the Trinity River confluence with Five Mile Creek. This was done because the 2013 CDC HMS model produced SPF discharges that were almost 10% higher than the updated InFRM WHA HEC-HMS model for the SPF event. To match the effective CDC discharges at the boundary with the extended CDC model, the 2013 model and 2024 SPF storm was used to develop an SPF inflow hydrograph for the extended CDC model. One potential cause of the higher flows in the effective 2013 CDC model is because it incorporates CDC permitted (future condition) projects in the HEC-HMS routing while the InFRM Trinity River WHA HEC-HMS model routing only includes existing/constructed projects. The 2013 CDC model was not needed to produce discharges on the East Fork.
5. Run the 2013 CDC model with the 2024 SPF storm to get the flow hydrograph at the Trinity River confluence with Five Mile Creek.
6. Link future land use InFRM Trinity River WHA HEC-HMS model to 2013 CDC model SPF results with the SPF storm to develop peak discharges below the Trinity River confluence with Five Mile Creek to get SPF discharges along the Trinity River and East Fork Trinity River.

Detailed steps performed to compute the SPF discharges can be found in Appendix 3. While the HMR52 routine produces a storm size of 10,000 square miles and point rainfall maximum of around 21 inches, the 72-hour basin average over the drainage area below USACE reservoirs is about 15.6 inches. The SPF storm computed for the Trinity River below Five Mile Creek is shown in Figure 5.

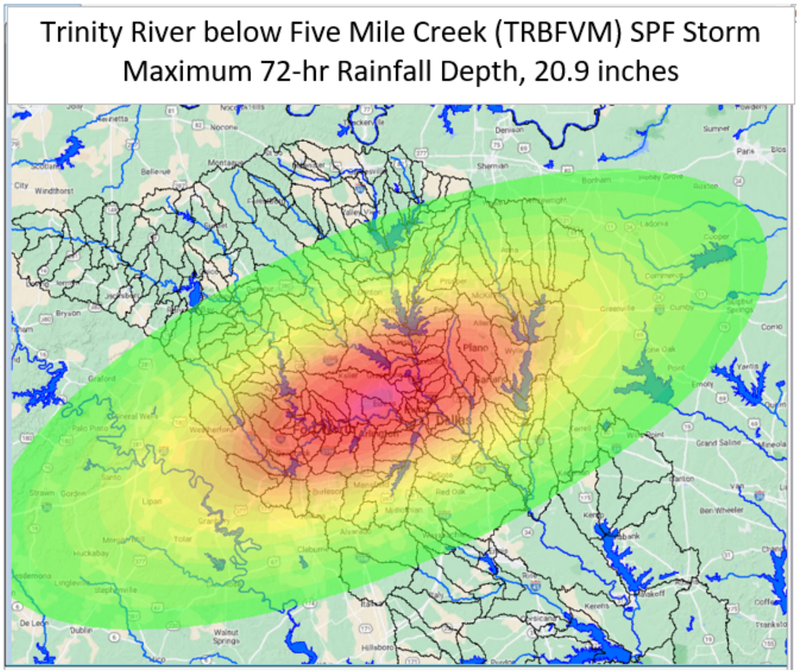


Figure 5: SPF Storm for Trinity River below Five Mile Creek

Figure 6 illustrates how the 2024 SPF storm centering and orientation for the Trinity River above Five Mile Creek is similar to the SPF storm computed for the 2013 CDC update. The 2024 SPF produced the same SPF discharge at the Trinity River confluence with Five Mile Creek.

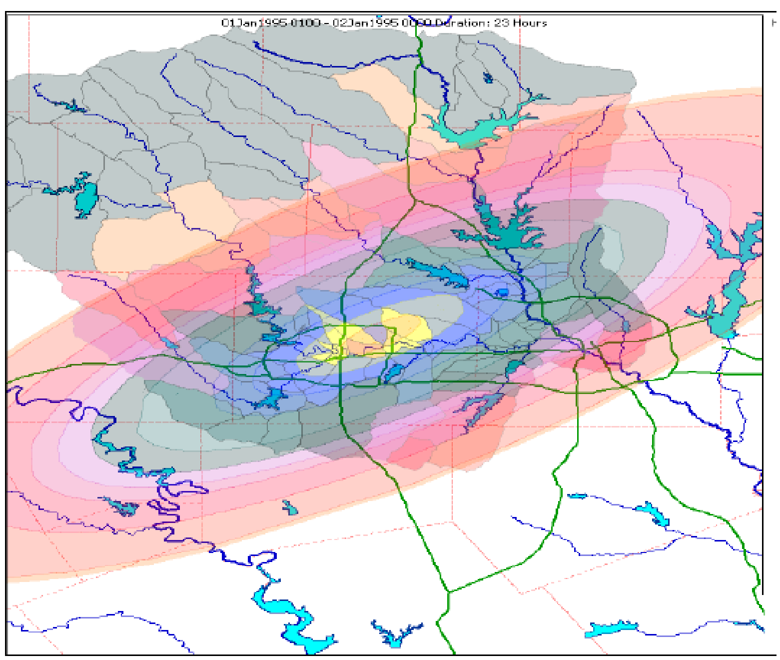


Figure 6: 2013 CDC Update SPF Storm for Trinity River below Five Mile Creek

Multiple SPF simulations were performed for the model extension. There were two storms on both the Trinity River and East Fork Trinity River which controlled discharges through the study area. Table 4 and Table 5 summarize the SPF storm characteristics used in HEC-MetVue. The storm extent for this design storm was 10,000 square miles. The HMR52 provides a function in Chapter 1.4 – Figure 1 that maximizes the rainfall for a 'storm size' without changing the storm extent. The 'Storm Size' in HMR52 allows the user to maximize the rainfall for their watershed and is typically a value close to the watershed's contributing area. If a smaller 'Storm Size' is selected in HMR52, the rainfall depth at the center will be higher but the total volume of the storm will be lower, concentrating the rainfall over the watershed. If a larger 'storm size' is selected in HMR52, the rainfall depth at the center will be lower but the total volume of the storm will be higher. The Storm Size identified in Table 4 represents the uncontrolled area downstream of USACE dams. SPF storm maps are included in Appendix 4.

Table 4: Trinity River SPF Storm Characteristics

Location Description	Storm Centering	Storm Size (sq. mi.)	Lon.	Lat.	Angle
Trinity River below Five Mile Creek	Above Five Mile Creek	1,273	-97.11	32.85	247
Trinity River above Ten Mile Creek	Above Five Mile Creek	1,273	-97.11	32.85	247
Trinity River below Ten Mile Creek	Above Five Mile Creek	1,273	-97.11	32.85	247
Trinity River above the East Fork Trinity River	Above Five Mile Creek	1,273	-97.11	32.85	247
Trinity River below Red Oak Creek	Below Red Oak Creek	2,189	-96.93	32.84	257
Trinity River near Rosser, TX USGS gage	Below Red Oak Creek	2,189	-96.93	32.84	257

Table 5: East Fork Trinity River SPF Storm Characteristics

Location Description	Storm Centering	Storm Size (sq mi)	Lon.	Lat.	Angle
Ray Hubbard Reservoir Outflow	Above Ray Hubbard	302	-96.6	32.99	132
East Fork Trinity River near Forney USGS gage	Above Ray Hubbard	302	-96.6	32.99	132
East Fork Trinity River below Buffalo Creek	Above Ray Hubbard	302	-96.6	32.99	132
East Fork Trinity River below South Mesquite Creek	Below South Mesquite Creek	446	-96.56	32.91	141
East Fork Trinity River near Crandall, TX USGS gage	Below South Mesquite Creek	446	-96.56	32.91	141
East Fork Trinity River above the Trinity River	Below South Mesquite Creek	446	-96.56	32.91	141

4.3 Results

The amount of urbanization in the Trinity River watershed above Henderson County is expected to nearly double from 18% to 32% percent by the year 2055. This is expected to result in an average increase of 11% in the 100-year peak discharge. Table 6 and Table 7 contain the 100-year and SPF peak discharges for the Trinity River and East Fork Trinity River respectively. Future peak discharges for the 2-year through 500-year events for the Trinity River basin are provided in Appendix 5. The 100-yr and SPF discharges at the boundary (Trinity River below Five Mile Creek) of the extended CDC model are within 1% of the discharges used in the effective CDC model and can be found in Table 9 (Section 5.5). Computation of SPF peak discharges were limited to the locations in the below tables since SPF peak discharges already exist in the effective CDC model, upstream of the Trinity River confluence with Five Mile Creek and can be found in the latest CDC Manual.

Table 6: Trinity River Future Condition Peak Discharges (100-year and SPF)

Location Description	HEC-RAS River Station	Future Discharges (cfs)	
		100-YEAR[1]	SPF[2]
Trinity River below Five Mile Creek	205777	130,900	299,000
Trinity River above Ten Mile Creek	176021	117,600	256,000
Trinity River below Ten Mile Creek	154267	117,200	257,000
Trinity River above the East Fork Trinity River	113969	115,400	241,000
Trinity River below Red Oak Creek	83613	155,500	301,000
Trinity River near Rosser, TX USGS gage	48916	152,800	289,000

[1] Elliptical storm results from updated InFRM WHA HEC-HMS Model Only

[2]Elliptical storm results from effective (2013) CDC HEC-HMS model and updated InFRM WHA HEC-HMS Model

Table 7: East Fork Trinity River Future Condition Peak Discharges (100-year and SPF)

Location Description	HEC-RAS River Station	Future Discharges (cfs)	
		100-YEAR[1]	SPF[2]
Ray Hubbard Reservoir Outflow	154701	70,700	175,000
East Fork Trinity River near Forney USGS gage	148653	79,100	189,000
East Fork Trinity River below Buffalo Creek	135946	81,600	194,000
East Fork Trinity River below South Mesquite Creek	111013	75,000	181,000
East Fork Trinity River near Crandall, TX USGS gage	68622	65,600	159,000
East Fork Trinity River above the Trinity River	23467	54,000	115,000

[1] Uniform rainfall results from updated InFRM WHA HEC-HMS Model

[2]Elliptical storm results from updated InFRM WHA HEC-HMS Model

5.0 Hydraulics

5.1 General

The current regional CDC Model is maintained by the USACE Fort Worth District and as of May 2023 can be downloaded directly from the NCTCOG website.

The USACE role in the CDC Process is the performance of a Technical Review of the CDC applications. The CDC applications are submitted to the USACE by member communities and reviewed by the USACE. The results of the review are stated in a letter submitted from the USACE to the member communities and the NCTCOG. The CDC applications are reviewed using the respective CDC Manuals in effect at the time of submittal. The CDC Manuals used throughout the CDC process are as follows:

- CDC Manual 1st Edition May 1991
- CDC Manual 2nd Edition August 1997
- CDC Manual 3rd Edition September 2002
- CDC Manual 4th Edition June 2010 (Amended 2020)

The Common Regional Criteria hydrologic and hydraulic criteria stated in each of the manuals were used to evaluate the impacts of the proposed CDC projects.

5.2 Data Collection

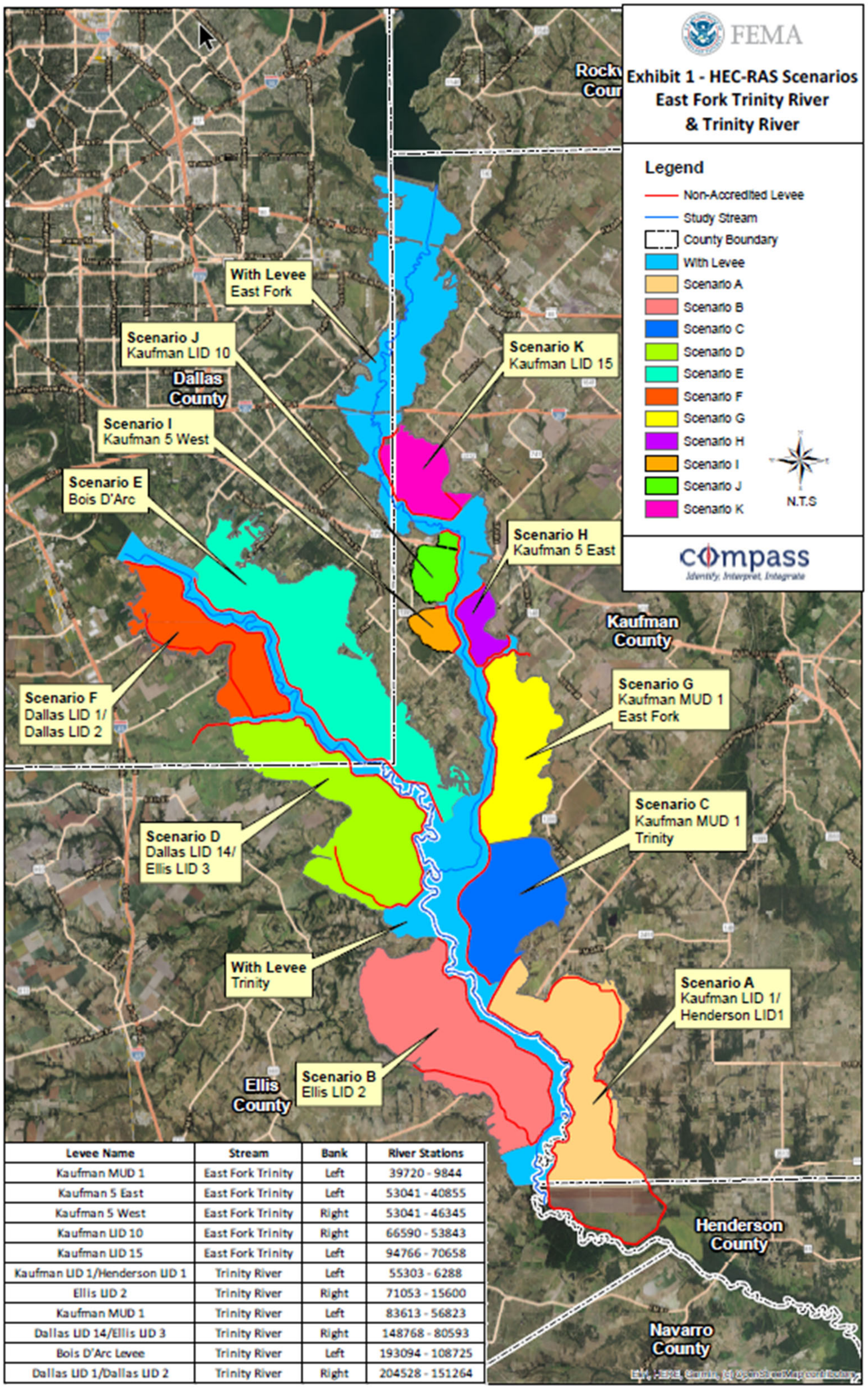
The FY2017 FEMA East Fork Trinity River and Upper Trinity River Watershed Risk Map Project HEC-RAS model was used as the base model for extending the CDC hydraulic HEC-RAS modeling. This model represents existing condition geometry and peak discharges and includes approximately 30 miles along the East Fork downstream of Ray Hubbard to the confluence with the Trinity River and about 38 additional miles on the Trinity River ending at Henderson County.

5.3 Methodology

The FEMA existing conditions hydraulic HEC-RAS model was updated with future peak discharges from the future land use hydrologic HEC-HMS model. The process of developing a future condition hydraulic HEC-RAS model consisted of the following steps:

- Adding future peak discharges into the HEC-RAS steady flow editor
- Determine reduced discharge steady peak discharges that could be applied to the regulatory with levee and natural valley scenarios based on assumed diverted flow that spills over the non-accredited levee using a supplemental HEC-RAS model.
- Performing 11 different natural valley steady flow simulations for each hydraulically significant non-accredited levee.
- Perform 2 With Levee steady flow simulations (1 East Fork and 1 Trinity Main Stem) confining flow within levees.

