Interagency Flood Risk Management (InFRM)

Watershed Hydrology Assessment for the White River Basin

April 2025

InFRM
INTERAGENCY FLOOD RISK MANAGEMENT

Table of Contents

The InFRM Team

As flooding remains the leading cause of natural-disaster loss across the United States, the Interagency Flood Risk Management (InFRM) team brings together federal agencies with mission areas in water resources, hazard mitigation, and emergency management to leverage their unique skillsets, resources, and expertise to reduce long term flood risk throughout the region. The Federal Emergency Management Agency (FEMA) Region VI began sponsorship of the InFRM team in 2014 to better align Federal resources across the States of Texas, Oklahoma, New Mexico, Louisiana, and Arkansas. The InFRM team is comprised of FEMA, the US Army Corps of Engineers (USACE), the US Geological Survey (USGS), and the National Weather Service (NWS), which serves under the National Oceanic and Atmospheric Administration (NOAA). One of the first initiatives undertaken by the InFRM team was performing Watershed Hydrology Assessments for large river basins in the region.

FEMA funded the Watershed Hydrology Assessments to leverage the technical expertise, available data, and scientific methodologies for hydrologic assessments through the InFRM team. This partnership allows FEMA to draw from the local knowledge, historic data, and field staff of its partner agencies and to develop forward leaning hydrologic assessments at a river basin level. These studies provide outcomes based on all available hydrologic approaches and provide suggestions for areas where the current flood hazard information may require update. FEMA will leverage these outcomes to assess the current flood hazard inventory, communicate areas of change with community technical and decision makers, and identify/prioritize future updates for Flood Insurance Rate Maps (FIRMs).

USACE has participated in the development of the Watershed Hydrology Assessments as a study manager and member of the InFRM team. USACE served in an advisory role in this study where USACE's expertise in the areas of hydraulics, hydrology, water management, and reservoir operations was required. USACE's primary scientific contributions to the study have been in its rainfall runoff watershed modeling and its reservoir analyses. The reservoir analyses in this study are based on USACE's first hand reservoir operations experience and the latest scientific techniques from USACE's Dam Safety program.

The USGS Lower Mississippi River Gulf Water Science Center has participated in the development of this study as an adviser and member of the InFRM team. USGS served in an advisory role for this study where USGS' expertise in stream gaging, modeling, and statistics was requested. USGS's primary scientific contribution to the study has been statistical support for flood flow frequency analysis. This flood flow frequency analysis included USGS first hand stream gaging expertise as well as advanced statistical science.

NWS has participated in the development of this study as an adviser and member of the InFRM team. NOAA NWS served in an advisory role of this study where expertise in NOAA NWS' area of practice in water, weather, and climate was requested. NOAA's primary scientific contribution to the study has been the NOAA Atlas 14 precipitation frequency estimates study for Arkansas and Missouri. This precipitation-frequency atlas was jointly developed by participants from the InFRM team and published by NOAA. NOAA Atlas 14 is intended as the U.S. Government source of precipitation frequency estimates and associated information for the United States and U.S. affiliated territories.

More information on the InFRM team and its current initiatives can be found on the InFRM website at www.InFRM.us.

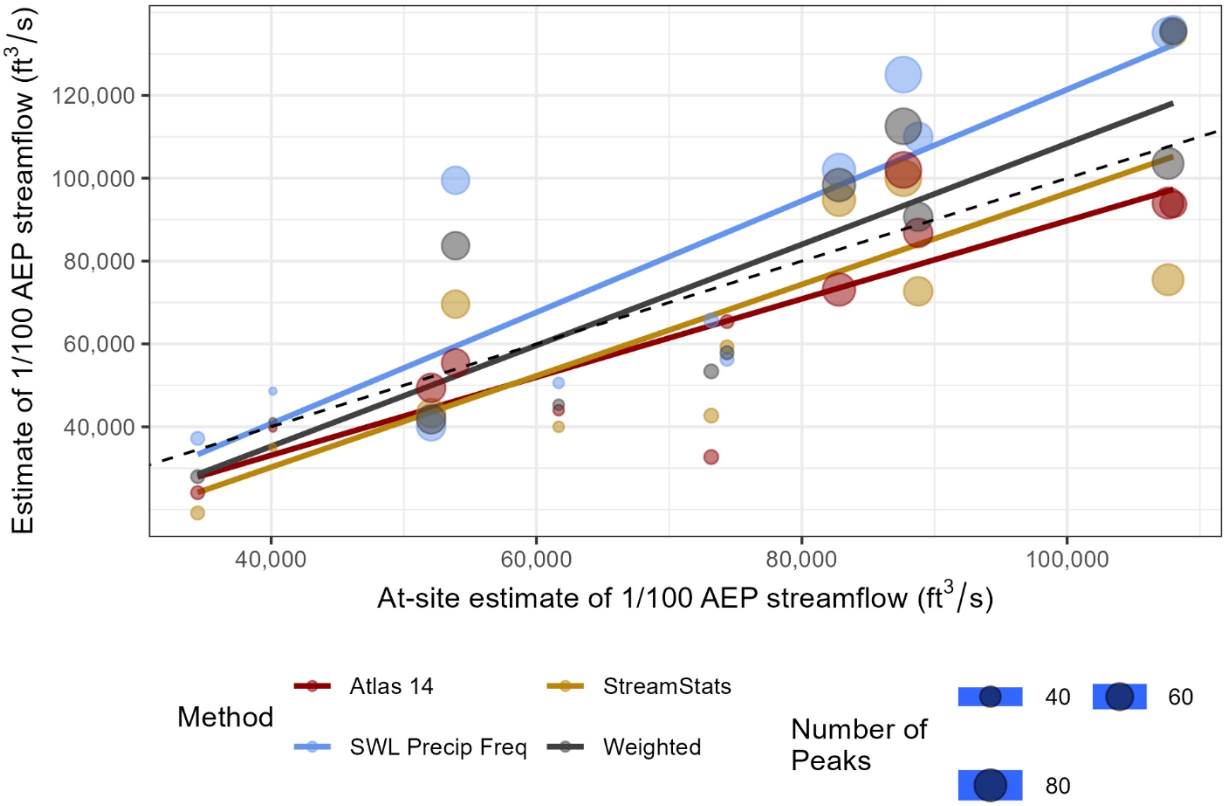
Executive Summary

The National Flood Insurance Program (NFIP) was created in 1968 to guide new development (and construction) away from flood hazard areas and to help transfer the costs of flood damages to the property owners through the payment of flood insurance premiums. The Federal Emergency Management Agency (FEMA) administers the NFIP. The standard that is generally used by FEMA in regulating development and in publishing flood insurance rate maps is the 1/100 annual exceedance probability (AEP) flood (100-yr flood). The 100-yr flood is defined as a flood which has a 1% chance of happening in any year. The factor that has the greatest influence on the depth and width of the 100-yr flood zone is the expected 1/100 AEP (100-yr) flow value.

This report summarizes new analyses that were completed as part of a study to estimate the 1/100 AEP flow, along with other frequency flows, for various stream reaches in the White River Basin. This study was conducted for FEMA Region VI by an Interagency Flood Risk Management (InFRM) team. The InFRM team includes subject matter experts (SME) from the U.S. Army Corps of Engineers (USACE), the U.S. Geological Survey (USGS), and the National Weather Service (NWS). The InFRM team used several different methods, including statistical hydrology, rainfall-runoff modeling, and reservoir period-of-record simulations, to calculate the 1/100 AEP (100-yr) flow and then compared those results to one another. The purpose of the study is to produce 100-yr flow values that are consistent and defendable across the basin.

Within the White River basin, several locations were selected to compare methods for estimating 1/100 AEP flows. All locations evaluated were analyzed for at-site estimates of peak flow frequencies by USGS and an updated regional skew value was provided specifically for the White River basin, which exists in Arkansas and Missouri. Previously, regional skew values varied at the border of Arkansas and Missouri. Flood frequency flows were updated by USGS as a part of the White River basin skew study. The at-site estimates of flood frequency flows that were computed using the updated regional skew value were compared to all other estimates of 1/100 AEP flows.

In general, it was found that using precipitation depths derived from annual maximum series (AMS) that included data until recent years typically yielded higher 1/100 AEP flows after routed through hydrologic models than other methods evaluated. Creating regional Generalized Extreme Value (GEV) distributions from the regional precipitation AMS allows stochastic simulation of flood frequency events. Within these analyses, it benefits to use Stage IV radar from recent, intense precipitation events to extract hourly precipitation depths which can be used a base to scale hourly precipitation depths for routing through hydrologic models.



The final recommendations for the White River Basin Hydrology Assessment were formulated through a rigorous process which required technical feedback and collaboration between all of the InFRM subject matter experts. This process included the following steps: (1) comparing the results of the various hydrologic methods to one another, (2) performing an investigation into the reasons for the differences in results at each location in the watershed, (3) selecting of the draft recommended methods, (4) performing interal and external technical reviews of the hydrologic analyses and the draft recommendations, and finally, (5) finalizing the study recommendations. Based on the analyses presented above, USGS StreamStats is likely a sufficient tool to use for evaluation of peak streamflows within the White River basin in Arkansas and Missouri. USGS StreamStats uses regression equations developed from many streamflow gaging stations across the region, fulfilling the need to trade space for time as it applies to estimation of flood frequency quantiles. If the responsible party has the means, it is beneficial to evaluate regional GEV distributions for varying AMS using surrounding precipitation gages which have data from that represents recent decades. This provides a means of evaluating stochastic simulations for specific AEP precipitation depths within HEC-HMS so that values from USGS StreamStats can be validated or weighted with flood frequency quantiles resulting from precipitation frequency analyses. Use of more recent, high intensity storms and Variable Clark Transforms is recommended to use for base hyetographs for stochastic simulations of precipitation frequency events. For locations on the White River downstream of USGS 07057370, White River near Norfork, AR, it is appropriate to use AMS of peak streamflow data, so long as sufficient record length can be produced. The same is true for location on the Black River below Corning, AR, where USGS StreamStats does not apply.

1 Study Background and Purpose

In 1968, Congress passed the National Flood Insurance Act to correct some of the shortcomings of the traditional flood control and flood relief programs. The NFIP was created to:

- Transfer the costs of private property flood losses to the property owners through flood insurance premiums.
- Provide property owners with financial assistance after floods that do not warrant federal disaster aid.
- Guide development away from flood hazard areas.
- Require that new construction be built in ways that would minimize or prevent damage during a flood.

The NFIP program is administered by FEMA within the Department of Homeland Security. The NFIP is charged with determination of the 1% annual chance flood risk and with mapping that flood risk on the Flood Insurance Rate Maps (FIRMs). FEMA Region VI has an inventory of hundreds of thousands of river miles that are in need of flood risk mapping updates or validation. FEMA has historically maintained the FIRMs at a community and county level, but recently shifted (2010) to analyzing flood analysis at a watershed level. This transition to watershed-based analysis requires a broader flood risk assessment than has historically been undertaken. Early in 2015, the Water Resources Branch of the USACE Fort Worth District began talking with FEMA Region VI representatives about ways that USACE's new basin-wide models could be leveraged in FEMA's flood risk mapping program.

In 2013, USACE established a program, known as Corps Water Management System (CWMS), to develop a comprehensive suite of models for every basin across the United States which contains a USACE asset. This modeling represents in excess of a $125 million dollar investment and provides the tools necessary to perform flood risk assessments at a larger watershed scale. Representatives of FEMA Region VI attended the CWMS implementation handoff meetings for the some of the basins. Subsequent discussions resulted in an interagency partnership between FEMA Region VI and USACE to produce basin-wide hydrology from these models for FEMA flood risk mapping. Additionally, USACE, the NWS and the USGS have conducted numerous hydrologic studies across Region VI, at the watershed and local scales, which can be leveraged for watershed scale flood risk assessments.

The objective of this interagency flood risk program is to establish consistent flood risk hydrology estimates across large river basins. These watershed assessments will examine the hydrology across the entire basin, reviewing non-stationary influences such as regulation and land use changes, to ensure all variables affecting flood risk in the watersheds are considered. The studies' scope includes a multi-layered analysis with the purpose of producing flood frequency discharges that are consistent and defendable across a given basin. The multi-layered analysis will employ a range of hydrologic methods (e.g. numerical modeling, statistical hydrology, etc.) to examine all available data affecting the hydrologic processes within the watersheds. The product of these basin-wide hydrology studies will be a hydrology report for use as a reference to evaluate against existing studies and also to support new local studies. These watershed hydrology assessments will also provide a tool set for use on local studies to provide the additional detail necessary to develop frequency flows at a smaller scale.

The basin-wide hydrology study for the White River Basin is being conducted for FEMA Region VI by the InFRM team which includes representatives from USACE, USGS, and NWS. The scope of this basin-wide hydrology study includes a multi-layered analysis with the purpose of producing flood frequency estimates that are consistent and defendable across the basin.

This report summarizes the hydrologic analyses that were completed to estimate frequency peak stream flows for reaches throughout the White River Basin. The results of all hydrologic analyses and the recommended frequency discharges are summarized herein.

1.1 Study Team Members

The following table lists the primary InFRM team members who participated in the development of the White River Basin Watershed Hydrology Assessment. Edmund Howe, Chief of Hydraulics and Hydrology from from USACE Little Rock District, served as the team lead for this study. In addition to those listed, the InFRM team would also like to acknowledge the many others who served supervisory and support roles during this study.

Table 1-1. Study Team Members

	Name	Agency	Office
1	Mike Biggs	Corps of Engineers	Little Rock
2	John Bourdeau, Jr.	FEMA	Region 6
3	Brian Breaker	Corps of Engineers	Little Rock
4	Brittany Bush	FEMA	Region 6
5	Holly Enlow	Corps of Engineers	Mississippi Valley
6	Kevin Fagot	Corps of Engineers	Little Rock
7	Nick Fang	University of Texas	Arlington
8	Rheannon Hart	Corps of Engineers	Little Rock
9	David Heimann	USGS	Central Midwest Water Science Center
10	Diane Howe	Corps of Engineers	Little Rock
11	Edmund Howe	Corps of Engineers	Little Rock
12	Gabe Knight	Corps of Engineers	Little Rock
13	Forrest Kolle	Corps of Engineers	Little Rock
14	James Lamport	Corps of Engineers	Mississippi Valley
15	Kathryn Martin	Corps of Engineers	Little Rock
16	Whitney Montague	State of Arkansas	Arkansas
17	Helena Mosser	Corps of Engineers	Fort Worth
18	Jennifer Short	Corps of Engineers	Little Rock
19	Maxwell Strickler	Corps of Engineers	Fort Worth
20	Daniel Wagner	USGS	Lower Mississippi – Gulf Water Science Center
21	Ronald Wanhanen	FEMA	Region 6
22	Christy Weiser	FEMA	Region 6

1.2 Technical Review Process

The InFRM Hydrology Assessments undergo a rigorous review process. Numerous peer reviews are performed by InFRM team members throughout the study. Each model, analysis, and technical product is peer reviewed as it is developed by an InFRM Subject Matter Expert (SME). Any technical issues that are discovered during the review process are thoroughly discussed and resolved, often with input from multiple team members. This same review process is also applied to the process of comparing and selecting final results. The draft results are shared with the rest of the InFRM team, and input is solicited from multiple subject matter experts. The draft study recommendations are then documented in the draft report.

The InFRM Academic Council also reviewed the methods and results of the InFRM White River Hydrology Assessment. The InFRM Academic Council is comprised of a select group of professors from local universities with unique skillsets, resources, and regional expertise in water resources and hydrology. Their involvement provides an independent and unbiased review of the InFRM team's methods and results. Collaboration with the InFRM Academic Council also helps the InFRM team to stay abreast with the latest advances in hydrologic science and technology. The primary InFRM Academic Council reviewer for the White River Hydrology Assessment was Dr. Nick Fang from the University of Texas at Arlington.

2 White River Basin

2.1 Watershed and River System Description

The White River Basin contains 27,818 square miles with about 38 percent of the drainage area in Missouri and 62 percent in Arkansas. The fan-shaped basin is about 250 miles long in a northerly direction and varies in width from 210 miles near the Missouri-Arkansas State line to about 50 miles near the mouth of the river. Approximately three-fourths of the basin is in the Ozark highlands where the topography consists of rough dissected plateaus, rugged hills, and rolling woodland. The eastern escarpment of the Ozark Mountains extends southwestward across the basin from the vicinity of Poplar Bluff, Missouri; along the west side of the Black River to Batesville, Arkansas, on the White River; and to the vicinity of Searcy, Arkansas, in the Little Red River Basin. East of the escarpment, the basin lies in the flat terrain of the Gulf Coastal Plain. The eastern watershed divide between the White and St. Francis Rivers is formed by Crowleys Ridge, which extends in a north-south direction and rises about 150 feet above the flood plain. A map of the basin is shown Figure 2-1.

Figure 2-1. White River Basin

The White River rises in the Boston Mountains southeast of Fayetteville, AR at an elevation of approximately 2,100 feet National Geodetic Vertical Datum of 1929 (NGVD29) and flows northeast. The upper reaches of the White River from the headwaters to Beaver Dam is characterized by steep slopes ranging from 8.5 feet per mile on War Eagle Creek to 14.4 feet per mile on the White River upstream of Fayetteville, AR. Beaver Dam is located at river mile 609.0 and controls the upper 1,186 square miles of the watershed. The river reach from Beaver Dam to Table Rock Dam is approximately 80 river miles (river mile 609 to river mile 528.8). The area surrounding Table Rock Lake in Missouri is part of the Mark

Twain National Forest. The upper reaches of the tributaries in this reach of the White River are generally steep similar to those above Beaver Dam and cause flashy runoff patterns in response to rainfall events. Downstream of Table Rock Dam to Bull Shoals Dam is approximately 110 river miles in length. The river channel downstream of Table Rock Dam to the head water of Bull Shoals Lake is occupied by Lake Taneycomo which extends from Ozark Beach Dam (also known as Powersite Dam) upstream to within about 1-1/2 miles of Table Rock Dam. The White River continues downstream of Bull Shoals Dam to ultimately confluence with the Mississippi River approximately 10 miles north of Rosedale, Mississippi.

The White River Basin has several major tributaries between the headwaters and Beaver Dam including the West Fork of the White River and War Eagle Creek. Between Beaver Dam and Table Rock Dam the major tributaries are Kings River and Long Creek from the south (river miles 572.4 and 529.0 respectively) and the James River (river mile 549.8) from the north.

Between Table Rock Dam and Bull Shoals Dam, Powersite Dam forms Lake Taneycomo. The combination of high bluffs on one bank and flood plain on the other typifies the river valley in this reach. The area around Branson continues to develop as a resort community featuring fishing, water sports, camping, and other activities that continue to encroach on the flood plain around Lake Taneycomo. Just downstream of Powersite Dam, the river turns toward the south and east and re-enters Arkansas in Bull Shoals Lake.

Between Bull Shoals Dam and Batesville, Arkansas, the Buffalo River and the North Fork River enter the main stem of the White River. The entire Buffalo River is uncontrolled. The North Fork River is controlled by Norfork Dam.

From Batesville, Arkansas, to Newport, Arkansas, the White River leaves the Ozark hills and enters the alluvial valley. Just above Newport, the Black River enters the White River and almost doubles the contributing drainage area.

At Newport, Arkansas, the White River turns and flows south towards Georgetown, Arkansas. The major tributary in this reach is the Little Red River. Approximately 60 percent of the Little Red River's watershed is controlled by Greers Ferry Dam.

From Georgetown, Arkansas to Clarendon, Arkansas, the White River extends further south into the Gulf Coastal Plain. In this reach, the flood plain is typically very flat and wide. Flood waters tend to inundate large areas and are very slow to recede.

From Clarendon, Arkansas, to the mouth, the White River and its tributaries have a wide, flat floodplain that allows flood waters to inundate larger areas. The first 9.8 miles of the White River serves as the link that connects the McClellan-Kerr Arkansas River Navigation System and the Mississippi River. A navigation canal connects the White River Entrance Channel to the Arkansas River.

Serious flooding in the White River Basin can result from short intense storms over concentrated portions of the basin and from extended periods of heavy precipitation over major portions of the basin. Although most serious floods occur during the spring, basin flooding can and has occurred throughout the year.

2.2 Major Floods in the Basin

Within the White River basin, recent decades have seen the largest flood events which have occurred since the completion of the flood risk management structures existing within the basin. Table 2-1 lists the record elevations, inflows, and releases for Beaver Lake, Table Rock Lake, Bull Shoals Lake, Norfork Lake, and Greers Ferry Lake. These flood events are described in greater detail below and times associated with descriptions in headers in the following paragraphs are referenced to when peak inflows occurred along the main stem of the White River.

Table 2-1. Table showing some of the largest recent events in the White River basin

Maximum Elevation (ft NGVD29)				
	April / May 2008	April / May 2011	December 2015 / January 2016	April / May 2017
Beaver Lake	1,132.21	1,131.62	1,132.04	1,131.25
Table Rock Lake	933.25	935.47	933.22	934.53
Bull Shoals Lake	695.03	696.52	692.66	692.86
Norfork Lake	581.84	580.95	572.06	579.97
Greers Ferry Lake	486.16	481.41	474.82	470.91
Maximum Daily Mean Inflow (ft^3/s)				
	April / May 2008	April / May 2011	December 2015 / January 2016	April / May 2017
Beaver Lake	83,200	114,900	110,500	65,800
Table Rock Lake	189,500	220,300	269,400	235,500
Bull Shoals Lake	125,500	230,000	176,600	180,600
Norfork Lake	100,700	111,700	115,700	211,400
Greers Ferry Lake	110,600	76,300	98,100	57,900
Maximum Release (ft^3/s)				
	April / May 2008	April / May 2011	December 2015 / January 2016	April / May 2017
Beaver Lake	93,010	70,800	92,300	56,500
Table Rock Lake	48,800	69,600	72,951	63,900
Bull Shoals Lake	35,200	58,729	30,400	14,500
Norfork Lake	81,884	37,100	9,200	52,700
Greers Ferry Lake	7,000	7,000	8,600	7,000
Maximum Flow (ft^3/s)				
	April / May 2008	April / May 2011	December 2015 / January 2016	April / May 2017
Newport	266,000	292,000	221,000	253,000

2.2.1 April / May 2008 Event

Significant rainfall occurred across Little Rock District's watersheds beginning in early March 2008. The greatest rainfall totals fell across much of western, northern, and portions of central Arkansas and the southern one third of Missouri. As reported by the National Weather Service, some areas received six-month rainfall amounts in a six-week period from 01 March 2008 to 12 April 2008. A late season snowfall that occurred on 05-06 March 2008 created saturated basin conditions leading to a high percentage of runoff occurring on subsequent rainfall events. Average basin rainfall amounts for the White River were above normal by 1.5, 7.8, and 4.1 inches in February, March, and April, respectively. Norfork Lake basin rainfall was 10.8 inches above normal in March.

The rainfall events especially targeted the upper White River and upper Black River basins. The five major reservoirs comprising the White River System – Beaver, Table Rock, Bull Shoals, Norfork, and Greers Ferry – established new pools of record during a 5-day period from 10 to 15 April 2008. Spillway releases were required at Beaver, Table Rock, Bull Shoals, and Norfork Dams. Clearwater Lake, in the upper Black River, received heavy rainfall pushing the lake level to near its spillway crest. Beaver Lake crested at elevation 1132.2 ft with a maximum release of 92,400 cfs. Table Rock Lake crested at elevation 933.2 ft with a maximum release of 48,300 cfs. Bull Shoals Lake crested at elevation 695.0 ft with a maximum release of 35,500 cfs. Norfork Lake crested at elevation 581.8 ft with a maximum release of 81,700 cfs. Greers Ferry Lake crested at elevation 486.2 ft with a maximum release of 7,000 cfs (no spillway discharge needed at Greers Ferry during this event).

In mid-March, the highest experienced stage of this event reached 33.9 ft at Newport. Without the reservoirs, it was computed that the natural stage would have been 37.1 ft, giving a reduction of 3.2 ft due to operation of the reservoirs.

According to local emergency management officials, below Beaver Dam, 25 homes we reported to have received flood damage, mainly in the reach near the U.S. Highway 62 bridge. The approaches to Arkansas Highway 187 bridge at Beaver were inundated, closing the road. Below Table Rock Dam, Missouri State Emergency Management Agency reported about 125 homes were adversely impacted due to high spillway releases and localized flooding of creeks. Downstream from Bull Shoals and Norfork Dams, many homes, businesses, and extensive acres of farmland were flooded. The Arkansas Department of Emergency Management reported 232 homes flooded along the main stem White River below Bull Shoals and Norfork Dams and 224 homes flooded along the White and/or Black Rivers near their confluence at Jacksonport that could not be attributed exclusively to either river. Extensive areas of agricultural lands were flooded from Newport to Augusta to Georgetown. The town of Georgetown was isolated for about a month as backwater inundated sections of Arkansas Highway 36 southeast of Searcy near West Point.

2.2.2 April / May 2011 Event

Rainfall during a five-week period in April and May 2011 caused widespread flooding along the White, Arkansas, and Black Rivers as well as many of their tributaries. Moderate rainfall occurred over the White River basin on 21 April with extreme amounts falling between 24 and 26 April. A second rainfall event occurred 20 to 29 May. The basins experienced rainfall that ranged from 200% to 425% of the average for April and 170% to 190% of the average for May. The stage at Newport peaked at 34.17 ft on 04 May. The natural stage was computed to be more than 40 ft. Reducing the stage by about six to seven feet reduced or prevented levee overtoppings from Newport to Clarendon.

Prior to the April and May rainfall, basin rainfall during February and March was near average and pool levels gradually rose as conservation storage was being replenished. With the large events that occurred in April and May, average basin rainfall amounts were from 5.65 to 14.04 inches above normal in April and 3.51 to 5.23 inches above normal for May. It was observed that the 72-hour rainfall occurring from

24 to 26 April had greater than a 1% annual chance of exceedance for Beaver, Table Rock, Bull Shoals, and Norfork basins. The 7-day rainfall event occurring over 21 to 28 April exceeded a 2% annual chance of exceedance for basin average rainfall on Beaver, Table Rock, Bull Shoals, and Norfork.

As a result of these extreme rainfall events, the five White River lakes experienced major rises in lake levels. Clearwater Lake, in the Black River system, also experienced a major rise. Beaver Lake crested at elevation 1131.76 feet with a maximum release of 52,400 cfs. Table Rock experienced a new period of record elevation of 935.47 feet on 27 April, and a new record release of 69,030 cfs. After the late May rainfall, Bull Shoals reach a new period of record pool elevation of 696.52 feet on 27 May, and a new record discharge of 58,775 cfs. Norfork Lake crested at elevation 579.4 feet with a maximum release of 30,081 cfs. Greers Ferry Lake crested at elevation 481.41 feet. With a surcharge operation not needed at Greers Ferry Lake, the maximum release was 6,476 cfs.

According to local emergency management officials, homes and property downstream from Beaver Dam were flooded by the large spillway discharges required from the 21-28 April rainfall. About three homes were reported to have received flood damage, mainly in the reach just upstream the US Highway 62 Bridge. The approaches to Arkansas Highway 187 Bridge at Beaver were inundated, closing the road. Below Table Rock Dam, Missouri State Emergency Management Agency reported about 125 homes were adversely impacted due to high localized flooding of Turkey Creek and Bull Creeks and large spillway releases. Downstream of Bull Shoals and Norfork Dams, many homes, businesses, and extensive acres of farmland were flooded. The Arkansas Department of Emergency Management reported 232 homes flooded along the main stem White River below Bull Shoals and Norfork Dams and 224 homes flooded along the White and Black Rivers near their confluence at Jacksonport that could not be attributed exclusively to either river. Extensive areas of agricultural lands were flooded from Newport to Augusta to Georgetown to Des Arc. The town of Georgetown was isolated for several weeks as backwater inundated sections of Arkansas Highway 36 southeast of Searcy near West Point. The town of Des Arc reported flooding of streets. Further downstream, homes and cabins were flooded near Clarendon and Lawrenceville.

2.2.3 June 2015 Event

Over the White River basin, heavy rainfall occurred from 07 to 10 May, 2015. Heavy rain fell again on the 25 and 26 May. Above normal rainfall continued into June and July over the White River basin. The 4-lake sub-system of Table Rock, Bull Shoals, Beaver, and Norfork reached a peak of 83% of flood storage in use during this event.

In May 2015, Beaver Lake crested at 1129.51 feet (.49 feet from top of flood pool). Beaver Lake experience a slightly higher crest in June 2015 at 1129.95 feet (.05 feet from top of flood pool). The maximum average daily release for Beaver in June 2015 was 15,216 cfs. In July 2015, Beaver crested at 1129.99 feet (.01 feet from top of flood pool) with a maximum release of 15,220 cfs.

In June 2015, Table Rock Lake experienced a peak pool elevation of 922.83 feet with a maximum daily average release of 21,650 cfs. In July 2015, Table Rock crested at 927.73 feet

Due to downstream flows being above regulating stage, the pool elevation at Bull Shoals rose steadily through the month of May and June. The maximum daily release for May and June was generally limited to firm power and minimum flow resulting in a pool elevation of 673.91 feet at the end of May and a pool elevation of 683.91 feet at the end of June. As Bull Shoals rose above 684.0 feet on 02 July, the releases from Table Rock became limited as the balancing requirement between Bull Shoals and Table Rock became initiated. Bull Shoals Lake peaked at elevation 692.66 feet in July 2015.

As with Bull Shoals Dam, Norfork Dam releases were also limited due to downstream conditions. In July 2015, Norfork Lake peaked at 572.06 feet.

Greers Ferry Lake peaked in early June 2015 at 474.08 feet and fell steadily through the remainder of June and in July.

According to local officials, the largest monetary damages were related to crop losses as the primary and secondary rise on the White and Black Rivers ruined the first and second plantings of many crops. Crop diversity was also impacted. Early plantings of rice and corn had to be followed by late in the season plantings of soybeans. Some fields were planted as many as three times in an attempt to make a crop of some kind. Some crops were also planted later in the season than normally viable. Agricultural damages within the State of Arkansas for the 2015 growing season were estimated by the University of Arkansas to be greater than 50 million dollars.

2.2.4 December 2015 / January 2016 Event

Immediately following the emptying of the reservoirs from the spring and summer 2015 inflow events, the White River reservoirs were again hit with another flood event. Starting in mid-November, waves of heavy rain began passing through the district about every two weeks with this pattern holding into January 2016.

This event resulted in the highest daily average inflow of record (269,224 cfs) and highest release of record (72,975 cfs; based on hourly data) at Table Rock in December, 2015. It was also the second highest daily average inflow of record (110,432 cfs) and the second highest release of record (92,363 cfs; based on hourly data) at Beaver Lake in December, 2015.

With the higher regulating stages at Newport being in effect during this time of year, re-capture of flood storage at Bull Shoals and Norfork was able to be performed more quickly than what typically occurs in the spring and summer months.

Flows in the uncontrolled area were very high during this event. The White River at Newport experienced the 17th highest crest of record and the 4th time to date it rose above 32 feet in the 21st century. According to local officials, flooding was widespread and homes were impacted along the White River from the mouth of the Buffalo River and all points downstream. Serious flooding also occurred on the Black River and tributaries and contributed to the crest of the White River from Newport, Arkansas and downstream. The Buffalo River at the stream gage on the U. S. Highway 65 bridge experienced the 5th highest crest of record and the 3rd time above 45 feet in the 21st century.

2.2.5 April / May 2017 Event

Rain events occurring on 20 to 21 April 2017 and 25 to 27 April 2017 lead to significant runoff in the White River basin and caused a saturated basin prior to forecasted heavy rainfall expected on 28 to 30 April. Initial projections indicated that the greatest impacts could occur at Beaver, Table Rock, Norfork, and Bull Shoals Lakes, but the heaviest precipitation occurred to the northeast with Clearwater Lake receiving a basin average of 10.1 inches of rainfall. This caused the auxiliary spillway at Clearwater Dam to be activated for the first time in the history of the project.

The four-lake system of Beaver, Table Rock, Bull Shoals, and Norfork peaked at 90.5% of flood storage capacity on May 22. Beaver, Table Rock, and Norfork Dams experienced surcharge operations. Table Rock Lake reached its second highest pool level in its period of record (second behind the 2011 event). The lead to the closure of the Kimberling City bridge (Missouri Highway 13) over the reservoir.

2.3 Previous Hydrology Studies

Existing HEC-HMS models were used for this study. The HEC-HMS models used in this study were initially developed for spillway adequacy studies of Bull Shoals Dam in 2013 and were subsequently imported for use in the Corps Water Management System (CWMS). HEC-HMS models existing for the White River watershed prior to 2013 used Snyder unit hydrograph transforms. In 2013, the existing Snyder unit hydrograph parameters were converted to Clark unit hydrograph parameters using HEC-1. Since the conversion of Snyder to Clark parameters, the models have undergone multiple calibrations. Operations within the system of reservoirs are evaluated using RiverWare™. The current state of the hydrologic models are discussed in Section 6 and the current state of the RiverWare™ models are discussed in Section 8.

2.4 Currently Effective FEMA Flows

Flow values from the FEMA flood insurance studies that are pertinent to this study are provided below. All counties in the White River basin were examined. Counties that had flow values pertinent to this study are as follows:

- Washington County, AR (2008)
- Baxter County, AR (2010)
- Taney County, MO (2012)
- Stone County, MO (2010)
- Greene County, MO (2010)
- Sharp County, AR (2011)
- Stone County, AR (1987)
- Independence County, AR (2012)
- Van Buren County, AR (1991)
- Shannon County, MO (1977)
- Ripley County, MO (2019)
- Butler County, MO (2010)
- Reynolds County, MO (1980)

- Jackson County, AR (2017)

There are 10 sites where a relatively direct comparison can be made between the USGS PeakFQ analysis and the FEMA Flood Insurance Study (FIS) values for the 1/100 AEP peak streamflows for these locations. In general, this data shows that the FEMA FIS values tend to be of a lower magnitude than the values computed from the PeakFQ analysis for this study for estimated 1/100 AEP peak streamflows (the peak streamflow that has a 1% chance of occurring in a given year). A FEMA FIS is a detailed examination of flood hazards in a community, analyzing historical data, hydrologic and hydraulic models, and topographic information to establish flood risk zones and support the development of Flood Insurance Rate Maps (FIRMs). The discrepancies in peak streamflow values may be because more recent data was used when evaluating peak streamflows for this study or because of updated regional skew coefficients and different methods for evaluating peak streamflow frequencies have become common practice since the FEMA FIS were performed.

Table 2-2. Summary of Comparison of USGS PeakFQ Analysis and FEMA FIS Flows

Site	Drainage area (sq mi)	Percent difference
West Fork White River east of Fayetteville, AR - 07048550	123	FEMA value 34% lower
Bull Creek near Walnut Shade, AR - 07053810	196	FEMA value 47% lower
James River near Springfield, MO - 07050700	245	FEMA value 16% lower
Spring River at Imboden, AR - 07069500	1,160	FEMA value 1% lower
Middle Fork Little Red River at Shirley, AR - 07075000	302	FEMA value 21% higher
South Fork Little Red River at Clinton, AR - 07075300	148	FEMA value 38% higher
Jacks Fork at Eminence, MO - 07066000	404	FEMA value 34% lower
Current River at Doniphan, MO - 07068000	2,050	FEMA value 7% lower
Little Black River below Fairdealing, MO - 07068510	194	FEMA value 64% lower
Logan Creek at Ellington, MO - 07061900	139	FEMA value 58% lower

2.4.1 Washington County, Arkansas and Incorporated Areas FIS – Revised May 16, 2008

Table 2-2. Washington County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Middle Fork of White River at confluence with White River	77	27,374			
			07048550 West Fork White River east of Fayetteville, AR	123	73,200
West Fork White River at mouth	122	48,000			
West Fork White River at Mile 13.3	83.1	40,900			
West Fork White River at downstream limits of detailed study	62.2	41,597			
			07048600 White River near Fayetteville, AR	399	108,000
White River downstream of confluence with Middle Fork White River	273	85,000			
White River upstream of confluence with Middle Fork White River	196	61,650			

2.4.2 Baxter County, Arkansas and Incorporated Areas FIS – Revised December 3, 2010

Table 2-3. Baxter County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
			07057300 Dodd Creek Tributary near Mountain Home, AR	0.743	1,060
Dodd Creek Tributary at confluence with Dodd Creek	2.1	7,650			
			07057500 North Fork River near Tecumseh, MO	562	108,000
North Fork River at confluence with White River	1,831	69,500			
White River at river mile 376.3 / downstream of confluence with North Fork River	9,885	295,000			
White River at river mile 397.0 / downstream of confluence with Jennings Creek	6,150	270,000			

2.4.3 Taney County, Missouri and Incorporated Areas FIS – Revised March 15, 2012

Table 2-4. Taney County, Missouri Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Bull Creek at State Highway F	191	32,371			
			07053810 Bull Creek near Walnut Shade, MO	196	61,700
White River approximately 33.8 miles downstream of East State Highway 76	5,264	183,000			
White River approximately 7.4 miles downstream of East State Highway 76	4,991	169,000			
White River approximately 800 feet upstream of East State Highway 76 at Forsyth	4,546	148,000			
White River approximately 4,400 feet upstream of Ozark Beach Dam	4,362	139,000			
White River approximately 200 feet upstream of Business U.S. Highway 65 at Branson	4,078	125,000			
White River approximately 5.7 miles upstream of the confluence with Cooper Creek	4,020	122,000			

2.4.4 Stone County, Missouri and Incorporated Areas FIS – May 20, 2010

Table 2-5. Stone County, Missouri Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Crane Creek below Missouri Pacific Railroad	56.6	17,600			
Crane Creek below Dodge Hollow	55.7	17,200			
Crane Creek above Dodge Hollow	42.4	14,000			
Crane Creek Northern Corporate Limit	41.4	13,700			
Dodge Hollow at confluence with Crane Creek	13.1	7,900			
			07052370 Dry Crane Creek near Crane, MO	11.5	6,280

2.4.5 Greene County, Missouri and Incorporated Areas FIS – December 17, 2010

Table 2-6. Greene County, Missouri Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
James River at Kinser Road	246	43,600			
			07050700 James River near Springfield, MO	245	52,100
			07052250 James River near Boaz, MO	458	65,200
			07052500 James River at Galena, MO	992	87,600

2.4.6 Sharp County, Arkansas and Incorporated Areas FIS – September 16, 2011

Table 2-7. Sharp County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Spring River at Imboden gage site	1,183	150,000			
Spring River above confluence with Forty Island Creek	877	111,000			
			07069500 Spring River at Imboden, AR	1,160	152,000

2.4.7 Stone County, Arkansas, Unincorporated Areas FIS – July 16, 1987

Table 2-8. Stone County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
White River at river mile 342.7	10,238	354,500			
South Sylamore Creek at its confluence with the White River	206.37	91,522			
			07060710 North Sylamore Creek near Fifty Six, AR	58.7	33,100

2.4.8 Independence County, Arkansas, Incorporated Areas FIS – March 15, 2012

Table 2-9. Independence County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
White River at Independence / Jackson County boundary	19,812	388,000			
White River at Batesville corporate limits	11,064	254,000			

2.4.9 Van Buren County, Arkansas, Unincorporated Areas FIS – August 19, 1991 and City of Clinton, Arkansas, Van Buren County FIS – November 6, 1991

Table 2-10. Van Buren County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
South Fork Little Red River at U.S. Route 65	148	61,700			
			07075300 South Fork of Little Red River at Clinton, AR	148	44,700
Middle Fork Little Red River at State Route 9	294	132,500			
			07075000 Middle Fork of Little Red River at Shirley, AR	302	109,000

2.4.10 City of Eminence, Missouri, Shannon County FIS – July 1977

Table 2-11. Shannon County, Missouri Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Jacks Fork River (from Figure 2 in FIS with a drainage area of 400 sq miles)	400	54,000			
			07065495 Jacks Fork at Alley Spring, MO (note: data from 1993 to present with 28 values shown on USGS site)	304	92,900
			07066000 Jacks Fork at Eminence, MO (note: data from 1895 to present with 102 values shown on USGS site)	404	81,300

2.4.11 Ripley County, Missouri and Incorporated Areas – November 1, 2019

Table 2-12. Ripley County, Missouri Effective FEMA Flows

FEMA flows				USGS flows		
Location	Drainage area (sq miles)	FEMA flow 1%	FEMA flow 1% +	Location	Drainage area (sq miles)	USGS flow
Current River at downstream limit of study	1,792	133,520	159,780			
Current River at Doniphan, MO	2,038	135,480	162,780			
				07066500 Current River near Eminence, MO	1,280	138,000
				07067000 Current River at Van Buren, MO	1,670	156,000
				07068000 Current River at Doniphan, MO	2,050	146,000

2.4.12 Butler County, Missouri and Incorporated Areas – November 26, 2010

Table 2-13. Butler County, Missouri Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Black River (Poplar Bluff Gage at U.S. Highway 60)	1,245	12,200			
			07061500 Black River near Annapolis, MO	492	100,000
Little Black River at County Highway 160	185	23,578			
			07068510 Little Black River below Fairdealing, MO	194	65,300

2.4.13 City of Ellington, Missouri, Reynolds County – July 16, 1980

Table 2-14. Reynolds County, Missouri Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Logan Creek at State Highway 21	146	28,200			
Logan Creek at Main Street	108	23,900			
			07061900 Logan Creek at Ellington, MO	139	67,400

2.4.14 Lawrence County, Arkansas and Incorporated Areas – December 18, 2012

Table 2-15. Lawrence County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
Spring River at U.S. Route 62	1,183	150,000			
Spring River at U.S. Route 62/63	1,061	135,000			
			USGS 07069500 Spring River at Imboden, AR	1,160	152,000

2.4.15 Jackson County, Arkansas and Incorporated Areas – June 7, 2017

Table 2-16. Jackson County, Arkansas Effective FEMA Flows

FEMA flows			USGS flows		
Location	Drainage area (sq miles)	FEMA flow	Location	Drainage area (sq miles)	USGS flow
White River at U.S. Highway 67	19,812	388,000			
White River at River Mile 246.2	19,812	388,000			

2.4.16 Other Counties

FEMA data from the following counties was examined and found not to contain information that was pertinent to this study. Flood insurance studies (FIS) in these counties are also shown below.

- Benton County, AR:
  - Benton County, Arkansas and Incorporated Areas, Volume 1 of 2, Effective 05Jun2012
  - Benton County, Arkansas and Incorporated Areas, Volume 2 of 2, Effective 05Jun2012
- Madison County, AR:
  - No flood insurance studies available.
- Carroll County, AR:
  - Carroll County, Arkansas and Incorporated Areas, Effective 17Mar2011
- Boone County, AR:
  - Boone County, Arkansas and Incorporated Areas, Effective 26Nov2010
- Newton County, AR
  - No flood insurance studies available
- Marion County, AR
  - No flood insurance studies available
- Searcy County, AR
  - No flood insurance studies available
- Ozark County, MO
  - Ozark County, Missouri and Incorporated Areas, Effective 28Sep2007
- Barry County, MO
  - Barry County, Missouri and Incorporated Areas, Effective 16Aug2006
- Douglas County, MO
  - City of Ava, Missouri, Douglas County, Effective 04Aug1988
- Howell County, MO
  - Howell County, Missouri and Incorporated Areas, Revised 07Apr2021
- Fulton County, AR
  - City of Mammoth Spring, Arkansas, Fulton County, Effective March 1980
- Izard County, AR
  - City of Calico Rock, Arkansas, Izard County, Effective June 1979
- Cleburne County, AR
  - Cleburne County, Arkansas and Incorporated Areas, Effective February 16, 2006
- Oregon County, MO
  - No flood insurance studies available
- Carter County, MO
  - No flood insurance studies available
- Iron County, MO
  - Iron County, Missouri and Incorporated Areas, Effective February 16, 2006
- Dent County, MO
  - Dent County, Missouri and Incorporated Areas, Effective September 18, 2020
- Texas County, MO

- City of Cabool, Missouri, Texas County, Effective February 1978
- City of Houston, Missouri, Texas County, Effective January 1977

- Webster County, MO
  - No flood insurance studies available
- Wayne County, MO
  - Wayne County, Missouri and Incorporated Areas, Effective June 16, 2011
- Randolph County, AR
  - Randolph County, Arkansas and Incorporated Areas, Effective May 2, 2012
- Clay County, AR
  - Clay County, Arkansas and Incorporated Areas, Effective August 3, 2016
- Greene County, AR
  - Greene County, Arkansas and Incorporated Areas, Revised May 16, 2013
- Craighead County, AR
  - Craighead County, Arkansas and Incorporated Areas, Effective September 27, 1991
- Poinsett County, AR
  - Poinsett County, Arkansas and Incorporated Areas, Effective February 4, 2011
- White County, AR
  - White County, Arkansas and Incorporated Areas, Effective May 2, 2012
- Woodruff County, AR
  - No flood insurance studies available

3 Methodology

The methodology that was used for this basin-wide hydrology study was a multi-layered analysis that calculated frequency flows in the White River Basin through several different methods and compared their results to each other before making final flow recommendations. The purpose of this analysis is to produce a set of frequency flows that are consistent and defendable across the basin.

The current study builds upon the information that was available from the previous hydrology studies by combining detailed data from different models, updating land use data, calibrating the models to multiple recent flood events, and updating statistical analyses to include the most recent flood events.

The multi-layered analysis for the current study of the basin consists of several main components: (1) statistical analysis of the stream gages and update of skew coefficient for the White River basin, (2) rainfall-runoff watershed modeling in the Hydraulic Engineering Center's Hydrologic Modeling System (HEC-HMS), (3) extended period-of-record modeling in RiverWare and other statistical means, and (4) a reservoir study of 5 USACE reservoirs. After completing all these different types of analyses, their results were then compared to each other and to the existing published frequency flows within the basin. Frequency flow recommendations were then made after consideration of all the known hydrologic information. Specific methods for components listed above are found in Chapter 4 through 10.

4 Data Collection

A variety of data was used for this study, including spatial and time-series data. Many sources are used to obtain this data, and many tools were used to process this data for different models and analyses. Most of the data sources and methods of data collection and analysis are described below.

4.1 Spatial Tools and Reference

ArcGIS version 10.2.2 (developed by the Environmental Systems Research Institute, Inc. (ESRI)), together with ArcHydro version 10.2 and HEC-River Analysis System extension (GeoRAS) version 10.2 were used to process and analyze the data necessary for hydraulic modeling.

Standard CWMS projection parameters used for this study are:

- Horizontal Datum: North American Datum 1983 (NAD 83)
- Projection: United States Contiguous Albers Equal Area Conic U.S. Geological Study (USGS) version
- Vertical Datum: North American Vertical Datum, 1988 (NAVD 88)

Linear units: U.S. feet.

4.2 Digital Elevation Model (DEM)

The USACE SWL Water Management team obtained 10-meter digital elevation models (DEMs) from the seamless USGS National Elevation Dataset (NED), accessed January 2016, for the White River watershed. The elevations of the NED are in meters. The vertical elevation units were converted from meters to feet and the dataset projected into the USACE Mapping, Modeling, and Consequences (MMC) standard map projection. The absolute vertical accuracy expressed as root mean square error is 2.15 feet. In addition, where necessary, high-resolution LiDAR was also processed into the MMC standard projection and utilized for hydraulic modeling.

4.3 Vector and Raster Geospatial Data

The CWMS mapping team utilized web mapping services and downloaded the NRCS hydrologic unit boundaries, soils, National Inventory of Dams (NID) dam locations, National Levee Database (NLD) levee centerlines as well as general base map layers. Additional vector data were obtained from the ESRI database and used in figures prepared for the final report. Raster data includes the National Land Cover Database 2011 land cover layer and the National Land Cover Database 2013 percent imperviousness layer from the http://www.mrlc.gov/ website accessed January 2016. ArcGIS version 10.2.2 (ESRI), with ArcHydro and HEC-GeoHMS version 10.2 were used to process and analyze the data necessary for hydrologic modeling and to generate the sub-basin boundaries.

4.4 Aerial Images

The CWMS mapping team utilized the ESRI Online World Imagery Basemap Services to verify the White River watershed boundaries as well as to delineate centerlines and other geographic features such as bank locations. In addition, Google Earth Pro was also used to locate important geographic features.

4.5 Soil Data

Soil hydrologic groups are important for determining hydrologic properties of soils. The USDA SSURGO data for the White River subbasins were used to determine ranges of initial rainfall constant loss rate parameters for the HEC-HMS model. Loss rates were calibrated based on observed events.

4.6 Precipitation Data

For the HEC-HMS model calibration for producing peak streamflow frequencies from precipitation data, precipitation data were obtained from National Oceanic and Atmospheric Administration (NOAA) Level 4 weather radar products collected from Next-Generation Radar (NEXRAD) precipitation data in netCDF format and converted to SHG GIS format (2 km grid cells) for storage and usage in HEC-DSS. The real-time Level 3 radar products received for forecasting for the White River watershed tended to underestimate rainfall. This general underestimation has been noted throughout multiple real-time events as well as various hydrologic studies. In hydrologic studies, the physical parameters in the hydrologic models had to be adjusted outside a normal range in order to gain a reasonable flow response. The use of Level 4 precipitation products allowed for more reasonable hydrologic parameterization. A detailed assessment of the differences between the Level 3 and Level 4 products was not completed and was considered outside the scope of this study. There are many studies evaluating the Level 4 product. Not all River Forecast Centers (RFC) generate precipitation with the same algorithms nor apply the same procedures to obtain the Level 4 product (Nelson, 2016). The Level 4 product is not convenient for real-time operations as the data processing lags approximately 24 hours behind the Level 3 product typically used.

The Livneh et al. (2015) hydrometeorological dataset was used to extend periods of record of streamflow back in time to represent longer periods of regulated streamflows for estimating current peak flow frequency quantiles.

4.7 Stream Flow Data

USGS streamflow data is used for calibrating the HEC-HMS models. Streamflow data is used to help validate and refine the model's performance. By comparing simulated streamflow outputs with observed USGS streamgage data at specific locations, adjustments are made to model parameters such as infiltration rates, runoff coefficients, and unit hydrographs to minimize discrepancies between modeled and observed flows. This calibration process ensures that the HEC-HMS model accurately represents watershed hydrology under various hydrometeorological conditions, improving its reliability for flood forecasting, water resource management, and infrastructure design. USGS streamgage locations are shown in and listed in.

Table 4-1. USGS Stations used for calibration of HEC-HMS models

USGS Station Number	USGS Station Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage Area (mi^2)
07050152	Roaring River at Roaring River State Park	36.5809722	-93.8336944	35.7
07052820	Flat Creek below Jenkins, MO	36.75075	-93.6187778	274
07052500	James River at Galena, MO	36.80538889	-93.4615833	987
07052152	Wilson Creek near Brookline, MO	37.14713889	-93.3754722	51
07052250	James River near Boaz, MO	37.0065833	-93.3646667	462

USGS Station Number	USGS Station Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage Area (mi^2)
07052345	Finley Creek below Riverdale, MO	36.97488889	-93.3278889	261
07053810	Bull Creek near Walnut Shade, MO	36.71775	-93.2068056	191
07050700	James River near Springfield, MO	37.1499722	-93.2033889	246
07054080	Beaver Creek at Bradleyville, MO	36.77963889	-92.9072778	298
07058000	Bryant Creek near Tecumseh, MO	36.6272222	-92.3060556	570
07057500	North Fork River near Tecumseh, MO	36.62302778	-92.2481389	561
07048550	West Fork White River east of Fayetteville, AR	36.05388889	-94.0830556	123
07048600	White River near Fayetteville, AR	36.07305556	-94.0811111	400
07047980	White River at Elkins, AR	36.0008333	-94.0036111	184
07048780	Richland Creek near Goshen, AR	36.04855556	-93.9742222	119
07049000	War Eagle Creek near Hindsville, AR	36.2	-93.855	263
07050500	Kings River near Berryville, AR	36.4272222	-93.6208333	527
07055646	Buffalo River near Boxley, AR	35.93888889	-93.405	57.4
07053250	Yocum Creek near Oak Grove, AR	36.45444444	-93.3561111	52.8
07055660	Buffalo River at Ponca, AR	36.0225	-93.3547222	116
07053207	Long Creek at Denver, AR	36.38944444	-93.3158333	104
07055680	Buffalo River at Pruitt, AR	36.05916667	-93.1377778	190
07055565	Crooked Creek at Harrison, AR	36.23257134	-93.0912871	72
07054410	Bear Creek near Omaha, AR	36.44944444	-93.075	133
07055875	Richland Creek near Witts Spring, AR	35.7972222	-92.9288889	67.4
07056000	Buffalo River near St. Joe, AR	35.98305556	-92.7472222	829
07056515	Bear Creek near Silver Hill, AR	35.94	-92.7133333	83.1
07055607	Crooked Creek at Kelly Crossing at Yellville, AR	36.23027778	-92.7094444	398
07056700	Buffalo River near Harriet, AR	36.06777778	-92.5775	1070
07075300	South Fork of Little Red River at Clinton, AR	35.58694444	-92.4513889	148
07057370	White River near Norfork, AR	36.2236111	-92.3	8040
07075000	Middle Fork of Little Red River at Shirley, AR	35.65666667	-92.2927778	302
07060710	North Sylamore Creek near Fifty Six, AR	35.99166667	-92.2138889	58.1

USGS Station Number	USGS Station Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage Area (mi^2)
07060500	White River at Calico Rock, AR	36.11666667	-92.1430556	9980
07058980	Bennetts River at Vidette, AR	36.42277778	-92.1183333	68.2
07060728	White River at Allison, AR	35.93916667	-92.1141667	10500
07059450	Big Creek near Elizabeth, AR	36.3575	-92.1125	51.9
07076530	Big Creek near Letona, AR	35.3619722	-91.8010278	72.6
07076517	Little Red River near Dewey, AR	35.43805556	-91.7458333	1340
07061000	White River at Batesville, AR	35.76027778	-91.6411111	11070
07076634	Little Red River at Judsonia, AR	35.2675	-91.6397222	1690
07076750	White River at Georgetown, AR	35.12888889	-91.4497222	22400
07074000	Strawberry River near Poughkeepsie, AR	36.1111111	-91.4494444	473
07077000	White River at DeValls Bluff, AR	34.79444444	-91.4447222	23400
07074850	White River near Augusta, AR	35.29444444	-91.3941667	20500
07074420	Black River at Elgin Ferry, AR	35.76555556	-91.3002778	8420
07074500	White River at Newport, AR	35.60527778	-91.2888889	19900
07072500	Black River at Black Rock, AR	36.1025	-91.0977778	7370
07061270	East Fork Black River near Lesterville, MO	37.55255556	-90.8424444	52.2
07061290	E. Fk. Black R. bl Lower Taum Sauk Reservoir	37.4936111	-90.8383333	87.3
07061500	Black River near Annapolis, MO	37.33813889	-90.78875	484
07061600	Black River below Annapolis, MO	37.32519444	-90.7646667	493
07061900	Logan Creek at Ellington, MO	37.2474722	-90.9654722	139
07062500	Black River at Leeper, MO	37.0587222	-90.687	987
07062575	Black River above Williamsville, MO	36.9725	-90.5969444	1007
07063000	Black River at Poplar Bluff, MO	36.75975	-90.3878333	1245
07064000	Black River near Corning, AR	36.40194444	-90.5413889	1750
07064440	Current River at Montauk State Park, MO	37.44791667	-91.6713611	58.8
07064533	Current River above Akers, MO	37.37569444	-91.5528056	295
07065200	Jacks Fork near Mountain View, MO	37.05652778	-91.6680278	185
07065495	Jacks Fork at Alley Spring, MO	37.14816667	-91.4430833	298
07066000	Jacks Fork at Eminence, MO	37.1540833	-91.3581667	398
07067000	Current River at Van Buren, MO	36.99138889	-91.0135	1667

USGS Station Number	USGS Station Name	Latitude (decimal degrees)	Longitude (decimal degrees)	Drainage Area (mi^2)
07068000	Current River at Doniphan, MO	36.6215	-90.8463889	2038
07068510	Little Black River below Fairdealing, MO	36.63152778	-90.5755833	194
07069000	Black River at Pocahontas, AR	36.25416667	-90.9702778	4840
07069295	South Fork Spring River at Saddle, AR	36.3522222	-91.6336111	265
07069305	Spring River at Spring Street Bridge at Hardy, AR	36.3136111	-91.4827778	845
07069500	Spring River at Imboden, AR	36.20555556	-91.1716667	1180
07071500	Eleven Point River near Bardley, MO	36.64869444	-91.2008333	793
07072000	Eleven Point River near Ravenden Springs, AR	36.34638889	-91.1141667	1130
07072500	Black River at Black Rock, AR	36.1025	-91.0977778	7370

Figure 4-1. Map showing USGS streamflow gaging stations used for HEC-HMS model calibrations and HEC-HMS basin model boundaries and subbasins

4.8 Reservoir Physical Data

4.8.1 Beaver Dam

Project structures include a concrete gravity dam with 7 Tainter gates flanked by concrete non-overflow sections, a powerhouse integral with the concrete dam, an earth-fill embankment, and 3 rim saddle embankments. The concrete gravity dam is 1,333 feet wide and the earth-file embankment extends the crest length to 2,575 feet. Dikes 1, 2, and 3 are located north of the main embankment with lengths of 840, 475, and 682 feet, respectively. Construction of Beaver Dam began in October 1959 and was completed in 1966. Construction of the powerhouse and switchyard began in 1963. The power generating units were on-line 2 years later, in May 1965: unit 1 began general power on May 14, 1965, and unit 2 began generating power on May 25, 1965.

4.8.2 Table Rock Dam

Project structures include a concrete gravity dam with 10 Tainter gates flanked by concrete non-overflow sections, a powerhouse integral with the concrete dam, a concrete auxiliary spillway structure with 8 Tainter gates, and earth-fill embankment sections abutting the concrete dam structures. The concrete gravity dam is 1,602 feet wide and the rolled earth fill embankment is 4,821 feet wide. Construction began in October 1952, the dam began filling in November 1958, and completed filling in May 1960. The dam was placed into operation on August 15, 1958. Construction of the first two generating units was started on January 31, 1957 and completed on June 5, 1959. Units three and four were installed starting on August 10, 1959 and completed on July 20, 1961.

The Corps completed construction of an auxiliary spillway in 2005 to provide additional release capacity for the safe operation of the dam during the most extreme rainfall events. The auxiliary gated spillway and embankment is located approximately 3,500 feet north of the existing dam. The auxiliary spillway was placed here because a natural draw occurs just upstream of the existing embankment at this location (former Moonshine Beach area) and because the existing embankment was shallower in this area, thereby reducing the construction cost. The auxiliary spillway includes a gated ogee spillway, earthen embankment, spillway bridge with roadway, and other features. Overall, the spillway is approximately 459 feet wide and provides a release capacity of 451,000 cfs. This increases the total spilling capacity of Table Rock Dam to about 1,009,000 cfs.

4.8.3 Bull Shoals Dam

Bull Shoals Dam is a concrete gravity structure with a crest length of 2,256 feet and a maximum height of 258.0 feet above the streambed. The top of the dam (elevation 708.0 feet) serves as a portion of Arkansas State Highway 178. The top of dam parapet wall is at elevation 711.08 feet. The right abutment includes a 508-foot bulkhead section at elevation 708.0 feet. Arkansas State Highway 178 crosses the bulkhead sections and dam. The overall crown of roadway width is approximately 26 feet. The left abutment, which includes the powerhouse facilities, is 940 feet in length. The hydropower facilities include four 40 megawatt (MW) power units (units 1 through 4) and four 45 MW units (units 5 through 8). The spillway is a gated ogee section with a gross length of 808 feet. The spillway includes 17 bays each 40 feet long, controlled by 28-foot-high Tainter gates.

In addition to the spillway gates, Bull Shoals has 16 gated flood-control conduits 4 feet by 9 feet in section. Each conduit has a capacity at the top of power pool (elevation 659.0 feet) of 3,500 cfs. Each conduit is controlled by two hydraulically operated slide gates designed to operate at full openings.

Construction on Bull Shoals began in April 1946 and filling of the reservoir began in July 1951. The first 2 of 4 initial hydropower units came online in September 1952 with the other two coming online in June 1953. Top of conservation pool was reached in March 1953. Hydropower units 5 and 6 came online in January and February of 1962. Hydropower units 7 and 8 came online in August and October of 1963.

4.8.4 Norfork Dam

Norfork Dam is a concrete gravity structure with a crest length of 2,624 feet and a maximum height of 216 feet above the streambed. The top of the dam (elevation 590.0 feet) serves as a portion of State Highway 177. The top of the dam parapet wall is at 593.2 feet. The right abutment includes a 1,796-foot bulkhead section at elevation 590.0 feet. Arkansas State Highway 177 crosses the bulkhead sections and dam. The overall crown of roadway width is approximately 42 feet. The right abutment also includes the powerhouse facilities which include two power units of 40.275 MW capacity each. The left abutment is 260 feet in length, and the operating tower is located on this side.

The spillway is a gated ogee section with a gross length of 568 feet. The spillway includes 12 bays each 40 feet long, controlled by 28-foot-high tainter gates. The crest elevation of the spillway is 552.0 feet, and the top of gates elevation in the fully closed position (and the top of flood control pool) is 580.0 feet. In addition to the spillway gates, Norfork Dam has 11 gated flood-control conduits 4 feet by 6 feet in section. Each conduit has a capacity at the top of power pool (elevation 553.75 feet) of 2,200 cfs. Each conduit is controlled by two hydraulically operated slide gates designed to operate at full openings.

A siphon system was installed at Norfork Dam in 2012 to provide an additional release to supplement house unit releases, hatchery releases, and leakage to meet a minimum flow of 300 cfs. The system is designed to be operated whenever hydropower generation is not underway. The siphon system includes a knife valve, cone valve, and a multi-level intake manifold consisting of a 42" steel pipe.

Construction on Norfork Dam began in October 1940 with filling beginning in June 1943. The top of conservation pool was reach in February 1945. The first hydropower unit came online in June 1944, and the second hydropower unit came online in February 1950. The siphon was completed in December 2012.

4.8.5 Greers Ferry Dam

Greers Ferry Dam is a concrete gravity structure with auxiliary earthen embankments (saddle dikes). The length of the main concrete dam is 1,704 feet with a maximum height of 243 feet above the streambed. The top of the dam is at elevation 503.0 feet and serves as a portion of Arkansas State Highway 5/25. The right abutment, which includes the powerhouse facilities consisting of two 48-megawatt (MW) power units, includes a 1,060-foot bulkhead section at elevation 503.0 feet. Arkansas State Highway 5/25 crosses the bulkhead sections and dam. The overall crown of the roadway has a width of approximately 26 feet. The left abutment is 364 feet in length. The saddle dikes are located west of the town of Heber Springs. Saddle Dike 1 is 4,500 feet in length and Saddle Dike 2 is 3,740 feet in length. Both saddle dikes have a crest elevation of 503.0 feet and a crest width of 20 feet.

The spillway is a gated ogee section with a net length of 240 feet and the crest is at elevation 453.0 feet. The spillway includes 6 bays each 40 feet wide, controlled by 36-foot-high Tainter gates. The elevation of the top of the gates in the fully closed position is 489.0 feet (top of flood pool is 487.0 feet). There is one gated conduit, 5 feet-8 inches wide by 10 feet high, with a discharge capacity of approximately 4,880 cfs with the pool at spillway crest (elevation 453.0 feet). The conduits are controlled by two hydraulically operated slide gates designed to operate at full opening.

Construction of the dam began in June 1957 with filling beginning in March 1962. Construction was completed in May 1964. The conservation pool was filled in April 1966. Commercial power generation began in March 1964.

4.9 Software and Documentation

Frequency analysis at selected gages sites was performed using PeakFQ (Cohn and other, 2013). PeakFQ is software developed and maintained by USGS. PeakFQ implements the Bulletin 17C (England and others, 2018) procedures for flood-frequency analysis of streamflow records, providing estimates of flood magnitudes and their corresponding variance for a range of annual exceedance probabilities. The output also includes estimates of the parameters of the log-Pearson Type III frequency distribution, including the logarithmic mean, standard deviation, skew, and mean square error of the skew. The output graph includes the fitted frequency curve, systematic peaks, low outliers, censored peaks, interval peaks, historic peaks, thresholds, and confidence limits.

R Statistical Software (R Core Team, 2023) is a free software environment for statistical computing and graphics. R was used with RStudio for the efficient computation of flow frequencies, long-term simulation of streamflows with machine learning techniques, and summation of model results.

Individual components of CWMS models used for modeling streamflows and reservoir operations within the White River Basin are listed in Table 4-2. The reservoir operational component of the CWMS model is RiverWare (Zagona and others, 2001). RiverWare is a river system modeling tool used for operational decision making (Section 8). The latest version of Riverware is 9.1. Table 4-2 lists the computer programs used in the development of the White River CWMS model.

Table 4-2. List of Computer Programs Required for CWMS Watershed Modeling

Program	Version	Capability	Developer
ArcGIS	10.2.2	Geographical Information System	ESRI
CWMS	3.0	Integrated real-time flow forecasting and reservoir operation	HEC
HEC-DSSVue	2.5	Plot, tabulate, edit, and manipulate data in a HEC-DSS database file	HEC
HEC-CWMSVue	2.5	Plot, tabulate, edit, and manipulate data in a CWMS database file	HEC
HEC-FIA	3.0	Flood Impact Analysis Model	HEC
HEC-GeoHMS	10.2	Watershed delineation/generating HEC-HMS input	HEC
HEC-GeoRAS	10.2	Generates HEC-RAS Geometry Input	HEC
HEC-HMS	4.1	Rainfall-runoff simulation	HEC
HEC-RAS	5.0	Steady and Unsteady Flow Analysis	HEC
HEC-ResSim	3.3	Reservoir operations model	HEC

5 Statistical Hydrology

5.1 Statistical Methods

Data was collected and analyzed for selected USGS streamflow gaging stations in the White River Basin. Table 5-1 provides a summary of the data for basins in the controlled and uncontrolled areas. This summary includes the number of active gages, the number of inactive gages, the range of contributing area for those gages, the range of the number of years of annual peak flow values available, and the range of Kendall's Tau parameter. The Kendall's Tau parameter was computed for each of these sites to determine if there is an increasing or decreasing trend in the annual peak flow values for the period of record. Kendall's Tau parameters close to 1 indicate a strong rising trend while values close to -1 indicate a strong falling trend. If the parameter is close to zero, then neither a falling or rising trend exists. The trend can be considered statistically significant of the p-value associated with the value of Kendall's Tau is less than or equal to 0.05.

Table 5-2 provides data on each USGS streamgage analyzed for this study. The data for each station includes geographic location, period of record, number of gaged and ungaged historic peaks, contributing area, and Kendall's Tau parameters.

Of the 76 streamgages analyzed (Figure 4-1), 40 are active gages and 36 are inactive gages. The contributing area for these gages ranges from less than one square mile to over 2,000 square miles. Available period of record data ranges from 20 years to 109 years. Seven streamgages, mostly existing in Southern Missouri, showed statistically significant, increasing trends in peak streamflows, which is indicated by a p-value less than or equal to 0.05 and a positive value of Kendall's Tau. For the streamgages evaluated for this study, the value of Kendall's Tau did exceed 0.300, however, this can be a function of limited period of record. For gages with more than 50 years of data, the largest value of Kendall's Tau was 0.200.

Table 5-1. Summary of USGS Streamflow Gages in the White River Basin

Number of Active Gages	Number of Inactive Gages	Range of Contributing Area (sq mi)	Range of Peak Values Available (gaged and historic)	Range of Kendall's Tau Parameter
Upstream of Beaver Dam				
3	2	1.19 to 399	21 to 62	0.004 to 0.083
Upstream of Table Rock Dam				
9	3	0.742 to 992	20 to 99	-0.019 to 0.308
Upstream of Bull Shoals Dam				
3	4	0.204 to 298	21 to 26	-0.065 to 0.351
Between Bull Shoals Dam and Confluence of White and North Fork Rivers				
5	4	0.743 to 828	21 to 82	-0.077 to 0.200
Upstream of Norfork Dam				
4	0	52.1 to 569	20 to 76	0.110 to 0.295
Downstream of Confluence of North Fork and White Rivers and Upstream of Black River Confluence				
1	4	0.26 to 58.7	21 to 54	-0.097 to 0.181
Black River Basin				
13	14	0.172 to 2,050	21 to 109	-0.271 to 0.304
Upstream of Greers Ferry Dam				
2	4	0.172 to 302	23 to 77	-0.071 to 0.154
Into Uncontrolled Little Red River				
0	1	0.698 to 0.698	37 to 37	0.041 to 0.041

Table 5-2. Individual Data for Selected U.S. Geological Survey Streamflow Gaging Stations in the White River Basin

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
Upstream of Beaver Dam										
07047975	Dog Branch at St. Paul, AR	35°49'32"	93°45'49"	NAD27	1961-1981	21	0	1.19	0.024	0.904
07048550	West Fork White River East of Fayetteville, AR	36°03'14"	94°04'59"	NAD83	1938-2020	27	1	123	0.031	0.835
07048600	White River near Fayetteville, AR	36°04'23"	94°04'52"	NAD83	1964-2020	57	0	399	0.060	0.513
07048940	War Eagle Creek near Witter, AR	35°54'05"	93°42'04"	NAD27	1961-1982	22	0	22.5	0.004	1.000
07049000	War Eagle Creek near Hindsville, AR	36°12'00"	93°51'18"	NAD83	1943-2020	61	1	265	0.083	0.347
Upstream of Table Rock										
07050200	Maxwell Creek at Kingston, AR	36°03"06"	93°31'03"	NAD27	1961-1981	21	0	2.78	-0.019	0.928
07050400	Freeman Branch at Berryville, AR	36°22'06"	93°33'33"	NAD27	1961-1980	20	0	0.742	0.063	0.721

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
07050500	Kings River near Berryville, AR	36°25'38"	93°37'15"	NAD83	1927-2020	82	1	529	0.020	0.795
07050545	North Carolina Creek near Marshfield, MO	37°14'52"	93°00'30"	NAD27	1997-2020	21	0	6.41	0.267	0.097
07050690	Pearson Creek near Springfield, MO	37°10'41"	93°11'54"	NAD83	2000-2020	21	0	21.4	0.129	0.432
07050700	James River near Springfield, MO	37°09'00"	93°12'12"	NAD83	1909-2020	65	1	245	0.114	0.180
07050800	Maple Grove Branch near Ozark, MO	37°04'20"	93°13'05"	NAD27	1959-1985	21	0	1.51	0.110	0.506
07052250	James River near Boaz, MO	37°00'24"	93°21'53"	NAD83	1973-2020	27	0	458	0.140	0.317
07052370	Dry Crane Creek near Crane, MO	36°56'18"	93°26'05"	NAD27	1997-2019	23	0	11.5	0.308	0.041
07052500	James River at Galena, MO	36°48'19"	93°27'42"	NAD83	1922-2020	99	0	992	0.175	0.010
07053207	Long Creek at Denver, AR	36°23'22"	93°18'57"	NAD83	1995-2020	23	0	103	0.091	0.561

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
07053250	Yocum Creek near Oak Grove, AR	36°27'16"	93°21'22"	NAD83	1994-2020	27	0	52.6	0.231	0.095
Upstream of Bull Shoals										
07053810	Bull Creek near Walnut Shade, MO	36°43'04"	93°12'25"	NAD83	1995-2020	25	0	196	0.287	0.047
07053950	Ingenthron Hollow near Forsyth, MO	36°43'52"	93°07'30"	NAD27	1959-1980	22	0	0.611	-0.048	0.778
07054080	Beaver Creek at Bradleyville, MO	36°46'47"	92°54'26"	NAD83	1995-2020	26	0	298	0.351	0.013
07054200	Yanell Branch near Kirbyville, MO	36°36'36"	93°05'47"	NAD27	1955-1979	24	0	0.328	-0.043	0.785
07054300	Gray Branch at Lutie, MO	36°35'05"	92°42'30"	NAD27	1957-1979	22	0	0.204	-0.065	0.692
07054400	Charley Creek near Omaha, AR	36°27'24"	93°04'46"	NAD27	1962-1983	20	1	3.39	0.205	0.217
07054410	Bear Creek near Omaha, AR	36°26'58"	93°04'30"	NAD83	1995-2020	25	0	133	0.193	0.183
Flows into Uncontrolled White (between Bull Shoals Dam and confluence of North Fork and White Rivers)										
07055550	Crooked Creek	36°09'01"	93°07'23"	NAD27	1961-1986	25	0	4.27	0.000	1.000

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
	Tributary near Dog Patch, AR									
07055607	Crooked Creek at Kelly Crossing at Yellville, AR	36°13'49"	92°42'34"	NAD83	1985-2020	34	0	402	-0.048	0.700
07055646	Buffalo River near Boxley, AR	35°56'20"	93°24'18"	NAD83	1994-2020	26	0	58.8	-0.077	0.597
07055650	Smith Creek near Boxley, AR	35°56'50"	93°23'52"	NAD27	1963-1983	21	0	8.34	0.200	0.216
07055800	Dry Branch near Vendor, AR	35°56'00"	93°06'46"	NAD27	1962-1983	20	1	6.13	0.132	0.436
07055875	Richland Creek near Witts Spring, AR	35°47'50"	92°55'44"	NAD83	1996-2020	25	0	67.3	0.023	0.889
07056000	Buffalo River near St. Joe, AR	35°58'59"	92°44'50"	NAD83	1915-2020	81	1	828	0.062	0.415
07056515	Bear Creek near Silver Hill, AR	35°56'24"	92°42'48"	NAD83	2000-2020	21	0	78.5	0.000	1.000
07057300	Dodd Creek Tributary near Mountain Home, AR	36°19'05"	92°24'01"	NAD27	1961-1986	26	0	0.743	0.058	0.692

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
Upstream of Norfork										
07057500	North Fork River near Tecumseh, MO	36°37'23"	92°14'53"	NAD83	1945-2020	76	0	562	0.110	0.160
07058000	Bryant Creek near Tecumseh, MO	36°37'38"	92°18'22"	NAD83	1945-2020	66	0	569	0.121	0.152
07058980	Bennetts River at Vidette, AR	36°25'22"	92°07'06"	NAD83	1995-2020	25	0	68.4	0.113	0.441
07059450	Big Creek near Elizabeth, AR	36°21'27"	92°06'45"	NAD83	1999-2020	20	0	52.1	0.295	0.074
Flows into Uncontrolled White (Downstream of confluence of North Fork and White Rivers and upstream of Black River confluence)										
07060600	Band Mill Creek near Brockwell, AR	36°08'02"	91°58'48"	NAD27	1961-1985	25	0	1.25	-0.097	0.513
07060670	Hughes Creek near Mountain View, AR	35°51'46"	92°08'47"	NAD27	1961-1981	21	0	3.22	0.048	0.786
07060710	North Sylamore Creek near Fifty Six, AR	35°59'30"	92°12'50"	NAD83	1966-2020	54	0	58.7	0.120	0.202
07060830	Wolf Bayou near Drasco, AR	35°39'36"	91°55'15"	NAD27	1963-1983	21	0	0.26	0.181	0.263

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
07061100	Gibbs Creek at Sulphur Rock, AR	35°45’32”	91°30’52”	NAD27	1962-1985	24	0	3.94	-0.072	0.637
Black River Basin										
07061260	East Fork Black River near Ironton, MO	37°36’14”	90°47’19”	NAD27	1997-2020	23	0	15.9	0.304	0.045
07061500	Black River near Annapolis, MO	37°20’17”	90°47’20”	NAD83	1939-2020	82	0	492	0.009	0.908
07061900	Logan Creek at Ellington, MO	37°14’51”	90°57’56”	NAD83	1954-2020	27	0	139	0.197	0.156
07063470	Tenmile Creek near Poplar Bluff, MO	36°46’59”	90°33’35”	NAD27	1997-2020	22	0	59.4	0.203	0.195
07064300	Fudge Hollow near Licking, MO	37°31’49”	91°44’13”	NAD83	1957-1979	23	0	1.93	0.237	0.119
07064500	Big Creek near Yukon, MO	37°13’58”	91°51’00”	NAD83	1935-1979	31	2	8.54	0.103	0.424
07065495	Jacks Fork at Alley Spring, MO	37°08’53”	91°26’35”	NAD83	1994-2020	27	0	304	0.145	0.297
07066000	Jacks Fork at Eminence, MO	37°09’15”	91°21’29”	NAD83	1922-2020	99	0	404	0.200	0.003

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
07066500	Current River near Eminence, MO	37°11'02"	91°15'30"	NAD27	1904-1975	54	0	1,280	0.180	0.056
07066800	Sycamore Creek near Winona, MO	37°02'45"	91°19'30"	NAD27	1958-1990	33	0	1.35	0.021	0.877
07067000	Current River at Van Buren, MO	36°59'29"	91°00'49"	NAD83	1904-2020	108	1	1,670	0.084	0.199
07068000	Current River at Doniphan, MO	36°37'19"	90°50'51"	NAD27	1904-2020	102	2	2,050	0.123	0.068
07068200	North Prong Little Black River at Hunter, MO	36°53'25"	90°50'30"	NAD27	1958-1982	25	0	1.28	-0.173	0.234
07068510	Little Black River below Fairdealing, MO	36°37'54"	90°34'31"	NAD27	1940-2020	48	0	194	0.156	0.120
07068870	Fourche River Tributary at Middlebrook, AR	36°27'46"	90°55'26"	NAD27	1961-1981	21	0	0.172	-0.119	0.468
07069100	Adams Branch near West Plains, MO	36°41'35"	91°48'06"	NAD27	1955-1979	25	0	3.17	-0.100	0.498

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
07069250	Brush Creek near Mammoth Spring, AR	36°25'36"	91°29'27"	NAD27	1961-2004	37	0	0.471	-0.197	0.089
07069290	Miller Creek near Salem, AR	36°20'13"	91°46'32"	NAD27	1961-1981	21	0	2.06	-0.271	0.091
07069500	Spring River at Imboden, AR	36°12'20"	91°10'18"	NAD83	1915-2020	84	1	1,160	0.060	0.422
07070200	Burnham Branch near Willow Springs, MO	36°56'00"	91°56'00"	NAD27	1959-1979	21	0	1.31	0.071	0.668
07071500	Eleven Point River near Bardley, MO	36°38'55"	91°12'03"	NAD83	1915-2020	99	1	784	0.062	0.363
07072000	Eleven Point River near Ravenden Springs, AR	36°20'47"	91°06'51"	NAD83	1930-2020	89	0	1,120	0.072	0.321
07072200	Hubble Creek near Pocahontas, AR	36°15'32"	91°02'02"	NAD27	1961-1985	25	0	1.28	-0.007	0.981
07073500	Piney Fork at Evening Shade	36°04'50"	91°36'39"	NAD27	1939-1998	60	0	99.8	-0.068	0.448
07074000	Strawberry River near	36°06'40"	91°26'58"	NAD83	1937-2020	84	0	473	0.035	0.637

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
	Poughkeepsie, AR									
07074200	Dry Branch Tributary near Sidney, AR	36°00'12"	91°35'06"	NAD27	1961-1983	21	1	1.2	0.029	0.880
07074250	Reeds Creek near Strawberry	35°58'58"	91°20'12"	NAD27	1963-1983	21	0	34.9	0.019	0.928
Upstream of Greers Ferry										
07074900	Trace C Trib nr Marshall ARK	35°52'14"	92°36'08"	NAD27	1961-1986	26	0	0.246	0.154	0.280
07074950	Tick Creek near Leslie, AR	35°51'20"	92°26'24"	NAD27	1961-1983	23	0	1.26	0.103	0.509
07075000	Middle Fork of Little Red River at Shirley, AR	35°39'24"	92°17'34"	NAD83	1935-2020	76	1	302	0.127	0.106
07075300	South Fork of Little Red River at Clinton, AR	35°35'13"	92°27'05"	NAD83	1962-2020	59	0	148	0.086	0.340
07075600	Choctaw Creek Tributary near Choctaw, AR	35°31'36"	92°25'02"	NAD27	1964-2004	36	0	1.33	0.098	0.406

Station number	Station name	Latitude	Longitude	Horizontal Datum	Period analyzed	Number of gaged peaks used	Number of historic peaks used	Contributing draining area (sq mi)	Kendall's Tau Parameters	
									Tau	p-value
07075800	Dill Branch Tributary near Ida, AR	35°32'33"	91°57'34"	NAD27	1964-2004	38	0	0.172	-0.071	0.537
Flows into Uncontrolled Little Red River										
07076630	Key Branch near Searcy, AR	35°14'47"	91°47'01"	NAD27	1961-2003	37	0	0.698	-0.236	0.041

5.2 Stream Gage Data and Statistical Flood Flow Frequency Results

A study was performed by the USGS in order to provide updated Bulletin 17C analyses at USGS streamgages within the White River basin (Wagner and others, 2021). This study used PeakFQ to perform Bulletin 17C analyses on USGS streamflow gaging stations containing peak streamflows within the White River Basin. A data release was provided by USGS, and the data release contains site information, basin characteristics, results of flood-frequency analysis, and a generalized (regional) flood skew for 76 selected streamgages operated by the U.S. Geological Survey (USGS) in the upper White River basin (4-digit hydrologic unit 1101) in southern Missouri and northern Arkansas. Ten basin characteristics were tested as explanatory variables in a generalized additive model (GAM; Wood, 2011) of flood skew, but a lack of statistical significance of the variables, including two-dimensional smooths of the locations of the streamgages and the centroids of their basins, indicated that a weighted mean flood skew of -0.132, with a mean squared error of 0.160 and standard error of 0.400, was appropriate (Wagner and others, 2021). Figure 5-1 through Figure 5-74 show the flood flow frequency curves for the selected sites within the White River Basin. Table 5-3 shows the peak streamflow frequency with confidence limits at the selected sites for the 1/2 to 1/500 AEP peak streamflows.

In the context of Bulletin 17C analyses, censoring intervals and interval-censored peaks refer to techniques used to handle uncertain or incomplete streamflow data when performing flood frequency analysis.

- Censoring Intervals: These are predefined discharge ranges used to account for measurement limitations, reporting thresholds, or known inaccuracies in streamflow records. When peak flow observations fall below or within these intervals, they are treated as censored values rather than precise measurements. This approach helps in reducing bias when incorporating uncertain or missing data into the Bulletin 17C flood frequency analysis.
- Interval-Censored Peaks: These are peak streamflow values that are not precisely known but instead fall within a known range. For example, if a flood event occurred but the exact peak discharge was not measured, hydrologists may define an interval (e.g., "between 5,000 and 6,000 cubic feet per second") based on indirect evidence, such as high-water marks or empirical relationships. Bulletin 17C accounts for these uncertainties by using statistical methods that properly integrate interval-censored data into the log-Pearson Type III (LP3) distribution used for flood frequency estimation.

Table 5-3. Information regarding peak streamflow thresholds and censoring for White River Basin regional skew study.

USGS Station Number	PILF Threshold (ft^3/s)	Number of PILFs	Number of Peaks	Number of Peaks Not Used	Number of Historic Peaks	Number of Censoring Interval Peaks	Number of Interval-Censored Peaks
07047975	NA	0	21	0	0	NA	NA
07048550	NA	0	28	0	1	55	NA
07048600	NA	0	57	0	0	NA	1
07048940	NA	0	22	0	0	NA	NA
07049000	7,000	6	62	0	1	15	NA
07050200	NA	0	21	0	0	NA	NA
07050400	NA	0	20	0	0	NA	NA
07050500	5,340	3	83	0	1	11	NA
07050545	1,000	9	24	3	0	23	5
07050690	897	7	21	0	0	NA	NA
07050700	5,420	8	66	0	1	46	1
07050800	NA	0	21	0	0	1	NA
07052250	8,340	3	27	0	0	20	NA
07052370	553	11	23	0	0	19	10
07052500	4,900	2	99	0	0	0	1
07053207	NA	0	24	1	0	1	1
07053250	NA	0	27	0	0	NA	1
07053810	2,970	1	25	0	0	0	NA
07053950	NA	0	22	0	0	0	1
07054080	6,230	5	26	0	0	NA	NA
07054200	107	12	24	0	0	0	1
07054300	NA	0	22	0	0	22	3
07054400	480	1	21	0	1	1	NA
07054410	NA	0	26	1	0	NA	1
07055550	250	2	25	0	0	0	NA
07055607	NA	0	36	2	0	0	3
07055646	NA	0	27	1	0	NA	1
07055650	NA	0	21	0	0	NA	NA
07055800	200	1	21	0	1	1	NA
07055875	NA	0	25	0	0	NA	NA
07056000	NA	0	82	0	1	24	NA
07056515	7,020	2	21	0	0	NA	NA
07057300	NA	0	26	0	0	NA	NA
07057500	NA	0	76	0	0	NA	NA
07058000	1,940	1	66	0	0	8	NA
07058980	3,430	6	26	1	0	NA	1
07059450	NA	0	22	2	0	NA	2
07060600	128	1	25	0	0	24	1
07060670	450	1	21	0	0	NA	NA

USGS Station Number	PILF Threshold (ft^3/s)	Number of PILFs	Number of Peaks	Number of Peaks Not Used	Number of Historic Peaks	Number of Censoring Interval Peaks	Number of Interval-Censored Peaks
07060710	NA	0	54	0	0	0	NA
07060830	NA	0	21	0	0	NA	NA
07061100	NA	0	24	0	0	NA	NA
07061260	NA	0	23	0	0	23	1
07061500	NA	0	82	0	0	NA	NA
07061900	462	3	27	0	0	NA	NA
07063470	2,360	1	22	0	0	0	NA
07064300	NA	0	23	0	0	NA	NA
07064500	NA	0	33	0	2	13	NA
07065495	NA	0	27	0	0	NA	NA
07066000	NA	0	99	0	0	NA	NA
07066500	15,700	17	55	1	0	16	1
07066800	NA	0	33	0	0	32	3
07067000	NA	0	109	0	1	8	NA
07068000	12,500	17	104	0	2	14	NA
07068200	NA	0	25	0	0	24	1
07068510	NA	0	48	0	0	30	NA
07068870	79	1	21	0	0	NA	NA
07069100	NA	0	25	0	0	NA	NA
07069250	NA	0	38	1	0	7	9
07069290	210	1	21	0	0	NA	NA
07069500	4,680	1	85	0	1	21	NA
07070200	100	7	21	0	0	20	6
07071500	4,380	21	100	0	1	6	NA
07072000	NA	0	89	0	0	1	NA
07072200	NA	0	25	0	0	NA	NA
07073500	NA	0	60	0	0	NA	NA
07074000	9,000	13	84	0	0	NA	NA
07074200	285	3	22	0	1	1	NA
07074250	NA	0	21	0	0	NA	NA
07074900	50	4	26	0	0	NA	NA
07074950	NA	0	23	0	0	NA	NA
07075000	NA	0	83	6	1	3	6
07075300	2,930	2	59	0	0	NA	NA
07075600	NA	0	37	1	0	0	1
07075800	10	1	38	0	0	39	2
07076630	125	6	37	0	0	2	NA

07047975 - Dog Branch at St. Paul, AR

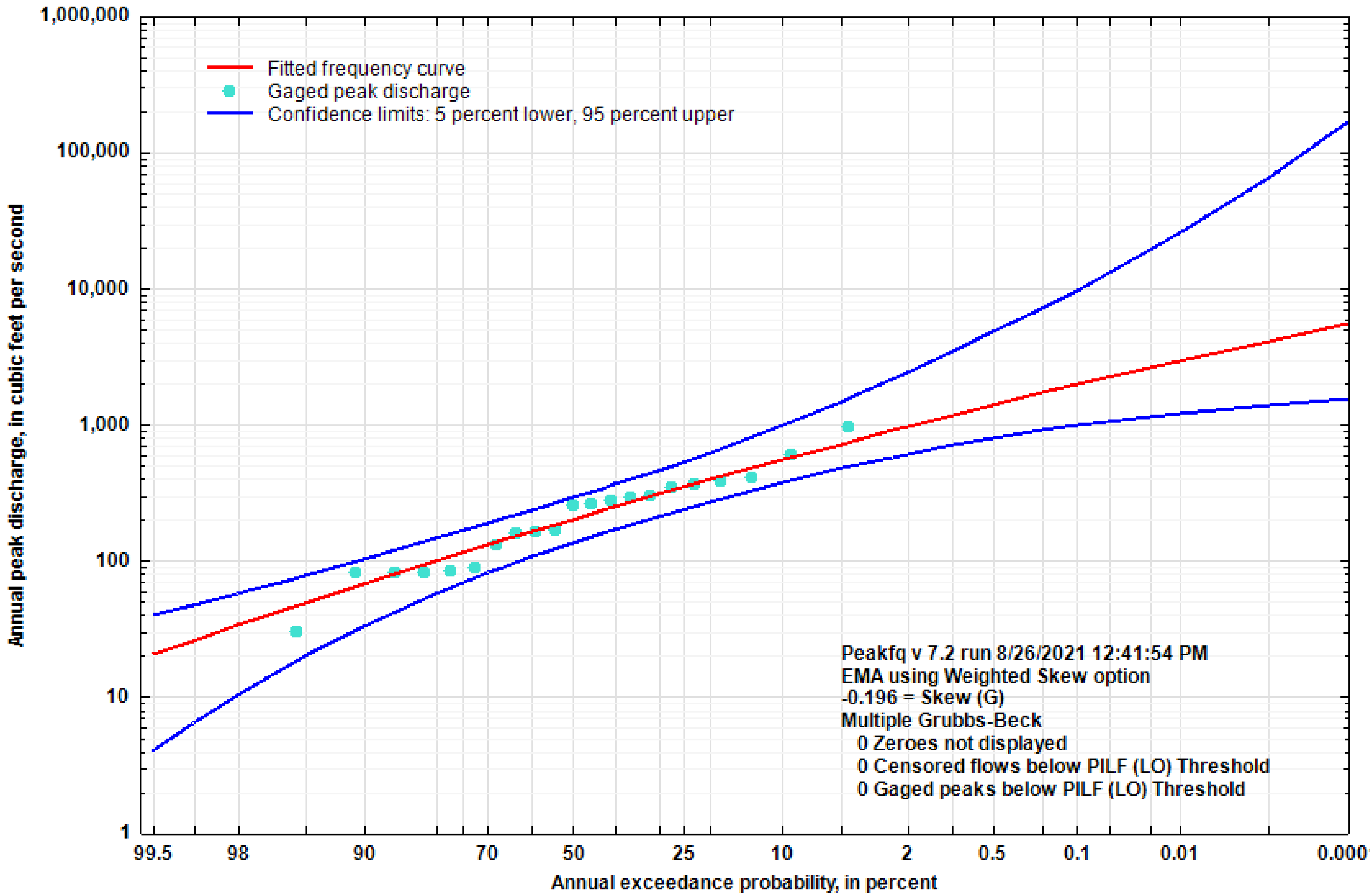


Figure 5-1. Flood Flow Frequency Curve for Dog Branch at St. Paul, AR

07048550 - West Fork White River east of Fayetteville, AR

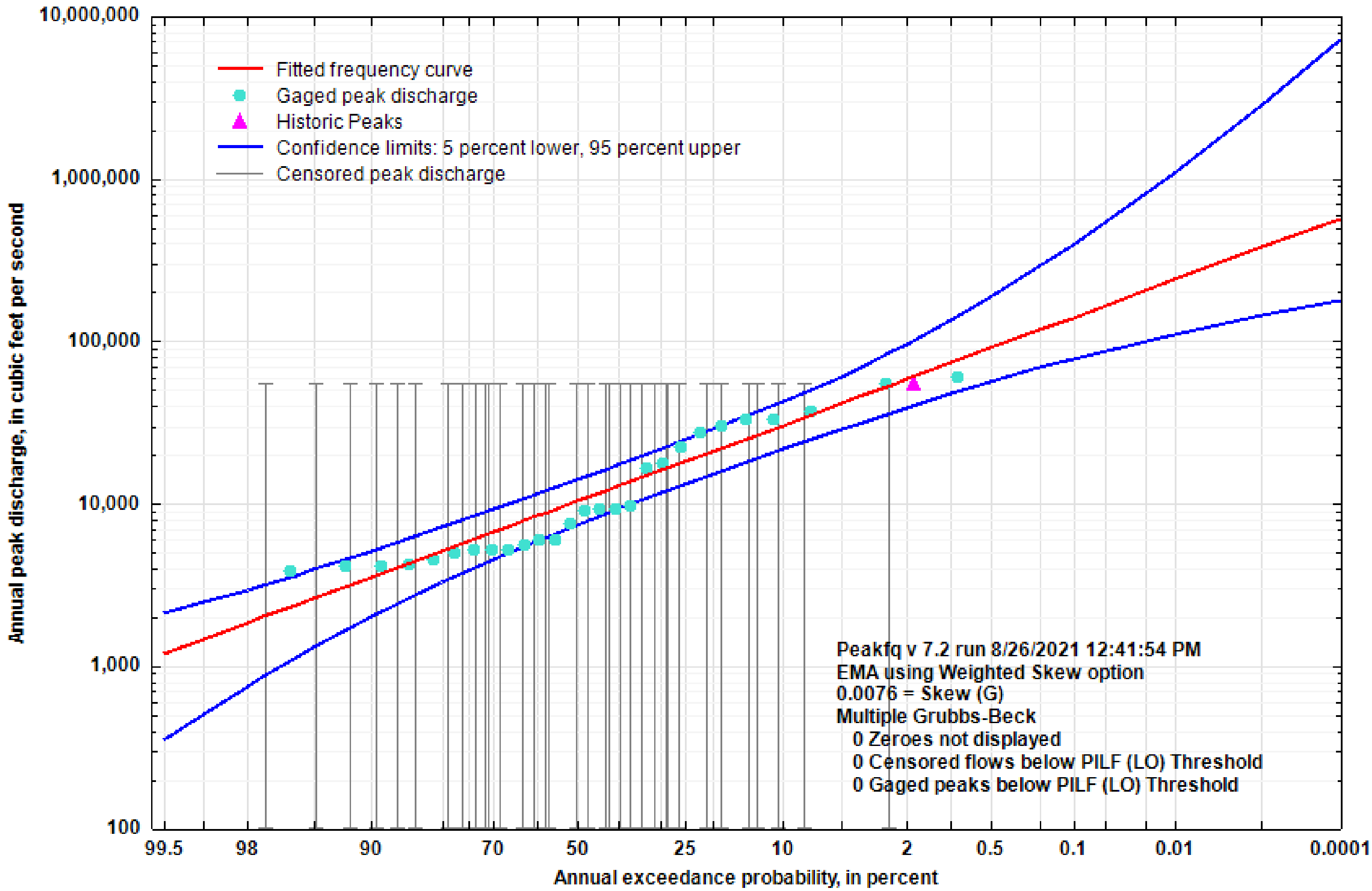


Figure 5-2. Flood Flow Frequency Curve for West Fork White River east of Fayetteville, AR

07048600 - White River near Fayetteville, AR

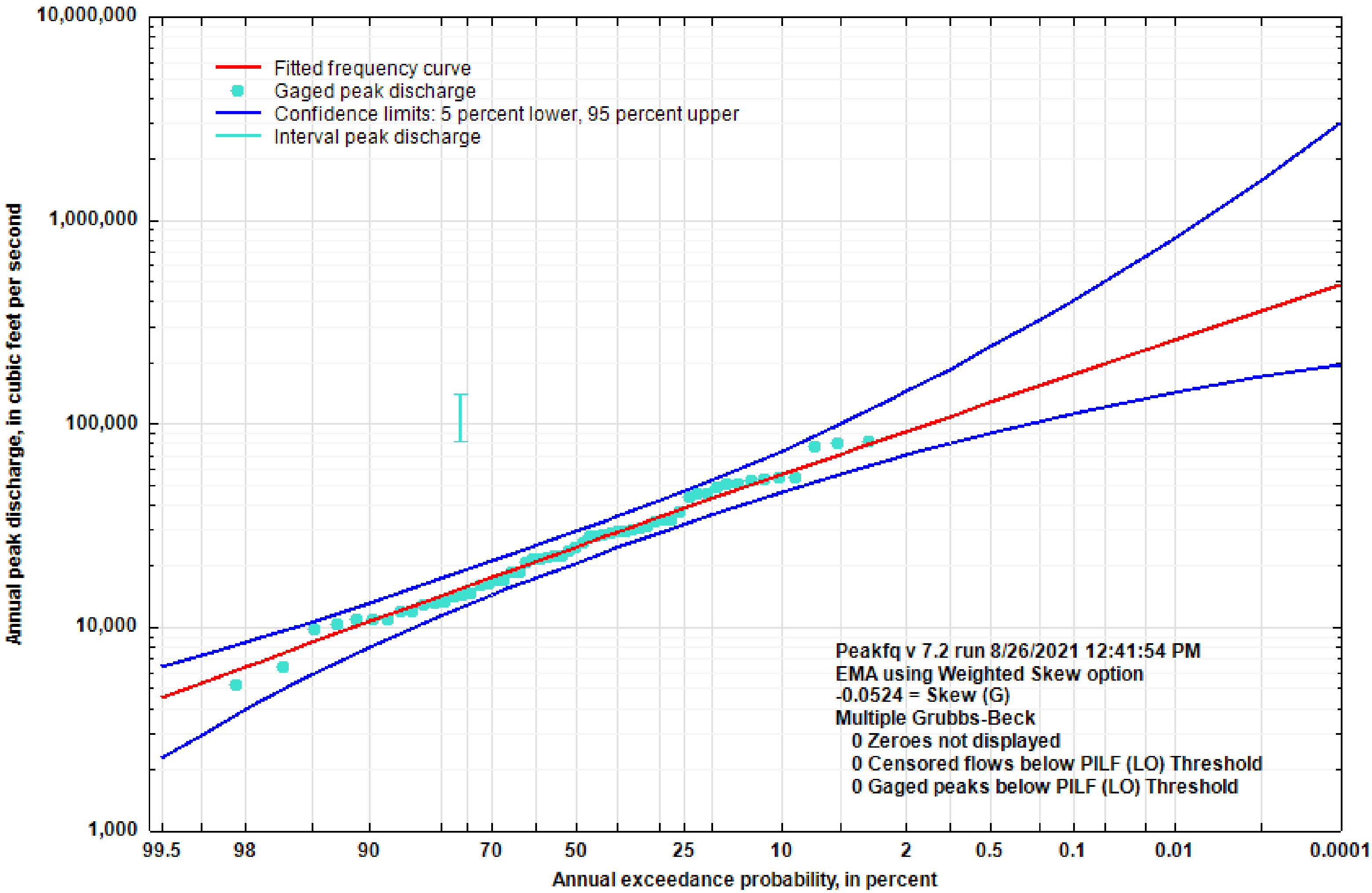


Figure 5-3. Flood Flow Frequency Curve for White River near Fayetteville, AR

07048940 - War Eagle Creek near Witter, AR

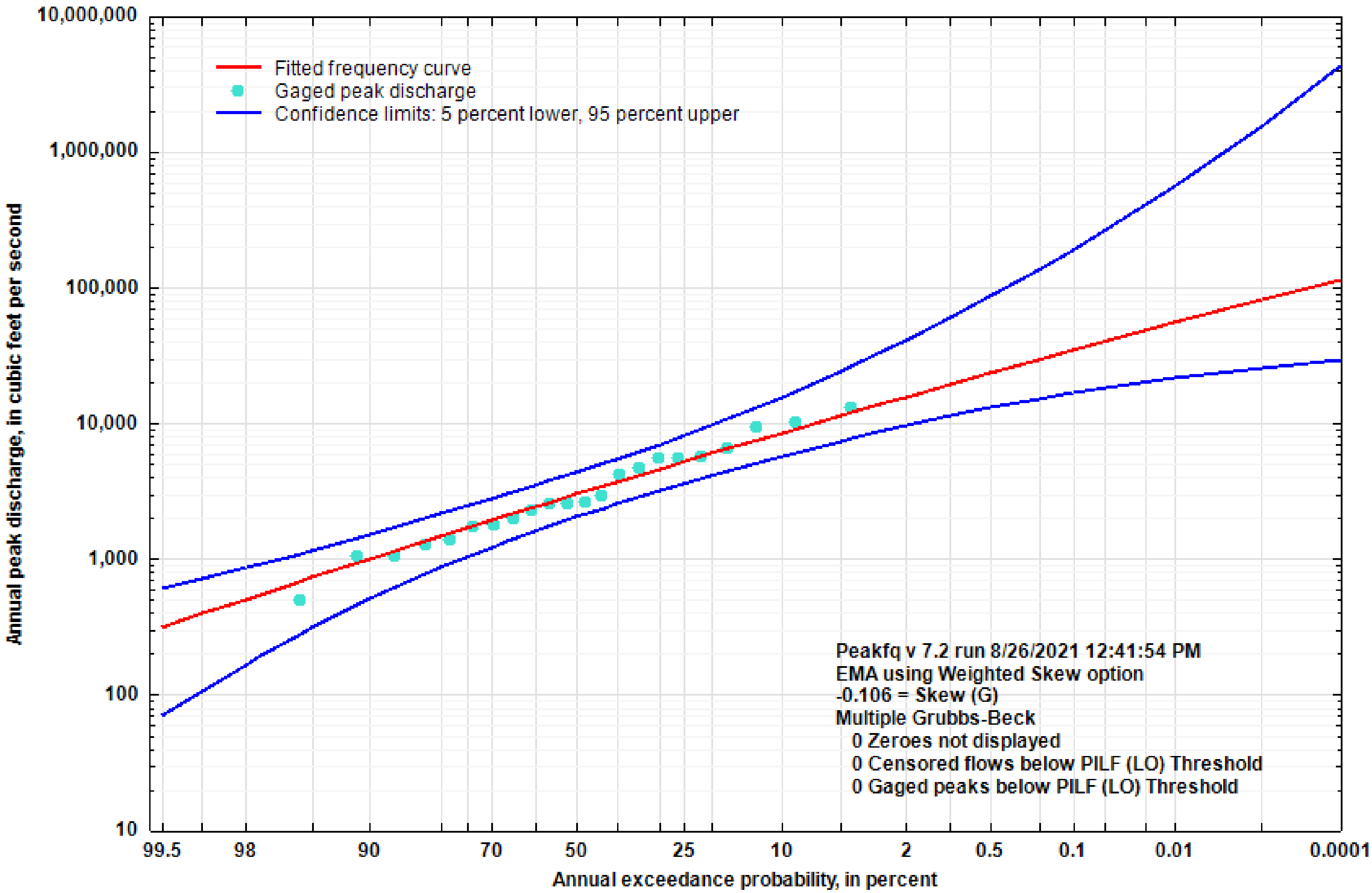


Figure 5-4. Flood Flow Frequency Curve for War Eagle Creek near Witter, AR

07049000 - War Eagle Creek near Hindsville, AR

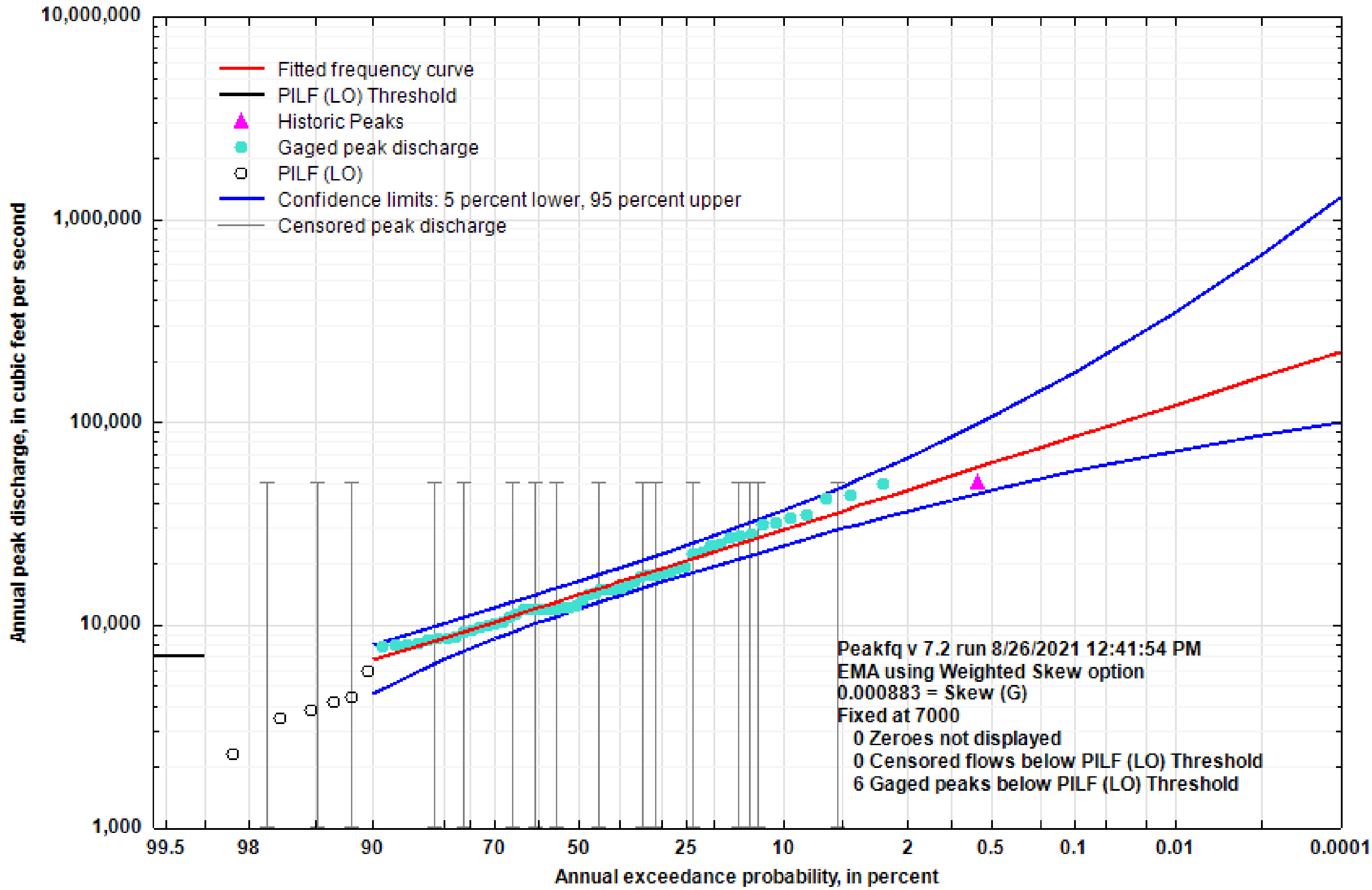


Figure 5-5. Flood Flow Frequency Curve for War Eagle Creek near Hindsville, AR

07050200 - Maxwell Creek at Kingston, AR

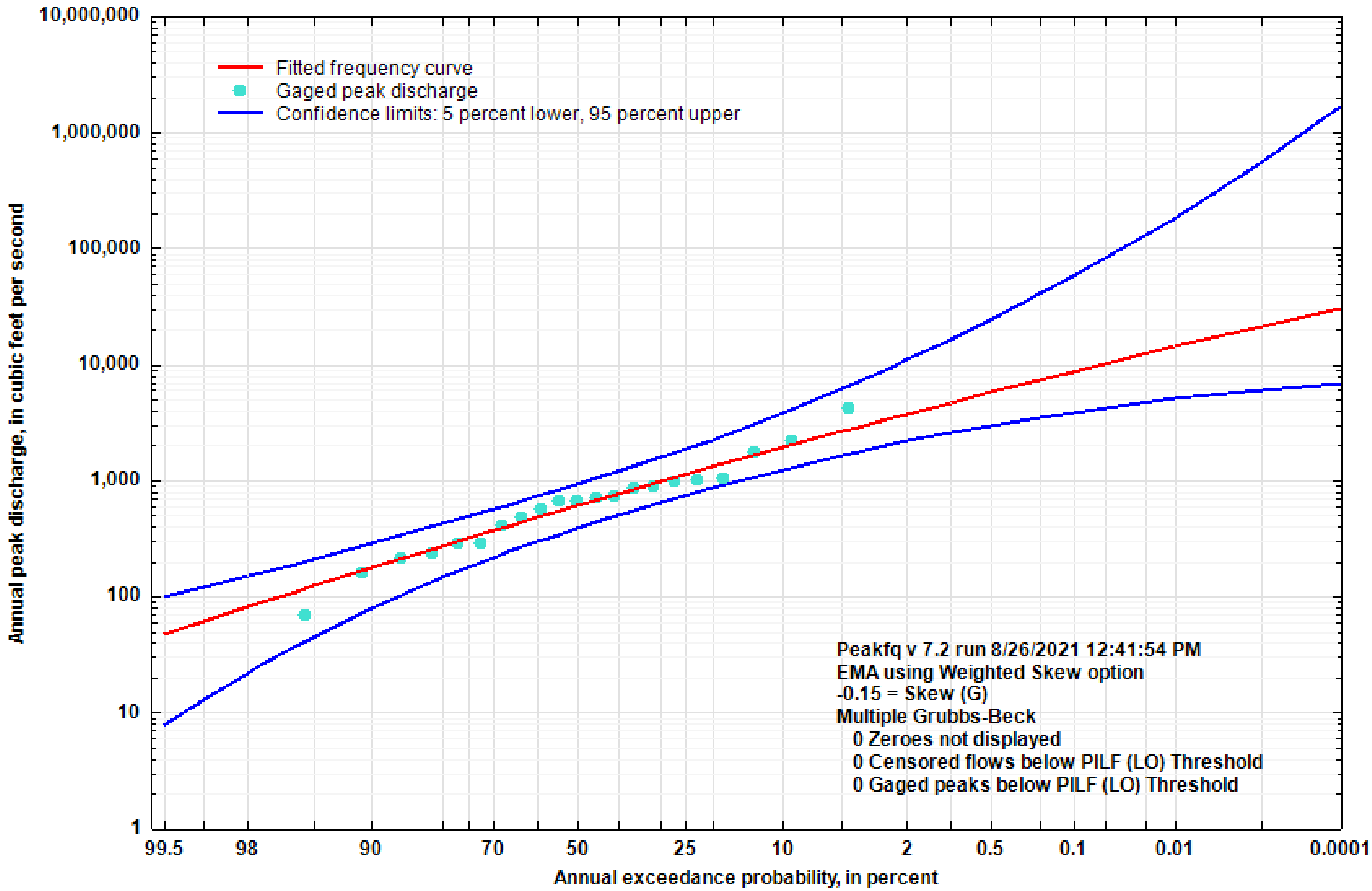


Figure 5-6. Flood Flow Frequency Curve for Maxwell Creek at Kingston, AR

07050400 - Freeman Branch at Berryville, AR

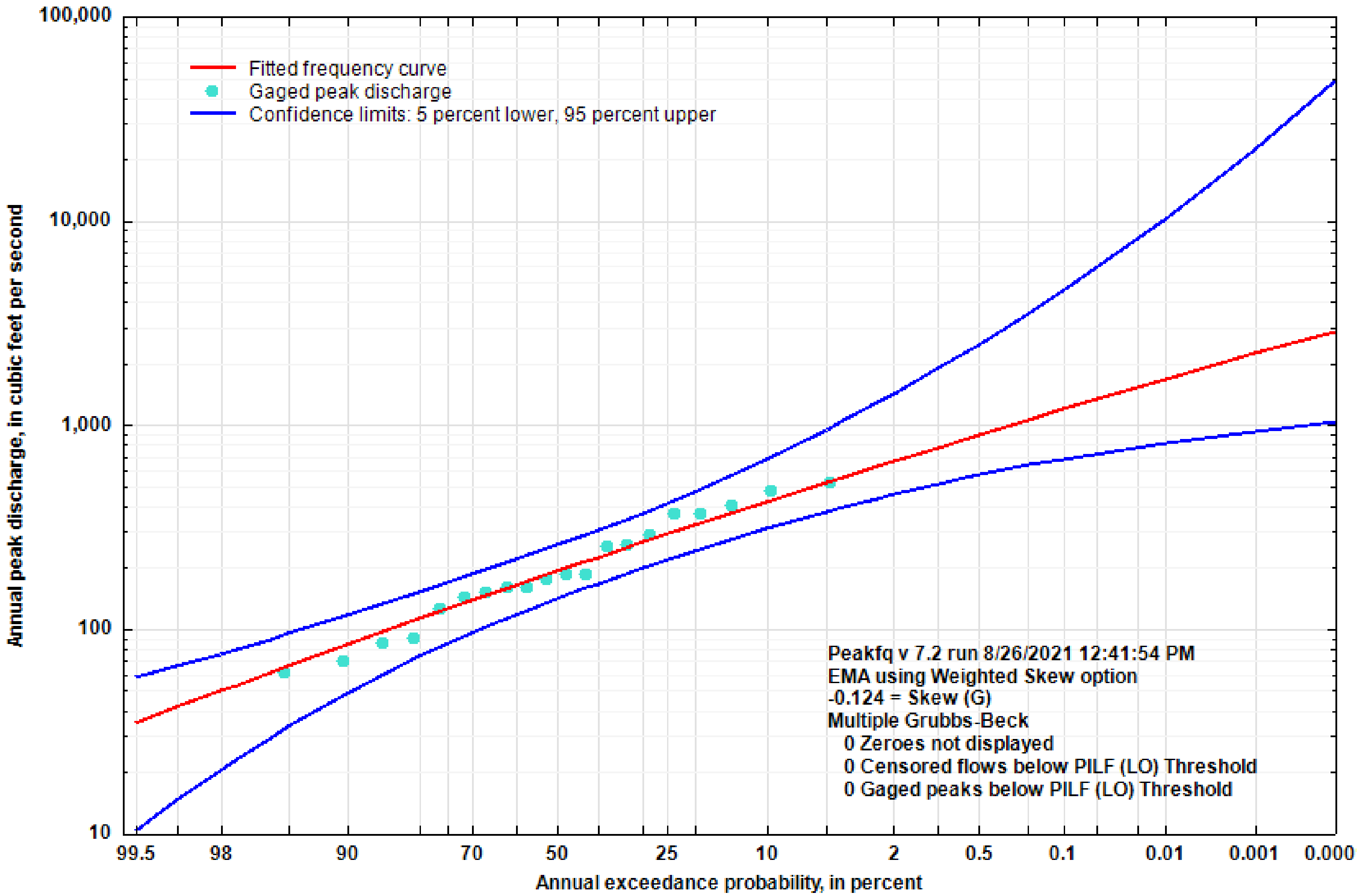


Figure 5-7. Flood Flow Frequency Curve for Freeman Branch at Berryville, AR

07050500 - Kings River near Berryville, AR

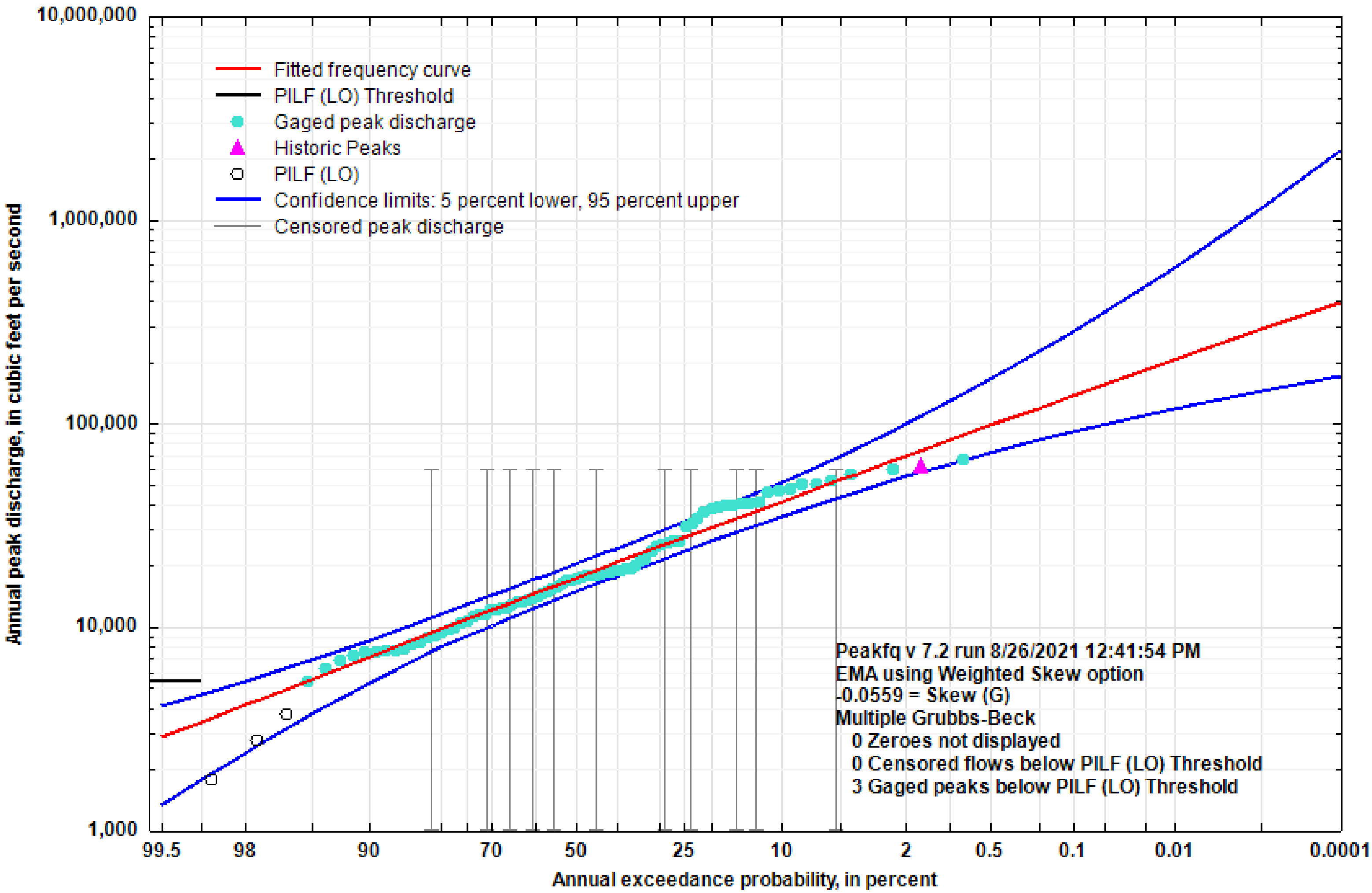


Figure 5-8. Flood Flow Frequency Curve for Kings River near Berryville, AR

07050545 - North Carolina Creek near Marshfield, MO

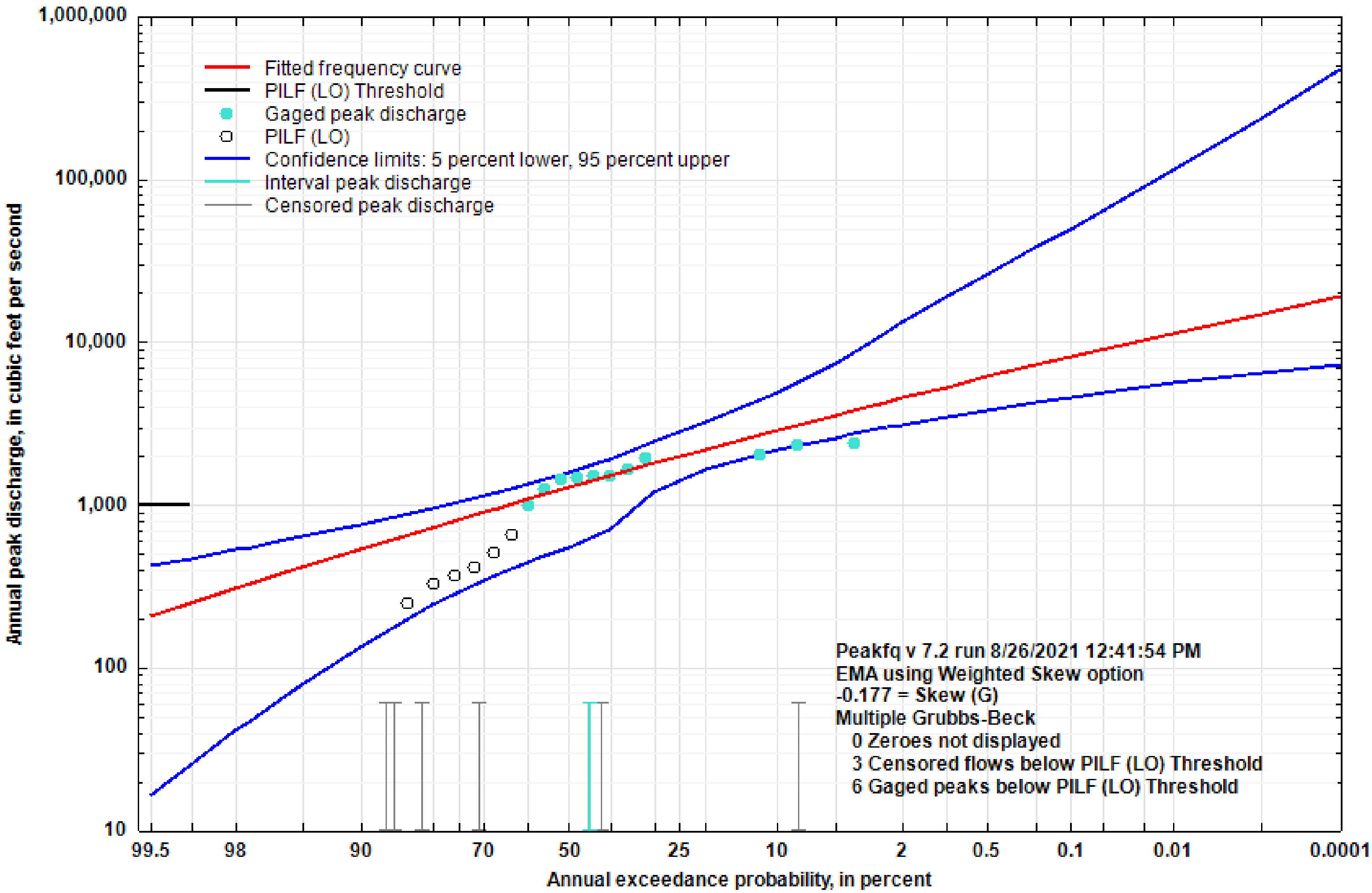


Figure 5-9. Flood Flow Frequency Curve for North Carolina Creek near Marshfield, MO

07050690 - Pearson Creek near Springfield, MO

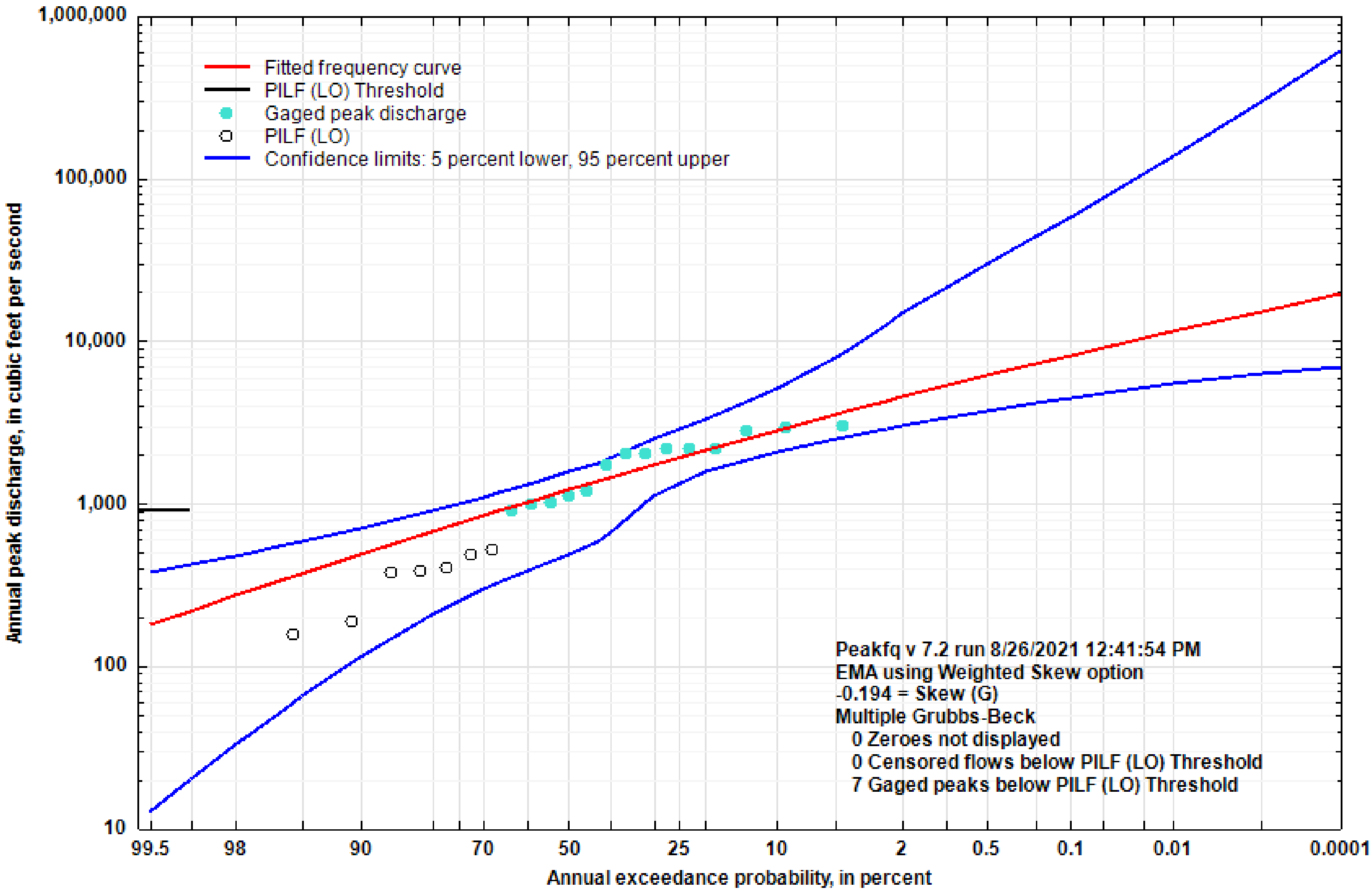


Figure 5-10. Flood Flow Frequency Curve for Pearson Creek near Springfield, MO

07050700 - James River near Springfield, MO

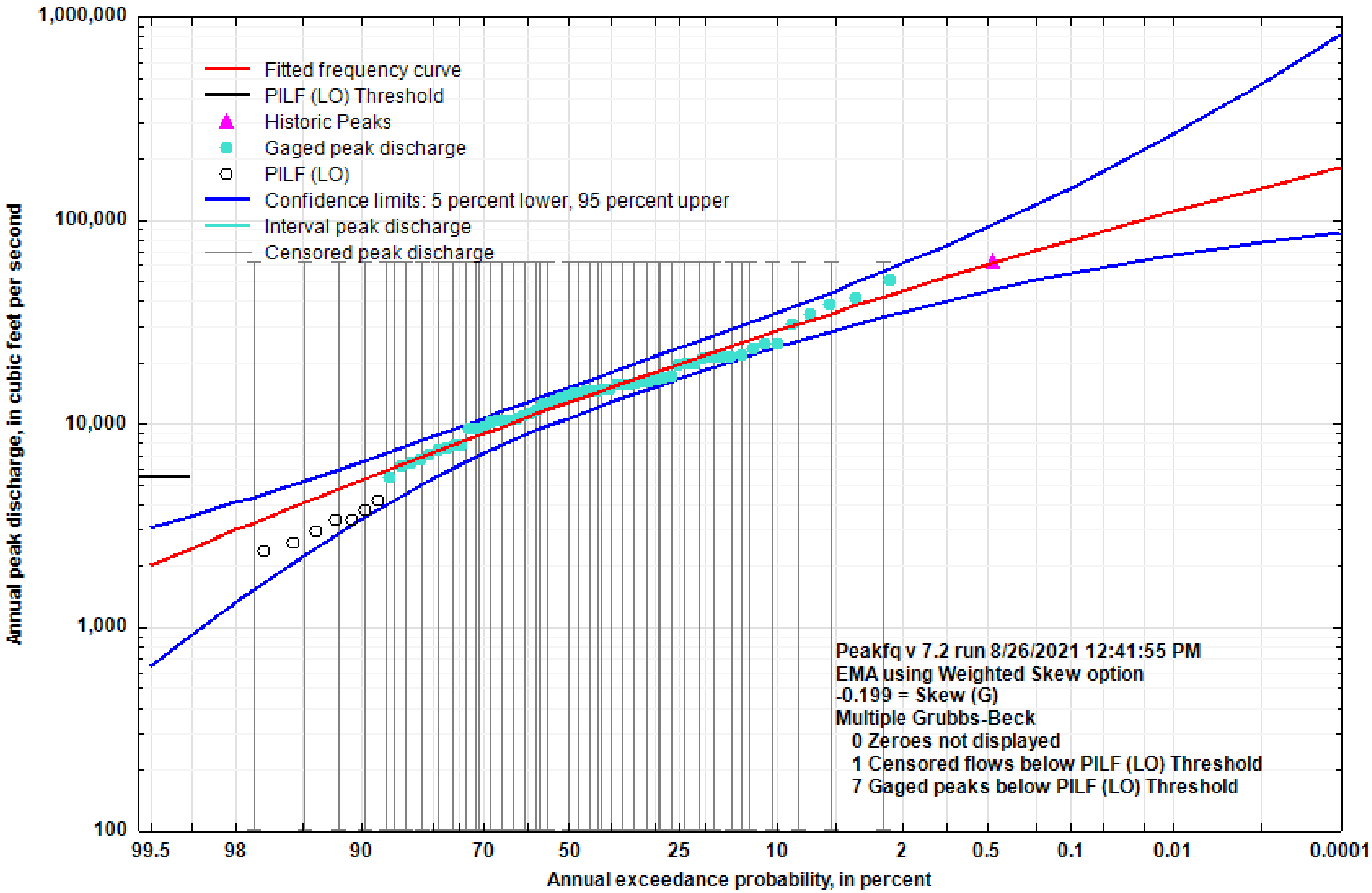


Figure 5-11. Flood Flow Frequency Curve for James River near Springfield, MO

07050800 - Maple Grove Branch near Ozark, MO

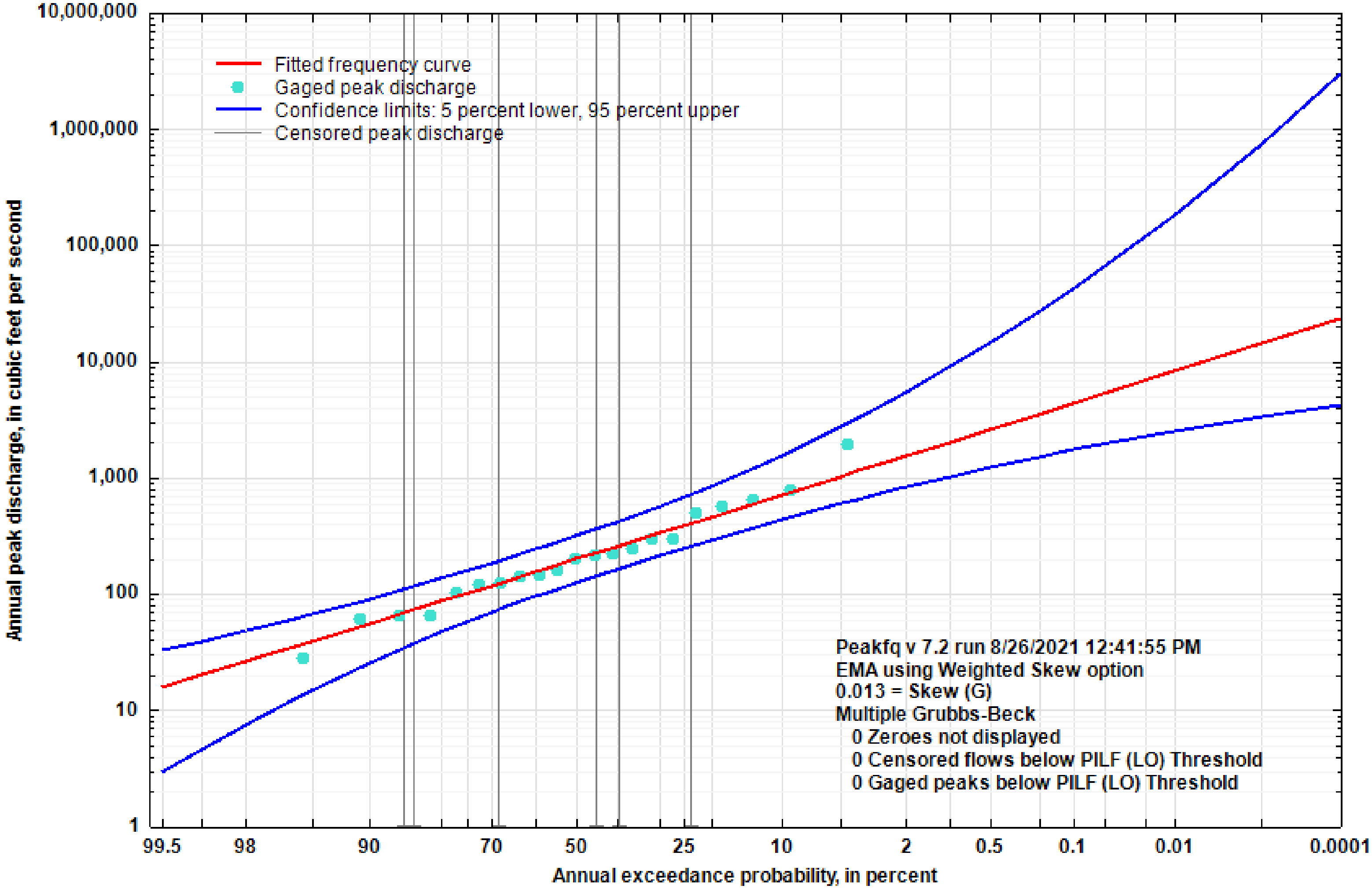


Figure 5-12. Flood Flow Frequency Curve for Maple Grove Branch near Ozark, MO

07052250 - James River near Boaz, MO

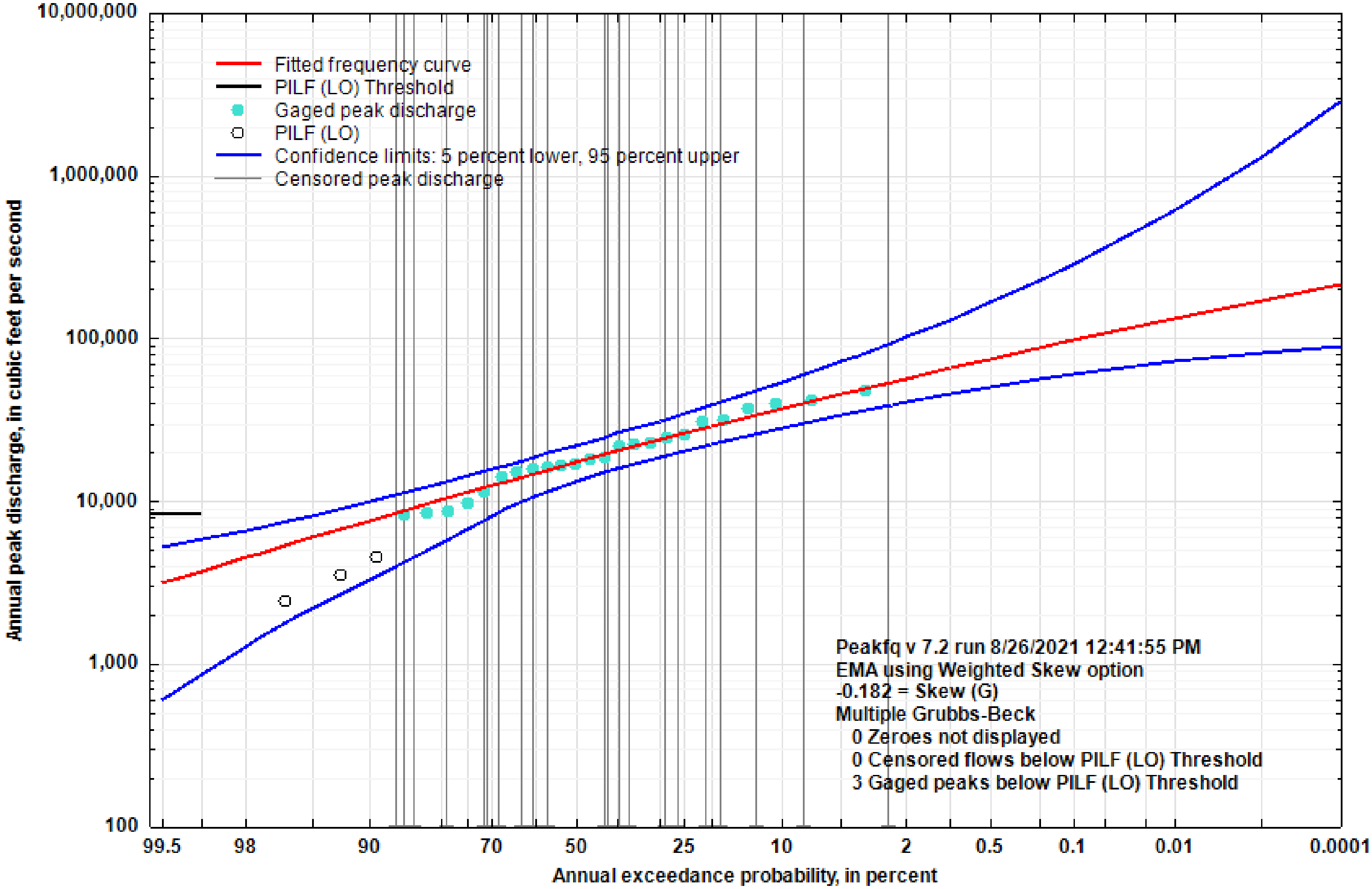


Figure 5-13. Flood Flow Frequency Curve for James River near Boaz, MO

07052370 - Dry Crane Creek near Crane, MO

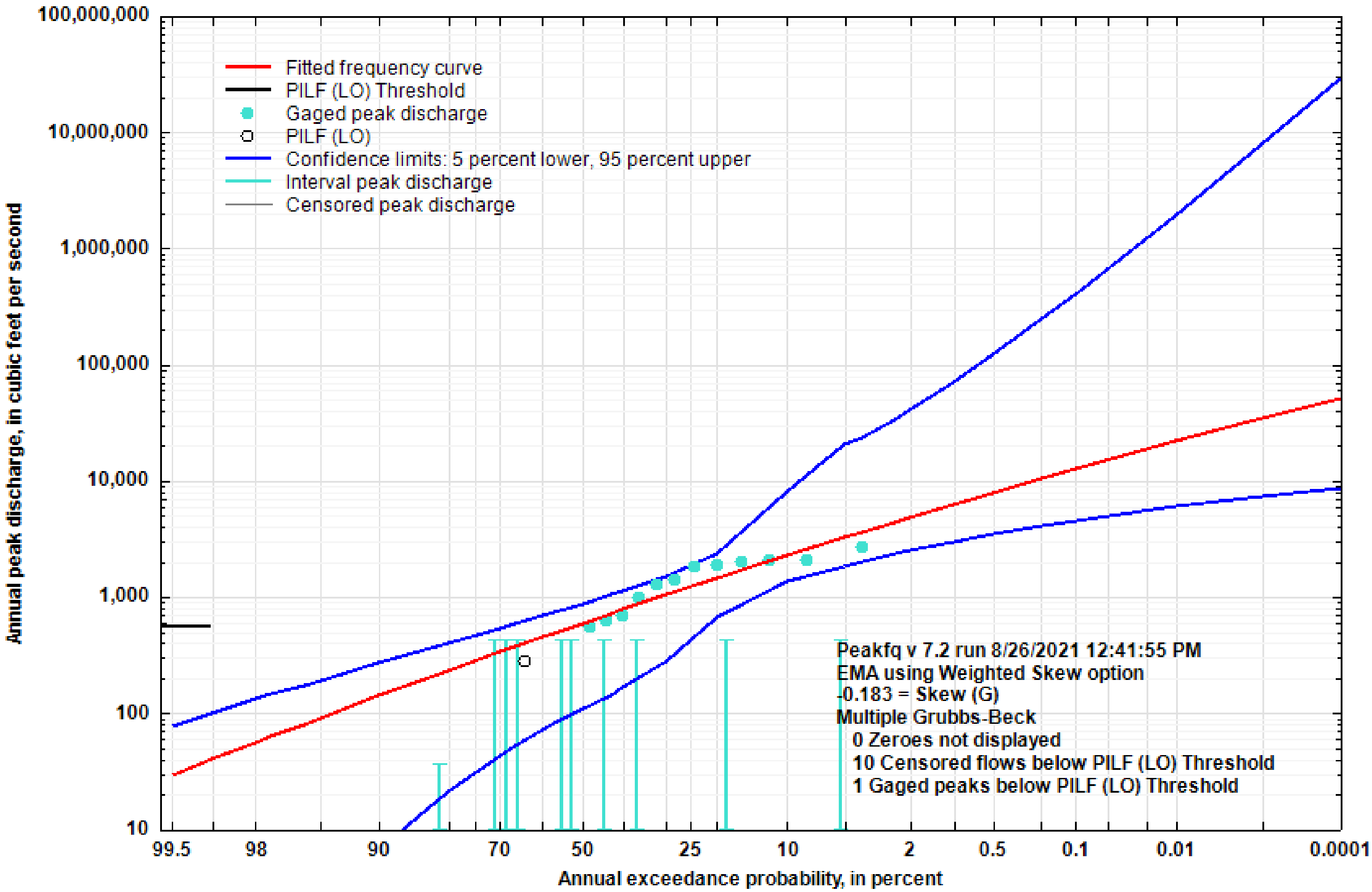


Figure 5-14. Flood Flow Frequency Curve for Dry Crane Creek near Crane, MO

07052500 - James River at Galena, MO

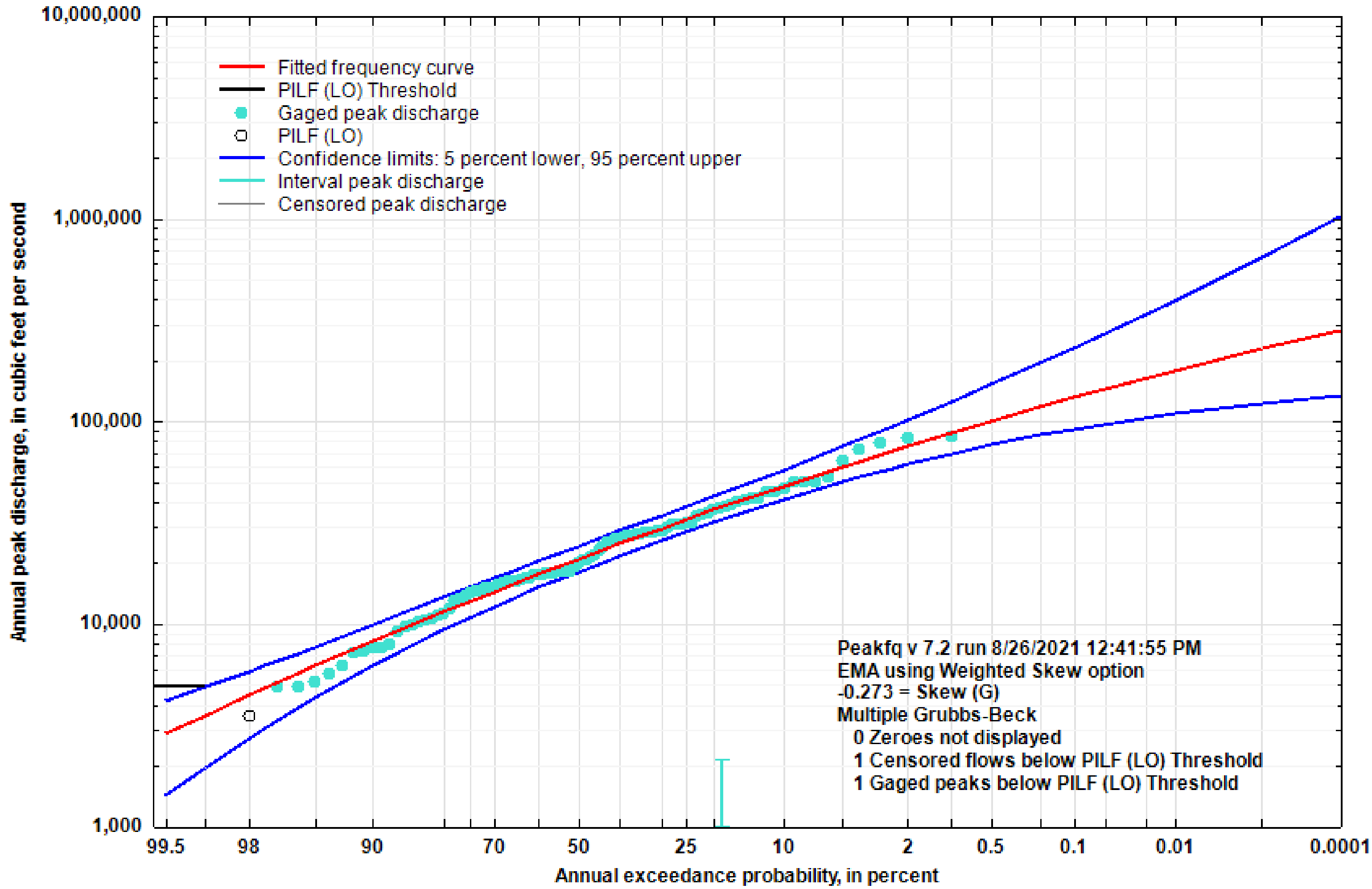


Figure 5-15. Flood Flow Frequency Curve for James River at Galena, MO

07053207 - Long Creek at Denver, AR

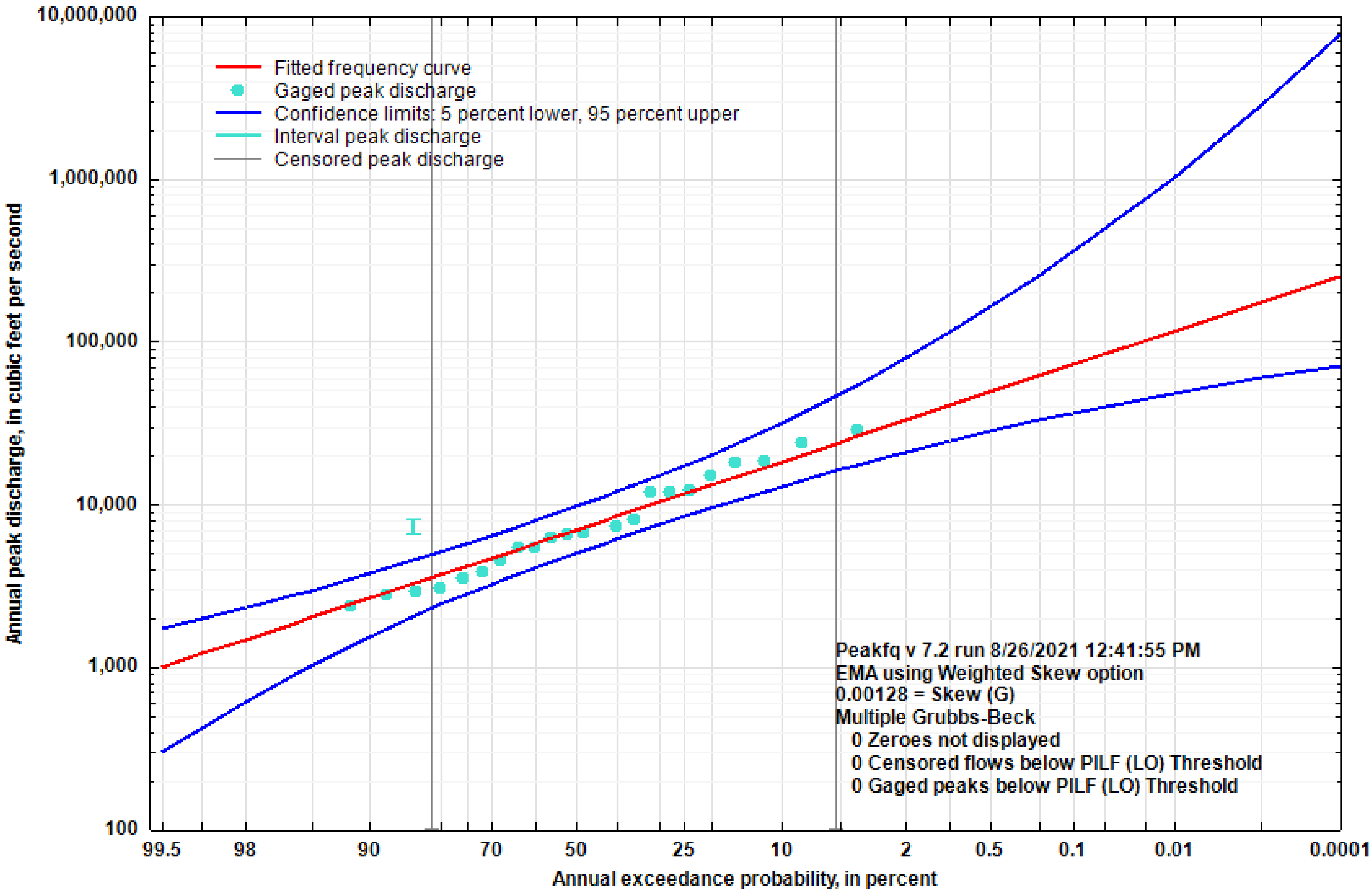


Figure 5-16. Flood Flow Frequency Curve for Long Creek at Denver, AR

07053250 - Yocum Creek near Oak Grove, AR

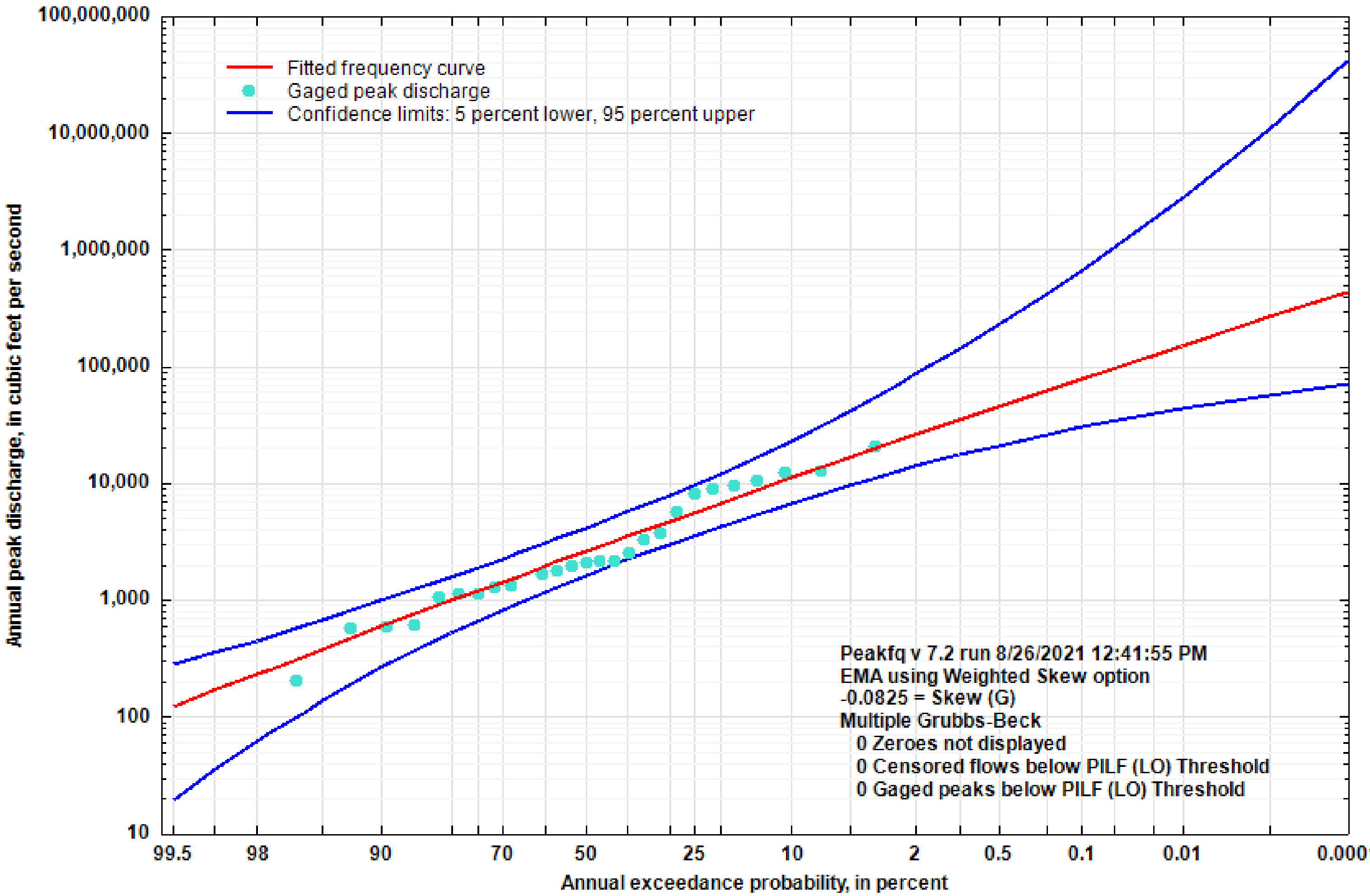


Figure 5-17. Flood Flow Frequency Curve for Yocum Creek near Oak Grove, AR

07053810 - Bull Creek near Walnut Shade, MO

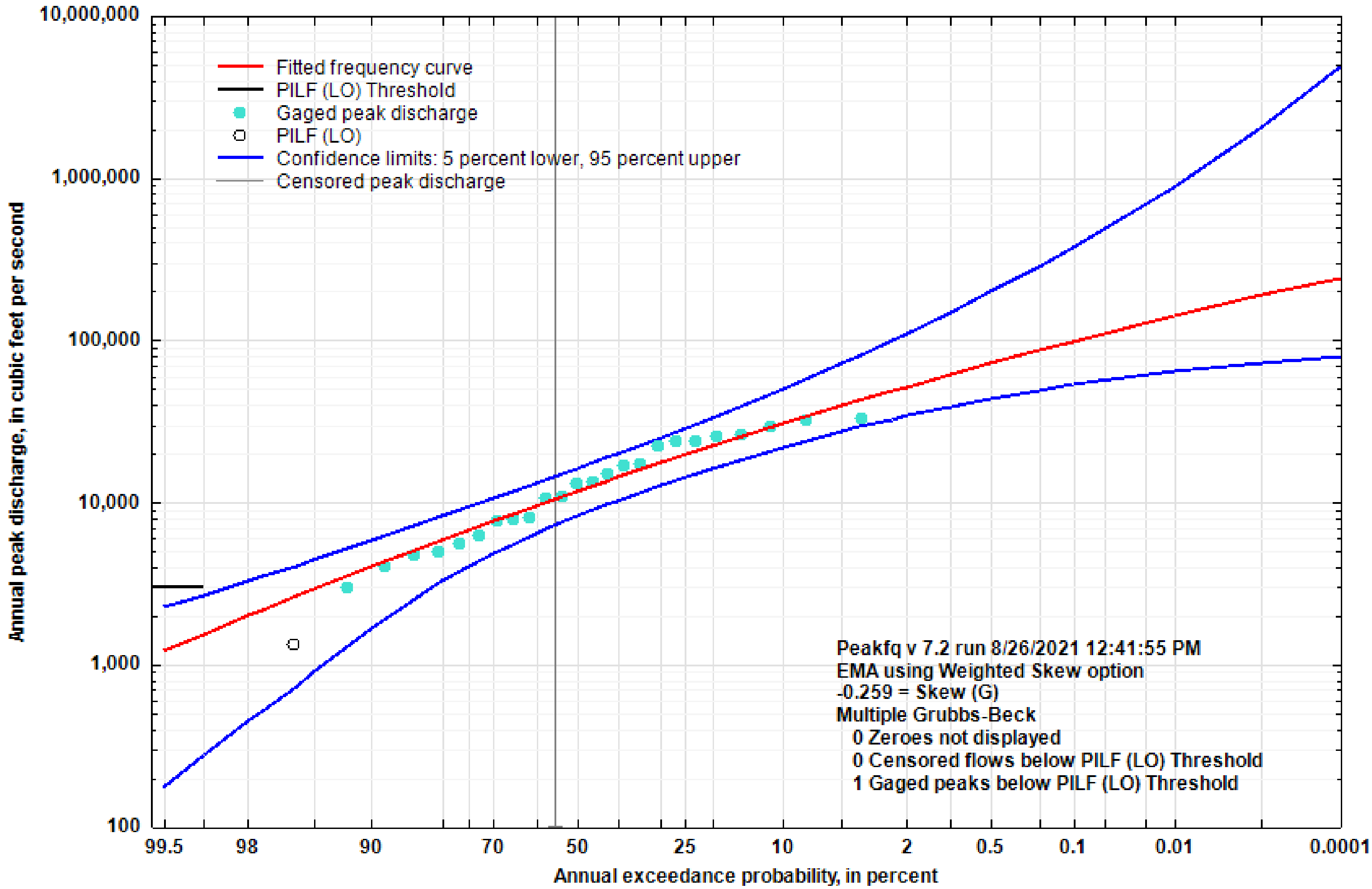


Figure 5-18. Flood Flow Frequency Curve for Bull Creek near Walnut Shade, MO

07053950 - Ingenthron Hollow near Forsyth, MO

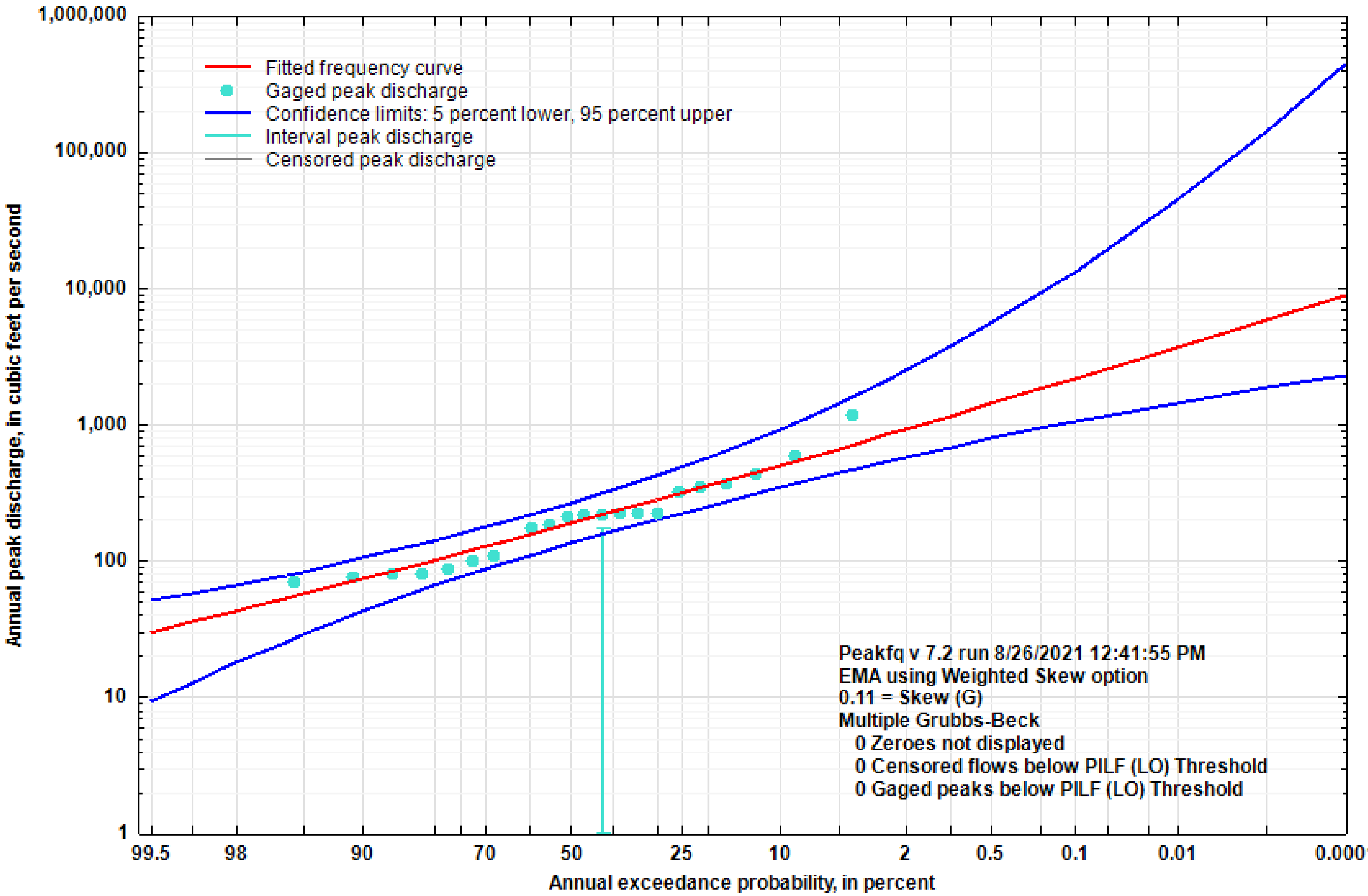


Figure 5-19. Flood Flow Frequency Curve for Ingenthron Hollow near Forsyth, MO

07054080 - Beaver Creek at Bradleyville, MO

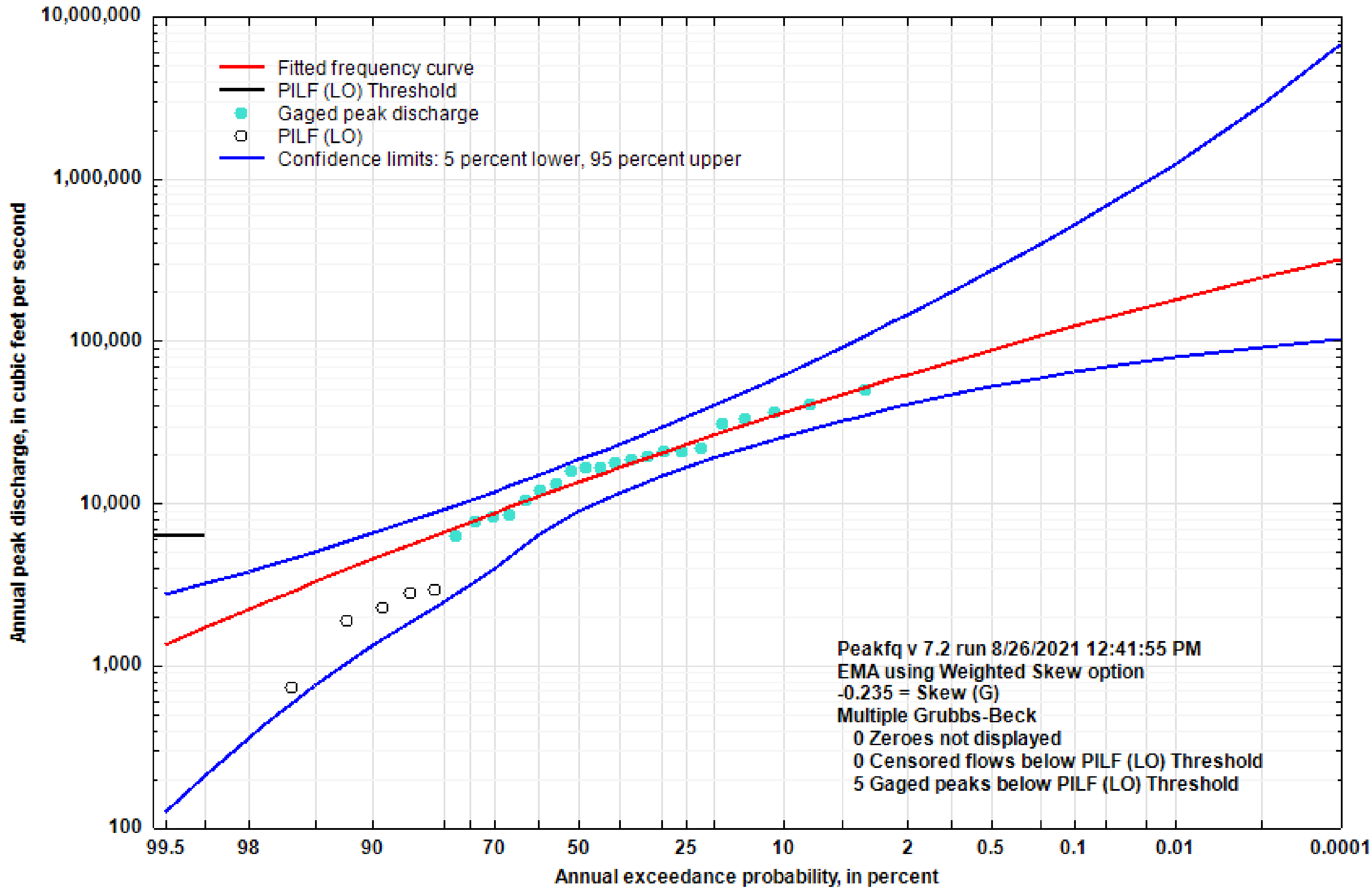


Figure 5-20. Flood Flow Frequency Curve for Beaver Creek at Bradleyville, MO

07054200 - Yanell Branch near Kirbyville, MO

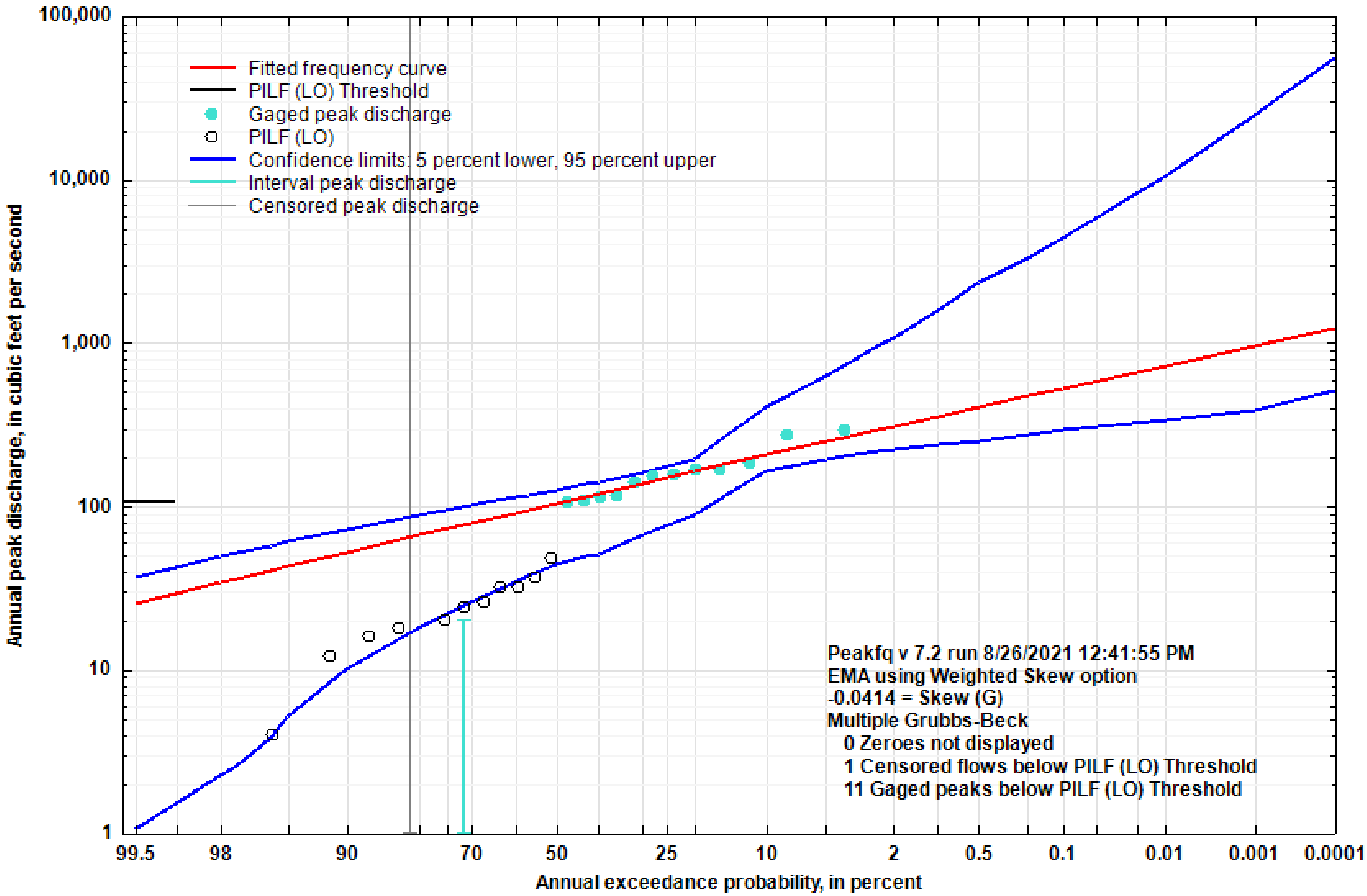


Figure 5-21. Flood Flow Frequency Curve for Yanell Branch near Kirbyville, MO

07054300 - Gray Branch at Lutie, MO

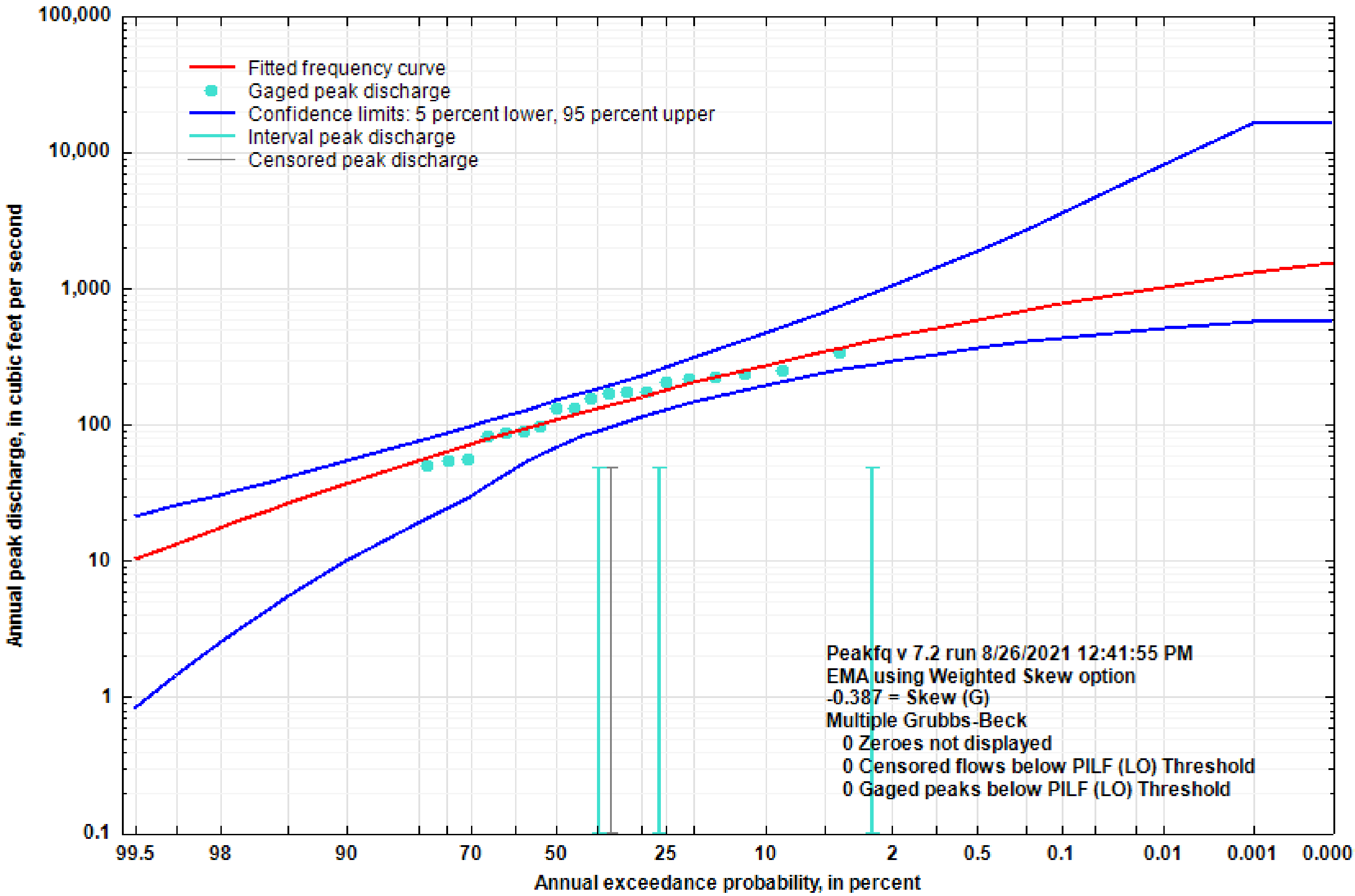


Figure 5-22. Flood Flow Frequency Curve for Gray Branch at Lutie, MO

07054400 - Charley Creek near Omaha, AR

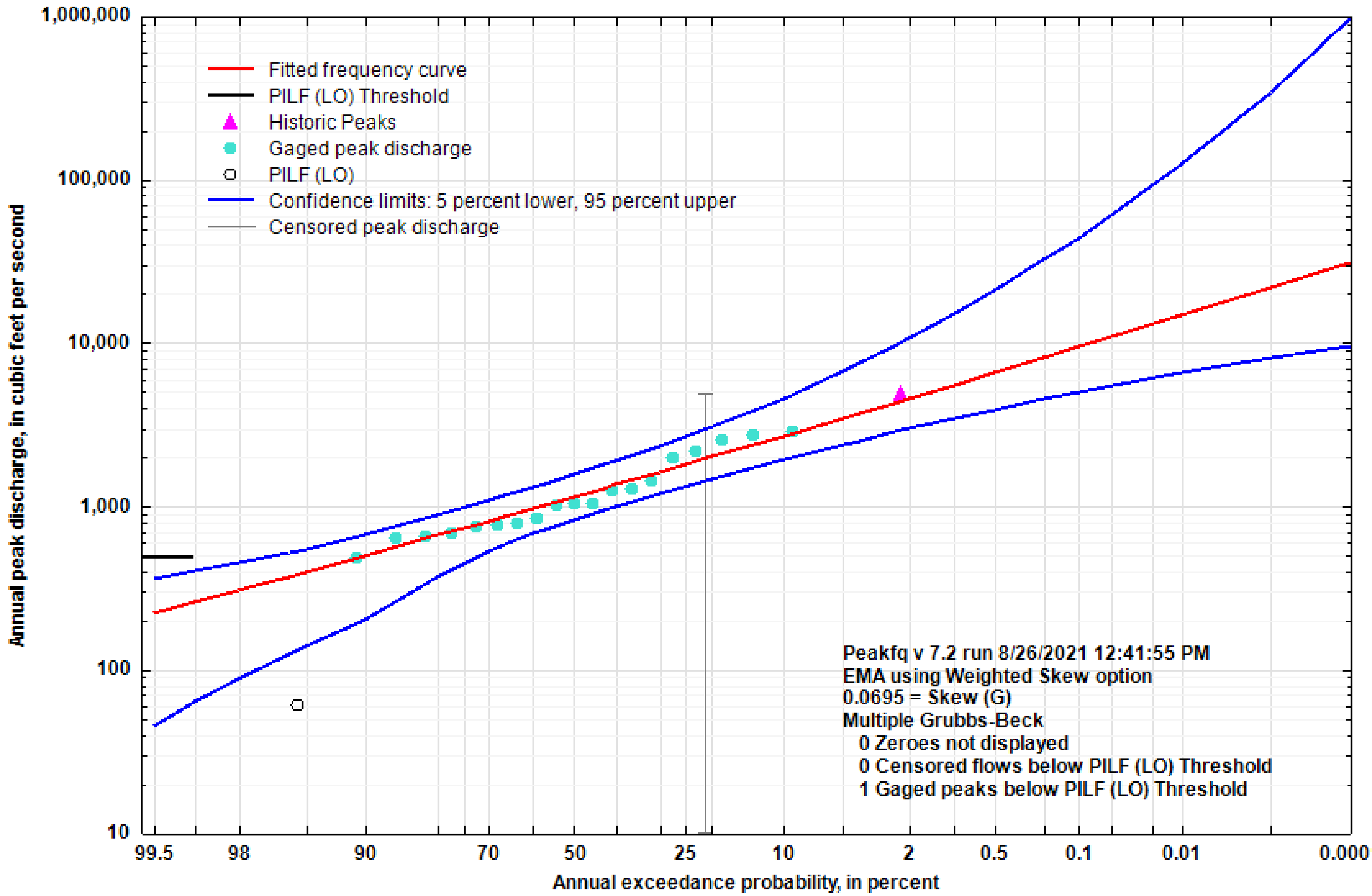


Figure 5-23. Flood Flow Frequency Curve for Charley Creek near Omaha, AR

07054410 - Bear Creek near Omaha, AR

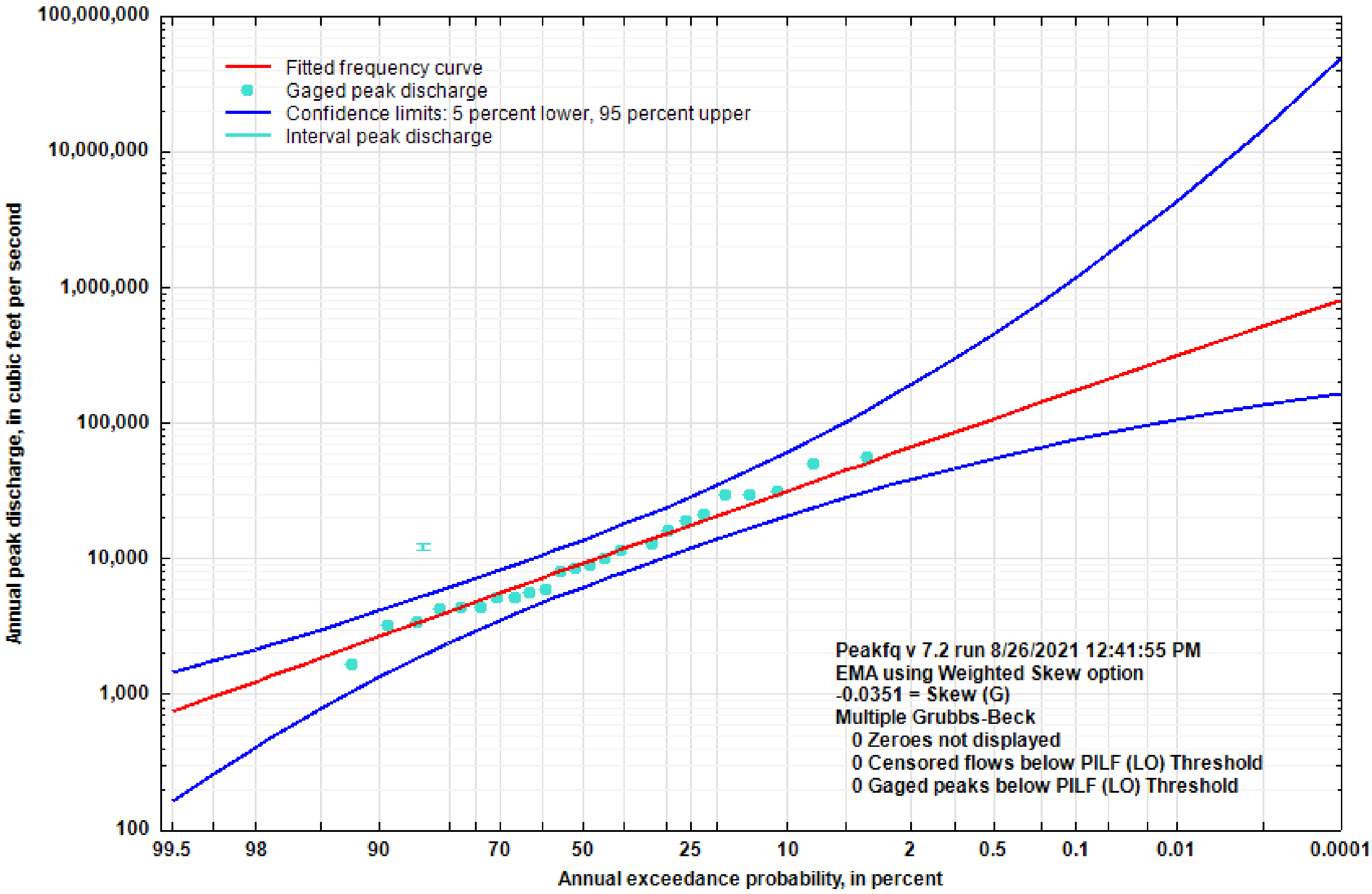


Figure 5-24. Flood Flow Frequency Curve for Bear Creek near Omaha, AR

07055550 - Crooked Creek Tributary near Dog Patch, AR

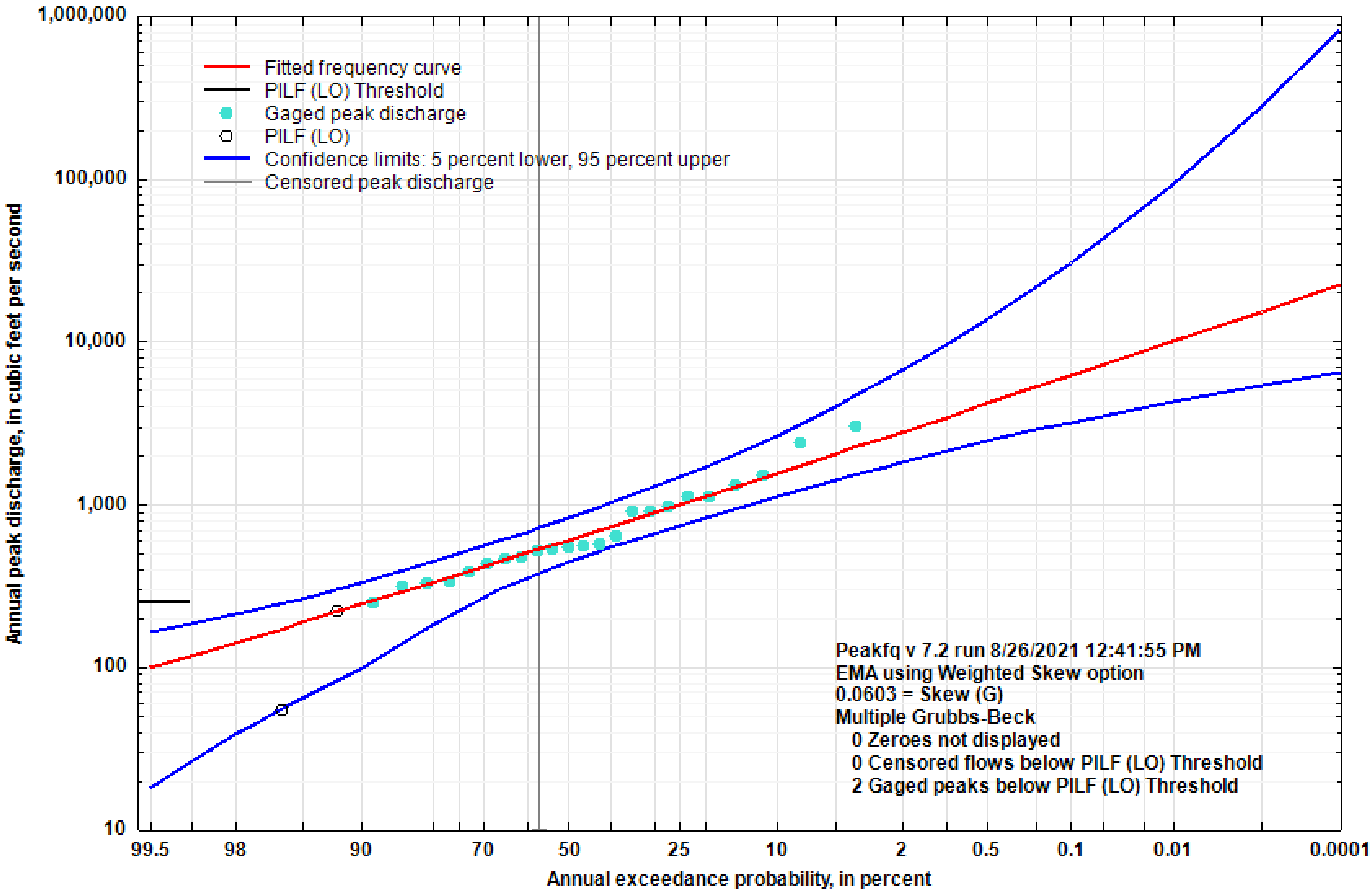


Figure 5-25. Flood Flow Frequency Curve for Crooked Creek Tributary near Dog Patch, AR

