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Hydrology of the Big Creek Watershed and Its Influence on the Lower Cache River

by
Misganaw Demissie, H. Vernon Knapp, Paminder Parmar, and Daniel J. Kriesant

March 2001

Illinois State Water Survey
Watershed Science Section
Champaign, Illinois

A Division of the Illinois Department of Natural Resources

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Abstract

A primary concern in the management of the Lower Cache River is the amount of sediment that is deposited in the river's valley in the vicinity of Buttonland Swamp. From previous monitoring studies it is known that floodwaters from Big Creek convey a significant amount of sediment and create a reverse flow condition in the Cache River that carries the sediment into Buttonland Swamp. This study investigated the potential influence of several management alternatives in reducing or eliminating the reverse flow condition in the Cache River, which would alleviate much of the sediment concern. Management alternatives include various options for detention storage in the Big Creek watershed as well as redirecting the lower portion of Big Creek to the west, away from Buttonland Swamp.

To evaluate the impact of these alternatives, the hydrology of the Big Creek watershed and its influence on the hydraulics of the Lower Cache River were investigated using two models. The HEC-1 flood hydrology model was used to simulate the rainfall-runoff response of tributaries draining to the Lower Cache River, with emphasis on Big Creek and estimating the impact of detention storage on the Big Creek flood flows. The UNET unsteady flow routing model was then used to evaluate the flow patterns in the Lower Cache River and the impact of management alternatives on flow direction, flood discharge, and stage.

Under existing conditions, the UNET model shows that reverse flow occurs in the Lower Cache River east of Big Creek confluence during all the flood events considered. Various detention alternatives in the Big Creek watershed have the potential to reduce the peak of the reverse flow by 26 to 76 percent. Of the detention alternatives examined, the larger detention facilities in the lower reaches of Big Creek appear to produce the greatest reduction in reverse flows. An alternative to divert the lower portion of Big Creek has the potential to totally eliminate reverse flows in the area immediately east of the Big Creek confluence with the Lower Cache River, but may cause increased flooding to the west. To eliminate most of the reverse flow east of Big Creek, and at the same time not increase flood stages farther west on the Lower Cache River, it may be necessary to use a combination of detention storage and either a partial or total diversion of the lower portion of Big Creek. For example, the use of the split flow alternative in combination with the many ponds and Cache valley detention alternatives reduces the peak reverse flows east of Big Creek by 81 percent for a 2-year flood and 92 percent for a 100-year flood. This combined alternative also accomplishes a reduction in the peak stages farther downstream west of Interstate 57 by approximately 0.5 foot.

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Introduction

The Big Creek watershed is one of the major tributaries draining into the Lower Cache River near the internationally recognized Cache River Wetlands. It not only contributes significant amounts of water to the Lower Cache River but also carries a higher sediment load than other tributaries in the area. Based on three years of data collected between 1985 and 1988, the Big Creek watershed contributed more than 70 percent of the sediment inflows (58,000 tons per year) into the Lower Cache River. Because of its high sediment yield and influence on the Lower Cache River, multiple agencies and organizations have identified the Big Creek watershed as one of the priority areas for watershed remediation.

The Lower Cache River is in the western half of the Cache River watershed located in the extreme southern part of Illinois, just north of the confluence of the Ohio and Mississippi Rivers (figure 1). The Cache River watershed covers parts of six southern Illinois counties: Union, Johnson, Alexander, Pulaski, Massac, and Pope. The total drainage area of the watershed is 737 square miles. Construction of Post Creek Cutoff in 1915 divided the Cache River watershed into the Upper Cache and Lower Cache River watersheds. The Upper Cache River watershed consists of the eastern part of the Cache River watershed with a drainage area of 368 square miles that drains directly to the Ohio River through the Post Creek Cutoff. The Lower Cache River watershed consists of the western part of the Cache River watershed with a drainage area of 358 square miles that drains to the Mississippi River through a diversion channel. Eleven square miles of the Lower Cache River continue to drain into the Ohio River through the original Cache River channel.

The Cache River levee along the western bank of the Post Creek Cutoff near Karnak separates the Upper and Lower Cache River watersheds. This levee was built in 1952 across the old Cache River Channel and forces drainage from the Upper Cache River to flow directly to the Ohio River through the Post Creek Cutoff. It also prevents any flood from the Ohio River from backing into the Lower Cache River. With the exception of local drainage along the Cache River levee, drainage from the Lower Cache River watershed was supposed to flow west into the Mississippi River. However, during flood events, some drainage from the Lower Cache River flowed east to the Post Creek through culverts in the Cache River Levee.

The hydraulics of the Lower Cache River are very complex. Since the separation of the Upper and Lower Cache Rivers, the Lower Cache River does not receive flow from the Upper Cache River to maintain a sustained flow in the downstream direction. Local tributaries, primarily Cypress Creek, Limekiln Slough, and Big Creek, provide the source of water for the

