North Central Texas Council of Governments

Integrating Transportation and Stormwater Infrastructure

Hydrology Modeling Updates for the Mountain Creek Watershed

August 2026

TEXAS WATER DEVELOPMENT BOARD

Texas Department of Transportation

This study was funded by the Texas Water Development Board and Texas Department of Transportation.

integrating Transportation & Stormwater Infrastructure

Integrating Transportation and Stormwater Infrastructure (TSI)

HEC-HMS Modeling for the Mountain Creek Watershed

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1 Executive Summary

An agreement between the Department of the Army represented by the US Army Corps of Engineers (USACE), Fort Worth District, and the North Central Texas Council of Governments (NCTCOG) in connection with the Integrated Watershed Based Planning for Regional Transportation and Stormwater Management in the Upper Trinity River Basin, Texas, was established to perform a study in the Mountain Creek area. The hydrologic study for the Mountain Creek Watershed will be to add detail to the Interagency Flood Risk Management (InFRM) Trinity Watershed Hydrologic Assessment (WHA) Hydrologic Engineering Center-Hydrologic Modeling System (HEC-HMS) model by adding additional subbasin and reach locations where flows will be developed with the additional subbasins and calibrated to match the InFRM WHA HEC-HMS results at their common locations. Then, the existing conditions basin model will be updated to match 2020 impervious conditions and one future condition basin model will be created representing the year 2070, based on future conditions data provided by the NCTCOG and Environmental Protection Agency Integrated Climate and Land use Scenarios (EPA ICLUS). These models will be used for two purposes: (1) to feed flows into the TSI Hydrologic Engineering Center-River Analysis System (HEC-RAS) models, and (2) to optimize project alternatives such as possible detention locations. The alternatives analysis will be performed by the University of Texas Arlington (UTA).

2 Data Sources

This section describes the data that was collected /reviewed for the hydrologic study effort, including geospatial and climatic information, field observations and previous reports for the study area.

2.1 GIS Data

Data from different sources were gathered and processed using the latest Geographic Information System (GIS) tool.

Table 2-1. GIS Data Sources

Data Type	Data Source	Description of the Data
Study Area	Subbasins from the Trinity InFRM WHA HEC-HMS model	Used as rough outline of the study area.
Terrain	Texas Water Development Board (TWDB)	Digital Elevation Model (DEM) of the West TSI study area with a 30-ft cell size that was generated from the 2021 TWDB seamless statewide LiDAR data.
Stream Centerlines	Future of Flood Risk Data (FFRD) National Hydrography Dataset (NHD)	Stream centerlines layers from the Trinity FFRD study and the NHD database.
Roads	Texas Department of Transportation (TXDOT)	Locations of current and future TXDOT roads
Bridges	Texas Department of Transportation (TXDOT)	Locations of current and future TXDOT bridges
Percent Impervious		Percent impervious raster for the current and future years generated from NCTCOG and EPA ICLUS land use data for the TSI project.
Percent Urban	North Central Texas Council of Governments (NCTCOG) and EPA	Percent urban raster for the current and future years generated from NCTCOG and EPA ICLUS land use data for the TSI project.
Dams	National Inventory of Dams (NID)	Dam locations from the National Inventory of Dams
Reservoirs	US Army Corps of Engineers, Fort Worth District Database (USACE-SWF)	A polygon shapefile of the major lakes and reservoirs in the Trinity River basin.

2.2 HEC-HMS data from Existing models

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 Mountain Creek area was completed using the basin-wide HEC-HMS model developed for the 2021 Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment (WHA) for the Trinity River as a starting point. The InFRM model was calibrated to multiple recent flood events, including those similar in magnitude to a 1% annual chance (100-yr) storm. Finally, frequency storms were incorporated into the InFRM HEC-HMS model using the latest published frequency rainfall depths from the National Oceanic and Atmospheric Administration (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 (InFRM, WHA for the Trinity River Basin, July 2021).

3 HEC-HMS Initial Model Development

For this study, additional detail was added to the InFRM Trinity WHA HEC-HMS model by adding additional subbasins and reach locations, where flows will be calculated for the TSI hydraulic modeling. First, an existing conditions (2016) basin model was developed with the additional subbasins and "calibrated" to match the InFRM WHA HEC-HMS results at their common locations. Then, the existing conditions basin model was updated to match 2020 impervious conditions and one future condition basin model was created representing the year 2070, based on future conditions data provided by the NCTCOG. These models will be used for two purposes: (1) to feed flows into the TSI HEC-RAS models, and (2) to optimize project alternatives such as possible detention locations. The alternatives analysis will be performed by UTA.

3.1 HEC-HMS Subbasin Locations

Approximate points for subbasin outlet locations were developed prior to the initiation of the Mountain Creek modeling. These subbasin locations were reviewed and approved by the rest of the TSI H&H team, including UTA, Tarrant Regional Water District (TRWD) and the NCTCOG. The guidelines and priorities for placing subbasin outlet locations are described below.

A subbasin outlet point was placed where each of the features listed below intersected with the stream centerlines layer. Engineering judgment was applied to keep the relative drainage areas and number of subbasins reasonable. At attempt was made to keep the subbasin areas in the range of 1 to 5 square miles with subbasins at the smaller end of that range being used in the areas with more urban development for existing or future conditions.

1. USGS Gages and/or WHA subbasin outlets
2. Above Significant Stream Confluences – points were placed on each stream just above the confluences, according to the stream centerlines file.
3. At Existing Dams – points were placed at the locations of existing dams, according to the NID layer, unless the dam did not appear to significantly impact flow or the NID attributes showed negligible flood storage capacity.
4. At Existing Bridges - points were placed where the streams intersected with the Existing TxDOT bridge layer. Engineering judgement was used to select bridge locations with the potential for upstream detention.
5. At Future Roads - points were placed where the streams intersected with the Future Road locations 2045 layer. Engineering judgement was used to select bridge locations with the potential for upstream detention.

The resulting points shapefile of subbasin outlets was used as a guide for the approximate number and desired locations of the subbasin outlets for the Mountain Creek area, as shown in Figure 3-1.

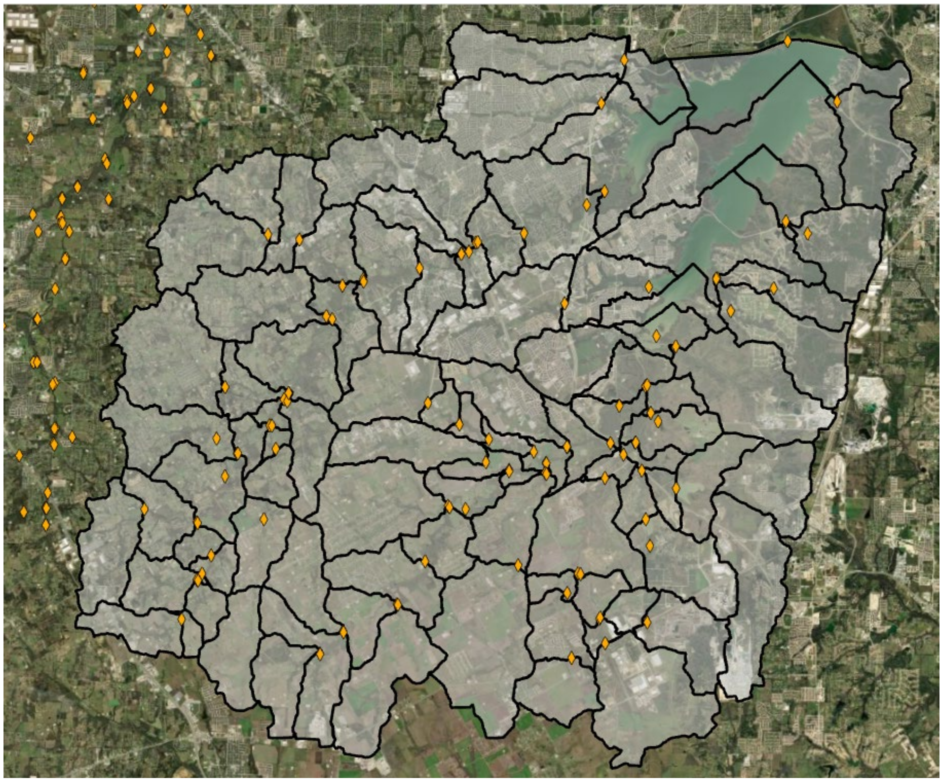


Figure 3-1. HEC-HMS Subbasin Location for TSI Mountain Creek Area.

3.2 HEC-HMS Subbasin Delineations

HEC-HMS version 4.11 was used to delineate the Mountain Creek Watershed from a 30-ft cell size DEM layer to 91 subbasins. HEC-HMS is provided with several capabilities such as terrain reconditioning, preprocess sinks and drainage, and identify stream, as well as, the use of break points, which can be placed at locations of downstream outlets. They are also used to split basins at bridges and detention basins. The goal is to refine the WHA larger basins to smaller subbasins and capture critical infrastructure in the model and assess impacts during flood events. The delineated Mountain Creek subbasins are shown in Figure 3-2.

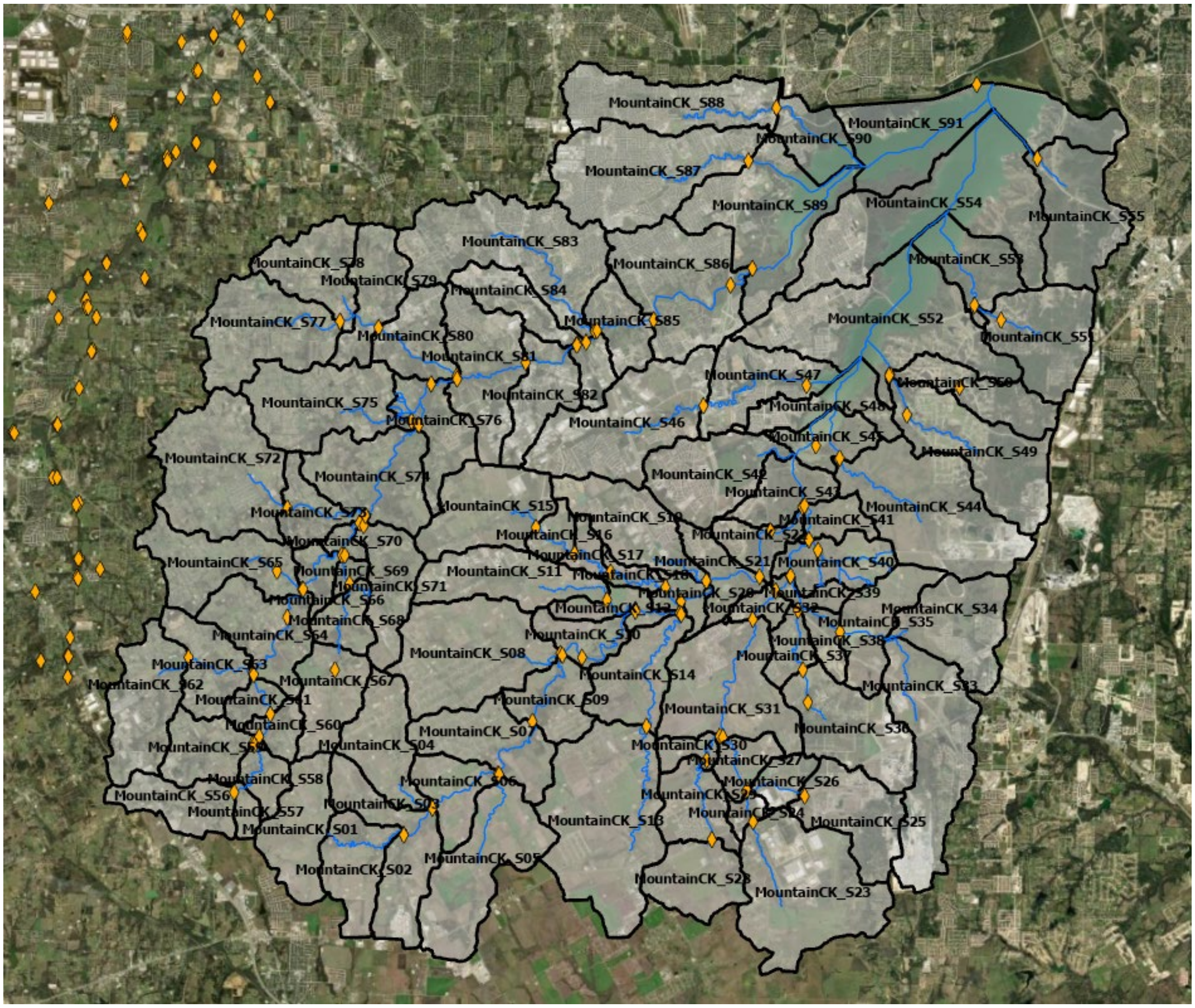


Figure 3-2. HEC-HMS Final Subbasin Delineation for TSI Mountain Creek Area.

Table 3-1. Initial HEC-HMS Subbasins

Subbasin Name	Area (Sq. Miles)	Subbasin Name	Area (Sq. Miles)	Subbasin Name	Area (Sq. Miles)	Subbasin Name	Area (Sq. Miles)
MountainCK_S01	2.48	MountainCK_S24	0.41	MountainCK_S46	4.83	MountainCK_S69	0.30
MountainCK_S02	2.09	MountainCK_S25	2.72	MountainCK_S47	2.52	MountainCK_S70	0.36
MountainCK_S03	3.07	MountainCK_S26	0.80	MountainCK_S48	1.78	MountainCK_S71	2.06
MountainCK_S04	2.38	MountainCK_S27	0.96	MountainCK_S49	3.94	MountainCK_S72	5.04
MountainCK_S05	3.98	MountainCK_S28	2.08	MountainCK_S50	2.01	MountainCK_S73	1.27
MountainCK_S06	1.61	MountainCK_S29	1.76	MountainCK_S51	3.10	MountainCK_S74	3.26
MountainCK_S07	2.75	MountainCK_S30	0.57	MountainCK_S52	6.63	MountainCK_S75	3.72
MountainCK_S08	4.73	MountainCK_S31	4.35	MountainCK_S53	2.05	MountainCK_S76	1.91
MountainCK_S09	1.71	MountainCK_S32	0.55	MountainCK_S54	7.04	MountainCK_S77	3.76
MountainCK_S10	1.18	MountainCK_S33	4.87	MountainCK_S55	3.39	MountainCK_S78	2.29
MountainCK_S11	2.81	MountainCK_S34	2.97	MountainCK_S56	1.79	MountainCK_S79	2.05
MountainCK_S12	0.98	MountainCK_S35	2.17	MountainCK_S57	0.41	MountainCK_S80	1.86
MountainCK_S13	6.57	MountainCK_S36	3.30	MountainCK_S58	0.82	MountainCK_S81	3.20
MountainCK_S14	2.39	MountainCK_S37	0.87	MountainCK_S59	1.76	MountainCK_S82	1.96
MountainCK_S15	3.14	MountainCK_S38	0.69	MountainCK_S60	0.74	MountainCK_S83	5.57
MountainCK_S16	0.67	MountainCK_S39	0.54	MountainCK_S61	0.65	MountainCK_S84	2.25
MountainCK_S17	0.53	MountainCK_S40a	0.60	MountainCK_S62	3.00	MountainCK_S85	1.45
MountainCK_S18	0.47	MountainCK_S40b	1.20	MountainCK_S63	1.95	MountainCK_S86	4.61
MountainCK_S19	2.69	MountainCK_S41	0.84	MountainCK_S64	2.63	MountainCK_S87	5.28
MountainCK_S20	0.73	MountainCK_S42	3.01	MountainCK_S65	2.97	MountainCK_S88	3.60
MountainCK_S21	1.27	MountainCK_S43	1.53	MountainCK_S66	0.73	MountainCK_S89	4.94
MountainCK_S22	1.11	MountainCK_S44	5.51	MountainCK_S67	2.03	MountainCK_S90	1.57
MountainCK_S23	5.50	MountainCK_S45	1.33	MountainCK_S68	1.06	MountainCK_S91	5.17

3.3 HEC-HMS Initial Parameters

First, an existing conditions (2016) basin model was developed with the new subbasin delineation and “calibrated” to match the InFRM WHA HEC-HMS results at their common locations. The 1% Annual Chace of Exceedance (ACE) or 100-year HEC-HMS initial hydrologic parameters were copied from the calibrated WHA HEC-HMS models and presented in the below tables. The WHA larger basins were overlayed on top of the delineated subbasins to validate the use of copied parameters for the new model. The following parameter tables in this section reflect 2016 conditions that coincide with the 100-yr WHA HEC-HMS model. These parameters were later updated for 2020 and 2070 conditions.