07055607 - Crooked Creek at Kelly Crossing at Yellville, AR

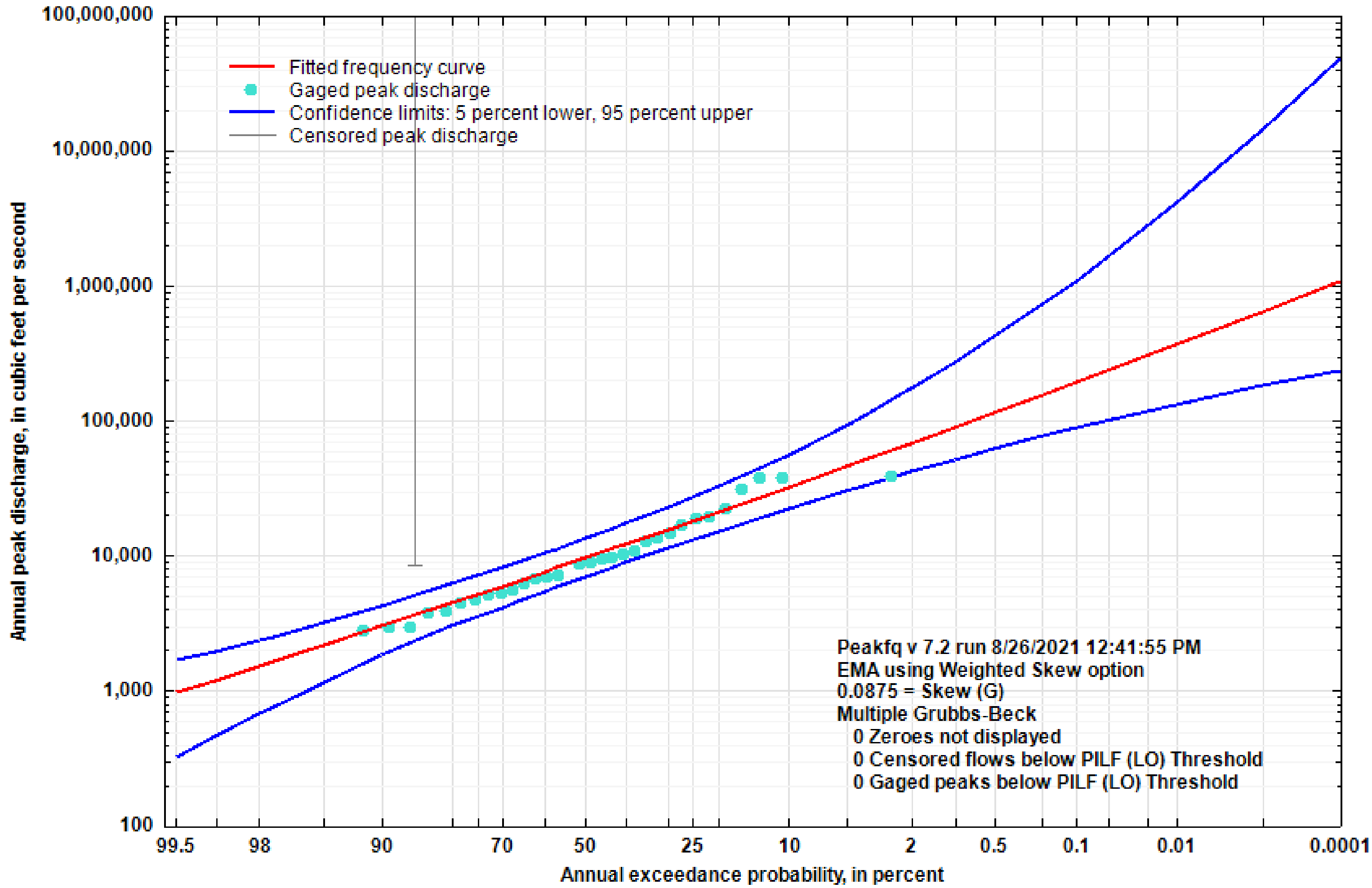


Figure 5-26. Flood Flow Frequency Curve for Crooked Creek at Kelly Crossing at Yellville, AR

07055646 - Buffalo River near Boxley, AR

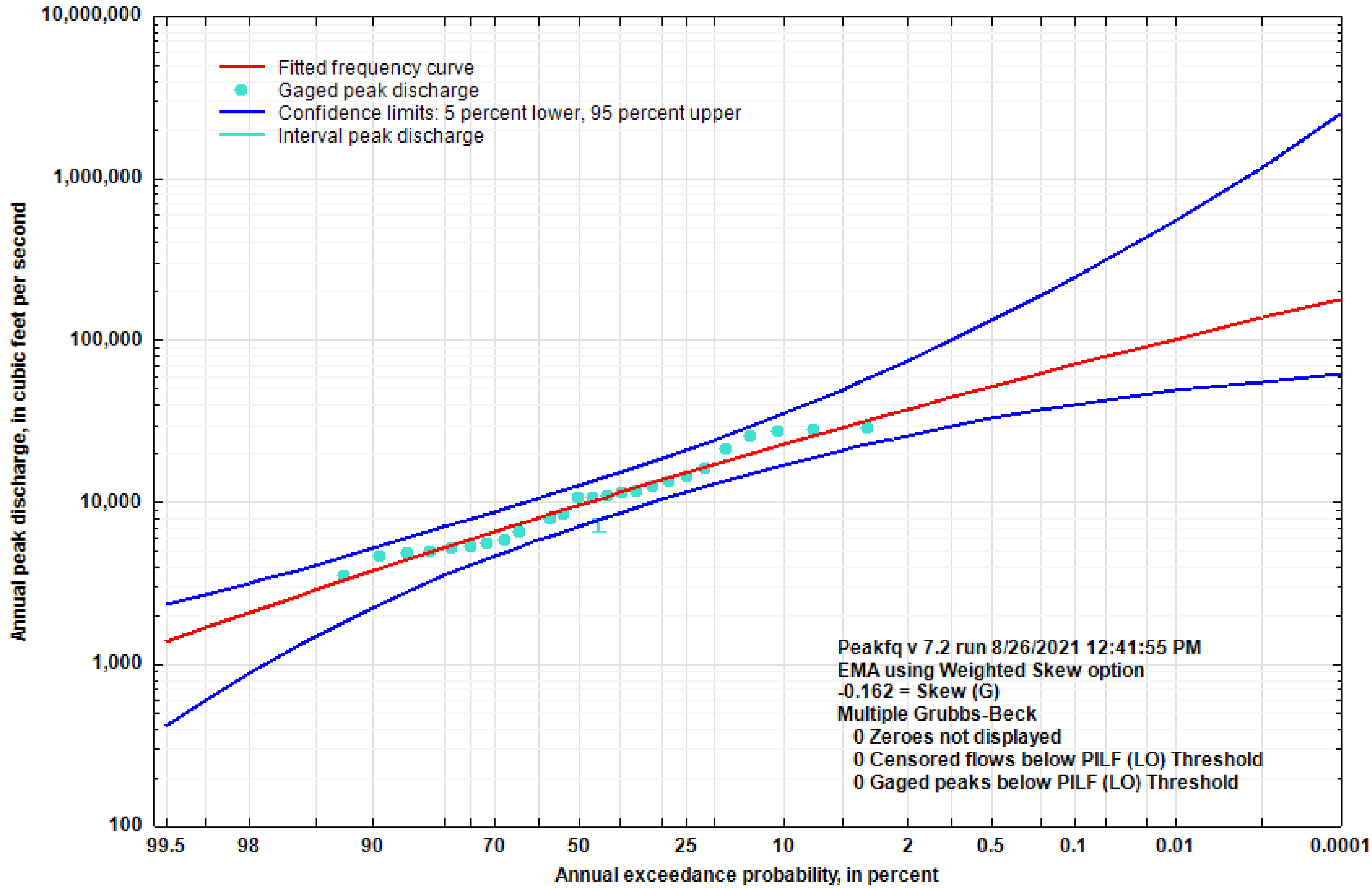


Figure 5-27. Flood Flow Frequency Curve for Buffalo River near Boxley, AR

07055650 - Smith Creek near Boxley, AR

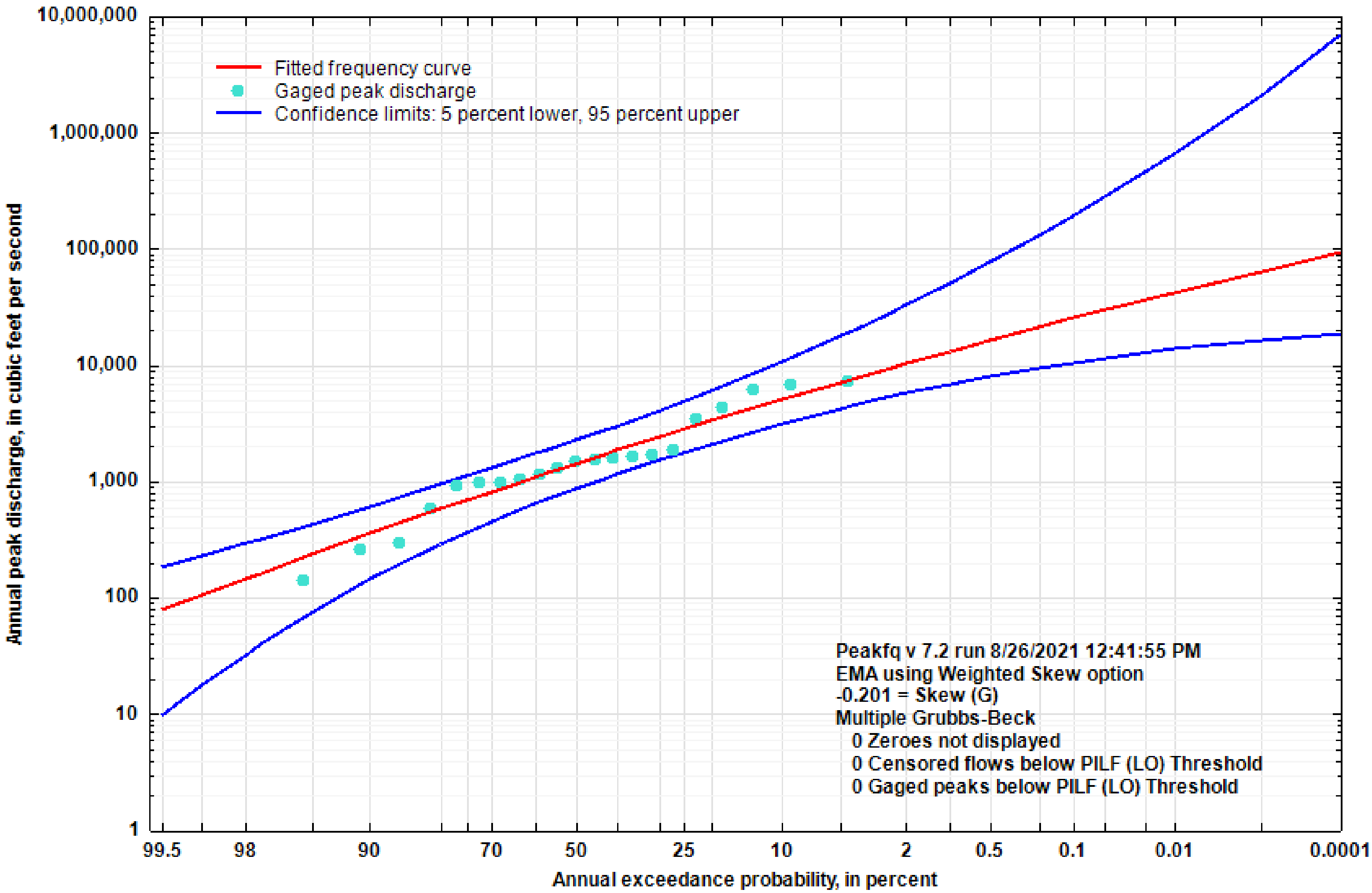


Figure 5-28. Flood Flow Frequency Curve for Smith Creek near Boxley, AR

07055800 - Dry Branch near Vendor, AR

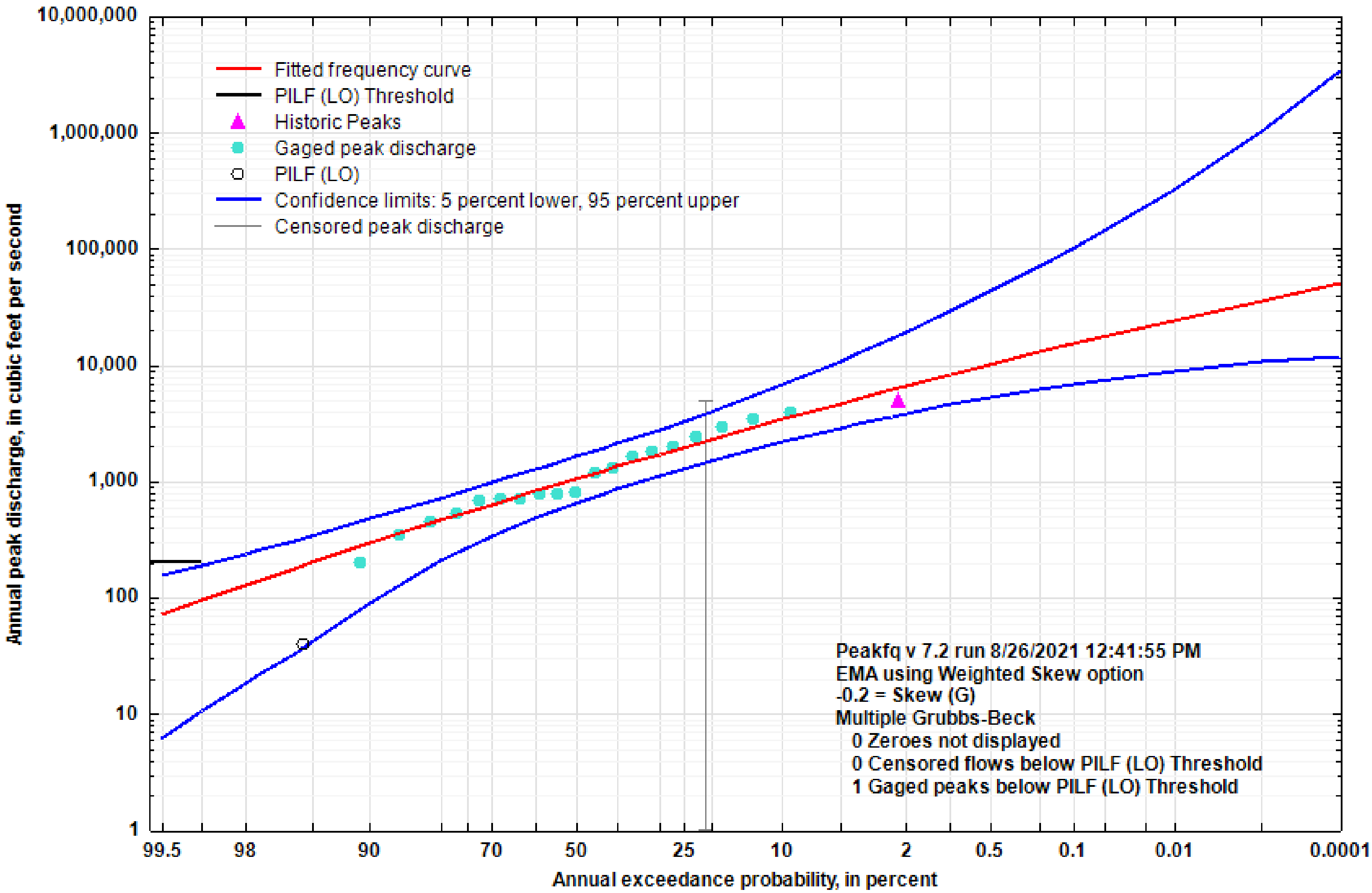


Figure 5-29. Flood Flow Frequency Curve for Dry Branch near Vendor, AR

07055875 - Richland Creek near Witts Spring, AR

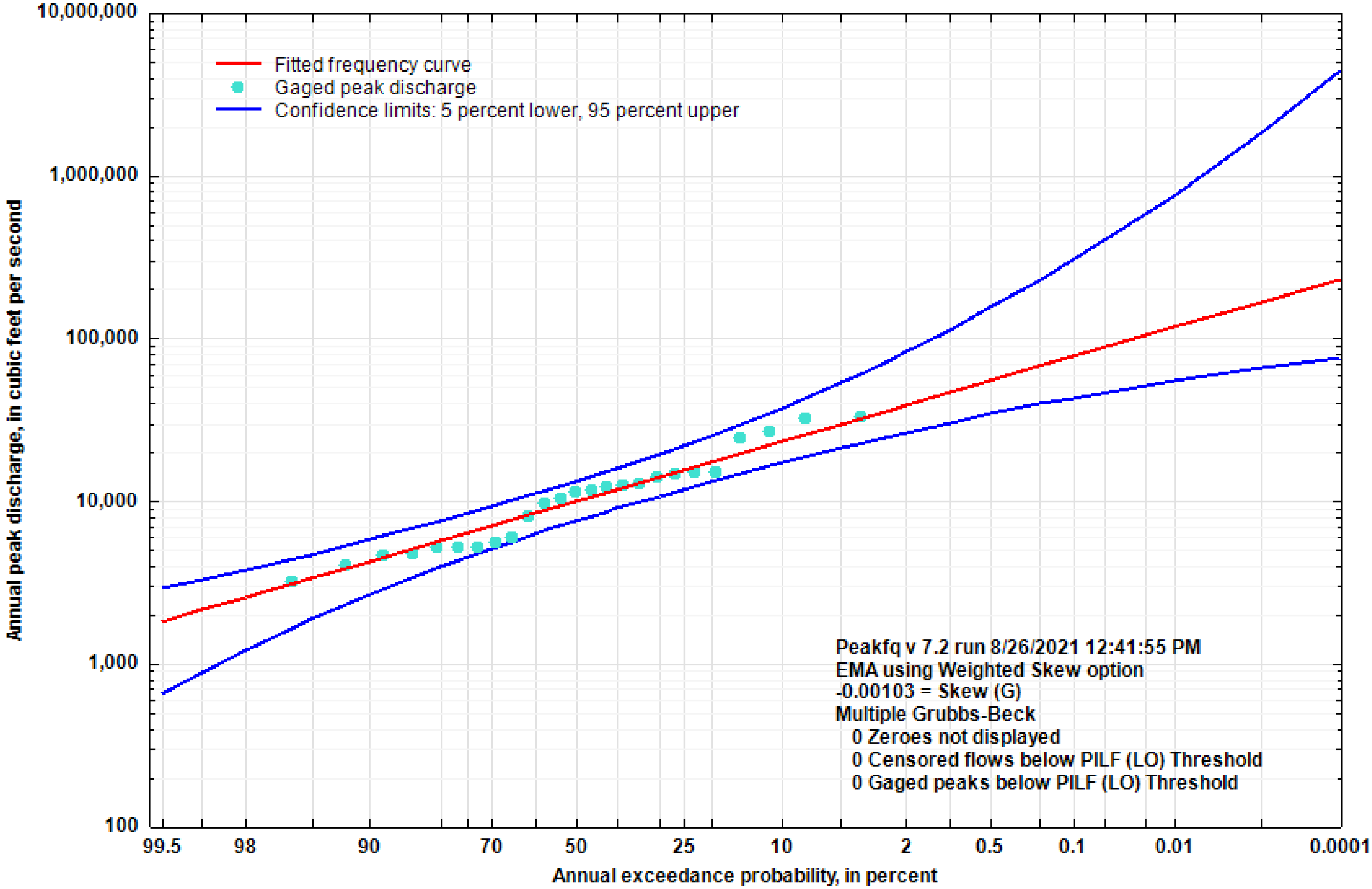


Figure 5-30. Flood Flow Frequency Curve for Richland Creek near Witts Spring, AR

07056000 - Buffalo River near St. Joe, AR

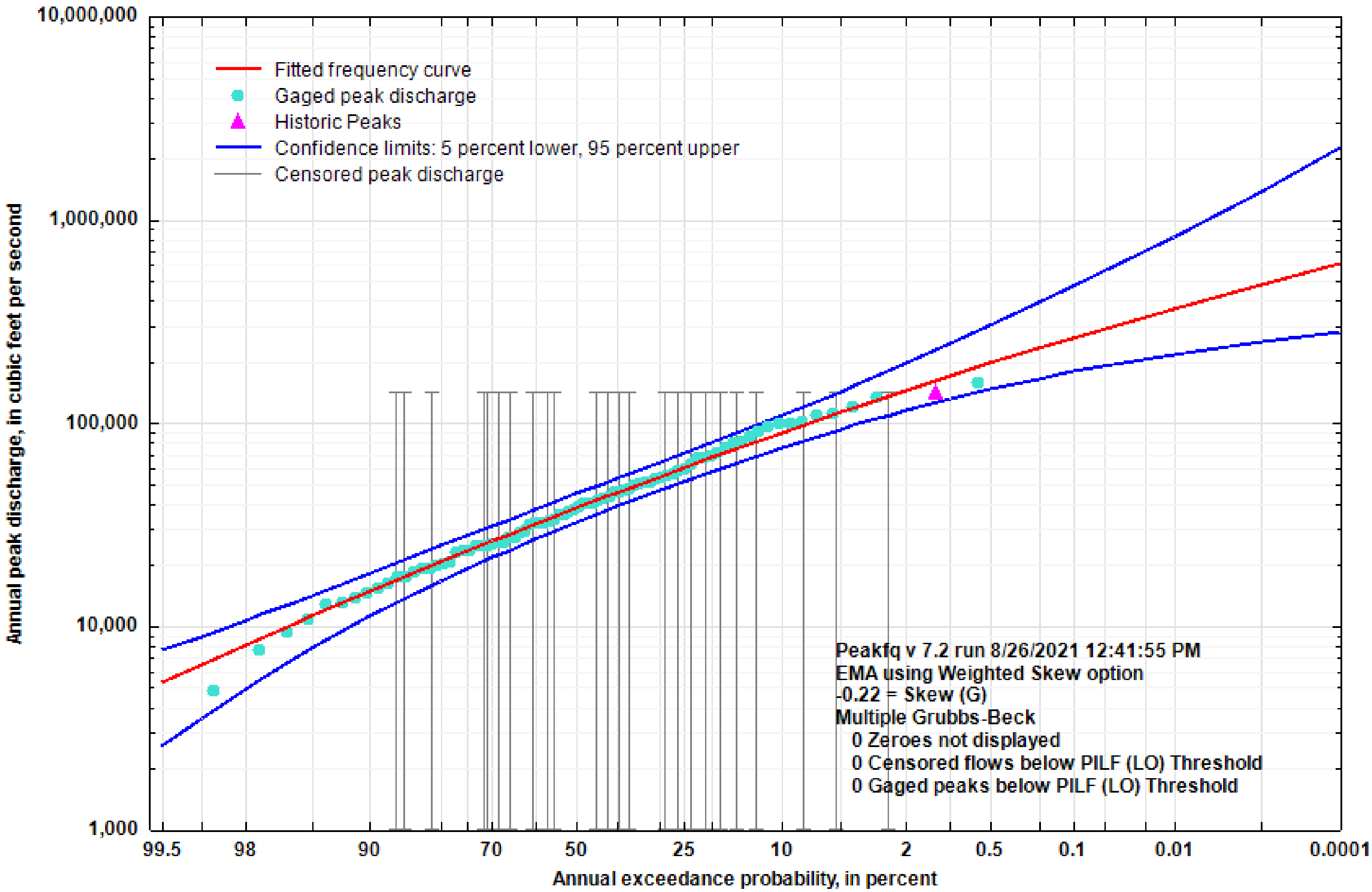


Figure 5-31. Flood Flow Frequency Curve for Buffalo River near St. Joe, AR

07056515 - Bear Creek near Silver Hill, AR

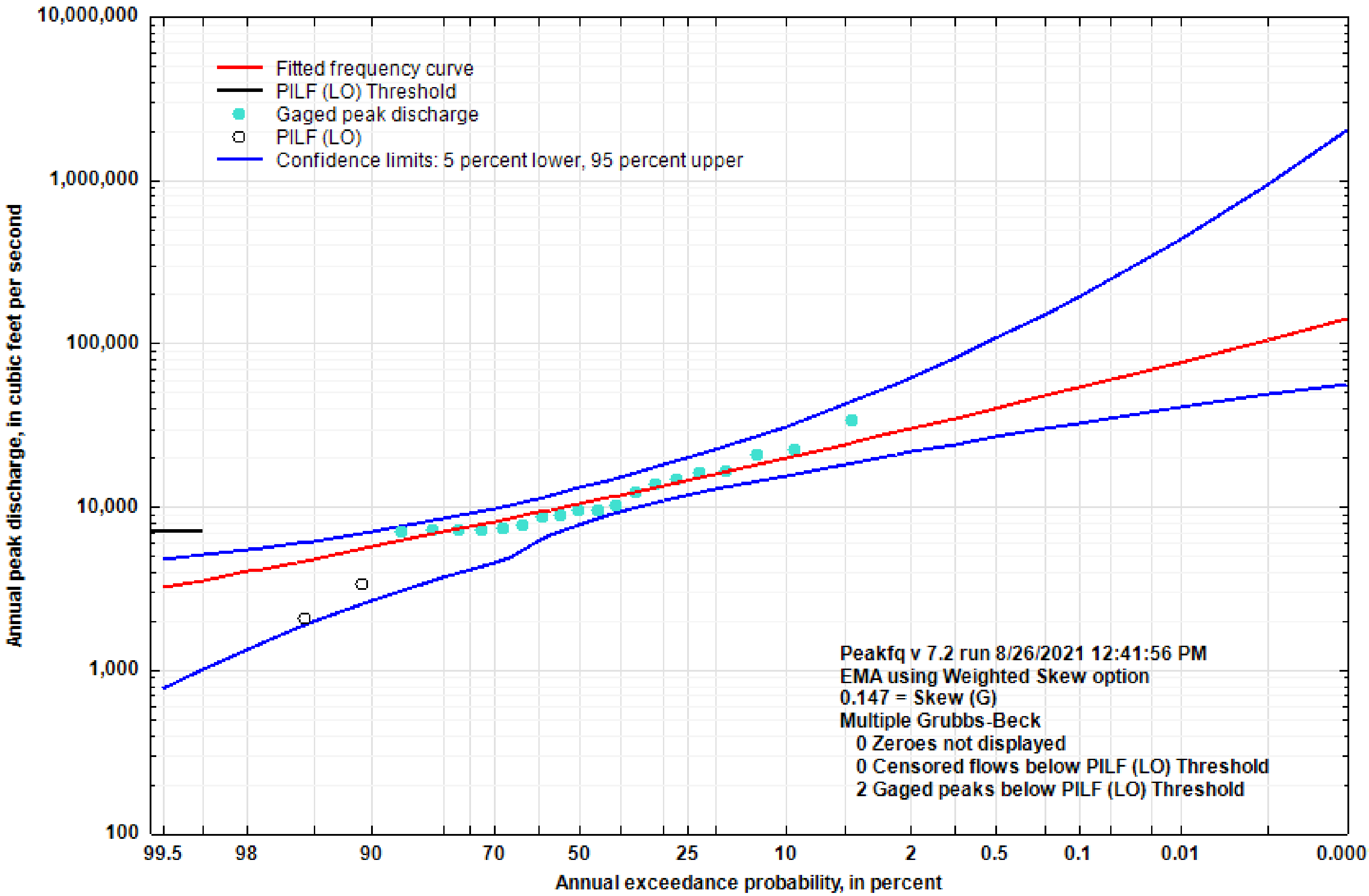


Figure 5-32. Flood Flow Frequency Curve for Bear Creek near Silver Hill, AR

07057300 - Dodd Creek Tributary near Mountain Home, AR

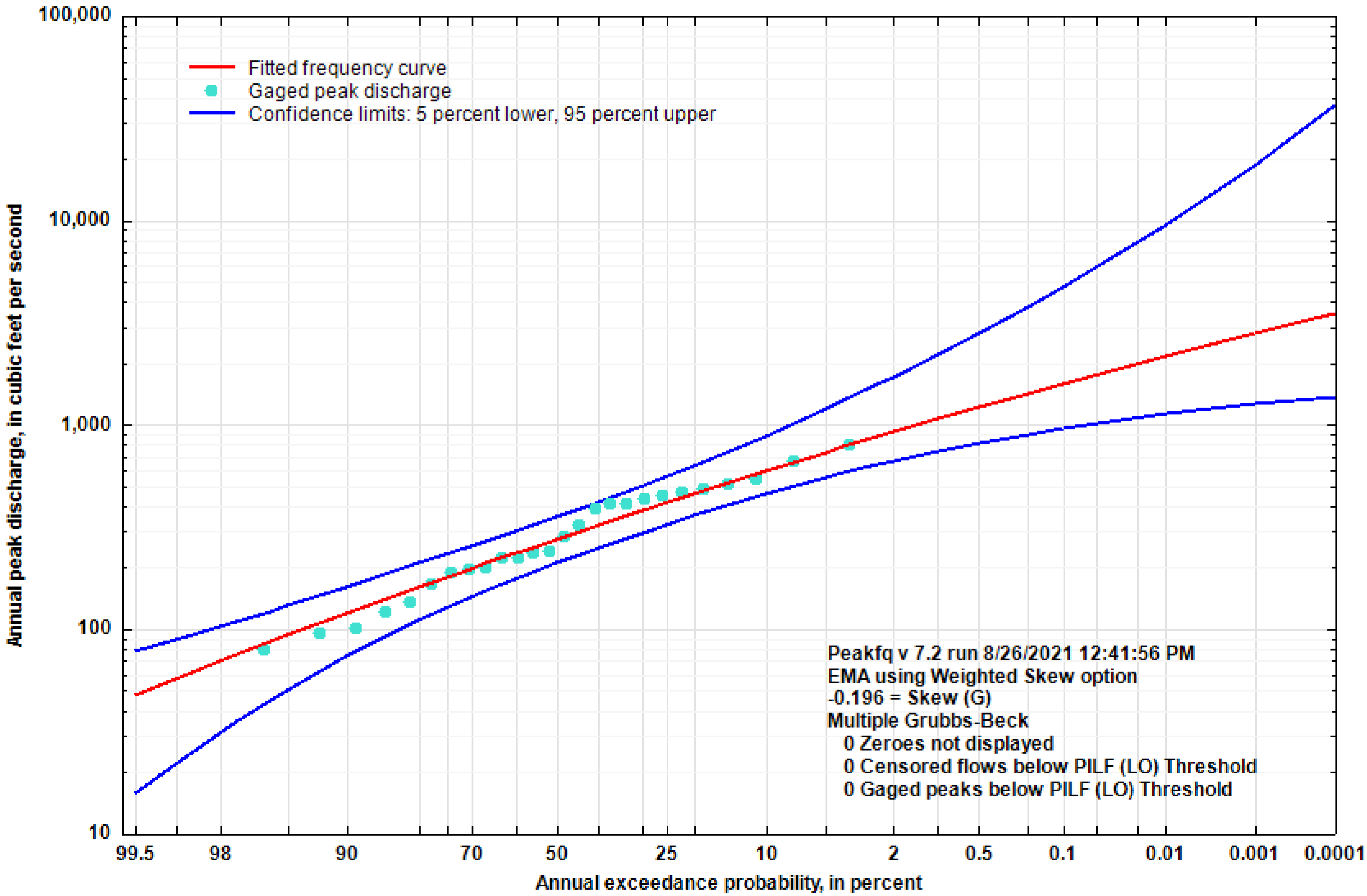


Figure 5-33. Flood Flow Frequency Curve for Dodd Creek Tributary near Mountain Home, AR

07057500 - North Fork River near Tecumseh, MO

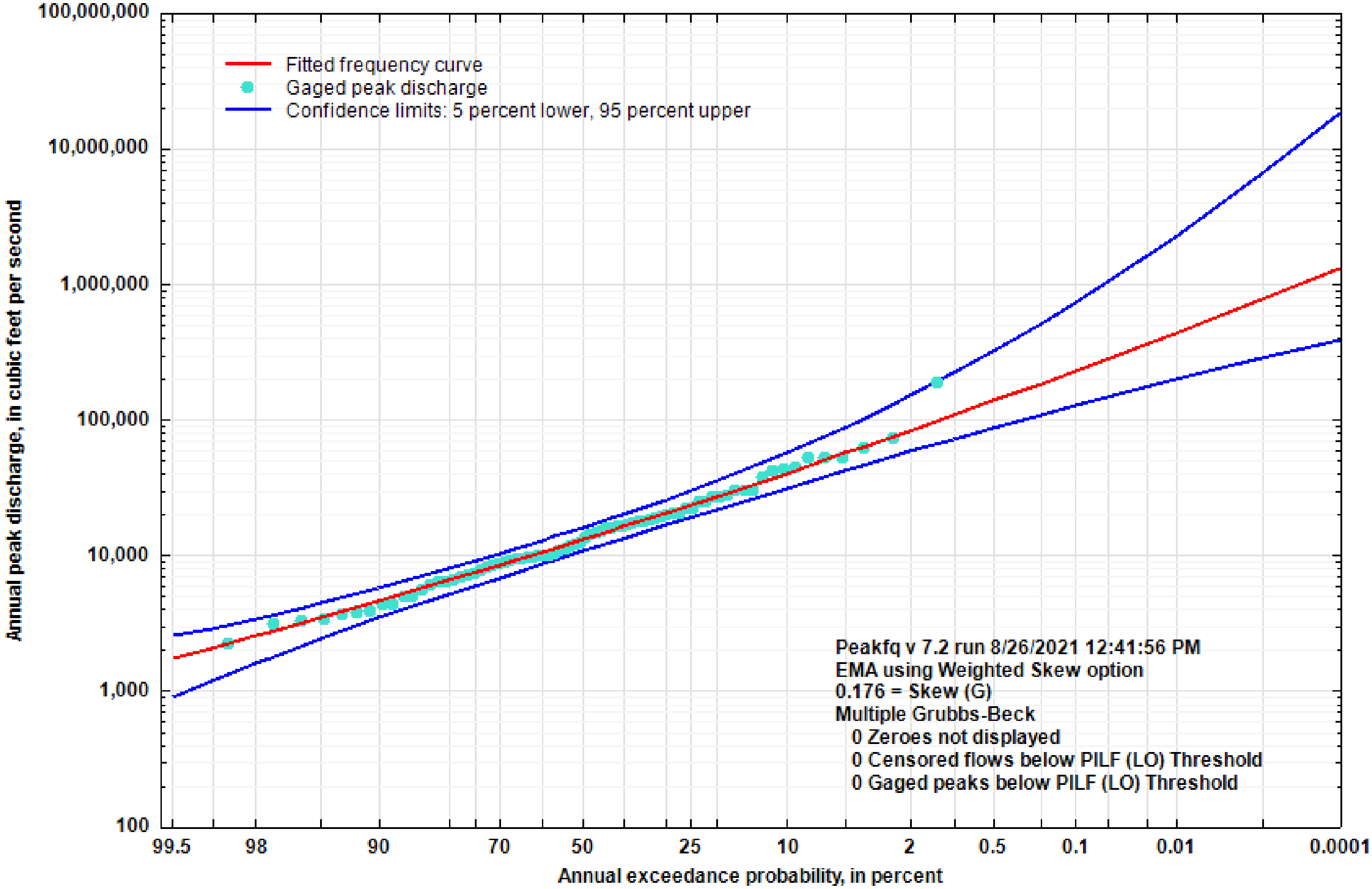


Figure 5-34. Flood Flow Frequency Curve for North Fork River near Tecumseh, MO

07058000 - Bryant Creek near Tecumseh, MO

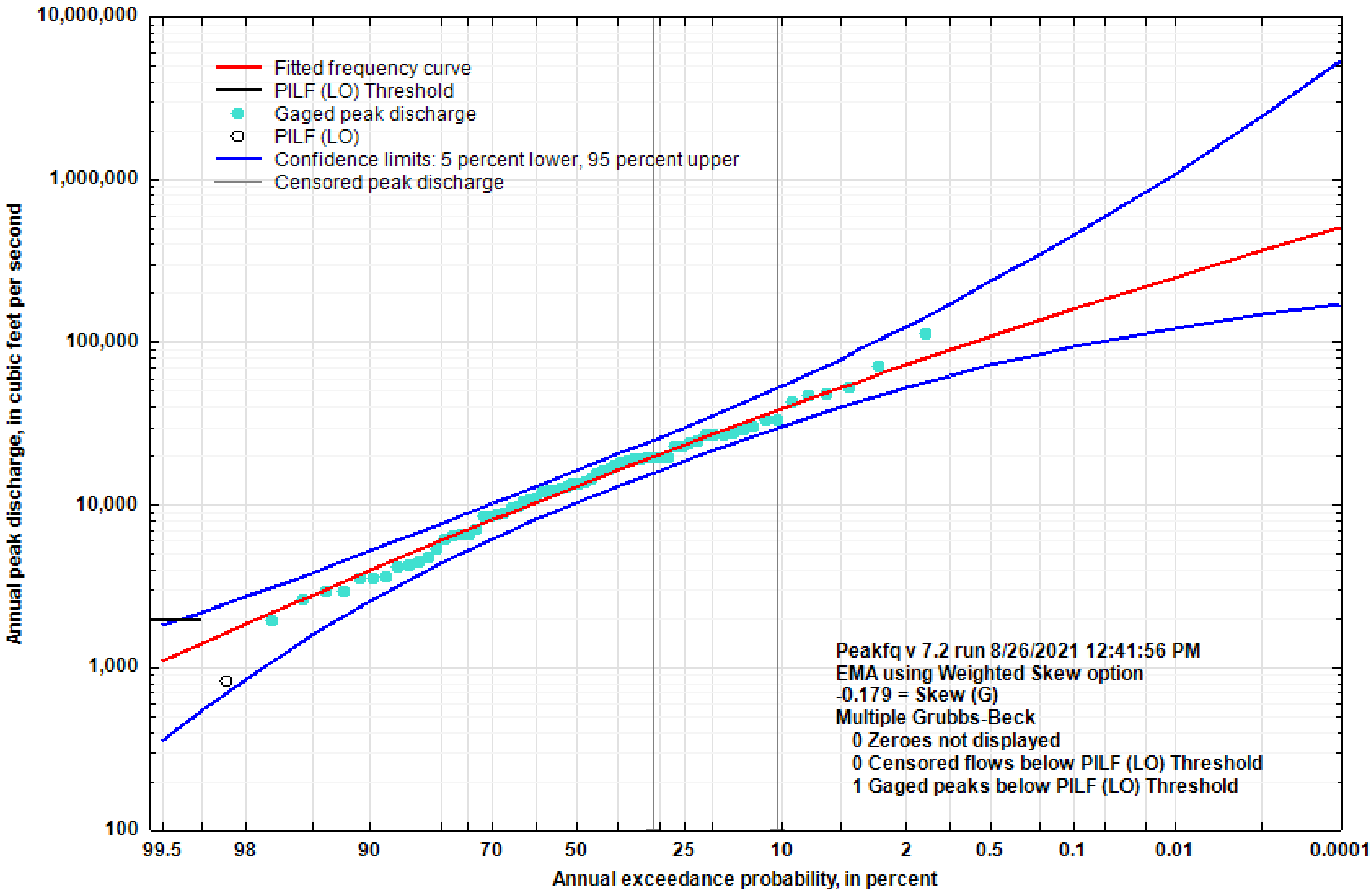


Figure 5-35. Flood Flow Frequency Curve for Bryant Creek near Tecumseh, MO

07058980 - Bennetts River at Vidette, AR

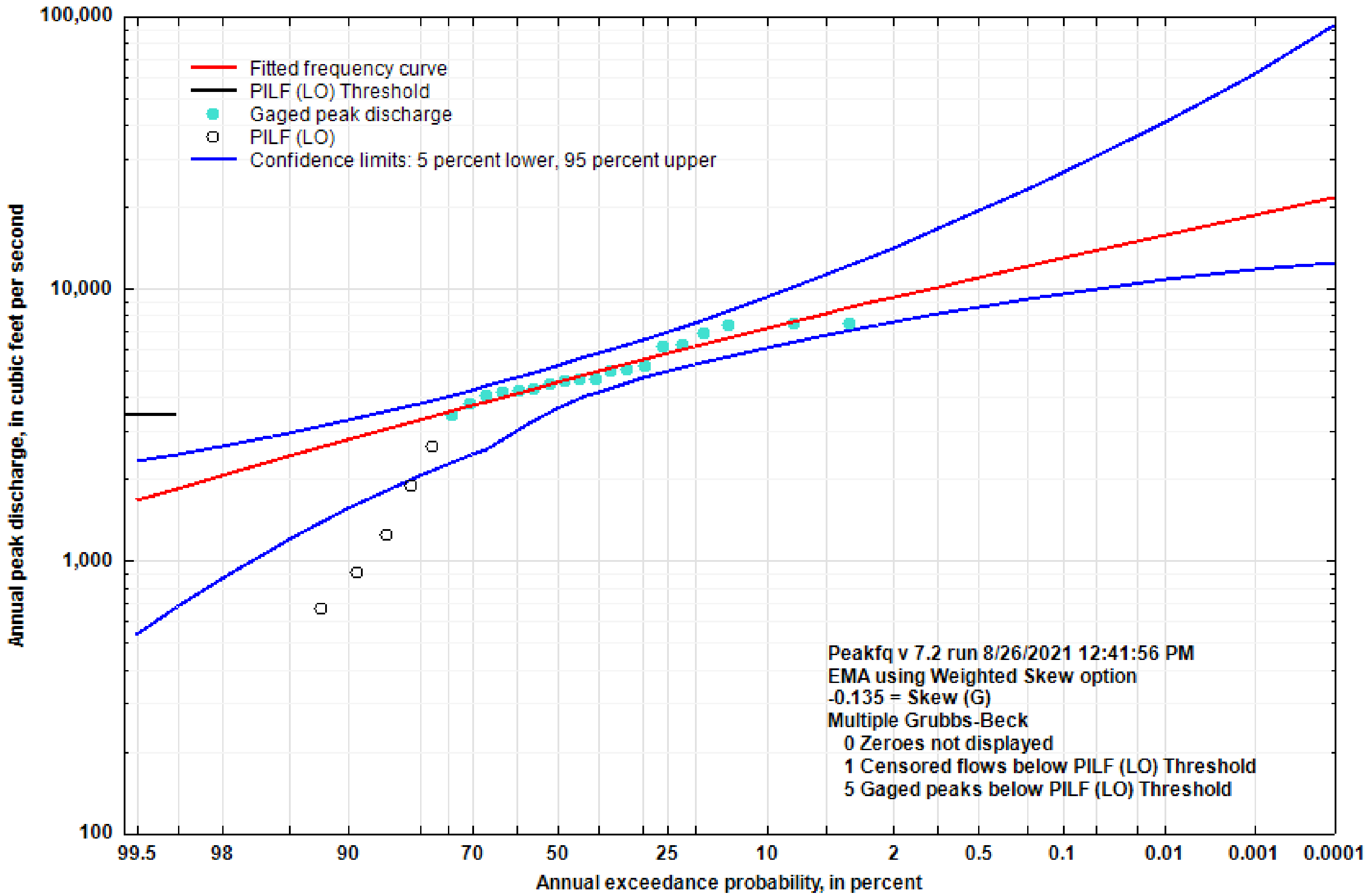


Figure 5-36. Flood Flow Frequency Curve for Bennetts River at Vidette, AR

07059450 - Big Creek near Elizabeth, AR

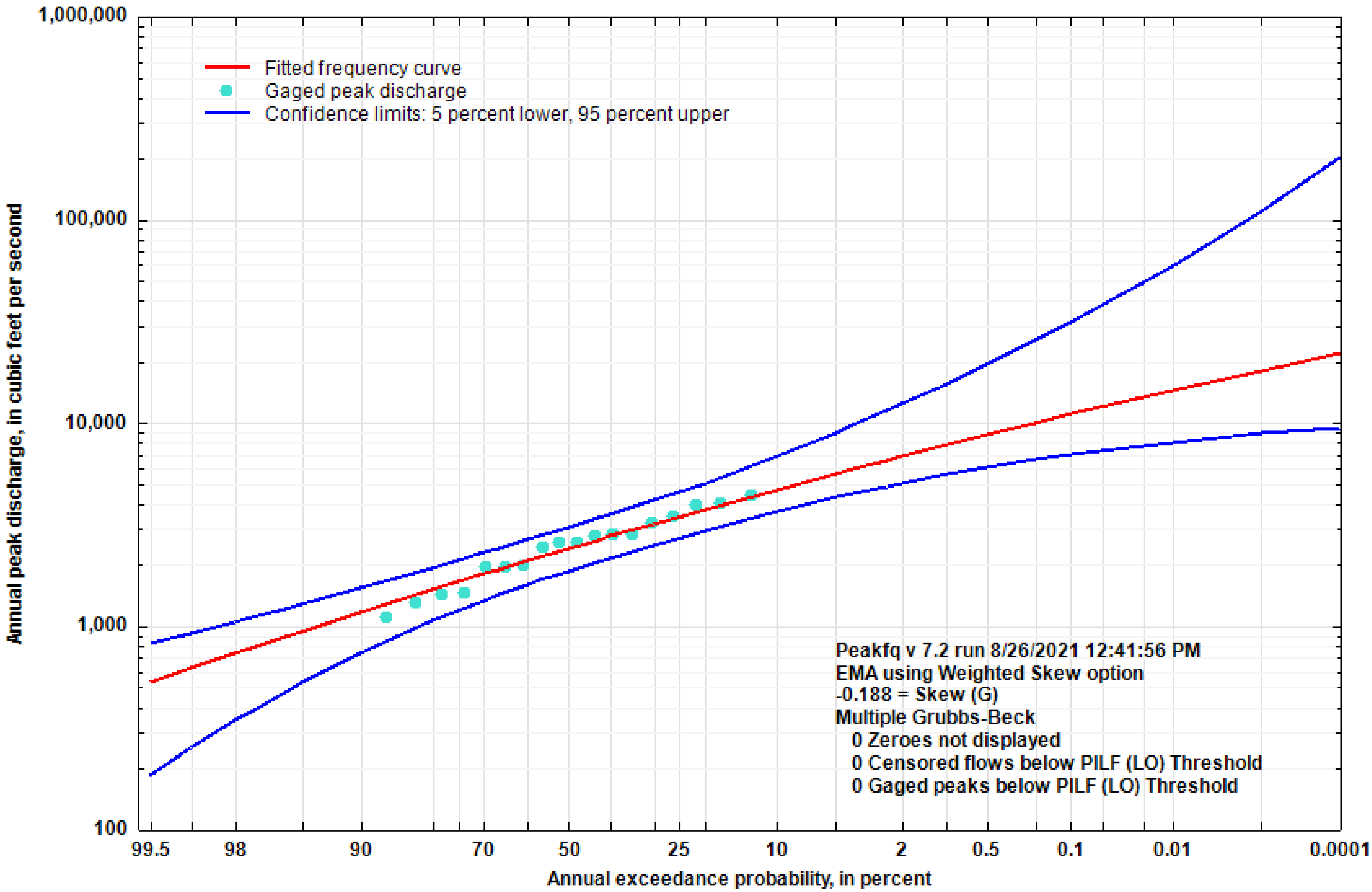


Figure 5-37. Flood Flow Frequency Curve for Big Creek near Elizabeth, AR

07060600 - Band Mill Creek near Brockwell, AR

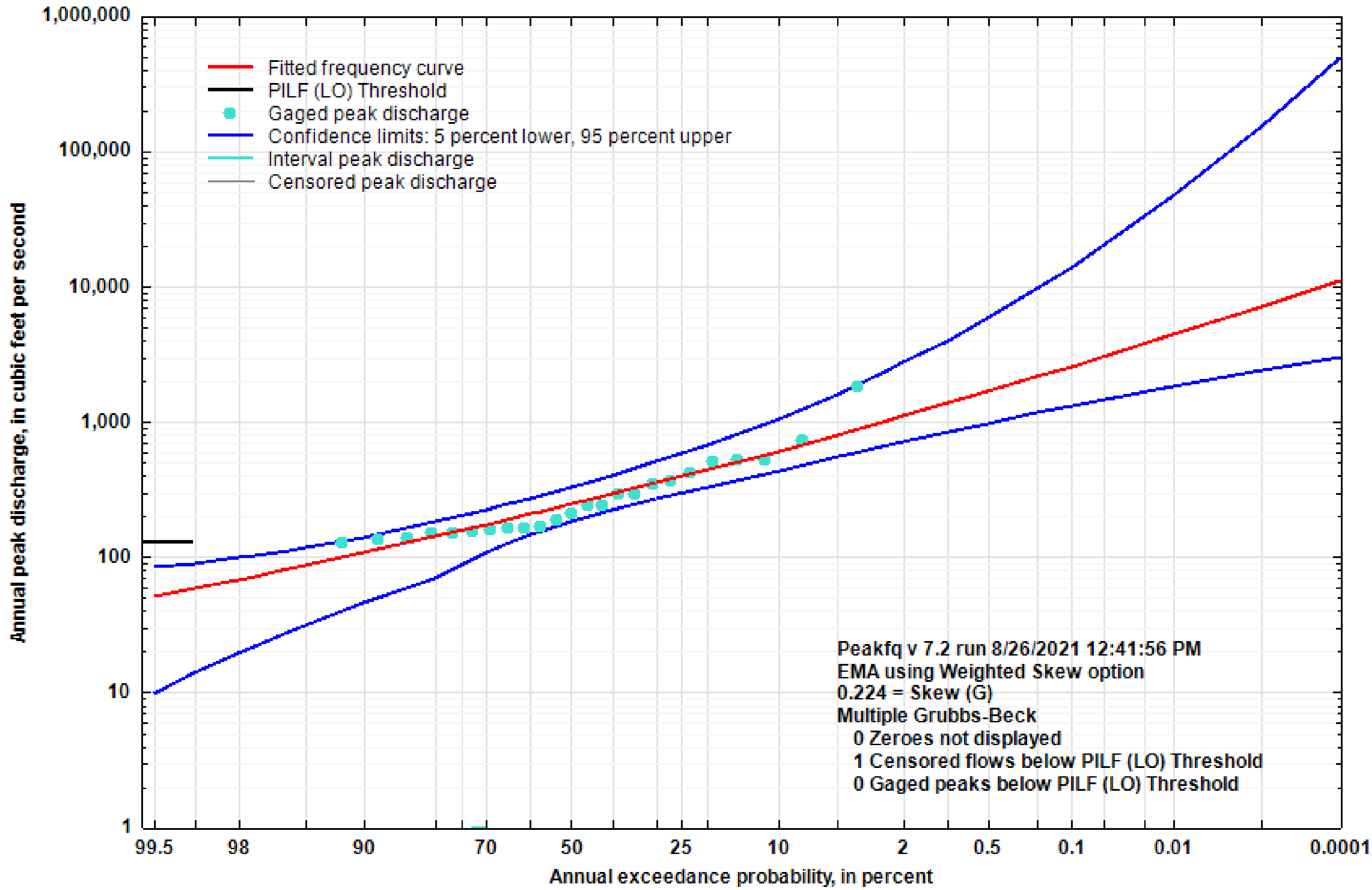


Figure 5-38. Flood Flow Frequency Curve for Band Mill Creek near Brockwell, AR

07060670 - Hughes Creek near Mountain View, AR

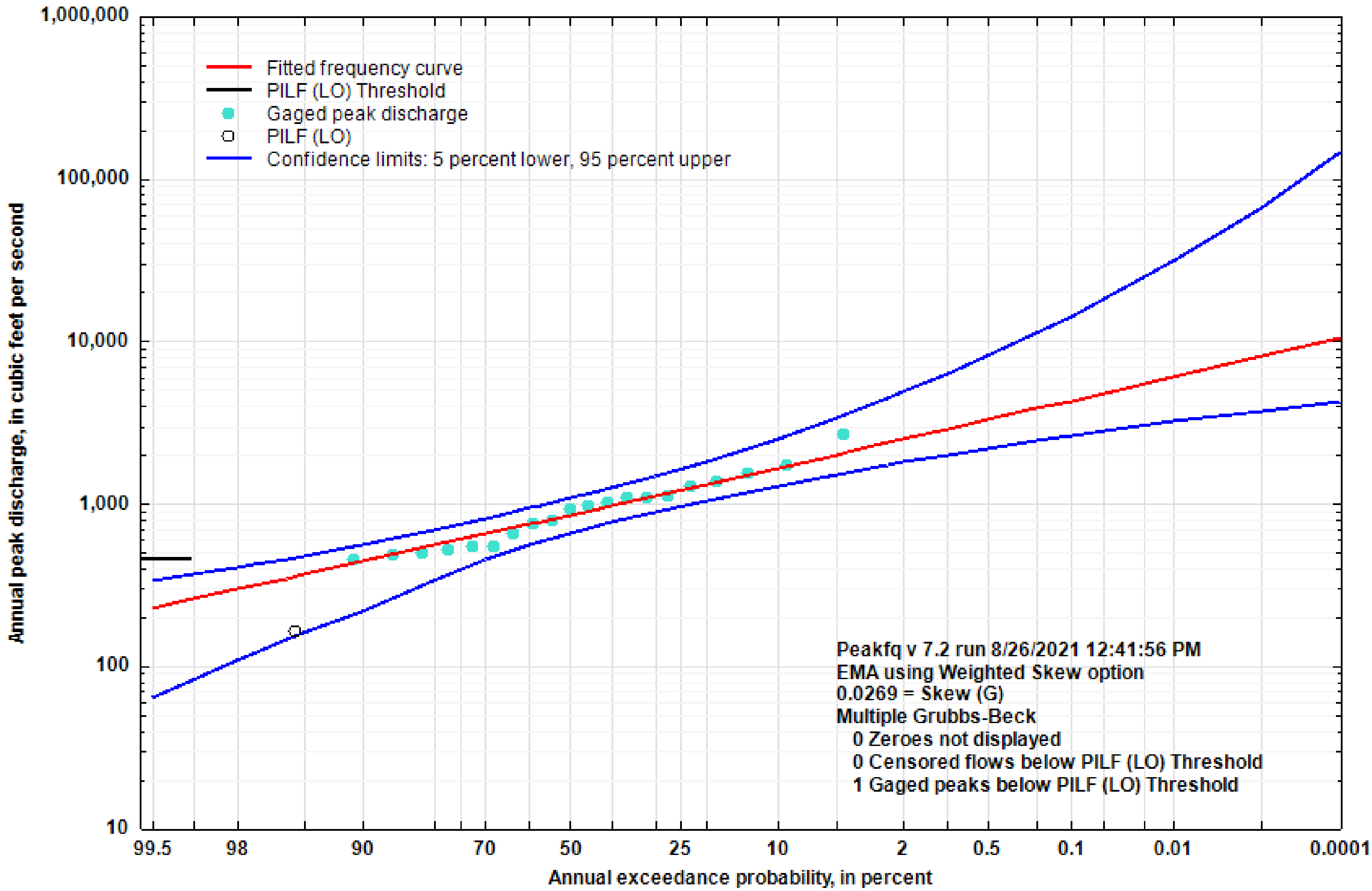


Figure 5-39. Flood Flow Frequency Curve for Hughes Creek near Mountain View, AR

07060710 - North Sylamore Creek near Fifty Six, AR

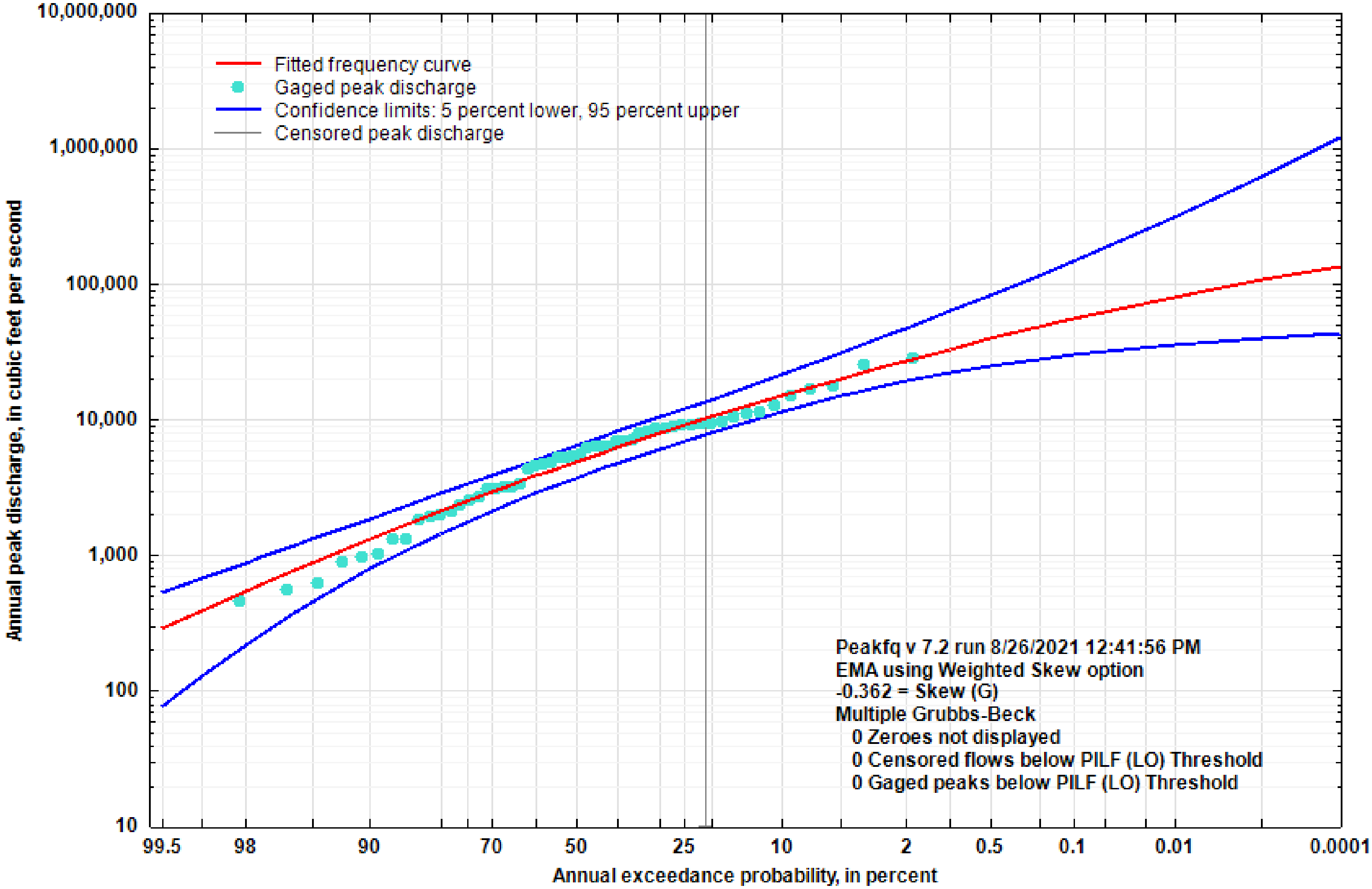


Figure 5-40. Flood Flow Frequency Curve for North Sylamore Creek near Fifty Six, AR

07060830 - Wolf Bayou near Drasco, AR

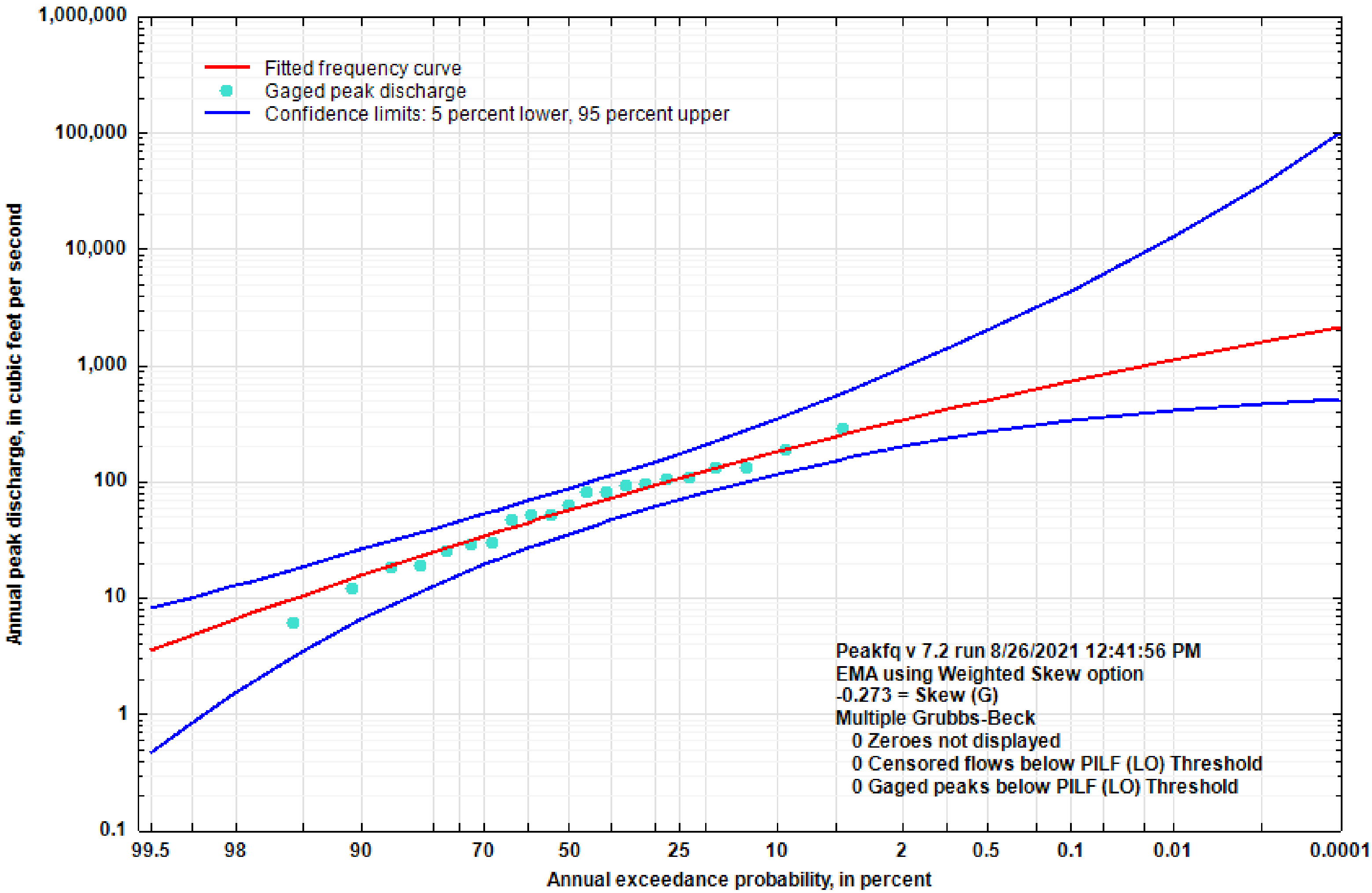


Figure 5-41. Flood Flow Frequency Curve for Wolf Bayou near Drasco, AR

07061100 - Gibbs Creek at Sulphur Rock, AR

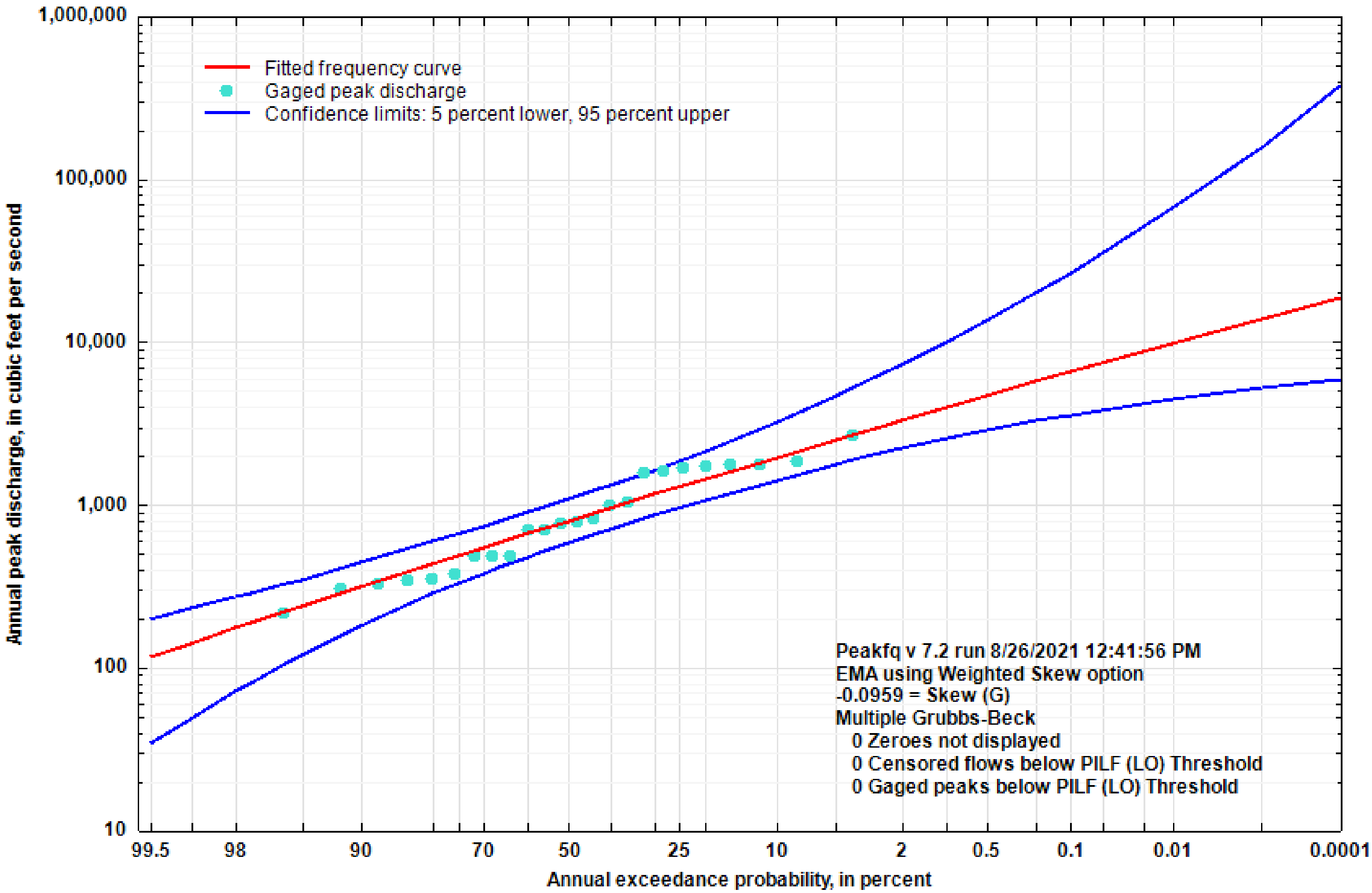


Figure 5-42. Flood Flow Frequency Curve for Gibbs Creek at Sulphur Rock, AR

07061260 - East Fork Black River near Ironton, MO

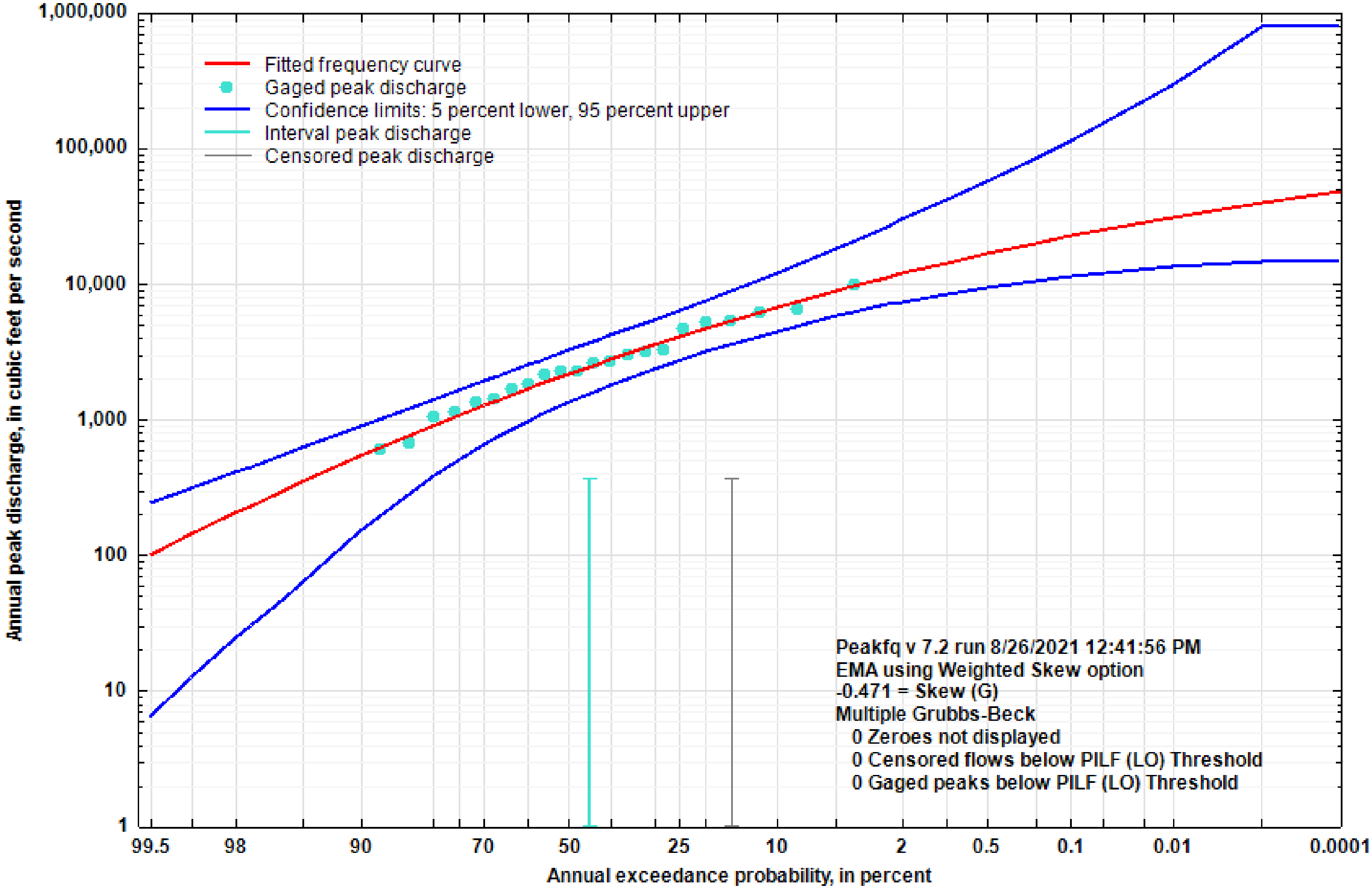


Figure 5-43. Flood Flow Frequency Curve for East Fork Black River near Ironton, MO

07061500 - Black River near Annapolis, MO

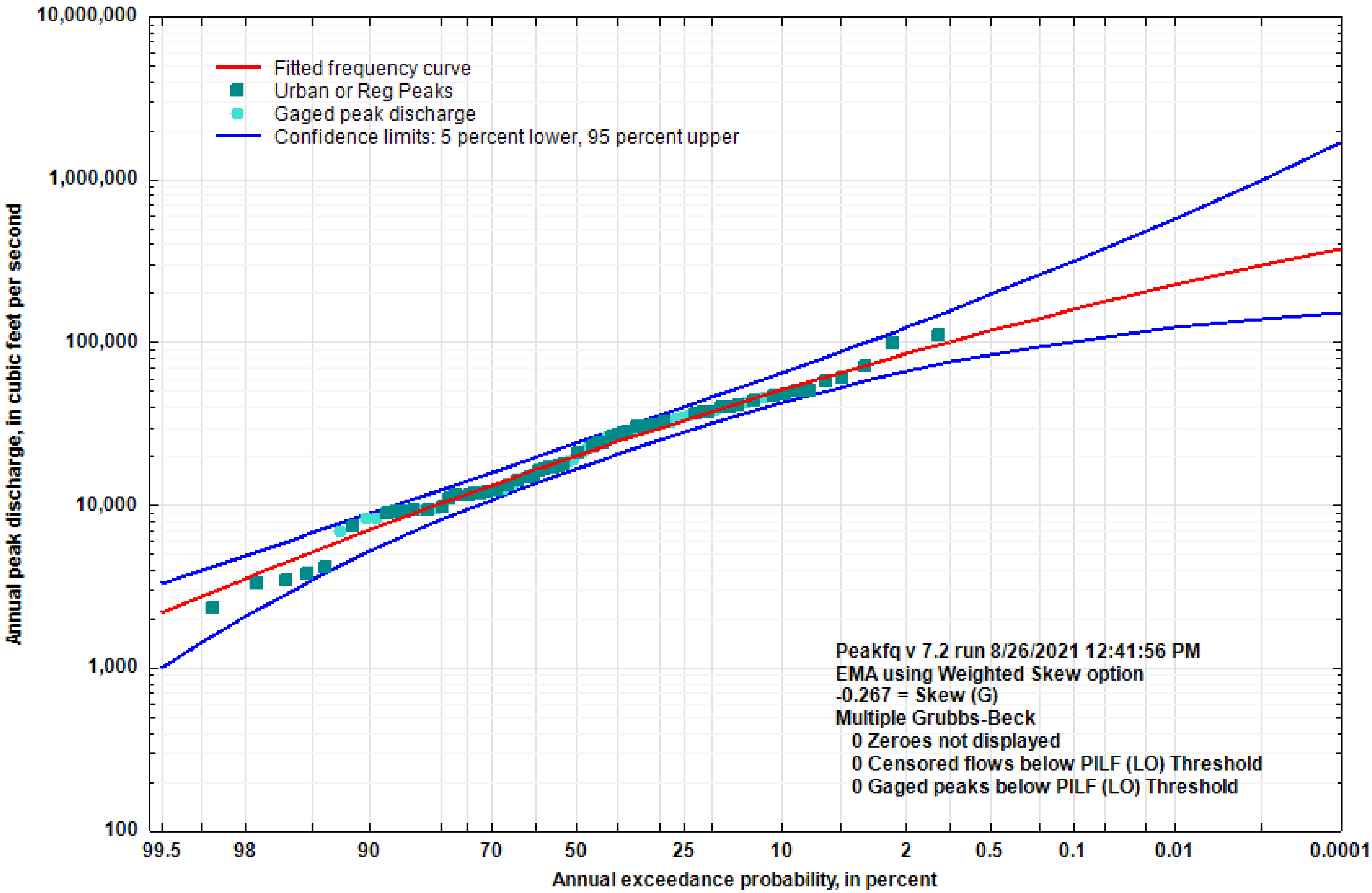


Figure 5-44. Flood Flow Frequency Curve for Black River near Annapolis, MO

07061900 - Logan Creek at Ellington, MO

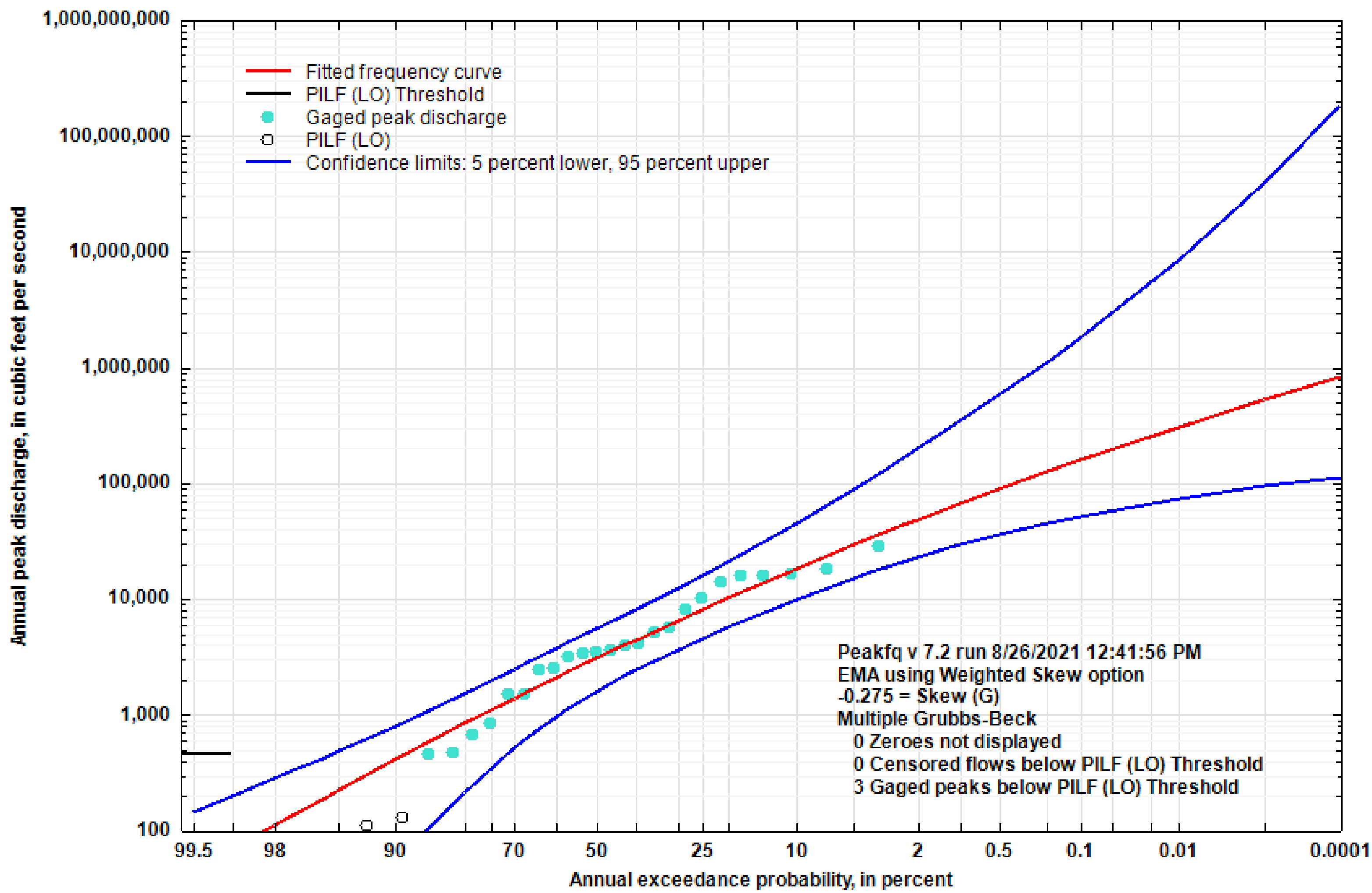


Figure 5-45. Flood Flow Frequency Curve for Logan Creek at Ellington, MO

07063470 - Tenmile Creek near Poplar Bluff, MO

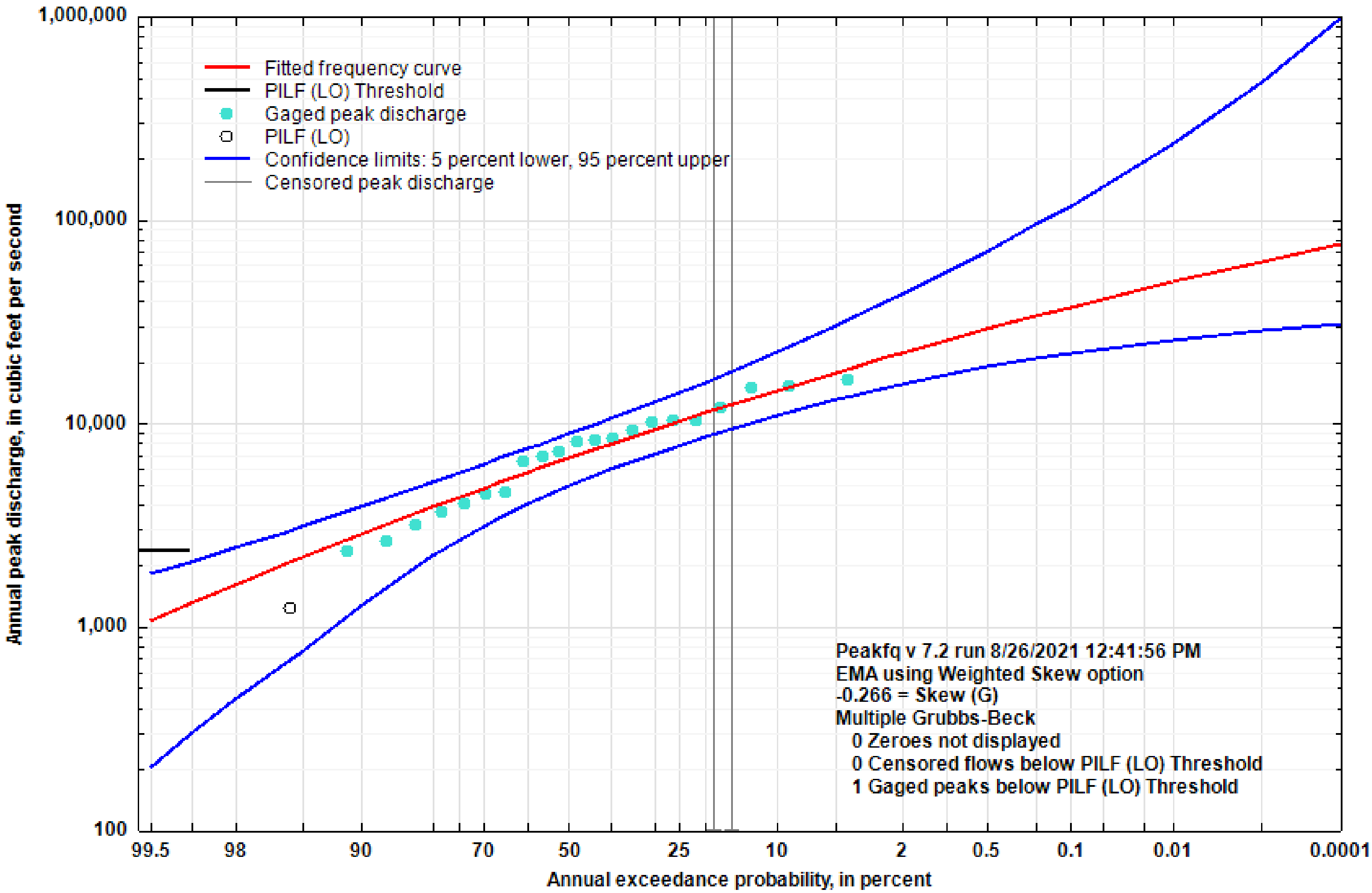


Figure 5-46. Flood Flow Frequency Curve for Tenmile Creek near Poplar Bluff, MO

07064300 - Fudge Hollow near Licking, MO

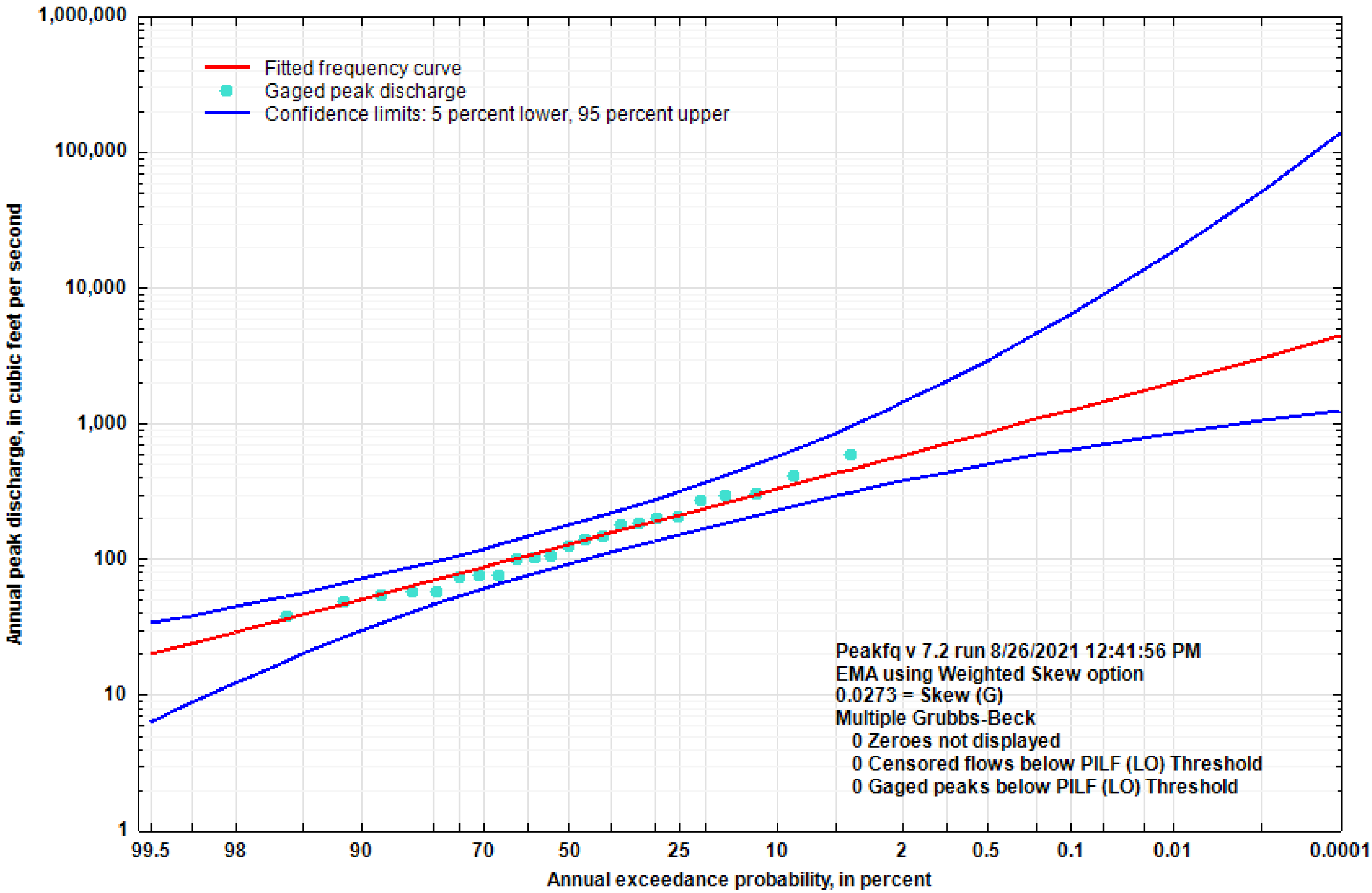


Figure 5-47. Flood Flow Frequency Curve for Fudge Hollow near Licking, MO

07064500 - Big Creek near Yukon, MO

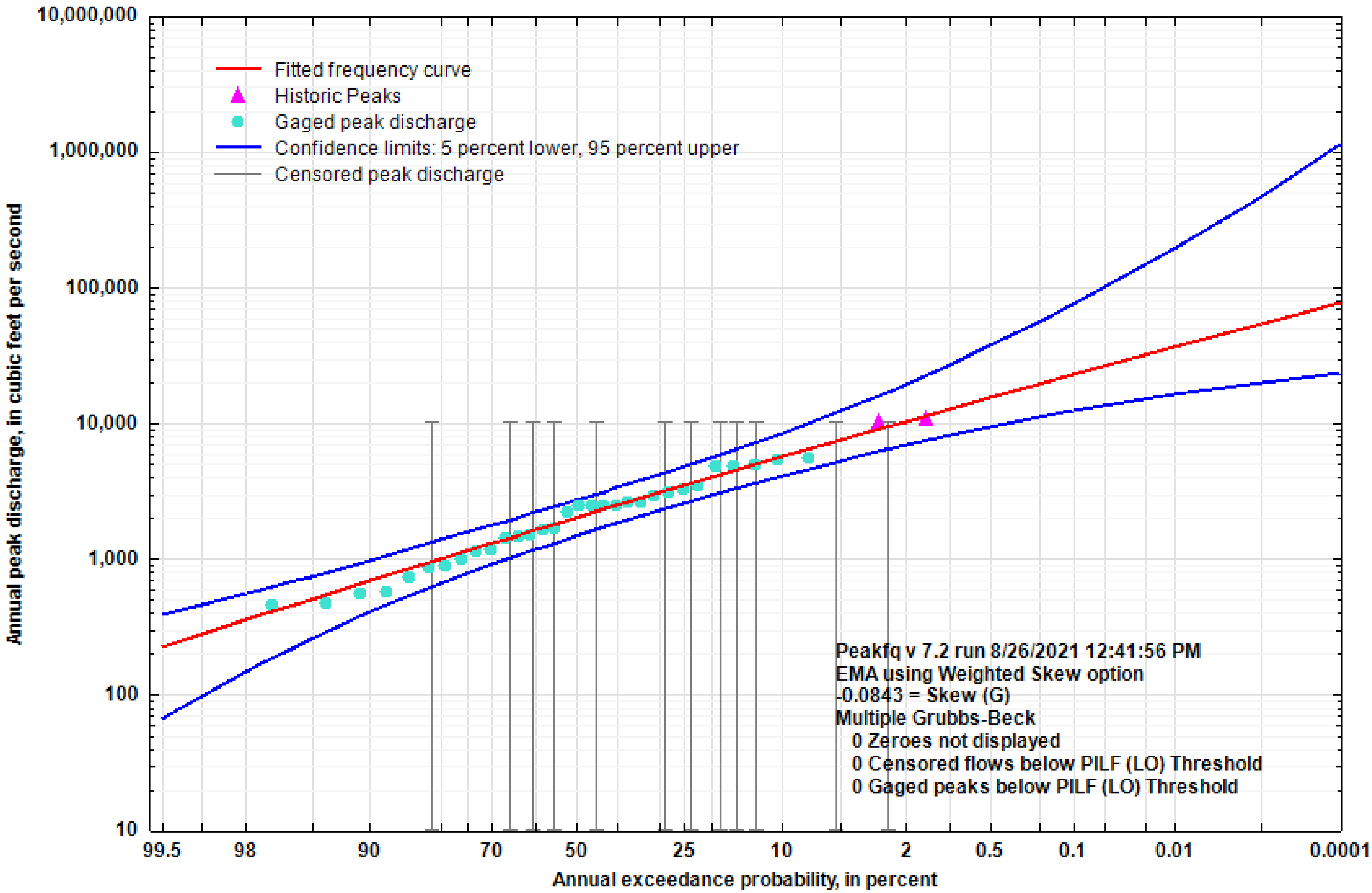


Figure 5-48. Flood Flow Frequency Curve for Big Creek near Yukon, MO

07065495 - Jacks Fork at Alley Spring, MO

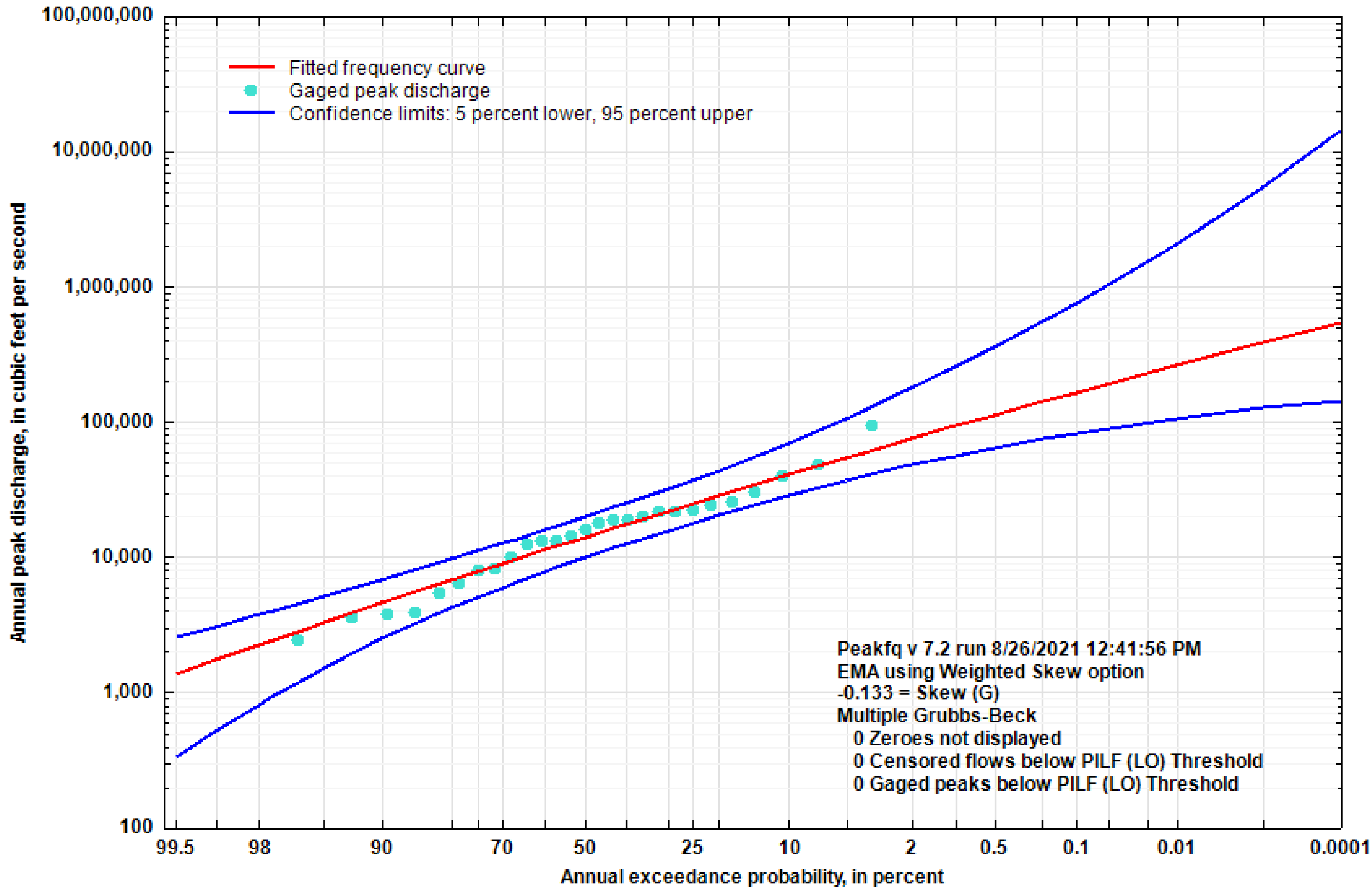


Figure 5-49. Flood Flow Frequency Curve for Jacks Fork at Alley Spring, MO

07066000 - Jacks Fork at Eminence, MO

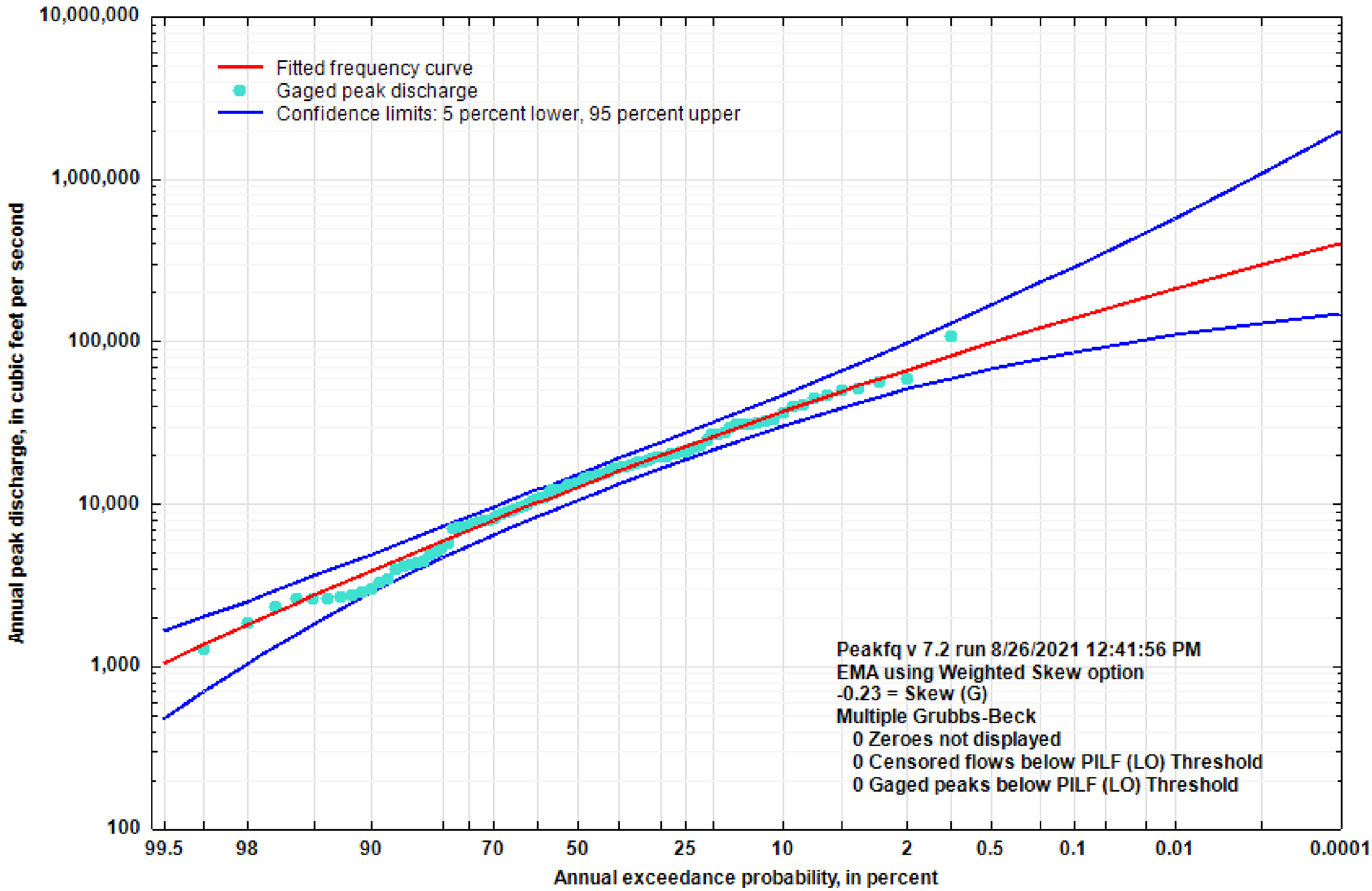


Figure 5-50. Flood Flow Frequency Curve for Jacks Fork at Eminence, MO

07066500 - Current River at Eminence, MO

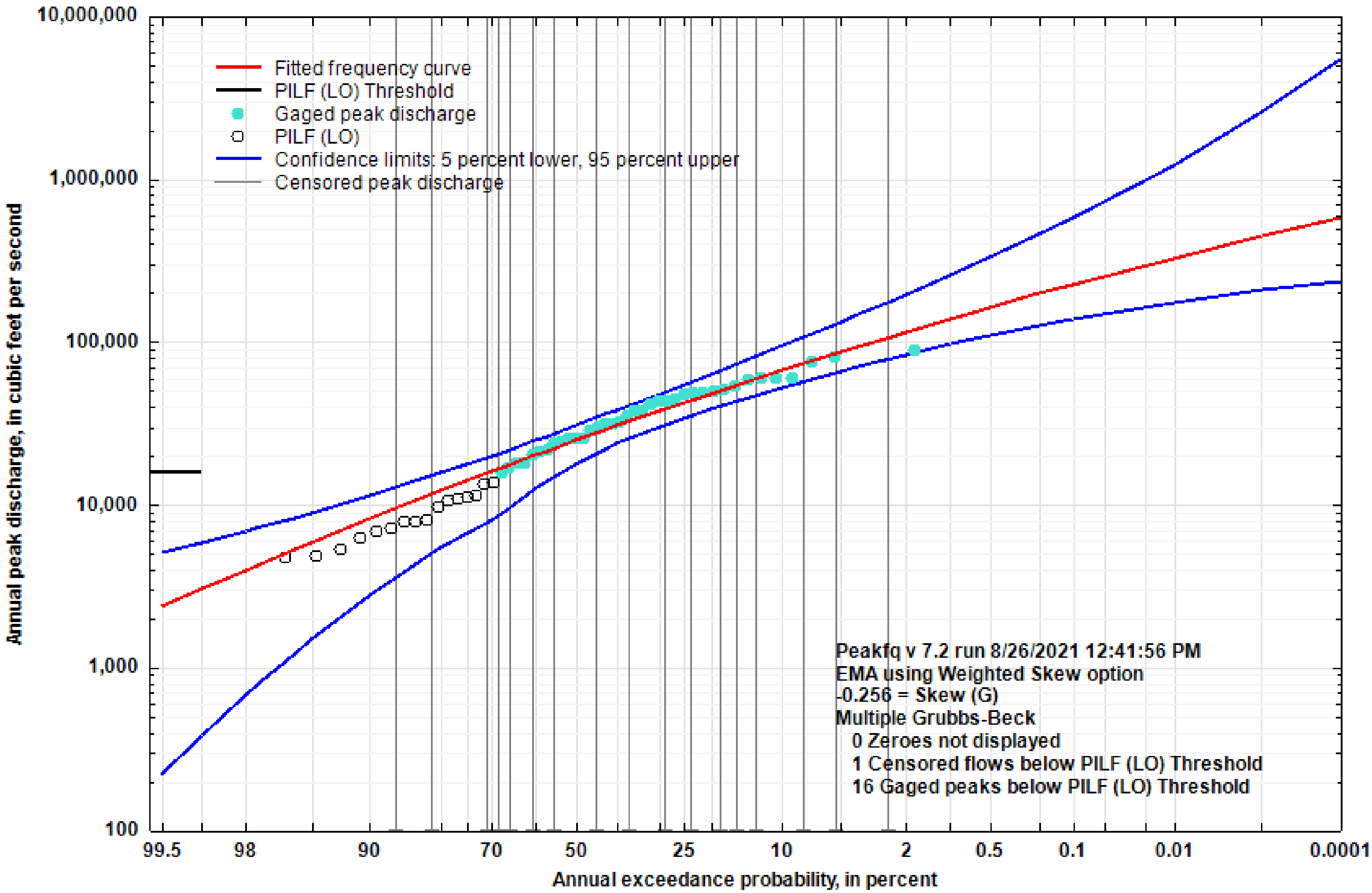


Figure 5-51. Flood Flow Frequency Curve for Current River at Eminence, MO

07066800 - Sycamore Creek near Winona, MO

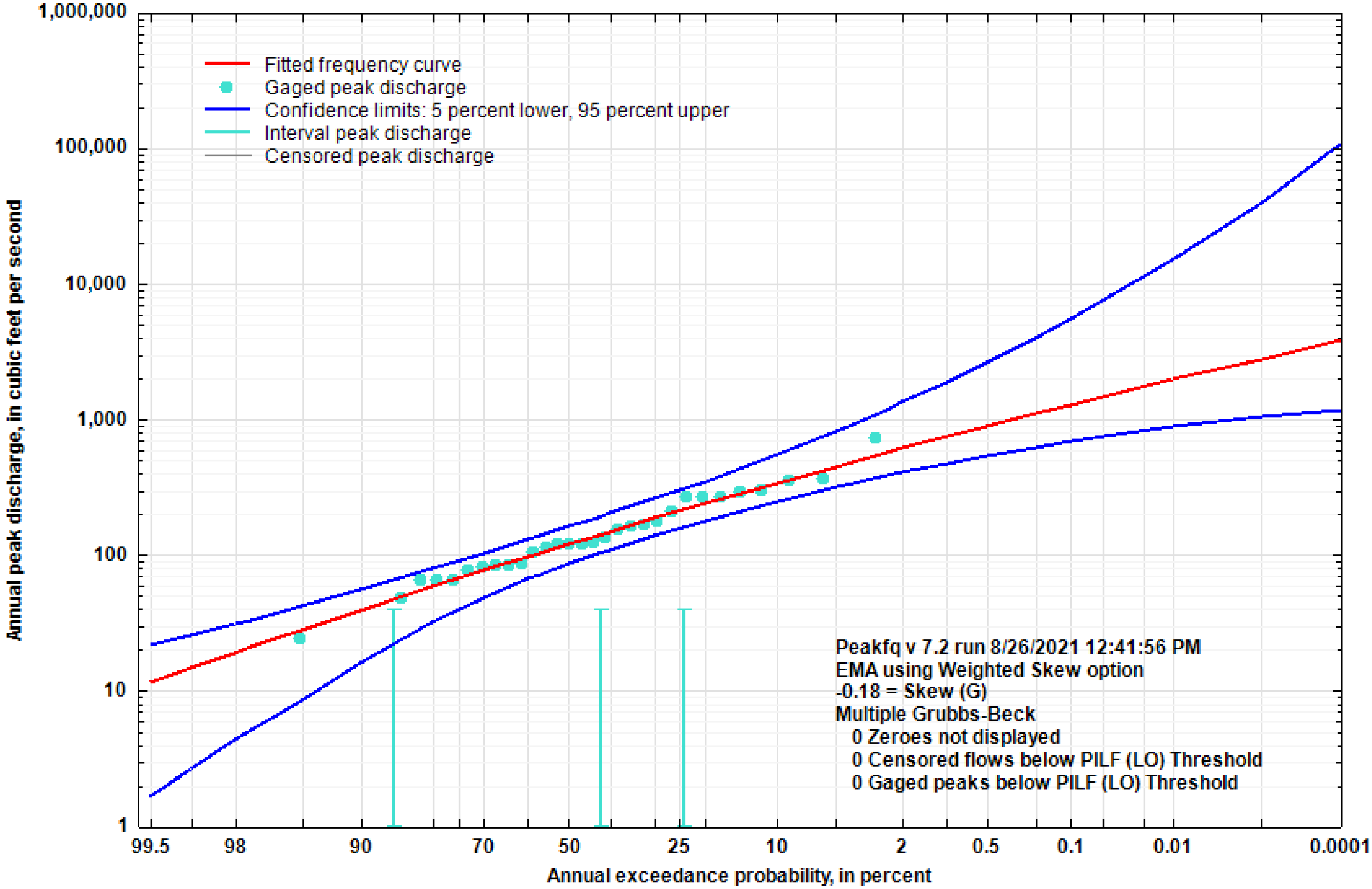


Figure 5-52. Flood Flow Frequency Curve for Sycamore Creek near Winona, MO

07067000 - Current River at Van Buren, MO

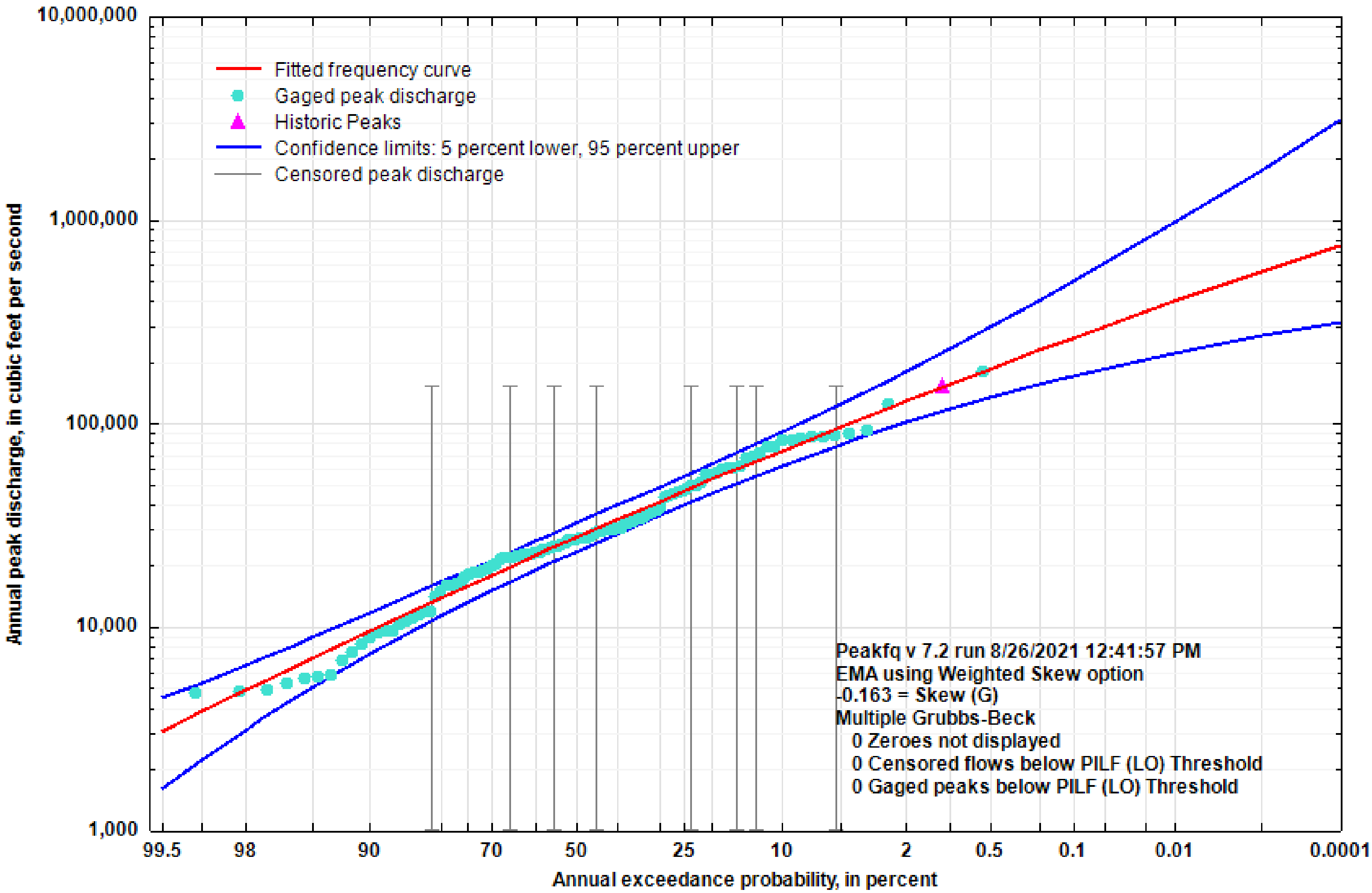


Figure 5-53. Flood Flow Frequency Curve for Current River at Van Buren, MO

07068000 - Current River at Doniphan, MO

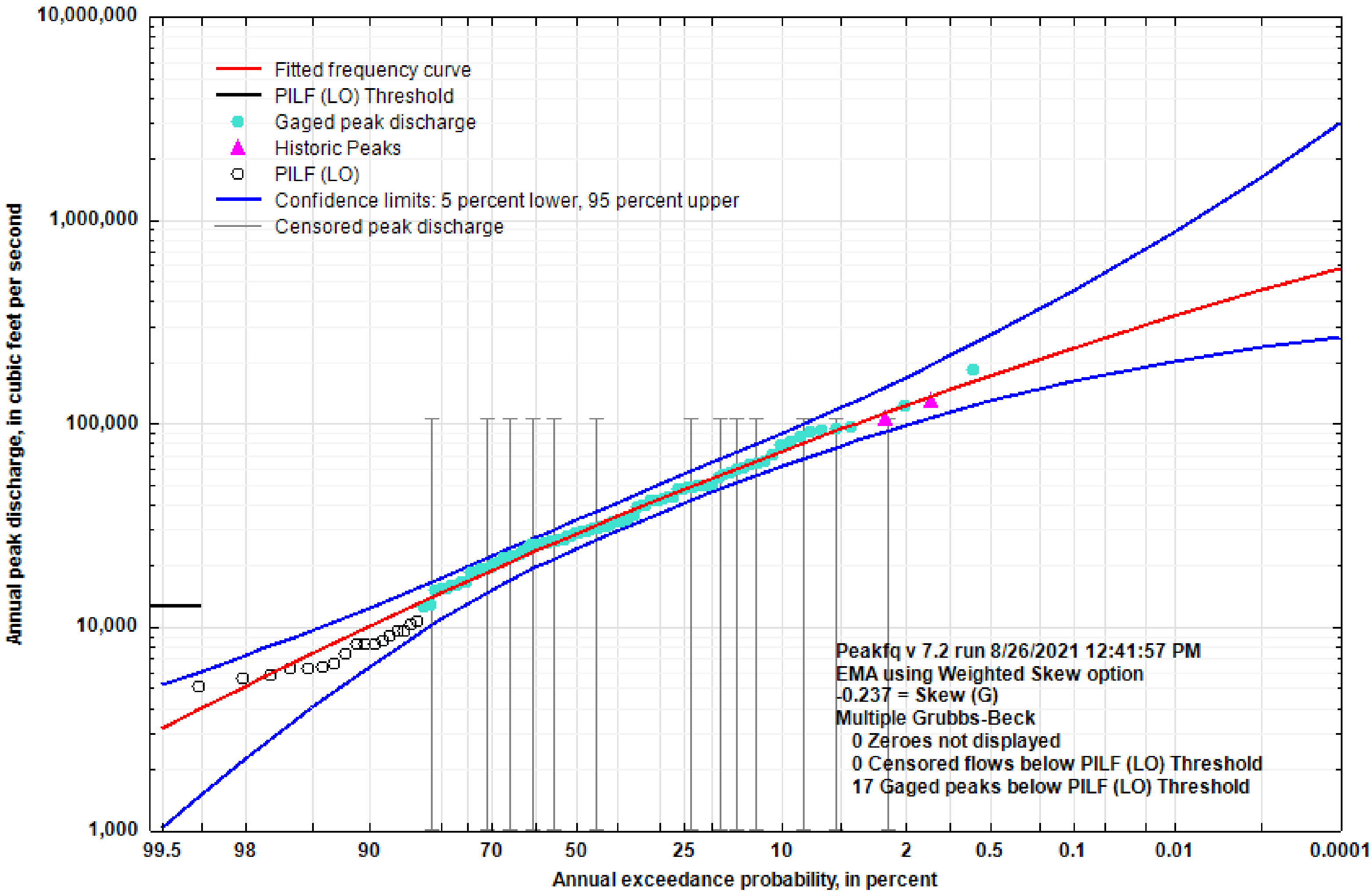


Figure 5-54. Flood Flow Frequency Curve for Current River at Doniphan, MO

07068200 - North Prong Little Black River at Hunter, MO

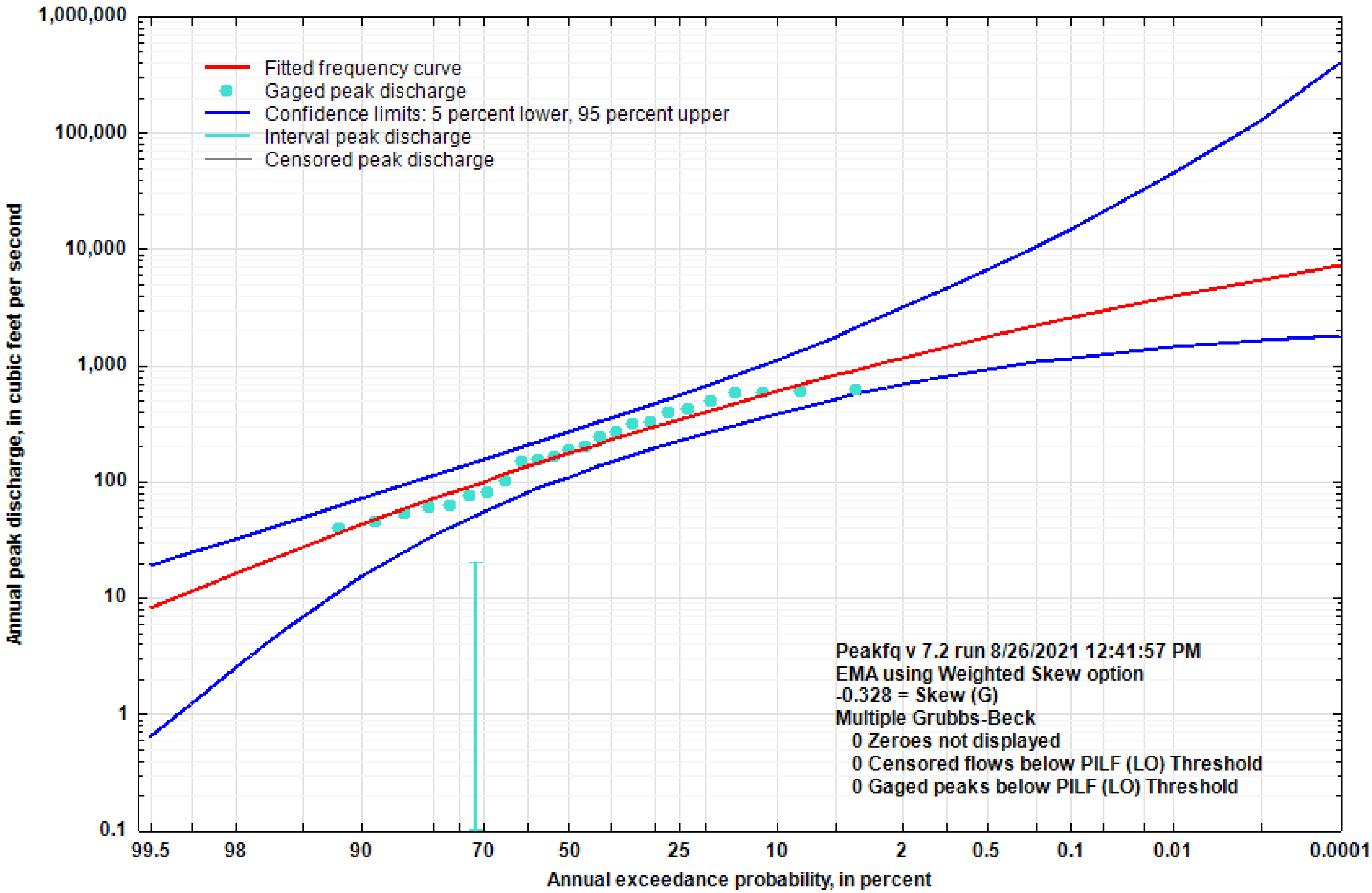


Figure 5-55. Flood Flow Frequency Curve for North Prong Little Black River at Hunter, MO

07068510 - Little Black River below Fairdealing, MO

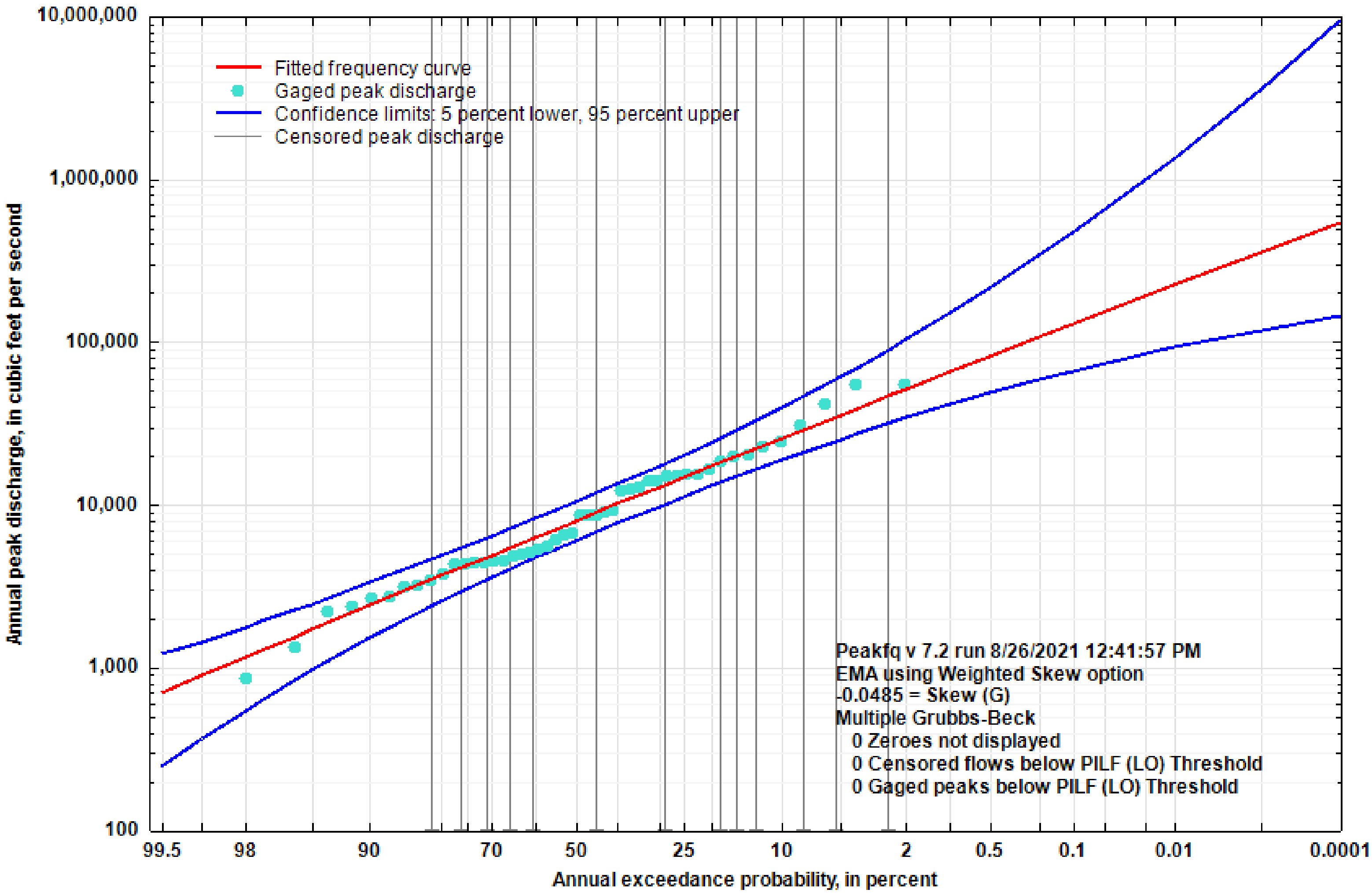


Figure 5-56. Flood Flow Frequency Curve for Little Black River below Fairdealing, MO

07068870 - Fourche River Tributary at Middlebrook, AR

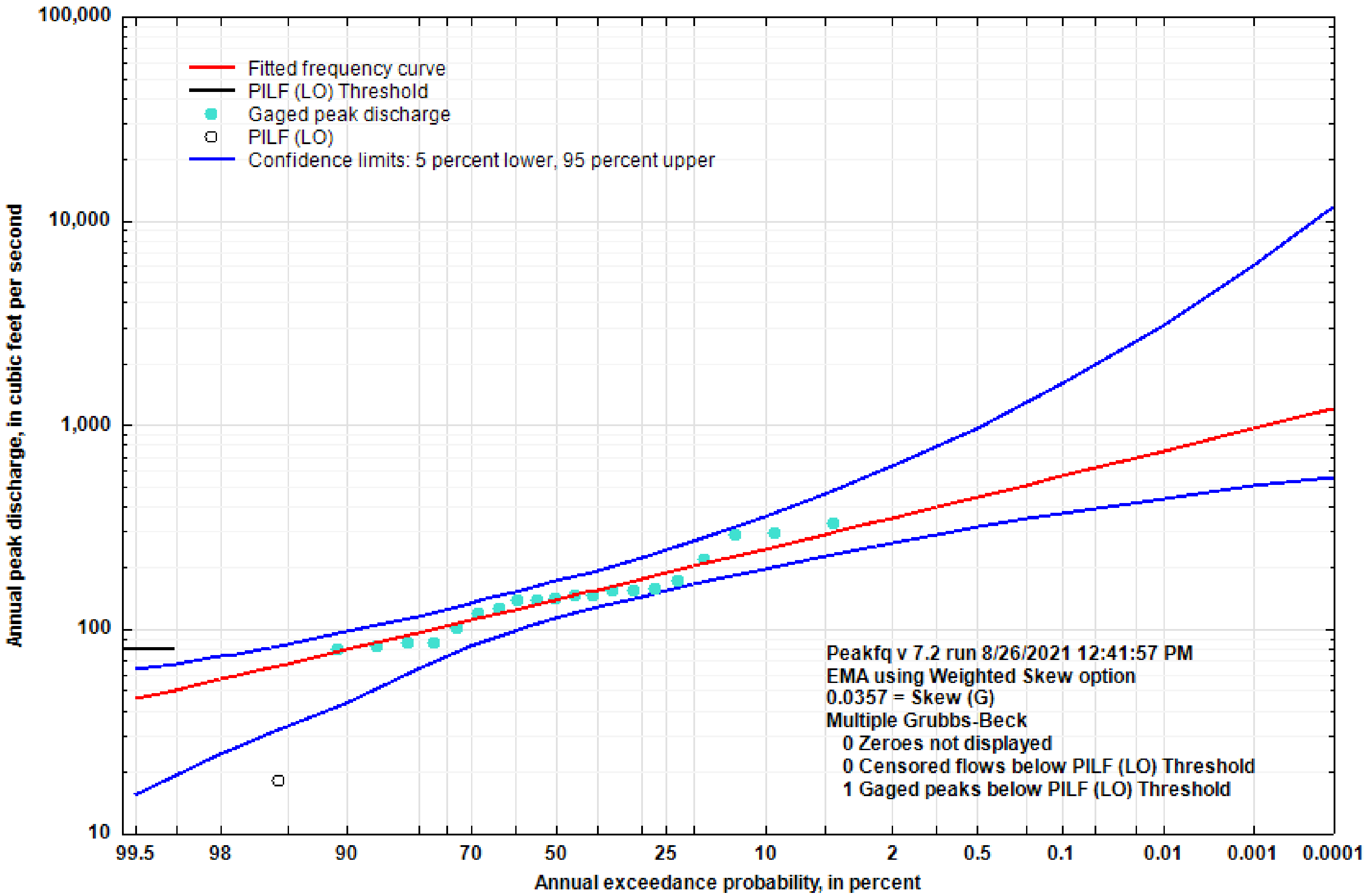


Figure 5-57. Flood Flow Frequency Curve for Fourche River Tributary at Middlebrook, AR

07069100 - Adams Branch near West Plains, MO

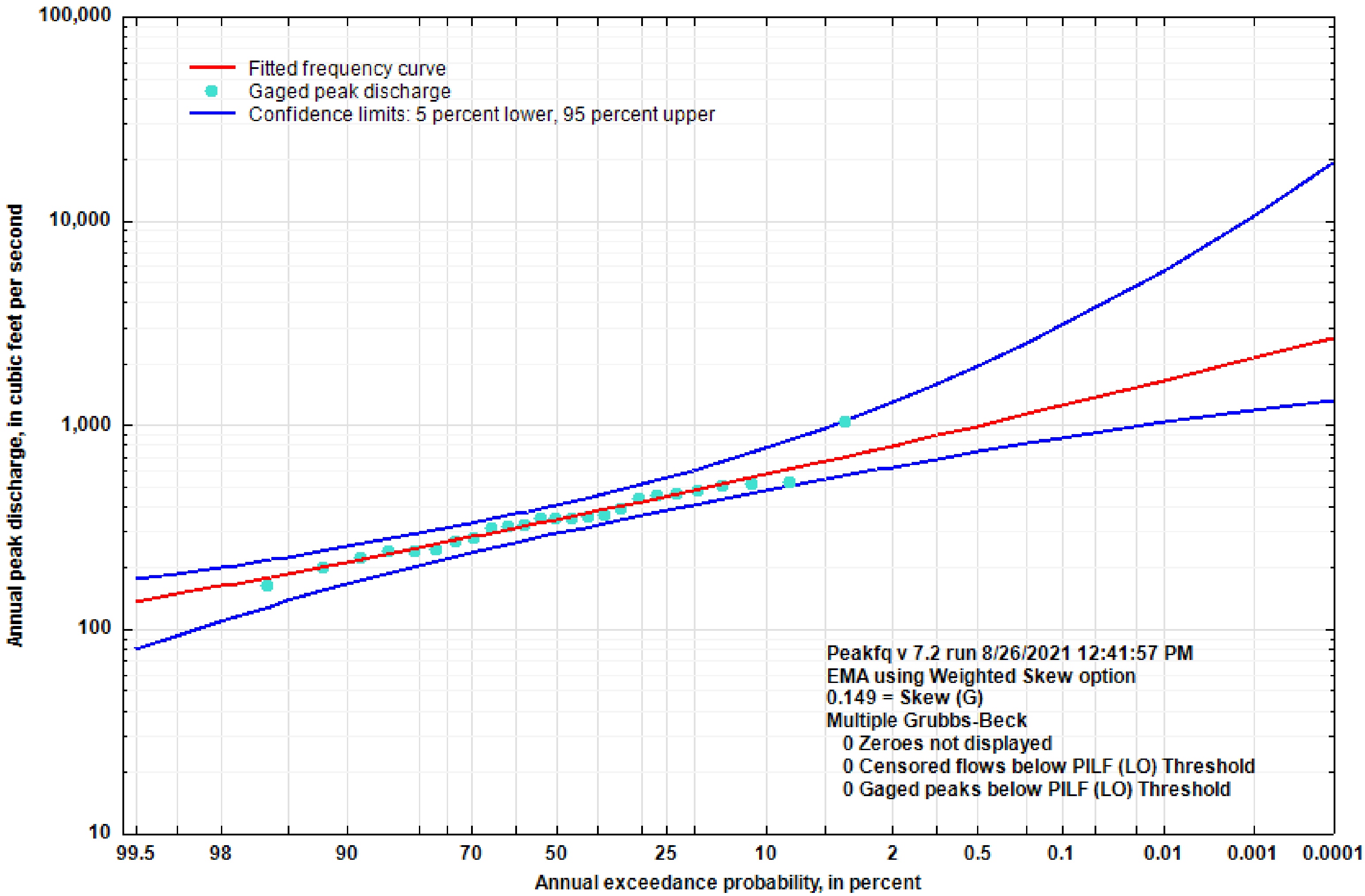


Figure 5-58. Flood Flow Frequency Curve for Adams Branch near West Plains, MO

07069250 - Brush Creek near Mammoth Spring, AR

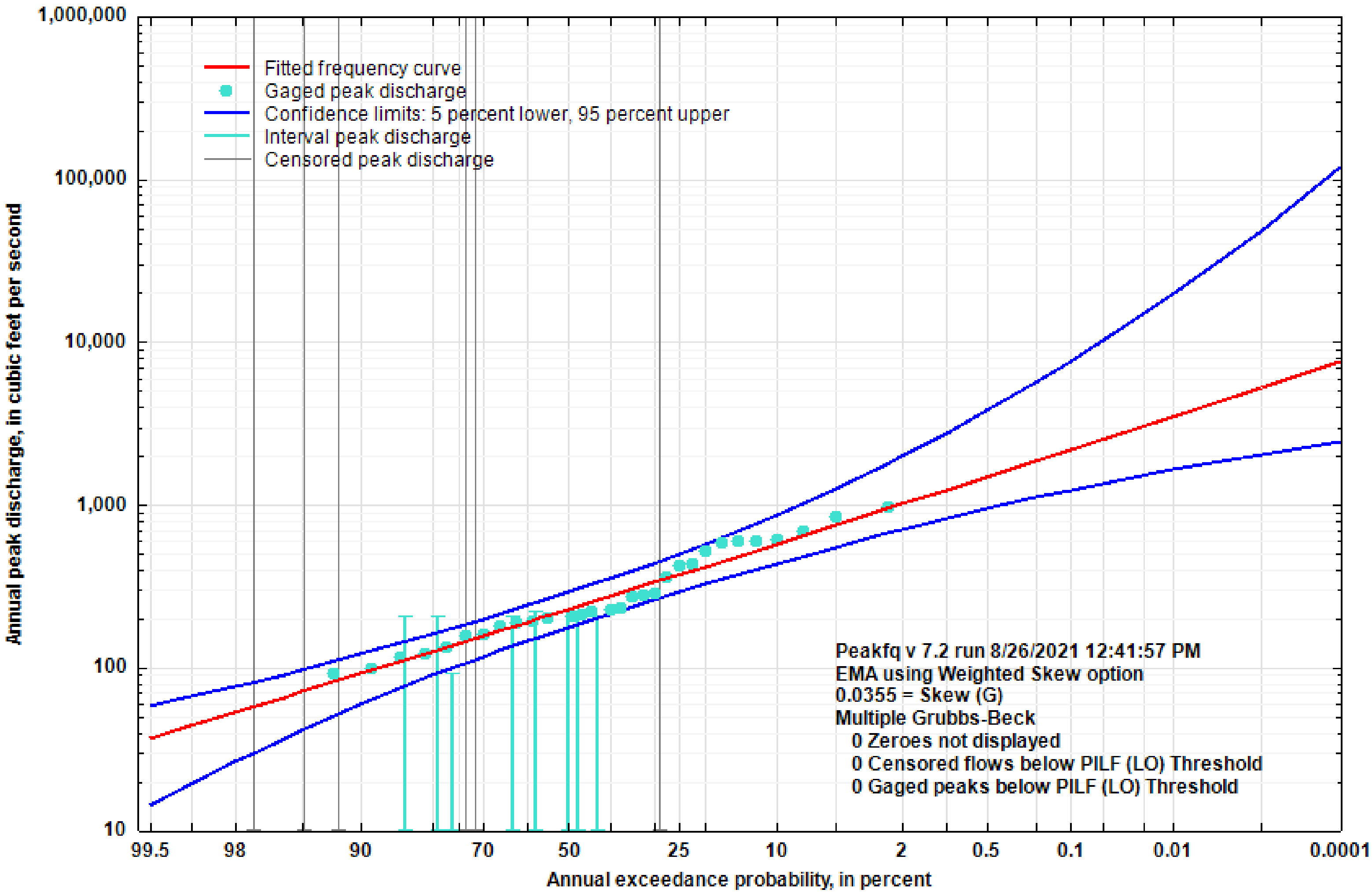


Figure 5-59. Flood Flow Frequency Curve for Brush Creek near Mammoth Spring, AR

07069290 – Miller Creek near Salem, AR

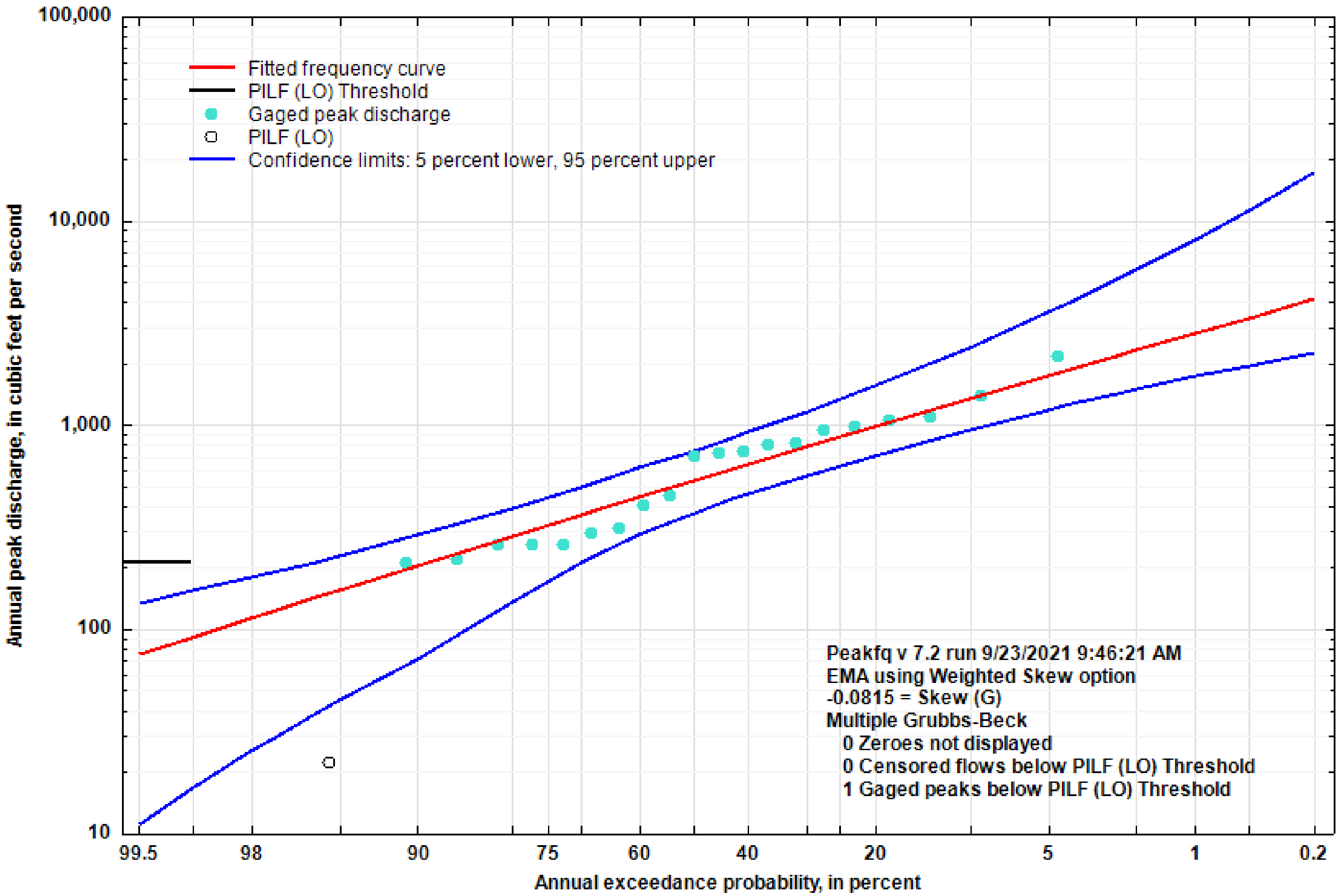


Figure 5-60. Flood Flow Frequency Curve for Miller Creek near Salem, AR

07069500 - Spring River at Imboden, AR

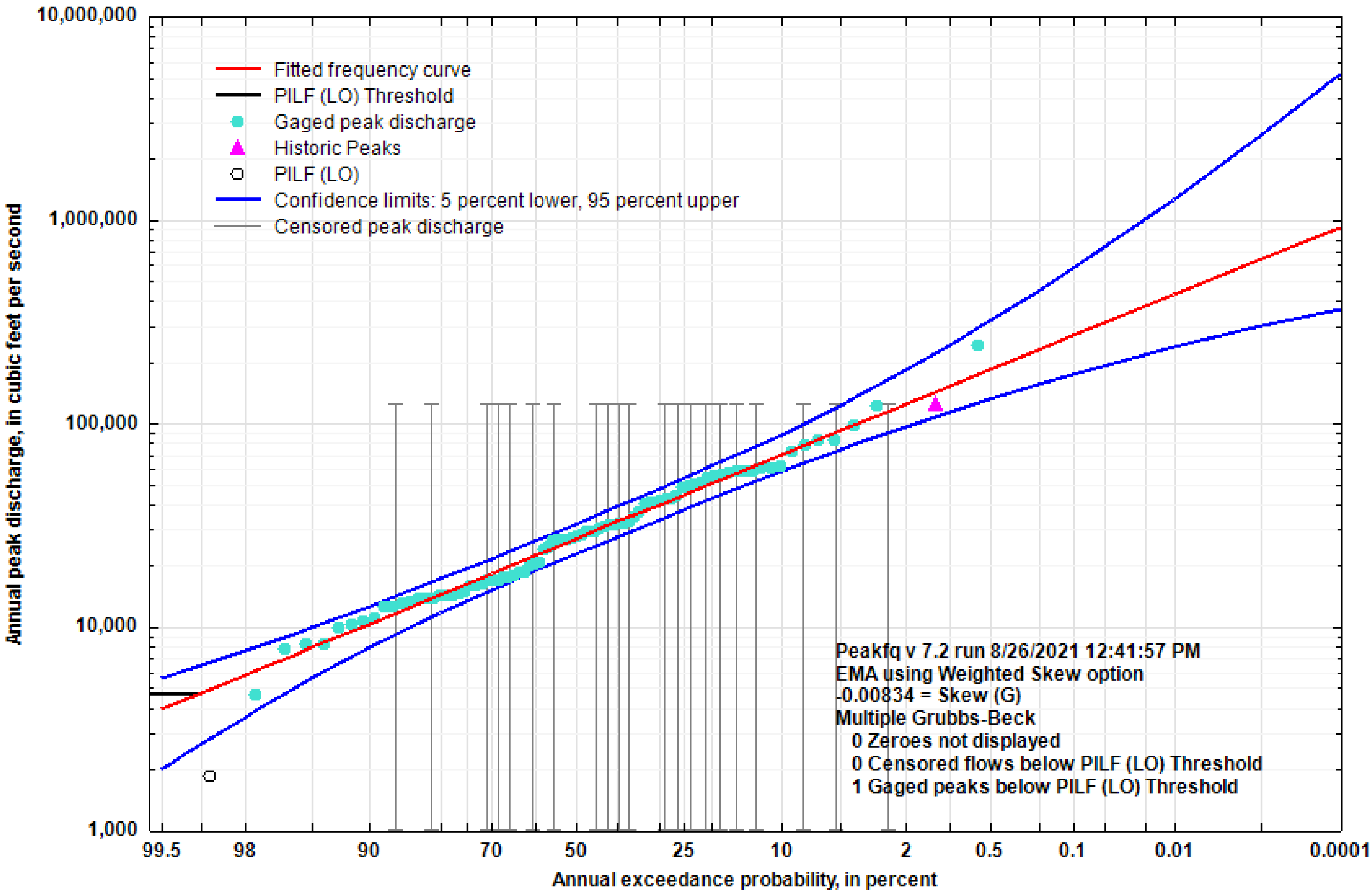


Figure 5-61. Flood Flow Frequency Curve for Spring River at Imboden, AR

07070200 - Burnham Branch near Willow Springs, MO

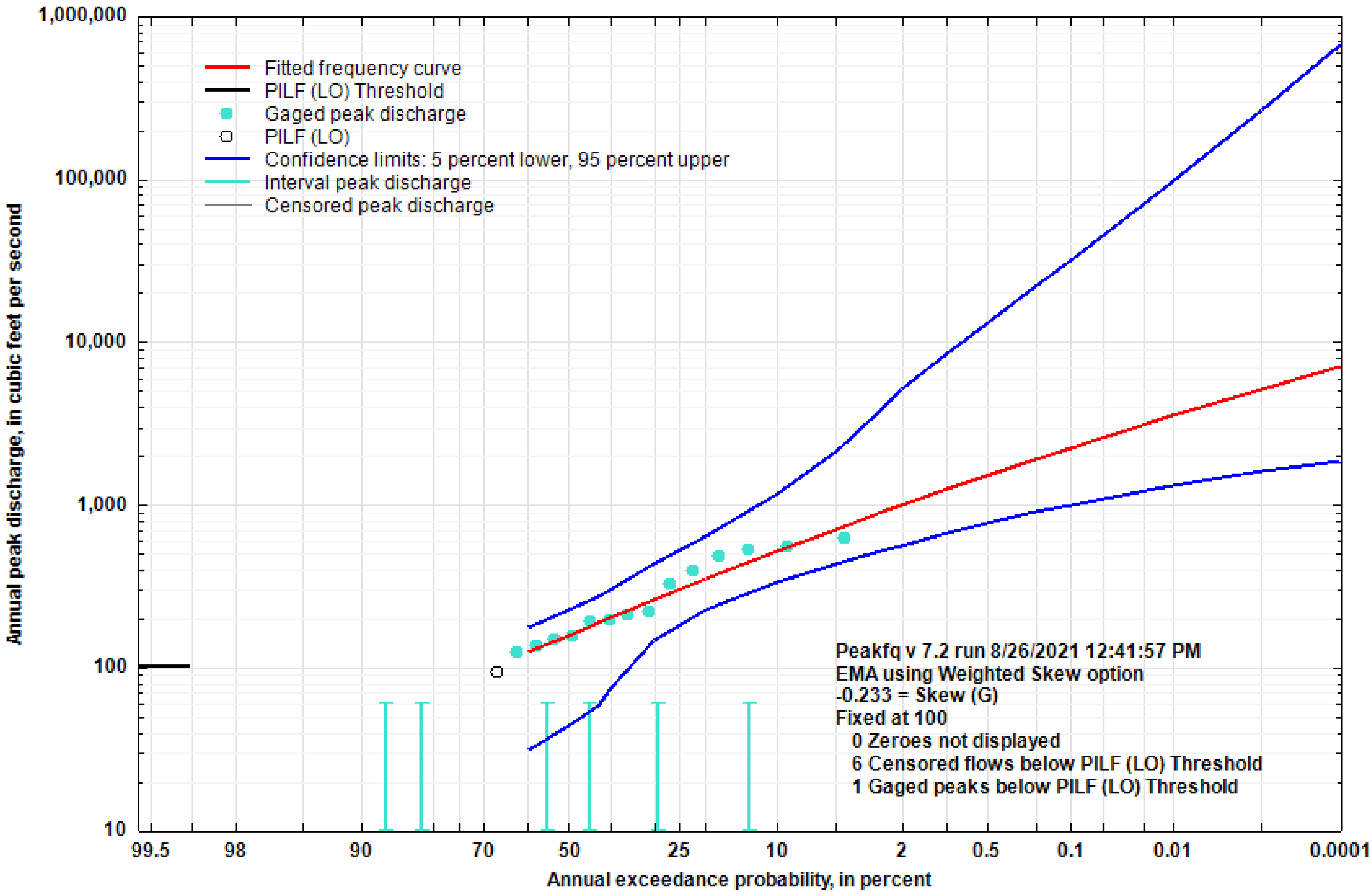


Figure 5-62. Flood Flow Frequency Curve for Burnham Branch near Willow Springs, MO

07071500 - Eleven Point River near Bardley, MO

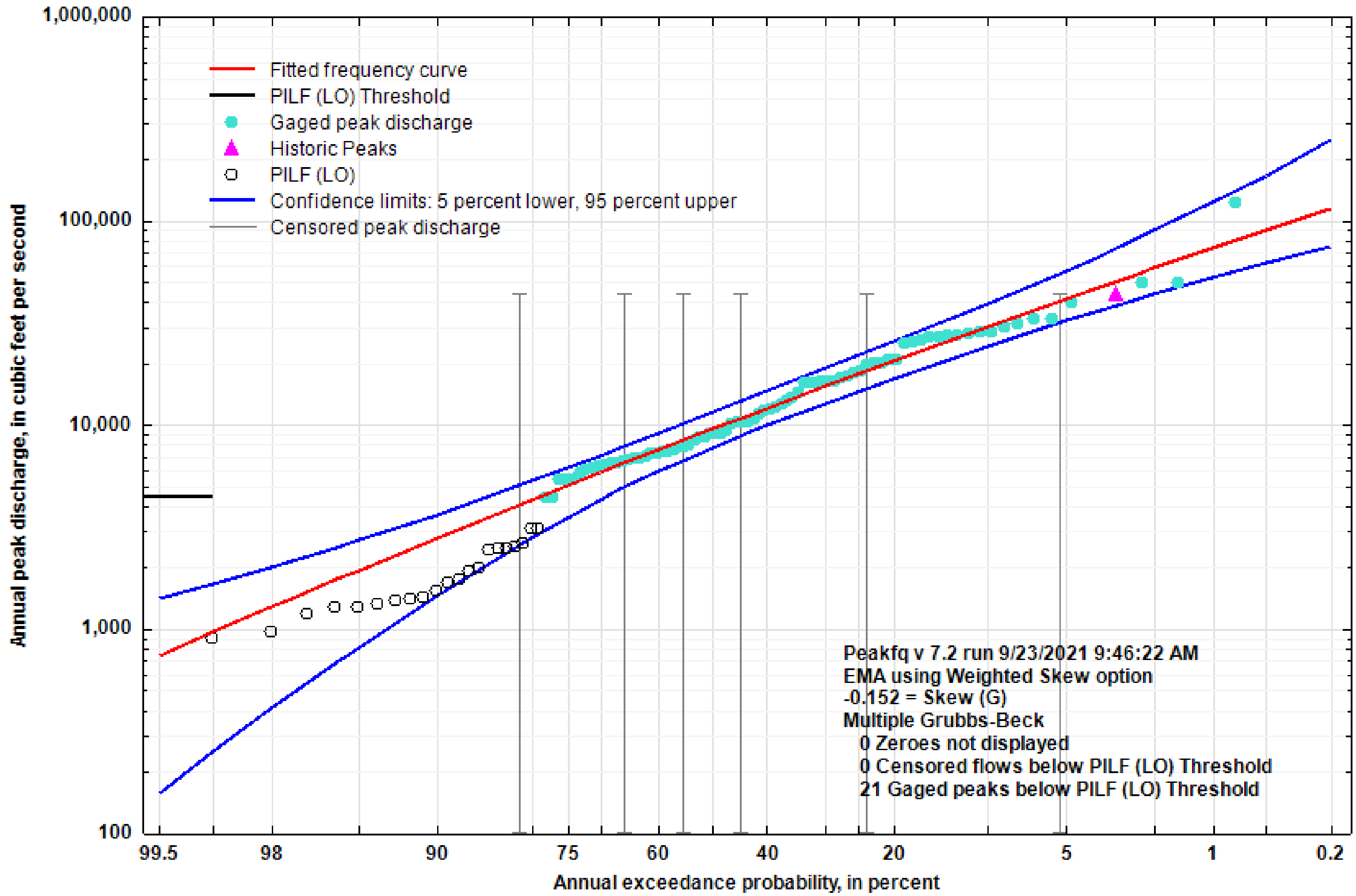


Figure 5-63. Flood Flow Frequency Curve for Eleven Point River near Bardley, MO

07071500 - Eleven Point River near Ravenden Springs, AR

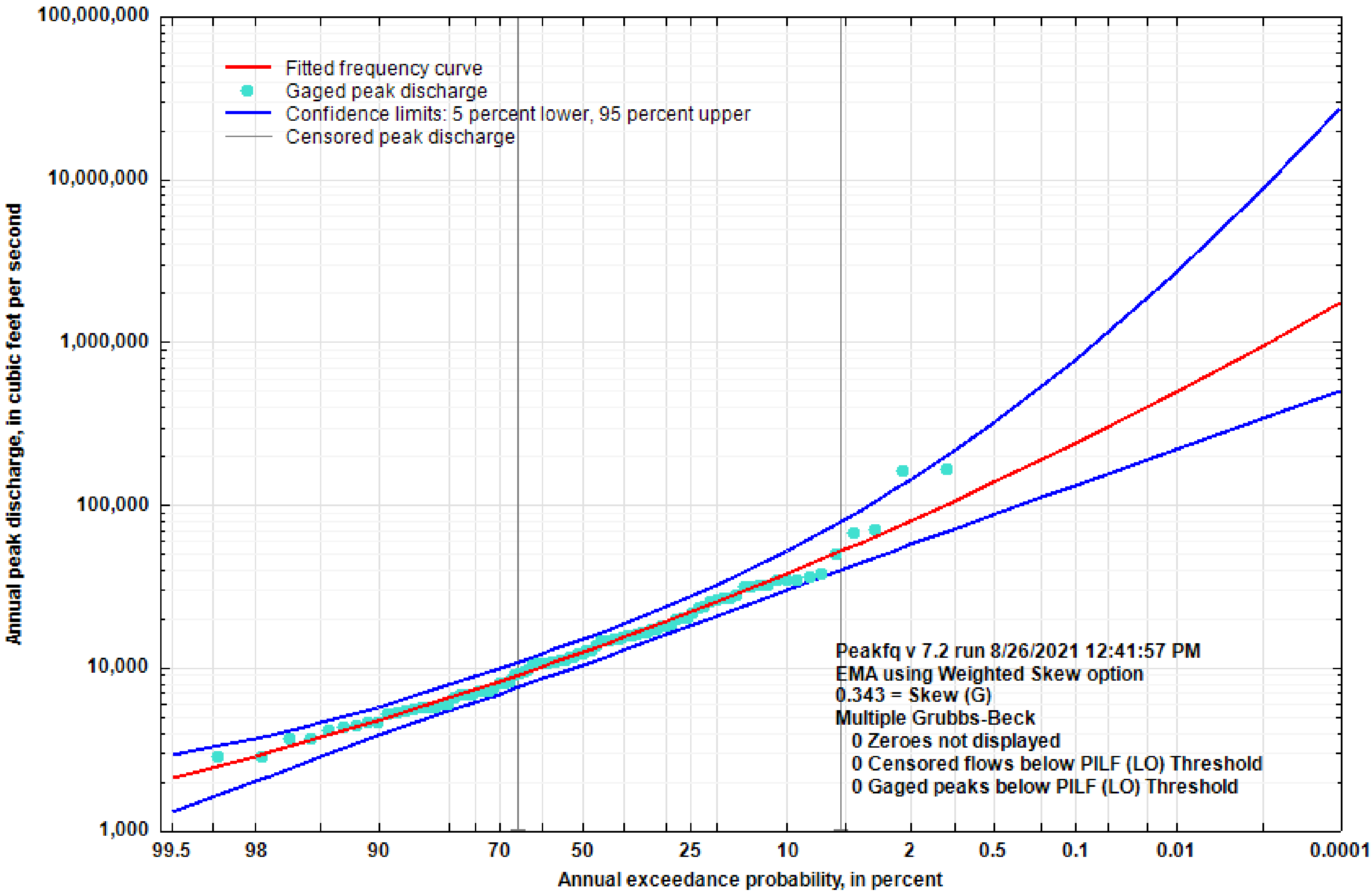


Figure 5-64. Flood Flow Frequency Curve for Eleven Point River near Ravenden Springs, AR

07072200 - Hubble Creek near Pocahontas, AR

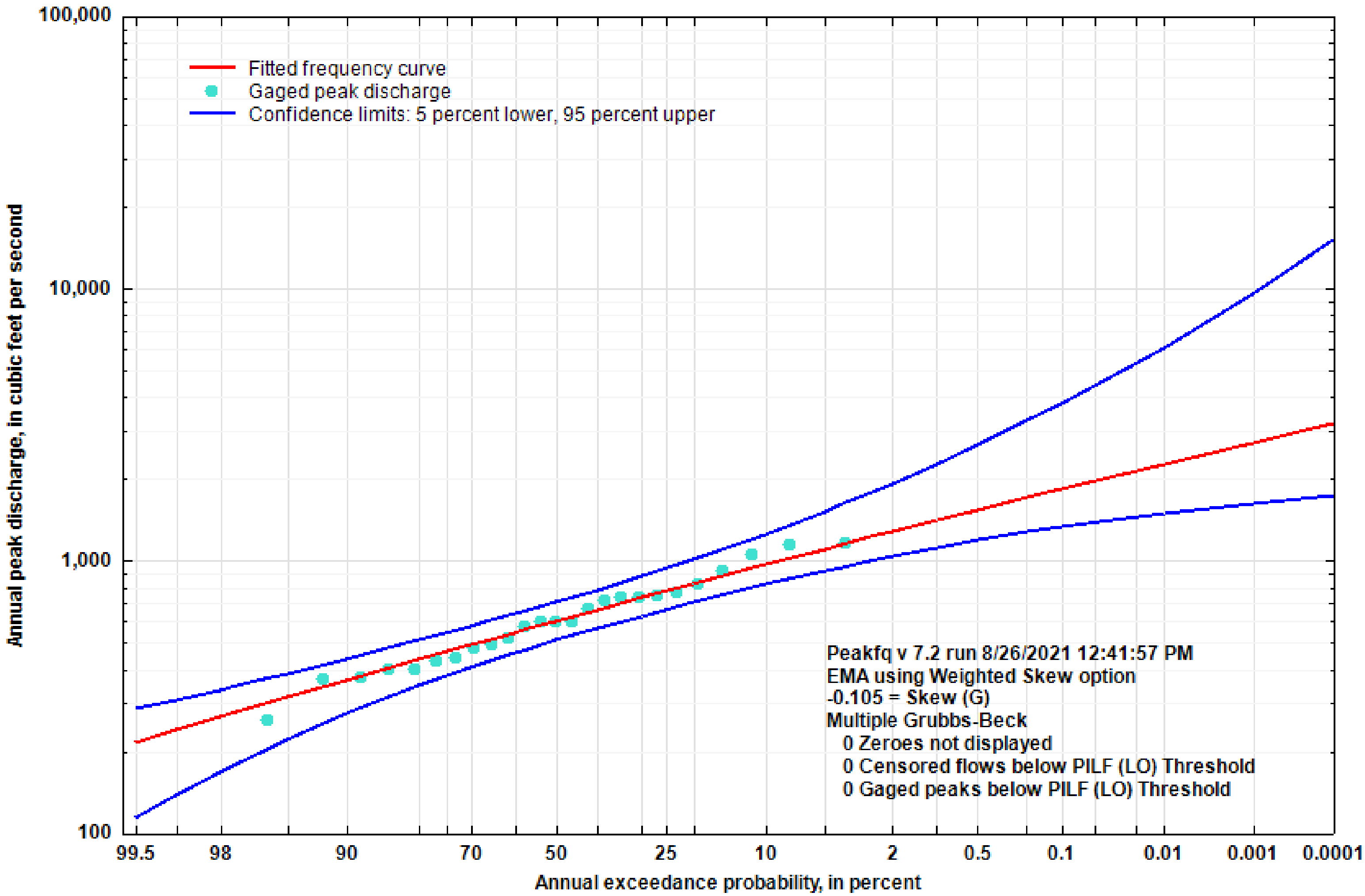


Figure 5-65. Flood Flow Frequency Curve for Hubble Creek near Pocahontas, AR

07073500 - Piney Fork at Evening Shade

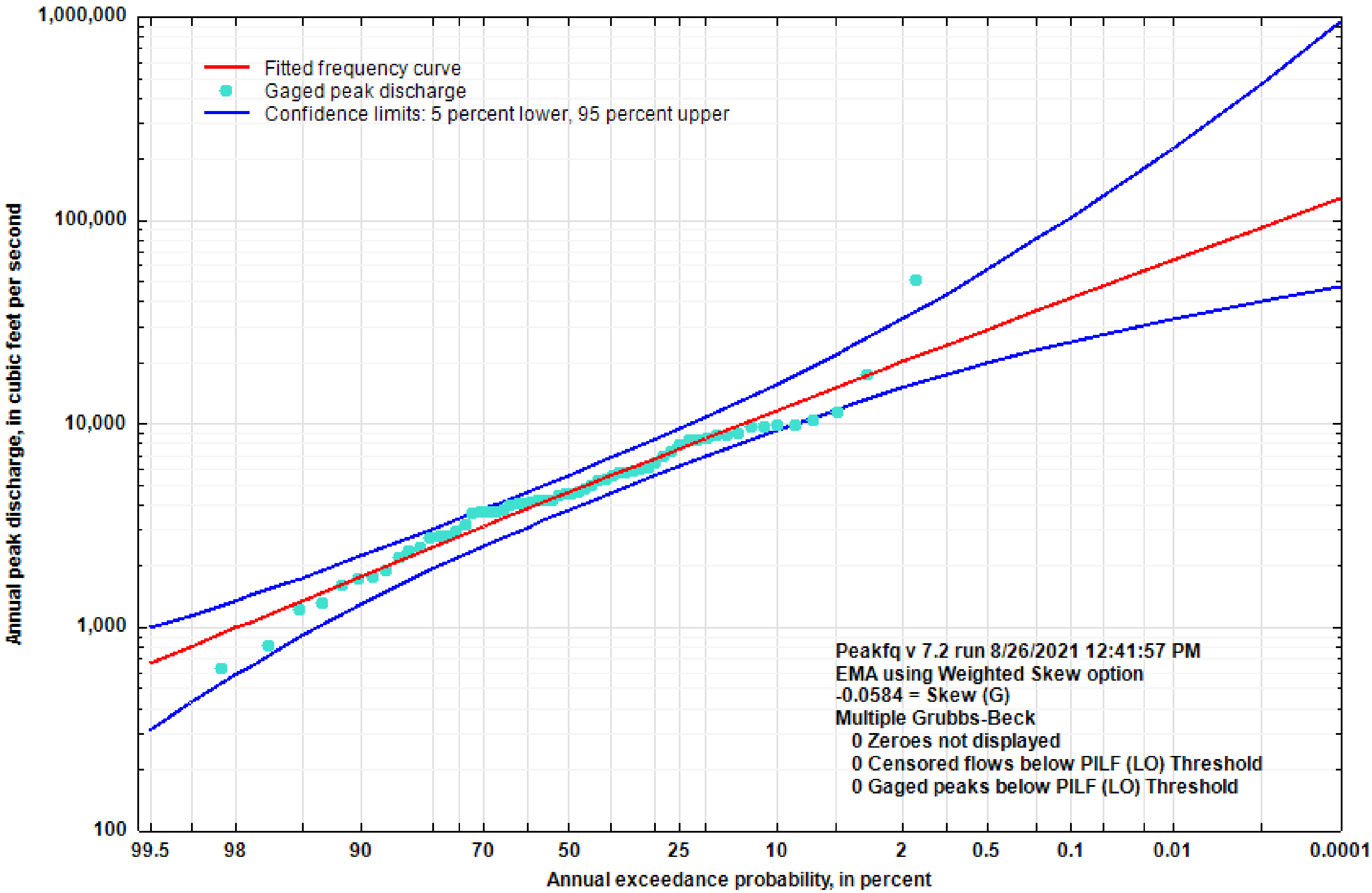


Figure 5-66. Flood Flow Frequency Curve for Piney Fork at Evening Shade

07074000 - Strawberry River near Poughkeepsie, AR

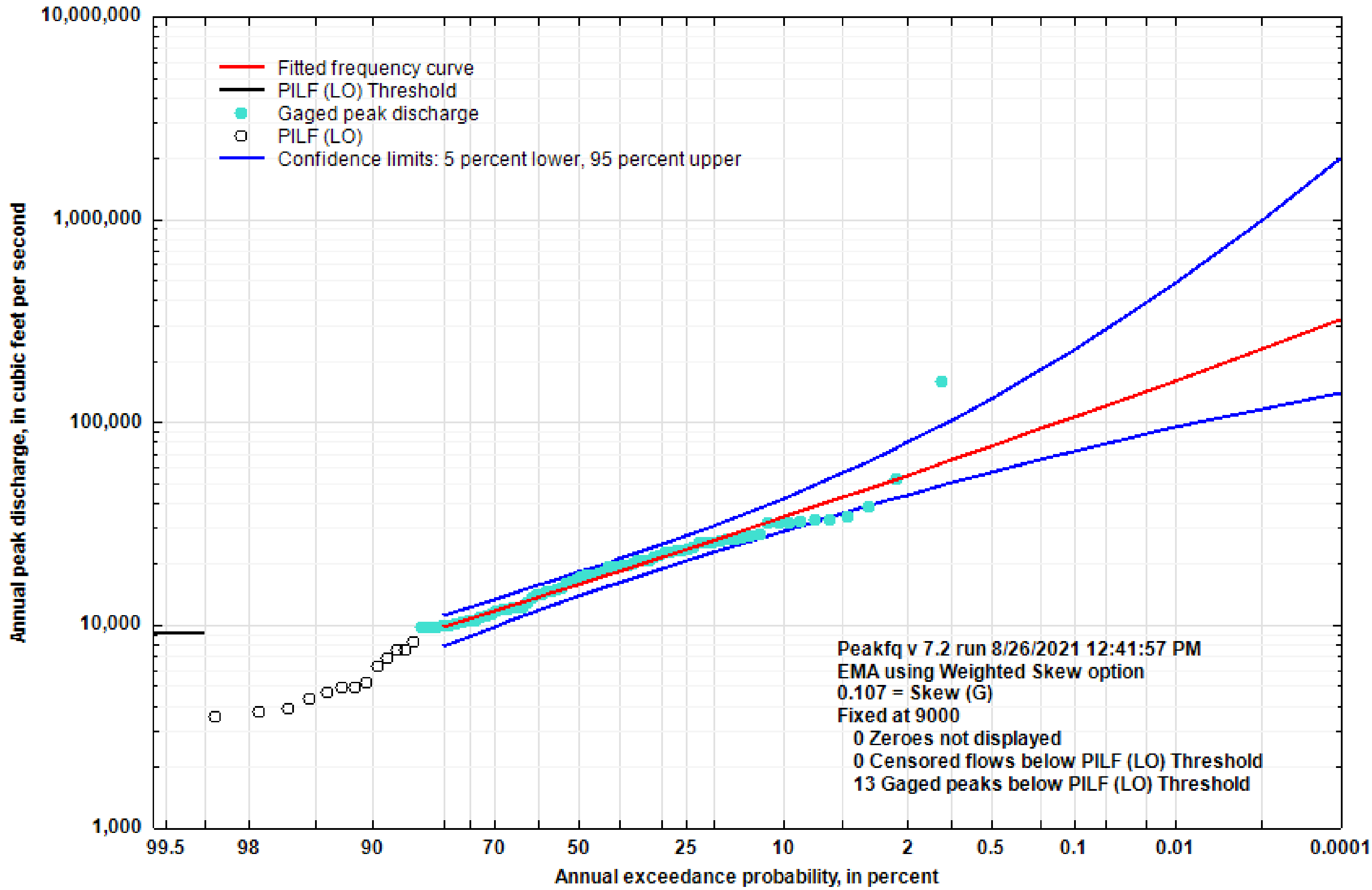


Figure 5-67. Flood Flow Frequency Curve for Strawberry River near Poughkeepsie, AR