A natural valley approach was applied to all hydraulically significant non-accredited levees in accordance with FEMA's Levee Analysis and Mapping (LAMP) guidance. The natural valley approach established an independent scenario for each hydraulically significant non-accredited levee that assumed full hydraulic conveyance on the landward side of each hydraulically significant non-accredited levee and assumed all other levee systems remained in place. There are 6 hydraulically significant non-accredited levees along the Trinity River and 5 along the East Fork Trinity River; therefore, 11 natural valley scenarios were simulated in HEC-RAS. It was assumed that each levee represented 1 levee system; multiple levees were not combined for consideration as 1 system. A With Levee HEC-RAS simulation was developed for the East Fork Trinity River and Trinity River that assumed all accredited levees and hydraulically significant nonaccredited levees remained in place. The With Levee HEC-RAS geometry represented baseline conditions from which each independent natural valley scenario was developed. Figure 7 provides a visual illustration of each natural valley and non-natural valley (With Levee) alternative, showing all hydraulically significant non-accredited levees within the study extents.



Levee Name	Stream	Bank	River Stations
Kaufman MUD 1	East Fork Trinity	Left	39720 - 9844
Kaufman 5 East	East Fork Trinity	Left	53041 - 40855
Kaufman 5 West	East Fork Trinity	Right	53041 - 46345
Kaufman LID 10	East Fork Trinity	Right	66590 - 53843
Kaufman LID 15	East Fork Trinity	Left	94766 - 70658
Kaufman LID 1/Henderson LID 1	Trinity River	Left	55303 - 6288
Ellis LID 2	Trinity River	Right	71053 - 15600
Kaufman MUD 1	Trinity River	Left	83613 - 56823
Dallas LID 14/Ellis LID 3	Trinity River	Right	148768 - 80593
Bois D'Arc Levee	Trinity River	Left	193094 - 108725
Dallas LID 1/Dallas LID 2	Trinity River	Right	204528 - 151264

Figure 7: HEC-RAS Scenarios for Trinity River and East Fork Trinity River

A supplemental With Levee HEC-RAS model was developed for the East Fork Trinity River and Trinity River that used lateral structures to represent several hydraulically significant non-accredited levees that were consistently overtopped within the HEC-RAS model for the 1% ACE using the USACE WHA discharges. All levees along the Trinity River were represented with lateral structures (except for the accredited Southside Wastewater Treatment Plant levee) and Kaufman Levee Improvement District (LID) 15 along the East Fork Trinity River was represented as a lateral structure. The purpose of the supplemental models was to develop reduced discharge steady flow files that could be applied to the regulatory With Levee and natural valley scenarios based on assumed diverted flow that spills over the non-accredited levees. A conservative assumption was made that the flow that does spill over a given levee will come back into the model at the downstream end of that given levee. In other words, any flow leaving a lateral structure that represented a given levee was returned into the first cross section downstream of that levee. The lateral structure weir coefficient was set to 0.1 in most cases for model convergence/stability, which is lower than desired but conservative towards establishing 1% ACE elevations. Figure 8 and Figure 9 illustrate the differences between the With Levee (Non-Natural Valley) and Natural Valley scenarios.

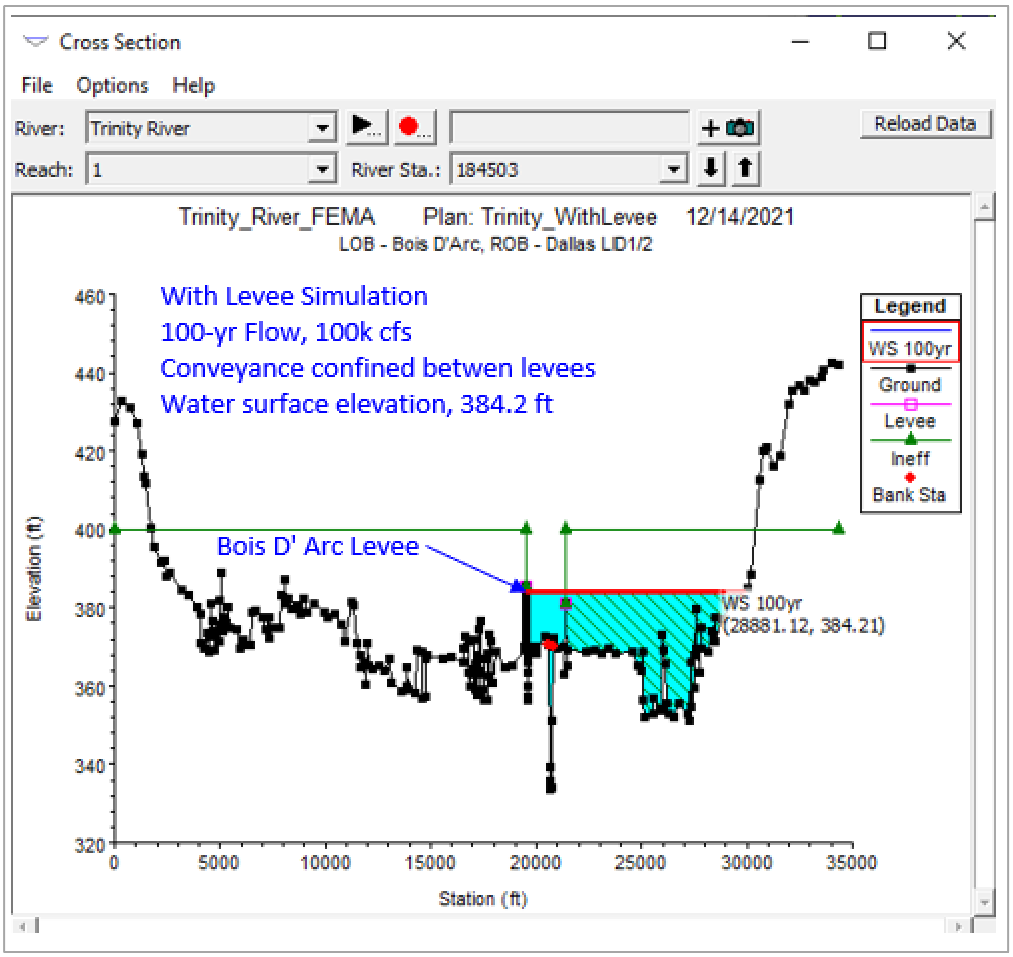


Figure 8: "With Levee" Scenario HEC-RAS Cross Section

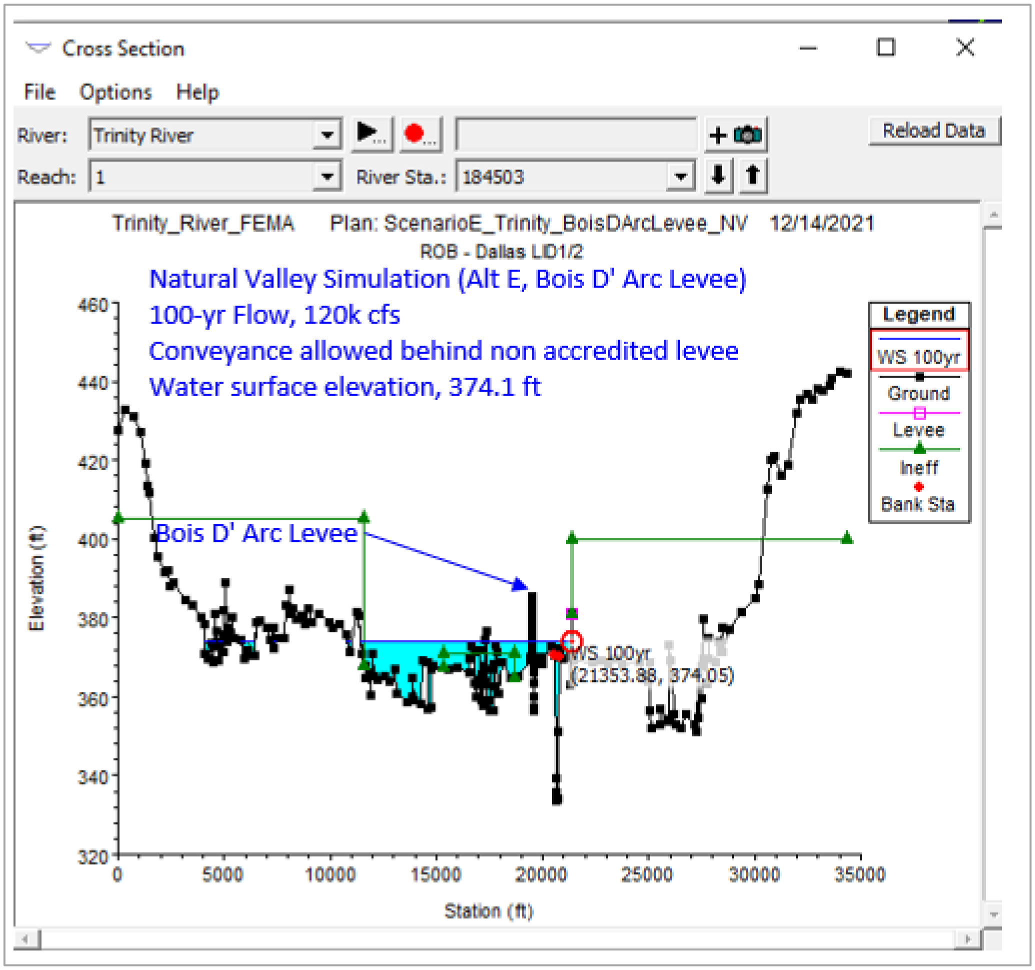


Figure 9: Bois D'Arc (Natural Valley) Scenario HEC-RAS Cross Section

Consideration was given to maintain the laterals representing several of the non-accredited levees within the final HEC-RAS models and trimming the cross sections accordingly based on the scenario. In coordination with FEMA, it was decided to keep the full cross section length and geometry for all model scenarios for ease of future model updates and for general consistency between the scenarios. This was accomplished while also setting up the models for the individual natural valley scenarios, by placing the levee points at all hydraulically significant non-accredited levees with ineffective flow area (IFA) elevations set high enough to be above all storm events. The reduced discharges from the With Levee supplemental models were fixed into the final HEC-RAS flow files by adding a flow break at every cross section and applying the computed discharges from the With Levee supplemental models to each cross section within the final models. For each independent natural valley scenario, the full discharge was simulated through the levee reach and the levee points and IFAs were removed for cross sections that intersected the levee. For example, the Bois D'Arc Levee natural valley scenario (Scenario E) removed the levee points and IFAs along the Bois D'Arc levee and the full flow from USACE was applied through the Bois D'Arc reach, while all other portions of the model matched the With Levee geometry with reduced discharges.

5.4 Model Structure

The CDC Model developed in this study consists of 2 project files and multiple plans. Each plan represents a specific set of geometric data and flow data. Table 8 contains the CDC Model HEC-RAS plan structure.

Table 8: CDC Model HEC-RAS Plan Structure

Scenario and Levee Name	River Stations	Bank	RAS Files
Trinity River (TR_FEMA.prj Project File)			
With Levee	205777-6288	N/A	p01,g01,f02
Scenario A, Kaufman LID 1/Henderson LID 1	55303-6288	Left	p02,g03,f03
Scenario B, Ellis LID 2	71053-15600	Right	p03,g04,f05
Scenario C, Kaufman MUD 1	83613-56823	Left	p04,g05,f06
Scenario D, Dallas LID 14/Ellis LID 3	148768-80593	Right	p05,g06,f07
Scenario E, Bois D'Arc Levee	193094-108725	Left	p06,g07,f08
Scenario F, Dallas LID 1/Dallas LID 2	204528-151264	Right	p07,g08,f09
East Fork Trinity River (EF_FEMA.prj Project File)			
With Levee	154701-9844	N/A	p11,g06,f03
Scenario G, Kaufman MUD 1	39720 -9844	Left	p01,g01,f05
Scenario H, Kaufman 5 East	53041-40855	Left	p02,g02,f03
Scenario I, Kaufman 5 West	53041-46345	Right	p03,g03,f03
Scenario J, Kaufman LID 10	66590-53843	Right	p04,g04,f03
Scenario K, Kaufman LID 15	94766-70658	Left	p05,g05,f01

5.5 Model Results

The future 100-year and SPF elevations for the Trinity River and East Fork Trinity River are summarized in Appendix 6. The 100-yr and SPF discharges at the boundary (Trinity River below Five Mile Creek) of the extended CDC model are within 1% of the discharges used in the effective CDC model and can be found in Table 9.

The downstream end of the currently effective CDC HEC-RAS model elevations does not precisely tie in with the extended CDC HEC-RAS model though the discharges are essentially the same. The extended CDC model matches the 100-year elevation but produces elevations approximately 2 feet higher for the SPF. The currently effective CDC model essentially starts with defined flow-stage relationships while the water surface elevations at the upstream limit of the extended model are determined by the steady flow hydraulic computations being performed in HEC-RAS. The differences between the effective model and the extended model are shown in Table 9.

Table 9: Results Comparison at Common Boundary of Effective and Extended CDC Models

Storm Event	Effective CDC model (XS 25457)		Extended CDC (XS 205777)	
	Discharge (cfs)	D/S WSEL (ft)	Discharge (cfs)	U/S WSEL (ft)
100-year	129,000	395.5	130,900	395.6
SPF	300,000	404.0	299,000	406.2

6.0 Conclusion

The amount of urbanization is expected to increase from 32% to 50% percent in the Trinity River watershed upstream of Henderson County and from 33% to 51% for the East Fork Trinity River by the year 2055. This is expected to result in an average increase in the 100-year peak discharge of 11% and 13% for the Trinity River upstream of Henderson County and East Fork Trinity River watershed respectively. The expected increases in urbanization and development have the potential to deplete flood storage and increase flood risk if mitigation actions are not undertaken to stabilize added flood risk. The increased discharges along the Main Stem of the Trinity River and East Fork Trinity River resulted in increases in the calculated water surface elevations, as expected. In some areas the increase was as high as 1.2 feet for the 100-year flood event, while the average increase was 0.6 feet and 0.8 feet for the Main Stem Trinity River and East Fork of the Trinity River respectively.

Urbanization will continue to increase throughout the Dallas-Fort Worth region. The extended CDC hydrologic and hydraulic modeling has opened the door for new opportunities and new communities to significantly stabilize flood risk along the East Fork and Trinity Main Stem through Henderson County.

6.1 Model Limitations and Needs for Future Study

- **Application to the CDC Criteria** – The study area involves complicated modeling scenarios wth multiple HEC-RAS runs (Natural Valley versus non Natural Valley assumptions) within the same river reach. This study did not address issues such as if the no rise requirements will apply to both the channel and overbank or behind levee area or how valley storage calculations should be evaluated.
- **Water Surface Elevation Differences at CDC Boundary** – Section 5.5 points out that the SPF elevation between the currently effective CDC model and the extended CDC model is almost 2 feet different. This study did not address how the difference between the two models should be addressed.
- **Consideration of Future Levee Raises** - In the current CDC Model, all of the levees are assumed to be infinitely high, i.e. no conveyance or storage behind the levees. Even though there may be levees that have 500-year protection, the assumption is no conveyance or storage behind (most all of the levee in the CDC Model are 500-year or greater levees). This was done assuming that one day the levee(s) may be raised so that by doing so, the loss of storage and the impact of conveyance would not be an issue (if conveyance and storage was considered behind the levee as the base condition, then raising the levee would result in a large loss of storage which then would be impossible to mitigate. Also, the increase in WSE by raising the levee above the SPF would be impossible to mitigate as well).