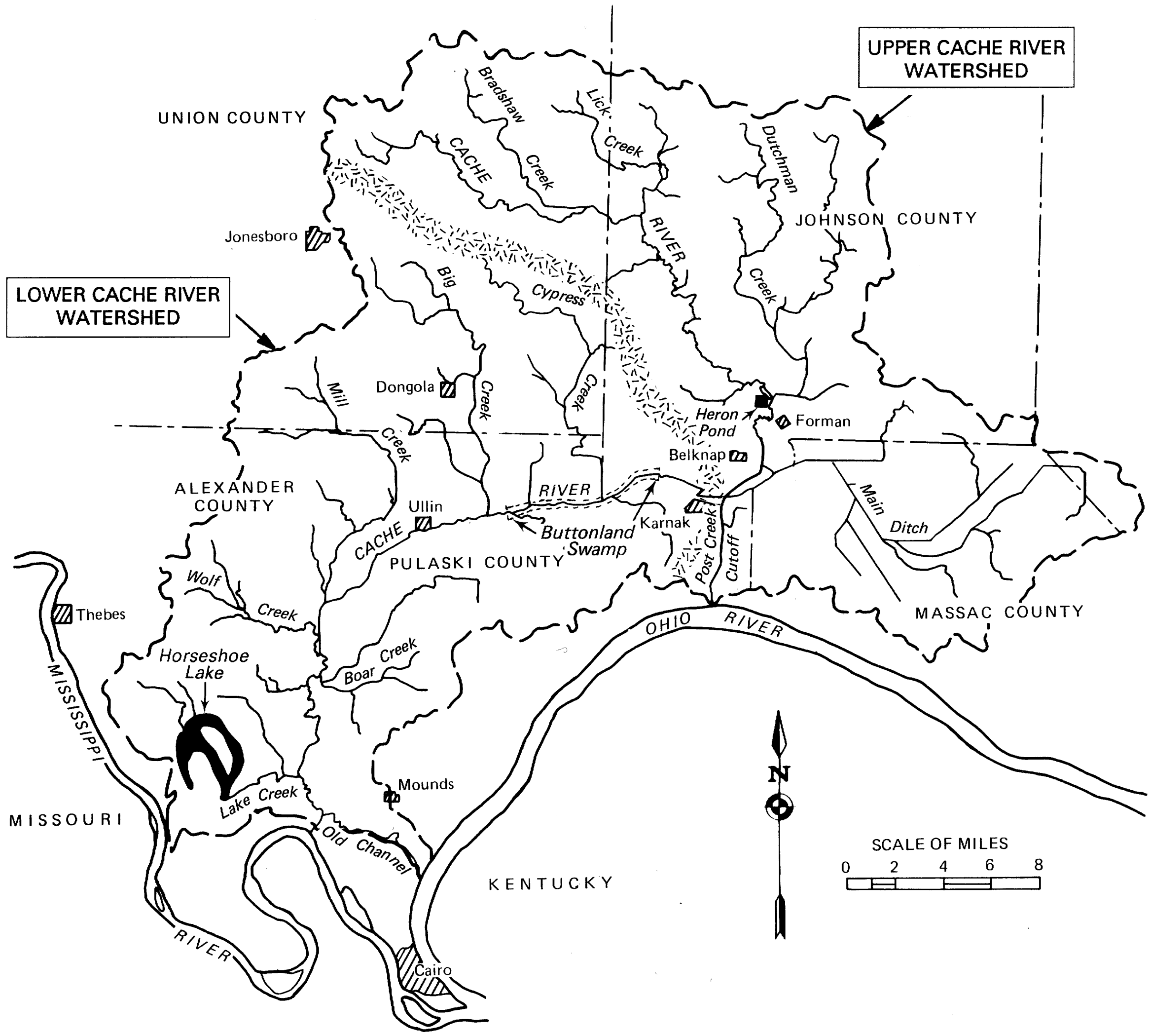


Figure 1. Location of the Cache River and its major tributaries

upper portion of the Lower Cache River. Big Creek, with a watershed area of 51.7 square miles (compared to 46.3 square miles for Cypress Creek and 22.1 square miles for Limekiln Slough), plays a dominant role in the Lower Cache River. Because of its slope and straightened channels, Big Creek generally has higher flood peaks than Cypress Creek.

Once water from tributaries enters the Lower Cache River, it can flow in an easterly direction towards two 48-inch culverts in the Cache River levee or flow in a westerly direction towards the Cache River outlet on the Mississippi River. If the flows are high enough where streambanks are overtopped, which is the case during most flood events, then water flows into the wetland areas that have large water storage capacity. A combination of several factors determines which way water flows in the upper parts of the Lower Cache River. Some of the factors are magnitude of floods, channel capacity and slope, flood heights, floodplain storage, outlet capacity, and resistance to flow.

The concern associated with the reverse flow is primarily due to a sedimentation problem in the Buttonland Swamp area of the Lower Cache River. The average annual sediment inflow into the upper segment of the Lower Cache River was estimated to be 82,200 tons based on 1985-1988 data (Demissie et al., 1992). The two largest tributaries, Big Creek and Cypress Creek, contributed 58,200 tons (71%) and 10,630 tons (13%), respectively. Because Big Creek is a major source of sediment to the area, it was assumed that any flow from Big Creek in an easterly direction would carry more sediment to the Buttonland Swamp area. The flow of sediment and high rate of sedimentation will continue to degrade the aquatic habitat in the Lower Cache River and the associated wetlands. Therefore, the resource planners and managers for the Lower Cache River have identified the reduction or prevention of reverse flow from Big Creek as one of the important factors in their restoration efforts.

The purpose of this research was to develop hydrologic and hydraulic models that can simulate the hydrology of the Big Creek watershed and the hydraulics of the Lower Cache River. The models were then used to evaluate different alternatives that either eliminate or reduce the magnitude and frequency of reverse flow in that portion of the Lower Cache River located just east of the junction of Big Creek. Preventing or reducing reverse flow to the east of Big Creek will prevent or reduce the movement of sediment from Big Creek into the Cache River Wetlands.

The alternatives considered included flood detention basins in the Big and Little Creek watersheds, in the Cache River valley, and partial or total diversion of the Big Creek flow to a point further west from its present outlet. The results of the modeling exercises are presented in the report.

Acknowledgments

The work upon which this report is based was supported in part by funds provided by the Illinois Department of Natural Resources (IDNR). Marvin Hubbell, the project manager for IDNR, was responsible for obtaining project funding. Matt Nelson of The Nature Conservancy was responsible for initiating and formulating the scope of study. Their cooperation and assistance are greatly appreciated.

The views expressed in this report are those of the authors and do not necessarily reflect the views of the Illinois State Water Survey (ISWS) or the sponsors.

Several ISWS staff contributed significantly to the Cache River project through data analysis and report preparation. We are especially grateful to Richard Allgire, Laura Keefer, and Amy Russell for their contributions. Eva Kingston edited the report, and Linda Hascall reviewed and assisted in the preparation of the figures. Becky Howard prepared the camera-ready copy.

Hydrology of the Big Creek Watershed and Vicinity

This study focuses on the Big Creek watershed and the area where Big Creek drains into the Lower Cache River. Demissie et al. (1990a) and IDNR (1997) provide more complete descriptions of the hydrology, land use, and climate of the Cache River, and the reader is referred to these publications for additional information.

Location Relative to the Lower Cache River

The Big Creek watershed and the Lower Cache River are shown (figure 1). Big Creek has a drainage area of 51.7 square miles and flows into the Cache River at River Mile 24.1. Located east of the Big Creek confluence on the Cache River is Buttonland Swamp, which extends roughly from the Cache Chapel Road eastward toward the Cache River Levee, which separates the Lower Cache River from the Upper Cache River. Big Creek, Cypress Creek, and Mill Creek are the three major tributaries that drain the northern portion of the Lower Cache River watershed. Cypress Creek has a drainage area of 46.3 square miles and flows into the east side of the Buttonland Swamp at River Mile 29.4. Mill Creek has a drainage area of 53 square miles and flows into the Cache River at River Mile 15.0, but during major flood events Mill Creek is known to overflow into Indian Camp Creek, which enters the Cache River near the town of Ullin (mile 20.5).