07074200 - Dry Branch Tributary near Sidney, AR

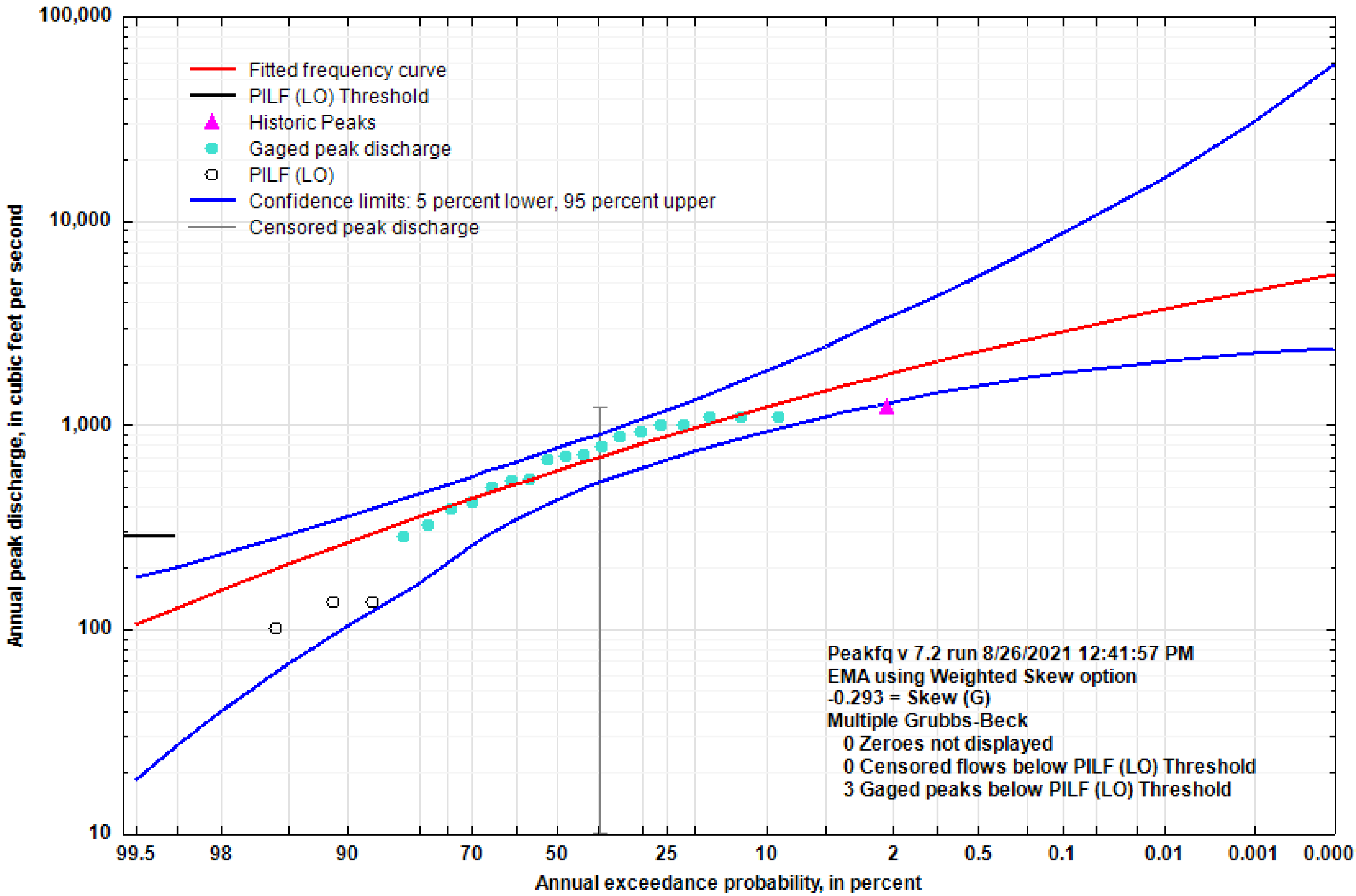


Figure 5-68. Flood Flow Frequency Curve for Dry Branch Tributary near Sidney, AR

07074250 - Reeds Creek near Strawberry

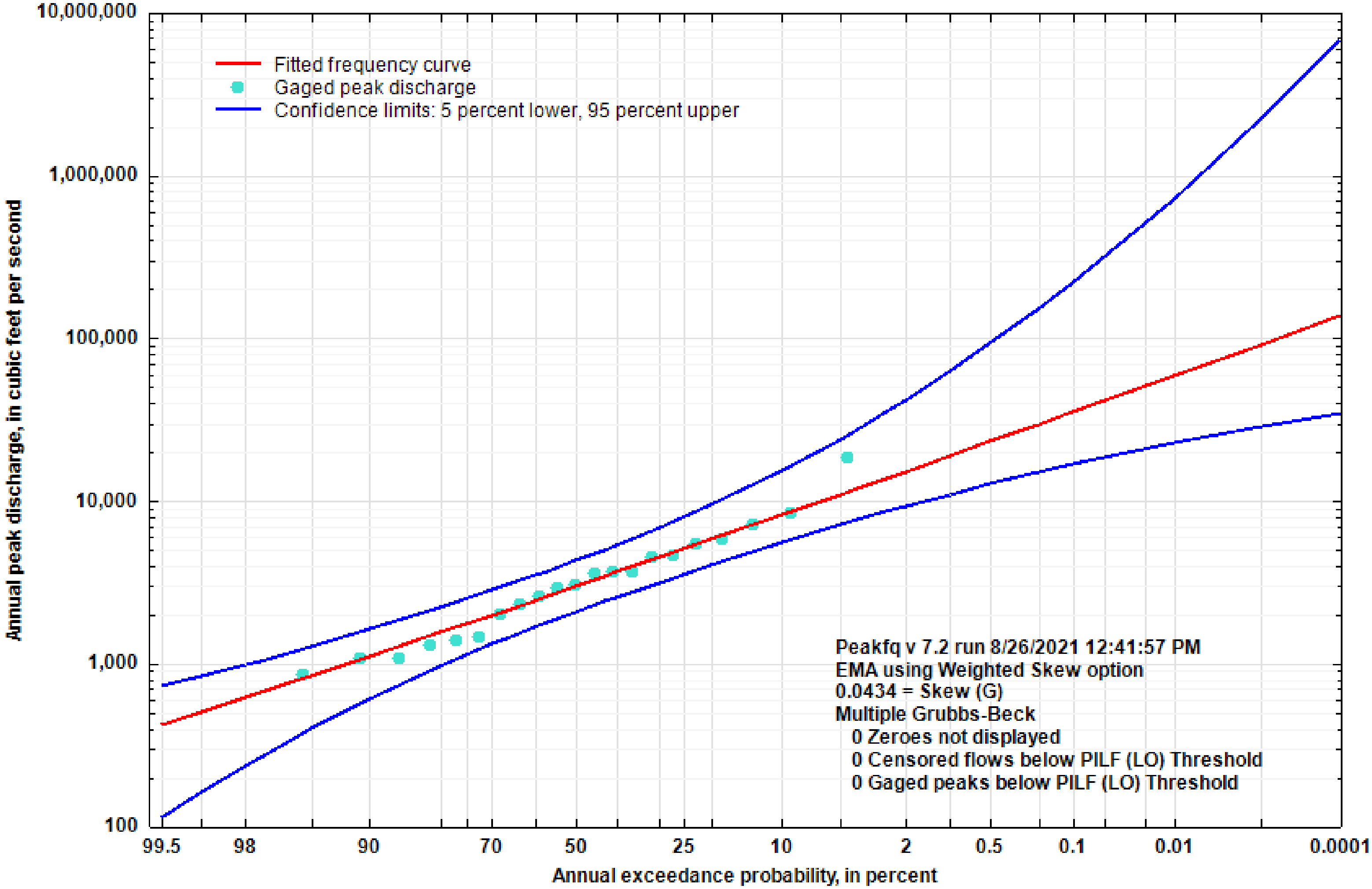


Figure 5-69. Flood Flow Frequency Curve for Reeds Creek near Strawberry

07074900 - Trace C Trib nr Marshall, Ark

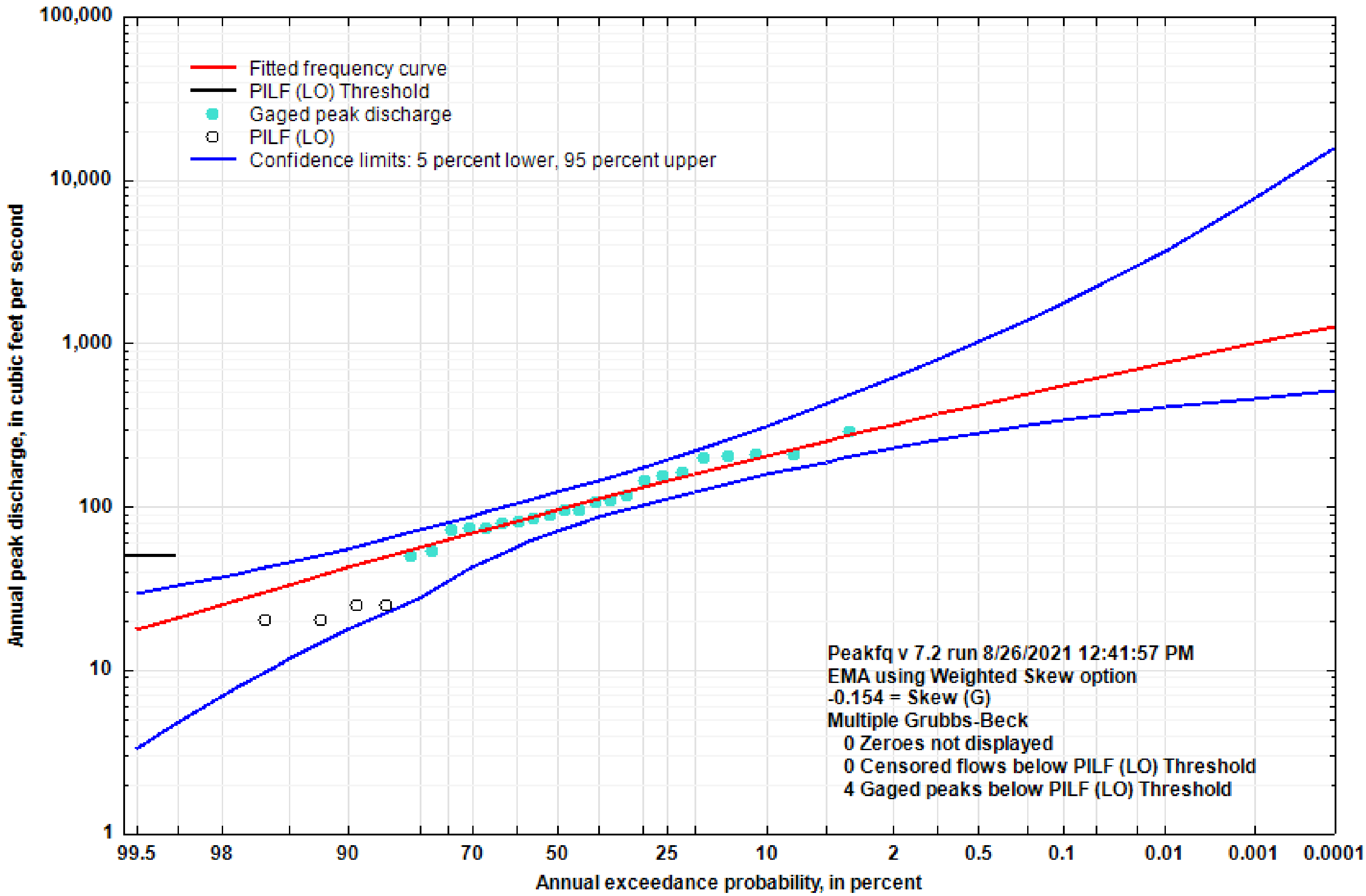


Figure 5-70. Flood Flow Frequency Curve for Trace C Trib nr Marshall, Ark

07074950 - Tick Creek near Leslie, AR

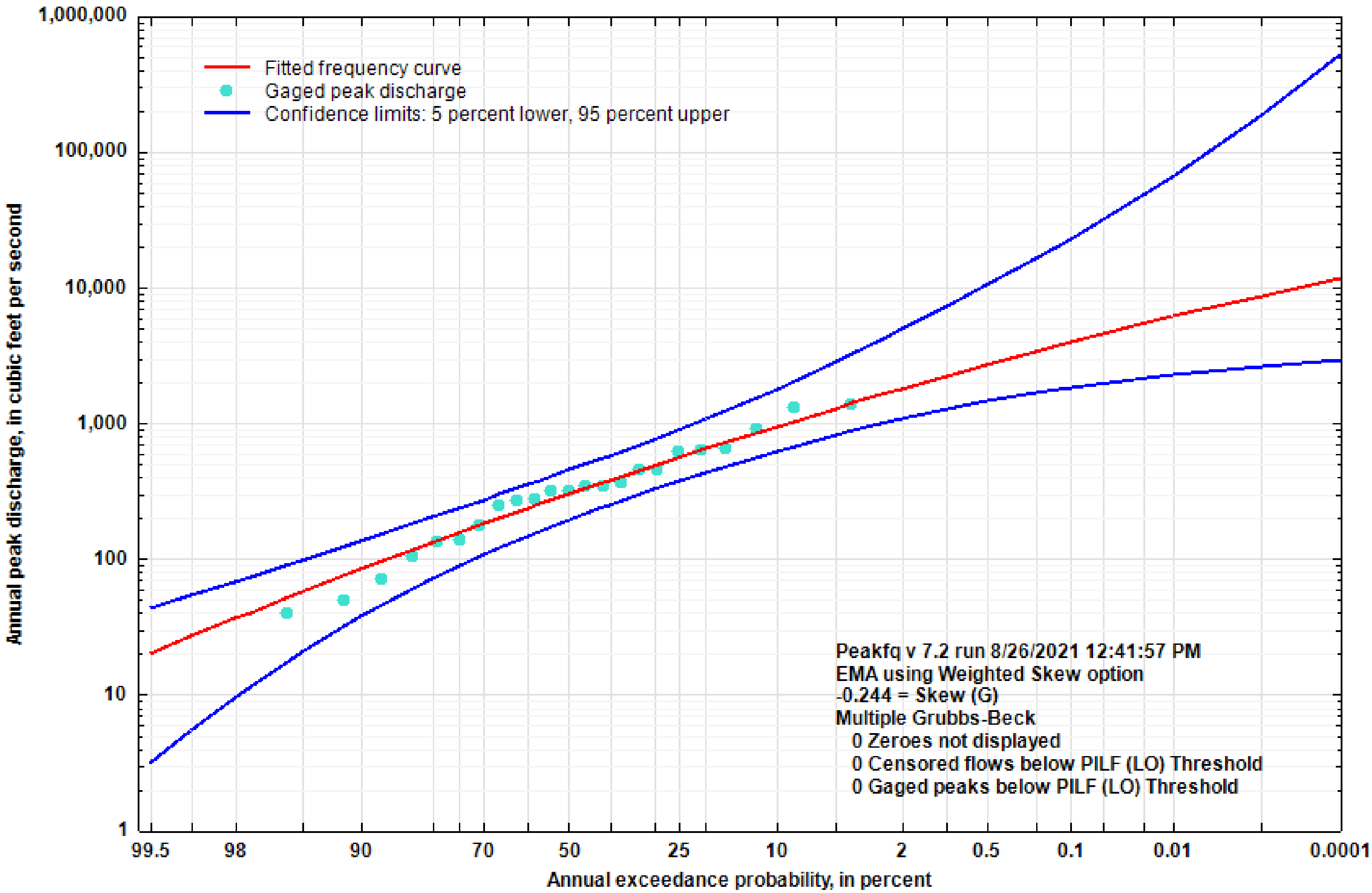


Figure 5-71. Flood Flow Frequency Curve for Tick Creek near Leslie, AR

07075000 - Middle Fork of Little Red River at Shirley, AR

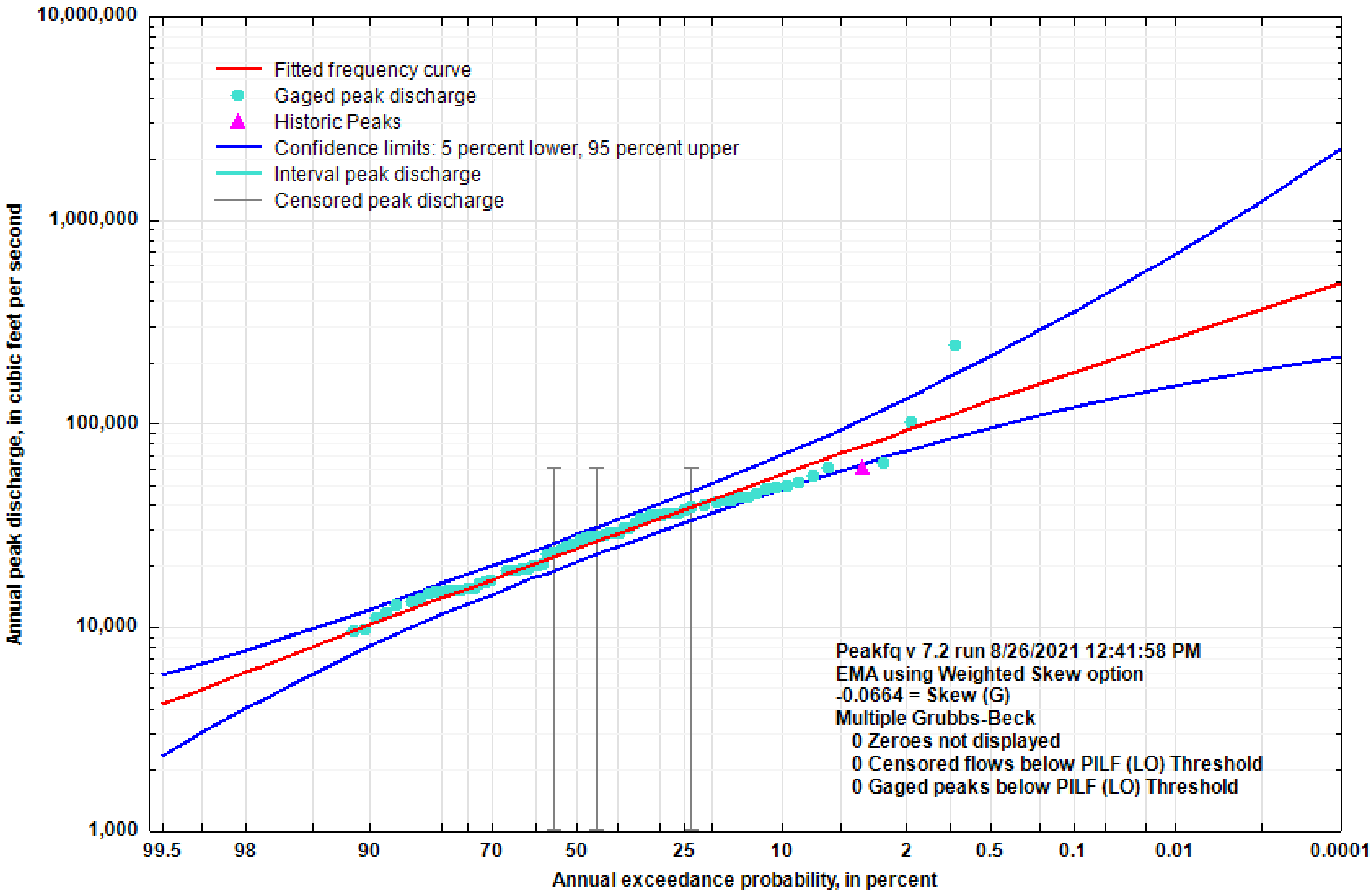


Figure 5-72. Flood Flow Frequency Curve for Middle Fork of Little Red River at Shirley, AR

07075300 - South Fork of Little Red River at Clinton, AR

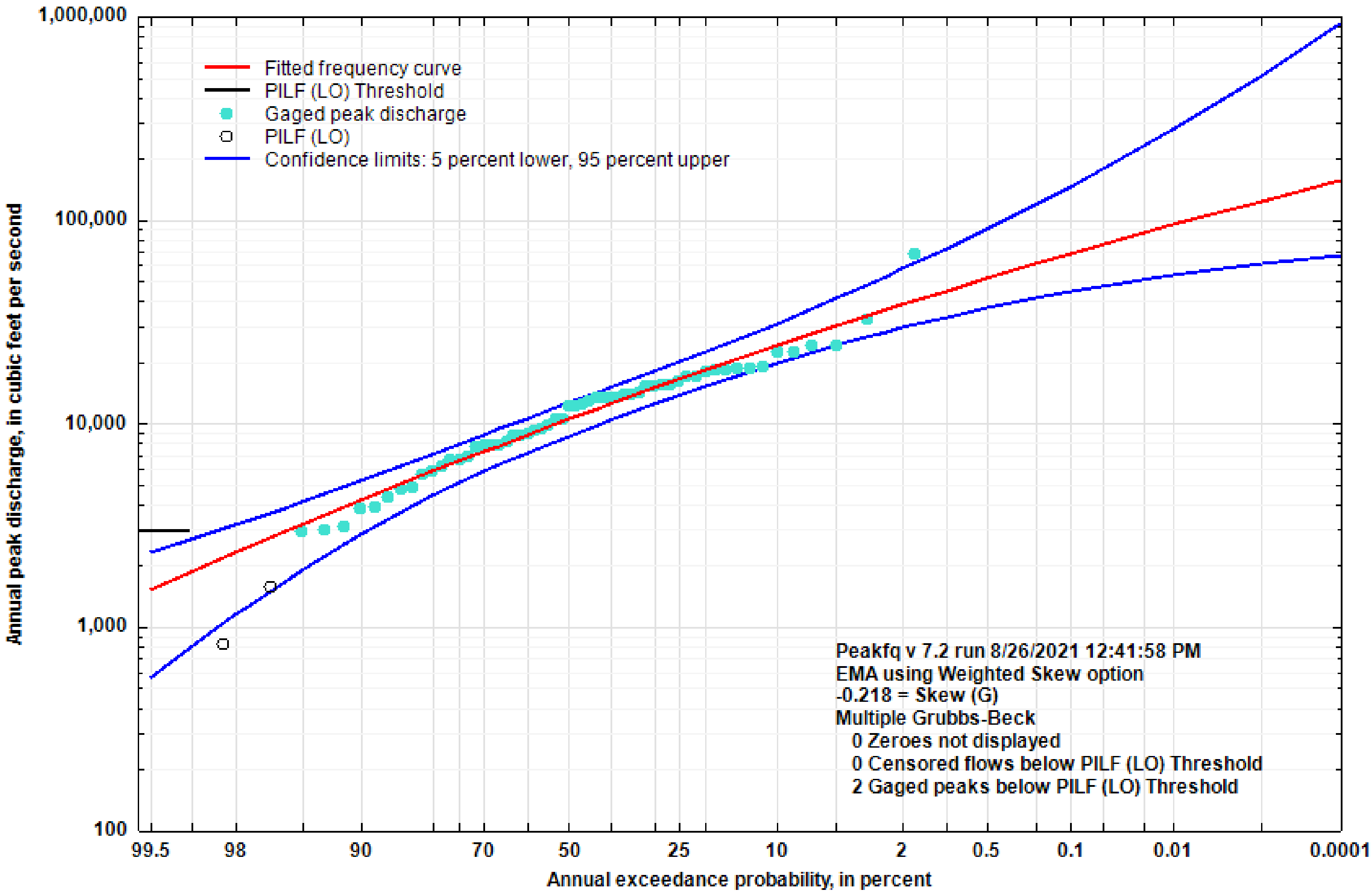


Figure 5-73. Flood Flow Frequency Curve for South Fork of Little Red River at Clinton, AR

07075600 - Choctaw Creek Tributary near Choctaw, AR

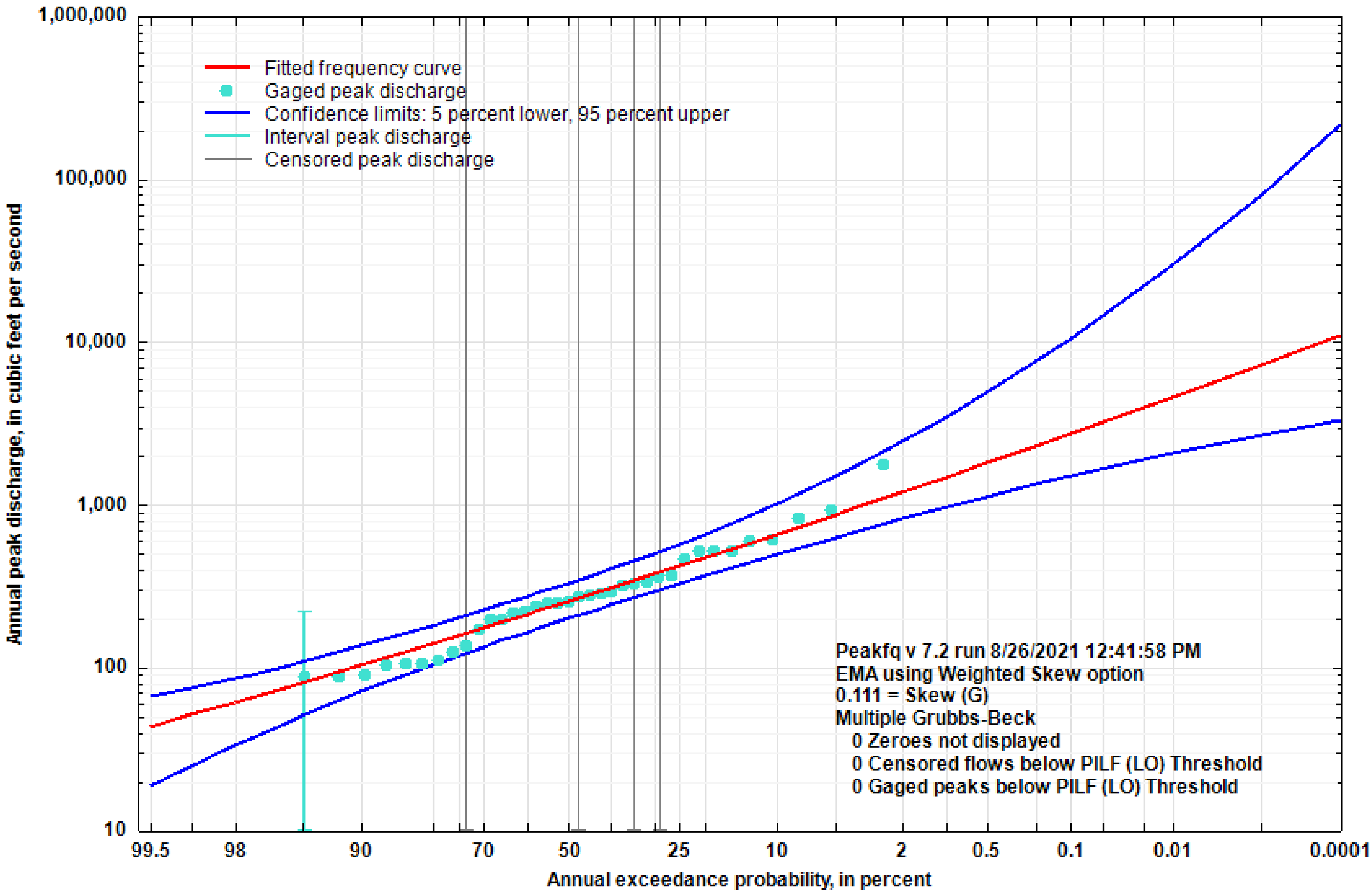


Figure 5-74. Flood Flow Frequency Curve for Choctaw Creek Tributary near Choctaw, AR

07075800 - Dill Branch Tributary near Ida, AR

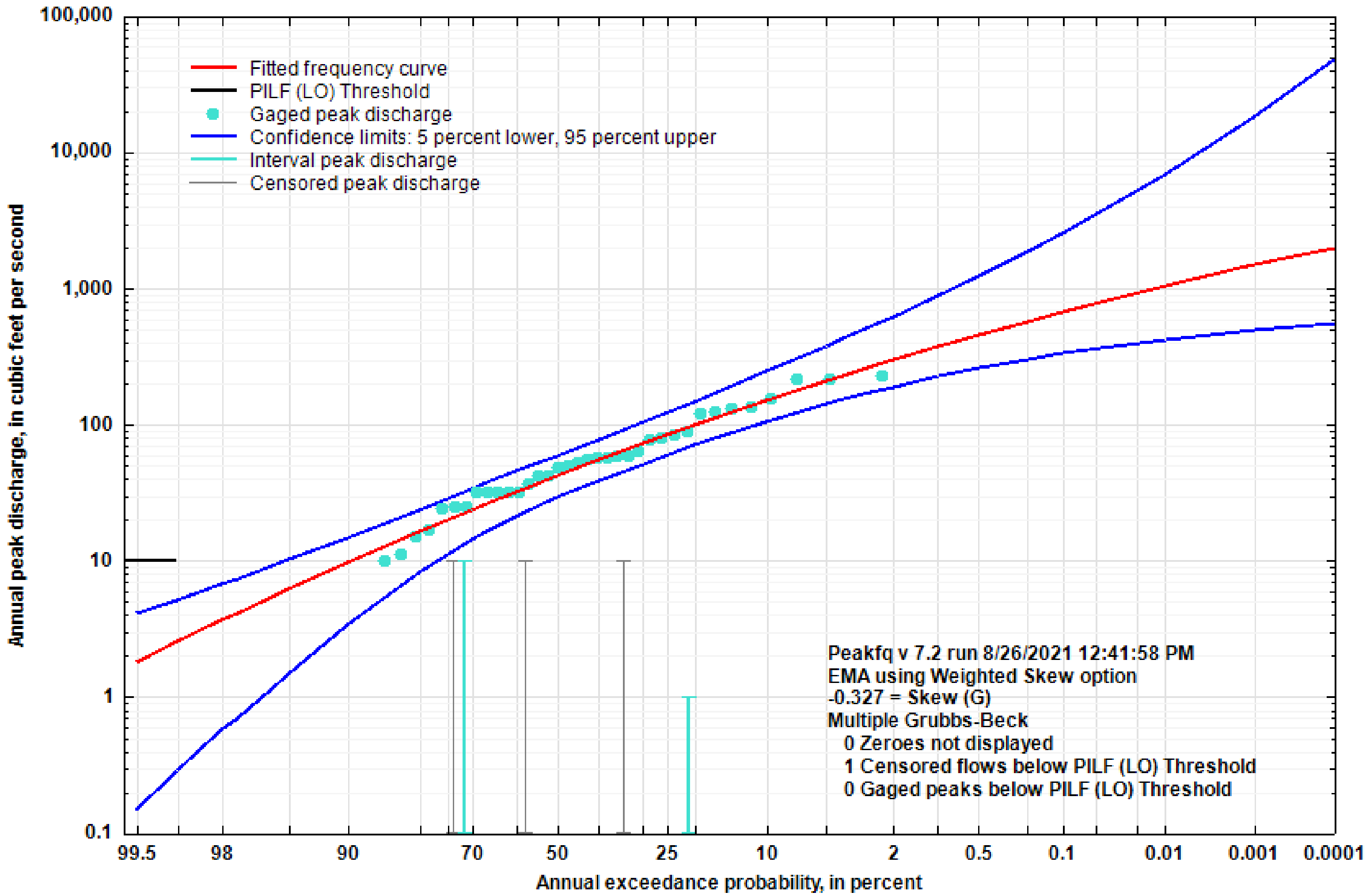


Figure 5-75. Flood Flow Frequency Curve for Dill Branch Tributary near Ida, AR

07076630 - Key Branch near Searcy, AR

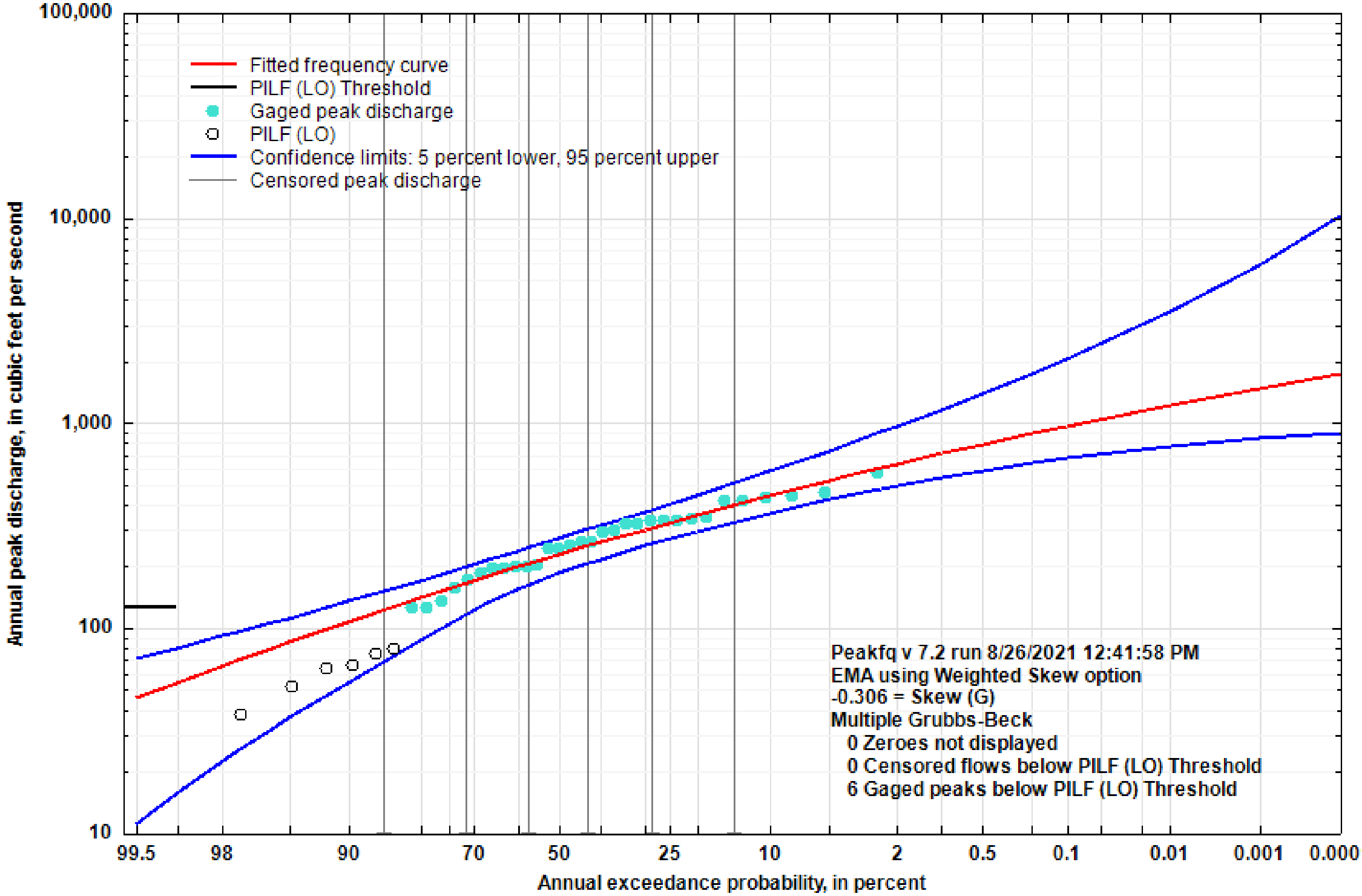


Figure 5-76. Flood Flow Frequency Curve for Key Branch near Searcy, AR

Table 5-4. Peak Streamflow Frequency for 2-yr to 500-yr Recurrence Intervals

Station number and name	Peak streamflow frequency by corresponding average return period (recurrence interval)							
	2-yr (ft^3/s)	5-yr (ft^3/s)	10-yr (ft^3/s)	25-yr (ft^3/s)	50-yr (ft^3/s)	100-yr (ft^3/s)	200-yr (ft^3/s)	500-yr (ft^3/s)
07047975 Dog Branch at St. Paul, AR								
Lower 95% CI	136	273	376	510	609	703	793	905
Estimate	**202**	**394**	**551**	**779**	**968**	**1,170**	**1,390**	**1,710**
Upper 95% CI	292	624	984	1,682	2,431	3,432	4,764	7,206
07048550 West Fork White River east of Fayetteville, AR								
Lower 95% CI	7,363	15,090	21,520	31,010	38,910	47,320	56,120	68,230
Estimate	**10,300**	**21,000**	**30,300**	**45,000**	**58,100**	**73,200**	**90,300**	**117,000**
Upper 95% CI	14,040	28,390	42,250	68,030	96,170	134,900	187,700	287,200
07048600 White River near Fayetteville, AR								
Lower 95% CI	20,530	35,200	45,820	59,650	69,900	79,930	89,760	102,400
Estimate	**24,600**	**42,300**	**56,000**	**75,400**	**91,200**	**108,000**	**126,000**	**152,000**
Upper 95% CI	29,440	52,510	73,430	108,800	142,800	184,600	235,500	320,200
07048940 War Eagle Creek near Witter, AR								
Lower 95% CI	2,032	4,124	5,751	7,962	9,645	11,320	12,960	15,080
Estimate	**2,990**	**5,980**	**8,520**	**12,300**	**15,600**	**19,300**	**23,400**	**29,400**
Upper 95% CI	4,342	9,619	15,570	27,550	40,990	59,680	85,440	134,700
07049000 War Eagle Creek near Hindsville, AR								
Lower 95% CI	11,970	19,420	24,650	31,380	36,370	41,280	46,100	52,350
Estimate	**14,000**	**22,800**	**29,400**	**38,600**	**46,000**	**53,900**	**62,300**	**74,200**
Upper 95% CI	16,350	27,360	36,710	51,870	66,230	83,730	105,000	140,300
07050200 Maxwell Creek at Kingston, AR								
Lower 95% CI	387	856	1,237	1,765	2,173	2,579	2,980	3,495
Estimate	**604**	**1,300**	**1,920**	**2,880**	**3,720**	**4,670**	**5,740**	**7,320**
Upper 95% CI	924	2,226	3,784	7,092	10,950	16,470	24,300	39,770
07050400 Freeman Branch at Berryville, AR								
Lower 95% CI	141	242	310	395	456	513	567	634

Estimate	**192**	**323**	**421**	**556**	**663**	**775**	**893**	**1,060**
Upper 95% CI	258	471	680	1,051	1,421	1,890	2,481	3,502
07050500 Kings River near Berryville, AR								
Lower 95% CI	14,820	26,180	34,690	46,080	54,740	63,360	71,920	83,110
Estimate	**17,400**	**30,800**	**41,400**	**56,600**	**69,200**	**82,800**	**97,500**	**119,000**
Upper 95% CI	20,340	36,830	51,390	75,880	99,650	129,000	165,100	225,400
07050545 North Carolina Creek near Marshfield, MO								
Lower 95% CI	549	1,660	2,163	2,709	3,098	3,470	3,828	4,280
Estimate	**1,280**	**2,180**	**2,860**	**3,790**	**4,520**	**5,290**	**6,080**	**7,190**
Upper 95% CI	1,592	3,223	4,853	8,483	13,190	19,130	25,920	37,780
07050690 Pearson Creek near Springfield, MO								
Lower 95% CI	487	1,568	2,064	2,608	2,993	3,363	3,716	4,160
Estimate	**1,210**	**2,120**	**2,810**	**3,760**	**4,510**	**5,300**	**6,120**	**7,270**
Upper 95% CI	1,558	3,291	5,085	9,193	14,650	21,340	29,270	43,340
07050700 James River near Springfield, MO								
Lower 95% CI	10,610	18,220	23,570	30,360	35,290	40,050	44,620	50,360
Estimate	**12,600**	**21,700**	**28,400**	**37,500**	**44,600**	**52,100**	**59,800**	**70,400**
Upper 95% CI	14,980	26,120	34,980	48,360	60,400	74,570	91,300	118,100
07050800 Maple Grove Branch near Ozark, MO								
Lower 95% CI	125	290	434	651	832	1,025	1,228	1,510
Estimate	**198**	**458**	**711**	**1,140**	**1,540**	**2,020**	**2,600**	**3,520**
Upper 95% CI	315	845	1,559	3,256	5,483	9,023	14,590	26,960
07052250 James River near Boaz, MO								
Lower 95% CI	13,110	22,310	28,260	35,570	40,730	45,600	50,190	55,860
Estimate	**17,200**	**28,500**	**36,700**	**47,800**	**56,300**	**65,200**	**74,400**	**86,900**
Upper 95% CI	21,990	38,670	53,540	78,020	101,300	129,800	165,000	224,600
07052370 Dry Crane Creek near Crane, MO								
Lower 95% CI	108	664	1,385	2,026	2,527	3,000	3,462	4,062
Estimate	**597**	**1,460**	**2,280**	**3,620**	**4,850**	**6,280**	**7,910**	**10,400**
Upper 95% CI	876	2,399	8,200	23,760	40,280	70,320	121,800	245,000
07052500 James River at Galena, MO								
Lower 95% CI	18,030	31,560	41,140	53,070	61,420	69,190	76,390	85,150

Estimate	**20,900**	**36,400**	**47,900**	**63,300**	**75,300**	**87,600**	**100,000**	**118,000**
Upper 95% CI	24,120	42,620	57,760	81,070	101,700	125,200	152,100	193,500
07053207 Long Creek at Denver, AR								
Lower 95% CI	5,000	9,439	12,830	17,440	21,000	24,580	28,170	32,920
Estimate	**6,930**	**13,100**	**18,200**	**26,000**	**32,700**	**40,100**	**48,400**	**60,900**
Upper 95% CI	9,613	20,040	31,450	54,050	79,220	114,100	162,100	253,600
07053250 Yocum Creek near Oak Grove, AR								
Lower 95% CI	1,618	4,242	6,715	10,560	13,810	17,300	20,970	26,020
Estimate	**2,600**	**6,740**	**11,000**	**18,500**	**25,700**	**34,500**	**45,000**	**62,100**
Upper 95% CI	4,121	12,070	23,010	49,450	84,290	139,600	226,000	416,300
07053810 Bull Creek near Walnut Shade, MO								
Lower 95% CI	8,226	16,130	21,820	29,050	34,210	39,070	43,610	49,140
Estimate	**11,700**	**22,300**	**30,600**	**42,300**	**51,700**	**61,700**	**72,200**	**86,900**
Upper 95% CI	16,230	33,100	49,950	80,070	110,400	149,200	198,600	285,200
07053950 Ingenthron Hollow near Forsyth, MO								
Lower 95% CI	134	252	344	472	573	678	786	934
Estimate	**187**	**355**	**499**	**723**	**921**	**1,150**	**1,410**	**1,810**
Upper 95% CI	264	566	915	1,640	2,490	3,723	5,500	9,084
07054080 Beaver Creek at Bradleyville, MO								
Lower 95% CI	8,764	18,760	25,450	34,050	40,340	46,370	52,130	59,310
Estimate	**13,400**	**25,900**	**35,900**	**50,200**	**61,900**	**74,400**	**87,800**	**107,000**
Upper 95% CI	18,400	39,260	61,350	102,600	145,200	199,800	269,400	391,200
07054200 Yanell Branch near Kirbyville, MO								
Lower 95% CI	44	88	163	202	221	238	252	275
Estimate	**104**	**164**	**206**	**264**	**309**	**356**	**406**	**474**
Upper 95% CI	126	193	408	717	1,082	1,602	2,328	3,311
07054300 Gray Branch at Lutie, MO								
Lower 95% CI	68	146	194	253	293	330	365	406
Estimate	**108**	**202**	**272**	**366**	**439**	**513**	**588**	**690**
Upper 95% CI	149	306	464	755	1,053	1,428	1,899	2,712
07054400 Charley Creek near Omaha, AR								
Lower 95% CI	834	1,468	1,922	2,526	2,988	3,452	3,919	4,536

Estimate	**1,150**	**2,010**	**2,700**	**3,720**	**4,580**	**5,530**	**6,580**	**8,130**
Upper 95% CI	1572	3,051	4,602	7,555	10,750	15,100	21,000	32,160
07054410 Bear Creek near Omaha, AR								
Lower 95% CI	6,107	13,770	20,360	30,030	37,910	46,160	54,690	66,280
Estimate	**9,140**	**20,600**	**31,300**	**48,900**	**65,100**	**84,200**	**106,000**	**141,000**
Upper 95% CI	13,640	34,320	60,090	117,300	187,500	293,000	449,500	774,800
07055550 Crooked Creek Tributary near Dog Patch, AR								
Lower 95% CI	441	821	1,104	1,492	1,795	2,103	2,417	2,838
Estimate	**604**	**1,120**	**1,550**	**2,200**	**2,770**	**3,400**	**4,120**	**5,190**
Upper 95% CI	824	1,698	2,647	4,513	6,593	9,497	13,540	21,410
07055607 Crooked Creek at Kelly Crossing at Yellville, AR								
Lower 95% CI	6,953	15,090	22,190	32,870	41,860	51,570	61,960	76,680
Estimate	**9,590**	**21,100**	**32,200**	**50,700**	**68,200**	**89,200**	**114,000**	**155,000**
Upper 95% CI	13,340	32,510	56,030	108,200	172,700	270,400	416,800	725,200
07055646 Buffalo River near Boxley, AR								
Lower 95% CI	7,076	12,790	16,870	22,060	25,790	29,340	32,700	36,850
Estimate	**9,490**	**16,900**	**22,700**	**30,800**	**37,300**	**44,100**	**51,400**	**61,800**
Upper 95% CI	12,570	23,930	35,030	54,770	74,550	99,560	131,100	185,400
07055650 Smith Creek near Boxley, AR								
Lower 95% CI	863	2,087	3,128	4,604	5,756	6,905	8,035	9,480
Estimate	**1,420**	**3,320**	**5,070**	**7,860**	**10,300**	**13,200**	**16,400**	**21,200**
Upper 95% CI	2,270	5,941	10,570	20,800	33,110	51,180	77,390	130,400
07055800 Dry Branch near Vendor, AR								
Lower 95% CI	650	1,489	2,168	3,110	3,836	4,558	5,266	6,173
Estimate	**1,050**	**2,310**	**3,420**	**5,130**	**6,620**	**8,290**	**10,100**	**12,900**
Upper 95% CI	1,630	3,961	6,734	12,590	19,380	29,090	42,870	70,160
07055875 Richland Creek near Witts Spring, AR								
Lower 95% CI	7,530	13,130	17,190	22,490	26,460	30,370	34,230	39,220
Estimate	**9,970**	**17,400**	**23,200**	**31,700**	**38,700**	**46,400**	**54,700**	**66,800**
Upper 95% CI	13,190	25,020	37,020	59,240	82,550	113,300	153,500	226,400
07056000 Buffalo River near St. Joe, AR								
Lower 95% CI	32,250	57,370	75,500	98,780	115,600	131,600	146,700	165,400

Estimate	**38,000**	**67,300**	**89,500**	**120,000**	**144,000**	**169,000**	**196,000**	**232,000**
Upper 95% CI	44,640	79,650	108,700	154,600	196,200	244,600	300,500	388,000
07056515 Bear Creek near Silver Hill, AR								
Lower 95% CI	7,784	12,660	15,450	18,960	21,550	24,110	26,640	29,940
Estimate	**10,400**	**15,800**	**19,900**	**25,500**	**30,000**	**34,800**	**39,900**	**47,200**
Upper 95% CI	13,010	22,130	30,830	46,240	61,680	81,210	105,800	148,400
07057300 Dodd Creek Tributary near Mountain Home, AR								
Lower 95% CI	211	358	457	578	662	740	812	899
Estimate	**276**	**461**	**596**	**778**	**919**	**1,060**	**1,220**	**1,420**
Upper 95% CI	356	629	880	1,304	1,708	2,199	2,794	3,778
07057500 North Fork River near Tecumseh, MO								
Lower 95% CI	10,690	21,800	31,440	46,020	58,450	72,130	87,070	108,800
Estimate	**13,100**	**27,200**	**40,400**	**62,200**	**82,800**	**108,000**	**137,000**	**185,000**
Upper 95% CI	16,070	35,220	56,410	99,520	149,000	219,500	319,000	514,400
07058000 Bryant Creek near Tecumseh, MO								
Lower 95% CI	10,150	21,160	30,100	42,590	52,250	61,910	71,470	83,840
Estimate	**12,800**	**26,700**	**38,500**	**56,400**	**71,800**	**88,800**	**107,000**	**135,000**
Upper 95% CI	16,110	34,680	53,340	87,990	124,200	171,400	232,200	339,900
07058980 Bennetts River at Vidette, AR								
Lower 95% CI	3,623	5,288	6,088	6,979	7,571	8,108	8,599	9,189
Estimate	**4,520**	**6,120**	**7,140**	**8,380**	**9,280**	**10,200**	**11,000**	**12,200**
Upper 95% CI	5,209	7,469	9,251	11,910	14,150	16,610	19,290	23,260
07059450 Big Creek near Elizabeth, AR								
Lower 95% CI	1,870	2,966	3,667	4,499	5,063	5,576	6,045	6,603
Estimate	**2,410**	**3,760**	**4,710**	**5,930**	**6,860**	**7,800**	**8,750**	**10,000**
Upper 95% CI	3,065	5,072	6,858	9,764	12,450	15,650	19,440	25,550
07060600 Band Mill Creek near Brockwell, AR								
Lower 95% CI	183	330	439	591	713	841	975	1,161
Estimate	**246**	**443**	**612**	**872**	**1,100**	**1,370**	**1,670**	**2,140**
Upper 95% CI	331	674	1,057	1,837	2,735	4,026	5,878	9,610
07060670 Hughes Creek near Mountain View, AR								
Lower 95% CI	661	1,037	1,277	1,576	1,791	1,998	2,198	2,452

Estimate	**850**	**1,310**	**1,650**	**2,110**	**2,480**	**2,860**	**3,260**	**3,830**
Upper 95% CI	1,081	1,823	2,519	3,709	4,870	6,319	8,126	11,220
07060710 North Sylamore Creek near Fifty Six, AR								
Lower 95% CI	3,696	8,054	11,490	16,000	19,200	22,140	24,810	27,970
Estimate	**4,900**	**10,500**	**15,100**	**21,800**	**27,300**	**33,100**	**39,300**	**48,000**
Upper 95% CI	6,387	13,990	21,430	34,530	47,360	63,190	82,640	115,200
07060830 Wolf Bayou near Drasco, AR								
Lower 95% CI	35	80	115	163	198	232	264	303
Estimate	**56**	**122**	**179**	**264**	**337**	**416**	**502**	**626**
Upper 95% CI	87	206	344	627	943	1,381	1,980	3,115
07061100 Gibbs Creek at Sulphur Rock, AR								
Lower 95% CI	581	1,064	1,416	1,875	2,214	2,543	2,861	3,265
Estimate	**796**	**1,440**	**1,960**	**2,700**	**3,310**	**3,970**	**4,690**	**5,710**
Upper 95% CI	1,082	2,131	3,207	5,206	7,297	10,040	13,620	20,050
07061260 East Fork Black River near Ironton, MO								
Lower 95% CI	1,347	3,145	4,492	6,204	7,403	8,495	9,477	10,610
Estimate	**2,160**	**4,680**	**6,720**	**9,600**	**11,900**	**14,200**	**16,700**	**20,000**
Upper 95% CI	3,230	7,488	12,030	20,660	29,700	41,550	57,010	84,910
07061500 Black River near Annapolis, MO								
Lower 95% CI	16,600	31,200	42,010	55,840	65,650	74,830	83,370	93,760
Estimate	**19,900**	**37,200**	**50,600**	**69,300**	**84,300**	**100,000**	**116,000**	**139,000**
Upper 95% CI	23,760	45,180	64,010	94,530	122,500	155,300	193,700	254,400
07061900 Logan Creek at Ellington, MO								
Lower 95% CI	1,584	5,726	10,010	17,010	23,040	29,480	36,160	45,170
Estimate	**3,090**	**10,200**	**18,400**	**33,500**	**48,700**	**67,400**	**90,000**	**127,000**
Upper 95% CI	5,512	20,990	45,380	109,200	197,600	342,700	576,400	1,110,000
07063470 Tenmile Creek near Poplar Bluff, MO								
Lower 95% CI	4,929	8,545	10,890	13,700	15,620	17,370	18,970	20,870
Estimate	**6,720**	**11,300**	**14,500**	**18,800**	**22,100**	**25,500**	**28,900**	**33,500**
Upper 95% CI	8,877	15,890	22,350	33,020	43,070	55,180	69,820	94,030
07064300 Fudge Hollow near Licking, MO								
Lower 95% CI	93	171	231	311	373	436	498	582

Estimate	**128**	**236**	**327**	**462**	**579**	**709**	**854**	**1,070**
Upper 95% CI	177	363	566	967	1,413	2,032	2,885	4,515
07064500 Big Creek near Yukon, MO								
Lower 95% CI	1,469	2,928	4,077	5,670	6,913	8,170	9,429	11,080
Estimate	**2,010**	**3,980**	**5,660**	**8,180**	**10,400**	**12,800**	**15,500**	**19,500**
Upper 95% CI	2,710	5,568	8,434	13,810	19,550	27,230	37,420	56,020
07065495 Jacks Fork at Alley Spring, MO								
Lower 95% CI	9,890	20,270	28,410	39,500	47,930	56,260	64,430	74,900
Estimate	**14,100**	**28,500**	**40,800**	**59,300**	**75,200**	**92,900**	**112,000**	**141,000**
Upper 95% CI	19,840	43,610	69,670	120,900	177,200	253,800	357,400	550,800
07066000 Jacks Fork at Eminence, MO								
Lower 95% CI	10,420	21,360	30,030	41,790	50,630	59,250	67,620	78,250
Estimate	**12,600**	**25,700**	**36,700**	**52,900**	**66,500**	**81,300**	**97,300**	**120,000**
Upper 95% CI	15,120	31,430	46,690	72,810	98,010	128,800	166,100	227,600
07066500 Current River near Eminence, MO								
Lower 95% CI	17,790	38,450	52,190	70,260	83,790	97,060	110,000	126,500
Estimate	**24,800**	**48,200**	**66,900**	**93,600**	**115,000**	**138,000**	**163,000**	**198,000**
Upper 95% CI	30,730	63,470	94,380	146,700	196,500	257,000	330,800	454,500
07066800 Sycamore Creek near Winona, MO								
Lower 95% CI	87	177	246	338	408	476	543	628
Estimate	**120**	**240**	**340**	**488**	**612**	**748**	**896**	**1,110**
Upper 95% CI	163	351	549	927	1,336	1,888	2,629	4,009
07067000 Current River at Van Buren, MO								
Lower 95% CI	23,350	44,850	61,470	83,900	100,900	117,700	134,300	155,800
Estimate	**27,400**	**52,800**	**73,400**	**103,000**	**128,000**	**156,000**	**185,000**	**227,000**
Upper 95% CI	32,200	62,860	90,450	136,500	180,300	233,100	296,600	399,900
07068000 Current River at Doniphan, MO								
Lower 95% CI	24,180	45,480	61,450	82,610	98,370	113,700	128,500	147,300
Estimate	**28,500**	**53,400**	**73,000**	**100,000**	**123,000**	**146,000**	**171,000**	**206,000**
Upper 95% CI	33,360	63,510	89,120	130,100	168,500	214,800	270,500	361,400
07068200 North Prong Little Black River at Hunter, MO								
Lower 95% CI	109	262	386	555	682	803	918	1,060

Estimate	**174**	**400**	**598**	**898**	**1,150**	**1,440**	**1,740**	**2,180**
Upper 95% CI	265	658	1,109	2,034	3,075	4,527	6,532	10,380
07068510 Little Black River below Fairdealing, MO								
Lower 95% CI	6,010	12,940	18,810	27,320	34,200	41,350	48,710	58,680
Estimate	**7,950**	**17,200**	**25,600**	**39,100**	**51,300**	**65,300**	**81,500**	**106,000**
Upper 95% CI	10,5000	24,120	39,220	69,550	103,600	150,900	215,800	339,300
07068870 Fourche River Tributary at Middlebrook, AR								
Lower 95% CI	112	165	197	236	264	290	315	346
Estimate	**139**	**202**	**246**	**304**	**349**	**394**	**442**	**508**
Upper 95% CI	171	267	353	492	622	779	968	1,281
07069100 Adams Branch near West Plains, MO								
Lower 95% CI	292	404	475	561	622	680	736	807
Estimate	**343**	**478**	**571**	**693**	**788**	**885**	**986**	**1,130**
Upper 95% CI	406	599	766	1,034	1,283	1,581	1,937	2,515
07069250 Brush Creek near Mammoth Spring, AR								
Lower 95% CI	177	324	436	588	705	824	944	1,104
Estimate	**227**	**417**	**574**	**808**	**1,010**	**1,230**	**1,480**	**1,860**
Upper 95% CI	290	570	856	1,393	1,965	2,729	3,744	5,605
07069290 Miller Creek near Salem, AR								
Lower 95% CI	369	705	943	1,257	1,491	1,722	1,947	2,238
Estimate	**533**	**984**	**1,350**	**1,880**	**2,320**	**2,810**	**3,330**	**4,100**
Upper 95% CI	747	1,539	2,392	4,018	5,761	8,098	11,220	17,000
07069500 Spring River at Imboden, AR								
Lower 95% CI	22,750	42,390	57,840	79,330	96,260	113,600	131,400	155,300
Estimate	**27,000**	**50,500**	**70,100**	**99,400**	**124,000**	**152,000**	**183,000**	**229,000**
Upper 95% CI	31,960	61,170	88,220	135,500	182,800	242,700	318,100	447,500
07070200 Burnham Branch near Willow Springs, MO								
Lower 95% CI	44	228	332	462	562	663	765	898
Estimate	**158**	**348**	**515**	**770**	**991**	**1,240**	**1,510**	**1,900**
Upper 95% CI	226	634	1,155	2,647	5,137	8,431	12,870	21,680
07071500 Eleven Point River near Bardley, MO								
Lower 95% CI	7,762	16,750	24,220	35,010	43,690	52,650	61,780	74,010

Estimate	**9,520**	**20,500**	**30,200**	**45,100**	**58,200**	**73,000**	**89,400**	**114,000**
Upper 95% CI	11,550	25,570	39,260	63,750	89,160	122,600	166,500	245,800
07072000 Eleven Point River near Ravenden Springs, AR								
Lower 95% CI	10,380	20,670	29,840	44,080	56,640	70,870	86,920	111,200
Estimate	**12,400**	**25,300**	**37,600**	**58,800**	**79,400**	**105,000**	**136,000**	**188,000**
Upper 95% CI	14,900	32,180	51,840	93,030	141,800	213,400	317,800	530,800
07072200 Hubble Creek near Pocahontas, AR								
Lower 95% CI	511	704	820	951	1,039	1,118	1,189	1,275
Estimate	**602**	**826**	**971**	**1,150**	**1,280**	**1,410**	**1,540**	**1,710**
Upper 95% CI	706	1,010	1,252	1,614	1,927	2,277	2,671	3,269
07073500 Piney Fork at Evening Shade								
Lower 95% CI	3,736	6,860	9,235	12,430	14,860	17,280	19,680	22,830
Estimate	**4,560**	**8,400**	**11,500**	**16,100**	**19,900**	**24,100**	**28,700**	**35,400**
Upper 95% CI	5,553	10,640	15,470	23,990	32,500	43,220	56,670	79,690
07074000 Strawberry River near Poughkeepsie, AR								
Lower 95% CI	13,790	22,540	28,870	37,260	43,630	50,040	56,490	65,050
Estimate	**15,800**	**26,000**	**33,900**	**45,300**	**54,700**	**64,900**	**76,000**	**92,200**
Upper 95% CI	18,090	30,780	42,000	60,800	79,090	101,900	130,200	178,400
07074200 Dry Branch Tributary near Sidney, AR								
Lower 95% CI	429	742	930	1,150	1,297	1,431	1,551	1,693
Estimate	**594**	**962**	**1,220**	**1,550**	**1,790**	**2,040**	**2,290**	**2,620**
Upper 95% CI	768	1,322	1,826	2,658	3,422	4,318	5,371	7,054
07074250 Reeds Creek near Strawberry								
Lower 95% CI	2,080	4,021	5,537	7,640	9,292	10,980	12,710	15,030
Estimate	**2,980**	**5,770**	**8,180**	**11,900**	**15,200**	**18,900**	**23,100**	**29,500**
Upper 95% CI	4,299	9,404	15,320	27,620	41,970	62,660	92,300	151,500
07074900 Trace C Trib nr Marshall, Ark								
Lower 95% CI	71	123	156	197	226	254	280	312
Estimate	**95**	**158**	**204**	**266**	**315**	**366**	**419**	**492**
Upper 95% CI	122	218	309	464	613	796	1,018	1,392
07074950 Tick Creek near Leslie, AR								
Lower 95% CI	194	434	627	890	1,086	1,276	1,458	1,683

Estimate	**301**	**650**	**952**	**1,410**	**1,800**	**2,220**	**2,690**	**3,370**
Upper 95% CI	452	1,070	1,789	3,269	4,933	7,239	10,400	16,410
07075000 Middle Fork of Little Red River at Shirley, AR								
Lower 95% CI	20,730	36,010	47,250	62,020	73,050	83,930	94,630	108,500
Estimate	**24,200**	**42,100**	**56,100**	**75,900**	**92,000**	**109,000**	**128,000**	**155,000**
Upper 95% CI	28,160	50,220	69,690	101,900	132,200	168,700	212,500	283,700
07075300 South Fork of Little Red River at Clinton, AR								
Lower 95% CI	8,648	15,140	19,710	25,450	29,530	33,370	36,970	41,400
Estimate	**10,400**	**18,200**	**24,000**	**32,000**	**38,200**	**44,700**	**51,500**	**60,800**
Upper 95% CI	12,560	22,460	30,960	44,630	57,310	72,400	90,320	119,300
07075600 Choctaw Creek Tributary near Choctaw, AR								
Lower 95% CI	200	366	496	677	820	968	1,121	1,330
Estimate	**256**	**475**	**661**	**946**	**1,200**	**1,480**	**1,800**	**2,300**
Upper 95% CI	329	660	1,010	1,693	2,447	3,484	4,905	7,600
07075800 Dill Branch Tributary near Ida, AR								
Lower 95% CI	29	71	106	154	190	226	260	303
Estimate	**42**	**100**	**152**	**231**	**299**	**375**	**458**	**578**
Upper 95% CI	60	148	245	430	627	892	1,244	1,892
07076630 Key Branch near Searcy, AR								
Lower 95% CI	184	296	364	442	495	543	585	636
Estimate	**228**	**356**	**442**	**550**	**630**	**710**	**788**	**890**
Upper 95% CI	274	444	581	784	960	1,159	1,385	1,734

5.3 Changes to Flood Flow Frequency Estimates Over Time

Changes to 1/100 AEP flood flow frequency estimates over time were performed by running PeakFQ sequentially with one year added for each subsequent analysis. The first analysis uses the first ten years of peak streamflow data for the gage location being analyzed. These results are shown in Figure 5-77 through Figure 5-84. Figure 5-77 through Figure 5-84 also contain the most 1/100 AEP peak streamflow results obtained from USGS StreamStats (US Geological Survey, 2019), which is a web application that allows a user to place a point on a stream grid and retrieve the most up-to-date regional regression equation results for flood frequency quantiles and associated confidence intervals. Table 5-5 lists the maximum and minimum 1/100 AEP peak streamflows from the iterative Bulletin 17C analysis. As seen in the iterative Bulletin 17C analysis plot for North Fork River near Tecumseh, MO and Bryant Creek near Tecumseh, MO, the 2017 flood created a significant increase in the estimated 1/100 AEP peak streamflow. It's uncertain how leverage these points would have with regards to impacts on regional regression equations. After floods of the magnitude which occurred during the 2017 flood event, regional regression equations should be updated at the basin scale.

Table 5-5. Comparison of maximum and minimum 1/100 AEP peak flows from iterative Bulletin 17C analyses, 1/100 AEP peak flows from USGS StreamStats, and 1/100 AEP peak flow from 2020 USGS Study.

USGS Station Number	USGS Station Name	Maximum Peak Flow from Iterating PeakFQ (ft^3/s)	Minimum Peak Flow from Iterating PeakFQ (ft^3/s)	Peak Flow from StreamStats (ft^3/s)	Peak Flow from 2020 USGS Study (ft^3/s)
07048600	White River near Fayetteville, AR	125,000	96,200	135,000	108,000
07049000	War Eagle Creek near Hindsville, AR	77,500	51,000	69,700	53,900
07050500	Kings River near Berryville, AR	97,500	77,900	94,700	82,800
07050700	James River near Springfield, MO	63,500	44,200	43,300	52,100
07052250	James River at Boaz, MO	111,000	43,900	75,500	108,000
07052500	James River at Galena, MO	77,300	47,500	59,300	65,200
07057500	North Fork River near Tecumseh, MO	89,400	54,600	100,000	87,600
07058000	Bryant Creek near Tecumseh, MO	91,000	41,800	72,700	88,000

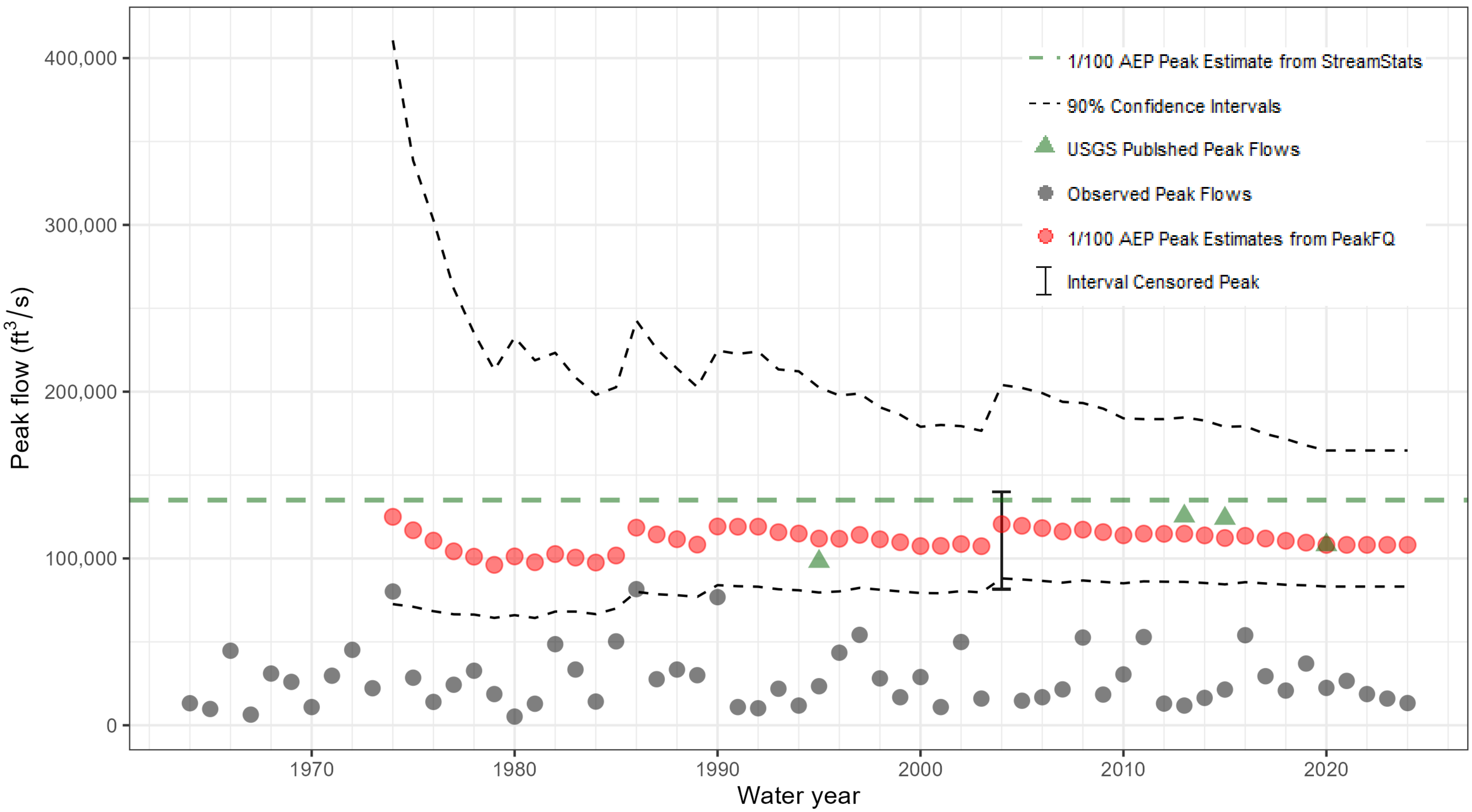


Figure 5-77. Change in 100-Year Flow over Time for White River near Fayetteville, AR (07048600).

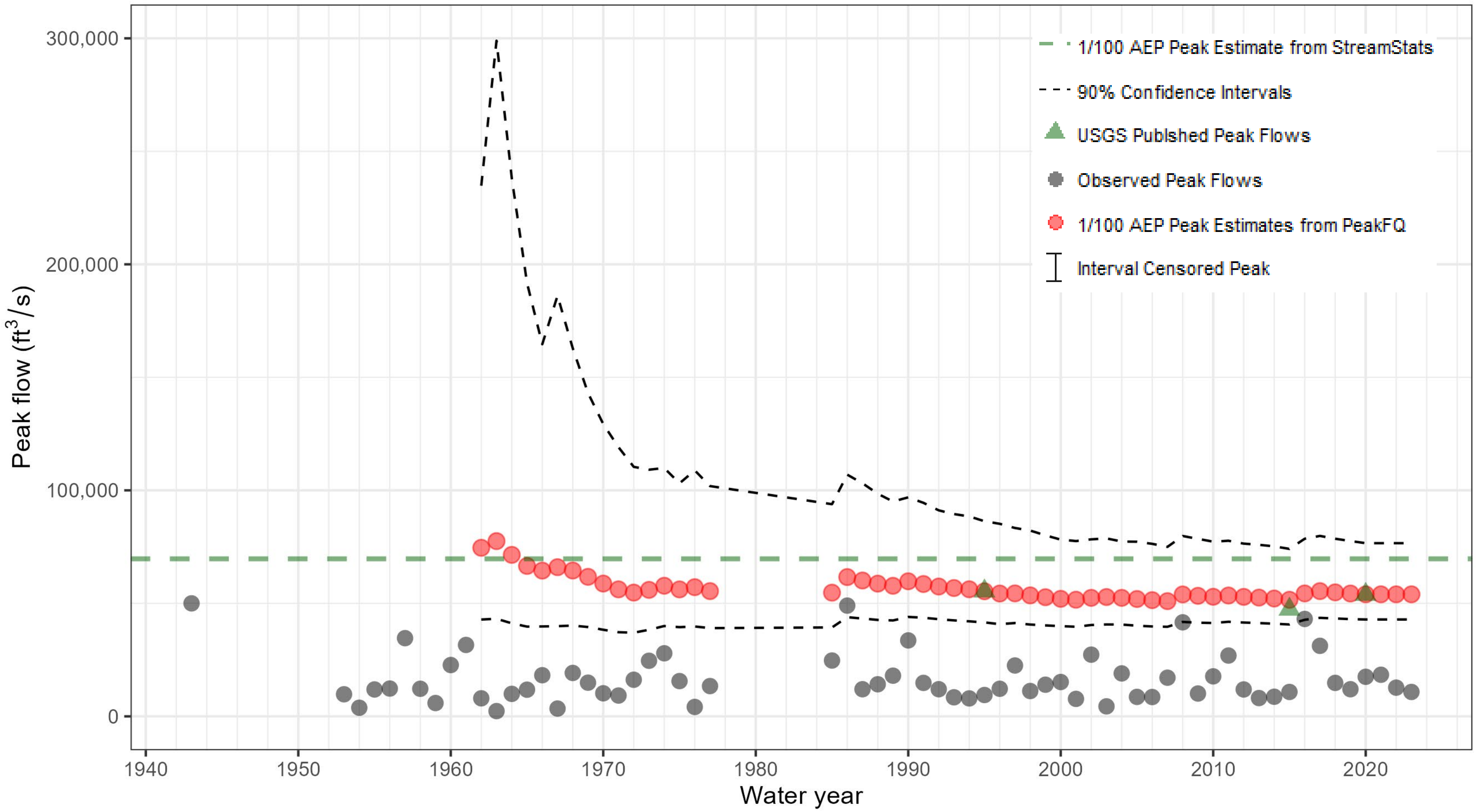


Figure 5-78. Change in 100-Year Flow over Time for War Eagle Creek near Hindsville, AR (07049000)

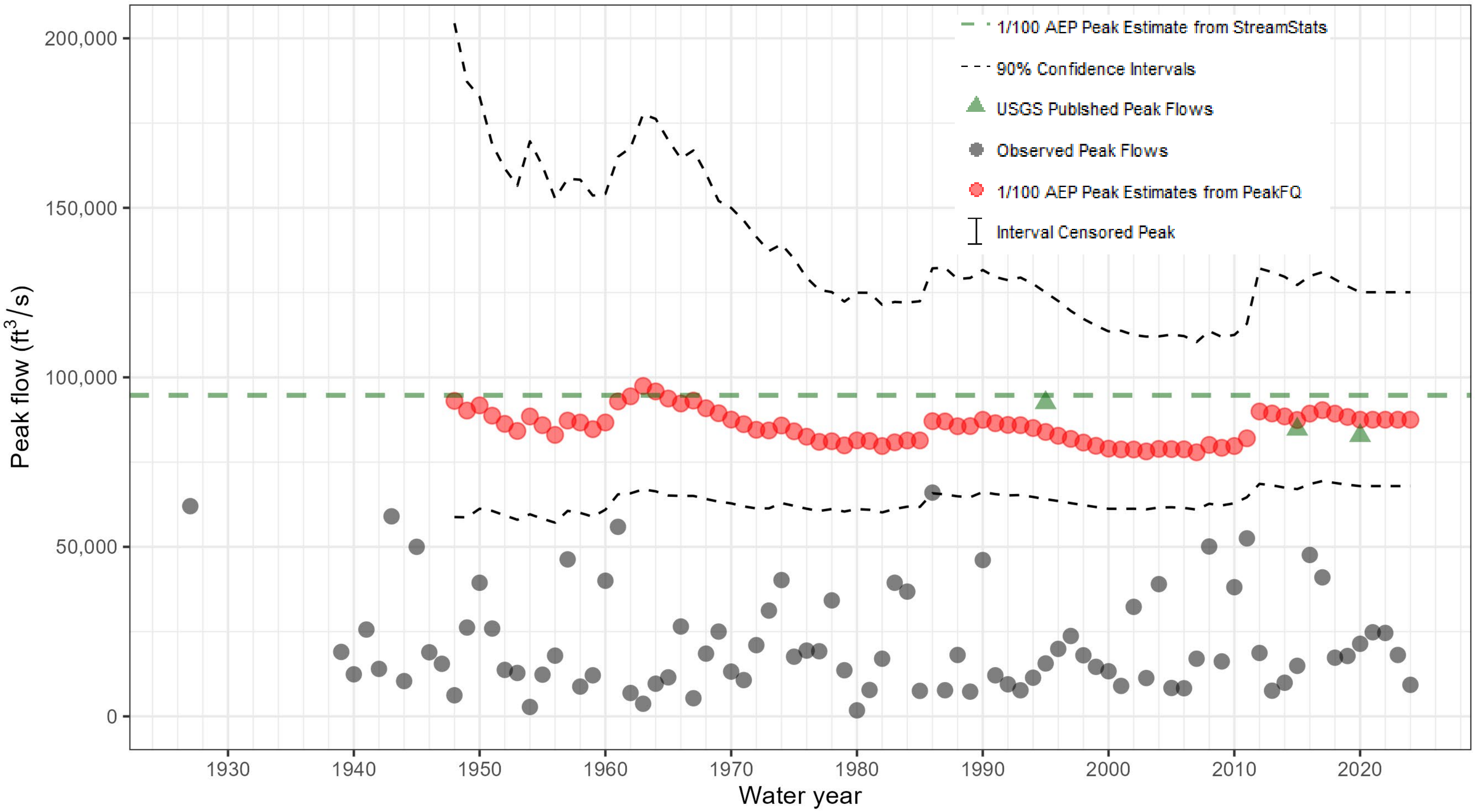


Figure 5-79. Change in 100-Year Flow over Time for Kings River near Berryville, AR (07050500)

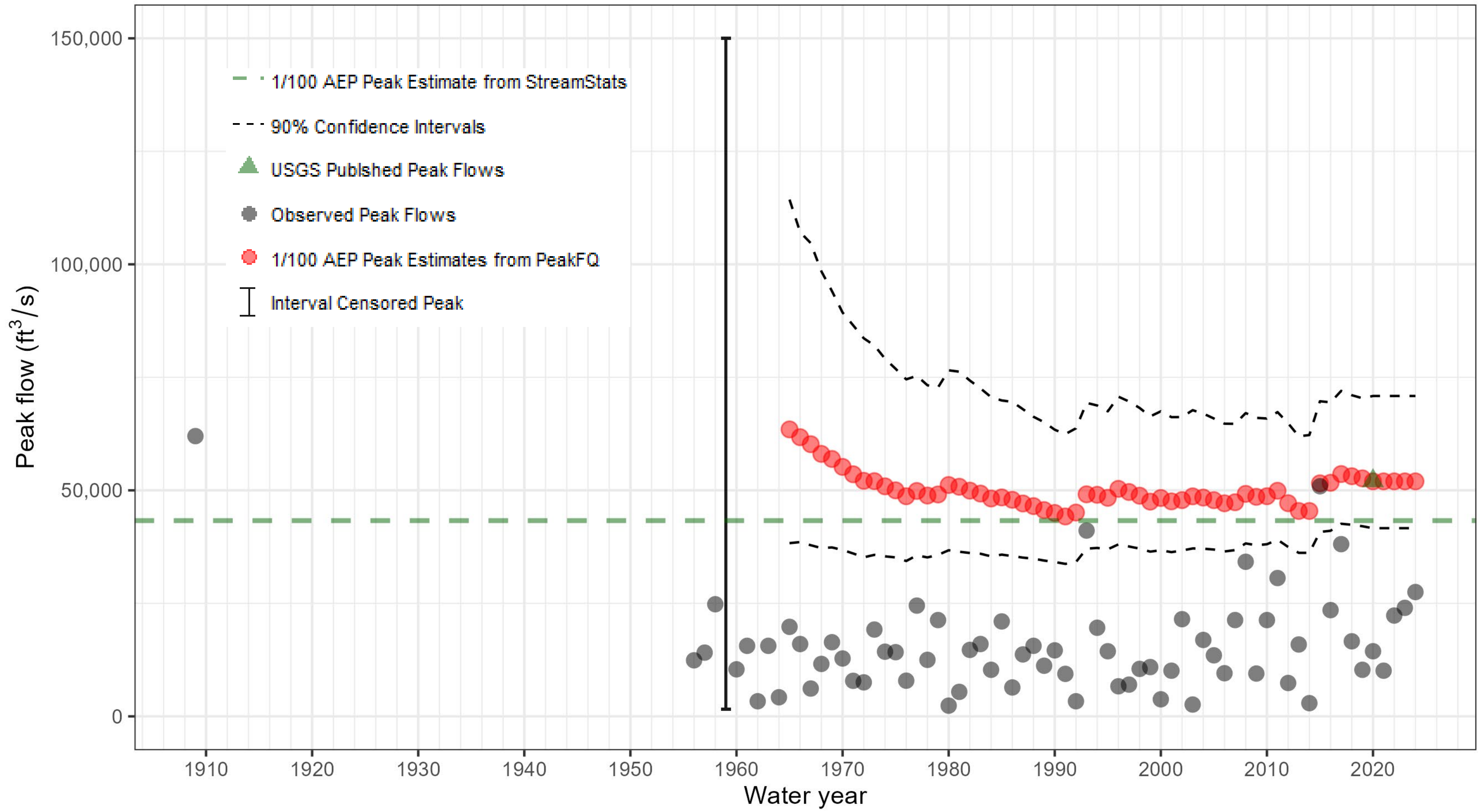


Figure 5-80. Change in 100-Year Flow over Time for James River near Springfield, MO (07050700)

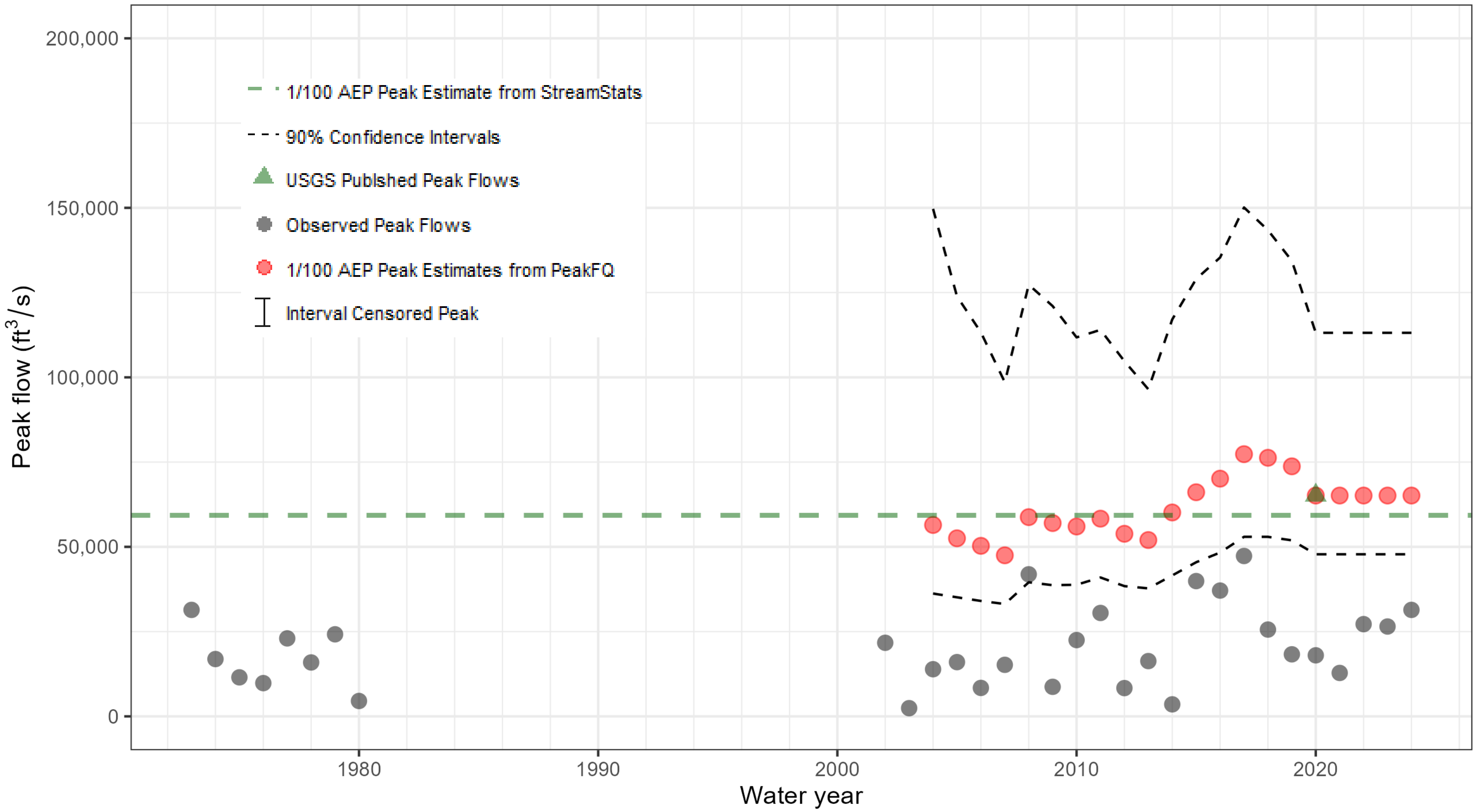


Figure 5-81. Change in 100-Year Flow over Time for James River at Boaz, MO (07052250)

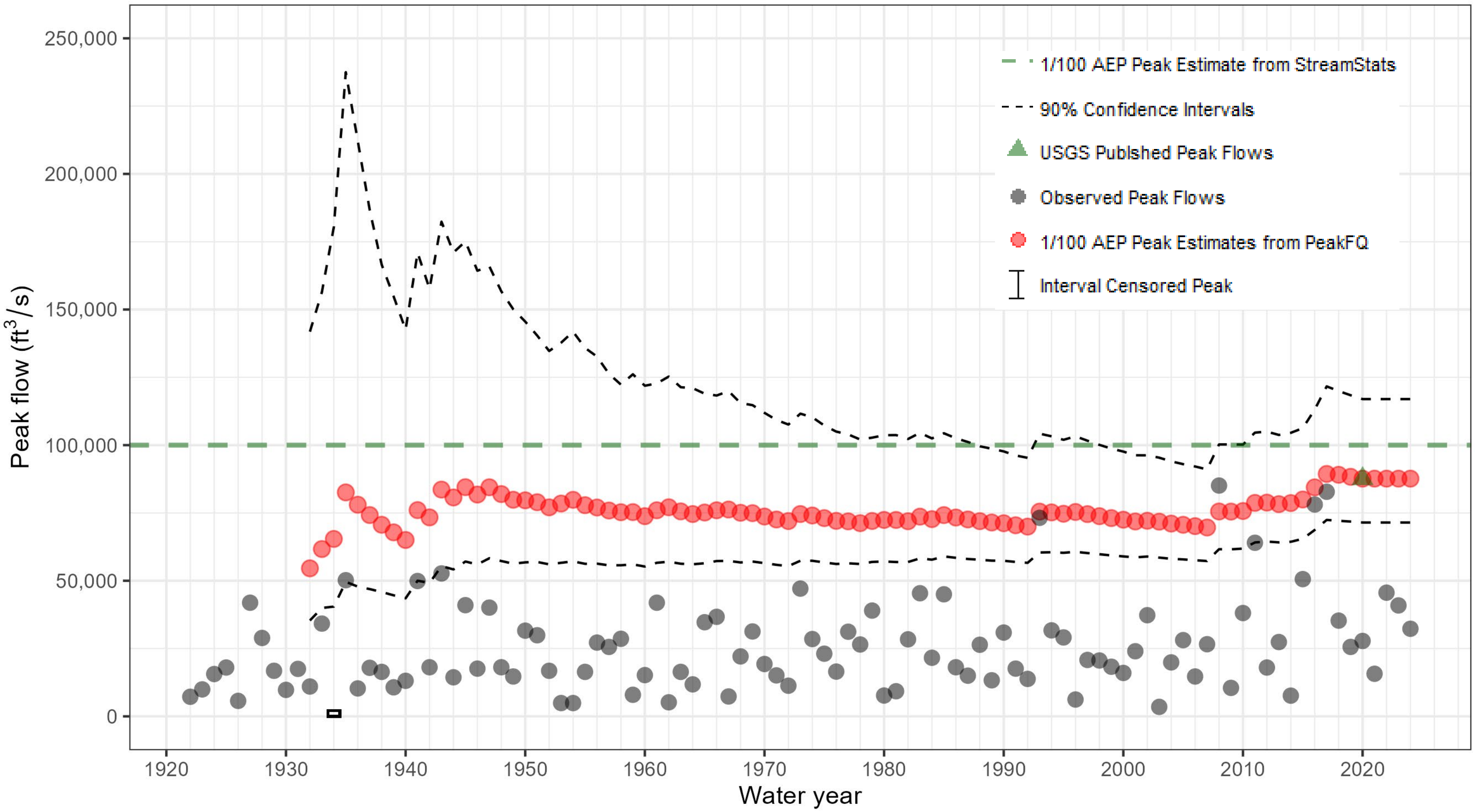


Figure 5-82. Change in 100-Year Flow over Time for James River at Galena, MO (07052500)

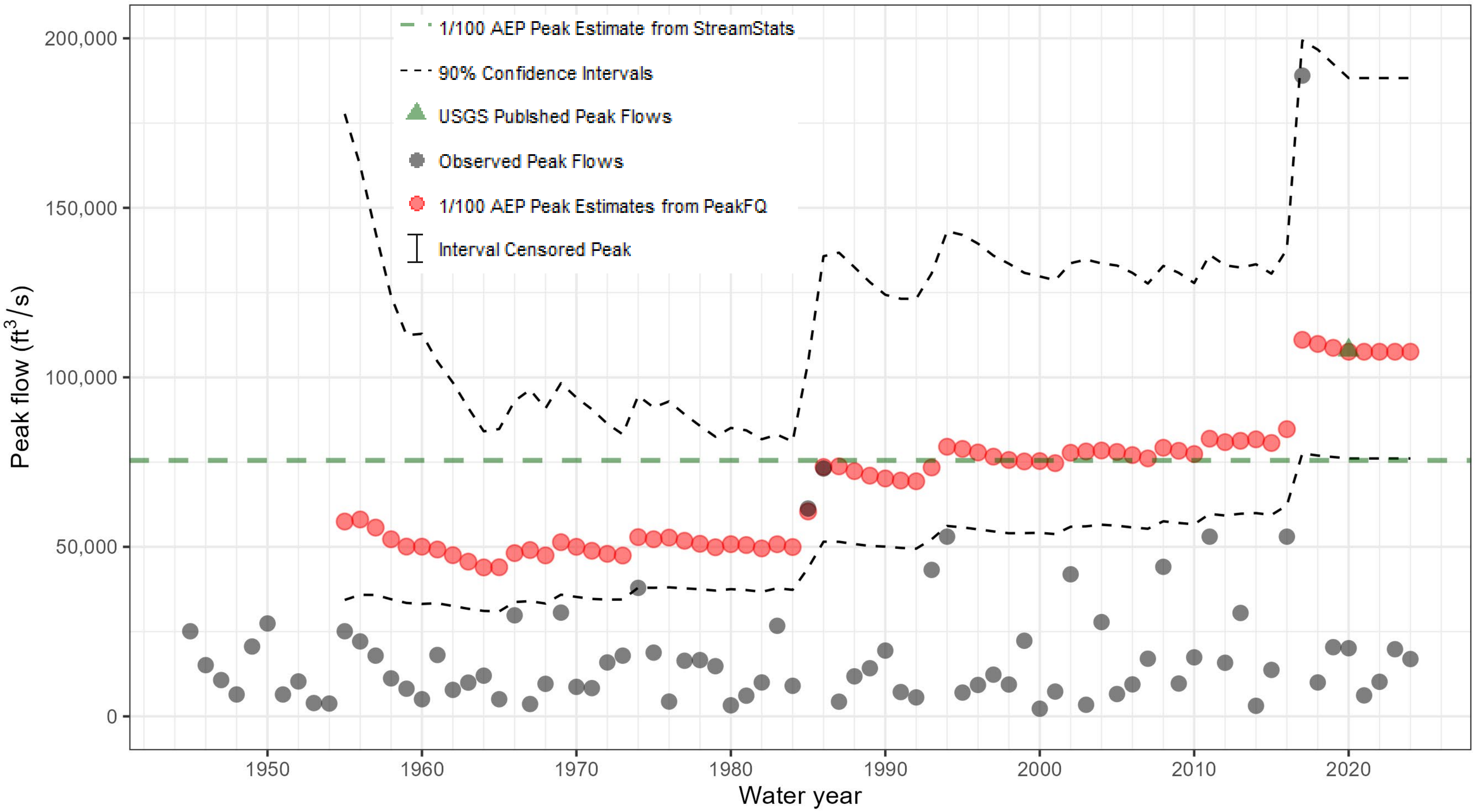


Figure 5-83. Change in 100-Year Flow over Time for North Fork River near Tecumseh, MO (07057500)

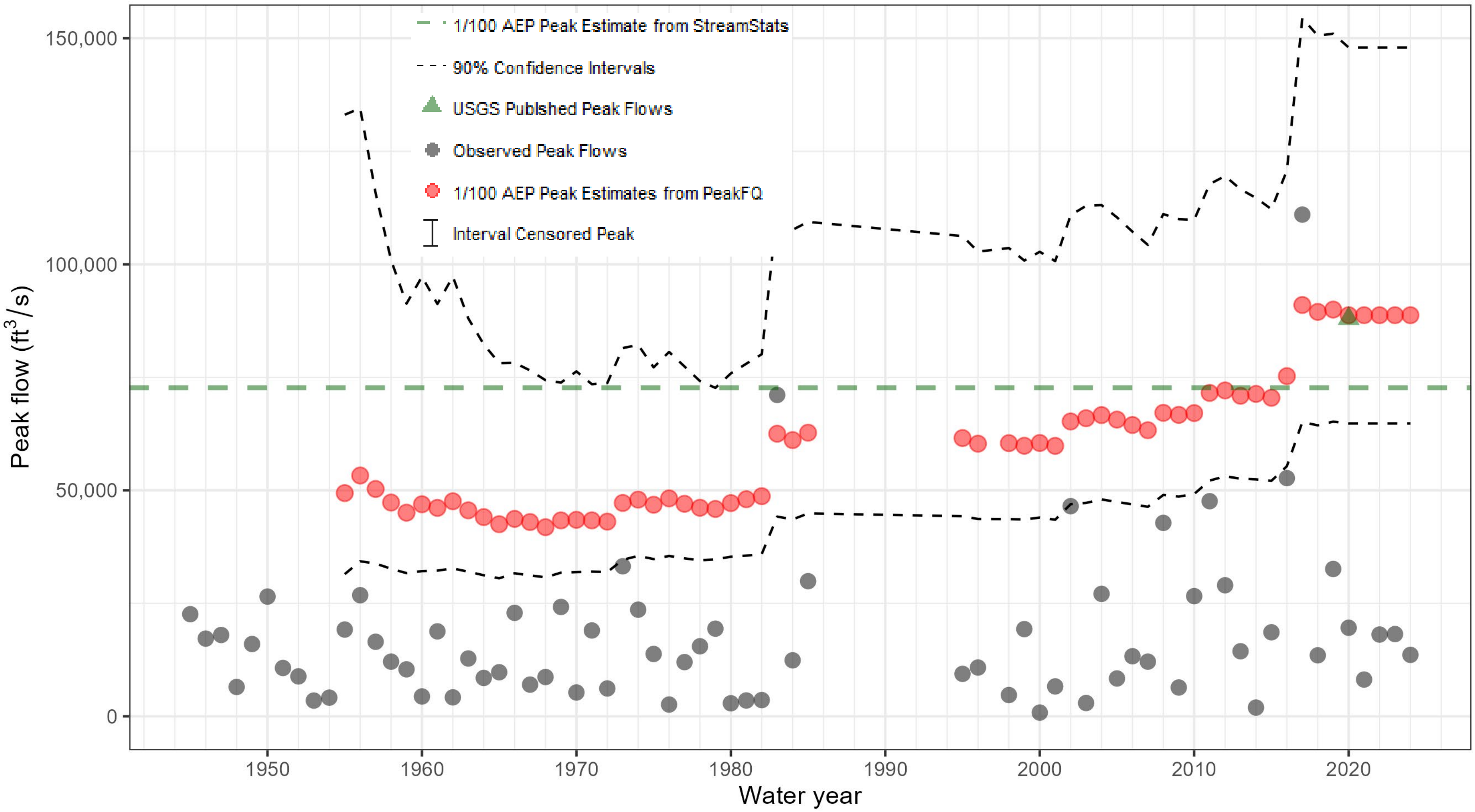
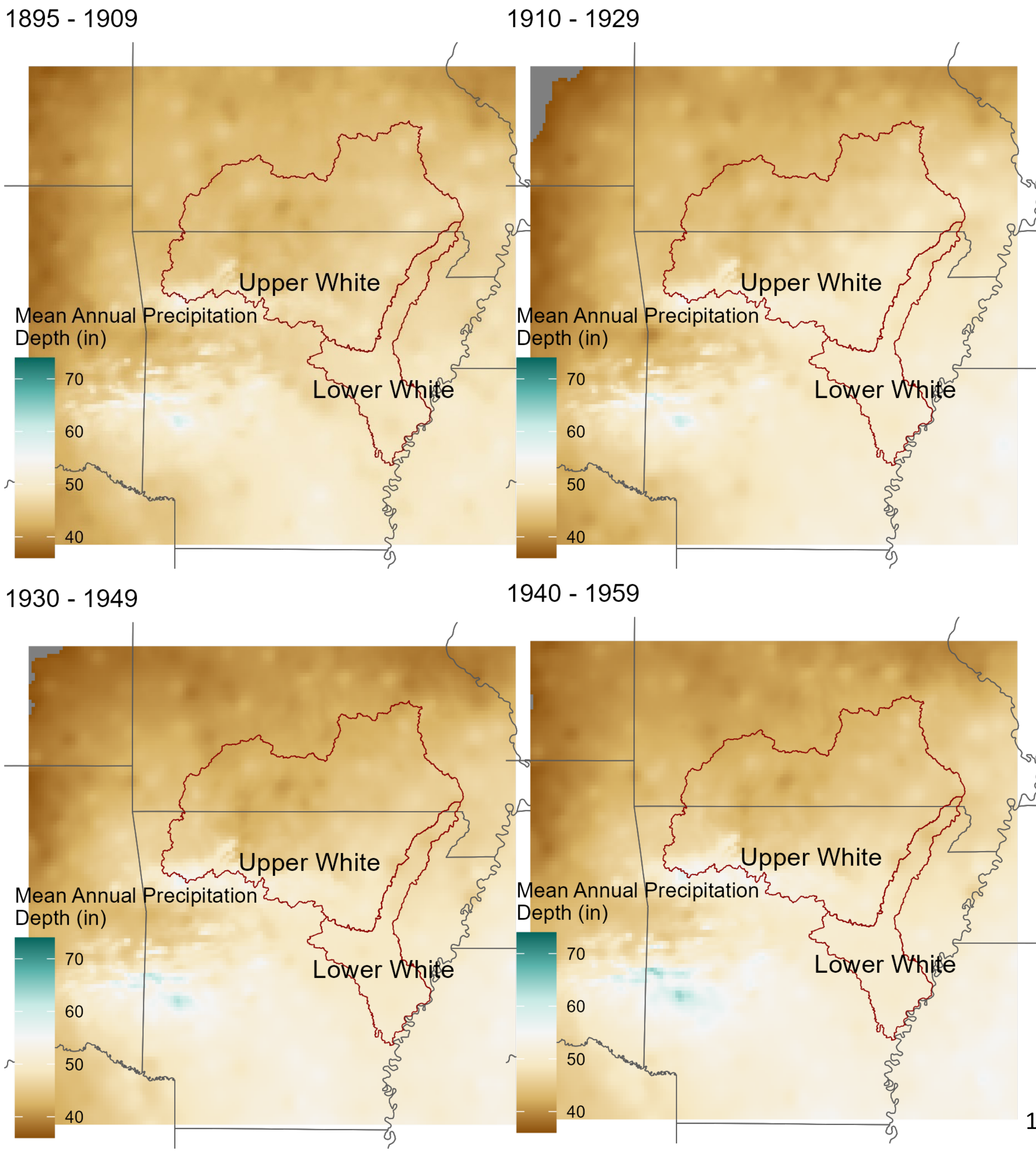


Figure 5-84. Change in 100-Year Flow over Time for Bryant Creek near Tecumseh, MO (07058000)

5.4 Influence of Climatic Variability

In general, multi-decadal oscillations in climate occur within and around the White River basin (Figure). Figure 5-83 shows multiple maps of average annual precipitation depth aggregated from PRISM data. The most recent period, 2000 to 2021, shows the highest amount of precipitation within the White River basin. Statistical estimates of peak streamflows, whether based on annual maximum series of peak streamflows or precipitation depths, need to cover multiple decades of data. At locations with streamgages or precipitation gages, it's often not the case that long-term records are available. In order to create a more robust estimate of AEP peak streamflows, it benefits the practitioner to use as much regional information as possible. Regional information is typically derived from multiple streamflow gaging stations or precipitation gages. By combining information from more than one location, we are essentially trading space for time.



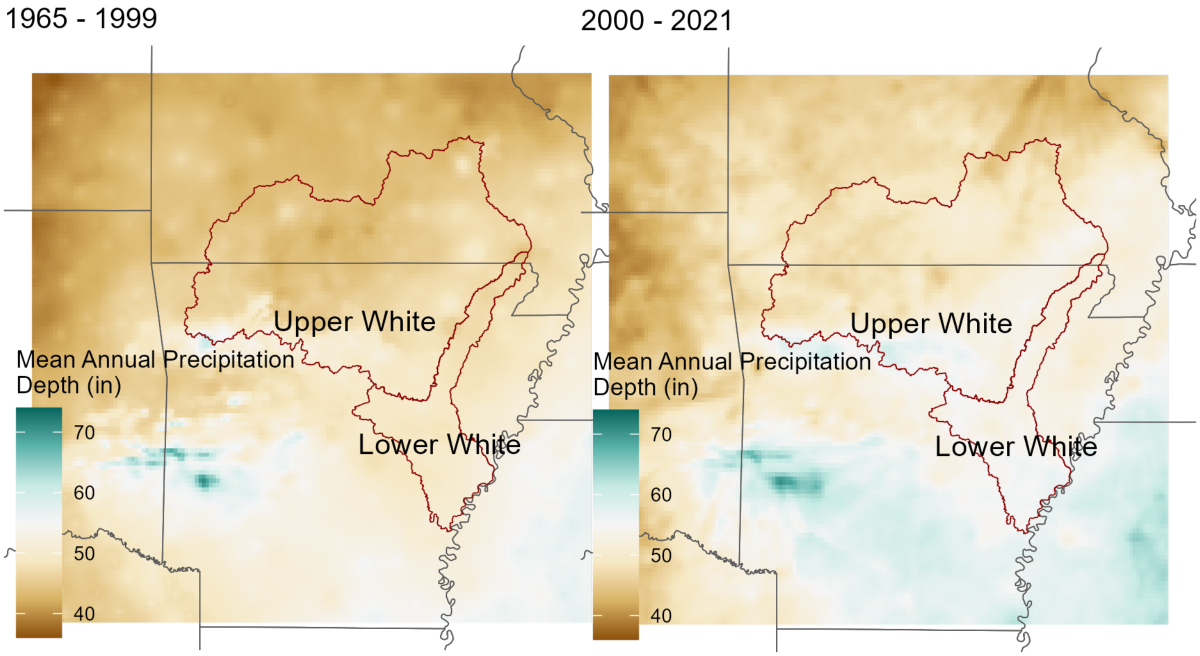


Figure 5-85. Maps showing multi-decadal annual average precipitation from PRISM data

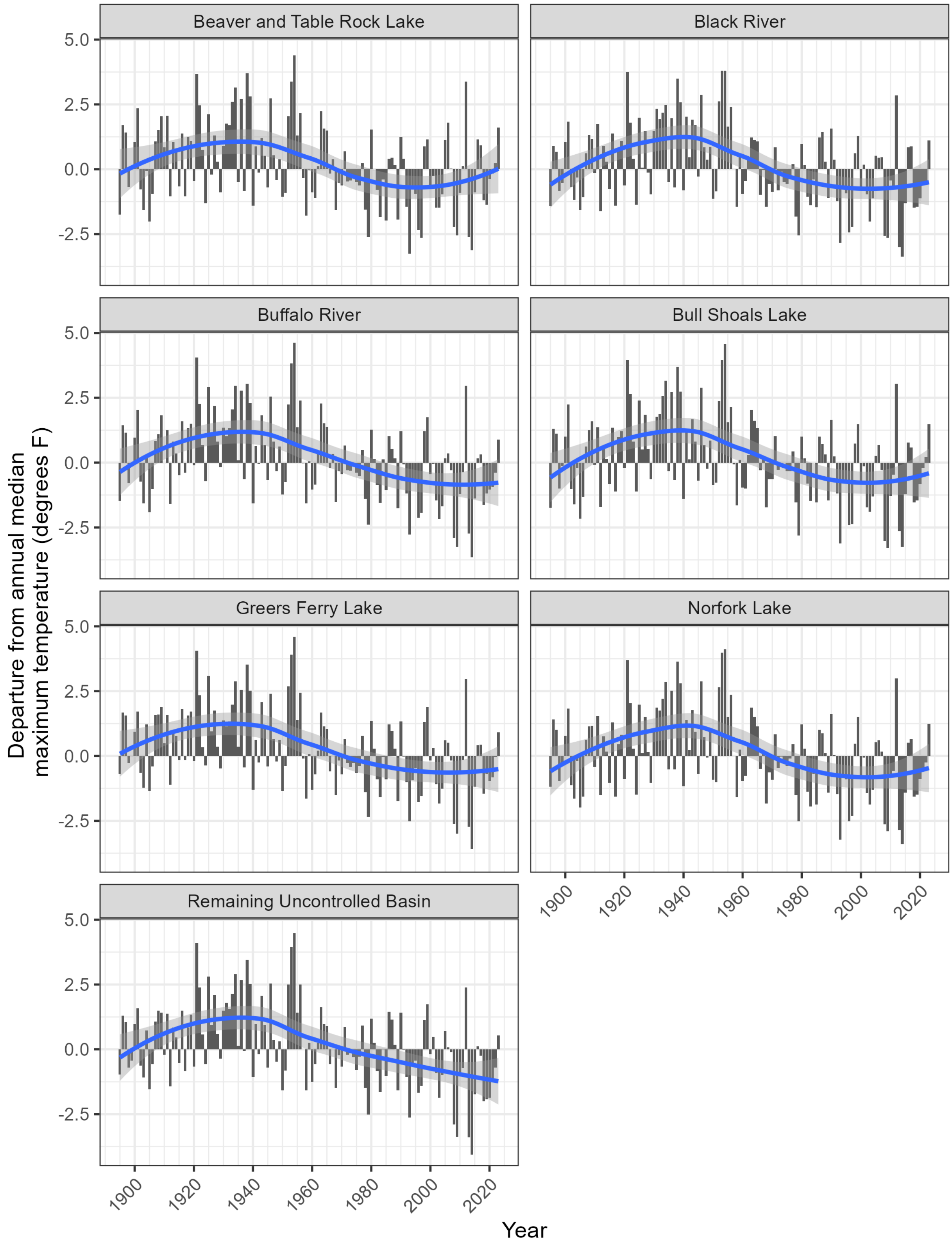


Figure 5-86. Plots showing departure from median monthly maximum temperatures for the White River Basin.

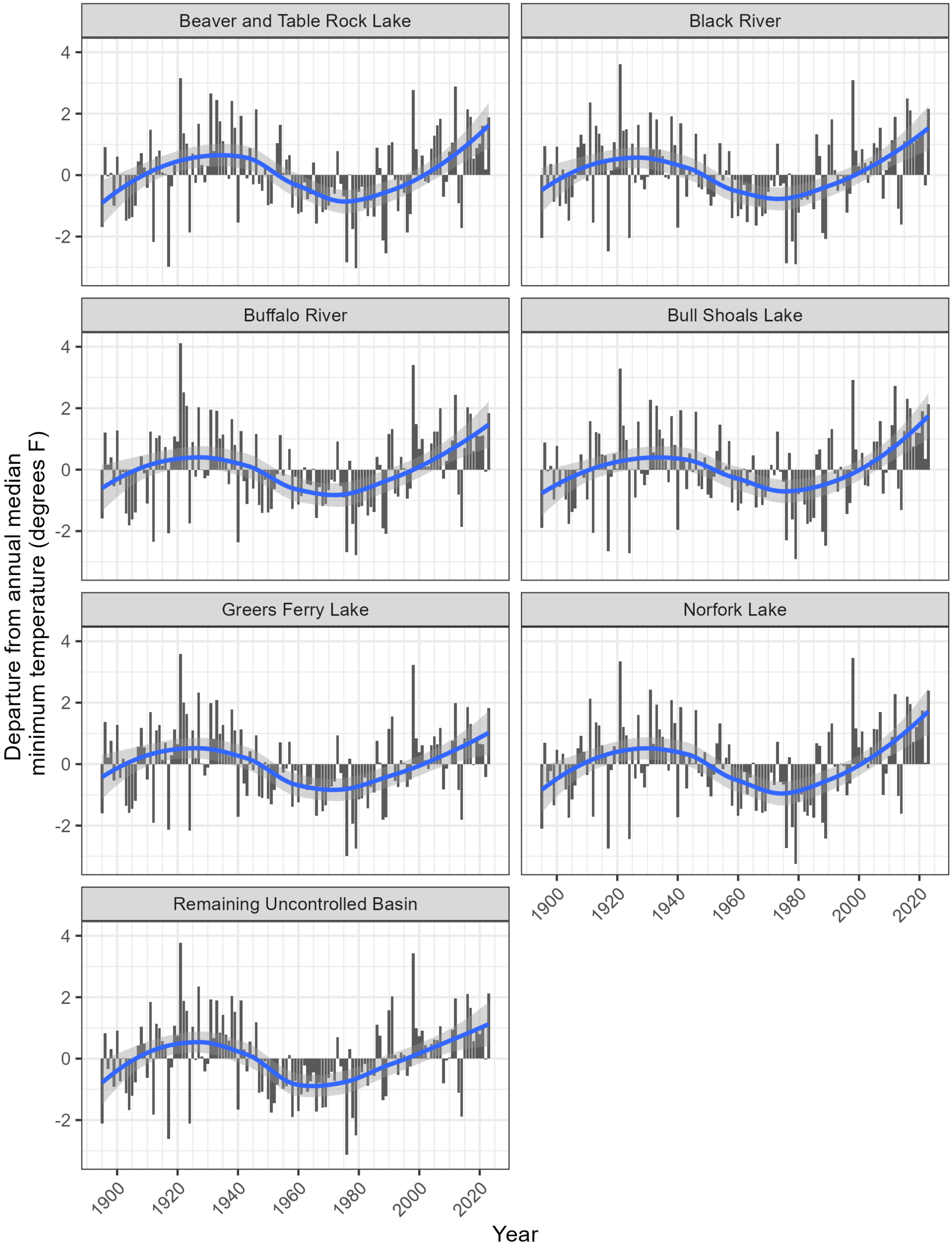


Figure 5-87. Plots showing departure from median monthly minimum temperatures for the White River Basin.

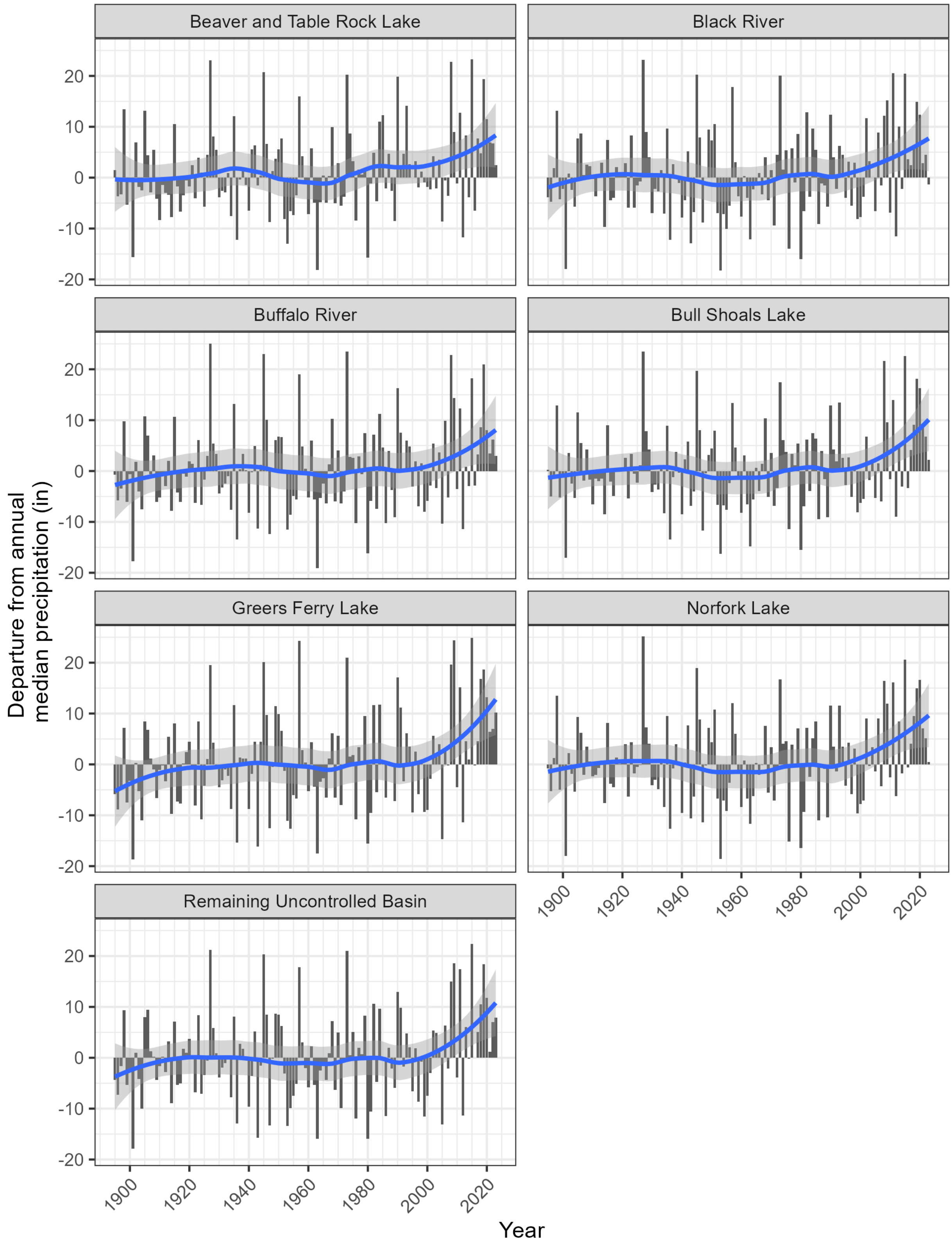


Figure 5-88. Plots showing departure from median monthly precipitation accumulation for the White River Basin.

5.5 Effects of Regulation on Statistical Estimates of Flood Flow Frequency

Flood flow frequencies for reservoir releases and frequencies for reservoir elevations should be performed from using long term simulations of reservoir operations or from data recorded or calculated at the reservoir which is informed by reservoir operations and reservoir geometries. Within the White River basin in Arkansas and Missouri, USACE Little Rock District (SWL) has used a combination of inflow volumes recorded at reservoirs, precipitation frequencies, hydrologic models, and reservoir operation models to estimate reservoir release frequencies and reservoir elevation frequencies. Streamflow data downstream of a reservoir that contains significant intervening flows between the reservoir and the location on the stream being evaluated can be estimated using traditional methods like B17C. One limitation that exists with this methodology is the existence of an appropriate record length of peak streamflow data. Many record extension methods can be applied. In recent years, machine learning techniques have become more prevalent for use in record extension for regulated streams.

In the case of USGS streamflow gaging station 07074500, White River at Newport, AR, the period of record of peak streamflow data extends back to 1886 and the period of record of regulated peak streamflow extends back to 1952. Multiple dams were constructed on the White River upstream of Newport between 1952 and 1965, therefore varying degrees of regulation existed between 1952 and 1965. Operational changes have occurred within the White River basin during the period from 1952 to current. In order to get a better estimate of the 1/100 and 1/500 AEP peak streamflows for White River at Newport, machine learning models can be used to extend the regulated period of record back to 1915 using Livneh climate data.

Estimates of regulated daily streamflows based upon observed daily streamflows, precipitation, and temperature were obtained via Random Forest regression using the randomForest package (Breiman, 2001) for R Statistical Software (R Core Team, 2024). A Random Forest model was created, using current, regulated daily flows as the response variable and precipitation and temperature data explanatory variables. Random Forest (referred to hereinafter as RF) is a statistical method based on classification trees built on many explanatory variables to predict a response variable (Breiman, 2001; Kuhn, 2016). RFs are a powerful generalization of regression trees and rule-based models. In a most basic form such models are a cascading organization of "if-then" statements. For a very elementary example, if drainage area is greater than 100 square miles, then streamflow is N else streamflow is M. In practice, a series of if-then statements topologically creates a tree for which there is one terminal node for each data point. RFs begin with many bootstrap samples from the data with approximately 63% of the original observations occurring at least once (Cutler et al, 2007). A classification tree uses tree predictors in which successive trees do not depend on earlier trees—each tree is independently constructed using a bootstrap sample of the data set and, in the end, a majority vote is taken for prediction of that observation (Breiman, 2001). Random Forests add an additional layer of randomness to bagging, in that each branch is split using the best among a subset of predictors randomly chosen at that branch (Breiman, 2001). Kuhn and others (2016) provides much conceptual detail and comparison to other predictive statistical approaches, and many references therein are cited.

RFs are useful to for the purpose of daily streamflow record extension because the cognitive complexity of the very many potential predictor variables that act in difficult-to-describe nonlinear ways to affect streamflow. Further, the use of meteorological variables with varying degrees of lag and summation adds complexity that is difficult to exhaustively explore. The major assumption made is that streamflows can be adequately modeled by a tree. The diagnostics and assessments reported herein show that this is the case. The particularly influential capability of RFs to "discover" important response tendencies for complex explanatory variable interactions that are cognitively difficult make RF an ideal statistical method to estimate streamflows (reservoir inflows) for this study.

Additional analysis was performed on the results from the RF regression. In the process of creating the RF regression models and making the RF regression predictions, all of the 1,200 trees for each of the predictions were retained resulting in 1,200 predicted values for each of the daily time steps. Utilizing the 1,200 predicted values for each daily time step prediction, an iterative process was used with R to find the quantile of the 1,200 predicted values of streamflow which was closest to the observed value of streamflow. The quantile of the 1,200 values which was closest to the observed value was retained for each prediction. The quantile was then compared to the predicted values and Generalized Additive Models (Wood and Augustin, 2002) were developed to predict new quantiles from the 1,200 tree values to estimate a new predicted streamflow value. The Generalized Additive Models (referred to hereinafter as GAMs) were used with explanatory variables and predicted streamflow values to correct bias observed at the tails of the RF regression estimates and to reduce variability in the predicted values of streamflow. For this study, the mgcv package (Wood, 2011) for R was used for implementation of GAMs. The resulting estimates of initial daily streamflow and bias corrected daily streamflow are compared to observed streamflow in Figure 5-89 and Figure 5-90.

After a time-series of annual maximum daily streamflows is created, conversion to annual maximum peak streamflow is achieved via GAM regression using relations between annual maximum daily streamflow and annual maximum peak streamflow from the period of record used to create the RF regression (Figure 5-91). The resulting annual maximum series (Figure 5-92) is used with B17C analyses to estimate flood frequency quantiles for White River at Newport.

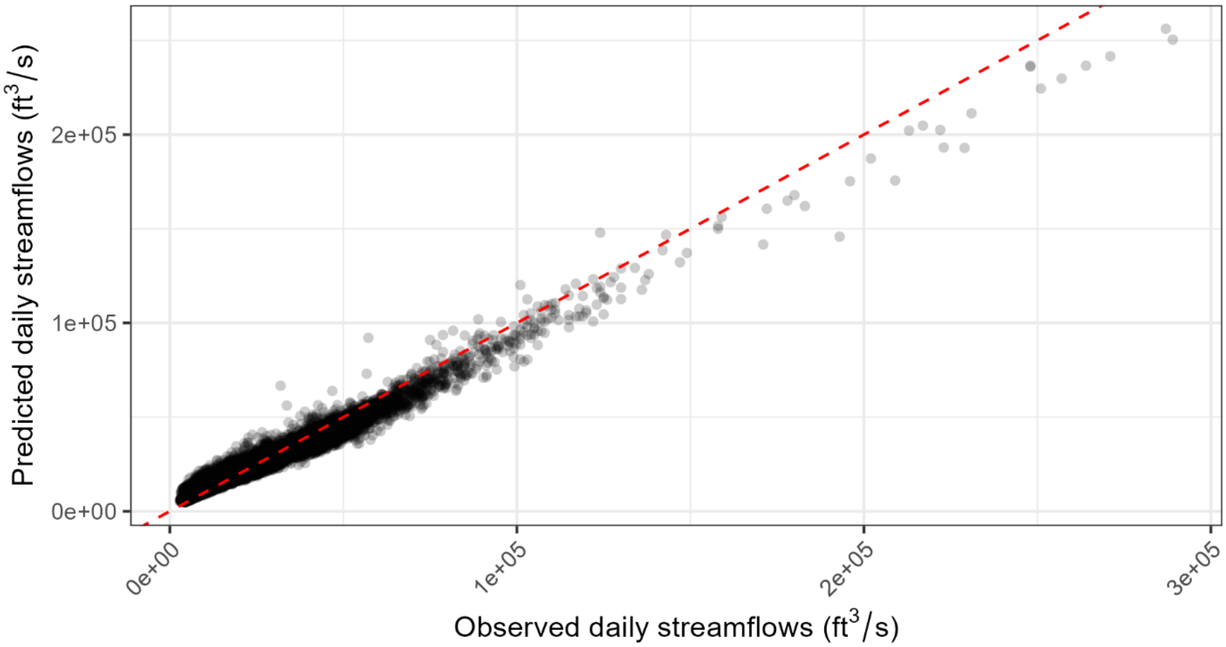


Figure 5-89. Observed and predicted daily streamflows for the regulated period of record for White River at Newport

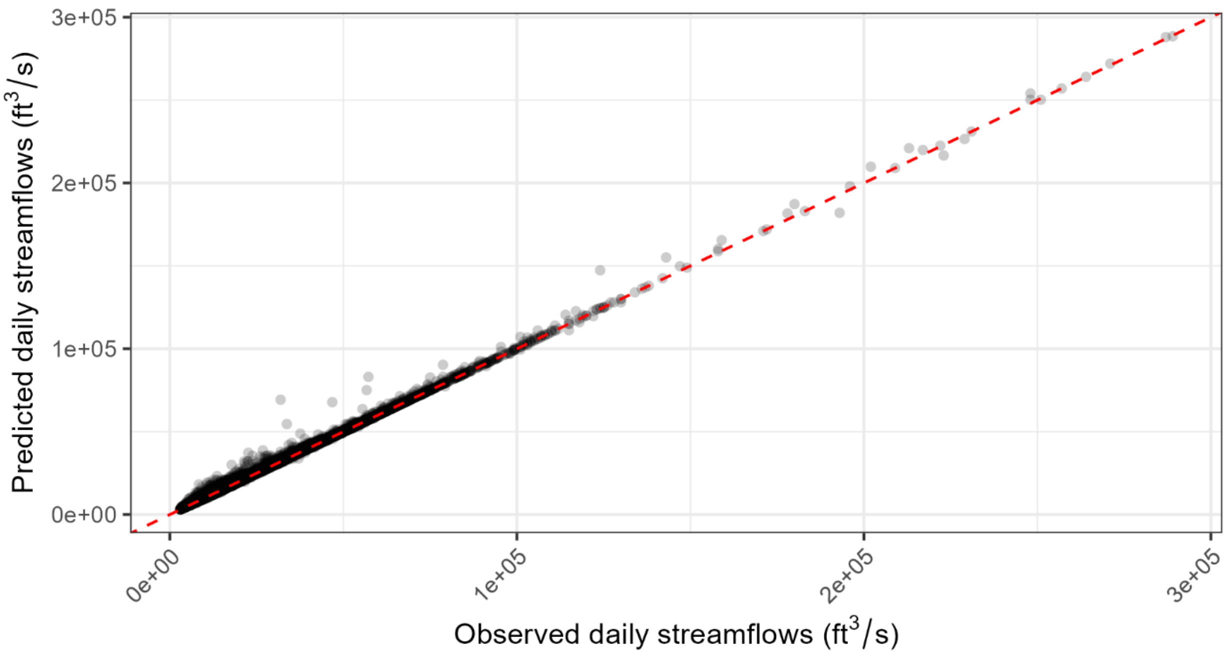


Figure 5-90. Observed and bias corrected predicted daily streamflows for the regulated period of record for White River at Newport

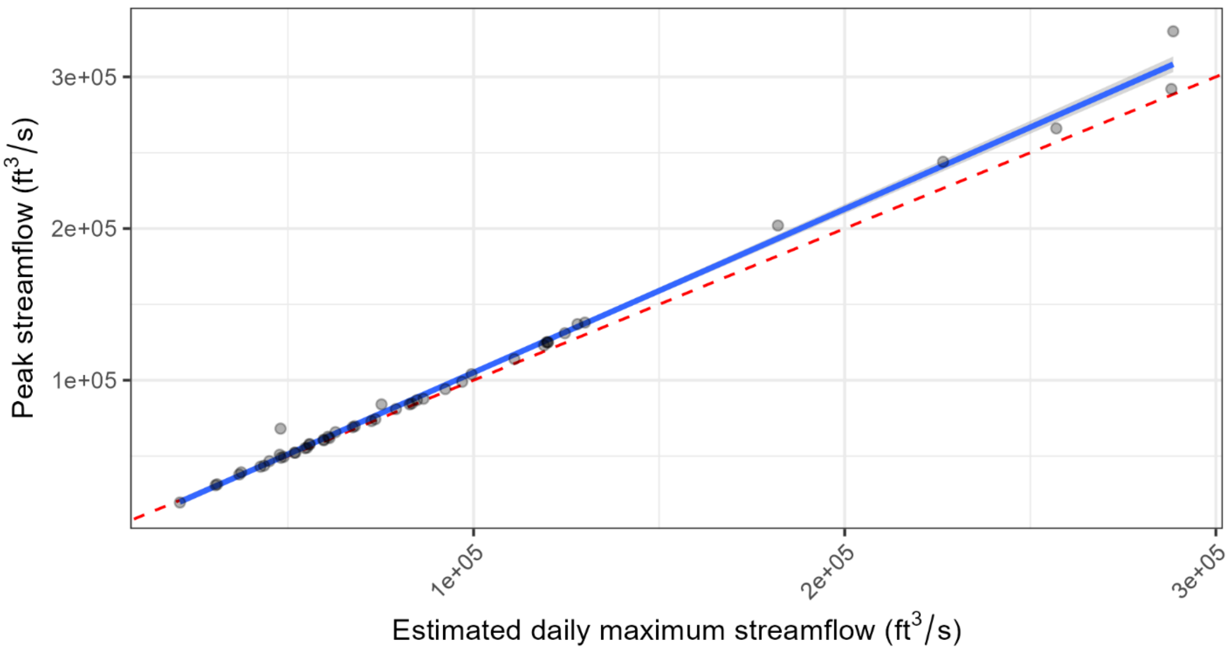


Figure 5-91. Bias corrected predicted daily streamflows and observed USGS peak streamflows for White River at Newport for recent years. The blue line is a GAM used to convert daily flows to peak flows and the red dashed line is a 1-to-1 line.

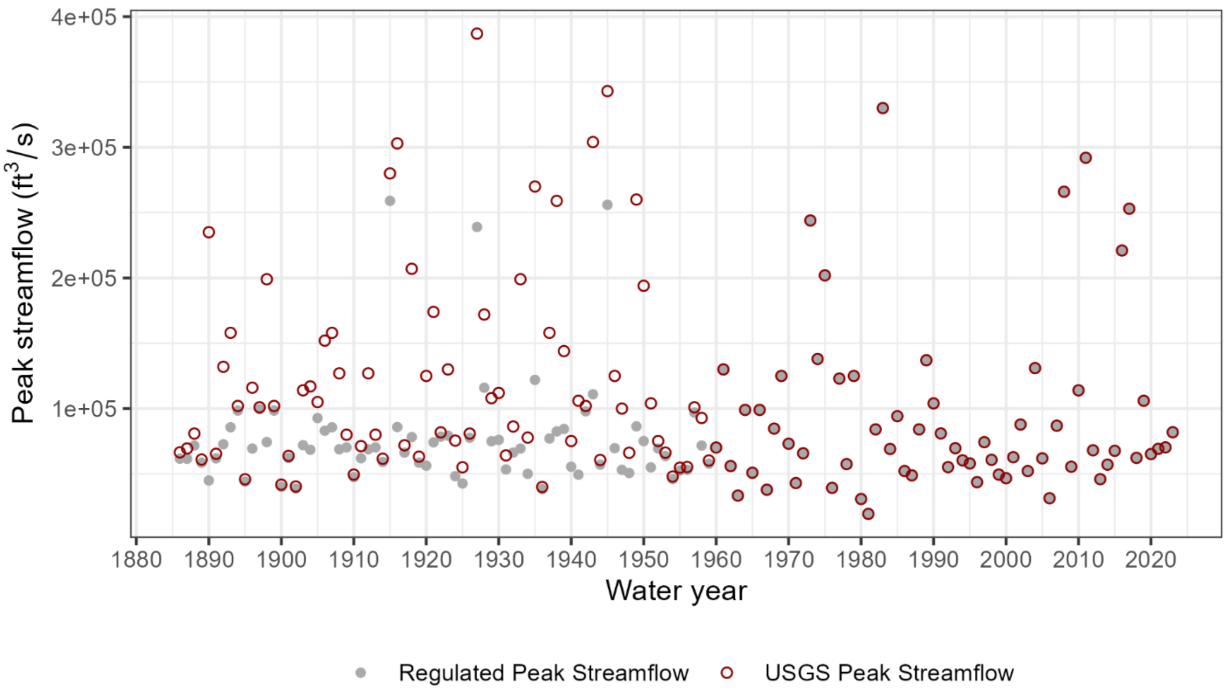


Figure 5-92. Annual maximum series of estimated, regulated streamflows and observed USGS peak streamflows for White River at Newport

6 Rainfall-Runoff Modeling in HEC-HMS

6.1 HEC-HMS Model from the White River CWMS Implementation

Existing HEC-HMS models were used for this study (Figure 4-1). The HEC-HMS models used in this study were initially developed for spillway adequacy studies of Bull Shoals Dam in 2013 and were subsequently imported for use in the Corps Water Management System (CWMS). Additional details regarding the CWMS models are described below.

6.2 Updates to the HEC-HMS Model

HEC-HMS models existing for the White River watershed prior to 2013 used Snyder unit hydrograph transforms. Snyder hydrograph parameters were estimated using the length of the longest flow path for the basin *(L)*, length (miles) from the concentration point along *L* to a point on *L* that is perpendicular to the watershed centroid *(Lca)*, stream slope *(S)*, and regression using basins for which Snyder parameters had been developed within the region.

In 2013, the existing Snyder unit hydrograph parameters were converted to Clark unit hydrograph parameters using HEC-1. Since the conversion of Snyder to Clark parameters, the models have undergone multiple calibrations and the degree to which time of concentration *(Tc)* and the storage coefficient *(R)* parameters have been adjusted over that period was not evaluated. However, for this study, the existing HEC-HMS model parameters were evaluated and adjusted where necessary.

6.3 HEC-HMS Model Initial Parameters

The initial parameters were derived from physical characteristics within each subbasin. Surficial geology and drainage area of the basins for USGS streamflow gaging stations were used to help estimate parameters for baseflows and recessions within the HEC-HMS model basins. Regression was typically performed with Generalized Additive Models (GAMs) using the mgvc package (Wood, 2011) for R Statistical Software (R Core Team, 2023).

6.4 HEC-HMS Model Calibration

In a hydrologic model, the conversion of precipitation to flow involves several key processes that simulate the movement and storage of water within a watershed. Loss rates represent the initial abstraction of precipitation through mechanisms such as infiltration, evaporation, and surface storage; this step ensures that only the portion of rainfall that contributes to runoff is considered. Loss rates used within the HEC-HMS models for this study include initial deficit, constant loss, and maximum deficit. Once the effective precipitation is determined, transform methods—such as unit hydrographs or other routing techniques—are used to model how this water moves overland and through the watershed to produce a runoff hydrograph. Variable Clark transforms were used for this study. The Variable Clark transforms use a Time of Concentration (T_C) and a Storage Coefficient (R) that varies with precipitation intensity. To simulate the delay and attenuation of flow as it travels through the ground, linear reservoir models are employed. These represent the storage-discharge relationship within the watershed, where outflow is proportional to the volume of water stored, capturing the gradual release of water that has entered the groundwater and interflow zones. Linear reservoir was used within the HEC-HMS models for this study to model baseflows and recessions. The Linear Reservoir parameters included two coefficients that describe the time after the peak of streamflow at which the interflow and groundwater flow return to the hydrograph (GW1 coefficient and GW2 coefficient) and the percentages of the flow for each component (GW1 fraction and GW2 fraction). Together, these components work to realistically model the time-varying process of converting rainfall into flow.

6.4.1 Calibration Methodology

The HEC-HMS model formulation included the following checks, refinements, and updates:

- Constant loss rates were checked using the most recent Soil Survey Geographic Database (SSURGO; Soil Survey Staff) data for soil hydrologic group.
- Percent impervious area was calculated using the 2016 National Land Cover Database (NLCD) percent impervious area layer (Yang, et al., 2018) and modified using equations from Sutherland (2000).
- Time of Concentration *(T_C)* and Storage Coefficient *(R)* values were evaluated and adjusted where necessary.
- Baseflow method was updated to the Linear Reservoir method from the Recession method.
- Storage-outflow relationships for Modified-Puls routing was updated by leveraging recent LiDAR elevation data.
- Storage-elevation relationships for Beaver and Norfork were updated by leveraging recent bathymetric surveys and LiDAR elevation data.

6.4.2 Calibrated Parameters

Final model parameterization was accomplished by hand in HEC-HMS. All model parameters were adjusted to make hydrograph shapes align with observed flows with regards to timing and peak flow magnitudes. Three calibration models and two validation models were developed. The calibration models used events for 2017, Dec 2015, and 2011. The validation models used events from Jun 2015 and 2008.

6.4.2.1 Initial Losses

A summary of initial deficit values for Beaver Lake subbasins is given in Table 6-1 and Figure 6-1. A summary of initial deficit values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-2 and Figure 6-2.

Table 6-1. Initial Deficit – Beaver Lake Subbasins

	Initial Deficit Dec 2015 Event (in)	Initial Deficit 2008 Event (in)	Initial Deficit 2011 Event (in)	Initial Deficit Jun 2015 Event (in)	Initial Deficit 2017 Event (in)	Mean Calibration Values (in)	Area of Subbasins (sq mi)
Minimum	0.12	0.11	0.1	0.11	0.12	0.11	2.605
1st quartile	0.14	0.14	0.13	0.14	0.14	0.14	15.717
Median	0.14	0.14	0.13	0.14	0.14	0.14	21.543
Mean	0.1436	0.1508	0.1615	0.1508	0.1436	0.1508	30.567
3rd quartile	0.14	0.16	0.2	0.16	0.14	0.16	36.721
Maximum	0.2	0.2	0.24	0.2	0.2	0.2	113.460

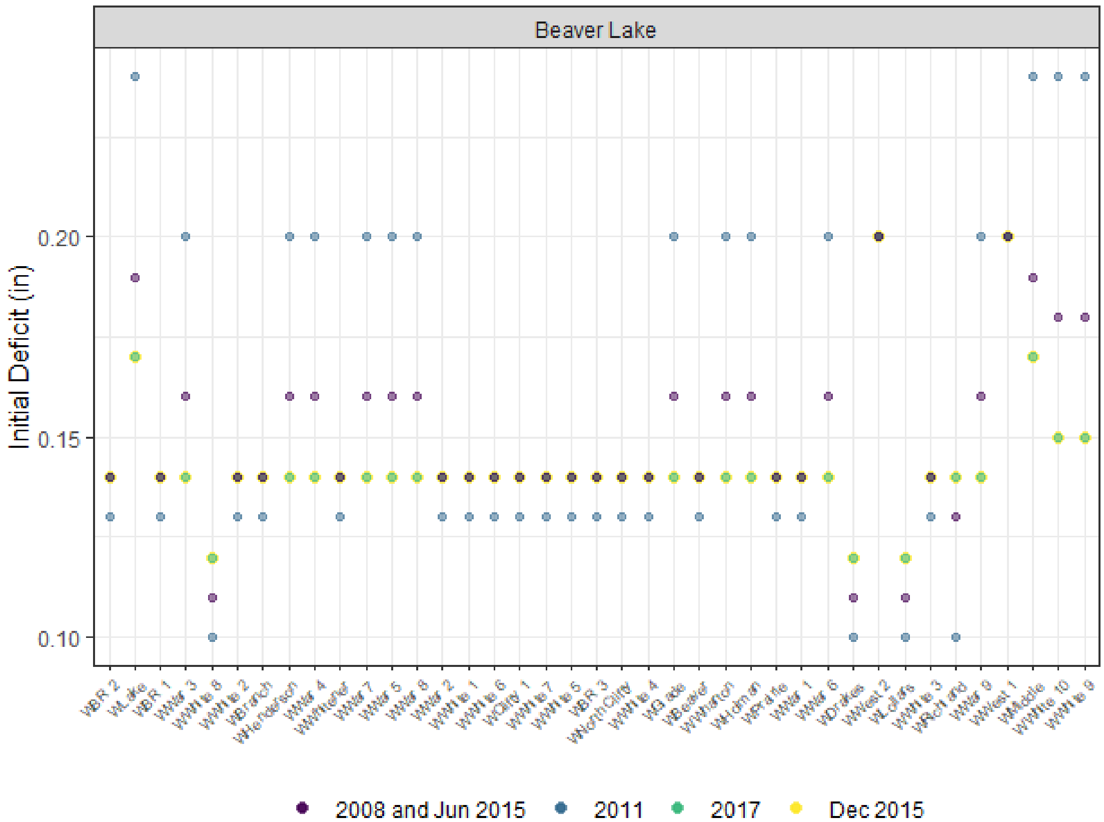


Figure 6-1. Initial Deficit - Beaver Lake Subbasins

Table 6-2. Initial Deficit – Bull Shoals and Table Rock Lakes Subbasins

	Initial Deficit Dec 2015 Event (in)	Initial Deficit 2008 Event (in)	Initial Deficit 2011 Event (in)	Initial Deficit Jun 2015 Event (in)	Initial Deficit 2017 Event (in)	Mean Calibration Values (in)	Area of Subbasins (sq mi)
Minimum	0.2700	0.2100	0.2700	0.2100	0.0600	0.2100	5.878
1st quartile	0.3500	0.4600	0.5200	0.4600	0.1000	0.4600	22.578
Median	0.6000	0.4600	0.5700	0.4600	0.1000	0.4600	36.181
Mean	0.5475	0.4532	0.5461	0.4532	0.2674	0.4532	43.180
3rd quartile	0.7100	0.5000	0.6000	0.5000	0.6000	0.5000	52.547
Maximum	0.9800	0.7900	0.7000	0.7900	0.8700	0.7900	167.220

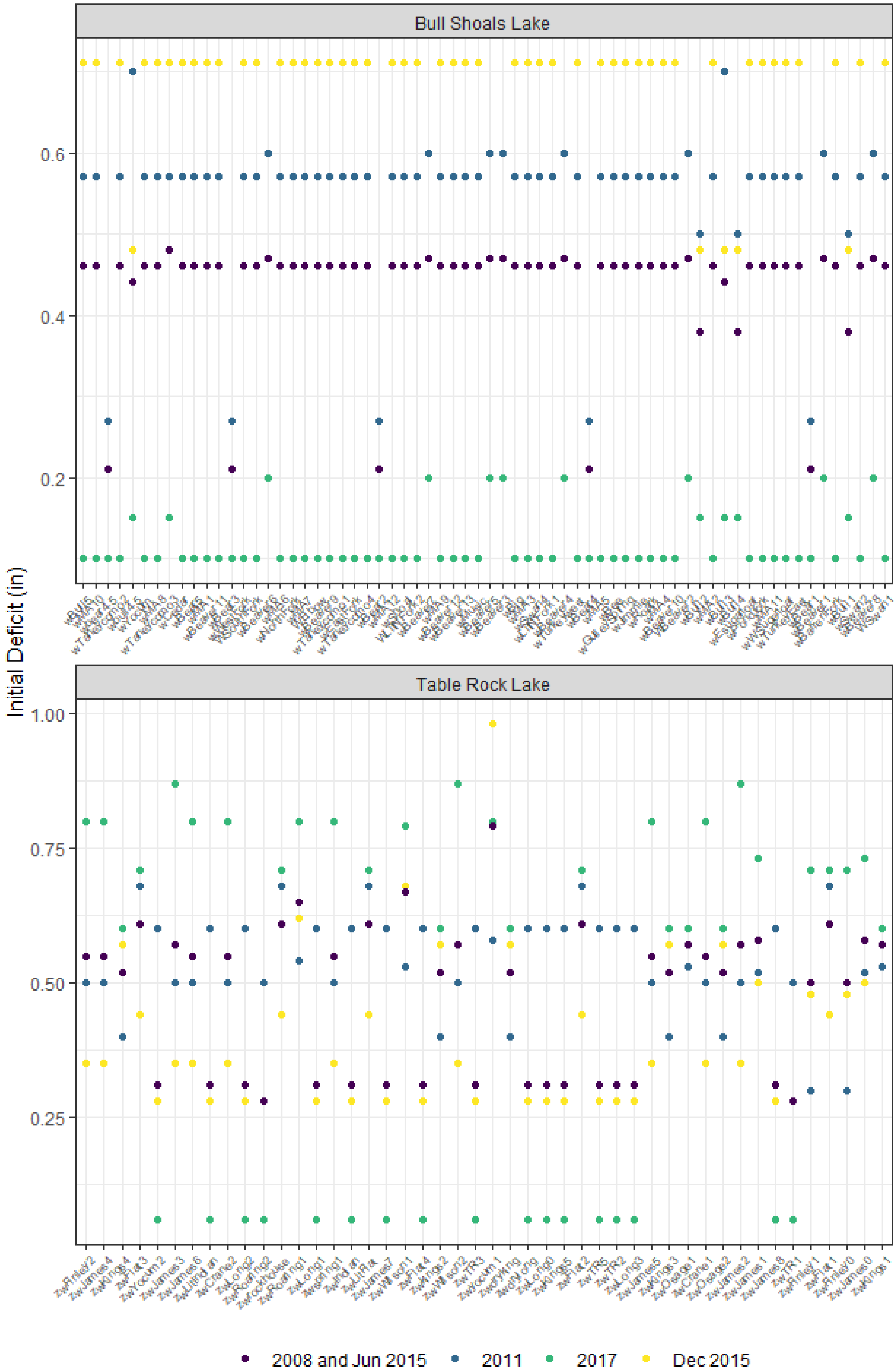


Figure 6-2. Initial Deficit – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.2 Constant Losses

A summary of constant loss values for Beaver Lake subbasins is given in Table 6-3 and Figure 6-3. A summary of constant loss values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-4 and Figure 6-4.

Table 6-3. Constant Losses – Beaver Lake Subbasins

	Constant Losses Dec 2015 Event (in)	Constant Losses 2008 Event (in)	Constant Losses 2011 Event (in)	Constant Losses Jun 2015 Event (in)	Constant Losses 2017 Event (in)	Mean Calibration Values (in)	Area of Subbasins (sq mi)
Minimum	0.03	0.03	0.02	0.03	0.02	0.03	2.605
1st quartile	0.06	0.05	0.05	0.05	0.03	0.05	15.717
Median	0.06	0.05	0.05	0.05	0.03	0.05	21.543
Mean	0.06949	0.05667	0.05692	0.05667	0.04282	0.05667	30.567
3rd quartile	0.09	0.07	0.07	0.07	0.04	0.07	36.721
Maximum	0.10	0.10	0.08	0.10	0.12	0.10	113.460

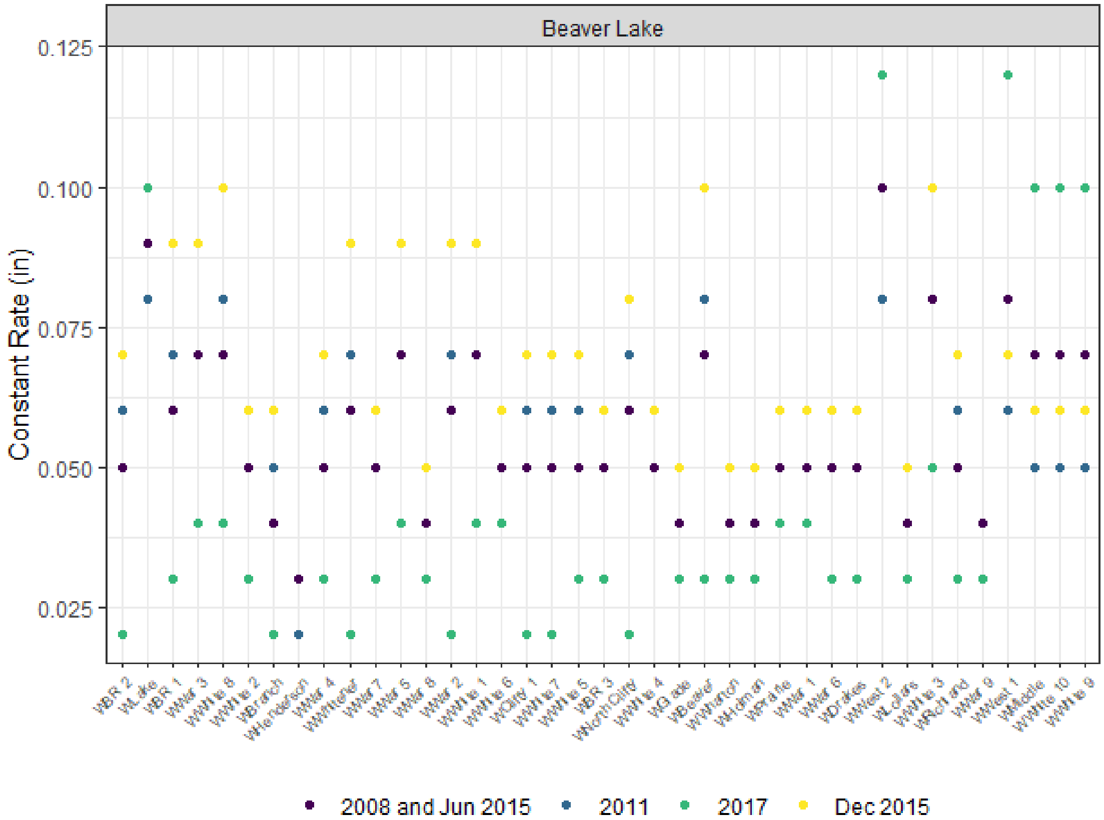


Figure 6-3. Constant Losses - Beaver Lake Subbasins

Table 6-4. Constant Losses – Bull Shoals and Table Rock Lakes Subbasins

	Constant Losses Dec 2015 Event (in)	Constant Losses 2008 Event (in)	Constant Losses 2011 Event (in)	Constant Losses Jun 2015 Event (in)	Constant Losses 2017 Event (in)	Mean Calibration Values (in)	Area of Subbasins (sq mi)
Minimum	0.02	0.03	0.02	0.03	0.01	0.03	5.878
1st quartile	0.06	0.05	0.05	0.05	0.01	0.05	22.578
Median	0.1	0.07	0.07	0.07	0.02	0.07	36.181
Mean	0.0992	0.08063	0.07759	0.08063	0.06411	0.08063	43.180
3rd quartile	0.12	0.1	0.08	0.1	0.09	0.1	52.547
Maximum	0.25	0.23	0.31	0.23	0.25	0.23	167.220

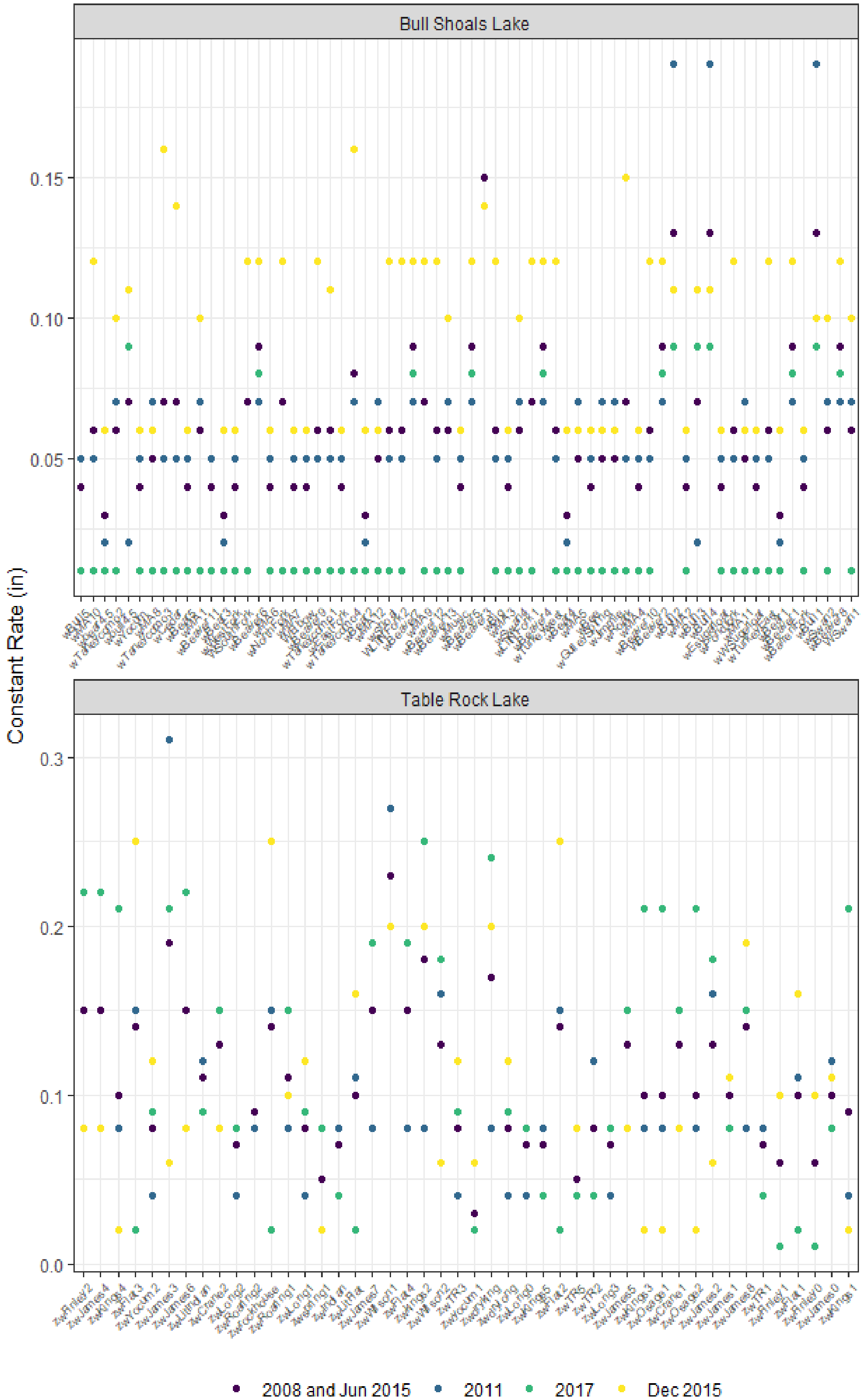


Figure 6-4. Constant Losses – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.3 Maximum Deficit

A summary of maximum deficit values for Beaver Lake subbasins is given in Table 6-5 and Figure 6-5. A summary of maximum deficit values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-6 and Figure 6-6.

Table 6-5. Maximum Deficit – Beaver Lake Subbasins

	Maximum Deficit Dec 2015 Event (in)	Maximum Deficit 2008 Event (in)	Maximum Deficit 2011 Event (in)	Maximum Deficit Jun 2015 Event (in)	Maximum Deficit 2017 Event (in)	Mean Calibration Values (in)	Area of Subbasins (sq mi)
Minimum	3.0	3.0	2.0	3.0	3.0	2.67	2.605
1st quartile	3.0	3.0	3.0	3.0	3.0	3.0	15.717
Median	3.0	3.0	3.0	3.0	3.0	3.0	21.543
Mean	3.0	3.0	3.231	3.0	3.0	3.076	30.567
3rd quartile	3.0	3.0	4.0	3.0	3.0	3.33	36.721
Maximum	3.0	3.0	4.0	3.0	3.0	3.33	113.460

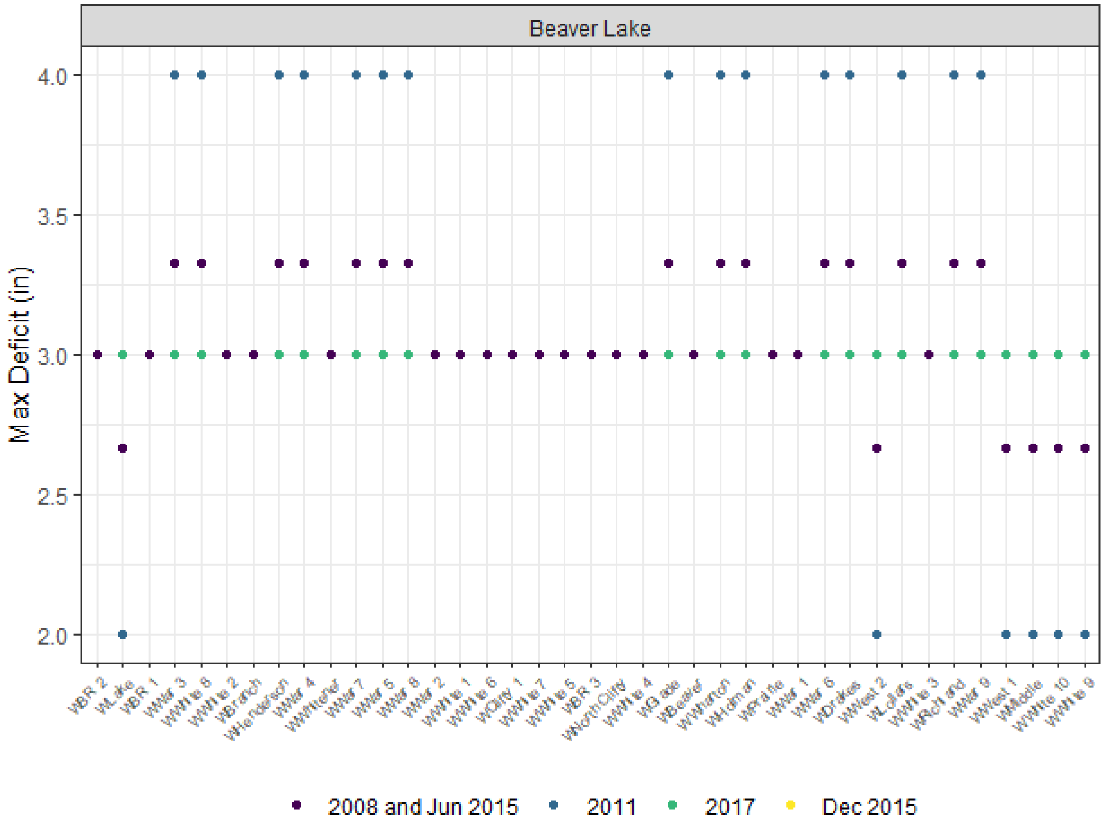


Figure 6-5. Maximum Deficit - Beaver Lake Subbasins

Table 6-6. Maximum Deficit – Bull Shoals and Table Rock Lakes Subbasins

	Maximum Deficit Dec 2015 Event (in)	Maximum Deficit 2008 Event (in)	Maximum Deficit 2011 Event (in)	Maximum Deficit Jun 2015 Event (in)	Maximum Deficit 2017 Event (in)	Mean Calibration Values (in)	Area of Subbasins (sq mi)
Minimum	2.100	2.030	2.000	2.030	2.000	2.030	5.878
1st quartile	3.300	3.300	3.300	3.300	3.300	3.300	22.578
Median	3.900	3.900	3.900	3.900	3.900	3.900	36.181
Mean	3.887	3.883	3.882	3.883	3.882	3.883	43.180
3rd quartile	4.000	4.000	4.000	4.000	4.000	4.000	52.547
Maximum	6.200	6.200	6.200	6.200	6.200	6.200	167.220

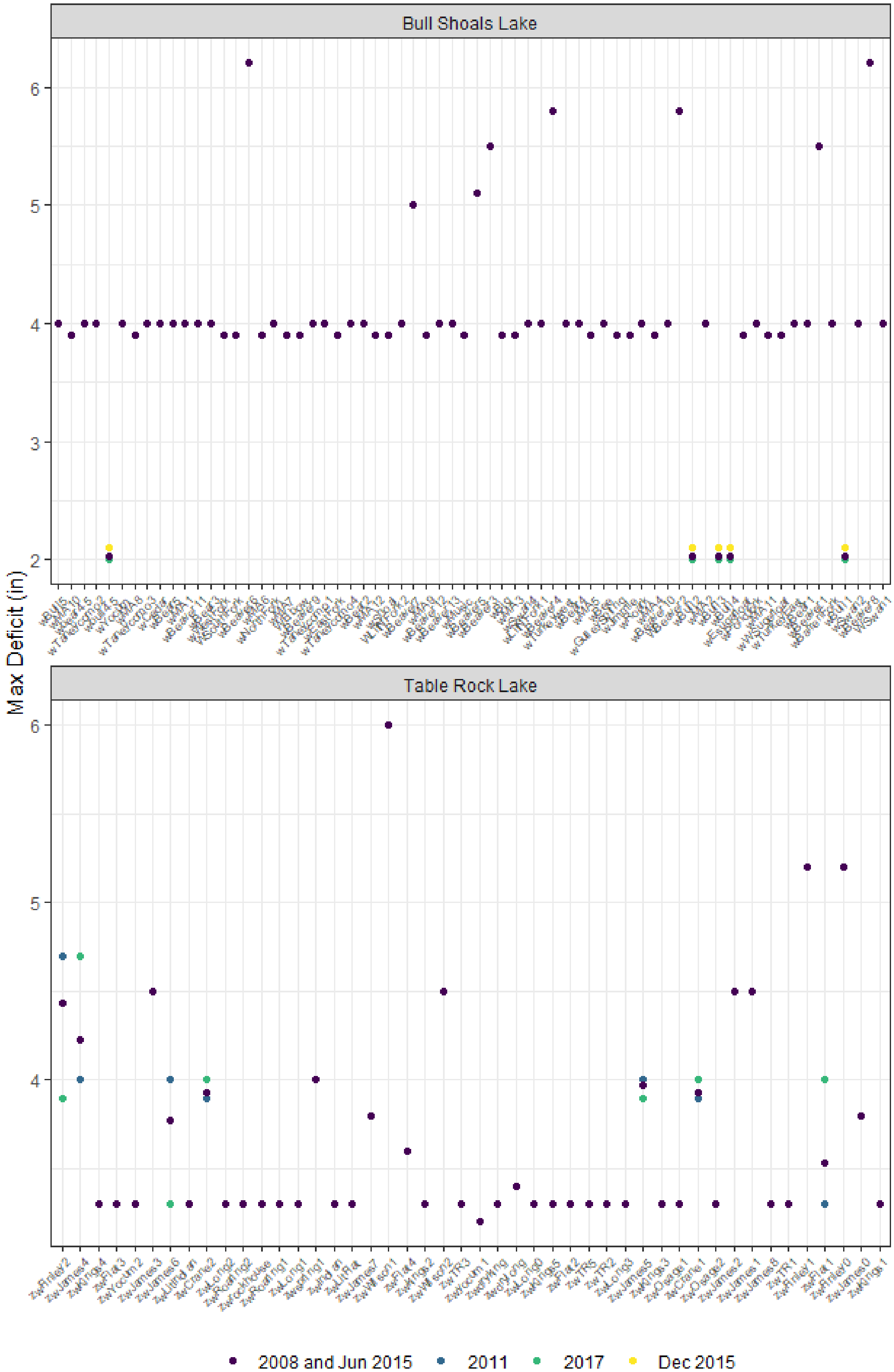


Figure 6-6. Maximum Deficit – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.4 Time of Concentration

A summary of time of concentration values for Beaver Lake subbasins is given in Table 6-7 and Figure 6-7. Time of concentration values by area for Beaver Lake subbasins are shown in Figure 6-8. A summary of time of concentration values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-8 and Figure 6-9. Time of concentration values by area for Table Rock Lake and Bull Shoals Lake subbasins is given in Figure 6-10.

Table 6-7. Time of Concentration – Beaver Lake Subbasins

	Time of Concentration Dec 2015 Event (hrs)	Time of Concentration 2008 Event (hrs)	Time of Concentration 2011 Event (hrs)	Time of Concentration Jun 2015 Event (hrs)	Time of Concentration 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	6.35	4.730	5.22	4.730	2.610	4.730	2.605
1st quartile	11.31	8.510	8.21	8.510	5.590	8.510	15.717
Median	12.31	9.670	10.53	9.670	6.180	9.670	21.543
Mean	12.07	9.409	10.12	9.409	6.039	9.409	30.567
3rd quartile	12.97	10.305	11.76	10.305	6.585	10.305	36.721
Maximum	16.58	14.090	16.93	14.090	8.750	14.090	113.460

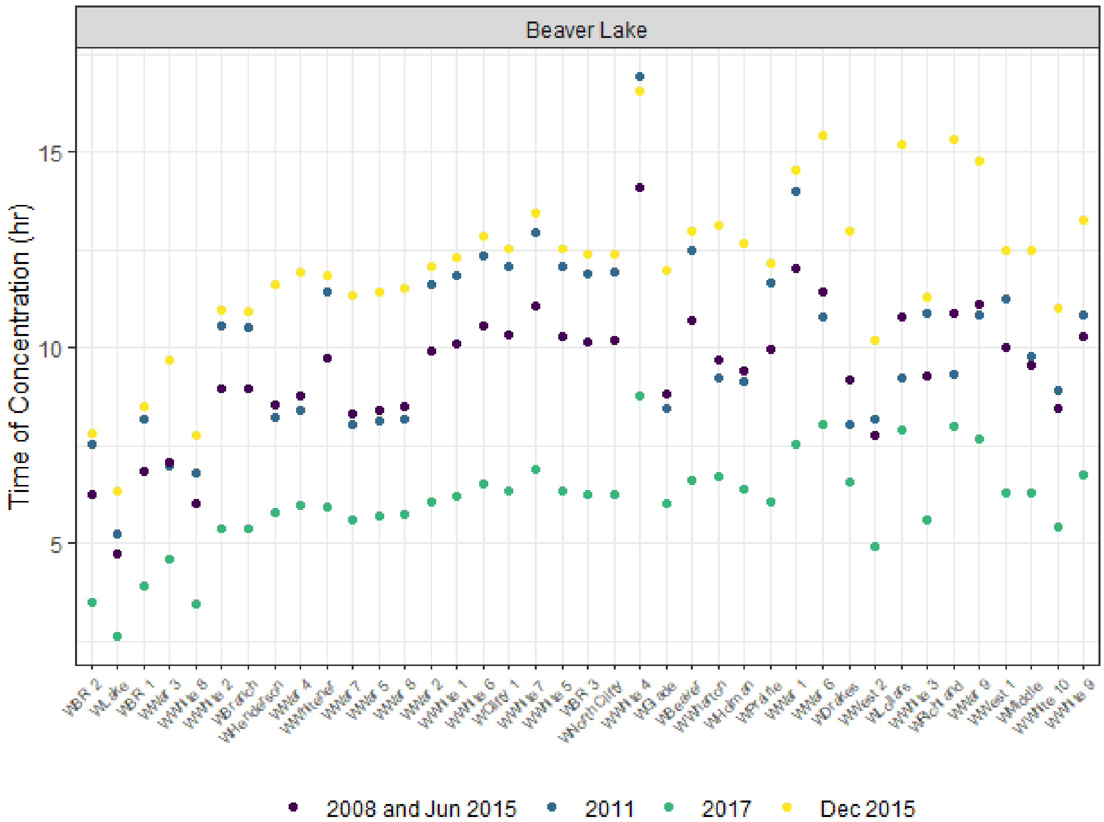


Figure 6-7. Time Concentration (by Subbasin) - Beaver Lake Subbasins

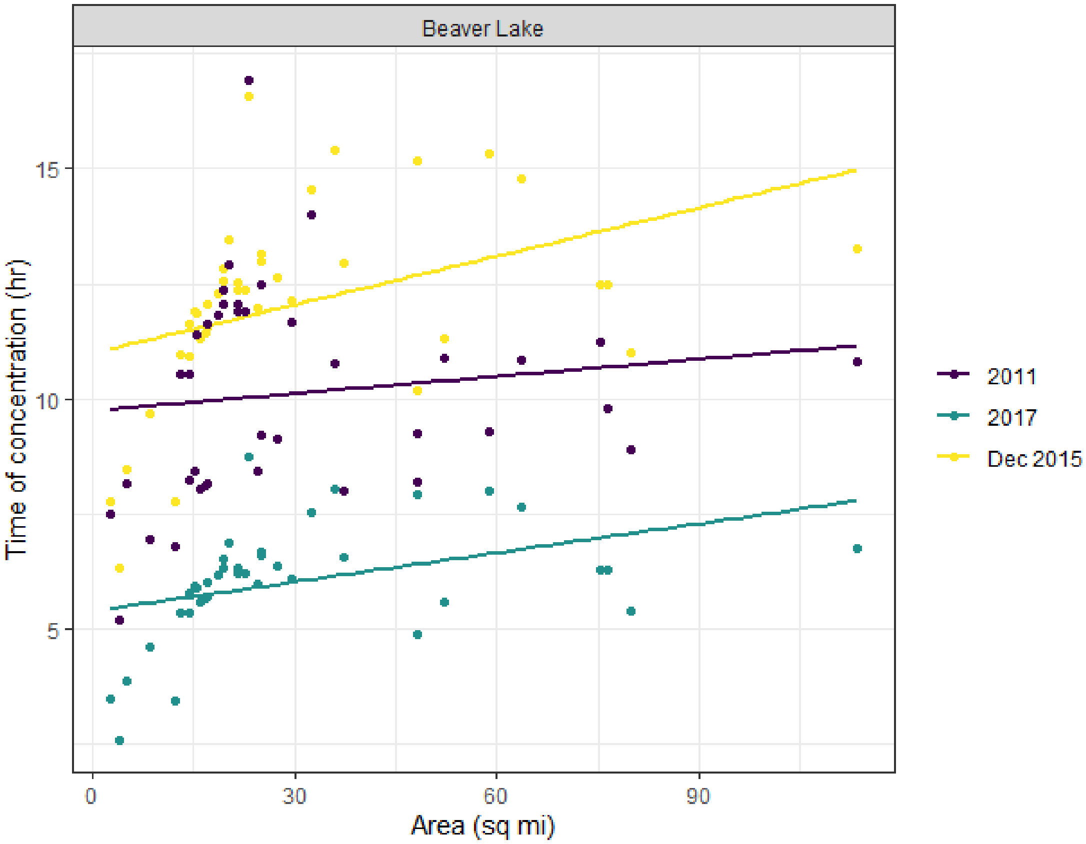


Figure 6-8. Time Concentration (by Area) - Beaver Lake Subbasins

Table 6-8. Time of Concentration – Bull Shoals and Table Rock Lakes Subbasins

	Time of Concentration Dec 2015 Event (hrs)	Time of Concentration 2008 Event (hrs)	Time of Concentration 2011 Event (hrs)	Time of Concentration Jun 2015 Event (hrs)	Time of Concentration 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	1.830	1.500	0.810	1.500	1.150	1.500	5.878
1st quartile	3.243	3.080	2.308	3.095	2.837	3.080	22.578
Median	4.805	4.290	3.770	4.290	3.855	4.290	36.181
Mean	5.636	5.162	4.972	5.165	4.878	5.162	43.180
3rd quartile	6.492	5.850	5.532	5.850	5.463	5.850	52.547
Maximum	17.400	17.190	19.500	17.190	16.360	17.190	167.220

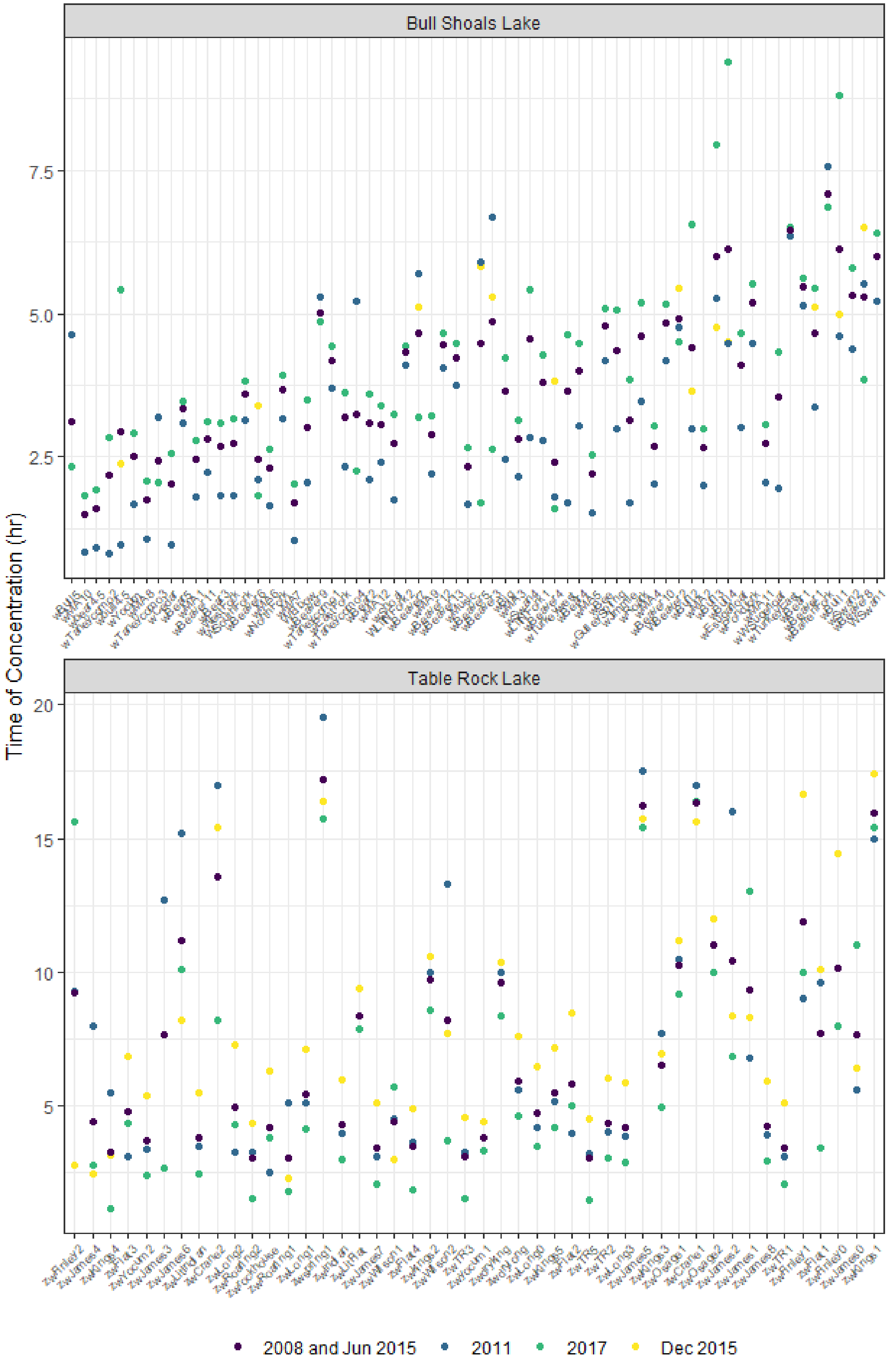


Figure 6-9. Time Concentration (by Subbasin) – Bull Shoals and Table Rock Lakes Subbasins

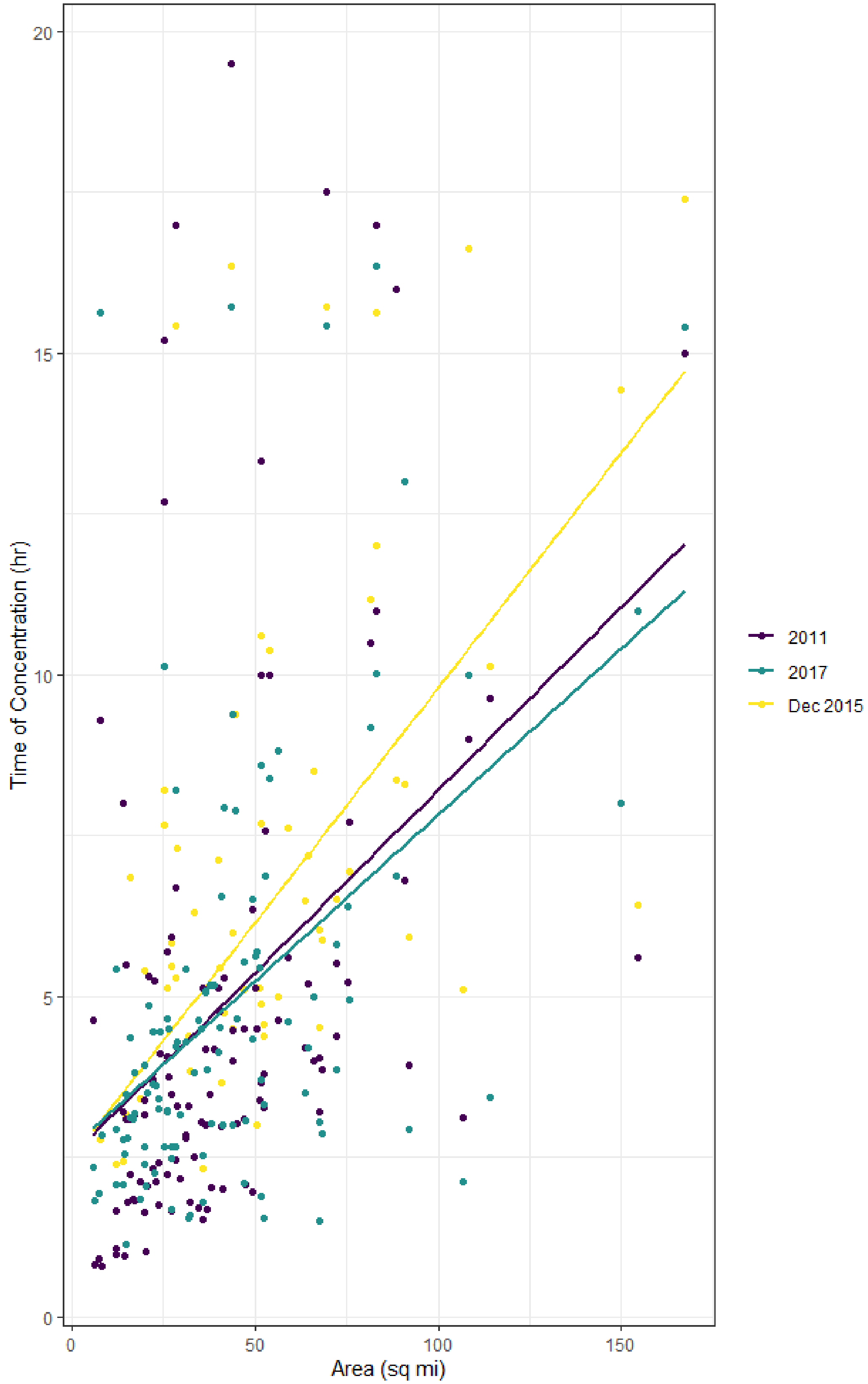


Figure 6-10. Time Concentration (by Area) – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.5 Storage Coefficient (R)

A summary of storage coefficient values for Beaver Lake subbasins is given in Table 6-9 and Figure 6-11. A summary of storage coefficient values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-10 and Figure 6-12.