7.0 References

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Appendix 1 – Existing and Future Percent Urban Values

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
Amon_G_Carter_S010	1	3	2
Amon_G_Carter_S020	1	1	0
Amon_G_Carter_S030	11	19	8
Bachman_Branch_S010	73	86	13
Bachman_Branch_S020	52	58	6
Bardwell_S010	41	57	16
Beans_Ck_S010	1	3	2
Beans_Ck_S020	3	8	5
Bear_Ck_S010	17	25	8
Bear_Ck_S020	17	52	35
Bedias_Ck_S010	3	6	3
Bedias_Ck_S020	3	7	4
Benbrook_S010	9	22	13
Benbrook_S020	21	62	41
Benbrook_S030	31	68	37
Big_Bear_Ck_S010	62	76	14
Big_Bear_Ck_S020	55	75	20
Big_Brown_Ck_S010	2	3	1
Big_Ck_S010	3	20	17
Big_Ck_S020	15	28	13
Big_Ck_S030	31	45	14
Big_Cleveland_S010	1	2	1
Big_Cleveland_S020	3	8	5
Big_Fossil_Ck_S010	51	78	27
Big_Sandy_Ck_S010	12	33	21
Big_Sandy_Ck_S020	29	30	1
Big_Sandy_Ck_S030	35	35	0
Big_Sandy_Ck_S040	28	28	0
Big_Sandy_Ck_S050	33	46	13
Bridgeport_S010	53	72	19
Bridgeport_S020	3	14	11
Bridgeport_S030	16	30	14
Bridgeport_S040	33	42	9
Brushy_Ck_S010	7	22	15
Brushy_Ck_S020	12	24	12
Brushy_Ck_S030	27	27	0
Brushy_Elm_Ck_S010	4	36	32

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
Brushy_Elm_Ck_S020	9	59	50
Buck_Ck_S010	3	3	0
Cedar_Ck_S010	11	22	11
Cedar_Ck_S020	19	21	2
Cedar_Ck_S030	11	38	27
Cedar_Ck_S040	22	48	26
Chambers_Ck_S010	18	37	19
Chambers_Ck_S020	9	25	16
Chambers_Ck_S030	12	33	21
Chambers_Ck_S040	12	23	11
Chambers_Ck_S050	12	12	0
Chambers_Ck_S060	23	23	0
Chambers_Ck_S070	17	27	10
Chambers_Ck_S080	24	36	12
Clear_Ck_S010	2	5	3
Clear_Ck_S020	3	3	0
Clear_Ck_S030	3	4	1
Clear_Ck_S040	9	19	10
Clear_Ck_S050	1	20	19
Clear_Ck_S060	16	22	6
Clear_Ck_S070	3	21	18
Clear_Ck_S080	29	35	6
Clear_Ck_S090	18	51	33
Clear_Ck_S100	36	59	23
Clear_Ck_S110	36	62	26
Clear_Ck_S120	31	80	49
Clear_Fork_S010	42	61	19
Clear_Fork_S020	36	50	14
Clear_Fork_S030	50	68	18
Clear_Fork_S040	68	82	14
Clear_Fork_S050	68	74	6
Denton_Ck_S010	2	2	0
Denton_Ck_S020	15	20	5
Denton_Ck_S030	19	51	32
Denton_Ck_S040	26	28	2
Denton_Ck_S050	30	54	24
Denton_Ck_S060	29	63	34
Denton_Ck_S070	29	69	40
Denton_Ck_S080	53	70	17

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
Doe_Branch_S010	22	72	50
Doe_Branch_S020	33	67	34
Dry_Ck_S010	44	46	2
Eagle_Mountain_S010	39	69	30
Eagle_Mountain_S020	25	66	41
Eagle_Mountain_S030	51	62	11
Eagle_Mountain_S040	47	74	27
East_Fork_S010	26	56	30
East_Fork_S020	15	34	19
East_Fork_S030	35	59	24
East_Fork_S040	43	61	18
East_Fork_S050	57	74	17
East_Fork_S060	34	61	27
East_Fork_S070	35	67	32
East_Fork_S080	39	61	22
East_Fork_S090	55	76	21
East_Fork_S100	34	60	26
East_Fork_S110	22	49	27
East_Fork_S120	13	27	14
Elm_Fork_S010	3	20	17
Elm_Fork_S020	2	34	32
Elm_Fork_S030	2	28	26
Elm_Fork_S040	6	26	20
Elm_Fork_S050	10	57	47
Elm_Fork_S060	4	29	25
Elm_Fork_S070	4	37	33
Elm_Fork_S080	35	57	22
Elm_Fork_S090	44	79	35
Elm_Fork_S100	67	80	13
Elm_Fork_S110	49	73	24
Elm_Fork_S120	68	76	8
Elm_Fork_S130	68	72	4
Elm_Fork_S140	64	76	12
Elm_Fork_S150	67	81	14
Elm_Fork_S160	64	77	13
Fairfield_Lake_S010	13	19	6
Fivemile_Ck_S010	55	78	23
Garrett_Ck_S010	26	49	23
Garrett_Ck_S020	26	53	27

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
Garrett_Ck_S030	32	56	24
Grapevine_S010	55	77	22
Hackberry_Ck_S010	74	88	14
Hackberry_Ck_S020	57	70	13
Hackberry_Ck_S030	65	87	22
Hickory_Ck_S010	28	43	15
Hickory_Ck_S020	28	32	4
Hickory_Ck_S030	38	85	47
Hickory_Ck_S040	27	80	53
Hickory_Ck_S050	53	74	21
Houston_County_Lake_S010	6	10	4
Indian_Ck_S010	22	30	8
Indian_Ck_S020	19	26	7
Indian_Ck_S030	14	28	14
Indian_Ck_S040	32	37	5
Joe_Pool_S010	17	52	35
Joe_Pool_S020	27	64	37
Joe_Pool_S030	39	70	31
Joe_Pool_S040	58	76	18
Joe_Pool_S050	57	75	18
Kings_Ck_S010	21	40	19
Kings_Ck_S020	19	42	23
Kings_Ck_S030	22	31	9
Lake_Arlington_S010	67	85	18
Lake_Halbert_S010	31	52	21
Lake_Kiowa_S010	8	48	40
Lake_Kiowa_S020	10	18	8
Lake_Worth_S010	40	72	32
Lake_Worth_S020	62	76	14
Lavon_S010	44	56	12
Lavon_S020	59	74	15
Lewisville_S010	55	80	25
Lewisville_S020	63	81	18
Lewisville_S030	38	51	13
Lewisville_S040	65	82	17
Lewisville_S050	60	78	18
LittleFossil_Ck_S010	58	78	20
Little_Elkhart_S010	2	4	2
Little_Elm_Ck_S010	10	67	57

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
Little_Elm_Ck_S020	20	64	44
Little_Elm_Ck_S030	14	65	51
Livingston_S010	3	7	4
Livingston_S020	15	34	19
Livingston_S030	28	36	8
Lk_Weatherford_S010	39	40	1
Lk_Weatherford_S020	49	63	14
Long_King_Ck_S010	2	9	7
Long_King_Ck_S020	6	32	26
Lost_Ck_S010	8	17	9
Lost_Ck_S020	1	3	2
Marine_Ck_S010	45	78	33
Marine_Ck_S020	59	76	17
Marys_Ck_S010	27	66	39
Menard_Ck_S010	1	9	8
Mountain_Ck_S010	52	71	19
Mountain_Ck_S020	65	77	12
Mountain_Ck_S030	47	71	24
Mustang_Ck_S010	23	40	17
Navarro_Mills_S010	3	14	11
Navarro_Mills_S020	4	14	10
Navarro_Mills_S030	10	20	10
Navarro_Mills_S040	44	44	0
New_Terrell_City_Lake_S010	21	26	5
Pecan_Ck_S010	35	41	6
Post_Oak_Ck_S010	39	62	23
Range_Ck_S010	3	3	0
Range_Ck_S020	2	4	2
Range_Ck_S030	5	9	4
Ray_Hubbard_S010	54	71	17
Ray_Hubbard_S020	65	81	16
Ray_Roberts_S010	20	34	14
Ray_Roberts_S020	45	74	29
Ray_Roberts_S030	35	63	28
Ray_Roberts_S040	33	38	5
Ray_Roberts_S050	15	18	3
Ray_Roberts_S060	45	53	8
Richland-Chambers_S010	39	45	6
Richland-Chambers_S020	58	63	5

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
Richland_Ck_S010	25	29	4
Richland_Ck_S020	5	16	11
Rowlett_Ck_S010	60	76	16
Salt_Ck_S010	33	49	16
Salt_Ck_S020	27	54	27
Silver_Ck_S010	37	53	16
Silver_Ck_S020	39	74	35
Sister_Grove_S010	14	30	16
Sister_Grove_S020	31	55	24
Spring_Ck_S010	2	13	11
Spring_Ck_S020	8	32	24
Tehuacana_Ck_S010	4	17	13
Tehuacana_Ck_S020	5	15	10
Tenmile_Ck_S010	44	71	27
Tenmile_Ck_S020	24	47	23
Timber_Ck_S010	2	38	36
Timber_Ck_S020	0	24	24
Timber_Ck_S030	3	28	25
Timber_Ck_S040	11	18	7
Trinity_River_S010	49	63	14
Trinity_River_S020	71	78	7
Trinity_River_S030	55	76	21
Trinity_River_S040	39	70	31
Trinity_River_S050	40	62	22
Trinity_River_S060	34	58	24
Trinity_River_S070	24	46	22
Trinity_River_S080	16	23	7
Trinity_River_S090	12	26	14
Trinity_River_S100	3	6	3
Trinity_River_S110	4	16	12
Trinity_River_S120	5	22	17
Trinity_River_S130	3	14	11
Trinity_River_S140	22	25	3
Trinity_River_S150	4	13	9
Trinity_River_S160	2	3	1
Trinity_River_S170	3	6	3
Trinity_River_S180	3	4	1
Trinity_River_S190	5	24	19
Trinity_River_S200	4	15	11

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
Trinity_River_S210	5	18	13
Trinity_River_S220	3	18	15
Trinity_River_S230	5	11	6
Trinity_River_S240	3	16	13
Trinity_River_S250	10	29	19
Upper_Keechi_Ck_S010	6	7	1
Upper_Keechi_Ck_S020	2	2	0
Upper_Keechi_Ck_S030	5	7	2
Upper_Keechi_Ck_S040	2	2	0
Village_Ck_S010	39	72	33
Village_Ck_S020	46	77	31
Village_Ck_S030	61	79	18
Walnut_Ck_S010	46	57	11
Walnut_Ck_S020	44	53	9
Walnut_Ck_S030	44	74	30
Waxahachie_Ck_S010	35	66	31
Waxahachie_Ck_S020	19	38	19
Waxahachie_Ck_S030	16	37	21
West_Fork_S010	1	1	0
West_Fork_S020	1	1	0
West_Fork_S030	1	1	0
West_Fork_S040	1	1	0
West_Fork_S050	1	1	0
West_Fork_S060	1	1	0
West_Fork_S070	1	1	0
West_Fork_S080	0	0	0
West_Fork_S090	1	1	0
West_Fork_S100	1	1	0
West_Fork_S110	1	1	0
West_Fork_S120	1	3	2
West_Fork_S130	1	1	0
West_Fork_S140	1	2	1
West_Fork_S150	1	1	0
West_Fork_S160	5	18	13
West_Fork_S170	39	61	22
West_Fork_S180	34	59	25
West_Fork_S190	42	56	14
West_Fork_S200	31	51	20
West_Fork_S210	35	61	26

Subbasin Name	Existing Percent Urban	Future Percent Urban	Percent Urban Increase
West_Fork_S220	33	61	28
West_Fork_S230	61	72	11
West_Fork_S240	54	79	25
West_Fork_S250	63	75	12
West_Fork_S260	61	79	18
West_Fork_S270	56	79	23
West_Fork_S280	59	82	23
West_Fork_S290	56	77	21
West_Fork_S300	72	81	9
West_Fork_S310	52	84	32
West_Fork_S320	31	83	52
West_Fork_S330	62	84	22
West_Fork_S340	62	76	14
White_Rock_Ck_S010	70	80	10
White_Rock_Ck_S020	69	77	8
White_Rock_Ck_S030	72	83	11
White_Rock_Ck_S040	57	78	21
Wilson_Ck_S010	44	71	27

Appendix 2 – Existing and Future Snyder Lag Time Values

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
Amon_G_Carter_S010	5.6	5.55	1
Amon_G_Carter_S020	5.3	5.30	0
Amon_G_Carter_S030	5.2	5.00	4
Bachman_Branch_S010	1.32	1.20	9
Bachman_Branch_S020	1.24	1.20	4
Bardwell_S010	2.23	2.03	9
Beans_Ck_S010	4.9	4.85	1
Beans_Ck_S020	2.7	2.64	2
Bear_Ck_S010	2.75	2.64	4
Bear_Ck_S020	0.85	0.70	17
Bedias_Ck_S010	16.5	16.27	1
Bedias_Ck_S020	16	15.70	2
Benbrook_S010	2.4	2.25	6
Benbrook_S020	2.7	2.14	21
Benbrook_S030	1.8	1.44	20
Big_Bear_Ck_S010	8.27	7.53	9
Big_Bear_Ck_S020	3.18	2.79	12
Big_Brown_Ck_S010	11.1	11.05	0
Big_Ck_S010	5.6	5.16	8
Big_Ck_S020	3.7	3.46	6
Big_Ck_S030	3.9	3.61	7
Big_Cleveland_S010	7.3	7.27	0
Big_Cleveland_S020	6.7	6.54	2
Big_Fossil_Ck_S010	3.6	3.02	16
Big_Sandy_Ck_S010	5.8	5.21	10
Big_Sandy_Ck_S020	7.7	7.66	1
Big_Sandy_Ck_S030	5	5.00	0
Big_Sandy_Ck_S040	7.5	7.50	0
Big_Sandy_Ck_S050	4.2	3.91	7
Bridgeport_S010	5.4	4.78	11
Bridgeport_S020	4.6	4.36	5
Bridgeport_S030	6.1	5.68	7
Bridgeport_S040	5.3	5.04	5
Brushy_Ck_S010	6.8	6.32	7

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
Brushy_Ck_S020	6.9	6.50	6
Brushy_Ck_S030	4.8	4.80	0
Brushy_Elm_Ck_S010	2.71	2.31	15
Brushy_Elm_Ck_S020	2.99	2.28	24
Buck_Ck_S010	4.46	4.46	0
Cedar_Ck_S010	22.4	21.21	5
Cedar_Ck_S020	6.2	6.14	1
Cedar_Ck_S030	6.6	5.74	13
Cedar_Ck_S040	7.1	6.16	13
Chambers_Ck_S010	11.5	10.41	9
Chambers_Ck_S020	8.7	8.04	8
Chambers_Ck_S030	13	11.68	10
Chambers_Ck_S040	11.5	10.89	5
Chambers_Ck_S050	10	10.00	0
Chambers_Ck_S060	5.5	5.50	0
Chambers_Ck_S070	5.5	5.23	5
Chambers_Ck_S080	5.81	5.45	6
Clear_Ck_S010	5.13	5.06	1
Clear_Ck_S020	4.43	4.43	0
Clear_Ck_S030	2.03	2.02	0
Clear_Ck_S040	3.87	3.68	5
Clear_Ck_S050	6.2	5.66	9
Clear_Ck_S060	1.15	1.12	3
Clear_Ck_S070	3.7	3.39	8
Clear_Ck_S080	8.13	7.87	3
Clear_Ck_S090	6.95	5.81	16
Clear_Ck_S100	4.18	3.65	13
Clear_Ck_S110	3.77	3.23	14
Clear_Ck_S120	5.6	4.13	26
Clear_Fork_S010	11	9.82	11
Clear_Fork_S020	2.9	2.68	8
Clear_Fork_S030	0.9	0.80	11
Clear_Fork_S040	1.6	1.45	9
Clear_Fork_S050	1.2	1.15	4
Denton_Ck_S010	7	7.00	0
Denton_Ck_S020	7	6.83	2
Denton_Ck_S030	3.96	3.32	16
Denton_Ck_S040	4.55	4.50	1

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
Denton_Ck_S050	4.9	4.28	13
Denton_Ck_S060	5.25	4.31	18
Denton_Ck_S070	7.12	5.62	21
Denton_Ck_S080	4.56	4.09	10
Doe_Branch_S010	5.21	3.88	25
Doe_Branch_S020	4.48	3.66	18
Dry_Ck_S010	5.7	5.63	1
Eagle_Mountain_S010	3.9	3.25	17
Eagle_Mountain_S020	3.3	2.60	21
Eagle_Mountain_S030	3.4	3.18	7
Eagle_Mountain_S040	3.1	2.61	16
East_Fork_S010	7	5.91	16
East_Fork_S020	12	10.88	9
East_Fork_S030	4.8	4.17	13
East_Fork_S040	5.3	4.76	10
East_Fork_S050	9.9	8.86	11
East_Fork_S060	7.9	6.74	15
East_Fork_S070	3.5	2.89	17
East_Fork_S080	5.4	4.74	12
East_Fork_S090	7.4	6.45	13
East_Fork_S100	5.7	4.90	14
East_Fork_S110	5.2	4.49	14
East_Fork_S120	9	8.39	7
Elm_Fork_S010	3.86	3.56	8
Elm_Fork_S020	4.72	4.02	15
Elm_Fork_S030	3.87	3.40	12
Elm_Fork_S040	3.69	3.34	9
Elm_Fork_S050	4.4	3.41	23
Elm_Fork_S060	3.67	3.24	12
Elm_Fork_S070	5.06	4.28	15
Elm_Fork_S080	4.65	4.09	12
Elm_Fork_S090	5.1	4.08	20
Elm_Fork_S100	5.9	5.39	9
Elm_Fork_S110	3.15	2.70	14
Elm_Fork_S120	6.6	6.25	5
Elm_Fork_S130	2.66	2.59	3
Elm_Fork_S140	2.61	2.41	8
Elm_Fork_S150	1.4	1.27	9