Additional, smaller tributaries flow into the Cache River in this reach. The most significant of these smaller tributaries, Limekiln Slough, has a drainage area of 22.1 square miles and flows into the west end of Buttonland Swamp at River Mile 25.2.

The floodplain of the Cache River is constricted east of the mouth of Big Creek. Figure 2 shows the area of the floodplain at a constant elevation of 330 feet above the 1929 National Geodetic Vertical Datum (NGVD). Also shown are the locations of major road crossings along the Lower Cache River. The Cache River floodplain is much wider in the Buttonland Swamp area from Cache Chapel Road east to Route 37, but narrower to the west near Big Creek. For perspective, the elevation of the 2-year flood in this reach is roughly 332 feet NGVD. As will be discussed later, a significant amount of water is detained in Buttonland Swamp during flood events. In addition, Big Creek, Limekiln Slough, and Cypress Creek flow into the Lower Cache River at a high point along the channel of the river. Figure 3 shows a profile of the bottom elevation of the Cache River from Route 51 to the Cache River Levee. The profile shows that the elevation of the Cache River channel is highest in the reach between Big Creek (River Mile 24.1), and Cypress Creek (River Mile 29.4), which is the general location of Buttonland Swamp.

East of the Cypress Creek confluence, the Cache River has a downward slope toward the Cache River Levee to the east. The Cache River in this reach appears to flow east during virtually all types of flow conditions. During low and medium flow conditions, the center of Buttonland Swamp in the vicinity of Perks Road is normally the drainage divide between the two portions of the Lower Cache River that flow west and east (Allgire, 1991). During flood conditions, all or part of Buttonland Swamp flows to the west. The location where the flow divides to flow east or west is not constant and varies during an event (IDNR, 1997).

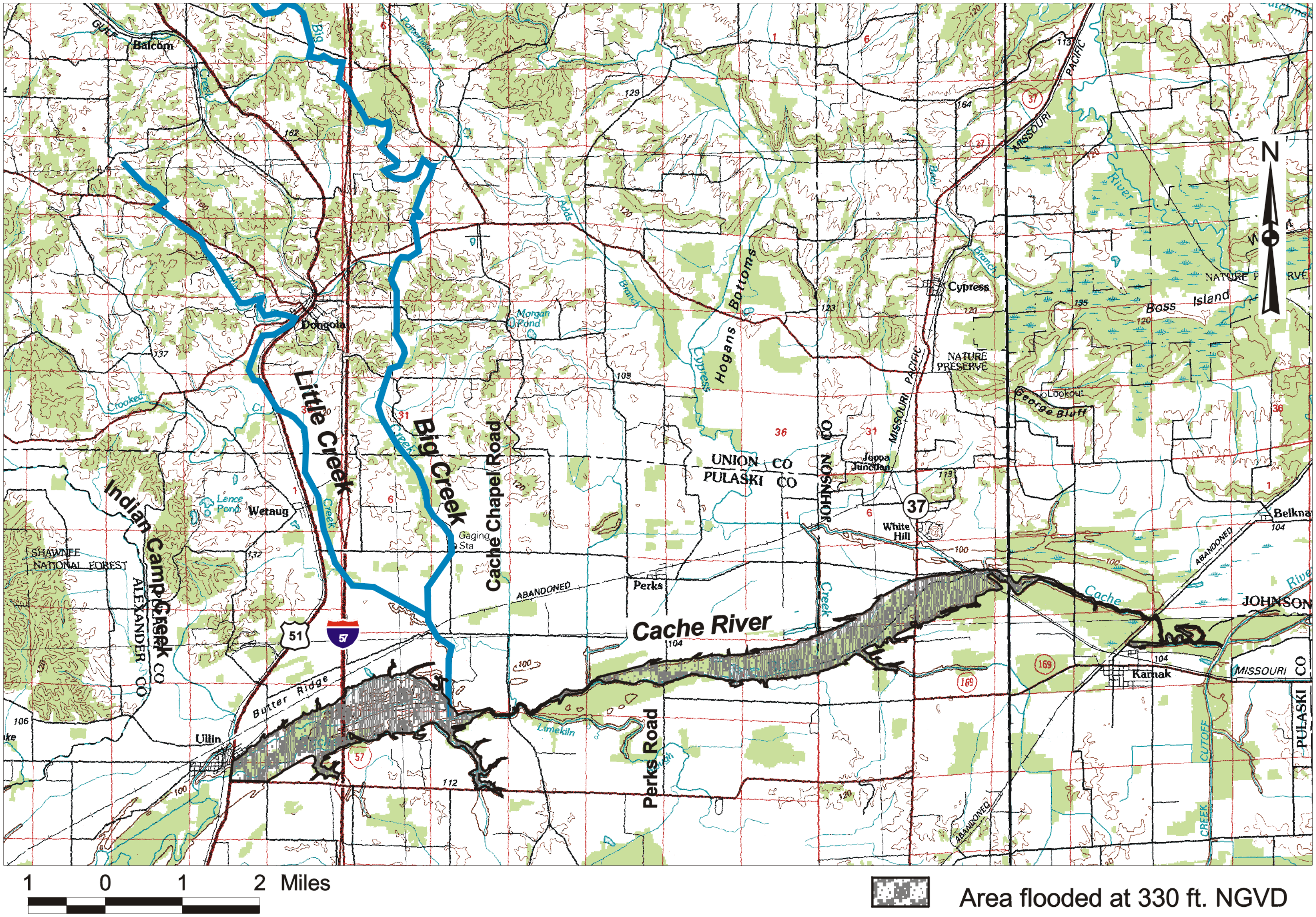


Figure 2. Area of the Lower Cache River floodplain flooded at an elevation of 330 feet NGVD