Table 6-9. Storage Coefficient – Beaver Lake Subbasins

	Storage Coefficient Dec 2015 Event (hrs)	Storage Coefficient 2008 Event (hrs)	Storage Coefficient 2011 Event (hrs)	Storage Coefficient Jun 2015 Event (hrs)	Storage Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	4.910	3.930	4.160	3.930	2.730	3.930	2.605
1st quartile	7.945	6.200	5.965	6.200	4.670	6.200	15.717
Median	8.700	7.560	7.290	7.560	5.540	7.560	21.543
Mean	8.694	7.219	7.422	7.219	5.544	7.219	30.567
3rd quartile	9.705	8.290	8.510	8.290	6.525	8.290	36.721
Maximum	12.900	10.940	11.320	10.940	8.600	10.940	113.460

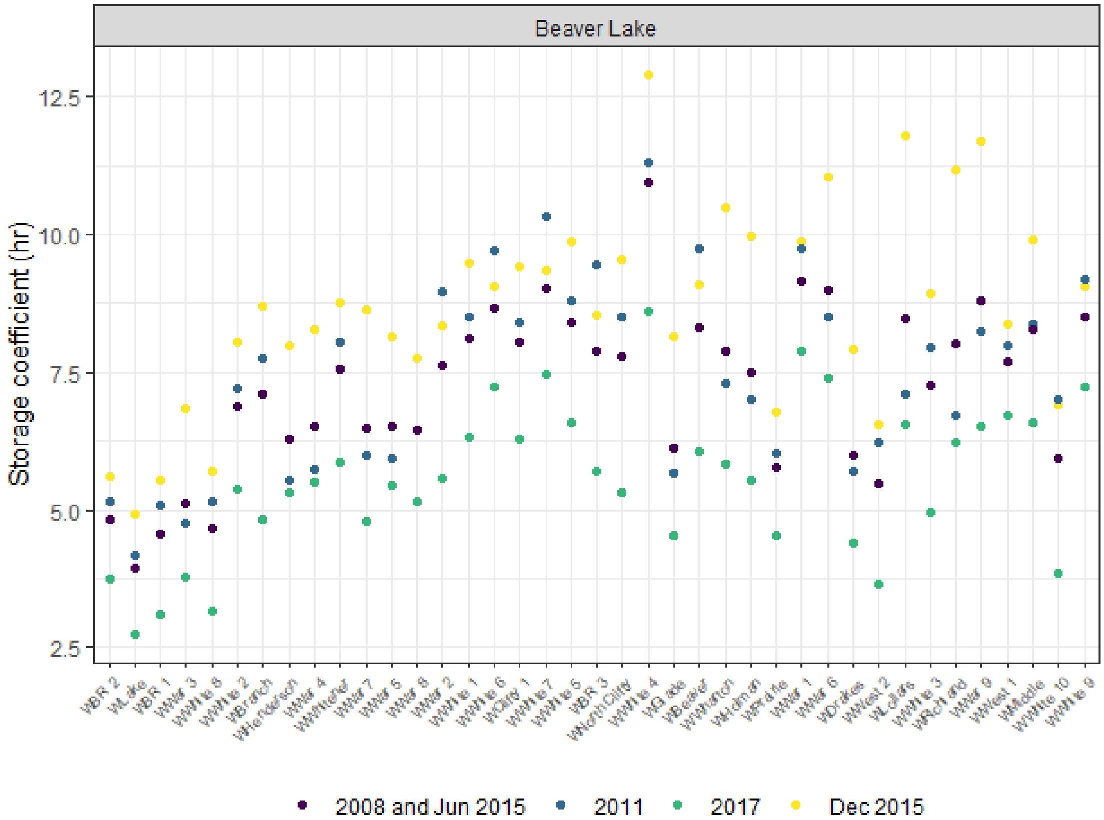


Figure 6-11. Storage Coefficient - Beaver Lake Subbasins

Table 6-10. Storage Coefficient – Bull Shoals and Table Rock Lakes Subbasins

	Storage Coefficient Dec 2015 Event (hrs)	Storage Coefficient 2008 Event (hrs)	Storage Coefficient 2011 Event (hrs)	Storage Coefficient Jun 2015 Event (hrs)	Storage Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	1.520	1.500	1.810	1.500	1.310	1.580	5.878
1st quartile	2.875	3.135	3.308	3.147	2.513	3.147	22.578
Median	4.445	5.000	4.770	5.000	4.105	5.000	36.181
Mean	6.070	5.575	5.905	5.580	4.872	5.616	43.180
3rd quartile	8.000	6.907	6.532	6.907	6.168	6.907	52.547
Maximum	19.860	17.530	19.00	17.530	16.880	17.530	167.220

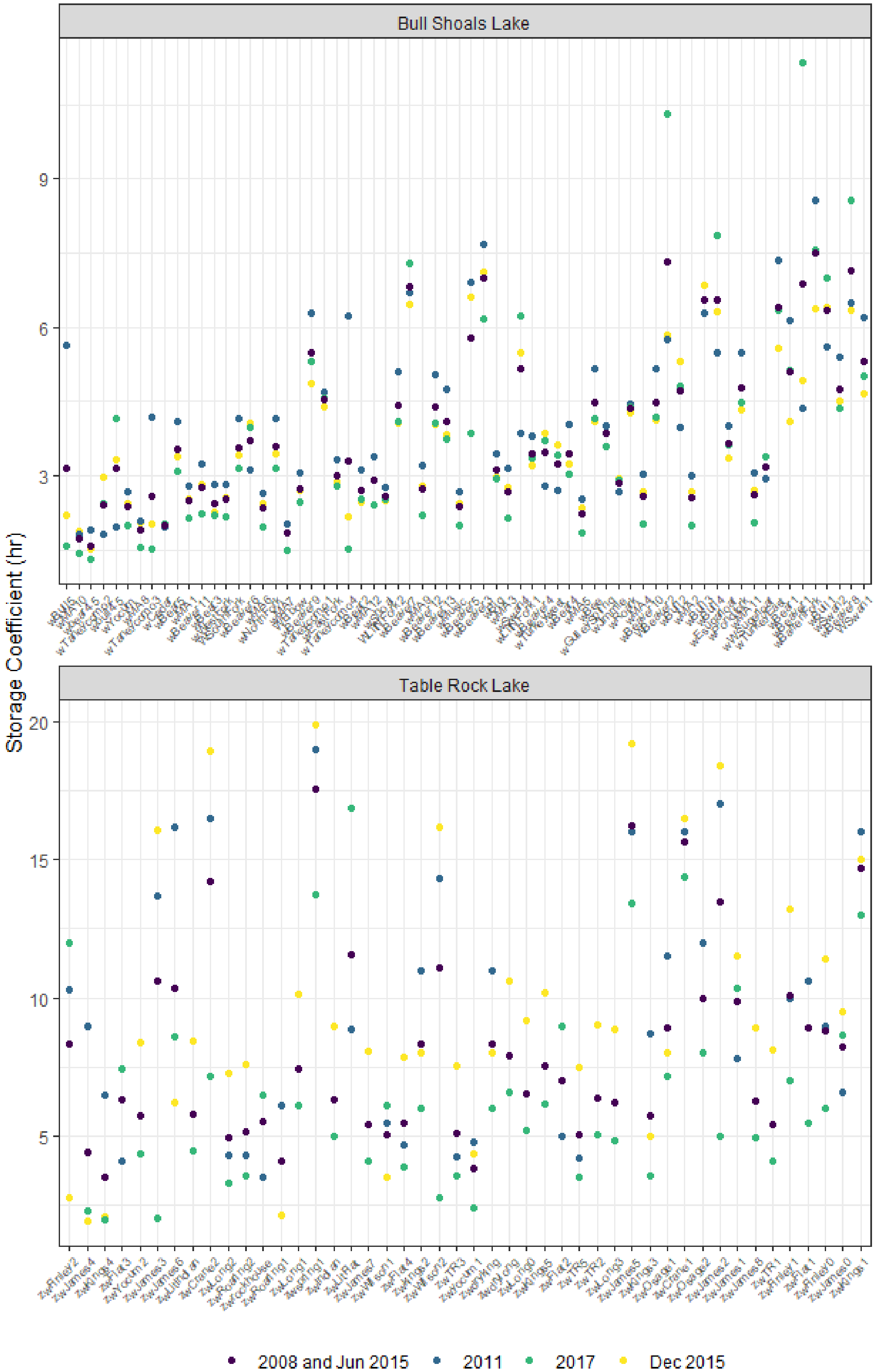


Figure 6-12. Storage Coefficient – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.6 R / (Tc + R)

A summary of R / (Tc + R) values for Beaver Lake subbasins is given in Table 6-11 and Figure 6-13. A summary of R / (Tc + R) values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-12 and Figure 6-14.

Table 6-11. R / (Tc + R) – Beaver Lake Subbasins

	R / (Tc + R) Dec 2015 Event (hrs)	R / (Tc + R) 2011 Event (hrs)	R / (Tc + R) 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	0.3584	0.3409	0.4002	0.3670	2.605
1st quartile	0.4065	0.4108	0.4592	0.4292	15.717
Median	0.4180	0.4225	0.4786	0.4371	21.543
Mean	0.4177	0.4226	0.4768	0.4331	30.567
3rd quartile	0.4358	0.4390	0.5032	0.4426	36.721
Maximum	0.4444	0.4612	0.5265	0.4649	113.460

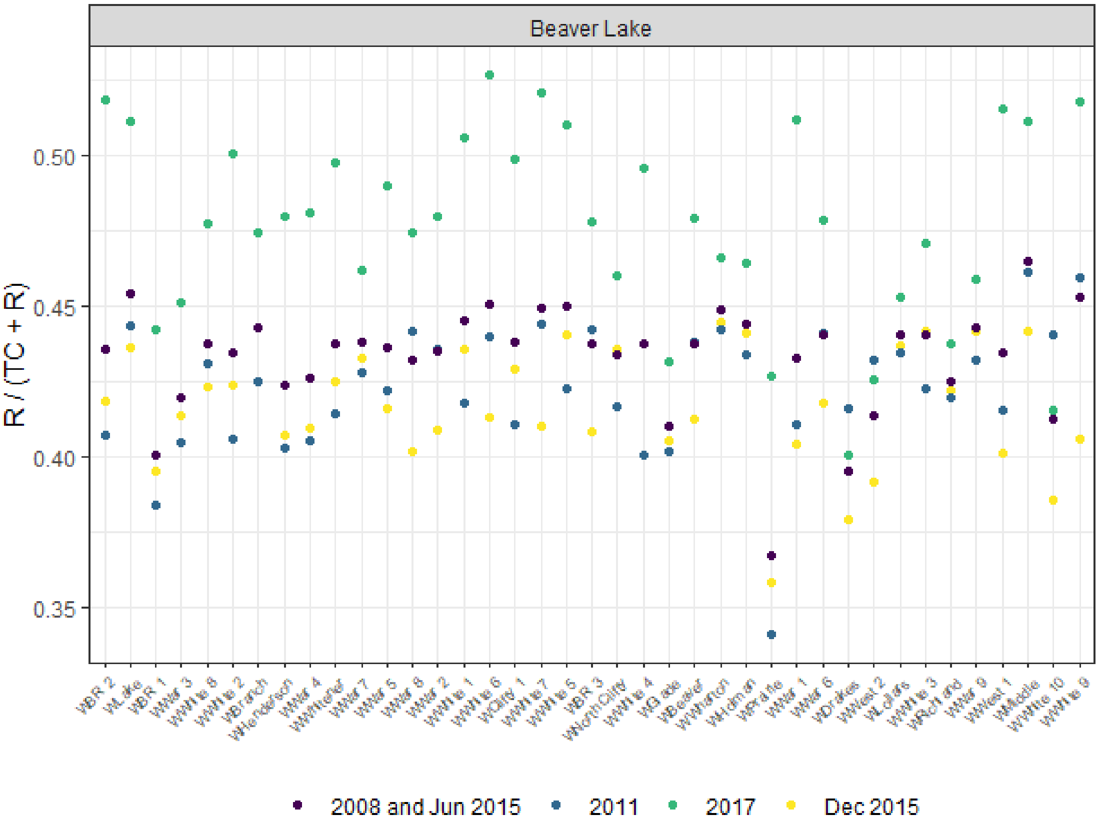


Figure 6-13. R / (Tc + R) - Beaver Lake Subbasins

Table 6-12. R / (Tc + R) – Bull Shoals and Table Rock Lakes Subbasins

	R / (Tc + R) Dec 2015 Event (hrs)	R / (Tc + R) 2011 Event (hrs)	R / (Tc + R) 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	0.4000	0.4776	0.4000	0.4588	5.878
1st quartile	0.4434	0.5414	0.4260	0.4845	22.578
Median	0.4860	0.5586	0.4476	0.5042	36.181
Mean	0.5029	0.5659	0.4995	0.5213	43.180
3rd quartile	0.5528	0.5891	0.5977	0.5675	52.547
Maximum	0.6871	0.6908	0.6998	0.6258	167.220

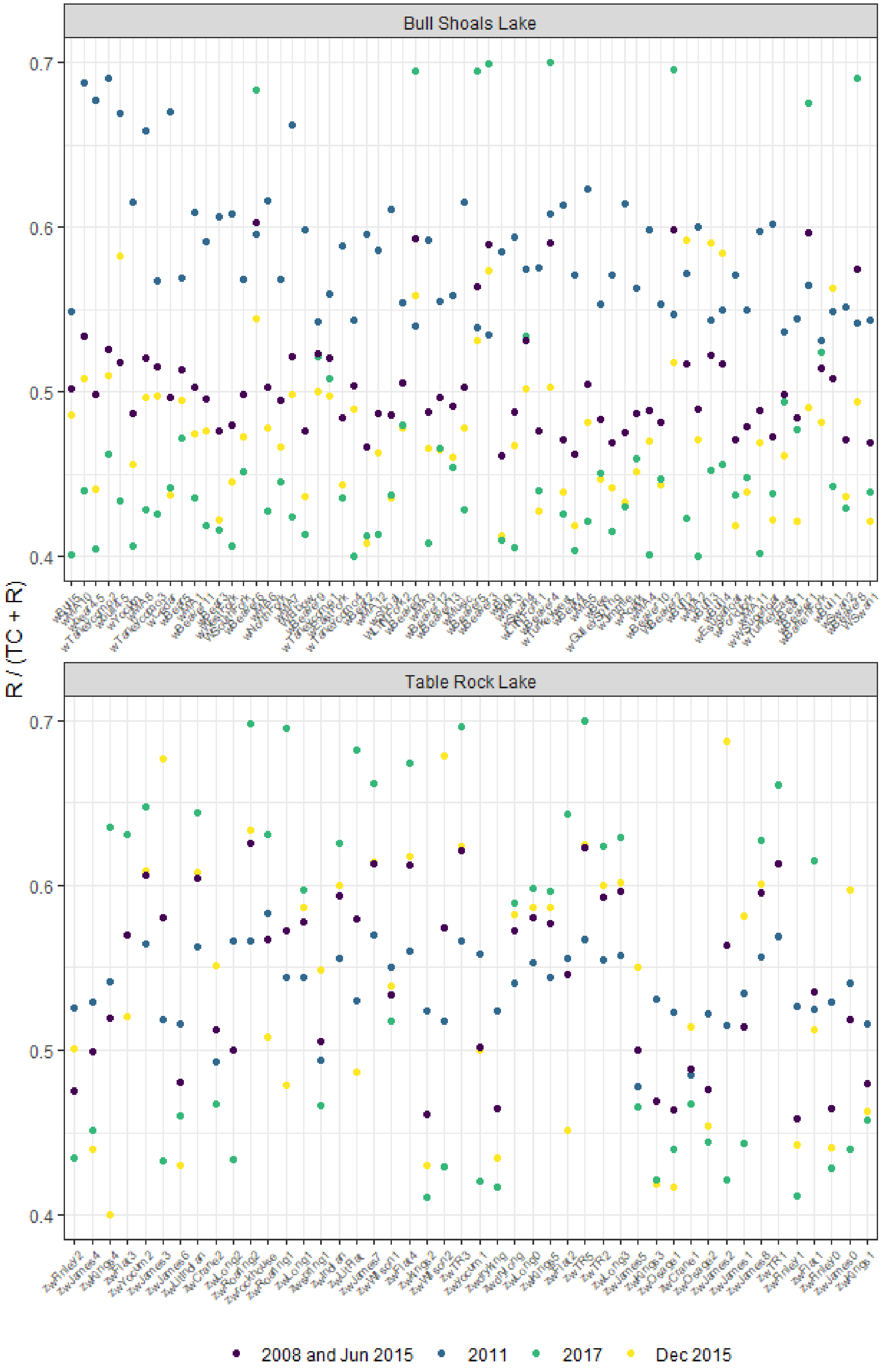


Figure 6-14. R / (Tc + R) – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.7 GW1 Coefficient

A summary of GW1 coefficient values for Beaver Lake subbasins is given in Table 6-13 and Figure 6-15. A summary of GW1 coefficient values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-14 and Figure 6-16.

Table 6-13. GW1 Coefficient – Beaver Lake Subbasins

	GW1 Coefficient Dec 2015 Event (hrs)	GW1 Coefficient 2008 Event (hrs)	GW1 Coefficient 2011 Event (hrs)	GW1 Coefficient Jun 2015 Event (hrs)	GW1 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	7.65	9.05	8.50	9.05	9.00	9.05	2.605
1st quartile	13.14	14.24	14.60	14.24	14.00	14.24	15.717
Median	15.57	17.18	17.30	17.18	17.00	17.18	21.543
Mean	15.55	17.06	17.28	17.06	18.36	17.06	30.567
3rd quartile	18.36	19.50	20.40	19.50	22.00	19.50	36.721
Maximum	24.21	27.04	26.90	27.04	32.00	27.04	113.460

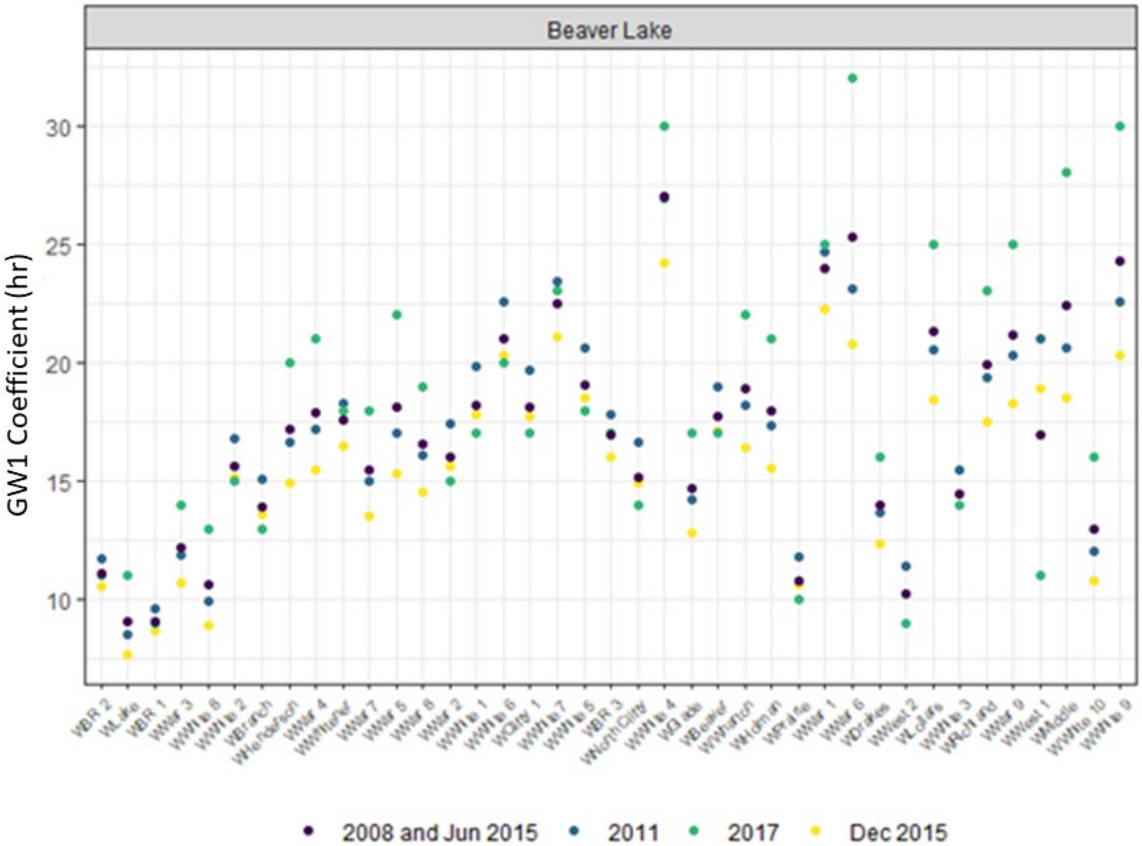


Figure 6-15. GW1 Coefficient - Beaver Lake Subbasins

Table 6-14. GW1 Coefficient – Bull Shoals and Table Rock Lakes Subbasins

	GW1 Coefficient Dec 2015 Event (hrs)	GW1 Coefficient 2008 Event (hrs)	GW1 Coefficient 2011 Event (hrs)	GW1 Coefficient Jun 2015 Event (hrs)	GW1 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	4.80	4.73	4.020	4.73	2.490	4.73	5.878
1st quartile	12.17	10.59	9.578	10.59	6.705	10.59	22.578
Median	18.90	15.53	14.340	15.53	12.120	15.53	36.181
Mean	21.21	17.64	17.847	17.64	13.851	17.64	43.180
3rd quartile	26.84	22.43	19.073	22.43	18.082	22.43	52.547
Maximum	59.58	57.94	73.080	57.94	50.640	57.94	167.220

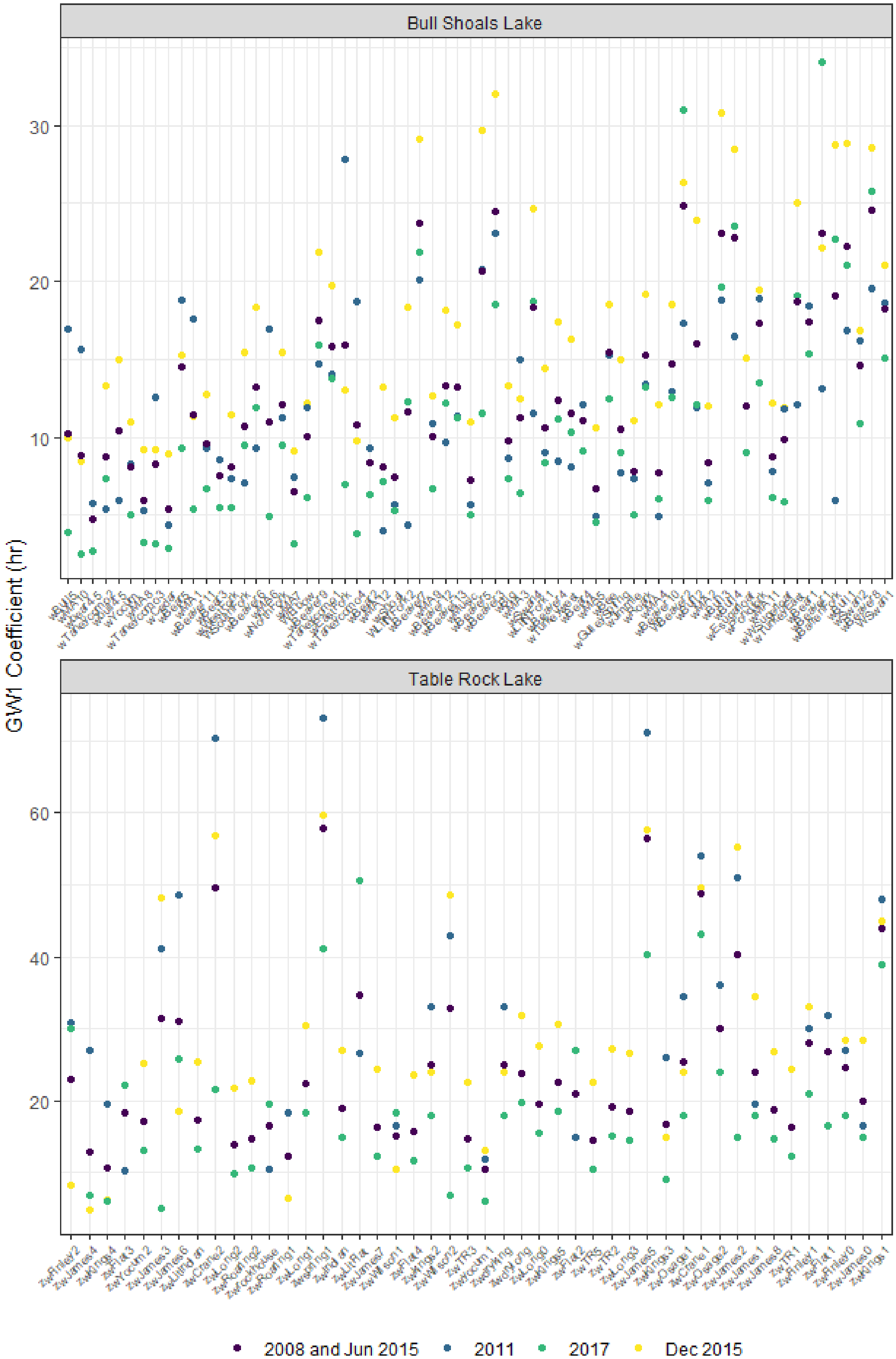


Figure 6-16. GW1 Coefficient – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.8 GW1 Fraction

A summary of GW1 fraction values for Beaver Lake subbasins is given in Table 6-15 and Figure 6-17. A summary of GW1 fraction values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-16 and Figure 6-18.

Table 6-15. GW1 Fraction – Beaver Lake Subbasins

	GW1 Fraction Dec 2015 Event	GW1 Fraction 2008 Event	GW1 Fraction 2011 Event	GW1 Fraction Jun 2015 Event	GW1 Fraction 2017 Event	Mean Calibration Values	Area of Subbasins (sq mi)
Minimum	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	2.605
1st quartile	0.5000	0.5700	0.6000	0.5700	0.5000	0.5700	15.717
Median	0.5000	0.6700	0.7000	0.6700	0.5000	0.6700	21.543
Mean	0.5282	0.6172	0.7872	0.6172	0.5282	0.6172	30.567
3rd quartile	0.5000	0.6700	1.0000	0.6700	0.5000	0.6700	36.721
Maximum	0.8000	0.7000	1.0000	0.7000	0.8000	0.7000	113.460

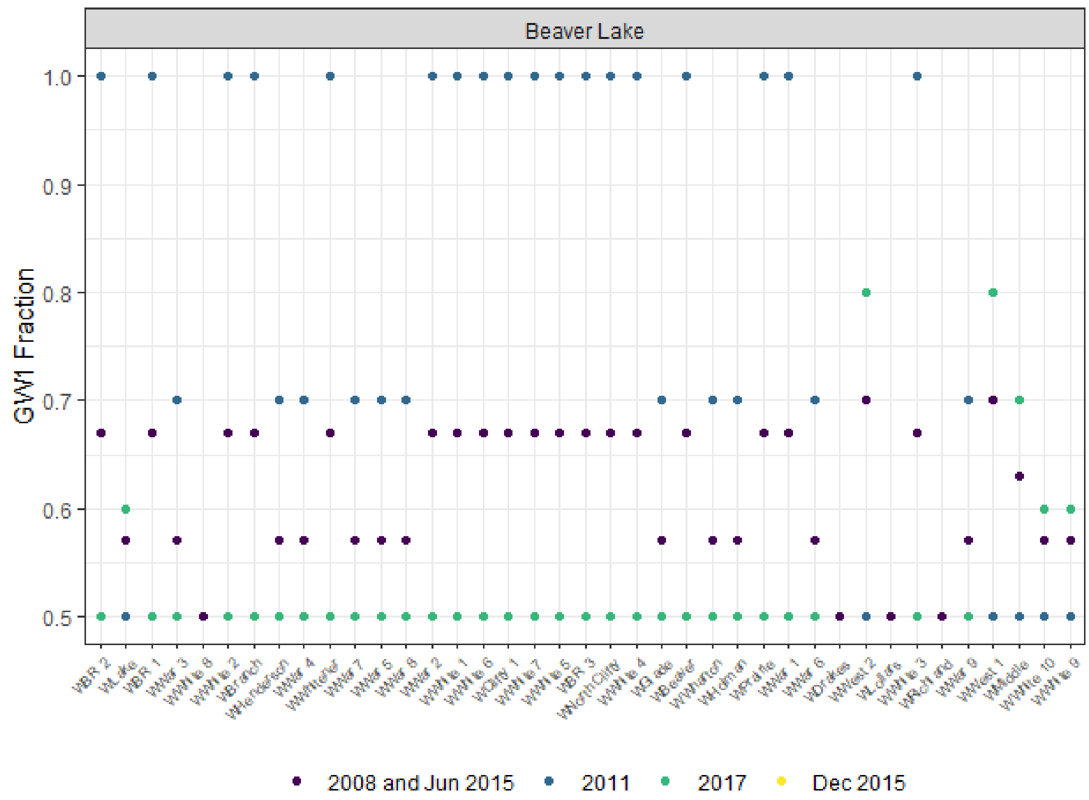


Figure 6-17. GW1 Fraction - Beaver Lake Subbasins

Table 6-16. GW1 Fraction – Bull Shoals and Table Rock Lakes Subbasins

	GW1 Fraction Dec 2015 Event	GW1 Fraction 2008 Event	GW1 Fraction 2011 Event	GW1 Fraction Jun 2015 Event	GW1 Fraction 2017 Event	Mean Calibration Values	Area of Subbasins (sq mi)
Minimum	0.1000	0.2700	0.2000	0.2700	0.0000	0.2700	5.878
1st quartile	0.3000	0.3300	0.5000	0.3300	0.2000	0.3300	22.578
Median	0.3000	0.3300	0.5000	0.3300	0.2000	0.3300	36.181
Mean	0.3522	0.4069	0.5170	0.4069	0.3455	0.4036	43.180
3rd quartile	0.5000	0.5000	0.5000	0.5000	0.5000	0.5000	52.547
Maximum	0.9000	0.6000	0.8000	0.6000	0.8000	0.6000	167.220

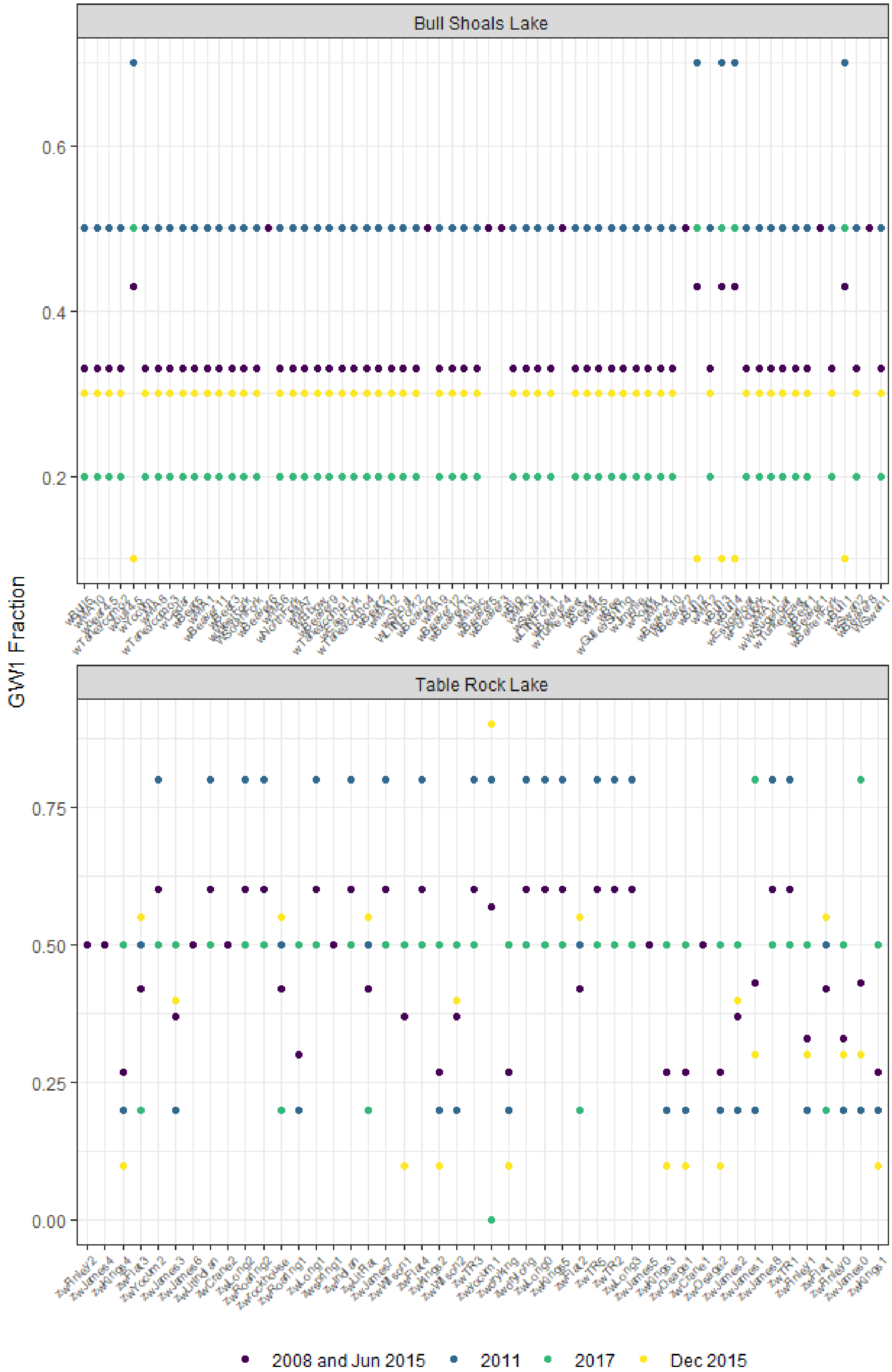


Figure 6-18. GW1 Fraction – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.9 GW2 Coefficient

A summary of GW2 coefficient values for Beaver Lake subbasins is given in Table 6-17 and Figure 6-19. A summary of GW2 coefficient values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-18 and Figure 6-20.

Table 6-17. GW2 Coefficient – Beaver Lake Subbasins

	GW2 Coefficient Dec 2015 Event (hrs)	GW2 Coefficient 2008 Event (hrs)	GW2 Coefficient 2011 Event (hrs)	GW2 Coefficient Jun 2015 Event (hrs)	GW2 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	30.69	31.83	34.1	31.83	30.7	31.83	2.605
1st quartile	52.52	54.45	58.35	54.45	52.5	54.45	15.717
Median	62.37	64.69	69.3	64.69	62.4	64.69	21.543
Mean	62.15	64.46	69.06	64.46	62.17	64.46	30.567
3rd quartile	73.39	76.11	81.55	76.11	73.4	76.11	36.721
Maximum	96.75	100.35	107.5	100.35	96.8	100.35	113.460

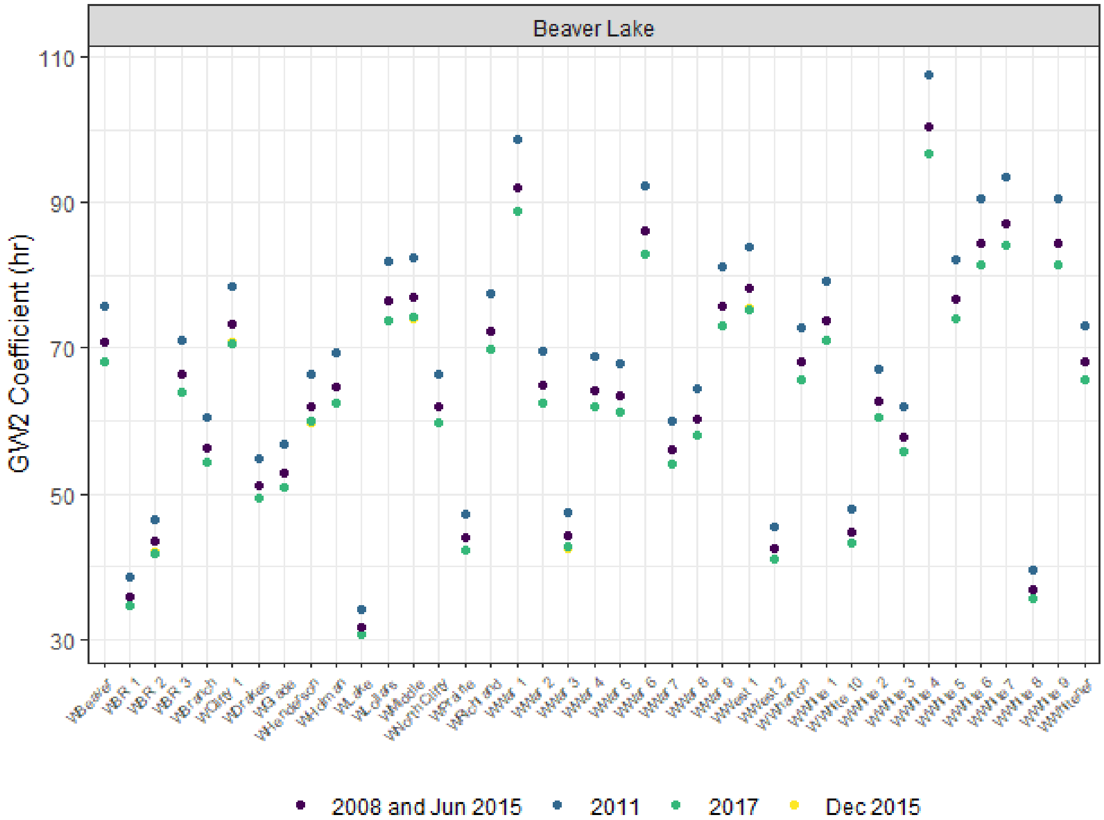


Figure 6-19. GW2 Coefficient - Beaver Lake Subbasins

Table 6-18. GW2 Coefficient – Bull Shoals and Table Rock Lakes Subbasins

	GW2 Coefficient Dec 2015 Event (hrs)	GW2 Coefficient 2008 Event (hrs)	GW2 Coefficient 2011 Event (hrs)	GW2 Coefficient Jun 2015 Event (hrs)	GW2 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)	Area of Subbasins (sq mi)
Minimum	16.00	15.77	13.40	15.77	8.30	15.77	5.878
1st quartile	40.58	35.30	31.93	35.30	22.35	35.30	22.578
Median	63.00	51.77	47.80	51.77	40.40	51.77	36.181
Mean	70.69	58.79	59.49	58.79	46.17	58.79	43.180
3rd quartile	89.45	74.78	63.58	74.78	60.27	74.78	52.547
Maximum	198.60	193.13	243.60	193.13	168.80	193.13	167.220

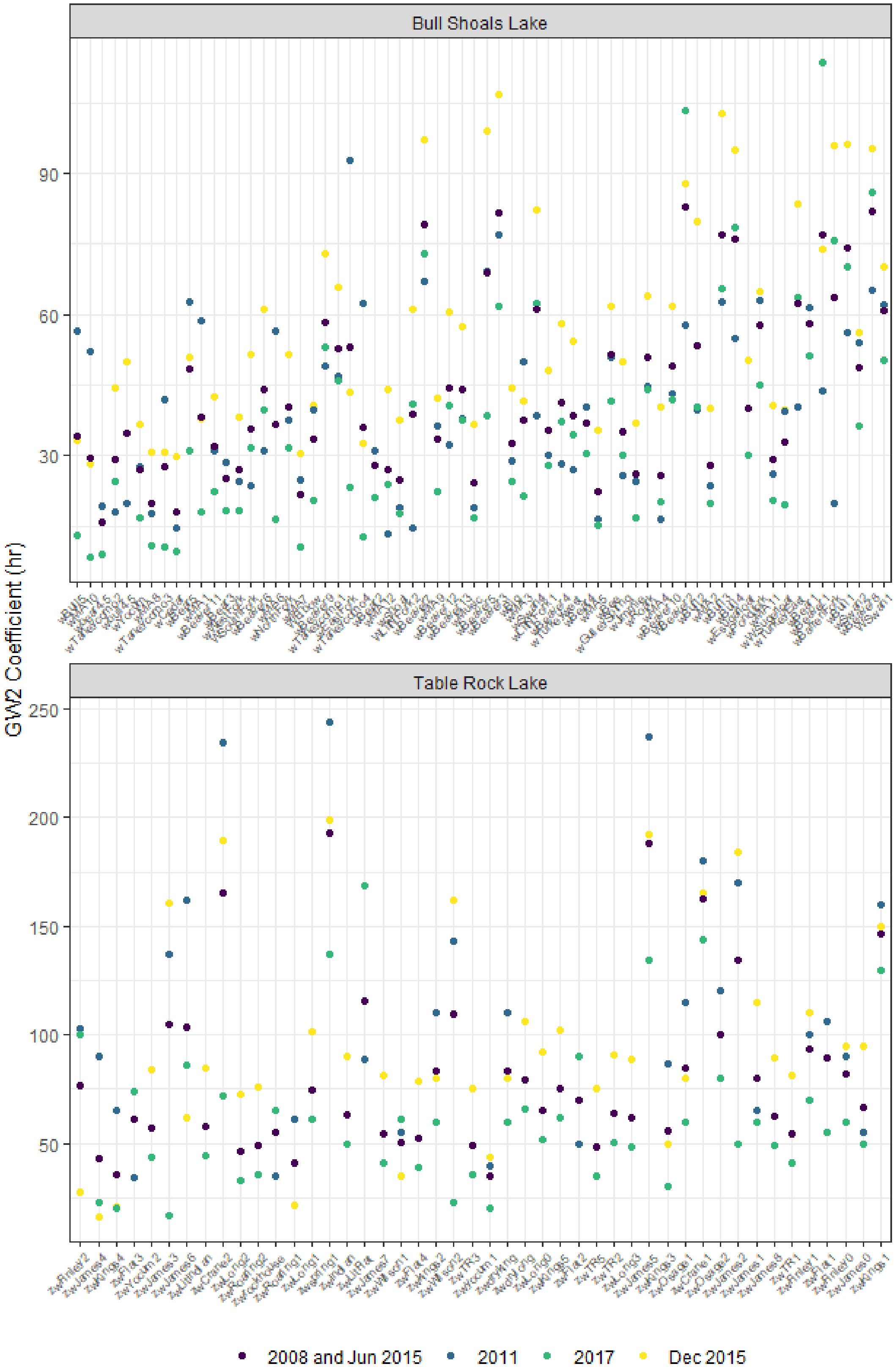


Figure 6-20. GW2 Coefficient – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.10 GW2 Fraction

A summary of GW2 fraction values for Beaver Lake subbasins is given in Table 6-19 and Figure 6-21. A summary of GW2 fraction values for Table Rock Lake and Bull Shoals Lake subbasins is given in Table 6-20 and Figure 6-22.

Table 6-19. GW2 Fraction – Beaver Lake Subbasins

	GW2 Fraction Dec 2015 Event	GW2 Fraction 2008 Event	GW2 Fraction 2011 Event	GW2 Fraction Jun 2015 Event	GW2 Fraction 2017 Event	Mean Calibration Values	Area of Subbasins (sq mi)
Minimum	0.2	0.3	0	0.3	0.2	0.3	2.605
1st quartile	0.5	0.33	0	0.33	0.5	0.33	15.717
Median	0.5	0.33	0.3	0.33	0.5	0.33	21.543
Mean	0.4718	0.3828	0.2128	0.3828	0.4718	0.3828	30.567
3rd quartile	0.5	0.43	0.4	0.43	0.5	0.43	36.721
Maximum	0.5	0.5	0.5	0.5	0.5	0.5	113.460

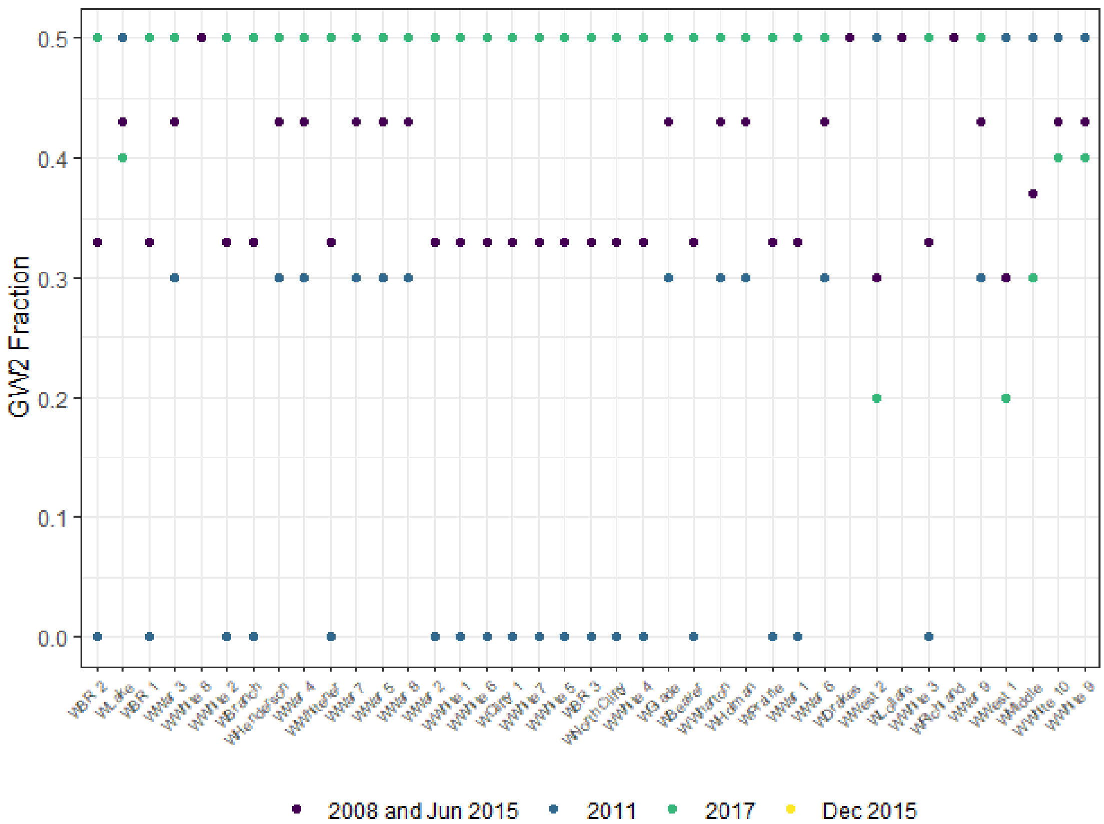


Figure 6-21. GW2 Fraction - Beaver Lake Subbasins

Table 6-20. GW2 Fraction – Bull Shoals and Table Rock Lakes Subbasins

	GW2 Fraction Dec 2015 Event	GW2 Fraction 2008 Event	GW2 Fraction 2011 Event	GW2 Fraction Jun 2015 Event	GW2 Fraction 2017 Event	Mean Calibration Values	Area of Subbasins (sq mi)
Minimum	0.1000	0.4000	0.2000	0.4000	0.2000	0.4000	5.878
1st quartile	0.5000	0.5000	0.3750	0.5000	0.5000	0.4950	22.578
Median	0.7000	0.6700	0.5000	0.6700	0.8000	0.6700	36.181
Mean	0.6424	0.5931	0.4647	0.5931	0.6545	0.5888	43.180
3rd quartile	0.7000	0.6700	0.5000	0.6700	0.8000	0.6700	52.547
Maximum	0.9000	0.7300	0.8000	0.7300	1.0000	0.7300	167.220

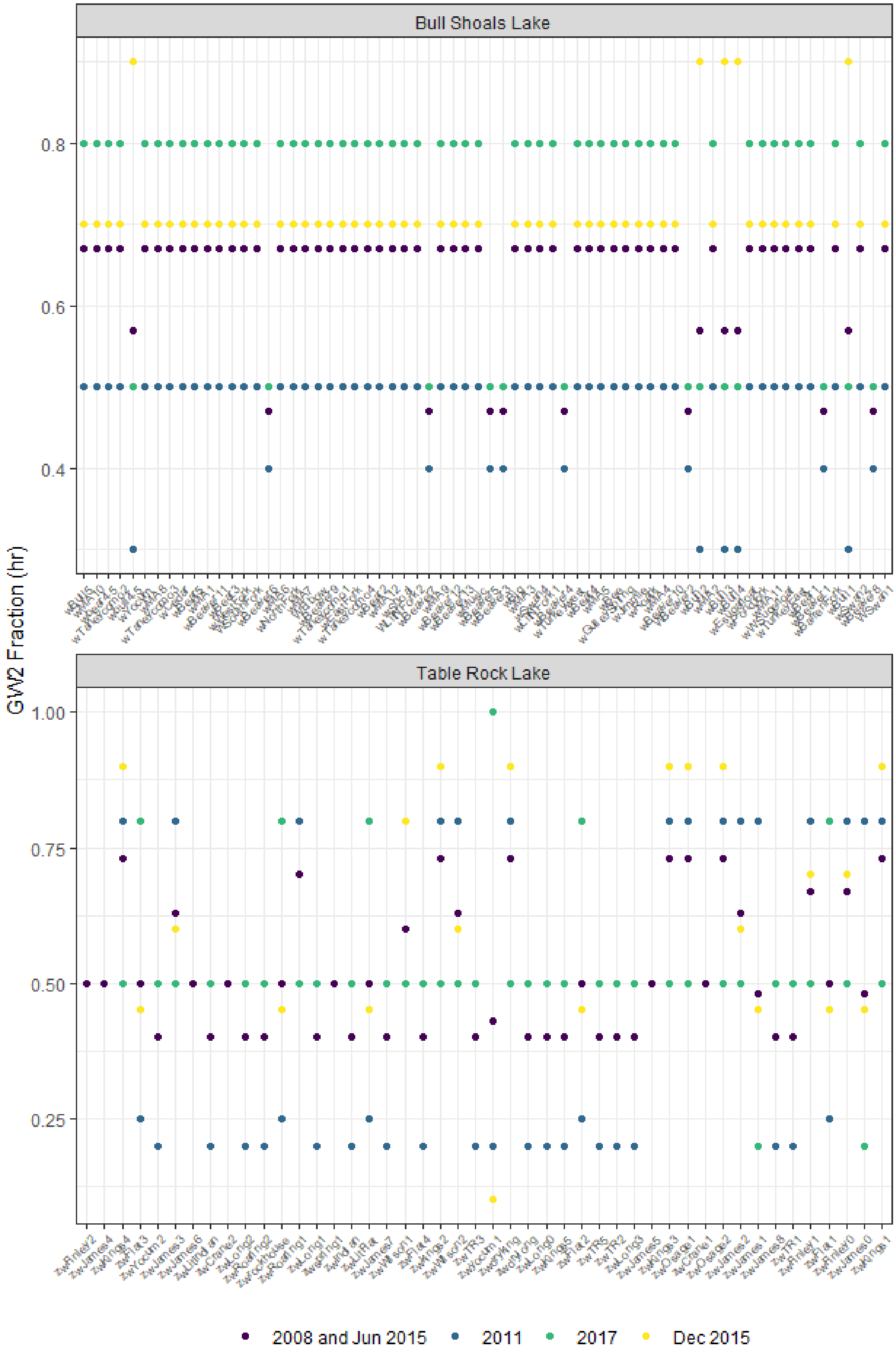


Figure 6-22. GW2 Fraction – Bull Shoals and Table Rock Lakes Subbasins

6.4.2.11 Variable Clark Parameters

Variable Clark parameters were developed using HEC-RAS 2D and synthetic storm events. The synthetic storm events were derived from Probable Maximum Precipitation (PMP) storm ellipses for their respective basins and were scaled so that the maximum precipitation values reached depths from 2 to 7 inches per hour. The HEC-RAS 2D models were calibrated to USGS streamgage locations and root-mean squared error (RMSE) was generally around 1.5. The same hyetographs that were applied to the HEC-RAS 2D models were applied to several subbasins within the HEC-HMS models. The HEC-HMS models were then calibrated so that the hydrograph peaks matched the results from the HEC-RAS 2D models (Figure 6-29 through Figure 6-32). The subbasins from the HMS models were selected to represent as much variability as possible in basin area, basin slope, stream slope, length of longest flow path, spatial distribution across the HMS model domain, and basin shape in order to represent the full range of physical basin characteristics upon which regressions were developed. The resulting maximum hourly precipitation depths and Tc and R values were used for the lower end of the Variable Clark curves. The Tc and R values within the HEC-HMS models were calibrated so that the resulting outflow hydrographs for the subbasins matched the hydrographs from the HEC-RAS 2D models . T_C and R values were used with excess precipitation values for the HEC-HMS calibration models for the upper end of the Variable Clark curves. Initial Tc and R values associated with an excess precipitation value of 1 inch were interpolated on log-scale from Tc and R values applied to calibration models and the resulting excess precipitation values from model runs. Tc and R curves for calibration subbasins are plotted in Figure 6-33 through Figure 6-36.

Variable Clark curves for all subbasins (Figure 6-37 through Figure 6-40) were obtained from regression using Cubist (Quinlan 1987, 1992, 1993a). Cubist is a prediction-oriented regression model. Although it initially creates a tree structure similar to tree boosting, it collapses each path through the tree into a rule. A regression model is fit for each rule based on the data subset defined by the rules. The set of rules are either pruned or combined. The candidate variables for the linear regression models are the predictors that were used in the parts of the rule that were pruned away. Cubist models were trained using the *caret* package (Kuhn, 2016) for R and implemented with the *Cubist* package (Kuhn and Quinlan, 2022) for R. Many explanatory variables were tested for all regression equations. Regression analyses for Tc and R used basin slope (ft/mi), basin area (mi^2), basin slope (ft/mi), length of longest flow path (mi), stream slope (ft/mi), coordinates of the basin centroid, and basin shape factor (dimensionless ratio) for explanatory variables (Table 6-21).

After Variable Clark curves were created for all subbasins for the HEC-HMS models, comparisons were made between the HEC-RAS model results and the HEC-HMS model results using the Variable Clark curves and using the calibrated Clark values for Tc and R. Comparisons were also made for reservoir inflows using the Tc and R values for the Clark method and the Variable Clark method.

Table 6-21. Model attribute usage for developing Cubist models for predicting Variable Clark transforms for subbasins

Regression Model Explanatory Variable	Regression Model Attribute Usage for Tc	Regression Model Attribute Usage for R
Percent Incremental Precipitation	100%	95%
Basin Shape Factor	35%	34%
Stream Slope (ft/mi)	48%	14%
Basin Area (mi^2)	35%	9%
Longest Flow Path Length (mi)	43%	16%
Basin Slope (ft/mi)	27%	40%

Table 6-22. Goodness-of-fit metrics for regressions for all Variable Clark curves for OLS (ordinary least squares) regression and machine learning regression.

Regression type	Curve	NRMSE %	PBIAS %	RSR	NSE	Modified NSE	R^2	Adjusted R^2
OLS	Tc	51.3	-3.9	0.51	0.74	0.61	0.74	0.67
Cubist	Tc	11.4	0	0.11	0.99	0.92	0.99	0.98
OLS	R	48.9	-2.8	0.49	0.76	0.61	0.79	0.76
Cubist	R	11.1	0.4	0.11	0.99	0.92	0.99	0.98

To verify the results from the Cubist regressions, eight subbasins were randomly selected for leave-one-out cross-validation (LOOCV). Each of the eight subbasins was removed from the data used to create the Cubist regression. The Cubist regression created without the holdout site was then used to predict values on the holdout site. This process was iteratively completed on all eight holdout subbasins and goodness-of-fit statistics were computed from the combined, predicted values. The results from LOOCV are plotted in Figure 6-23 to Figure 6-28. It should be noted that, by evaluating Figure 6-23 and Figure 6-24, the mean of the difference in hours between the calibrated and Cubist curves is essentially zero for all precipitation intensities evaluated. Goodness-of-fit metrics for the LOOCV are listed in Table 6-23 and Table 6-24.

Table 6-23. Goodness-of-fit metrics for LOOCV subbasins for Tc

Regression type	Value Type	NRMSE %	PBIAS %	RSR	NSE	Modified NSE	R^2	Adjusted R^2
Cubist	Percentage	22.7	0.6	0.23	0.95	0.85	0.95	0.93
OLS	Percentage	47	-5.7	0.47	0.78	0.64	0.79	0.71
Cubist	Hours	16.1	1	0.16	0.97	0.87	0.97	0.97
OLS	Hours	40.9	-4.1	0.41	0.83	0.65	0.85	0.81

Table 6-24 Goodness-of-fit metrics for LOOCV subbasins for R

Regression type	Value Type	NRMSE %	PBIAS %	RSR	NSE	Modified NSE	R^2	Adjusted R^2
Cubist	Percentage	23.8	0.4	0.24	0.94	0.8	0.94	0.93
OLS	Percentage	89.4	-15.8	0.89	0.19	0.41	0.45	0.36
Cubist	Hours	19.3	-0.1	0.19	0.96	0.83	0.96	0.94
OLS	Hours	72.6	-19.2	0.73	0.47	0.48	0.54	0.4

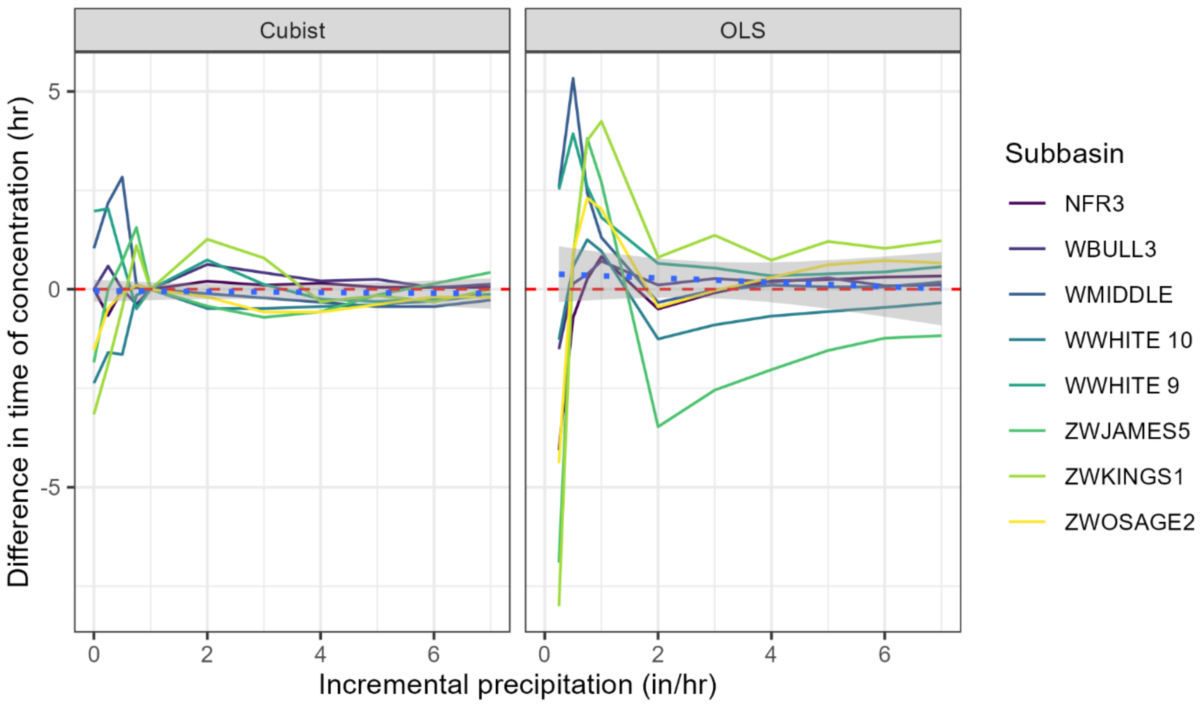


Figure 6-23. Plots showing differences in calibrated Tc values vs Tc values estimated by regression. Blue dotted line with confidence interval is linear regression of all values. Red dashed line is at Y = 0.

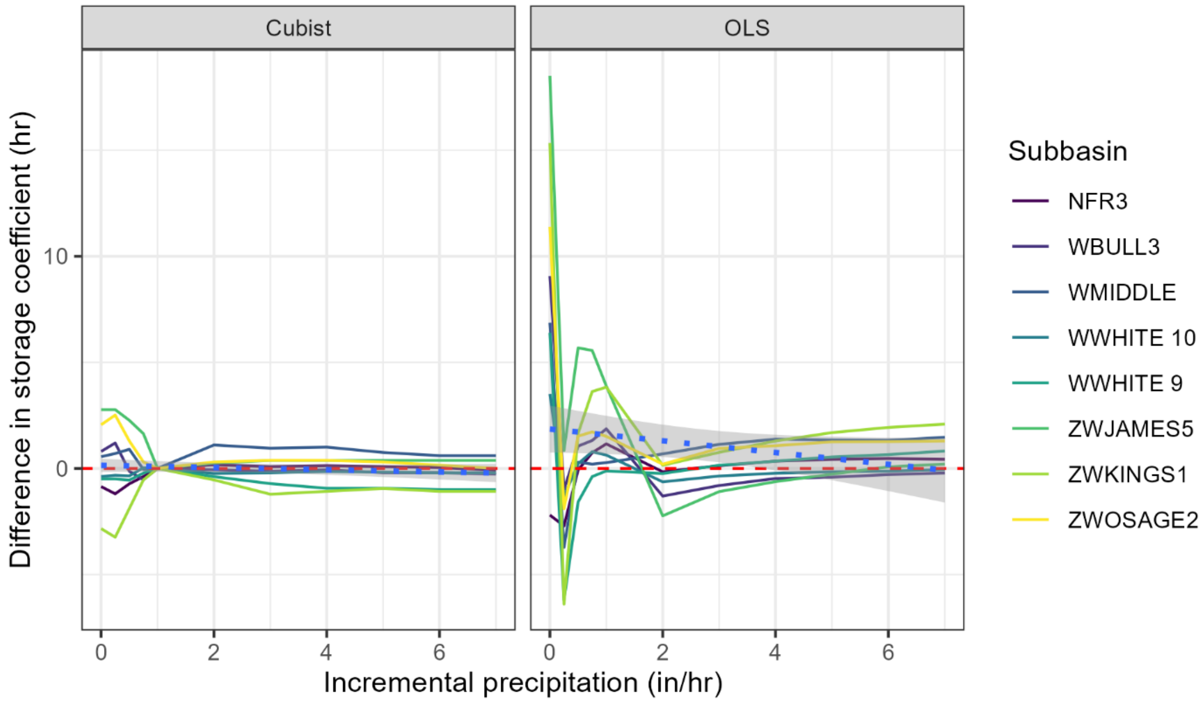


Figure 6-24. Plots showing differences in calibrated R values vs R values estimated by regression. Blue dotted line with confidence interval is linear regression of all values. Red dashed line is at Y = 0.

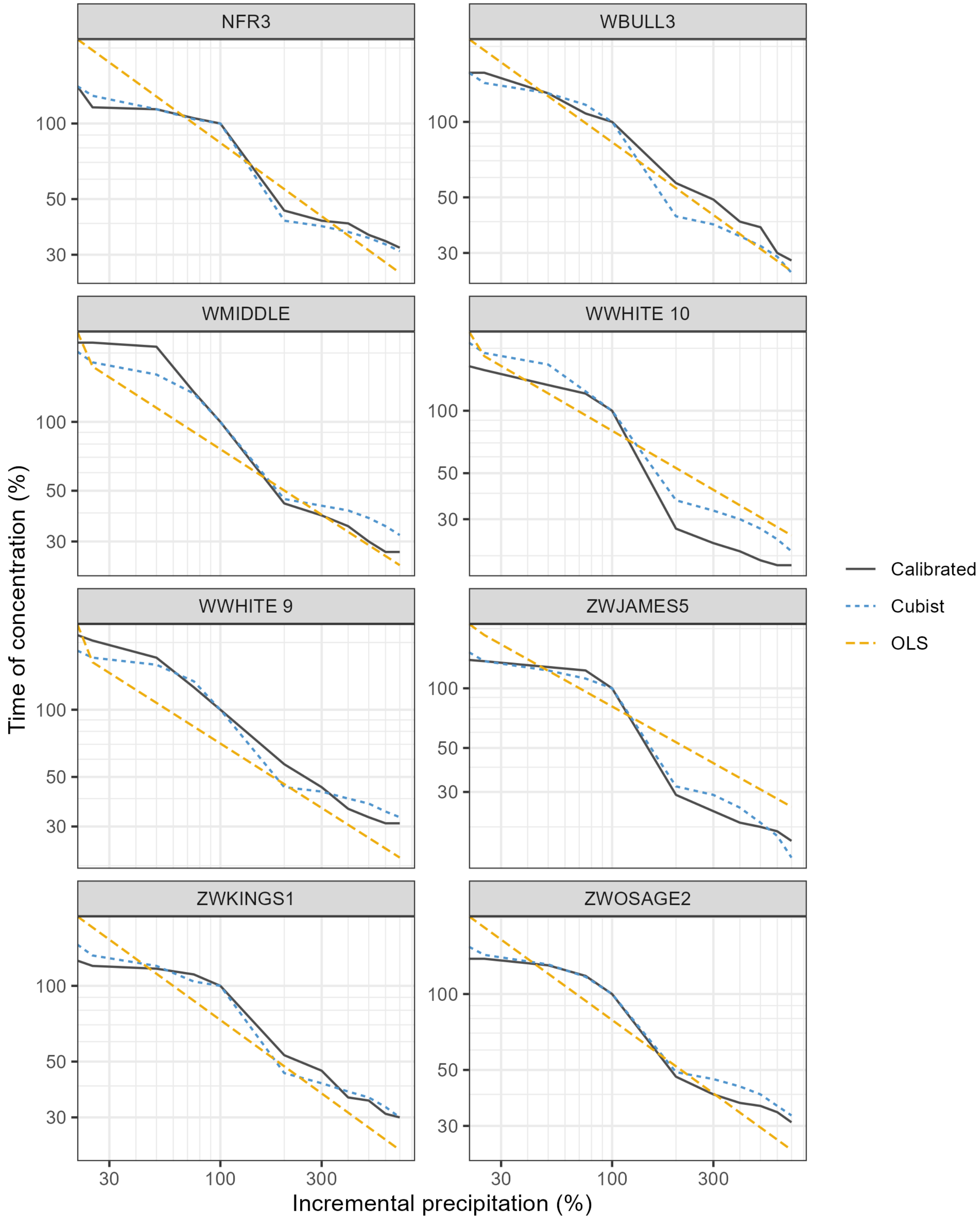


Figure 6-25. Plots showing results, in percentages, for LOOCV for Tc

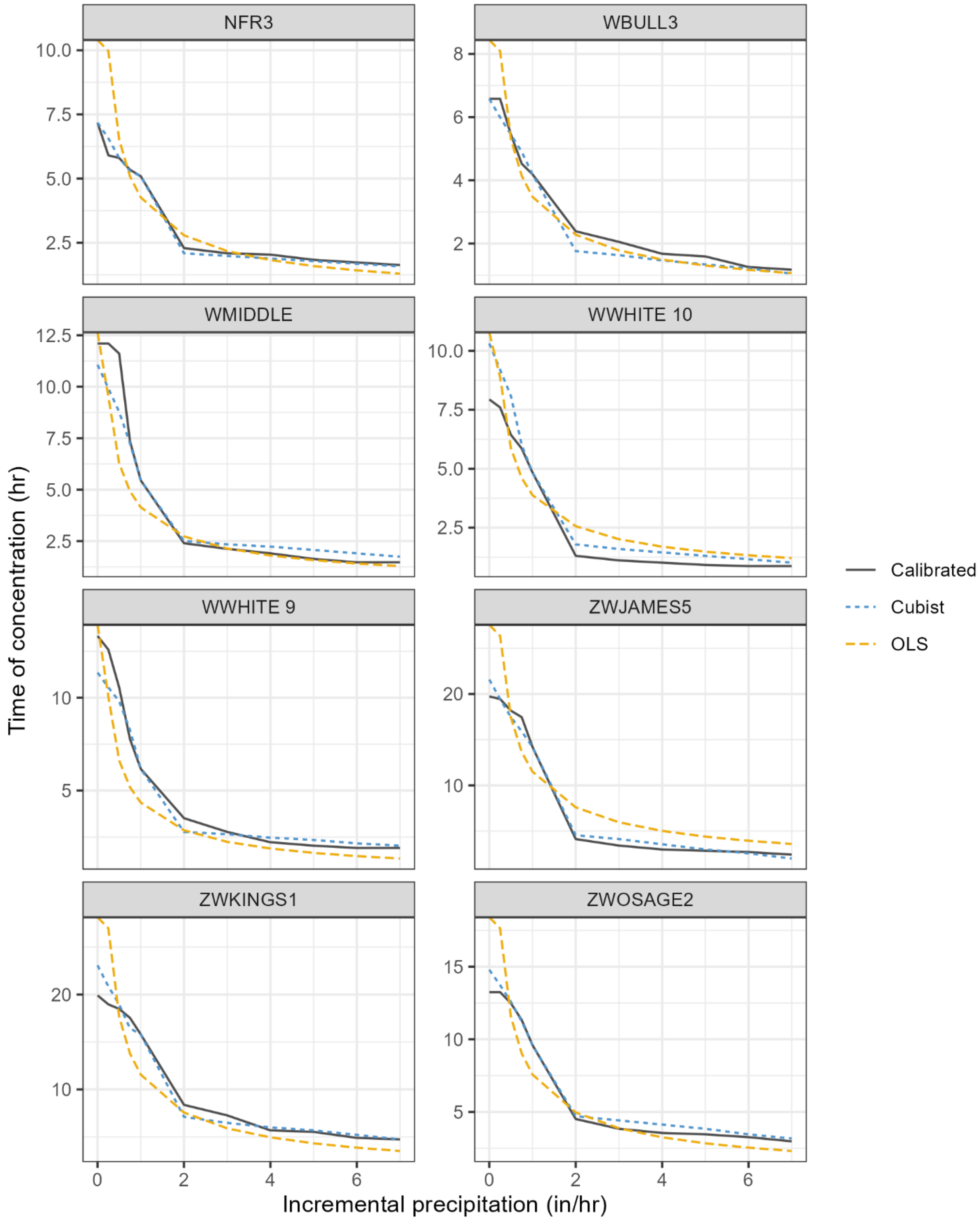


Figure 6-26. Plots showing results, in hours, for LOOCV for Tc

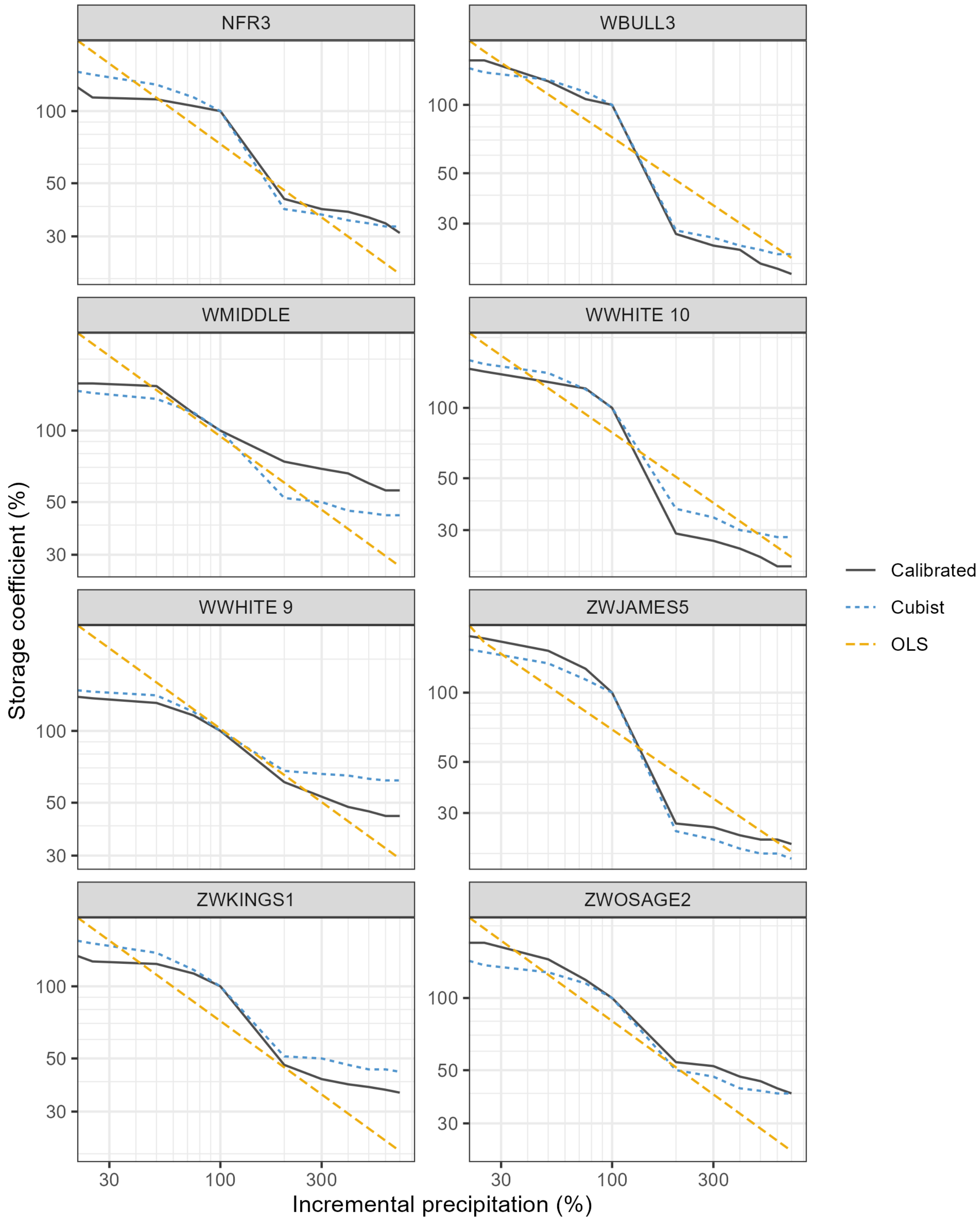


Figure 6-27. Plots showing results, in percentages, for LOOCV for R

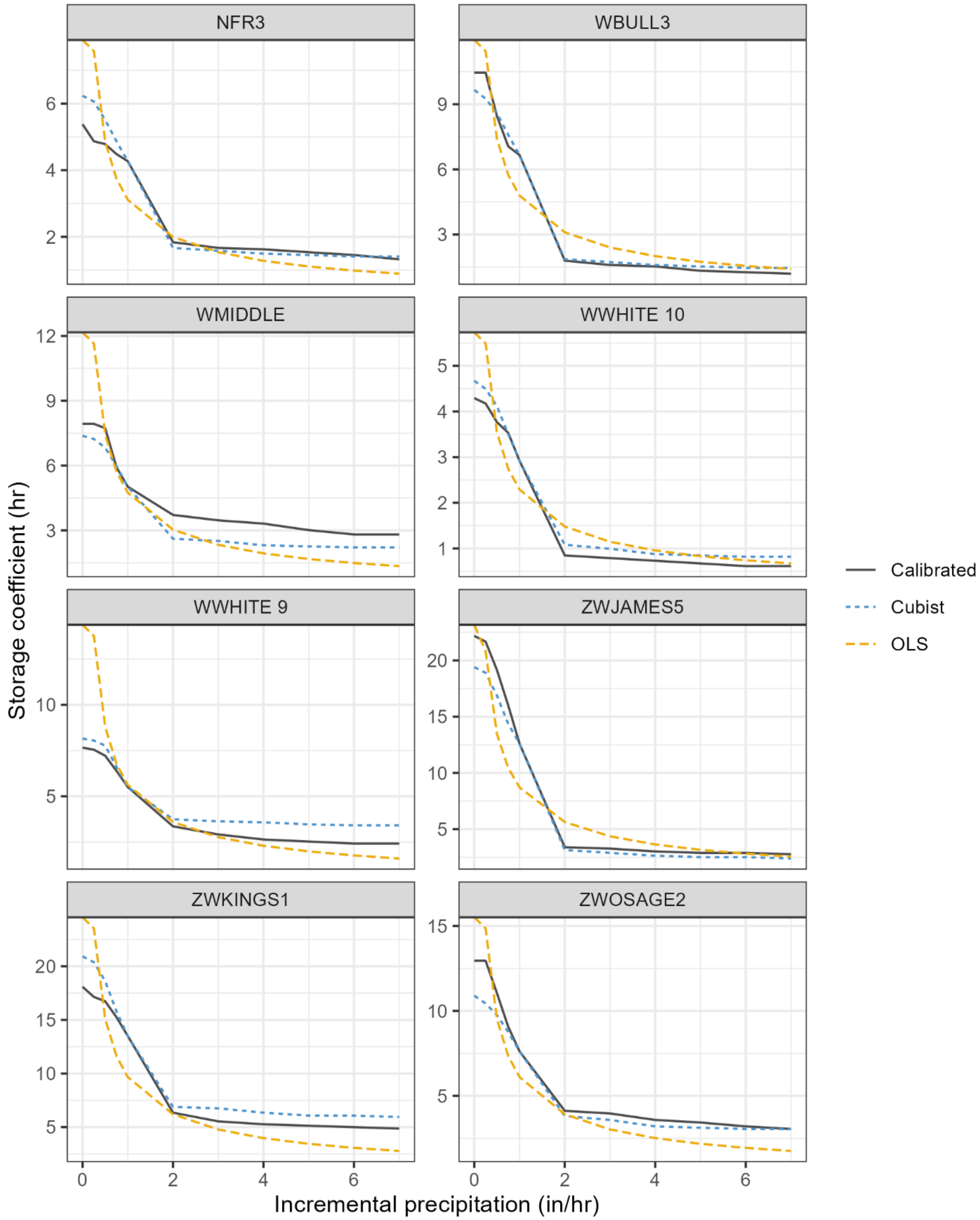


Figure 6-28. Plots showing results, in hours, for LOOCV for R

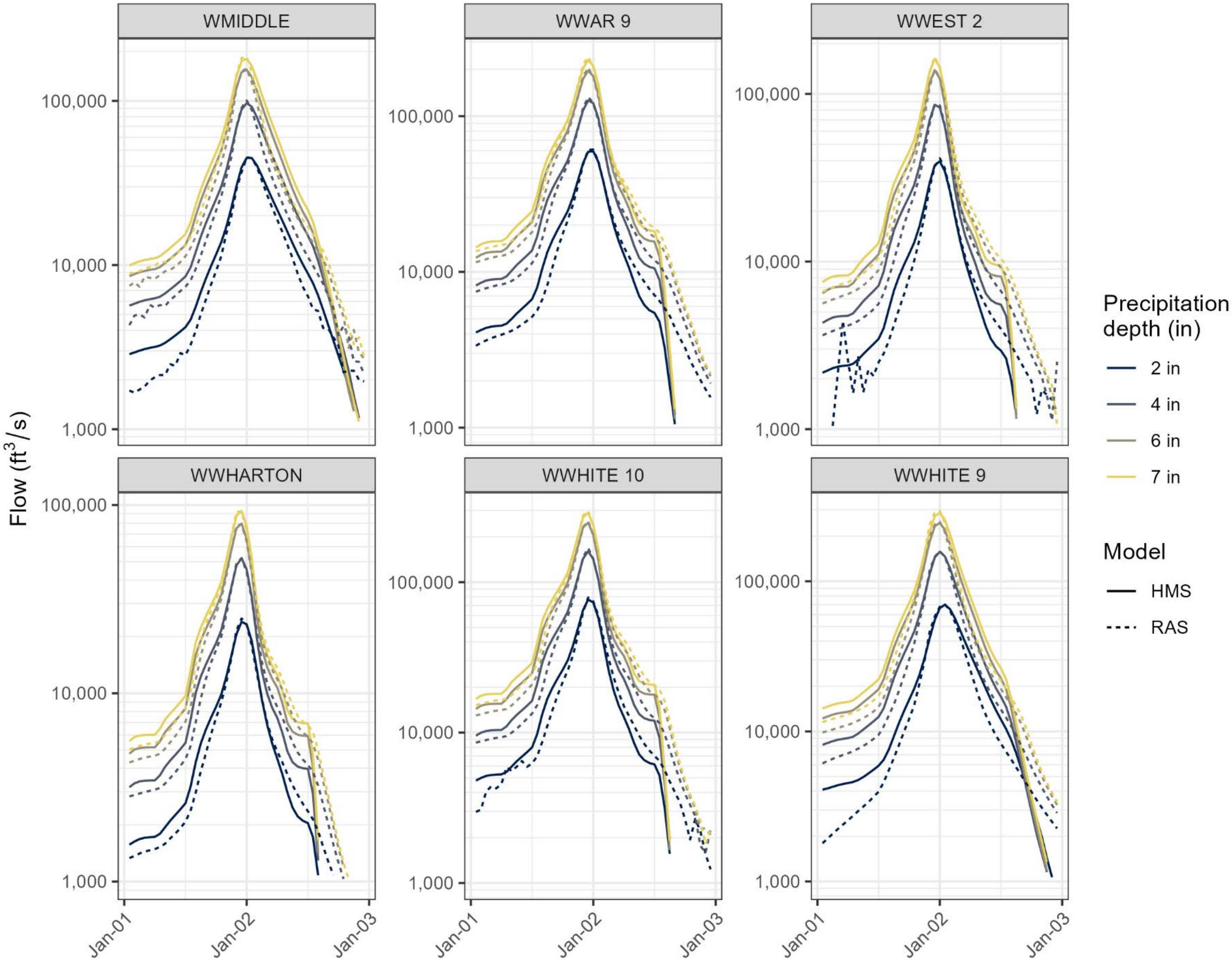


Figure 6-29. Plots showing HEC-RAS 2D and HEC-HMS calibration subbasins within Beaver Lake Watershed

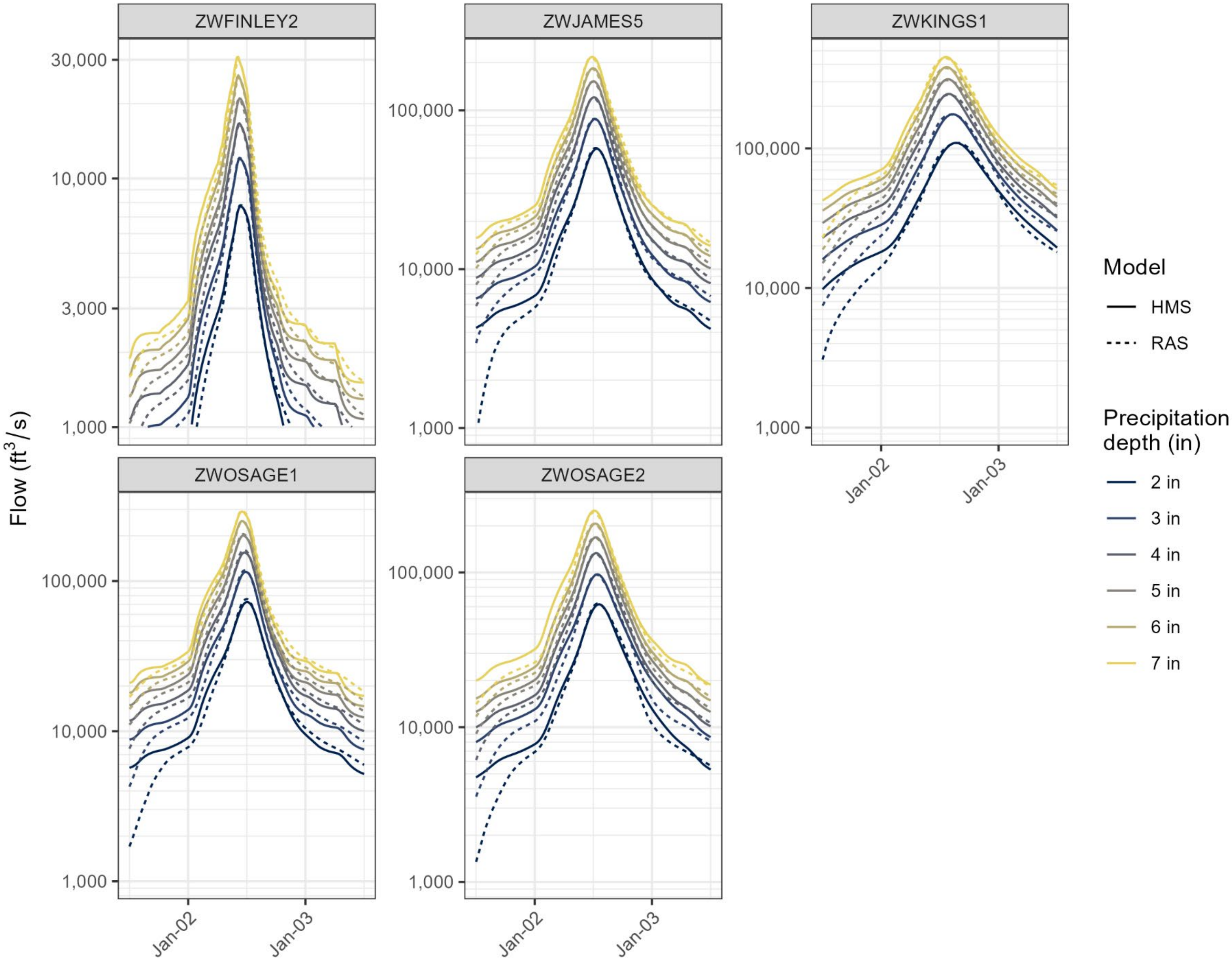


Figure 6-30. Plots showing HEC-RAS 2D and HEC-HMS calibration subbasins within Table Rock Lake Watershed

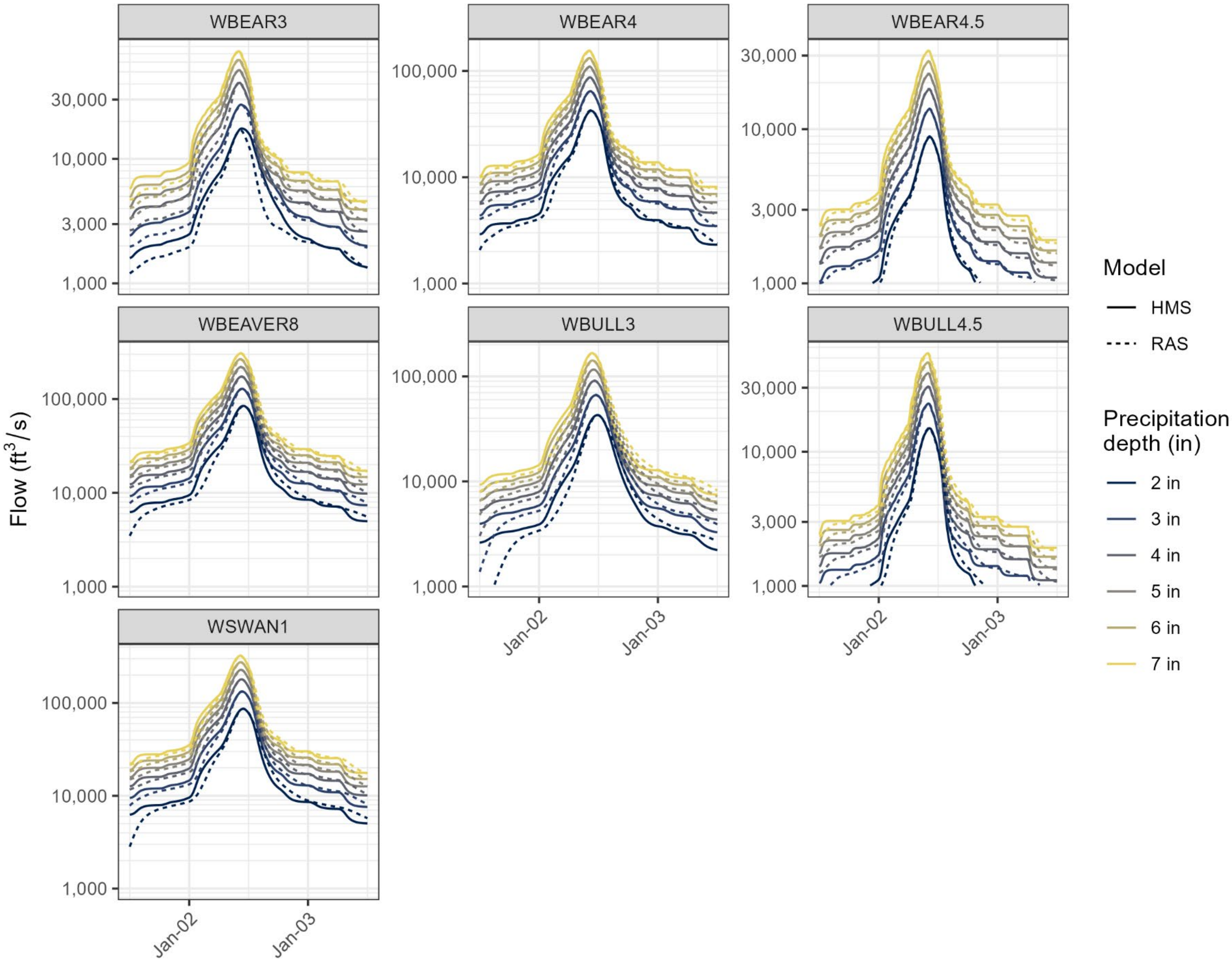


Figure 6-31. Plots showing HEC-RAS 2D and HEC-HMS calibration subbasins within Bull Shoals Lake Watershed

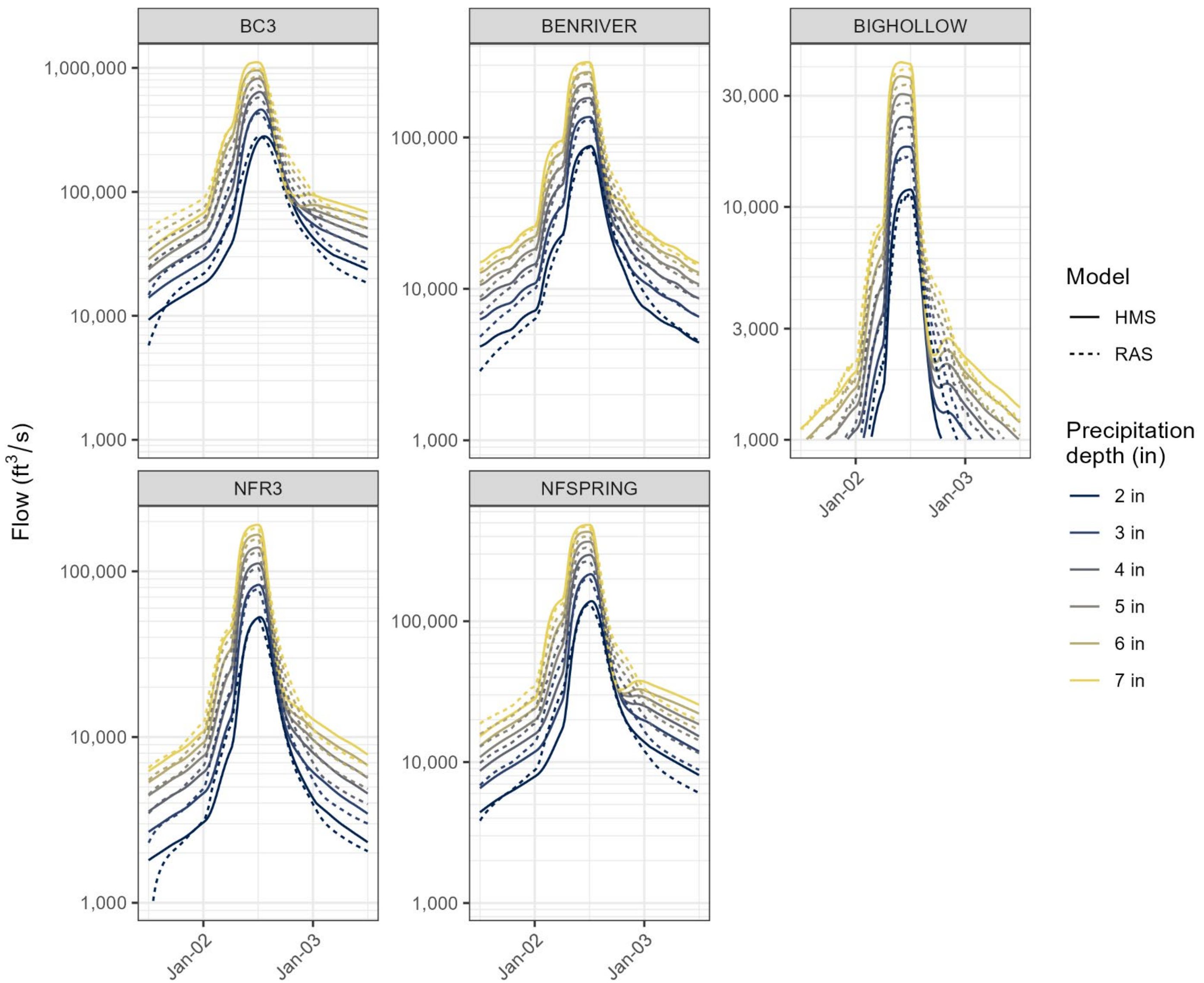


Figure 6-32. Plots showing HEC-RAS 2D and HEC-HMS calibration subbasins within Norfork Lake Watershed

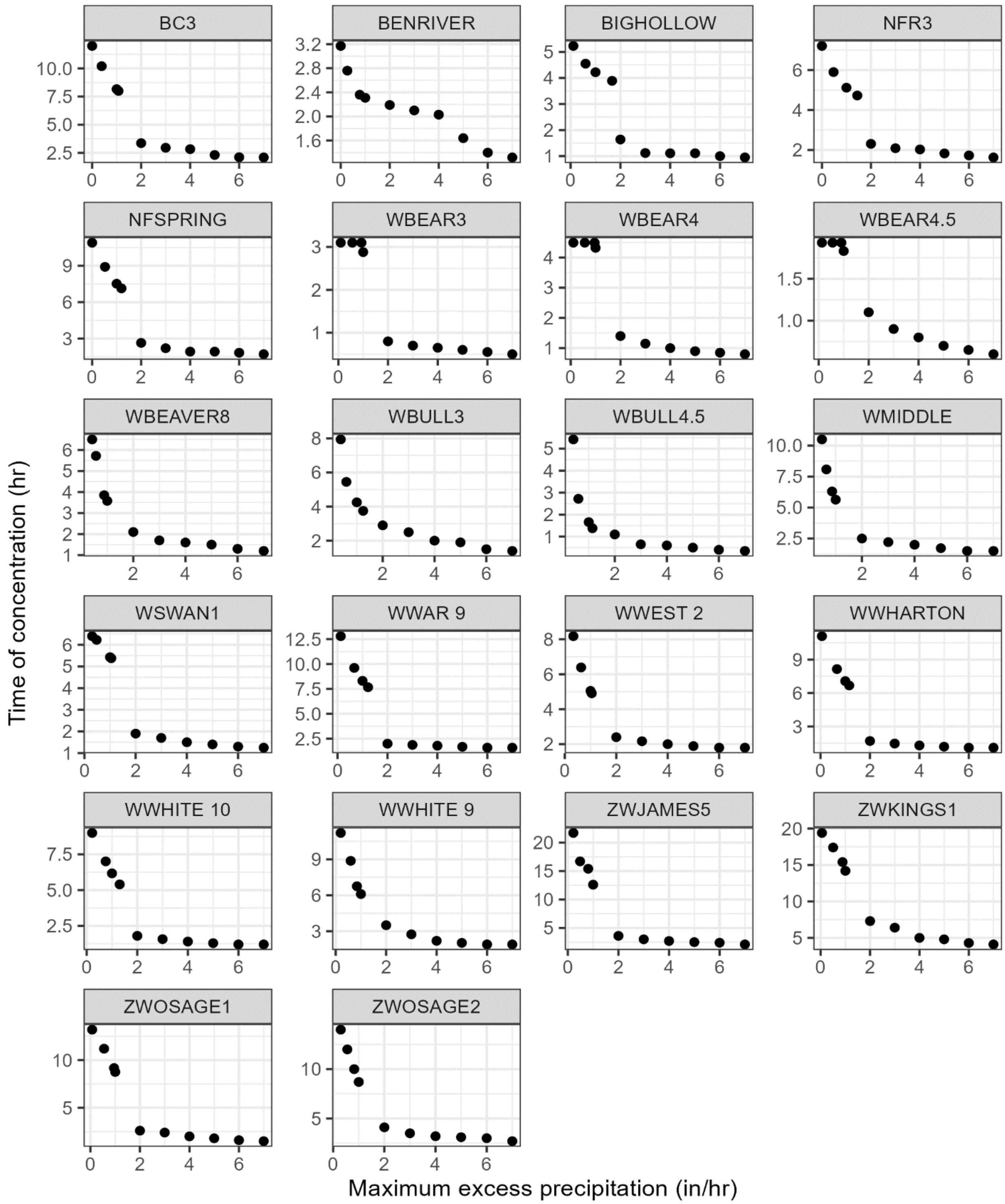


Figure 6-33 Plots showing Tc and maximum excess precipitation for subbasins used for creating Variable Clark curves

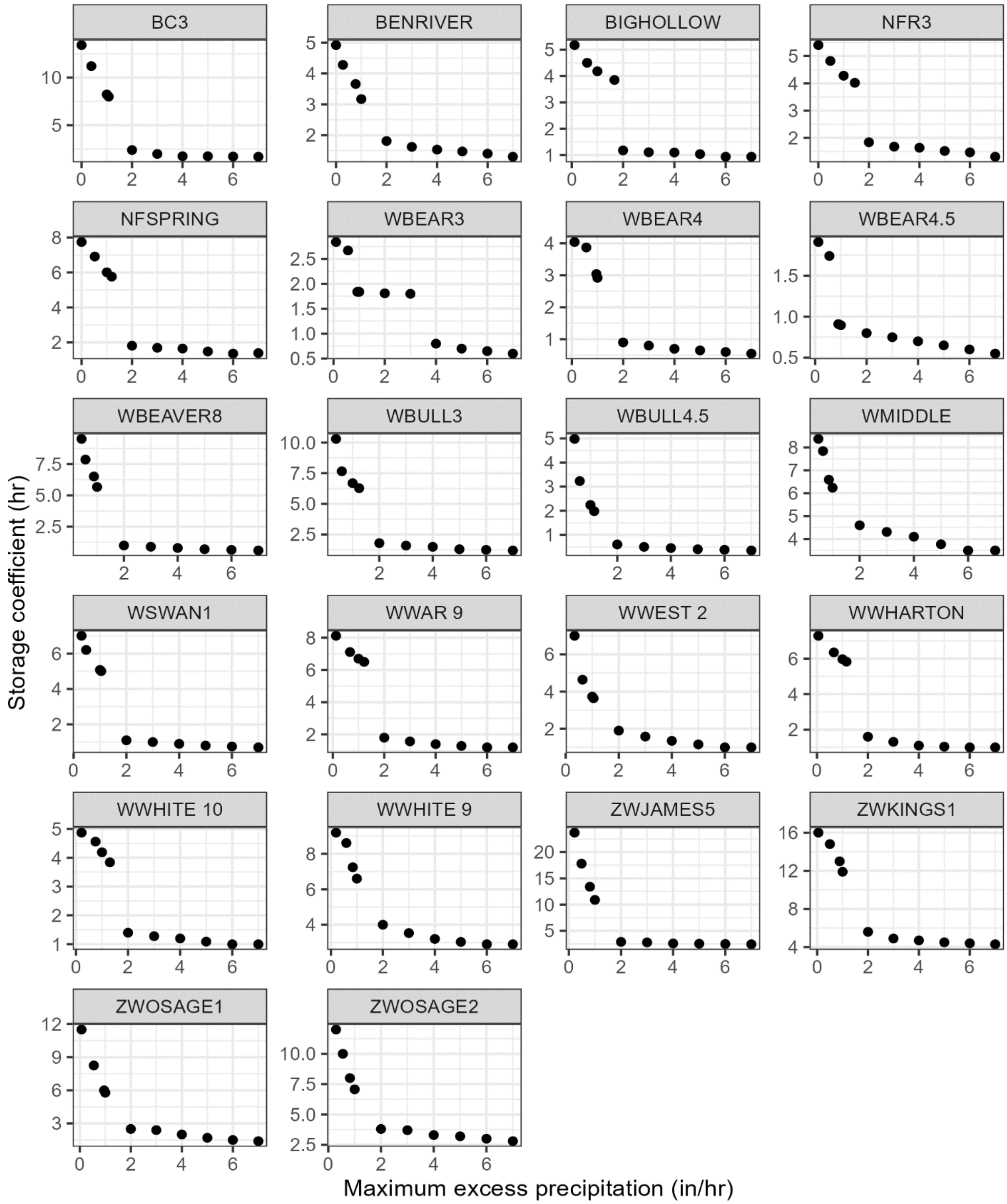


Figure 6-34. Plots showing R and maximum excess precipitation for subbasins used for creating Variable Clark curves

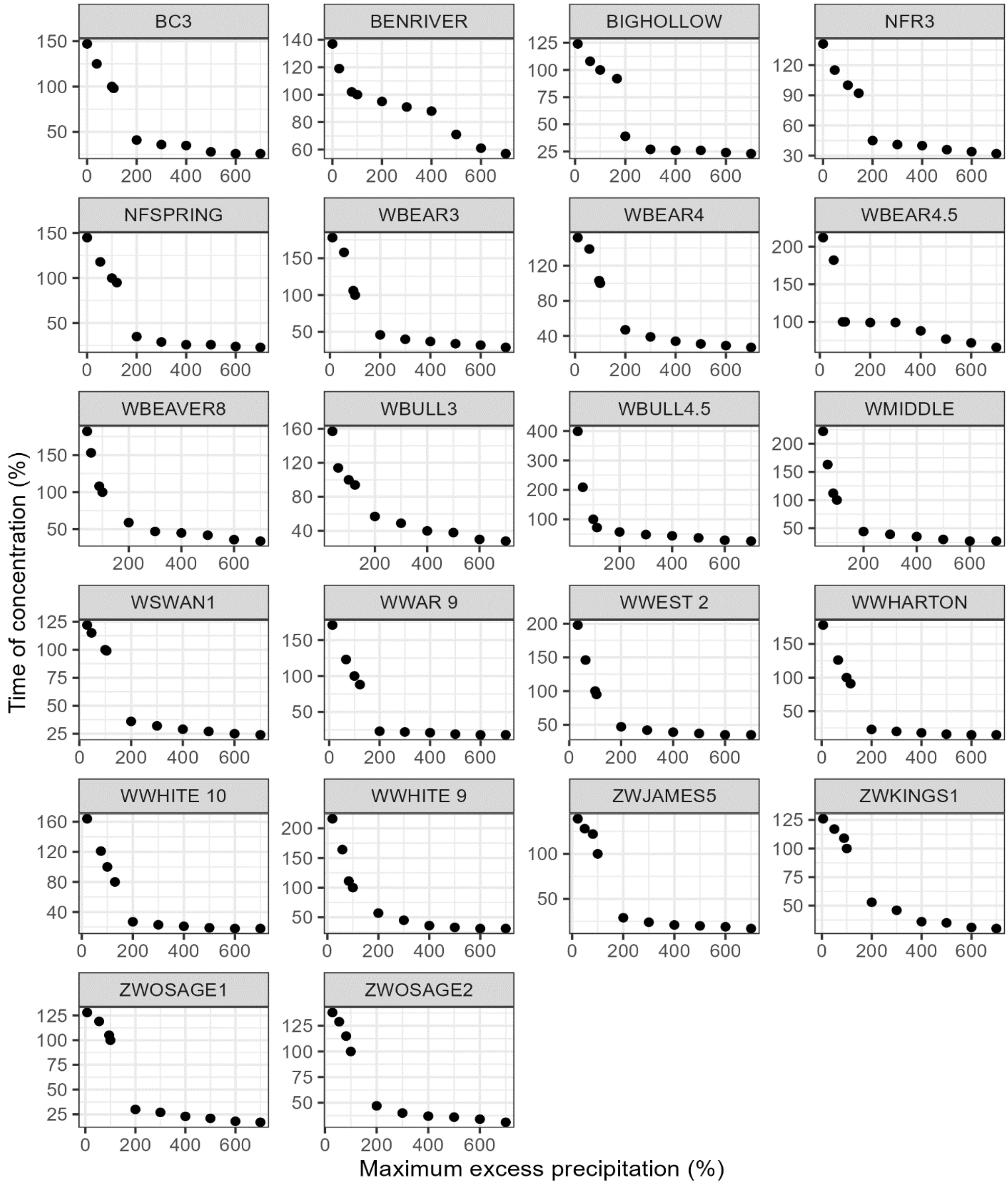


Figure 6-35. Plots showing Tc percentage and maximum excess precipitation percentage for subbasins used for creating Variable Clark curves

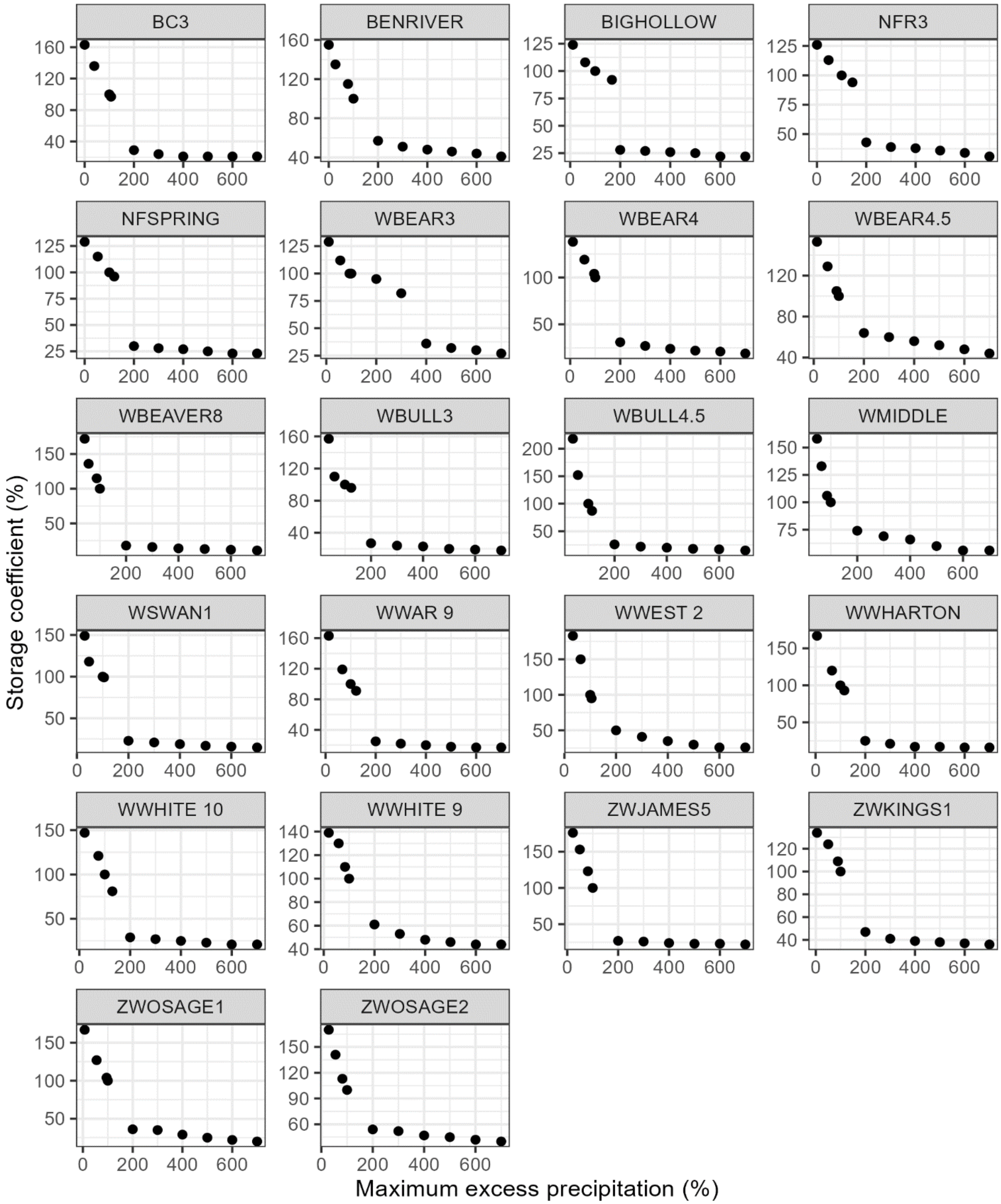


Figure 6-36. Plots showing R percentage and maximum excess precipitation percentage for subbasins used for creating Variable Clark curves.

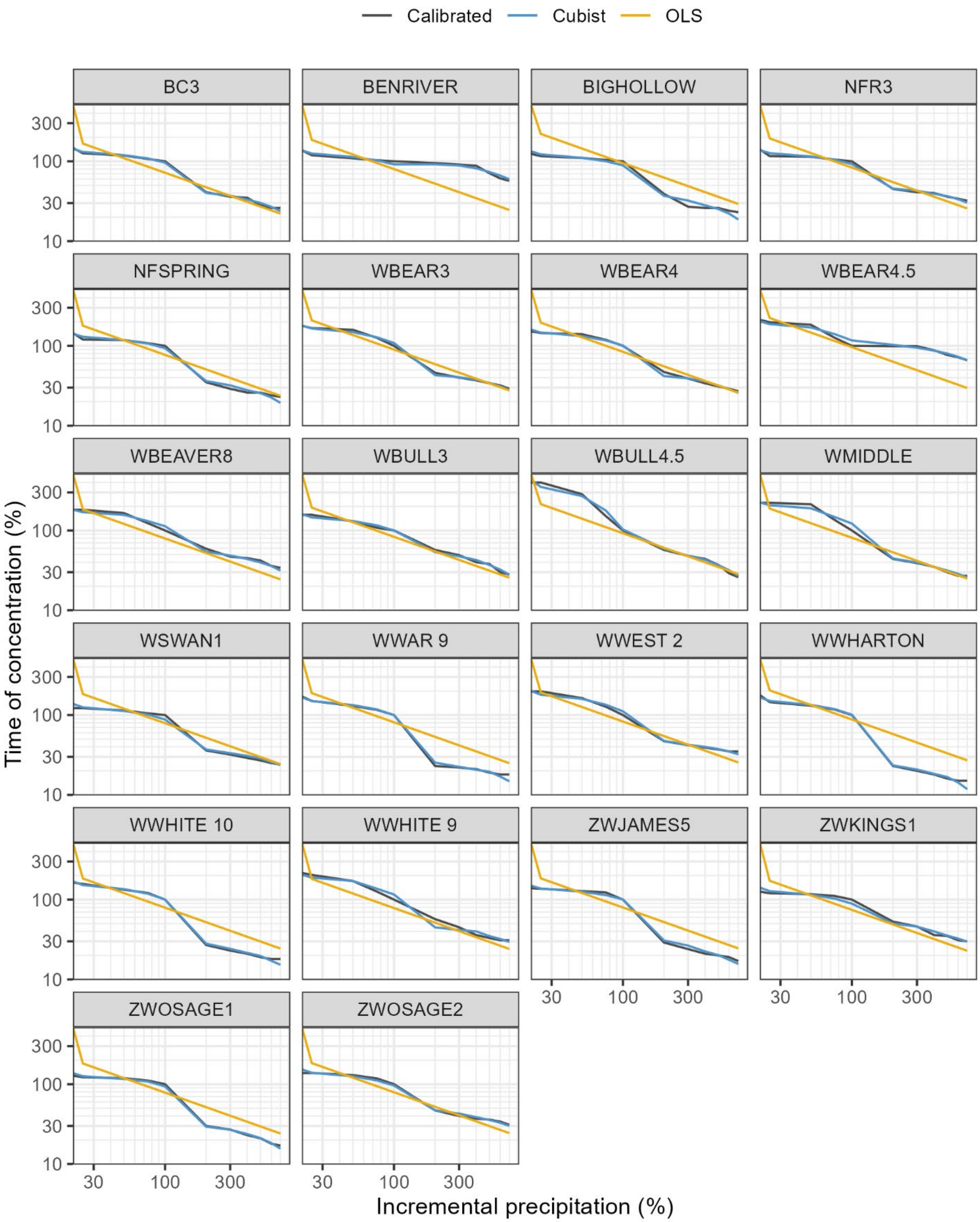


Figure 6-37. Plots showing calibrated Tc curves and predicted Tc curves from Cubist and from Ordinary Least Square (OLS) regression.

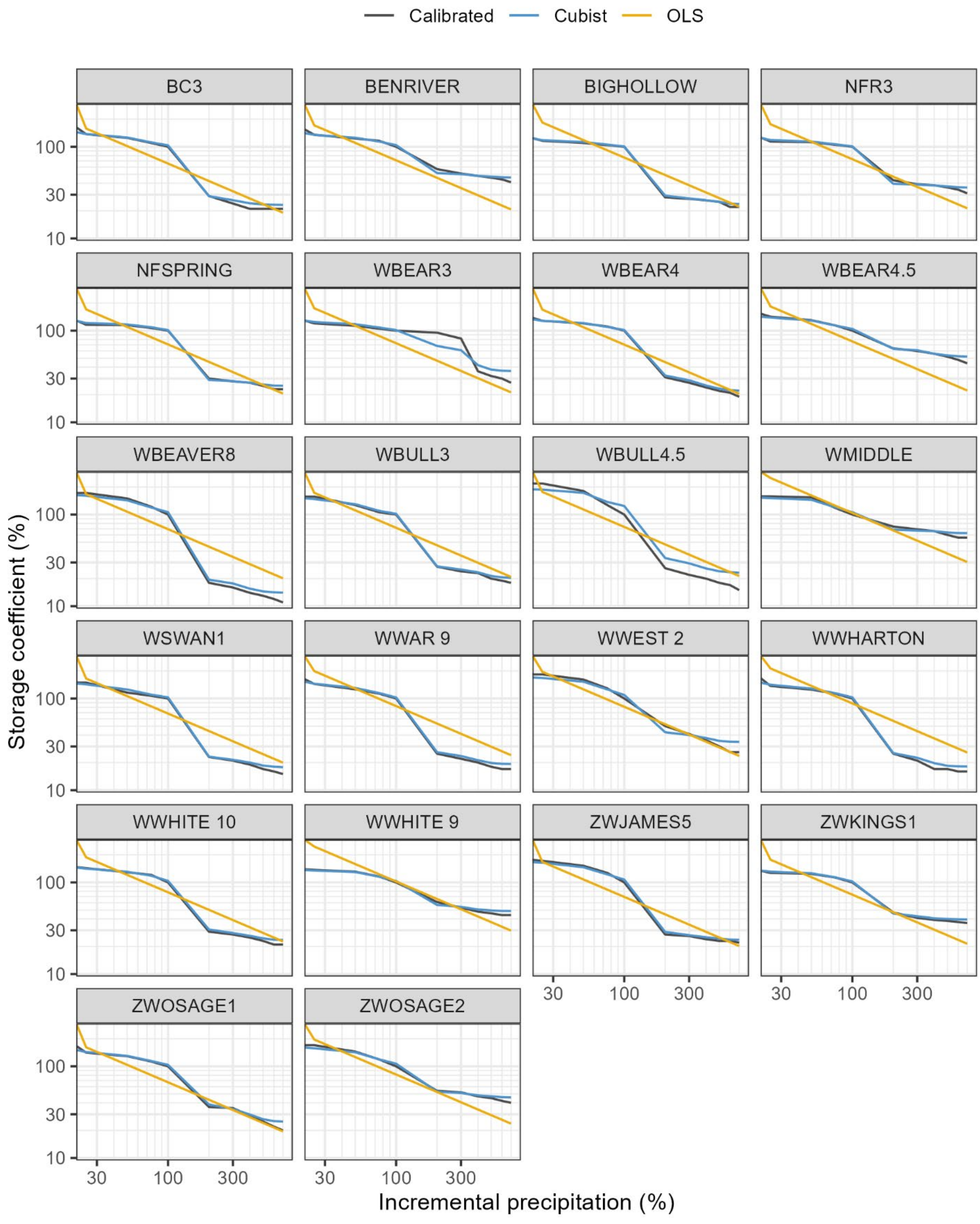


Figure 6-38. Plots showing calibrated R curves and predicted R curves from Cubist and from Ordinary Least Square (OLS) regression.

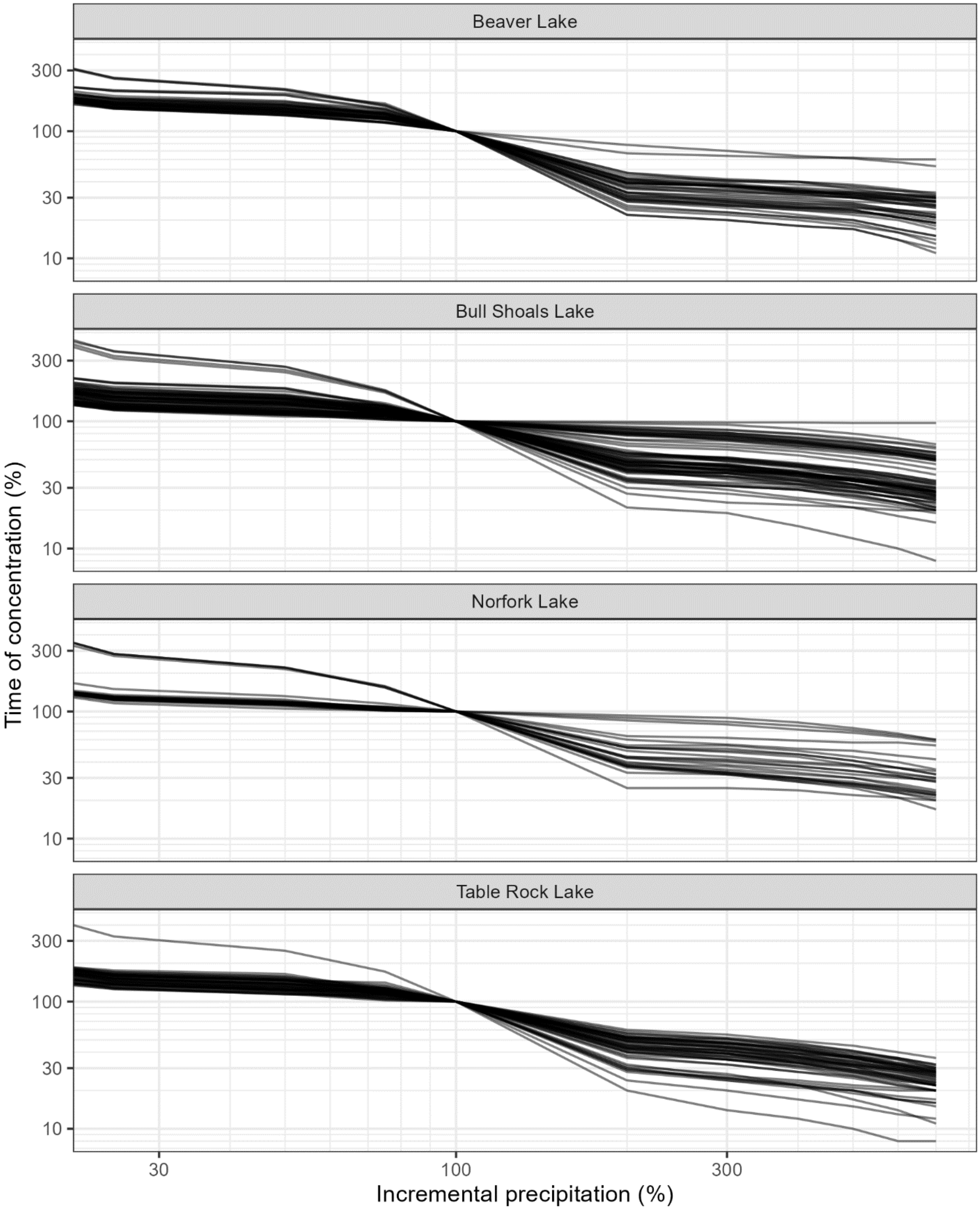


Figure 6-39. Plots showing variable Tc curves for selected HEC-HMS subbasins

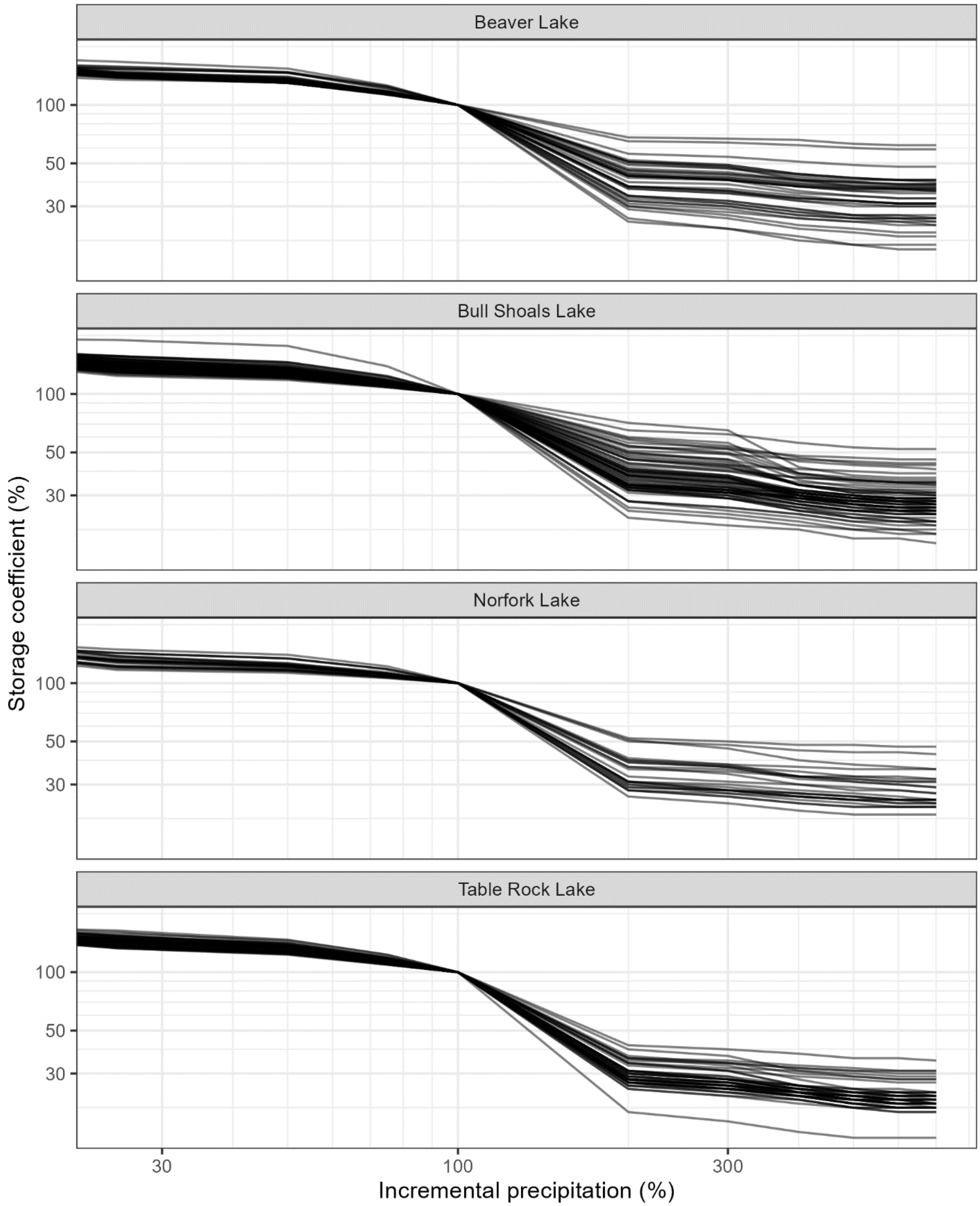


Figure 6-40. Plots showing variable R curves for selected HEC-HMS subbasins

6.4.3 Calibration Results

While most calibration and validation events showed good results, there were a few instances where modeled flows did not match observed flows well. For the 2017 event, JWAR 3 WAREANGLE HINDSVILLE appeared to have bad observed data. For the Dec 2015 event and the 2011 event, JWEST WESTFORK GAGE appeared to have bad gage data.

6.4.3.1 2017 Calibration Event (28Apr2017 to 02May2017)

The results for the calibration of the 2017 event are shown in Figure 6-41 through Figure 6-64.

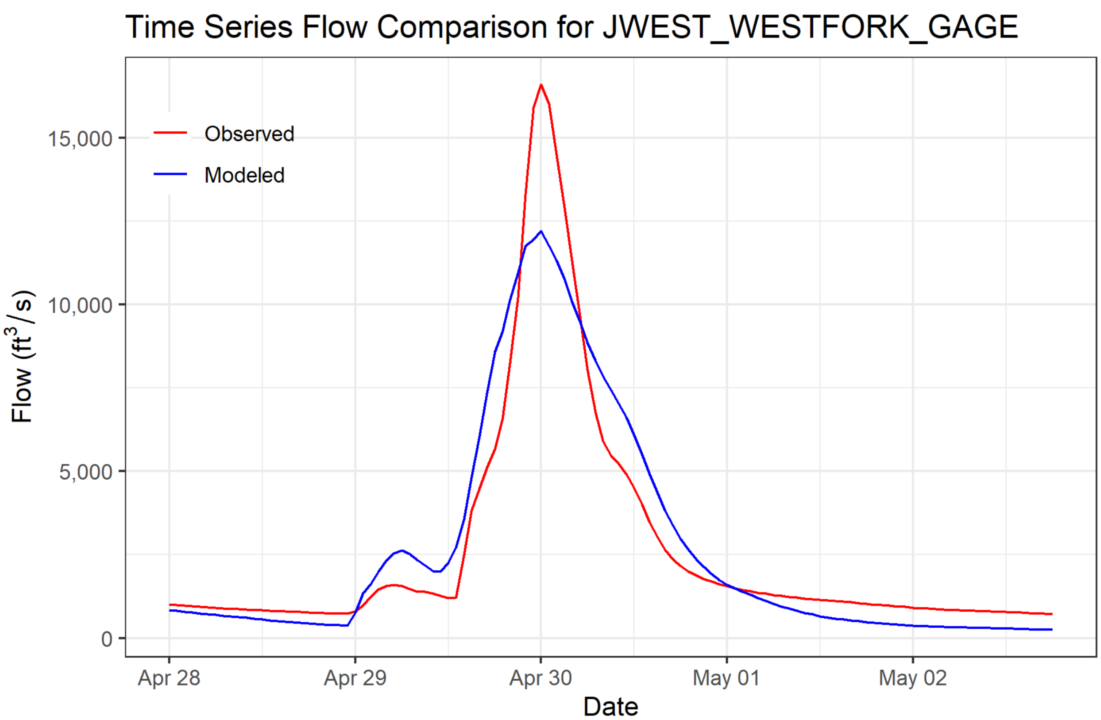


Figure 6-41. Calibration Results for JWEST_WESTFORK_GAGE HEC-HMS Junction – West Fork of White River east of Fayetteville, AR Gage (07048550, 2017 Event)

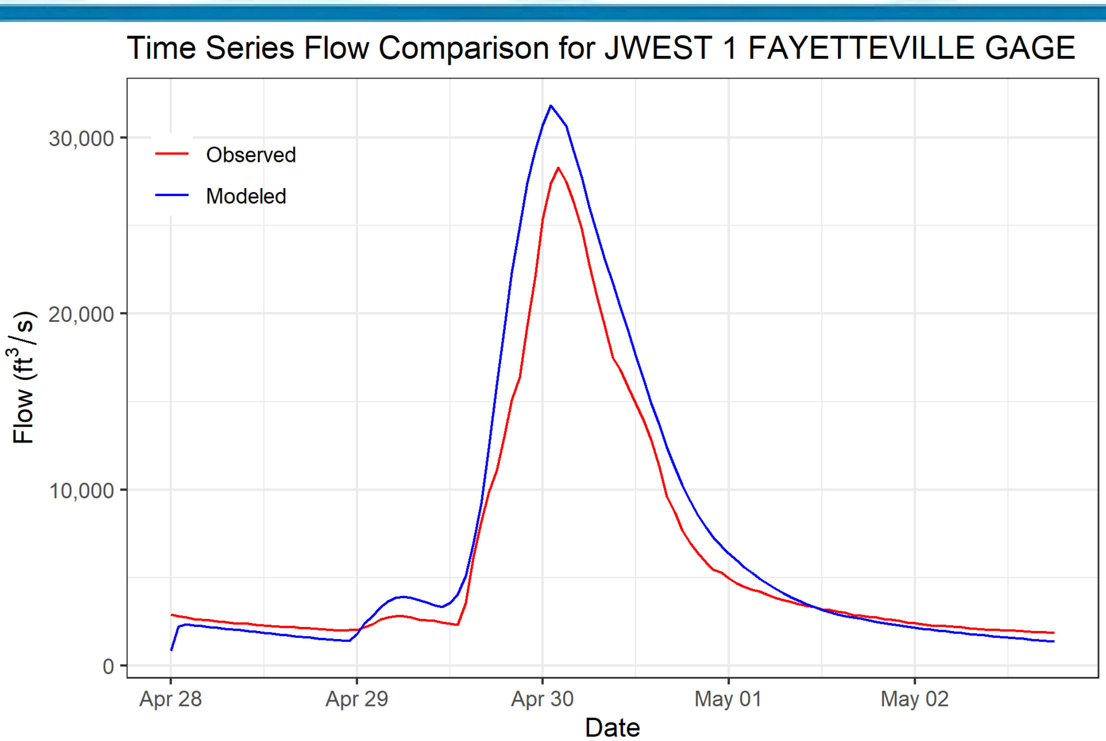


Figure 6-42. Calibration Results for JWEST 1 FAYETTEVILE GAGE HEC-HMS Junction – White River at Fayetteville, AR Gage (07048600, 2017 Event)

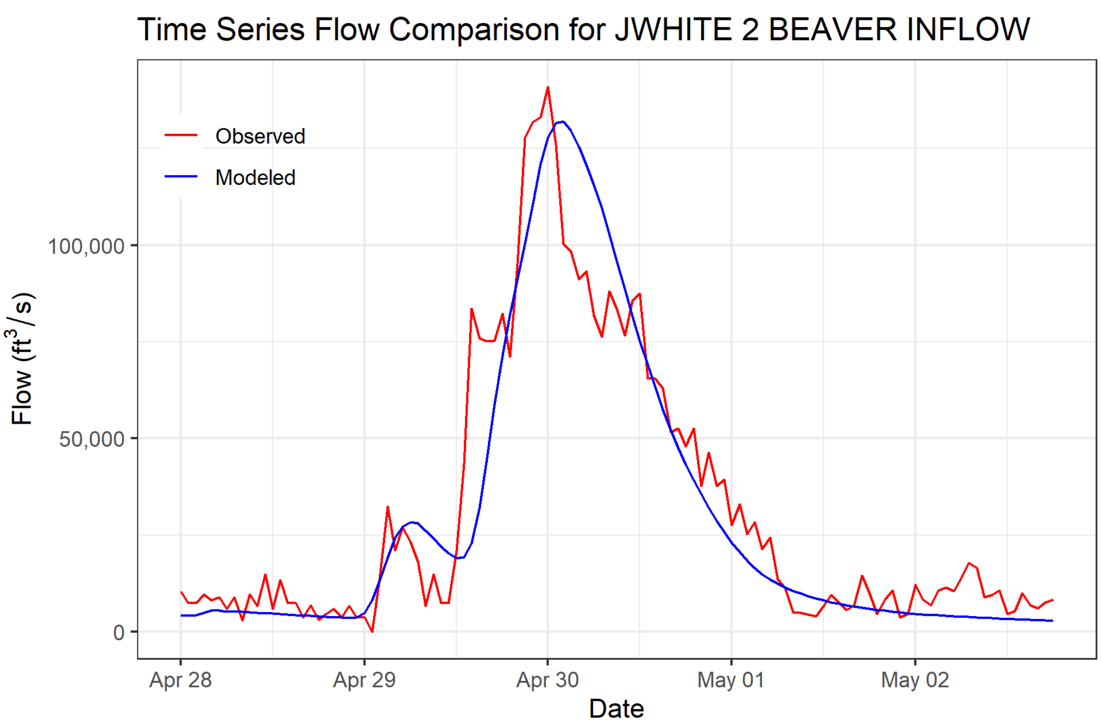


Figure 6-43. Calibration Results for JWHITE 2 BEAVER INFLOW HEC-HMS Junction – Inflow to Beaver Lake (2017 Event)

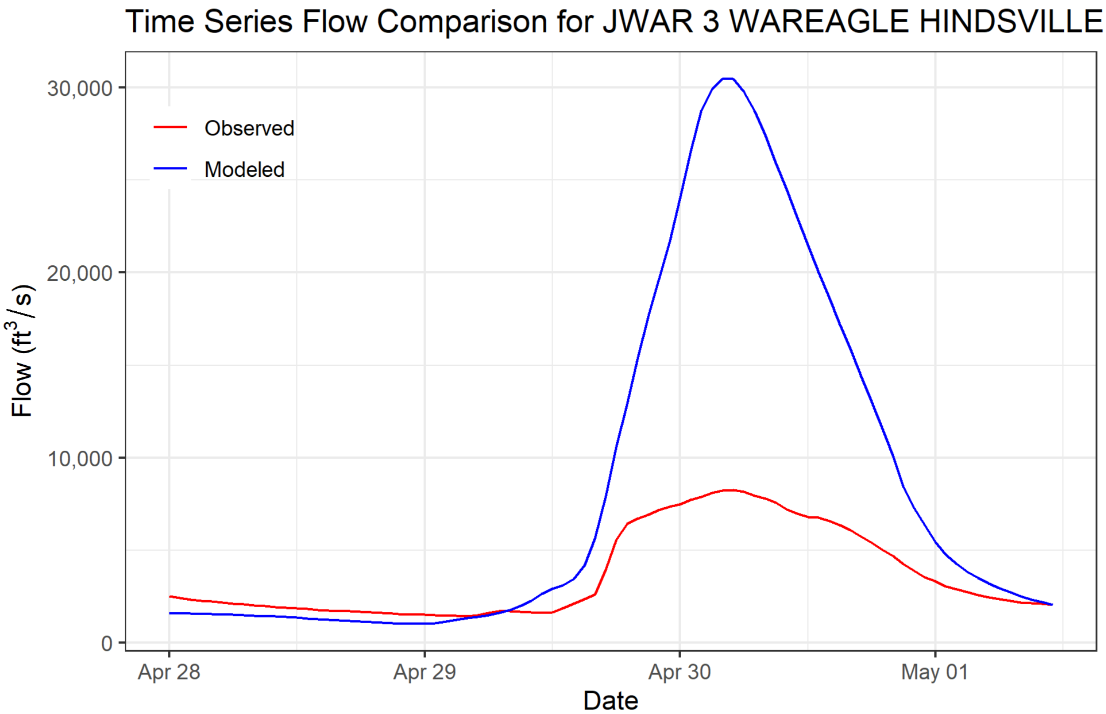


Figure 6-44. Calibration Results for JWAR 3 WAREAGLE HINDSVILLE HEC-HMS Junction – War Eagle Creek near Hindsville, AR Gage (07049000, 2017 Event)

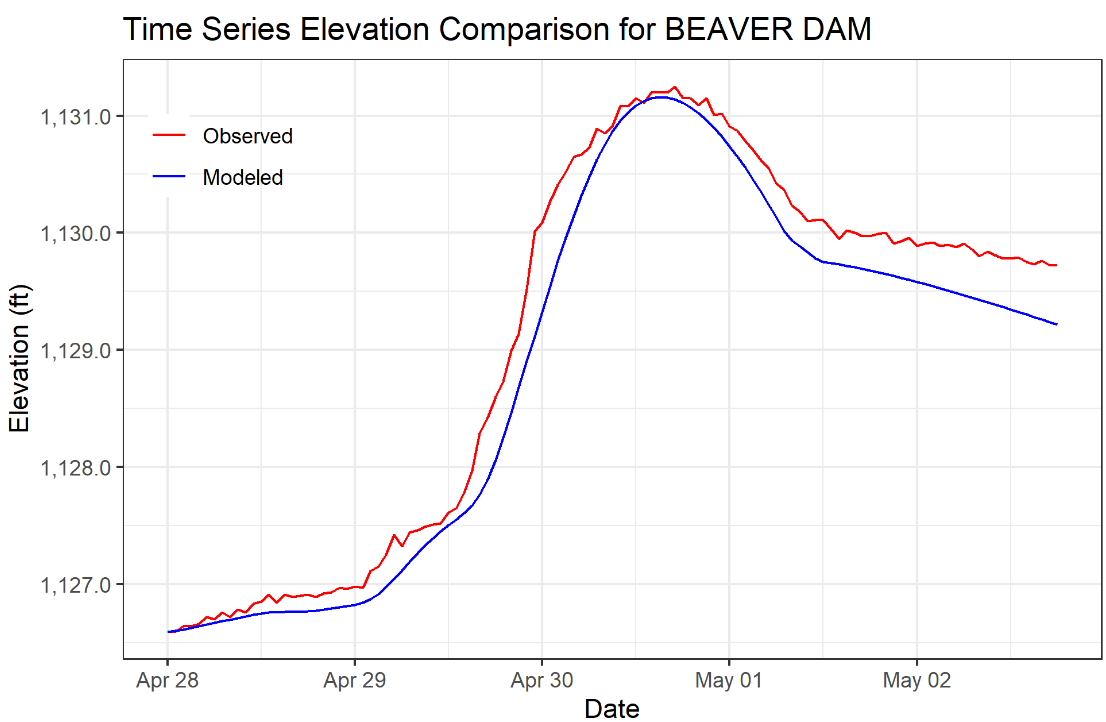


Figure 6-45. Calibration Results for BEAVER DAM HEC-HMS Junction – Elevation at Beaver Dam (2017 Event)

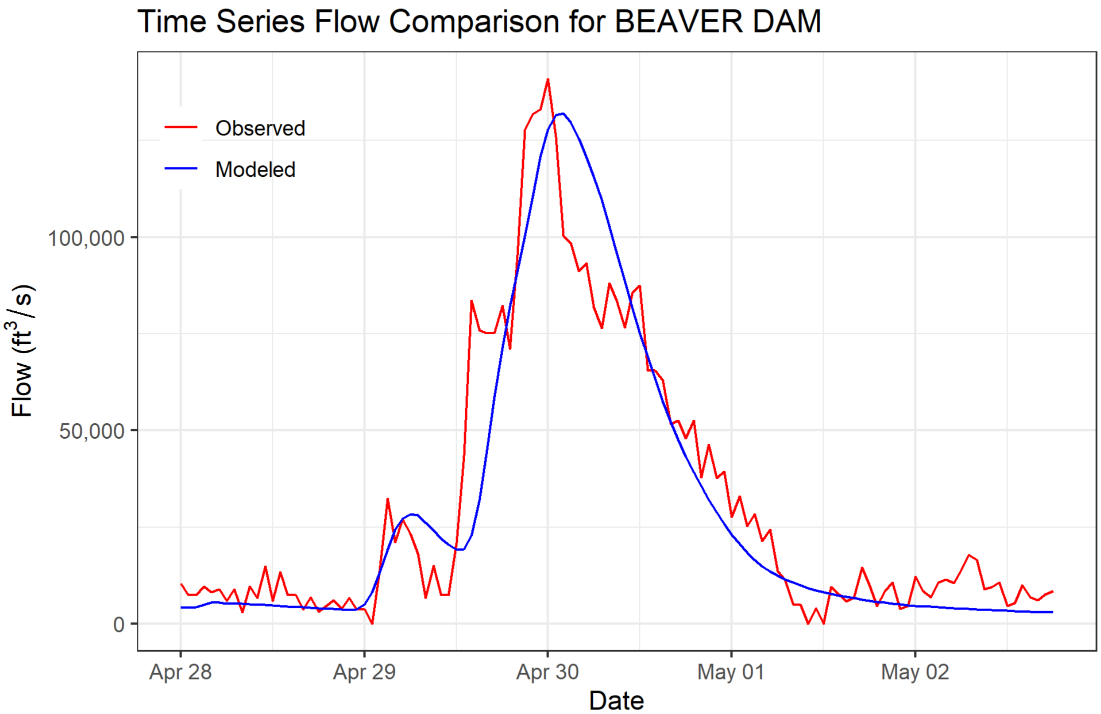


Figure 6-46. Calibration Results for BEAVER DAM HEC-HMS Junction – Flow at Beaver Dam (2017 Event)

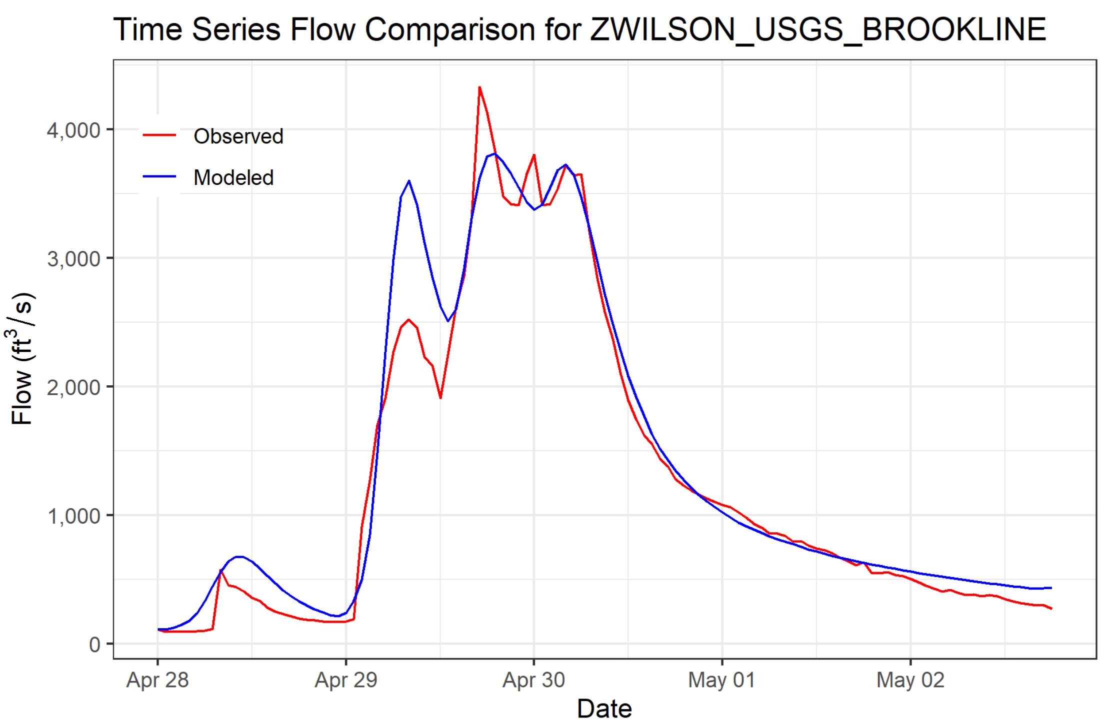


Figure 6-47. Calibration Results for ZWILSON_USGS_BROOKLINE HEC-HMS Junction – Wilson Creek near Brookline, MO Gage (07052152, 2017 Event)

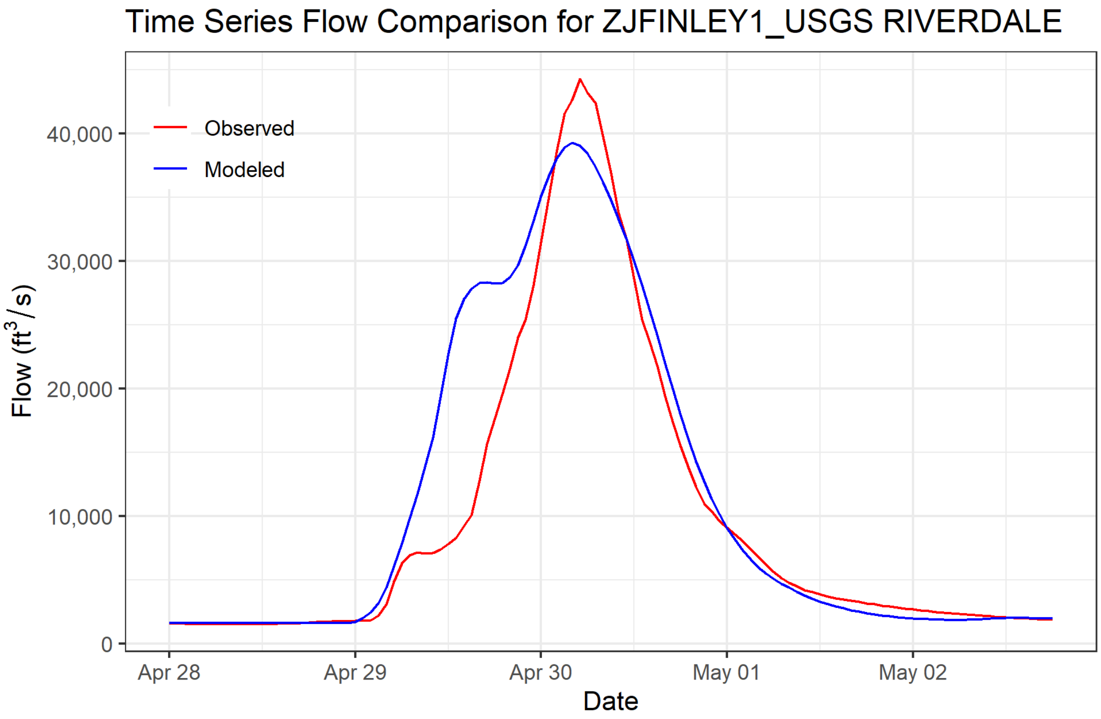


Figure 6-48. Calibration Results for ZJFINLEY1_USGS RIVERDALE HEC-HMS Junction – Finley Creek below Riverdale, MO Gage (07052345, 2017 Event)

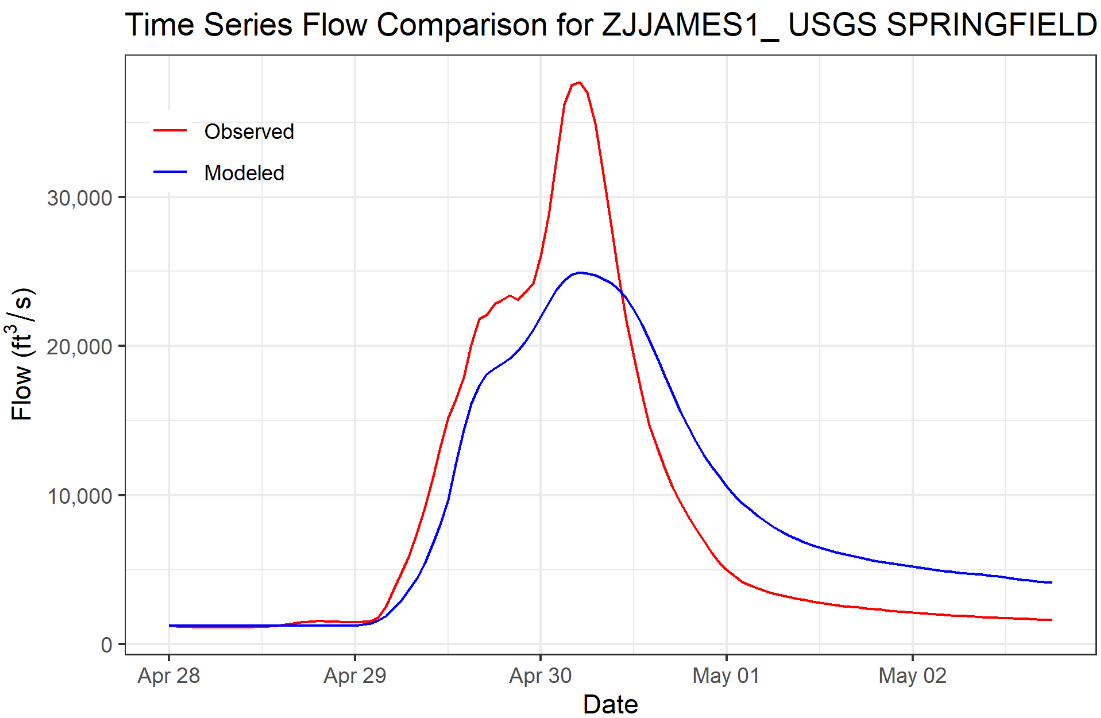


Figure 6-49. Calibration Results for ZJAMES1_USGS SPRINGFIELD HEC-HMS Junction – James River near Springfield, MO Gage (07050700, 2017 Event)

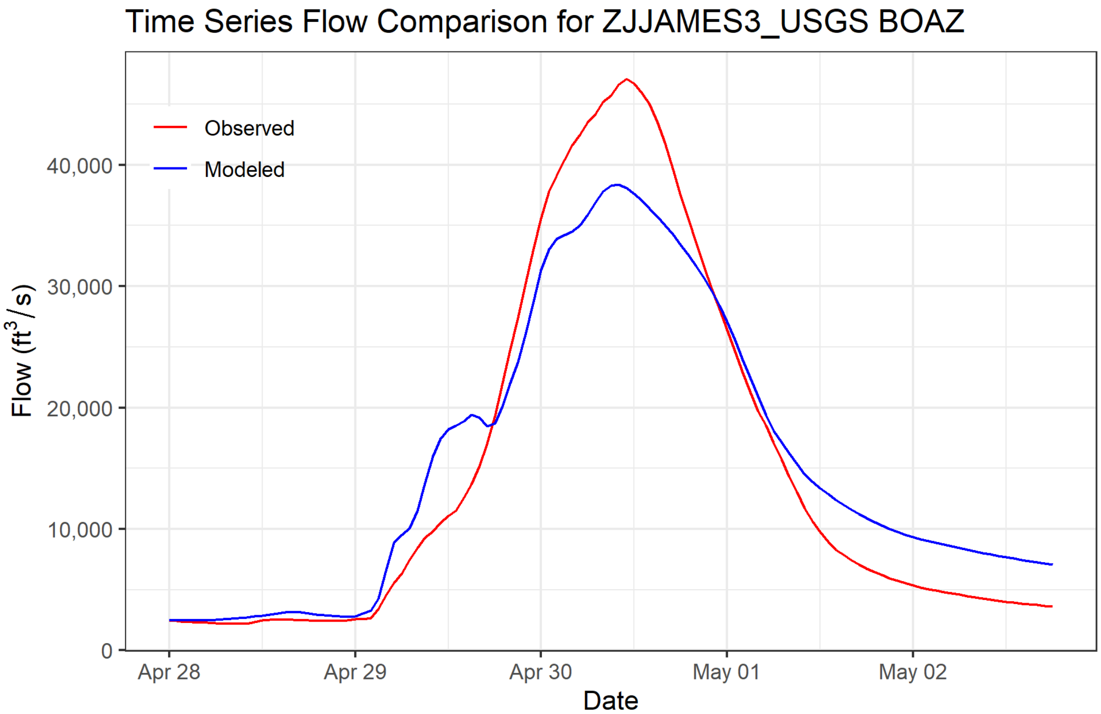


Figure 6-50. Calibration Results for ZJAMES3_USGS BOAZ HEC-HMS Junction – James River near Boaz, MO Gage (07052250, 2017 Event)

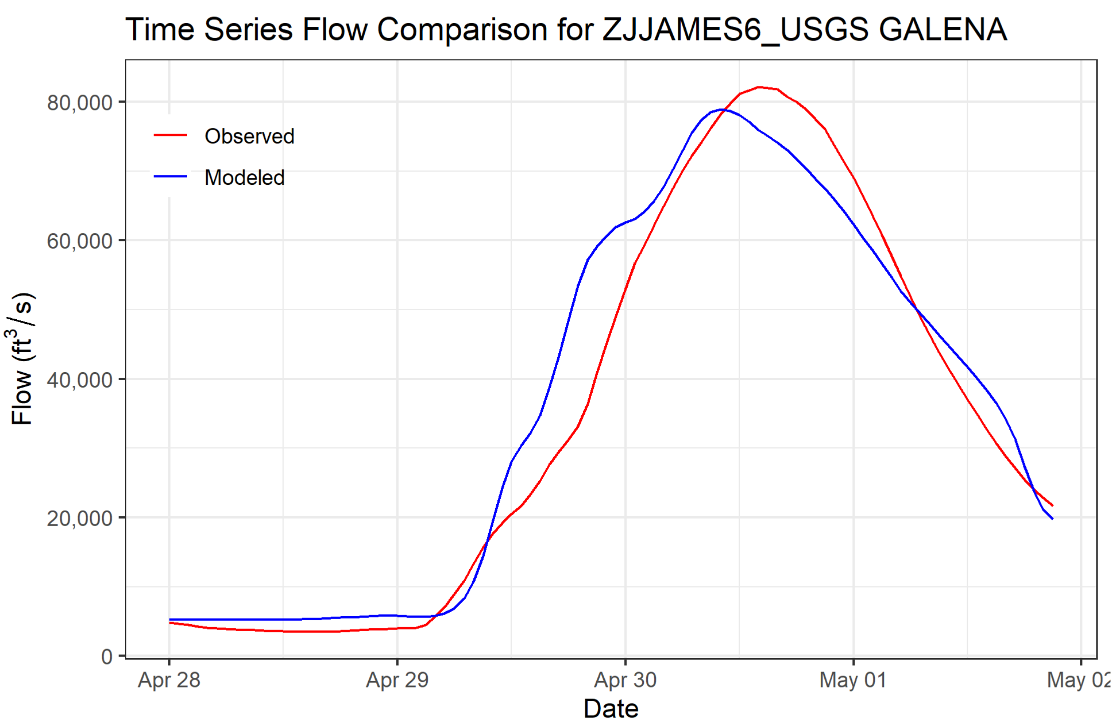


Figure 6-51. Calibration Results for ZJAMES6_USGS GALENA HEC-HMS Junction – James River at Galena, MO Gage (07052500, 2017 Event)

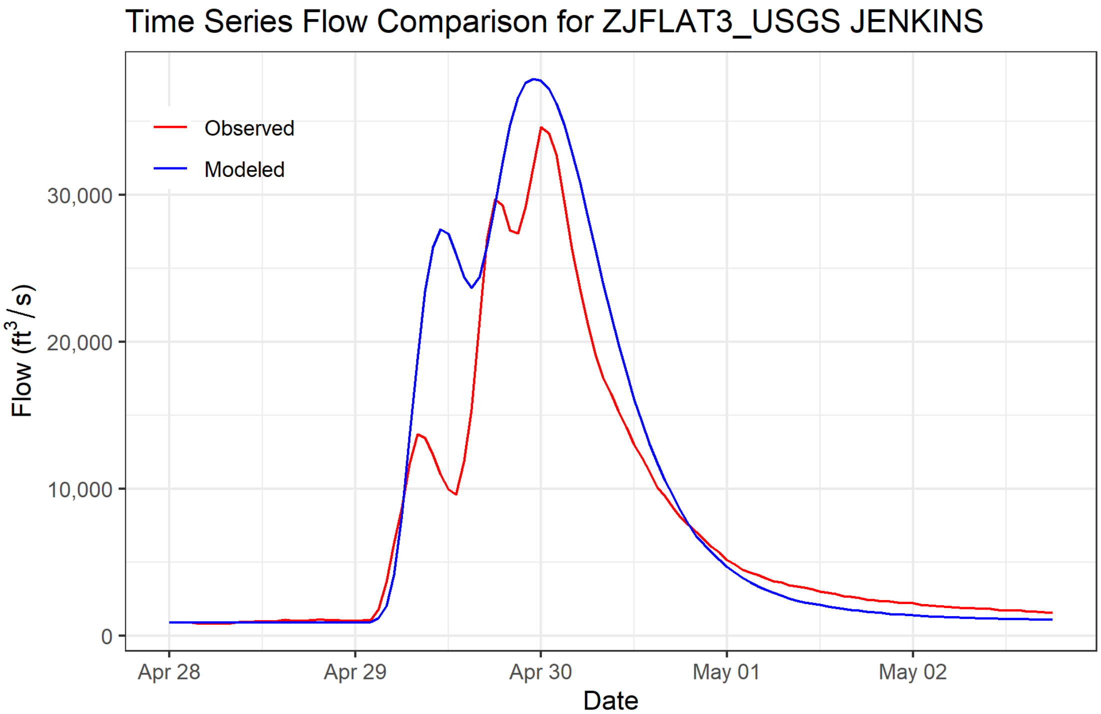


Figure 6-52. Calibration Results for ZJFLAT3_USGS JENKINS HEC-HMS Junction – Flat Creek below Jenkins, MO Gage (07052820, 2017 Event)

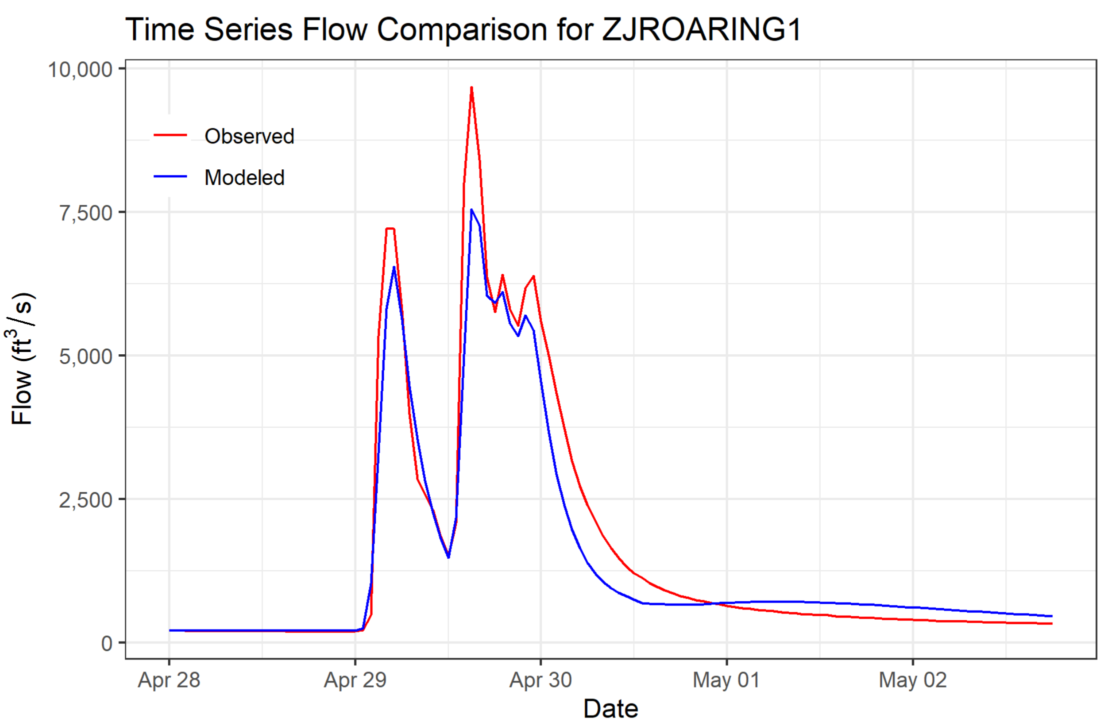


Figure 6-53. Calibration Results for ZJROARING1 HEC-HMS Junction – Roaring River at Roaring River State Park Gage (07050152, 2017 Event)

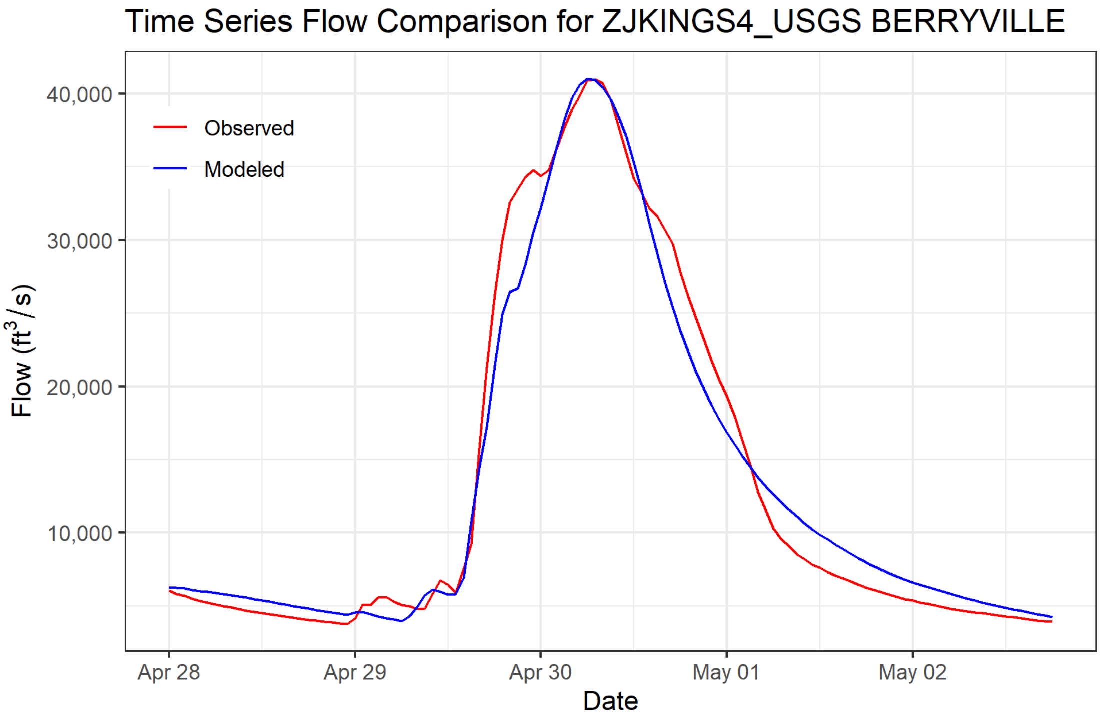


Figure 6-54. Calibration Results for ZJKINGS4_USGS BERRYVILLE HEC-HMS Junction – Kings River near Berryville, AR Gage (07050500, 2017 Event)

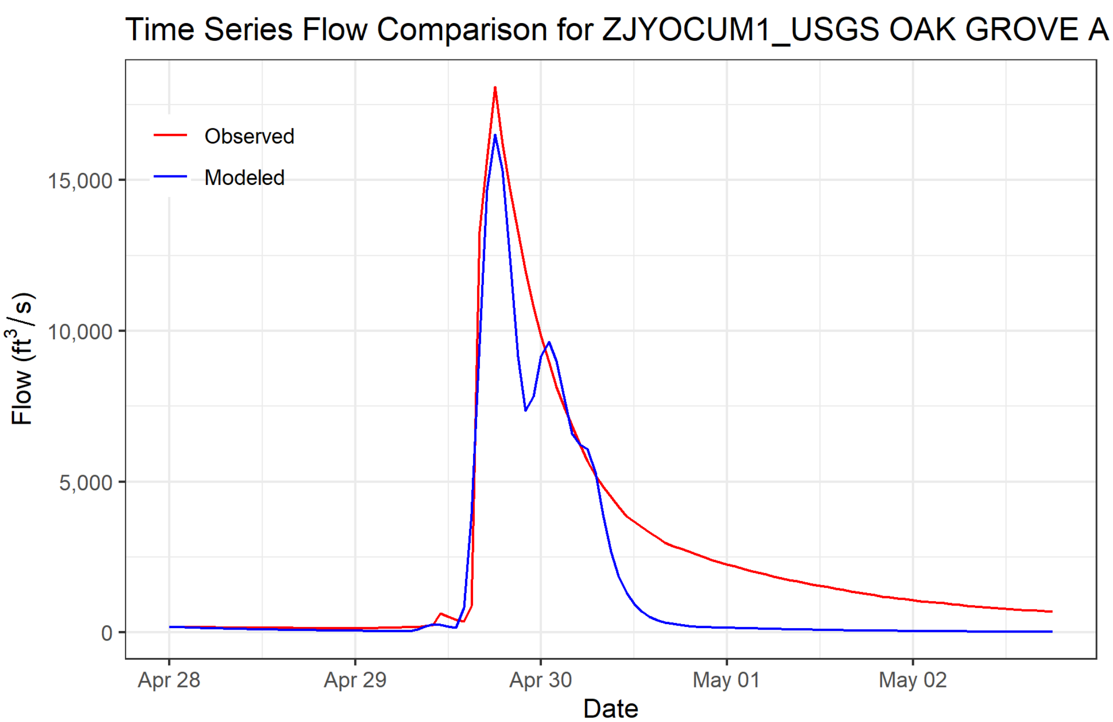


Figure 6-55. Calibration Results for ZJYOCUM1_USGS OAK GROVE AR HEC-HMS Junction – Yocum Creek near Oak Grove, AR Gage (07053250, 2017 Event)

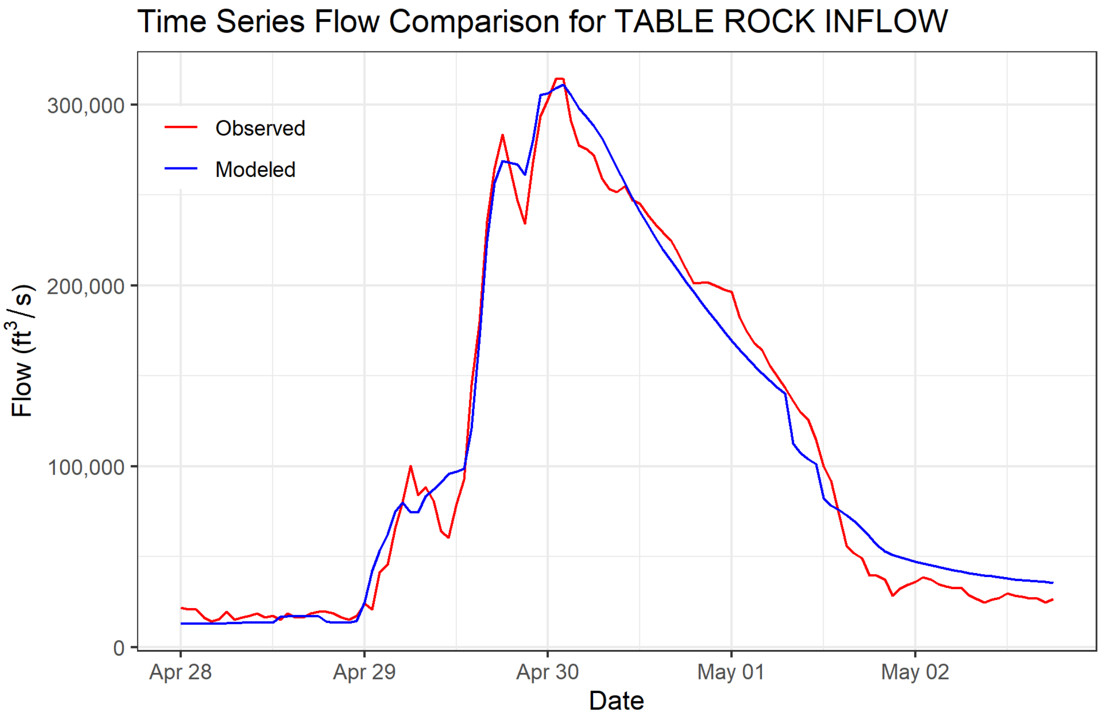


Figure 6-56. Calibration Results for TABLE ROCK INFLOW HEC-HMS Junction – Inflow to Table Rock Lake (2017 Event)

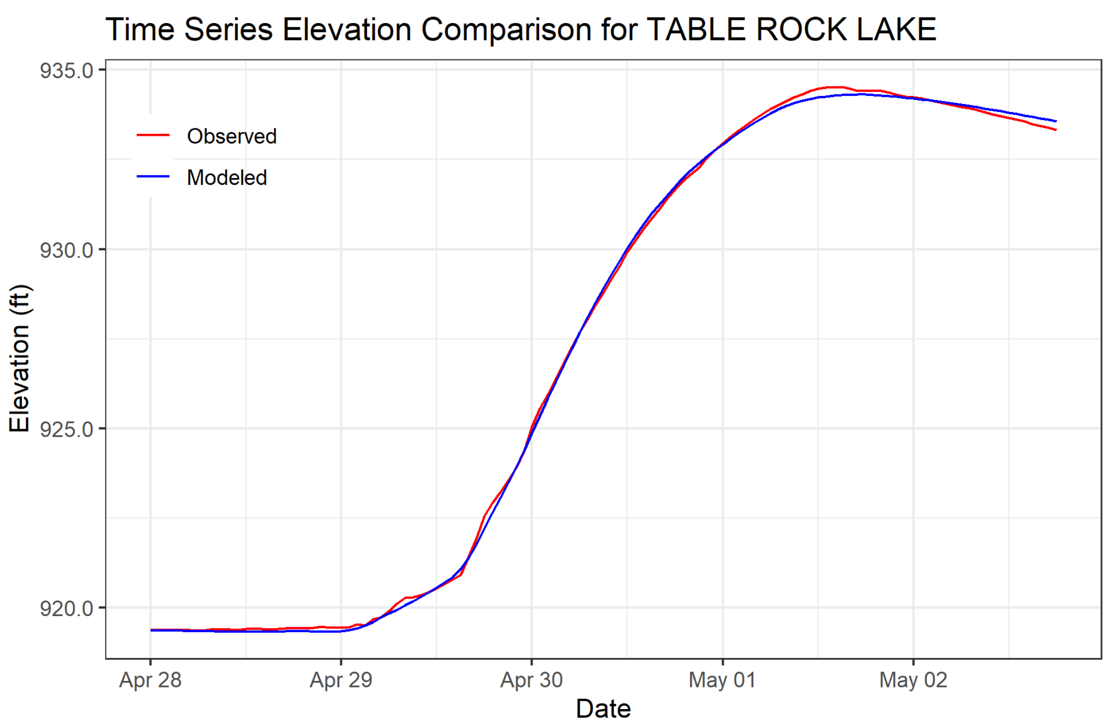


Figure 6-57. Calibration Results for TABLE ROCK LAKE HEC-HMS Junction – Elevation at Table Rock Lake (2017 Event)

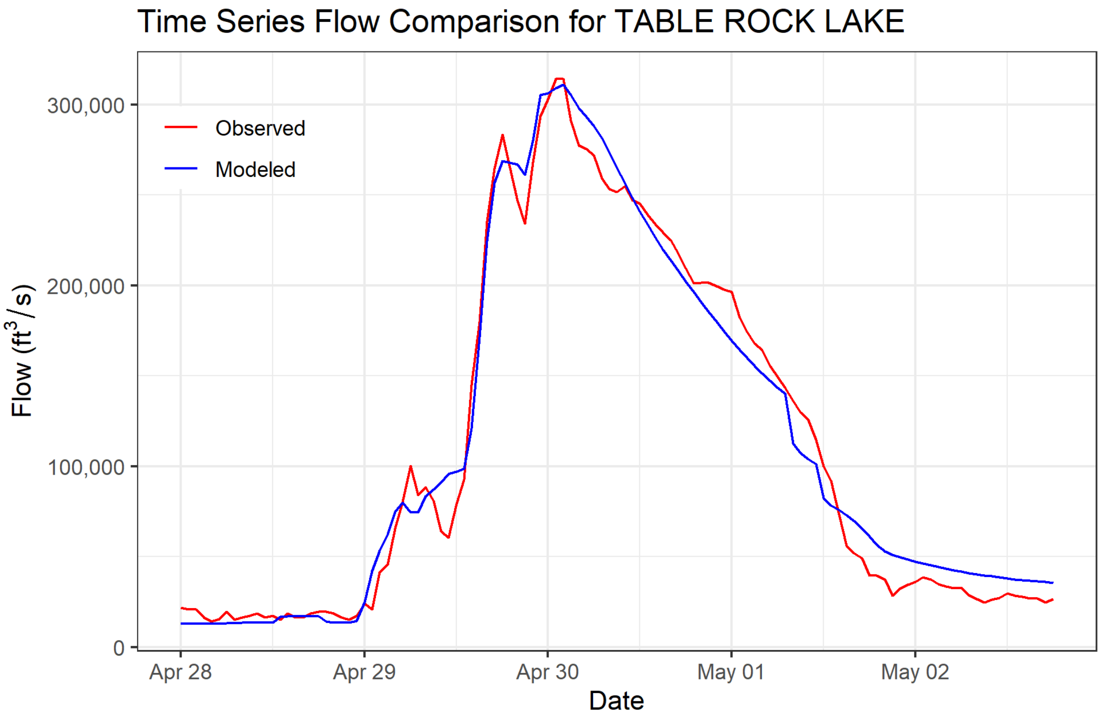


Figure 6-58. Calibration Results for TABLE ROCK LAKE HEC-HMS Junction – Flow at Table Rock Lake (2017 Event)

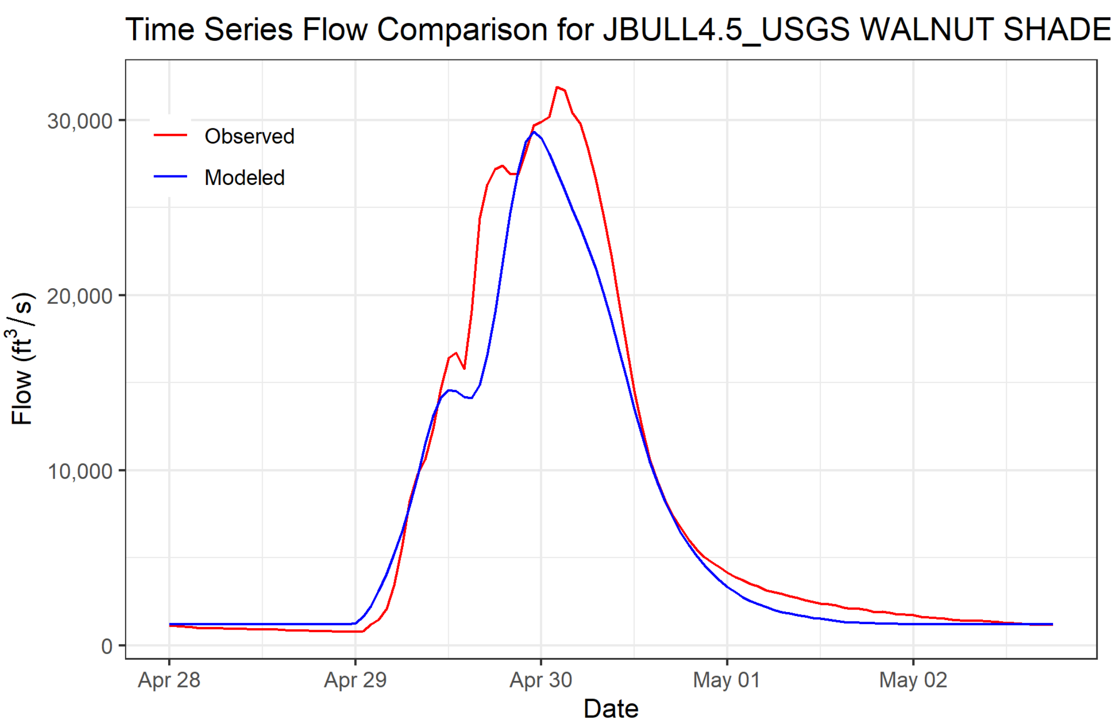


Figure 6-59. Calibration Results for JBULL4.5_USGS WALNUT SHADE HEC-HMS Junction – Bull Creek near Walnut Shade, MO Gage (07053810, 2017 Event)

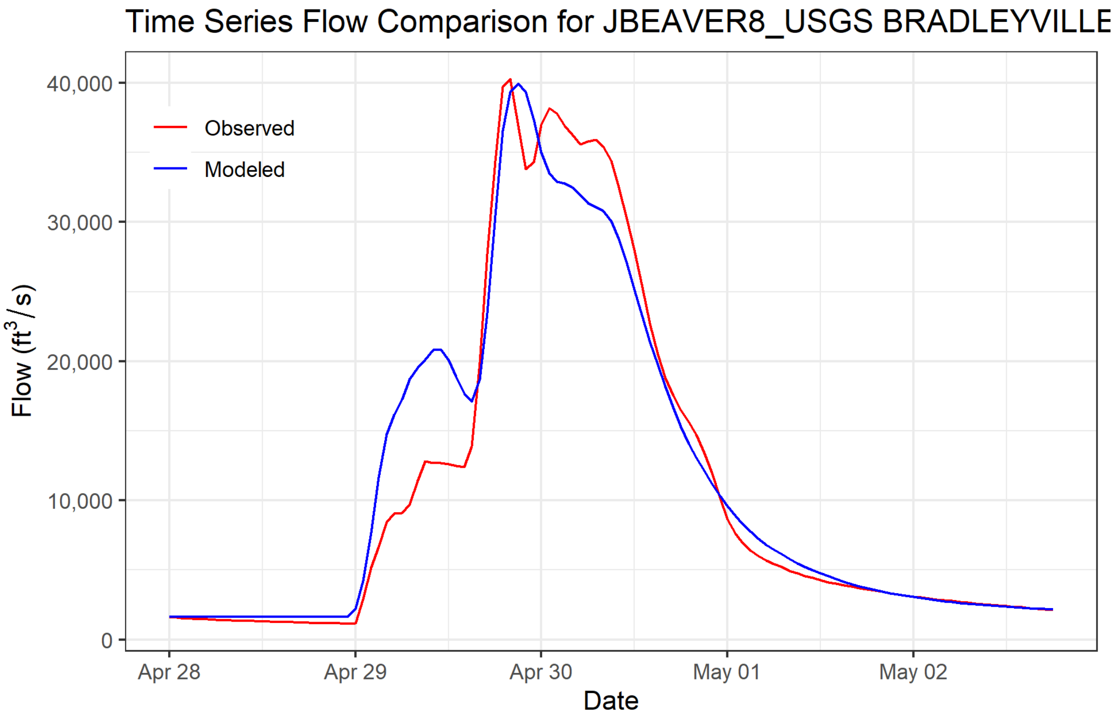


Figure 6-60. Calibration Results for JBEAVER8_USGS BRADLEYVILLE HEC-HMS Junction – Beaver Creek at Bradleyville, MO Gage (07054080, 2017 Event)

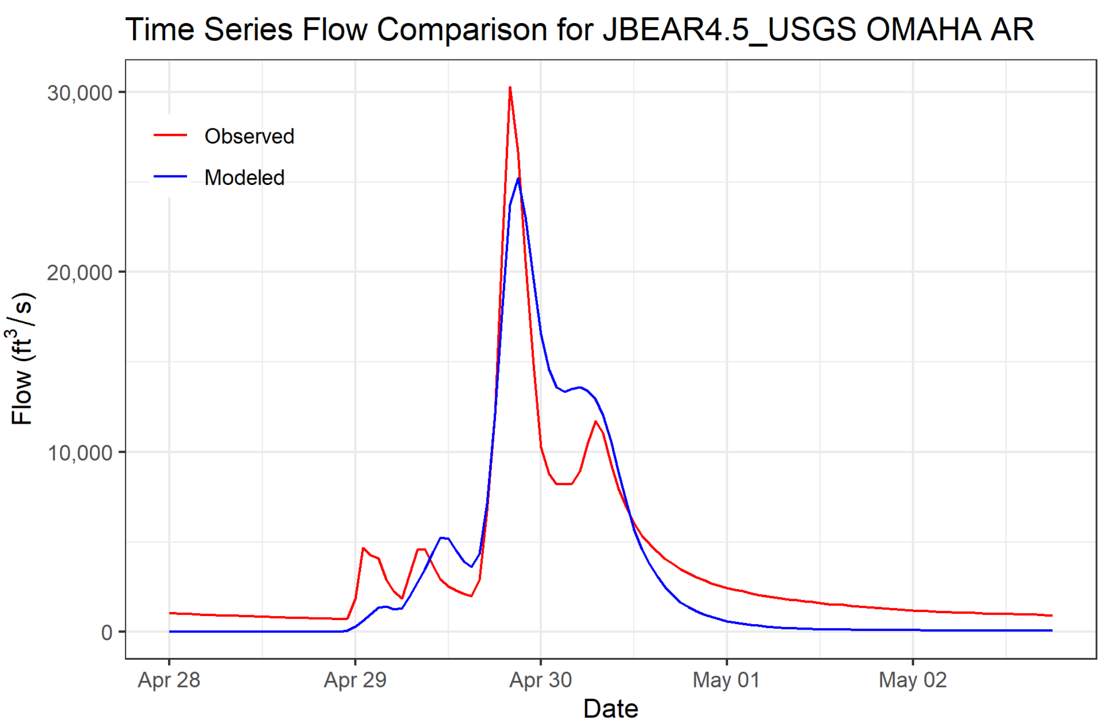


Figure 6-61. Calibration Results for JBEAR4.5_USGS OMAHA AR HEC-HMS Junction – Bear Creek near Omaha, AR Gage (07054410, 2017 Event)

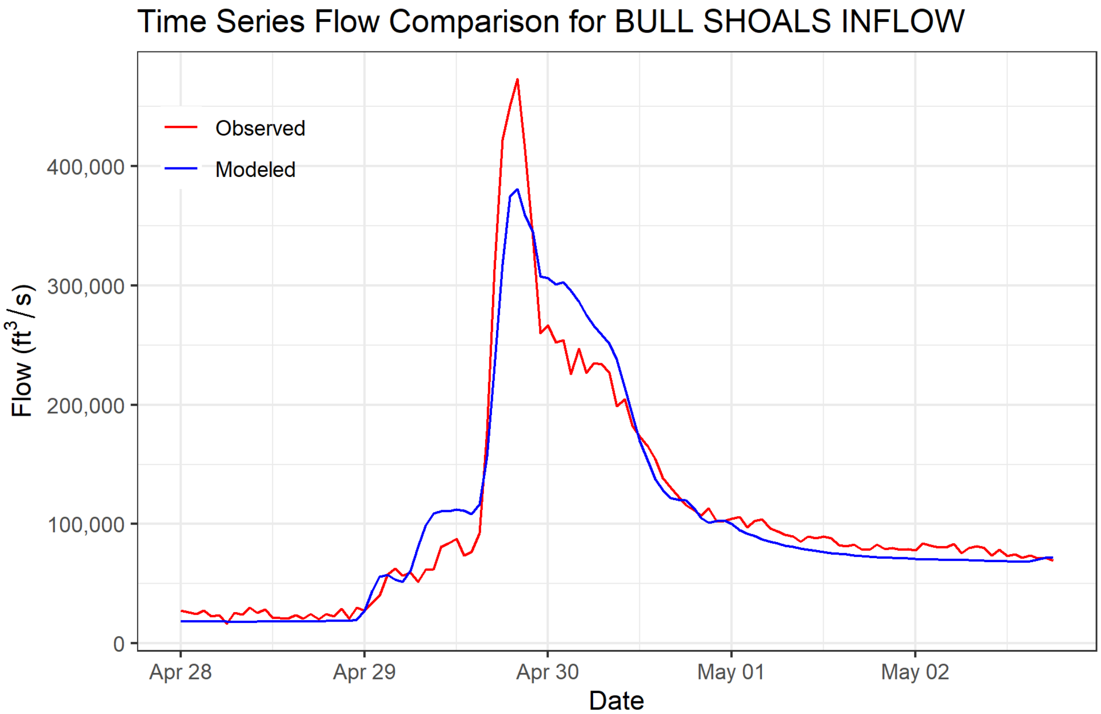


Figure 6-62. Calibration Results for BULL SHOALS INFLOW HEC-HMS Junction – Inflow to Bull Shoals Lake (2017 Event)

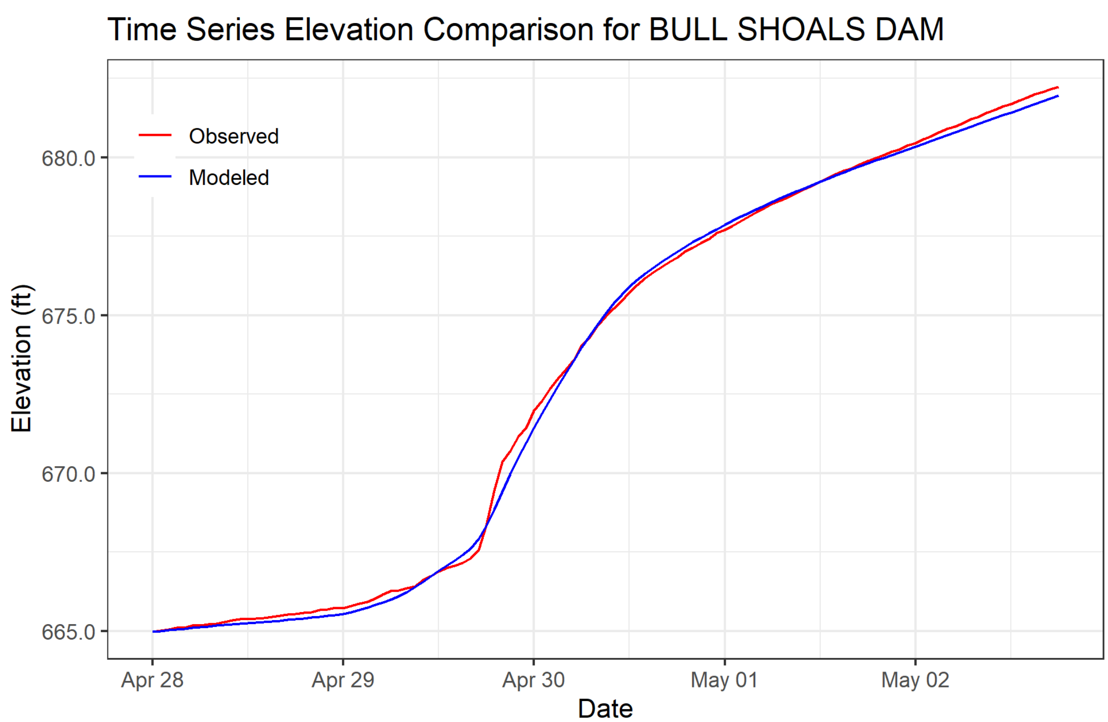


Figure 6-63. Calibration Results for BULL SHOALS DAM HEC-HMS Junction – Elevation at Bull Shoals Lake (2017 Event)

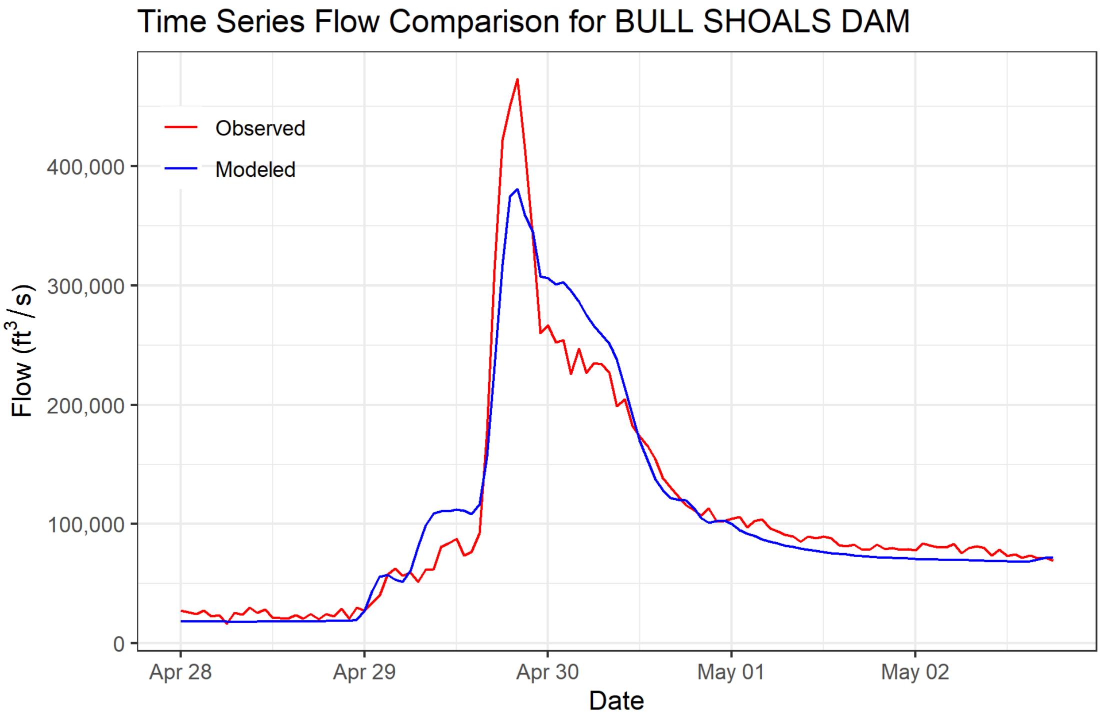


Figure 6-64. Calibration Results for BULL SHOALS DAM HEC-HMS Junction – Flow at Bull Shoals Dam (2017 Event)

6.4.3.2 2015 Calibration Event (26Dec2015 to 04Jan2016)

The results for the calibration of the 2015 event are shown in Figure 6-65 through Figure 6-88.