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
Elm_Fork_S160	0.94	0.86	8
Fairfield_Lake_S010	5.5	5.34	3
Fivemile_Ck_S010	3.1	2.66	14
Garrett_Ck_S010	5.3	4.67	12
Garrett_Ck_S020	4.7	4.04	14
Garrett_Ck_S030	2.5	2.18	13
Grapevine_S010	2.44	2.11	13
Hackberry_Ck_S010	1.96	1.77	10
Hackberry_Ck_S020	1.37	1.26	8
Hackberry_Ck_S030	1.05	0.90	14
Hickory_Ck_S010	3.69	3.40	8
Hickory_Ck_S020	4.86	4.76	2
Hickory_Ck_S030	3.49	2.58	26
Hickory_Ck_S040	3.11	2.25	28
Hickory_Ck_S050	2.08	1.82	13
Houston_County_Lake_S010	3.5	3.43	2
Indian_Ck_S010	12.7	12.18	4
Indian_Ck_S020	7.5	7.24	4
Indian_Ck_S030	11.1	10.34	7
Indian_Ck_S040	5.2	5.06	3
Joe_Pool_S010	4.07	3.36	17
Joe_Pool_S020	6.1	4.92	19
Joe_Pool_S030	6.7	5.54	17
Joe_Pool_S040	1	0.89	11
Joe_Pool_S050	1.62	1.44	11
Kings_Ck_S010	22	19.88	10
Kings_Ck_S020	28	24.77	12
Kings_Ck_S030	7.6	7.25	5
Lake_Arlington_S010	1.4	1.23	12
Lake_Halbert_S010	1.9	1.69	11
Lake_Kiowa_S010	3.1	2.51	19
Lake_Kiowa_S020	2.41	2.32	4
Lake_Worth_S010	4.5	3.69	18
Lake_Worth_S020	3.3	3.00	9
Lavon_S010	5.3	4.94	7
Lavon_S020	4.3	3.90	9
Lewisville_S010	3.71	3.14	15
Lewisville_S020	1.63	1.44	12

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
Lewisville_S030	3.09	2.87	7
Lewisville_S040	2.32	2.06	11
Lewisville_S050	2.19	1.94	11
LittleFossil_Ck_S010	2.3	2.01	12
Little_Elkhart_S010	11.6	11.49	1
Little_Elm_Ck_S010	5	3.63	27
Little_Elm_Ck_S020	6.59	5.13	22
Little_Elm_Ck_S030	6.68	5.01	25
Livingston_S010	17	16.68	2
Livingston_S020	5	4.53	9
Livingston_S030	6	5.75	4
Lk_Weatherford_S010	6.8	6.76	1
Lk_Weatherford_S020	2.1	1.93	8
Long_King_Ck_S010	7.5	7.26	3
Long_King_Ck_S020	10.8	9.48	12
Lost_Ck_S010	4	3.83	4
Lost_Ck_S020	4.3	4.26	1
Marine_Ck_S010	1	0.81	19
Marine_Ck_S020	0.8	0.71	11
Marys_Ck_S010***100-year	1.5	1.19	20
Menard_Ck_S010	27	26.01	4
Mountain_Ck_S010	2.3	2.04	11
Mountain_Ck_S020	1.3	1.20	8
Mountain_Ck_S030	1.39	1.20	14
Mustang_Ck_S010	3.38	3.09	9
Navarro_Mills_S010	4.8	4.55	5
Navarro_Mills_S020	6.54	6.23	5
Navarro_Mills_S030	9.29	8.84	5
Navarro_Mills_S040	5.33	5.33	0
New_Terrell_City_Lake_S010	3.7	3.61	3
Pecan_Ck_S010	6.35	6.14	3
Post_Oak_Ck_S010	3.3	2.88	13
Range_Ck_S010	2.4	2.40	0
Range_Ck_S020	4.9	4.85	1
Range_Ck_S030	3.8	3.73	2
Ray_Hubbard_S010	5.1	4.57	10
Ray_Hubbard_S020	5.4	4.84	10
Ray_Roberts_S010	1.47	1.37	7

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
Ray_Roberts_S020	1	0.83	17
Ray_Roberts_S030	1.53	1.30	15
Ray_Roberts_S040	1.65	1.61	3
Ray_Roberts_S050	1	0.99	1
Ray_Roberts_S060	1	0.95	5
Richland-Chambers_S010	8.12	7.85	3
Richland-Chambers_S020	7.23	7.00	3
Richland_Ck_S010	7.38	7.23	2
Richland_Ck_S020	7	6.64	5
Rowlett_Ck_S010	4.1	3.69	10
Salt_Ck_S010	4.3	3.93	9
Salt_Ck_S020	4.4	3.78	14
Silver_Ck_S010	4.9	4.47	9
Silver_Ck_S020	5	4.02	20
Sister_Grove_S010	12.7	11.71	8
Sister_Grove_S020	6.3	5.49	13
Spring_Ck_S010	3.57	3.39	5
Spring_Ck_S020	2.47	2.19	11
Tehuacana_Ck_S010	7.6	7.14	6
Tehuacana_Ck_S020	16	15.25	5
Tenmile_Ck_S010	6.5	5.49	16
Tenmile_Ck_S020	5	4.41	12
Timber_Ck_S010	5.1	4.25	17
Timber_Ck_S020	1.85	1.65	11
Timber_Ck_S030	4.1	3.62	12
Timber_Ck_S040	2	1.93	3
Trinity_River_S010	1.79	1.64	8
Trinity_River_S020	1.98	1.89	5
Trinity_River_S030	2.1	1.83	13
Trinity_River_S040	3	2.48	17
Trinity_River_S050	9	7.89	12
Trinity_River_S060	10	8.70	13
Trinity_River_S070	9.5	8.42	11
Trinity_River_S080	27.7	26.74	3
Trinity_River_S090	12	11.19	7
Trinity_River_S100	17	16.76	1
Trinity_River_S110	19.3	18.22	6
Trinity_River_S120	18.7	17.21	8

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
Trinity_River_S130	28.5	27.04	5
Trinity_River_S140	1.6	1.58	2
Trinity_River_S150	11.6	11.11	4
Trinity_River_S160	14	13.94	0
Trinity_River_S170	17.8	17.55	1
Trinity_River_S180	24	23.89	0
Trinity_River_S190	18	16.40	9
Trinity_River_S200	5.5	5.22	5
Trinity_River_S210	8.5	7.98	6
Trinity_River_S220	13	12.09	7
Trinity_River_S230	16.6	16.13	3
Trinity_River_S240	20.5	19.26	6
Trinity_River_S250	19	17.27	9
Upper_Keechi_Ck_S010	7.7	7.66	0
Upper_Keechi_Ck_S020	9	9.00	0
Upper_Keechi_Ck_S030	17.3	17.14	1
Upper_Keechi_Ck_S040	7.7	7.70	0
Village_Ck_S010	5.2	4.24	18
Village_Ck_S020	1.6	1.31	18
Village_Ck_S030	5.4	4.78	11
Walnut_Ck_S010	3	2.81	6
Walnut_Ck_S020	3.4	3.22	5
Walnut_Ck_S030	2.8	2.32	17
Waxahachie_Ck_S010	4.13	3.43	17
Waxahachie_Ck_S020	2.37	2.14	10
Waxahachie_Ck_S030	3.5	3.14	10
West_Fork_S010	5.5	5.50	0
West_Fork_S020	7.2	7.20	0
West_Fork_S030	8	8.00	0
West_Fork_S040	6.8	6.80	0
West_Fork_S050	5.8	5.80	0
West_Fork_S060	8.4	8.40	0
West_Fork_S070	6.7	6.70	0
West_Fork_S080	4	4.00	0
West_Fork_S090	6.8	6.80	0
West_Fork_S100	6	6.00	0
West_Fork_S110	6.6	6.60	0
West_Fork_S120	7.8	7.73	1

Subbasin Name	Existing Lag Time (hours)	Future Lag Time (hour)	Percent Reduction in Lag Time
West_Fork_S130	3.6	3.60	0
West_Fork_S140	5.3	5.28	0
West_Fork_S150	6	6.00	0
West_Fork_S160	5.2	4.88	6
West_Fork_S170	5.5	4.82	12
West_Fork_S180	2.4	2.07	14
West_Fork_S190	3.3	3.04	8
West_Fork_S200	4.4	3.93	11
West_Fork_S210	4.6	3.95	14
West_Fork_S220	5	4.24	15
West_Fork_S230	4.1	3.81	7
West_Fork_S240	0.6	0.51	15
West_Fork_S250	1.7	1.57	8
West_Fork_S260	2.3	2.04	11
West_Fork_S270	1.9	1.63	14
West_Fork_S280	2.9	2.48	14
West_Fork_S290	4.9	4.27	13
West_Fork_S300	3.5	3.28	6
West_Fork_S310	0.8	0.65	19
West_Fork_S320	1.51	1.09	28
West_Fork_S330	2.26	1.94	14
West_Fork_S340	2	1.82	9
White_Rock_Ck_S010	2.6	2.42	7
White_Rock_Ck_S020	1.1	1.04	5
White_Rock_Ck_S030	1.3	1.20	8
White_Rock_Ck_S040	2.1	1.83	13
Wilson_Ck_S010	10.2	8.62	15

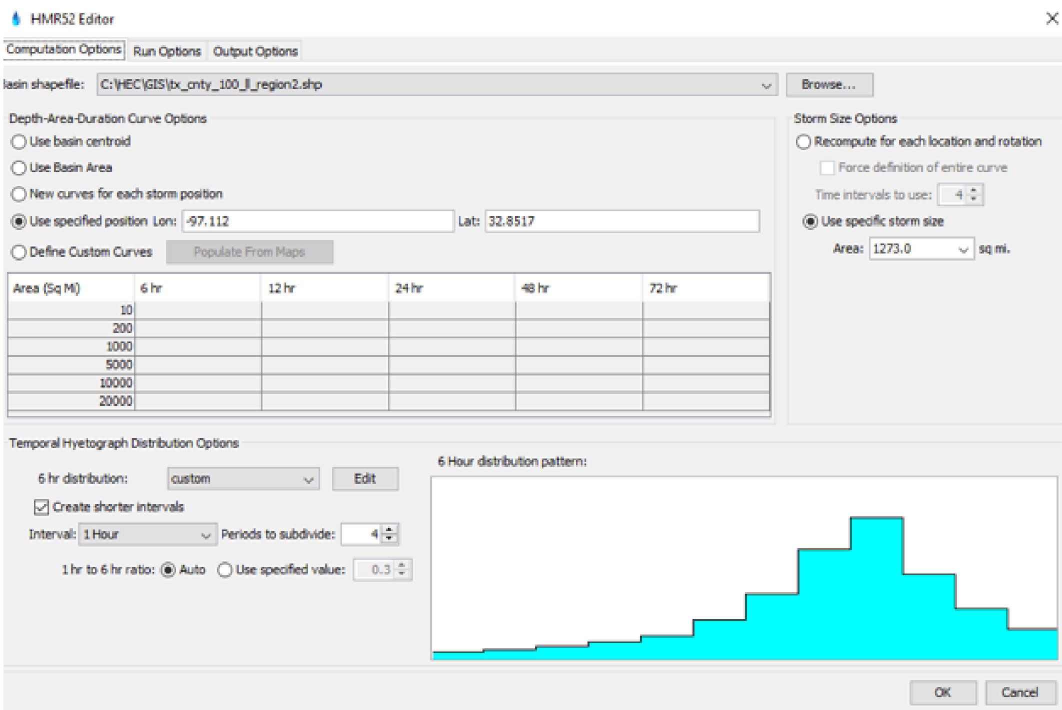
Appendix 3 – SPF Storm Computation Process

SPF Computation Process (Example-Trinity River below Five Mile Ck)

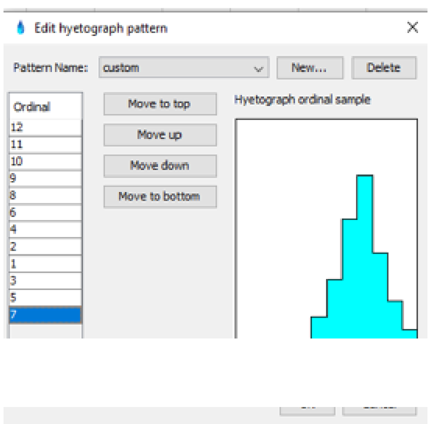
Populate HMR52 Editor in Metvue

Angles in MetVue should be listed clockwise from North. Requires conversion from WHA angles listed counter-clockwise from positive x-axis.

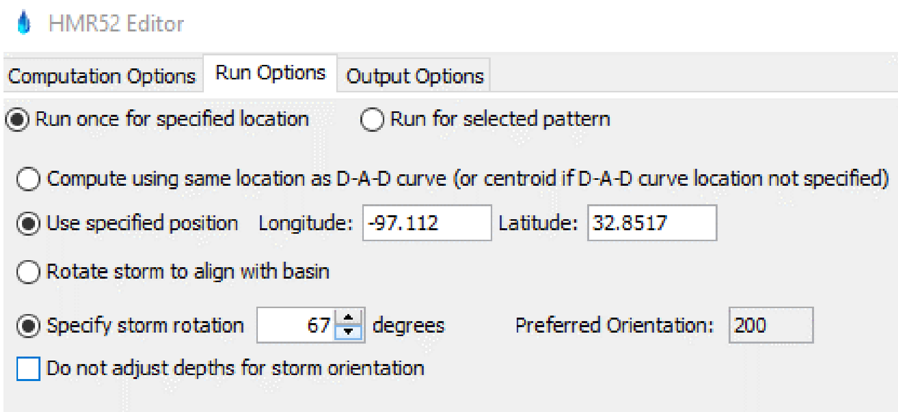
Computation Options Tab - Main



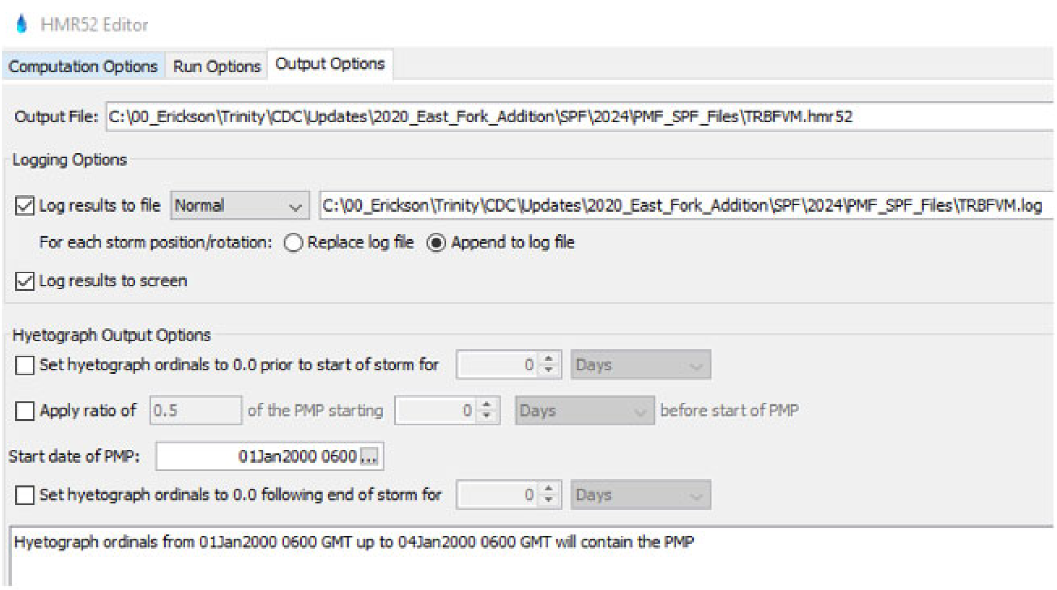
Computation Options Tab - Custom hyetograph pattern