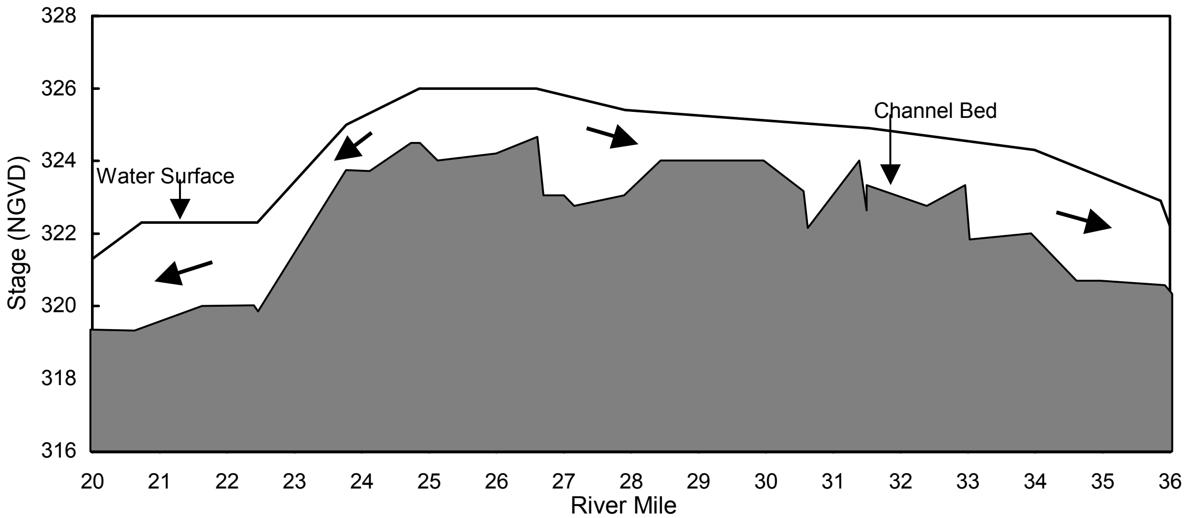


Figure 3. Channel bed profile for the Lower Cache River and direction of flow for low and medium flow conditions

Hydrologic Data

Precipitation Data

Available Records. There is one long-term precipitation record for the immediate vicinity of the Big Creek watershed, from the raingage at Anna. Daily precipitation has been recorded at this gage since 1896. The Illinois State Water Survey operated three additional gages from 1985-1993. The locations of these gages are identified as sites RG1, RG2, and RG3 (figure 4). Data from these gages were used in the hydrologic modeling of Big Creek, described later in this report.

Average Annual Precipitation. Figure 5 shows the annual average precipitation at Anna over the 100-year period of record, along with a 10-year moving average of precipitation. The long-term average annual precipitation at Anna is 47.3 inches, but average precipitation amounts have fluctuated from this long-term value over the years. The wettest 10-year period on record (1942-1951) had an average annual precipitation of 54 inches. The annual precipitation at Anna exceeded 71 inches in 1945 and 1950. During the two driest 10-year periods (1911-1920 and 1959-1968), the average precipitation was less than 43 inches. The lowest annual precipitation occurred in 1980 (30.4 inches). There is no apparent long-term trend in the average precipitation. The amount of rainfall is fairly uniform throughout the year. May has the highest average monthly rainfall (4.83 inches), and February has the lowest average rainfall (3.14 inches).

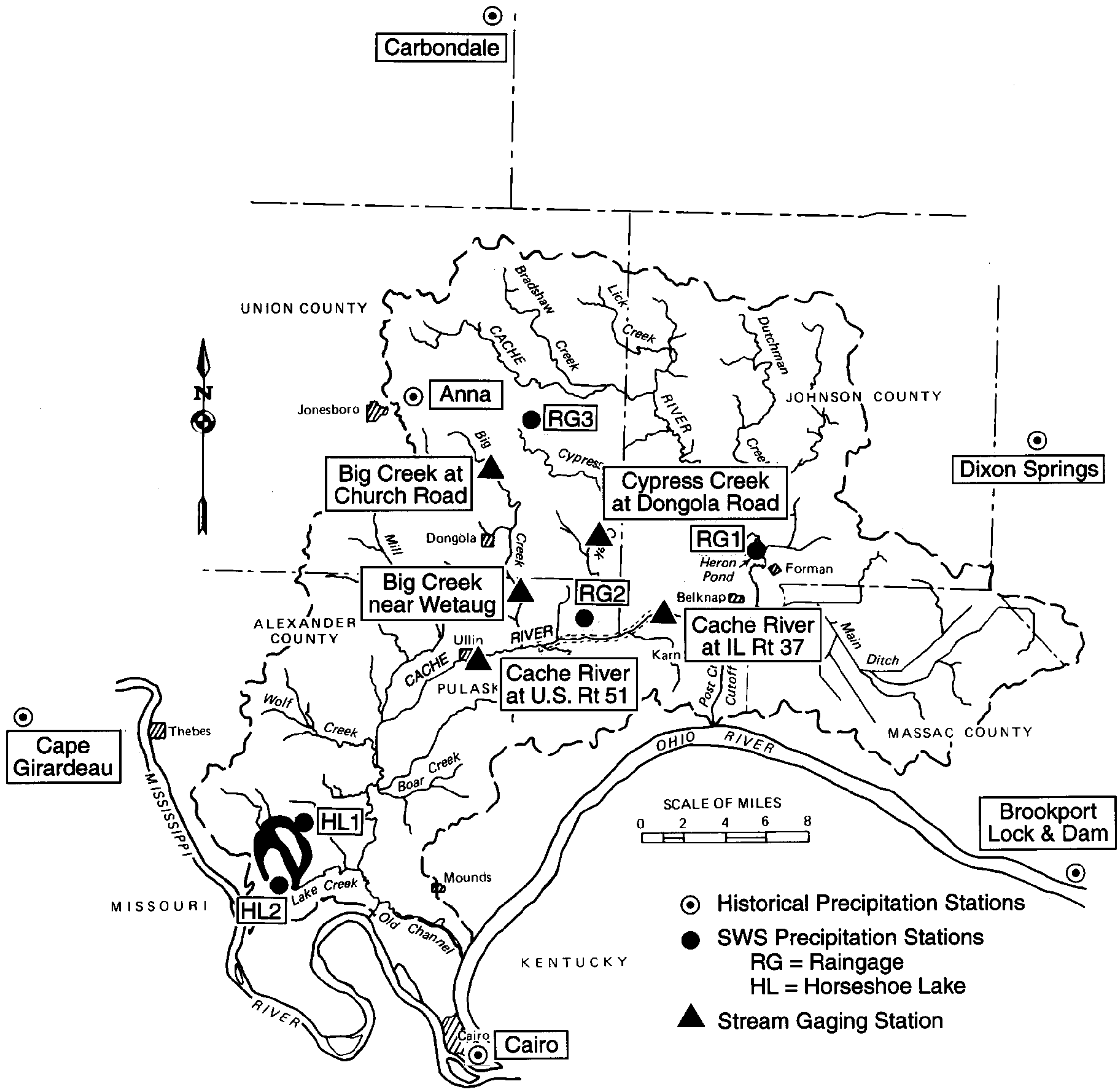


Figure 4. Locations of precipitation gaging stations near Big Creek and the Lower Cache River