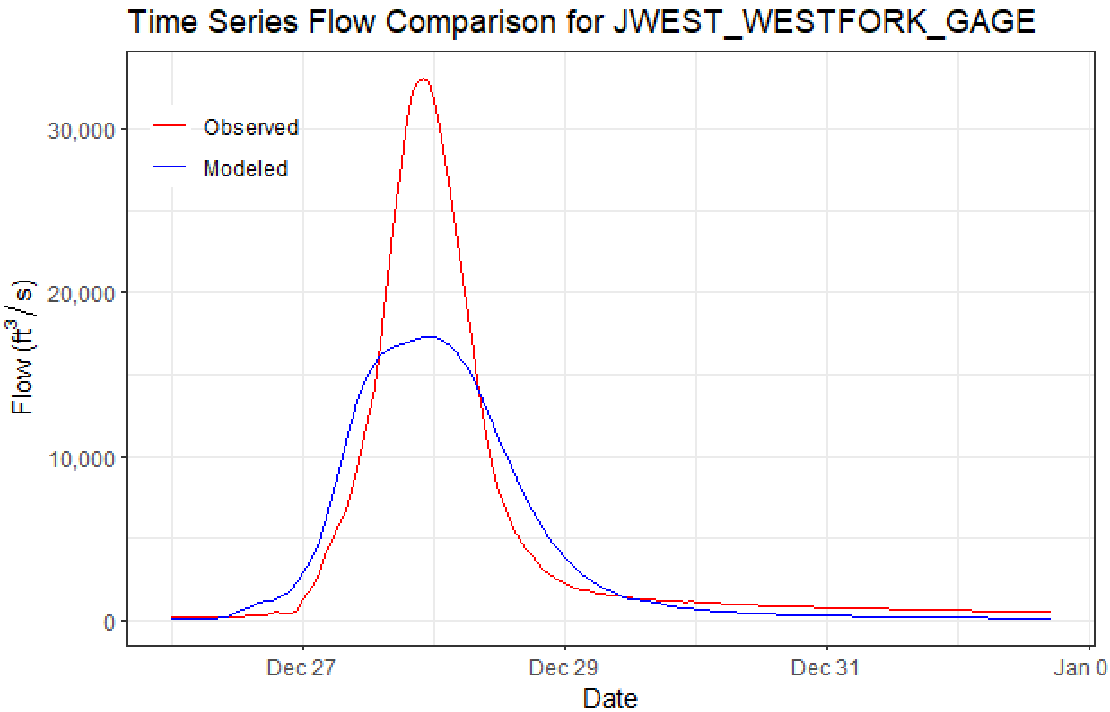


Figure 6-65. Calibration Results for JWEST_WESTFORK_GAGE HEC-HMS Junction – West Fork of White River east of Fayetteville, AR Gage (07048550, 2015 Event)

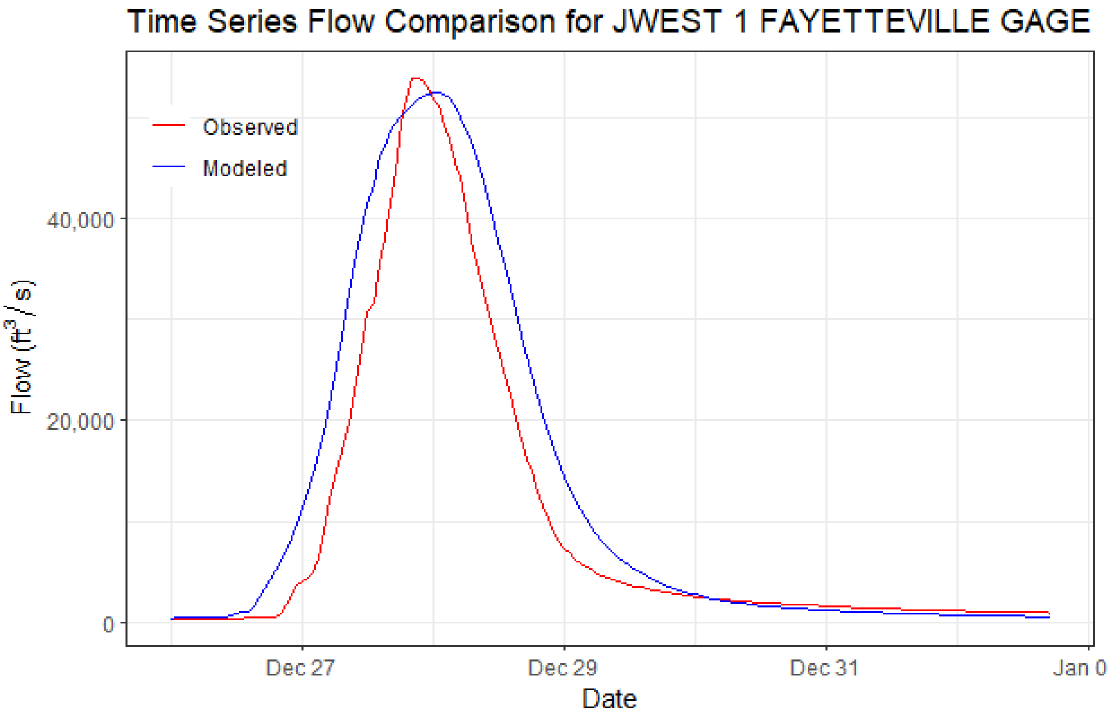


Figure 6-66. Calibration Results for JWEST 1 FAYETTEVILE GAGE HEC-HMS Junction – White River at Fayetteville, AR Gage (07048600, 2015 Event)

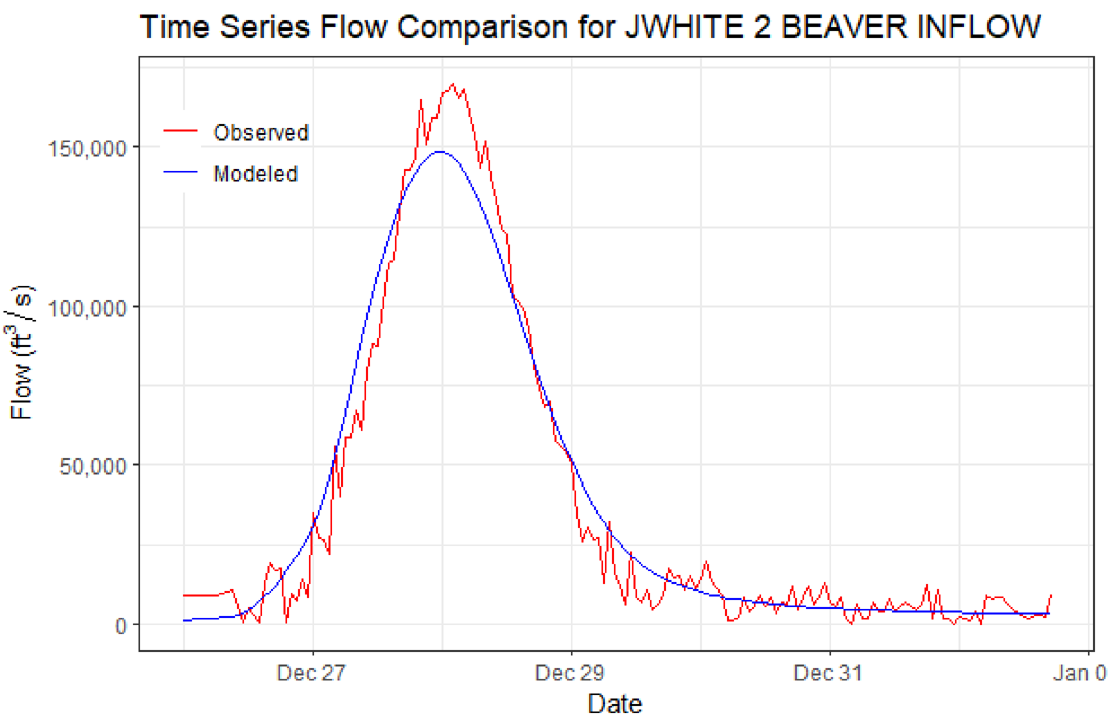


Figure 6-67. Calibration Results for JWHITE2 BEAVER INFLOW HEC-HMS Junction – Inflow to Beaver Lake (2015 Event)

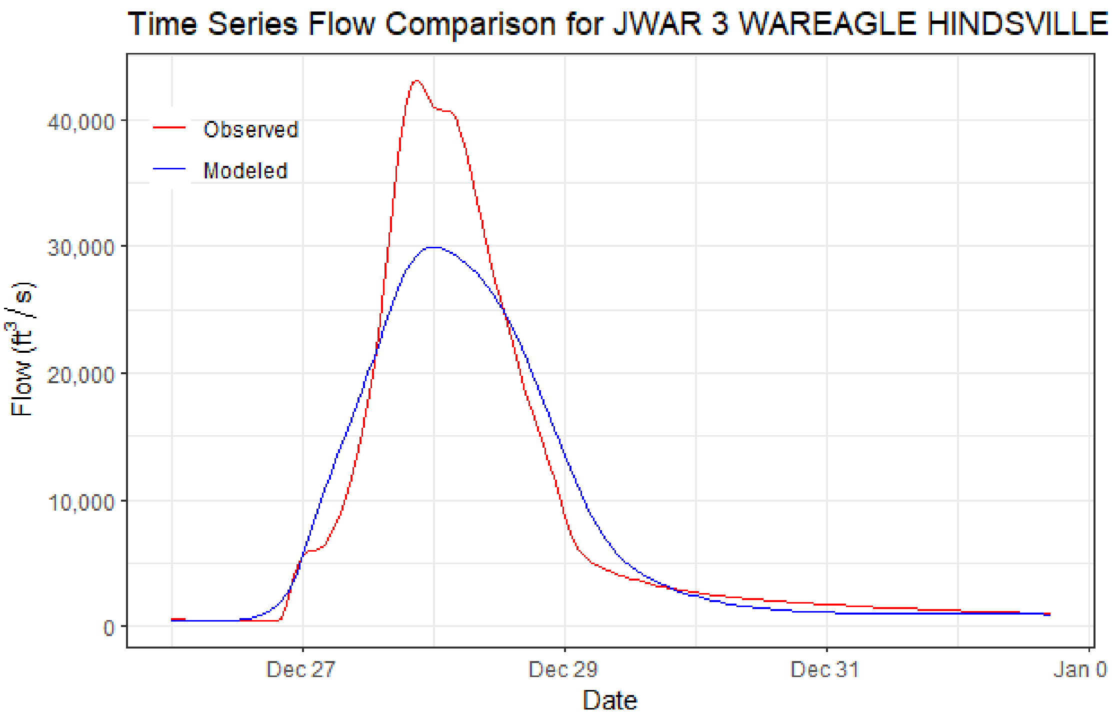


Figure 6-68. Calibration Results for JWAR3 WAREAGLE HINDSVILLE HEC-HMS Junction – War Eagle Creek near Hindsville, AR Gage (07049000, 2015 Event)

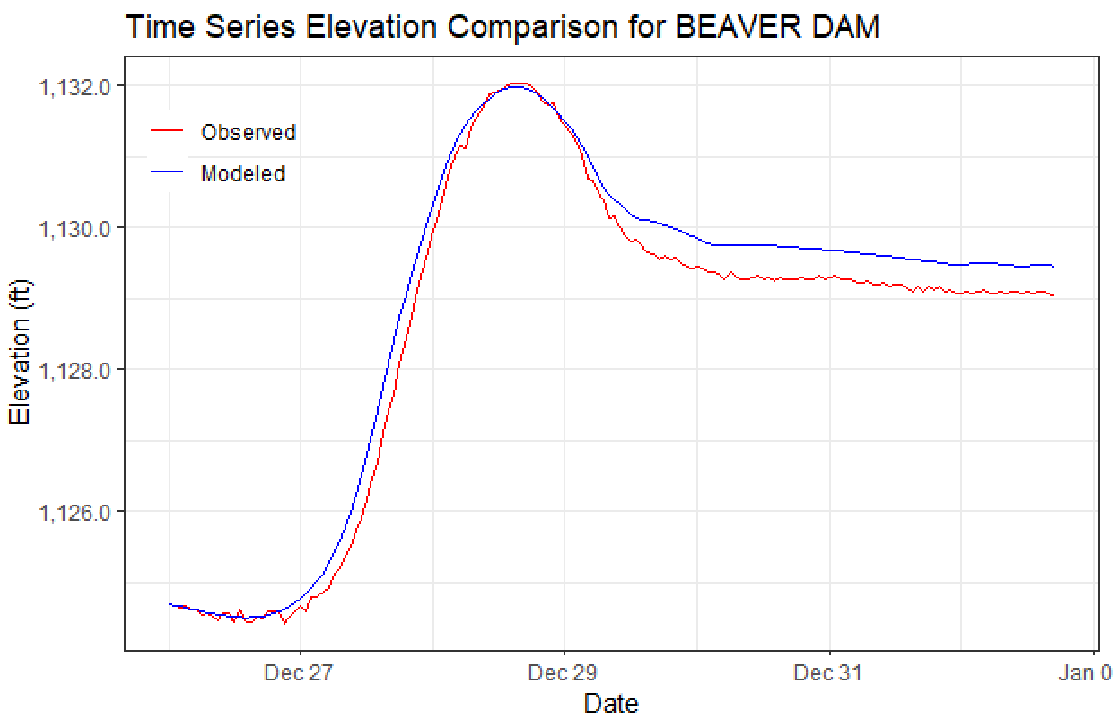


Figure 6-69. Calibration Results for BEAVER DAM HEC-HMS Junction – Elevation at Beaver Dam (2015 Event)

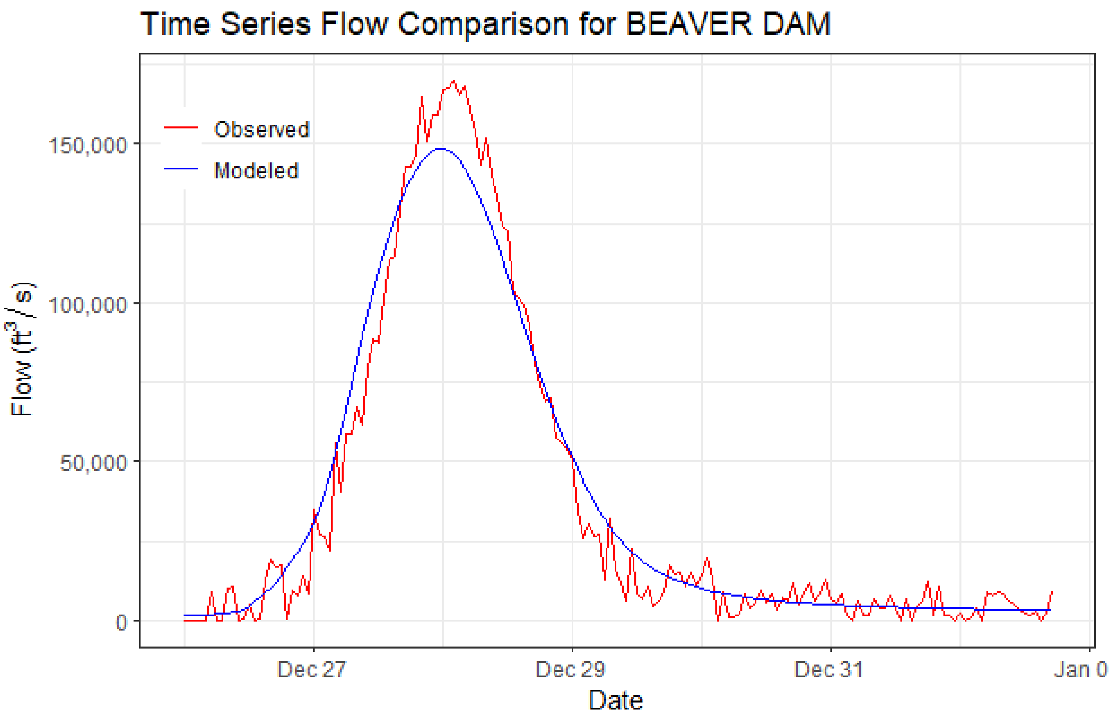


Figure 6-70. Calibration Results for BEAVER DAM HEC-HMS Junction – Flow at Beaver Dam (2015 Event)

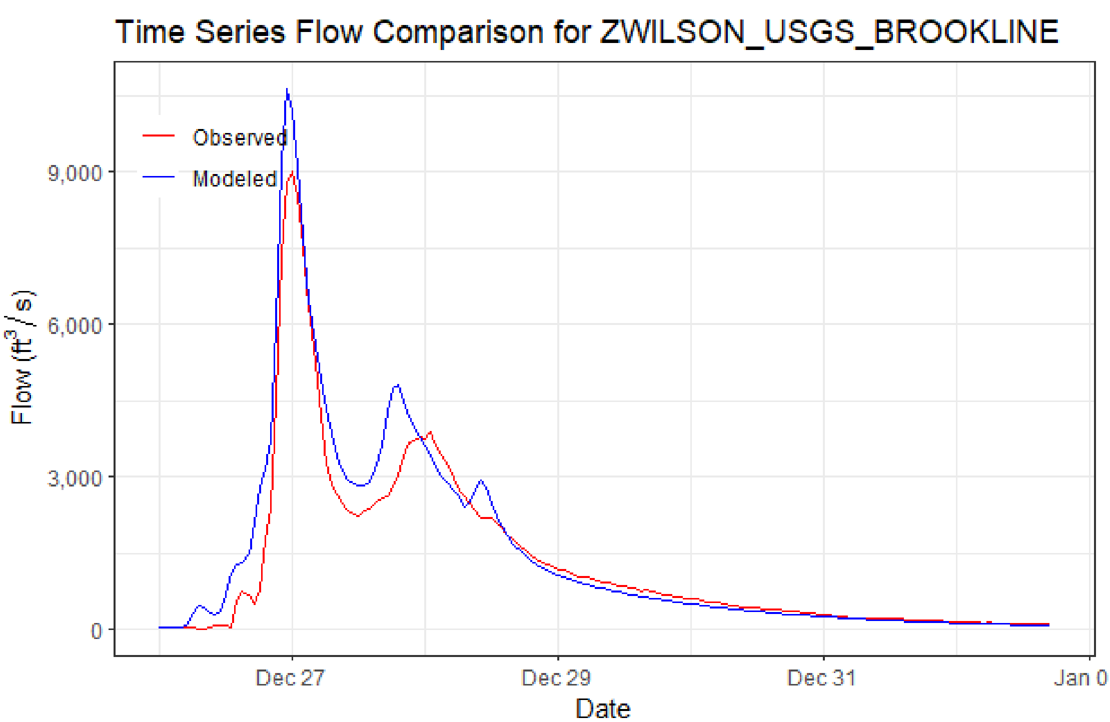


Figure 6-71. Calibration Results for ZWILSON_USGS_BROOKLINE HEC-HMS Junction – Wilson Creek near Brookline, MO Gage (07052152, 2015 Event)

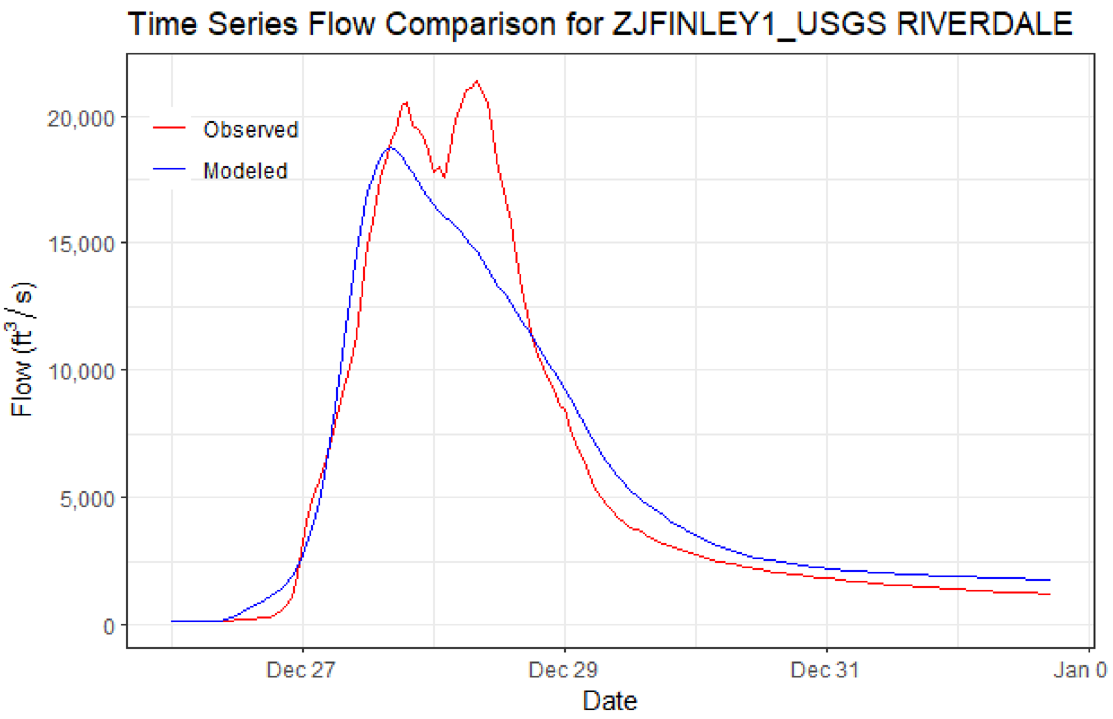


Figure 6-72. Calibration Results for ZJFINLEY1_USGS RIVERDALE HEC-HMS Junction – Finley Creek below Riverdale, MO Gage (07052345, 2015 Event)

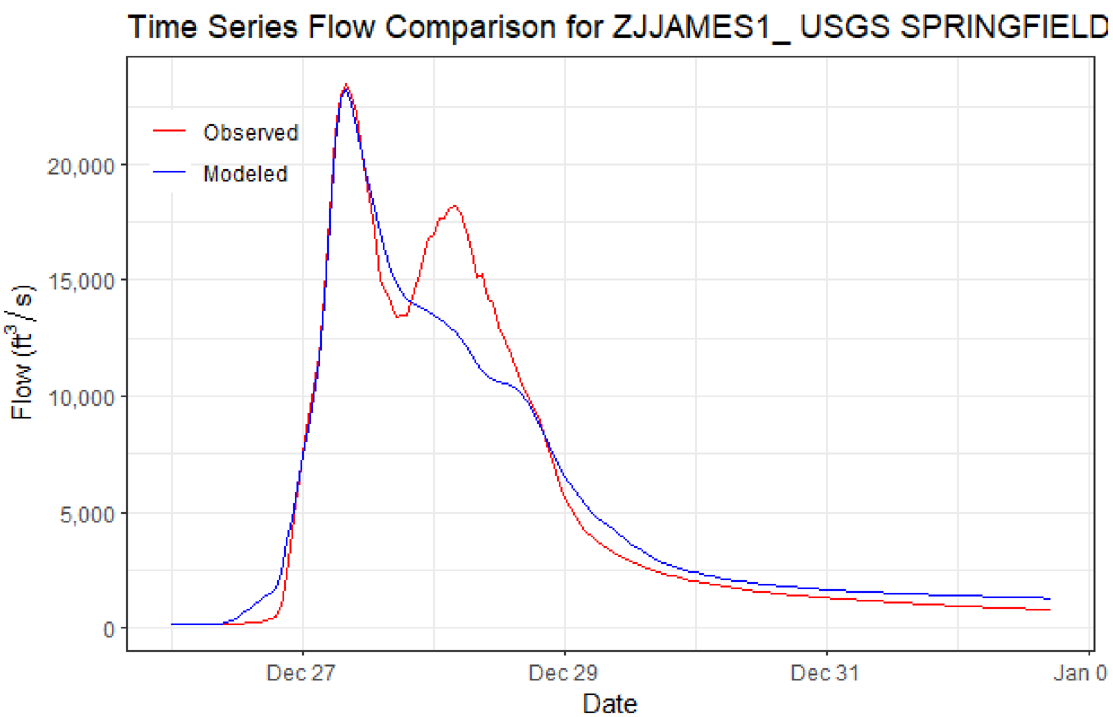


Figure 6-73. Calibration Results for ZJJAMES1_USGS SPRINGFIELD HEC-HMS Junction – James River near Springfield, MO Gage (07050700, 2015 Event)

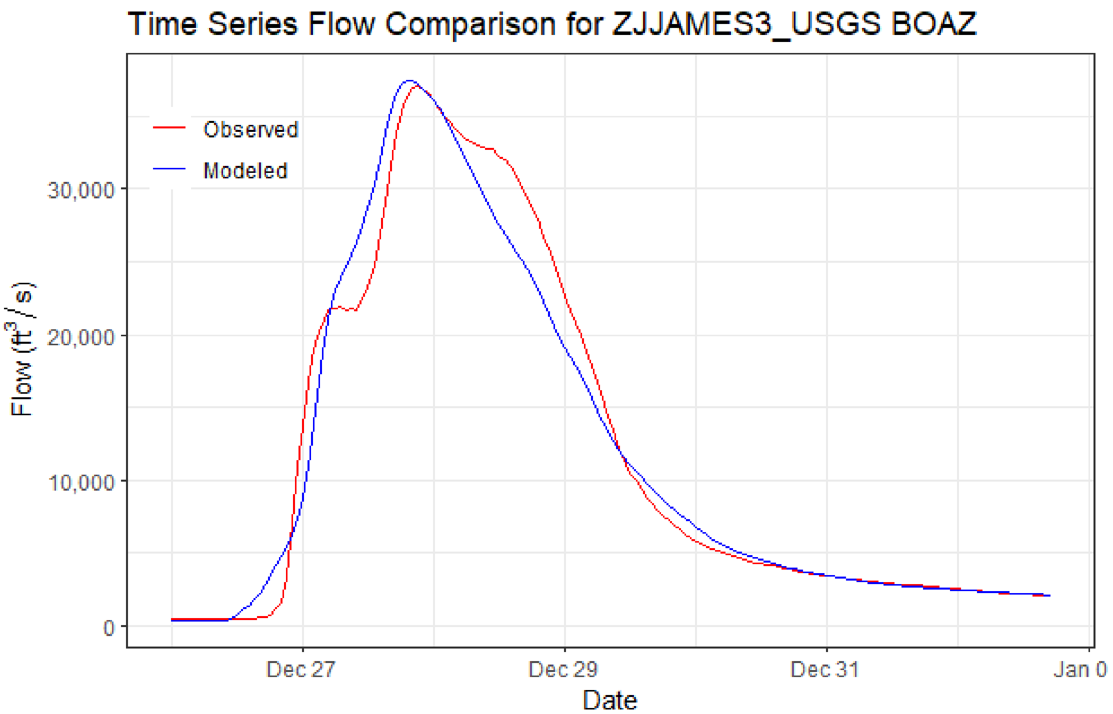


Figure 6-74. Calibration Results for ZJJAMES3_USGS BOAZ HEC-HMS Junction – James River near Boaz, MO Gage (07052250, 2015 Event)

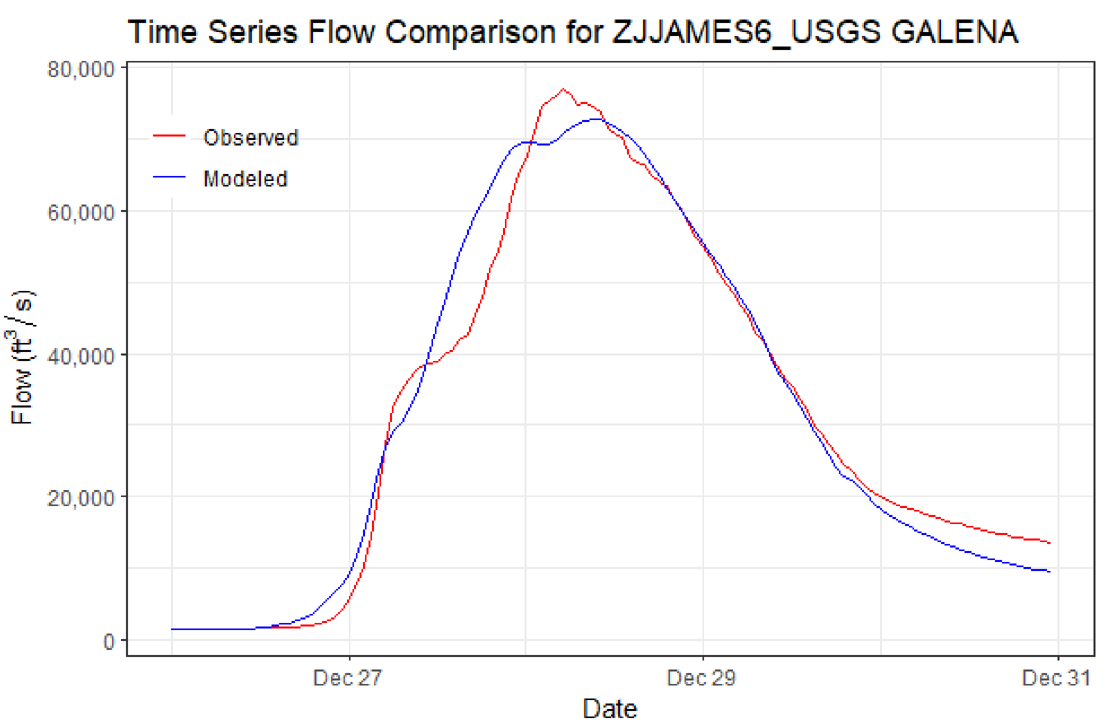


Figure 6-75. Calibration Results for ZJJAMES6_USGS GALENA HEC-HMS Junction – James River near Galena, MO Gage (07052500, 2015 Event)

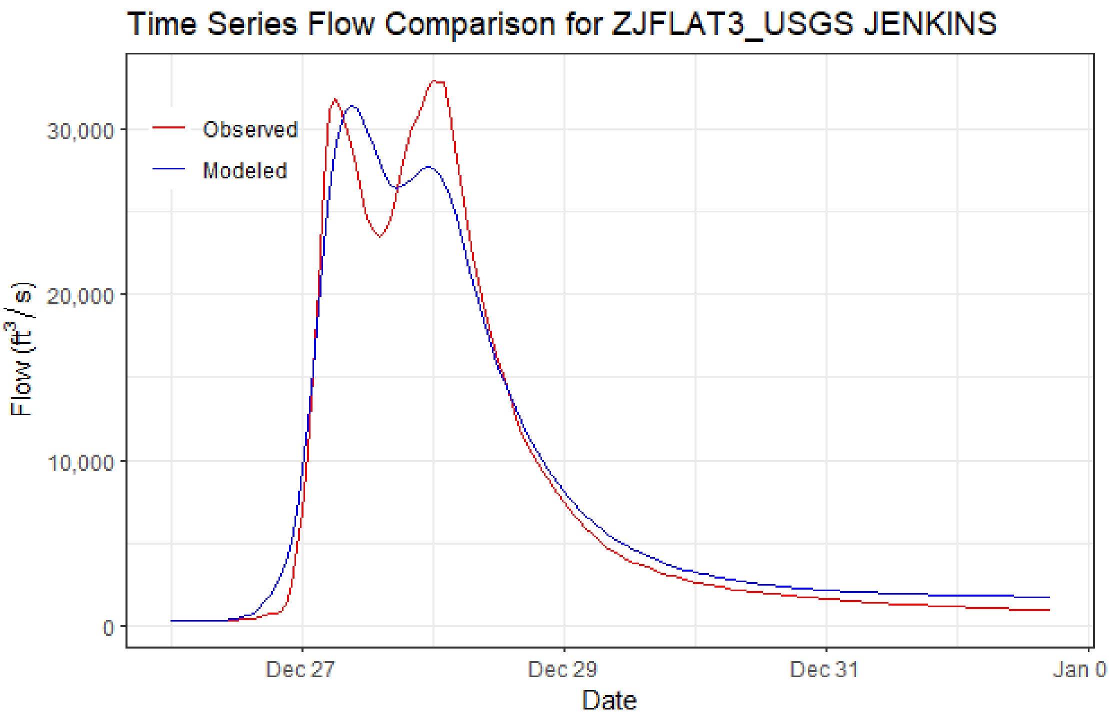


Figure 6-76. Calibration Results for ZJFLAT3_USGS JENKINS HEC-HMS Junction – Flat Creek below Jenkins, MO Gage (07052820, 2015 Event)

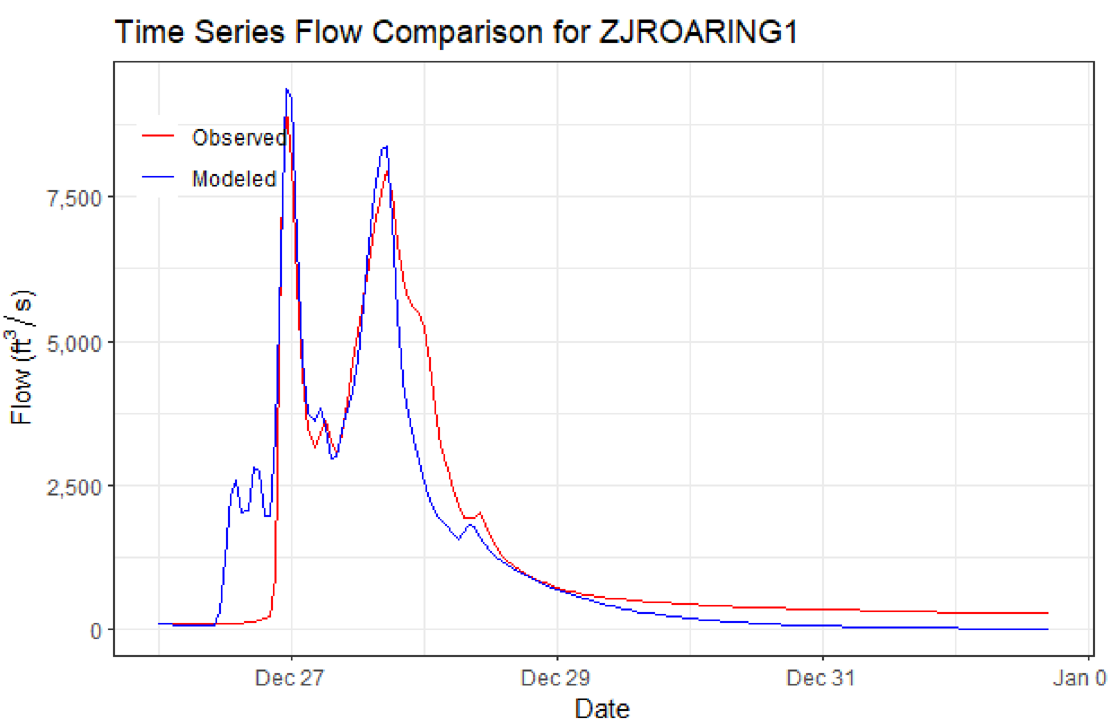


Figure 6-77. Calibration Results for ZJROARING1 HEC-HMS Junction – Roaring River at Roaring River State Park Gage (07050152, 2015 Event)

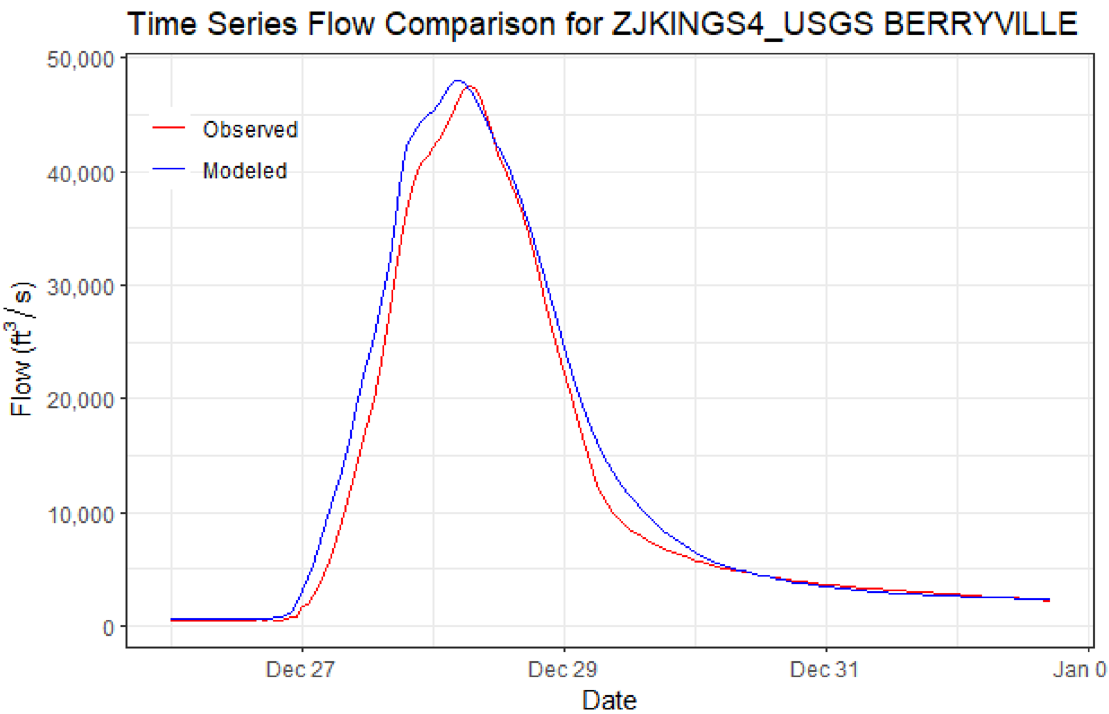


Figure 6-78. Calibration Results for ZJKINGS4_USGS BERRYVILLE HEC-HMS Junction – Kings River near Berryville, AR Gage (07050500, 2015 Event)

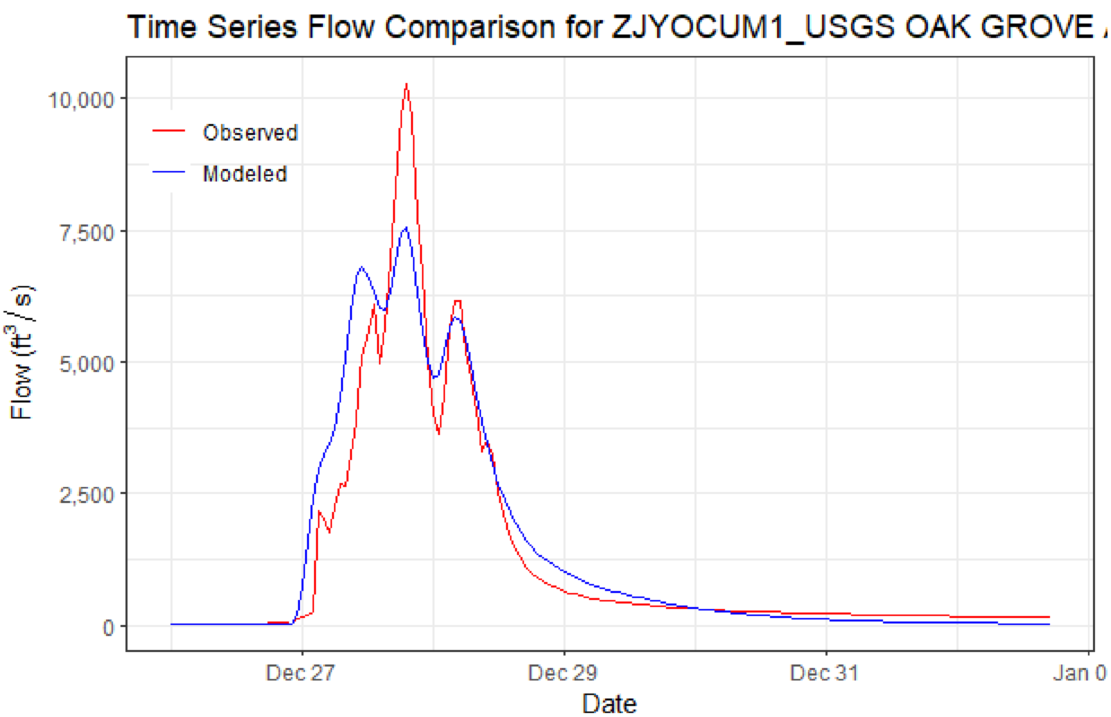


Figure 6-79. Calibration Results for ZJYOCUM_USGS OAK GROVE AR HEC-HMS Junction – Yocum Creek near Oak Grove, AR Gage (07053250, 2015 Event)

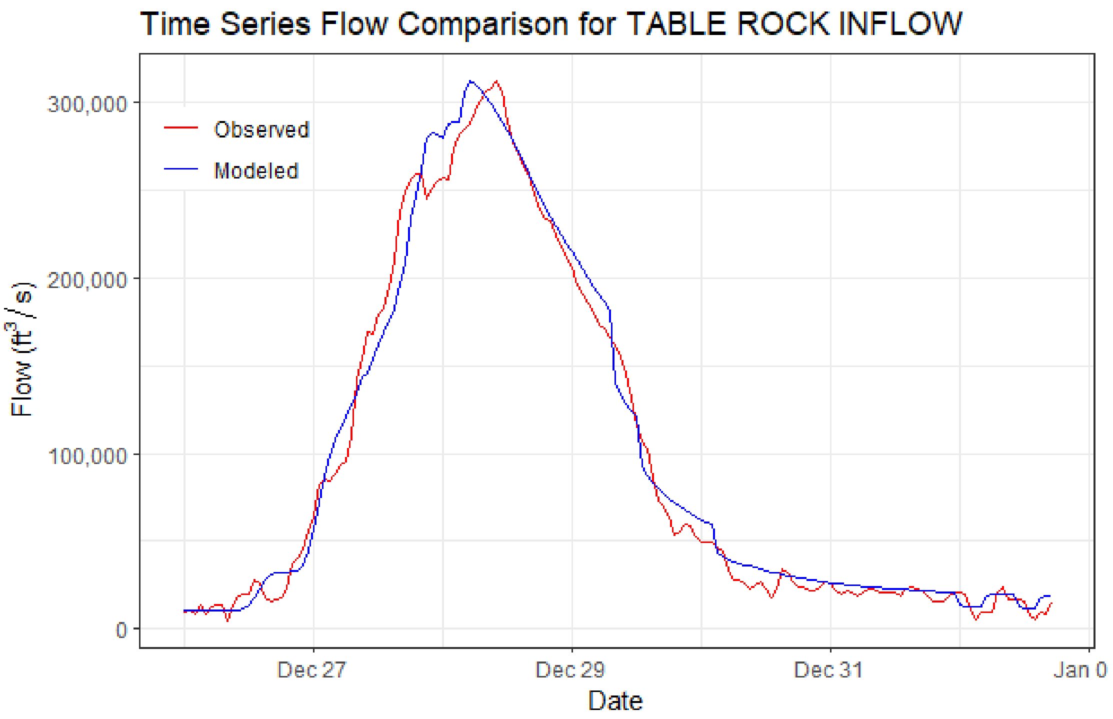


Figure 6-80. Calibration Results for TABLE ROCK INFLOW HEC-HMS Junction – Inflow to Table Rock Lake (2015 Event)

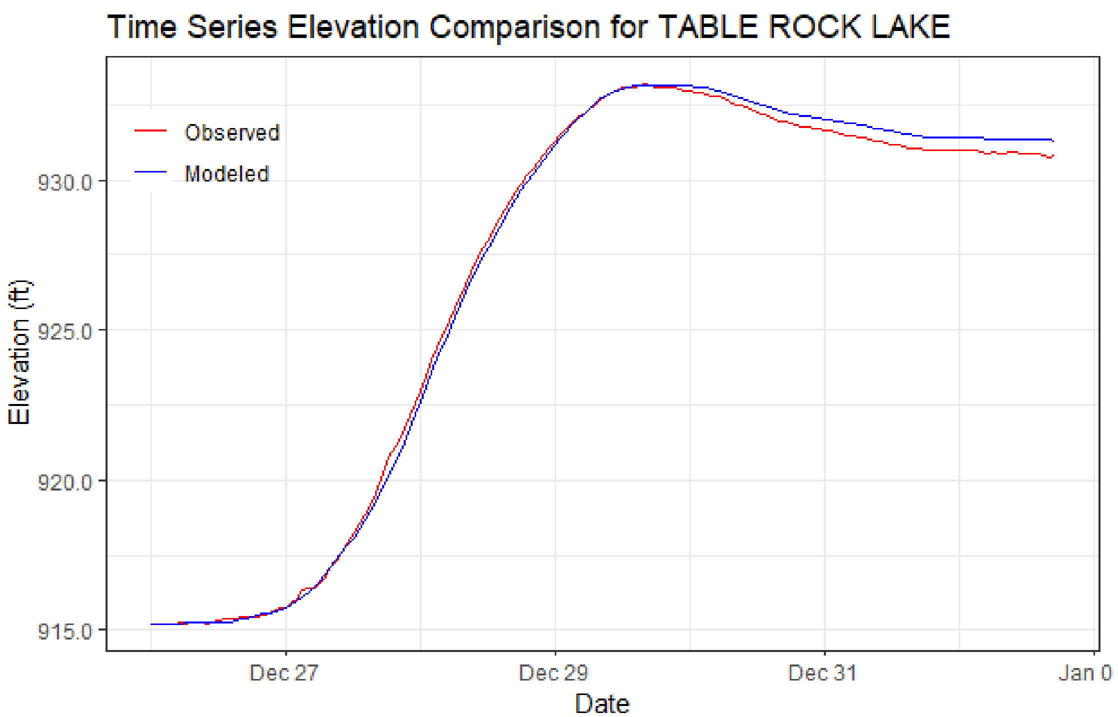


Figure 6-81. Calibration Results for TABLE ROCK LAKE HEC-HMS Junction – Elevation at Table Rock Lake (2015 Event)

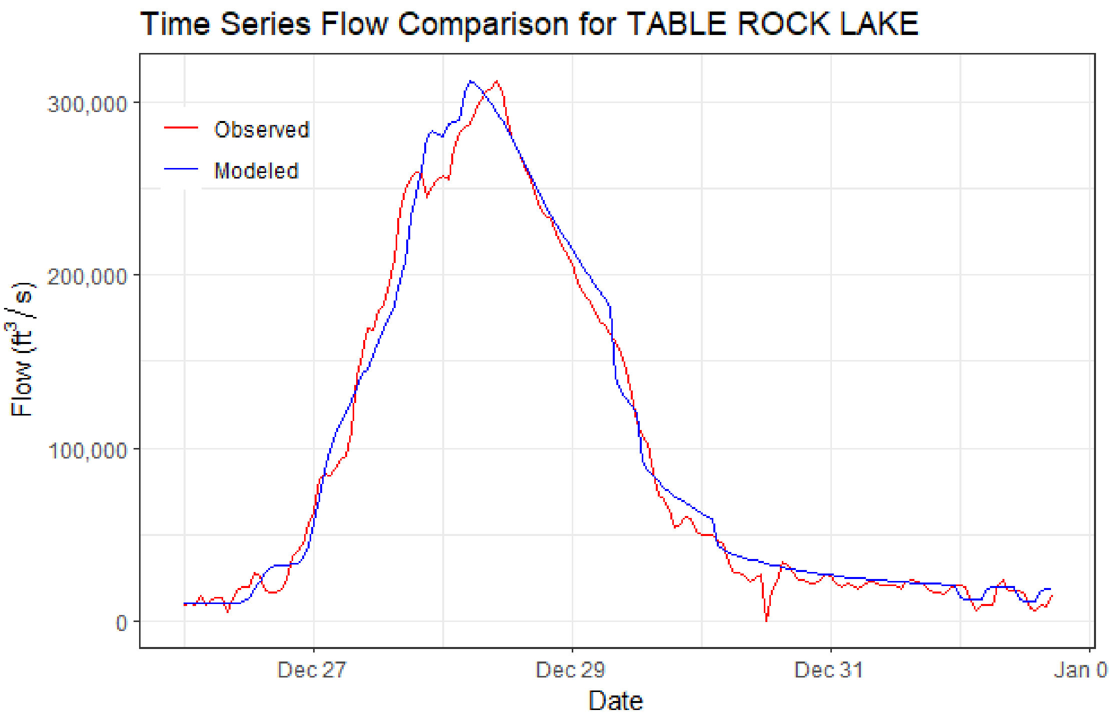


Figure 6-82. Calibration Results for TABLE ROCK LAKE HEC-HMS Junction – Flow at Table Rock Lake (2015 Event)

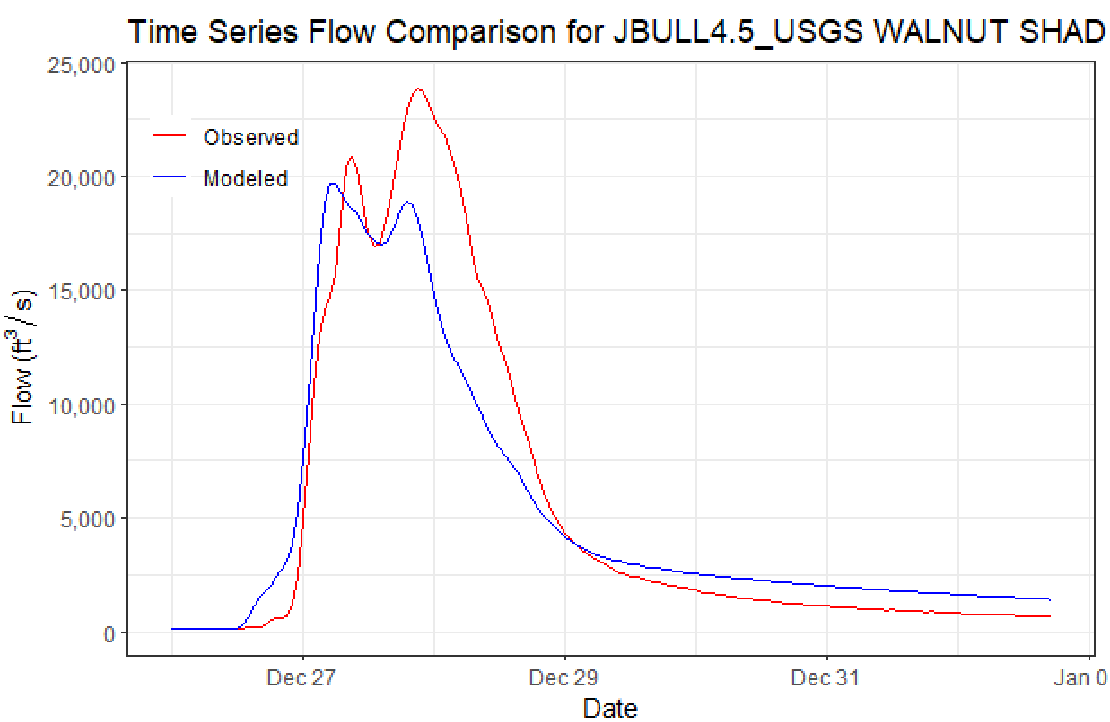


Figure 6-83. Calibration Results for JBULL4.5_USGS WALNUT SHADE HEC-HMS Junction – Bull Creek near Walnut Shade, MO Gage (07053810, 2015 Event)

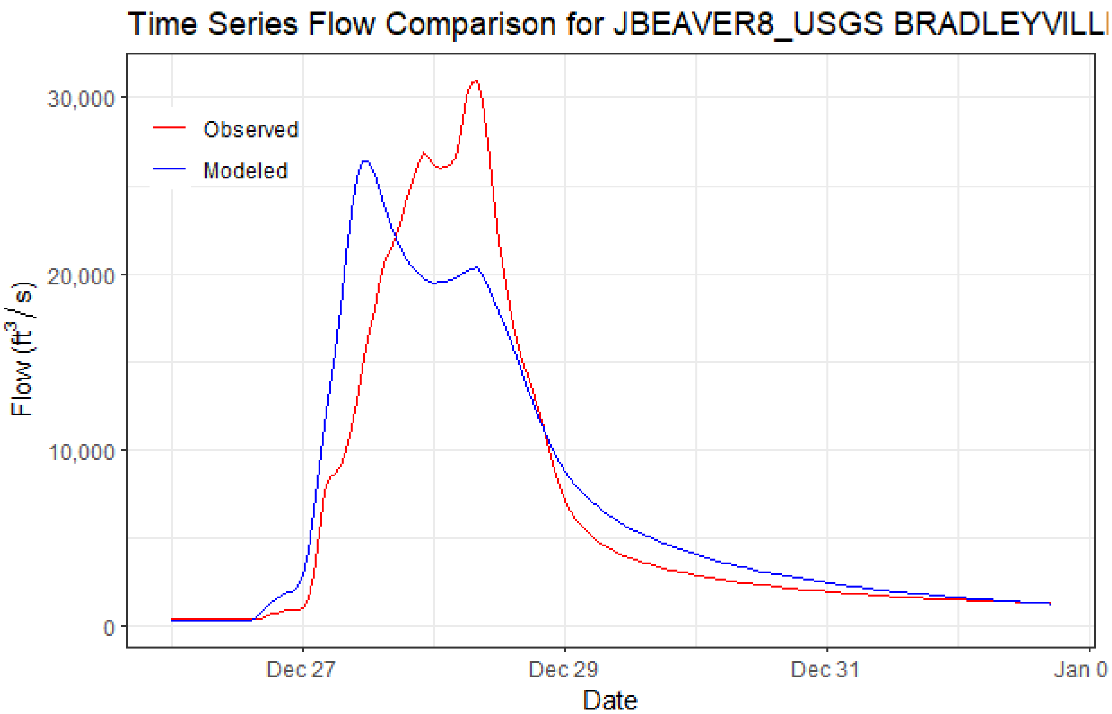


Figure 6-84. Calibration Results for JBEAVER8_USGS BRADLEYVILLE HEC-HMS Junction – Beaver Creek at Bradleyville, MO Gage (07054080, 2015 Event)

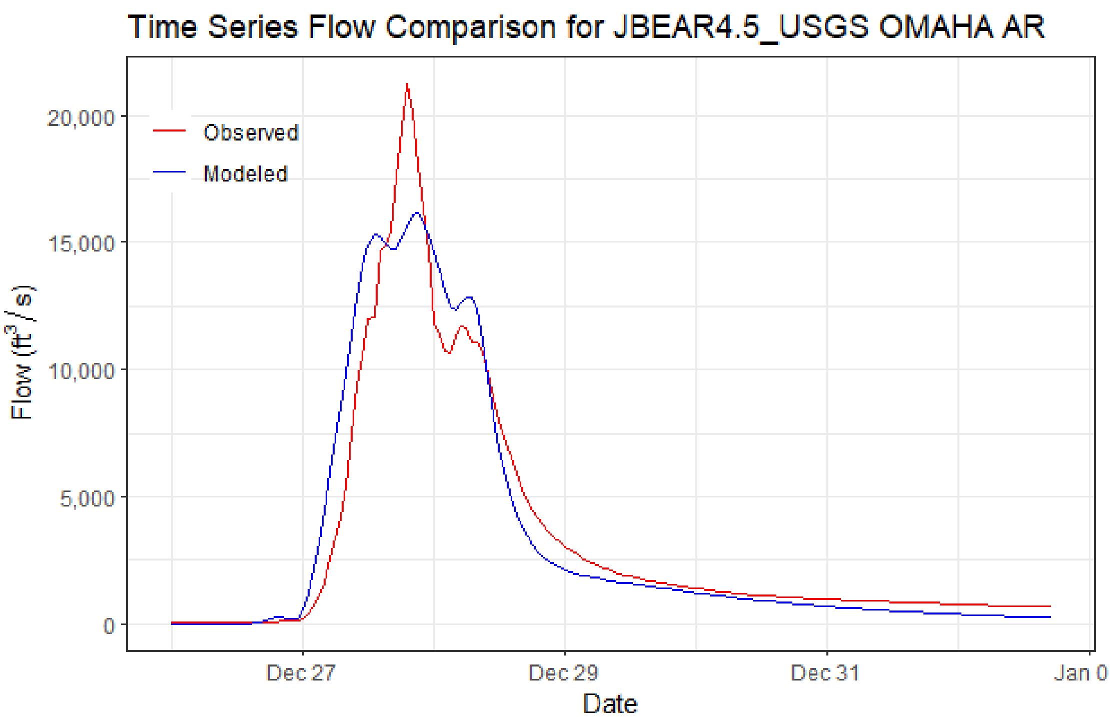


Figure 6-85. Calibration Results for JBEAR4.5_USGS OMAHA AR HEC-HMS Junction – Bear Creek near Omaha, AR Gage (07054410, 2015 Event)

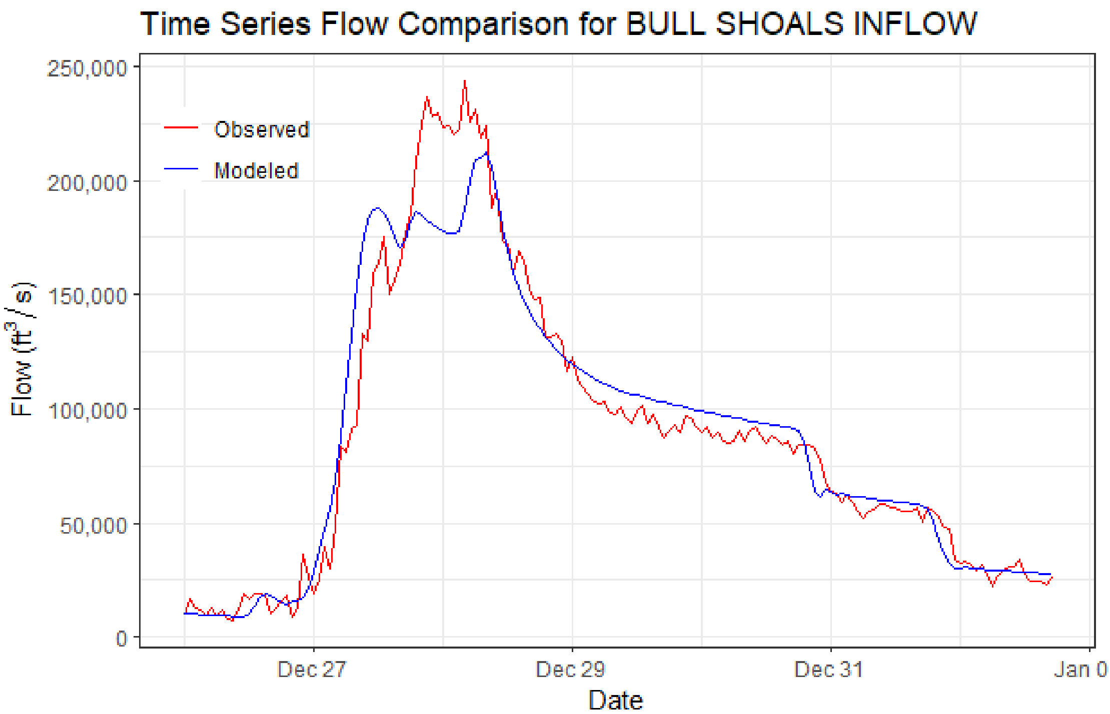


Figure 6-86. Calibration Results for BULL SHOALS INFLOW HEC-HMS Junction – Inflow to Bull Shoals Lake (2015 Event)

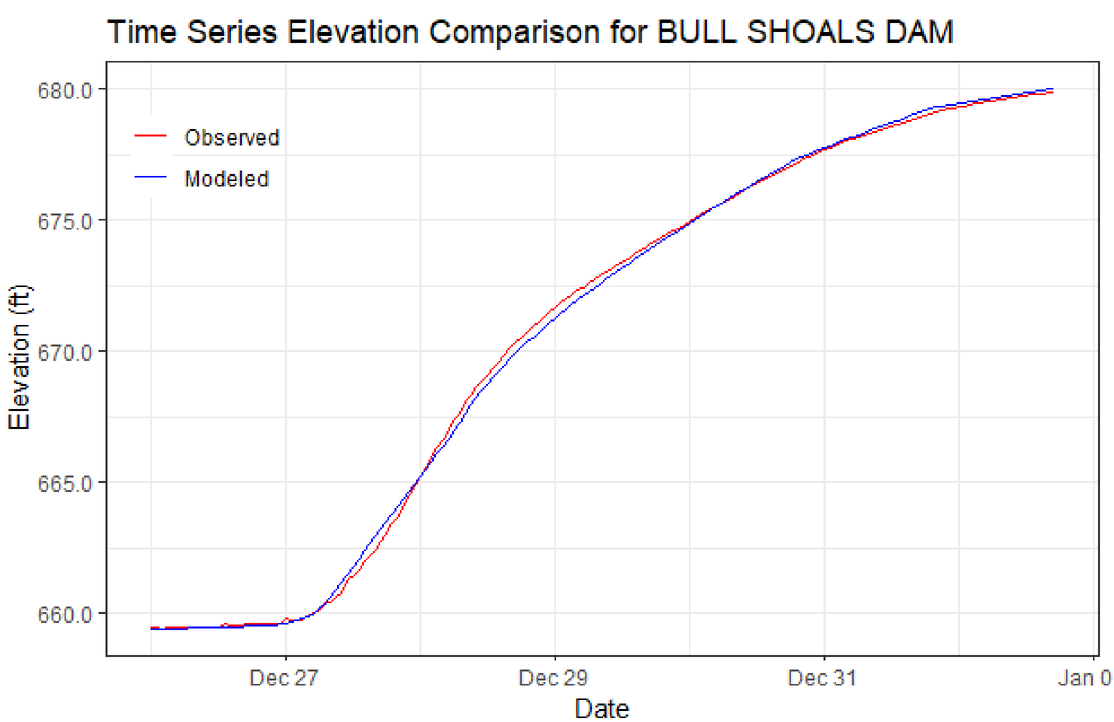


Figure 6-87. Calibration Results for BULL SHOALS DAM HEC-HMS Junction – Elevation at Bull Shoals Lake (2015 Event)

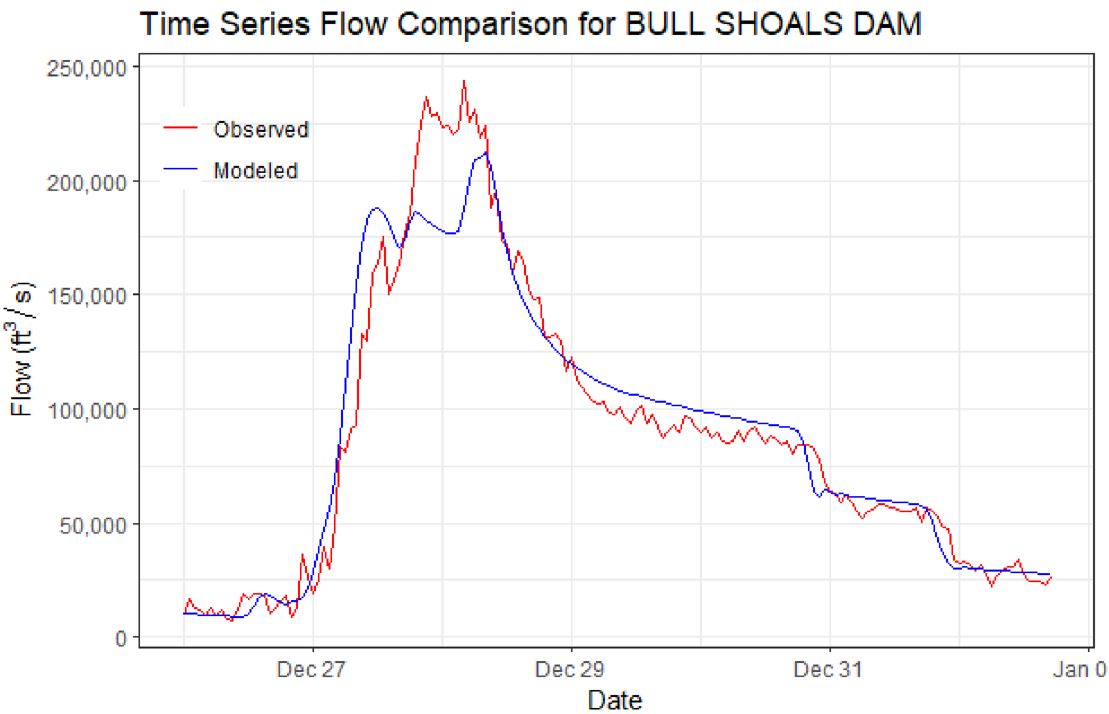


Figure 6-88. Calibration Results for BULL SHOALS DAM HEC-HMS Junction – Flow at Bull Shoals Dam (2015 Event)

6.4.3.3 2011 Calibration Event (20Apr2011 to 01May2011)

The results of the calibration of the 2011 event are shown in Figure 6-89 through Figure 6-112.

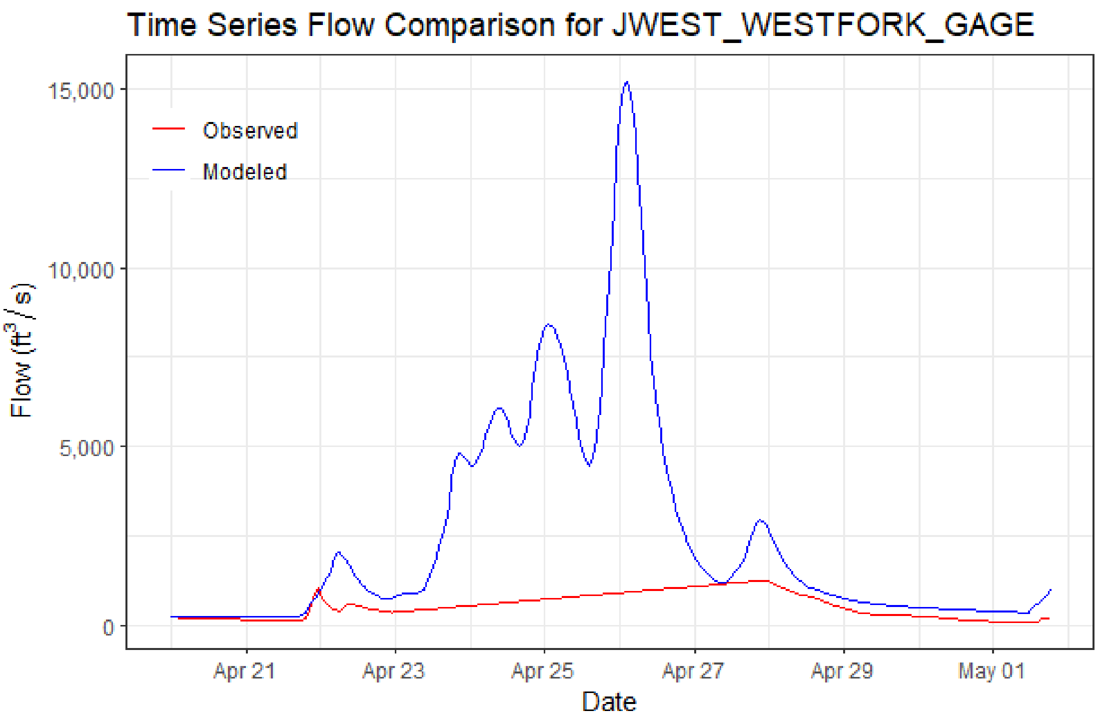


Figure 6-89. Calibration Results for JWEST_WESTFORK_GAGE HEC-HMS Junction – West Fork of White River east of Fayetteville Gage (07048550, 2011 Event)

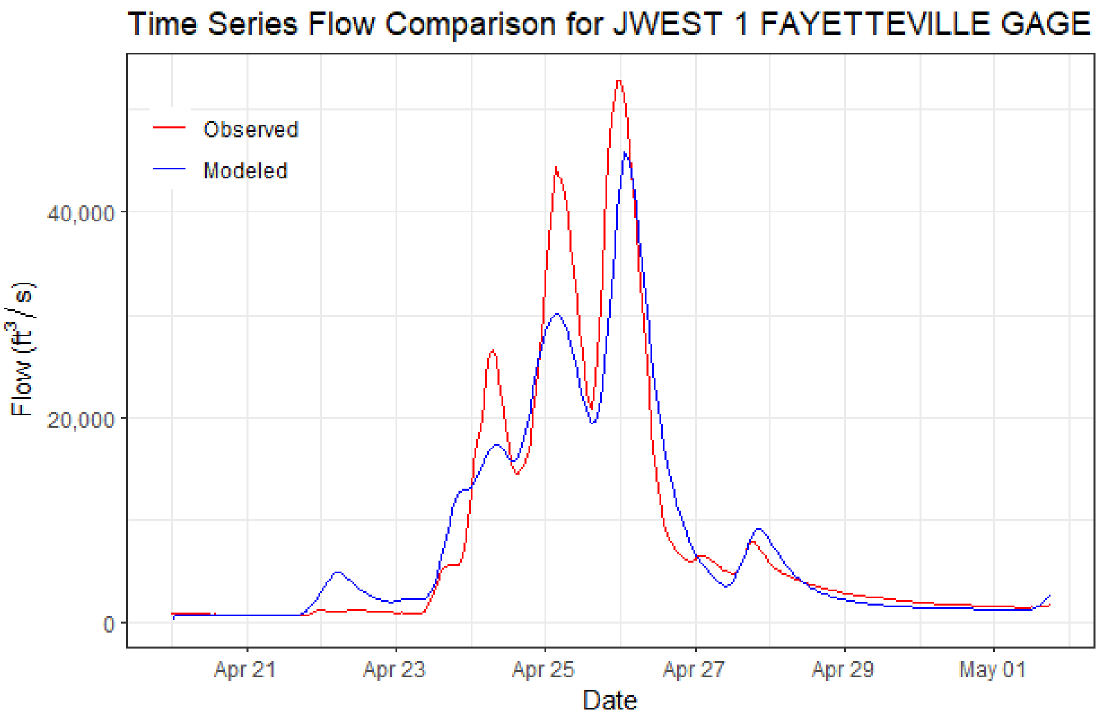


Figure 6-90. Calibration Results for JWEST 1 FAYETTEVILLE GAGE HEC-HMS Junction – White River at Fayetteville, AR Gage (07048600, 2011 Event)

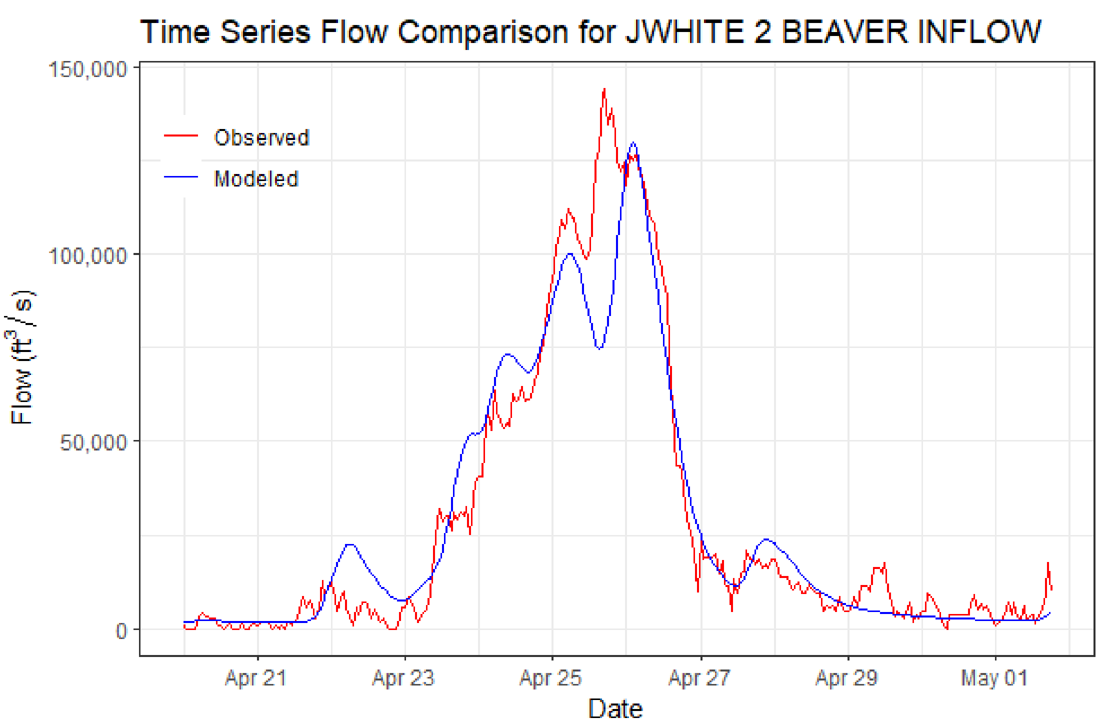


Figure 6-91. Calibration Results for JWHITE 2 BEAVER INFLOW HEC-HMS Junction – Inflow to Beaver Lake (2011 Event)

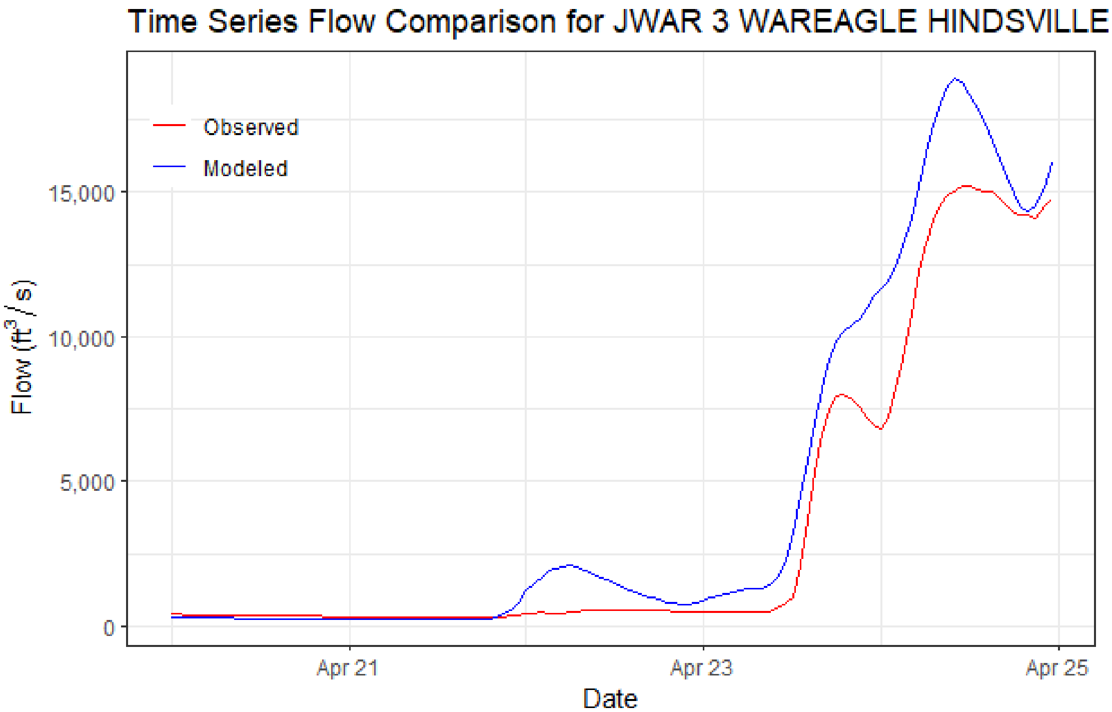


Figure 6-92. Calibration Results for JWAR3 WAREAGLE HINDSVILLE HEC-HMS Junction – War Eagle Creek near Hindsville, AR Gage (07049000, 2011 Event)

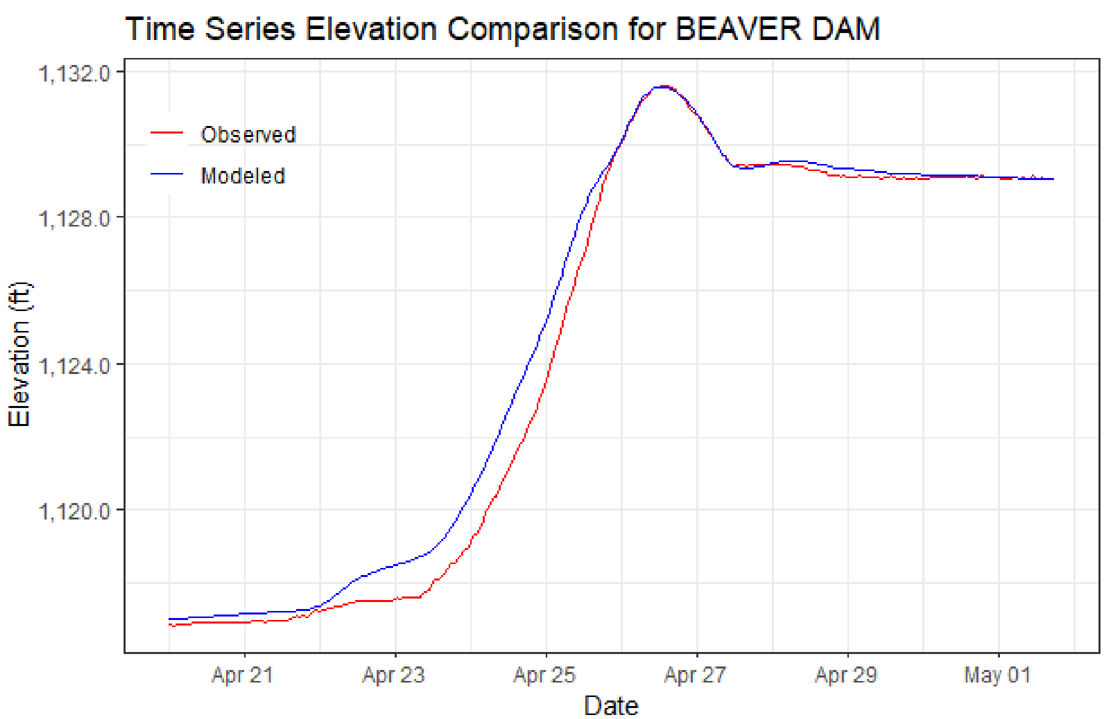


Figure 6-93. Calibration Results for BEAVER DAM HEC-HMS Junction – Elevation at Beaver Dam (2011 Event)

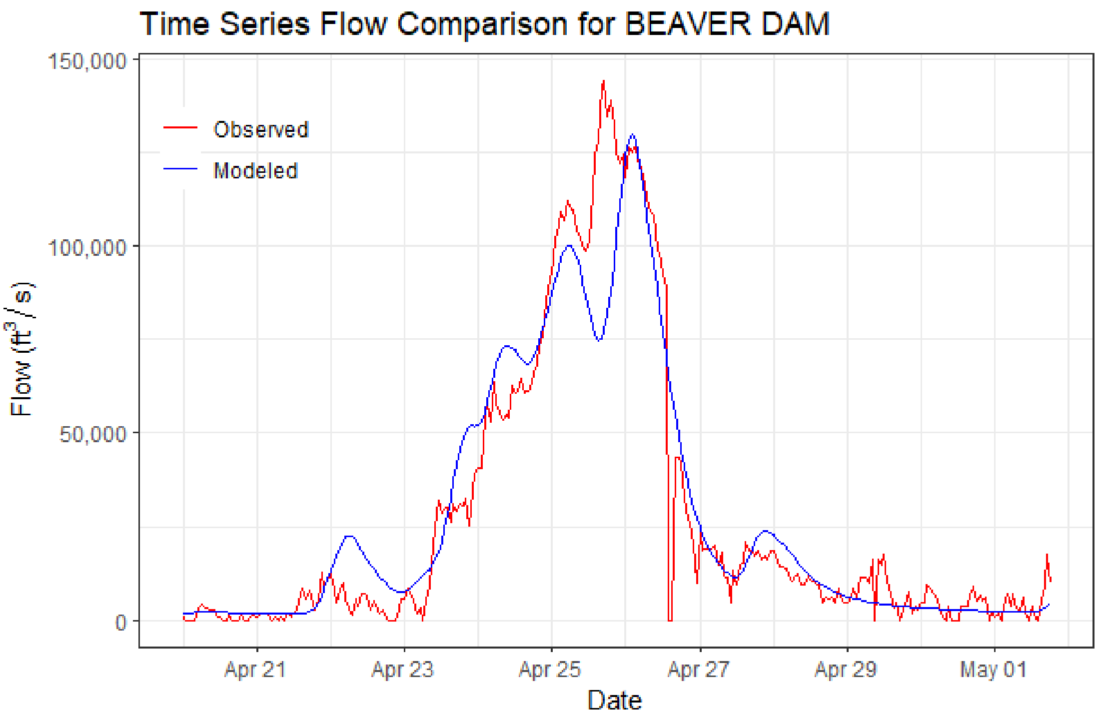


Figure 6-94. Calibration Results for BEAVER DAM HEC-HMS Junction – Flow at Beaver Dam (2011 Event)

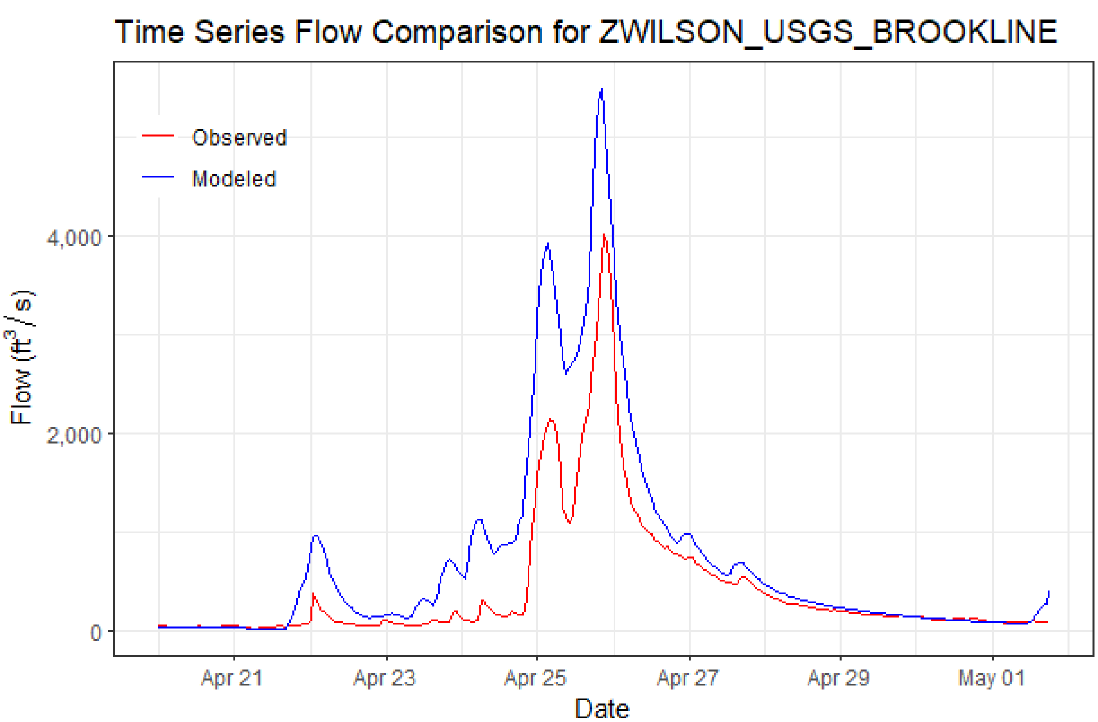


Figure 6-95. Calibration Results for ZWILSON_USGS_BROOKLINE HEC-HMS Junction – Wilson Creek near Brookline, MO Gage (07052152, 2011 Event)

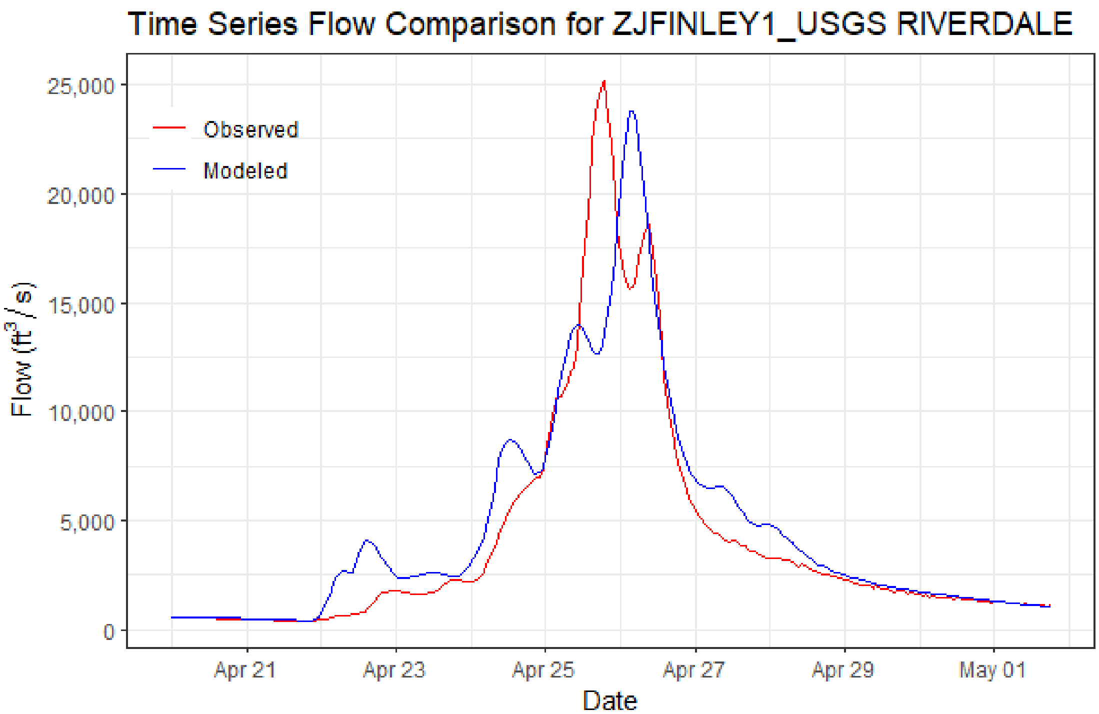


Figure 6-96. Calibration Results for ZJFINLEY1_USGS RIVERDALE HEC-HMS Junction – Finley Creek below Riverdale, MO Gage (07052345, 2011 Event)

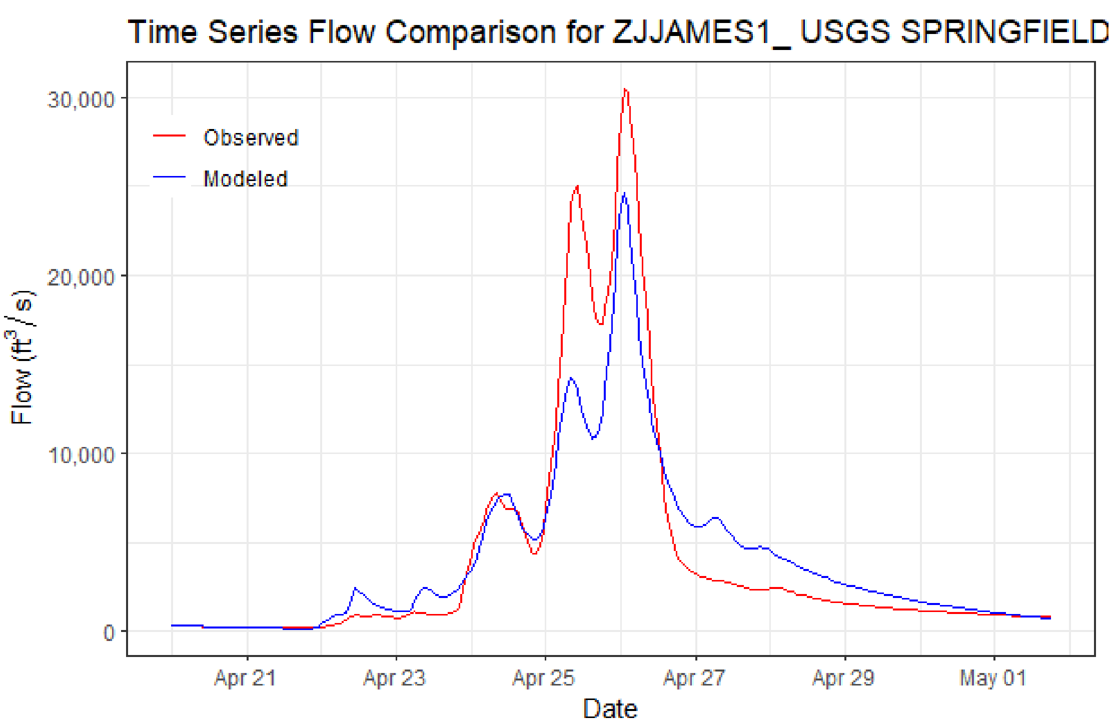


Figure 6-97. Calibration Results for ZJJAMES1_USGS SPRINGFIELD HEC-HMS Junction – James River near Springfield, MO Gage (07050700, 2011 Event)

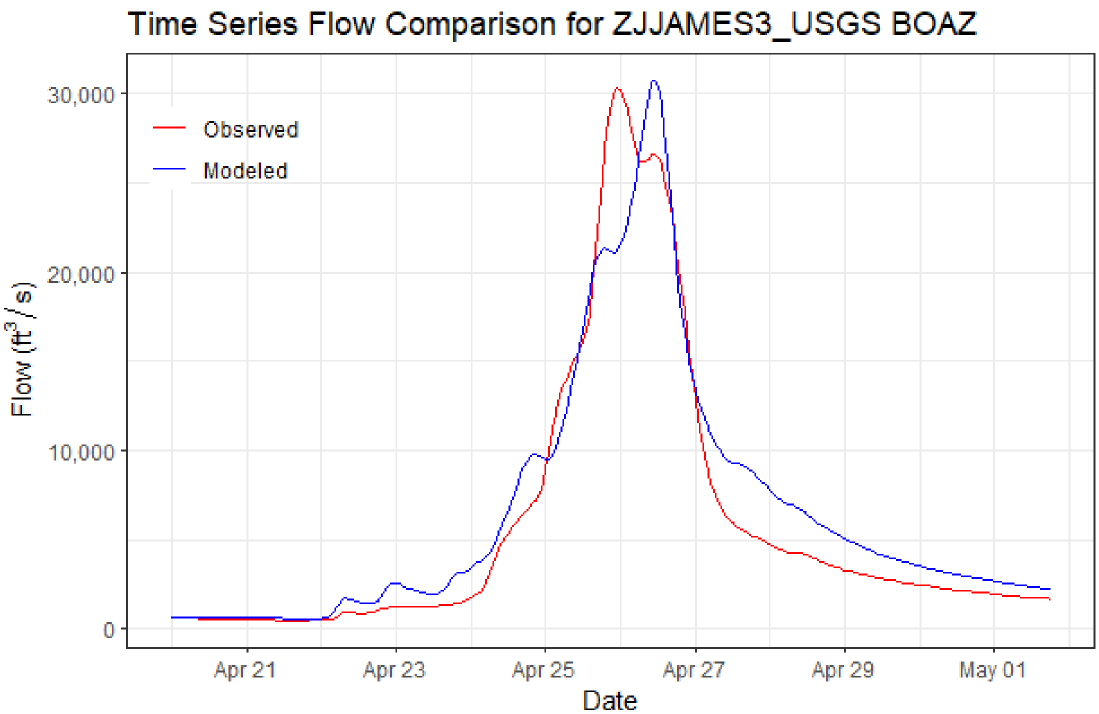


Figure 6-98. Calibration Results for ZJJAMES3_USGS BOAZ HEC-HMS Junction – James River near Boaz, MO Gage (07052250, 2011 Event)

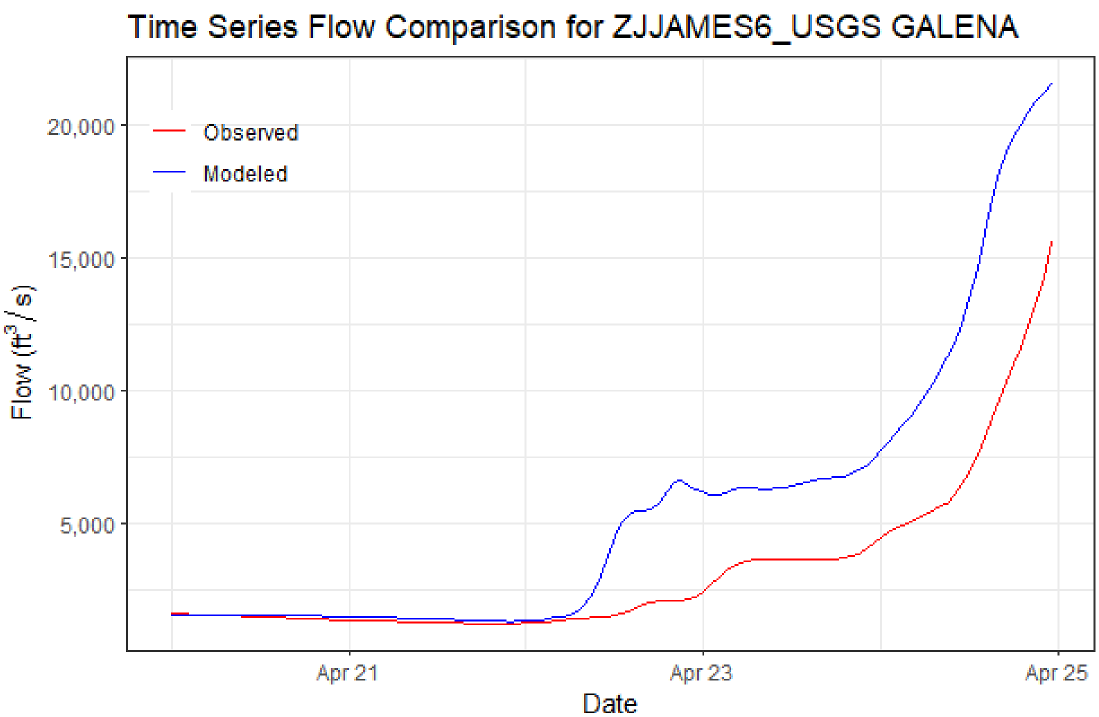


Figure 6-99. Calibration Results for ZJJAMES6_USGS GALENA HEC-HMS Junction – James River at Galena, MO Gage (07052500, 2011 Event)

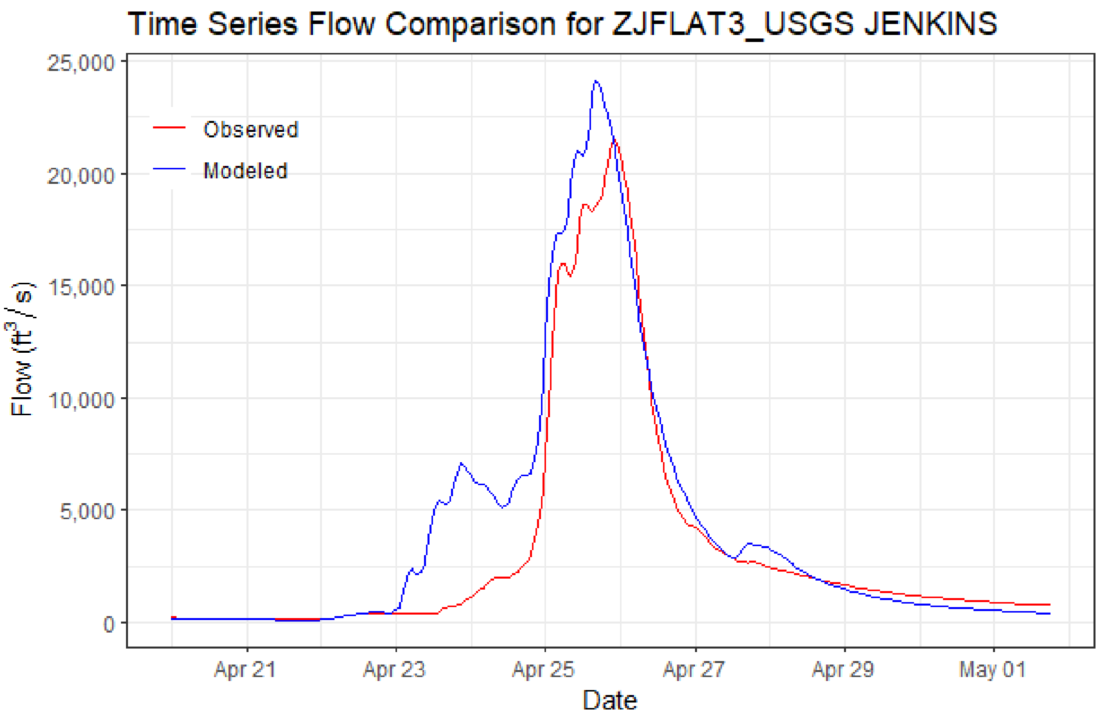


Figure 6-100. Calibration Results for ZJFLAT3_USGS JENKINS HEC-HMS Junction – Flat Creek below Jenkins, MO Gage (07052820, 2011 Event)

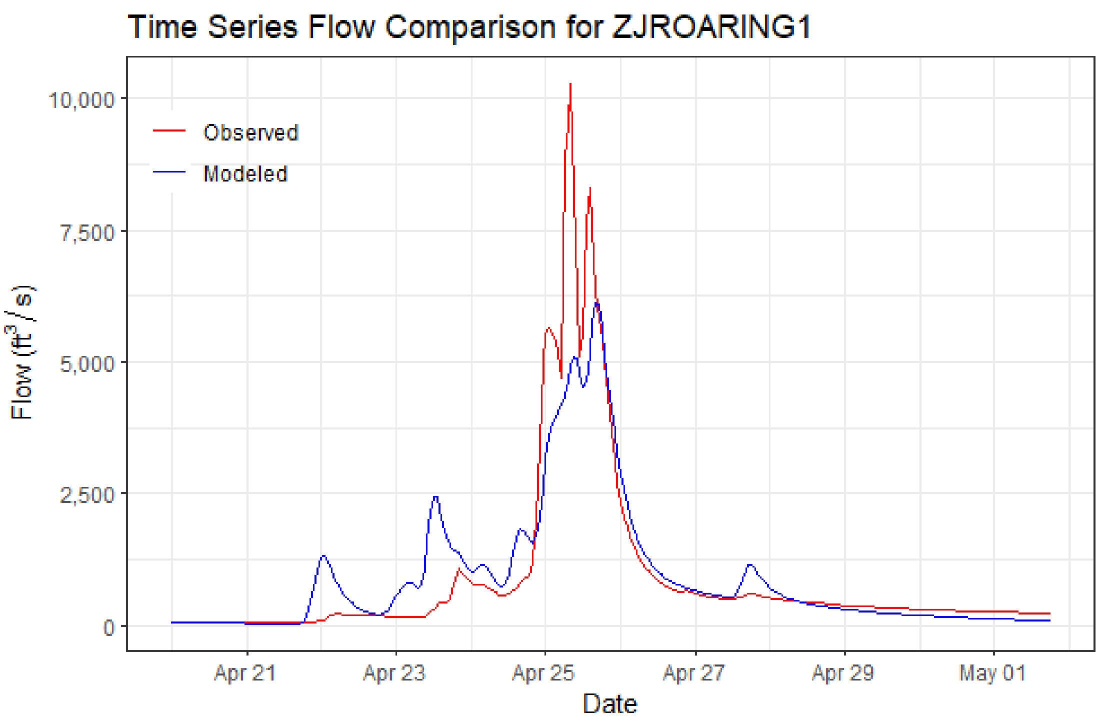


Figure 6-101. Calibration Results for ZJROARING1 HEC-HMS Junction – Roaring River at Roaring River State Park Gage (07050152, 2011 Event)

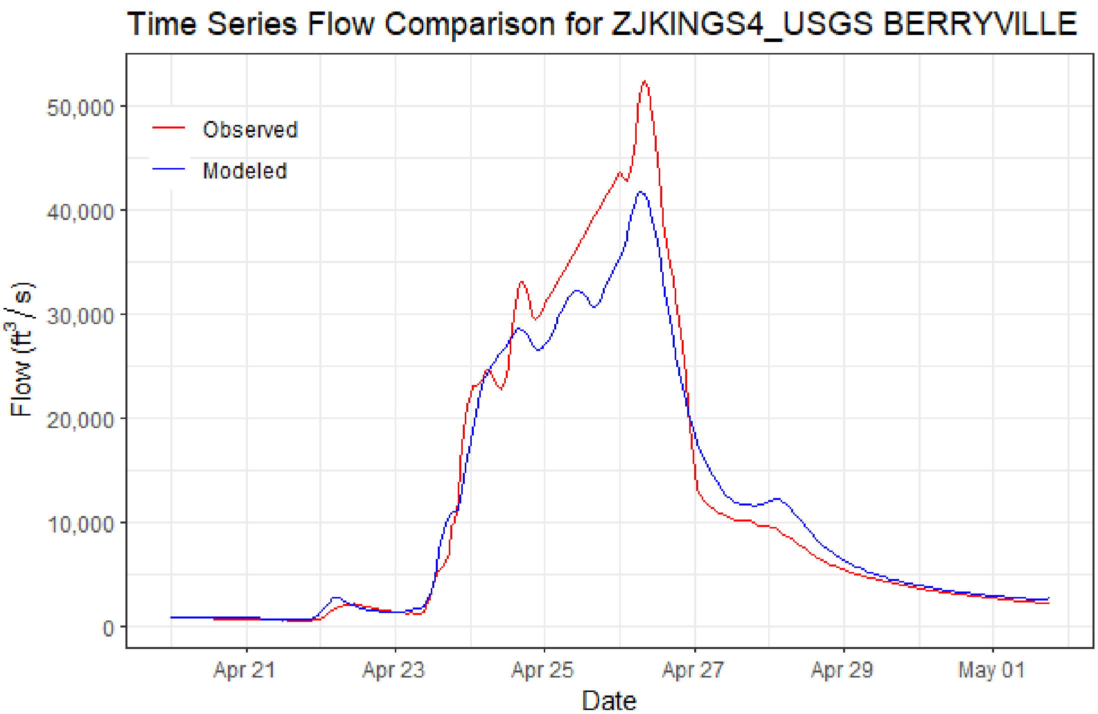


Figure 6-102. Calibration Results for ZJKINGS4_USGS BERRYVILLE HEC-HMS Junction – Kings River near Berryville, AR Gage (07050500, 2011 Event)

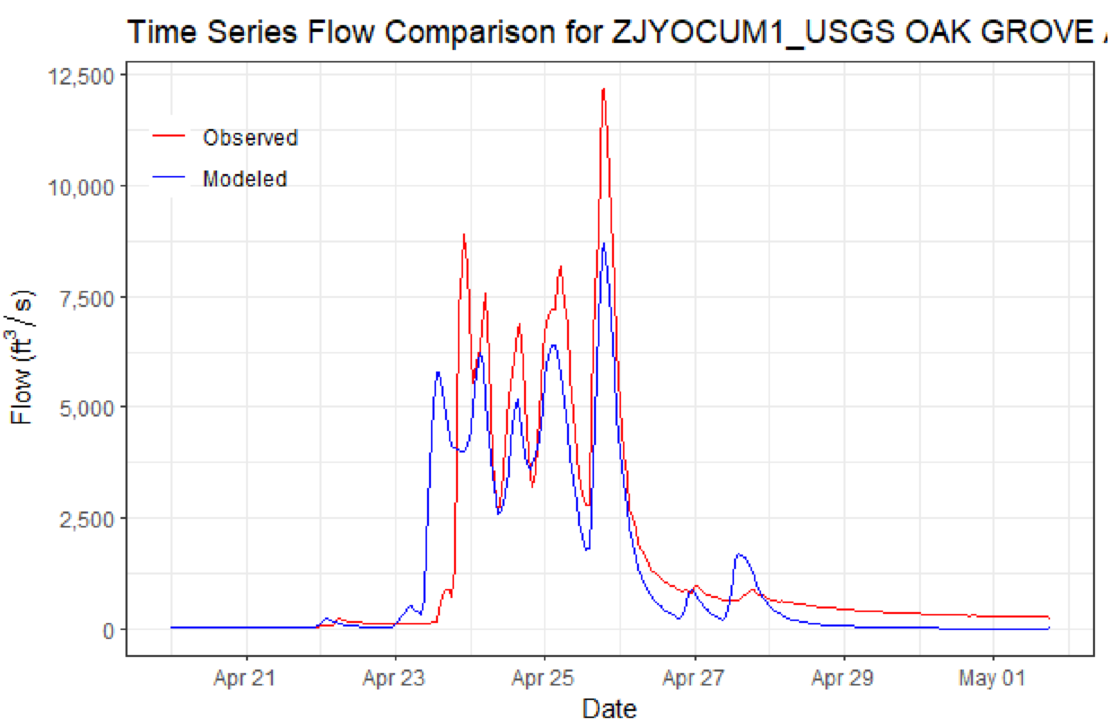


Figure 6-103. Calibration Results for ZJYOCUM1_USGS OAK GROVE AR HEC-HMS Junction – Yocum Creek near Oak Grove, AR Gage (07053250, 2011 Event)

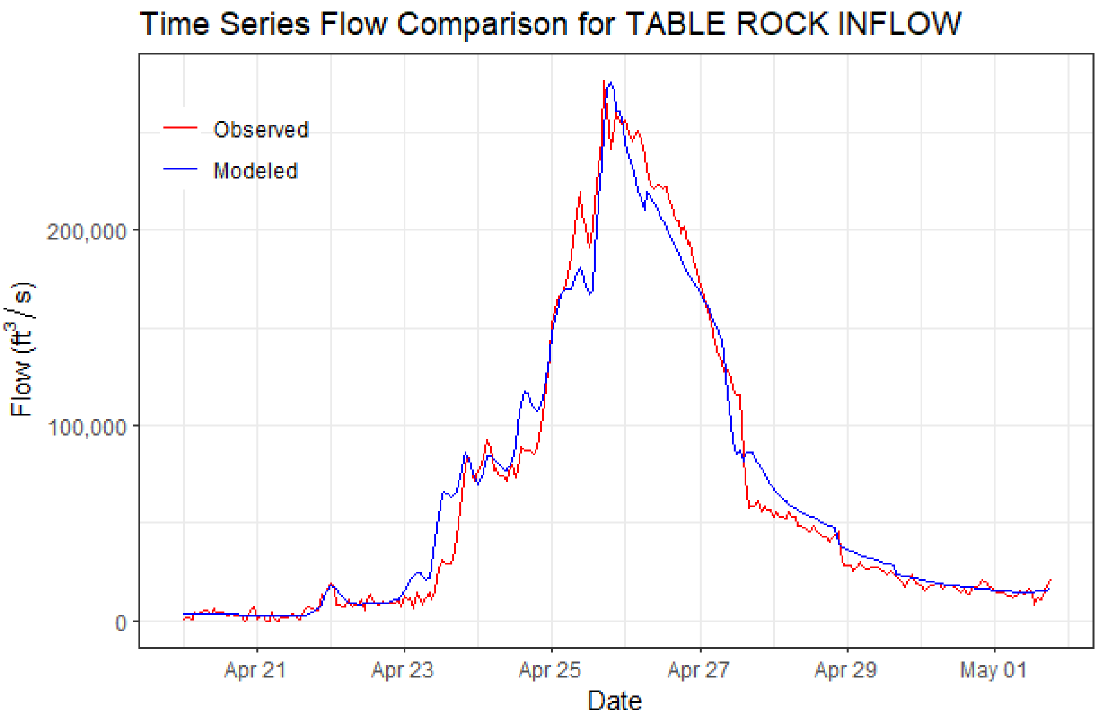


Figure 6-104. Calibration Results for TABLE ROCK INFLOW HEC-HMS Junction – Inflow to Table Rock Lake (2011 Event)

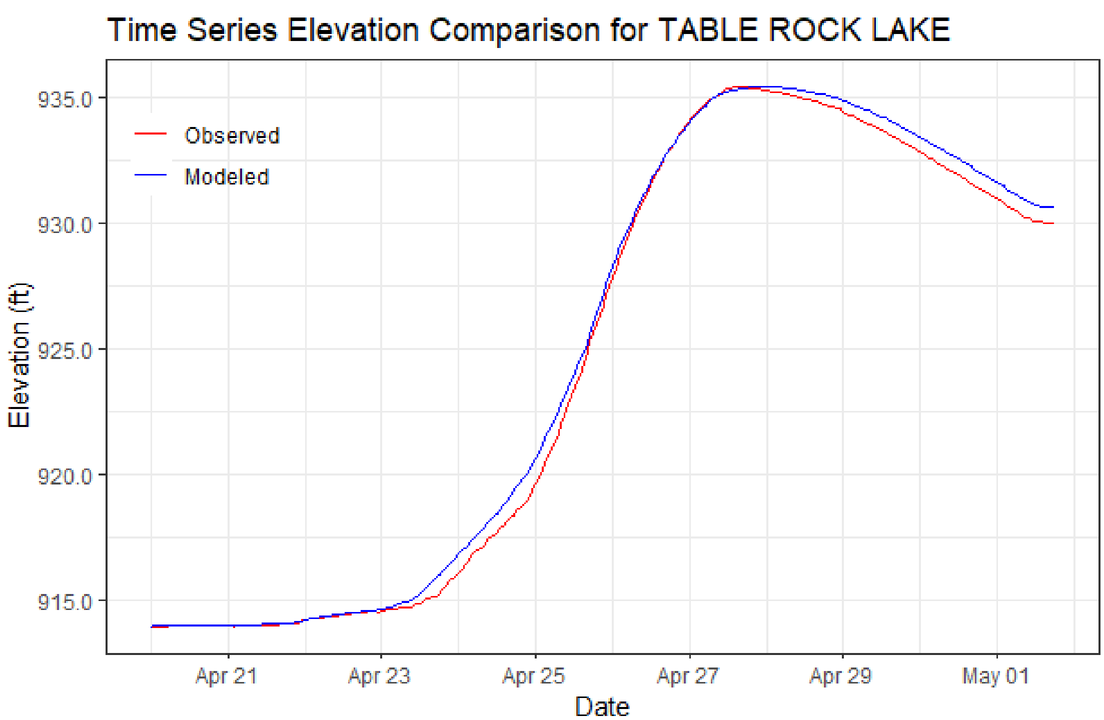


Figure 6-105. Calibration Results for TABLE ROCK LAKE HEC-HMS Junction – Elevation at Table Rock Lake (2011 Event)

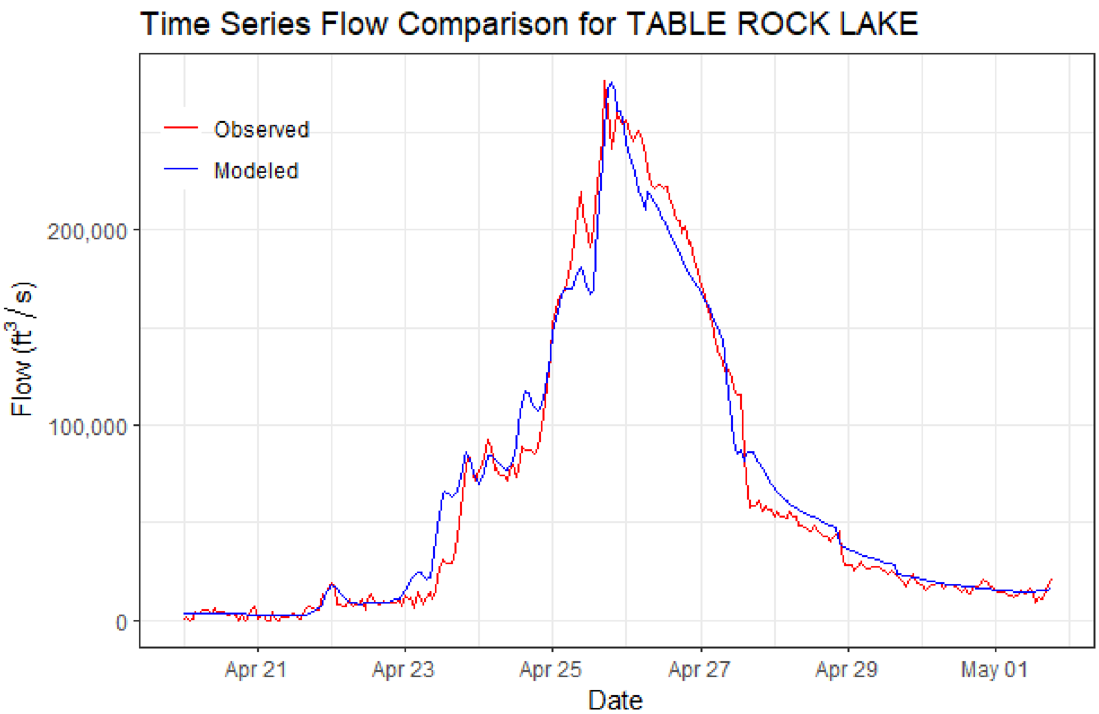


Figure 6-106. Calibration Results for TABLE ROCK LAKE HEC-HMS Junction – Flow at Table Rock Lake (2011 Event)

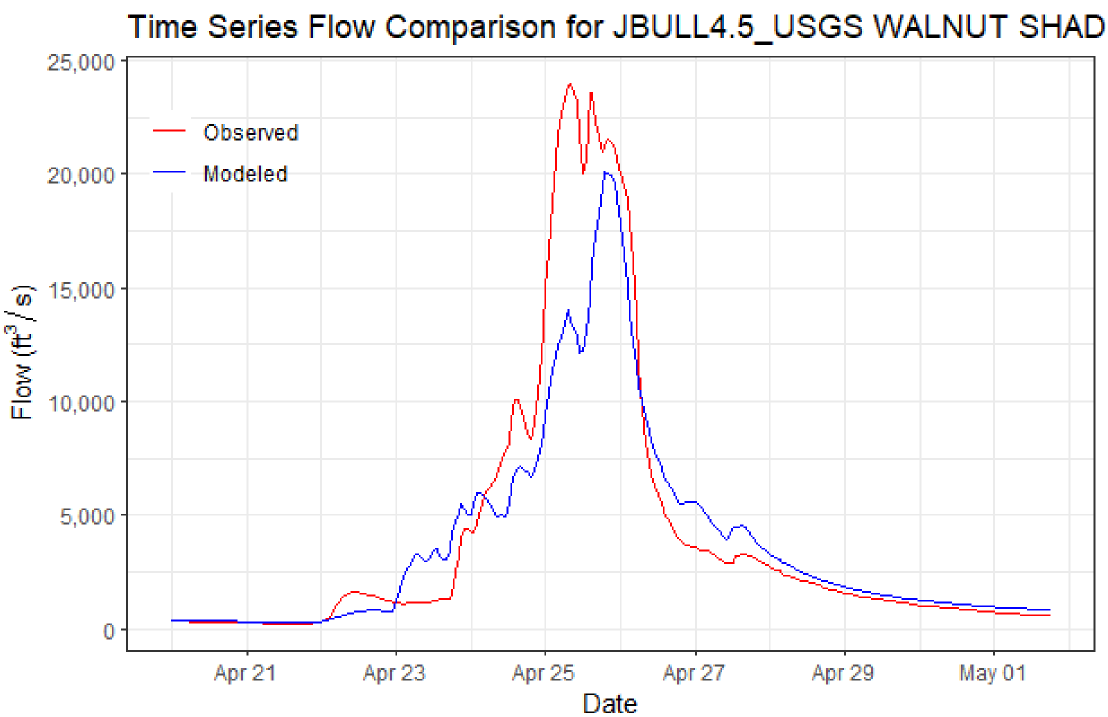


Figure 6-107. Calibration Results for JBULL4.5_USGS WALNUT SHADE HEC-HMS Junction – Bull Creek near Walnut Shade, MO Gage (07053810, 2011 Event)

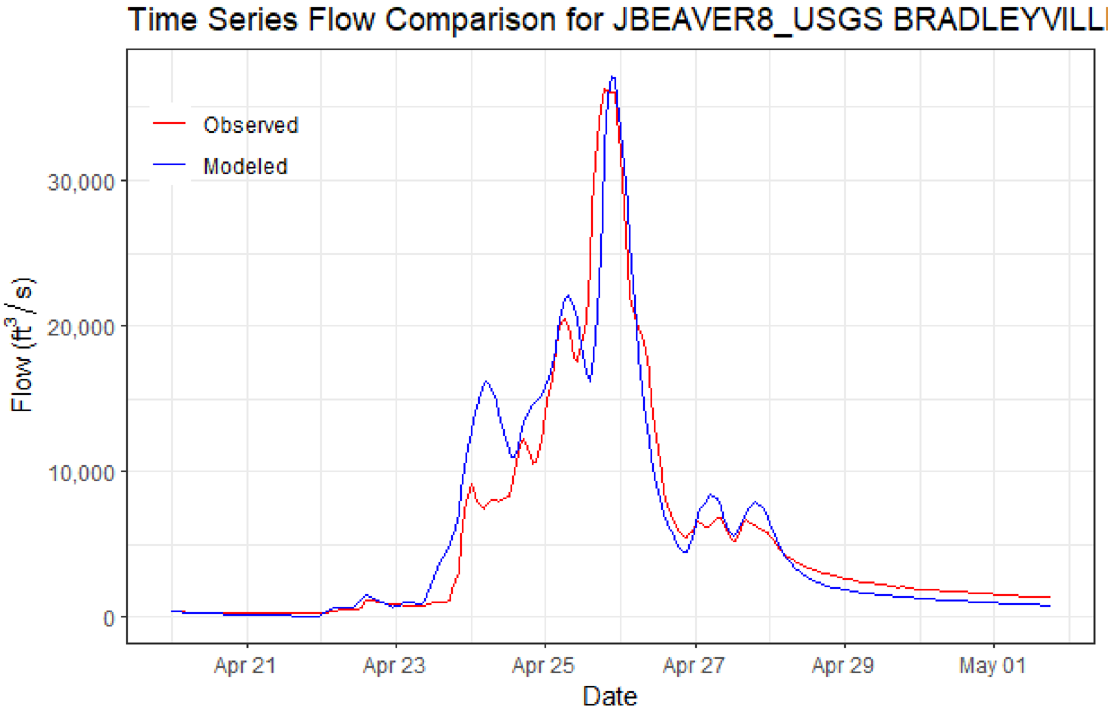


Figure 6-108. Calibration Results for JBEAVER8_USGS BRADLEYVILLE HEC-HMS Junction – Beaver Creek at Bradleyville, MO Gage (07054080, 2011 Event)

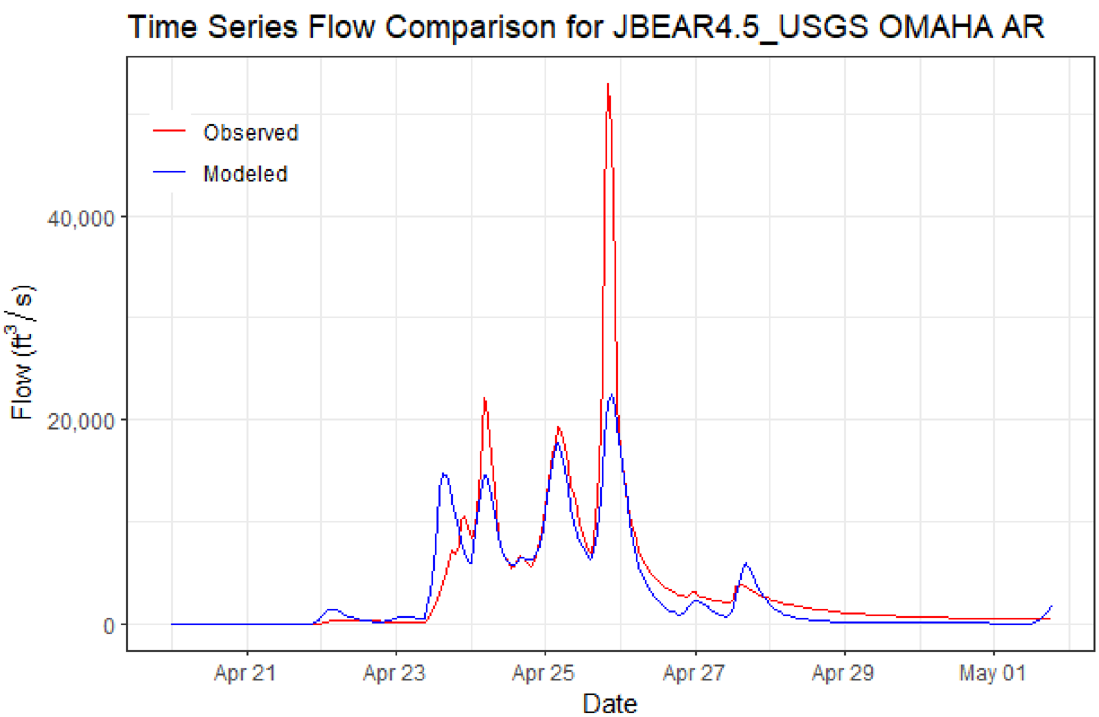


Figure 6-109. Calibration Results for JBEAR4.5_USGS OMAHA AR HEC-HMS Junction – Bear Creek near Omaha, AR Gage (07054410, 2011 Event)

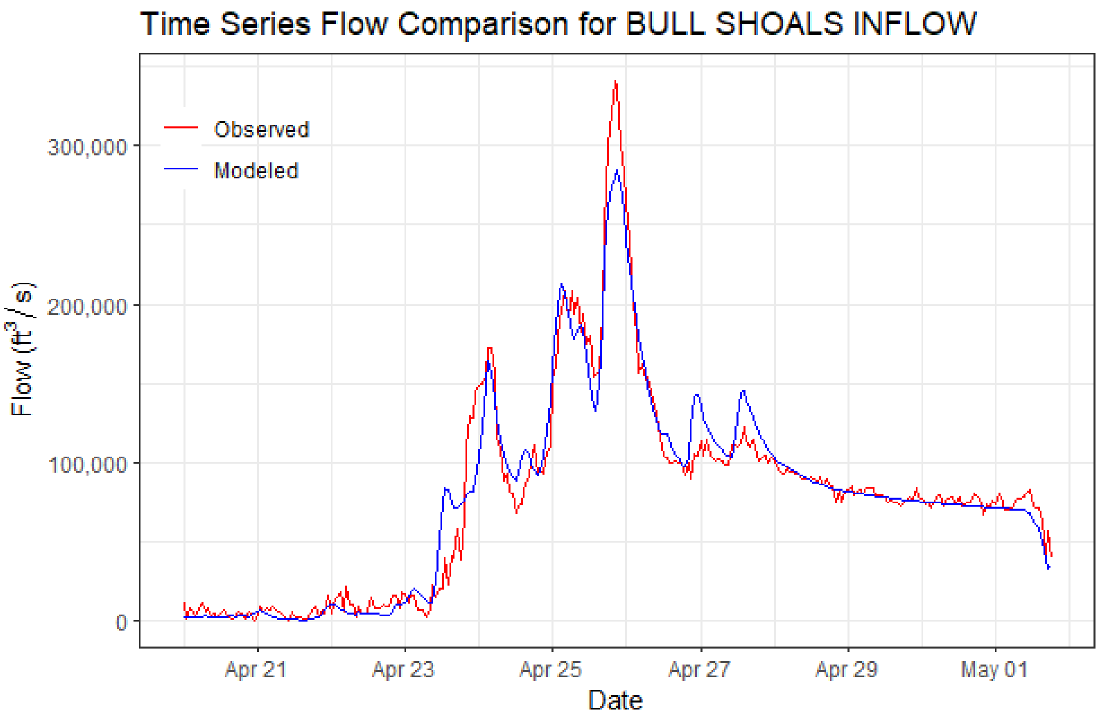


Figure 6-110. Calibration Results for BULL SHOALS INFLOW HEC-HMS Junction – Inflow to Bull Shoals Lake (2011 Event)

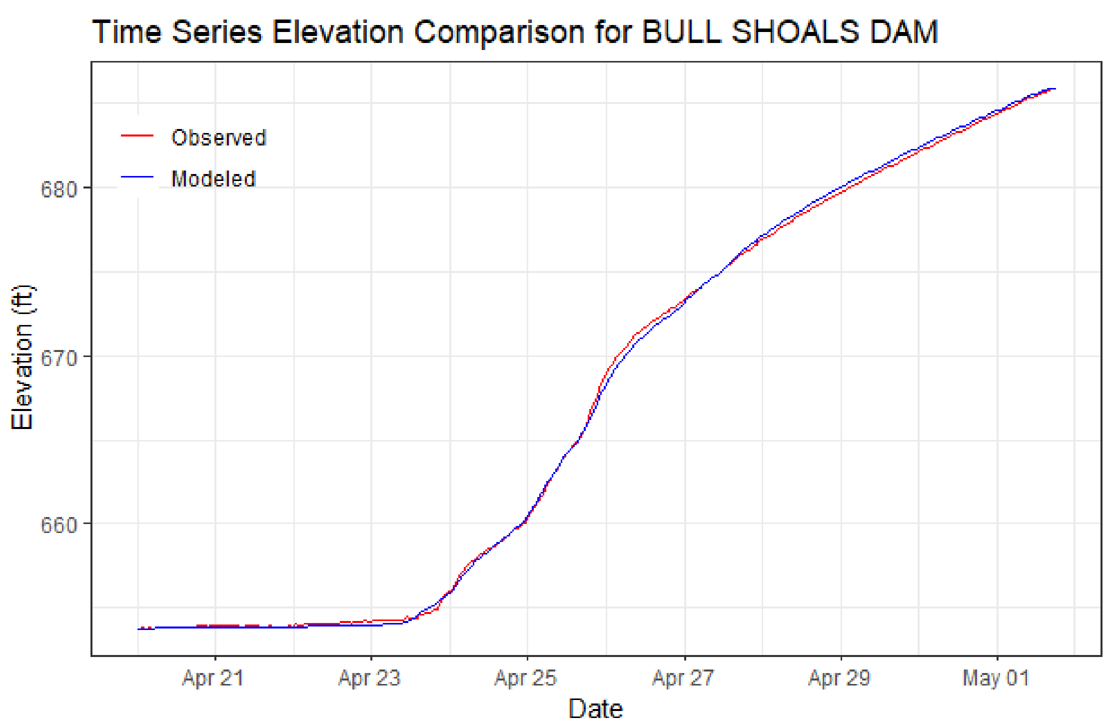


Figure 6-111. Calibration Results for BULL SHOALS DAM HEC-HMS Junction – Elevation at Bull Shoals Lake (2011 Event)

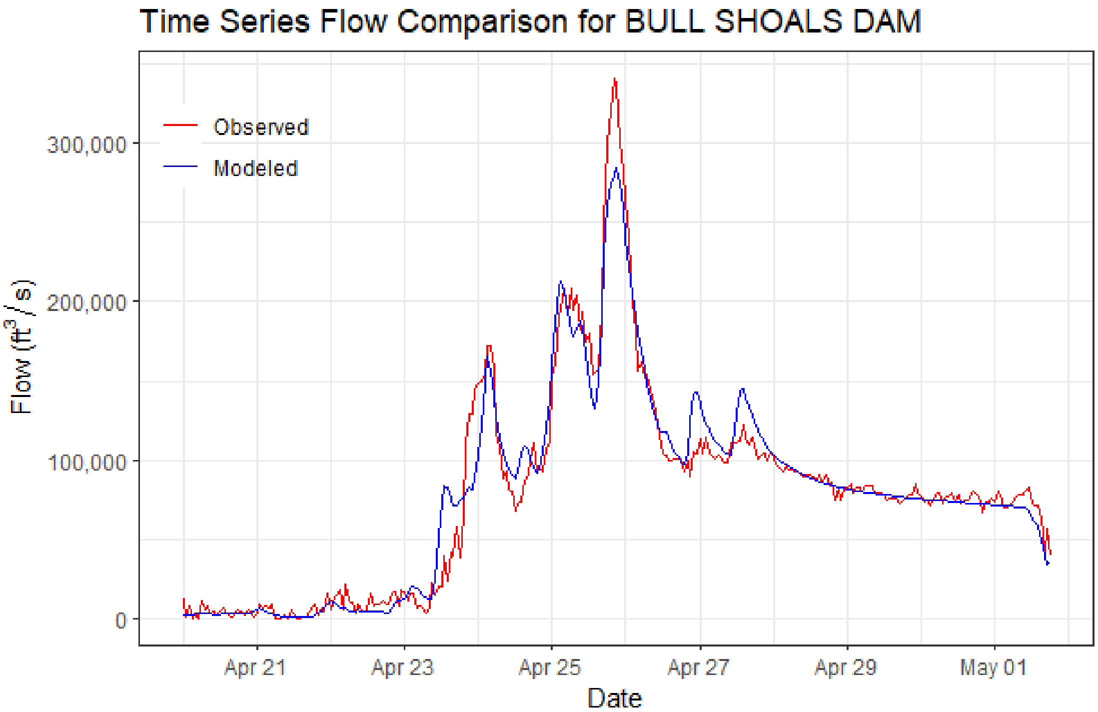


Figure 6-112. Calibration Results for BULL SHOALS DAM HEC-HMS Junction – Flow at Bull Shoals Dam (2011 Event)

6.4.3.4 2008 Validation Event (09Apr2008 to 15May2008)

The results for the validation of the 2008 event are shown in Figure 6-113 through Figure 6-135.