Run Options Tab

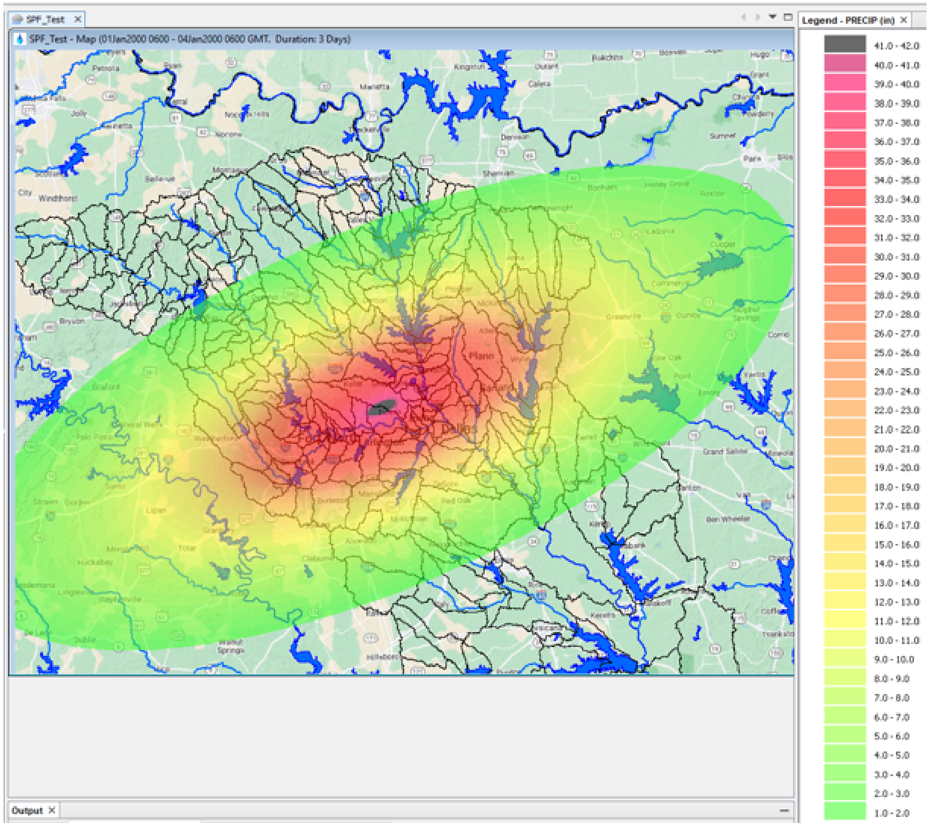


Output Options Tab



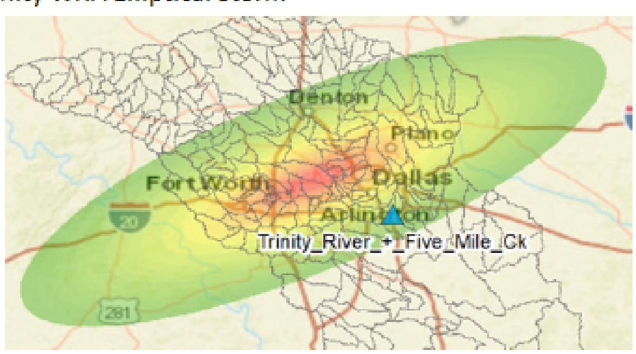
Check .log file after creating PMF storm and check coordinates, storm area and rotation

HMR PMP Storm is visible after selecting "Ok".

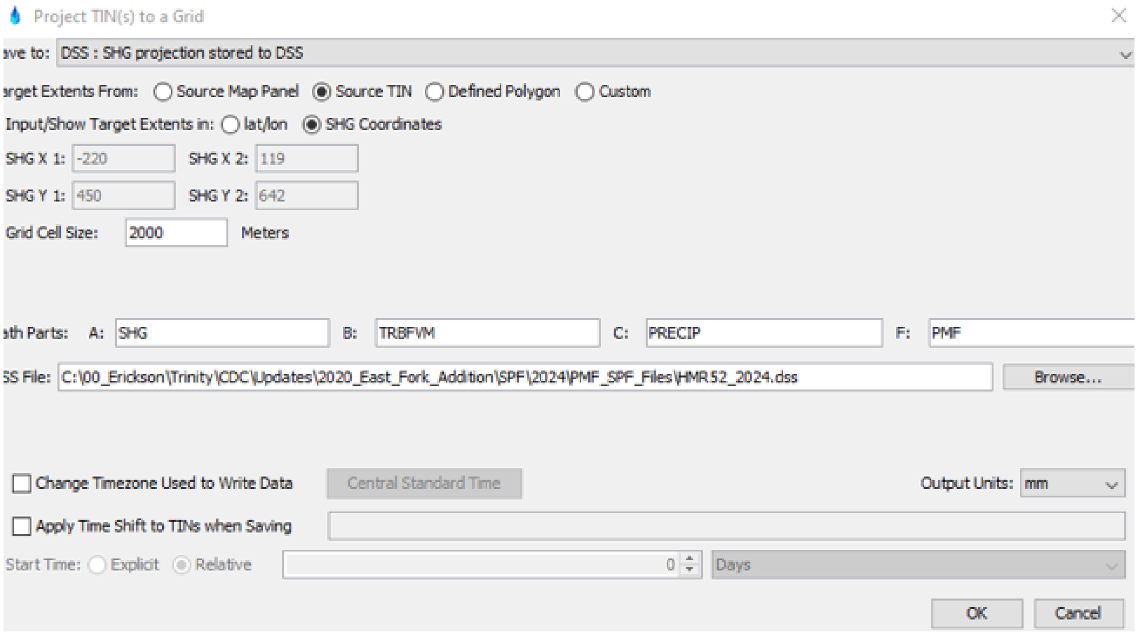


Check to see if storm orientation matches InFRM Trinity WHA Elliptical Storm orientation

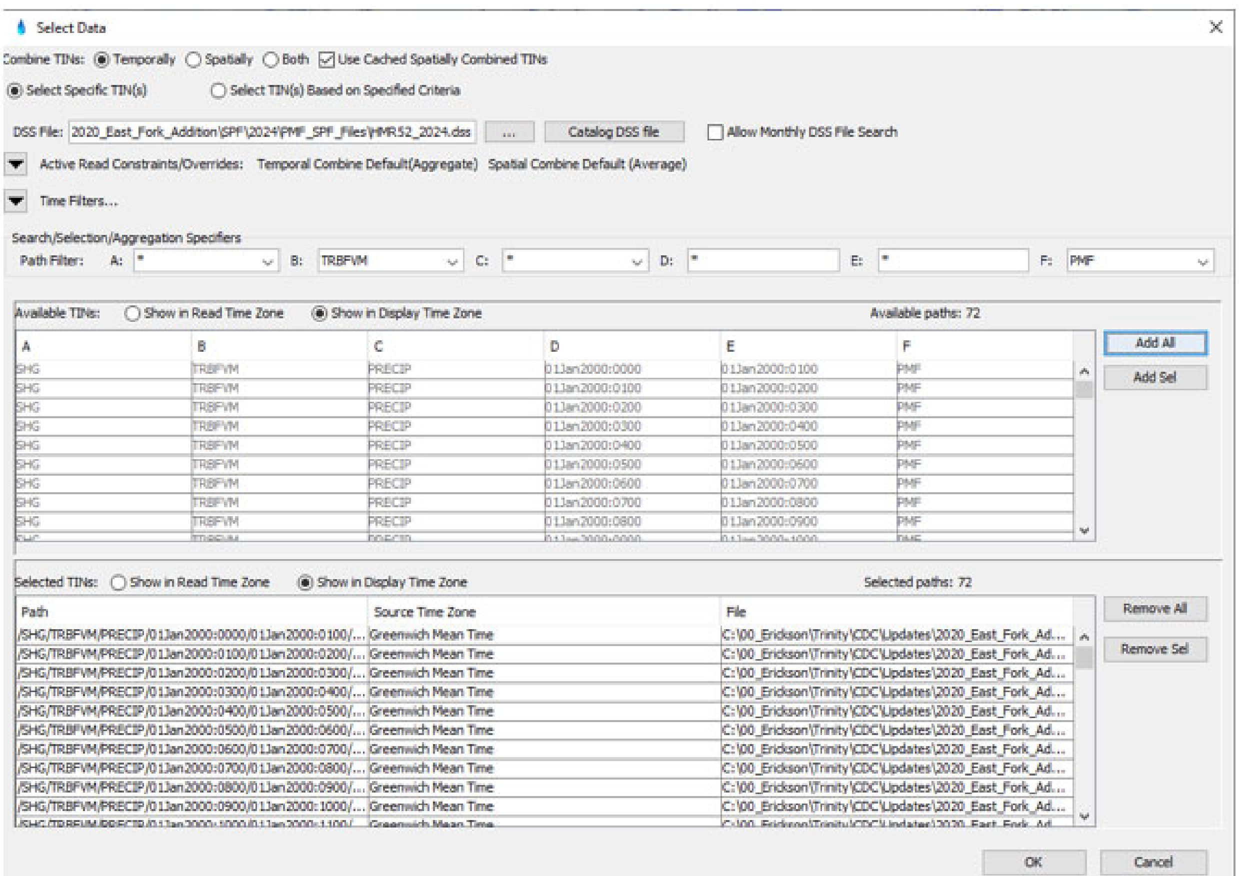
InFRM Trinity WHA Elliptical Storm



Save PMF Storm to Gridded DSS file

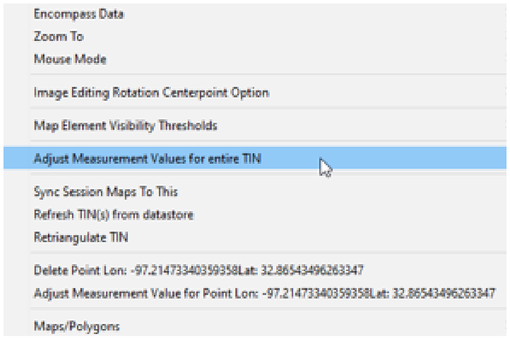


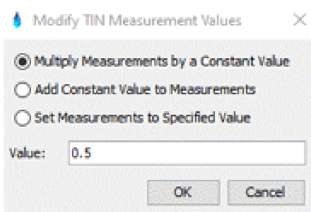
Add PMP gridded DSS file into Metvue (Select DSS Paths)



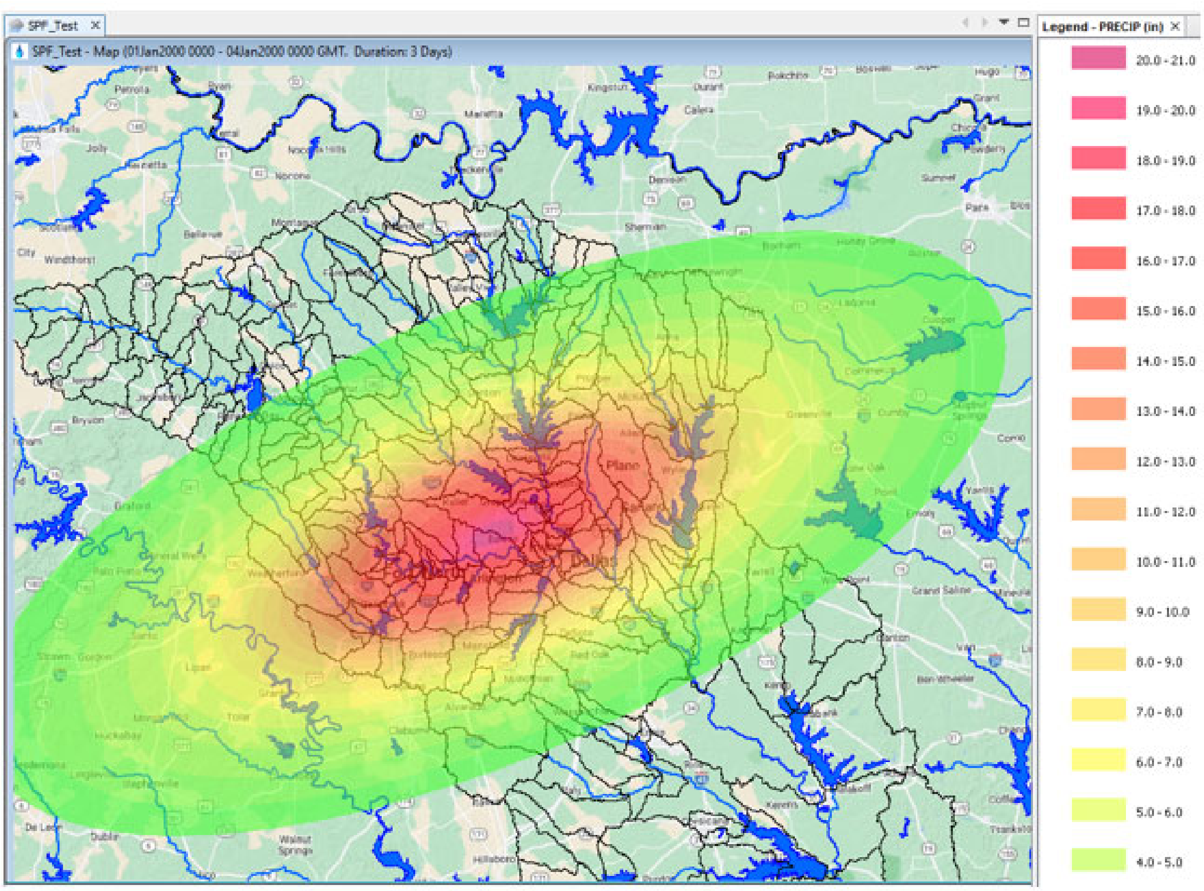
Create SPF storm by reducing PMF storm by 50%.

Right click on map and select "Adjust Measurement Values for entire TIN"

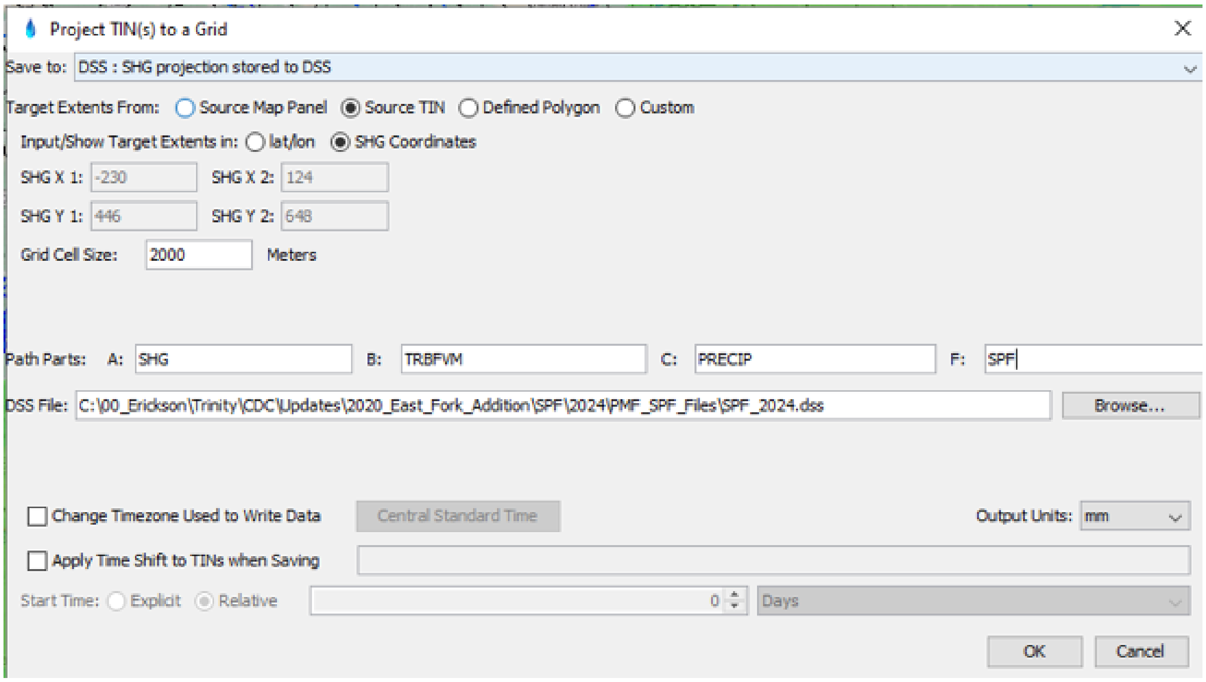




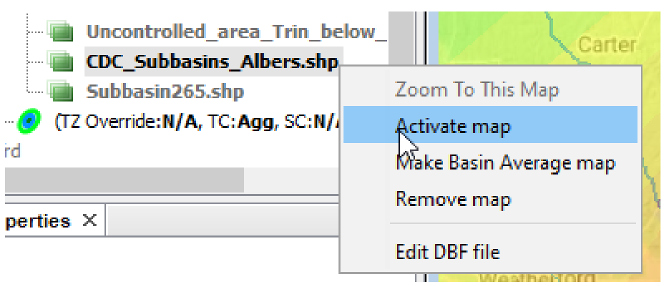
Notice the resulting storm totals have been reduced by 50% from the PMF storm.