3.3.1 Initial Subbasin Parameters

Percent Imperviousness

Imperviousness for the entire watershed was extracted from the NLCD database for 2016 conditions, which was the same dataset used in the InFRM WHA. then applied to the individual subbasins. Table 3-2 shows the calculated subbasin impervious values for 2016.

Initial and Constant Losses

The initial losses and loss rate parameters were assumed the same for the delineated basins that coincided with the WHA basins.

Table 3-2. HEC-HMS Subbasin 100-yr Loss Parameters for 2016 (WHA) conditions

Subbasin Name	Percent Impervious	Initial Loss (in)	Loss Rate (in/hr)	Subbasin Name	Percent Impervious	Initial Loss (in)	Loss Rate (in/hr)
MountainCK_S01	0.98	0.75	0.07	MountainCK_S46	17.59	1.41	0.08
MountainCK_S02	2.60	0.75	0.07	MountainCK_S47	29.05	1.41	0.08
MountainCK_S03	4.93	0.75	0.07	MountainCK_S48	44.62	1.41	0.08
MountainCK_S04	2.14	0.75	0.07	MountainCK_S49	7.28	1.41	0.08
MountainCK_S05	2.98	0.75	0.07	MountainCK_S50	7.28	1.41	0.08
MountainCK_S06	2.64	0.75	0.07	MountainCK_S51	8.80	1.41	0.08
MountainCK_S07	4.79	0.75	0.07	MountainCK_S52	40.93	1.41	0.08
MountainCK_S08	4.04	0.75	0.07	MountainCK_S53	26.27	1.41	0.08
MountainCK_S09	3.67	0.75	0.07	MountainCK_S54	45.58	1.41	0.08
MountainCK_S10	1.62	1.41	0.08	MountainCK_S55	5.92	1.41	0.08
MountainCK_S11	5.68	1.41	0.08	MountainCK_S56	7.98	0.83	0.09
MountainCK_S12	1.18	1.41	0.08	MountainCK_S57	1.45	0.83	0.09
MountainCK_S13	4.49	1.41	0.08	MountainCK_S58	1.05	0.83	0.09
MountainCK_S14	2.37	1.41	0.08	MountainCK_S59	3.49	0.83	0.09
MountainCK_S15	1.26	1.41	0.08	MountainCK_S60	4.35	0.83	0.09
MountainCK_S16	2.97	1.41	0.08	MountainCK_S61	1.36	0.83	0.09
MountainCK_S17	1.54	1.41	0.08	MountainCK_S62	8.17	0.83	0.09
MountainCK_S18	4.68	1.41	0.08	MountainCK_S63	3.98	0.83	0.09
MountainCK_S19	6.09	1.41	0.08	MountainCK_S64	1.11	0.83	0.09
MountainCK_S20	1.19	1.41	0.08	MountainCK_S65	2.77	0.83	0.09
MountainCK_S21	3.18	1.41	0.08	MountainCK_S66	0.75	0.83	0.09
MountainCK_S22	1.56	1.41	0.08	MountainCK_S67	3.26	0.83	0.09
MountainCK_S23	9.80	1.41	0.08	MountainCK_S68	0.73	0.83	0.09
MountainCK_S24	12.60	1.41	0.08	MountainCK_S69	0.16	0.83	0.09
MountainCK_S25	22.54	1.41	0.08	MountainCK_S70	1.54	0.83	0.09
MountainCK_S26	9.03	1.41	0.08	MountainCK_S71	4.27	0.83	0.09
MountainCK_S27	1.10	1.41	0.08	MountainCK_S72	3.00	0.83	0.09
MountainCK_S28	5.39	1.41	0.08	MountainCK_S73	1.46	0.83	0.09
MountainCK_S29	4.54	1.41	0.08	MountainCK_S74	1.33	0.83	0.09
MountainCK_S30	1.53	1.41	0.08	MountainCK_S75	4.01	0.83	0.09
MountainCK_S31	0.88	1.41	0.08	MountainCK_S76	1.23	0.83	0.09
MountainCK_S32	6.41	1.41	0.08	MountainCK_S77	4.40	0.83	0.09
MountainCK_S33	12.59	1.41	0.08	MountainCK_S78	4.36	0.83	0.09
MountainCK_S34	13.62	1.41	0.08	MountainCK_S79	5.00	0.83	0.09
MountainCK_S35	1.34	1.41	0.08	MountainCK_S80	9.40	0.83	0.09
MountainCK_S36	14.21	1.41	0.08	MountainCK_S81	16.73	0.83	0.09
MountainCK_S37	3.50	1.41	0.08	MountainCK_S82	33.62	0.83	0.09
MountainCK_S38	3.39	1.41	0.08	MountainCK_S83	26.49	0.83	0.09
MountainCK_S39	1.62	1.41	0.08	MountainCK_S84	32.83	0.83	0.09
MountainCK_S40a	0.29	1.41	0.08	MountainCK_S85	22.19	0.83	0.09
MountainCK_S40b	0.29	1.41	0.08	MountainCK_S86	29.58	0.81	0.08
MountainCK_S41	0.41	1.41	0.08	MountainCK_S87	38.80	0.77	0.07
MountainCK_S42	6.91	1.41	0.08	MountainCK_S88	39.53	0.77	0.07
MountainCK_S43	0.76	1.41	0.08	MountainCK_S89	36.68	0.77	0.07

Subbasin Name	Percent Impervious	Initial Loss (in)	Loss Rate (in/hr)	Subbasin Name	Percent Impervious	Initial Loss (in)	Loss Rate (in/hr)
MountainCK_S44	3.30	1.41	0.08	MountainCK_S90	42.56	0.77	0.07
MountainCK_S45	36.23	1.41	0.08	MountainCK_S91	58.30	0.77	0.07

Snyder's Transform Parameters

The Snyder's Unit Hydrograph method was used to route excess precipitation to the outlet of each subbasin. Initial estimates for unit hydrograph parameters for the subbasins were made using a Snyder's lag time equation which utilizes measured watershed characteristics in addition to a calibrated coefficient (Ct). The below equation from the Texas Commission on Environmental Quality (TCEQ), Hydrologic and Hydraulic Guidelines for Dams in Texas, was used to estimate the Snyder lag time based on measurable 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 1 – Snyder Unit Hydrograph Equation

The calibrated C_t and peaking coefficient for this watershed were back calculated from the InFRM WHA calibrated HEC-HMS model for the Trinity River Basin. The Snyder Unit Hydrograph (UH) parameters were transformed from the WHA basins by utilizing the calibrated C_t coefficient values to recompute lag time for each delineated subbasin with the new physical hydrologic parameters (L, Lcs and S) for each new subbasin.

Table 3-3. HEC-HMS Subbasin Snyder's Transform Parameters

Subbasin Name	Lag Time (hr)	Peaking Coefficient	Subbasin Name	Lag Time (hr)	Peaking Coefficient
MountainCK_S01	1.28	0.70	MountainCK_S46	1.83	0.70
MountainCK_S02	2.62	0.70	MountainCK_S47	1.99	0.70
MountainCK_S03	2.63	0.70	MountainCK_S48	1.37	0.70
MountainCK_S04	3.07	0.70	MountainCK_S49	2.14	0.70
MountainCK_S05	3.52	0.70	MountainCK_S50	1.77	0.70
MountainCK_S06	2.39	0.70	MountainCK_S51	1.66	0.70
MountainCK_S07	2.54	0.70	MountainCK_S52	2.04	0.70
MountainCK_S08	3.43	0.70	MountainCK_S53	1.44	0.70
MountainCK_S09	2.58	0.70	MountainCK_S54	1.96	0.70
MountainCK_S10	1.80	0.70	MountainCK_S55	1.92	0.70
MountainCK_S11	1.88	0.70	MountainCK_S56	2.30	0.70
MountainCK_S12	1.47	0.70	MountainCK_S57	1.28	0.70
MountainCK_S13	2.23	0.70	MountainCK_S58	1.72	0.70
MountainCK_S14	1.91	0.70	MountainCK_S59	2.19	0.70
MountainCK_S15	1.45	0.70	MountainCK_S60	1.10	0.70
MountainCK_S16	0.96	0.70	MountainCK_S61	1.55	0.70
MountainCK_S17	1.14	0.70	MountainCK_S62	2.32	0.70
MountainCK_S18	1.32	0.70	MountainCK_S63	2.12	0.70
MountainCK_S19	2.12	0.70	MountainCK_S64	2.79	0.70
MountainCK_S20	1.04	0.70	MountainCK_S65	2.37	0.70
MountainCK_S21	1.19	0.70	MountainCK_S66	1.94	0.70
MountainCK_S22	1.33	0.70	MountainCK_S67	2.06	0.70
MountainCK_S23	1.77	0.70	MountainCK_S68	1.79	0.70
MountainCK_S24	0.80	0.70	MountainCK_S69	1.29	0.70
MountainCK_S25	1.46	0.70	MountainCK_S70	1.51	0.70
MountainCK_S26	1.13	0.70	MountainCK_S71	2.83	0.70
MountainCK_S27	1.06	0.70	MountainCK_S72	2.36	0.70
MountainCK_S28	0.88	0.70	MountainCK_S73	2.33	0.70
MountainCK_S29	1.44	0.70	MountainCK_S74	2.59	0.70
MountainCK_S30	1.13	0.70	MountainCK_S75	3.19	0.70
MountainCK_S31	1.62	0.70	MountainCK_S76	2.65	0.70
MountainCK_S32	0.81	0.70	MountainCK_S77	2.64	0.70
MountainCK_S33	2.13	0.70	MountainCK_S78	2.29	0.70
MountainCK_S34	1.60	0.70	MountainCK_S79	1.76	0.70
MountainCK_S35	1.14	0.70	MountainCK_S80	2.43	0.70
MountainCK_S36	1.71	0.70	MountainCK_S81	1.69	0.70
MountainCK_S37	1.12	0.70	MountainCK_S82	2.52	0.70
MountainCK_S38	1.17	0.70	MountainCK_S83	3.69	0.70
MountainCK_S39	1.10	0.70	MountainCK_S84	2.37	0.70
MountainCk_S40a	1.05	0.70	MountainCK_S85	1.68	0.70
MountainCk_S40b	0.93	0.70	MountainCK_S86	1.37	0.70
MountainCK_S41	1.10	0.70	MountainCK_S87	1.09	0.70
MountainCK_S42	1.72	0.70	MountainCK_S88	1.10	0.70
MountainCK_S43	1.27	0.70	MountainCK_S89	0.93	0.70

Subbasin Name	Lag Time (hr)	Peaking Coefficient	Subbasin Name	Lag Time (hr)	Peaking Coefficient
MountainCK_S44	1.95	0.70	MountainCK_S90	0.63	0.70
MountainCK_S45	1.11	0.70	MountainCK_S91	0.65	0.70

Baseflows

Baseflows were assumed the same for the delineated basins that coincided with the WHA basins.

Table 3-4. HEC-HMS Subbasin Baseflow Parameters

Subbasin Name	Initial (cfs/mi^2)	Recession Constant	Ratio to Peak	Subbasin Name	Initial (cfs/mi^2)	Recession Constant	Ratio to Peak
MountainCK_S01	0.02	0.4	0.02	MountainCK_S46	0.06	0.46	0.02
MountainCK_S02	0.02	0.4	0.02	MountainCK_S47	0.06	0.46	0.02
MountainCK_S03	0.02	0.4	0.02	MountainCK_S48	0.06	0.46	0.02
MountainCK_S04	0.02	0.4	0.02	MountainCK_S49	0.06	0.46	0.02
MountainCK_S05	0.02	0.4	0.02	MountainCK_S50	0.06	0.46	0.02
MountainCK_S06	0.02	0.4	0.02	MountainCK_S51	0.06	0.46	0.02
MountainCK_S07	0.02	0.4	0.02	MountainCK_S52	0.06	0.46	0.02
MountainCK_S08	0.02	0.4	0.02	MountainCK_S53	0.06	0.46	0.02
MountainCK_S09	0.02	0.4	0.02	MountainCK_S54	0.06	0.46	0.02
MountainCK_S10	0.06	0.46	0.02	MountainCK_S55	0.06	0.46	0.02
MountainCK_S11	0.06	0.46	0.02	MountainCK_S56	0.06	0.54	0.02
MountainCK_S12	0.06	0.46	0.02	MountainCK_S57	0.06	0.54	0.02
MountainCK_S13	0.06	0.46	0.02	MountainCK_S58	0.06	0.54	0.02
MountainCK_S14	0.06	0.46	0.02	MountainCK_S59	0.06	0.54	0.02
MountainCK_S15	0.06	0.46	0.02	MountainCK_S60	0.06	0.54	0.02
MountainCK_S16	0.06	0.46	0.02	MountainCK_S61	0.06	0.54	0.02
MountainCK_S17	0.06	0.46	0.02	MountainCK_S62	0.06	0.54	0.02
MountainCK_S18	0.06	0.46	0.02	MountainCK_S63	0.06	0.54	0.02
MountainCK_S19	0.06	0.46	0.02	MountainCK_S65	0.06	0.54	0.02
MountainCK_S20	0.06	0.46	0.02	MountainCK_S64	0.06	0.54	0.02
MountainCK_S21	0.06	0.46	0.02	MountainCK_S66	0.06	0.54	0.02
MountainCK_S22	0.06	0.46	0.02	MountainCK_S67	0.06	0.54	0.02
MountainCK_S23	0.06	0.46	0.02	MountainCK_S68	0.06	0.54	0.02
MountainCK_S24	0.06	0.46	0.02	MountainCK_S69	0.06	0.54	0.02
MountainCK_S25	0.06	0.46	0.02	MountainCK_S70	0.06	0.54	0.02
MountainCK_S26	0.06	0.46	0.02	MountainCK_S71	0.06	0.54	0.02
MountainCK_S27	0.06	0.46	0.02	MountainCK_S72	0.06	0.54	0.02
MountainCK_S28	0.06	0.46	0.02	MountainCK_S73	0.06	0.54	0.02
MountainCK_S29	0.06	0.46	0.02	MountainCK_S74	0.06	0.54	0.02
MountainCK_S30	0.06	0.46	0.02	MountainCK_S75	0.06	0.54	0.02
MountainCK_S31	0.06	0.46	0.02	MountainCK_S76	0.06	0.54	0.02
MountainCK_S32	0.06	0.46	0.02	MountainCK_S77	0.06	0.54	0.02
MountainCK_S33	0.06	0.46	0.02	MountainCK_S78	0.06	0.54	0.02
MountainCK_S34	0.06	0.46	0.02	MountainCK_S79	0.06	0.54	0.02
MountainCK_S35	0.06	0.46	0.02	MountainCK_S80	0.06	0.54	0.02

Subbasin Name	Initial (cfs/mi^2)	Recession Constant	Ratio to Peak	Subbasin Name	Initial (cfs/mi^2)	Recession Constant	Ratio to Peak
MountainCK_S36	0.06	0.46	0.02	MountainCK_S81	0.06	0.54	0.02
MountainCK_S37	0.06	0.46	0.02	MountainCK_S82	0.06	0.54	0.02
MountainCK_S38	0.06	0.46	0.02	MountainCK_S83	0.06	0.54	0.02
MountainCK_S39	0.06	0.46	0.02	MountainCK_S84	0.06	0.54	0.02
MountainCk_S40b	0.06	0.46	0.02	MountainCK_S85	0.06	0.46	0.02
MountainCk_S40a	0.06	0.46	0.02	MountainCK_S86	0.06	0.45	0.02
MountainCK_S41	0.06	0.46	0.02	MountainCK_S87	0.06	0.45	0.02
MountainCK_S42	0.06	0.46	0.02	MountainCK_S88	0.06	0.45	0.02
MountainCK_S43	0.06	0.46	0.02	MountainCK_S89	0.06	0.45	0.02
MountainCK_S44	0.06	0.46	0.02	MountainCK_S90	0.06	0.45	0.02
MountainCK_S45	0.06	0.46	0.02	MountainCK_S91	0.06	0.45	0.02

3.3.2 Initial Routing Parameters

The initial routing parameters for all the HEC-HMS reaches were estimated using the modified Puls method.

Modified Puls Routing

Modified Puls storage discharge-curves were calculated from a simple 1D steady-flow model that was created for that specific purpose. A wide range of steady state flows were run in the 1D HEC-RAS model, and the storage-discharge curves were extracted between specified cross sections bounding reaches of interest. The number of sub-reaches for each reach were determined using the reach type criteria that is stream slope dependent. In the case of this study, the number of sub reaches was between 1 and 2, a value of 1 is assigned for steep reaches with little attenuation with slopes greater than 4%. Average reaches with average attenuation of 2 were given for steam slopes between 1% and 4%.