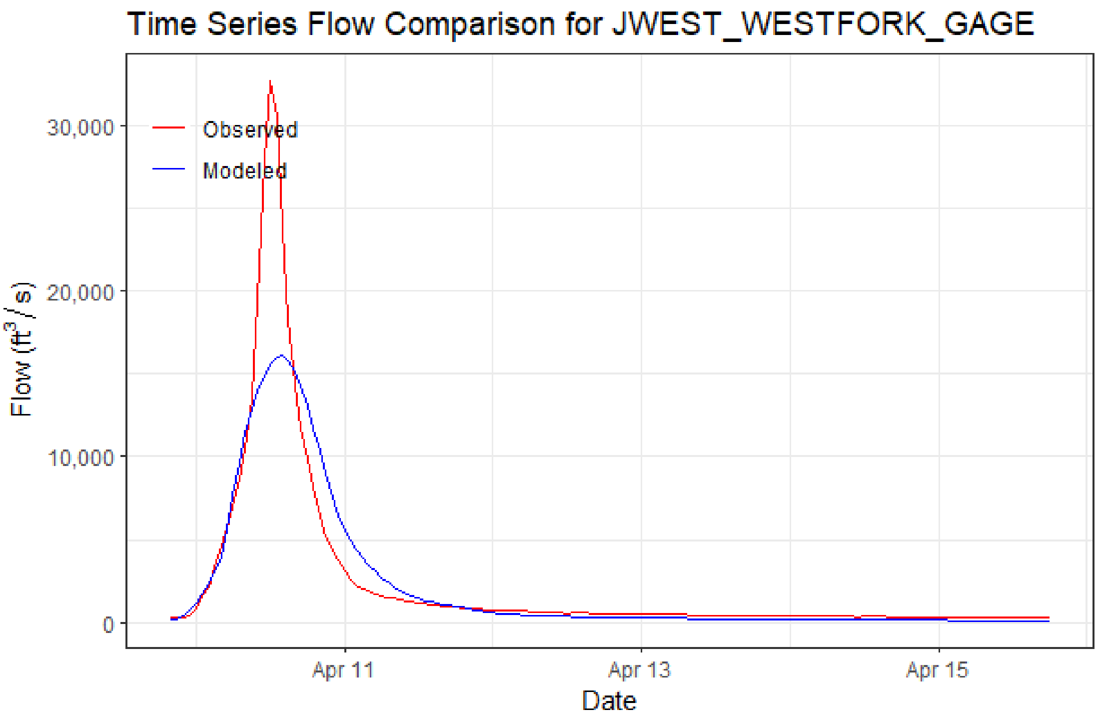


Figure 6-113. Validation Results for JWEST_WESTFORK_GAGE HEC-HMS Junction – West Fork of White River east of Fayetteville, AR Gage (2008 Event)

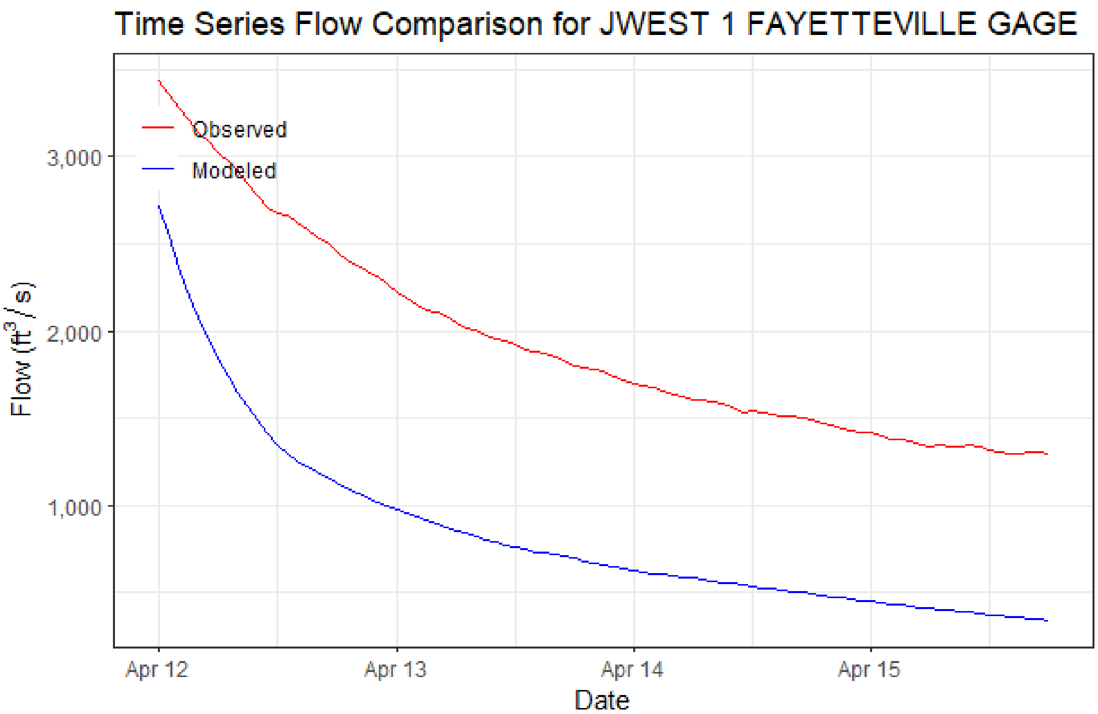


Figure 6-114. Validation Results for JWEST 1 FAYETTEVILLE GAGE HEC-HMS Junction – White River at Fayetteville, AR Gage (2008 Event)

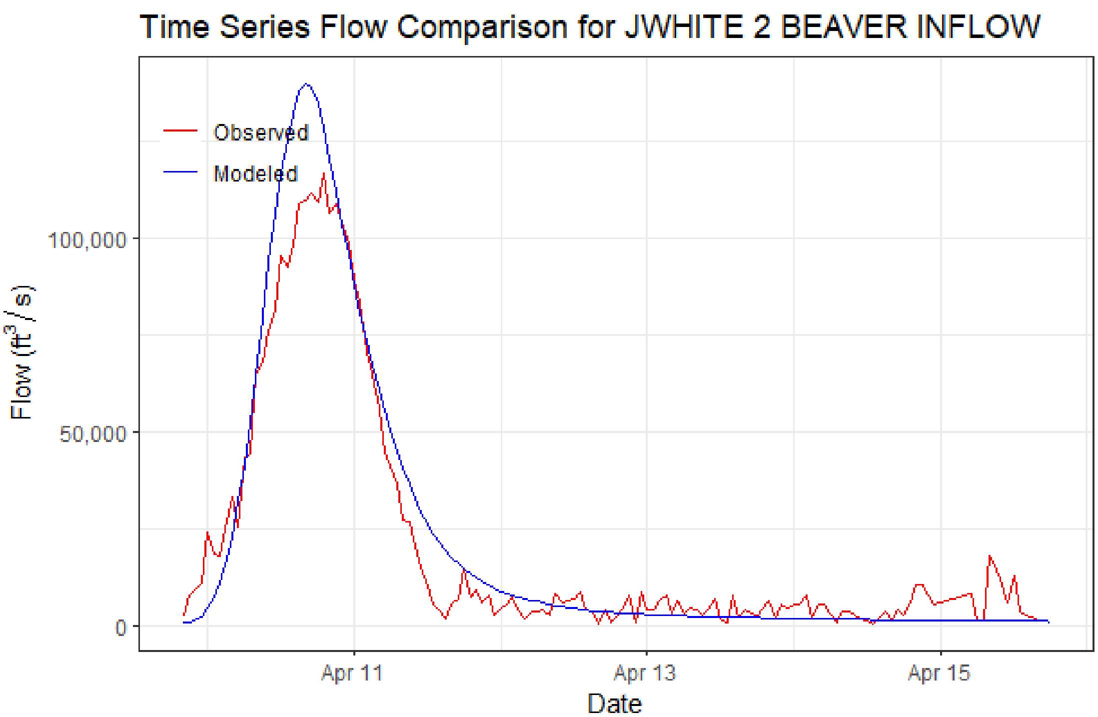


Figure 6-115. Validation Results for JWHITE 2 BEAVER INFLOW HEC-HMS Junction – Inflow to Beaver Lake (2008 Event)

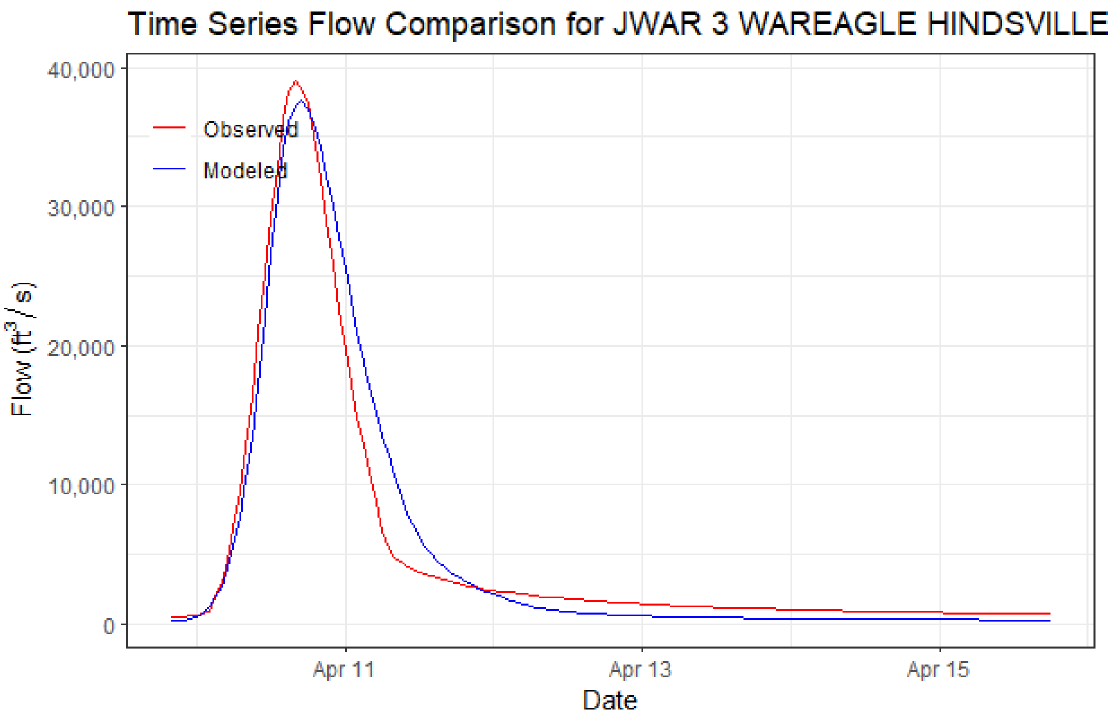


Figure 6-116. Validation Results for JWAR 3 WAREAGLE HINDSVILLE HEC-HMS Junction – War Eagle Creek near Hindsville, AR Gage (2008 Event)

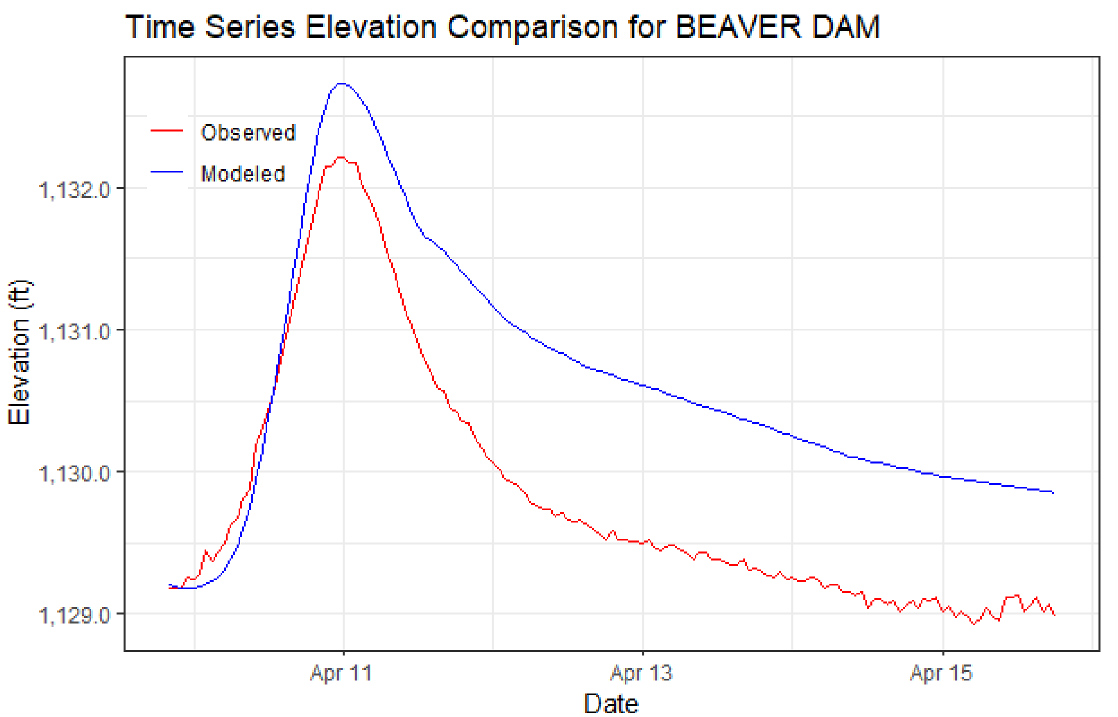


Figure 6-117. Validation Results for BEAVER DAM HEC-HMS Junction – Elevation at Beaver Dam (2008 Event)

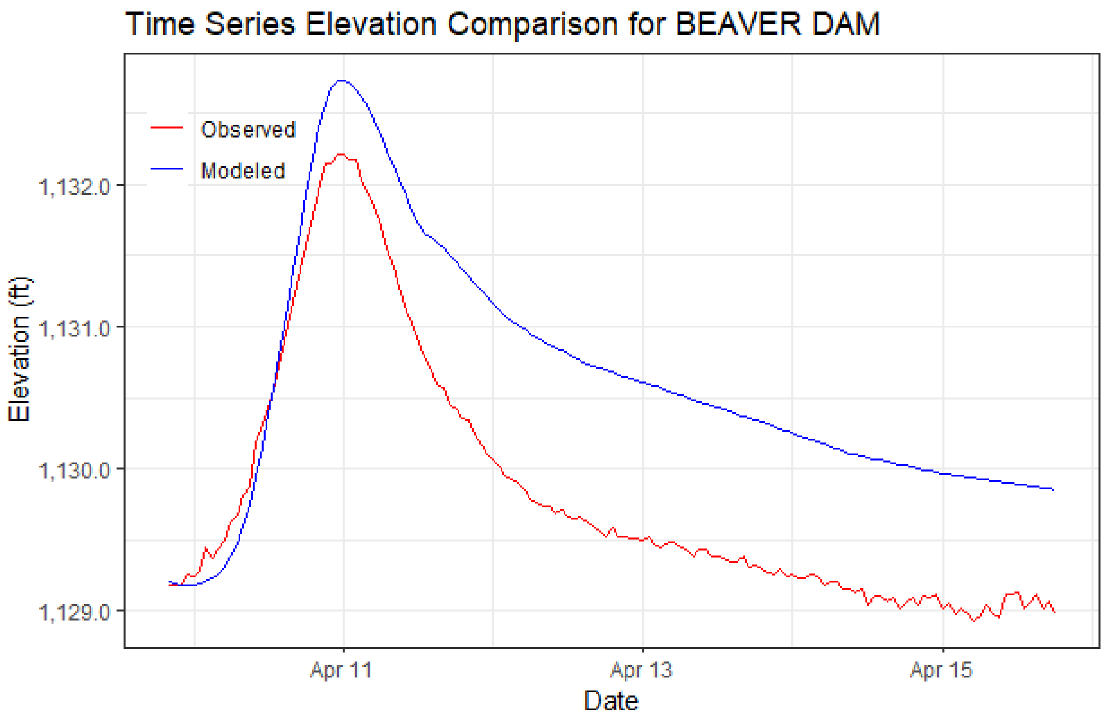


Figure 6-118. Validation Results for BEAVER DAM HEC-HMS Junction – Flow at Beaver Dam (2008 Event)

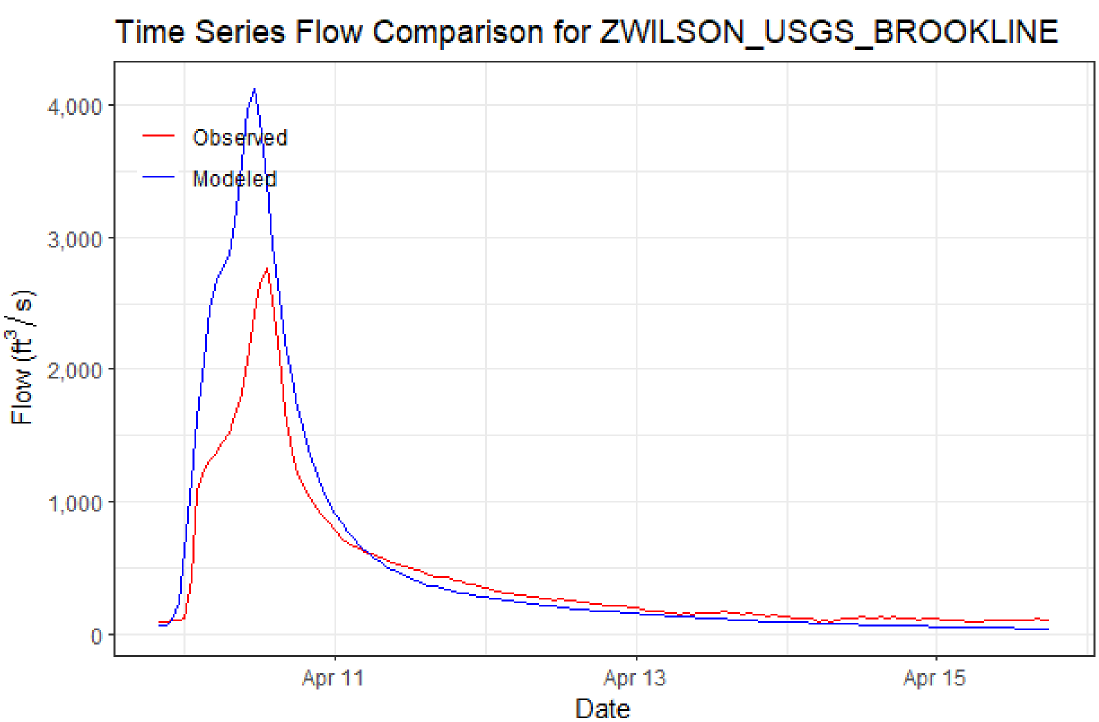


Figure 6-119. Validation Results for ZWILSON_USGS_BROOKLINE HEC-HMS Junction – Wilson Creek near Brookline, MO Gage (2008 Event)

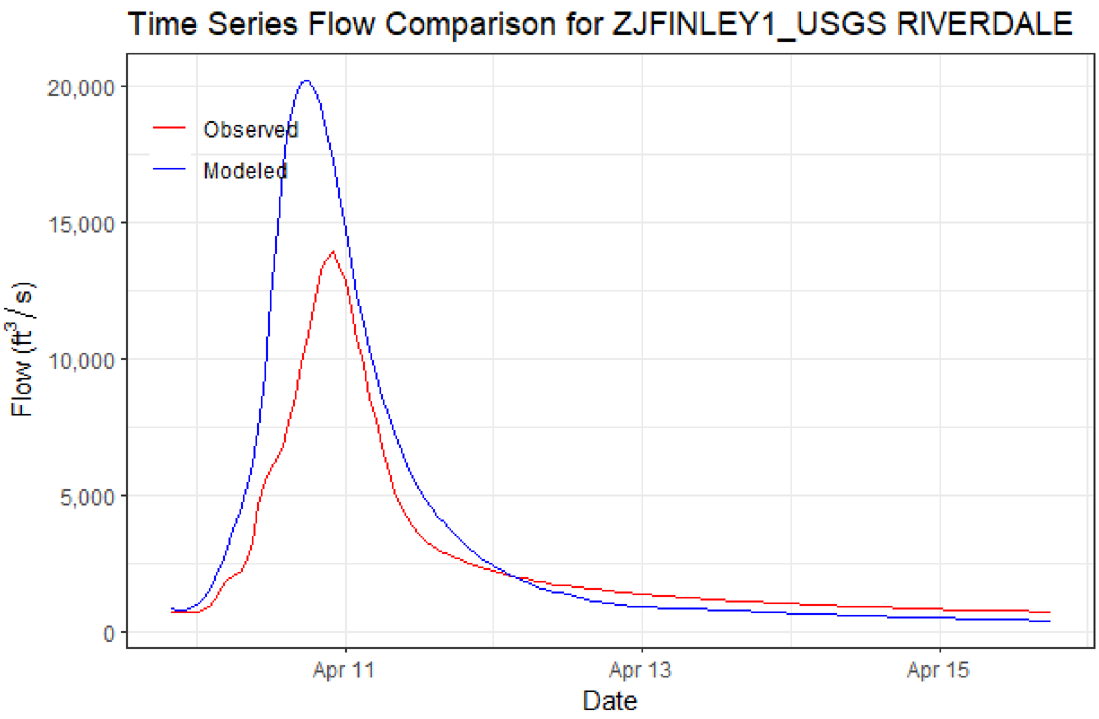


Figure 6-120. Validation Results for ZJFINLEY1_USGS RIVERDALE HEC-HMS Junction – Finley Creek below Riverdale, MO Gage (2008 Event)

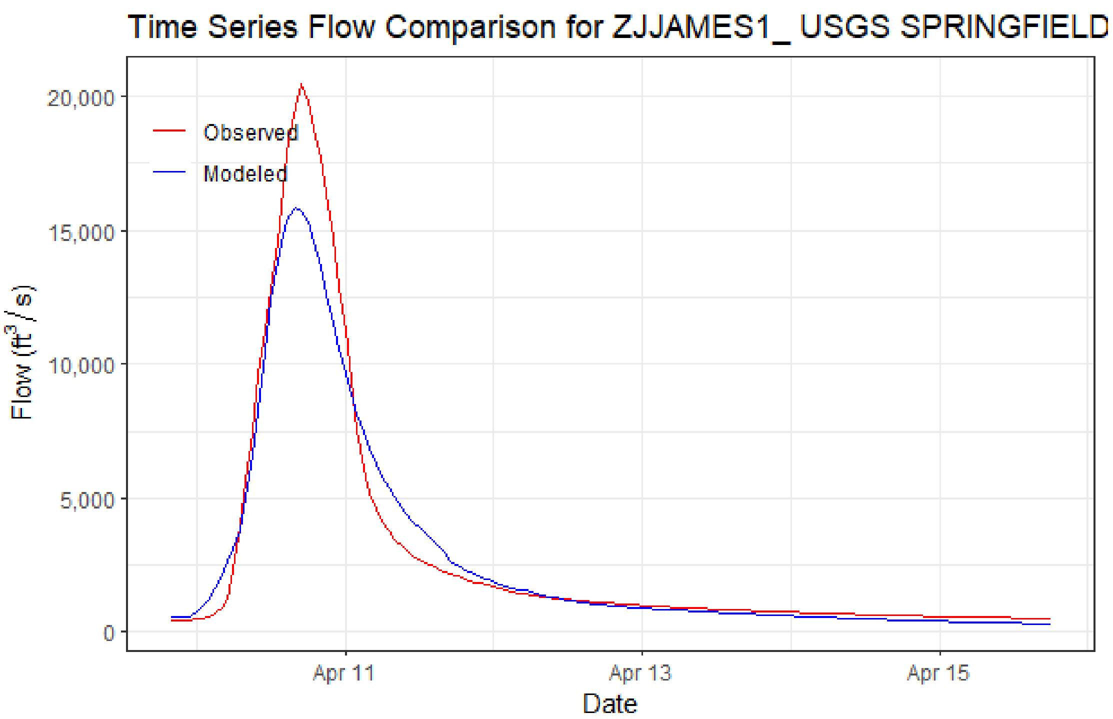


Figure 6-121. Validation Results for ZJJAMES1_USGS SPRINGFIELD HEC-HMS Junction – James River near Springfield, MO Gage (2008 Event)

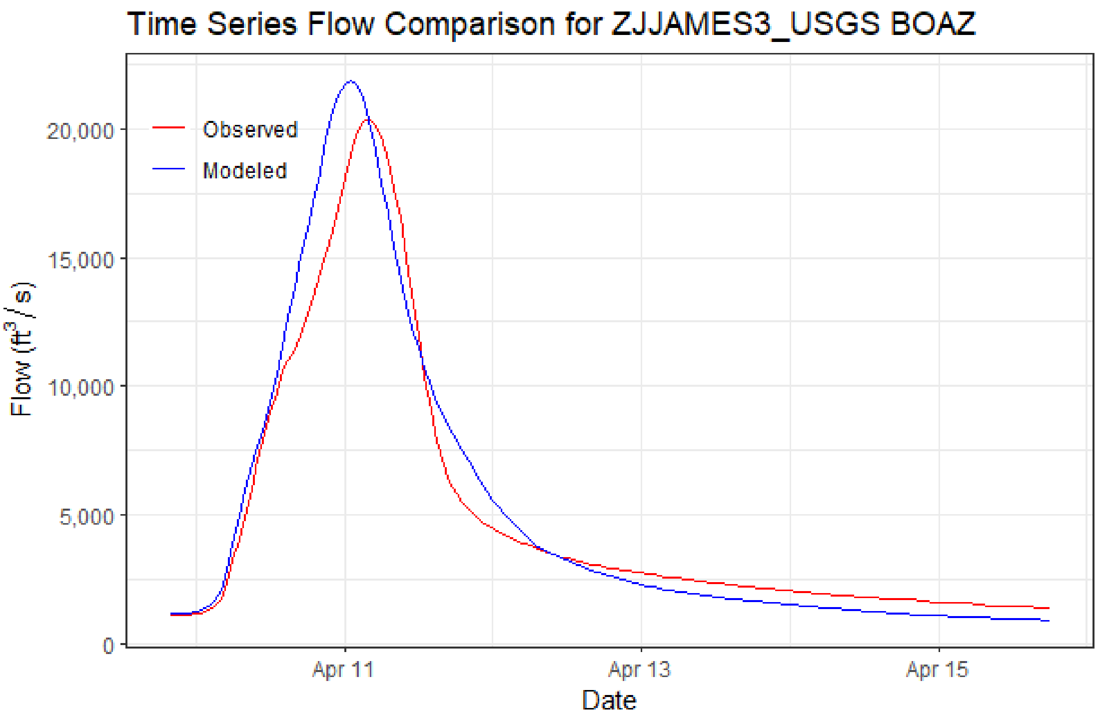


Figure 6-122. Validation Results for ZJJAMES3_USGS BOAZ HEC-HMS Junction – James River near Boaz, MO Gage (2008 Event)

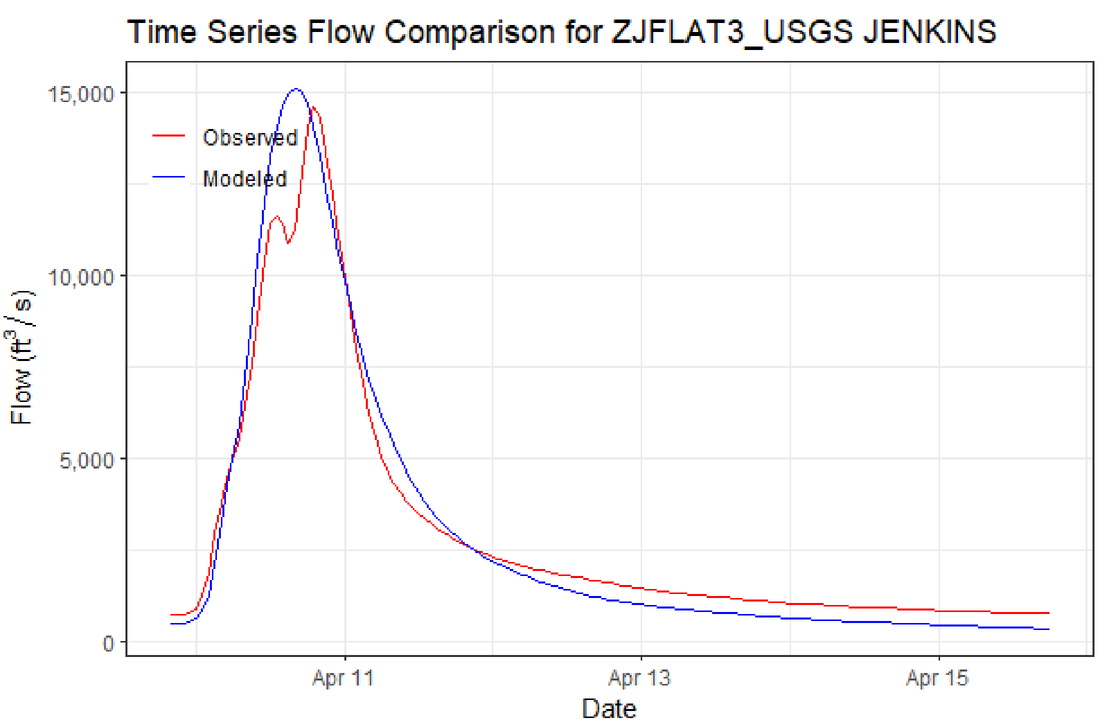


Figure 6-123. Validation Results for ZJFLAT3_USGS JENKINS HEC-HMS Junction – Flat Creek below Jenkins, MO Gage (2008 Event)

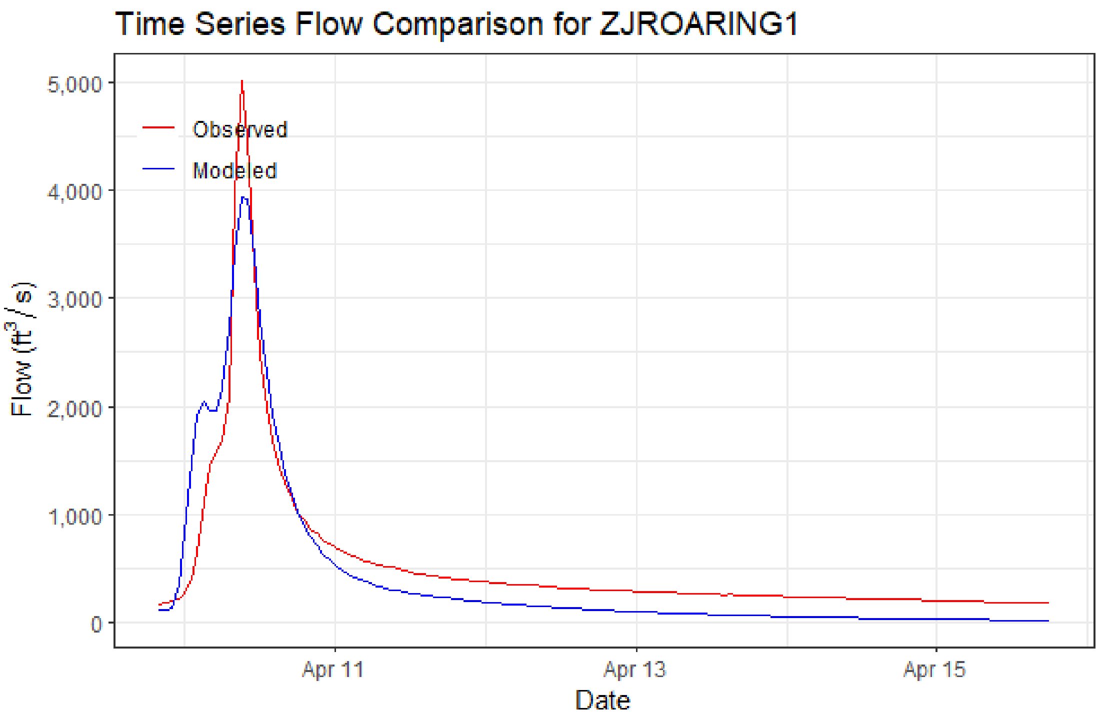


Figure 6-124. Validation Results for ZJROARING1 HEC-HMS Junction – Roaring River at Roaring River State Park Gage (2008 Event)

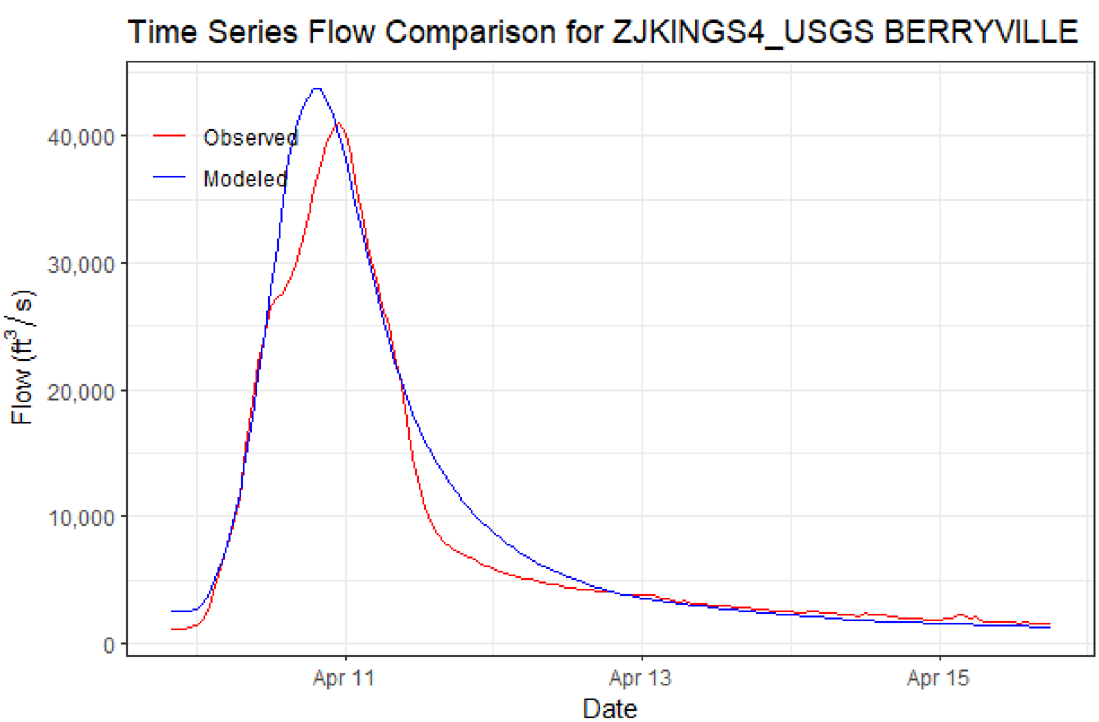


Figure 6-125. Validation Results for ZJKINGS4_USGS BERRYVILLE HEC-HMS Junction – Kings River near Berryville, AR Gage (2008 Event)

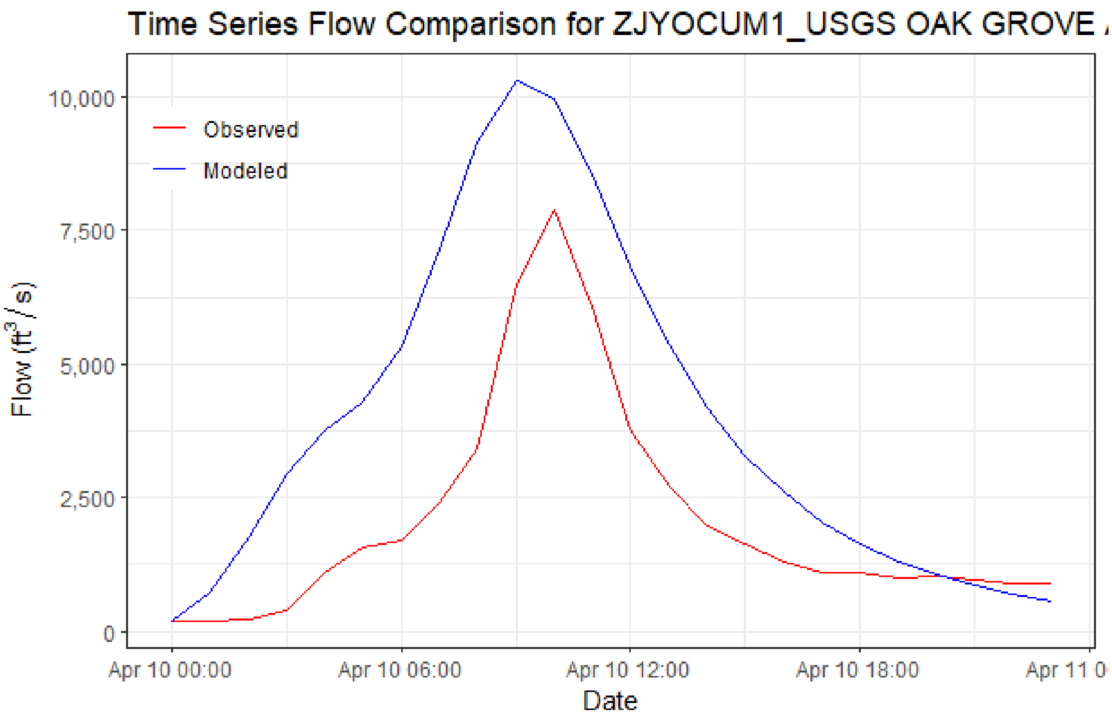


Figure 6-126. Validation Results for ZJYOCUM_USGS OAK GROVE AR HEC-HMS Junction – Yocum Creek near Oak Grove, AR Gage (2008 Event)

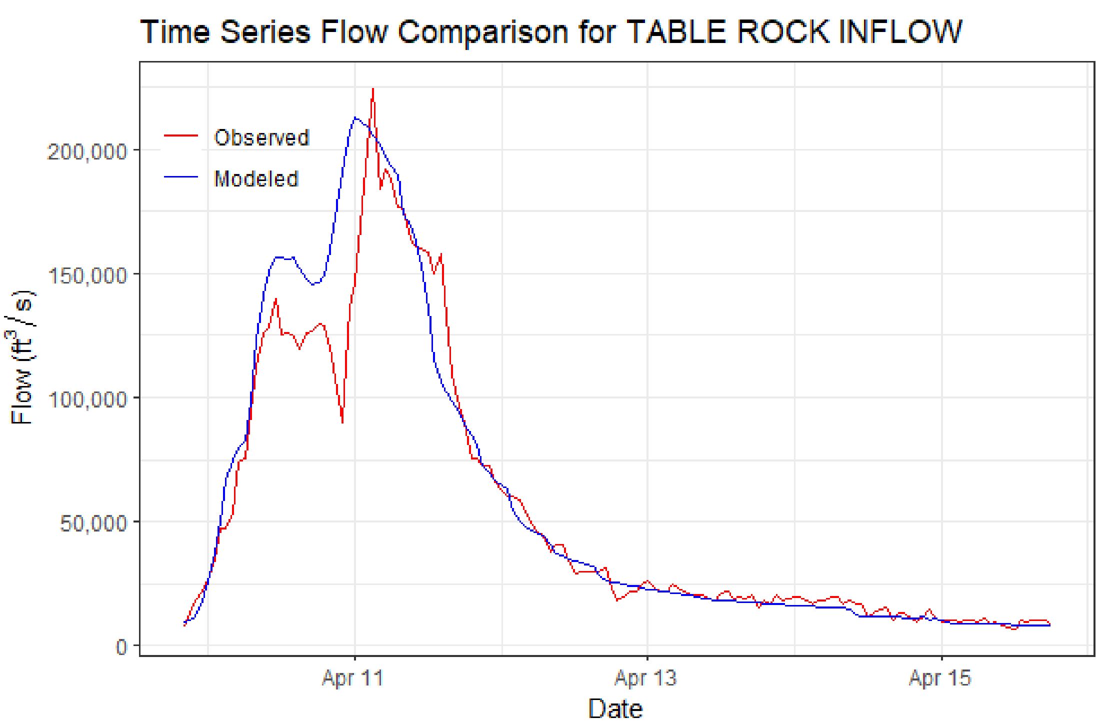


Figure 6-127. Validation Results for TABLE ROCK INFLOW HEC-HMS Junction – Inflow to Table Rock Lake (2008 Event)

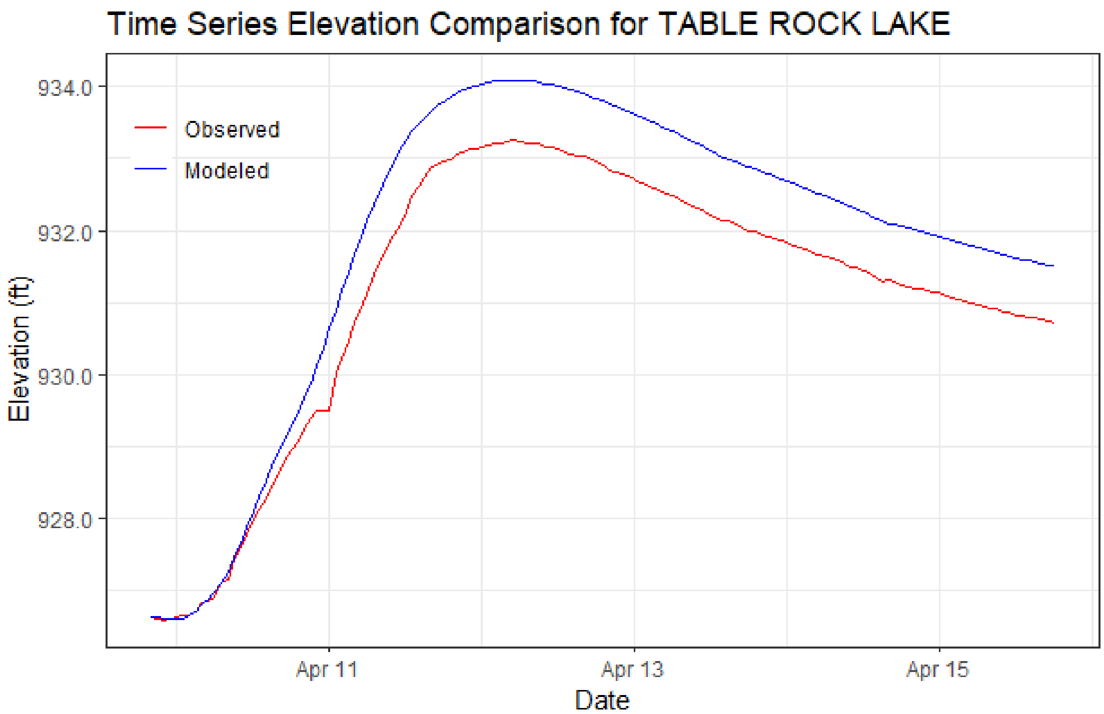


Figure 6-128. Validation Results for TABLE ROCK LAKE HEC-HMS Junction – Elevation at Table Rock Lake (2008 Event)

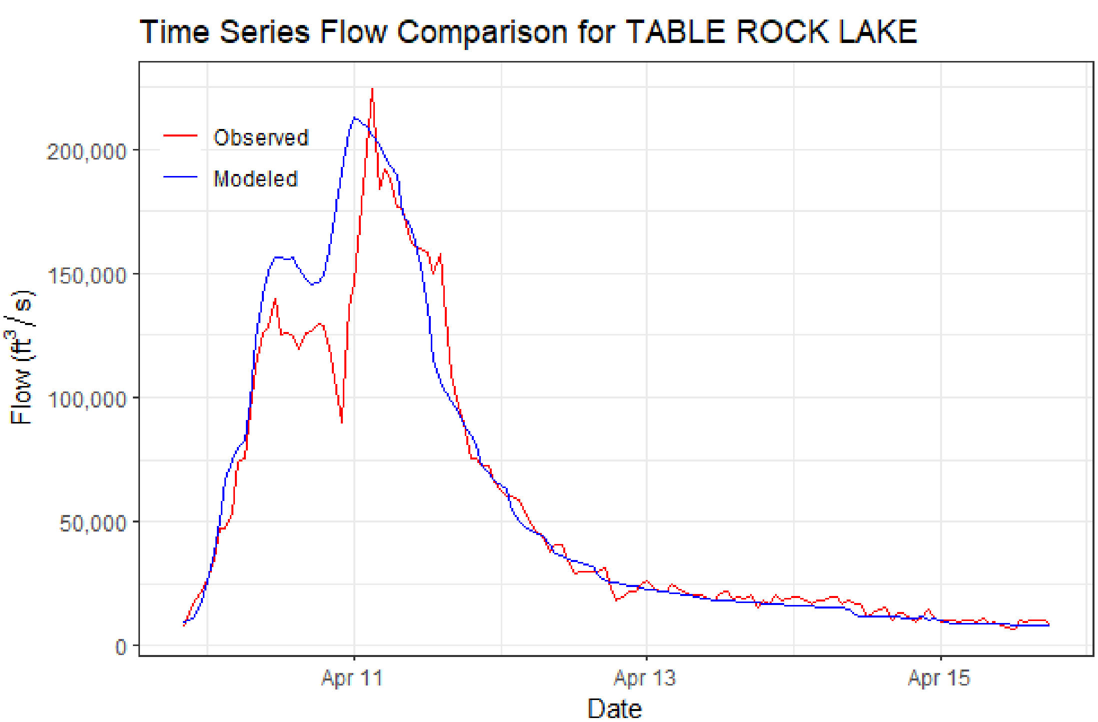


Figure 6-129. Validation Results for TABLE ROCK LAKE HEC-HMS Junction – Flow at Table Rock Lake (2008 Event)

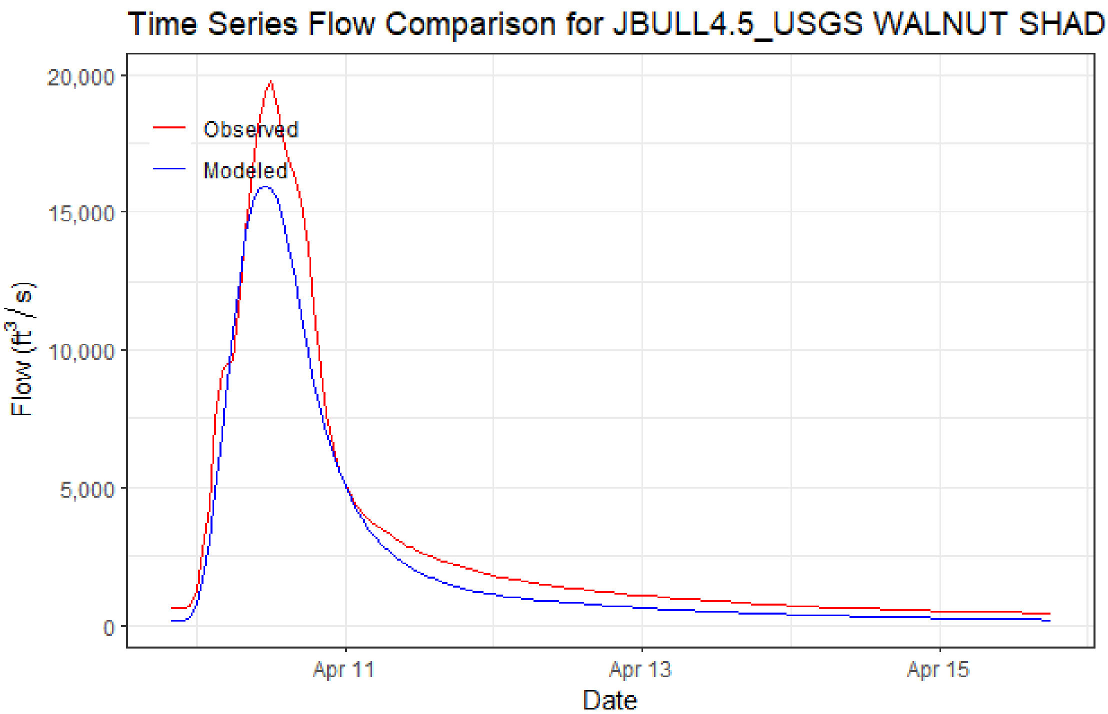


Figure 6-130. Validation Results for JBULL4.5_USGS WALNUT SHADE HEC-HMS Junction – Bull Creek near Walnut Shade, MO Gage (2008 Event)

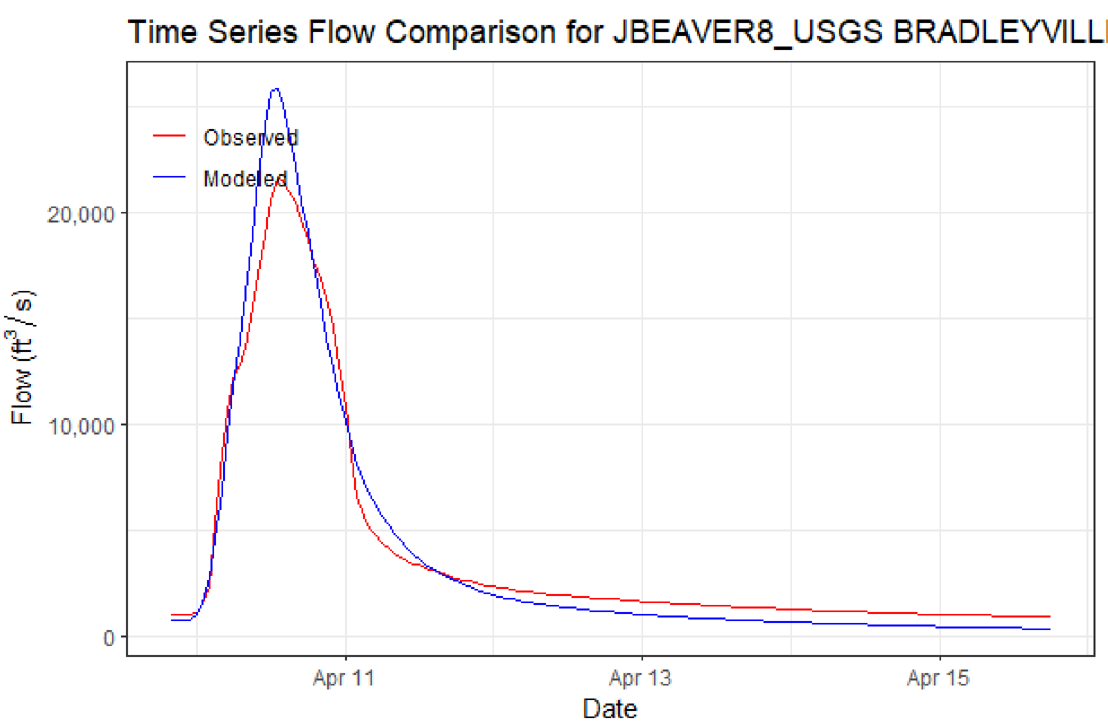


Figure 6-131. Validation Results for JBEAVER8_USGS BRADLEYVILLE HEC-HMS Junction – Beaver Creek at Bradleyville, MO Gage (2008 Event)

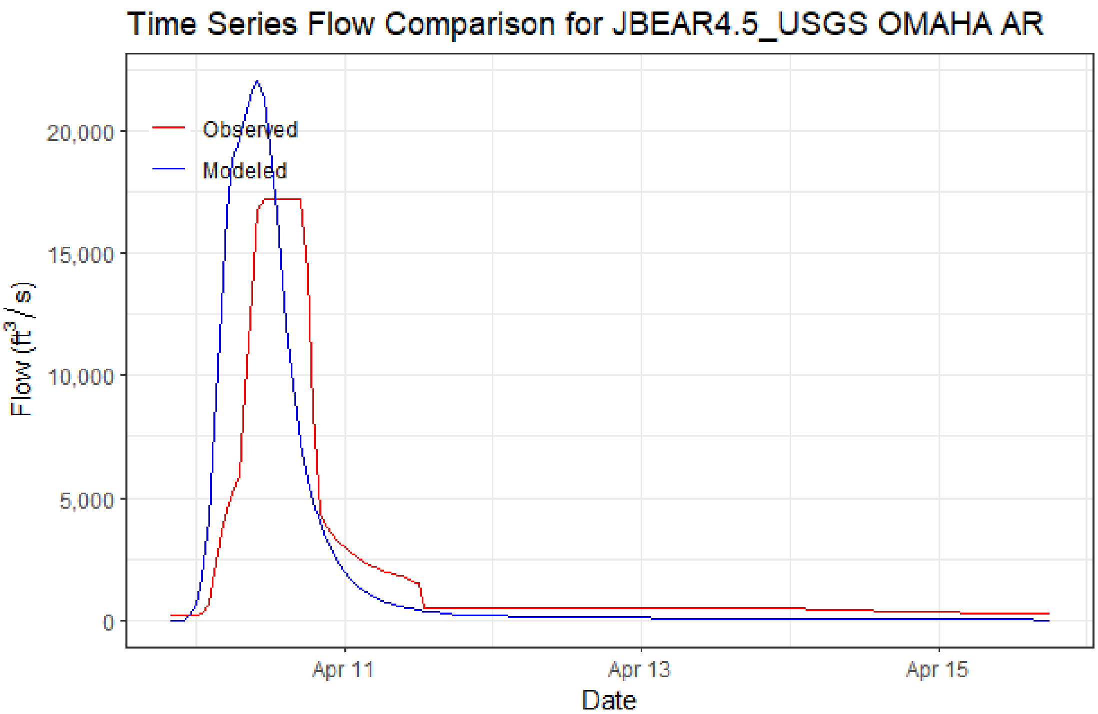


Figure 6-132. Validation Results for JBEAR4.5_USGS OMAHA HEC-HMS Junction – Bear Creek near Omaha, AR Gage (2008 Event)

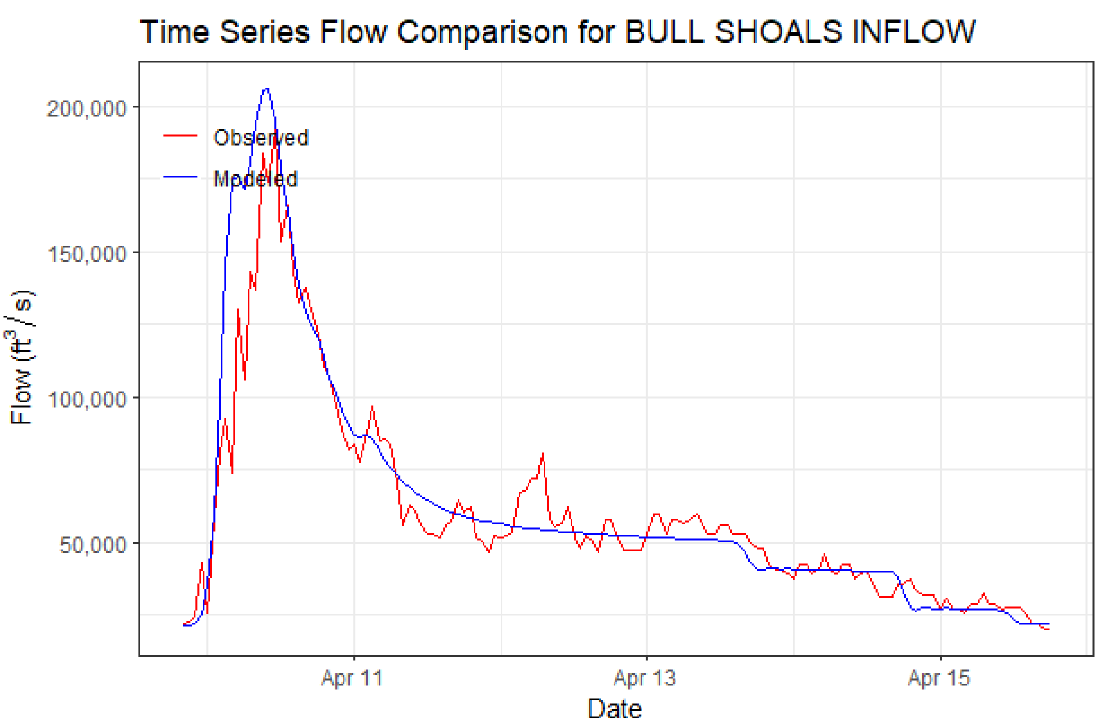


Figure 6-133. Validation Results for BULL SHOALS INFLOW HEC-HMS Junction – Inflow to Bull Shoals Lake (2008 Event)

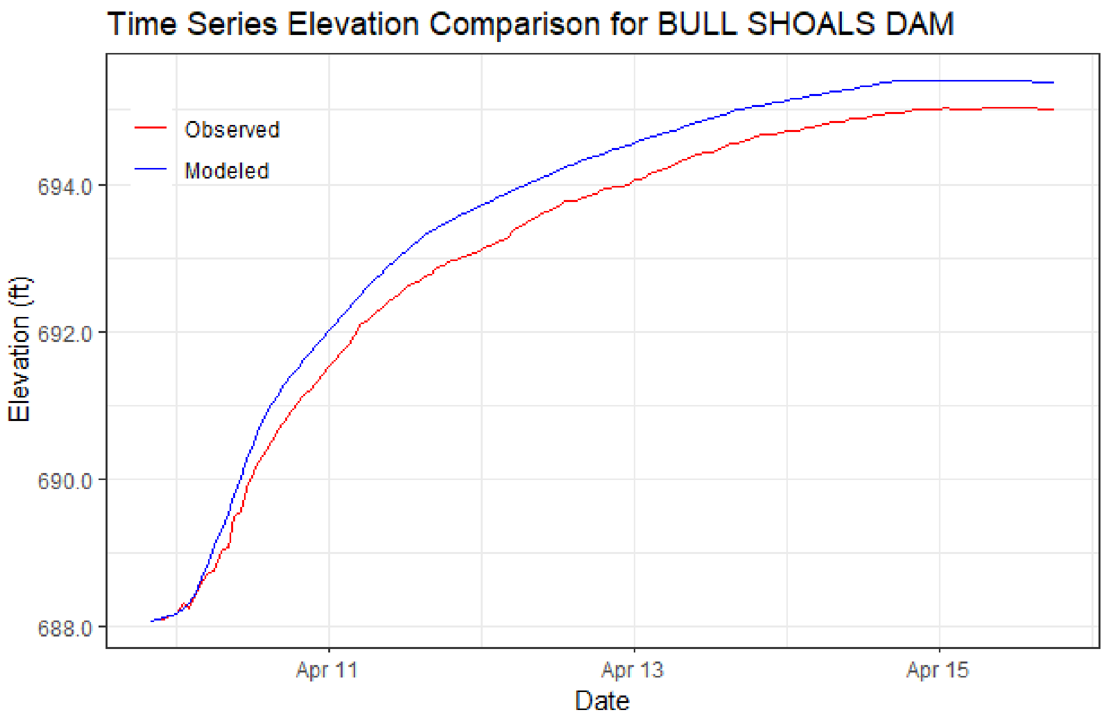


Figure 6-134. Validation Results for BULL SHOALS DAM HEC-HMS Junction – Elevation at Bull Shoals Lake (2008 Event)

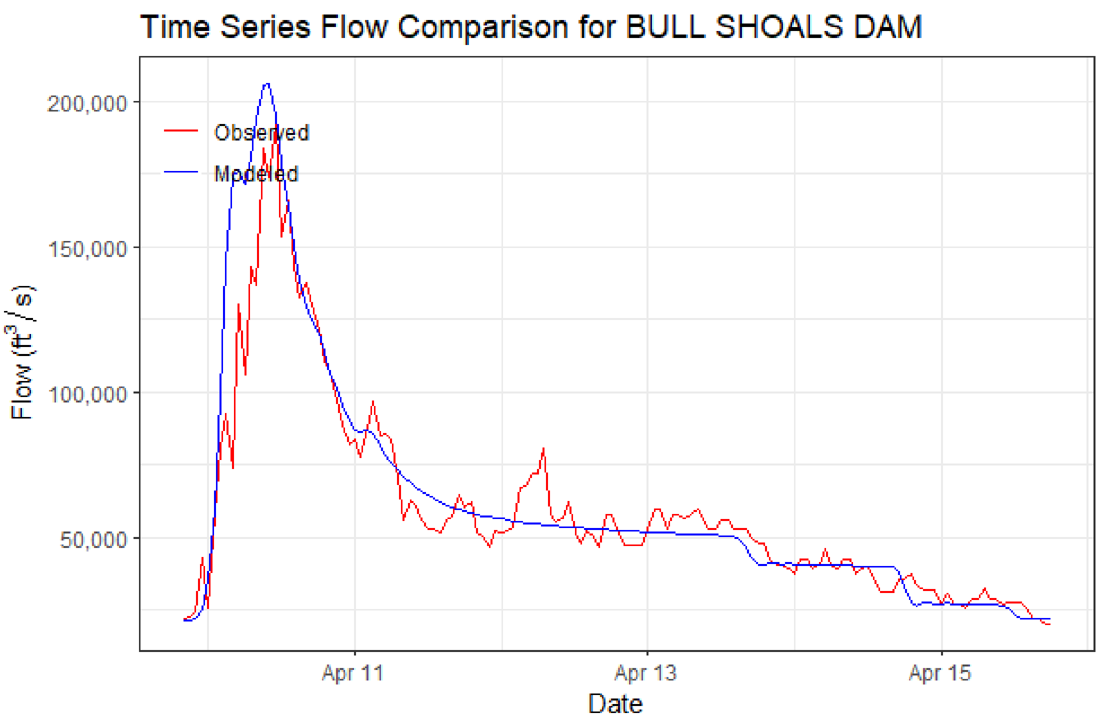


Figure 6-135. Validation Results for BULL SHOALS DAM HEC-HMS Junction – Flow at Bull Shoals Dam (2008 Event)

6.4.3.5 2015 Validation Event (18Jun2015 to 25Jun2015)

The results for the validation of the 2015 validation event are shown in Figure 6-136 through Figure 6-159.

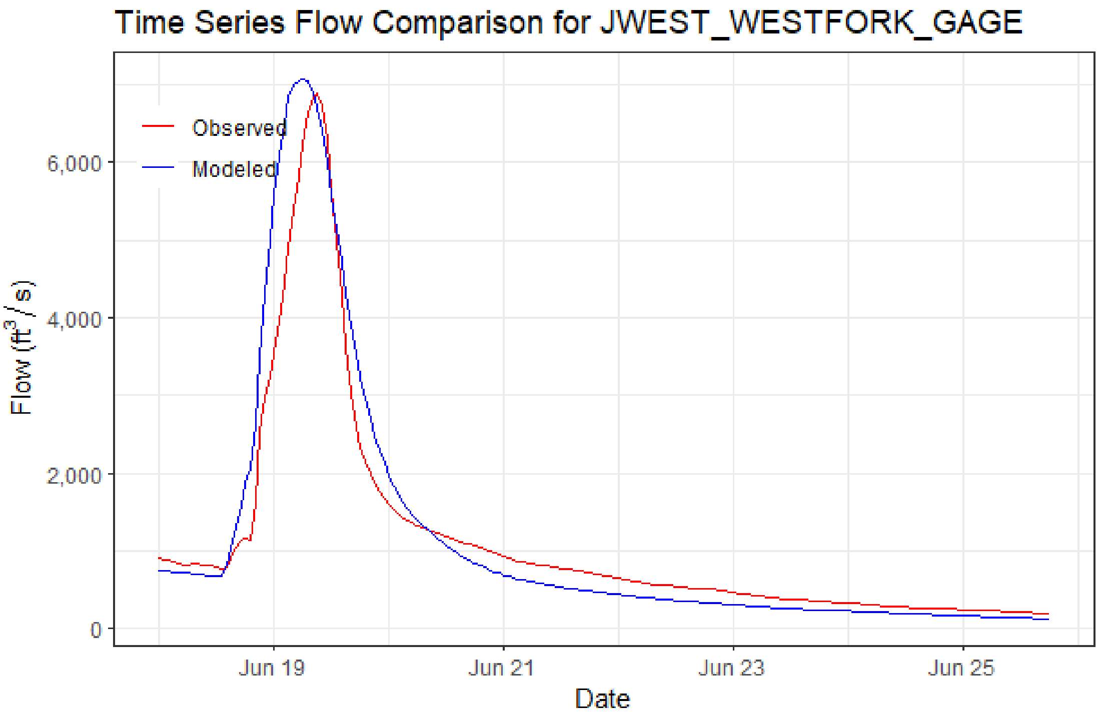


Figure 6-136. Validation Results for JWEST_WESTFORK_GAGE HEC-HMS Junction – West Fork of White River east of Fayetteville, AR Gage (2015 Event)

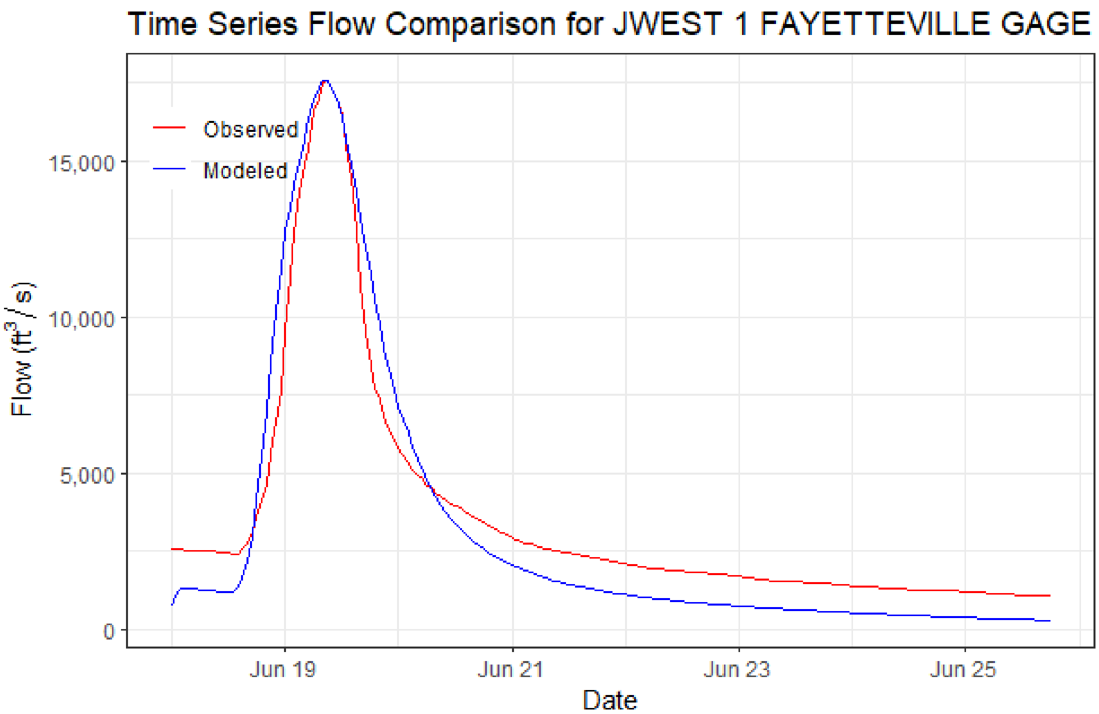


Figure 6-137. Validation Results for JWEST 1 FAYETTEVILLE GAGE HEC-HMS Junction – White River at Fayetteville, AR Gage (2015 Event)

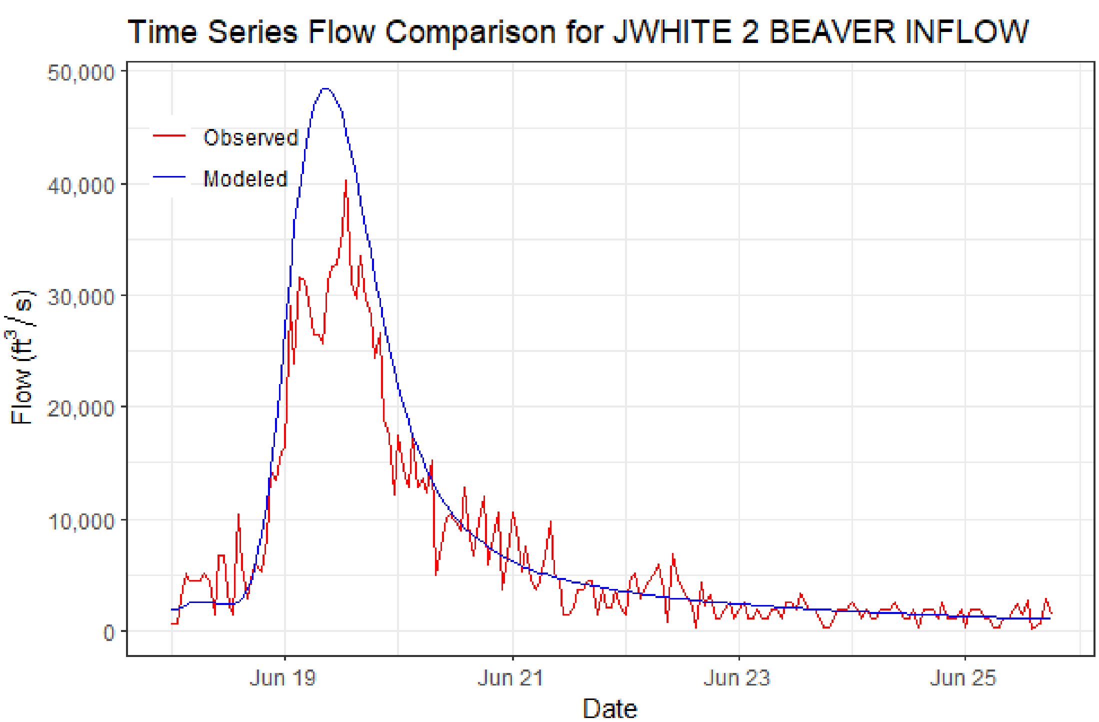


Figure 6-138. Validation Results for JWHITE 2 BEAVER INFLOW HEC-HMS Junction – Inflow to Beaver Lake (2015 Event)

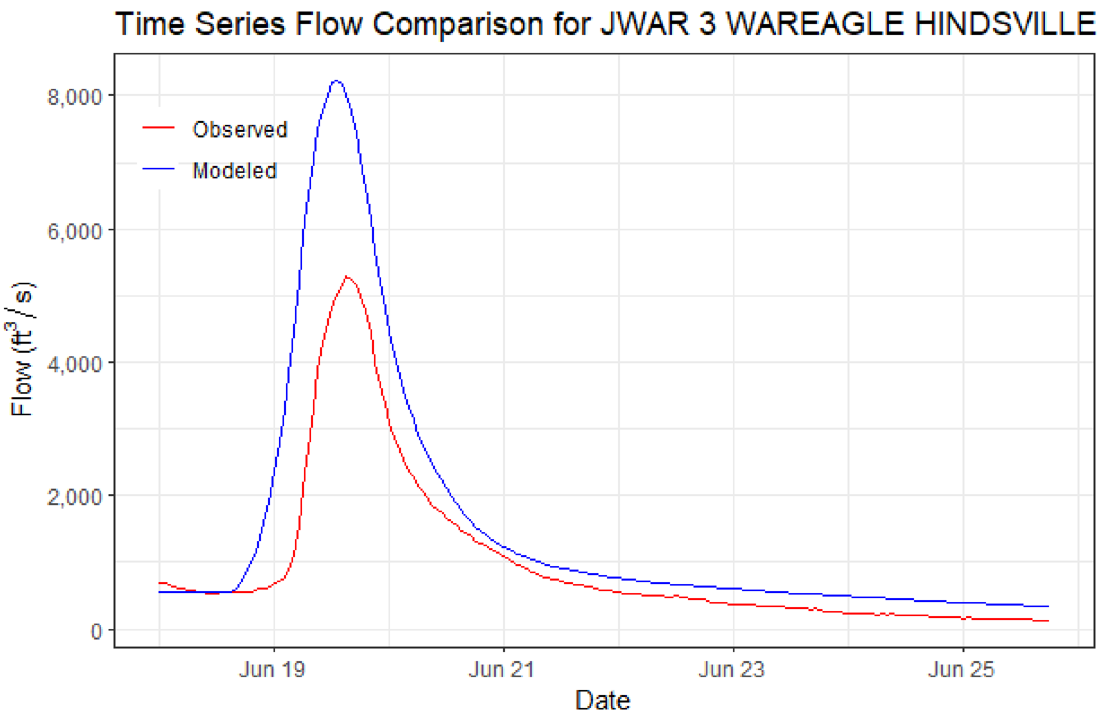


Figure 6-139. Validation Results for JWAR 3 WAREAGLE HINDSVILLE HEC-HMS Junction – War Eagle Creek near Hindsville, AR Gage (2015 Event)

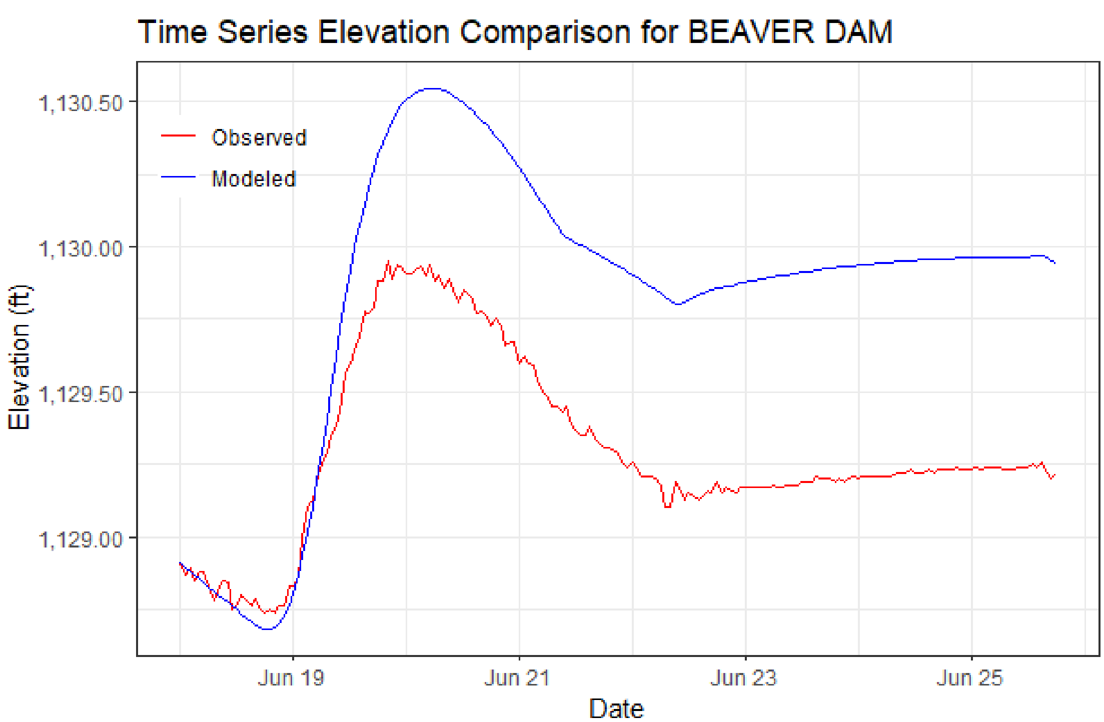


Figure 6-140. Validation Results for BEAVER DAM HEC-HMS Junction – Elevation at Beaver Dam (2015 Event)

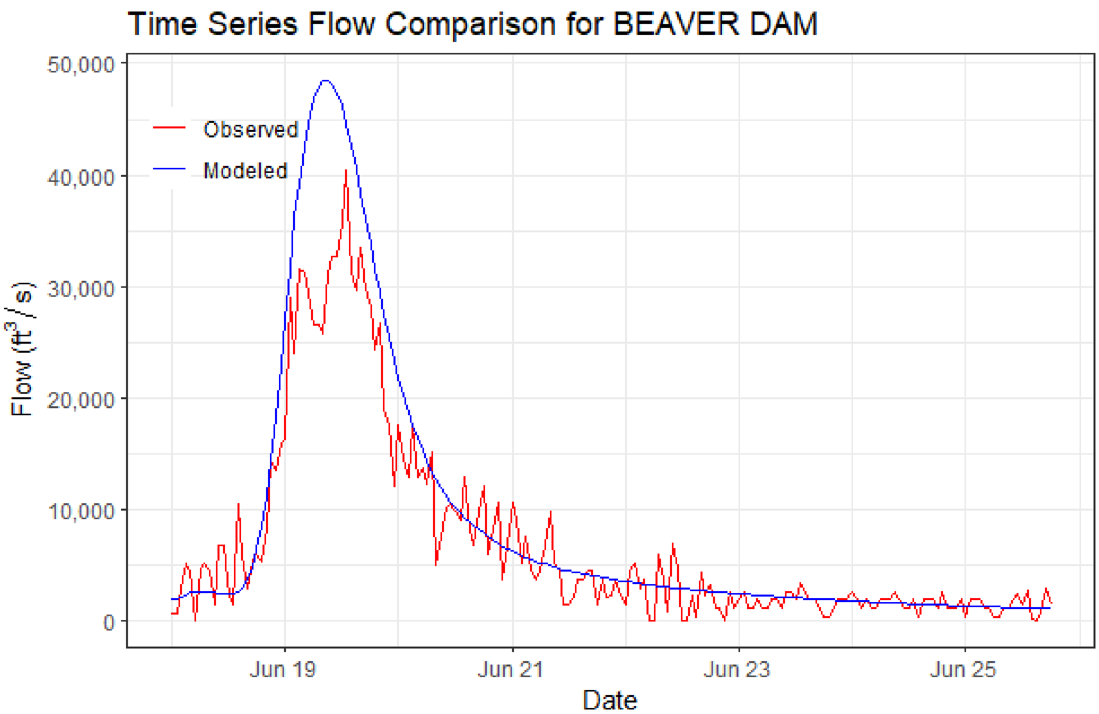


Figure 6-141. Validation Results for BEAVER DAM HEC-HMS Junction – Flow at Beaver Dam (2015 Event)

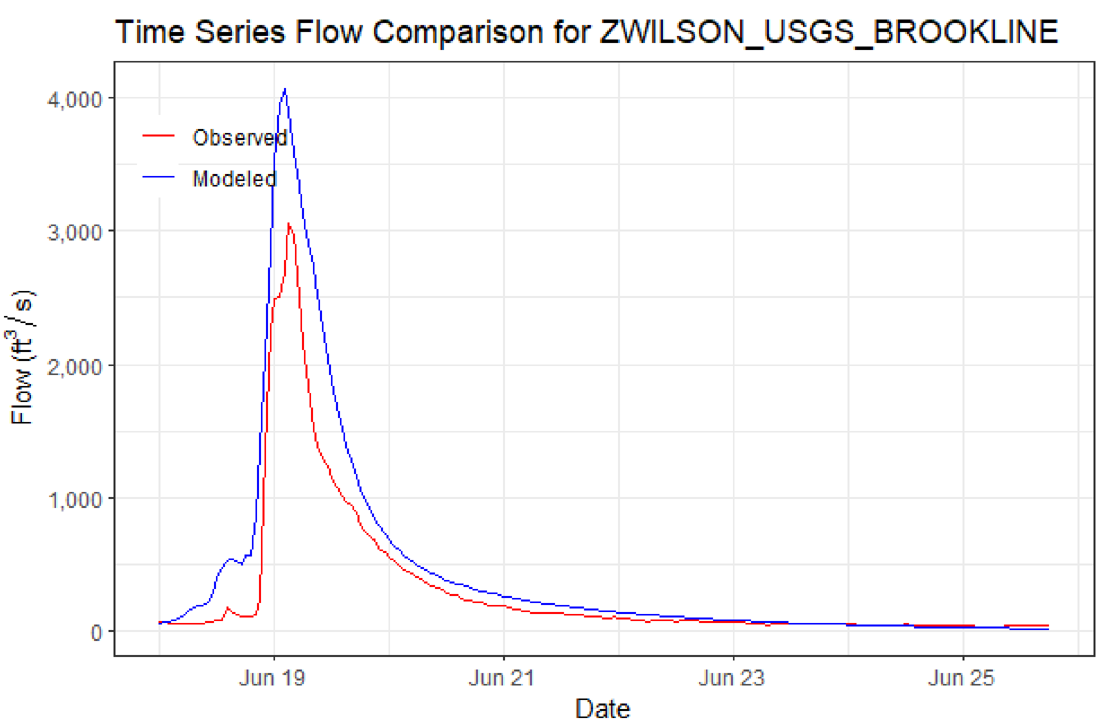


Figure 6-142. Validation Results for ZWILSON_USGS_BROOKLINE HEC-HMS Junction – Wilson Creek near Brookline, MO Gage (2015 Event)

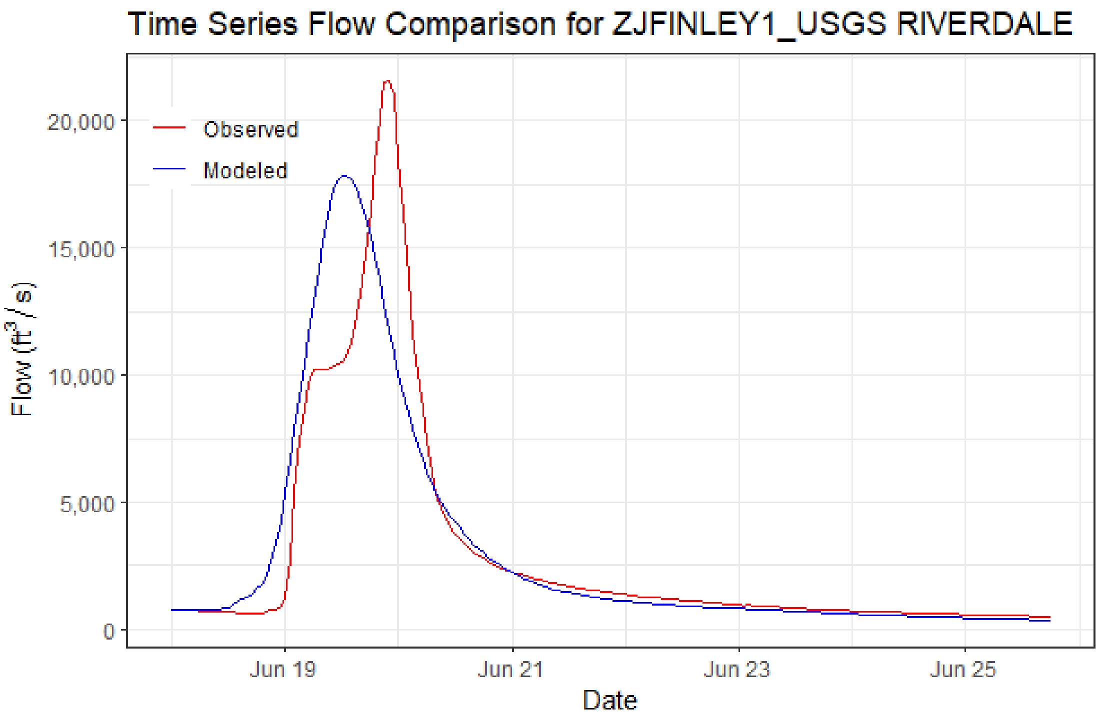


Figure 6-143. Validation Results for ZJFINLEY1_USGS RIVERDALE HEC-HMS Junction – Finley Creek below Riverdale, MO Gage (2015 Event)

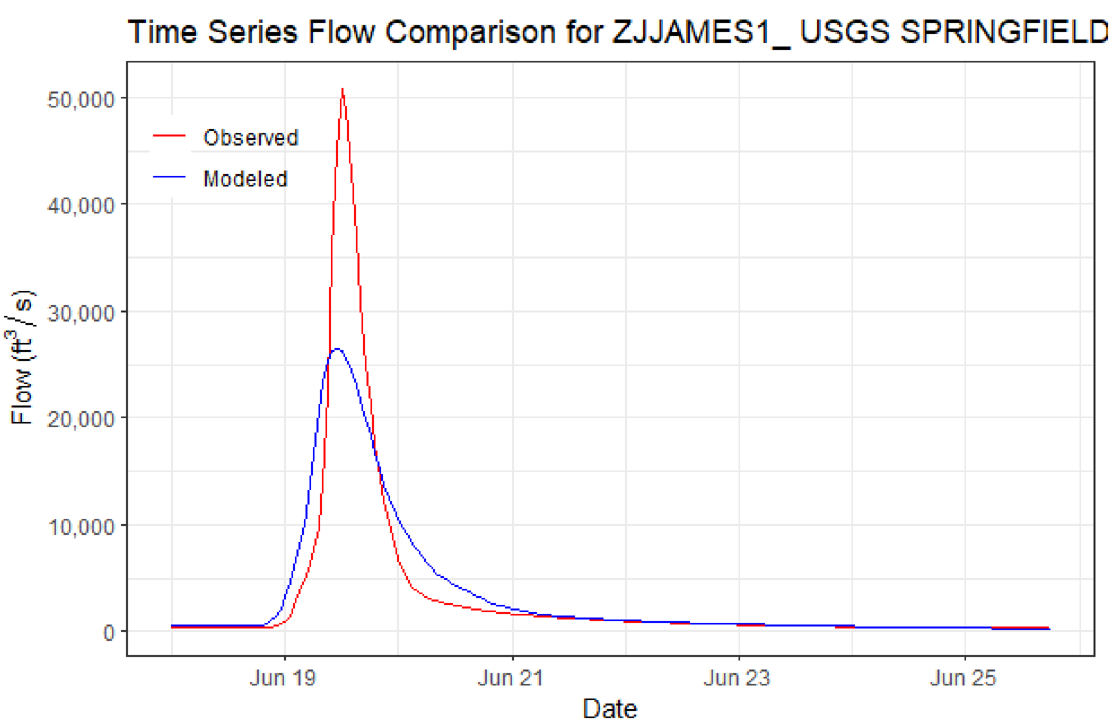


Figure 6-144. Validation Results for ZJJAMES_USGS SPRINGFIELD HEC-HMS Junction – James River near Springfield, MO Gage (2015 Event)

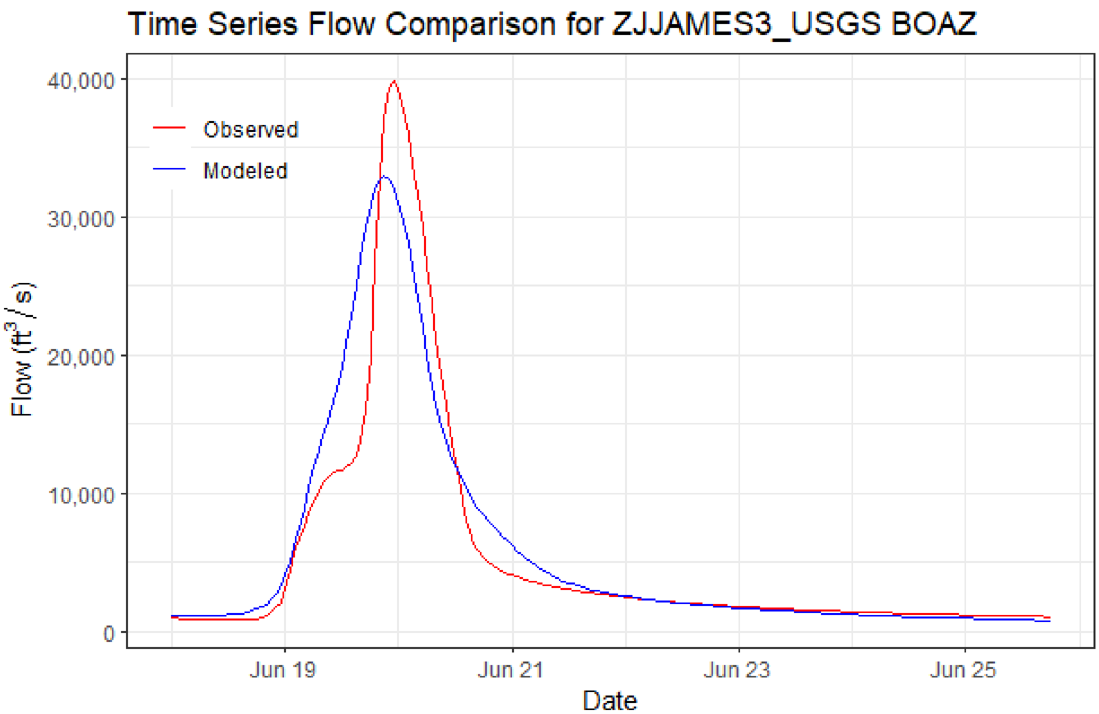


Figure 6-145. Validation Results for ZJJAMES3_USGS BOAZ HEC-HMS Junction – James River near Boaz, MO Gage (2015 Event)

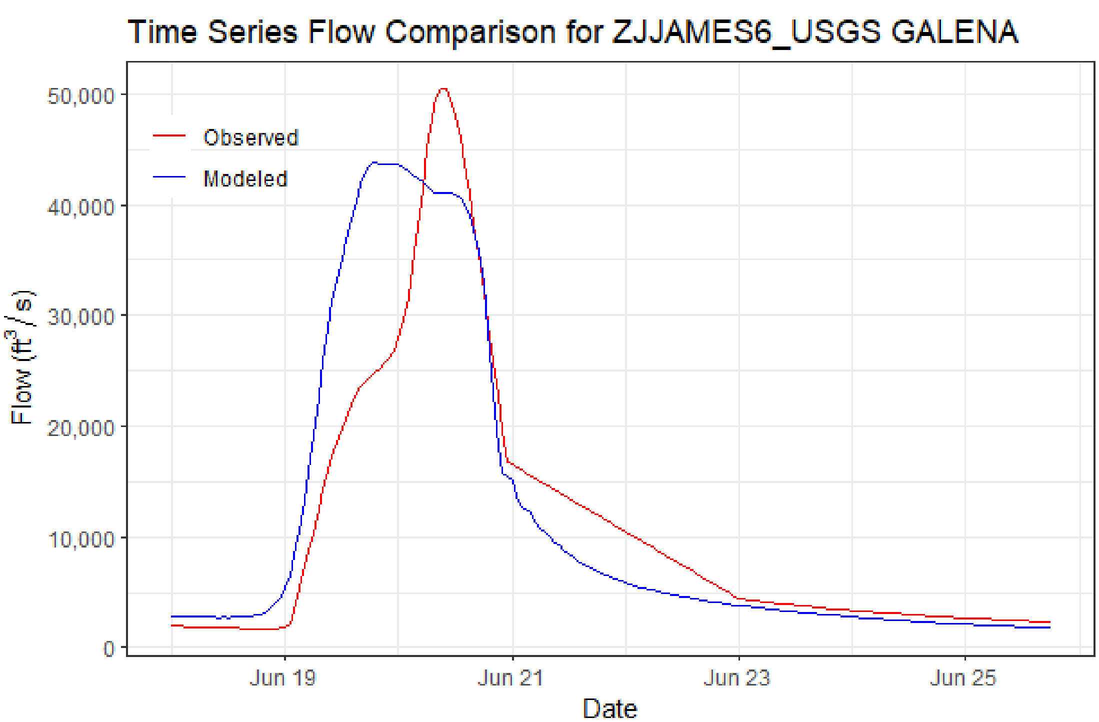


Figure 6-146. Validation Results for ZJJAMES6_USGS GALENA HEC-HMS Junction – James River at Galena, MO Gage (2015 Event)

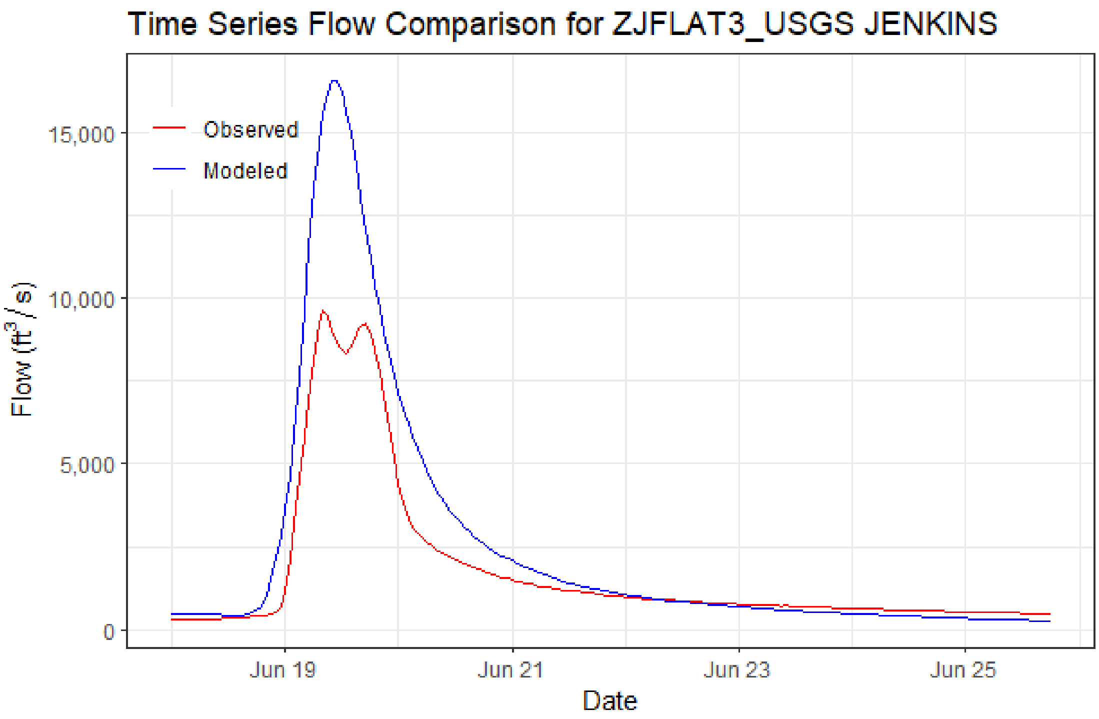


Figure 6-147. Validation Results for ZJFLAT3_USGS JENKINS HEC-HMS Junction – Flat Creek below Jenkins, MO Gage (2015 Event)

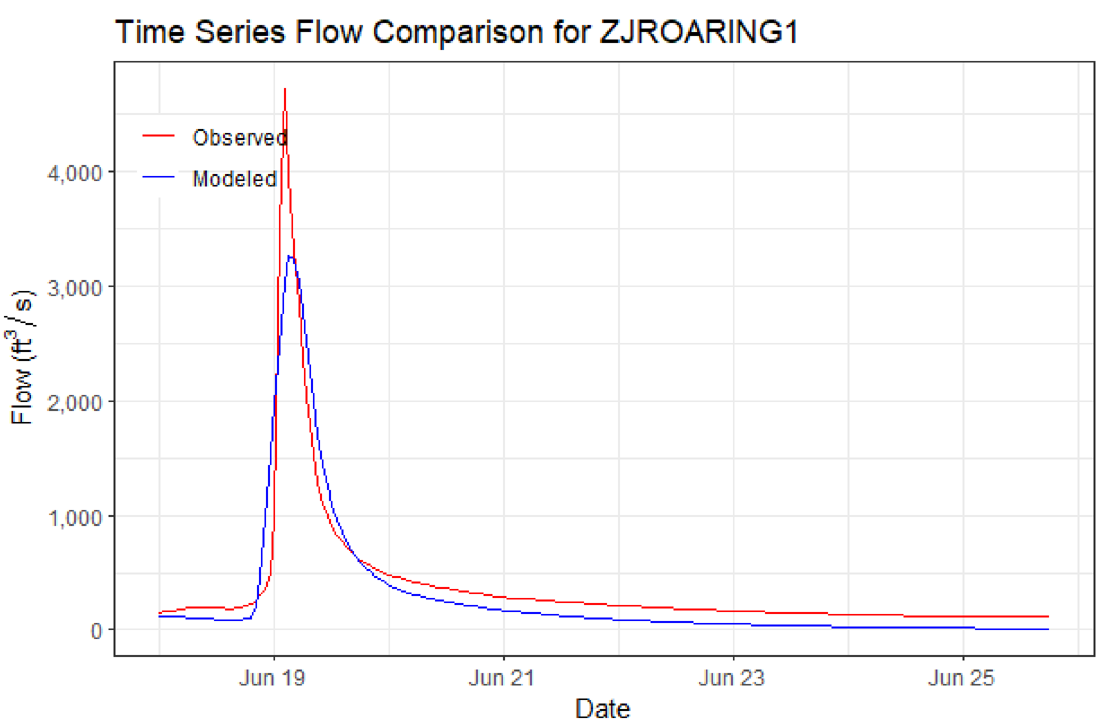


Figure 6-148. Validation Results for ZJROARING1 HEC-HMS Junction – Roaring River at Roaring River State Park Gage (2015 Event)

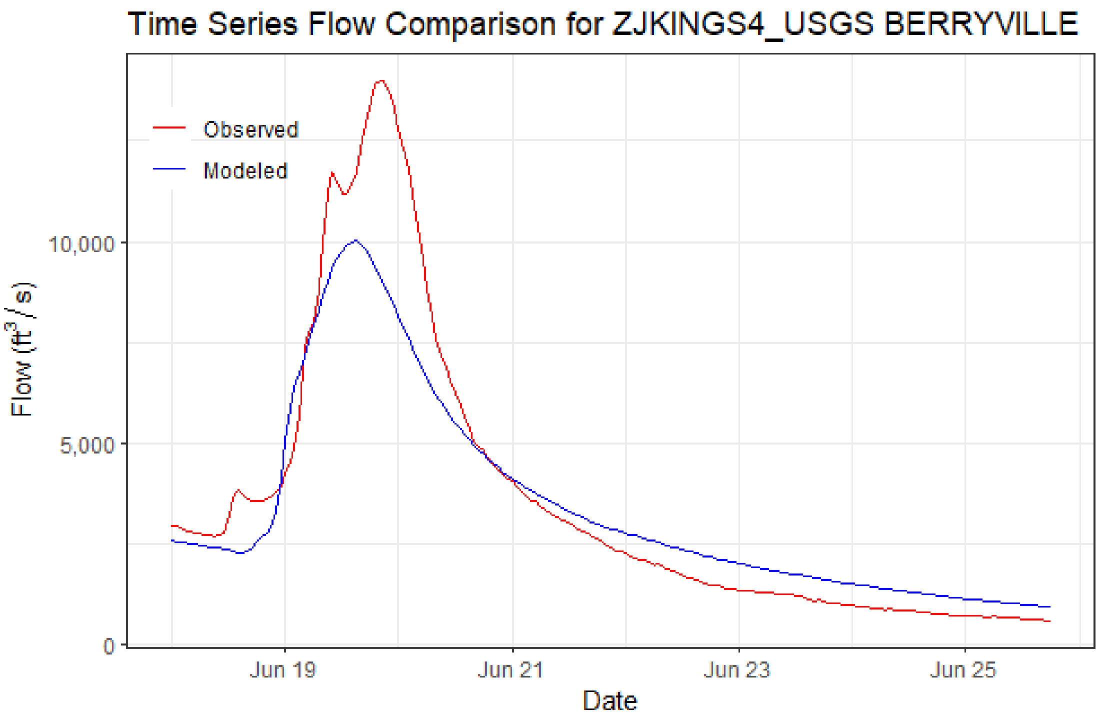


Figure 6-149. Validation Results for ZJKINGS4_USGS BERRYVILLE HEC-HMS Junction – Kings River near Berryville, AR Gage (2015 Event)

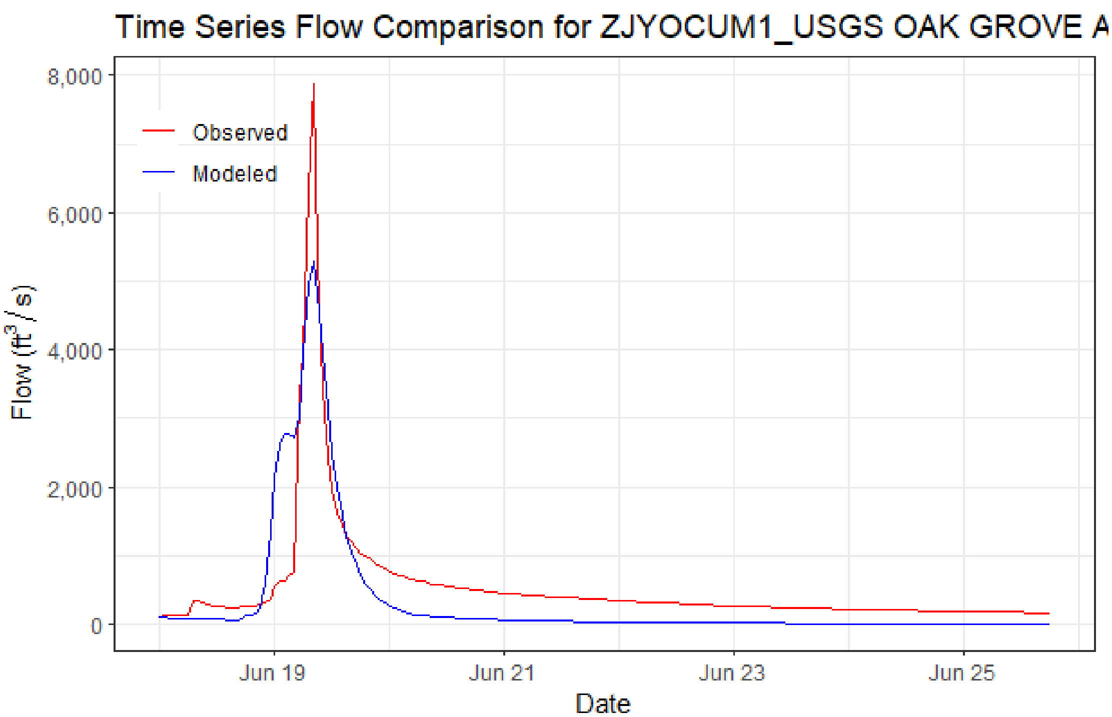


Figure 6-150. Validation Results for ZJYOCUM1_USGS OAK GROVE AR HEC-HMS Junction – Yocum Creek near Oak Grove, AR Gage (2015 Event)

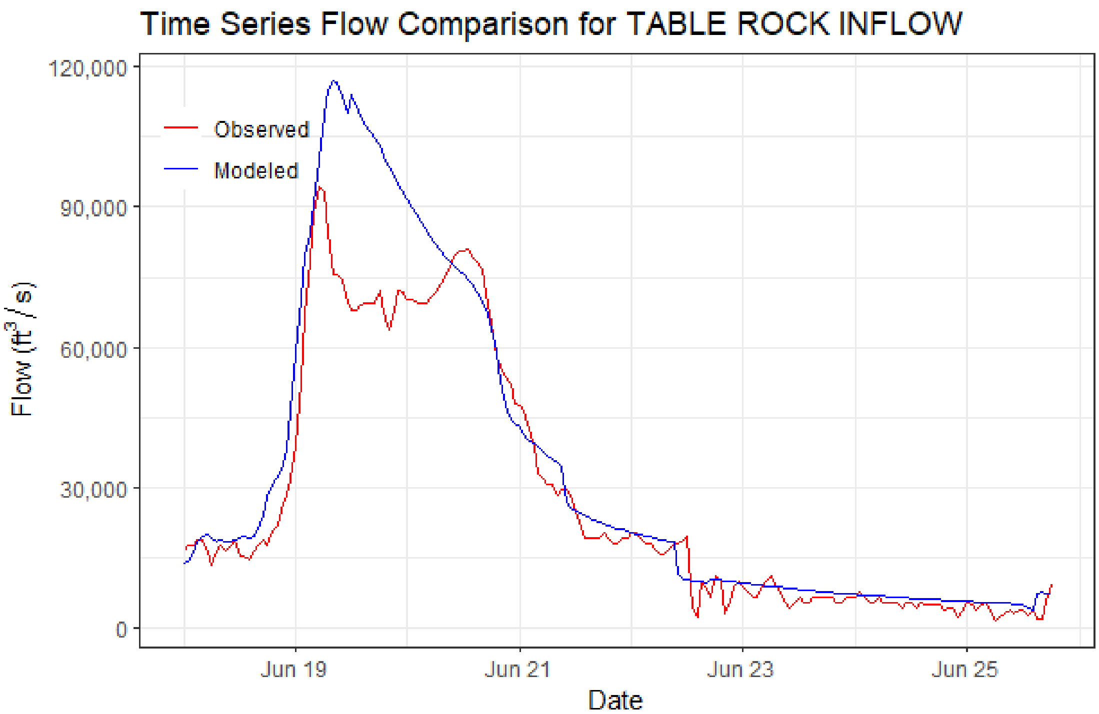


Figure 6-151. Validation Results for TABLE ROCK INFLOW HEC-HMS Junction – Inflow to Table Rock Lake (2015 Event)

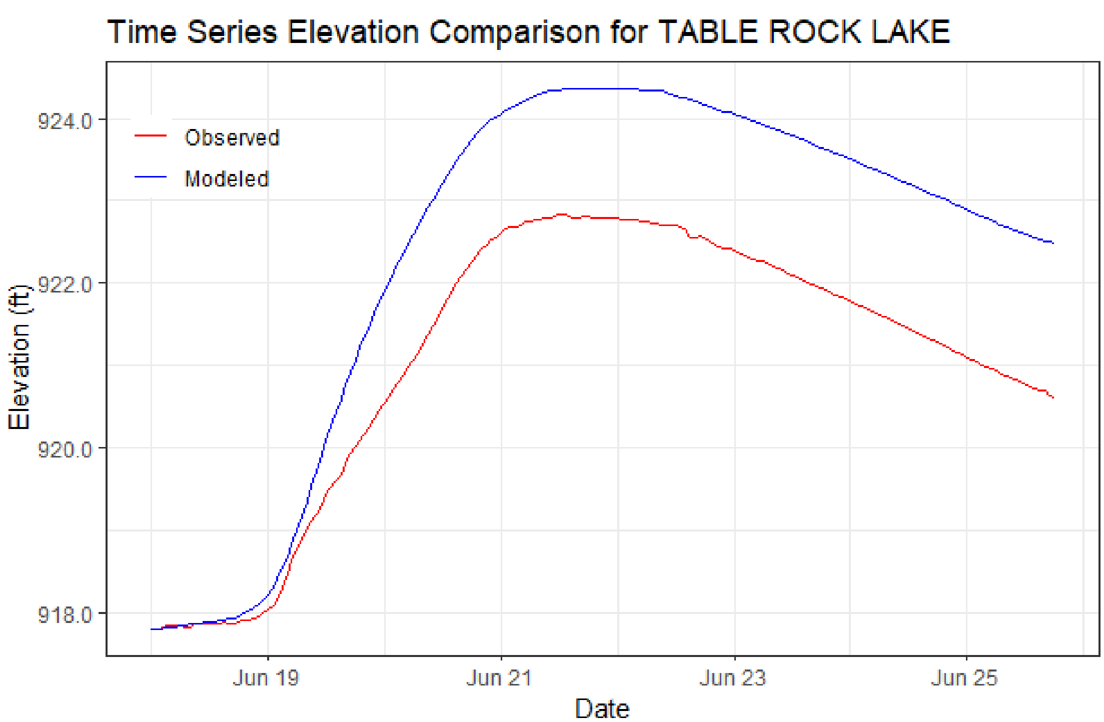


Figure 6-152. Validation Results for TABLE ROCK LAKE HEC-HMS Junction – Elevation at Table Rock Lake (2015 Event)

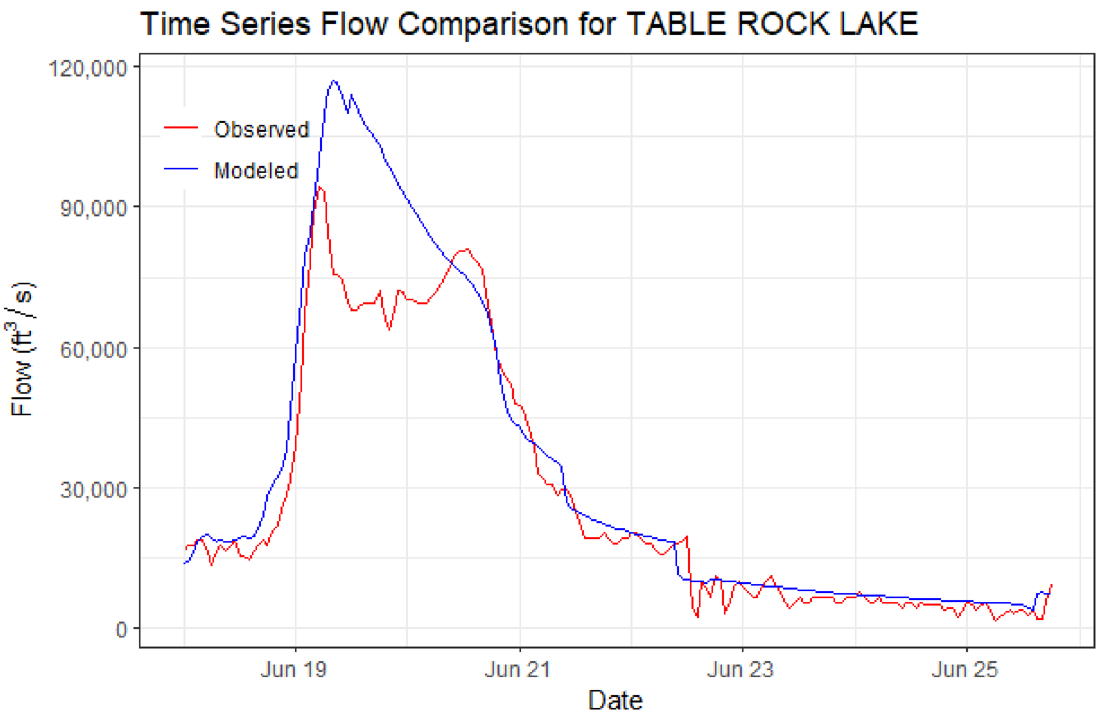


Figure 6-153. Validation Results for TABLE ROCK LAKE HEC-HMS Junction – Flow at Table Rock Lake (2015 Event)

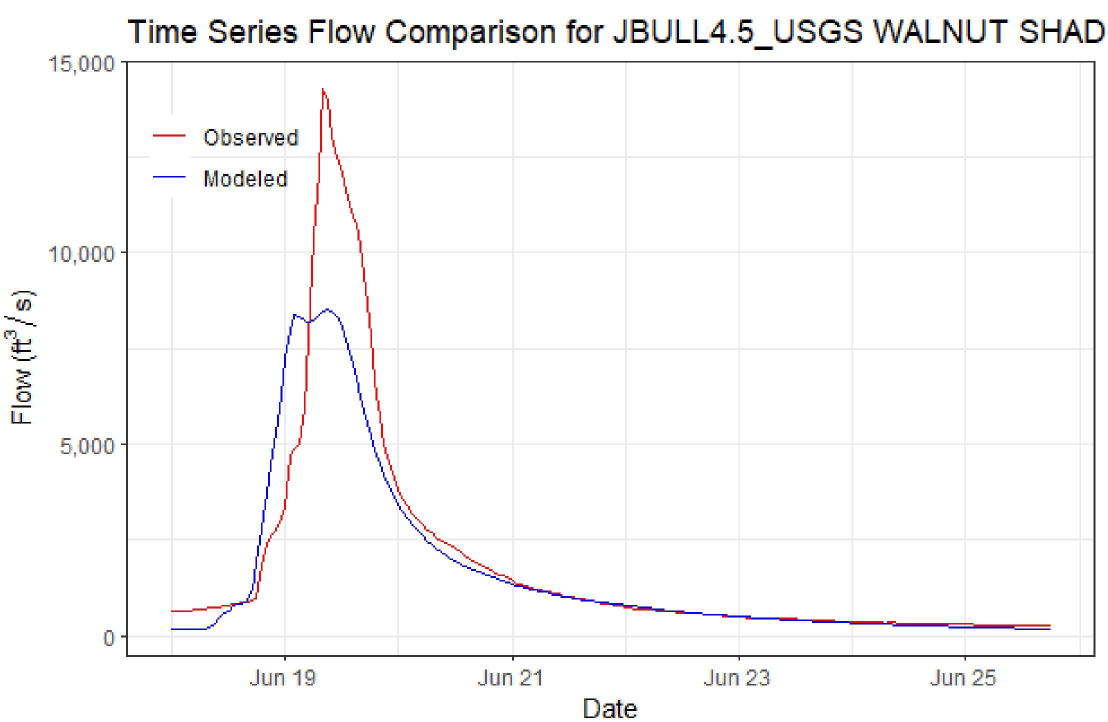


Figure 6-154. Validation Results for JBULL4.5_USGS WALNUT SHADE HEC-HMS Junction – Bull Creek near Walnut Shade, MO Gage (2015 Event)

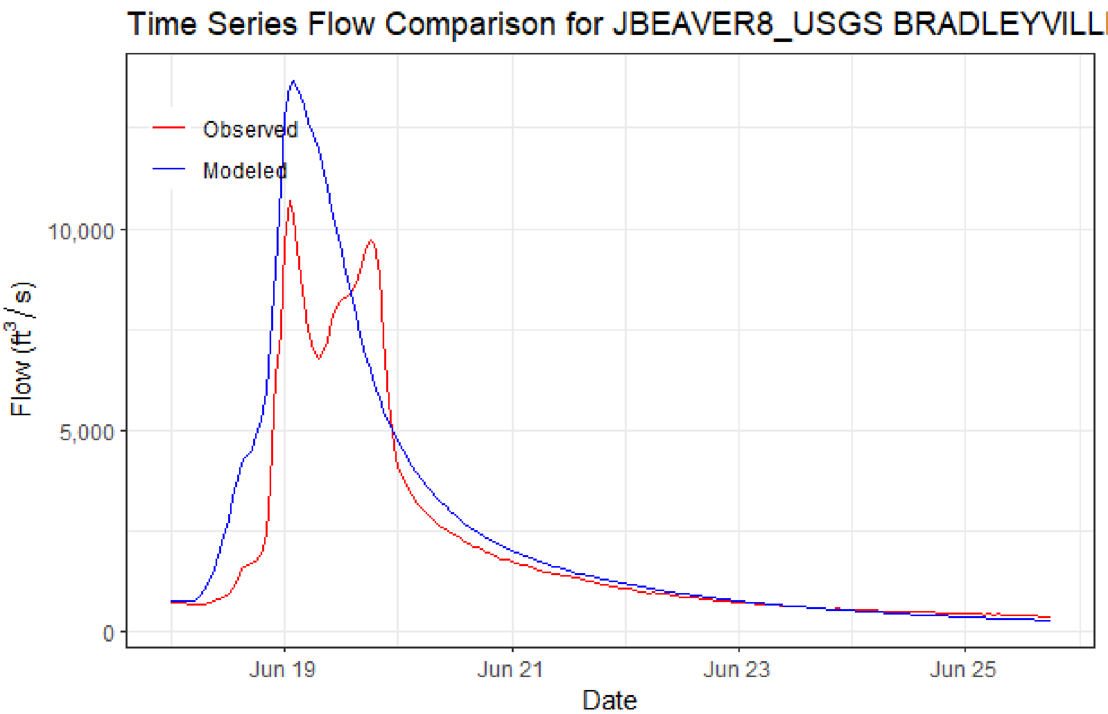


Figure 6-155. Validation Results for JBEAVER8_USGS BRADLEYVILLE HEC-HMS Junction – Beaver Creek at Bradleyville, MO Gage (2015 Event)

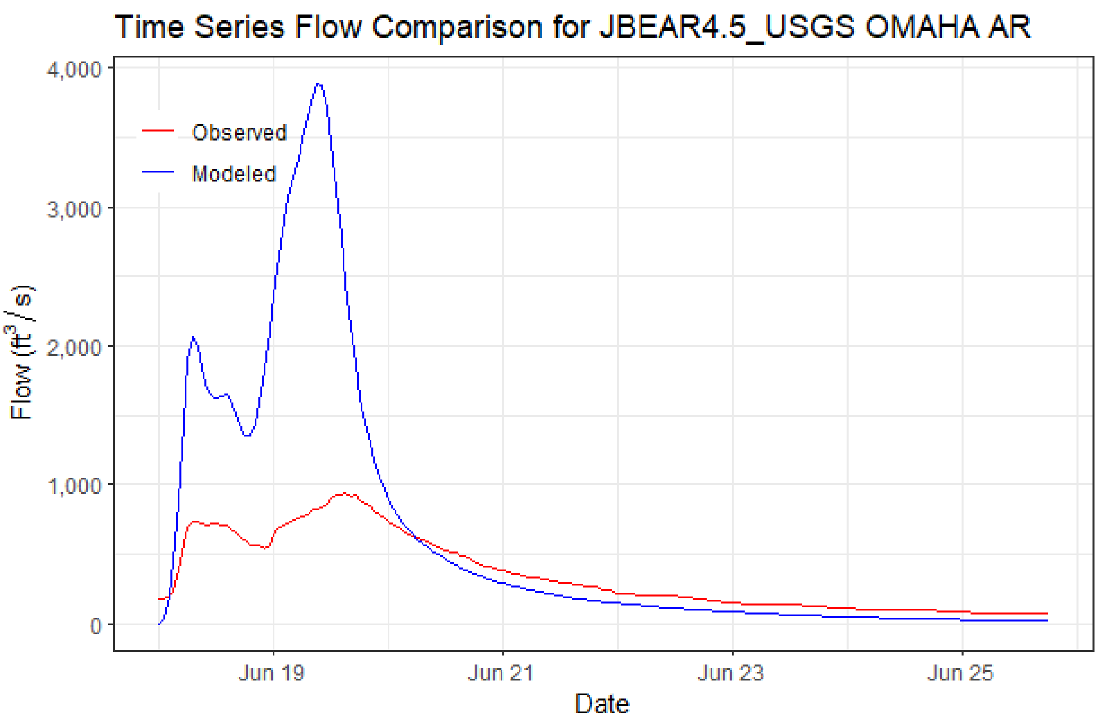


Figure 6-156. Validation Results for JBEAR4.5_USGS OMAHA AR HEC-HMS Junction – Bear Creek near Omaha, AR Gage (2015 Event)

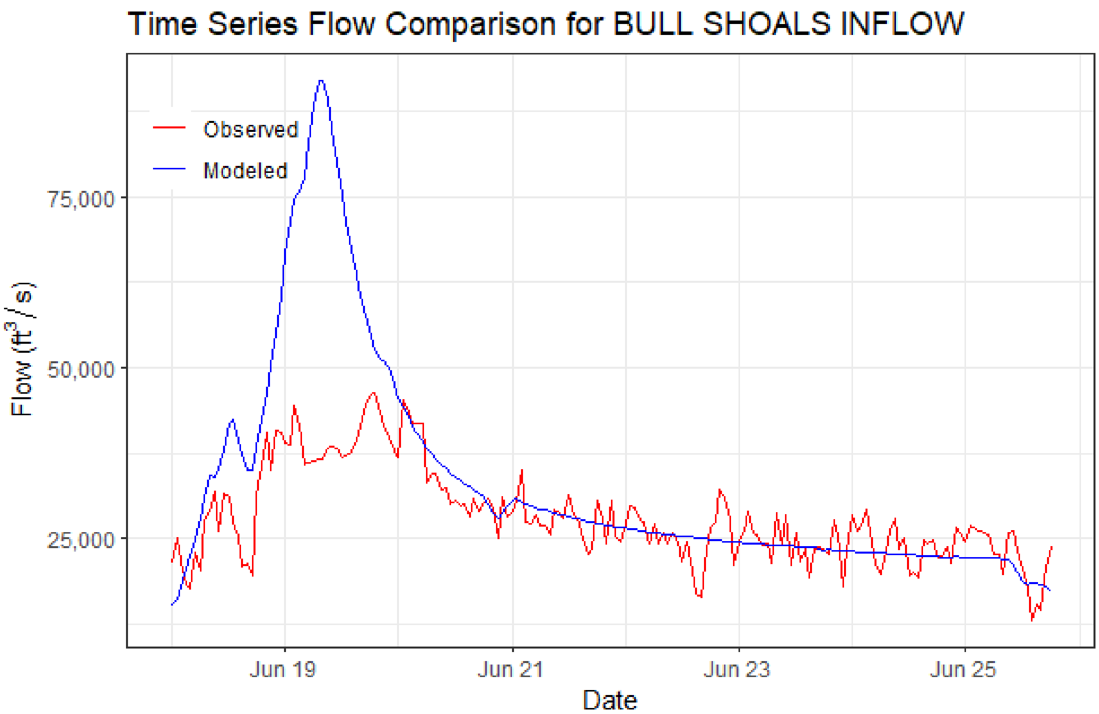


Figure 6-157. Validation Results for BULL SHOALS INFLOW HEC-HMS Junction – Inflow to Bull Shoals Lake Gage (2015 Event)

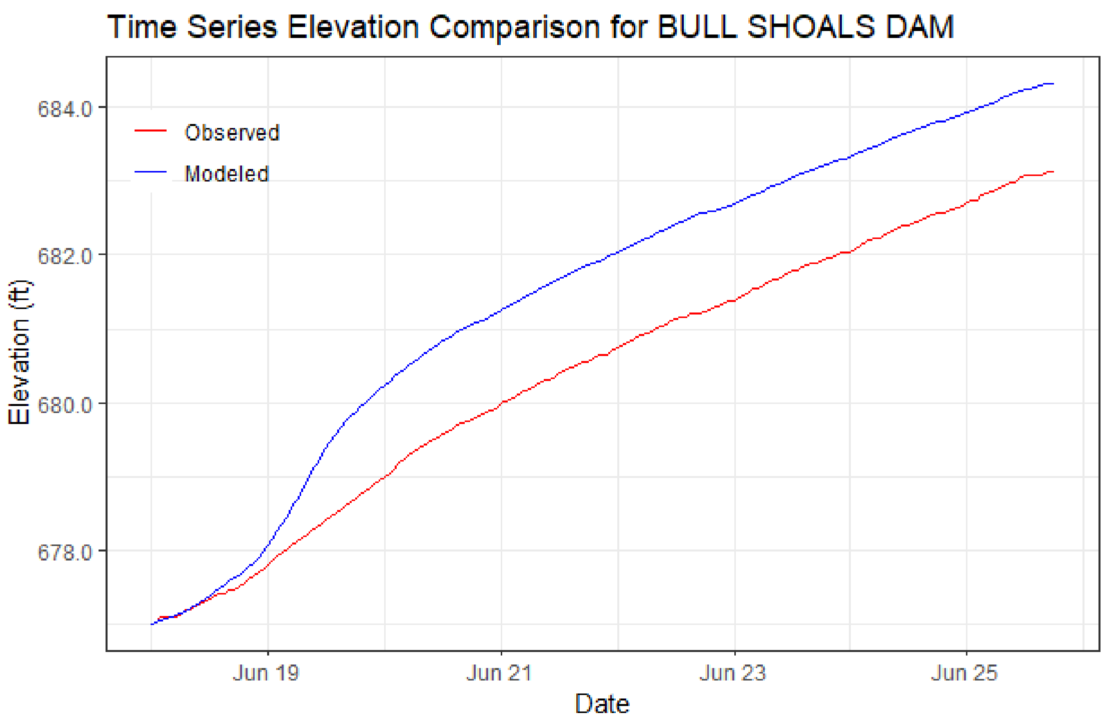


Figure 6-158. Validation Results for BULL SHOALS DAM HEC-HMS Junction – Elevation at Bull Shoals Lake Gage (2015 Event)

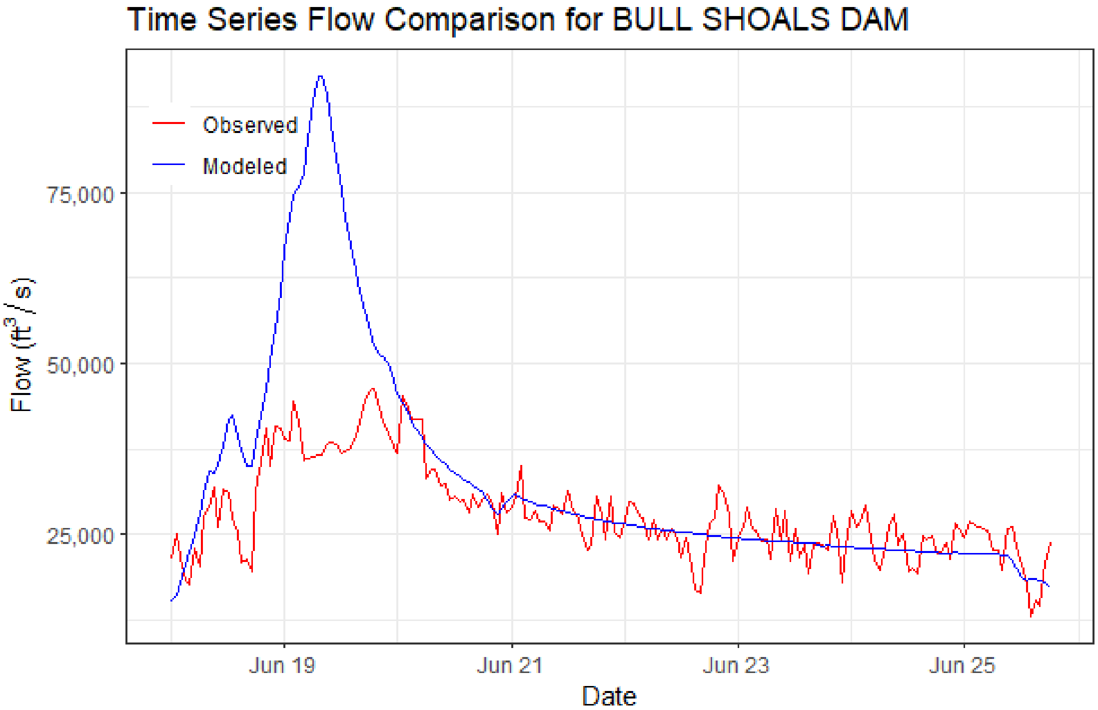


Figure 6-159. Validation Results for BULL SHOALS DAM HEC-HMS Junction – Flow at Bull Shoals Lake Gage (2015 Event)

7 Synthetic Storms and Stochastic Simulation

Spatial information expansion is based on using flood information from neighboring catchments to improve flood frequency estimates at the site of interest. Trading space for time, or a lack of time, results in having more information available for flood frequency analyses. Regional precipitation-frequency results can be used to expand the knowledge of the watershed, similar to regional skew information. Incorporating regional precipitation-frequency provides additional record length, decreasing the uncertainty in the results.

A precipitation frequency analysis was conducted for the White River watershed. Estimates of the frequency of 72-hour precipitation frequencies were achieved through a process of precipitation gage selection and evaluation, derivation of L-moment statistics for each precipitation gage, regionalization of precipitation gages based on L-moment statistics, and interpolation of L-moment statistics to create gridded estimates of distribution parameters.

The methods followed for the precipitation frequency analyses are based largely on the seminal monograph from 1997 (Hosking and Wallis 1997). Regional precipitation frequency analyses have been performed across many areas for many years. This regional precipitation frequency study was performed for the purposes of dam and levee safety analyses. All computations performed related to statistical analyses were performed in R Statistical Software (R Core Team 2023) utilizing the lmomco (Asquith 2017) and lmomRFA (Hosking 2019) packages for R Statistical Software.

Several regression methods were evaluated for predicting L-moments across spatially gridded data. Random Forest (RF, Breman 2001) consistently produced the best performance metrics. This is likely due, in large part, to the explanatory variables that were used. Aspect, or the compass direction that a slope faces, was an important explanatory variable for many of the analyses. RF was the best regression method tested to deal with non-linear explanatory variables like aspect. Additionally, RF is well suited to deal with the large sample size and complex interactions occurring among explanatory variables used for the study. Slope and aspect were resampled to larger resolutions using bilinear interpolation. For final regressions for L-mean, L-CV, and L-skew used the top four predictors identified by RF.

Table 7-1. Performance metrics for various regression methods for L-moments used in precipitation frequency analyses. OLS = Ordinary Least Squares; WLS = Weighted Least Squares; GAM = Generalized Additive Model; RF = Random Forest; SWM_L = Support Vector

Machine with Linear Kernel; SVM_R = Support Vector Machine with Radial Kernel; NN = Neural Network

Response Variable	Model	MAE	RMSE	NRMSE (%)	PBIAS (%)	RSR	NSE	mNSE	R^2	Adjusted R^2
L-Mean	OLS	0.11	0.15	82.5	0.0	0.83	0.31	0.19	0.31	0.31
L-Mean	WLS	0.11	0.15	82.7	-0.1	0.83	0.30	0.20	0.31	0.30
L-Mean	GAM	0.11	0.14	81.6	0.0	0.82	0.32	0.21	0.32	0.32
L-Mean	RF	0.05	0.07	42.0	-0.1	0.42	0.82	0.60	0.87	0.87
L-Mean	SVM_L	0.10	0.14	80.2	0.0	0.80	0.35	0.25	0.35	0.35
L-Mean	SVM_R	0.07	0.12	69.7	0.3	0.70	0.51	0.46	0.52	0.52
L-Mean	NN	0.14	0.18	99.2	-0.1	0.99	0.00	0.00	NA	NA
L-CV	OLS	0.01	0.02	90.5	-0.1	0.90	0.18	0.09	0.18	0.18
L-CV	WLS	0.01	0.02	90.6	0.3	0.91	0.18	0.09	0.18	0.18
L-CV	GAM	0.01	0.02	86.0	-0.1	0.86	0.26	0.14	0.26	0.26
L-CV	RF	0.01	0.01	37.5	-0.2	0.37	0.86	0.63	0.89	0.89
L-CV	SVM_L	0.01	0.02	88.4	0.6	0.88	0.22	0.12	0.22	0.22
L-CV	SVM_R	0.01	0.02	77.4	0.2	0.77	0.40	0.27	0.40	0.40
L-CV	NN	0.02	0.02	99.9	0.0	1.00	0.00	0.00	NA	NA
L-Skew	OLS	0.05	0.06	99.6	0.0	1.00	0.01	0.01	0.01	0.01
L-Skew	WLS	0.05	0.06	99.6	0.6	1.00	0.01	0.01	0.01	0.01
L-Skew	GAM	0.05	0.06	98.5	0.1	0.98	0.03	0.02	0.03	0.03
L-Skew	RF	0.02	0.03	42.5	0.0	0.43	0.82	0.57	0.92	0.90
L-Skew	SVM_L	0.05	0.06	98.3	0.3	0.98	0.03	0.02	0.04	0.04
L-Skew	SVM_R	0.04	0.05	88.6	0.6	0.89	0.21	0.14	0.22	0.21
L-Skew	NN	0.05	0.06	99.9	0.0	1.00	0.00	0.00	NA	NA

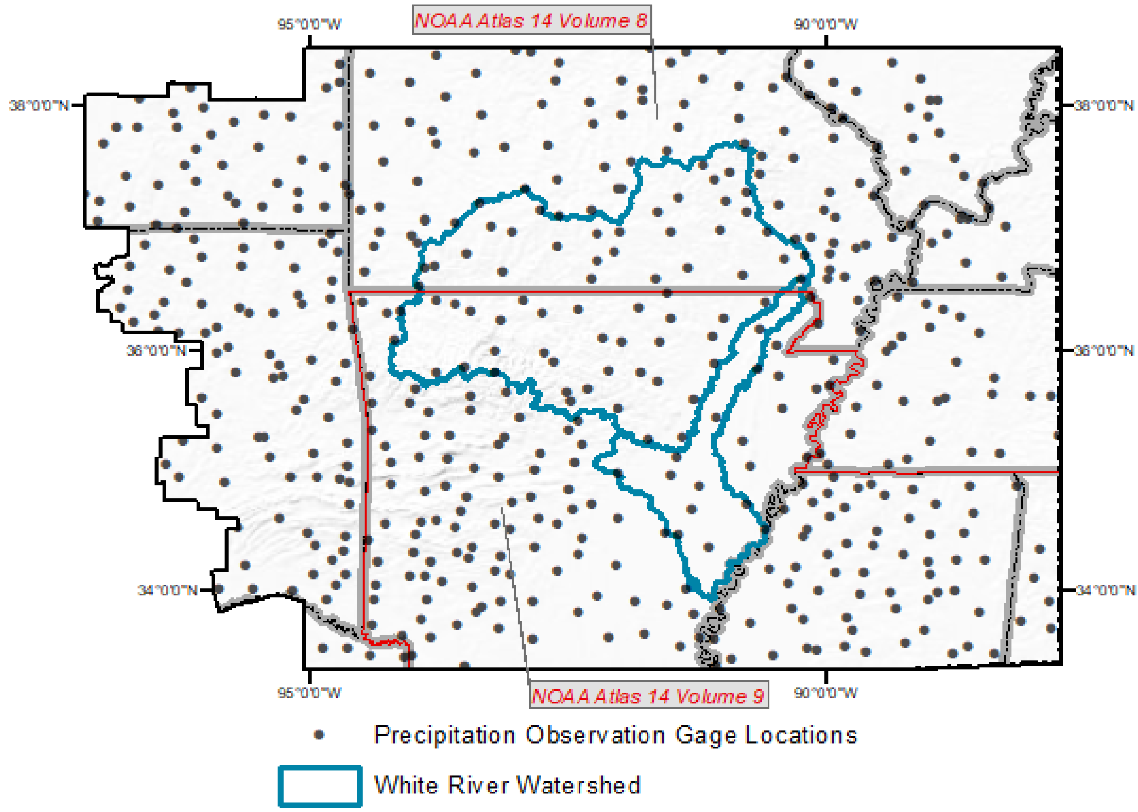


Figure 7-1. NOAA Atlas 14 precipitation observation stations used for precipitation frequency analysis.

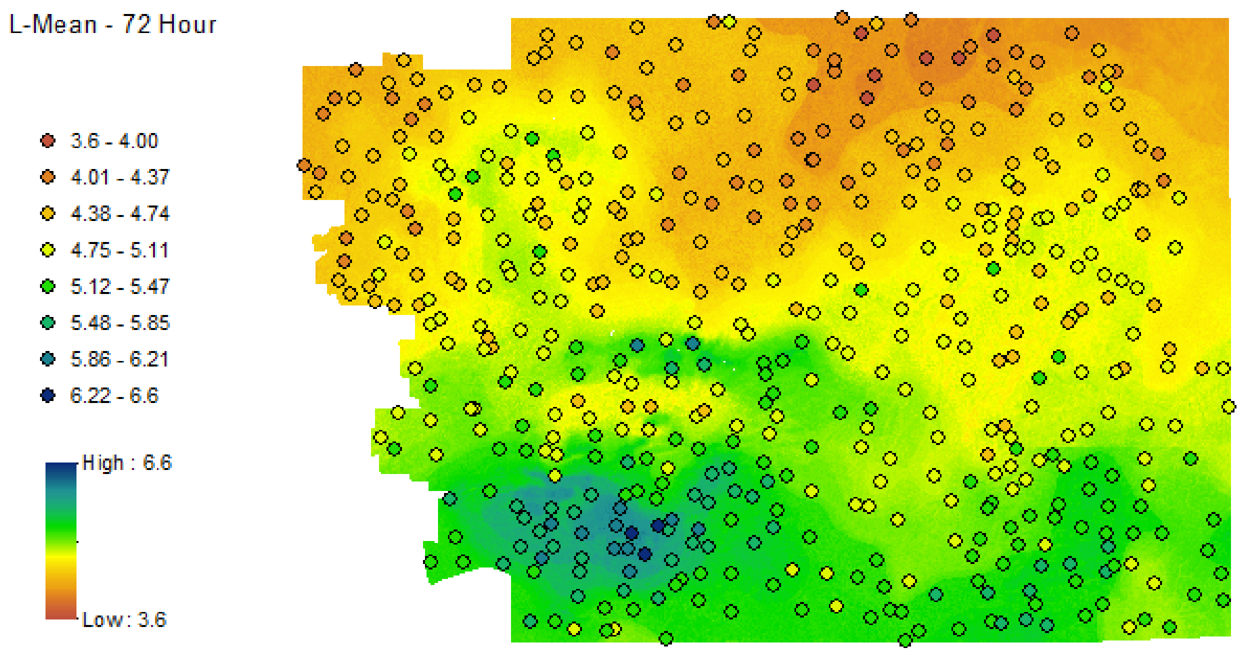


Figure 7-2. Map showing gridded estimates of L-mean for the study area

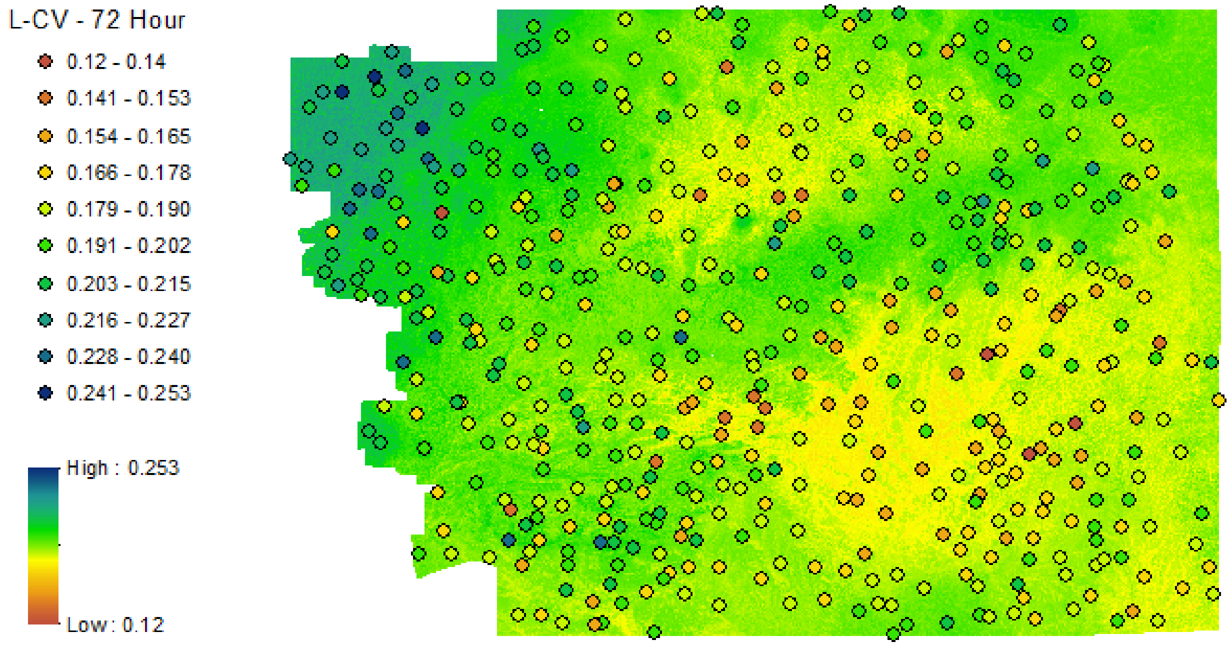


Figure 7-3. Map showing gridded estimates of L-CV for the study area

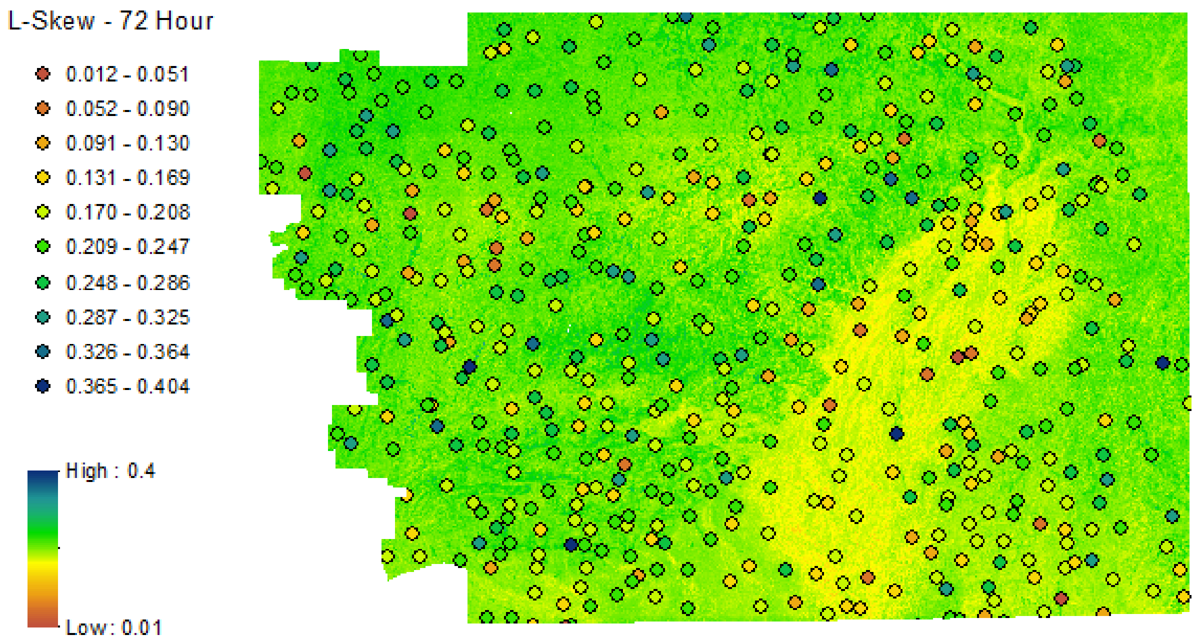


Figure 7-4. Map showing gridded estimates of L-skew for the study area

Historical hyetographs were extracted from NOAA Stage IV radar data and scaled to the 3-day basin-average areal rainfall-frequency depths associated with stratified sampling based on the Generalized Extreme Value (GEV) distributions calculated from L-moment data for specific basins which contribute flow to a streamgage. The hyetographs were scaled to match 72-hour precipitation depths associated with the stratified sampling routine. Depth-area-reduction (Figure 7-5) was applied to precipitation depths associated with the stratified sampling based on basin area and precipitation depth. The resulting hyetographs were routed through HEC-HMS models calibrated to the events from which the original hyetographs were created. HEC-HMS models used for stochastic simulations used Variable Clark Transforms.

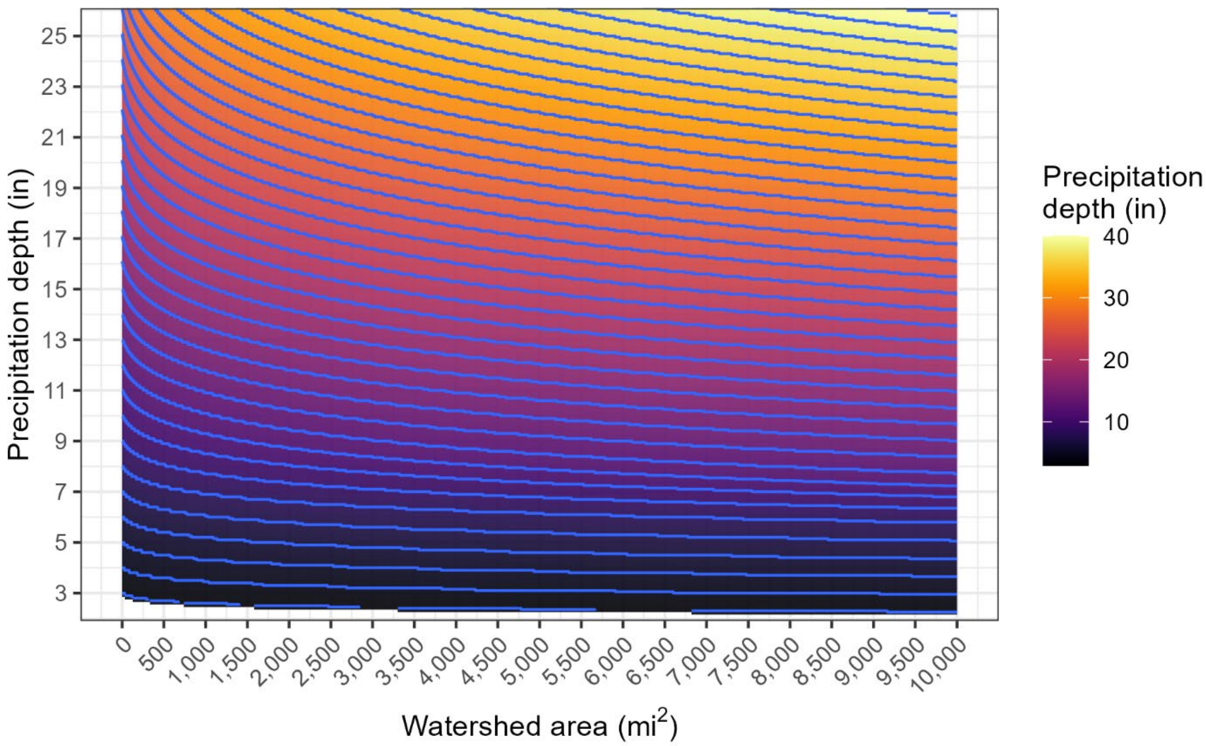


Figure 7-5. Plot showing results of depth-area-reduction analysis based on all sites used in the analysis.

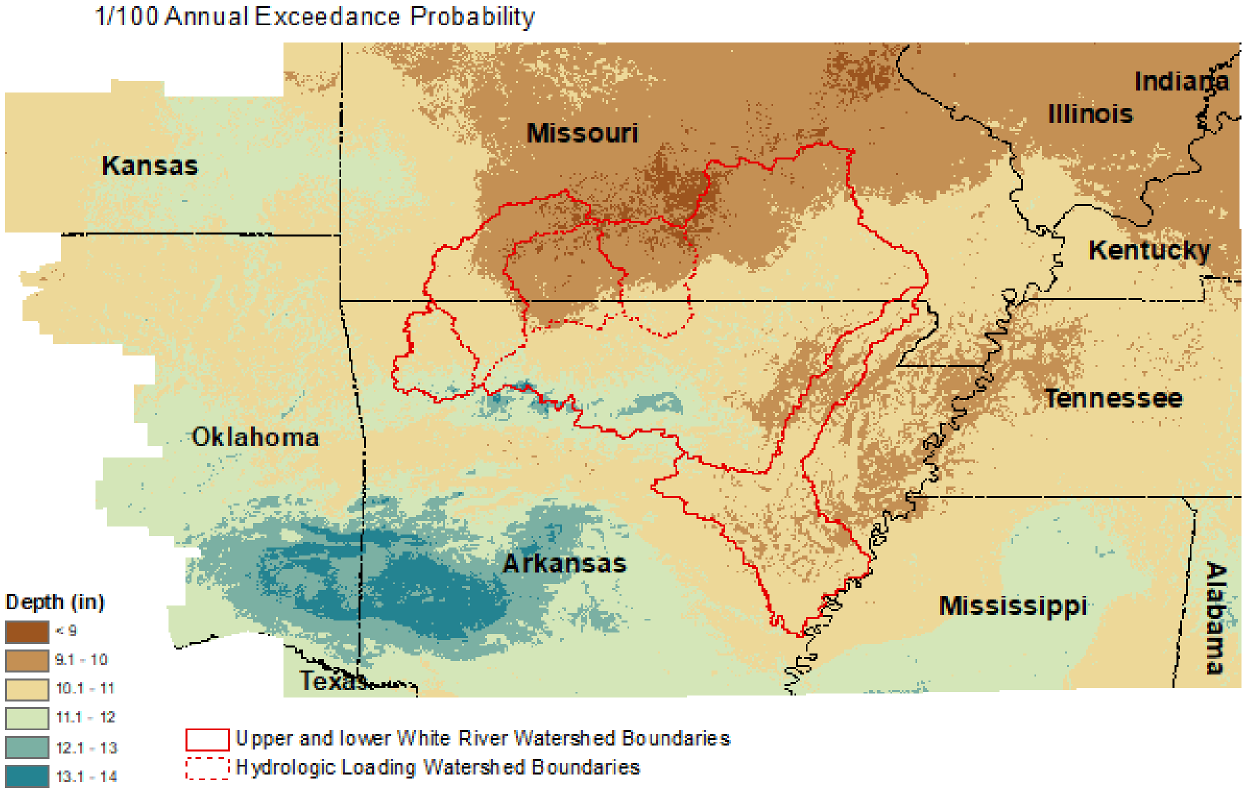


Figure 7-6. 1/100 AEP, 72-hour precipitation depths for the White River basin in AR and MO from SWL precipitation frequency study

7.1 Stochastic Simulation and Uncertainty Analysis

For each specific location for which 1/100 AEP peak streamflows (the peak streamflow that has a 1% chance of occurring in a given year) were evaluated, the parameters of the generalized extreme value (GEV) distribution resulting from the precipitation frequency study were extracted. The effective record length (ERL) for regions within the precipitation frequency study was estimated based on variance of predicted precipitation depths within each specific region. A number of random samples equivalent to the ERL was produced from the base distribution and a new GEV distribution was created from the random samples produced. From this new GEV distribution, precipitation depth quantiles were produced. Based on drainage area of the catchment above the location for which the 1/100 AEP estimate of peak streamflow was being estimated, the precipitation depths were reduced based on the values shown in Figure 229. Repeating this process 500 times with two or three different storm events, representing different distributions of rainfall and antecedent conditions, and then routing the rainfall through a hydrologic model allows for the computation of uncertainty and a mean peak streamflow based on the GEV distribution estimated from the precipitation frequency study referenced above.

8 Riverware™ Analysis

8.1 RiverWare White River Period of Record Model

In the 1980's Ron Hula developed SUPER, as part of a request from Southwest Division to develop a reservoir system modeling software. The SUPER program became part of Southwestern Division Modeling System for the Simulation of the Regulation of a Mutli-purpose Reservoir System. Ron Hula worked with districts within SWD to develop multi-purpose reservoir systems for each of their systems at a daily timestep. The White River was one of these systems including Beaver, Table Rock, Bull Shoals on the White River mainstem, Norfork on the North Fork, Greers Ferry on the Little Red River, and Clearwater on the Black River. It was used as a planning tool, to investigate the effect changes would have on the system. It can model a wide variety of changes from operational, to system, to climate. In the 2000's the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) an organization within the University of Colorado Boulder, was tasked with replicating SUPER within a new program called RiverWare™. RiverWare™ became the new official period of record (POR) model on the White River. It was continued to be used as a planning tool in investigating the changes to the White River system over time has on the system. SUPER methods were implemented in RiverWare™, methods and rules have been improved as technology has gotten better. The hydrology is also updated periodically, and the model is currently available from 1940-2017. The White River POR model includes surcharge, flood, firm power, water supply, water accounting, hydropower, low/minimum flow and temperature minimum flow operations.

8.2 Introduction to Riverware Modeling

RiverWare is a reservoir and river system modeling tool. It is developed by Center for Advance Decision Support for Water and Environmental Systems (CADSWES) at the University of Colorado Boulder. The White River period of record model is a daily time step model which simulates reservoir operations and flows on the White River from 1940-2017 from the headwaters of Beaver, Norfork, and Clearwater down to Georgetown. The White River model simulates reservoirs operations at Beaver, Table Rock, Bull Shoals, and Norfork on the upper White River, Georgetown on the Little Red and Clearwater on the Black River (Figure 8-1). All flows are then routed down to Georgetown. It models the current water control plan. The period of record model is a comparison model used for evaluating different operational scenarios.

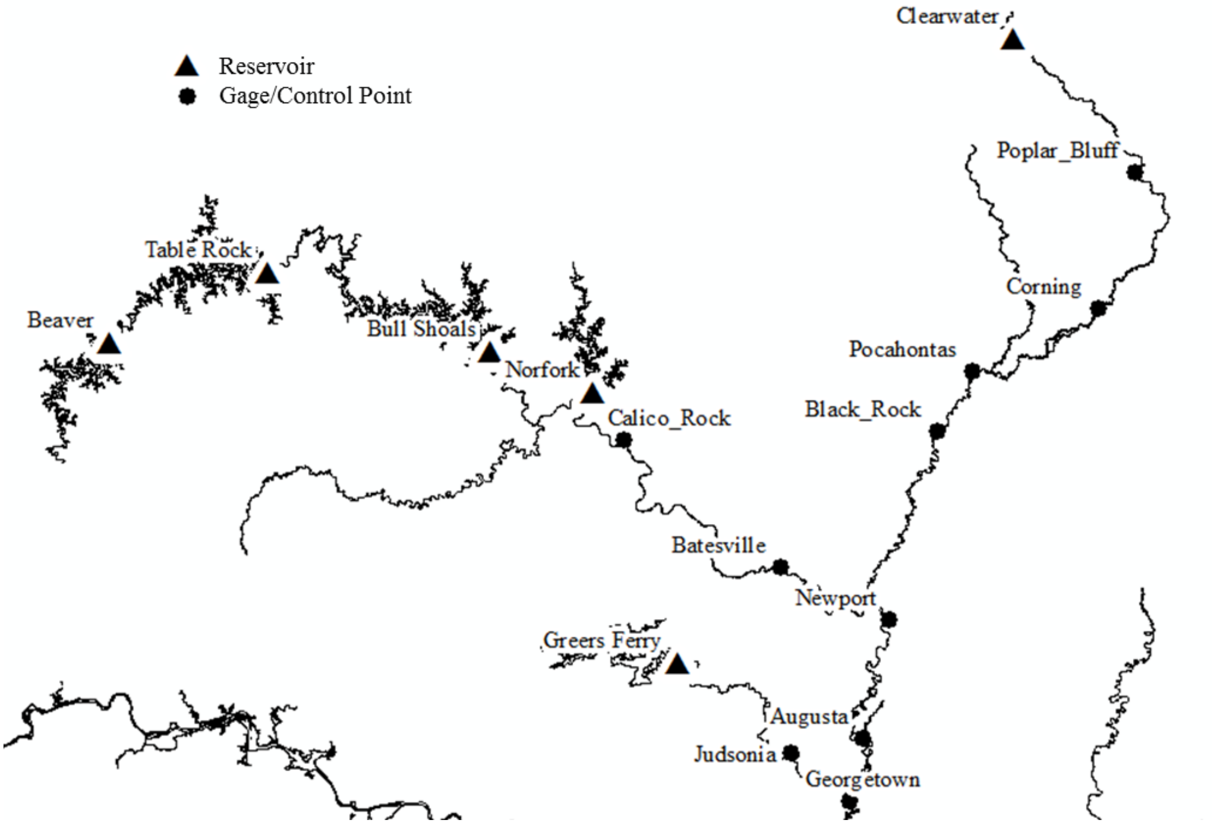


Figure 8-1. Norfork, White, and Black Rivers showing reservoir (triangles) and important gages (circles) used in hydrology update of the White River RiverWare period of record model.

8.3 Data Used in the RiverWare Model

The physical data for a system includes the reservoir pertinent data such as elevation storage and area curves, induced surcharge, and free flow rating curves, hydropower curves, evaporation table, seepage, and pertinent level such as top of conservation pool, and top of flood pool. This data is maintained and updated as new information becomes available, such as new bathymetric surveys of the lakes. The physical data also includes the regulation limits of all downstream constraints. All of these regulation details are set as outlined in the current water control manuals.

The model is updated periodically with hydrology data developed from USGS and Corps gages. The gage data and locations are listed in Table 1.

Table 8-1: USGS and USACE gages included in the RiverWare model.

Location Name	USGS Gage Number	Parameters
Beaver Lake	-	Elevation, Inflow, Release
Table Rock Lake	-	Elevation, Inflow, Release
Bull Shoals Lake	-	Elevation, Inflow, Release
Norfork Lake	-	Elevation, Inflow, Release
Calico Rock, White River	07060500	Flow
Batesville, White River	07061000	Flow
Clearwater Lake	07062000	Elevation, Inflow, Release
Poplar Bluff, Black River	07063000	Flow
Corning, Black River	07064000	Flow
Pocahontas, Black River	07069000	Flow
Black Rock, Black River	07072500	Flow
Poughkeepsie, Strawberry R	07074000	-
Newport, White River	07074500	Flow
Augusta, White River	07074850	Flow
Greers Ferry Lake		Elevation, Inflow, Release
Judsonia, Little Red River	07076634	Flow
Georgetown, White River	07076750	Flow

8.4 Methodology Used to Develop the POR Hydrology

An incremental local is the runoff that occurs between two points. These points can be two gages or a reservoir and a gage. For the White River period of record RiverWare model incremental locals are needed for the reservoir and major gages (Figure 1). To calculate the incremental local for a gage downstream of a reservoir the reservoir releases are routed to the gage and the difference is taken between the observed flow at the gage and the reservoir releases. To calculate incremental locals for a gage downstream of another gage, the upstream gage observed flow is routed to the downstream gage and the difference is taken.

$$Q_{incremental\ local} = Q_{obs} - Q_{routed\ release}$$

$$Q_{incremental\ local} = Q_{obs} - Q_{routed\ upstream\ gage}$$

Overall, the incremental and hydrologic local calculations obtain reasonable results, but occasionally negative values are calculated for the incremental locals. These negative values may be due to inaccurate rating curves, differences between observed and modeled routing, water flowing around gages, river diversions, and evapotranspiration from the river. All these reasons could result in negative locals. In order to get rid of negative locals a script was written that would transform the negative locals to 0. Most of the gages were modified using this script.

8.5 RiverWare Operation Model Application

The White River POR model simulates the White River reservoirs operations from 1940-2017. Not all of the dams were built at this time. The model simulates the White River with current operations like all of the dams are in existence from 1940-2017. This allows for a comparison of operations for the longest period with available hydrology.

The December 2015 storm event is shown in Figure 8-2 - Figure 8-7. The period of record modeled data is shown with observed data. Overall, the period of record model matches well to observed data. The general trends of reservoir operations are followed with minor differences occurring at the initial opening and shutting down of releases. At the time of a storm regulators have many different event specific conditions that could be occurring such as turbines inoperable, unique downstream constraints etc. Due to this the period of record model will not perfectly match historic events but comes reasonably close and is a good comparison model.

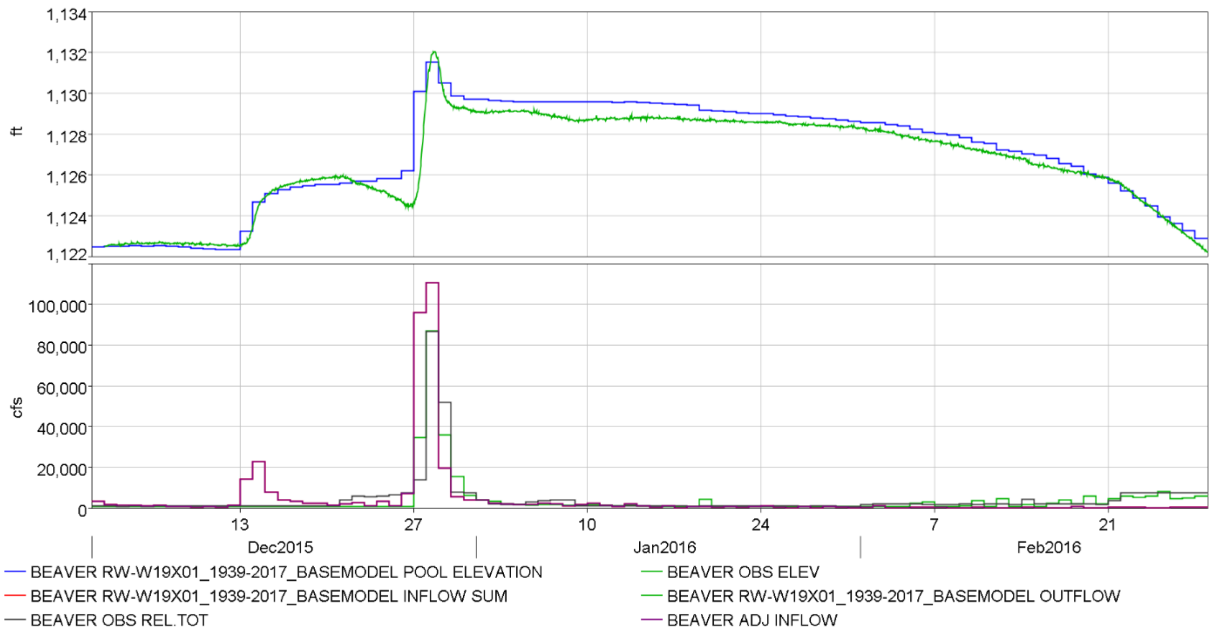


Figure 8-2. Observed and modeled pool elevation for Beaver Dam for Dec 2015 storm event.

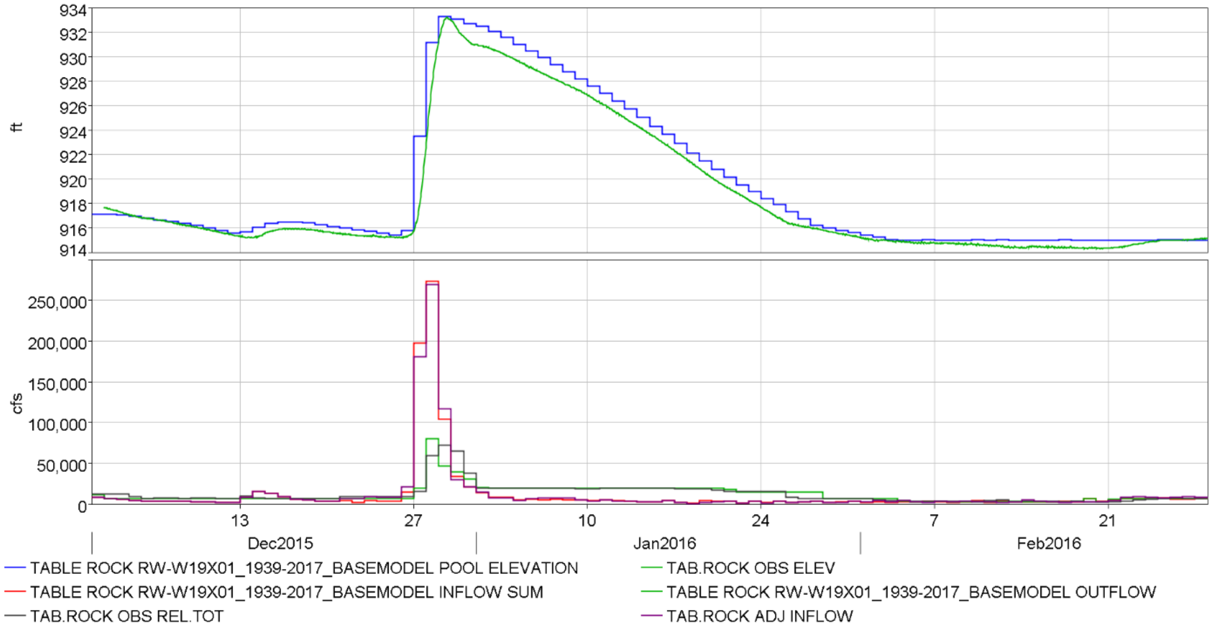


Figure 8-3. Observed and modeled pool elevation for Table Rock Dam for Dec 2015 storm event.

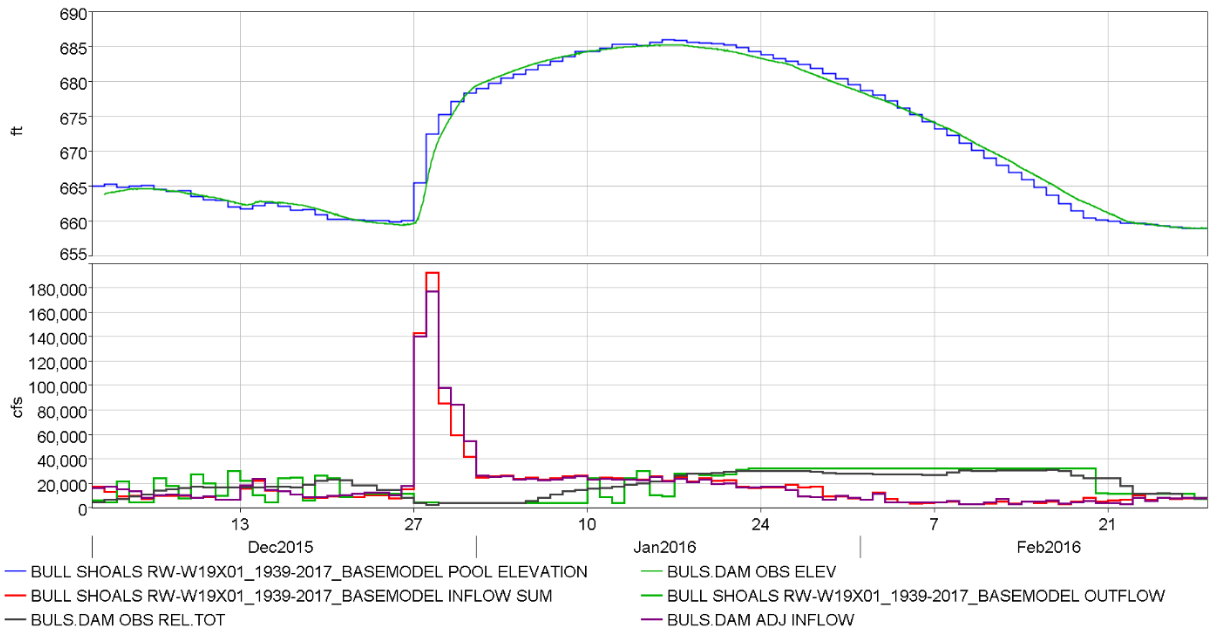


Figure 8-4. Observed and modeled pool elevation for Bull Shoals Dam for Dec 2015 storm event.

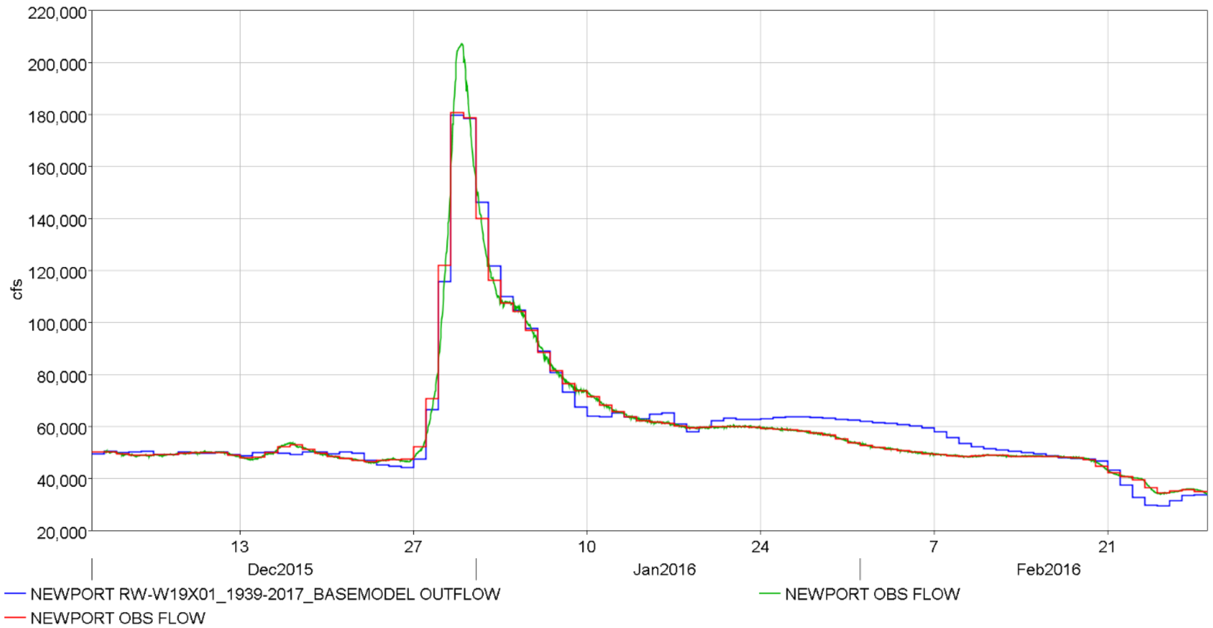


Figure 8-5. Observed and modeled pool elevation for Newport for Dec 2015 storm event.

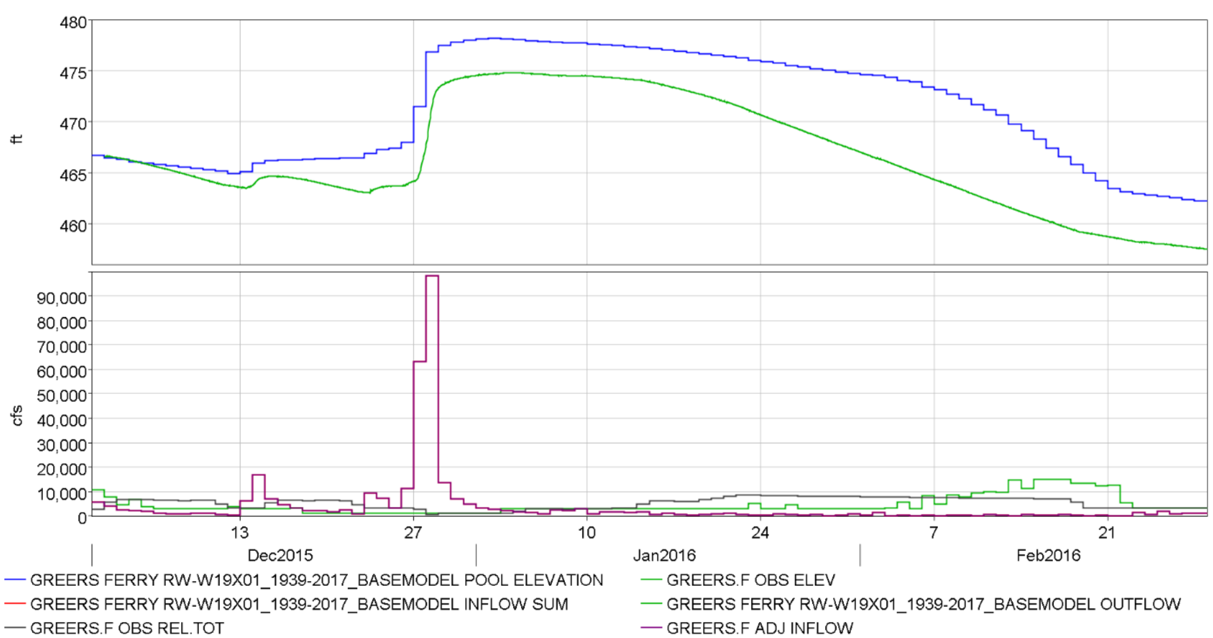


Figure 8-6. Observed and modeled pool elevation for Greers Ferry Dam for Dec 2015 storm event.

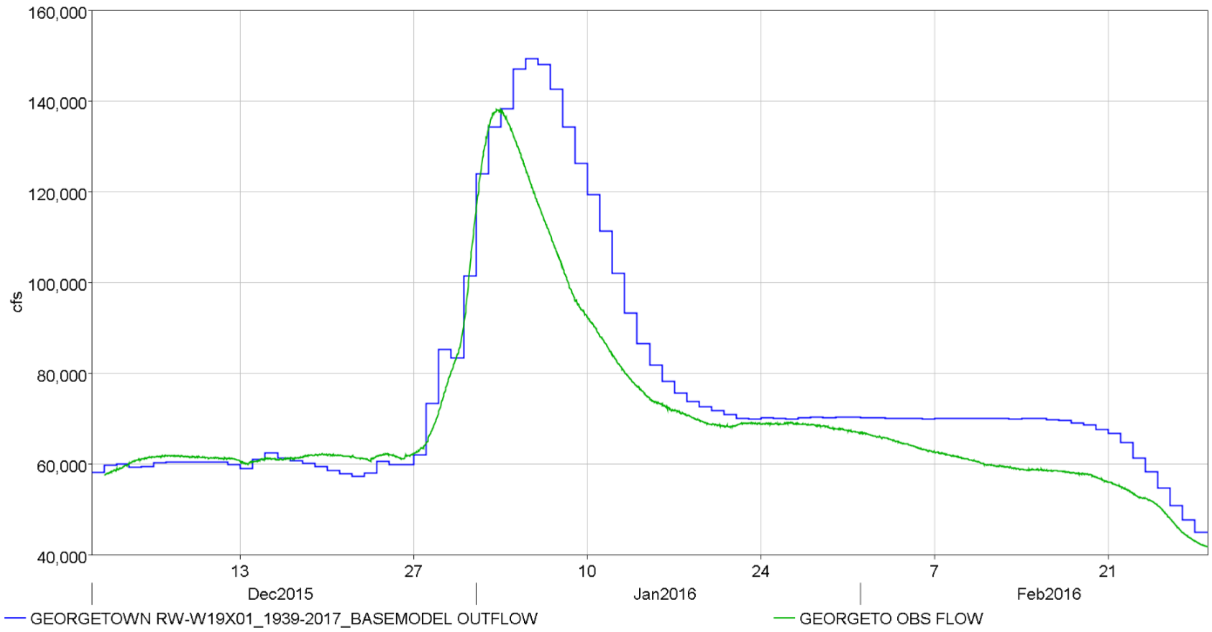


Figure 8-7. Observed and modeled pool elevation for Georgetown for Dec 2015 storm event.

The period of record model is compared to observed data from 1940-2017 in plots Figure 8-8 - Figure 8-24 for pool elevation, inflow, and releases. The models have data from 1940-2017. The observed data is shown as available. The White River lakes were built from the 1940's to 1960's and the time needed to fill the conservation pool varied for each lake.

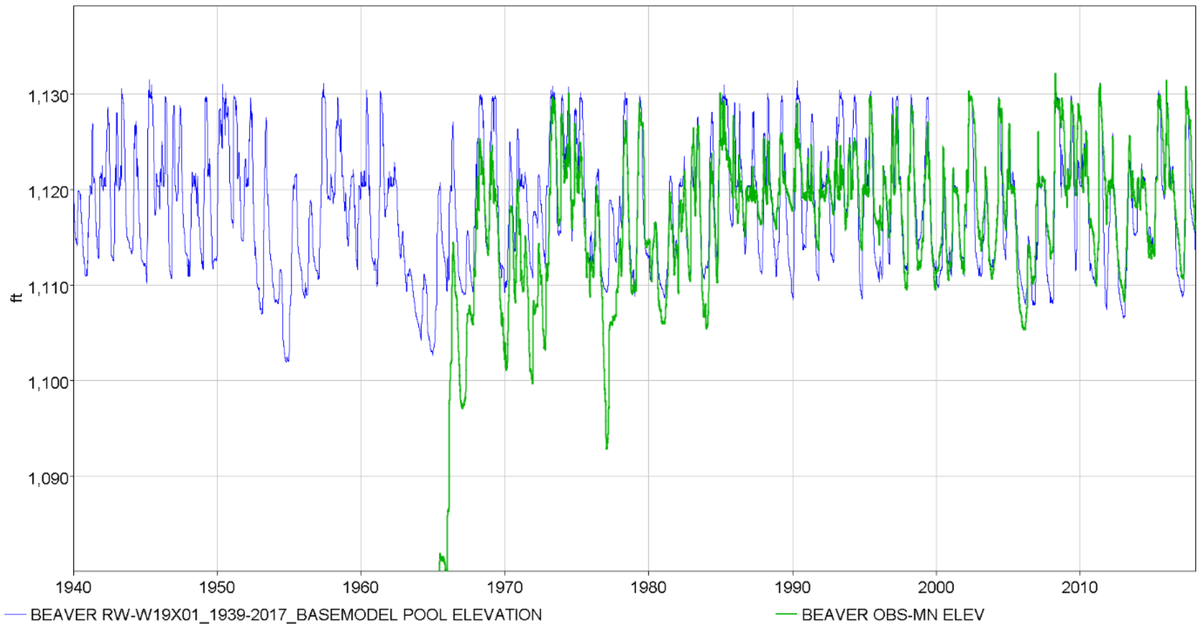


Figure 8-8. Observed and modeled pool elevation for Beaver Dam from 1940-2017.

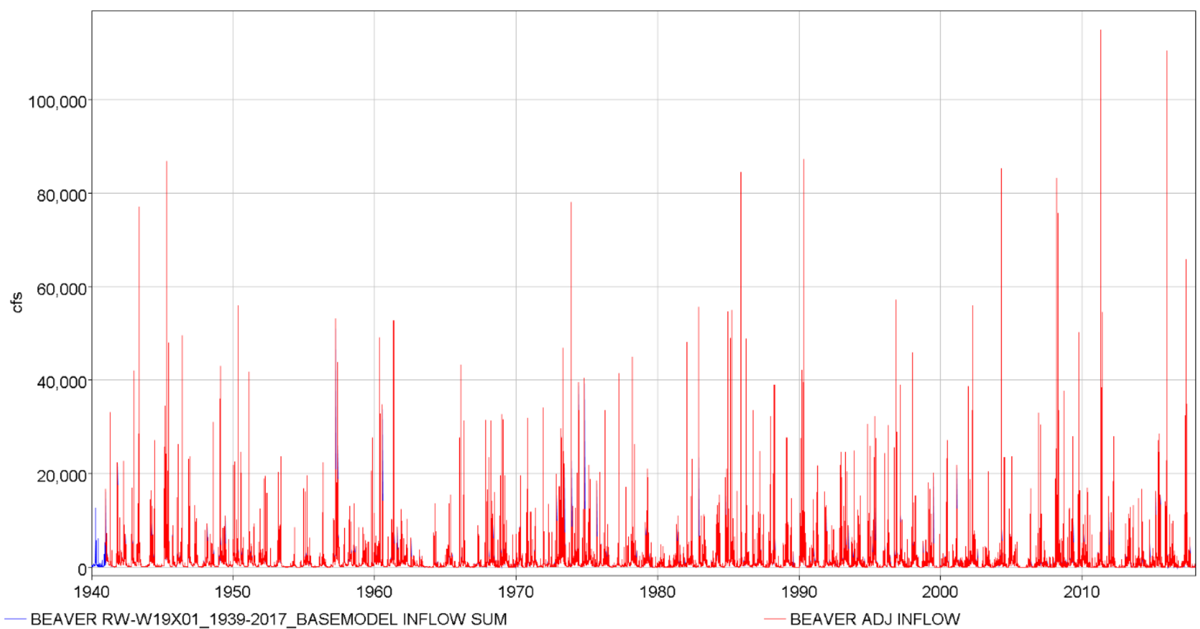


Figure 8-9. Observed and modeled inflow for Beaver Dam from 1940-2017.

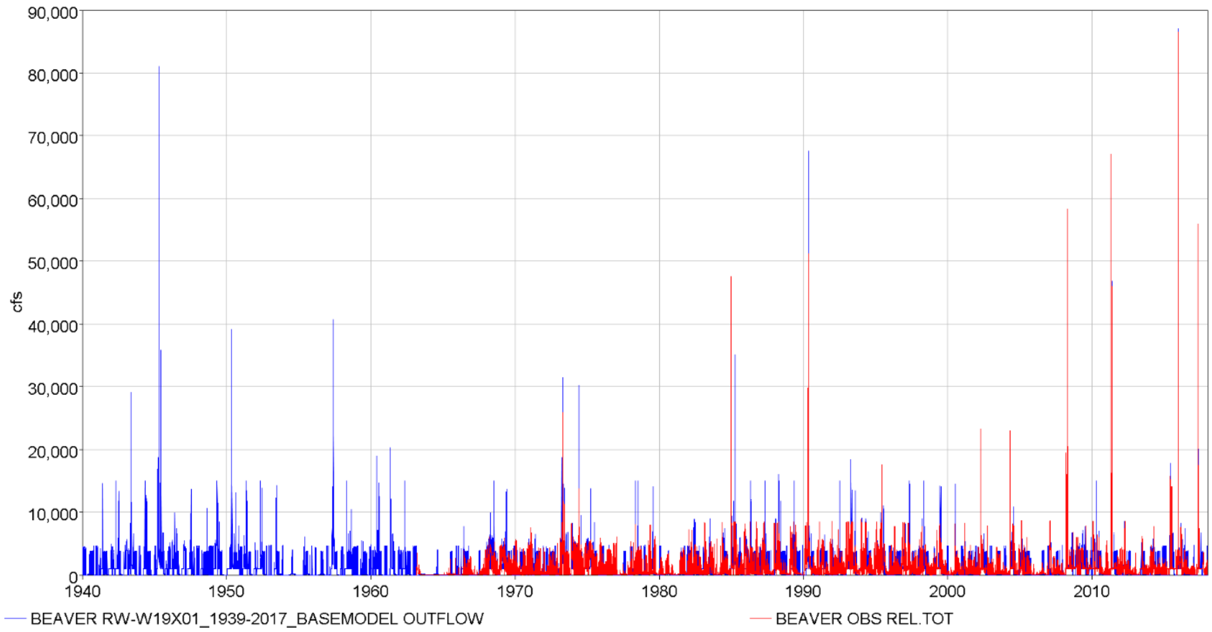


Figure 8-10. Observed and modeled releases for Beaver Dam from 1940-2017.

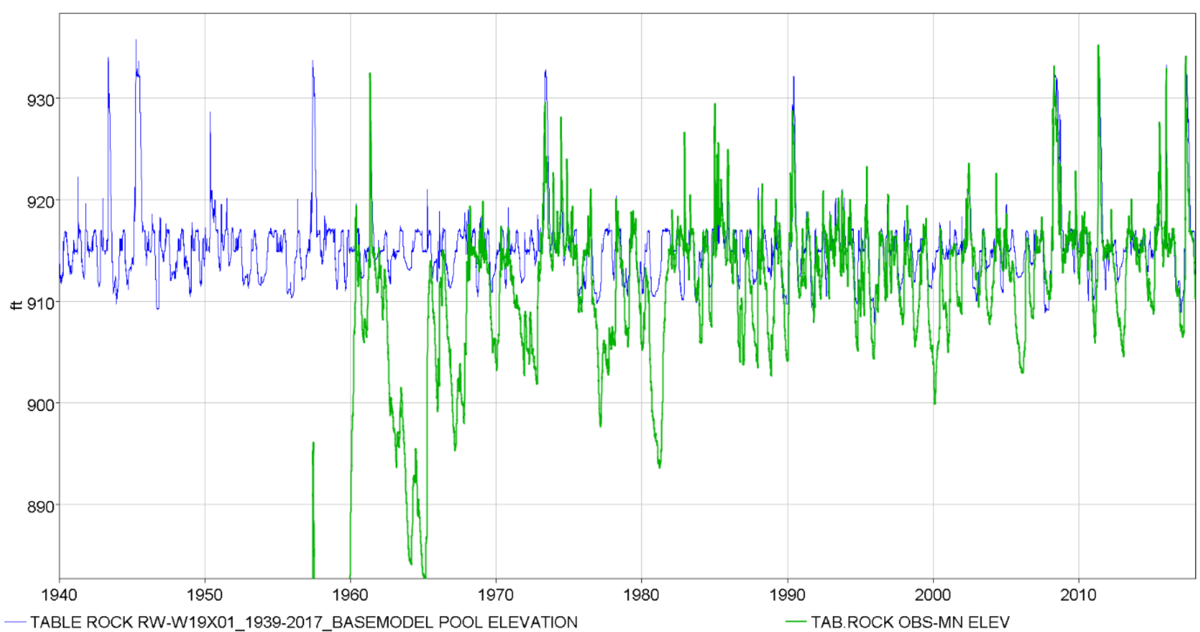


Figure 8-11. Observed and modeled pool elevation for Table Rock Dam from 1940-2017.

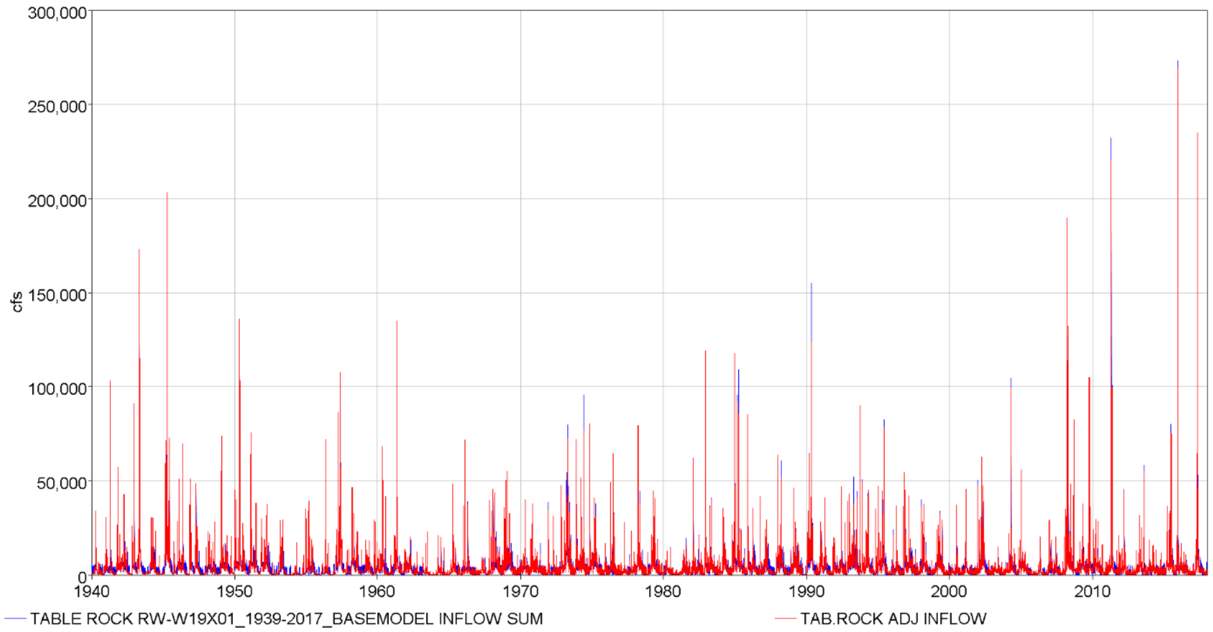


Figure 8-12. Observed and modeled inflow for Table Rock Dam from 1940-2017.

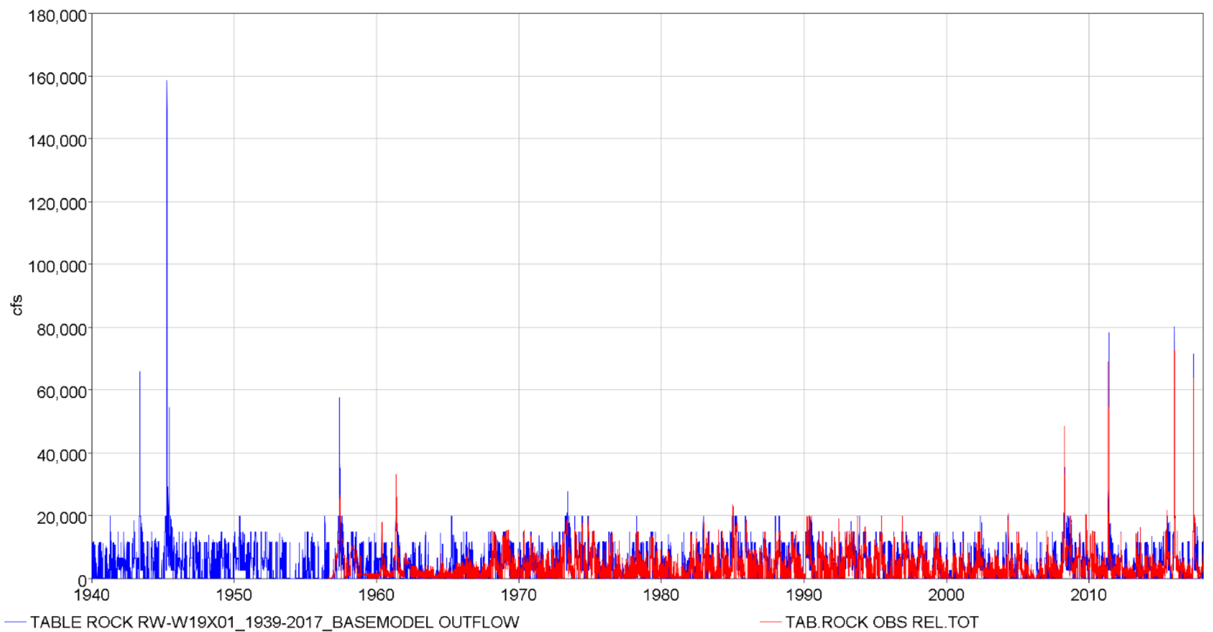


Figure 8-13. Observed and modeled releases for Table Rock Dam from 1940-2017.

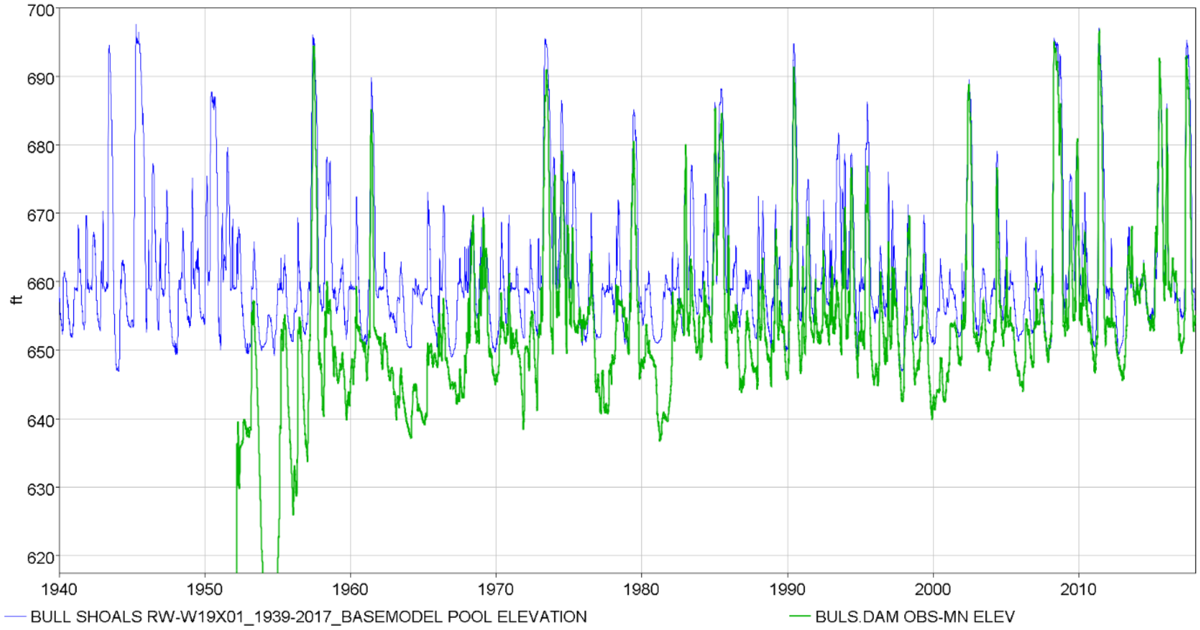


Figure 8-14. Observed and modeled pool elevation for Bull Shoals Dam from 1940-2017.

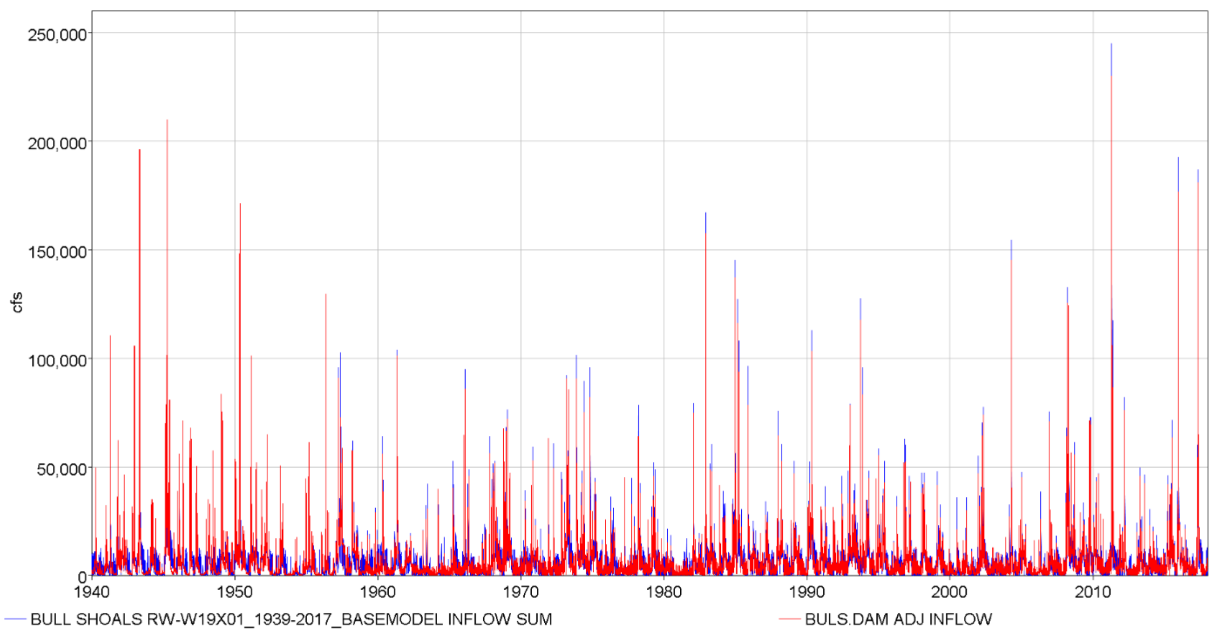


Figure 8-15. Observed and modeled inflow for Bull Shoals Dam from 1940-2017.