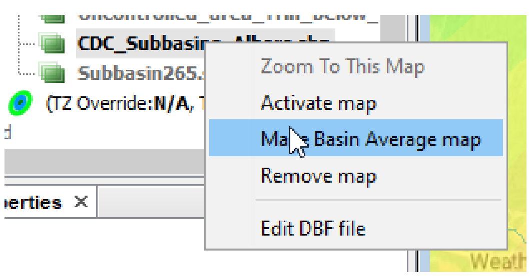


Save SPF Storm to Gridded DSS file

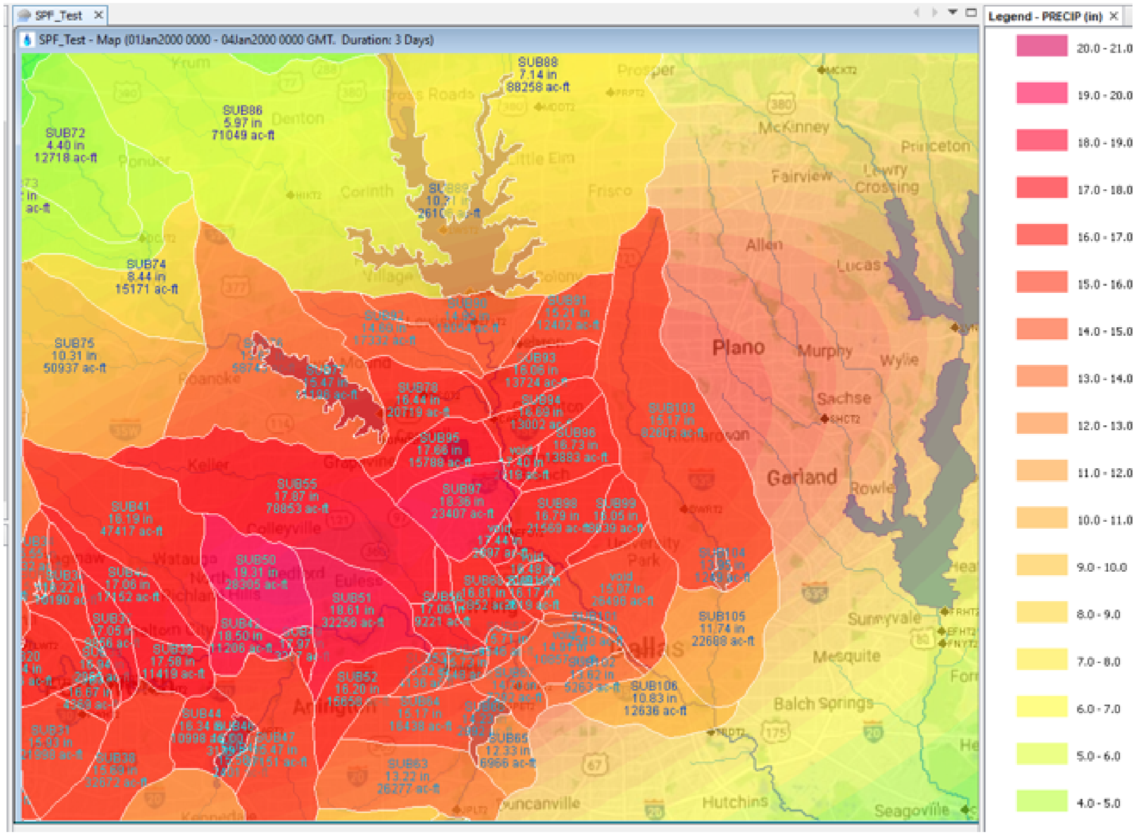


Activate CDC Subbasins Shapefile by right clicking the map layer and selecting "Activate"

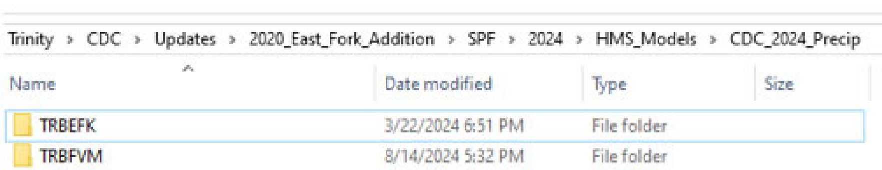




SPS subbasin averages will be visible

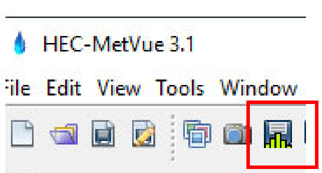


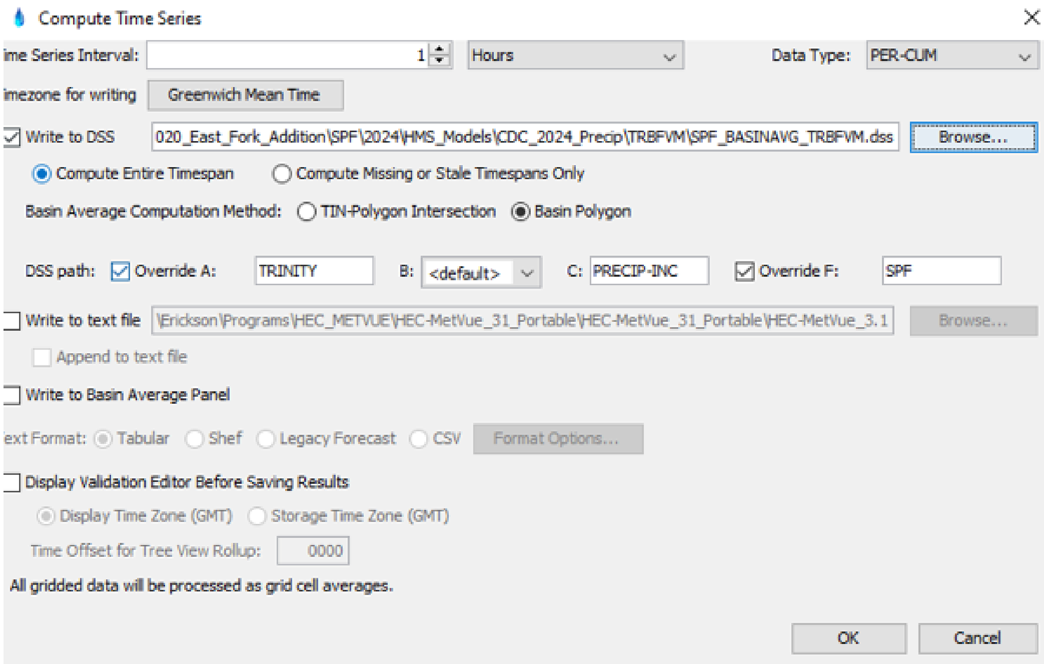
Copy the 2013 CDC HMS model to a new folder named after the junction of interest (i.e TRBFVM for Trinity below five mile creek)



Create a subbasin average dss file

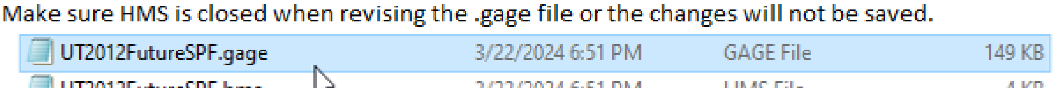
Select the Create Subbasin Time Series from TIN tool



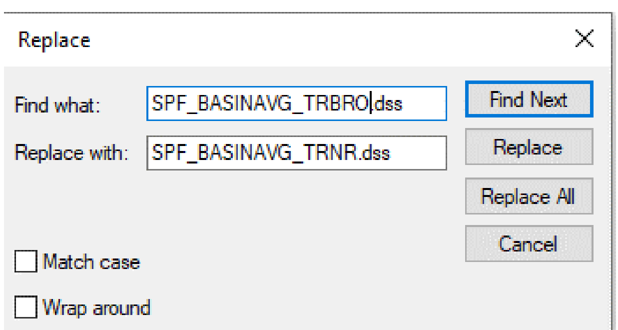


Change the DSS file and Pathnames for the Walker Branch gages to link to the SPS basin average dss file recently created.

Make sure HMS is closed when revising the .gage file or the changes will not be saved.



Open the file in notepad and use the Find and Replace tool

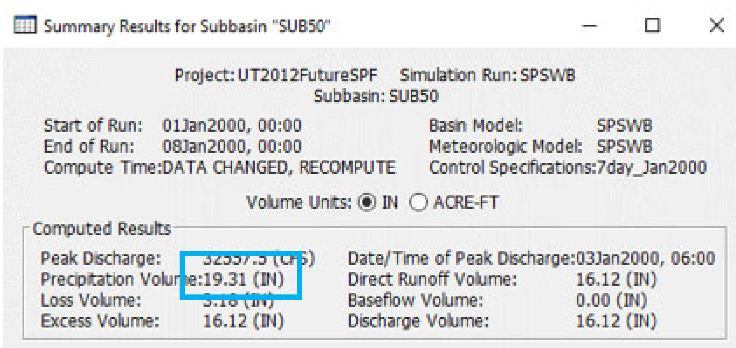


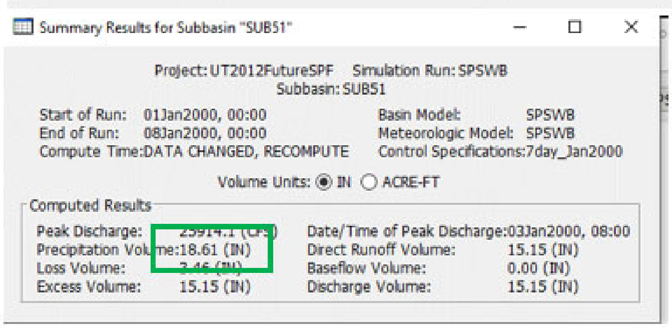
The revised file should look like the example below.

```
Gage: SUB101WB
     Last Modified Date: 10 November 2012
     Last Modified Time: 18:05:25
     Reference Height Units: Feet
     Reference Height: 32.808
     Gage Type: Precipitation
     Precipitation Type: Incremental
     Units: IN
     Data Type: PER-CUM
     Data Source Type: External DSS
     Variant: Variant-1
       Last Variant Modified Date: 22 March 2024
       Last Variant Modified Time: 23:14:09
       Default Variant: Yes
       DSS File Name: SPF_BASINAVG_TRBFVM.dss
       DSS Pathname: /TRINITY/SUB101/PRECIP-INC/01JAN2000/1HOUR/SPF/
       Start Time: 1 January 2000, 00:00
       End Time: 4 January 2000, 00:00
     End Variant: Variant-1
End:
```

Run the SPSWB Simulation Run

Verify the subbasin average precipitation volume totals match between Metvue (see previous screnshot of SPF storm in Metvue) and HMS





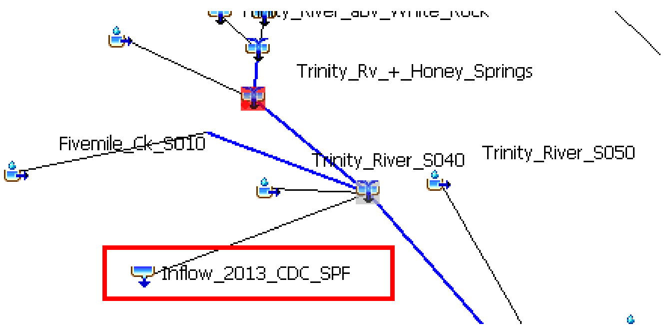
Open the Future Condition (20255) Elliptical Design Storm Model (Updated from Trinity WHA)

Copy 500yr Future Condition Basin model. This is required for each location in the Summary of Discharges table because the basin model will link to the 2013 CDC HMS model where the 2024 SPF simulation was made.

Note the HMS model elements upstream of the "Trinity_River_+Five_Mile_Ck" junction are disconnected so that the inflow to this junction is coming from the 2013 CDC model (with 2024 SPF Storm)

Basin Name: 500yr_Fut_SPF_CDC_TRNR
Element Name: Trinity_River_R050

Description:	ROUTE FROM TRINITY RIVER AT BELOW DALLAS GAGE(RM491.83) TO FIVE MILE CR. (RM486.55)
Downstream:	--None--
Routing Method:	Modified Puls
Loss/Gain Method:	--None--



Basin Name: 500yr_Fut_SPF_CDC_TRNR
Element Name: Inflow_2013_CDC_SPF

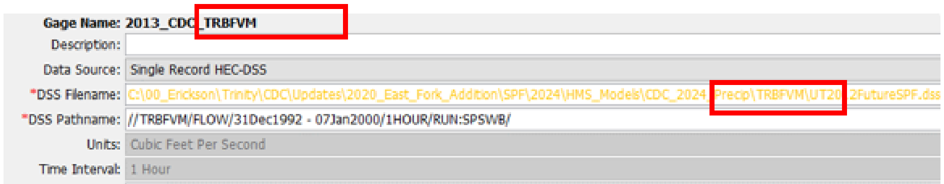
Description:	
Downstream:	Trinity_River_+_Five_Mile_Ck
Area (MI2)	0.01
Flow Method:	Discharge Gage

Basin Name: 500yr_Fut_SPF_CDC_TRBFVM
Element Name: Inflow_2013_CDC_SPF

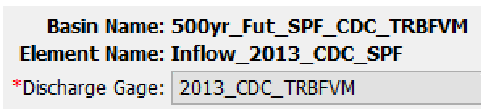
Discharge Gage:	2013_CDC_TRBFVM

Create discharge gage for junction of interest by copying an existing discharge gage

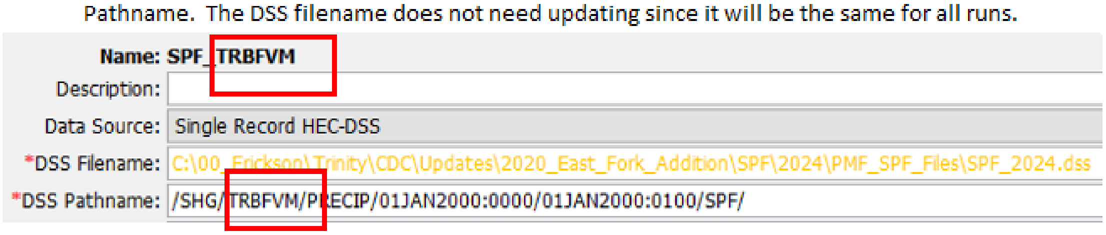
The DSS Pathname will be the same for all the simulations but the DSS Filename will need to be updated to point to the specific folder containing the specific storm and HMS model for the junction of interest. Notice below how the Gage Name and the folder are for the same junction.



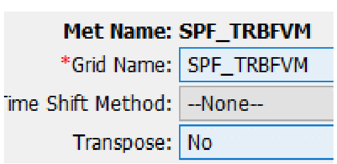
Go back into the basin model and make sure that the "Inflow_2013_CDC_SPF" element is pointing to the new Time-Series Gage that was just created.