Table 3-5. HEC-HMS Modified Puls Routing Parameters

Reach Name	Length (mi)	Storage-Discharge Curve	Subreaches
R_MountainCK01	2.47	Storage-Discharge MC_R01	1
R_MountainCK02	0.88	Storage-Discharge MC_R02	1
R_MountainCK03	1.77	Storage-Discharge MC_R03	1
R_MountainCK04	1.73	Storage-Discharge MC_R04	1
R_MountainCK05	2.05	Storage-Discharge MC_R05	1
R_MountainCK06	0.68	Storage-Discharge MC_R06	1
R_MountainCK07	2.19	Storage-Discharge MC_R07	2
R_MountainCK08	0.96	Storage-Discharge MC_R08	1

Reach Name	**Length (mi)**	**Storage-Discharge Curve**	**Subreaches**
R_MountainCK09	0.95	Storage-Discharge MC_R09	1
R_MountainCK10	3.63	Storage-Discharge MC_R10	3
R_MountainCK11	0.26	Storage-Discharge MC_R11	1
R_MountainCK12	1.28	Storage-Discharge MC_R12	1
R_MountainCK13	1.47	Storage-Discharge MC_R13	1
R_MountainCK14	1.94	Storage-Discharge MC_R14	1
R_MountainCK15	0.58	Storage-Discharge MC_R15	1
R_MountainCK16	0.89	Storage-Discharge MC_R16	1
R_MountainCK17		Storage-Discharge MC_R17	1
R_MountainCK18	1.12	Storage-Discharge MC_R18	1
R_MountainCK19	0.93	Storage-Discharge MC_R19	1
R_MountainCK20	0.67	Storage-Discharge MC_R20_FIS	1
R_MountainCK21	1.14	Storage-Discharge MC_R21_FIS	1
R_MountainCK22	1.55	Storage-Discharge MC_R22_FIS	2
R_MountainCK23	2.19	Storage-Discharge MC_R23_FIS	2
R_MountainCK24	1.02	Storage-Discharge MC_R24_FIS	2
R_MountainCK25	2.97	Storage-Discharge MC_R25_FIS	3
R_MountainCK26	0.78	Storage-Discharge MC_R26_FIS	1
R_MountainCK27	0.40	Storage-Discharge MC_R27_FIS	1
R_MountainCK28	0.99	Storage-Discharge MC_R28	1
R_MountainCK29	0.99	Storage-Discharge MC_R29	1
R_MountainCK30	1.52	Storage-Discharge MC_R30	1
R_MountainCK31	0.65	Storage-Discharge MC_R31	1
R_MountainCK32	0.75	Storage-Discharge MC_R32_FIS	1
R_MountainCK33	0.81	Storage-Discharge MC_R33	1
R_MountainCK34	1.01	Storage-Discharge MC_R34	1
R_MountainCK37	1.19	Storage-Discharge MC_R37	1
R_MountainCK39	3.61	Storage-Discharge MC_R39_FIS	3
R_MountainCK42	0.11	Storage-Discharge MC_R42	1
R_MountainCK45	2.46	Storage-Discharge MC_R45	2
R_MountainCK48	1.43	Storage-Discharge MC_R48	1
R_MountainCK49	0.23	Storage-Discharge MC_R49	1
R_MountainCK50	0.58	Storage-Discharge MC_R50	1
R_MountainCK51	1.15	Storage-Discharge MC_R51	1
R_MountainCK52	1.66	Storage-Discharge MC_R52	1
R_MountainCK53	1.71	Storage-Discharge MC_R53	1
R_MountainCK54	0.94	Storage-Discharge MC_R54	1
R_MountainCK55	1.59	Storage-Discharge MC_R55	1
R_MountainCK56	1.55	Storage-Discharge MC_R56	1
R_MountainCK59	0.67	Storage-Discharge MC_R59	1

Reach Name	Length (mi)	Storage-Discharge Curve	Subreaches
R_MountainCK60	0.94	Storage-Discharge MC_R60	1
R_MountainCK61	0.30	Storage-Discharge MC_R61	1
R_MountainCK62	1.97	Storage-Discharge MC_R62	1
R_MountainCK63	2.51	Storage-Discharge MC_R63	1
R_MountainCK64	0.45	Storage-Discharge MC_R64_FIS	1
R_MountainCK67	0.61	Storage-Discharge MC_R67_FIS	1
R_MountainCK68	0.62	Storage-Discharge MC_R68_FIS	1
R_MountainCK69	0.30	Storage-Discharge MC_R69	1
R_MountainCK70	0.63	Storage-Discharge MC_R70	1
R_MountainCK72	2.09	Storage-Discharge MC_R72_FIS	1
R_MountainCK73	1.63	Storage-Discharge MC_R73_FIS	1
R_MountainCK74	1.33	Storage-Discharge MC_R74_FIS	1
R_MountainCK75	0.54	Storage-Discharge MC_R75_FIS	1
R_MountainCK76	1.43	Storage-Discharge MC_R76_FIS	1
R_MountainCK77	2.48	Storage-Discharge MC_R77_FIS	2
R_MountainCK79	2.41	Storage-Discharge MC_R79	2
R_MountainCK81	2.42	Storage-Discharge MC_R81_FIS	2

4 HEC-HMS Model Calibration

After calculating initial model parameters, sensitivity analyses were performed to assess whether adjustments were necessary so that the results of the detailed HEC-HMS model match the results of the original InFRM WHA HEC-HMS model as closely as possible.

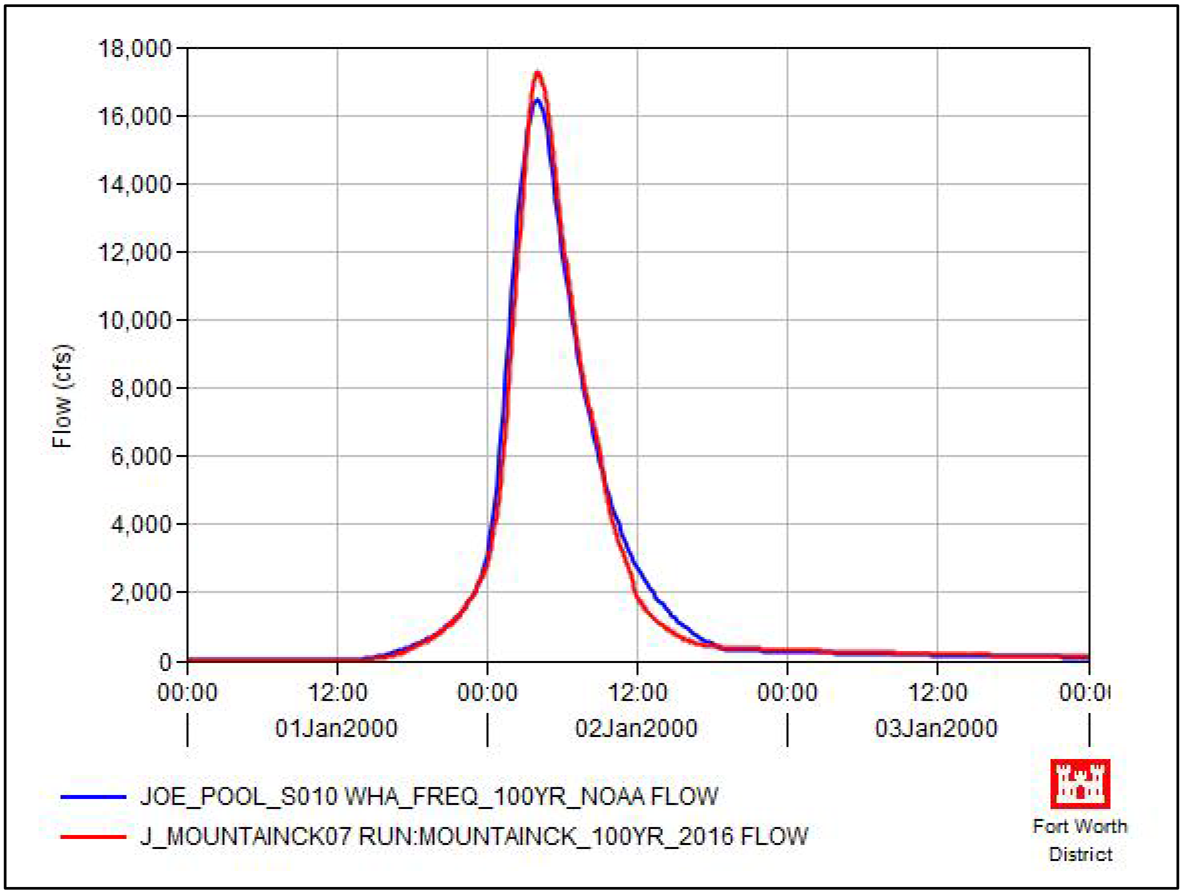
4.1 Calibration Methodology

The calibration criteria for the Mountain Creek Watershed are satisfied once model parameters produced the best matching results between the detailed WHA model and the InFRM WHA HEC-HMS model. A performance rating of statistics was also used as an indicator of how well the model performed during calibration. The following calibration performance metrics from the WHA was used as a guide to give results the appropriate rating.

Performance Rating	NSE	RSR	PBIAS
Very Good	$0.80 \leq NSE < 1.00$	$0 \leq RSR \leq 0.50$	$0 \leq PBIAS \leq \pm 5$
Good	$0.70 \leq NSE < 0.80$	$0.50 < RSR \leq 0.60$	$\pm 5 < PBIAS < \pm 10$
Satisfactory	$0.50 \leq NSE < 0.70$	$0.60 < RSR \leq 0.70$	$\pm 10 \leq PBIAS \leq \pm 25$
Unsatisfactory	$NSE < 0.50$	$RSR > 0.70$	$PBIAS > \pm 25$

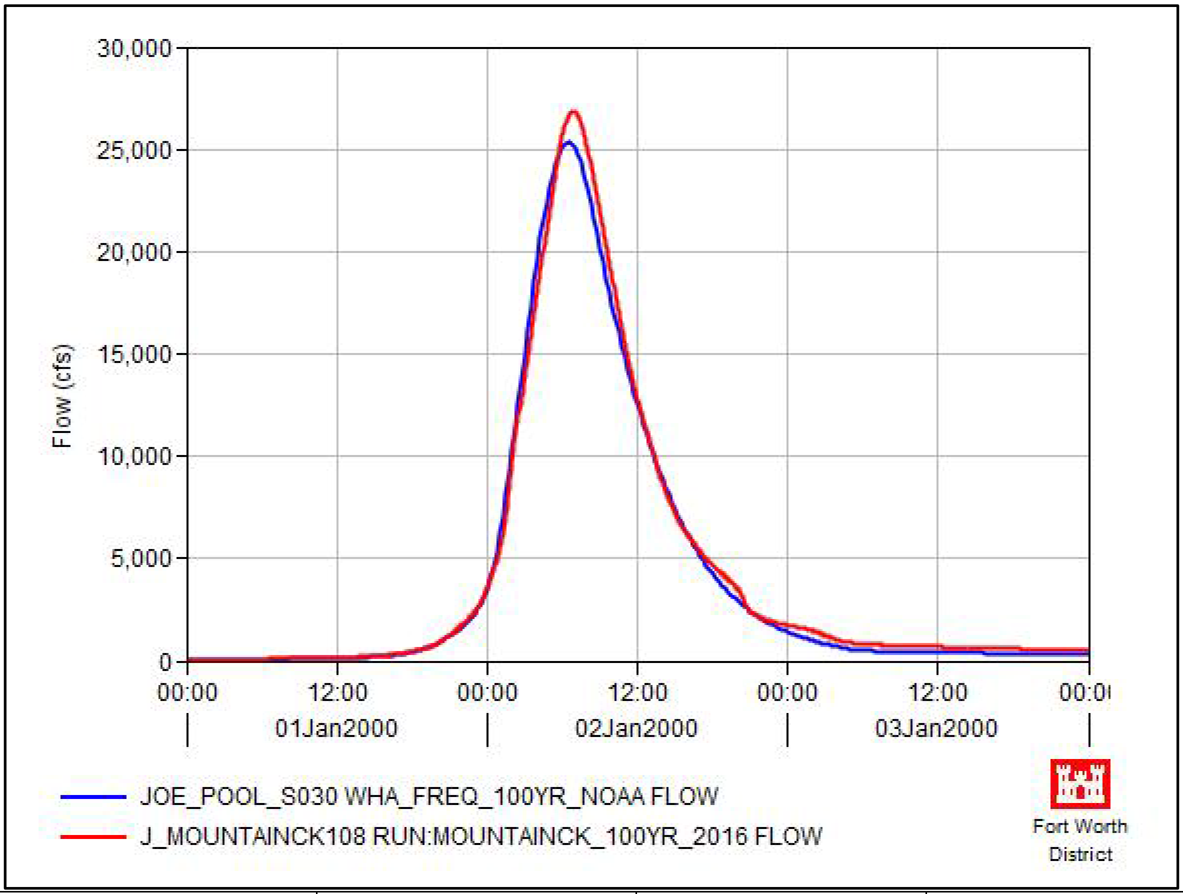
4.2 Calibration Results

Below highlights the results for the 1% ACE (100-yr) calibrations results at available computation points. These computation points from the Mountain Creek model were calibrated to match the results of the Trinity River Basin model at similar computation points. For calibration the storm area parameter in the met Model used the total WHA drainage area for each junction being calibrated. J_MountainCK07 used a storm area of 25.953, J_MountainCK108 used a storm area of 62.877, and J_MountainCK114 used a storm area of 224.17.



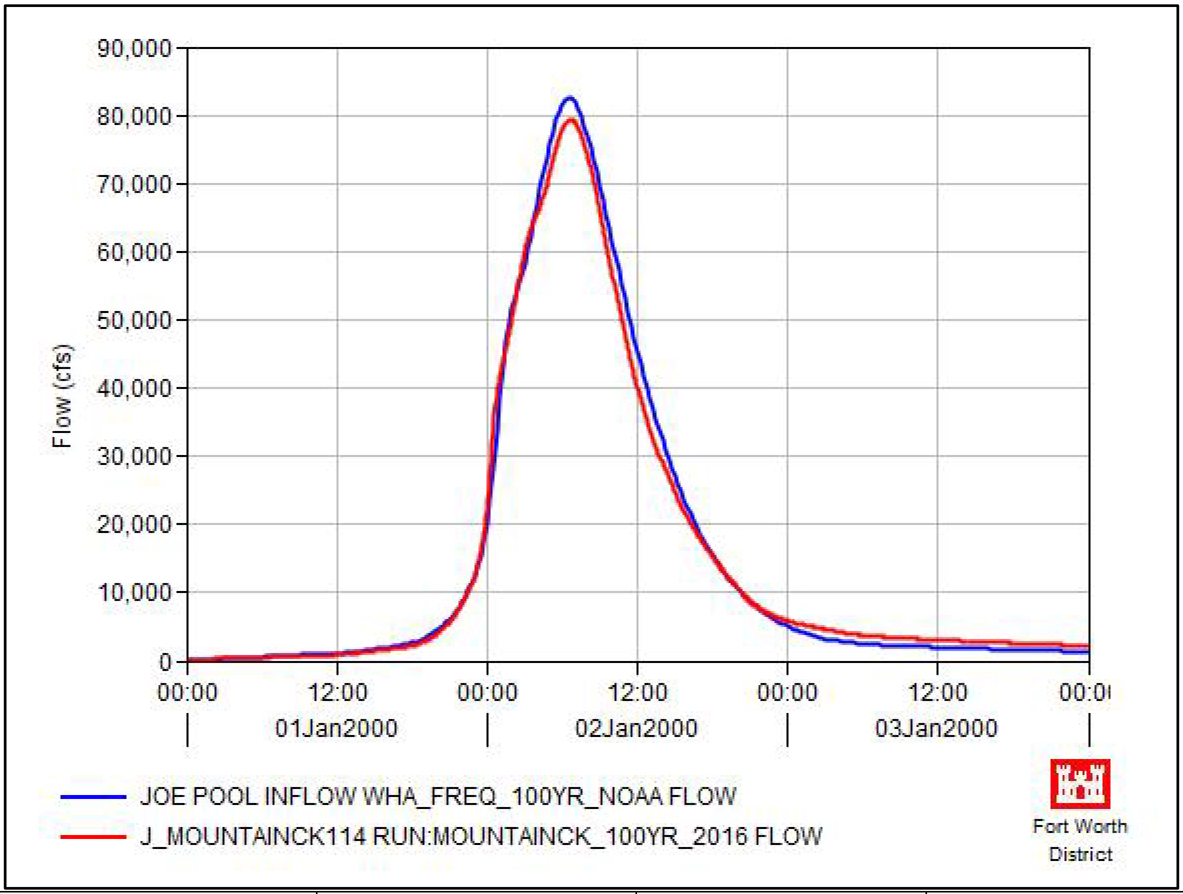
Performance Rating	RMSE Std Dev	Nash-Sutcliffe	Percent Bias
Very Good	0.1	0.982	-9.81%

Figure 4-1. Calibrated Hydrograph at Mountain Ck nr Venus, TX (J_ MountainCK07)