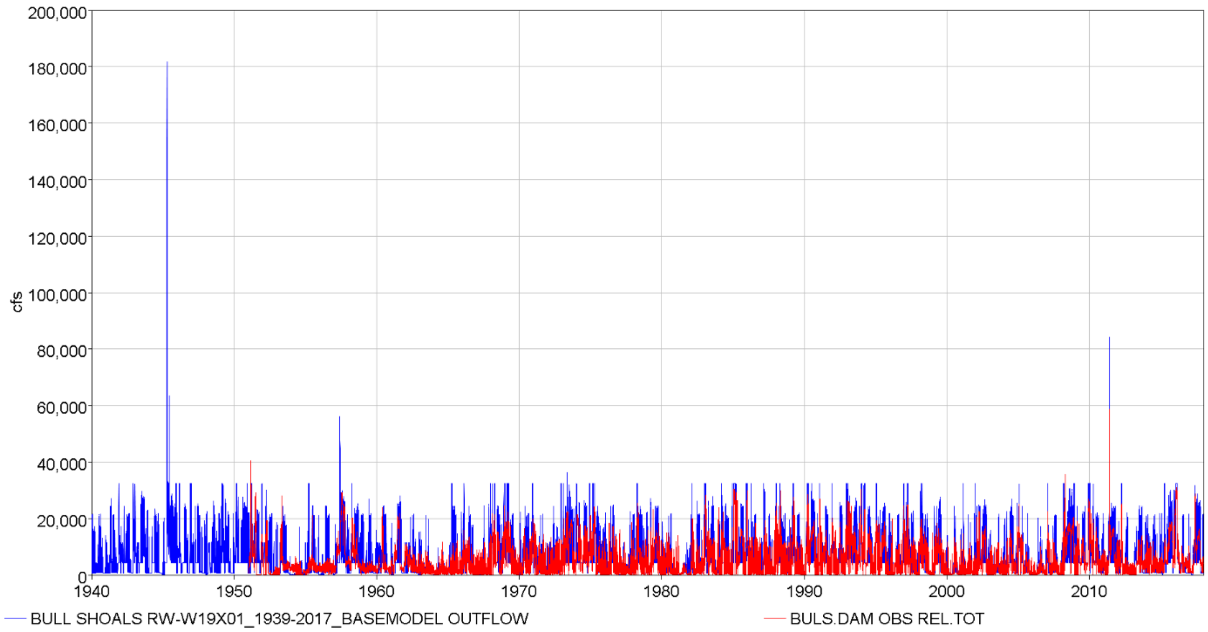


Figure 8-16. Observed and modeled outflow for Bull Shoals Dam from 1940-2017.

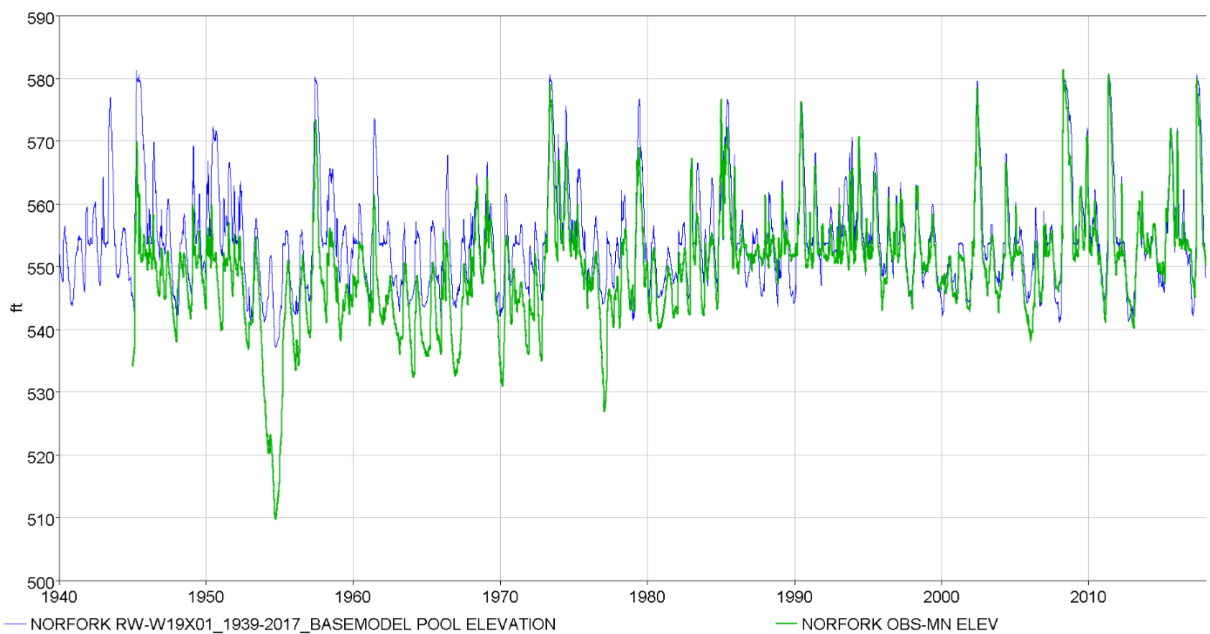


Figure 8-17. Observed and modeled pool elevation for Norfork Dam from 1940-2017.

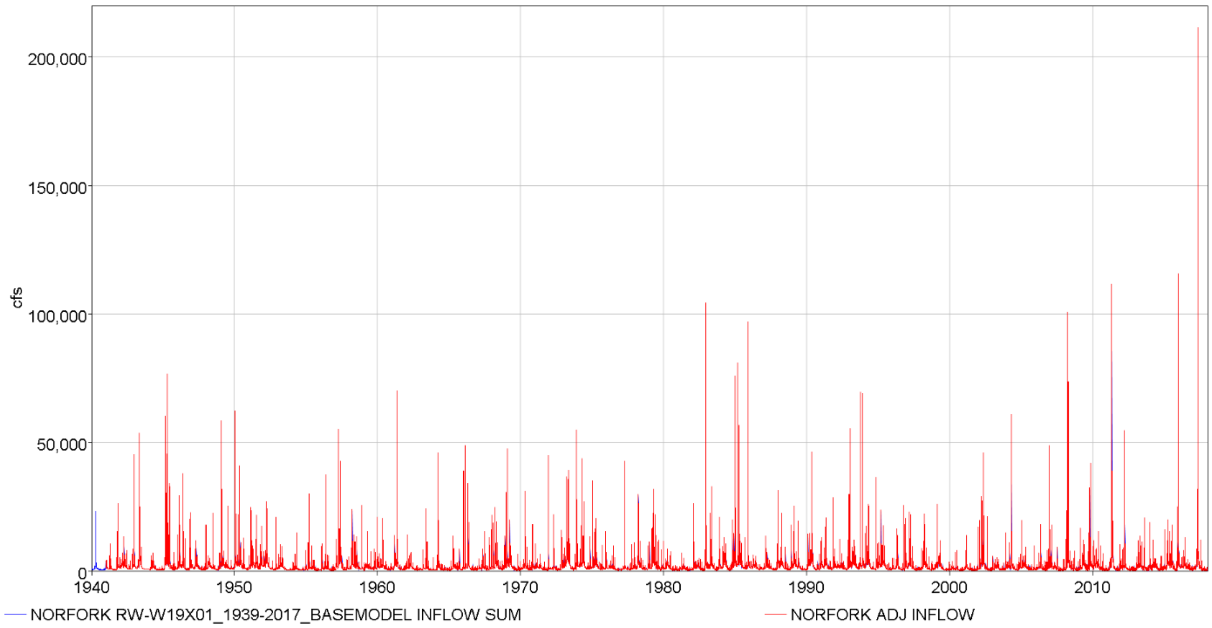


Figure 8-18. Observed and modeled inflow for Norfork Dam from 1940-2017.

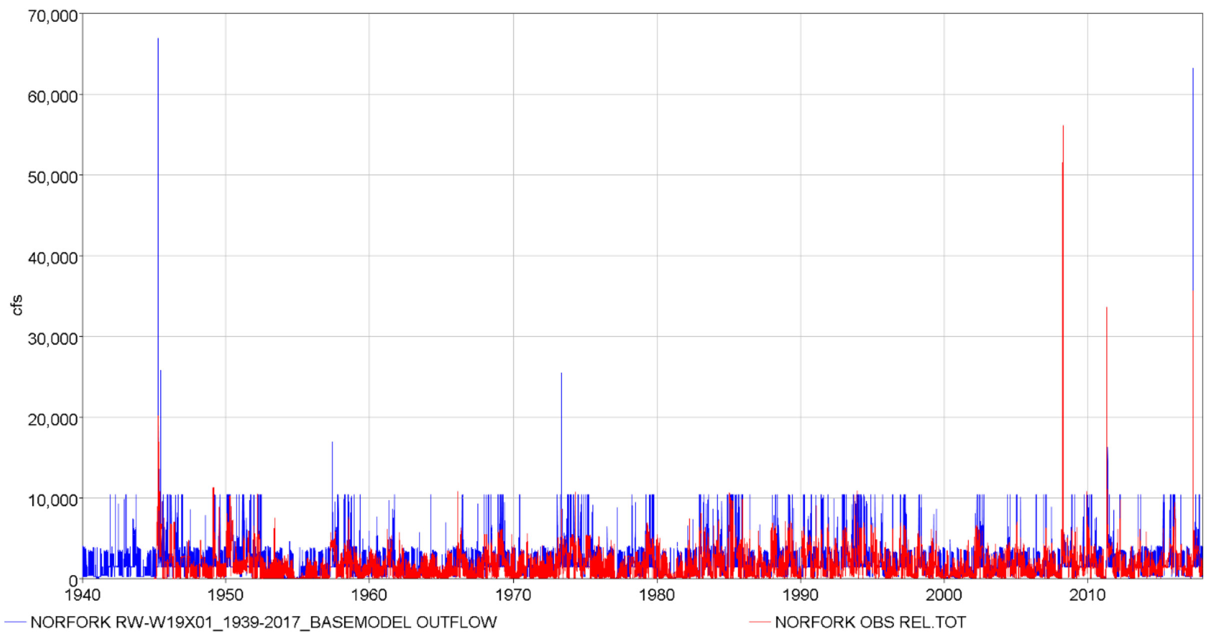


Figure 8-19. Observed and modeled releases for Norfork Dam from 1940-2017.

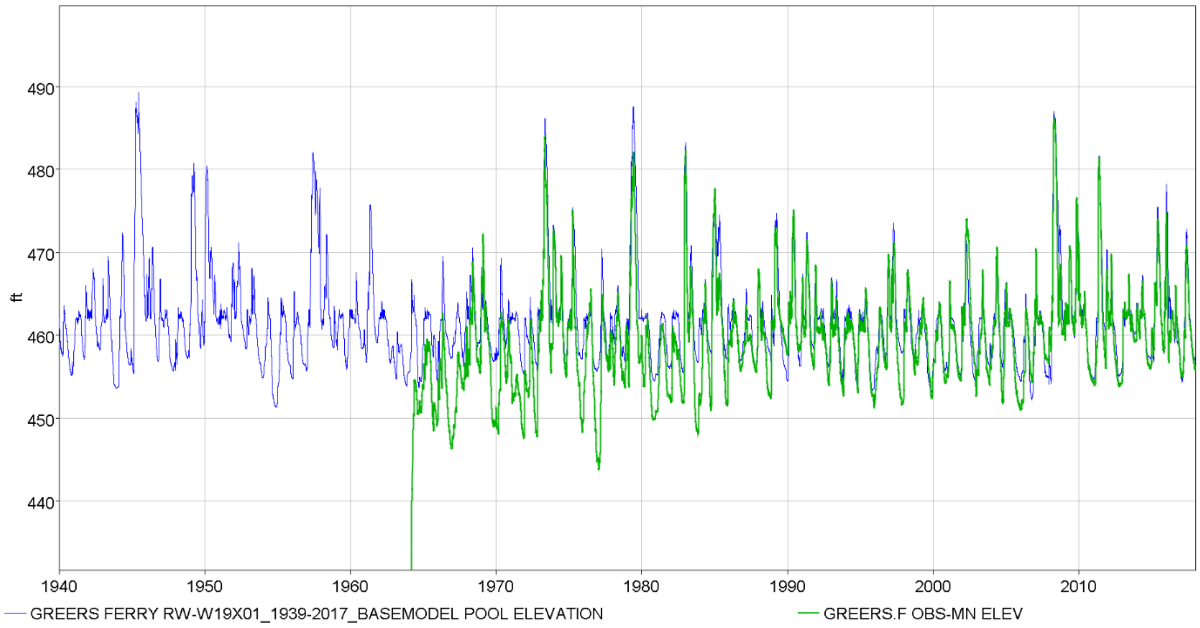


Figure 8-20. Observed and modeled pool elevation for Greers Ferry Dam from 1940-2017.

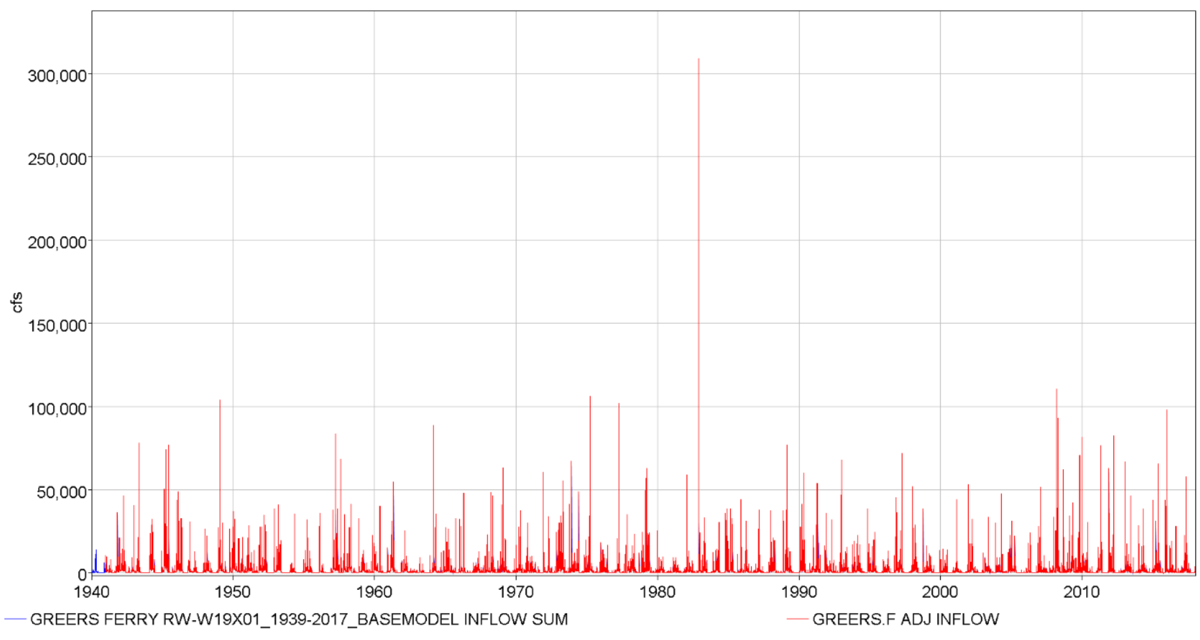


Figure 8-21. Observed and modeled inflow for Greers Ferry Dam from 1940-2017.

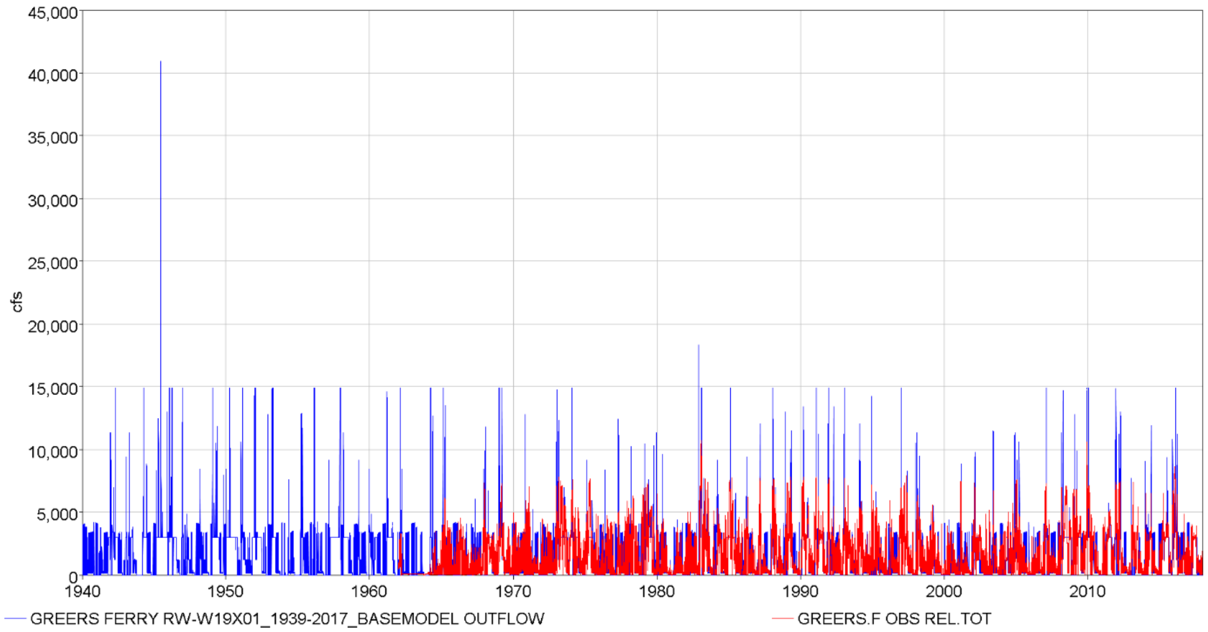


Figure 8-22. Observed and modeled releases for Greers Ferry Dam from 1940-2017.

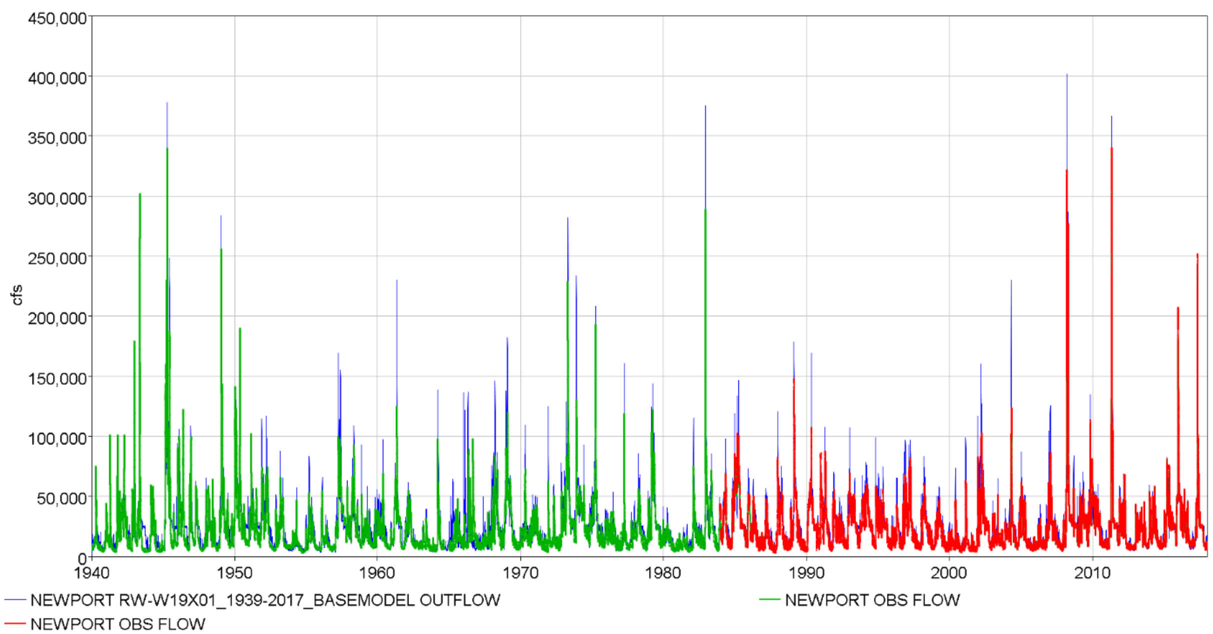


Figure 8-23. Observed and modeled flow at Newport from 1940-2017.

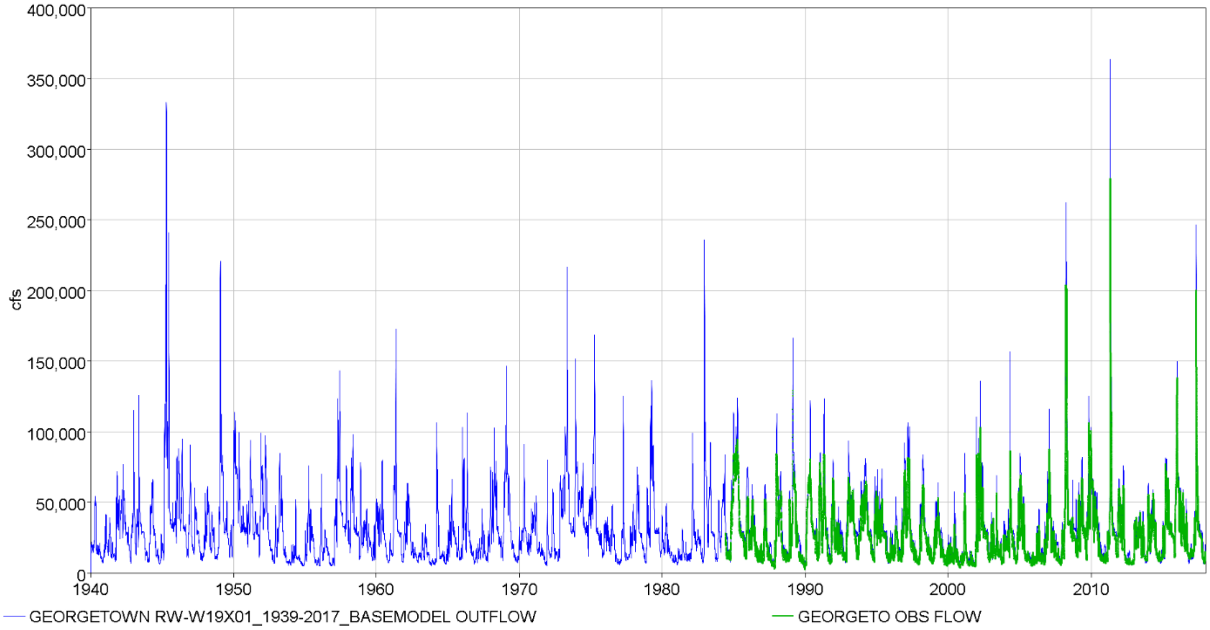


Figure 8-24. Observed and modeled flow at Georgetown from 1940-2017.

8.6 RiverWare Model Results and Discussion

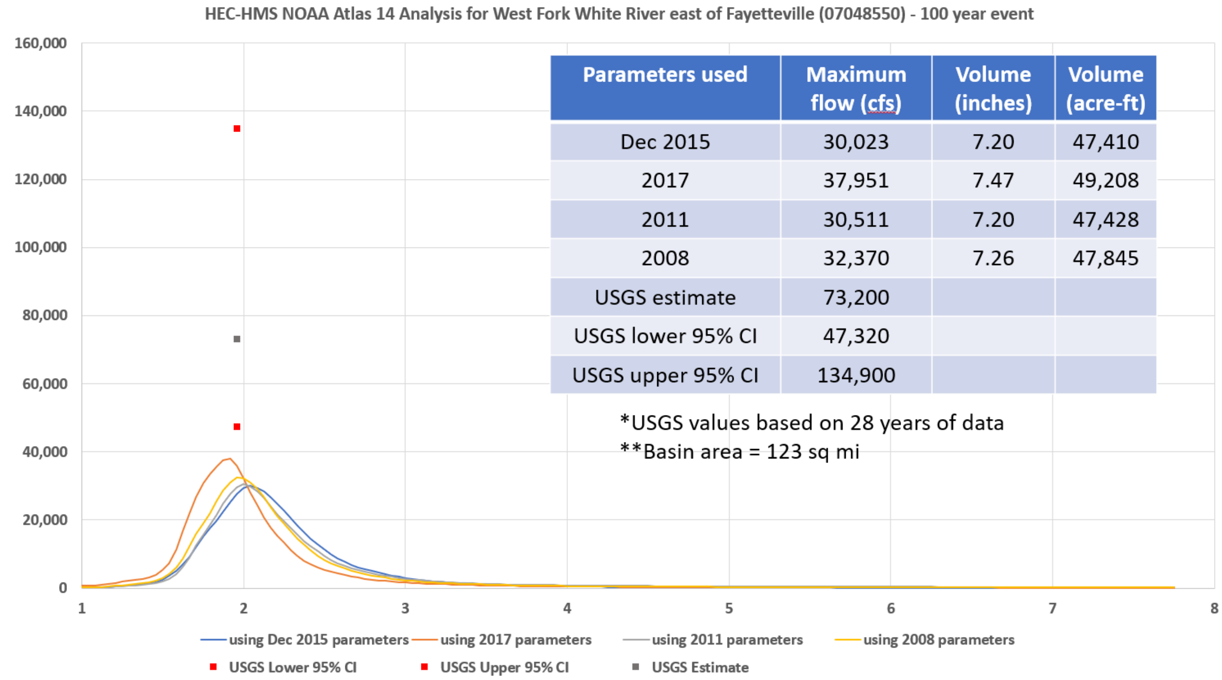
The White River period of record model modeled the White River system from January 1940-December 2017. The model results were compared to observed data for the time period historical data was available. These results are shown in Figure 8-2 - Figure 8-24. The December 2015 event matched well between observed and modeled data with minor differences due to event specific conditions. The period of record has a reasonable match between observed and modeled data in the most recent years. The period of record model simulates the current water control plan, which will lead to a better match in the most recent years. The model data will be used for statistical analysis.

9 Rainfall Runoff Modeling in HEC-HMS with NOAA Atlas 14 Rainfall Depths

Figure 9-3 through Figure 9-34 shows the NOAA Atlas 14 (Perica and other, 2013) results for selected sites in the White River Basin for the 100-year (1% AEP) event and for the 500-year (0.2% AEP) event. A range of values at each site is provided based on calibration parameters for a variety of events. The PeakFQ results are also plotted on these figures for comparison.

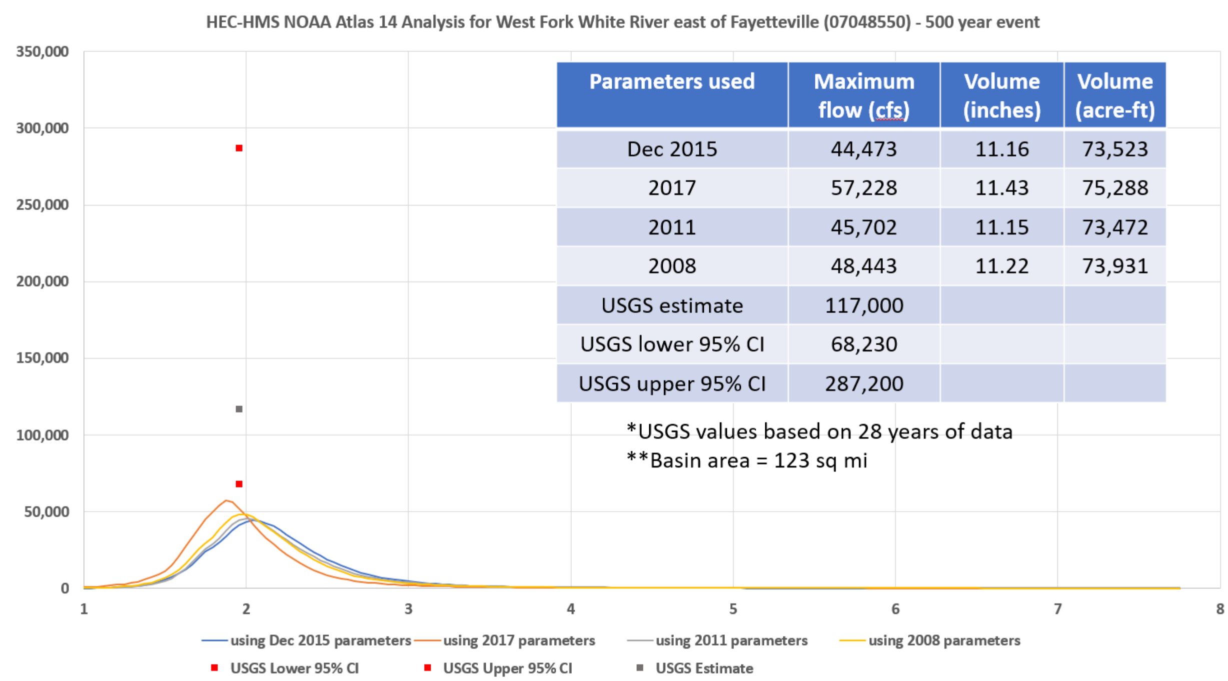
The NOAA Atlas 14 results are provided for the following locations:

- West Fork White River east of Fayetteville, AR (07048550)
- White River near Fayetteville, AR (07048600)
- War Eagle Creek near Hindsville, AR (07049000)
- Kings River near Berryville, AR (07050500)
- James River near Springfield, MO (07050700)
- James River at Boaz, MO (07052250)
- James River at Galena, MO (07052500)
- Long Creek at Denver, AR (07053207)
- Yocum Creek near Oak Grove, AR (07053250)
- Bull Creek near Walnut Shade, MO (07053810)
- Beaver Creek at Bradleyville, MO (07054080)
- Crooked Creek at Kelly Crossing, AR (07055607)
- Richland Creek near Witts Spring, AR (07055875)
- Buffalo River at St. Joe, AR (07056000)
- North Fork River near Tecumseh, MO (07057500)
- Bryant Creek near Tecumseh, MO (07058000)
- Strawberry River at Poughkeepsie, AR (07074000)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	30,023	7.20	47,410
2017	37,951	7.47	49,208
2011	30,511	7.20	47,428
2008	32,370	7.26	47,845
USGS estimate	73,200		
USGS lower 95% CI	47,320		
USGS upper 95% CI	134,900		

Figure 9-1. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for West Fork White River east of Fayetteville, AR (07048550)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	44,473	11.16	73,523
2017	57,228	11.43	75,288
2011	45,702	11.15	73,472
2008	48,443	11.22	73,931
USGS estimate	117,000		
USGS lower 95% CI	68,230		
USGS upper 95% CI	287,200		

Figure 9-2. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for West Fork White River east of Fayetteville, AR (07048550)

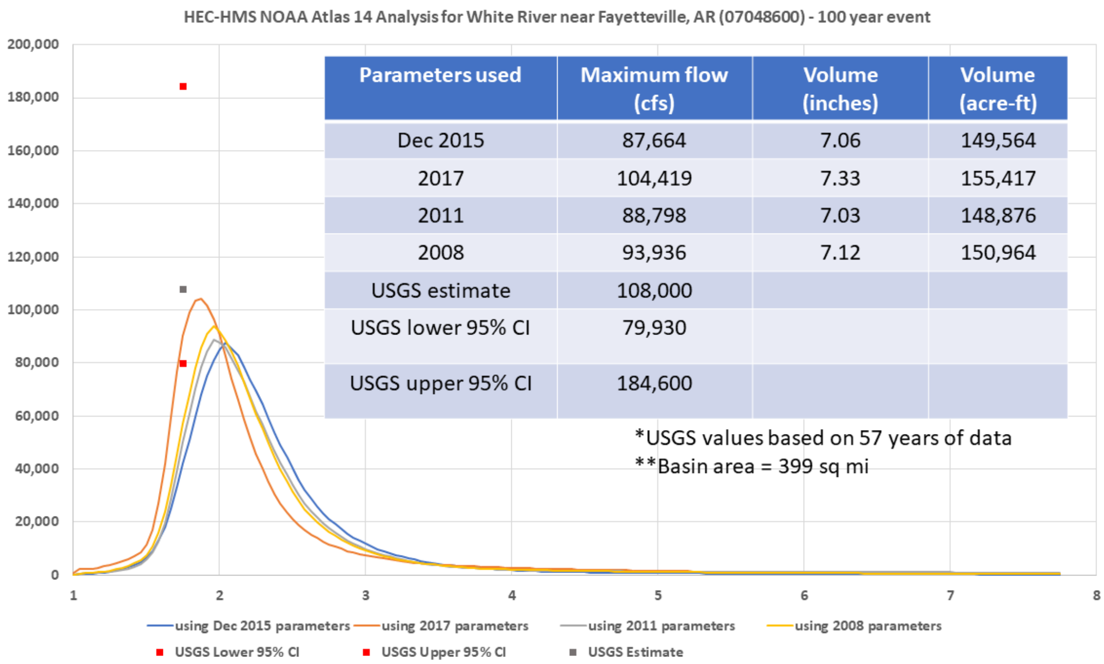


Figure 9-3. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for White River near Fayetteville, AR (07048600)

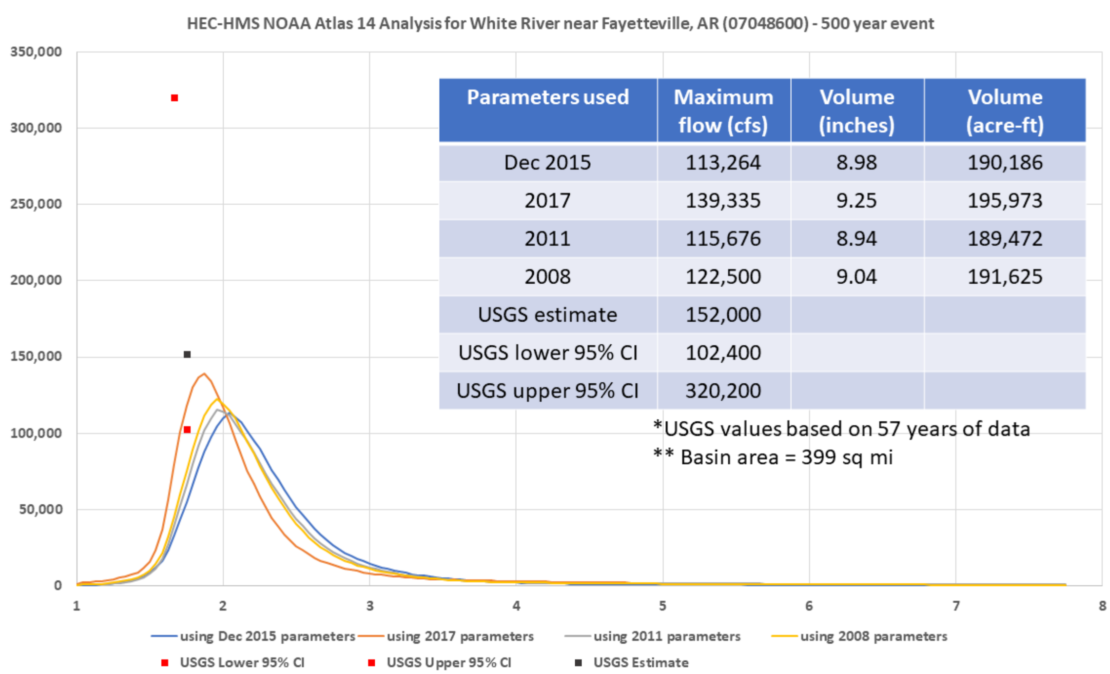


Figure 9-4. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for White River near Fayetteville, AR (07048600)

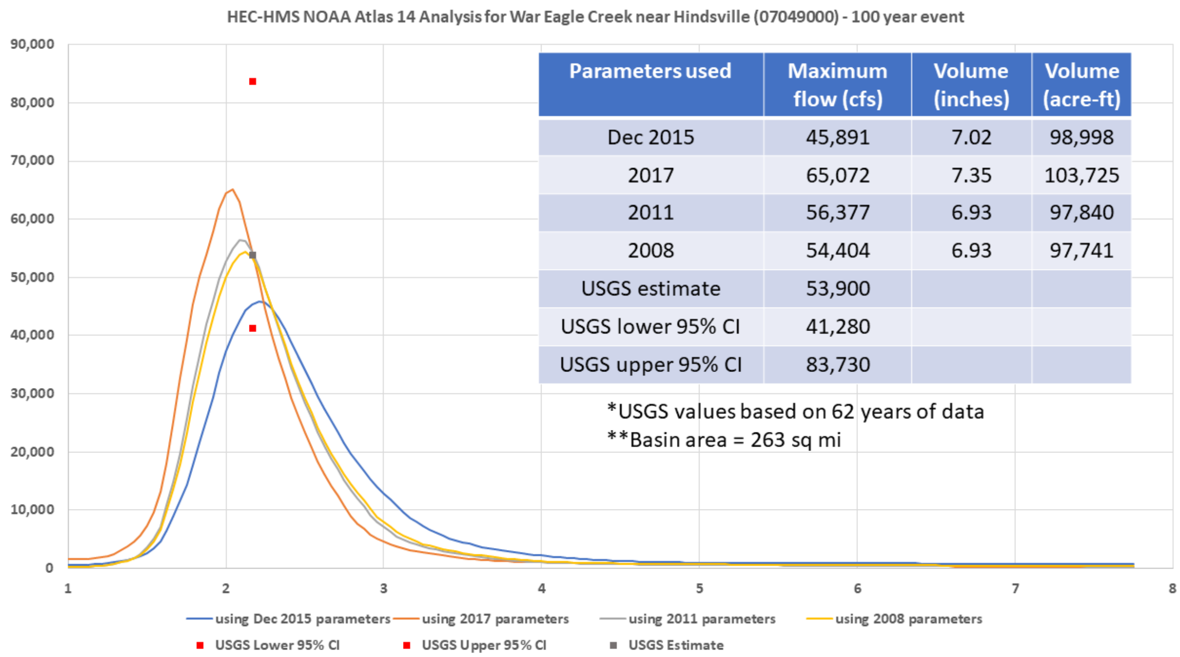


Figure 9-5. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for War Eagle Creek near Hindsville, AR (07049000)

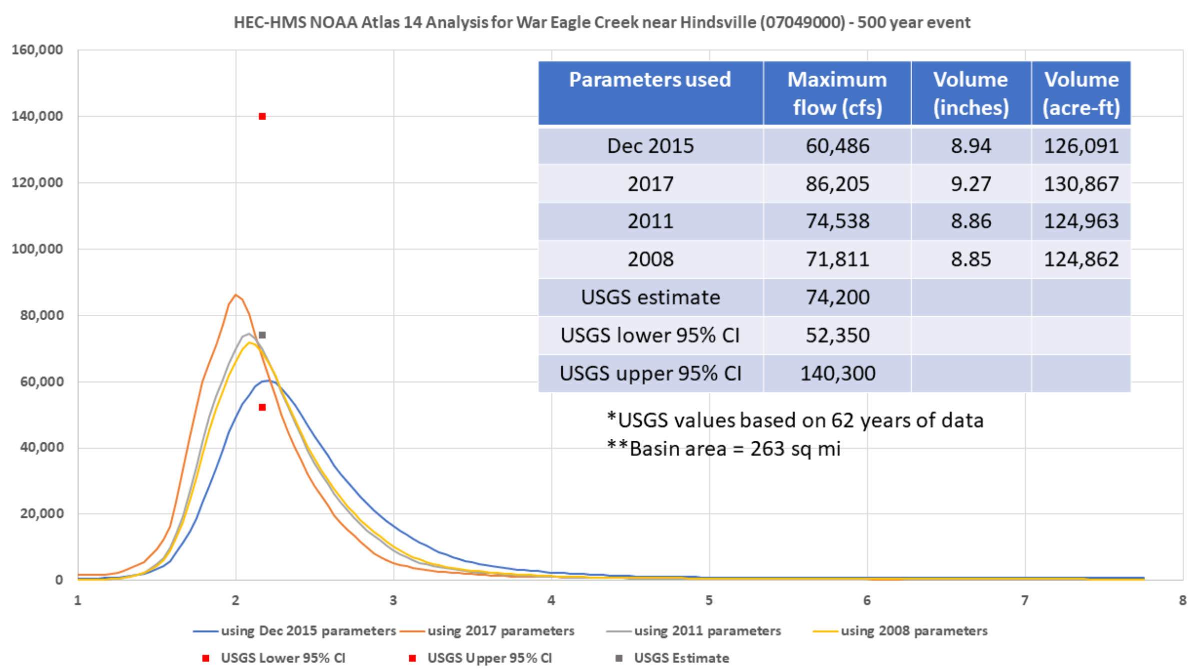


Figure 9-6. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for War Eagle Creek near Hindsville, AR (07049000)

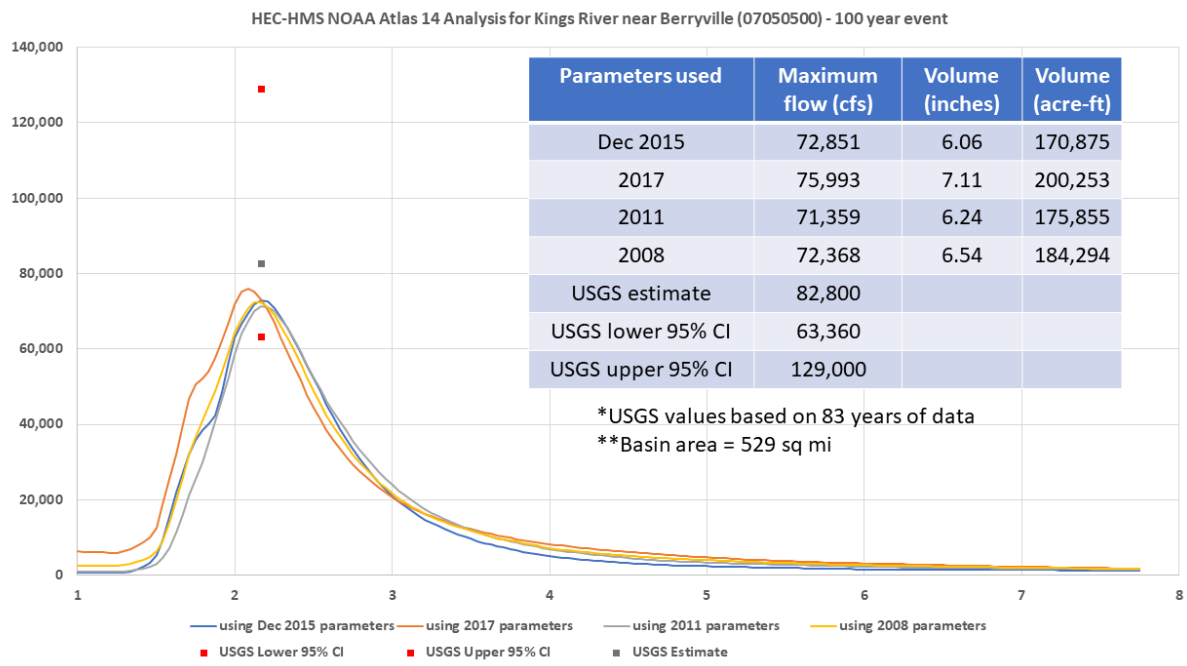


Figure 9-7. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Kings River near Berryville, AR (07050500)

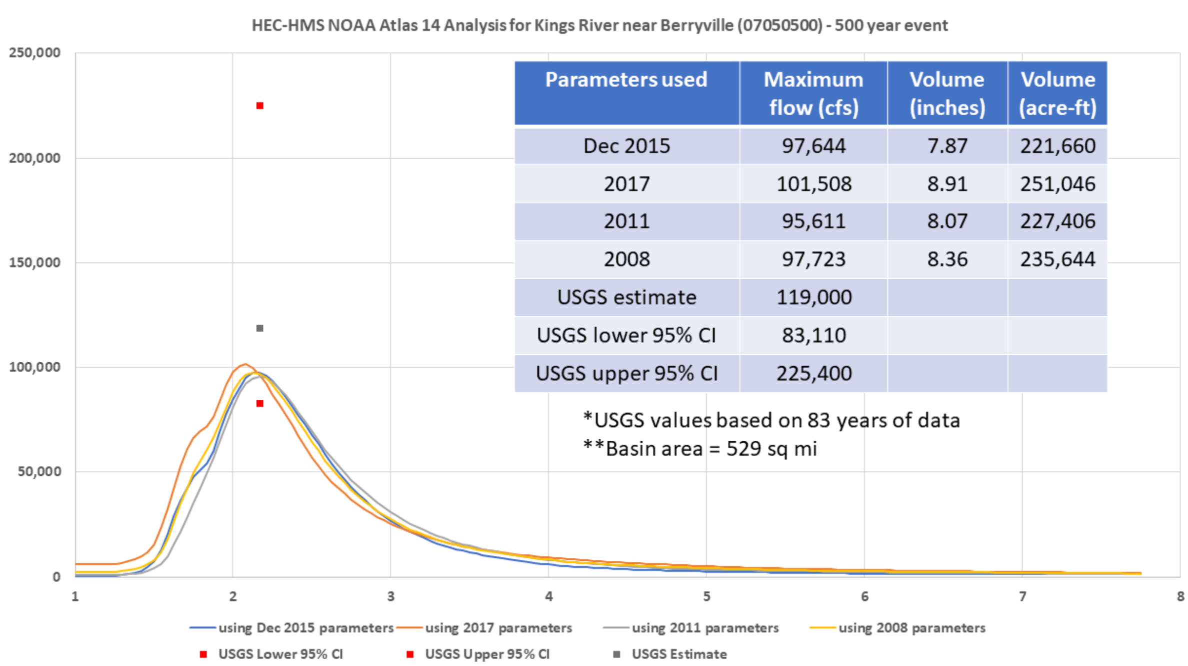
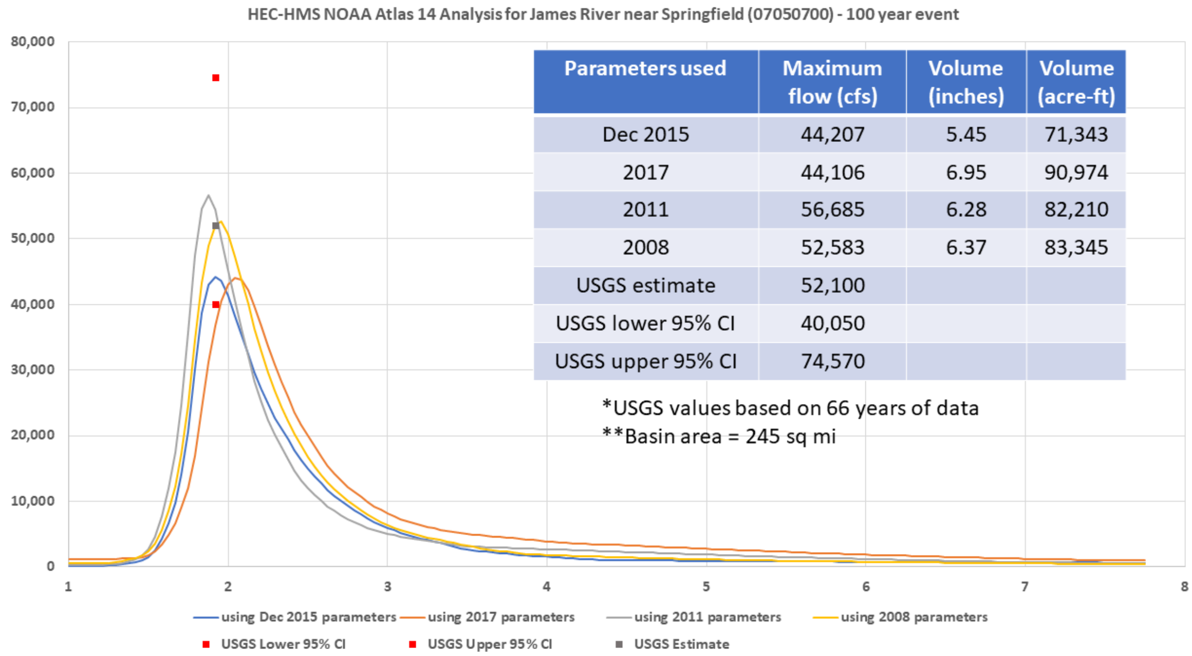
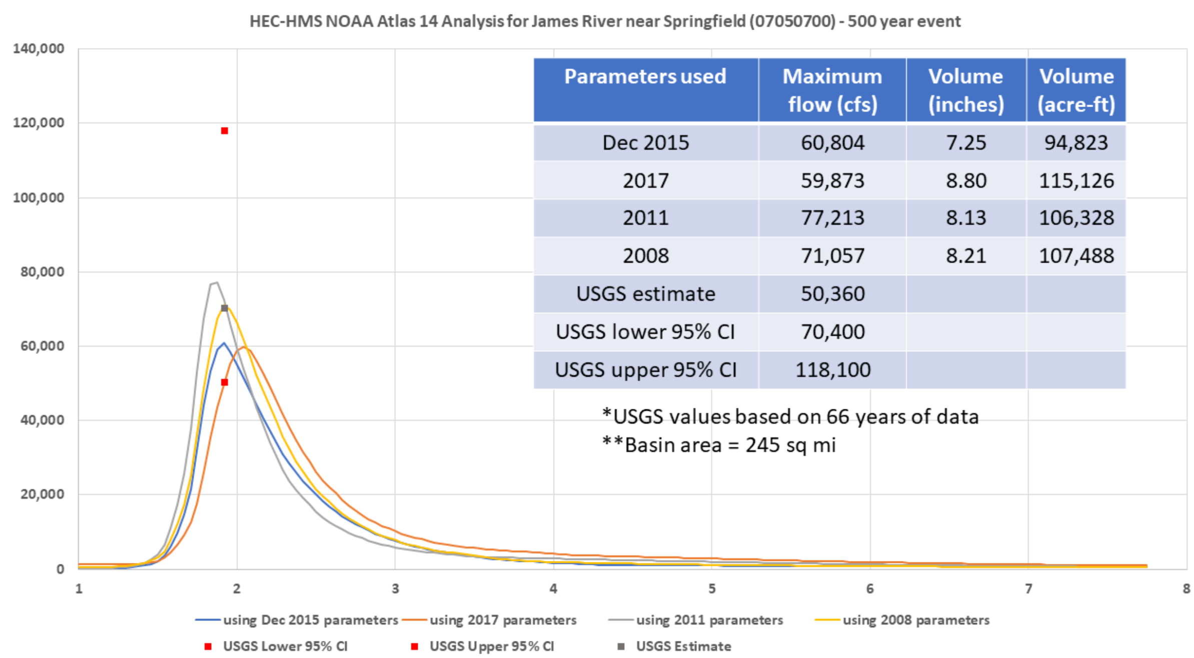


Figure 9-8. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Kings River near Berryville, AR (07050500)



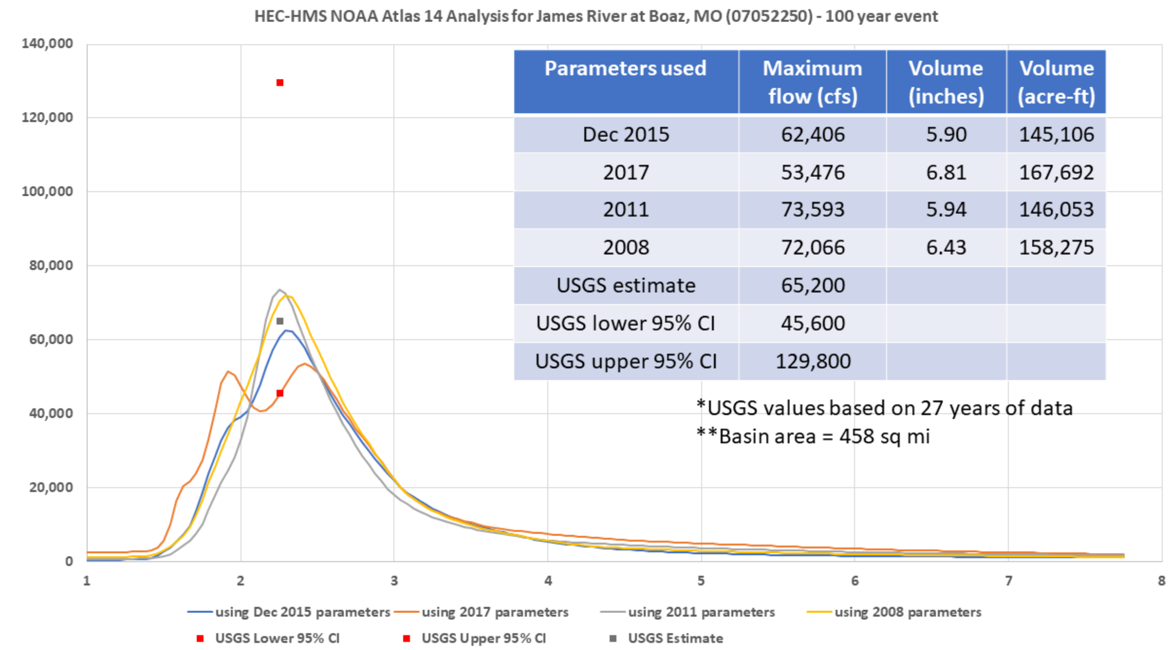
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	44,207	5.45	71,343
2017	44,106	6.95	90,974
2011	56,685	6.28	82,210
2008	52,583	6.37	83,345
USGS estimate	52,100		
USGS lower 95% CI	40,050		
USGS upper 95% CI	74,570		

Figure 9-9. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for James River near Springfield, MO (07050700)



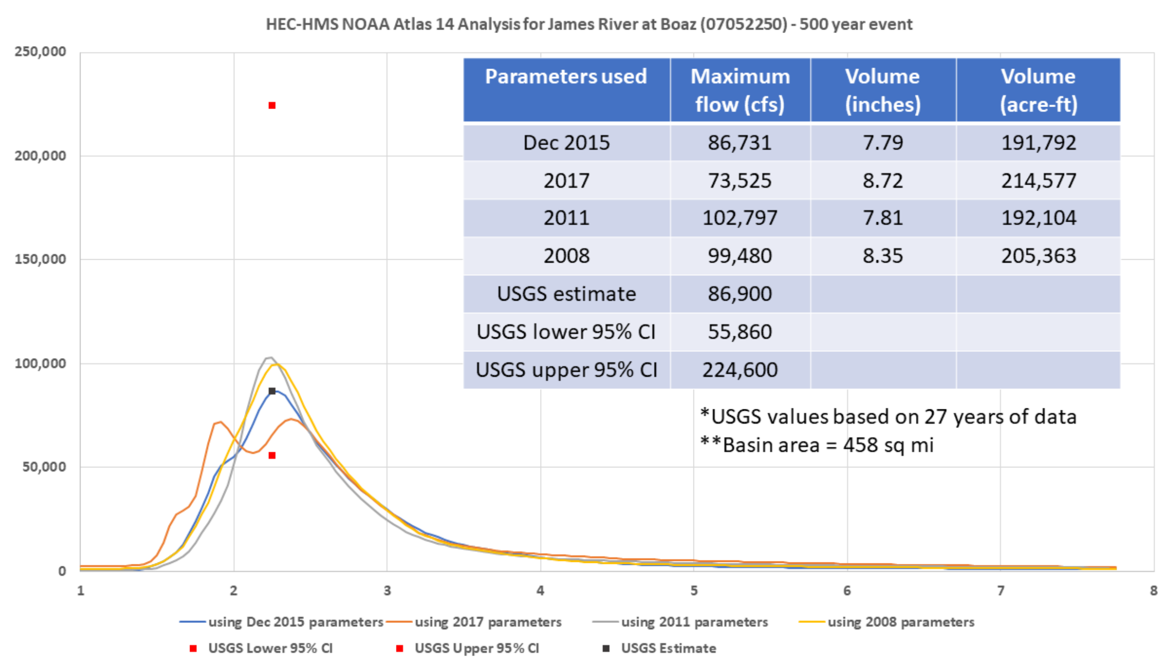
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	60,804	7.25	94,823
2017	59,873	8.80	115,126
2011	77,213	8.13	106,328
2008	71,057	8.21	107,488
USGS estimate	50,360		
USGS lower 95% CI	70,400		
USGS upper 95% CI	118,100		

Figure 9-10. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for James River near Springfield, MO (07050700)



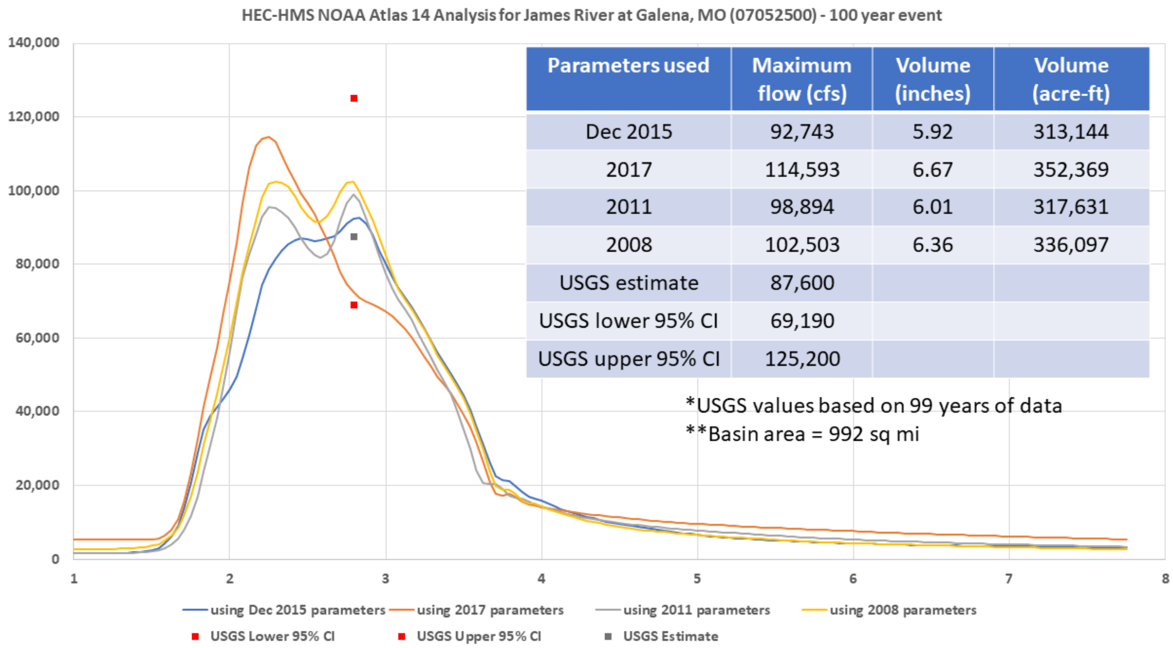
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	62,406	5.90	145,106
2017	53,476	6.81	167,692
2011	73,593	5.94	146,053
2008	72,066	6.43	158,275
USGS estimate	65,200		
USGS lower 95% CI	45,600		
USGS upper 95% CI	129,800		

Figure 9-11. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for James River at Boaz, MO (07052250)



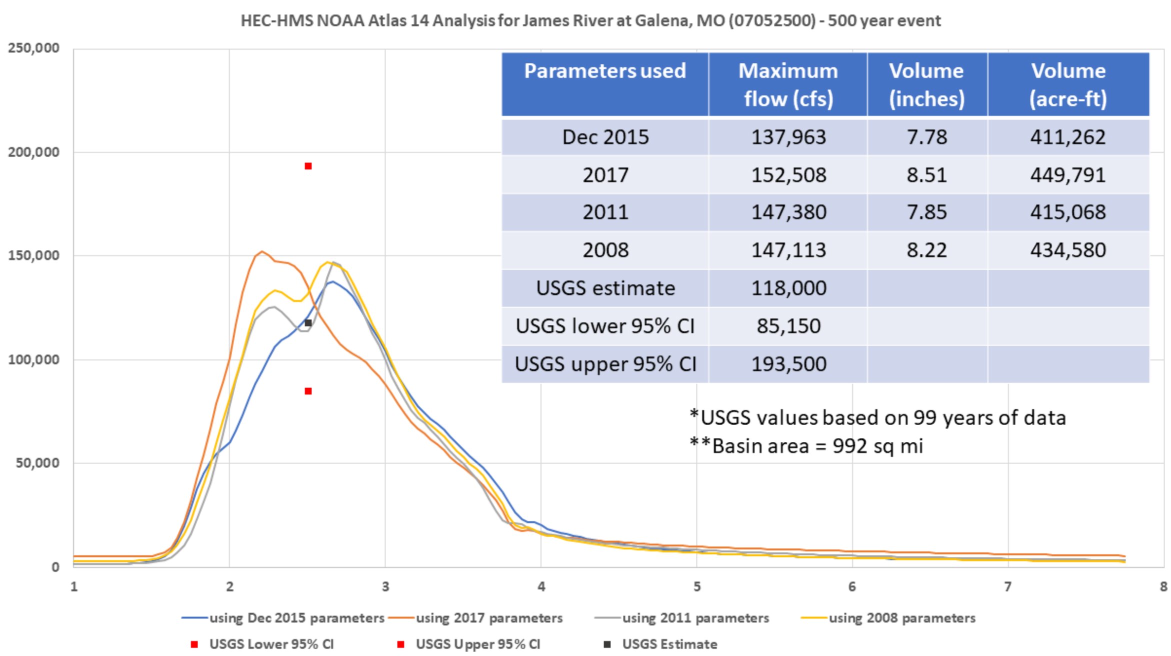
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	86,731	7.79	191,792
2017	73,525	8.72	214,577
2011	102,797	7.81	192,104
2008	99,480	8.35	205,363
USGS estimate	86,900		
USGS lower 95% CI	55,860		
USGS upper 95% CI	224,600		

Figure 9-12. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for James River at Boaz, MO (07052250)



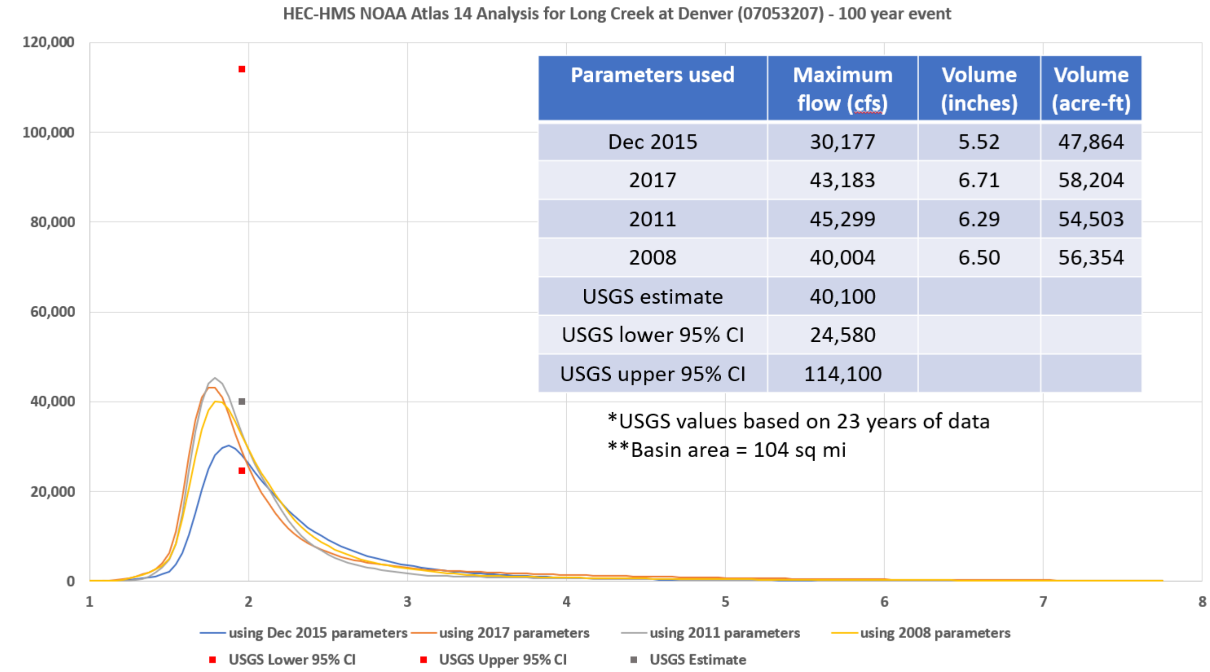
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	92,743	5.92	313,144
2017	114,593	6.67	352,369
2011	98,894	6.01	317,631
2008	102,503	6.36	336,097
USGS estimate	87,600		
USGS lower 95% CI	69,190		
USGS upper 95% CI	125,200		

Figure 9-13. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for James River at Galena, MO (07052500)



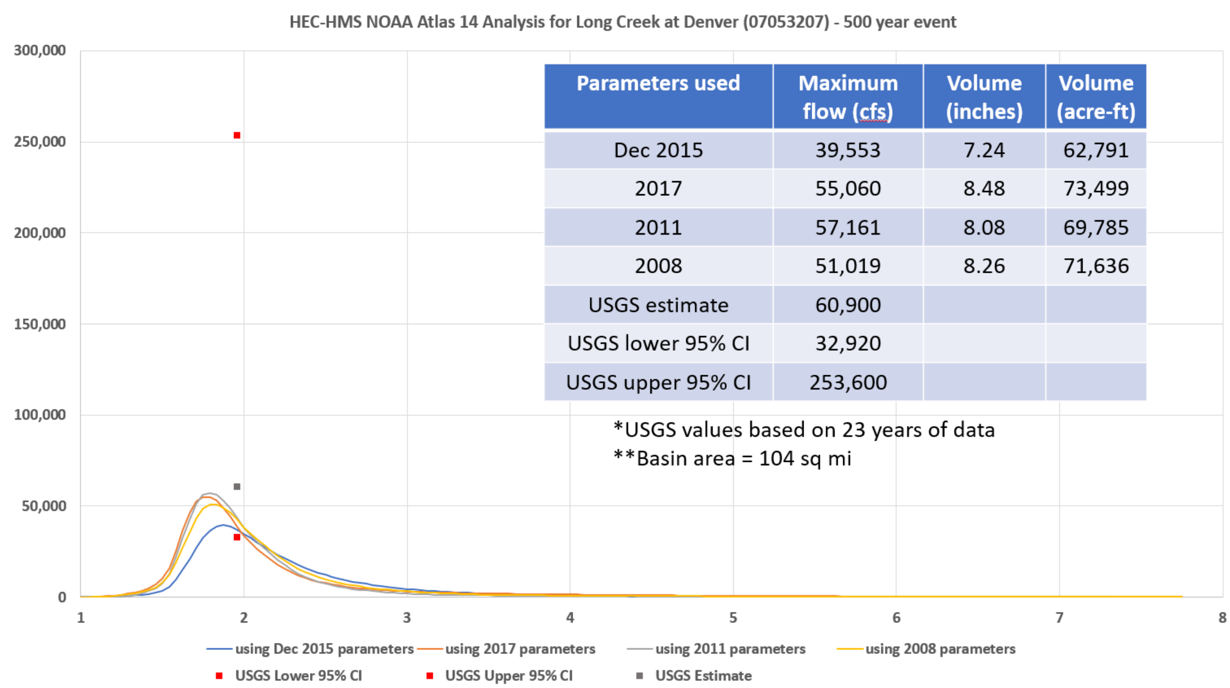
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	137,963	7.78	411,262
2017	152,508	8.51	449,791
2011	147,380	7.85	415,068
2008	147,113	8.22	434,580
USGS estimate	118,000		
USGS lower 95% CI	85,150		
USGS upper 95% CI	193,500		

Figure 9-14. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for James River at Galena, MO (07052500)



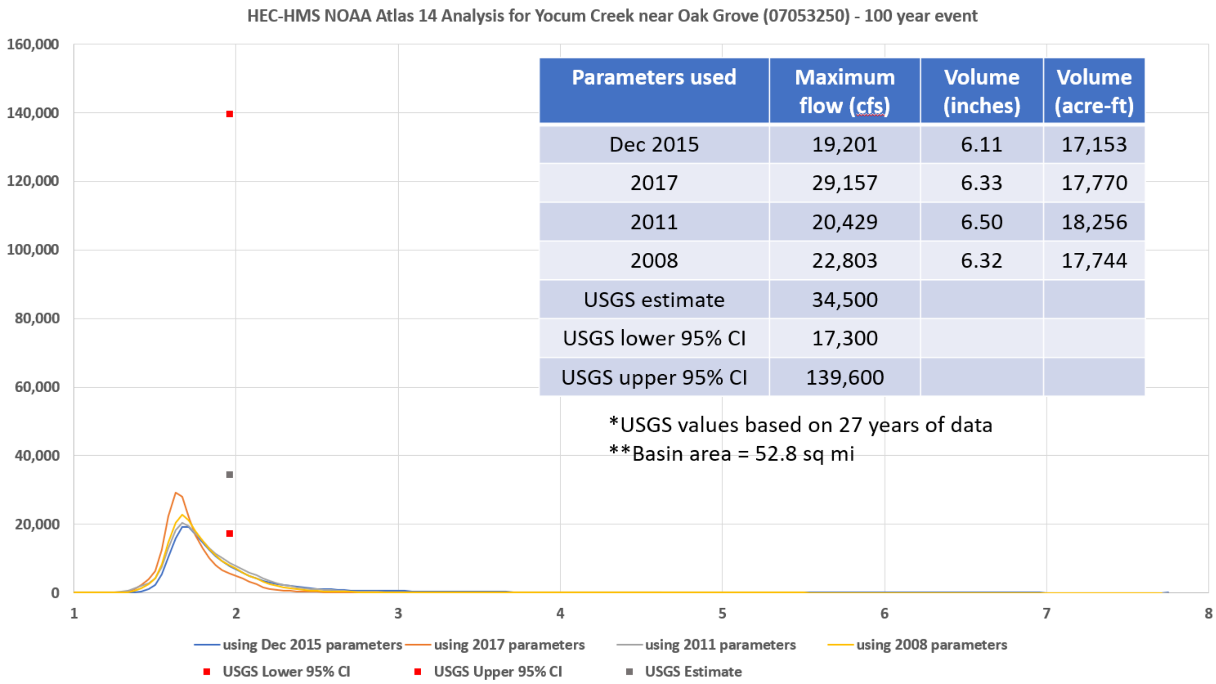
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	30,177	5.52	47,864
2017	43,183	6.71	58,204
2011	45,299	6.29	54,503
2008	40,004	6.50	56,354
USGS estimate	40,100		
USGS lower 95% CI	24,580		
USGS upper 95% CI	114,100		

Figure 9-15. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Long Creek at Denver, AR (07053207)



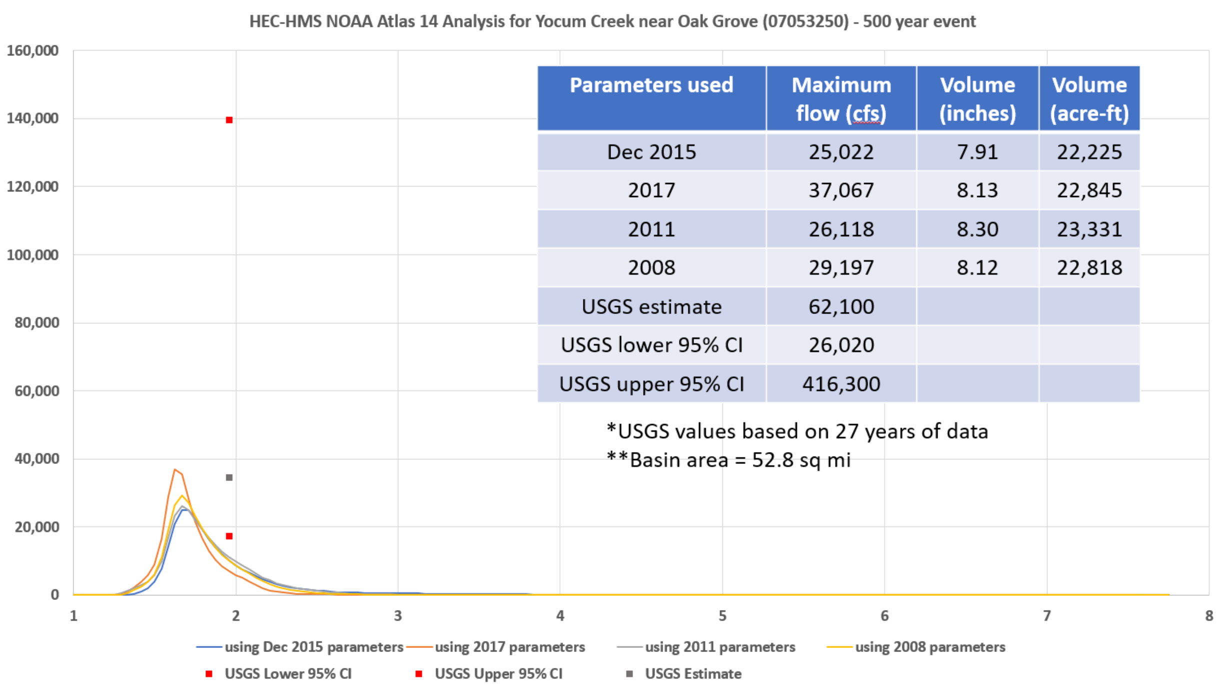
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	39,553	7.24	62,791
2017	55,060	8.48	73,499
2011	57,161	8.08	69,785
2008	51,019	8.26	71,636
USGS estimate	60,900		
USGS lower 95% CI	32,920		
USGS upper 95% CI	253,600		

Figure 9-16. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Long Creek at Denver, AR (07053207)



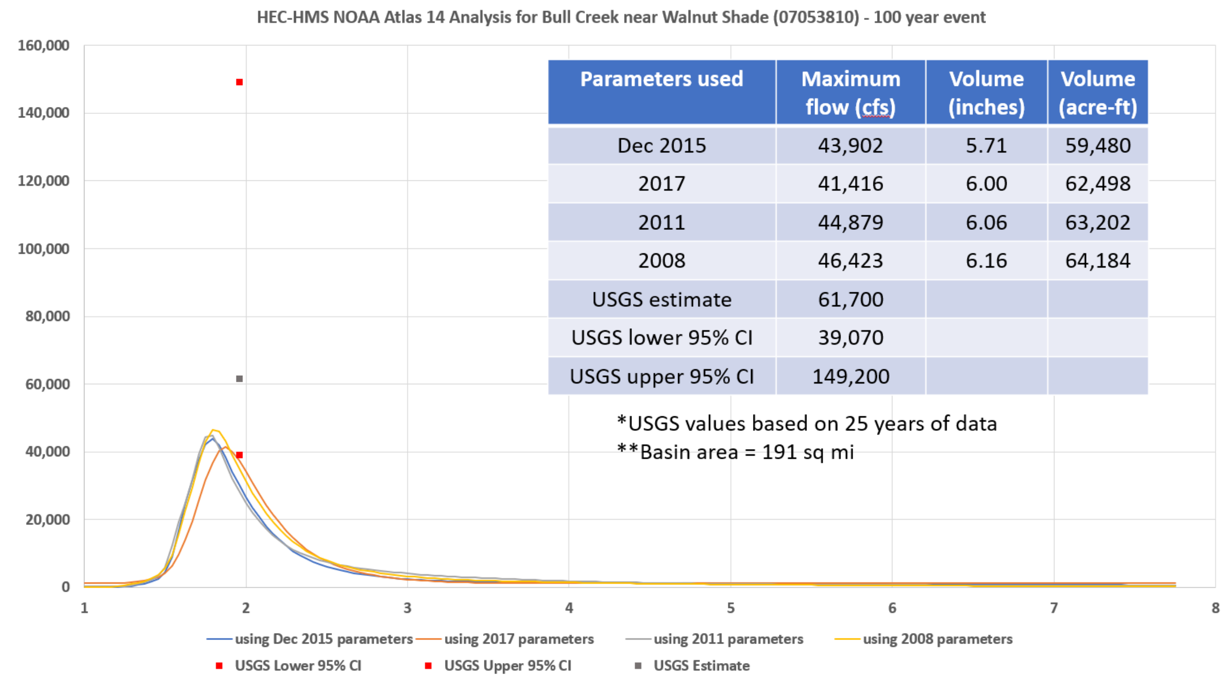
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	19,201	6.11	17,153
2017	29,157	6.33	17,770
2011	20,429	6.50	18,256
2008	22,803	6.32	17,744
USGS estimate	34,500		
USGS lower 95% CI	17,300		
USGS upper 95% CI	139,600		

Figure 9-17. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Yocum Creek near Oak Grove, AR (07053250)



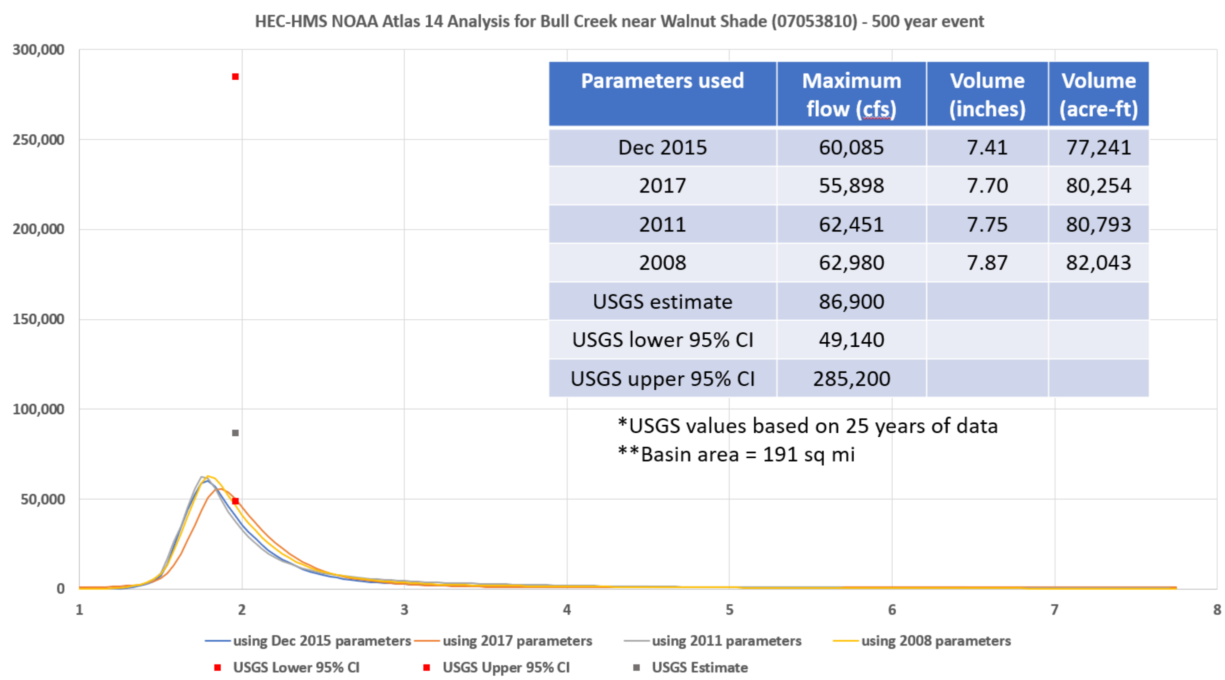
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	25,022	7.91	22,225
2017	37,067	8.13	22,845
2011	26,118	8.30	23,331
2008	29,197	8.12	22,818
USGS estimate	62,100		
USGS lower 95% CI	26,020		
USGS upper 95% CI	416,300		

Figure 9-18. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Yocum Creek near Oak Grove, AR (07053250)



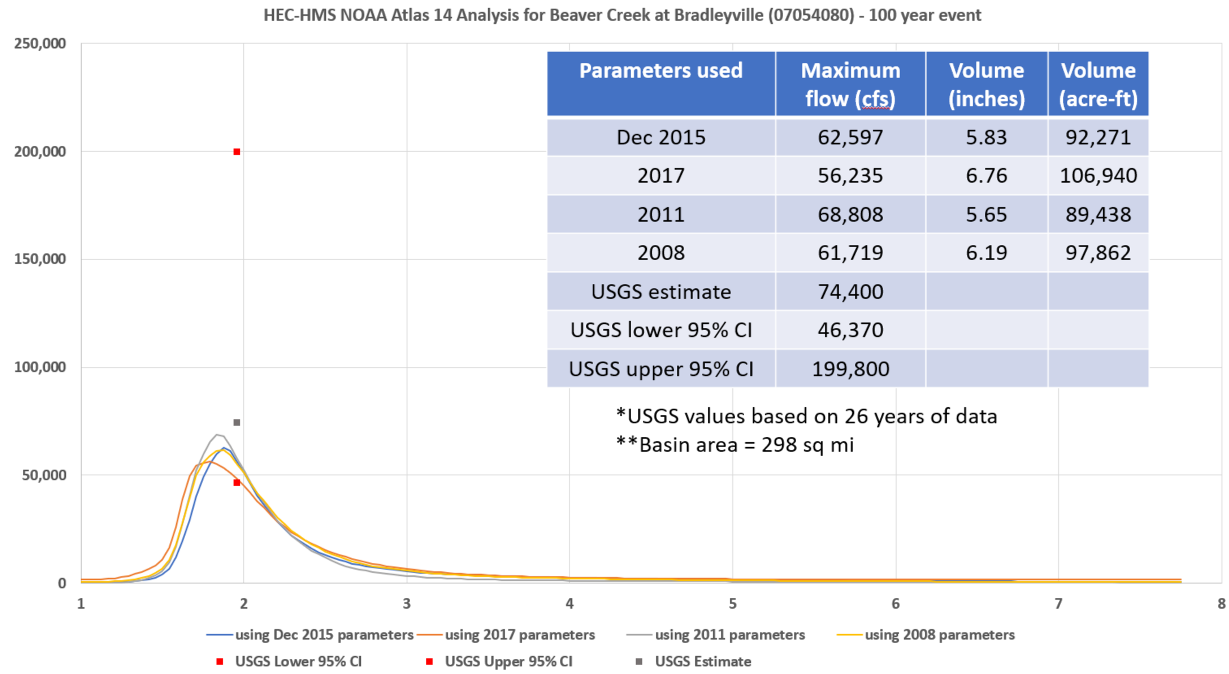
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	43,902	5.71	59,480
2017	41,416	6.00	62,498
2011	44,879	6.06	63,202
2008	46,423	6.16	64,184
USGS estimate	61,700		
USGS lower 95% CI	39,070		
USGS upper 95% CI	149,200		

Figure 9-19. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Bull Creek near Walnut Shade, MO (07053810)



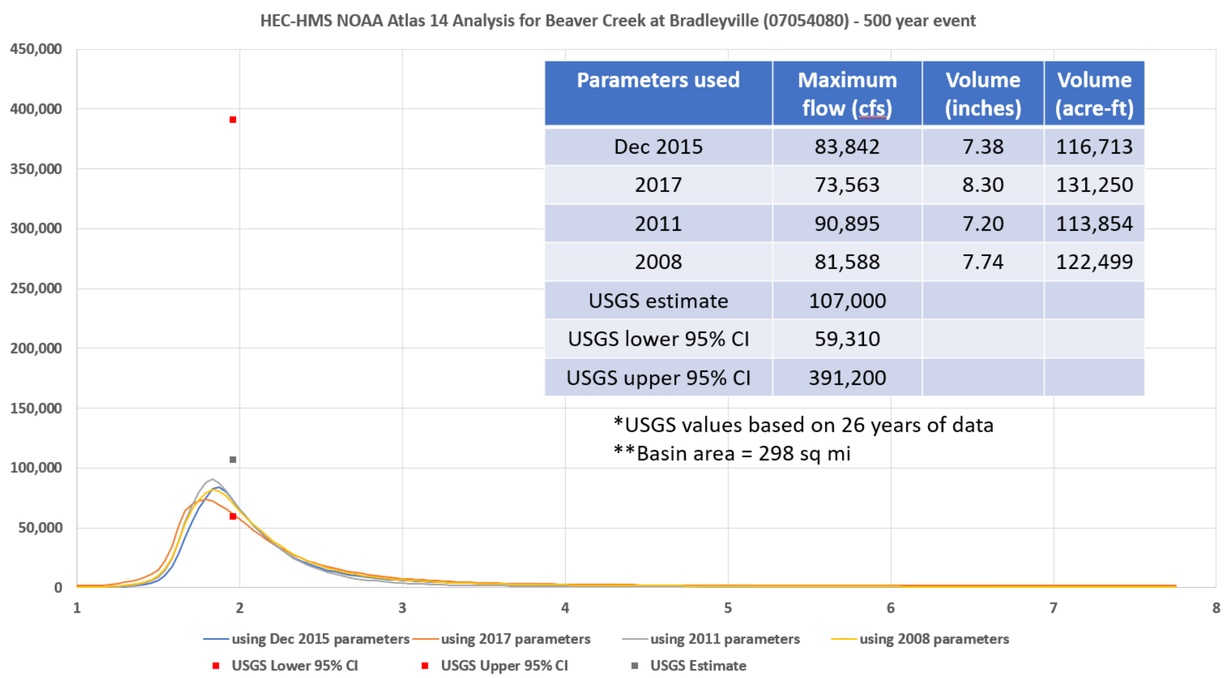
Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	60,085	7.41	77,241
2017	55,898	7.70	80,254
2011	62,451	7.75	80,793
2008	62,980	7.87	82,043
USGS estimate	86,900		
USGS lower 95% CI	49,140		
USGS upper 95% CI	285,200		

Figure 9-20. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Bull Creek near Walnut Shade, MO (07053810)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	62,597	5.83	92,271
2017	56,235	6.76	106,940
2011	68,808	5.65	89,438
2008	61,719	6.19	97,862
USGS estimate	74,400		
USGS lower 95% CI	46,370		
USGS upper 95% CI	199,800		

Figure 9-21. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Beaver Creek at Bradleyville, MO (07054080)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	83,842	7.38	116,713
2017	73,563	8.30	131,250
2011	90,895	7.20	113,854
2008	81,588	7.74	122,499
USGS estimate	107,000		
USGS lower 95% CI	59,310		
USGS upper 95% CI	391,200		

Figure 9-22. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Beaver Creek at Bradleyville, MO (07054080)

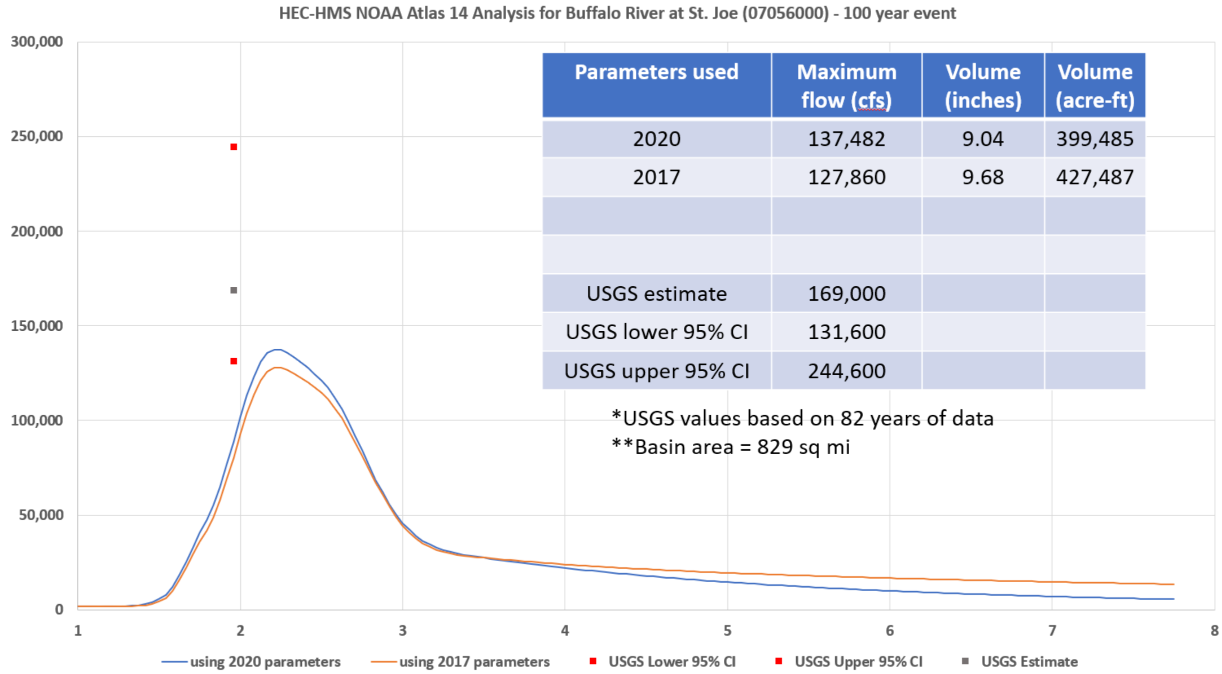


Figure 9-23. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Buffalo River at St. Joe, AR (07056000)

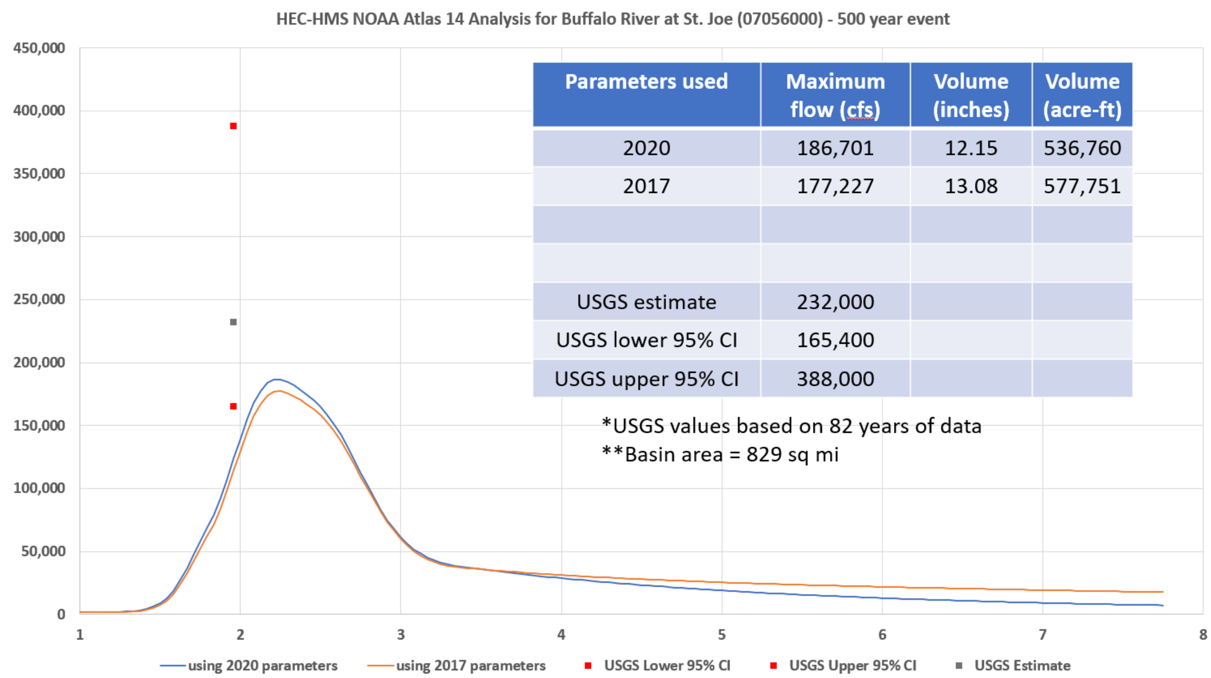
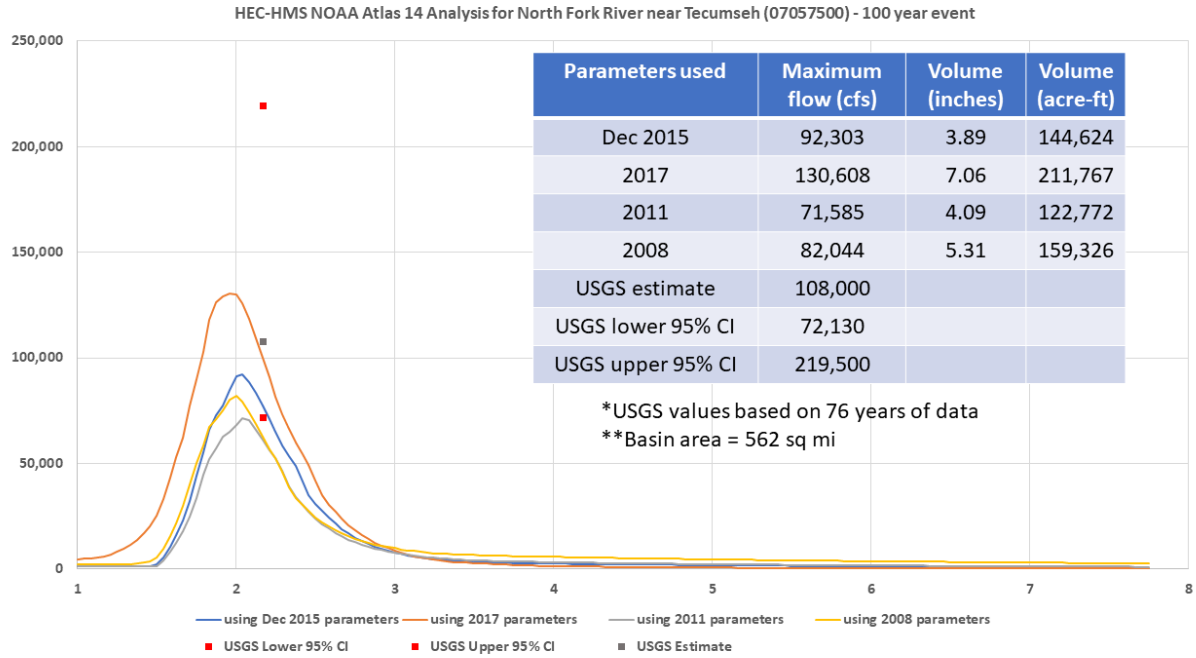
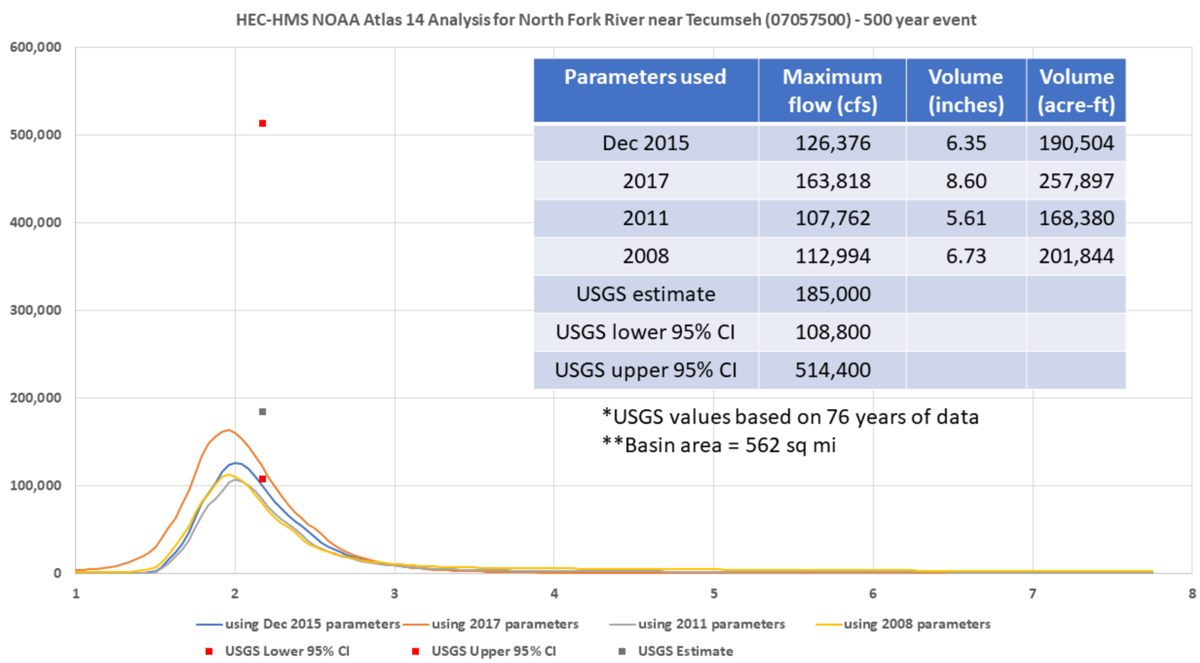


Figure 9-24. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Buffalo River at St. Joe, AR (07056000)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	92,303	3.89	144,624
2017	130,608	7.06	211,767
2011	71,585	4.09	122,772
2008	82,044	5.31	159,326
USGS estimate	108,000		
USGS lower 95% CI	72,130		
USGS upper 95% CI	219,500		

Figure 9-25. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for North Fork River near Tecumseh, MO (07057500)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	126,376	6.35	190,504
2017	163,818	8.60	257,897
2011	107,762	5.61	168,380
2008	112,994	6.73	201,844
USGS estimate	185,000		
USGS lower 95% CI	108,800		
USGS upper 95% CI	514,400		

Figure 9-26. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for North Fork River near Tecumseh, MO (07057500)

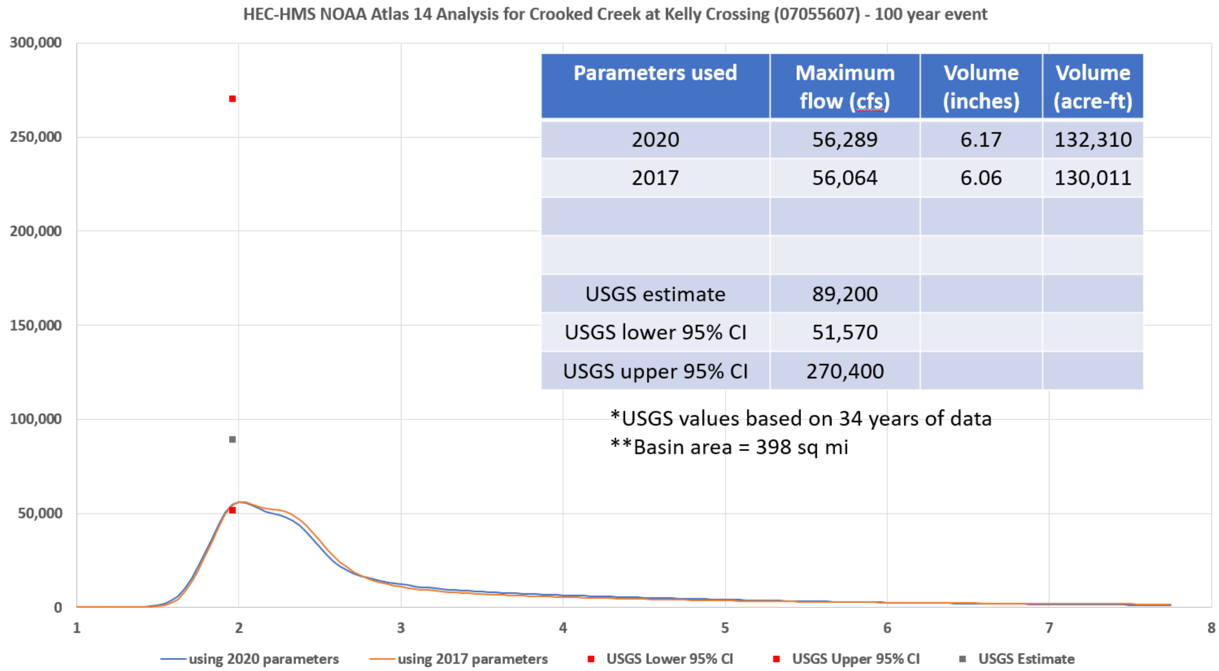


Figure 9-27. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Crooked Creek at Kelly Crossing, AR (07055607)

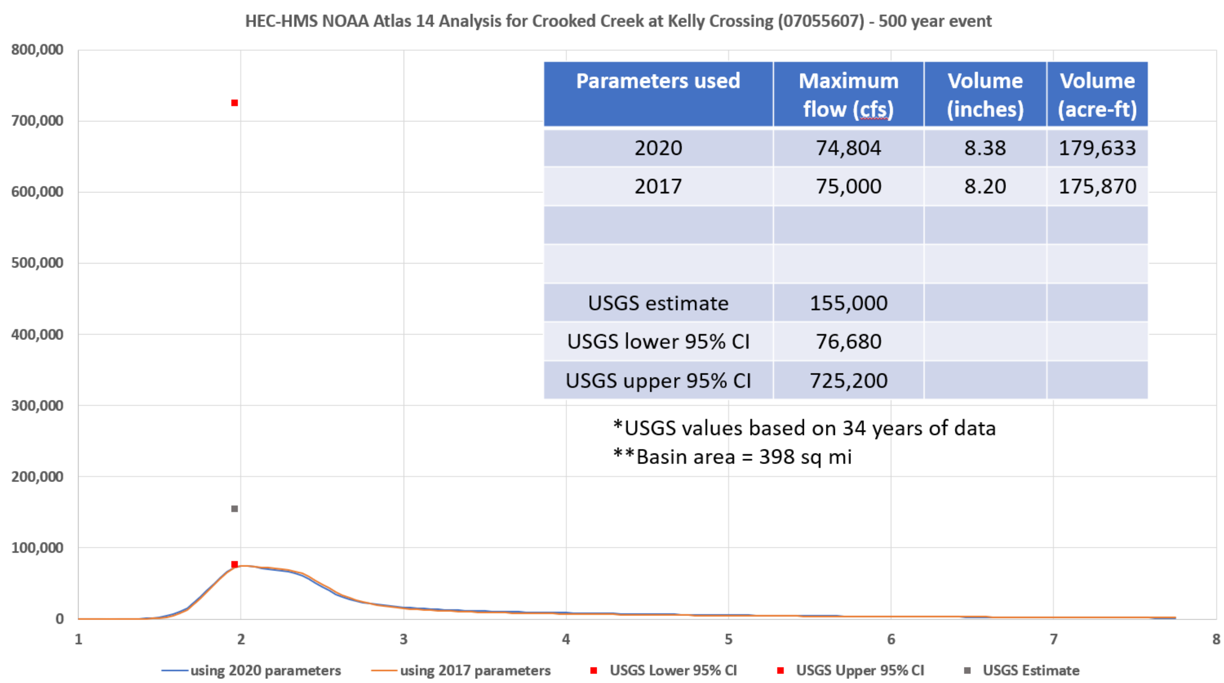


Figure 9-28. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Crooked Creek at Kelly Crossing, AR (07055607)

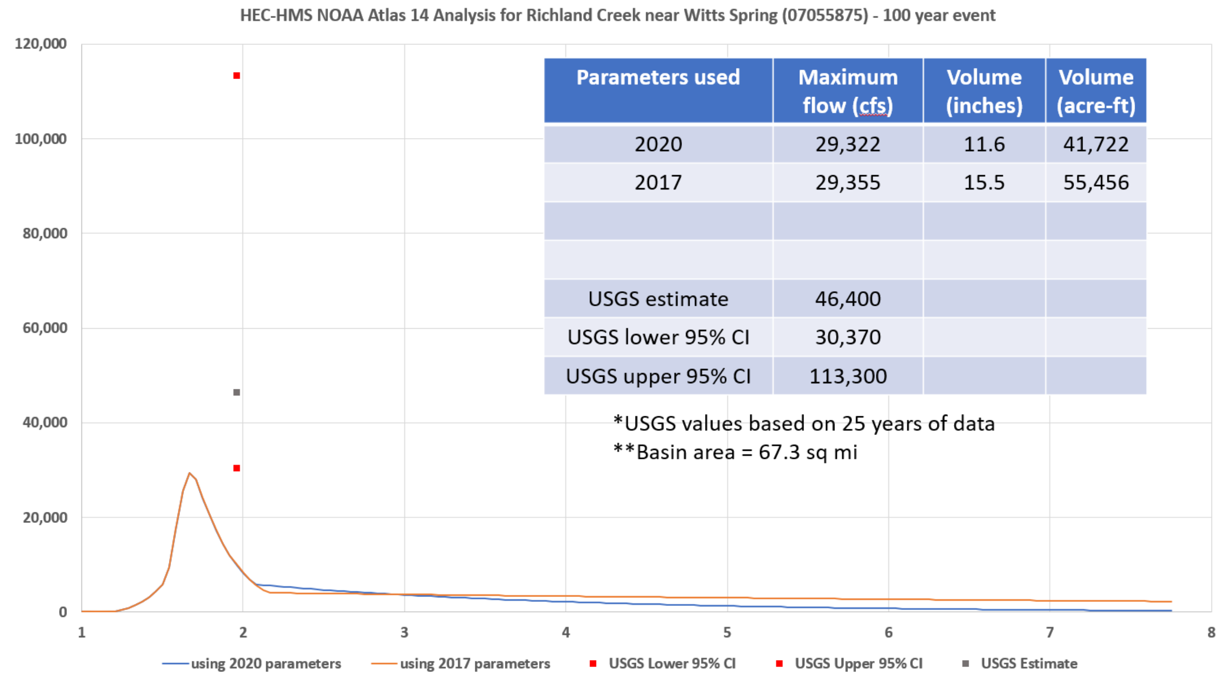


Figure 9-29. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Richland Creek near Witts Spring, AR (07055875)

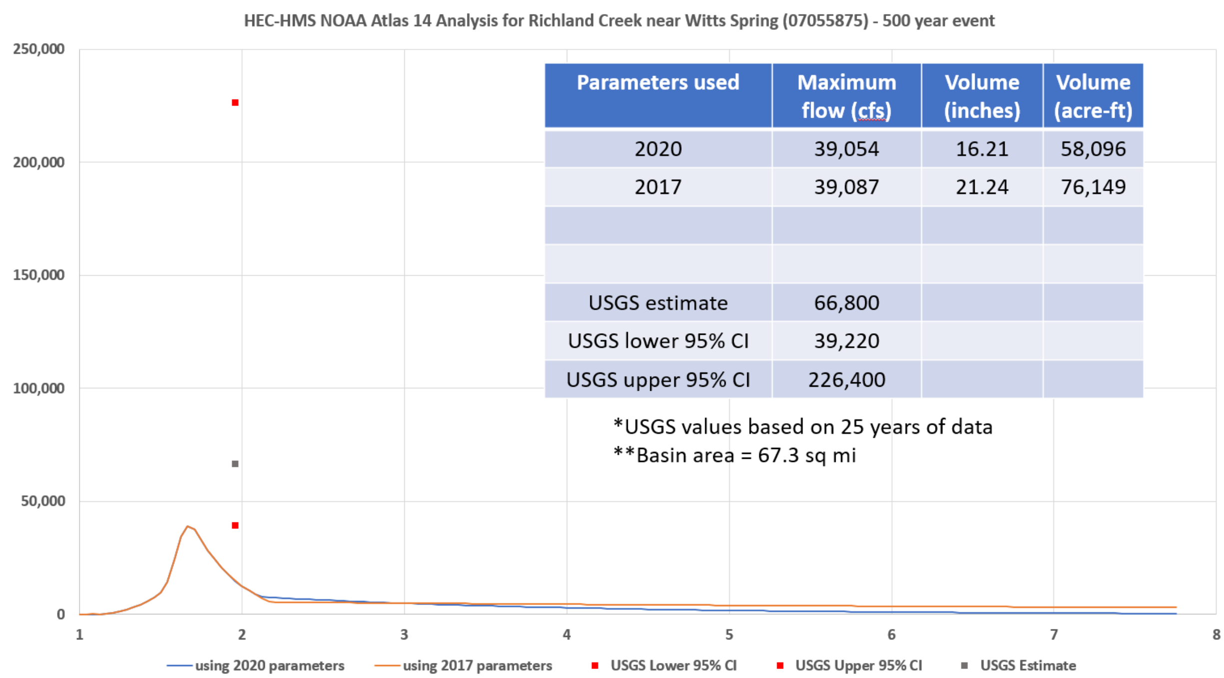
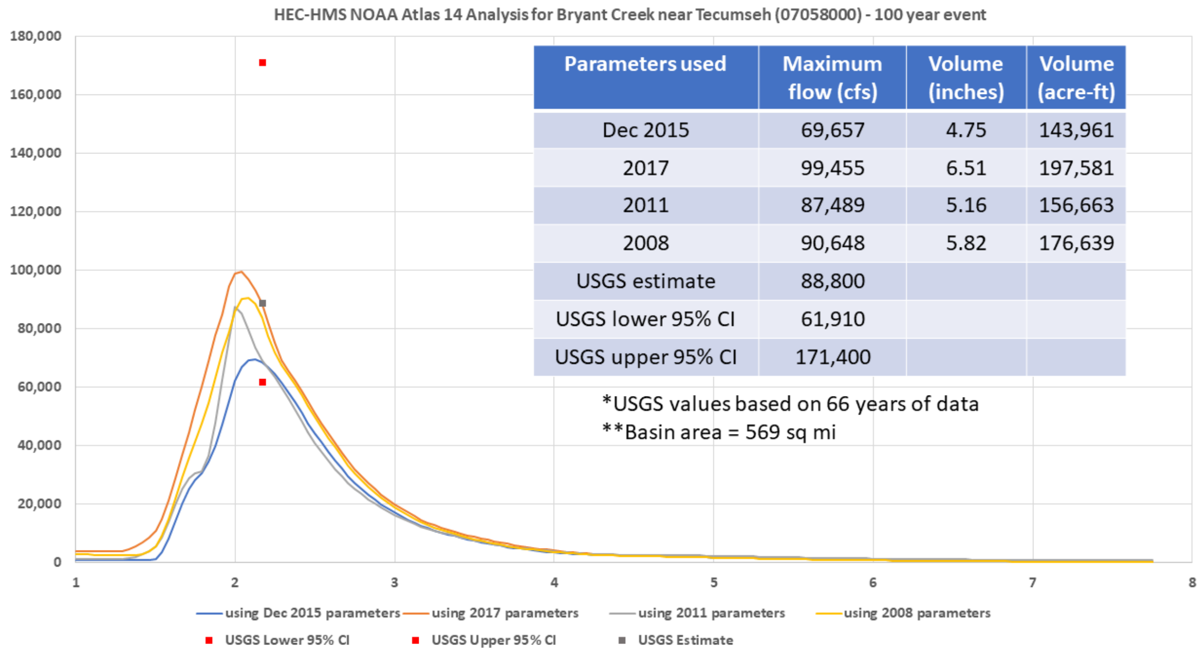
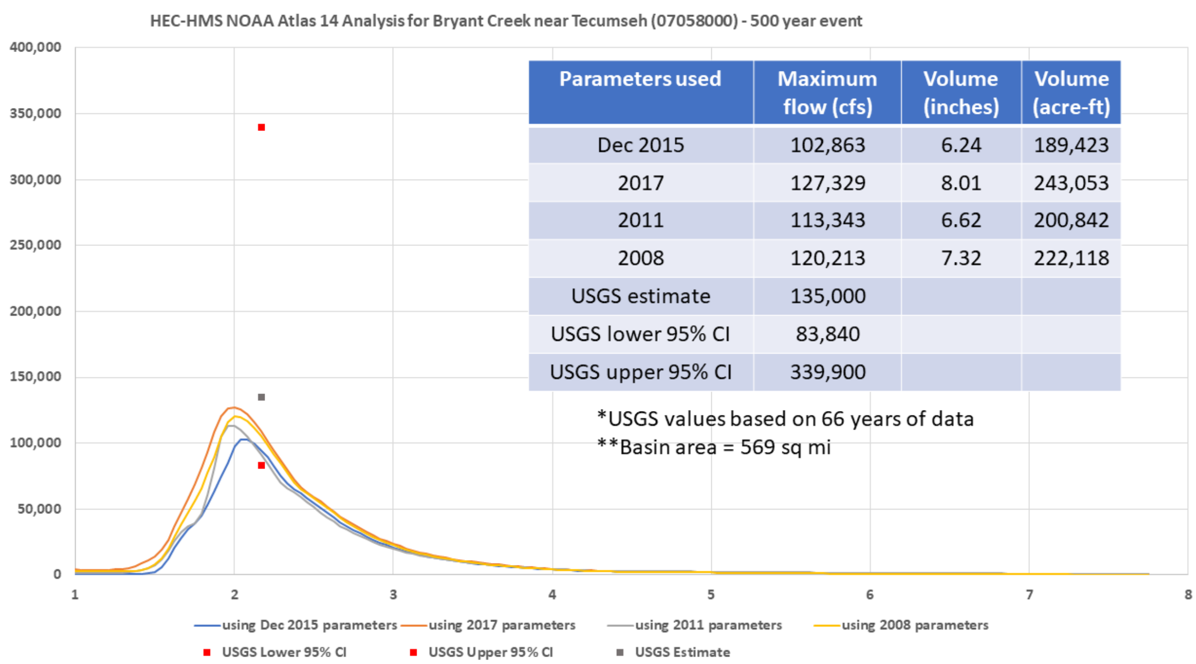


Figure 9-30. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Richland Creek near Witts Spring, AR (07055875)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	69,657	4.75	143,961
2017	99,455	6.51	197,581
2011	87,489	5.16	156,663
2008	90,648	5.82	176,639
USGS estimate	88,800		
USGS lower 95% CI	61,910		
USGS upper 95% CI	171,400		

Figure 9-31. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Bryant Creek near Tecumseh, MO (07058000)



Parameters used	Maximum flow (cfs)	Volume (inches)	Volume (acre-ft)
Dec 2015	102,863	6.24	189,423
2017	127,329	8.01	243,053
2011	113,343	6.62	200,842
2008	120,213	7.32	222,118
USGS estimate	135,000		
USGS lower 95% CI	83,840		
USGS upper 95% CI	339,900		

Figure 9-32. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Bryant Creek near Tecumseh, MO (07058000)

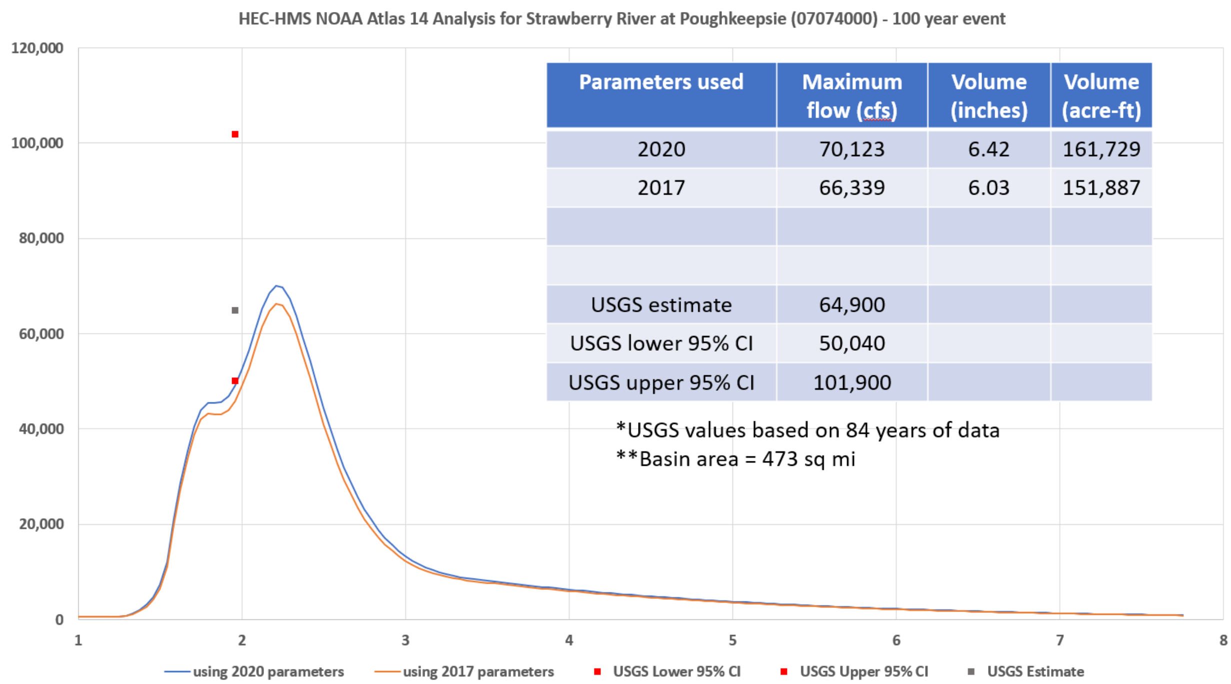


Figure 9-33. HEC-HMS NOAA Atlas 14 Analysis (100-year event) for Strawberry River at Poughkeepsie, AR (07074000)

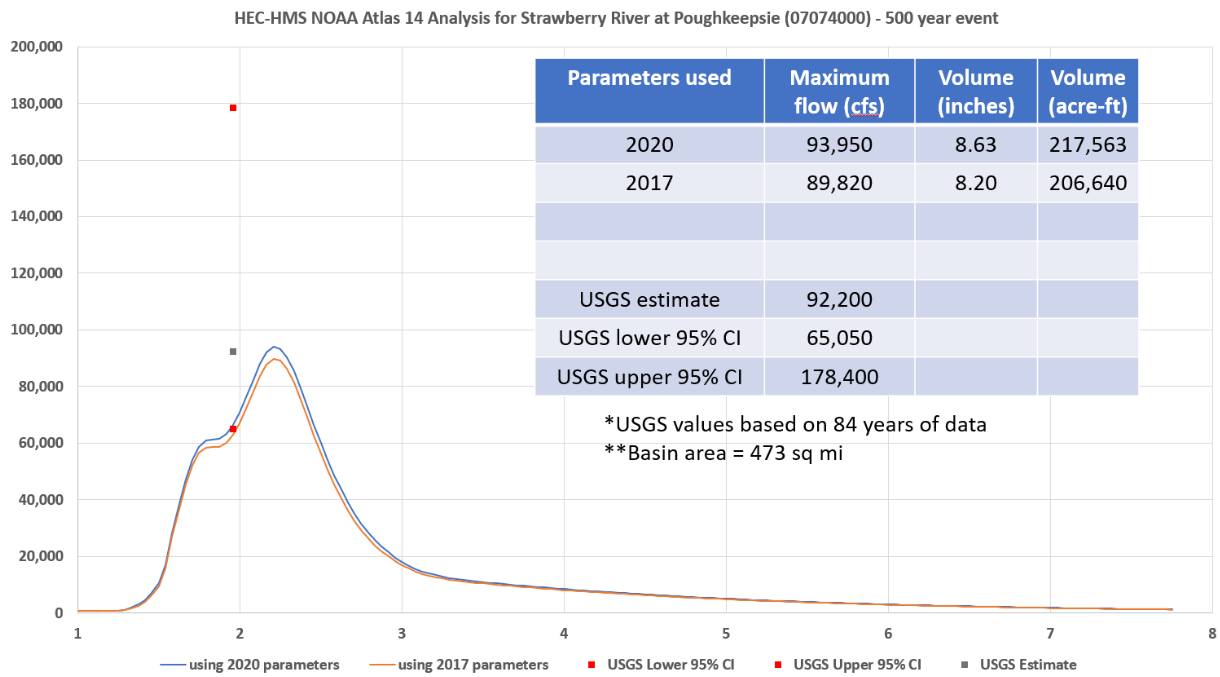
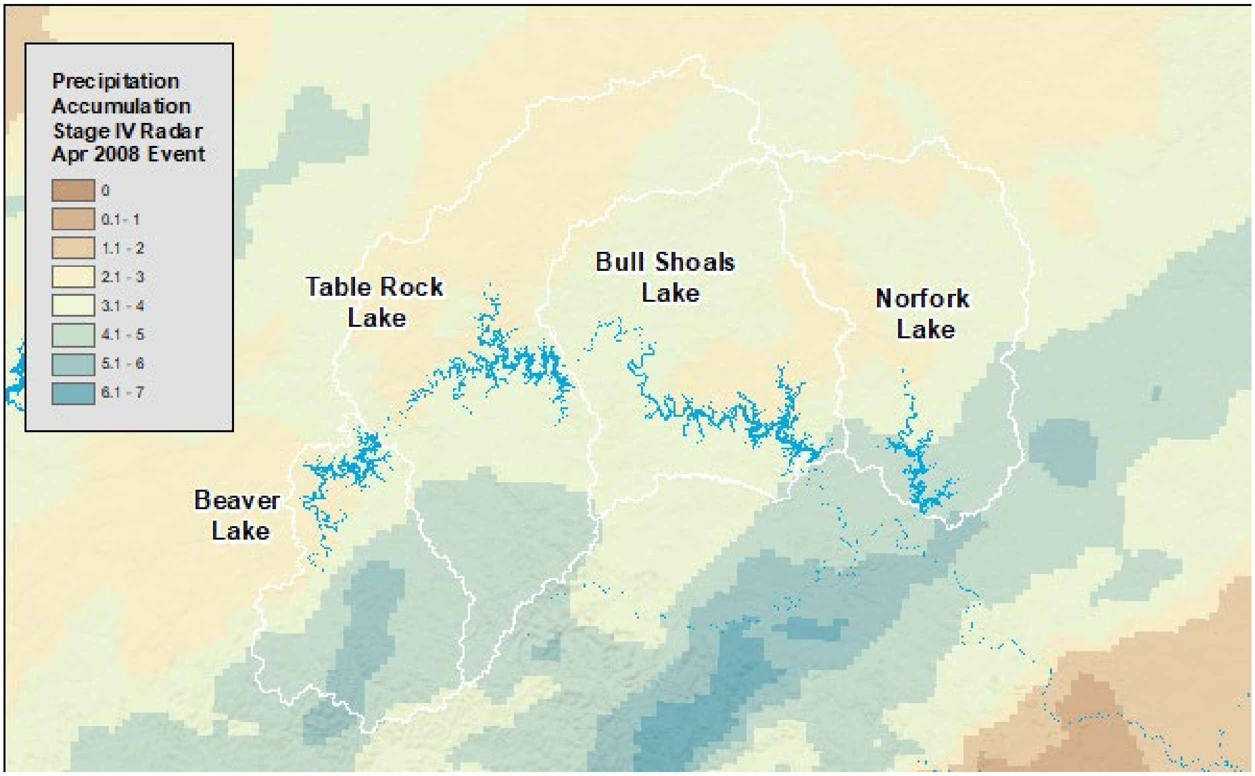


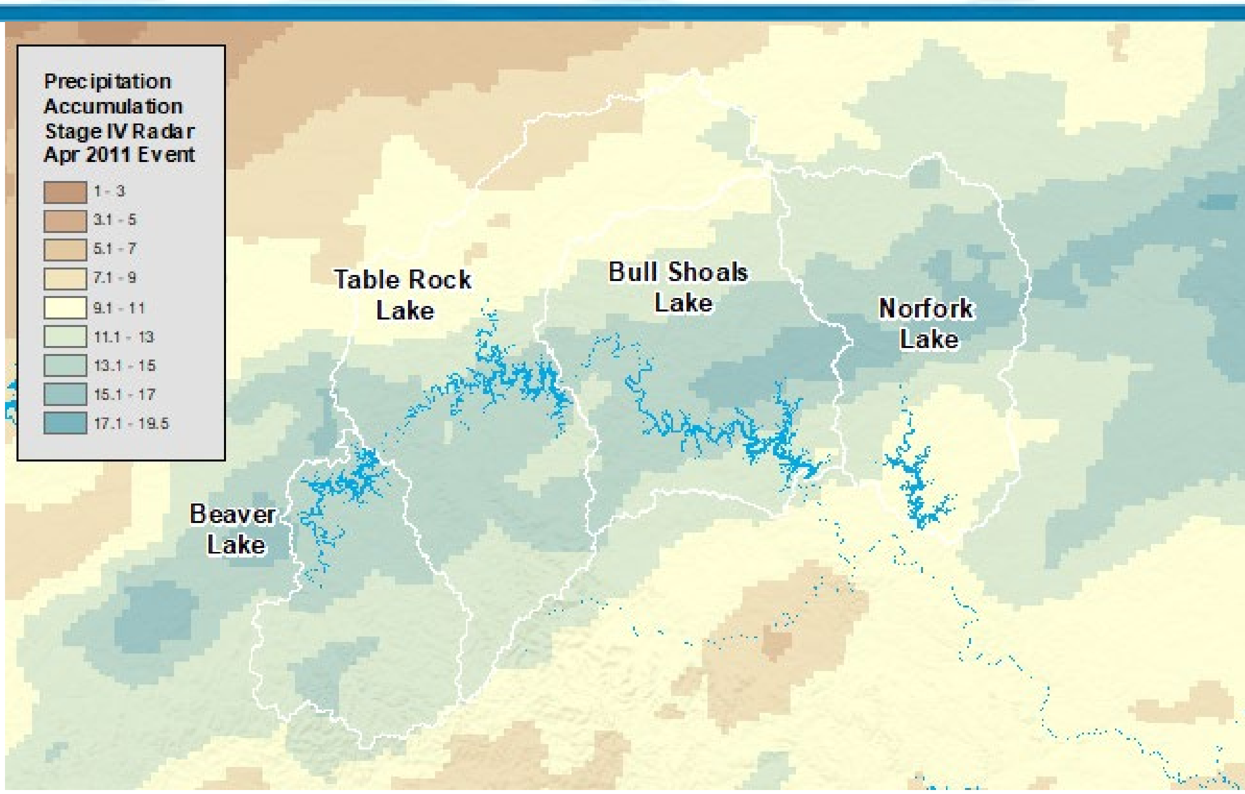
Figure 9-34. HEC-HMS NOAA Atlas 14 Analysis (500-year event) for Strawberry River at Poughkeepsie, AR (07074000)

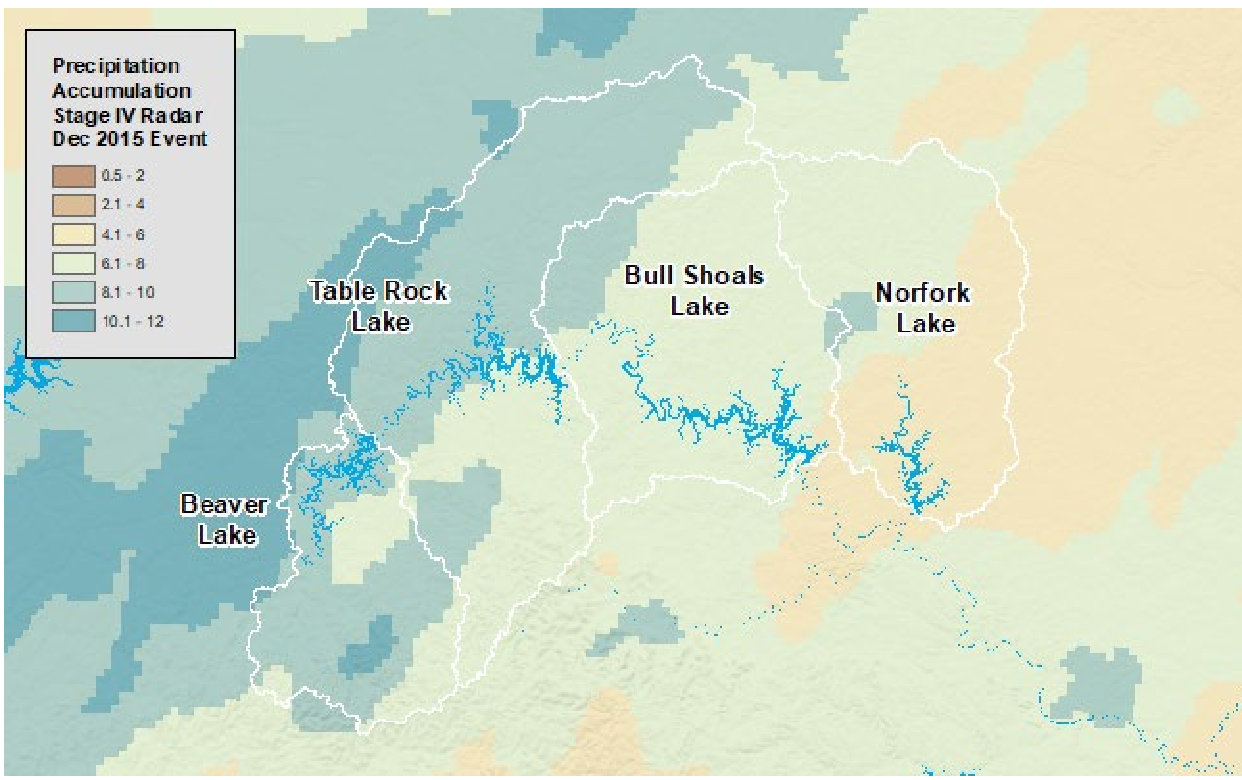
10 Rainfall Runoff Modeling in HEC-HMS with SWL 72-hour Precipitation Frequency Depths

USACE SWL performed a precipitation frequency study for the purposes of evaluating frequency statistics for high hazard dams. Elevation frequency statistics for USACE SWL dams within the White River basin use results from the SWL precipitation frequency study along with annual maximum series of inflow volumes in order to estimate elevation and release frequencies for USACE SWL dams within the White River basin. Results from the SWL precipitation frequency study were evaluated efficacy with regards to estimating 1/100 AEP peak streamflows within the White River basin.

Using the process described above, hydrologic simulations were performed for multiple stream gage locations. For each stream gage location, two or three storms were used as a base from which to apply adjustments to hourly 72-hour precipitation depths. The storms (Figure 10-1) were then routed in HEC-HMS. For each analysis, stratified sampling was used from a base GEV distribution to create 200 iterations of the final storm patterns were used to produce a mean peak streamflow and confidence intervals. Additionally, normal distributions were created from resulting peak flows in order to use to provide a means to apply weighted 1/100 AEP quantiles to Bayesian analyses of peak streamflows. Table 10-1 lists results from the analyses. Figures Figure 10-2 – Figure 10-13 plot results for specific streamgages.




Precipitation
Accumulation
Stage IV Radar
Apr 2011 Event
1 - 3
3.1 - 5
5.1 - 7
7.1 - 9
9.1 - 11
11.1 - 13
13.1 - 15
15.1 - 17
17.1 - 19.5
Table Rock
Lake
Bull Shoals
Lake
Norfork
Lake
Beaver
Lake


Precipitation
Accumulation
Stage IV Radar
Dec 2015 Event
0.5 - 2
2.1 - 4
4.1 - 6
6.1 - 8
8.1 - 10
10.1 - 12
Table Rock
Lake
Bull Shoals
Lake
Norfork
Lake
Beaver
Lake

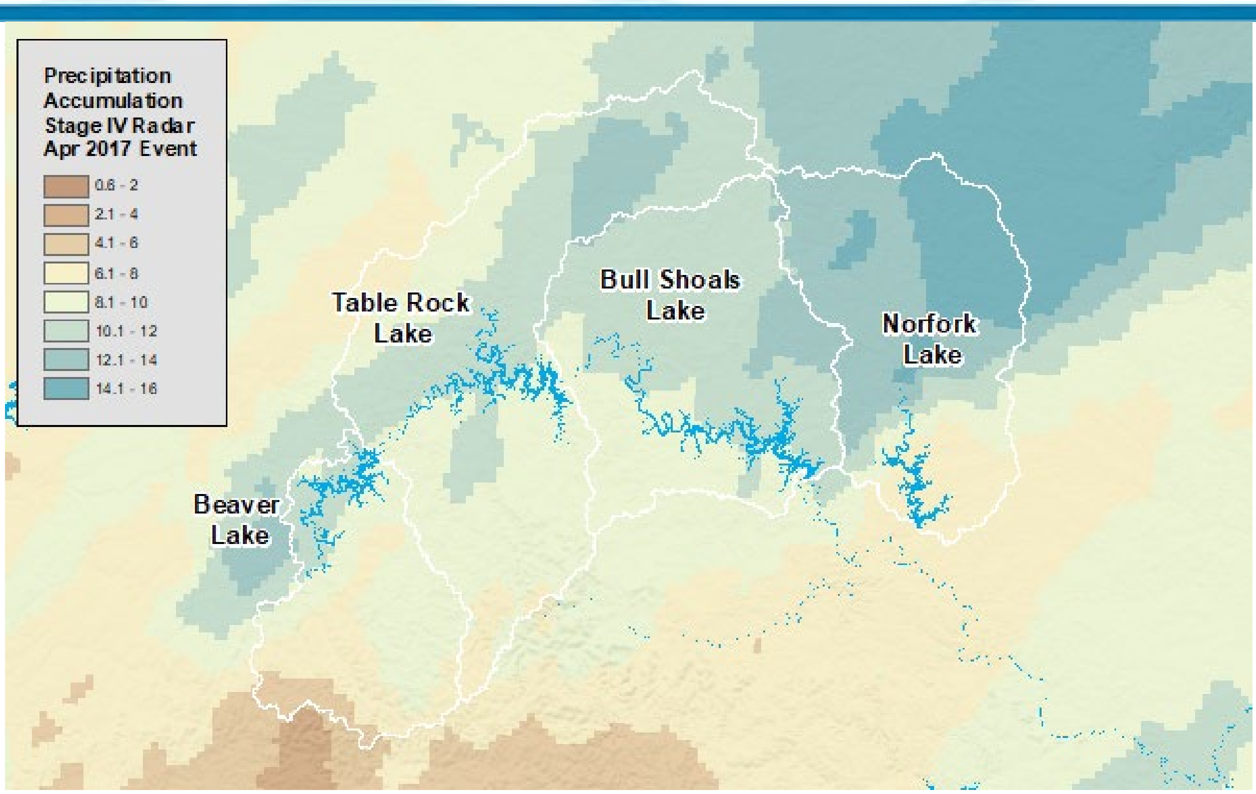


Figure 10-1. Precipitation distribution from Apr 2008, Apr 2011, Dec 2015, and Apr 2017 flood event

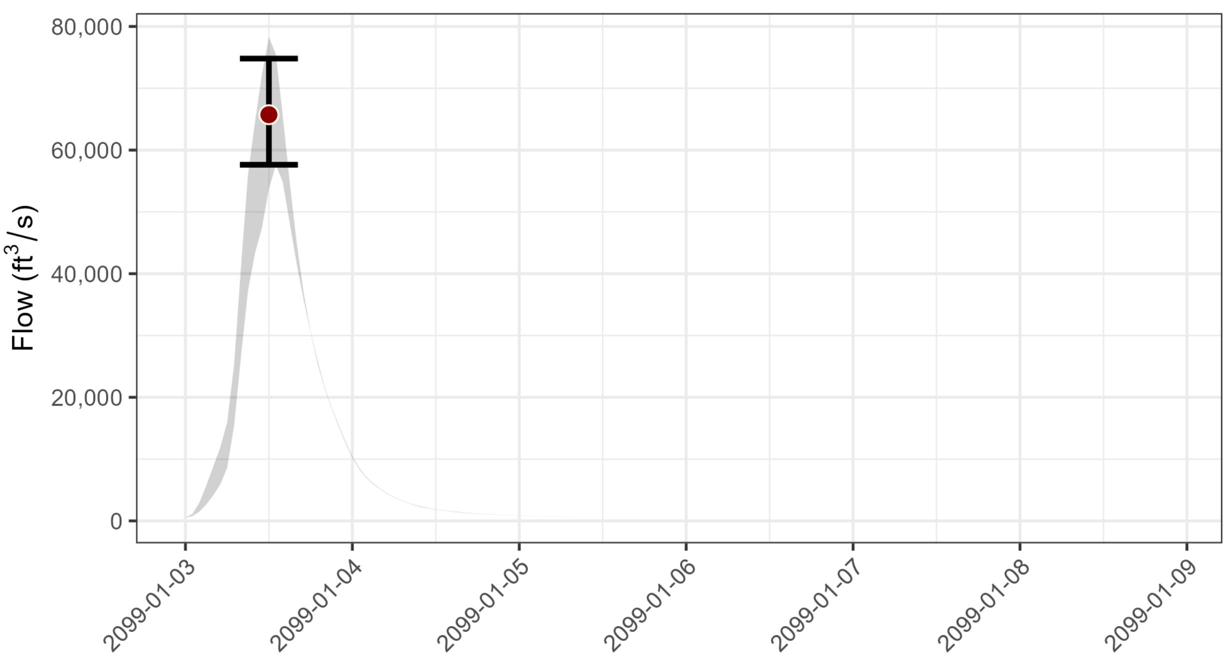


Figure 10-2 Results from stochastic precipitation frequency for USGS 07048550

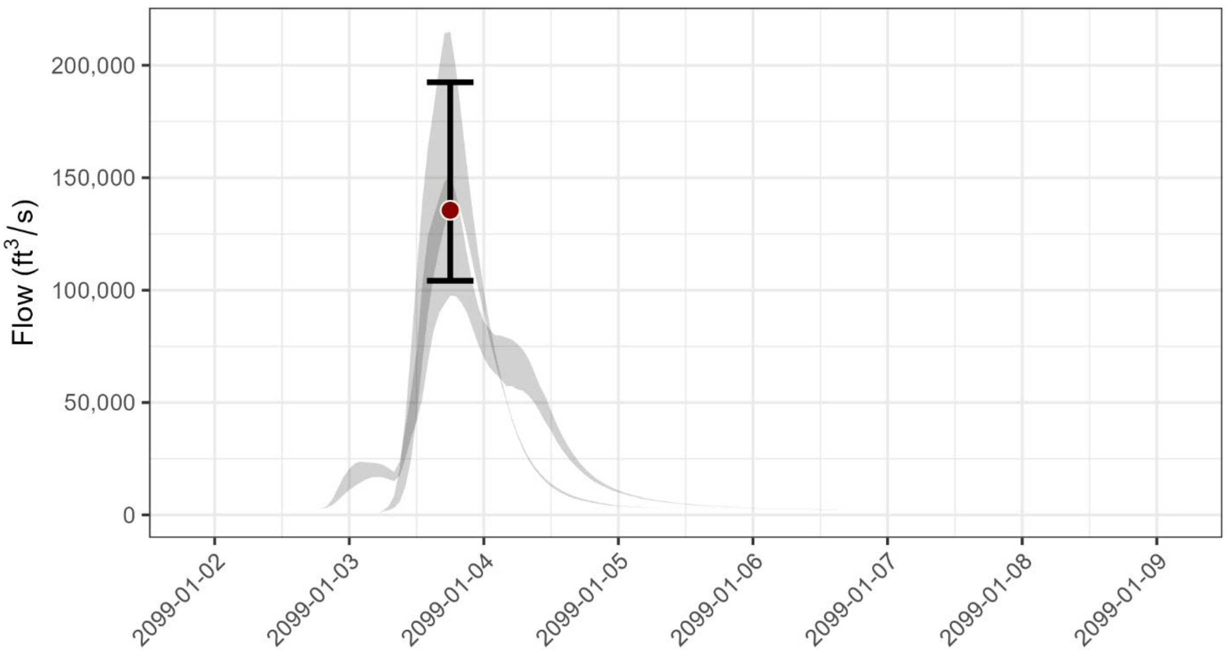


Figure 10-3 Results from stochastic precipitation frequency for USGS 07048600

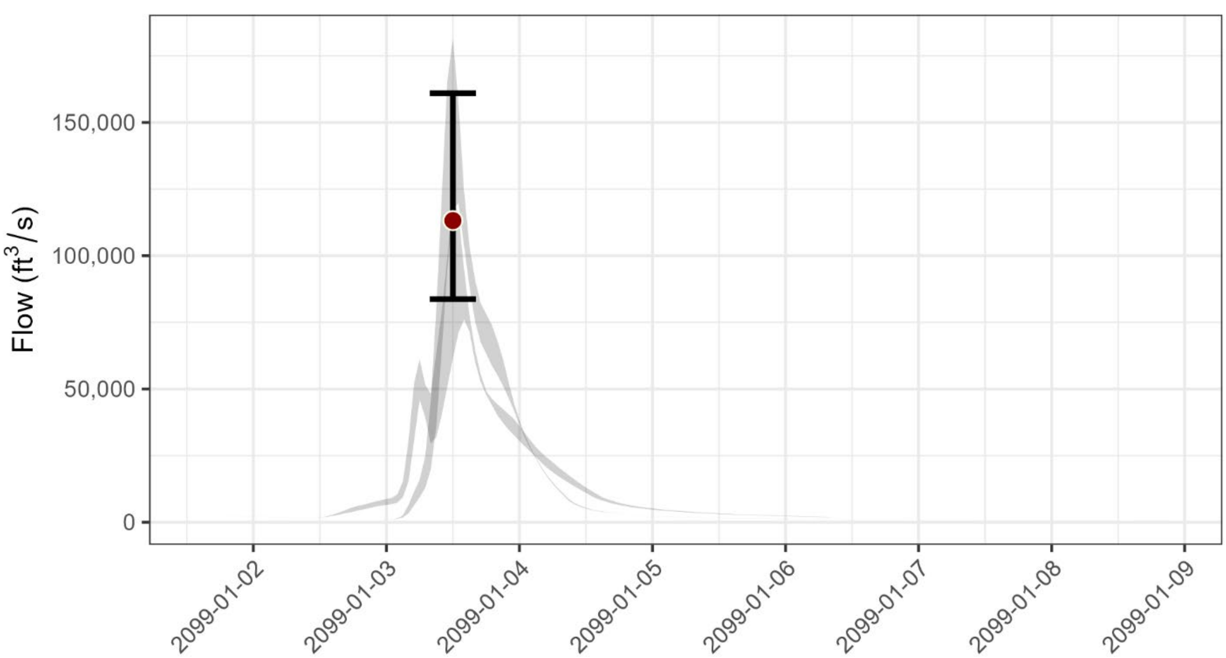


Figure 10-4 Results from stochastic precipitation frequency for USGS 07049000

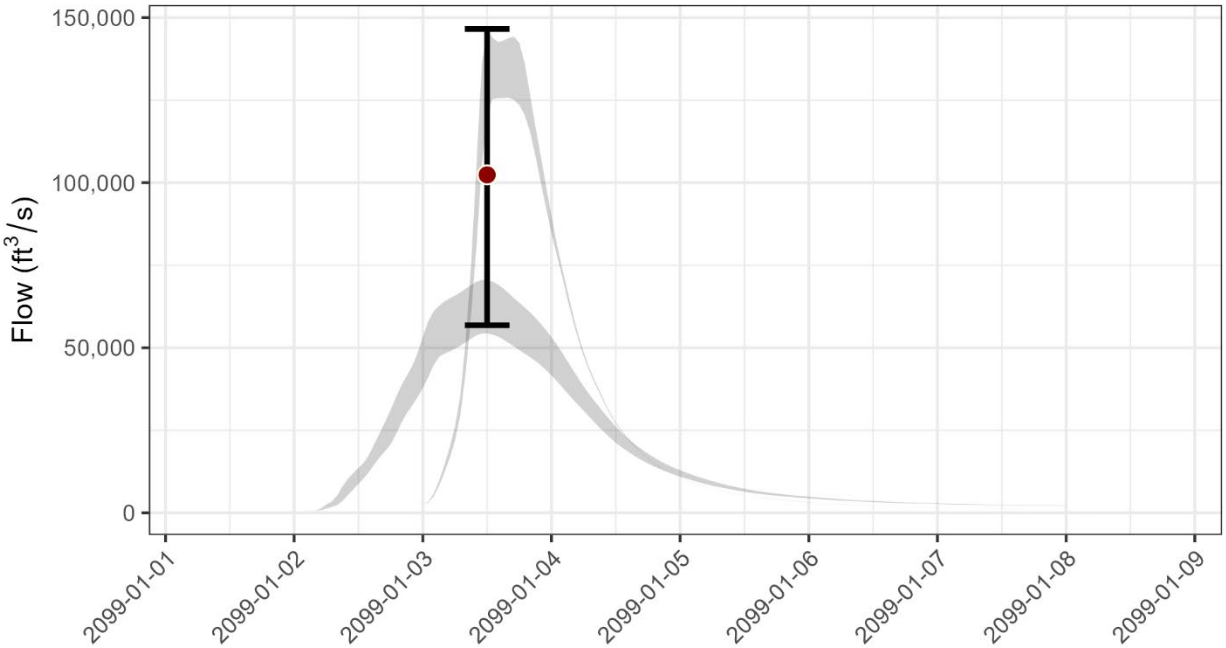


Figure 10-5 Results from stochastic precipitation frequency for USGS 07050500

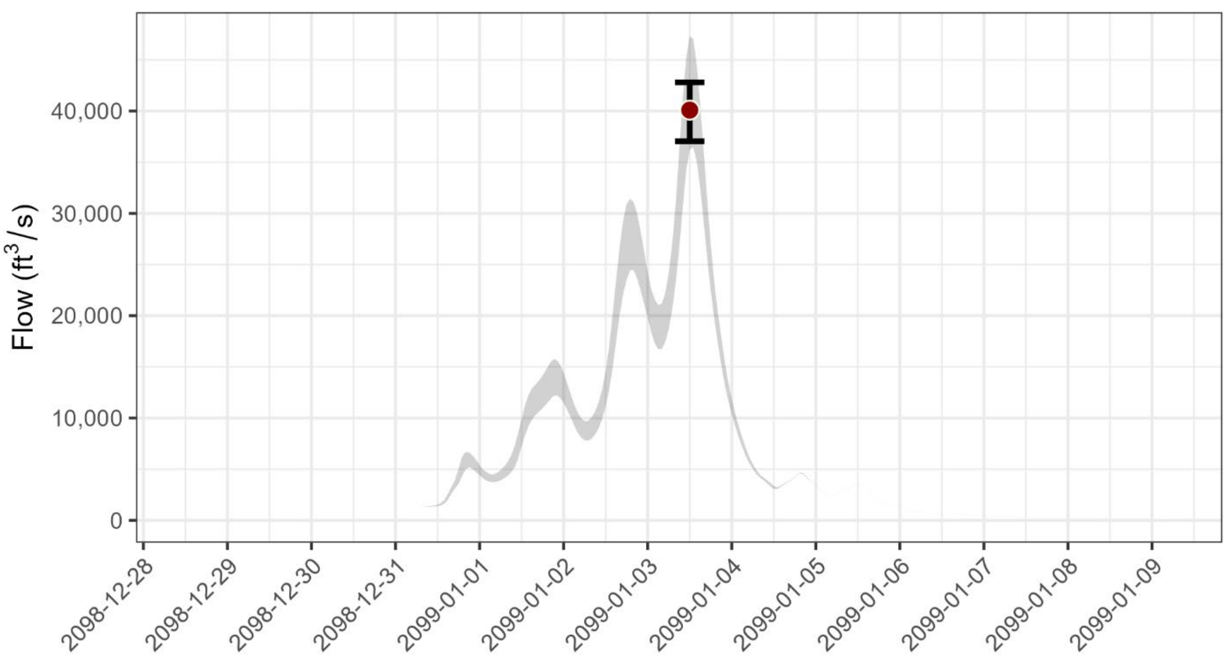


Figure 10-6 Results from stochastic precipitation frequency for USGS 07050700

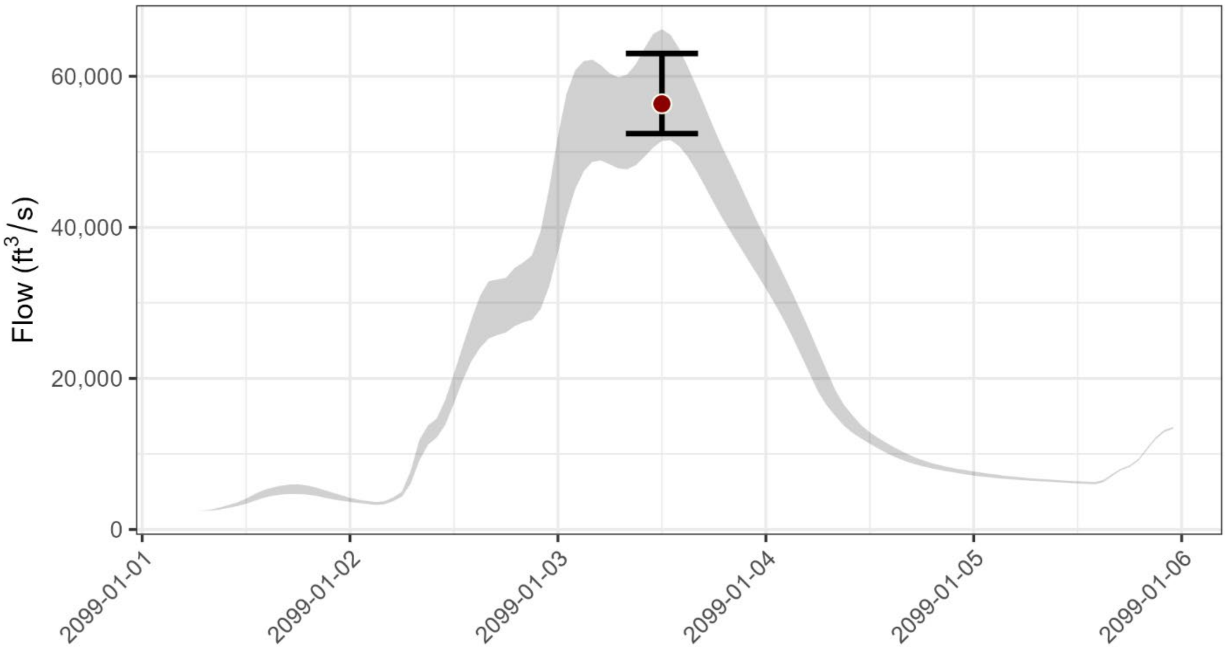


Figure 10-7 Results from stochastic precipitation frequency for USGS 07052250

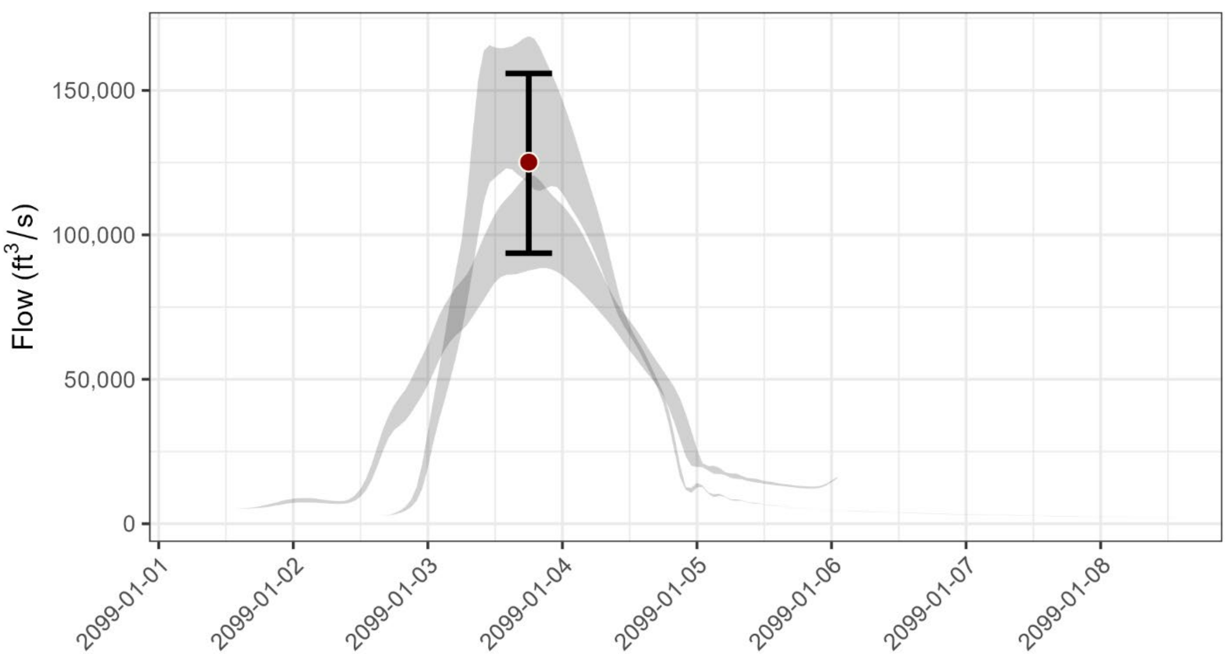


Figure 10-8 Results from stochastic precipitation frequency for USGS 07052500

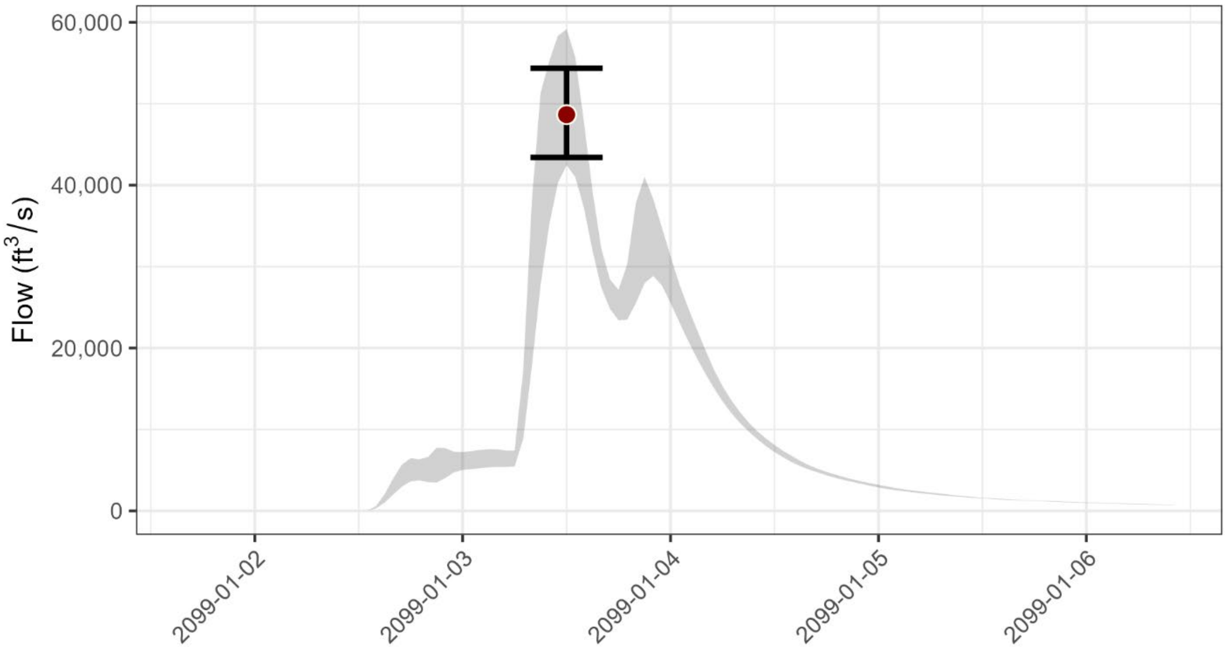


Figure 10-9 Results from stochastic precipitation frequency for USGS 07053207

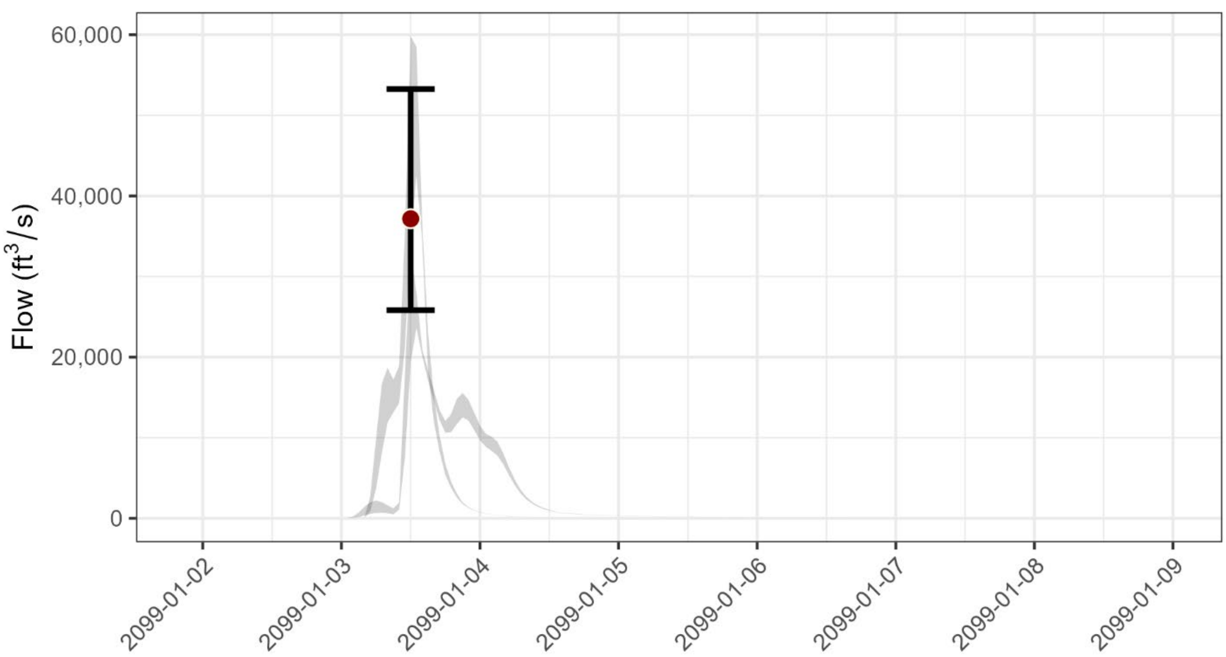


Figure 10-10 Results from stochastic precipitation frequency for USGS 07053250

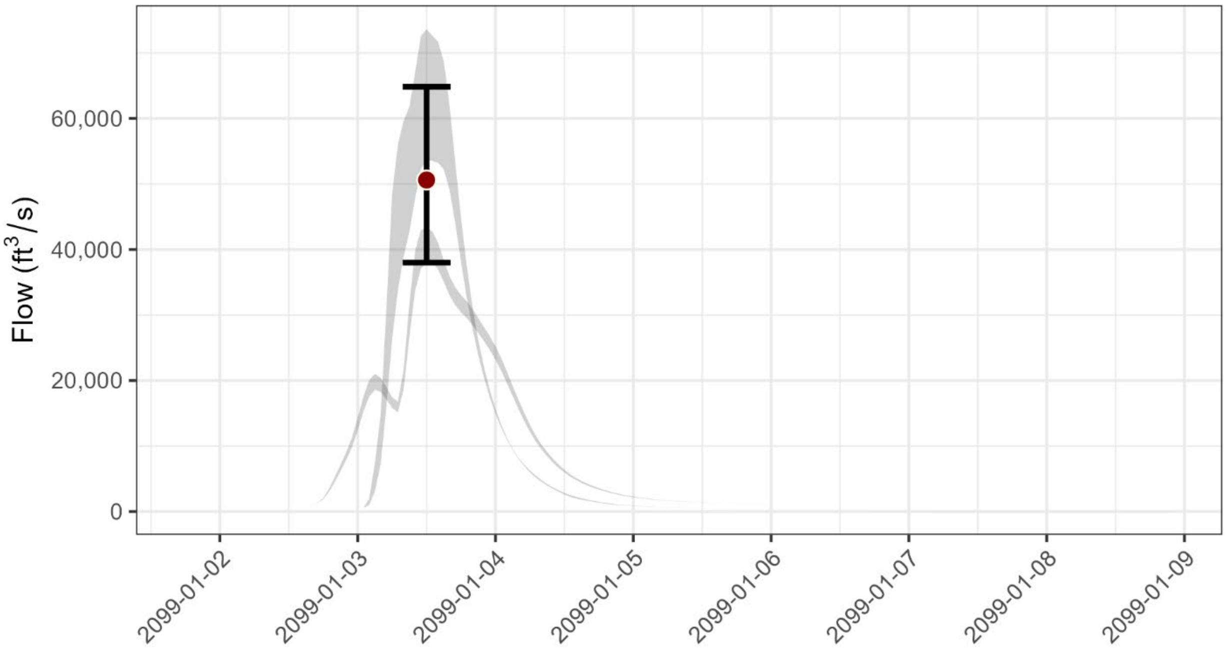


Figure 10-11 Results from stochastic precipitation frequency for USGS 07053810

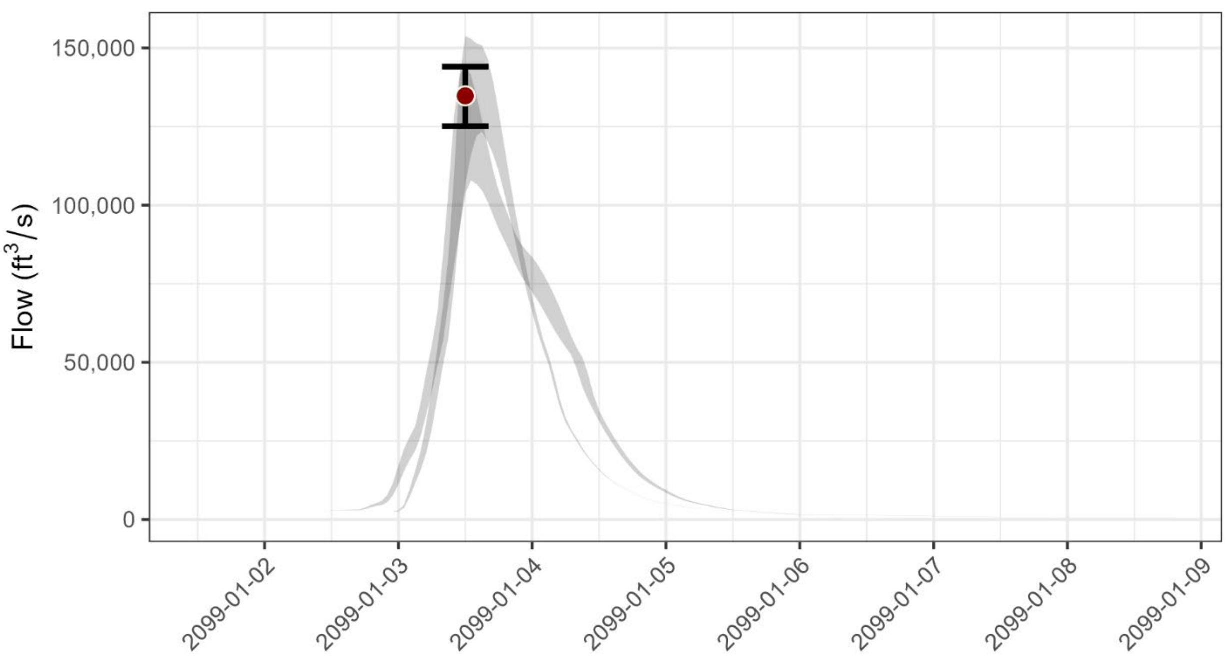


Figure 10-12 Results from stochastic precipitation frequency for USGS 07057500

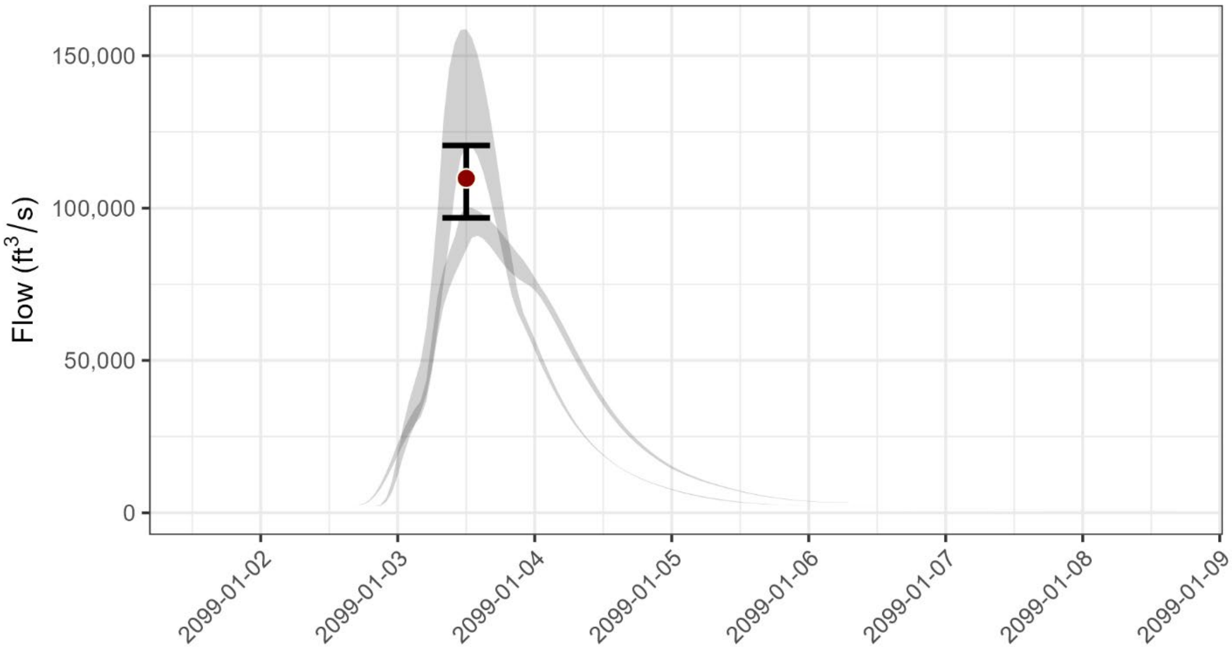


Figure 10-13 Results from stochastic precipitation frequency for USGS 07058000

Table 10-1. Parameters of Normal Distribution resulting from stochastic simulations at selected stream gage locations.

USGS Station Number	Mu	Sigma	Events
07048550	65,700	5340	Apr 2008, Apr 2017
07048600	136,000	29,300	Apr 2008, Apr 2017
07049000	113,000	24,300	Apr 2008, Apr 2017
07050500	102,000	38,800	Apr 2008, Dec 2015
07050700	40,100	1,990	Apr 2011
07052250	56,300	3,420	Apr 2017
07052500	125,000	22,100	Apr 2008, Apr 2017
07053207	48,700	3,250	Apr 2017
07057500	135,000	7,630	Apr 2008, Apr 2017
07058000	110,000	12,400	Apr 2008, Apr 2017

11 Comparison of Frequency Flow Estimates

Table 11-1 provides a comparison of the values from Bulletin 17C performed in PeakFQ (Section 5.2), USGS Streamstats (Section 5.3), NOAA Atlas 14 (Section 9), SWL precipitation frequency study (Section 10), and FEMA flood insurance studies (Section 2.4). Results are available for all sites for PeakFQ and Streamstats, and for limited sites for precipitation frequency and FEMA Flood Insurance Studies.

Table 11-1. Comparison of Frequency Flow Estimates for 1% Chance Event

Site	PeakFQ	StreamStats	NOAA Atlas 14	FEMA FIS	SWL Precipitation Frequency Study
07047975 Dog Branch at St. Paul, AR	1,170	1,162			
07048550 West Fork White River east of Fayetteville, AR	73,200	41,500	30,023 to 37,951	48,000	65,700
07048600 White River near Fayetteville, AR	108,000	135,000	87,664 to 104,419		136,000
07048940 War Eagle Creek near Witter, AR	19,300	19,700			
07049000 War Eagle Creek near Hindsville, AR	53,900	69,700	45,891 to 65,072		99,500
07050200 Maxwell Creek at Kingston, AR	4,670	4,320			
07050400 Freeman Branch at Berryville, AR	775	946			
07050500 Kings River near Berryville, AR	82,800	94,700	71,359 to 75,993		102,000
07050545 North Carolina Creek near Marshfield, MO	5,290	4,040			
07050690 Pearson Creek near Springfield, MO	5,300	8,530			
07050700 James River near Springfield, MO	52,100	43,300	44,106 to 56,685	43,600	40,100
07050800 Maple Grove Branch near Ozark, MO	2,020	1,590			
07052250 James River near Boaz, MO	65,200	59,300	53,476 to 73,593		56,300
07052370 Dry Crane Creek near Crane, MO	6,280	5,840			
07052500 James River at Galena, MO	87,600	100,000	92,743 to 114,593		125,000
07053207 Long Creek at Denver, AR	40,100	35,000	30,177 to 45,299		48,600
07053250 Yocum Creek near Oak Grove, AR	34,500	19,000	19,201 to 29,157		37,200

Site	PeakFQ	StreamStats	NOAA Atlas 14	FEMA FIS	SWL Precipitation Frequency Study
07053810 Bull Creek near Walnut Shade, MO	61,700	40,000	41,416 to 46,423	32,371	50,600
07053950 Ingenthron Hollow near Forsyth, MO	1,150	1,020			
07054080 Beaver Creek at Bradleyville, MO	74,400	49,400	56,235 to 68,808		
07054200 Yanell Branch near Kirbyville, MO	356	547			
07054300 Gray Branch at Lutie, MO	513	503			
07054400 Charley Creek near Omaha, AR	5,530	2,550			
07054410 Bear Creek near Omaha, AR	84,200	43,400			
07055550 Crooked Creek Tributary near Dog Patch, AR	3,400	3,640			
07055607 Crooked Creek at Kelly Crossing at Yellville, AR	84,260	76,700	56,064 to 56,289		
07055646 Buffalo River near Boxley, AR	44,100	28,100			
07055650 Smith Creek near Boxley, AR	13,200	7,830			
07055800 Dry Branch near Vendor, AR	8,290	7,180			
07055875 Richland Creek near Witts Spring, AR	46,400	46,400	29,322 to 29,355		
07056000 Buffalo River near St. Joe, AR	169,000	169,000	127,860 to 137,482		
07056515 Bear Creek near Silver Hill, AR	34,800	30,900			
07057300 Dodd Creek Tributary near Mountain Home, AR	1,060	816			
07057500 North Fork River near Tecumseh, MO	108,000	75,500	71,585 to 130,608		135,000
07058000 Bryant Creek near Tecumseh, MO	88,800	72,700	69,657 to 99,455		110,000
07058980 Bennetts River at Vidette, AR	10,200	17,600			
07059450 Big Creek near Elizabeth, AR	7,800	13,100			
07060600 Band Mill Creek near Brockwell, AR	1,370	1,330			
07060670 Hughes Creek near Mountain View, AR	2,860	4,940			
07060710 North Sylamore Creek near Fifty Six, AR	33,100	28,800			
07060830 Wolf Bayou near Drasco, AR	416	452			

Site	PeakFQ	StreamStats	NOAA Atlas 14	FEMA FIS	SWL Precipitation Frequency Study
07061100 Gibbs Creek at Sulphur Rock, AR	3,970	4,470			
07061260 East Fork Black River near Ironton, MO	14,200	9,150			
07061500 Black River near Annapolis, MO	100,000	72,900			
07061900 Logan Creek at Ellington, MO	67,400	31,200		28,200	
07063470 Tenmile Creek near Poplar Bluff, MO	25,500	14,300			
07064300 Fudge Hollow near Licking, MO	709	2,000			
07064500 Big Creek near Yukon, MO	12,800	6,560			
07065495 Jacks Fork at Alley Spring, MO	92,900	45,400			
07066000 Jacks Fork at Eminence, MO	81,300	55,800		54,000	
07066500 Current River near Eminence, MO	138,000	144,000			
07066800 Sycamore Creek near Winona, MO	748	1,960			
07067000 Current River at Van Buren, MO	156,000	150,000			
07068000 Current River at Doniphan, MO	146,000	153,000		135,480	
07068200 North Prong Little Black River at Hunter, MO	1,440	1,780			
07068510 Little Black River below Fairdealing, MO	65,300	33,100		23,578	
07068870 Fourche River Tributary at Middlebrook, AR	394	387			
07069100 Adams Branch near West Plains, MO	885	2,520			
07069250 Brush Creek near Mammoth Springs, AR	1,230	995			
07069290 Miller Creek near Salem, AR	2,810	2,500			
07069500 Spring River at Imboden, AR	152,000	72,700		150,000	
07070200 Burnham Branch near Willow Springs, MO	1,240	1,820			
07071500 Eleven Point River near Bardley, MO	73,000	84,900			
07072000 Eleven Point River near Ravenden Springs, AR	105,000	130,000			
07072200 Hubble Creek near Pocahontas, AR	1,410	964			
07073500 Piney Fork at Evening Shade	24,100	19,200			
07074000 Strawberry River near Poughkeepsie, AR	64,900	63,700	66,339 to 70,123		

Site	PeakFQ	StreamStats	NOAA Atlas 14	FEMA FIS	SWL Precipitation Frequency Study
07074200 Dry Branch Tributary near Sidney, AR	2,040	1,560			
07074250 Reeds Creek near Strawberry	18,900	13,400			
07074900 Trace C Trib nr Marshall, Ark	366	619			
07074950 Tick Creek near Leslie, AR	2,220	2,490			
07075000 Middle Fork of Little Red River at Shirley, AR	109,000	68,300		132,500	
07075300 South Fork of Little Red River at Clinton, AR	44,700	46,500		61,700	
07075600 Choctaw Creek Tributary near Choctaw, AR	1,480	1,590			
07075800 Dill Branch Tributary near Ida, AR	375	452			
07076630 Key Branch near Searcy, AR	710	1390			

At 12 locations with streamflow gaging stations, comparisons were made among at-site estimates using weighted skew of the 1/100 AEP peak streamflow, the NOAA Atlas 14 derived 1/100 AEP peak streamflow, the 1/100 AEP peak streamflow from USGS StreamStats, and the 1/100 AEP peak streamflow resulting from stochastic simulation using the SWL precipitation frequency study results. In general, the NOAA Atlas 14 methods resulted in the lowest overall 1/100 AEP peak streamflows. The results from the stochastic simulation using the SWL precipitation frequency study typically yield the highest 1/100 AEP peak streamflow results. The 72-hour, 1/100 AEP isopluvial maps resulting from the NOAA Atlas 14 Volume 9 study (Figure 11-2) show slightly lower precipitation depths than the SWL precipitation frequency study (Figure 11-3). NOAA Atlas 14 Volume 9 uses precipitation data that goes through 2014. Perhaps, in the future, with the release of NOAA Atlas 15, the study results may be a closer match. It is also possible that the SWL precipitation frequency estimates produce higher peaks than StreamStats because StreamStats estimates are based on the complete series of record of peak streamflow data for all gages, which may have consisted of periods when storm intensity was lower than storms seen in recent decades. Using current, high intensity storms to create rainfall-runoff models will result in higher peak streamflows for gaged locations within the White River basin.