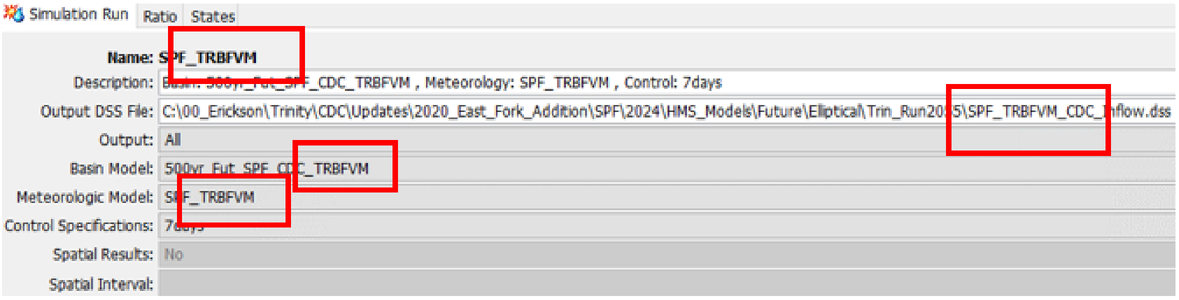
Create a new Precipitation Gridset that will point to the 2024 SPF Storm that was created for the location of interest. This can be done by copying an existing gridset and updating the DSS Pathname. The DSS filename does not need updating since it will be the same for all runs.



Create a new Meterologic Model that will point to the Precipitation Gridset just created.

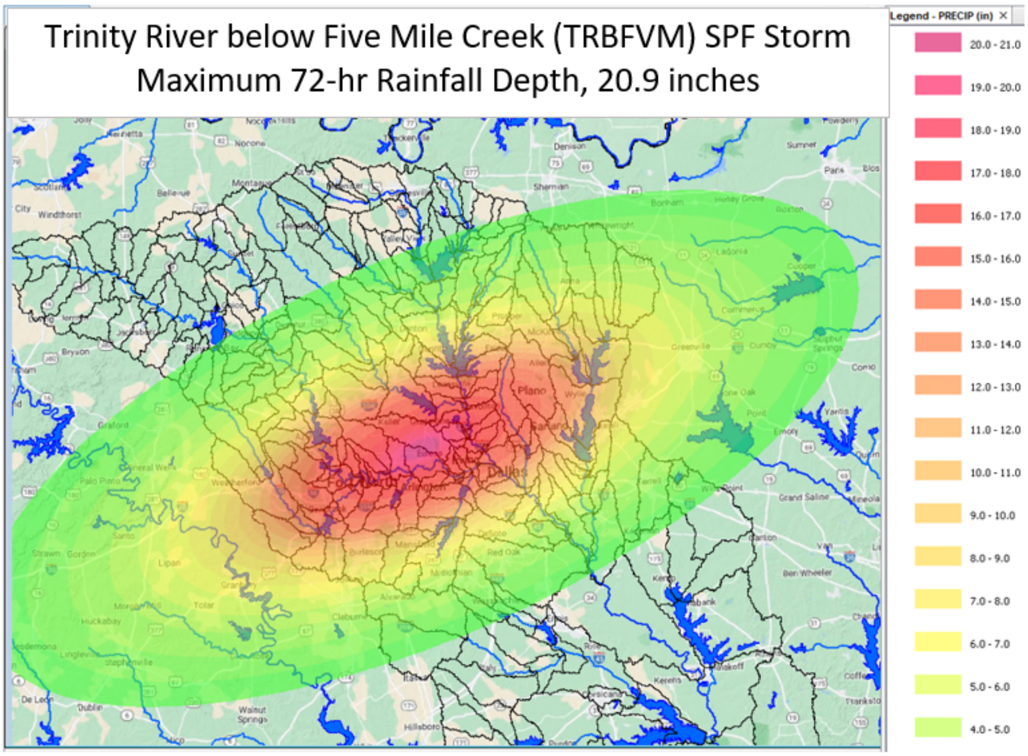


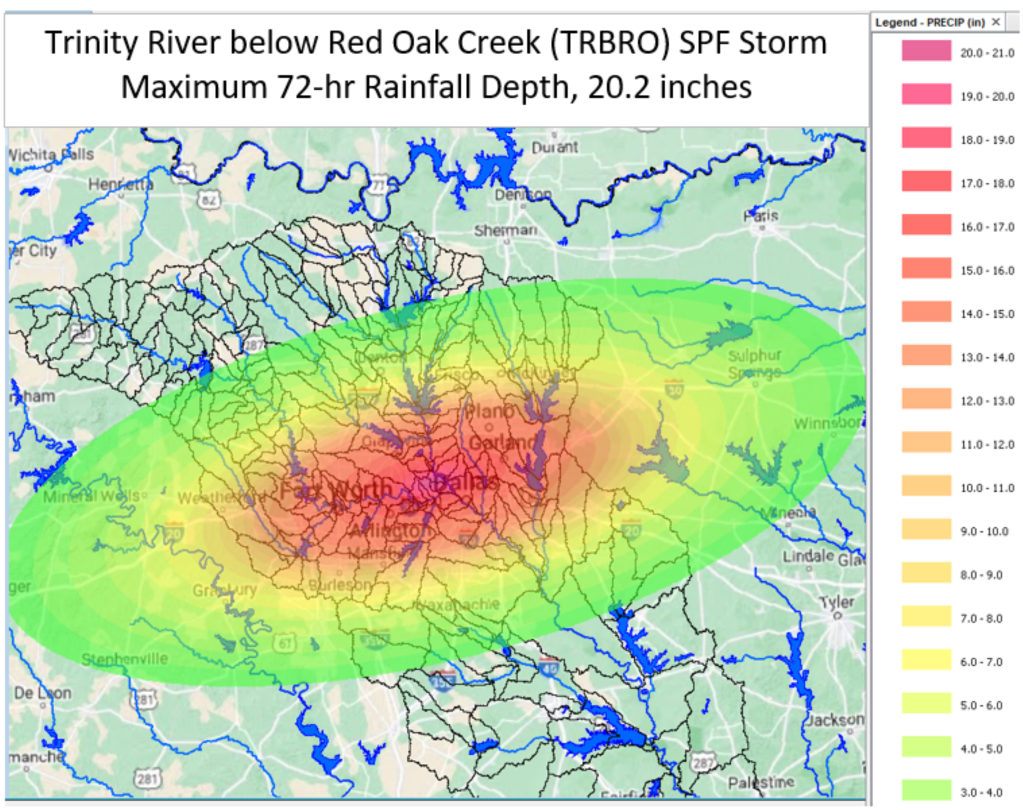
Create a Simulation Run using the Basin Model and Meteorologic Model that were recently created.

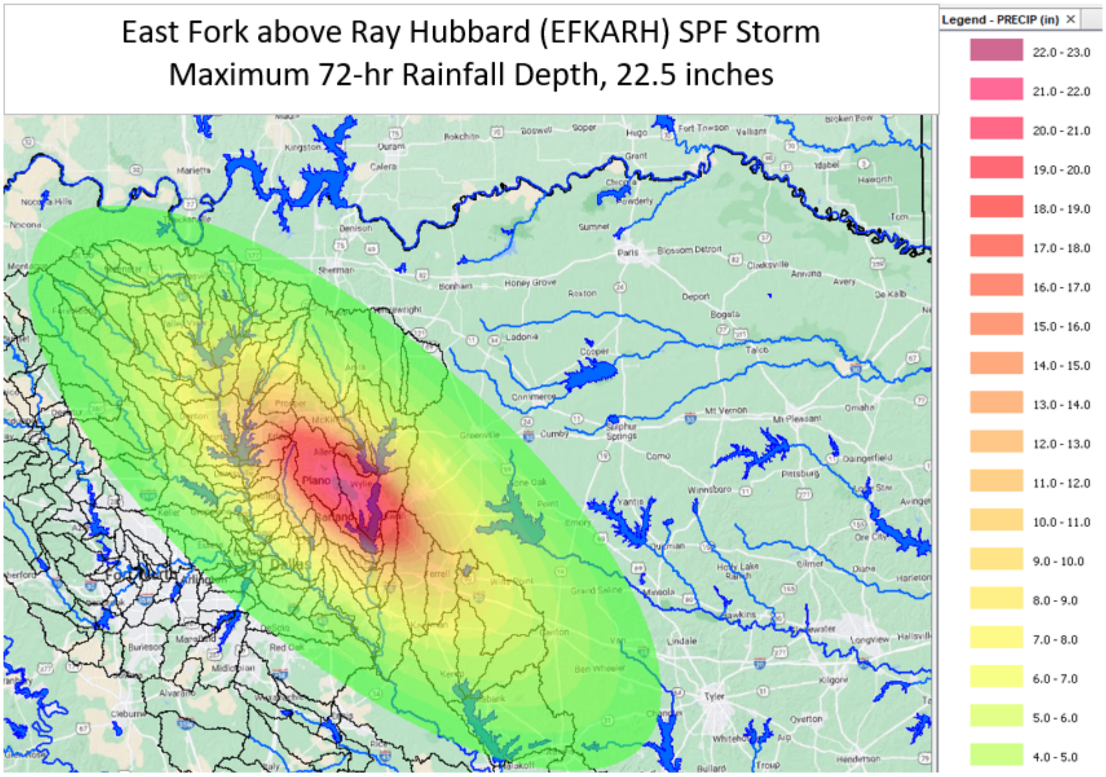


Run Simulation and record results from the Global Summary Results Table

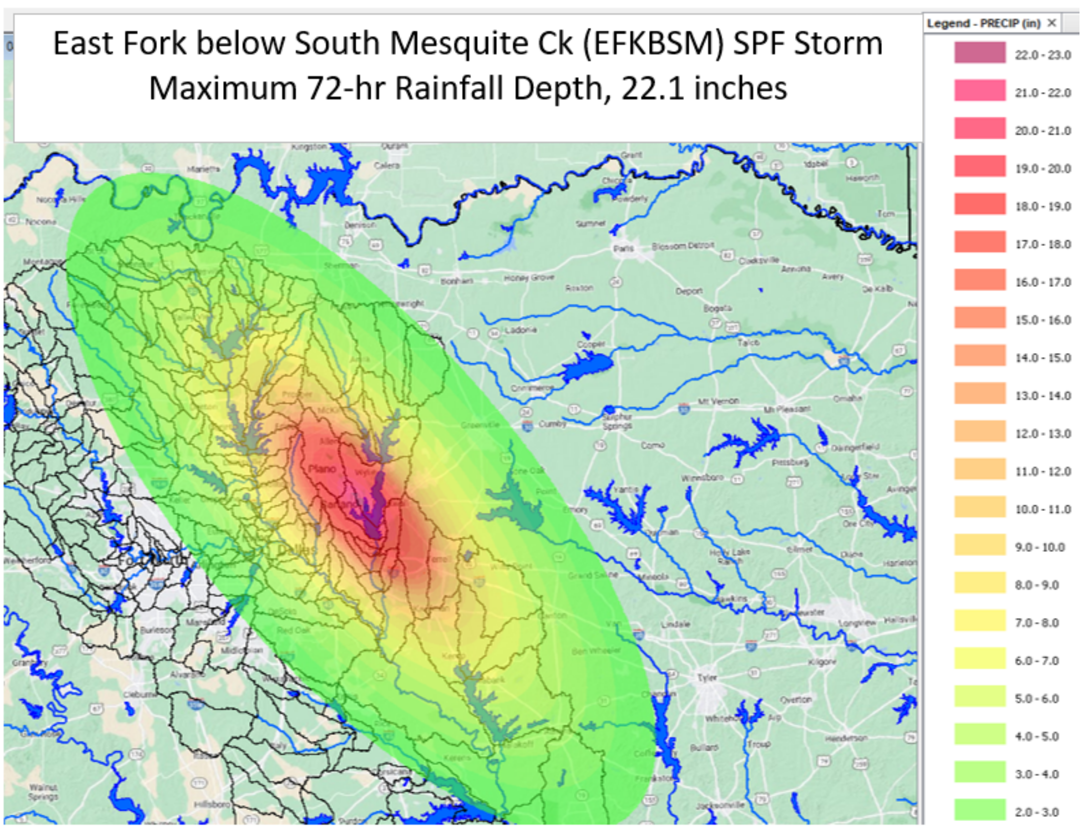
Appendix 4 – Standard Project Flood Storm Maps







East Fork above Ray Hubbard (EFKARH) SPF Storm
Maximum 72-hr Rainfall Depth, 22.5 inches



East Fork below South Mesquite Ck (EFKBSM) SPF Storm
Maximum 72-hr Rainfall Depth, 22.1 inches

Appendix 5 – Future Peak Discharges (2-year thru 500-year)

Location Description	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%	Hydrologic Method
	sq mi	2-YEAR	5-YEAR	10-YEAR	25-YEAR	50-YEAR	100-YEAR	200-YEAR	500-YEAR	
Trinity River below Five Mile Creek	3328.8	28,700	44,300	59,700	84,800	106,100	130,900	158,200	199,200	Elliptical HEC-HMS
Trinity River above Ten Mile Creek	3367.7	26,100	38,400	52,700	75,900	97,700	117,600	141,500	176,800	Elliptical HEC-HMS
Trinity River below Ten Mile Creek	3469.8	26,100	38,500	52,800	75,800	97,100	117,200	140,600	176,100	Elliptical HEC-HMS
Trinity River above the East Fork Trinity River	3529.4	24,800	35,900	49,400	72,100	92,300	115,400	137,300	171,100	Elliptical HEC-HMS
East Fork Trinity River below Honey Creek	167.9	7,600	12,000	16,200	23,000	29,100	36,500	43,600	53,100	Uniform HEC-HMS
East Fork Trinity River near McKinney, TX USGS gage	190.1	8,700	13,500	18,100	25,400	31,900	39,800	47,500	57,800	Uniform HEC-HMS
East Fork Trinity River above Wilson Creek	214.8	8,900	13,700	18,200	25,300	31,600	39,500	47,300	57,600	Uniform HEC-HMS
East Fork Trinity River below Wilson Creek	292.3	13,200	19,900	25,900	35,100	43,200	53,400	63,400	76,900	Uniform HEC-HMS
Sister Grove Creek near Blue Ridge USGS gage	83.2	2,300	3,900	5,300	7,800	9,900	12,500	15,000	18,300	Uniform HEC-HMS
Sister Grove Creek above Indian Creek	121.2	4,100	6,600	8,500	11,200	13,400	15,900	18,400	21,800	Uniform HEC-HMS
Indian Creek at SH 78 nr Farmersville, TX USGS gage	104.6	3,400	5,400	7,300	10,100	12,600	15,700	18,700	22,700	Uniform HEC-HMS
Indian Creek below Pilot Grove Creek	205.8	6,300	11,000	15,000	20,900	26,000	32,300	38,200	46,300	Uniform HEC-HMS
Indian Creek above Sister Grove Creek	235.9	6,900	11,900	16,100	22,600	28,000	35,100	41,600	50,400	Uniform HEC-HMS
Indian Creek below Sister Grove Creek	357.1	9,600	16,200	21,900	30,800	38,500	48,600	58,000	70,700	Uniform HEC-HMS
Lavon Lake Inflow	768.2	32,400	51,100	63,200	80,200	91,900	104,000	120,400	143,200	Elliptical HEC-HMS
Lake Lavon Outflow	768.2	8,000	8,000	12,100	23,600	28,400	41,600	60,400	81,600	Reservoir Study
Rowlett Creek near Sachse, TX USGS gage	119.9	18,200	30,300	40,100	51,600	59,900	69,000	77,900	90,300	Uniform HEC-HMS
Ray Hubbard Lake Inflow	301.8	31,600	49,700	64,400	83,400	98,300	115,100	131,400	153,800	Uniform HEC-HMS
Ray Hubbard Lake Outflow (East Frk blw Ray Hubbard Data)	301.8	12,000	22,200	31,800	43,400	53,200	70,700	90,900	107,100	Uniform HEC-HMS
East Fork Trinity River near Forney USGS gage	349.9	14,200	25,800	36,800	50,300	61,400	79,100	104,300	123,500	Uniform HEC-HMS
East Fork Trinity River above Buffalo Creek	359.5	13,800	23,500	31,900	47,700	59,400	76,200	101,300	122,300	Uniform HEC-HMS
East Fork Trinity River below Buffalo Creek	393.9	14,800	25,000	34,000	50,700	63,300	81,600	108,400	131,200	Uniform HEC-HMS
East Fork Trinity River above South Mesquite Creek	416.9	11,500	20,700	30,300	43,700	55,500	71,600	92,900	119,600	Uniform HEC-HMS

Location Description	Drainage Area*	50%	20%	10%	4%	2%	1%	0.50%	0.20%	Hydrologic Method
East Fork Trinity River below South Mesquite Creek	446.4	12,200	21,700	31,700	45,600	58,000	75,000	97,900	125,800	Uniform HEC-HMS
East Fork Trinity River above Mustang Creek	465.5	11,700	20,400	28,200	39,500	50,500	64,100	79,600	105,800	Uniform HEC-HMS
East Fork Trinity River near Crandall, TX USGS gage	484.8	12,000	20,900	28,800	40,400	51,600	65,600	81,600	108,300	Uniform HEC-HMS
East Fork Trinity River above the Trinity River	484.8	11,300	18,600	25,200	34,200	43,000	54,000	64,900	80,400	Uniform HEC-HMS
Trinity River below the East Fork Trinity River	4014.2	33,900	50,400	68,900	99,800	125,200	154,200	184,300	228,900	Elliptical HEC-HMS
Trinity River below Red Oak Creek	4245.5	34,100	53,300	69,700	100,600	126,400	155,500	186,100	231,300	Elliptical HEC-HMS
Trinity River near Rosser, TX USGS gage	4349.6	32,500	47,600	63,500	94,200	121,000	152,800	181,200	225,200	Elliptical HEC-HMS

*Drainage area is uncontrolled area downstream of USACE dams.