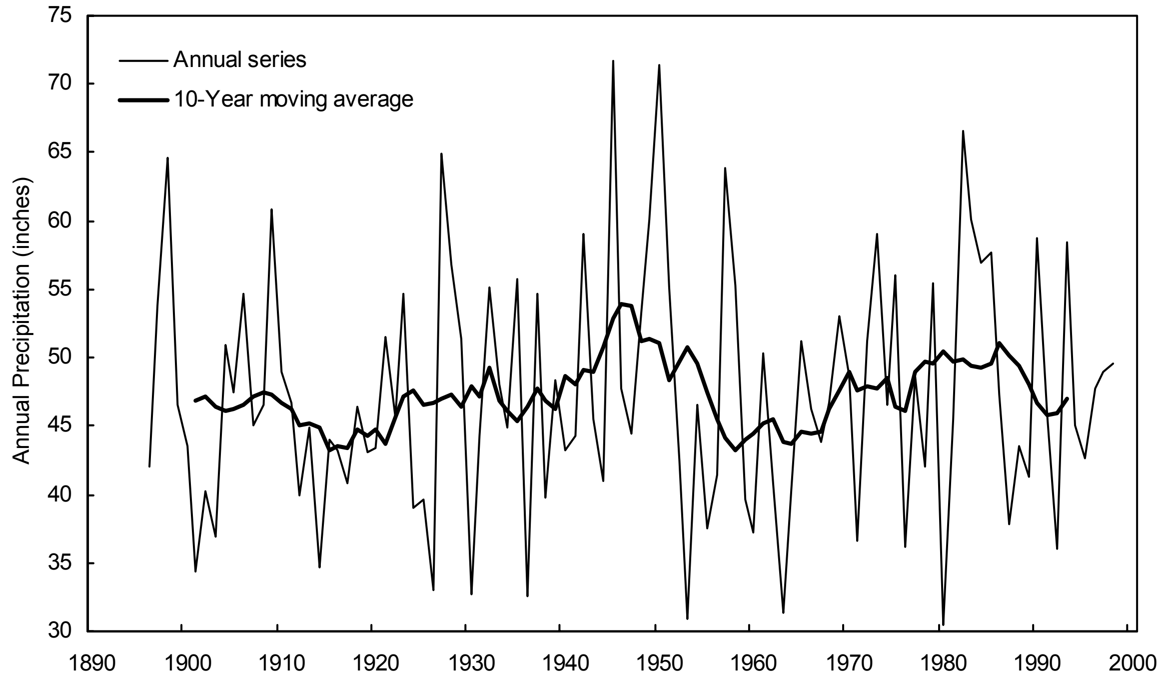


Figure 5. Annual precipitation and 10-year moving average of precipitation at Anna

Heavy Rainfall. Table 1 gives the frequency relationships for heavy rainfall, as determined by Huff and Angel (1989) for the Anna precipitation record and for the southern Illinois region. The frequencies of heavy rainfall for Anna and the region are very similar, although the regional estimate of the 100-year rainfall is 5 percent higher than the estimate for Anna.

Table 2 shows the occurrence by decade of heavy rainfall events at Anna as identified by daily rainfall amounts in excess of 3.5 inches, approximately a 2-year rainfall event. The occurrence of heavy rainfall has been fairly uniform over the period of record at the Anna gage, with the decades of the 1910s and 1980s containing the greatest number of heavy rainfall events. The two largest rainfall events occurred on January 22, 1999 (6.70 inches), and July 27, 1909 (6.15 inches).

Table 1. Recurrence Intervals of 24-hour Point Rainfall: Anna and Southern Illinois Region

Recurrence interval (years)	*24-hour rainfall, inches*	
	Anna	*Southern Illinois*
2	3.75	3.62
5	4.66	4.51
10	5.32	5.21
25	6.40	6.23
50	7.10	7.11
100	7.80	8.27

Source: Huff and Angel (1989)

Table 2. Number of Daily Rainfall Events Greater than 3.5 Inches

Decade	*Number of rainfall events*
1900s	4
1910s	7
1920s	3
1930s	5
1940s	4
1950s	4
1960s	2
1970s	5
1980s	7
1990s	4

Daily Streamflow Data

A continuous recording streamgage was operated by the U.S. Geological Survey (USGS) on Big Creek at Perks Road near Wetaug for 31 years, between October 1940 and September 1971. The Illinois State Water Survey (ISWS) resumed streamgage operation at the Big Creek site at Perks Road in April 1985. Big Creek at this gage location flows through a concrete weir; thus the discharge-stage relationship at the gage is essentially unchanged over the period of gaging. Discharge estimates for the 1940-1971 period of record conducted by USGS and the 1985-1998 period of record conducted by ISWS are summarized below. The drainage area of Big Creek at the gaging location is 32.2 square miles.

The ISWS established additional continuous streamgages in the Lower and Upper Cache River basins in 1985 and 1986 to monitor the hydrologic responses of different watershed areas (Demissie et al., 1990). Most gages were discontinued after only three years, but two gages, Cypress Creek at Dongola Road and the Cache River at U.S. Route 51, have been recording continuously since that time. The stage records from 1985 to 1989 were converted to daily discharges and reported in Demissie et al. (1990). The remaining data are being converted to daily discharge estimates. Additional stage data, not used to compute discharges, have been collected on the Cache River at Illinois Route 37 since 1986. A new continuous discharge gaging station was installed on Big Creek at Church Road near Dongola in 2000.

Figure 6 plots the average runoff for each year of record at the Big Creek gage near Wetaug. The mean flow over the composite period of record was 34.5 cubic feet per second (cfs), equivalent to an average annual runoff of 14.8 inches from the watershed. The maximum annual runoff was observed in 1950, with a runoff total in excess of 43 inches. The minimum annual runoff, approximately 5 inches, was observed in 1954.

A visual examination of figure 6 suggests a declining trend in the average flow. During the first ten years of record, 1942-1952, the average flow at the Big Creek gage was approximately 20 inches per year. In contrast, the average flow since 1953 has been