Performance Rating	RMSE Std Dev	Nash-Sutcliffe	Percent Bias
Very Good	0.1	0.997	1.65%

Figure 4-2. Calibration Hydrograph at Walnut Ck nr Mansfield, TX (J_MountainCK108)



Performance Rating	RMSE Std Dev	Nash-Sutcliffe	Percent Bias
Very Good	0.1	0.995	3.09%

Figure 4-3. Calibration Hydrograph for Joe Pool Lake Inflow (J_MountainCK114)

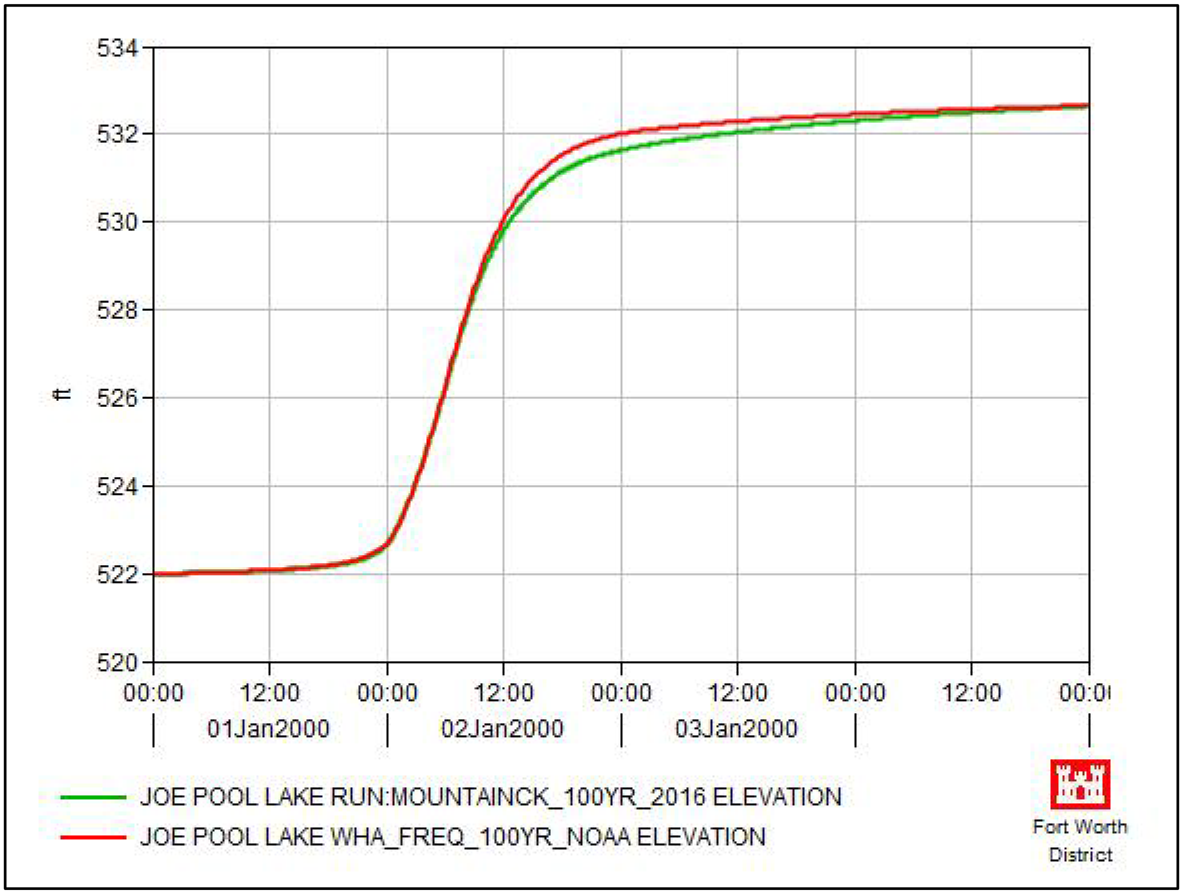


Figure 4-4. Calibration Plot for Pool Elevations at Joe Pool Lake

4.3 Calibrated HEC-HMS Parameters

The HEC-HMS parameters that were modified to allow for better model “calibration” with the InFRM WHA HEC-HMS model were subbasin lag times, baseflows and the reach number of subreaches. The parameters were modified and iterated upon in order to find achieve the best calibration.

5 Final Existing Conditions HEC-HMS Model for TSI

With the adjusted parameters implemented, the HEC-HMS model matched the results of the Trinity basin model and fell within range of the "Very Good" performance rating for the 1% ACE (100-year) event.

5.1 TSI 2020 Existing Conditions HEC-HMS Model

For the 2020 existing conditions basin model, all HMS model parameters will remain the same as were completed in section 4 except for the percent impervious and the initial losses. For the percent impervious, the 2020 impervious data provided by the NCTCOG was used to update the values in the HEC-HMS detailed model.

Table 5-1. Existing Conditions Percent Imperviousness

Subbasin	2016 % Impervious	2020 % Impervious	Subbasin	2016 % Impervious	2020 % Impervious
MountainCK_S01	0.98	3.68	MountainCK_S46	17.59	20.98
MountainCK_S02	2.60	3.76	MountainCK_S47	29.05	29.05
MountainCK_S03	4.93	8.80	MountainCK_S48	44.62	44.62
MountainCK_S04	2.14	4.74	MountainCK_S49	7.28	10.64
MountainCK_S05	2.98	4.92	MountainCK_S50	7.28	12.09
MountainCK_S06	2.64	3.93	MountainCK_S51	8.80	15.56
MountainCK_S07	4.79	6.67	MountainCK_S52	40.93	41.27
MountainCK_S08	4.04	6.38	MountainCK_S53	26.27	27.44
MountainCK_S09	3.67	6.75	MountainCK_S54	45.58	45.71
MountainCK_S10	1.62	5.12	MountainCK_S55	5.92	13.47
MountainCK_S11	5.68	10.10	MountainCK_S56	7.98	9.53
MountainCK_S12	1.18	2.60	MountainCK_S57	1.45	2.78
MountainCK_S13	4.49	6.55	MountainCK_S58	1.05	4.01
MountainCK_S14	2.37	5.58	MountainCK_S59	3.49	7.01
MountainCK_S15	1.26	4.49	MountainCK_S60	4.35	10.40
MountainCK_S16	2.97	11.24	MountainCK_S61	1.36	4.50
MountainCK_S17	1.54	3.53	MountainCK_S62	8.17	9.78
MountainCK_S18	4.68	8.02	MountainCK_S63	3.98	8.53
MountainCK_S19	6.09	8.96	MountainCK_S64	1.11	3.83
MountainCK_S20	1.19	2.29	MountainCK_S65	2.77	5.82
MountainCK_S21	3.18	6.47	MountainCK_S66	0.75	1.80
MountainCK_S22	1.56	4.38	MountainCK_S67	3.26	5.90
MountainCK_S23	9.80	9.80	MountainCK_S68	0.73	2.92
MountainCK_S24	12.60	16.03	MountainCK_S69	0.16	1.87
MountainCK_S25	22.54	22.54	MountainCK_S70	1.54	3.88
MountainCK_S26	9.03	9.10	MountainCK_S71	4.27	7.08

Subbasin	2016 % Impervious	2020 % Impervious	Subbasin	2016 % Impervious	2020 % Impervious
MountainCK_S27	1.10	2.03	MountainCK_S72	3.00	10.79
MountainCK_S28	5.39	7.70	MountainCK_S73	1.46	5.67
MountainCK_S29	4.54	11.29	MountainCK_S74	1.33	4.40
MountainCK_S30	1.53	2.27	MountainCK_S75	4.01	10.39
MountainCK_S31	0.88	2.22	MountainCK_S76	1.23	11.29
MountainCK_S32	6.41	6.41	MountainCK_S77	4.40	9.34
MountainCK_S33	12.59	18.55	MountainCK_S78	4.36	8.98
MountainCK_S34	13.62	18.63	MountainCK_S79	5.00	10.00
MountainCK_S35	1.34	2.52	MountainCK_S80	9.40	18.26
MountainCK_S36	14.21	14.21	MountainCK_S81	16.73	25.04
MountainCK_S37	3.50	6.46	MountainCK_S82	33.62	41.67
MountainCK_S38	3.39	5.81	MountainCK_S83	26.49	33.30
MountainCK_S39	1.62	3.01	MountainCK_S84	32.83	39.38
MountainCK_S40a	0.29	1.95	MountainCK_S85	22.19	24.60
MountainCK_S40b	0.29	1.95	MountainCK_S86	29.58	35.35
MountainCK_S41	0.41	1.56	MountainCK_S87	38.80	43.03
MountainCK_S42	6.91	10.01	MountainCK_S88	39.53	43.14
MountainCK_S43	0.76	3.02	MountainCK_S89	36.68	39.74
MountainCK_S44	3.30	6.56	MountainCK_S90	42.56	43.62
MountainCK_S45	36.23	39.01	MountainCK_S91	58.30	58.30

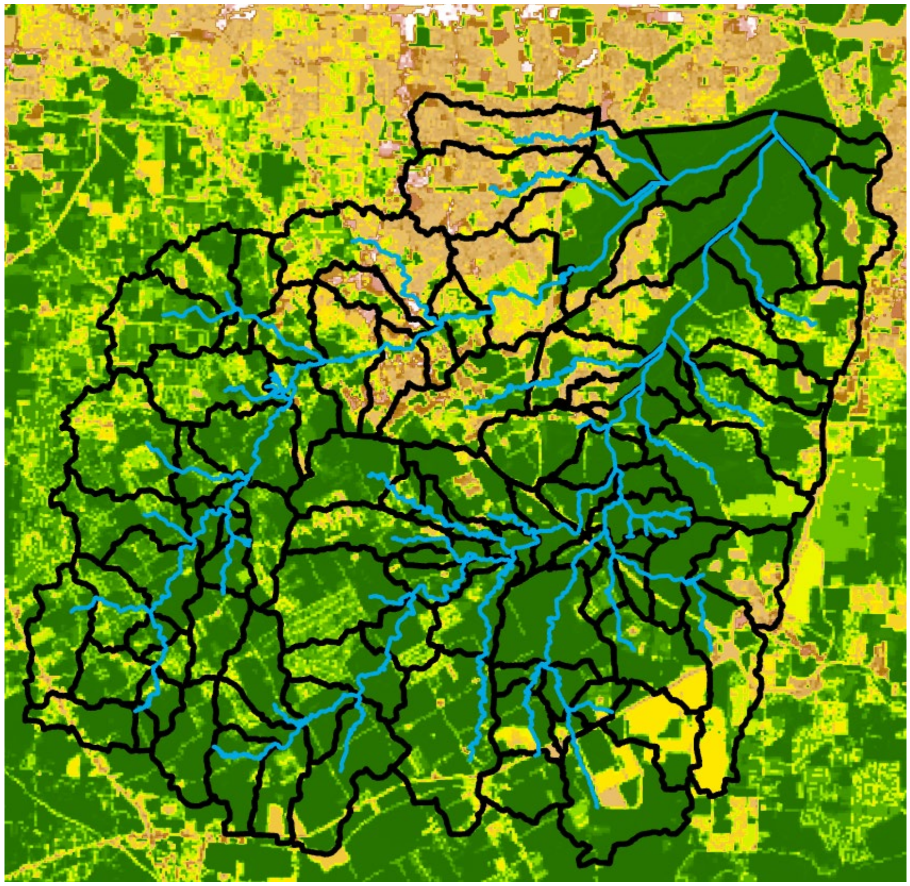


Figure 5-1. Map of Existing 2020 Percent Imperviousness from NCTCOG

5.1.2 2020 Conditions Loss Rates

The default frequency loss rates are used for the 2020 basin models for the 1% ACE (100-yr) frequency storm as well as the 2% ACE (50-yr) and 0.2% ACE (500-yr) storms. For the 50% ACE (2-yr) and 10% ACE (10-yr) storms, the final WHA frequency loss rates are used since those were calibrated to the Bulletin 17C results at the downstream gages.

Table 5-2. 2020 Existing Conditions Loss Rates

Subbasin	**50% ACE (2-year)**		**10% ACE (10-year)**		**2% ACE (50-year)**		**1% ACE (100-year)**		**0.2% ACE (500-year)**	
	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
MountainCK_S01	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S02	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S03	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S04	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S05	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S06	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S07	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S08	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S09	1.52	0.2	1.13	0.14	0.85	0.1	0.75	0.07	0.5	0.05
MountainCK_S10	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S11	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S12	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S13	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S14	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S15	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S16	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S17	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S18	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S19	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S20	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S21	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S22	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S23	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S24	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S25	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S26	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S27	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S28	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S29	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S30	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S31	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S32	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S33	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S34	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S35	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S36	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06

Subbasin	**50% ACE (2-year)**		**10% ACE (10-year)**		**2% ACE (50-year)**		**1% ACE (100-year)**		**0.2% ACE (500-year)**	
	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
MountainCK_S37	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S38	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S39	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S40a	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S40b	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S41	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S42	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S43	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S44	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S45	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S46	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S47	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S48	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S49	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S50	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S51	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S52	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S53	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S54	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S55	1.7	0.21	1.66	0.15	0.88	0.11	0.78	0.08	0.52	0.06
MountainCK_S56	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S57	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S58	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S59	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S60	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S61	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S62	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S63	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S64	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S65	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S66	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S67	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S68	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S69	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S70	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S71	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S72	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07

Subbasin	50% ACE (2-year)		10% ACE (10-year)		2% ACE (50-year)		1% ACE (100-year)		0.2% ACE (500-year)	
	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)	Initial (in)	Constant (in/hr)
MountainCK_S73	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S74	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S75	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S76	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S77	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S78	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S79	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S80	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S81	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S82	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S83	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S84	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S85	1.8	0.23	1.76	0.19	0.97	0.12	0.83	0.09	0.55	0.07
MountainCK_S86	1.75	0.23	1.28	0.16	0.95	0.11	0.81	0.08	0.54	0.06
MountainCK_S87	1.59	0.21	1.18	0.15	0.88	0.1	0.77	0.07	0.52	0.05
MountainCK_S88	1.59	0.21	1.18	0.15	0.88	0.1	0.77	0.07	0.52	0.05
MountainCK_S89	1.59	0.21	1.18	0.15	0.88	0.1	0.77	0.07	0.52	0.05
MountainCK_S90	1.59	0.21	1.18	0.15	0.88	0.1	0.77	0.07	0.52	0.05
MountainCK_S91	1.59	0.21	1.18	0.15	0.88	0.1	0.77	0.07	0.52	0.05

5.2 TSI 2070 Future Conditions HEC-HMS Model

For the 2070 future conditions basin model, all HMS model parameters will remain the same as were completed for 2020 conditions except for the percent impervious, the Snyder's lag times and the routing storage volumes. For the percent impervious, the 2070 impervious data provided by the NCTCOG and EPA ICLUS was used to update the impervious values in the HEC-HMS detailed model for future conditions.

The Snyder's lag times were reduced to account for the 2070 future conditions percent urbanization. Regional studies in North Texas have shown that as a watershed is transformed from rural to urban, its Snyder' lag time also decreases. Therefore, reduction ratios were applied to the existing conditions lag times for each subbasin.

For the Modified Puls routing reaches, the storage-discharge curves were modified to account for the valley storage that could be lost due to future development. Effective FEMA FIS floodway models in the watershed were used to estimate future conditions storage-discharge curves by assuming that the floodway encroachments represent the portion of the floodplain that could be lost to future development.

5.2.1 Future Conditions 2070 Percent Imperiousness

The watershed 2070 percent imperviousness was extracted from ArcMap GIS. The future values are listed in Table 5.3.