From the StreamStats and SWL Precipitation frequency study results, a weighted estimate was created based on the inverse of the log base 10 difference of the upper confidence limit of the estimate and the lower confidence limit of the estimate. All estimates are plotted in Figure 11-1. From the sites evaluated, the USGS StreamStats program provided the estimates closest to the at-site with regional skew estimates, which are all less than 100 years in record length. However, inclusion of more recent precipitation frequency-based estimates may take in to account recent increases seen in precipitation frequencies which may be muted using short period of record streamgages or streamgages where the majority of the period of record was during decades when precipitation accumulation totals and storm intensities were not on par with those experienced in recent decades.

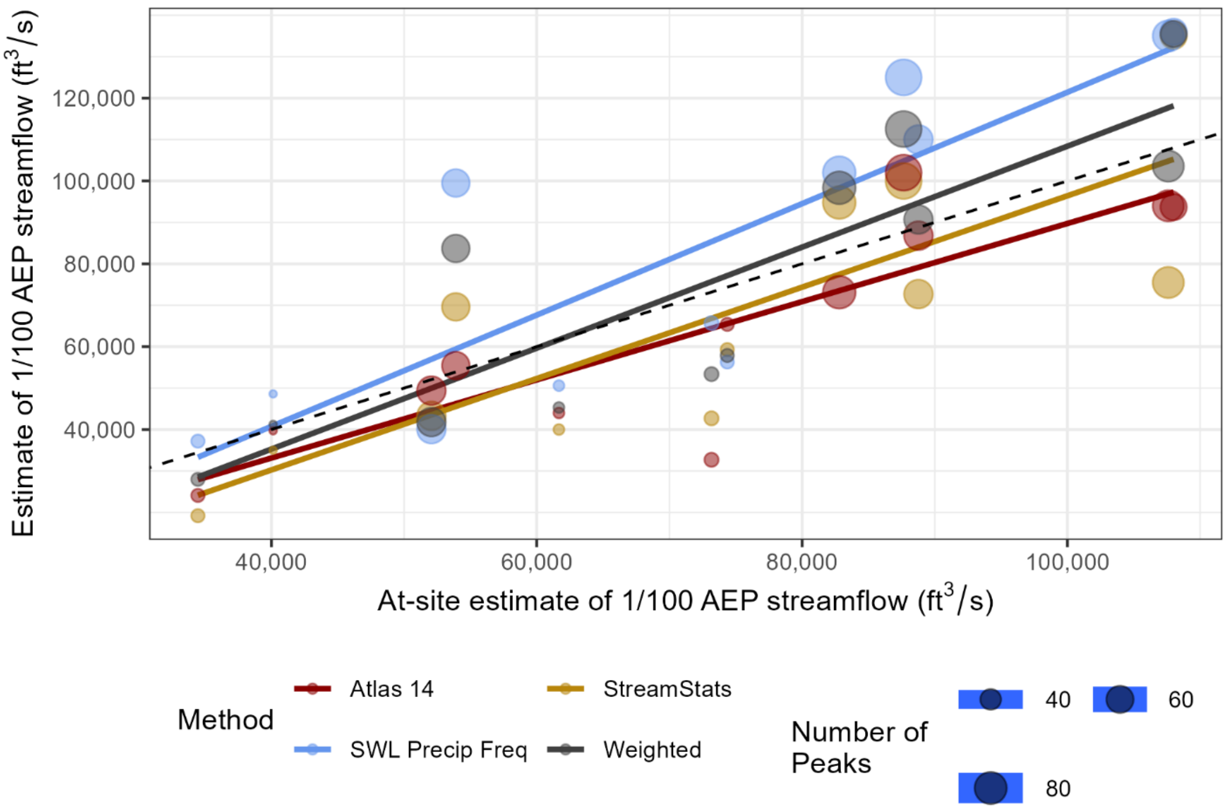


Figure 11-1 Comparison of at-site estimates of 1/100 AEP peak streamflows vs other methods of computing 1/100 AEP peak streamflows for selected gaged locations within the White River basin

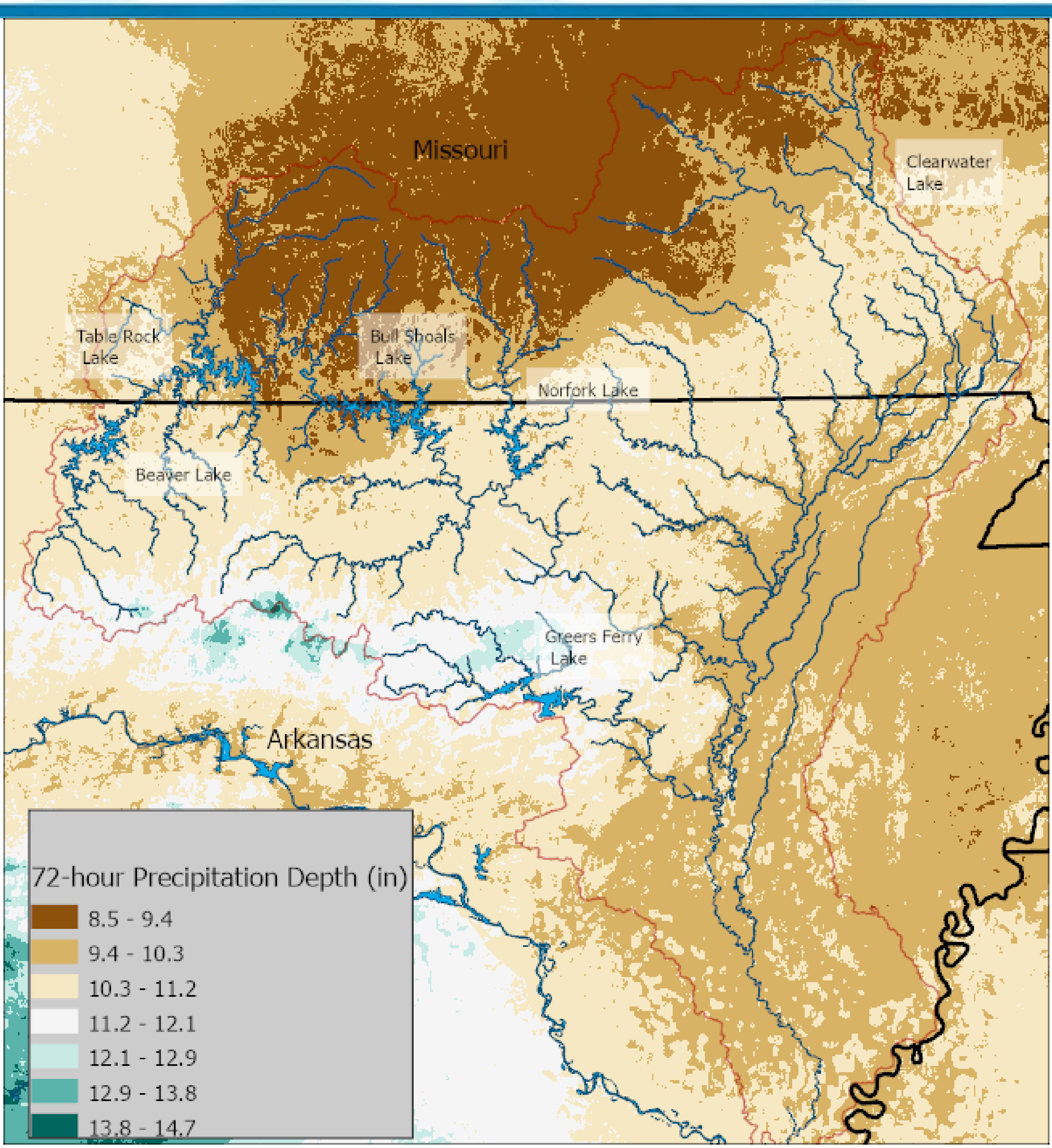


Figure 11-2 1/100 AEP, 72-hour precipitation depth isopluvial map from SWL precipitation frequency study

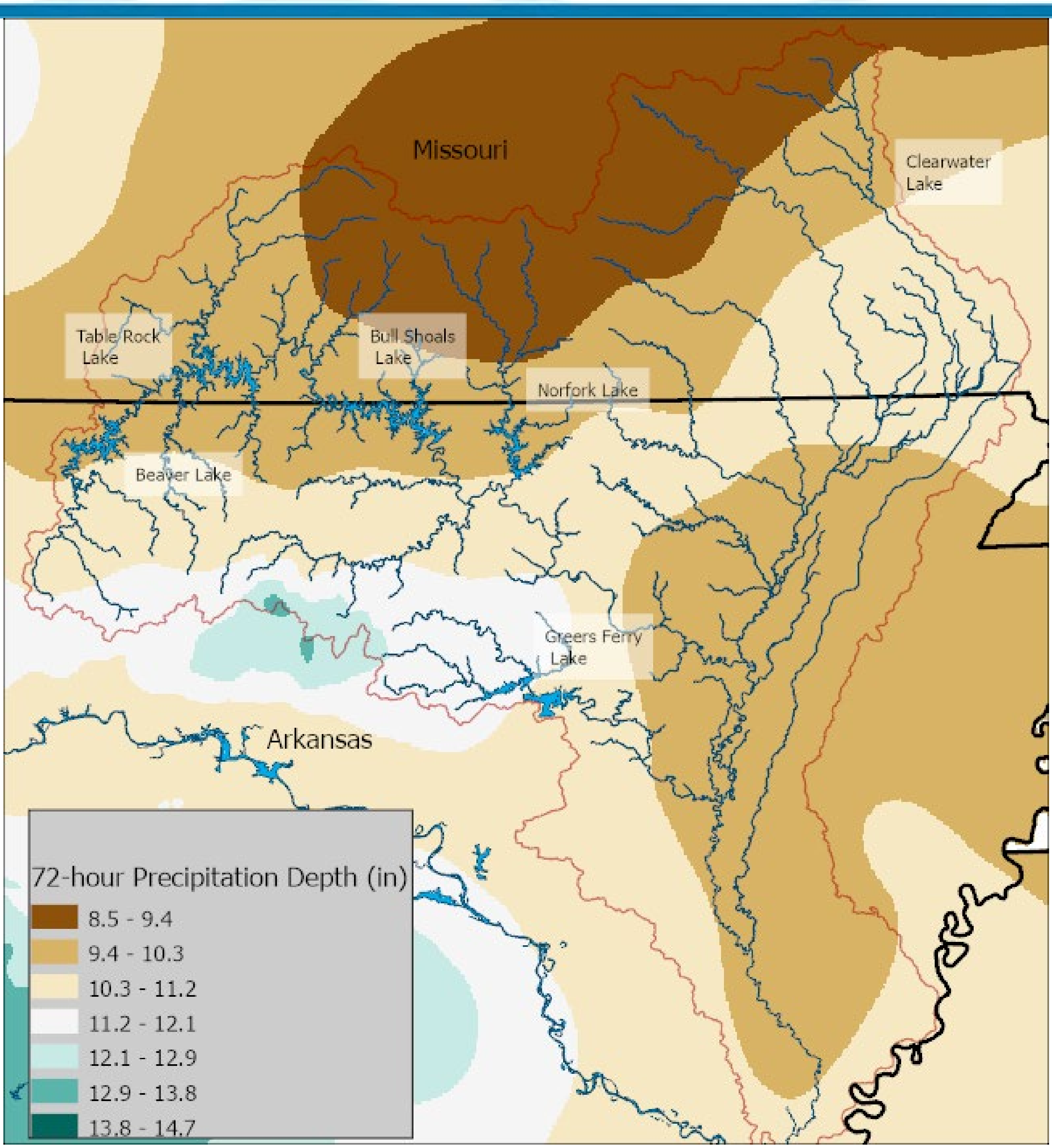


Figure 11-3 1/100 AEP, 72-hour precipitation depth isopluvial map from NOAA Atlas 14 Vol 8 and Vol 9

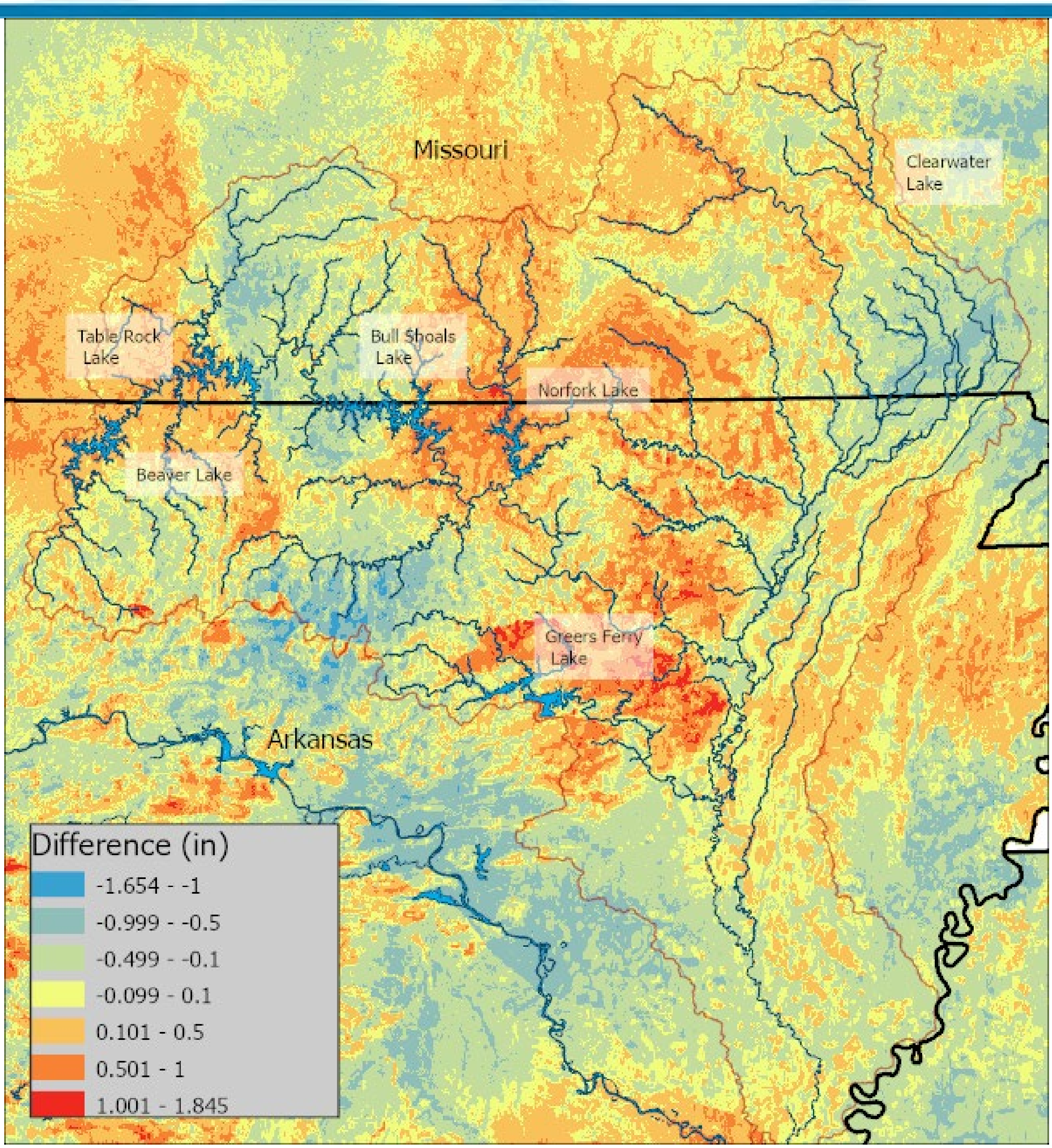


Figure 11-4. Difference between 72-hour SWL 1/100 AEP precipitation frequency depths and NOAA Atlas 14 1/100 AEP precipitation frequency depths

For streams on the main stem of the Lower White River and the Black River below Pocahontas, regional regression equations can not be applied. For these streams, which have varying degrees of regulation and alteration within their respective watersheds, estimates of 1/50, 1/100, 1/500 AEP peak streamflows can be obtained for the altered/regulated period of record. A comparison of frequency curves for White River at Newport produced from using the systematic, regulated record of peak streamflows and the extended period record of streamflows is shown in Figure 11-5.

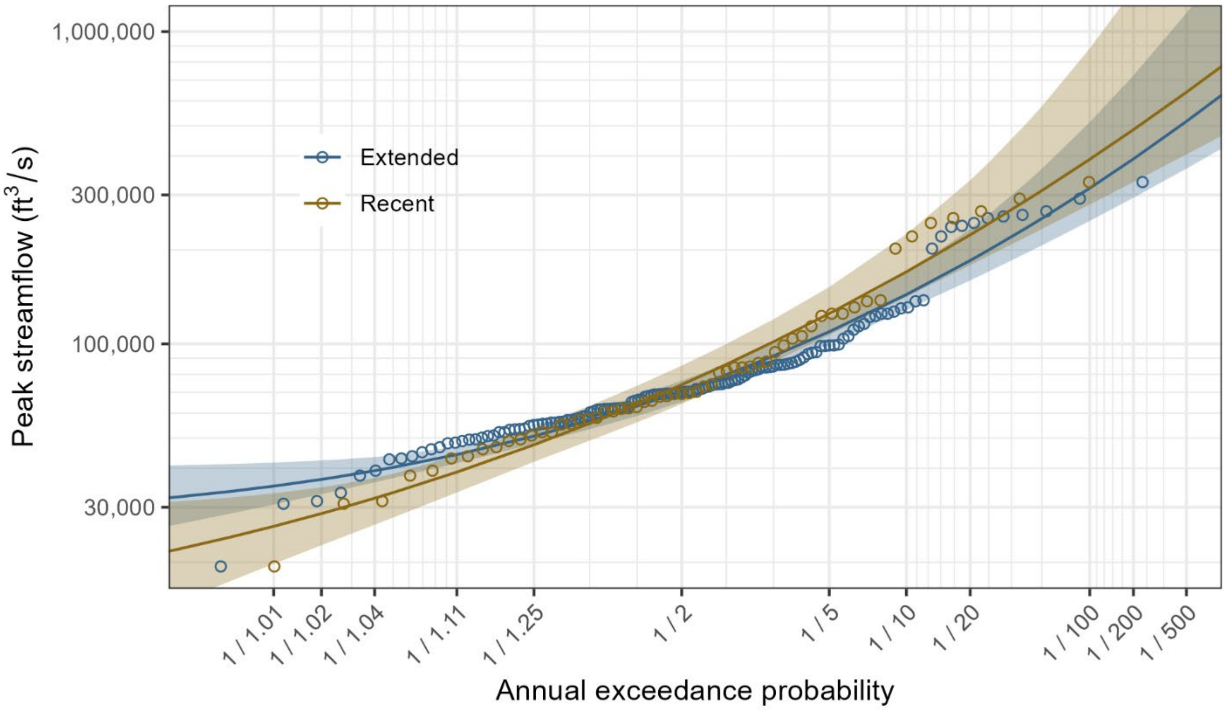


Figure 11-5 Comparison of regulated to extended period of record AEP streamflows for USGS 07074500 White River at Newport AR

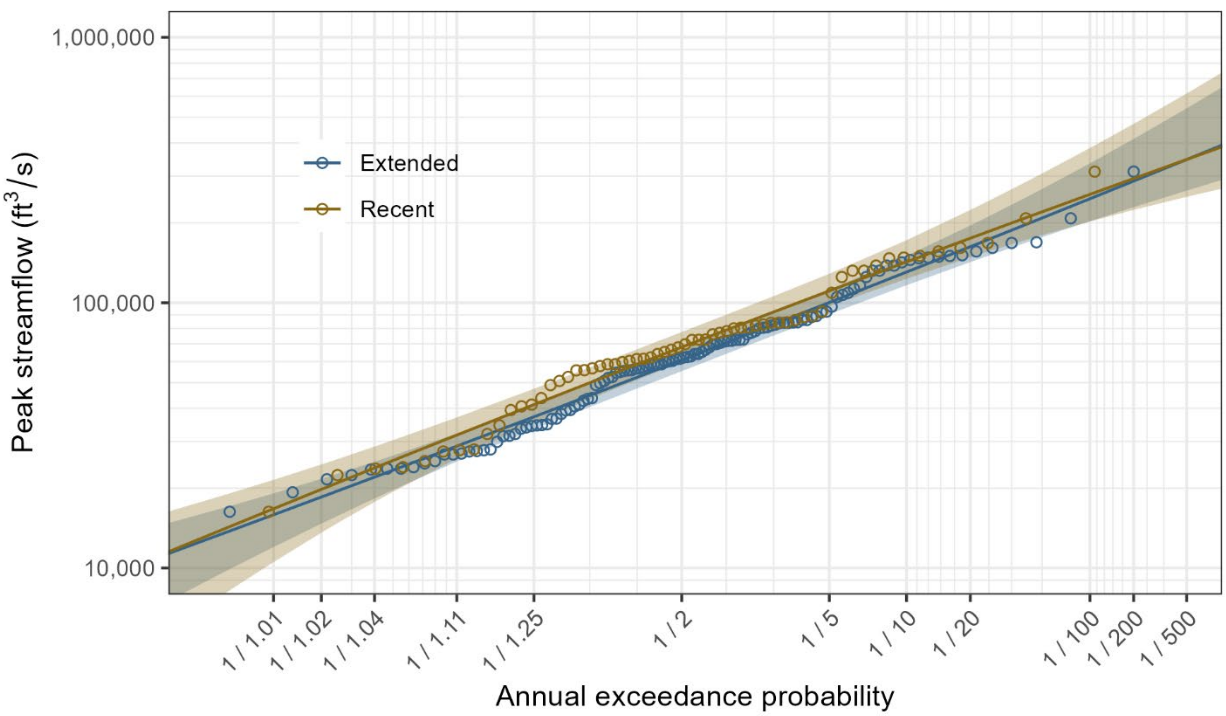


Figure 11-6 Comparison of regulated to extended period of record AEP streamflows for USGS 07061000 White River at Batesville AR

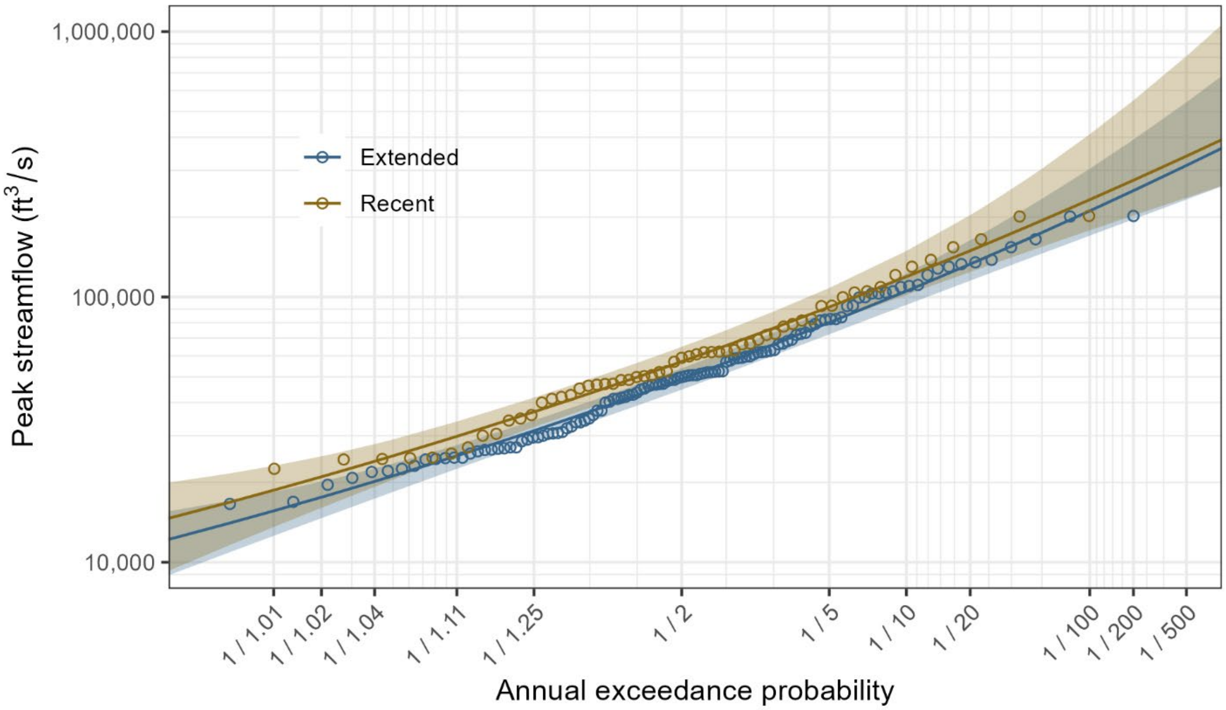


Figure 11-7 Comparison of regulated to extended period of record AEP streamflows for USGS 07060500 White River at Calico Rock AR

12 Frequency Flow Recommendations

Based on the analyses presented above, USGS StreamStats is likely a sufficient tool to use for evaluation of peak streamflows within the White River basin in Arkansas and Missouri. USGS StreamStats uses regression equations developed from many streamflow gaging stations across the region, fulfilling the need to trade space for time as it applies to estimation of flood frequency quantiles. If the responsible party has the means, it is beneficial to evaluate regional GEV distributions for varying AMS using surrounding precipitation gages which have data from that represents recent decades. This provides a means of evaluating stochastic simulations for specific AEP precipitation depths within HEC-HMS so that values from USGS StreamStats can be validated or weighted with flood frequency quantiles resulting from precipitation frequency analyses. Use of more recent, high intensity storms and Variable Clark Transforms is recommended to use for base hyetographs for stochastic simulations of precipitation frequency events.

For this study, NOAA Atlas 14 temporal patterns in the HEC-HMS hypothetical storm precipitation method were applied to streamflow gaging station locations at with at least 20 years of peak streamflow record data was applied. Within the White River basin, this methodology generally produced 1/100 AEP peak streamflows which were lower than at-site estimates using the regional skew coefficient developed by Wagner and other, 2021. Perhaps, in the future, when NOAA Atlas 15 is produced, this method may result in higher peak streamflow quantiles.

For locations on the White River downstream of USGS 07057370, White River near Norfork, AR, it is appropriate to use AMS of peak streamflow data, so long as sufficient record length can be produced. The same is true for location on the Black River below Corning, AR, where USGS StreamStats does not apply.

13 Reservoir Study

All reservoirs within the White River basin have been evaluated for elevation and release frequencies using a combination of long-term hydrologic simulations in RiverWare, stochastic precipitation frequency-based simulations using R Statistical Software and RiverSmart (which uses RiverWare), and record extensions using statistical relations between regulated inflow volumes and observed peak streamflows for streamgages that existed around the locations of existing USACE dams. Inflow volumes were estimated from peak streamflows using GAMs with 3 smoothed splines. Results are plotted and listed below.

13.1 Bull Shoals Lake

For elevation and release frequencies for Bull Shoals Lake, USGS streamflow gaging station 07055000, White River near Flippin, AR, was used to extend the record of 4-day inflow volumes to 1927. Stochastic simulation was used along with reservoir geometry curves to estimate AEPs for elevation and release frequencies.

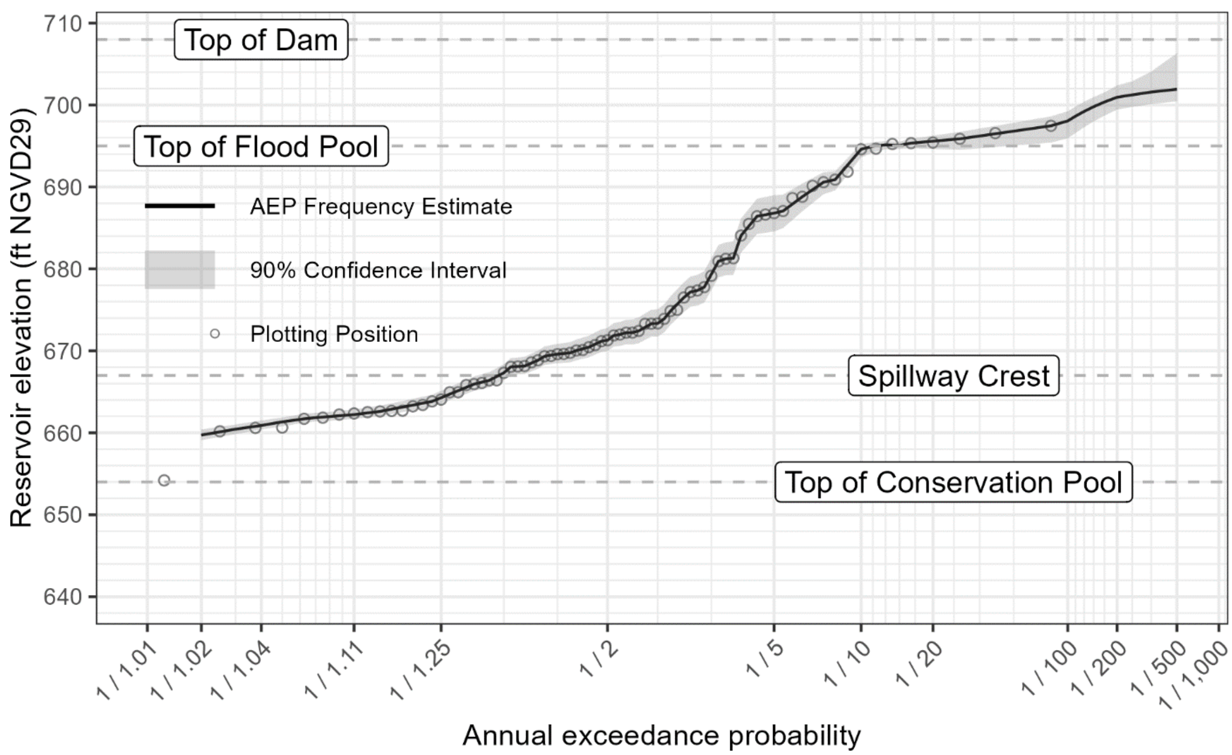


Figure 13-1 Elevation frequency plot for Bull Shoals Dam

Probability	Lower	Expected	Upper	AEP
0.900	693.43	694.42	695.05	1 / 10
0.950	694.54	695.52	696.21	1 / 20
0.960	694.46	695.73	696.54	1 / 25
0.980	694.92	696.75	697.80	1 / 50
0.990	695.70	697.82	698.99	1 / 100
0.998	700.46	701.92	706.31	1 / 500

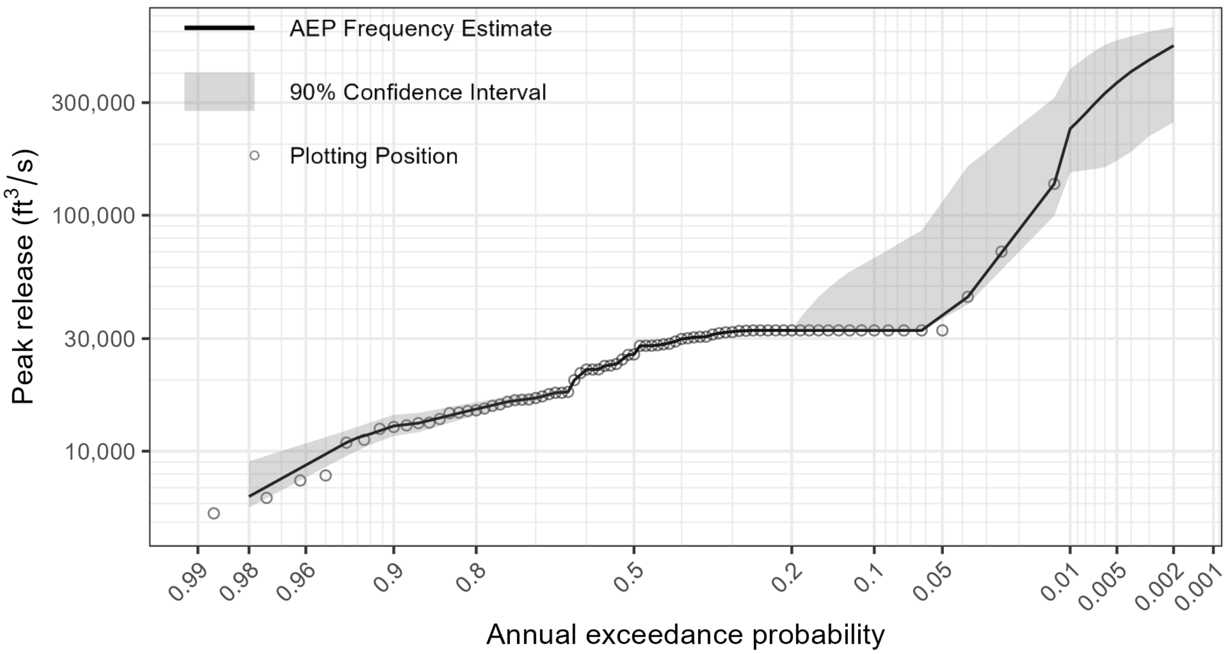


Figure 13-2 Release frequency plot for Bull Shoals Dam

Probability	Lower	Expected	Upper	AEP
0.900	32,400	32,500	65,900	1 / 10
0.950	36,800	38,300	118,000	1 / 20
0.960	40,800	43,600	151,000	1 / 25
0.980	76,800	97,500	257,000	1 / 50
0.990	152,000	232,000	417,000	1 / 100
0.998	248,000	523,000	626,000	1 / 500

13.2 Norfork Lake

For elevation and release frequencies for Norfork Lake, USGS streamflow gaging station 07058500, North Fork River at Tecumseh, MO, was used to extend the record of 4-day inflow volumes to 1905. Stochastic simulation was used along with reservoir geometry curves to estimate AEPs for elevation and release frequencies.

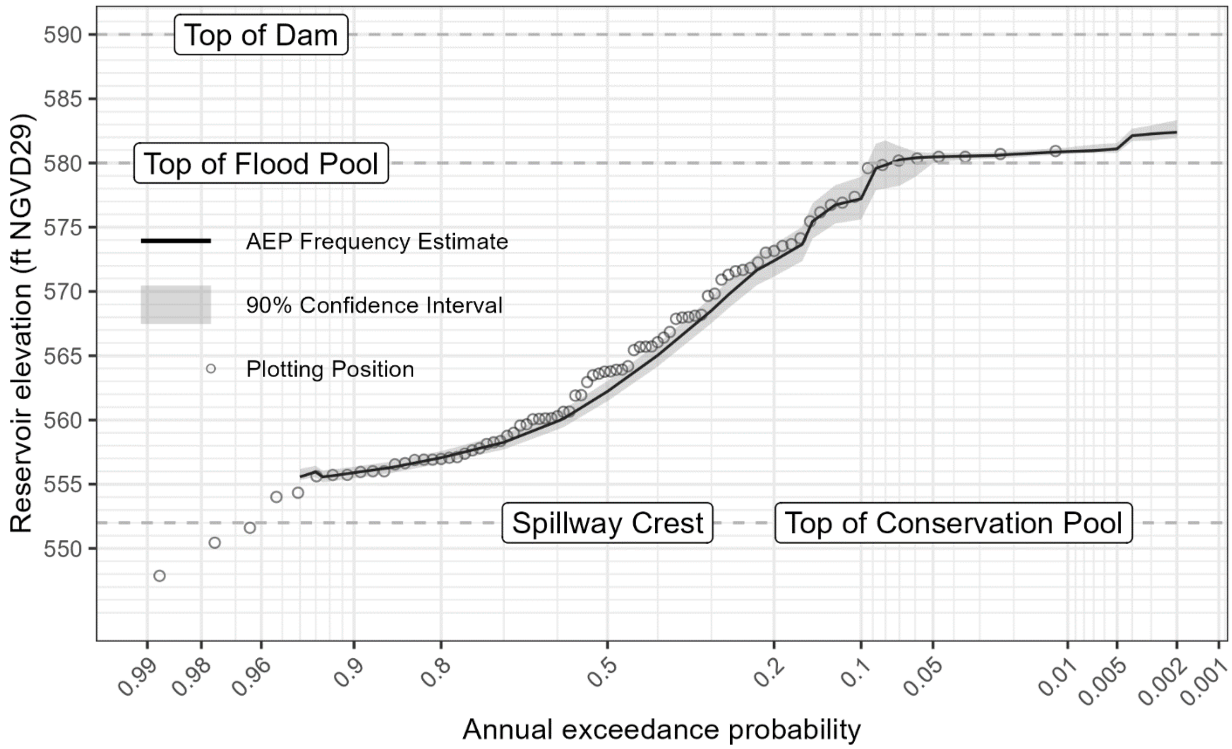


Figure 13-3 Elevation frequency plot for Norfork Dam

Probability	Lower	Value	Upper	AEP
0.900	575.76	577.22	578.85	1 / 10
0.950	578.06	579.93	581.94	1 / 20
0.960	578.02	580.07	582.30	1 / 25
0.980	577.57	580.39	581.97	1 / 50
0.990	579.48	580.70	581.37	1 / 100
0.998	581.26	582.11	583.57	1 / 500

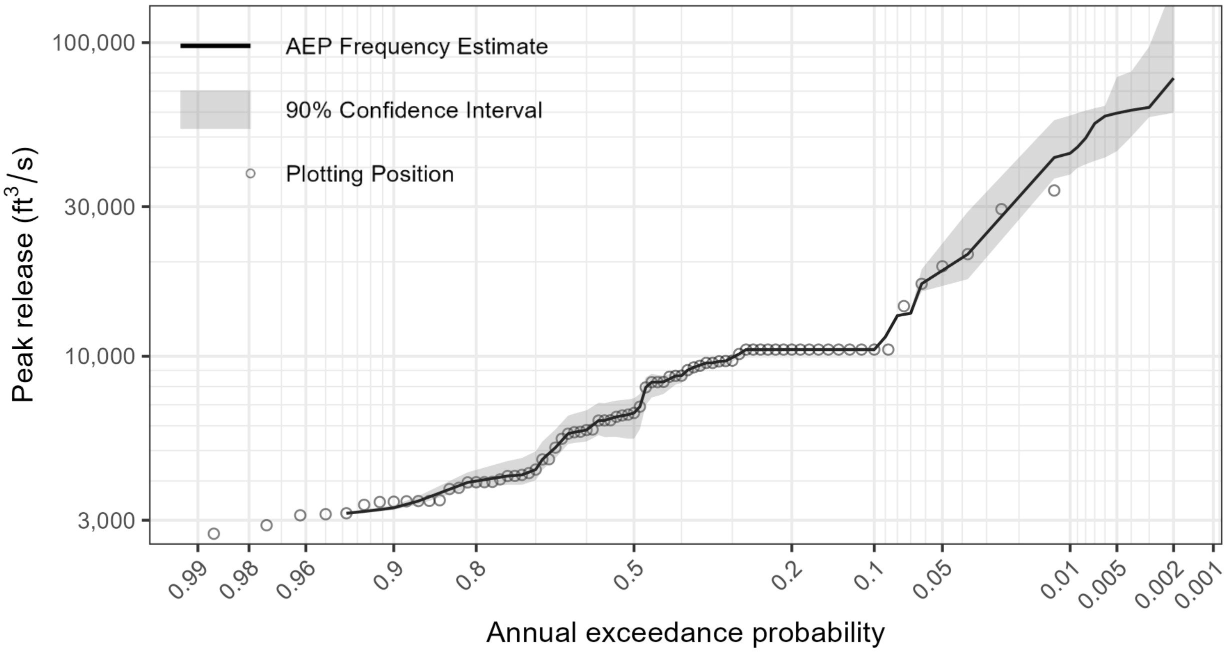


Figure 13-4 Release frequency plot for Norfork Dam

Probability	Lower	Value	Upper	AEP
0.900	10,300	10,500	10,700	1 / 10
0.950	16,800	19,000	23,400	1 / 20
0.960	17,500	20,700	27,700	1 / 25
0.980	29,500	34,800	46,300	1 / 50
0.990	38,000	44,400	58,500	1 / 100
0.998	59,800	77,000	153,000	1 / 500

13.3 Clearwater Lake

For elevation and release frequencies for Clearwater Lake, USGS streamflow gaging station 07061500, Black River near Annapolis, MO, was used to extend the record of 3-day inflow volumes to 1904. Stochastic simulation was used along with reservoir geometry curves to estimate AEPs for elevation and release frequencies.

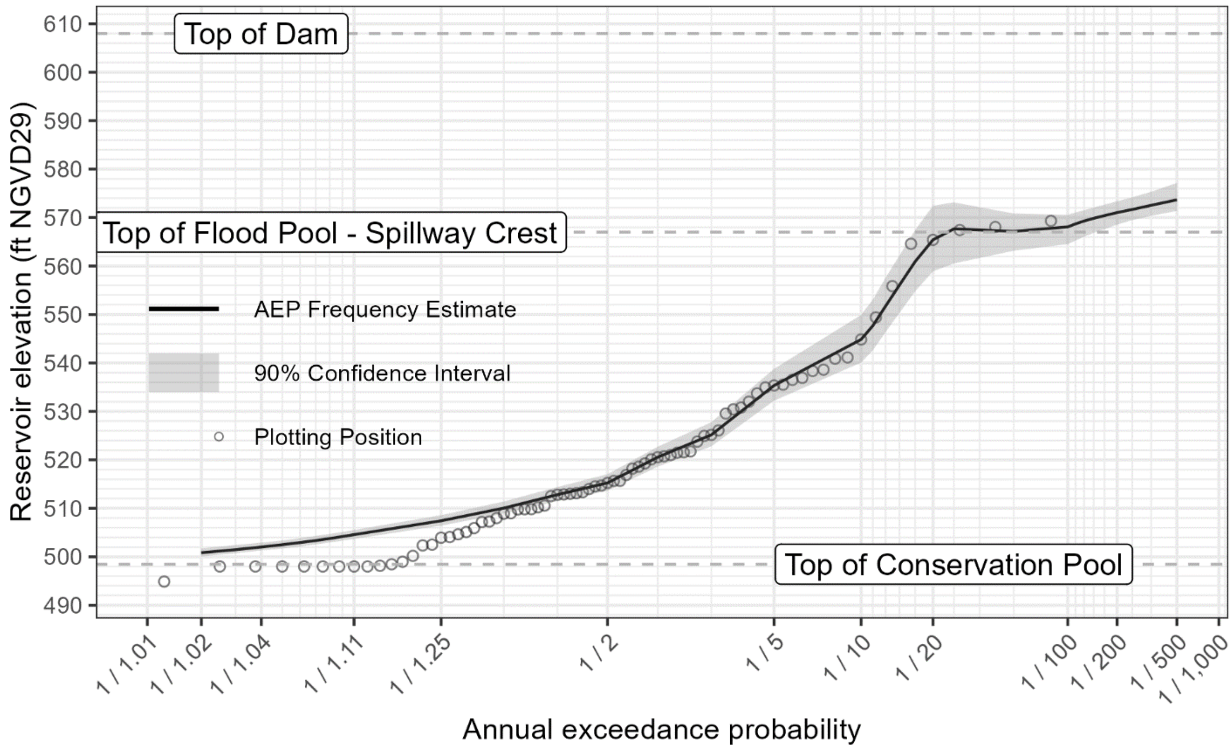


Figure 13-5 Elevation frequency plot for Clearwater Dam

Probability	Lower	Value	Upper	AEP
0.900	539.57	544.84	550.66	1 / 10
0.950	557.93	565.40	572.82	1 / 20
0.960	559.53	566.11	572.47	1 / 25
0.980	562.74	567.54	571.76	1 / 50
0.990	564.47	568.58	571.59	1 / 100
0.998	571.37	574.73	579.63	1 / 500

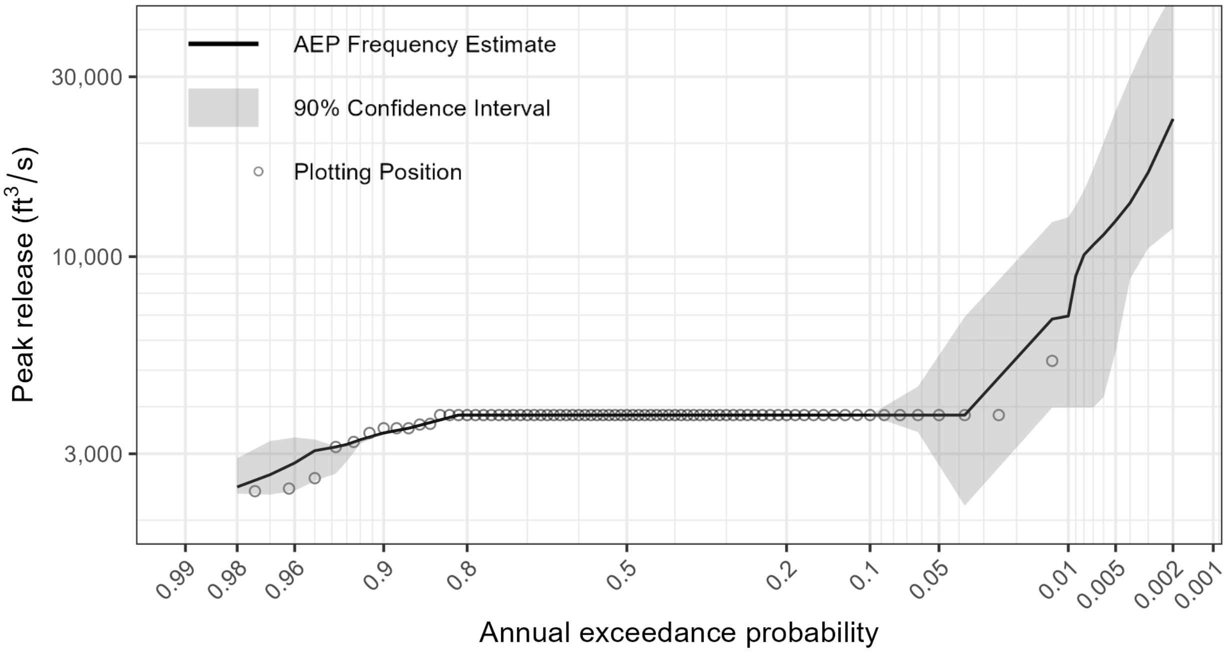


Figure 13-6 Release frequency plot for Clearwater Dam

Probability	Lower	Value	Upper	AEP
0.900	3,800	3,800	3,800	1 / 10
0.950	2,740	3,800	5,590	1 / 20
0.960	2,290	3,800	6,630	1 / 25
0.980	3,320	5,730	10,400	1 / 50
0.990	3,980	6,960	12,700	1 / 100
0.998	11,900	23,200	50,300	1 / 500

13.4 Greers Ferry Lake

For elevation and release frequencies for Greers Ferry Lake, USGS streamflow gaging station 07076000, Little Red River near Heber Springs, AR, was used to extend the record of 4-day inflow volumes to 1882. Stochastic simulation was used along with reservoir geometry curves to estimate AEPs for elevation and release frequencies.

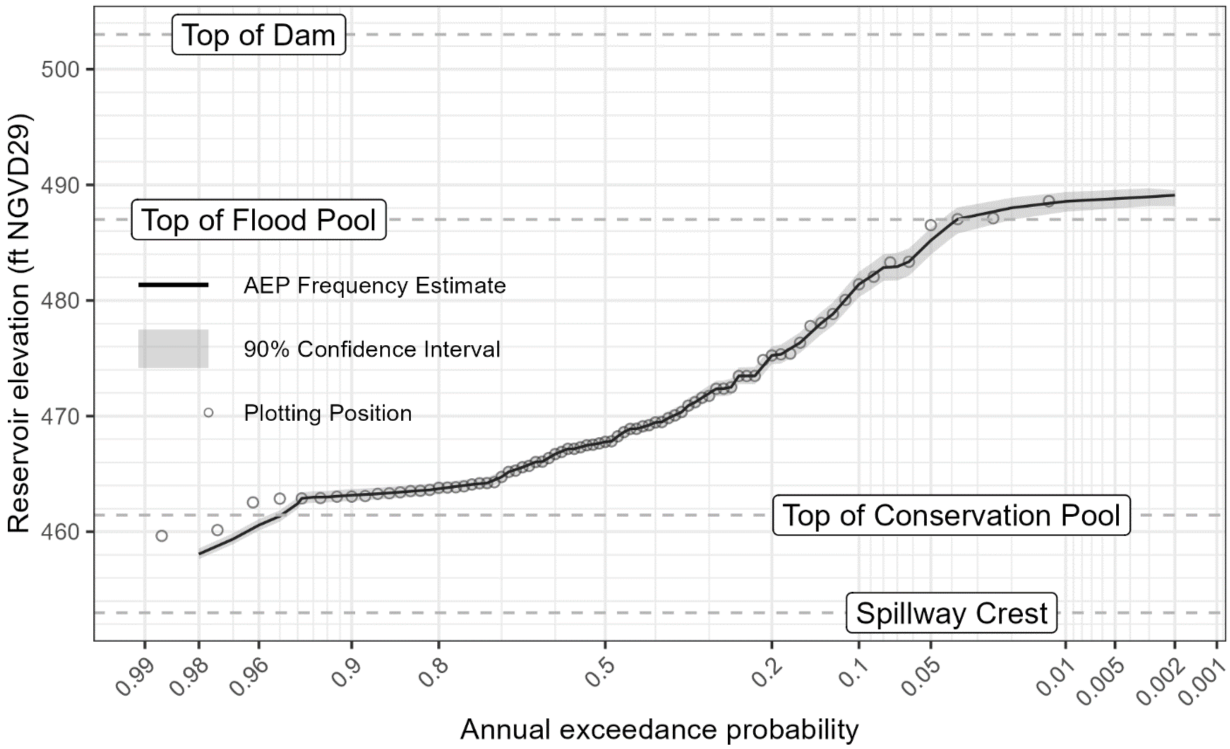


Figure 13-7 Elevation frequency plot for Greers Ferry Dam

Probability	Lower	Value	Upper	AEP
0.900	480.30	481.40	482.47	1 / 10
0.950	483.96	485.19	486.26	1 / 20
0.960	485.43	486.66	487.69	1 / 25
0.980	486.99	488.01	488.88	1 / 50
0.990	487.68	488.57	489.37	1 / 100
0.998	488.15	489.10	489.54	1 / 500

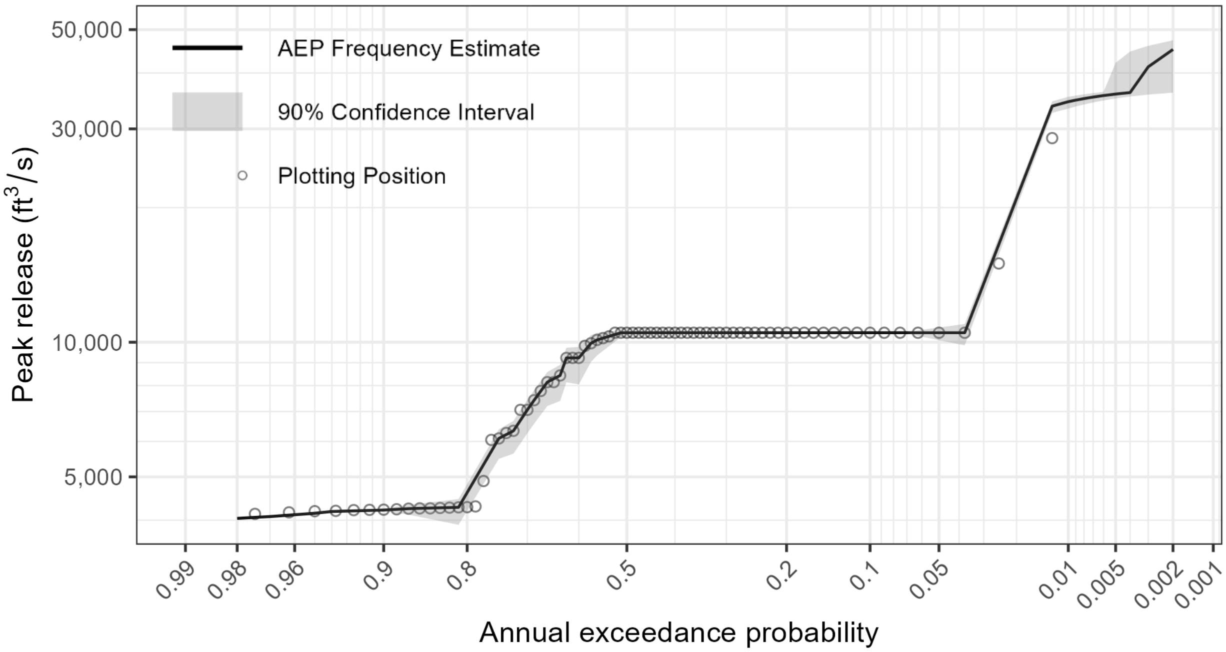


Figure 13-8 Release frequency plot for Greers Ferry Dam

Probability	Lower	Value	Upper	AEP
0.900	10,500	10,500	10,500	1 / 10
0.950	10,100	10,500	10,800	1 / 20
0.960	9,890	10,500	10,900	1 / 25
0.980	22,700	23,800	24,500	1 / 50
0.990	33,300	34,500	35,400	1 / 100
0.998	36,100	45,200	47,300	1 / 500

14 References

Breman, L. 2001. “Random Forests.” Machine Learning 45: 5–32.

Cohn, T.A., England, J.F., Berenbrock, C.E., Mason, R. R., Stedinger, J.R., and Lamontagne, J.R., 2013, A generalized Grubbs-Beck test statistic for detecting multiple potentially influential low outliers in flood series: Water Resources Research, v. 49, no. 8, p. 5047–5058.

Cohn, T.A., Lane, W.L., and Baier, W.G., 1997, An algorithm for computing moments-based flood quantile estimates when historical flood information is available: Water Resources Research, v. 33, no. 9, p. 2089–2096.

Cohn, T.A., Lane, W.L., and Stedinger, J.R., 2001,Confidence intervals for Expected Moments Algorithm flood quantile estimates: Water Resources Research, v. 37, no. 6, p. 1695–1706.

Cutler, D. R., T. C. Edwards, K. H. Jr. Beard, A. Cutler, K. T. Hess, J. Gibson, and J. J. and Lawler. 2007. “Random Forests for Classification in Ecology.” Ecology 88: 2783–92.

England, J.F., Jr., Cohn, T.A., Faber, B.A., Stedinger, J.R., Thomas, W.O., Jr., Veilleux, A.G., Kiang, J.E., and Mason, R.R., Jr., 2018, Guidelines for determining flood flow frequency—Bulletin 17C (ver. 1.1, May 2019): U.S. Geological Survey Techniques and Methods, book 4, chap. B5, 148 p., https://doi.org/10.3133/tm4B5.

Kuhn, Max. 2016. Caret: Classification and Regression Training. https://CRAN.R-project.org/package=caret.

Kuhn M, Quinlan R (2022). _Cubist: Rule- And Instance-Based Regression Modeling_. R package version 0.4.4, https://CRAN.R-project.org/package=Cubist.

Liaw, Andy, and Matthew Wiener. 2002. “Classification and Regression by randomForest.” R News 2 (3): 18–22. https://CRAN.R-project.org/doc/Rnews/.

Livneh, B., Bohn, T., Pierce, D. et al. A spatially comprehensive, hydrometeorological data set for Mexico, the U.S., and Southern Canada 1950–2013. Sci Data 2, 150042 (2015). https://doi.org/10.1038/sdata.2015.42.

R Core Team. 2023. R: A Language and Environment for Statistical Computing. Vienna, Austria: R Foundation for Statistical Computing. https://www.R-project.org/.

Sanja Perica, Deborah Martin, Sandra Pavlovic, Ishani Roy, Michael St. Laurent, Carl Trypaluk, DaleUnruh, Michael Yekta, Geoffrey Bonnin (2013). NOAA Atlas 14 Volume 9 Version 2,Precipitation-Frequency Atlas of the United States, Southeastern States. NOAA, NationalWeather Service, Silver Spring, MD.

U.S. Geological Survey, 2019, The StreamStats program, online at https://streamstats.usgs.gov/ss/

Wagner, D.M., Voss, J.D., Claybrooke, R.D., and Heimann, D.C., 2021, Annual peak-flow data and results of flood-frequency analysis for 76 selected streamflow gaging stations operated by the U.S. Geological Survey in the upper White River basin, Missouri and Arkansas, computed using an updated generalized (regional) flood skew: U.S. Geological Survey data release, https://doi.org/10.5066/P9C3L7IN.

Wood, S. N. 2011. “Fast Stable Restricted Maximum Likelihood and Marginal Likelihood Estimation of Semiparametric Generalized Linear Models.” Journal of the Royal Statistical Society (B) 73 (1): 3–36.

Wood, S. N., and N. Augustin. 2002. “GAMs with Integrated Model Selection Using Penalized Regression Splines and Applications to Environmental Modelling.” Ecological Modelling 157: 157–77.

Zagona, E.A., Fulp, T.J., Shane, R., Magee, T. and Goranflo, H.M. (2001), RIVERWARE: A GENERALIZED TOOL FOR COMPLEX RESERVOIR SYSTEM MODELING[1]. JAWRA Journal of the American Water Resources Association, 37: 913-929. https://doi.org/10.1111/j.1752-1688.2001.tb05522.x

Appendix A

Initial Deficit Values

Beaver Lake Subbasins

Table 14-1. Initial Deficit for Beaver Lake Subbasins

Subbasin	Initial Deficit Dec 2015 Event (in)	Initial Deficit 2008 Event (in)	Initial Deficit 2011 Event (in)	Initial Deficit Jun 2015 Event (in)	Initial Deficit 2017 Event (in)	Mean Calibration Values (in)
WWhite 9	0.15	0.18	0.24	0.18	0.15	0.18
WWhite 10	0.15	0.18	0.24	0.18	0.15	0.18
WMiddle	0.17	0.19	0.24	0.19	0.17	0.19
WLake	0.17	0.19	0.24	0.19	0.17	0.19
WWest 1	0.2	0.2	0.2	0.2	0.2	0.2
WWest 2	0.2	0.2	0.2	0.2	0.2	0.2
WWhite 8	0.12	0.11	0.1	0.11	0.12	0.11
WLollars	0.12	0.11	0.1	0.11	0.12	0.11
WDrakes	0.12	0.11	0.1	0.11	0.12	0.11
WRichland	0.14	0.13	0.1	0.13	0.14	0.13
WBR 3	0.14	0.14	0.13	0.14	0.14	0.14
WWhitener	0.14	0.14	0.13	0.14	0.14	0.14
WBR 2	0.14	0.14	0.13	0.14	0.14	0.14
WWhite 7	0.14	0.14	0.13	0.14	0.14	0.14
WBR 1	0.14	0.14	0.13	0.14	0.14	0.14
WWar 9	0.14	0.16	0.2	0.16	0.14	0.16
WHenderson	0.14	0.16	0.2	0.16	0.14	0.16
WWar 8	0.14	0.16	0.2	0.16	0.14	0.16
WWharton	0.14	0.16	0.2	0.16	0.14	0.16
WWar 7	0.14	0.16	0.2	0.16	0.14	0.16
WWar 6	0.14	0.16	0.2	0.16	0.14	0.16
WHolman	0.14	0.16	0.2	0.16	0.14	0.16
WGlade	0.14	0.16	0.2	0.16	0.14	0.16
WWar 5	0.14	0.16	0.2	0.16	0.14	0.16
WWar 4	0.14	0.16	0.2	0.16	0.14	0.16
WWar 3	0.14	0.16	0.2	0.16	0.14	0.16
WClifty 1	0.14	0.14	0.13	0.14	0.14	0.14
WWar 2	0.14	0.14	0.13	0.14	0.14	0.14
WWar 1	0.14	0.14	0.13	0.14	0.14	0.14
WWhite 6	0.14	0.14	0.13	0.14	0.14	0.14
WWhite 5	0.14	0.14	0.13	0.14	0.14	0.14
WBranch	0.14	0.14	0.13	0.14	0.14	0.14
WPrairie	0.14	0.14	0.13	0.14	0.14	0.14
WWhite 4	0.14	0.14	0.13	0.14	0.14	0.14
WWhite 3	0.14	0.14	0.13	0.14	0.14	0.14
WBeaver	0.14	0.14	0.13	0.14	0.14	0.14
WNorth Clifty	0.14	0.14	0.13	0.14	0.14	0.14
WWhite 1	0.14	0.14	0.13	0.14	0.14	0.14

WWhite 2	0.14	0.14	0.13	0.14	0.14	0.14

Bull Shoals and Table Rock Lakes Subbasins

Table 14-2. Initial Deficit for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	Initial Deficit Dec 2015 Event (in)	Initial Deficit 2008 Event (in)	Initial Deficit 2011 Event (in)	Initial Deficit Jun 2015 Event (in)	Initial Deficit 2017 Event (in)	Mean Calibration Values (in)
zwRoaring1	0.62	0.65	0.54	0.65	0.80	0.65
zwTR1	0.28	0.28	0.50	0.28	0.06	0.28
zwRoaring2	0.28	0.28	0.50	0.28	0.06	0.28
zwKings1	0.57	0.57	0.53	0.57	0.60	0.57
zwdryking	0.57	0.52	0.40	0.52	0.60	0.52
zwkings2	0.57	0.52	0.40	0.52	0.60	0.52
zwOsage1	0.57	0.57	0.53	0.57	0.60	0.57
zwOsage2	0.57	0.52	0.40	0.52	0.60	0.52
zwKings3	0.57	0.52	0.40	0.52	0.60	0.52
zwKings4	0.57	0.52	0.40	0.52	0.60	0.52
zwTR2	0.28	0.31	0.60	0.31	0.06	0.31
zwKings5	0.28	0.31	0.60	0.31	0.06	0.31
zwIndian	0.28	0.31	0.60	0.31	0.06	0.31
zwLitIndian	0.28	0.31	0.60	0.31	0.06	0.31
zwJames0	0.50	0.58	0.52	0.58	0.73	0.58
zwJames1	0.50	0.58	0.52	0.58	0.73	0.58
zwWilson1	0.68	0.67	0.53	0.67	0.79	0.67
zwJames2	0.35	0.57	0.50	0.57	0.87	0.57
zwWilson2	0.35	0.57	0.50	0.57	0.87	0.57
zwJames3	0.35	0.57	0.50	0.57	0.87	0.57
zwFinley0	0.48	0.50	0.30	0.50	0.71	0.50
zwFinley1	0.48	0.50	0.30	0.50	0.71	0.50
zwFlat1	0.44	0.61	0.68	0.61	0.71	0.61
zwJames4	0.35	0.55	0.50	0.55	0.80	0.55
zwFinley2	0.35	0.55	0.50	0.55	0.80	0.55
zwCrane1	0.35	0.55	0.50	0.55	0.80	0.55
zwspring1	0.35	0.55	0.50	0.55	0.80	0.55
zwJames5	0.35	0.55	0.50	0.55	0.80	0.55
zwCrane2	0.35	0.55	0.50	0.55	0.80	0.55
zwJames6	0.35	0.55	0.50	0.55	0.80	0.55
zwLitFlat	0.44	0.61	0.68	0.61	0.71	0.61
zwFlat2	0.44	0.61	0.68	0.61	0.71	0.61
zwrockhouse	0.44	0.61	0.68	0.61	0.71	0.61
zwFlat3	0.44	0.61	0.68	0.61	0.71	0.61
zwFlat4	0.28	0.31	0.60	0.31	0.06	0.31
zwJames7	0.28	0.31	0.60	0.31	0.06	0.31
zwJames8	0.28	0.31	0.60	0.31	0.06	0.31
zwTR3	0.28	0.31	0.60	0.31	0.06	0.31
zwLong0	0.28	0.31	0.60	0.31	0.06	0.31
zwdrylong	0.28	0.31	0.60	0.31	0.06	0.31
zwLong1	0.28	0.31	0.60	0.31	0.06	0.31
zwyocum1	0.98	0.79	0.58	0.79	0.80	0.79
zwLong2	0.28	0.31	0.60	0.31	0.06	0.31
zwYocum2	0.28	0.31	0.60	0.31	0.06	0.31

zwLong3	0.28	0.31	0.60	0.31	0.06	0.31
zwTR5	0.28	0.31	0.60	0.31	0.06	0.31
wTurkeywest	0.71	0.46	0.57	0.46	0.10	0.46
wTaneycomo1	0.71	0.46	0.57	0.46	0.10	0.46
wRoark	0.71	0.46	0.57	0.46	0.10	0.46
wTaneycomo2	0.71	0.46	0.57	0.46	0.10	0.46
wBull1	0.48	0.38	0.50	0.38	0.15	0.38
wBull2	0.48	0.38	0.50	0.38	0.15	0.38
wBull4	0.48	0.38	0.50	0.38	0.15	0.38
wBull3	0.48	0.44	0.70	0.44	0.15	0.44
wbull4.5	0.48	0.44	0.70	0.44	0.15	0.44
wTaneycomo3	0.71	0.48	0.57	0.48	0.15	0.48
wBull5	0.71	0.46	0.57	0.46	0.10	0.46
WSwan1	0.71	0.46	0.57	0.46	0.10	0.46
wSwan2	0.71	0.46	0.57	0.46	0.10	0.46
wSwan4	0.71	0.46	0.57	0.46	0.10	0.46
wTaneycomo4	0.71	0.46	0.57	0.46	0.10	0.46
wBeaver1	0.60	0.47	0.60	0.47	0.20	0.47
WBeaver2	0.60	0.47	0.60	0.47	0.20	0.47
wBeaver4	0.60	0.47	0.60	0.47	0.20	0.47
wBeaver3	0.60	0.47	0.60	0.47	0.20	0.47
wBeaver5	0.60	0.47	0.60	0.47	0.20	0.47
wBeaver6	0.60	0.47	0.60	0.47	0.20	0.47
wBeaver8	0.60	0.47	0.60	0.47	0.20	0.47
wBeaver7	0.60	0.47	0.60	0.47	0.20	0.47
wBeaver10	0.71	0.46	0.57	0.46	0.10	0.46
wBeaver9	0.71	0.46	0.57	0.46	0.10	0.46
wBeaver12	0.71	0.46	0.57	0.46	0.10	0.46
wBeaver11	0.71	0.46	0.57	0.46	0.10	0.46
wBeaver13	0.71	0.46	0.57	0.46	0.10	0.46
wMA1	0.71	0.46	0.57	0.46	0.10	0.46
wCedar	0.71	0.46	0.57	0.46	0.10	0.46
wMA2	0.71	0.46	0.57	0.46	0.10	0.46
wBee	0.71	0.46	0.57	0.46	0.10	0.46
wYocum	0.71	0.46	0.57	0.46	0.10	0.46
wBear1	0.27	0.21	0.27	0.21	0.10	0.21
wBear2	0.27	0.21	0.27	0.21	0.10	0.21
wBear4	0.27	0.21	0.27	0.21	0.10	0.21
wBear3	0.27	0.21	0.27	0.21	0.10	0.21
wbear4.5	0.27	0.21	0.27	0.21	0.10	0.21
wBear5	0.71	0.46	0.57	0.46	0.10	0.46
WElbow	0.71	0.46	0.57	0.46	0.10	0.46
wMA3	0.71	0.46	0.57	0.46	0.10	0.46
wWSugerloaf	0.71	0.46	0.57	0.46	0.10	0.46
wEsugarloaf	0.71	0.46	0.57	0.46	0.10	0.46
wShoal	0.71	0.46	0.57	0.46	0.10	0.46
wMA4	0.71	0.46	0.57	0.46	0.10	0.46
wEastFork	0.71	0.46	0.57	0.46	0.10	0.46
wWestFork	0.71	0.46	0.57	0.46	0.10	0.46
wBig	0.71	0.46	0.57	0.46	0.10	0.46
wMA5	0.71	0.46	0.57	0.46	0.10	0.46
wMA6	0.71	0.46	0.57	0.46	0.10	0.46
wMusic	0.71	0.46	0.57	0.46	0.10	0.46
wMA7	0.71	0.46	0.57	0.46	0.10	0.46
wLitNFork1	0.71	0.46	0.57	0.46	0.10	0.46
WLitNFork2	0.71	0.46	0.57	0.46	0.10	0.46

wTurkeyEast	0.71	0.46	0.57	0.46	0.10	0.46
wBarrenFork	0.71	0.46	0.57	0.46	0.10	0.46
wPondfork	0.71	0.46	0.57	0.46	0.10	0.46
wNorthFork	0.71	0.46	0.57	0.46	0.10	0.46
WSouthFork	0.71	0.46	0.57	0.46	0.10	0.46
wMA9	0.71	0.46	0.57	0.46	0.10	0.46
wMA10	0.71	0.46	0.57	0.46	0.10	0.46
wGulleySpring	0.71	0.46	0.57	0.46	0.10	0.46
wMA8	0.71	0.46	0.57	0.46	0.10	0.46
wJimmie	0.71	0.46	0.57	0.46	0.10	0.46
wMA11	0.71	0.46	0.57	0.46	0.10	0.46
wMA12	0.71	0.46	0.57	0.46	0.10	0.46

Constant Loss Values

Beaver Lake Subbasins

Table 14-3. Constant Loss for Beaver Lake Subbasins

Subbasin	Constant Loss Dec 2015 Event (in)	Constant Loss 2008 Event (in)	Constant Loss 2011 Event (in)	Constant Loss Jun 2015 Event (in)	Constant Loss 2017 Event (in)	Mean Calibration Values (in)
WWhite 9	0.06	0.07	0.05	0.07	0.1	0.07
WWhite 10	0.06	0.07	0.05	0.07	0.1	0.07
WMiddle	0.06	0.07	0.05	0.07	0.1	0.07
WLake	0.1	0.09	0.08	0.09	0.1	0.09
WWest 1	0.07	0.08	0.06	0.08	0.12	0.08
WWest 2	0.1	0.1	0.08	0.1	0.12	0.1
WWhite 8	0.1	0.07	0.08	0.07	0.04	0.07
WLollars	0.05	0.04	0.04	0.04	0.03	0.04
WDrakes	0.06	0.05	0.05	0.05	0.03	0.05
WRichland	0.07	0.05	0.06	0.05	0.03	0.05
WBR 3	0.06	0.05	0.05	0.05	0.03	0.05
WWhitener	0.09	0.06	0.07	0.06	0.02	0.06
WBR 2	0.07	0.05	0.06	0.05	0.02	0.05
WWhite 7	0.07	0.05	0.06	0.05	0.02	0.05
WBR 1	0.09	0.06	0.07	0.06	0.03	0.06
WWar 9	0.04	0.04	0.04	0.04	0.03	0.04
WHenderson	0.03	0.03	0.02	0.03	0.03	0.03
WWar 8	0.05	0.04	0.04	0.04	0.03	0.04
WWharton	0.05	0.04	0.04	0.04	0.03	0.04
WWar 7	0.06	0.05	0.05	0.05	0.03	0.05
WWar 6	0.06	0.05	0.05	0.05	0.03	0.05
WHolman	0.05	0.04	0.04	0.04	0.03	0.04
WGlade	0.05	0.04	0.04	0.04	0.03	0.04
WWar 5	0.09	0.07	0.07	0.07	0.04	0.07
WWar 4	0.07	0.05	0.06	0.05	0.03	0.05
WWar 3	0.09	0.07	0.07	0.07	0.04	0.07
WClifty 1	0.07	0.05	0.06	0.05	0.02	0.05
WWar 2	0.09	0.06	0.07	0.06	0.02	0.06
WWar 1	0.06	0.05	0.05	0.05	0.04	0.05
WWhite 6	0.06	0.05	0.05	0.05	0.04	0.05
WWhite 5	0.07	0.05	0.06	0.05	0.03	0.05
WBranch	0.06	0.04	0.05	0.04	0.02	0.04

WPrairie	0.06	0.05	0.05	0.05	0.04	0.05
WWhite 4	0.06	0.05	0.05	0.05	0.05	0.05
WWhite 3	0.1	0.08	0.08	0.08	0.05	0.08
WBeaver	0.1	0.07	0.08	0.07	0.03	0.07
WNorth Clifty	0.08	0.06	0.07	0.06	0.02	0.06
WWhite 1	0.09	0.07	0.07	0.07	0.04	0.07
WWhite 2	0.06	0.05	0.05	0.05	0.03	0.05

Bull Shoals and Table Rock Lakes Subbasins

Table 14-4. Constant Loss for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	Constant Loss Dec 2015 Event (in)	Constant Loss 2008 Event (in)	Constant Loss 2011 Event (in)	Constant Loss Jun 2015 Event (in)	Constant Loss 2017 Event (in)	Mean Calibration Values (in)
zwRoaring1	0.10	0.11	0.08	0.11	0.15	0.11
zwTR1	0.08	0.07	0.08	0.07	0.04	0.07
zwRoaring2	0.09	0.09	0.08	0.09	0.09	0.09
zwKings1	0.02	0.09	0.04	0.09	0.21	0.09
zwdryking	0.20	0.17	0.08	0.17	0.24	0.17
zwkings2	0.20	0.18	0.08	0.18	0.25	0.18
zwOsage1	0.02	0.10	0.08	0.10	0.21	0.10
zwOsage2	0.02	0.10	0.08	0.10	0.21	0.10
zwKings3	0.02	0.10	0.08	0.10	0.21	0.10
zwKings4	0.02	0.10	0.08	0.10	0.21	0.10
zwTR2	0.08	0.08	0.12	0.08	0.04	0.08
zwKings5	0.08	0.07	0.08	0.07	0.04	0.07
zwIndian	0.08	0.07	0.08	0.07	0.04	0.07
zwLitIndian	0.12	0.11	0.12	0.11	0.09	0.11
zwJames0	0.11	0.10	0.12	0.10	0.08	0.10
zwJames1	0.11	0.10	0.10	0.10	0.08	0.10
zwWilson1	0.20	0.23	0.27	0.23	0.23	0.23
zwJames2	0.06	0.13	0.16	0.13	0.18	0.13
zwWilson2	0.06	0.13	0.16	0.13	0.18	0.13
zwJames3	0.06	0.19	0.31	0.19	0.21	0.19
zwFinley0	0.10	0.06	0.06	0.06	0.01	0.06
zwFinley1	0.10	0.06	0.06	0.06	0.01	0.06
zwFlat1	0.16	0.10	0.11	0.10	0.02	0.10
zwJames4	0.08	0.15	0.15	0.15	0.22	0.15
zwFinley2	0.08	0.15	0.15	0.15	0.22	0.15
zwCrane1	0.08	0.13	0.15	0.13	0.15	0.13
zwspring1	0.02	0.05	0.05	0.05	0.08	0.05
zwJames5	0.08	0.13	0.15	0.13	0.15	0.13
zwCrane2	0.08	0.13	0.15	0.13	0.15	0.13
zwJames6	0.08	0.15	0.15	0.15	0.22	0.15
zwLitFlat	0.16	0.10	0.11	0.10	0.02	0.10
zwFlat2	0.25	0.14	0.15	0.14	0.02	0.14
zwrockhouse	0.25	0.14	0.15	0.14	0.02	0.14
zwFlat3	0.25	0.14	0.15	0.14	0.02	0.14
zwFlat4	0.19	0.15	0.08	0.15	0.19	0.15
zwJames7	0.19	0.15	0.08	0.15	0.19	0.15
zwJames8	0.19	0.14	0.08	0.14	0.15	0.14
zwTR3	0.12	0.08	0.04	0.08	0.09	0.08

zwLong0	0.08	0.07	0.04	0.07	0.08	0.07
zwdrylong	0.12	0.08	0.04	0.08	0.09	0.08
zwLong1	0.12	0.08	0.04	0.08	0.09	0.08
zwyocum1	0.06	0.03	0.02	0.03	0.02	0.03
zwLong2	0.08	0.07	0.04	0.07	0.08	0.07
zwYocum2	0.12	0.08	0.04	0.08	0.09	0.08
zwLong3	0.08	0.07	0.04	0.07	0.08	0.07
zwTR5	0.08	0.05	0.04	0.05	0.04	0.05
wTurkeywest	0.12	0.06	0.05	0.06	0.01	0.06
wTaneycomo1	0.11	0.06	0.05	0.06	0.01	0.06
wRoark	0.15	0.07	0.05	0.07	0.01	0.07
wTaneycomo2	0.10	0.06	0.07	0.06	0.01	0.06
wBull1	0.10	0.13	0.19	0.13	0.09	0.13
wBull2	0.11	0.13	0.19	0.13	0.09	0.13
wBull4	0.11	0.13	0.19	0.13	0.09	0.13
wBull3	0.11	0.07	0.02	0.07	0.09	0.07
wbull4.5	0.11	0.07	0.02	0.07	0.09	0.07
wTaneycomo3	0.16	0.07	0.05	0.07	0.01	0.07
wBull5	0.05	0.04	0.05	0.04	0.01	0.04
WSwan1	0.10	0.06	0.07	0.06	0.01	0.06
wSwan2	0.10	0.06	0.07	0.06	0.01	0.06
wSwan4	0.10	0.06	0.07	0.06	0.01	0.06
wTaneycomo4	0.16	0.08	0.07	0.08	0.01	0.08
wBeaver1	0.12	0.09	0.07	0.09	0.08	0.09
WBeaver2	0.12	0.09	0.07	0.09	0.08	0.09
wBeaver4	0.12	0.09	0.07	0.09	0.08	0.09
wBeaver3	0.14	0.15	0.15	0.15	0.15	0.15
wBeaver5	0.12	0.09	0.07	0.09	0.08	0.09
wBeaver6	0.12	0.09	0.07	0.09	0.08	0.09
wBeaver8	0.12	0.09	0.07	0.09	0.08	0.09
wBeaver7	0.12	0.09	0.07	0.09	0.08	0.09
wBeaver10	0.12	0.06	0.05	0.06	0.01	0.06
wBeaver9	0.12	0.06	0.05	0.06	0.01	0.06
wBeaver12	0.12	0.06	0.05	0.06	0.01	0.06
wBeaver11	0.05	0.04	0.05	0.04	0.01	0.04
wBeaver13	0.10	0.06	0.07	0.06	0.01	0.06
wMA1	0.10	0.06	0.07	0.06	0.01	0.06
wCedar	0.14	0.07	0.05	0.07	0.01	0.07
wMA2	0.06	0.04	0.05	0.04	0.01	0.04
wBee	0.06	0.04	0.05	0.04	0.01	0.04
wYocum	0.06	0.04	0.05	0.04	0.01	0.04
wBear1	0.06	0.03	0.02	0.03	0.01	0.03
wBear2	0.06	0.03	0.02	0.03	0.01	0.03
wBear4	0.06	0.03	0.02	0.03	0.01	0.03
wBear3	0.06	0.03	0.02	0.03	0.01	0.03
wbear4.5	0.06	0.03	0.02	0.03	0.01	0.03
wBear5	0.06	0.04	0.05	0.04	0.01	0.04
WElbow	0.06	0.04	0.05	0.04	0.01	0.04
wMA3	0.06	0.04	0.05	0.04	0.01	0.04
wWSugerloaf	0.06	0.04	0.05	0.04	0.01	0.04
wEsugarloaf	0.06	0.04	0.05	0.04	0.01	0.04
wShoal	0.12	0.06	0.05	0.06	0.01	0.06
wMA4	0.06	0.04	0.05	0.04	0.01	0.04
wEastFork	0.06	0.04	0.05	0.04	0.01	0.04
wWestFork	0.06	0.04	0.05	0.04	0.01	0.04
wBig	0.12	0.06	0.05	0.06	0.01	0.06

wMA5	0.06	0.05	0.07	0.05	0.01	0.05
wMA6	0.06	0.04	0.05	0.04	0.01	0.04
wMusic	0.06	0.04	0.05	0.04	0.01	0.04
wMA7	0.06	0.04	0.05	0.04	0.01	0.04
wLitNFork1	0.12	0.07	0.07	0.07	0.01	0.07
WLitNFork2	0.12	0.06	0.05	0.06	0.01	0.06
wTurkeyEast	0.12	0.06	0.05	0.06	0.01	0.06
wBarrenFork	0.06	0.04	0.05	0.04	0.01	0.04
wPondfork	0.12	0.06	0.05	0.06	0.01	0.06
wNorthFork	0.12	0.07	0.07	0.07	0.01	0.07
WSouthFork	0.12	0.07	0.07	0.07	0.01	0.07
wMA9	0.12	0.07	0.07	0.07	0.01	0.07
wMA10	0.12	0.06	0.05	0.06	0.01	0.06
wGulleySpring	0.06	0.05	0.07	0.05	0.01	0.05
wMA8	0.06	0.05	0.07	0.05	0.01	0.05
wJimmie	0.06	0.05	0.07	0.05	0.01	0.05
wMA11	0.06	0.05	0.07	0.05	0.01	0.05
wMA12	0.06	0.05	0.07	0.05	0.01	0.05

Maximum Deficit Values

Beaver Lake Subbasins

Table 14-5. Maximum Deficit for Beaver Lake Subbasins

Subbasin	Maximum Deficit Dec 2015 Event (in)	Maximum Deficit 2008 Event (in)	Maximum Deficit 2011 Event (in)	Maximum Deficit Jun 2015 Event (in)	Maximum Deficit 2017 Event (in)	Mean Calibration Values (in)
WWhite 9	3	3	2	3	3	2.67
WWhite 10	3	3	2	3	3	2.67
WMiddle	3	3	2	3	3	2.67
WLake	3	3	2	3	3	2.67
WWest 1	3	3	2	3	3	2.67
WWest 2	3	3	2	3	3	2.67
WWhite 8	3	3	4	3	3	3.33
WLollars	3	3	4	3	3	3.33
WDrakes	3	3	4	3	3	3.33
WRichland	3	3	4	3	3	3.33
WBR 3	3	3	3	3	3	3.00
WWhitener	3	3	3	3	3	3.00
WBR 2	3	3	3	3	3	3.00
WWhite 7	3	3	3	3	3	3.00
WBR 1	3	3	3	3	3	3.00
WWar 9	3	3	4	3	3	3.33
WHenderson	3	3	4	3	3	3.33
WWar 8	3	3	4	3	3	3.33
WWharton	3	3	4	3	3	3.33
WWar 7	3	3	4	3	3	3.33
WWar 6	3	3	4	3	3	3.33
WHolman	3	3	4	3	3	3.33
WGlade	3	3	4	3	3	3.33
WWar 5	3	3	4	3	3	3.33

WWar 4	3	3	4	3	3	3.33
WWar 3	3	3	4	3	3	3.33
WClifty 1	3	3	3	3	3	3.00
WWar 2	3	3	3	3	3	3.00
WWar 1	3	3	3	3	3	3.00
WWhite 6	3	3	3	3	3	3.00
WWhite 5	3	3	3	3	3	3.00
WBranch	3	3	3	3	3	3.00
WPrairie	3	3	3	3	3	3.00
WWhite 4	3	3	3	3	3	3.00
WWhite 3	3	3	3	3	3	3.00
WBeaver	3	3	3	3	3	3.00
WNorth Clifty	3	3	3	3	3	3.00
WWhite 1	3	3	3	3	3	3.00
WWhite 2	3	3	3	3	3	3.00

Bull Shoals and Table Rock Lakes Subbasins

Table 14-6. Maximum Deficit for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	Maximum Deficit Dec 2015 Event (in)	Maximum Deficit 2008 Event (in)	Maximum Deficit 2011 Event (in)	Maximum Deficit Jun 2015 Event (in)	Maximum Deficit 2017 Event (in)	Mean Calibration Values (in)
zwRoaring1	3.3	3.30	3.3	3.30	3.3	3.30
zwTR1	3.3	3.30	3.3	3.30	3.3	3.30
zwRoaring2	3.3	3.30	3.3	3.30	3.3	3.30
zwKings1	3.3	3.30	3.3	3.30	3.3	3.30
zwdryking	3.3	3.30	3.3	3.30	3.3	3.30
zwkings2	3.3	3.30	3.3	3.30	3.3	3.30
zwOsage1	3.3	3.30	3.3	3.30	3.3	3.30
zwOsage2	3.3	3.30	3.3	3.30	3.3	3.30
zwKings3	3.3	3.30	3.3	3.30	3.3	3.30
zwKings4	3.3	3.30	3.3	3.30	3.3	3.30
zwTR2	3.3	3.30	3.3	3.30	3.3	3.30
zwKings5	3.3	3.30	3.3	3.30	3.3	3.30
zwIndian	3.3	3.30	3.3	3.30	3.3	3.30
zwLitIndian	3.3	3.30	3.3	3.30	3.3	3.30
zwJames0	3.8	3.80	3.8	3.80	3.8	3.80
zwJames1	4.5	4.50	4.5	4.50	4.5	4.50
zwWilson1	6.0	6.00	6.0	6.00	6.0	6.00
zwJames2	4.5	4.50	4.5	4.50	4.5	4.50
zwWilson2	4.5	4.50	4.5	4.50	4.5	4.50
zwJames3	4.5	4.50	4.5	4.50	4.5	4.50
zwFinley0	5.2	5.20	5.2	5.20	5.2	5.20
zwFinley1	5.2	5.20	5.2	5.20	5.2	5.20
zwFlat1	3.3	3.53	3.3	3.53	4.0	3.53
zwJames4	4.0	4.23	4.0	4.23	4.7	4.23
zwFinley2	4.7	4.43	4.7	4.43	3.9	4.43
zwCrane1	3.9	3.93	3.9	3.93	4.0	3.93
zwspring1	4.0	4.00	4.0	4.00	4.0	4.00
zwJames5	4.0	3.97	4.0	3.97	3.9	3.97
zwCrane2	3.9	3.93	3.9	3.93	4.0	3.93
zwJames6	4.0	3.77	4.0	3.77	3.3	3.77

zwLitFlat	3.3	3.30	3.3	3.30	3.3	3.30
zwFlat2	3.3	3.30	3.3	3.30	3.3	3.30
zwrockhouse	3.3	3.30	3.3	3.30	3.3	3.30
zwFlat3	3.3	3.30	3.3	3.30	3.3	3.30
zwFlat4	3.6	3.60	3.6	3.60	3.6	3.60
zwJames7	3.8	3.80	3.8	3.80	3.8	3.80
zwJames8	3.3	3.30	3.3	3.30	3.3	3.30
zwTR3	3.3	3.30	3.3	3.30	3.3	3.30
zwLong0	3.3	3.30	3.3	3.30	3.3	3.30
zwdrylong	3.4	3.40	3.4	3.40	3.4	3.40
zwLong1	3.3	3.30	3.3	3.30	3.3	3.30
zwyocum1	3.2	3.20	3.2	3.20	3.2	3.20
zwLong2	3.3	3.30	3.3	3.30	3.3	3.30
zwYocum2	3.3	3.30	3.3	3.30	3.3	3.30
zwLong3	3.3	3.30	3.3	3.30	3.3	3.30
zwTR5	3.3	3.30	3.3	3.30	3.3	3.30
wTurkeywest	4.0	4.00	4.0	4.00	4.0	4.00
wTaneycomo1	4.0	4.00	4.0	4.00	4.0	4.00
wRoark	4.0	4.00	4.0	4.00	4.0	4.00
wTaneycomo2	4.0	4.00	4.0	4.00	4.0	4.00
wBull1	2.1	2.03	2.0	2.03	2.0	2.03
wBull2	2.1	2.03	2.0	2.03	2.0	2.03
wBull4	2.1	2.03	2.0	2.03	2.0	2.03
wBull3	2.1	2.03	2.0	2.03	2.0	2.03
wbull4.5	2.1	2.03	2.0	2.03	2.0	2.03
wTaneycomo3	4.0	4.00	4.0	4.00	4.0	4.00
wBull5	4.0	4.00	4.0	4.00	4.0	4.00
WSwan1	4.0	4.00	4.0	4.00	4.0	4.00
wSwan2	4.0	4.00	4.0	4.00	4.0	4.00
wSwan4	4.0	4.00	4.0	4.00	4.0	4.00
wTaneycomo4	4.0	4.00	4.0	4.00	4.0	4.00
wBeaver1	5.5	5.50	5.5	5.50	5.5	5.50
WBeaver2	5.8	5.80	5.8	5.80	5.8	5.80
wBeaver4	5.8	5.80	5.8	5.80	5.8	5.80
wBeaver3	5.5	5.50	5.5	5.50	5.5	5.50
wBeaver5	5.1	5.10	5.1	5.10	5.1	5.10
wBeaver6	6.2	6.20	6.2	6.20	6.2	6.20
wBeaver8	6.2	6.20	6.2	6.20	6.2	6.20
wBeaver7	5.0	5.00	5.0	5.00	5.0	5.00
wBeaver10	4.0	4.00	4.0	4.00	4.0	4.00
wBeaver9	4.0	4.00	4.0	4.00	4.0	4.00
wBeaver12	4.0	4.00	4.0	4.00	4.0	4.00
wBeaver11	4.0	4.00	4.0	4.00	4.0	4.00
wBeaver13	4.0	4.00	4.0	4.00	4.0	4.00
wMA1	4.0	4.00	4.0	4.00	4.0	4.00
wCedar	4.0	4.00	4.0	4.00	4.0	4.00
wMA2	4.0	4.00	4.0	4.00	4.0	4.00
wBee	4.0	4.00	4.0	4.00	4.0	4.00
wYocum	4.0	4.00	4.0	4.00	4.0	4.00
wBear1	4.0	4.00	4.0	4.00	4.0	4.00
wBear2	4.0	4.00	4.0	4.00	4.0	4.00
wBear4	4.0	4.00	4.0	4.00	4.0	4.00
wBear3	4.0	4.00	4.0	4.00	4.0	4.00
wbear4.5	4.0	4.00	4.0	4.00	4.0	4.00
wBear5	4.0	4.00	4.0	4.00	4.0	4.00
WElbow	3.9	3.90	3.9	3.90	3.9	3.90

wMA3	3.9	3.90	3.9	3.90	3.9	3.90
wWSugerloaf	3.9	3.90	3.9	3.90	3.9	3.90
wEsugarloaf	3.9	3.90	3.9	3.90	3.9	3.90
wShoal	3.9	3.90	3.9	3.90	3.9	3.90
wMA4	3.9	3.90	3.9	3.90	3.9	3.90
wEastFork	3.9	3.90	3.9	3.90	3.9	3.90
wWestFork	3.9	3.90	3.9	3.90	3.9	3.90
wBig	3.9	3.90	3.9	3.90	3.9	3.90
wMA5	3.9	3.90	3.9	3.90	3.9	3.90
wMA6	3.9	3.90	3.9	3.90	3.9	3.90
wMusic	3.9	3.90	3.9	3.90	3.9	3.90
wMA7	3.9	3.90	3.9	3.90	3.9	3.90
wLitNFork1	4.0	4.00	4.0	4.00	4.0	4.00
WLitNFork2	4.0	4.00	4.0	4.00	4.0	4.00
wTurkeyEast	4.0	4.00	4.0	4.00	4.0	4.00
wBarrenFork	4.0	4.00	4.0	4.00	4.0	4.00
wPondfork	4.0	4.00	4.0	4.00	4.0	4.00
wNorthFork	4.0	4.00	4.0	4.00	4.0	4.00
WSouthFork	3.9	3.90	3.9	3.90	3.9	3.90
wMA9	3.9	3.90	3.9	3.90	3.9	3.90
wMA10	3.9	3.90	3.9	3.90	3.9	3.90
wGulleySpring	3.9	3.90	3.9	3.90	3.9	3.90
wMA8	3.9	3.90	3.9	3.90	3.9	3.90
wJimmie	3.9	3.90	3.9	3.90	3.9	3.90
wMA11	3.9	3.90	3.9	3.90	3.9	3.90
wMA12	3.9	3.90	3.9	3.90	3.9	3.90

Time of Concentration Values

Beaver Lake Subbasins

Table 14-7. Time of Concentration for Beaver Lake Subbasins

Subbasin	Time of Concentration Dec 2015 Event (hrs)	Time of Concentration 2008 Event (hrs)	Time of Concentration 2011 Event (hrs)	Time of Concentration Jun 2015 Event (hrs)	Time of Concentration 2017 Event (hrs)	Mean Calibration Values (hrs)
WWhite 9	13.25	10.27	10.82	10.27	6.75	10.27
WWhite 10	11.00	8.44	8.92	8.44	5.40	8.44
WMiddle	12.50	9.53	9.78	9.53	6.30	9.53
WLake	6.35	4.73	5.22	4.73	2.61	4.73
WWest 1	12.50	10.02	11.25	10.02	6.30	10.02
WWest 2	10.18	7.76	8.19	7.76	4.91	7.76
WWhite 8	7.76	6.00	6.79	6.00	3.46	6.00
WLollars	15.19	10.78	9.24	10.78	7.91	10.78
WDrakes	12.97	9.19	8.02	9.19	6.58	9.19
WRichland	15.32	10.87	9.31	10.87	7.99	10.87
WBR 3	12.37	10.16	11.90	10.16	6.22	10.16

WWhitener	11.86	9.73	11.41	9.73	5.91	9.73
WBR 2	7.78	6.26	7.52	6.26	3.47	6.26
WWhite 7	13.45	11.08	12.92	11.08	6.87	11.08
WBR 1	8.48	6.85	8.18	6.85	3.89	6.85
WWar 9	14.78	11.10	10.84	11.10	7.67	11.10
WHenderson	11.62	8.54	8.23	8.54	5.77	8.54
WWar 8	11.54	8.48	8.17	8.48	5.72	8.48
WWharton	13.13	9.67	9.21	9.67	6.68	9.67
WWar 7	11.33	8.32	8.03	8.32	5.60	8.32
WWar 6	15.40	11.41	10.78	11.41	8.04	11.41
WHolman	12.65	9.39	9.13	9.39	6.39	9.39
WGlade	11.98	8.80	8.44	8.80	5.99	8.80
WWar 5	11.45	8.42	8.13	8.42	5.67	8.42
WWar 4	11.92	8.76	8.42	8.76	5.95	8.76
WWar 3	9.68	7.09	6.97	7.09	4.61	7.09
WClifty 1	12.55	10.31	12.06	10.31	6.33	10.31
WWar 2	12.07	9.91	11.61	9.91	6.04	9.91
WWar 1	14.56	12.03	13.99	12.03	7.53	12.03
WWhite 6	12.85	10.57	12.35	10.57	6.51	10.57
WWhite 5	12.53	10.30	12.05	10.30	6.32	10.30
WBranch	10.94	8.94	10.53	8.94	5.36	8.94
WPrairie	12.14	9.97	11.68	9.97	6.08	9.97
WWhite 4	16.58	14.09	16.93	14.09	8.75	14.09
WWhite 3	11.30	9.25	10.88	9.25	5.58	9.25
WBeaver	12.98	10.68	12.48	10.68	6.59	10.68
WNorth Clifty	12.38	10.17	11.91	10.17	6.23	10.17
WWhite 1	12.31	10.11	11.84	10.11	6.18	10.11
WWhite 2	10.96	8.96	10.54	8.96	5.37	8.96

Bull Shoals and Table Rock Lakes Subbasins

Table 14-8. Time of Concentration for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	Time of Concentration Dec 2015 Event (hrs)	Time of Concentration 2008 Event (hrs)	Time of Concentration 2011 Event (hrs)	Time of Concentration Jun 2015 Event (hrs)	Time of Concentration 2017 Event (hrs)	Mean Calibration Values (hrs)
zwRoaring1	2.31	3.08	5.12	3.08	1.81	3.08
zwTR1	5.11	3.44	3.11	3.44	2.11	3.44
zwRoaring2	4.38	3.08	3.30	3.08	1.55	3.08
zwKings1	17.40	15.93	15.00	15.93	15.40	15.93
zwdryking	10.39	9.59	10.00	9.59	8.39	9.59
zwkings2	10.60	9.73	10.00	9.73	8.60	9.73
zwOsage1	11.17	10.28	10.50	10.28	9.17	10.28
zwOsage2	12.01	11.01	11.00	11.01	10.01	11.01
zwKings3	6.94	6.53	7.70	6.53	4.94	6.53
zwKings4	3.15	3.27	5.50	3.27	1.15	3.27
zwTR2	6.04	4.37	4.04	4.37	3.04	4.37
zwKings5	7.19	5.52	5.19	5.52	4.19	5.52
zwIndian	5.99	4.32	3.99	4.32	2.99	4.32
zwLitIndian	5.47	3.80	3.47	3.80	2.47	3.80
zwJames0	6.41	7.67	5.60	7.67	11.00	7.67
zwJames1	8.29	9.36	6.80	9.36	13.00	9.36
zwWilson1	3.00	4.40	4.50	4.40	5.69	4.40

zwJames2	8.37	10.41	16.00	10.41	6.87	10.41
zwWilson2	7.69	8.23	13.32	8.23	3.69	8.23
zwJames3	7.66	7.67	12.69	7.67	2.66	7.67
zwFinley0	14.44	10.15	8.00	10.15	8.00	10.15
zwFinley1	16.63	11.88	9.00	11.88	10.00	11.88
zwFlat1	10.12	7.73	9.63	7.73	3.44	7.73
zwJames4	2.44	4.41	8.00	4.41	2.78	4.41
zwFinley2	2.78	9.23	9.29	9.23	15.62	9.23
zwCrane1	15.62	16.33	17.00	16.33	16.36	16.33
zwspring1	16.36	17.19	19.50	17.19	15.72	17.19
zwJames5	15.72	16.21	17.50	16.21	15.42	16.21
zwCrane2	15.42	13.54	17.00	13.54	8.20	13.54
zwJames6	8.20	11.17	15.20	11.17	10.12	11.17
zwLitFlat	9.38	8.38	7.88	8.38	7.88	8.38
zwFlat2	8.49	5.82	3.99	5.82	4.99	5.82
zwrockhouse	6.31	4.21	2.51	4.21	3.81	4.21
zwFlat3	6.85	4.77	3.10	4.77	4.35	4.77
zwFlat4	4.88	3.47	3.66	3.47	1.88	3.47
zwJames7	5.10	3.43	3.10	3.43	2.10	3.43
zwJames8	5.93	4.26	3.93	4.26	2.93	4.26
zwTR3	4.55	3.12	3.26	3.12	1.55	3.12
zwLong0	6.49	4.73	4.20	4.73	3.49	4.73
zwdrylong	7.61	5.94	5.61	5.94	4.61	5.94
zwLong1	7.13	5.46	5.13	5.46	4.13	5.46
zwyocum1	4.39	3.83	3.80	3.83	3.31	3.83
zwLong2	7.29	4.96	3.29	4.96	4.29	4.96
zwYocum2	5.39	3.72	3.39	3.72	2.39	3.72
zwLong3	5.87	4.20	3.87	4.20	2.87	4.20
zwTR5	4.51	3.08	3.21	3.08	1.51	3.08
wTurkeywest	4.63	3.65	1.70	3.65	4.63	3.65
wTaneycomo1	4.44	4.19	3.69	4.19	4.44	4.19
wRoark	5.18	4.61	3.47	4.61	5.18	4.61
wTaneycomo2	2.85	2.17	0.81	2.17	2.85	2.17
wBull1	4.98	6.14	4.62	6.14	8.82	6.14
wBull2	3.66	4.40	2.98	4.40	6.56	4.40
wBull4	4.50	6.12	4.48	6.12	9.38	6.12
wBull3	4.75	5.99	5.28	5.99	7.94	5.99
wbull4.5	2.38	2.93	0.98	2.93	5.42	2.93
wTaneycomo3	2.06	2.44	3.20	2.44	2.06	2.44
wBull5	2.34	3.11	4.64	3.11	2.34	3.11
WSwan1	6.40	6.00	5.21	6.00	6.40	6.00
wSwan2	5.80	5.33	4.39	5.33	5.80	5.33
wSwan4	5.43	4.57	2.85	4.57	5.43	4.57
wTaneycomo4	2.26	3.25	5.23	3.25	2.26	3.25
wBeaver1	5.12	4.65	3.38	4.65	5.44	4.65
WBeaver2	5.45	4.91	4.77	4.91	4.52	4.91
wBeaver4	3.83	2.41	1.81	2.41	1.60	2.41
wBeaver3	5.29	4.87	6.68	4.87	2.65	4.87
wBeaver5	5.83	4.48	5.91	4.48	1.69	4.48
wBeaver6	3.40	2.45	2.11	2.45	1.84	2.45
wBeaver8	6.50	5.29	5.51	5.29	3.85	5.29
wBeaver7	5.12	4.67	5.70	4.67	3.20	4.67
wBeaver10	5.17	4.84	4.18	4.84	5.17	4.84
wBeaver9	4.86	5.01	5.30	5.01	4.86	5.01
wBeaver12	4.65	4.45	4.06	4.45	4.65	4.45
wBeaver11	3.11	2.82	2.24	2.82	3.11	2.82

wBeaver13	4.49	4.24	3.74	4.24	4.49	4.24
wMA1	2.80	2.47	1.80	2.47	2.80	2.47
wCedar	2.55	2.02	0.97	2.02	2.55	2.02
wMA2	3.00	2.67	2.00	2.67	3.00	2.67
wBee	5.09	4.78	4.17	4.78	5.09	4.78
wYocum	2.92	2.50	1.67	2.50	2.92	2.50
wBear1	5.62	5.46	5.13	5.46	5.62	5.46
wBear2	3.60	3.10	2.11	3.10	3.60	3.10
wBear4	4.49	4.01	3.04	4.01	4.49	4.01
wBear3	3.10	2.68	1.84	2.68	3.10	2.68
wbear4.5	1.93	1.59	0.91	1.59	1.93	1.59
wBear5	3.47	3.35	3.10	3.35	3.47	3.35
WElbow	3.49	3.01	2.05	3.01	3.49	3.01
wMA3	3.15	2.82	2.15	2.82	3.15	2.82
wWSugerloaf	4.33	3.54	1.96	3.54	4.33	3.54
wEsugarloaf	4.65	4.11	3.02	4.11	4.65	4.11
wShoal	3.25	2.75	1.76	2.75	3.25	2.75
wMA4	3.03	2.70	2.03	2.70	3.03	2.70
wEastFork	3.63	3.20	2.33	3.20	3.63	3.20
wWestFork	3.18	2.73	1.82	2.73	3.18	2.73
wBig	4.23	3.64	2.45	3.64	4.23	3.64
wMA5	2.53	2.20	1.53	2.20	2.53	2.20
wMA6	2.65	2.32	1.65	2.32	2.65	2.32
wMusic	2.67	2.34	1.67	2.34	2.67	2.34
wMA7	2.04	1.71	1.04	1.71	2.04	1.71
wLitNFork1	4.28	3.79	2.80	3.79	4.28	3.79
WLitNFork2	4.44	4.33	4.10	4.33	4.44	4.33
wTurkeyEast	6.50	6.45	6.35	6.45	6.50	6.45
wBarrenFork	6.87	7.10	7.57	7.10	6.87	7.10
wPondfork	5.53	5.18	4.49	5.18	5.53	5.18
wNorthFork	3.93	3.67	3.16	3.67	3.93	3.67
WSouthFork	3.82	3.60	3.15	3.60	3.82	3.60
wMA9	3.22	2.89	2.22	2.89	3.22	2.89
wMA10	1.83	1.50	0.83	1.50	1.83	1.50
wGulleySpring	5.06	4.37	3.00	4.37	5.06	4.37
wMA8	2.08	1.75	1.08	1.75	2.08	1.75
wJimmie	3.86	3.14	1.69	3.14	3.86	3.14
wMA11	3.06	2.73	2.06	2.73	3.06	2.73
wMA12	3.40	3.07	2.40	3.40	3.40	3.07

Storage Coefficient (R) Values

Beaver Lake Subbasins

Table 14-9. Storage Coefficient (R) for Beaver Lake Subbasins

Subbasin	Storage Coefficient Dec 2015 Event (hrs)	Storage Coefficient 2008 Event (hrs)	Storage Coefficient 2011 Event (hrs)	Storage Coefficient Jun 2015 Event (hrs)	Storage Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)
WWhite 9	9.05	8.49	9.19	8.49	7.24	8.49
WWhite 10	6.91	5.92	7.01	5.92	3.84	5.92
WMiddle	9.89	8.28	8.37	8.28	6.59	8.28
WLake	4.91	3.93	4.16	3.93	2.73	3.93
WWest 1	8.38	7.69	7.99	7.69	6.70	7.69
WWest 2	6.55	5.47	6.23	5.47	3.64	5.47
WWhite 8	5.69	4.66	5.14	4.66	3.16	4.66
WLollars	11.79	8.48	7.10	8.48	6.55	8.48
WDrakes	7.91	6.00	5.71	6.00	4.39	6.00
WRichland	11.17	8.03	6.72	8.03	6.21	8.03
WBR 3	8.53	7.89	9.44	7.89	5.69	7.89
WWhitener	8.77	7.56	8.06	7.56	5.85	7.56
WBR 2	5.59	4.83	5.16	4.83	3.73	4.83
WWhite 7	9.34	9.04	10.32	9.04	7.47	9.04
WBR 1	5.54	4.57	5.09	4.57	3.08	4.57
WWar 9	11.69	8.81	8.25	8.81	6.50	8.81
WHenderson	7.98	6.28	5.55	6.28	5.32	6.28
WWar 8	7.74	6.45	6.46	6.45	5.16	6.45
WWharton	10.50	7.87	7.29	7.87	5.83	7.87
WWar 7	8.64	6.48	6.00	6.48	4.80	6.48
WWar 6	11.06	8.98	8.51	8.98	7.38	8.98
WHolman	9.98	7.50	6.99	7.50	5.54	7.50
WGlade	8.16	6.12	5.66	6.12	4.54	6.12
WWar 5	8.16	6.51	5.93	6.51	5.44	6.51
WWar 4	8.27	6.51	5.74	6.51	5.51	6.51
WWar 3	6.83	5.12	4.74	5.12	3.79	5.12
WClifty 1	9.43	8.04	8.41	8.04	6.29	8.04
WWar 2	8.34	7.62	8.95	7.62	5.56	7.62
WWar 1	9.86	9.17	9.75	9.17	7.89	9.17
WWhite 6	9.05	8.66	9.70	8.66	7.24	8.66
WWhite 5	9.86	8.42	8.81	8.42	6.58	8.42
WBranch	8.70	7.10	7.77	7.10	4.83	7.10
WPrairie	6.78	5.78	6.04	5.78	4.52	5.78
WWhite 4	12.90	10.94	11.32	10.94	8.60	10.94
WWhite 3	8.93	7.28	7.96	7.28	4.96	7.28
WBeaver	9.10	8.30	9.73	8.30	6.06	8.30
WNorth Clifty	9.55	7.79	8.51	7.79	5.30	7.79
WWhite 1	9.49	8.10	8.49	8.10	6.33	8.10
WWhite 2	8.06	6.88	7.20	6.88	5.38	6.88

Bull Shoals and Table Rock Lakes Subbasins

Table 14-10. Storage Coefficient (R) for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	Time of Concentration Dec 2015 Event (hrs)	Time of Concentration 2008 Event (hrs)	Time of Concentration 2011 Event (hrs)	Time of Concentration Jun 2015 Event (hrs)	Time of Concentration 2017 Event (hrs)	Mean Calibration Values (hrs)
zwRoaring1	2.12	4.12	6.12	4.12	4.12	4.12
zwTR1	8.11	5.44	4.11	5.44	4.11	5.44

zwRoaring2	7.58	5.15	4.30	5.15	3.58	5.15
zwKings1	15.00	14.67	16.00	14.67	13.00	14.67
zwdryking	8.00	8.33	11.00	8.33	6.00	8.33
zwkings2	8.00	8.33	11.00	8.33	6.00	8.33
zwOsage1	8.00	8.90	11.50	8.90	7.20	8.90
zwOsage2	10.00	10.00	12.00	10.00	8.00	10.00
zwKings3	5.00	5.77	8.70	5.77	3.60	5.77
zwKings4	2.10	3.53	6.50	3.53	2.00	3.53
zwTR2	9.04	6.37	5.04	6.37	5.04	6.37
zwKings5	10.19	7.52	6.19	7.52	6.19	7.52
zwIndian	8.99	6.32	4.99	6.32	4.99	6.32
zwLitIndian	8.47	5.80	4.47	5.80	4.47	5.80
zwJames0	9.50	7.77	6.60	7.77	8.64	8.25
zwJames1	11.50	9.31	7.80	9.31	10.37	9.89
zwWilson1	3.50	5.04	5.50	5.04	6.11	5.04
zwJames2	18.38	13.46	17.00	13.46	5.00	13.46
zwWilson2	16.20	11.10	14.32	11.10	2.78	11.10
zwJames3	16.05	10.59	13.69	10.59	2.03	10.59
zwFinley0	11.40	8.17	9.00	8.17	6.00	8.80
zwFinley1	13.20	9.33	10.00	9.33	7.00	10.07
zwFlat1	10.63	8.92	10.63	8.92	5.50	8.92
zwJames4	1.92	4.30	9.00	4.30	2.29	4.40
zwFinley2	2.79	8.36	10.29	8.36	12.00	8.36
zwCrane1	16.50	15.62	16.00	15.62	14.36	15.62
zwspring1	19.86	17.53	19.00	17.53	13.72	17.53
zwJames5	19.22	16.21	16.00	16.21	13.42	16.21
zwCrane2	18.92	14.21	16.50	14.21	7.20	14.21
zwJames6	6.20	10.34	16.20	10.34	8.63	10.34
zwLitFlat	8.88	11.55	8.88	11.55	16.88	11.55
zwFlat2	6.99	6.99	4.99	6.99	8.99	6.99
zwrockhouse	6.51	5.51	3.51	5.51	6.51	5.51
zwFlat3	7.42	6.31	4.10	6.31	7.42	6.31
zwFlat4	7.88	5.47	4.66	5.47	3.88	5.47
zwJames7	8.10	5.43	4.10	5.43	4.10	5.43
zwJames8	8.93	6.26	4.93	6.26	4.93	6.26
zwTR3	7.55	5.12	4.26	5.12	3.55	5.12
zwLong0	9.20	6.53	5.20	6.53	5.20	6.53
zwdrylong	10.61	7.94	6.61	7.94	6.61	7.94
zwLong1	10.13	7.46	6.13	7.46	6.13	7.46
zwyocum1	4.39	3.86	4.80	3.86	2.40	3.86
zwLong2	7.29	4.96	4.29	4.96	3.29	4.96
zwYocum2	8.39	5.72	4.39	5.72	4.39	5.72
zwLong3	8.87	6.20	4.87	6.20	4.87	6.20
zwTR5	7.51	5.08	4.21	5.08	3.51	5.08
wTurkeywest	3.62	3.25	2.70	3.25	3.43	3.25
wTaneycomo1	4.39	4.55	4.69	4.55	4.58	4.55
wRoark	4.27	4.38	4.47	4.38	4.40	4.38
wTaneycomo2	2.97	2.41	1.81	2.41	2.45	2.41
wBull1	6.41	6.34	5.62	6.34	7.00	6.34
wBull2	5.32	4.71	3.98	4.71	4.82	4.71
wBull4	6.32	6.55	5.48	6.55	7.86	6.55
wBull3	6.85	6.56	6.28	6.56	6.56	6.56
wbull4.5	3.32	3.15	1.98	3.15	4.15	3.15
wTaneycomo3	2.04	2.59	4.20	2.59	1.53	2.59
wBull5	2.21	3.14	5.64	3.14	1.57	3.14
WSwan1	4.67	5.30	6.21	5.30	5.01	5.30

wSwan2	4.50	4.50	5.39	4.50	4.36	4.75
wSwan4	5.48	5.18	3.85	5.18	6.22	5.18
wTaneycomo4	2.17	3.30	6.23	3.30	1.51	3.30
wBeaver1	4.92	6.88	4.38	6.88	11.34	6.88
WBeaver2	5.85	7.32	5.77	7.32	10.33	7.32
wBeaver4	3.87	3.47	2.81	3.47	3.73	3.47
wBeaver3	7.12	6.99	7.68	6.99	6.16	6.99
wBeaver5	6.61	5.79	6.91	5.79	3.85	5.79
wBeaver6	4.07	3.72	3.11	3.72	3.97	3.72
wBeaver8	6.34	7.14	6.51	7.14	8.58	7.14
wBeaver7	6.47	6.82	6.70	6.82	7.29	6.82
wBeaver10	4.12	4.49	5.18	4.49	4.18	4.49
wBeaver9	4.87	5.49	6.30	5.49	5.30	5.49
wBeaver12	4.04	4.39	5.06	4.39	4.06	4.39
wBeaver11	2.83	2.77	3.24	2.77	2.24	2.77
wBeaver13	3.83	4.10	4.74	4.10	3.74	4.10
wMA1	2.53	2.50	2.80	2.50	2.16	2.50
wCedar	1.98	1.78	1.97	1.78	2.02	1.99
wMA2	2.67	2.56	3.00	2.56	2.00	2.56
wBee	4.11	4.48	5.17	4.48	4.17	4.48
wYocum	2.45	2.37	2.67	2.37	2.00	2.37
wBear1	4.09	5.12	6.13	5.12	5.13	5.12
wBear2	2.48	2.57	3.11	2.57	2.53	2.71
wBear4	3.23	3.26	4.04	3.26	3.04	3.44
wBear3	2.27	2.31	2.84	2.31	2.21	2.44
wbear4.5	1.52	1.50	1.91	1.50	1.31	1.58
wBear5	3.40	3.53	4.10	3.53	3.10	3.53
WElbow	2.70	2.74	3.05	2.74	2.46	2.74
wMA3	2.77	2.69	3.15	2.69	2.15	2.69
wWSugerloaf	3.17	2.81	2.96	2.81	3.38	3.17
wEsugarloaf	3.35	3.66	4.02	3.66	3.62	3.66
wShoal	2.51	2.60	2.76	2.60	2.53	2.60
wMA4	2.69	2.58	3.03	2.58	2.03	2.58
wEastFork	2.89	3.01	3.33	3.01	2.80	3.01
wWestFork	2.55	2.52	2.82	2.52	2.18	2.52
wBig	2.97	3.12	3.45	3.12	2.94	3.12
wMA5	2.35	2.24	2.53	2.24	1.84	2.24
wMA6	2.43	2.35	2.65	2.35	1.98	2.35
wMusic	2.45	2.37	2.67	2.37	2.00	2.37
wMA7	2.03	1.86	2.04	1.86	1.50	1.86
wLitNFork1	3.20	3.45	3.80	3.45	3.36	3.45
WLitNFork2	4.07	4.42	5.10	4.42	4.10	4.42
wTurkeyEast	5.57	6.42	7.35	6.42	6.35	6.42
wBarrenFork	6.38	7.51	8.57	7.51	7.57	7.51
wPondfork	4.33	4.77	5.49	4.77	4.49	4.77
wNorthFork	3.44	3.59	4.16	3.59	3.16	3.59
WSouthFork	3.43	3.58	4.15	3.58	3.15	3.58
wMA9	2.81	2.75	3.22	2.75	2.22	2.75
wMA10	1.89	1.64	1.83	1.64	1.44	1.72
wGulleySpring	4.00	3.64	4.00	3.64	3.60	3.87
wMA8	2.05	1.90	2.08	1.90	1.56	1.90
wJimmie	2.95	2.53	2.69	2.53	2.92	2.85
wMA11	2.71	2.61	3.06	2.61	2.06	2.61
wMA12	2.93	2.91	3.40	3.40	2.40	2.91

R / (Tc + R)

Beaver Lake Subbasins

Table 14-11. R / (Tc + R) for Beaver Lake Subbasins

Subbasin	R / (Tc + R) Dec 2015 Event	R / (Tc + R) 2011 Event	R / (Tc + R) 2017 Event	Mean Calibration Values
WWhite 9	0.41	0.46	0.52	0.45
WWhite 10	0.39	0.44	0.42	0.41
WMiddle	0.44	0.46	0.51	0.46
WLake	0.44	0.44	0.51	0.45
WWest 1	0.40	0.42	0.52	0.43
WWest 2	0.39	0.43	0.43	0.41
WWhite 8	0.42	0.43	0.48	0.44
WLollars	0.44	0.43	0.45	0.44
WDrakes	0.38	0.42	0.40	0.39
WRichland	0.42	0.42	0.44	0.42
WBR 3	0.41	0.44	0.48	0.44
WWhitener	0.43	0.41	0.50	0.44
WBR 2	0.42	0.41	0.52	0.44
WWhite 7	0.41	0.44	0.52	0.45
WBR 1	0.40	0.38	0.44	0.40
WWar 9	0.44	0.43	0.46	0.44
WHenderson	0.41	0.40	0.48	0.42
WWar 8	0.40	0.44	0.47	0.43
WWharton	0.44	0.44	0.47	0.45
WWar 7	0.43	0.43	0.46	0.44
WWar 6	0.42	0.44	0.48	0.44
WHolman	0.44	0.43	0.46	0.44
WGlade	0.41	0.40	0.43	0.41
WWar 5	0.42	0.42	0.49	0.44
WWar 4	0.41	0.41	0.48	0.43
WWar 3	0.41	0.40	0.45	0.42
WClifty 1	0.43	0.41	0.50	0.44
WWar 2	0.41	0.44	0.48	0.43
WWar 1	0.40	0.41	0.51	0.43
WWhite 6	0.41	0.44	0.53	0.45
WWhite 5	0.44	0.42	0.51	0.45
WBranch	0.44	0.42	0.47	0.44
WPrairie	0.36	0.34	0.43	0.37
WWhite 4	0.44	0.40	0.50	0.44
WWhite 3	0.44	0.42	0.47	0.44
WBeaver	0.41	0.44	0.48	0.44
WNorth Clifty	0.44	0.42	0.46	0.43
WWhite 1	0.44	0.42	0.51	0.44

WWhite 2	0.42	0.41	0.50	0.43

Bull Shoals and Table Rock Lakes Subbasins

Table 14-12. R / (Tc + R) for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	Reservoir	R / (Tc + R) Dec 2015 Event	R / (Tc + R) Dec 2011 Event
zwRoaring1	Table Rock Lake	0.48	0.54
zwTR1	Table Rock Lake	0.61	0.57
zwRoaring2	Table Rock Lake	0.63	0.57
zwKings1	Table Rock Lake	0.46	0.52
zwdryking	Table Rock Lake	0.44	0.52
zwkings2	Table Rock Lake	0.43	0.52
zwOsage1	Table Rock Lake	0.42	0.52
zwOsage2	Table Rock Lake	0.45	0.52
zwKings3	Table Rock Lake	0.42	0.53
zwKings4	Table Rock Lake	0.40	0.54
zwTR2	Table Rock Lake	0.60	0.56
zwKings5	Table Rock Lake	0.59	0.54
zwIndian	Table Rock Lake	0.60	0.56
zwLitIndian	Table Rock Lake	0.61	0.56
zwJames0	Table Rock Lake	0.60	0.54
zwJames1	Table Rock Lake	0.58	0.53
zwWilson1	Table Rock Lake	0.54	0.55
zwJames2	Table Rock Lake	0.69	0.52
zwWilson2	Table Rock Lake	0.68	0.52
zwJames3	Table Rock Lake	0.68	0.52
zwFinley0	Table Rock Lake	0.44	0.53
zwFinley1	Table Rock Lake	0.44	0.53

zwFlat1	Table Rock Lake	0.51	0.52
zwJames4	Table Rock Lake	0.44	0.53
zwFinley2	Table Rock Lake	0.50	0.53
zwCrane1	Table Rock Lake	0.51	0.48
zwspring1	Table Rock Lake	0.55	0.49
zwJames5	Table Rock Lake	0.55	0.48
zwCrane2	Table Rock Lake	0.55	0.49
zwJames6	Table Rock Lake	0.43	0.52
zwLitFlat	Table Rock Lake	0.49	0.53
zwFlat2	Table Rock Lake	0.45	0.56
zwrockhouse	Table Rock Lake	0.51	0.58
zwFlat3	Table Rock Lake	0.52	0.57
zwFlat4	Table Rock Lake	0.62	0.56
zwJames7	Table Rock Lake	0.61	0.57
zwJames8	Table Rock Lake	0.60	0.56
zwTR3	Table Rock Lake	0.62	0.57
zwLong0	Table Rock Lake	0.59	0.55
zwdrylong	Table Rock Lake	0.58	0.54
zwLong1	Table Rock Lake	0.59	0.54
zwyocum1	Table Rock Lake	0.50	0.56
zwLong2	Table Rock Lake	0.50	0.57
zwYocum2	Table Rock Lake	0.61	0.56
zwLong3	Table Rock Lake	0.60	0.56
zwTR5	Table Rock Lake	0.62	0.57
wTurkeywest	Bull Shoals Lake	0.44	0.61
wTaneycomo1	Bull Shoals Lake	0.50	0.56
wRoark	Bull Shoals Lake	0.45	0.56
wTaneycomo2	Bull Shoals Lake	0.51	0.69

wBull1	Bull Shoals Lake	0.56	0.55
wBull2	Bull Shoals Lake	0.59	0.57
wBull4	Bull Shoals Lake	0.58	0.55
wBull3	Bull Shoals Lake	0.59	0.54
wbull4.5	Bull Shoals Lake	0.58	0.67
wTaneycomo3	Bull Shoals Lake	0.50	0.57
wBull5	Bull Shoals Lake	0.49	0.55
WSwan1	Bull Shoals Lake	0.42	0.54
wSwan2	Bull Shoals Lake	0.44	0.55
wSwan4	Bull Shoals Lake	0.50	0.57
wTaneycomo4	Bull Shoals Lake	0.49	0.54
wBeaver1	Bull Shoals Lake	0.49	0.56
WBeaver2	Bull Shoals Lake	0.52	0.55
wBeaver4	Bull Shoals Lake	0.50	0.61
wBeaver3	Bull Shoals Lake	0.57	0.53
wBeaver5	Bull Shoals Lake	0.53	0.54
wBeaver6	Bull Shoals Lake	0.54	0.60
wBeaver8	Bull Shoals Lake	0.49	0.54
wBeaver7	Bull Shoals Lake	0.56	0.54
wBeaver10	Bull Shoals Lake	0.44	0.55
wBeaver9	Bull Shoals Lake	0.50	0.54
wBeaver12	Bull Shoals Lake	0.46	0.55
wBeaver11	Bull Shoals Lake	0.48	0.59
wBeaver13	Bull Shoals Lake	0.46	0.56
wMA1	Bull Shoals Lake	0.47	0.61
wCedar	Bull Shoals Lake	0.44	0.67
wMA2	Bull Shoals Lake	0.47	0.60
wBee	Bull Shoals Lake	0.45	0.55

wYocum	Bull Shoals Lake	0.46	0.62
wBear1	Bull Shoals Lake	0.42	0.54
wBear2	Bull Shoals Lake	0.41	0.60
wBear4	Bull Shoals Lake	0.42	0.57
wBear3	Bull Shoals Lake	0.42	0.61
wbear4.5	Bull Shoals Lake	0.44	0.68
wBear5	Bull Shoals Lake	0.49	0.57
WElbow	Bull Shoals Lake	0.44	0.60
wMA3	Bull Shoals Lake	0.47	0.59
wWSugerloaf	Bull Shoals Lake	0.42	0.60
wEsugarloaf	Bull Shoals Lake	0.42	0.57
wShoal	Bull Shoals Lake	0.44	0.61
wMA4	Bull Shoals Lake	0.47	0.60
wEastFork	Bull Shoals Lake	0.44	0.59
wWestFork	Bull Shoals Lake	0.45	0.61
wBig	Bull Shoals Lake	0.41	0.58
wMA5	Bull Shoals Lake	0.48	0.62
wMA6	Bull Shoals Lake	0.48	0.62
wMusic	Bull Shoals Lake	0.48	0.62
wMA7	Bull Shoals Lake	0.50	0.66
wLitNFork1	Bull Shoals Lake	0.43	0.58
WLitNFork2	Bull Shoals Lake	0.48	0.55
wTurkeyEast	Bull Shoals Lake	0.46	0.54
wBarrenFork	Bull Shoals Lake	0.48	0.53
wPondfork	Bull Shoals Lake	0.44	0.55
wNorthFork	Bull Shoals Lake	0.47	0.57
WSouthFork	Bull Shoals Lake	0.47	0.57
wMA9	Bull Shoals Lake	0.47	0.59

wMA10	Bull Shoals Lake	0.51	0.69
wGulleySpring	Bull Shoals Lake	0.44	0.57
wMA8	Bull Shoals Lake	0.50	0.66
wJimmie	Bull Shoals Lake	0.43	0.61
wMA11	Bull Shoals Lake	0.47	0.60
wMA12	Bull Shoals Lake	0.46	0.59

GW1 Values

Beaver Lake Subbasins

Table 14-13. GW1 Coefficient for Beaver Lake Subbasins

Subbasin	GW1 Coefficient Dec 2015 Event (hrs)	GW1 Coefficient 2008 Event (hrs)	GW1 Coefficient 2011 Event (hrs)	GW1 Coefficient Jun 2015 Event (hrs)	GW1 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)
WWhite 9	20.34	24.31	22.6	24.31	30	24.31
WWhite 10	10.80	12.93	12.0	12.93	16	12.93
WMiddle	18.54	22.38	20.6	22.38	28	22.38
WLake	7.65	9.05	8.5	9.05	11	9.05
WWest 1	18.90	16.97	21.0	16.97	11	16.97
WWest 2	10.26	10.22	11.4	10.22	9	10.22
WWhite 8	8.91	10.60	9.9	10.60	13	10.60
WLollars	18.45	21.32	20.5	21.32	25	21.32
WDrakes	12.33	14.01	13.7	14.01	16	14.01
WRichland	17.46	19.95	19.4	19.95	23	19.95
WBR 3	16.02	16.94	17.8	16.94	17	16.94
WWhitener	16.47	17.59	18.3	17.59	18	17.59
WBR 2	10.53	11.08	11.7	11.08	11	11.08
WWhite 7	21.06	22.49	23.4	22.49	23	22.49
WBR 1	8.64	9.08	9.6	9.08	9	9.08
WWar 9	18.27	21.19	20.3	21.19	25	21.19
WHenderson	14.94	17.18	16.6	17.18	20	17.18
WWar 8	14.49	16.53	16.1	16.53	19	16.53
WWharton	16.38	18.86	18.2	18.86	22	18.86
WWar 7	13.50	15.50	15.0	15.50	18	15.50
WWar 6	20.79	25.30	23.1	25.30	32	25.30
WHolman	15.57	17.96	17.3	17.96	21	17.96
WGlade	12.78	14.66	14.2	14.66	17	14.66
WWar 5	15.30	18.10	17.0	18.10	22	18.10
WWar 4	15.48	17.89	17.2	17.89	21	17.89
WWar 3	10.71	12.20	11.9	12.20	14	12.20
WClifty 1	17.73	18.14	19.7	18.14	17	18.14
WWar 2	15.66	16.02	17.4	16.02	15	16.02
WWar 1	22.23	23.98	24.7	23.98	25	23.98

WWhite 6	20.34	20.98	22.6	20.98	20	20.98
WWhite 5	18.54	19.05	20.6	19.05	18	19.05
WBranch	13.59	13.90	15.1	13.90	13	13.90
WPrairie	10.62	10.81	11.8	10.81	10	10.81
WWhite 4	24.21	27.04	26.9	27.04	30	27.04
WWhite 3	13.95	14.48	15.5	14.48	14	14.48
WBeaver	17.10	17.70	19.0	17.70	17	17.70
WNorth Clifty	14.94	15.18	16.6	15.18	14	15.18
WWhite 1	17.82	18.21	19.8	18.21	17	18.21
WWhite 2	15.12	15.64	16.8	15.64	15	15.64

Bull Shoals and Table Rock Lakes Subbasins

Table 14-14. GW1 Coefficient for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	GW1 Coefficient Dec 2015 Event (hrs)	GW1 Coefficient 2008 Event (hrs)	GW1 Coefficient 2011 Event (hrs)	GW1 Coefficient Jun 2015 Event (hrs)	GW1 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)
zwRoaring1	6.36	12.36	18.36	12.36	12.36	12.36
zwTR1	24.33	16.33	12.33	16.33	12.33	16.33
zwRoaring2	22.74	14.74	10.74	14.74	10.74	14.74
zwKings1	45.00	44.00	48.00	44.00	39.00	44.00
zwdryking	24.00	25.00	33.00	25.00	18.00	25.00
zwkings2	24.00	25.00	33.00	25.00	18.00	25.00
zwOsage1	24.00	25.50	34.50	25.50	18.00	25.50
zwOsage2	30.00	30.00	36.00	30.00	24.00	30.00
zwKings3	15.00	16.70	26.10	16.70	9.00	16.70
zwKings4	6.30	10.60	19.50	10.60	6.00	10.60
zwTR2	27.12	19.12	15.12	19.12	15.12	19.12
zwKings5	30.57	22.57	18.57	22.57	18.57	22.57
zwIndian	26.97	18.97	14.97	18.97	14.97	18.97
zwLitIndian	25.41	17.41	13.41	17.41	13.41	17.41
zwJames0	28.50	20.00	16.50	20.00	15.00	20.00
zwJames1	34.50	24.00	19.50	24.00	18.00	24.00
zwWilson1	10.50	15.11	16.50	15.11	18.33	15.11
zwJames2	55.14	40.38	51.00	40.38	15.00	40.38
zwWilson2	48.60	32.84	42.96	32.84	6.96	32.84
zwJames3	48.15	31.43	41.07	31.43	5.07	31.43
zwFinley0	28.50	24.50	27.00	24.50	18.00	24.50
zwFinley1	33.00	28.00	30.00	28.00	21.00	28.00
zwFlat1	31.89	26.76	31.89	26.76	16.50	26.76
zwJames4	4.80	12.89	27.00	12.89	6.87	12.89
zwFinley2	8.37	23.08	30.87	23.08	30.00	23.08
zwCrane1	49.50	48.86	54.00	48.86	43.08	48.86
zwspring1	59.58	57.94	73.08	57.94	41.16	57.94
zwJames5	57.66	56.36	71.16	56.36	40.26	56.36
zwCrane2	56.76	49.54	70.26	49.54	21.60	49.54
zwJames6	18.60	31.03	48.60	31.03	25.89	31.03
zwLitFlat	26.64	34.64	26.64	34.64	50.64	34.64
zwFlat2	20.97	20.97	14.97	20.97	26.97	20.97
zwrockhouse	19.53	16.53	10.53	16.53	19.53	16.53
zwFlat3	22.26	18.26	10.26	18.26	22.26	18.26
zwFlat4	23.64	15.64	11.64	15.64	11.64	15.64

zwJames7	24.30	16.30	12.30	16.30	12.30	16.30
zwJames8	26.79	18.79	14.79	18.79	14.79	18.79
zwTR3	22.65	14.65	10.65	14.65	10.65	14.65
zwLong0	27.60	19.60	15.60	19.60	15.60	19.60
zwdrylong	31.83	23.83	19.83	23.83	19.83	23.83
zwLong1	30.39	22.39	18.39	22.39	18.39	22.39
zwyocum1	13.17	10.39	12.00	10.39	6.00	10.39
zwLong2	21.87	13.87	9.87	13.87	9.87	13.87
zwYocum2	25.17	17.17	13.17	17.17	13.17	17.17
zwLong3	26.61	18.61	14.61	18.61	14.61	18.61
zwTR5	22.53	14.53	10.53	14.53	10.53	14.53
wTurkeywest	16.29	11.56	8.10	11.56	10.29	11.56
wTaneycomo1	19.74	15.85	14.07	15.85	13.74	15.85
wRoark	19.20	15.27	13.41	15.27	13.20	15.27
wTaneycomo2	13.35	8.71	5.43	8.71	7.35	8.71
wBull1	28.86	22.24	16.86	22.24	21.00	22.24
wBull2	23.94	15.98	11.94	15.98	12.06	15.98
wBull4	28.44	22.82	16.44	22.82	23.58	22.82
wBull3	30.84	23.12	18.84	23.12	19.68	23.12
wbull4.5	14.94	10.42	5.94	10.42	10.38	10.42
wTaneycomo3	9.18	8.32	12.60	8.32	3.18	8.32
wBull5	9.93	10.26	16.92	10.26	3.93	10.26
WSwan1	21.03	18.23	18.63	18.23	15.03	18.23
wSwan2	16.89	14.65	16.17	14.65	10.89	14.65
wSwan4	24.66	18.29	11.55	18.29	18.66	18.29
wTaneycomo4	9.78	10.75	18.69	10.75	3.78	10.75
wBeaver1	22.14	23.10	13.14	23.10	34.02	23.10
WBeaver2	26.31	24.87	17.31	24.87	30.99	24.87
wBeaver4	17.43	12.35	8.43	12.35	11.19	12.35
wBeaver3	32.04	24.52	23.04	24.52	18.48	24.52
wBeaver5	29.73	20.67	20.73	20.67	11.55	20.67
wBeaver6	18.33	13.19	9.33	13.19	11.91	13.19
wBeaver8	28.53	24.60	19.53	24.60	25.74	24.60
wBeaver7	29.10	23.69	20.10	23.69	21.87	23.69
wBeaver10	18.54	14.68	12.96	14.68	12.54	14.68
wBeaver9	21.90	17.51	14.73	17.51	15.90	17.51
wBeaver12	18.18	13.34	9.66	13.34	12.18	13.34
wBeaver11	12.72	9.59	9.33	9.59	6.72	9.59
wBeaver13	17.22	13.26	11.34	13.26	11.22	13.26
wMA1	11.40	11.46	17.58	11.46	5.40	11.46
wCedar	8.91	5.39	4.35	5.39	2.91	5.39
wMA2	12.00	8.35	7.05	8.35	6.00	8.35
wBee	18.51	15.42	15.24	15.42	12.51	15.42
wYocum	11.01	8.10	8.28	8.10	5.01	8.10
wBear1	18.39	17.39	18.39	17.39	15.39	17.39
wBear2	9.33	8.33	9.33	8.33	6.33	8.33
wBear4	12.12	11.12	12.12	11.12	9.12	11.12
wBear3	8.52	7.52	8.52	7.52	5.52	7.52
wbear4.5	5.73	4.73	5.73	4.73	2.73	4.73
wBear5	15.30	14.48	18.84	14.48	9.30	14.48
WElbow	12.15	10.07	11.91	10.07	6.15	10.07
wMA3	12.45	11.28	14.94	11.28	6.45	11.28
wWSugerloaf	11.88	9.86	11.82	9.86	5.88	9.86
wEsugarloaf	15.06	12.05	12.03	12.05	9.06	12.05
wShoal	11.28	7.42	5.70	7.42	5.28	7.42
wMA4	12.09	7.70	4.92	7.70	6.09	7.70

wEastFork	12.99	15.93	27.81	15.93	6.99	15.93
wWestFork	11.46	8.08	7.32	8.08	5.46	8.08
wBig	13.35	9.78	8.64	9.78	7.35	9.78
wMA5	10.59	6.71	4.95	6.71	4.59	6.71
wMA6	10.95	10.96	16.98	10.96	4.95	10.96
wMusic	11.01	7.23	5.67	7.23	5.01	7.23
wMA7	9.12	6.55	7.41	6.55	3.12	6.55
wLitNFork1	14.40	10.61	9.03	10.61	8.40	10.61
WLitNFork2	18.30	11.67	4.41	11.67	12.30	11.67
wTurkeyEast	25.05	18.72	12.06	18.72	19.05	18.72
wBarrenFork	28.71	19.11	5.91	19.11	22.71	19.11
wPondfork	19.47	17.29	18.93	17.29	13.47	17.29
wNorthFork	15.48	12.06	11.22	12.06	9.48	12.06
WSouthFork	15.45	10.66	7.08	10.66	9.45	10.66
wMA9	12.66	10.06	10.86	10.06	6.66	10.06
wMA10	8.49	8.88	15.66	8.88	2.49	8.88
wGulleySpring	15.00	10.56	7.68	10.56	9.00	10.56
wMA8	9.24	5.92	5.28	5.92	3.24	5.92
wJimmie	11.07	7.84	7.38	7.84	5.07	7.84
wMA11	12.18	8.74	7.86	8.74	6.18	8.74
wMA12	13.20	8.14	4.02	8.14	7.20	8.14

GW1 Fraction Values

Beaver Lake Subbasins

Table 14-15. GW1 Fraction for Beaver Lake Subbasins

Subbasin	GW1 Fraction Dec 2015 Event	GW1 Fraction 2008 Event	GW1 Fraction 2011 Event	GW1 Fraction Jun 2015 Event	GW1 Fraction 2017 Event	Mean Calibration Values
WWhite 9	0.6	0.57	0.5	0.57	0.6	0.57
WWhite 10	0.6	0.57	0.5	0.57	0.6	0.57
WMiddle	0.7	0.63	0.5	0.63	0.7	0.63
WLake	0.6	0.57	0.5	0.57	0.6	0.57
WWest 1	0.8	0.70	0.5	0.70	0.8	0.70
WWest 2	0.8	0.70	0.5	0.70	0.8	0.70
WWhite 8	0.5	0.50	0.5	0.50	0.5	0.50
WLollars	0.5	0.50	0.5	0.50	0.5	0.50
WDrakes	0.5	0.50	0.5	0.50	0.5	0.50
WRichland	0.5	0.50	0.5	0.50	0.5	0.50
WBR 3	0.5	0.67	1.0	0.67	0.5	0.67
WWhitener	0.5	0.67	1.0	0.67	0.5	0.67
WBR 2	0.5	0.67	1.0	0.67	0.5	0.67
WWhite 7	0.5	0.67	1.0	0.67	0.5	0.67
WBR 1	0.5	0.67	1.0	0.67	0.5	0.67
WWar 9	0.5	0.57	0.7	0.57	0.5	0.57
WHenderson	0.5	0.57	0.7	0.57	0.5	0.57
WWar 8	0.5	0.57	0.7	0.57	0.5	0.57
WWharton	0.5	0.57	0.7	0.57	0.5	0.57

WWar 7	0.5	0.57	0.7	0.57	0.5	0.57
WWar 6	0.5	0.57	0.7	0.57	0.5	0.57
WHolman	0.5	0.57	0.7	0.57	0.5	0.57
WGlade	0.5	0.57	0.7	0.57	0.5	0.57
WWar 5	0.5	0.57	0.7	0.57	0.5	0.57
WWar 4	0.5	0.57	0.7	0.57	0.5	0.57
WWar 3	0.5	0.57	0.7	0.57	0.5	0.57
WClifty 1	0.5	0.67	1.0	0.67	0.5	0.67
WWar 2	0.5	0.67	1.0	0.67	0.5	0.67
WWar 1	0.5	0.67	1.0	0.67	0.5	0.67
WWhite 6	0.5	0.67	1.0	0.67	0.5	0.67
WWhite 5	0.5	0.67	1.0	0.67	0.5	0.67
WBranch	0.5	0.67	1.0	0.67	0.5	0.67
WPrairie	0.5	0.67	1.0	0.67	0.5	0.67
WWhite 4	0.5	0.67	1.0	0.67	0.5	0.67
WWhite 3	0.5	0.67	1.0	0.67	0.5	0.67
WBeaver	0.5	0.67	1.0	0.67	0.5	0.67
WNorth Clifty	0.5	0.67	1.0	0.67	0.5	0.67
WWhite 1	0.5	0.67	1.0	0.67	0.5	0.67
WWhite 2	0.5	0.67	1.0	0.67	0.5	0.67

Bull Shoals and Table Rock Lakes Subbasins

Table 14-16. GW1 Fraction for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	GW1 Fraction Dec 2015 Event	GW1 Fraction 2008 Event	GW1 Fraction 2011 Event	GW1 Fraction Jun 2015 Event	GW1 Fraction 2017 Event	Mean Calibration Values
zwRoaring1	0.20	0.30	0.2	0.30	0.5	0.30
zwTR1	0.50	0.60	0.8	0.60	0.5	0.60
zwRoaring2	0.50	0.60	0.8	0.60	0.5	0.60
zwKings1	0.10	0.27	0.2	0.27	0.5	0.27
zwdryking	0.10	0.27	0.2	0.27	0.5	0.27
zwkings2	0.10	0.27	0.2	0.27	0.5	0.27
zwOsage1	0.10	0.27	0.2	0.27	0.5	0.27
zwOsage2	0.10	0.27	0.2	0.27	0.5	0.27
zwKings3	0.10	0.27	0.2	0.27	0.5	0.27
zwKings4	0.10	0.27	0.2	0.27	0.5	0.27
zwTR2	0.50	0.60	0.8	0.60	0.5	0.60
zwKings5	0.50	0.60	0.8	0.60	0.5	0.60
zwIndian	0.50	0.60	0.8	0.60	0.5	0.60
zwLitIndian	0.50	0.60	0.8	0.60	0.5	0.60
zwJames0	0.30	0.40	0.2	0.40	0.8	0.43
zwJames1	0.30	0.40	0.2	0.40	0.8	0.43
zwWilson1	0.10	0.40	0.5	0.40	0.5	0.37
zwJames2	0.40	0.37	0.2	0.37	0.5	0.37
zwWilson2	0.40	0.37	0.2	0.37	0.5	0.37
zwJames3	0.40	0.37	0.2	0.37	0.5	0.37
zwFinley0	0.30	0.33	0.2	0.33	0.5	0.33
zwFinley1	0.30	0.33	0.2	0.33	0.5	0.33
zwFlat1	0.55	0.50	0.5	0.50	0.2	0.42
zwJames4	0.50	0.50	0.5	0.50	0.5	0.50

zwFinley2	0.50	0.50	0.5	0.50	0.5	0.50
zwCrane1	0.50	0.50	0.5	0.50	0.5	0.50
zwspring1	0.50	0.50	0.5	0.50	0.5	0.50
zwJames5	0.50	0.50	0.5	0.50	0.5	0.50
zwCrane2	0.50	0.50	0.5	0.50	0.5	0.50
zwJames6	0.50	0.50	0.5	0.50	0.5	0.50
zwLitFlat	0.55	0.50	0.5	0.50	0.2	0.42
zwFlat2	0.55	0.50	0.5	0.50	0.2	0.42
zwrockhouse	0.55	0.50	0.5	0.50	0.2	0.42
zwFlat3	0.55	0.50	0.5	0.50	0.2	0.42
zwFlat4	0.50	0.60	0.8	0.60	0.5	0.60
zwJames7	0.50	0.60	0.8	0.60	0.5	0.60
zwJames8	0.50	0.60	0.8	0.60	0.5	0.60
zwTR3	0.50	0.60	0.8	0.60	0.5	0.60
zwLong0	0.50	0.60	0.8	0.60	0.5	0.60
zwdrylong	0.50	0.60	0.8	0.60	0.5	0.60
zwLong1	0.50	0.60	0.8	0.60	0.5	0.60
zwyocum1	0.90	0.57	0.8	0.57	0.0	0.57
zwLong2	0.50	0.60	0.8	0.60	0.5	0.60
zwYocum2	0.50	0.60	0.8	0.60	0.5	0.60
zwLong3	0.50	0.60	0.8	0.60	0.5	0.60
zwTR5	0.50	0.60	0.8	0.60	0.5	0.60
wTurkeywest	0.30	0.33	0.5	0.33	0.2	0.33
wTaneycomo1	0.30	0.33	0.5	0.33	0.2	0.33
wRoark	0.30	0.33	0.5	0.33	0.2	0.33
wTaneycomo2	0.30	0.33	0.5	0.33	0.2	0.33
wBull1	0.10	0.43	0.7	0.43	0.5	0.43
wBull2	0.10	0.43	0.7	0.43	0.5	0.43
wBull4	0.10	0.43	0.7	0.43	0.5	0.43
wBull3	0.10	0.43	0.7	0.43	0.5	0.43
wbull4.5	0.10	0.43	0.7	0.43	0.5	0.43
wTaneycomo3	0.30	0.33	0.5	0.33	0.2	0.33
wBull5	0.30	0.33	0.5	0.33	0.2	0.33
WSwan1	0.30	0.33	0.5	0.33	0.2	0.33
wSwan2	0.30	0.33	0.5	0.33	0.2	0.33
wSwan4	0.30	0.33	0.5	0.33	0.2	0.33
wTaneycomo4	0.30	0.33	0.5	0.33	0.2	0.33
wBeaver1	0.50	0.50	0.5	0.50	0.5	0.50
WBeaver2	0.50	0.50	0.5	0.50	0.5	0.50
wBeaver4	0.50	0.50	0.5	0.50	0.5	0.50
wBeaver3	0.50	0.50	0.5	0.50	0.5	0.50
wBeaver5	0.50	0.50	0.5	0.50	0.5	0.50
wBeaver6	0.50	0.50	0.5	0.50	0.5	0.50
wBeaver8	0.50	0.50	0.5	0.50	0.5	0.50
wBeaver7	0.50	0.50	0.5	0.50	0.5	0.50
wBeaver10	0.30	0.33	0.5	0.33	0.2	0.33
wBeaver9	0.30	0.33	0.5	0.33	0.2	0.33
wBeaver12	0.30	0.33	0.5	0.33	0.2	0.33
wBeaver11	0.30	0.33	0.5	0.33	0.2	0.33
wBeaver13	0.30	0.33	0.5	0.33	0.2	0.33
wMA1	0.30	0.33	0.5	0.33	0.2	0.33
wCedar	0.30	0.33	0.5	0.33	0.2	0.33
wMA2	0.30	0.33	0.5	0.33	0.2	0.33
wBee	0.30	0.33	0.5	0.33	0.2	0.33
wYocum	0.30	0.33	0.5	0.33	0.2	0.33
wBear1	0.30	0.33	0.5	0.33	0.2	0.33

wBear2	0.30	0.33	0.5	0.33	0.2	0.33
wBear4	0.30	0.33	0.5	0.33	0.2	0.33
wBear3	0.30	0.33	0.5	0.33	0.2	0.33
wbear4.5	0.30	0.33	0.5	0.33	0.2	0.33
wBear5	0.30	0.33	0.5	0.33	0.2	0.33
WElbow	0.30	0.33	0.5	0.33	0.2	0.33
wMA3	0.30	0.33	0.5	0.33	0.2	0.33
wWSugerloaf	0.30	0.33	0.5	0.33	0.2	0.33
wEsugarloaf	0.30	0.33	0.5	0.33	0.2	0.33
wShoal	0.30	0.33	0.5	0.33	0.2	0.33
wMA4	0.30	0.33	0.5	0.33	0.2	0.33
wEastFork	0.30	0.33	0.5	0.33	0.2	0.33
wWestFork	0.30	0.33	0.5	0.33	0.2	0.33
wBig	0.30	0.33	0.5	0.33	0.2	0.33
wMA5	0.30	0.33	0.5	0.33	0.2	0.33
wMA6	0.30	0.33	0.5	0.33	0.2	0.33
wMusic	0.30	0.33	0.5	0.33	0.2	0.33
wMA7	0.30	0.33	0.5	0.33	0.2	0.33
wLitNFork1	0.30	0.33	0.5	0.33	0.2	0.33
WLitNFork2	0.30	0.33	0.5	0.33	0.2	0.33
wTurkeyEast	0.30	0.33	0.5	0.33	0.2	0.33
wBarrenFork	0.30	0.33	0.5	0.33	0.2	0.33
wPondfork	0.30	0.33	0.5	0.33	0.2	0.33
wNorthFork	0.30	0.33	0.5	0.33	0.2	0.33
WSouthFork	0.30	0.33	0.5	0.33	0.2	0.33
wMA9	0.30	0.33	0.5	0.33	0.2	0.33
wMA10	0.30	0.33	0.5	0.33	0.2	0.33
wGulleySpring	0.30	0.33	0.5	0.33	0.2	0.33
wMA8	0.30	0.33	0.5	0.33	0.2	0.33
wJimmie	0.30	0.33	0.5	0.33	0.2	0.33
wMA11	0.30	0.33	0.5	0.33	0.2	0.33
wMA12	0.30	0.33	0.5	0.33	0.2	0.33

GW2 Coefficient Values

Beaver Lake Subbasins

Table 14-17. GW2 Coefficient for Beaver Lake Subbasins

Subbasin	GW2 Coefficient Dec 2015 Event (hrs)	GW2 Coefficient 2008 Event (hrs)	GW2 Coefficient 2011 Event (hrs)	GW2 Coefficient Jun 2015 Event (hrs)	GW2 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)
WWhite 9	81.45	84.48	90.5	84.48	81.5	84.48
WWhite 10	43.20	44.80	48.0	44.80	43.2	44.80
WMiddle	74.16	76.92	82.4	76.92	74.2	76.92
WLake	30.69	31.83	34.1	31.83	30.7	31.83
WWest 1	75.42	78.21	83.8	78.21	75.4	78.21
WWest 2	40.95	42.48	45.5	42.48	41.0	42.48
WWhite 8	35.55	36.88	39.5	36.88	35.6	36.88

WLollars	73.71	76.44	81.9	76.44	73.7	76.44
WDrakes	49.41	51.24	54.9	51.24	49.4	51.24
WRichland	69.84	72.41	77.6	72.41	69.8	72.41
WBR 3	63.99	66.36	71.1	66.36	64.0	66.36
WWhitener	65.79	68.23	73.1	68.23	65.8	68.23
WBR 2	41.94	43.48	46.6	43.48	41.9	43.48
WWhite 7	84.06	87.19	93.4	87.19	84.1	87.19
WBR 1	34.65	35.95	38.5	35.95	34.7	35.95
WWar 9	73.08	75.79	81.2	75.79	73.1	75.79
WHenderson	59.85	62.08	66.5	62.08	59.9	62.08
WWar 8	58.05	60.22	64.5	60.22	58.1	60.22
WWharton	65.61	68.04	72.9	68.04	65.6	68.04
WWar 7	54.00	56.00	60.0	56.00	54.0	56.00
WWar 6	82.98	86.06	92.2	86.06	83.0	86.06
WHolman	62.37	64.69	69.3	64.69	62.4	64.69
WGlade	51.03	52.91	56.7	52.91	51.0	52.91
WWar 5	61.20	63.47	68.0	63.47	61.2	63.47
WWar 4	62.01	64.30	68.9	64.30	62.0	64.30
WWar 3	42.66	44.25	47.4	44.25	42.7	44.25
WClifty 1	70.74	73.35	78.6	73.35	70.7	73.35
WWar 2	62.55	64.88	69.5	64.88	62.6	64.88
WWar 1	88.74	92.01	98.6	92.01	88.7	92.01
WWhite 6	81.45	84.48	90.5	84.48	81.5	84.48
WWhite 5	73.98	76.73	82.2	76.73	74.0	76.73
WBranch	54.36	56.39	60.4	56.39	54.4	56.39
WPrairie	42.39	43.96	47.1	43.96	42.4	43.96
WWhite 4	96.75	100.35	107.5	100.35	96.8	100.35
WWhite 3	55.80	57.87	62.0	57.87	55.8	57.87
WBeaver	68.22	70.74	75.8	70.74	68.2	70.74
WNorth Clifty	59.67	61.89	66.3	61.89	59.7	61.89
WWhite 1	71.19	73.83	79.1	73.83	71.2	73.83
WWhite 2	60.48	62.73	67.2	62.73	60.5	62.73

Bull Shoals and Table Rock Lakes Subbasins

Table 14-18. GW2 Coefficient for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	GW2 Coefficient Dec 2015 Event (hrs)	GW2 Coefficient 2008 Event (hrs)	GW2 Coefficient 2011 Event (hrs)	GW2 Coefficient Jun 2015 Event (hrs)	GW2 Coefficient 2017 Event (hrs)	Mean Calibration Values (hrs)
zwRoaring1	21.2	41.20	61.2	41.20	41.2	41.20
zwTR1	81.1	54.43	41.1	54.43	41.1	54.43
zwRoaring2	75.8	49.13	35.8	49.13	35.8	49.13
zwKings1	150.0	146.67	160.0	146.67	130.0	146.67
zwdryking	80.0	83.33	110.0	83.33	60.0	83.33
zwkings2	80.0	83.33	110.0	83.33	60.0	83.33
zwOsage1	80.0	85.00	115.0	85.00	60.0	85.00
zwOsage2	100.0	100.00	120.0	100.00	80.0	100.00
zwKings3	50.0	55.67	87.0	55.67	30.0	55.67
zwKings4	21.0	35.33	65.0	35.33	20.0	35.33
zwTR2	90.4	63.73	50.4	63.73	50.4	63.73
zwKings5	101.9	75.23	61.9	75.23	61.9	75.23
zwIndian	89.9	63.23	49.9	63.23	49.9	63.23

zwLitIndian	84.7	58.03	44.7	58.03	44.7	58.03
zwJames0	95.0	66.67	55.0	66.67	50.0	66.67
zwJames1	115.0	80.00	65.0	80.00	60.0	80.00
zwWilson1	35.0	50.37	55.0	50.37	61.1	50.37
zwJames2	183.8	134.60	170.0	134.60	50.0	134.60
zwWilson2	162.0	109.47	143.2	109.47	23.2	109.47
zwJames3	160.5	104.77	136.9	104.77	16.9	104.77
zwFinley0	95.0	81.67	90.0	81.67	60.0	81.67
zwFinley1	110.0	93.33	100.0	93.33	70.0	93.33
zwFlat1	106.3	89.20	106.3	89.20	55.0	89.20
zwJames4	16.0	42.97	90.0	42.97	22.9	42.97
zwFinley2	27.9	76.93	102.9	76.93	100.0	76.93
zwCrane1	165.0	162.87	180.0	162.87	143.6	162.87
zwspring1	198.6	193.13	243.6	193.13	137.2	193.13
zwJames5	192.2	187.87	237.2	187.87	134.2	187.87
zwCrane2	189.2	165.13	234.2	165.13	72.0	165.13
zwJames6	62.0	103.43	162.0	103.43	86.3	103.43
zwLitFlat	88.8	115.47	88.8	115.47	168.8	115.47
zwFlat2	69.9	69.90	49.9	69.90	89.9	69.90
zwrockhouse	65.1	55.10	35.1	55.10	65.1	55.10
zwFlat3	74.2	60.87	34.2	60.87	74.2	60.87
zwFlat4	78.8	52.13	38.8	52.13	38.8	52.13
zwJames7	81.0	54.33	41.0	54.33	41.0	54.33
zwJames8	89.3	62.63	49.3	62.63	49.3	62.63
zwTR3	75.5	48.83	35.5	48.83	35.5	48.83
zwLong0	92.0	65.33	52.0	65.33	52.0	65.33
zwdrylong	106.1	79.43	66.1	79.43	66.1	79.43
zwLong1	101.3	74.63	61.3	74.63	61.3	74.63
zwyocum1	43.9	34.63	40.0	34.63	20.0	34.63
zwLong2	72.9	46.23	32.9	46.23	32.9	46.23
zwYocum2	83.9	57.23	43.9	57.23	43.9	57.23
zwLong3	88.7	62.03	48.7	62.03	48.7	62.03
zwTR5	75.1	48.43	35.1	48.43	35.1	48.43
wTurkeywest	54.3	38.53	27.0	38.53	34.3	38.53
wTaneycomo1	65.8	52.83	46.9	52.83	45.8	52.83
wRoark	64.0	50.90	44.7	50.90	44.0	50.90
wTaneycomo2	44.5	29.03	18.1	29.03	24.5	29.03
wBull1	96.2	74.13	56.2	74.13	70.0	74.13
wBull2	79.8	53.27	39.8	53.27	40.2	53.27
wBull4	94.8	76.07	54.8	76.07	78.6	76.07
wBull3	102.8	77.07	62.8	77.07	65.6	77.07
wbull4.5	49.8	34.73	19.8	34.73	34.6	34.73
wTaneycomo3	30.6	27.73	42.0	27.73	10.6	27.73
wBull5	33.1	34.20	56.4	34.20	13.1	34.20
WSwan1	70.1	60.77	62.1	60.77	50.1	60.77
wSwan2	56.3	48.83	53.9	48.83	36.3	48.83
wSwan4	82.2	60.97	38.5	60.97	62.2	60.97
wTaneycomo4	32.6	35.83	62.3	35.83	12.6	35.83
wBeaver1	73.8	77.00	43.8	77.00	113.4	77.00
WBeaver2	87.7	82.90	57.7	82.90	103.3	82.90
wBeaver4	58.1	41.17	28.1	41.17	37.3	41.17
wBeaver3	106.8	81.73	76.8	81.73	61.6	81.73
wBeaver5	99.1	68.90	69.1	68.90	38.5	68.90
wBeaver6	61.1	43.97	31.1	43.97	39.7	43.97
wBeaver8	95.1	82.00	65.1	82.00	85.8	82.00
wBeaver7	97.0	78.97	67.0	78.97	72.9	78.97

wBeaver10	61.8	48.93	43.2	48.93	41.8	48.93
wBeaver9	73.0	58.37	49.1	58.37	53.0	58.37
wBeaver12	60.6	44.47	32.2	44.47	40.6	44.47
wBeaver11	42.4	31.97	31.1	31.97	22.4	31.97
wBeaver13	57.4	44.20	37.8	44.20	37.4	44.20
wMA1	38.0	38.20	58.6	38.20	18.0	38.20
wCedar	29.7	17.97	14.5	17.97	9.7	17.97
wMA2	40.0	27.83	23.5	27.83	20.0	27.83
wBee	61.7	51.40	50.8	51.40	41.7	51.40
wYocum	36.7	27.00	27.6	27.00	16.7	27.00
wBear1	61.3	57.97	61.3	57.97	51.3	57.97
wBear2	31.1	27.77	31.1	27.77	21.1	27.77
wBear4	40.4	37.07	40.4	37.07	30.4	37.07
wBear3	28.4	25.07	28.4	25.07	18.4	25.07
wbear4.5	19.1	15.77	19.1	15.77	9.1	15.77
wBear5	51.0	48.27	62.8	48.27	31.0	48.27
WElbow	40.5	33.57	39.7	33.57	20.5	33.57
wMA3	41.5	37.60	49.8	37.60	21.5	37.60
wWSugerloaf	39.6	32.87	39.4	32.87	19.6	32.87
wEsugarloaf	50.2	40.17	40.1	40.17	30.2	40.17
wShoal	37.6	24.73	19.0	24.73	17.6	24.73
wMA4	40.3	25.67	16.4	25.67	20.3	25.67
wEastFork	43.3	53.10	92.7	53.10	23.3	53.10
wWestFork	38.2	26.93	24.4	26.93	18.2	26.93
wBig	44.5	32.60	28.8	32.60	24.5	32.60
wMA5	35.3	22.37	16.5	22.37	15.3	22.37
wMA6	36.5	36.53	56.6	36.53	16.5	36.53
wMusic	36.7	24.10	18.9	24.10	16.7	24.10
wMA7	30.4	21.83	24.7	21.83	10.4	21.83
wLitNFork1	48.0	35.37	30.1	35.37	28.0	35.37
WLitNFork2	61.0	38.90	14.7	38.90	41.0	38.90
wTurkeyEast	83.5	62.40	40.2	62.40	63.5	62.40
wBarrenFork	95.7	63.70	19.7	63.70	75.7	63.70
wPondfork	64.9	57.63	63.1	57.63	44.9	57.63
wNorthFork	51.6	40.20	37.4	40.20	31.6	40.20
WSouthFork	51.5	35.53	23.6	35.53	31.5	35.53
wMA9	42.2	33.53	36.2	33.53	22.2	33.53
wMA10	28.3	29.60	52.2	29.60	8.3	29.60
wGulleySpring	50.0	35.20	25.6	35.20	30.0	35.20
wMA8	30.8	19.73	17.6	19.73	10.8	19.73
wJimmie	36.9	26.13	24.6	26.13	16.9	26.13
wMA11	40.6	29.13	26.2	29.13	20.6	29.13
wMA12	44.0	27.13	13.4	27.13	24.0	27.13

GW2 Fraction Values

Beaver Lake Subbasins

Table 14-19. GW2 Fraction for Beaver Lake Subbasins

Subbasin	GW2 Fraction Dec 2015 Event	GW2 Fraction 2008 Event	GW2 Fraction 2011 Event	GW2 Fraction Jun 2015 Event	GW2 Fraction 2017 Event	Mean Calibration Values
WWhite 9	0.4	0.43	0.5	0.43	0.4	0.43

WWhite 10	0.4	0.43	0.5	0.43	0.4	0.43
WMiddle	0.3	0.37	0.5	0.37	0.3	0.37
WLake	0.4	0.43	0.5	0.43	0.4	0.43
WWest 1	0.2	0.30	0.5	0.30	0.2	0.30
WWest 2	0.2	0.30	0.5	0.30	0.2	0.30
WWhite 8	0.5	0.50	0.5	0.50	0.5	0.50
WLollars	0.5	0.50	0.5	0.50	0.5	0.50
WDrakes	0.5	0.50	0.5	0.50	0.5	0.50
WRichland	0.5	0.50	0.5	0.50	0.5	0.50
WBR 3	0.5	0.33	0.0	0.33	0.5	0.33
WWhitener	0.5	0.33	0.0	0.33	0.5	0.33
WBR 2	0.5	0.33	0.0	0.33	0.5	0.33
WWhite 7	0.5	0.33	0.0	0.33	0.5	0.33
WBR 1	0.5	0.33	0.0	0.33	0.5	0.33
WWar 9	0.5	0.43	0.3	0.43	0.5	0.43
WHenderson	0.5	0.43	0.3	0.43	0.5	0.43
WWar 8	0.5	0.43	0.3	0.43	0.5	0.43
WWharton	0.5	0.43	0.3	0.43	0.5	0.43
WWar 7	0.5	0.43	0.3	0.43	0.5	0.43
WWar 6	0.5	0.43	0.3	0.43	0.5	0.43
WHolman	0.5	0.43	0.3	0.43	0.5	0.43
WGlade	0.5	0.43	0.3	0.43	0.5	0.43
WWar 5	0.5	0.43	0.3	0.43	0.5	0.43
WWar 4	0.5	0.43	0.3	0.43	0.5	0.43
WWar 3	0.5	0.43	0.3	0.43	0.5	0.43
WClifty 1	0.5	0.33	0.0	0.33	0.5	0.33
WWar 2	0.5	0.33	0.0	0.33	0.5	0.33
WWar 1	0.5	0.33	0.0	0.33	0.5	0.33
WWhite 6	0.5	0.33	0.0	0.33	0.5	0.33
WWhite 5	0.5	0.33	0.0	0.33	0.5	0.33
WBranch	0.5	0.33	0.0	0.33	0.5	0.33
WPrairie	0.5	0.33	0.0	0.33	0.5	0.33
WWhite 4	0.5	0.33	0.0	0.33	0.5	0.33
WWhite 3	0.5	0.33	0.0	0.33	0.5	0.33
WBeaver	0.5	0.33	0.0	0.33	0.5	0.33
WNorth Clifty	0.5	0.33	0.0	0.33	0.5	0.33
WWhite 1	0.5	0.33	0.0	0.33	0.5	0.33
WWhite 2	0.5	0.33	0.0	0.33	0.5	0.33

Bull Shoals and Table Rock Lakes Subbasins

Table 14-20. GW2 Fraction for Bull Shoals and Table Rock Lakes Subbasins

Subbasin	GW2 Fraction Dec 2015 Event	GW2 Fraction 2008 Event	GW2 Fraction 2011 Event	GW2 Fraction Jun 2015 Event	GW2 Fraction 2017 Event	Mean Calibration Values
zwRoaring1	0.80	0.70	0.80	0.70	0.5	0.70
zwTR1	0.50	0.40	0.20	0.40	0.5	0.40
zwRoaring2	0.50	0.40	0.20	0.40	0.5	0.40
zwKings1	0.90	0.73	0.80	0.73	0.5	0.73
zwdryking	0.90	0.73	0.80	0.73	0.5	0.73
zwkings2	0.90	0.73	0.80	0.73	0.5	0.73

zwOsage1	0.90	0.73	0.80	0.73	0.5	0.73
zwOsage2	0.90	0.73	0.80	0.73	0.5	0.73
zwKings3	0.90	0.73	0.80	0.73	0.5	0.73
zwKings4	0.90	0.73	0.80	0.73	0.5	0.73
zwTR2	0.50	0.40	0.20	0.40	0.5	0.40
zwKings5	0.50	0.40	0.20	0.40	0.5	0.40
zwIndian	0.50	0.40	0.20	0.40	0.5	0.40
zwLitIndian	0.50	0.40	0.20	0.40	0.5	0.40
zwJames0	0.45	0.60	0.80	0.60	0.2	0.48
zwJames1	0.45	0.60	0.80	0.60	0.2	0.48
zwWilson1	0.80	0.60	0.50	0.60	0.5	0.60
zwJames2	0.60	0.63	0.80	0.63	0.5	0.63
zwWilson2	0.60	0.63	0.80	0.63	0.5	0.63
zwJames3	0.60	0.63	0.80	0.63	0.5	0.63
zwFinley0	0.70	0.67	0.80	0.67	0.5	0.67
zwFinley1	0.70	0.67	0.80	0.67	0.5	0.67
zwFlat1	0.45	0.50	0.25	0.50	0.8	0.50
zwJames4	0.50	0.50	0.50	0.50	0.5	0.50
zwFinley2	0.50	0.50	0.50	0.50	0.5	0.50
zwCrane1	0.50	0.50	0.50	0.50	0.5	0.50
zwspring1	0.50	0.50	0.50	0.50	0.5	0.50
zwJames5	0.50	0.50	0.50	0.50	0.5	0.50
zwCrane2	0.50	0.50	0.50	0.50	0.5	0.50
zwJames6	0.50	0.50	0.50	0.50	0.5	0.50
zwLitFlat	0.45	0.50	0.25	0.50	0.8	0.50
zwFlat2	0.45	0.50	0.25	0.50	0.8	0.50
zwrockhouse	0.45	0.50	0.25	0.50	0.8	0.50
zwFlat3	0.45	0.50	0.25	0.50	0.8	0.50
zwFlat4	0.50	0.40	0.20	0.40	0.5	0.40
zwJames7	0.50	0.40	0.20	0.40	0.5	0.40
zwJames8	0.50	0.40	0.20	0.40	0.5	0.40
zwTR3	0.50	0.40	0.20	0.40	0.5	0.40
zwLong0	0.50	0.40	0.20	0.40	0.5	0.40
zwdrylong	0.50	0.40	0.20	0.40	0.5	0.40
zwLong1	0.50	0.40	0.20	0.40	0.5	0.40
zwyocum1	0.10	0.43	0.20	0.43	1.0	0.43
zwLong2	0.50	0.40	0.20	0.40	0.5	0.40
zwYocum2	0.50	0.40	0.20	0.40	0.5	0.40
zwLong3	0.50	0.40	0.20	0.40	0.5	0.40
zwTR5	0.50	0.40	0.20	0.40	0.5	0.40
wTurkeywest	0.70	0.67	0.50	0.67	0.8	0.67
wTaneycomo1	0.70	0.67	0.50	0.67	0.8	0.67
wRoark	0.70	0.67	0.50	0.67	0.8	0.67
wTaneycomo2	0.70	0.67	0.50	0.67	0.8	0.67
wBull1	0.90	0.57	0.30	0.57	0.5	0.57
wBull2	0.90	0.57	0.30	0.57	0.5	0.57
wBull4	0.90	0.57	0.30	0.57	0.5	0.57
wBull3	0.90	0.57	0.30	0.57	0.5	0.57
wbull4.5	0.90	0.57	0.30	0.57	0.5	0.57
wTaneycomo3	0.70	0.67	0.50	0.67	0.8	0.67
wBull5	0.70	0.67	0.50	0.67	0.8	0.67
WSwan1	0.70	0.67	0.50	0.67	0.8	0.67
wSwan2	0.70	0.67	0.50	0.67	0.8	0.67
wSwan4	0.70	0.67	0.50	0.67	0.8	0.67
wTaneycomo4	0.70	0.67	0.50	0.67	0.8	0.67
wBeaver1	0.50	0.50	0.40	0.50	0.5	0.47

WBeaver2	0.50	0.50	0.40	0.50	0.5	0.47
wBeaver4	0.50	0.50	0.40	0.50	0.5	0.47
wBeaver3	0.50	0.50	0.40	0.50	0.5	0.47
wBeaver5	0.50	0.50	0.40	0.50	0.5	0.47
wBeaver6	0.50	0.50	0.40	0.50	0.5	0.47
wBeaver8	0.50	0.50	0.40	0.50	0.5	0.47
wBeaver7	0.50	0.50	0.40	0.50	0.5	0.47
wBeaver10	0.70	0.67	0.50	0.67	0.8	0.67
wBeaver9	0.70	0.67	0.50	0.67	0.8	0.67
wBeaver12	0.70	0.67	0.50	0.67	0.8	0.67
wBeaver11	0.70	0.67	0.50	0.67	0.8	0.67
wBeaver13	0.70	0.67	0.50	0.67	0.8	0.67
wMA1	0.70	0.67	0.50	0.67	0.8	0.67
wCedar	0.70	0.67	0.50	0.67	0.8	0.67
wMA2	0.70	0.67	0.50	0.67	0.8	0.67
wBee	0.70	0.67	0.50	0.67	0.8	0.67
wYocum	0.70	0.67	0.50	0.67	0.8	0.67
wBear1	0.70	0.67	0.50	0.67	0.8	0.67
wBear2	0.70	0.67	0.50	0.67	0.8	0.67
wBear4	0.70	0.67	0.50	0.67	0.8	0.67
wBear3	0.70	0.67	0.50	0.67	0.8	0.67
wbear4.5	0.70	0.67	0.50	0.67	0.8	0.67
wBear5	0.70	0.67	0.50	0.67	0.8	0.67
WElbow	0.70	0.67	0.50	0.67	0.8	0.67
wMA3	0.70	0.67	0.50	0.67	0.8	0.67
wWSugerloaf	0.70	0.67	0.50	0.67	0.8	0.67
wEsugarloaf	0.70	0.67	0.50	0.67	0.8	0.67
wShoal	0.70	0.67	0.50	0.67	0.8	0.67
wMA4	0.70	0.67	0.50	0.67	0.8	0.67
wEastFork	0.70	0.67	0.50	0.67	0.8	0.67
wWestFork	0.70	0.67	0.50	0.67	0.8	0.67
wBig	0.70	0.67	0.50	0.67	0.8	0.67
wMA5	0.70	0.67	0.50	0.67	0.8	0.67
wMA6	0.70	0.67	0.50	0.67	0.8	0.67
wMusic	0.70	0.67	0.50	0.67	0.8	0.67
wMA7	0.70	0.67	0.50	0.67	0.8	0.67
wLitNFork1	0.70	0.67	0.50	0.67	0.8	0.67
WLitNFork2	0.70	0.67	0.50	0.67	0.8	0.67
wTurkeyEast	0.70	0.67	0.50	0.67	0.8	0.67
wBarrenFork	0.70	0.67	0.50	0.67	0.8	0.67
wPondfork	0.70	0.67	0.50	0.67	0.8	0.67
wNorthFork	0.70	0.67	0.50	0.67	0.8	0.67
WSouthFork	0.70	0.67	0.50	0.67	0.8	0.67
wMA9	0.70	0.67	0.50	0.67	0.8	0.67
wMA10	0.70	0.67	0.50	0.67	0.8	0.67
wGulleySpring	0.70	0.67	0.50	0.67	0.8	0.67
wMA8	0.70	0.67	0.50	0.67	0.8	0.67
wJimmie	0.70	0.67	0.50	0.67	0.8	0.67
wMA11	0.70	0.67	0.50	0.67	0.8	0.67
wMA12	0.70	0.67	0.50	0.67	0.8	0.67