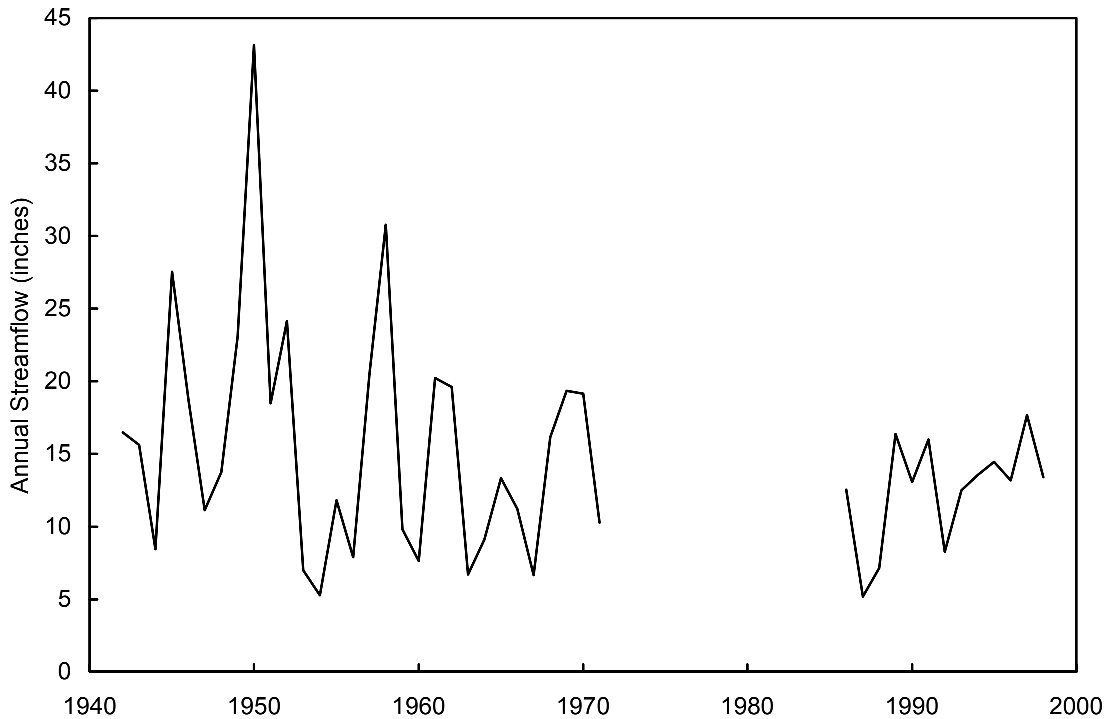


Figure 6. Annual streamflow for Big Creek near Wetaug, 1942-1971

approximately 13 inches per year. As a first step to examine the possible existence of a trend in streamflows, the annual streamflow at Big Creek was compared with the coincident annual precipitation, as observed at the Anna precipitation gage. Figure 7 gives this comparison between streamflow and precipitation, and separates the coincident records into three time periods: 1942-1952, 1953-1971, and 1986-1998. An examination of figure 7 indicates that the annual streamflow correlates well to the coincident annual precipitation. The period 1942-1952 experienced higher streamflows, but also had higher precipitation, with four years having an annual precipitation in excess of 55 inches. Thus, the general relationship of streamflow to precipitation during this time appears to be consistent with that observed for later years.

Figure 8 shows the flow duration curve for Big Creek for two periods: 1942-1971 and 1985-1998. The flow duration curve provides information on the distribution of flow amounts, giving estimates of the probability that selected flow amounts will be exceeded. The daily flows on Big Creek range from more than 500 cfs to less than 1 cfs. This large range of flows is typical of small watersheds in southern Illinois. However, unlike many other small gaged watersheds in this region of the state, Big Creek has a greater magnitude of sustained low flows during dry periods, such that zero flows on the creek are uncommon. Figure 8 shows a change in the flow duration curve between the two periods of gaging, 1942-1971 and 1985-1998. Streamflows since 1985 have a smaller range of flow conditions, with less probability of extremely high flows above 500 cfs, and less probability of extremely low flows below 1 cfs.