Table 5-3. 2070 Future Conditions Percent Imperviousness

Subbasin	2020 % Impervious	2070 % Impervious	Subbasin	2020 % Impervious	2070 % Impervious
MountainCK_S01	3.68	32.90	MountainCK_S46	20.98	63.65
MountainCK_S02	3.76	28.94	MountainCK_S47	29.05	50.71
MountainCK_S03	8.80	27.99	MountainCK_S48	44.62	57.80
MountainCK_S04	4.74	39.10	MountainCK_S49	10.64	44.20
MountainCK_S05	4.92	19.70	MountainCK_S50	12.09	39.83
MountainCK_S06	3.93	20.58	MountainCK_S51	15.56	48.84
MountainCK_S07	6.67	37.19	MountainCK_S52	41.27	58.52
MountainCK_S08	6.38	32.36	MountainCK_S53	27.44	29.70
MountainCK_S09	6.75	36.86	MountainCK_S54	45.71	55.87
MountainCK_S10	5.12	31.39	MountainCK_S55	13.47	40.81
MountainCK_S11	10.10	36.37	MountainCK_S56	9.53	35.23
MountainCK_S12	2.60	36.77	MountainCK_S57	2.78	19.47
MountainCK_S13	6.55	26.72	MountainCK_S58	4.01	35.04
MountainCK_S14	5.58	31.62	MountainCK_S59	7.01	35.23
MountainCK_S15	4.49	50.79	MountainCK_S60	10.40	41.75
MountainCK_S16	11.24	39.43	MountainCK_S61	4.50	33.66
MountainCK_S17	3.53	39.16	MountainCK_S62	9.78	43.25
MountainCK_S18	8.02	30.36	MountainCK_S63	8.53	45.27
MountainCK_S19	8.96	42.63	MountainCK_S64	3.83	43.18
MountainCK_S20	2.29	28.06	MountainCK_S65	5.82	40.01
MountainCK_S21	6.47	33.26	MountainCK_S66	1.80	25.52
MountainCK_S22	4.38	42.37	MountainCK_S67	5.90	38.32
MountainCK_S23	9.80	26.17	MountainCK_S68	2.92	30.10
MountainCK_S24	16.03	43.23	MountainCK_S69	1.87	28.12
MountainCK_S25	22.54	40.45	MountainCK_S70	3.88	39.18
MountainCK_S26	9.10	36.82	MountainCK_S71	7.08	35.98
MountainCK_S27	2.03	30.56	MountainCK_S72	10.79	51.02
MountainCK_S28	7.70	35.50	MountainCK_S73	5.67	34.76
MountainCK_S29	11.29	27.40	MountainCK_S74	4.40	32.61
MountainCK_S30	2.27	2.27	MountainCK_S75	10.39	44.37
MountainCK_S31	2.22	21.27	MountainCK_S76	11.29	42.80
MountainCK_S32	6.41	36.40	MountainCK_S77	9.34	42.99
MountainCK_S33	18.55	50.71	MountainCK_S78	8.98	43.93

Subbasin	2020 % Impervious	2070 % Impervious	Subbasin	2020 % Impervious	2070 % Impervious
MountainCK_S34	18.63	45.19	MountainCK_S79	10.00	43.11
MountainCK_S35	2.52	52.12	MountainCK_S80	18.26	48.98
MountainCK_S36	14.21	55.68	MountainCK_S81	25.04	58.18
MountainCK_S37	6.46	32.71	MountainCK_S82	41.67	64.34
MountainCK_S38	5.81	41.64	MountainCK_S83	33.30	63.87
MountainCK_S39	3.01	36.30	MountainCK_S84	39.38	69.08
MountainCK_S40a	1.95	35.71	MountainCK_S85	24.60	46.13
MountainCK_S40b	1.95	35.71	MountainCK_S86	35.35	51.44
MountainCK_S41	1.56	34.06	MountainCK_S87	43.03	60.11
MountainCK_S42	10.01	47.33	MountainCK_S88	43.14	62.94
MountainCK_S43	3.02	42.31	MountainCK_S89	39.74	50.43
MountainCK_S44	6.56	58.75	MountainCK_S90	43.62	60.08
MountainCK_S45	39.01	57.65	MountainCK_S91	58.30	59.63

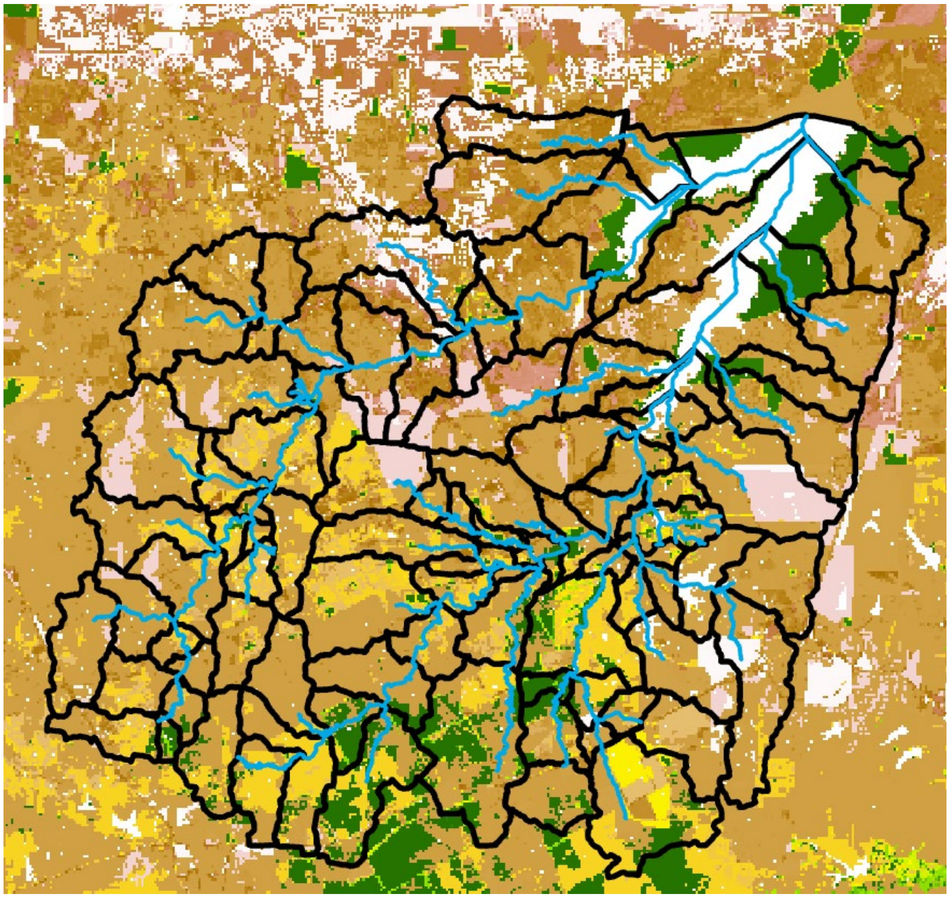


Figure 5-2. Map of Future Conditions 2070 Percent Imperviousness from the combined NCTCOG and EPA dataset

5.2.2 Future Conditions 2070 Lag Times

Estimates of future conditions Lag Times are anticipated to be reduced due to urbanization, where future imperiousness will increase. Future Lag Times are estimated by utilizing a reduction that can be obtained from a Lag Time reduction ratio table, which relates the urbanization percentage to a ratio of lag time over 0% urban lag time. The reduction rations were based on percent of urbanization increase, which were developed from the Fort Worth District urban studies (Nelson, 1979) (Rodman, 1977) (USACE, 1989).

Table 5-2. Future Conditions Snyder's Lag Times

Subbasin Name	Existing 2020 Pct Urban	Existing 2020 Lag Time (hrs)	Future 2070 Pct Urban	Future 2070 Lag Time (hrs)	Subbasin Name	Existing 2020 Pct Urban	Existing 2020 Lag Time (hrs)	Future 2070 Pct Urban	Future 2070 Lag Time (hrs)
MountainCK_S01	17	1.28	65	0.97	MountainCK_S46	27	1.83	86	1.26
MountainCK_S02	17	2.62	57	2.10	MountainCK_S47	27	1.99	77	1.47
MountainCK_S03	17	2.63	58	2.09	MountainCK_S48	27	1.37	77	1.01
MountainCK_S04	17	3.07	80	2.11	MountainCK_S49	27	2.14	75	1.60
MountainCK_S05	17	3.52	37	3.17	MountainCK_S50	27	1.77	70	1.37
MountainCK_S06	17	2.39	40	2.12	MountainCK_S51	27	1.66	82	1.18
MountainCK_S07	17	2.54	74	1.82	MountainCK_S52	27	2.04	78	1.50
MountainCK_S08	17	3.43	74	2.46	MountainCK_S53	27	1.44	36	1.37
MountainCK_S09	17	2.58	80	1.77	MountainCK_S54	27	1.96	69	1.53
MountainCK_S10	27	1.80	71	1.39	MountainCK_S55	27	1.92	67	1.52
MountainCK_S11	27	1.88	78	1.38	MountainCK_S56	39	2.30	74	1.85
MountainCK_S12	27	1.47	78	1.07	MountainCK_S57	39	1.28	39	1.28
MountainCK_S13	27	2.23	51	1.95	MountainCK_S58	39	1.72	73	1.40
MountainCK_S14	27	1.91	67	1.51	MountainCK_S59	39	2.19	82	1.66
MountainCK_S15	27	1.45	83	1.02	MountainCK_S60	39	1.10	81	0.84
MountainCK_S16	27	0.96	80	0.70	MountainCK_S61	39	1.55	70	1.28
MountainCK_S17	27	1.14	79	0.83	MountainCK_S62	39	2.32	84	1.74
MountainCK_S18	27	1.32	66	1.05	MountainCK_S63	39	2.12	84	1.59
MountainCK_S19	27	2.12	80	1.53	MountainCK_S64	39	2.37	81	1.82
MountainCK_S20	27	1.04	59	0.86	MountainCK_S65	39	2.79	81	2.14
MountainCK_S21	27	1.19	60	0.99	MountainCK_S66	39	1.94	62	1.70
MountainCK_S22	27	1.33	70	1.03	MountainCK_S67	39	2.06	79	1.60
MountainCK_S23	27	1.77	52	1.54	MountainCK_S68	39	1.79	72	1.46
MountainCK_S24	27	0.80	67	0.63	MountainCK_S69	39	1.29	73	1.05
MountainCK_S25	27	1.46	86	1.01	MountainCK_S70	39	1.51	76	1.19
MountainCK_S26	27	1.13	75	0.85	MountainCK_S71	39	2.83	79	2.20

Subbasin Name	Existing 2020 Pct Urban	Existing 2020 Lag Time (hrs)	Future 2070 Pct Urban	Future 2070 Lag Time (hrs)	Subbasin Name	Existing 2020 Pct Urban	Existing 2020 Lag Time (hrs)	Future 2070 Pct Urban	Future 2070 Lag Time (hrs)
MountainCK_S27	27	1.06	51	0.93	MountainCK_S72	39	2.36	85	1.76
MountainCK_S28	27	0.88	67	0.70	MountainCK_S73	39	2.33	81	1.79
MountainCK_S29	27	1.44	56	1.23	MountainCK_S74	39	2.59	79	2.01
MountainCK_S30	27	1.13	27	1.13	MountainCK_S75	39	3.19	81	2.45
MountainCK_S31	27	1.62	60	1.34	MountainCK_S76	39	2.65	81	2.03
MountainCK_S32	27	0.81	75	0.60	MountainCK_S77	39	2.64	80	2.04
MountainCK_S33	27	2.13	86	1.47	MountainCK_S78	39	2.29	81	1.75
MountainCK_S34	27	1.60	84	1.13	MountainCK_S79	39	1.76	79	1.37
MountainCK_S35	27	1.14	85	0.79	MountainCK_S80	39	2.43	82	1.85
MountainCK_S36	27	1.71	88	1.16	MountainCK_S81	39	1.69	85	1.26
MountainCK_S37	27	1.12	81	0.81	MountainCK_S82	39	2.52	85	1.88
MountainCK_S38	27	1.17	81	0.84	MountainCK_S83	39	3.69	85	2.74
MountainCK_S39	27	1.10	77	0.81	MountainCK_S84	39	2.37	88	1.72
MountainCK_S40a	27	0.93	70	0.72	MountainCK_S85	39	1.68	74	1.35
MountainCK_S40b	27	1.05	70	0.81	MountainCK_S86	58	1.37	82	1.17
MountainCK_S41	27	1.10	76	0.82	MountainCK_S87	57	1.09	85	0.90
MountainCK_S42	27	1.72	81	1.23	MountainCK_S88	57	1.10	87	0.90
MountainCK_S43	27	1.27	67	1.00	MountainCK_S89	57	0.93	71	0.84
MountainCK_S44	27	1.95	88	1.33	MountainCK_S90	57	0.63	81	0.54
MountainCK_S45	27	1.11	80	0.80	MountainCK_S91	57	0.65	66	0.61

5.2.3 Future Conditions 2070 Loss Rates

The same loss rates will be used for 2070 conditions as were used for 2020 conditions.

5.2.4 Future Conditions 2070 Routing

Future urbanization is also expected to reduce the flood storage capacity (also known as valley storage) of the stream. In the HEC-HMS model, this is represented through a reduction in the routing storage values in the Modified Puls storage-discharge curves. For this purpose, effective FEMA FIS floodway models in the watershed were used to estimate a future conditions storage-discharge curve by assuming that floodway encroachments represent the portion of the floodplain that could be lost to future development. For stream reaches without a regulatory floodway, a typical percent difference in storage was calculated from multiple nearby reaches of similar drainage area that did have floodway models, and that percent difference curve was then applied to the stream reaches without regulatory floodways to estimate the future conditions storage-discharge curves.

Figures 5-3 to 5-5 show the Percent Difference curves that were calculated from the regulatory floodway models on the tributaries of the West Fork as well as the average percent difference curves that were applied to the other stream reaches of varying drainage areas. Table 5-6 shows the reaches with the updated future conditions storage-discharge curves.

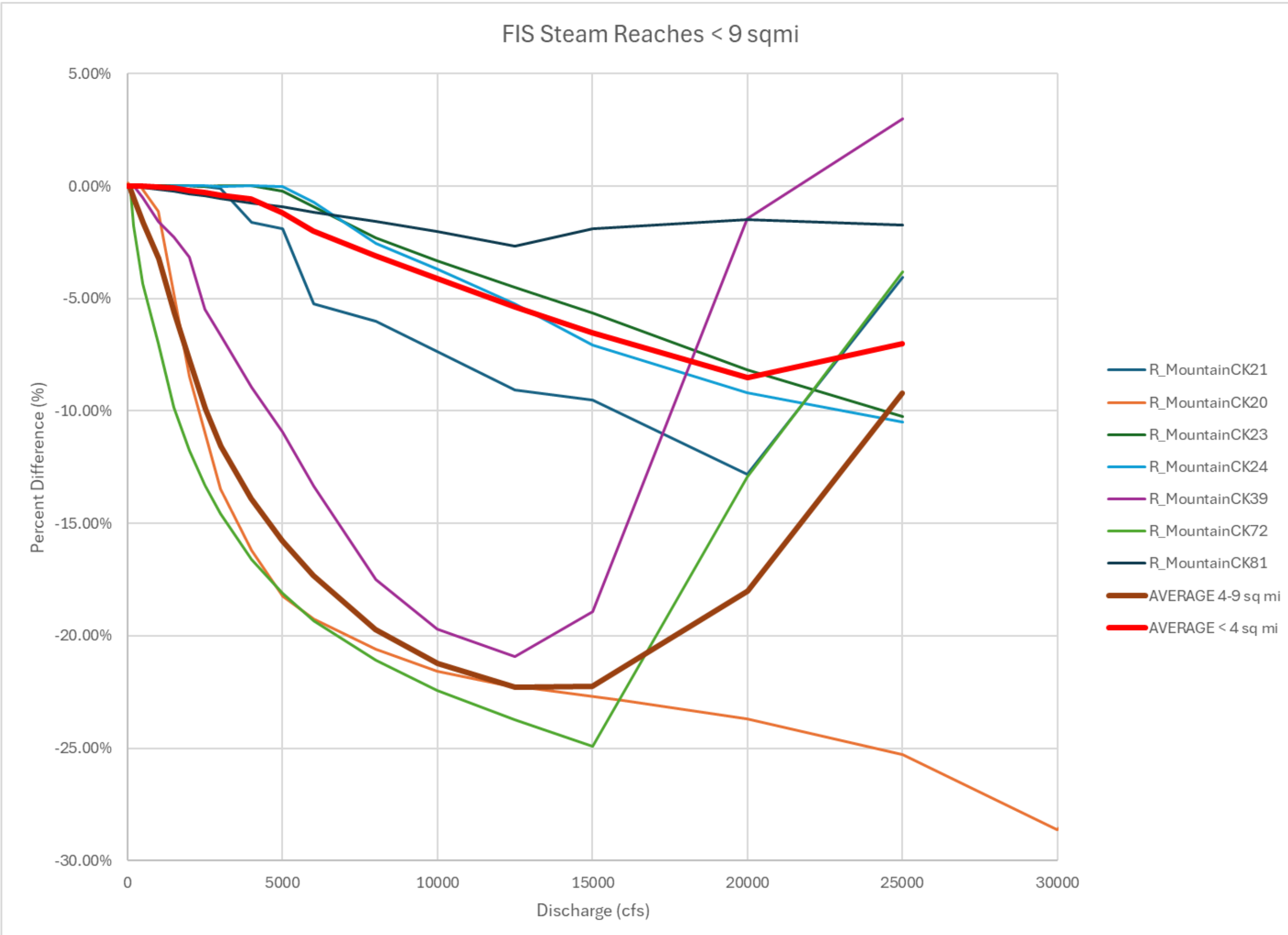


Figure 5-3. Percent Reduction Curves for Future Conditions Valley Storage for Stream Reaches with less than 9 square miles of Drainage Area