Appendix 6 – Water Surface Elevation Summary

Trinity River 100 Year and SPF Water Surface Elevation Summary

River Sta	**100year Water Surface Elevation (ft)**					**SPF Water Surface Elevation (ft)**				
	Left Bank		Between Levees	Right Bank		Left Bank		Between Levees	Right Bank	
205777			395.6					406.2		
204528			395.5	(F) Dallas LID 1/Dallas LID 2 Levee	386.1			406.1	(F) Dallas LID 1/Dallas LID 2 Levee	392.5
200569			394.7		383.1			404.8		388.2
198513			393.2		380.4			402.4		386.2
196991			392.1		379.6			400.7		385.7
195872			391.3		379.2			399.4		385.4
194145			390.3		378.6			397.8		385.1
193094	380.5	(E) Bois D'Arc Levee	389.8		378.4	387.3	(E) Bois D'Arc Levee	397.0		385.0
191491	378.5		389.3		378.3	384.6		396.0		384.9
189380	376.6		388.8		378.1	382.3		395.2		384.7
187750	376.2		388.4		377.7	381.9		394.4		384.4
186516	375.6		387.9		377.5	381.0		393.5		384.2
186264	375.2		386.0		377.1	380.7		392.8		384.1
184503	374.5		384.7		376.8	379.8		390.8		383.7
181750	373.8		382.6		376.0	379.0		387.9		382.8
179572	372.5		381.4		375.4	377.2		385.9		382.2
178698	372.1		380.9		375.1	376.5		385.1		381.9
176021	369.8		380.0		374.7	373.7		384.3		381.6
172483	367.3		379.1		374.3	371.4		383.4		381.2
169025	366.3		378.1		373.8	370.8		382.3		380.7
167085	365.6		377.3		373.5	370.4		381.6		380.4
165454	365.3		376.9		373.3	370.2		381.3		380.0
165204	365.1		376.8		373.2	370.2		381.1		380.0
164199	364.4		376.1		373.0	369.8		380.6		379.7
162832	363.9		375.4		372.8	369.5		380.0		379.4
161707	363.6		374.9		372.8	369.4		379.7		379.4
159456	362.9		374.2		372.7	369.1		379.3		379.2
157344	362.1		373.7		372.6	368.8		379.1		379.2
154267	361.8		372.9		372.5	368.6		378.7		379.0
151264	361.4		372.4		372.4	368.3		378.5		378.7
148768	361.3		372.0	(D) Dallas LID	361.8	368.2		378.4	(D) Dallas LID	367.9
147333	361.0		371.6		360.9	368.0		377.9		367.0
145717	360.9		371.0		359.9	367.9		377.0		366.0
143893	360.6		370.0		359.1	367.6		375.6		365.3
141890	360.5		369.1		358.5	367.5		374.5		364.8

139225	360.4		368.2		358.1	367.4		373.2		364.6
137179	360.2		367.0		357.8	367.3		371.7		364.3
135104	360.1		366.2		357.3	367.1		370.7		363.9
133245	360.0		365.6		357.0	367.0		370.0		363.6
131382	359.9		365.4		356.9	366.9		369.8		363.4
129561	359.8		364.8		356.7	366.8		369.2		363.3
127110	359.7		363.9		356.5	366.7		368.3		363.0
124996	359.6		362.9		356.4	366.5		367.4		362.9
123554	359.5		362.4		356.3	366.4		366.9		362.8
122155	359.5		362.0		356.2	366.4		366.6		362.7
120905	359.4		361.7		356.2	366.3		366.3		362.6
118211	359.3		361.0		356.1	366.1		365.8		362.6
116211	358.7		360.5		356.1	365.4		365.5		362.5
113969	358.1		359.9		356.0	364.6		365.2		362.5
112556	357.8		359.5		356.0	364.2		365.0		362.5
110130	357.2		358.5		356.0	363.3		364.5		362.4
108725	357.0		358.0		356.0	363.0		364.3		362.4
107532			357.8		356.0			364.2		362.4
104348			357.4		355.9			363.9		362.4
96265			357.1		355.9			363.6		362.4
95077			357.0		355.9			363.6		362.4
91978			356.8		355.9			363.3		362.3
83613	351.7	(C) Kaufman MUD 1 Levee	356.1		355.8	356.9	(C) Kaufman MUD 1 Levee	362.6		362.3
80593	351.7		355.9		355.8	356.9		362.3		362.3
76398	351.7		355.7			356.9		362.2		
74608	351.7		355.5			356.9		361.9		
72672	351.6		355.1			356.9		361.4		
71053	351.6		354.8	(B) Ellis LID 2 Levee	347.3	356.8		360.9	(B) Ellis LID 2 Levee	352.0
68028	351.6		354.1		343.9	356.8		359.9		348.3
65984	351.6		353.3		342.5	356.7		358.8		346.6
64637	351.6		353.0		341.5	356.7		358.4		345.5
62238	351.5		352.7		340.2	356.7		358.0		344.0
59702	351.5		352.1		339.2	356.7		357.3		342.8
56823	351.5		351.5		338.3	356.6		356.6		342.1
55303	341.4	(A) Kaufman LID	351.3		337.3	346.0	(A) Kaufman LID	356.4		341.5
53117	338.3		351.0		336.4	343.0		356.0		340.6
51036	337.9		350.4		336.0	342.1		355.0		340.2
48916	337.1		349.2		335.6	341.2		353.2		339.8
46568	336.2		347.5		335.3	340.1		350.7		339.5
45073	335.7		346.3		335.1	339.5		348.6		339.3
44793	335.0		344.7		334.8	339.0		348.0		339.2

43746	334.7		344.3		334.8	338.7		347.6		339.1
42372	334.3		344.0		334.7	338.3		347.2		339.0
39787	333.1		343.8		334.6	337.3		346.9		338.9
38724	332.9		343.2		334.5	337.0		346.3		338.8
37337	332.4		342.6		334.4	336.5		345.6		338.7
35159	331.7		341.6		334.3	335.7		344.4		338.5
32786	330.6		341.0		334.3	334.5		343.7		338.5
30239	329.8		339.9		334.1	333.7		342.6		338.3
28041	328.8		339.2		334.1	332.6		341.8		338.2
26191	327.9		338.3		333.9	331.8		340.9		338.0
24046	326.3		337.4		333.8	330.2		340.1		337.8
19761	323.8		335.8		333.7	328.4		338.7		337.7
17358	323.3		334.7		333.5	327.9		337.9		337.5
15600	323.0		333.1		333.2	327.6		336.9		337.1
13539	322.6		332.9			327.3		336.8		
11371	322.2		332.5			327.0		336.4		
9505	322.0		331.9			326.9		335.9		
7604	321.9		330.8			326.8		335.3		
6288	321.8		330.1			326.7		334.8		

East Fork of Trinity River 100 Year and SPF Water Surface Elevation Summary

River Sta	100year Water Surface Elevation (ft)					SPF Water Surface Elevation (ft)				
	Left Bank		East Fork Main	Right Bank		Left Bank		Trinity Main	Right Bank	
154701			400.0					407.2		
153755			398.7					405.2		
152745			397.8					404.5		
151671			397.5					404.1		
150670			397.4					404.0		
149657			397.3					403.9		
148653			397.3					403.8		
147648			397.2					403.7		
146847			397.1					403.7		
145933			396.6					403.5		
145581			395.4					399.1		
144984			394.9					398.8		
144246			394.7					398.5		
141955			394.4					398.0		
140162			394.3					397.6		
137347			394.2					397.5		
135946			394.1					397.4		
134267			394.0					397.2		
133019			393.9					397.0		
131615			393.8					396.6		
131320			392.9					396.6		
131178			389.5					394.8		
130522			388.9					394.6		
129244			388.2					394.3		
128203			387.6					393.9		
127187			387.1					393.6		
126440			386.7					393.3		
125131			386.2					393.0		
124014			385.7					392.7		
123188			385.5					392.5		
122311			385.1					392.3		
120494			384.8					392.0		
118625			384.5					391.7		
115837			384.3					391.6		
114150			384.1					391.4		
112120			384.0					391.3		
111013			383.8					391.1		
108510			383.7					391.0		
107423			383.6					390.8		
106628			383.5					390.8		
105627			383.4					390.7		
104782			383.3					390.6		
103602			383.2					390.5		
102905			382.9					390.4		
102352			381.2					385.9		
101670			380.9					385.8		
100387			380.7					385.7		
97061			380.5					385.4		

96048			380.3					385.1		
94766	376	(K) Kaufman LID 15 Levee	380.0			381.6	(K) Kaufman LID 15 Levee	384.5		
93866	374		379.7			380.4		383.9		
91923	372		379.0			379.5		382.9		
90416	371		378.4			379.2		382.3		
89281	370		378.0			378.9		381.8		
88315	369.9		377.6			378.8		381.3		
86331	369.5		376.6			378.7		380.4		
85652	369.0		376.0			378.6		380.0		
84705	368.5		374.8			378.5		379.2		
83642	368.4		373.9			378.4		378.8		
83532	368.3		373.8			378.4		378.7		
82836	368.3		373.2			378.4		378.5		
81963	368.2		372.6			378.4		378.4		
81004	368.0		372.1			378.4		378.3		
77836	367.9		371.4			378.3		378.2		
77092	367.8		371.2			378.3		378.2		
75815	367.7		370.8			378.3		378.2		
74927	367.7		369.5			378.2		378.2		
72977	367.5		368.5			378.2		378.2		
72378	367.4		368.1			378.1		378.2		
70658	367.3		367.6			378.1		378.2		
68622			367.3					378.2		
66590			367.0	(J) Kaufman LID 10 Levee	366.0			378.0	(J) Kaufman LID 10 Levee	376.7
64748			366.7		365.8			377.7		376.6
63490			366.5		365.7			377.6		376.5
62827			366.4		365.6			377.5		376.5
62107			366.3		365.5			377.5		376.5
61773			366.1		365.4			377.4		376.5
61239			365.7		365.2			376.3		375.8
61008			365.6		365.2			376.3		375.8
59796			365.4		365.1			376.1		375.7
58768			365.2		365.0			376.0		375.7
57547			365.1		365.0			375.8		375.7
56456			365.0		364.9			375.7		375.6
54807			364.9		364.9			375.6		375.6
54191			364.8		364.8			375.5		375.6
53843			364.7		364.7			375.5		375.5
53041	360.3	(H) Kaufman 5 East Levee	364.6	(I) Kaufman 5 W Levee	362.0	371.6	(H) Kaufman 5 East Levee	375.4	(I) Kaufman 5 W Levee	373.5
52589	360.3		364.6		361.9	371.6		375.3		373.4
51649	360.3		364.3		361.8	371.5		374.9		373.3

50644	360.2		364.0		361.8	371.5		374.3		373.3
49796	360.2		363.7		361.7	371.5		374.0		373.2
48320	360.2		363.4		361.7	371.5		373.5		373.2
47200	360.1		363.1		361.6	371.4		373.0		373.1
46345	360.1		362.9		361.5	371.4		373.0		373.0
45584	360.0		361.3			371.4		372.9		
44251	359.9		360.9			371.3		372.6		
42906	359.9		360.3			371.3		371.7		
42075	359.8		360.0			371.2		371.4		
40855	359.7		359.6			371.1		371.0		
39720	352.2		359.4			358.0		370.7		
38555	350.9 (351.7*)		359.1			355.9 (356.9*)		370.3		
37574	349.9 (351.7*)		358.9			354.6 (356.9*)		370.1		
36633	349.0 (351.7*)		358.7			353.4 (356.9*)		369.8		
35477	348.2 (351.7*)		358.0			352.4 (356.9*)		368.8		
34584	347.7 (351.7*)		357.7 (358.0*)			351.8 (356.9*)		368.3		
33667	347.1 (351.7*)		357.4 (358.0*)			351.1 (356.9*)		367.9		
32592	346.5 (351.7*)		356.9 (358.0*)			350.6 (356.9*)		367.1		
31621	346.0 (351.7*)		356.5 (358.0*)			350.1 (356.9*)		366.5		
30803	345.8 (351.7*)		356.2 (358.0*)			349.9 (356.9*)		366.1		
29740	345.6 (351.7*)		355.8 (358.0*)			349.7 (356.9*)		365.5		
28442	345.3 (351.7*)		355.1 (358.0*)			349.4 (356.9*)		364.3		
27695	345.1 (351.7*)		354.9 (358.0*)			349.2 (356.9*)		363.8 (364.3*)		
26944	345.0 (351.7*)		354.6 (358.0*)			349.0 (356.9*)		363.2 (364.3*)		
26212	344.8 (351.7*)		354.2 (358.0*)			348.8 (356.9*)		362.6 (364.3*)		
25584	344.6 (351.7*)	(G) Kaufman MUD 1 Levee	353.9 (358.0*)			348.6 (356.9*)	(G) Kaufman MUD 1 Levee	362.1 (364.3*)		
24832	344.3 (351.7*)		353.6 (358.0*)			348.3 (356.9*)		361.3 (364.3*)		
23467	344.0 (351.7*)		353.1 (358.0*)			347.9 (356.9*)		360.7 (364.3*)		
22521	343.8 (351.7*)		352.8 (358.0*)			347.7 (356.9*)		360.0 (364.3*)		
21721	343.6 (351.7*)		352.5 (358.0*)			347.5 (356.9*)		359.3 (364.3*)		
21095	343.5 (351.7*)		352.3 (358.0*)			347.4 (356.9*)		358.9 (364.3*)		
20992	343.5 (351.7*)		352.2 (358.0*)			347.3 (356.9*)		359.0 (364.3*)		
20892	343.4 (351.7*)		352.2 (358.0*)			347.3 (356.9*)		358.8 (364.3*)		
19745	343.2 (351.7*)		351.7 (358.0*)			347.1 (356.9*)		357.8 (364.3*)		
18741	343.1 (351.7*)		351.5 (358.0*)			346.9 (356.9*)		357.4 (364.3*)		
16998	342.8 (351.7*)		351.3 (358.0*)			346.6 (356.9*)		357.1 (364.3*)		
16194	342.7 (351.7*)		351.2 (357.8*)			346.5 (356.9*)		357.0 (364.2*)		
14669	342.5 (351.7*)		350.8 (357.4*)			346.2 (356.9*)		356.6 (363.9*)		
12629	342.0 (351.7*)		350.2 (357.1*)			345.7 (356.9*)		355.9 (363.6*)		
11232	341.6 (351.7*)		349.8 (357.0*)			345.2 (356.9*)		355.5 (363.6*)		
9844	341.2 (351.7*)		349.4 (356.8*)			344.8 (356.9*)		355.2 (363.3*)		

Note: (*) Water Surface Elevation from the Trinity River backwater