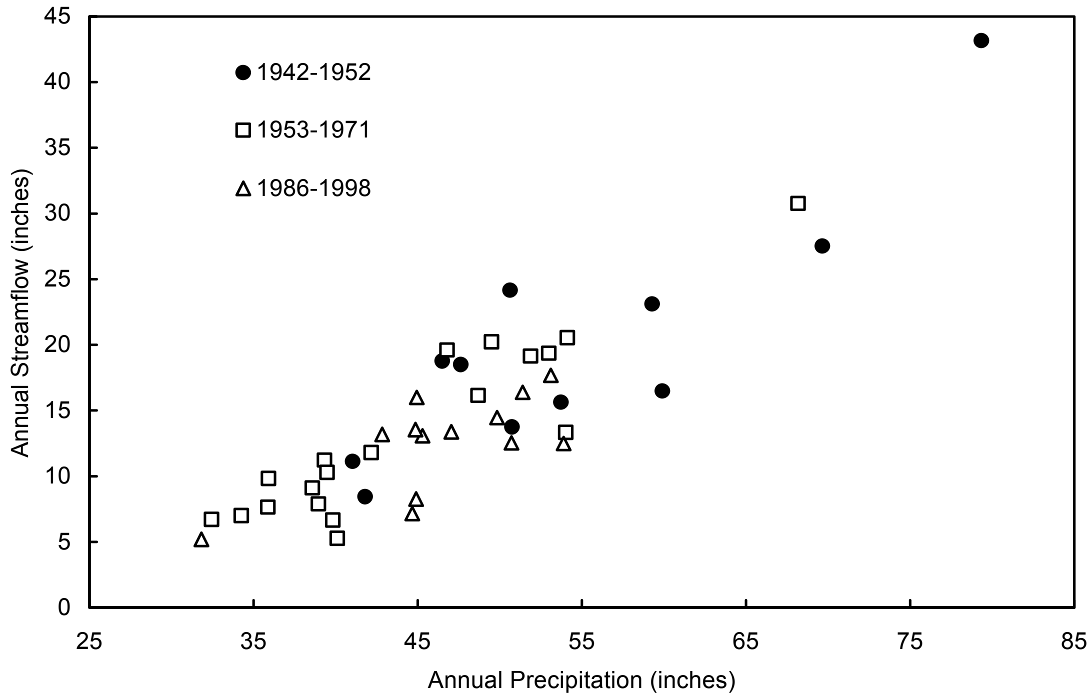


Figure 7. Comparison of annual streamflow with coincident annual precipitation

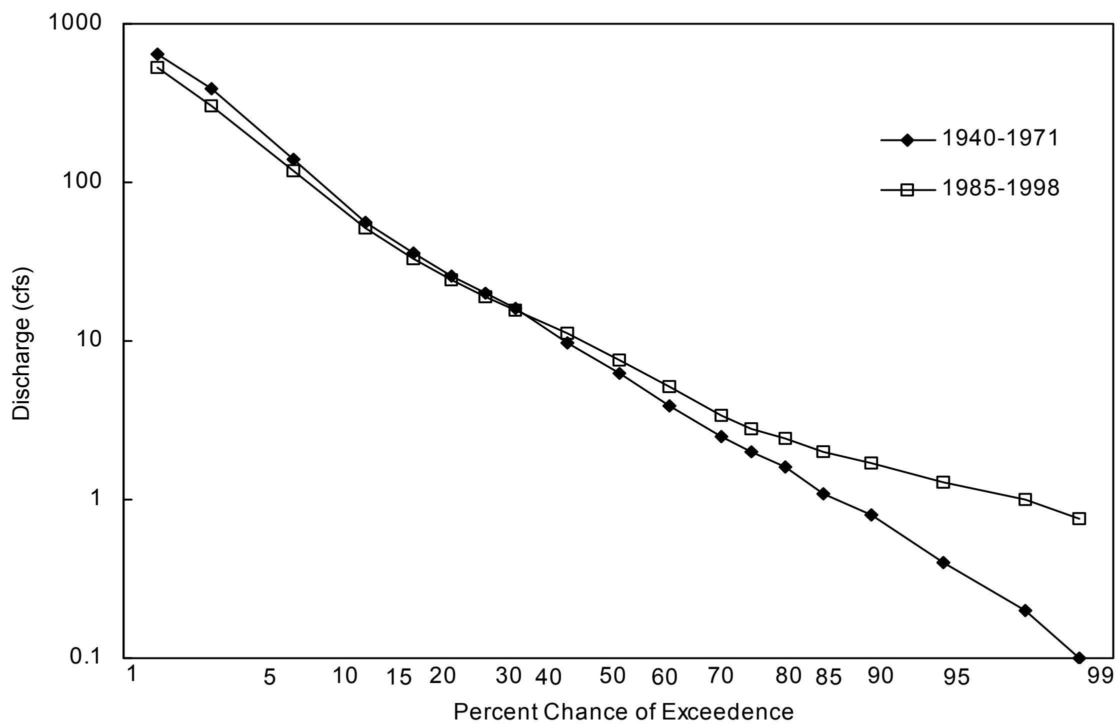


Figure 8. Flow duration curve of daily streamflows, Big Creek near Wetaug

Figure 9 shows the monthly distribution of flows at the Big Creek gage. Flows in Big Creek are highest during the period from December-May. Although flood events are somewhat more common in late spring and early summer, they have occurred during all seasons of the year.

Flood Peak and High Flow Data

The annual maximum flood stage at the Big Creek gage has been measured for 59 years, from 1941 to the present. Discharges associated with these peak stages are estimated using the rating curve established at the gage during its operation as a continuous recording gage. Figure 10 shows the annual series of peak discharges and there is a definite trend. The top three flood peaks were all observed during the first five years of gage operation. Following the initial ten years of record, there has continued to be a slight decreasing trend in the peakflows.

The 7-day high flow, the highest average flow measured during a 7-day consecutive period during any one year, is used to provide additional information concerning the volume of flood flows from Big Creek. Figure 11 plots the annual 7-day high flows for the two gaging periods: 1941-1971 and 1985-1998.

From both figures 10 and 11, it is clear that Big Creek has experienced a notable reduction in both flood peaks and flood volume. The cause-effect relationship associated with the reduction in flood peaks and flood storage is not known and was not investigated as part of this study. However, as illustrated in table 2, there does not appear to be any noticeable change in the occurrence of heavy rainfall events that may produce major flooding.