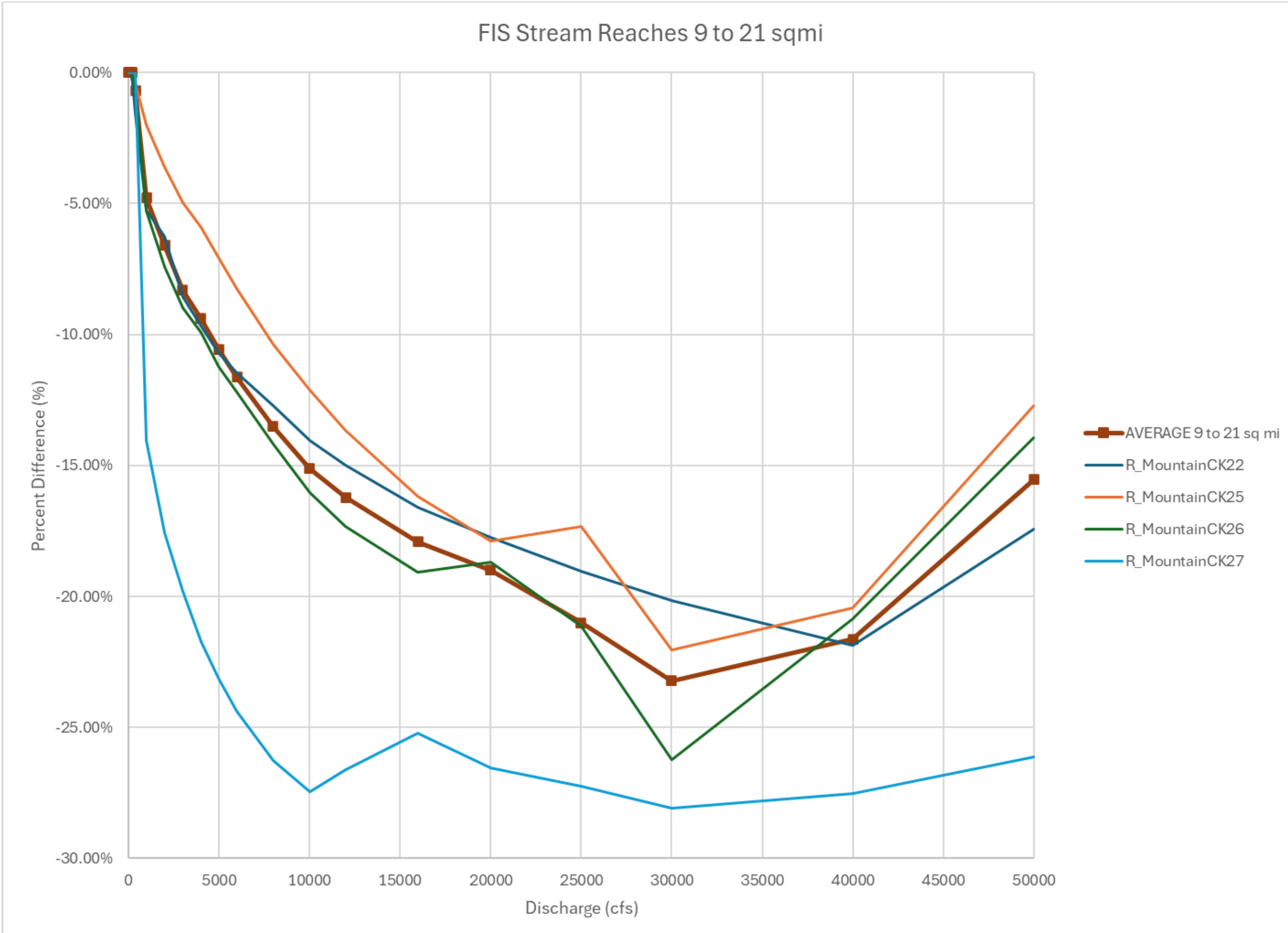


Figure 5-4. Percent Reduction Curves for Future Conditions Valley Storage for Stream Reaches with 9 to 22 square miles of Drainage Area

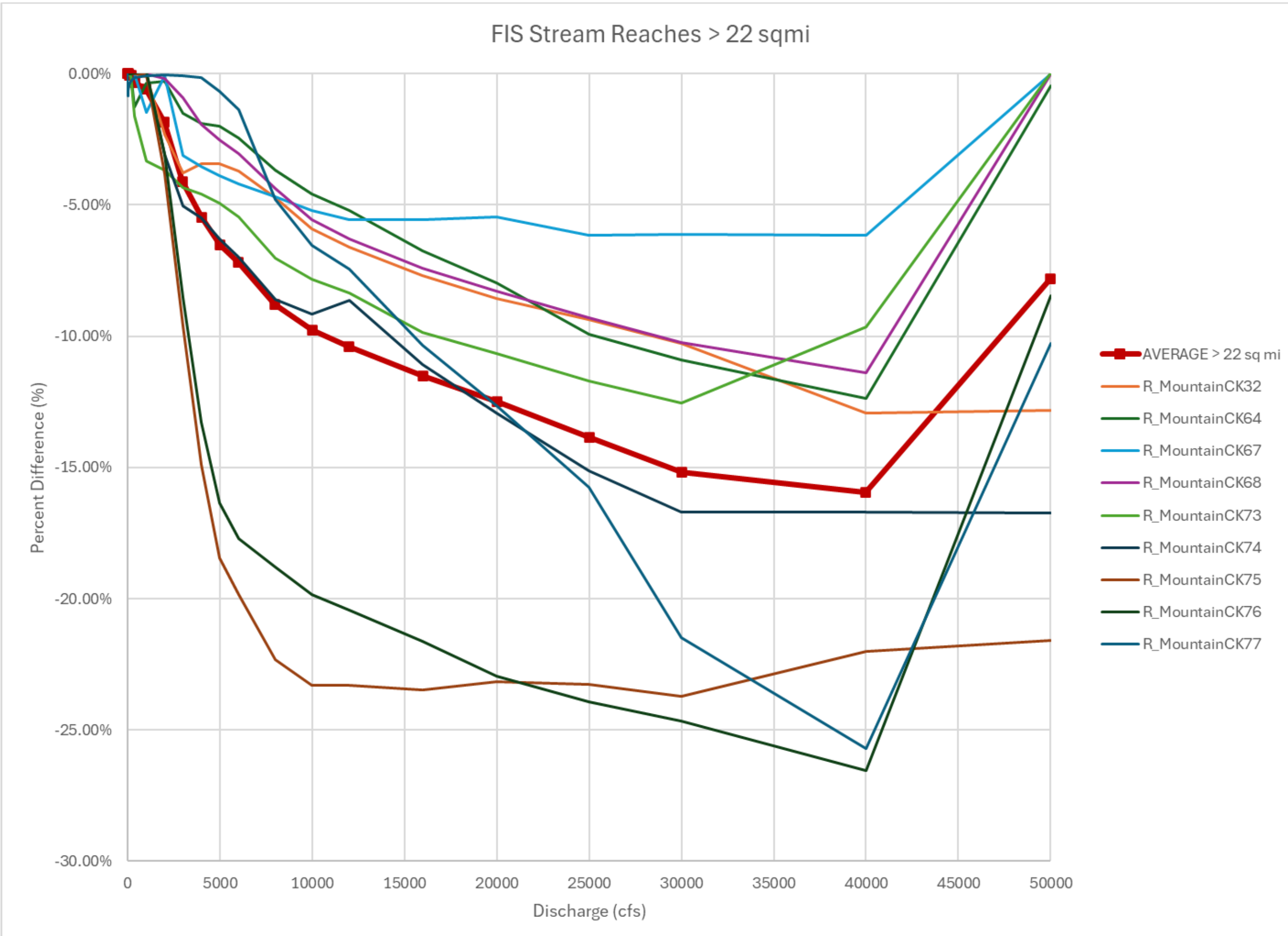


Figure 5-5. Percent Reduction Curves for Future Conditions Valley Storage for West Fork Reaches with greater than 22 square miles of Drainage Area

Table 5-6. Future Conditions Routing Storage-Discharge Curves.

Reach Name	Storage-Discharge Curve	Subreaches
R_MountainCK01	MC_R01_Encroached	1
R_MountainCK02	MC_R02_Encroached	1
R_MountainCK03	MC_R03_Encroached	1
R_MountainCK04	MC_R04_Encroached	1
R_MountainCK05	MC_R05_Encroached	1
R_MountainCK06	MC_R06_Encroached	1
R_MountainCK07	MC_R07_Encroached	2
R_MountainCK08	MC_R08_Encroached	1
R_MountainCK09	MC_R09_Encroached	1
R_MountainCK10	MC_R10_Encroached	3
R_MountainCK11	MC_R11_Encroached	1

Reach Name	Storage-Discharge Curve	Subreaches
R_MountainCK12	MC_R12_Encroached	1
R_MountainCK13	MC_R13_Encroached	1
R_MountainCK14	MC_R14_Encroached	1
R_MountainCK15	MC_R15_Encroached	1
R_MountainCK16	MC_R16_Encroached	1
R_MountainCK17	MC_R17_Encroached	1
R_MountainCK18	MC_R18_Encroached	1
R_MountainCK19	MC_R19_Encroached	1
R_MountainCK20	MC_R20_FIS_Encroached	1
R_MountainCK21	MC_R21_FIS_Encroached	1
R_MountainCK22	MC_R22_FIS_Encroached	2
R_MountainCK23	MC_R23_FIS_Encroached	2
R_MountainCK24	MC_R24_FIS_Encroached	2
R_MountainCK25	MC_R25_FIS_Encroached	3
R_MountainCK26	MC_R26_FIS_Encroached	1
R_MountainCK27	MC_R27_FIS_Encroached	1
R_MountainCK28	MC_R28_Encroached	1
R_MountainCK29	MC_R29_Encroached	1
R_MountainCK30	MC_R30_Encroached	1
R_MountainCK31	MC_R31_Encroached	1
R_MountainCK32	MC_R32_FIS_Encroached	1
R_MountainCK33	MC_R33_Encroached	1
R_MountainCK34	MC_R34_Encroached	1
R_MountainCK37	MC_R37_Encroached	1
R_MountainCK39	MC_R39_FIS_Encroached	3
R_MountainCK42	MC_R42_Encroached	1
R_MountainCK45	MC_R45_Encroached	2
R_MountainCK48	MC_R48_Encroached	1
R_MountainCK49	MC_R49_Encroached	1
R_MountainCK50	MC_R50_Encroached	1
R_MountainCK51	MC_R51_Encroached	1
R_MountainCK52	MC_R52_Encroached	1
R_MountainCK53	MC_R53_Encroached	1
R_MountainCK54	MC_R54_Encroached	1
R_MountainCK55	MC_R55_Encroached	1
R_MountainCK56	MC_R56_Encroached	1
R_MountainCK59	MC_R59_Encroached	1
R_MountainCK60	MC_R60_Encroached	1
R_MountainCK61	MC_R61_Encroached	1
R_MountainCK62	MC_R62_Encroached	1
R_MountainCK63	MC_R63_Encroached	1
R_MountainCK64	MC_R64_FIS_Encroached	1

Reach Name	**Storage-Discharge Curve**	**Subreaches**
R_MountainCK67	MC_R67_FIS_Encroached	1
R_MountainCK68	MC_R68_FIS_Encroached	1
R_MountainCK69	MC_R69_Encroached	1
R_MountainCK70	MC_R70_Encroached	1
R_MountainCK72	MC_R72_FIS_Encroached	1
R_MountainCK73	MC_R73_FIS_Encroached	1
R_MountainCK74	MC_R74_FIS_Encroached	1
R_MountainCK75	MC_R75_FIS_Encroached	1
R_MountainCK76	MC_R76_FIS_Encroached	1
R_MountainCK77	MC_R77_FIS_Encroached	2
R_MountainCK79	MC_R79_Encroached	2
R_MountainCK81	MC_R81_FIS_Encroached	2

6 Final HEC-HMS Results

Five discharge frequency results for the 2020, and 2070 (existing and future conditions) are illustrated in the following sections.

6.1 Frequency Storms

The WHA study uniform storms NOAA14 precipitation depths were applied to the entire watershed. Five frequencies were generated for this study: 50% ACE (2-year), 10% ACE (10-year), 2% ACE (50-year), 1% ACE (100-year), and 0.2% ACE (500-year). The 1% ACE (100-year) 2016 existing conditions simulation run utilized storm area reductions, based upon the WHA subbasin areas, but all other simulated future conditions' frequencies were not reduced to provide more conservative answers.

6.2 Frequency Discharge Results for Existing 2020 Conditions

Table 6-1 illustrates the 2020 existing conditions discharge frequency peaks for the Mountain Creek Watershed.

Table 6-1. Summary of Existing 2020 Conditions Discharges for the Mountain Creek Watershed

Frequency and Peak Discharge (cfs)

		2-yr 2020	**10-yr 2020**	**50-yr 2020**	**100-yr 2020**	**500-yr 2020**
HMS Element	DA sqmi	Peak Q (cfs)	Peak Q (cfs)	Peak Q (cfs)	Peak Q (cfs)	Peak Q (cfs)
J_MountainCK01	2.5	1132	2313	3346	3844	5030
J_MountainCK02	4.6	1199	2737	4180	4900	6335
J_MountainCK03	10	2384	5322	8124	9506	12642
J_MountainCK04	15.6	3283	7279	11436	13536	17723
J_MountainCK05	18.4	3733	8060	12741	14980	19933
J_MountainCK06	24.8	4441	9606	15537	18666	25474
J_MountainCK07 Mountain Creek nr Venus	**24.8**	**4395**	**9584**	**15475**	**18591**	**25400**
J_MountainCK08	26	4347	9641	15570	18535	25733
J_MountainCK09	2.8	898	2031	3033	3512	4672
J_MountainCK10	2.8	835	1929	2954	3241	3994
J_MountainCK11	28.8	4644	10289	16756	19892	28392
J_MountainCK12	29.8	4441	10193	16856	20047	28540
J_MountainCK13	6.6	1747	4110	6254	7287	9766
J_MountainCK14	6.6	1059	3188	5031	6123	8672
J_MountainCK15	36.4	5470	12935	21679	25494	36238
J_MountainCK16	38.7	5538	13336	22542	26577	37913
J_MountainCK17	3.1	1217	2740	4021	4627	6096
J_MountainCK18	3.8	1055	2860	4040	4813	6373

J_MountainCK19	4.3	839	2612	4091	4840	6514
J_MountainCK20	4.8	756	2201	3932	4718	6468
J_MountainCK21	4.8	754	2191	3806	4584	6358
J_MountainCK22	43.6	6132	15101	25717	30549	43366
J_MountainCK23	47	6180	15377	26604	31927	45319
J_MountainCK24	48.3	6031	15069	26167	31583	45039
J_MountainCK25	48.3	5885	14878	25930	31338	44789
J_MountainCK26	49.4	5807	14753	25838	31288	44798
J_MountainCK27	5.5	1841	4145	6162	7124	9454
J_MountainCK28	5.9	1732	4039	6171	7214	9688
J_MountainCK29	2.7	1165	2414	3503	4016	5279
J_MountainCK30	3.5	1316	2790	4108	4732	6476
J_MountainCK31	9.4	2959	6690	10125	11802	15936
J_MountainCK32	10.4	2787	6807	10514	12349	16832
J_MountainCK33	2.1	1253	2621	3708	4213	5451
J_MountainCK34	3.8	1278	3303	5117	5965	7990
J_MountainCK35	4.4	1271	3543	5600	6560	8861
J_MountainCK36	14.8	4010	10111	15735	18459	25152
J_MountainCK37	19.2	3444	9921	16792	20122	28252
J_MountainCK38	19.7	3254	9442	16652	19885	27370
J_MountainCK39	19.7	3197	9354	16573	19773	27278
J_MountainCK40	4.9	1469	3224	4833	5605	7481
J_MountainCK41	3	1153	2459	3602	4144	5469
J_MountainCK42	7.9	2525	5502	8198	9487	12625
Mountain Creek WS SCS Site10	10	138	277	958	1936	5192
J_MountainCK43	10	138	277	958	1936	5192
Mountain Creek WS SCS Site 9	3.3	127	247	381	642	1342
J_MountainCK44	3.3	127	247	381	642	1342
J_MountainCK45	4.2	443	953	1415	1644	2164
J_MountainCK46	0.7	327	712	1026	1174	1534
J_MountainCK47	14.9	785	1701	2541	2955	6747
J_MountainCK48	15.4	843	2014	3155	3706	6848
J_MountainCK49	35.1	3457	10043	17996	21526	31429
Mountain Creek WS SCS Site11	1.2	69	181	358	501	936
J_MountainCk40b	1.2	69	181	358	501	936
J_MountainCK50	36.9	3331	9671	17629	21410	31885
J_MountainCK51	37.8	3217	9447	17477	21374	32000
J_MountainCK52	87.1	8843	23258	40285	49722	74516
J_MountainCK53	91.7	8361	21987	39138	48606	73892
J_MountainCK54	91.7	8361	21987	39138	48606	73892
J_MountainCK55	5.5	1655	3834	5764	6688	8916
J_MountainCK56	98.5	8620	22869	41187	51368	77987
J_MountainCK57	4.8	1693	3620	5348	6173	8186

J_MountainCK58	4.8	1285	3084	4760	5557	7467
J_MountainCK59	107.6	8914	24026	44101	55260	83782
J_MountainCK60	3.9	1121	2565	3874	4502	6019
J_MountainCK61	5.9	1756	4004	6027	6998	9342
J_MountainCK62	113.6	8998	24541	45795	57619	87396
J_MountainCK63	3.1	1143	2482	3655	4212	5571
J_MountainCK64	125.3	10056	25327	48107	60815	92265
J_MountainCK65	135.8	12076	28009	49682	63051	95778
J_MountainCK66	1.8	408	1011	1586	1845	2455
J_MountainCK67	2.2	489	1233	1941	2260	3011
J_MountainCK68	3	676	1710	2573	3009	3948
J_MountainCK69	4.8	1082	2733	4160	4851	6437
J_MountainCK70	5.5	1186	2997	4549	5308	7163
J_MountainCK71	6.2	1273	2872	4770	5602	7671
J_MountainCK72	3	679	1680	2635	3067	4082
J_MountainCK73	4.9	1080	2311	3894	4647	6317
J_MountainCK74	11.1	2353	5145	8661	10235	13988
J_MountainCK75	11.1	1978	4543	8011	9577	13199
J_MountainCK76	11.1	1946	4233	7784	9375	12974
J_MountainCK77	3	637	1627	2573	3000	3999
J_MountainCK78	16.7	2856	6010	11435	13849	19306
J_MountainCK79	17.4	2254	5765	11093	13492	19053
J_MountainCK80	2	495	1248	1948	2263	3004
J_MountainCK82	3.1	671	1737	2732	3175	4192
J_MountainCK84	3.4	704	1809	2842	3358	4502
J_MountainCK85	20.8	2743	6759	13242	16027	22704
J_MountainCK86	21.2	2558	6625	12963	15839	22546
J_MountainCK87	23.3	2814	7130	14042	17184	24531
J_MountainCK88	5	1136	2797	4388	5107	6799
J_MountainCK89	6.3	1079	2846	4722	5534	7573
J_MountainCK90	29.6	3845	9257	18005	21917	31310
J_MountainCK91	32.8	3105	8520	17086	21228	30852
J_MountainCK92	3.7	631	1588	2566	3012	4046
J_MountainCK93	36.6	3398	9402	18905	23474	34182
J_MountainCK96	36.6	3334	9277	18666	23197	33832
J_MountainCK97	36.6	3330	9266	18645	23168	33791
J_MountainCK98	38.5	3413	9555	19326	24038	35150
J_MountainCK99	3.8	755	1893	3008	3513	4692
J_MountainCK100	6.1	1235	3141	4982	5819	7768
J_MountainCK102	8.1	1549	4145	6661	7805	10473
J_MountainCK103	1.9	439	1028	1599	1858	2472
J_MountainCK104	48.4	4339	12121	24155	29944	43818
J_MountainCK105	51.6	4098	11695	23851	29763	43393

J_MountainCK106	53.6	4040	11759	24009	29968	42312
J_MountainCK107	61.4	4532	13253	27021	33696	47331
J_MountainCK108 Walnut Ck nr Mansfield	**62.9**	**4489**	**13103**	**26810**	**33431**	**47306**
J_MountainCK109	67.5	4506	12801	25869	32173	46748
J_MountainCK110	5.3	2992	5488	7691	8694	11143
J_MountainCK111	72.8	4893	13770	27540	34122	49430
J_MountainCK112	3.6	2030	3722	5218	5899	7561
J_MountainCK113	82.9	7368	14587	28178	35005	50792
J_MountainCK114 Inflow to Joe Pool Lake	**223.8**	**16708**	**40058**	**78075**	**97933**	**146838**
Joe Pool Lake	223.8	0	0	0	0	0

6.3 Frequency Discharge Results for Future 2070 Conditions

Table 6-2 illustrates the 2070 future conditions discharge frequency peaks for the Mountain Creek Watershed.

Table 6-2. Summary of Future 2070 Conditions Discharges for the Mountain Creek Area

Frequency and Peak Discharge (cfs)

		2-yr 2070	**10-yr 2070**	**50-yr 2070**	**100-yr 2070**	**500-yr 2070**
HMS Element	DA sqmi	Peak Q (cfs)	Peak Q (cfs)	Peak Q (cfs)	Peak Q (cfs)	Peak Q (cfs)
J_MountainCK01	2.5	1576	2879	4070	4633	6008
J_MountainCK02	4.6	1619	3308	4929	5682	7202
J_MountainCK03	10	3458	6776	10024	11623	14853
J_MountainCK04	15.6	4314	9033	13754	15688	20588
J_MountainCK05	18.4	4767	9942	15120	17340	23104
J_MountainCK06	24.8	5920	11768	18937	22199	29909
J_MountainCK07 Mountain Ck nr Venus	**24.8**	**5885**	**11744**	**18852**	**22147**	**29830**
J_MountainCK08	26	5682	11836	18740	22349	30357
J_MountainCK09	2.8	1363	2655	3804	4344	5688
J_MountainCK10	2.8	1266	2494	3354	3654	4786
J_MountainCK11	28.8	6011	12653	20119	24218	33810
J_MountainCK12	29.8	5941	12705	20262	24432	34251
J_MountainCK13	6.6	2252	4713	6966	8043	10682
J_MountainCK14	6.6	1466	3897	6041	7228	9942
J_MountainCK15	36.4	7366	16400	25807	30976	43323
J_MountainCK16	38.7	7517	17035	26937	32364	45398
J_MountainCK17	3.1	2037	3695	5173	5856	7574
J_MountainCK18	3.8	1867	3677	5046	5791	7455

J_MountainCK19	4.3	1487	3238	4846	5583	7496
J_MountainCK20	4.8	1291	2957	4774	5569	7627
J_MountainCK21	4.8	1269	2868	4640	5458	7530
J_MountainCK22	43.6	8481	19591	31011	37090	51799
J_MountainCK23	47	8611	19944	32369	38723	53438
J_MountainCK24	48.3	8445	19391	32066	38513	52434
J_MountainCK25	48.3	8289	19154	31825	38240	51877
J_MountainCK26	49.4	8217	19067	31790	38228	51472
J_MountainCK27	5.5	2296	4712	6847	7856	10340
J_MountainCK28	5.9	2180	4692	6974	8041	10688
J_MountainCK29	2.7	1701	3194	4490	5090	6590
J_MountainCK30	3.5	1819	3527	5048	5908	8024
J_MountainCK31	9.4	3739	7851	11603	13428	17900
J_MountainCK32	10.4	3697	8160	12289	14318	19293
J_MountainCK33	2.1	1681	3116	4318	4867	6238
J_MountainCK34	3.8	1703	3797	5710	6590	8805
J_MountainCK35	4.4	1711	4079	6268	7305	9827
J_MountainCK36	14.8	5388	12172	18425	21514	29008
J_MountainCK37	19.2	4700	12396	20392	24162	33456
J_MountainCK38	19.7	4467	11874	20041	23755	32790
J_MountainCK39	19.7	4418	11805	19952	23659	32668
J_MountainCK40	4.9	2411	4468	6372	7268	9518
J_MountainCK41	3	1752	3255	4592	5214	6773
J_MountainCK42	7.9	4054	7549	10733	12223	15962
Mountain Creek WS SCS Site10	10	191	331	1482	2637	5762
J_MountainCK43	10	191	331	1482	2637	5762
Mountain Creek WS SCS Site 9	3.3	179	293	504	791	1494
J_MountainCK44	3.3	179	293	504	791	1494
J_MountainCK45	4.2	666	1263	1783	2025	2596
J_MountainCK46	0.7	500	924	1287	1454	1872
J_MountainCK47	14.9	1219	2278	3215	3655	7537
J_MountainCK48	15.4	1365	2700	3987	4567	7674
J_MountainCK49	35.1	4841	12726	21615	25760	38009
Mountain Creek WS SCS Site11	1.2	91	215	398	548	1000
J_MountainCk40b	1.2	91	215	398	548	1000
J_MountainCK50	36.9	4606	12140	21107	25502	38216
J_MountainCK51	37.8	4485	11935	21039	25529	38324
J_MountainCK52	87.1	12508	29946	50375	61034	84027
J_MountainCK53	91.7	11902	28593	47358	57816	82699
J_MountainCK54	91.7	11902	28593	47358	57816	82699
J_MountainCK55	5.5	3039	5450	7697	8748	11402
J_MountainCK56	98.5	12370	29832	49563	60487	86559
J_MountainCK57	4.8	2836	4988	7006	7947	10332

J_MountainCK58	4.8	2139	4236	6279	7222	9619
J_MountainCK59	107.6	12887	31524	52916	64413	92192
J_MountainCK60	3.9	1758	3364	4843	5541	7284
J_MountainCK61	5.9	2700	5192	7473	8548	11226
J_MountainCK62	113.6	13086	32392	55112	66975	96241
J_MountainCK63	3.1	1790	3302	4659	5291	6878
J_MountainCK64	125.3	16402	33571	58143	70188	101429
J_MountainCK65	135.8	18486	37437	60336	72606	107117
J_MountainCK66	1.8	610	1272	1897	2182	2871
J_MountainCK67	2.2	744	1578	2358	2713	3571
J_MountainCK68	3	1008	2022	2997	3459	4484
J_MountainCK69	4.8	1653	3365	4896	5712	7389
J_MountainCK70	5.5	1689	3766	5351	6263	8276
J_MountainCK71	6.2	1563	3752	5726	6730	9022
J_MountainCK72	3	1132	2261	3329	3817	5009
J_MountainCK73	4.9	1779	3050	4820	5615	7560
J_MountainCK74	11.1	3328	6780	10519	12325	16582
J_MountainCK75	11.1	2590	6061	9890	11627	15870
J_MountainCK76	11.1	2499	5780	9696	11439	15661
J_MountainCK77	3	932	1906	2853	3285	4332
J_MountainCK78	16.7	3932	8406	14408	17067	23468
J_MountainCK79	17.4	3385	8130	14145	16879	23677
J_MountainCK80	2	795	1621	2388	2737	3587
J_MountainCK82	3.1	1049	2152	3231	3765	4734
J_MountainCK84	3.4	985	2215	3375	3957	5078
J_MountainCK85	20.8	4112	9667	16905	20143	28245
J_MountainCK86	21.2	3808	9455	16723	19957	28216
J_MountainCK87	23.3	4023	10216	18152	21699	30774
J_MountainCK88	5	1990	3831	5599	6408	8398
J_MountainCK89	6.3	1888	4111	6068	7093	9473
J_MountainCK90	29.6	5332	13071	23191	27714	39393
J_MountainCK91	32.8	4824	12166	22240	27121	38948
J_MountainCK92	3.7	1076	2161	3241	3737	4939
J_MountainCK93	36.6	5330	13462	24570	30038	43212
J_MountainCK96	36.6	5265	13278	24276	29662	42107
J_MountainCK97	36.6	5260	13256	24233	29610	41921
J_MountainCK98	38.5	5421	13697	25117	30743	43437
J_MountainCK99	3.8	1246	2507	3727	4285	5642
J_MountainCK100	6.1	2065	4161	6180	7105	9345
J_MountainCK102	8.1	2636	5463	8305	9567	12639
J_MountainCK103	1.9	698	1359	1996	2288	3002
J_MountainCK104	48.4	7132	17142	31077	38047	54039
J_MountainCK105	51.6	6842	16815	30846	37209	51098

J_MountainCK106	53.6	6788	16963	30901	35940	50090
J_MountainCK107	61.4	7619	19086	34728	39854	55314
J_MountainCK108 Walnut Ck nr Mansfield	**62.9**	**7565**	**19004**	**34627**	**39984**	**54458**
J_MountainCK109	67.5	7524	18558	34201	39973	52066
J_MountainCK110	5.3	3671	6313	8729	9821	12514
J_MountainCK111	72.8	8062	19877	36317	42363	54319
J_MountainCK112	3.6	2535	4324	5972	6716	8555
J_MountainCK113	82.9	9898	20383	37408	43719	55805
J_MountainCK114 Inflow to Joe Pool Lake	**223.8**	**25978**	**54594**	**98184**	**116663**	**160616**
Joe Pool Lake	223.8	0	0	0	0	0

The differences in peak flows between existing (2020) and future (2070) conditions are further illustrated in the following figures. Figure 6-1 shows that the percent increase in the 100-year peak discharge ranges from 10% to 30% with a median increase of 21%.

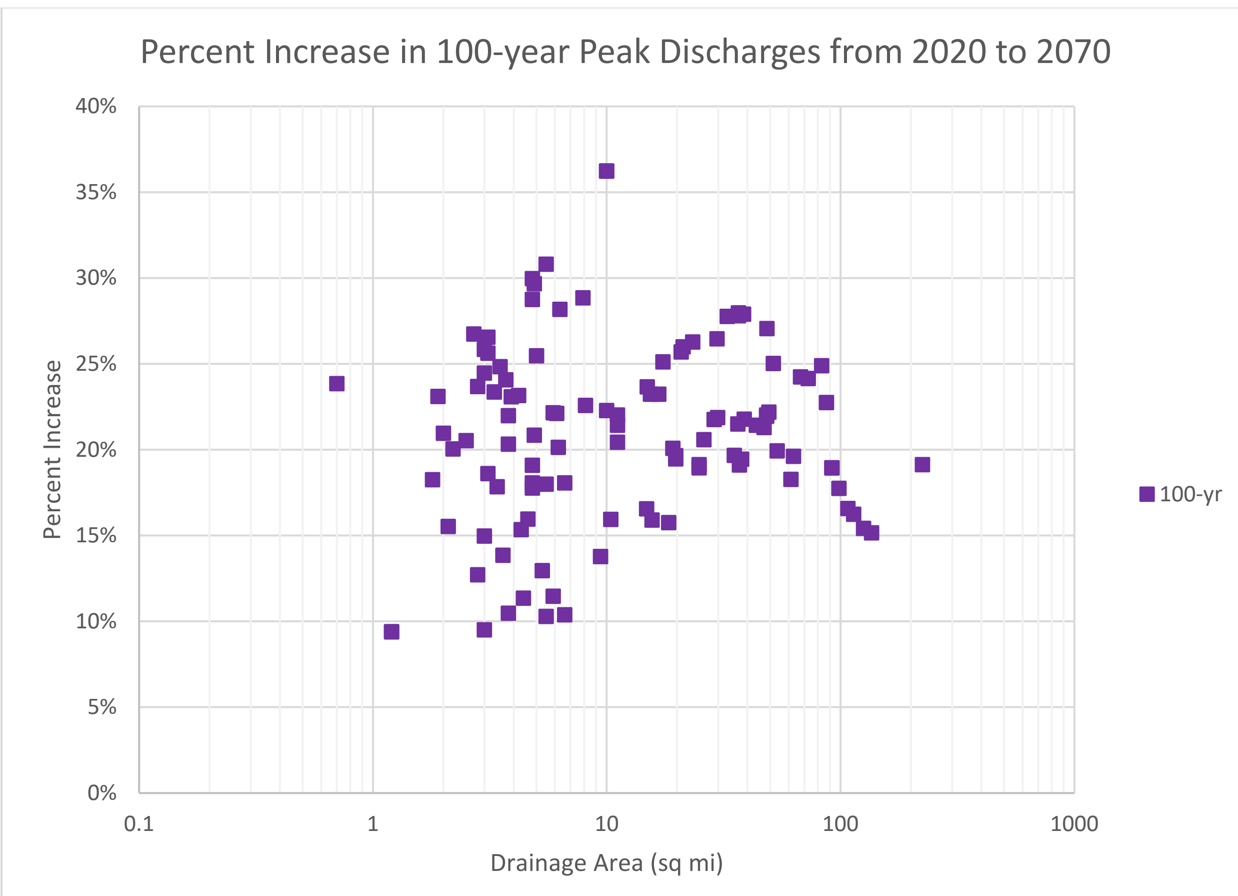


Figure 6-1. Percent Differences between Existing and Future Conditions 100-year Peak Discharges

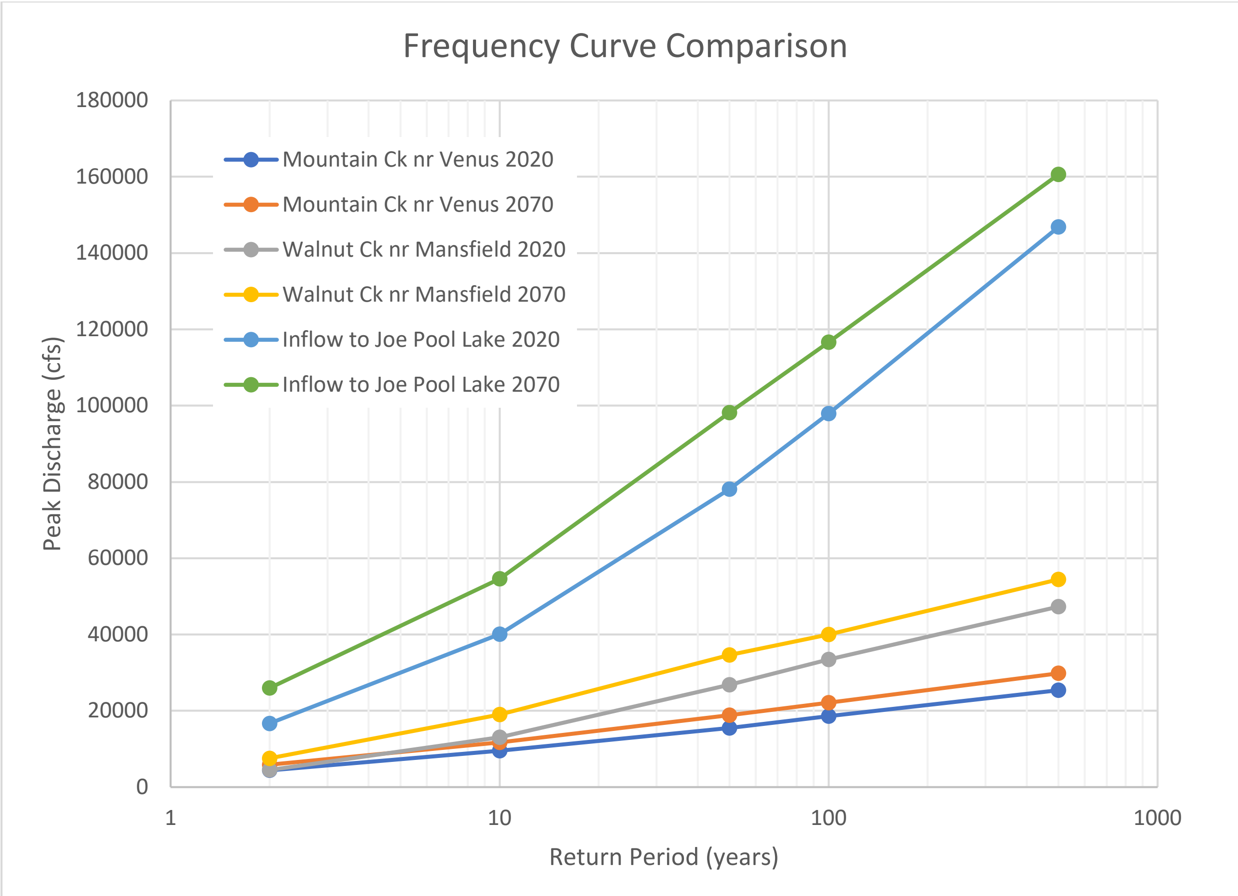


Figure 6-2. Flow Frequency Curves for Existing and Future Conditions at Selected Locations

Figure 6-2 shows consistent increases of several thousand cfs across all frequencies. Figure 6-3 shows that the 2-year flood had the largest increases, ranging from 30% to 80% across all locations, while the increases in the 10-year to 500-year discharges ranged from 10% to 40% across all locations.

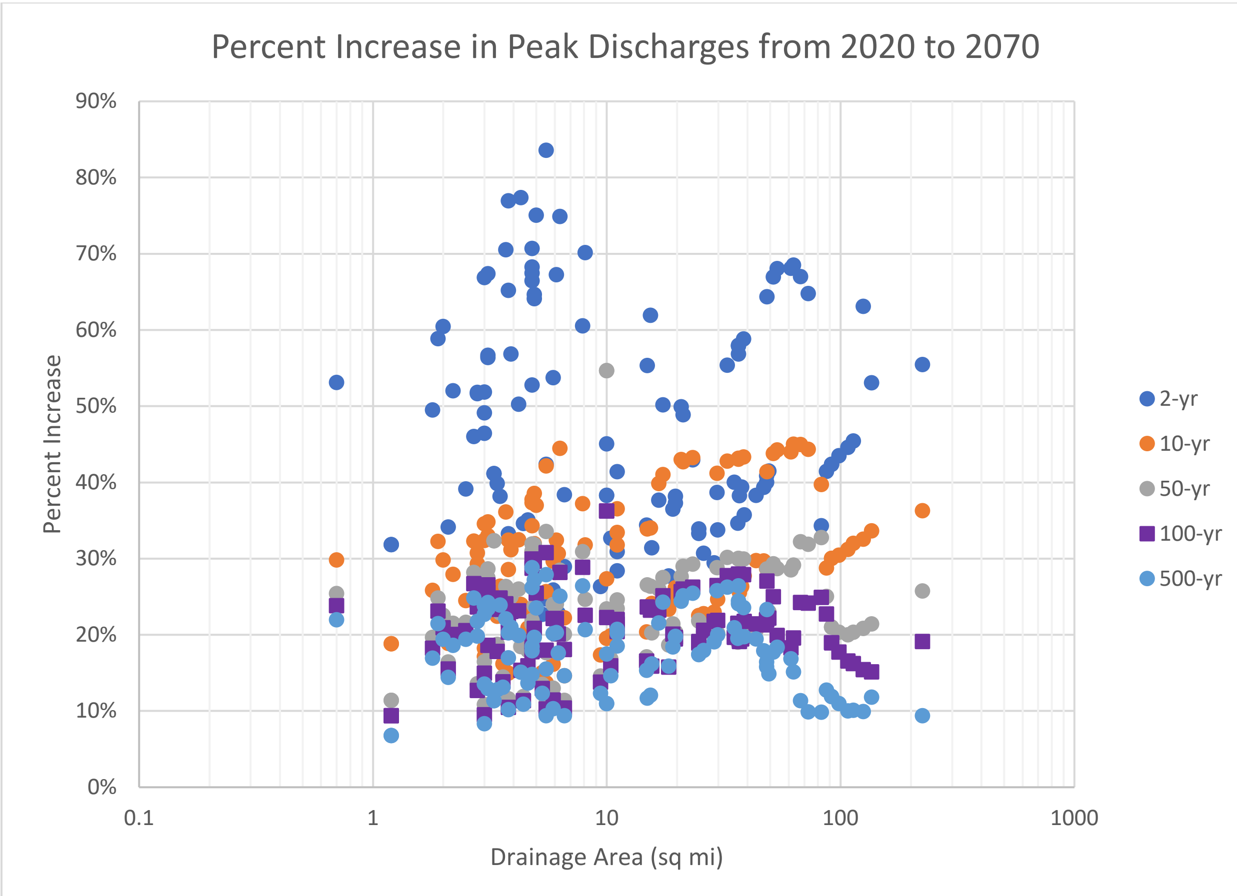


Figure 6-3. Percent Differences between Existing and Future Conditions

7 Conclusions

The general trend of runoff when taking to account urbanization or future conditions imperviousness, increase the discharge peaks on the watershed. Table 6-3 and Figure 6-4 illustrate the increase in peak discharge due to future urbanization at selected locations in the watershed. From this figure, once can see that the largest increases occur at the 50% ACE (2-year) and 10% ACE (10-year) frequencies, ranging from 34% to 69% at the 2-year and 23% to 45% at the 10-year. For the more rare events (50-year to 500-year), the increases due to future urbanization become more consistent, ranging from 10% to 30%.

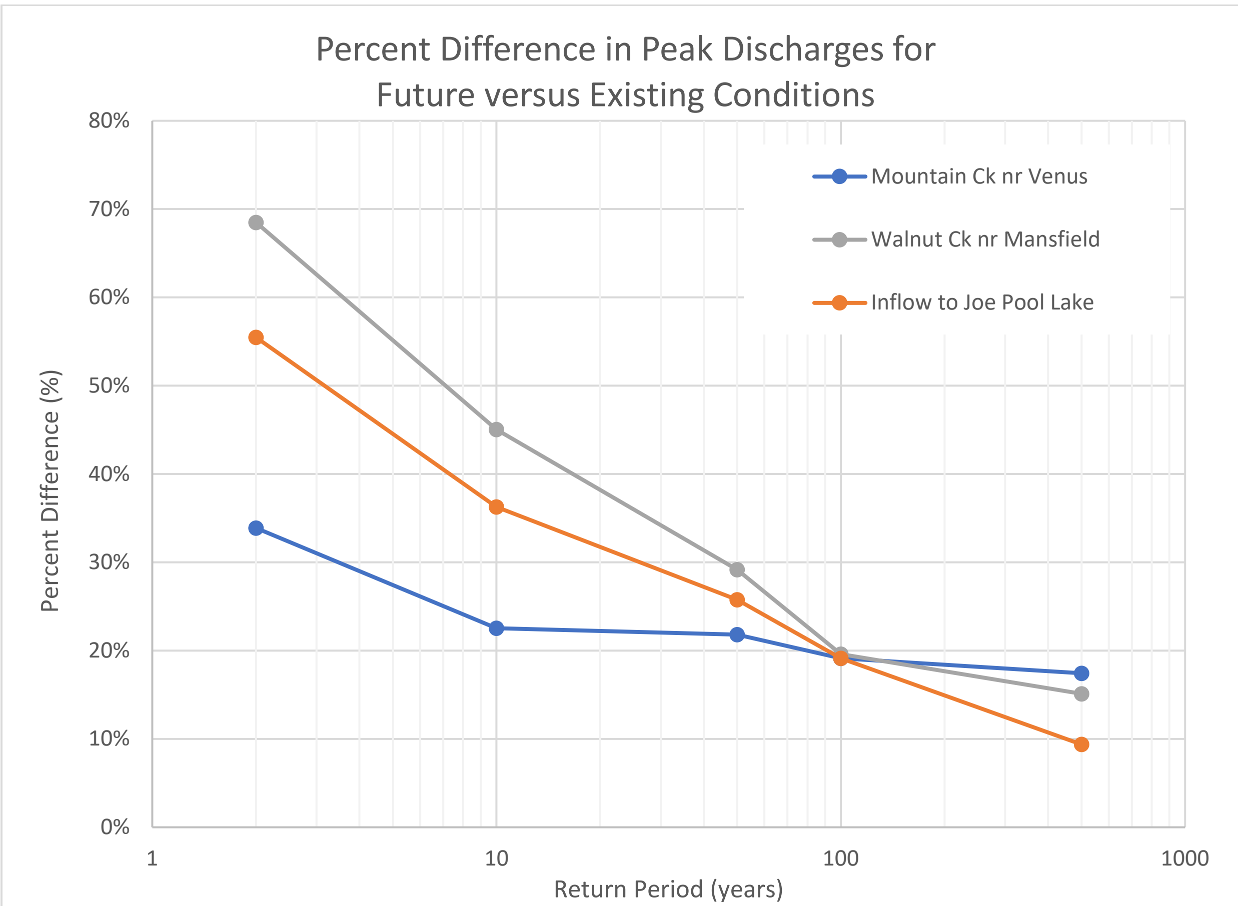


Figure 6-4. Percent Differences from Existing to Future Conditions versus Frequency

Table 6-3. 2070 Peak Discharge Percent Increase from 2020 Conditions

Annual Chance of Exceedance (ACE%)	Frequency (Years)	Mountain Ck nr Venus, TX J_MountainCK07	Walnut Ck nr Mansfield, TX J_MountainCK108	Inflow to Joe Pool Lake J_MountainCK114
50	2	34%	69%	55%
10	10	23%	45%	36%
2	50	22%	29%	26%
1	100	19%	20%	19%
0.2	500	17%	15%	9%

Another interesting portion of the results for the Mountain Creek watershed in particular is the potential increase in peak pool elevations at Joe Pool Lake under future conditions. Table 6-4 and Figure 6-5 illustrate these increases in peak pool elevation. As one can see from the table below, the difference in peak pool elevations at Joe Pool Lake is quite consistent across the frequences, ranging from 1.0 to 1.3 feet. This is because Joe Pool Lake's pool elevation is primarily dependent on the total volume of inflow.

Table 6-4. Peak Pool Elevation Increases from 2020 to 2070 Conditions at Joe Pool Lake

Annual Chance of Exceedance (ACE%)	Frequency (Years)	2020 Peak Elev (ft NAVD88)	2070 Peak Elev (ft NAVD88)	Difference Peak Elev feet
50	2	525.0	526.3	1.3
10	10	528.6	529.9	1.4
2	50	532.5	533.7	1.3
1	100	534.6	535.7	1.1
0.2	500	539.3	540.2	1.0

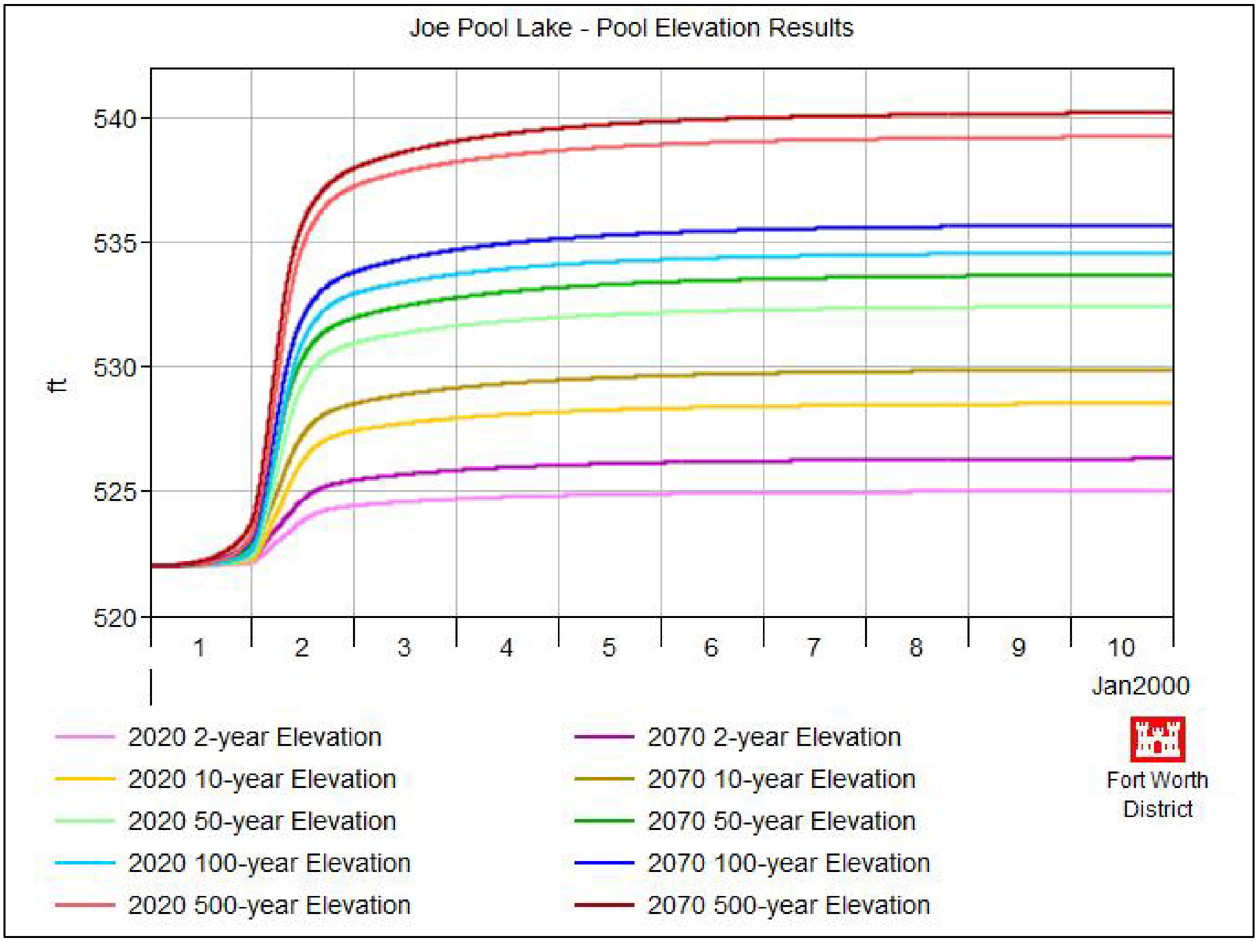


Figure 6-5. Pool Elevations for 2020 and 2070 Conditions at Joe Pool Lake

8 References

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