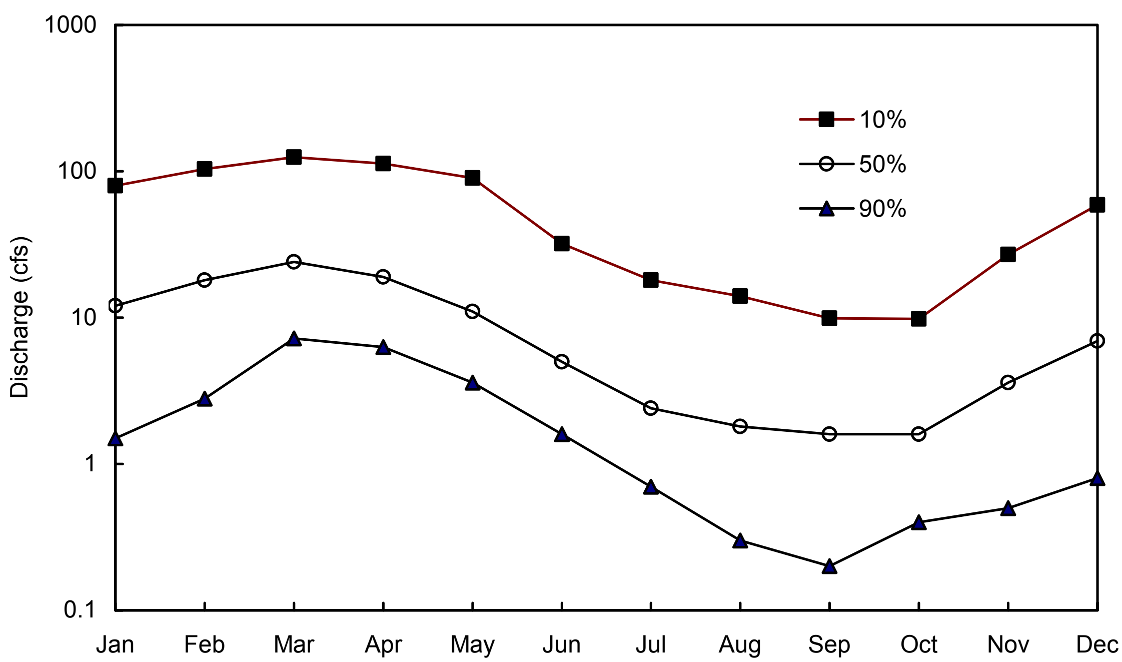


Figure 9. Monthly distribution of streamflows, Big Creek near Wetaug

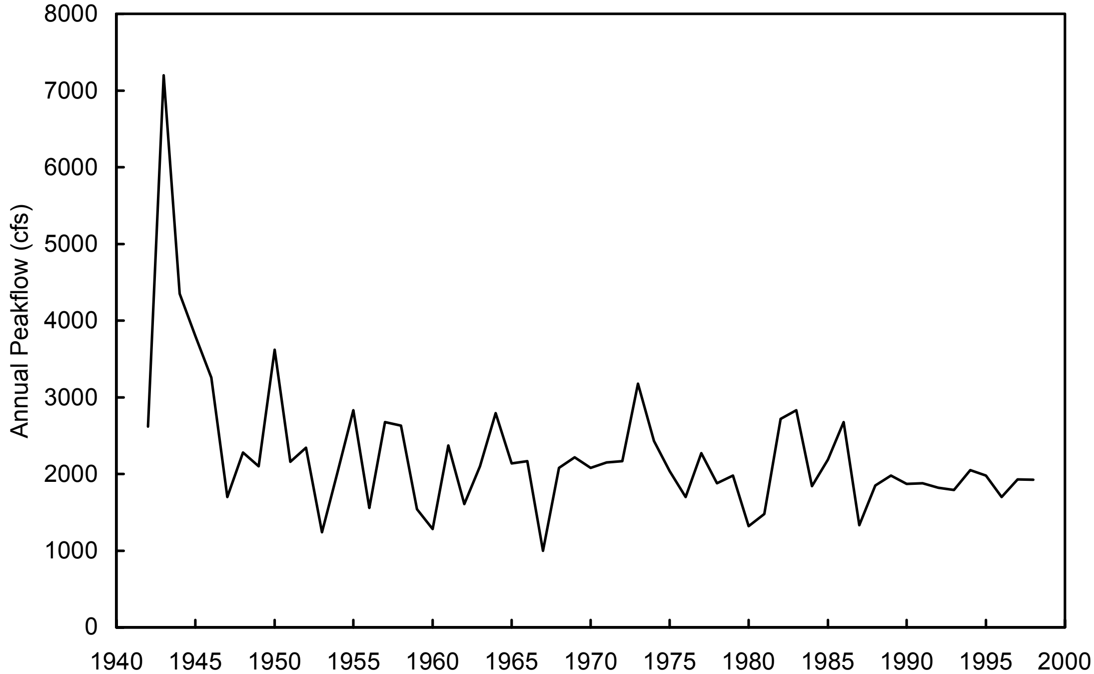


Figure 10. Annual peakflows for Big Creek near Wetaug

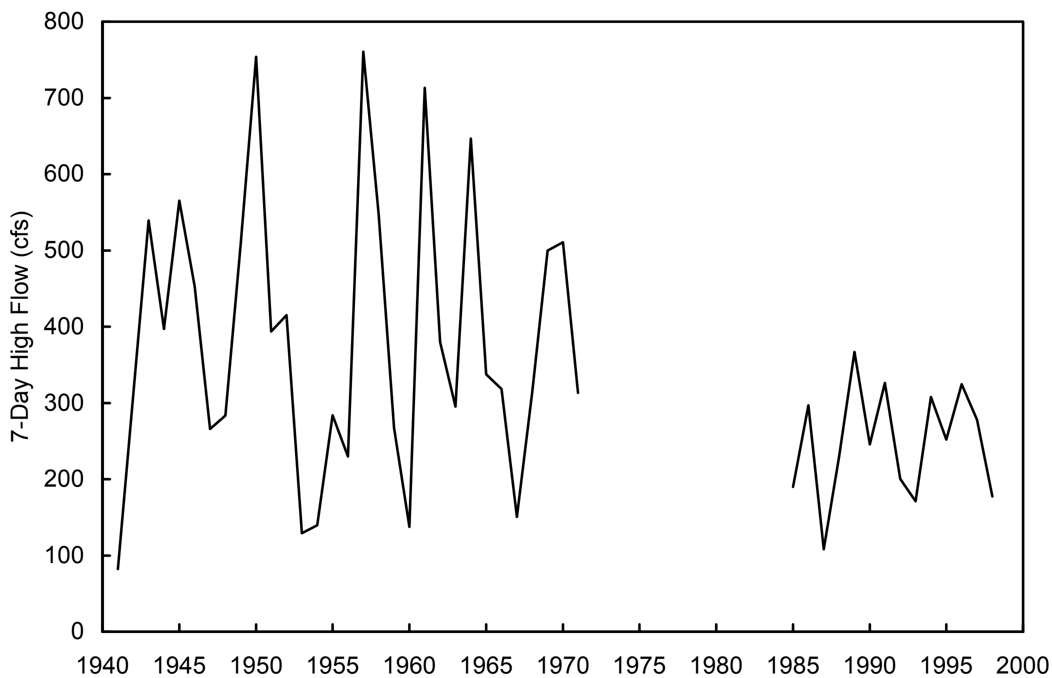


Figure 11. Annual 7-day high flows for Big Creek near Wetaug

Flood Frequency. To determine the peakflow rates for each flood event, a frequency analysis was performed using the Hydrologic Engineering Center Flood Frequency Analysis software (HEC-FFA). The results of the flood frequency analysis are given in appendix A. The 2-, 5-, and 100-year peakflows calculated for Big Creek were 2,100, 2,800, and 5,200 cfs, respectively. The impact of flooding trends on these flood frequency estimates was not examined.

Historical daily data from each major event were examined to provide a qualitative assessment of the corresponding volume of runoff expected with each of the flood events. To estimate the expected volume corresponding to the 100-year flood, the daily flow data from all major flood events were examined. The stormwater volumes for each event were determined as the total flow over the 4-day flood hydrograph minus the baseflow, which was estimated at the beginning of the flood event. The volumes for the four events with the largest volume were 8,328, 7,710, 7,326, and 7,070 acre-feet. A total runoff of 8,000 acre-feet is roughly equivalent to 4.6 inches of runoff over the entire watershed.

To estimate the runoff volume associated with the 5-year event, seven storms with peakflows between 2,600 and 3,000 cfs were examined, and their median runoff was determined to be 2.2 inches. To estimate a runoff volume for the 2-year event, ten storms with peakflows between 2,000 and 2,200 cfs were examined, and their median runoff was determined to be 1.6 inches.

Stage Data on the Mississippi and Ohio Rivers

During flood events on either the Mississippi or Ohio Rivers, water will back up from the Mississippi River into the channel and floodplain of the Cache River. During extreme flood events on these rivers, the backwater potentially can affect the portion of the Lower Cache River near the Big Creek confluence. Thus, it was necessary to determine the potential impact of the backwater for use in modeling floods in the vicinity of Big Creek and Buttonland Swamp.

Water level data on the Ohio River at Cairo were examined to determine if floods in the Big Creek vicinity occur concurrently with, or experience other impacts from backwaters from the Mississippi and Ohio Rivers. The gage location is near the confluence of the two big rivers. Elevation data on the Mississippi River near the mouth of the Lower Cache River were not available for analysis. Flood elevations at the mouth of the Lower Cache River can be 5-6 feet higher than at Cairo. Figure 12 compares the peak discharges at the Big Creek gage with the concurrent stages recorded at Cairo. When Big Creek is experiencing a major flood, the stages at Cairo are typically in the range of 305-315 feet in elevation (NGVD). High water on the Mississippi and Ohio Rivers has occurred at the same time as selected floods on Big Creek. However, in general, it is unlikely for the Lower Cache River to be experiencing significant backwater effects from the Mississippi and Ohio Rivers at the same time that the watersheds in the vicinity of Big Creek are flooding.

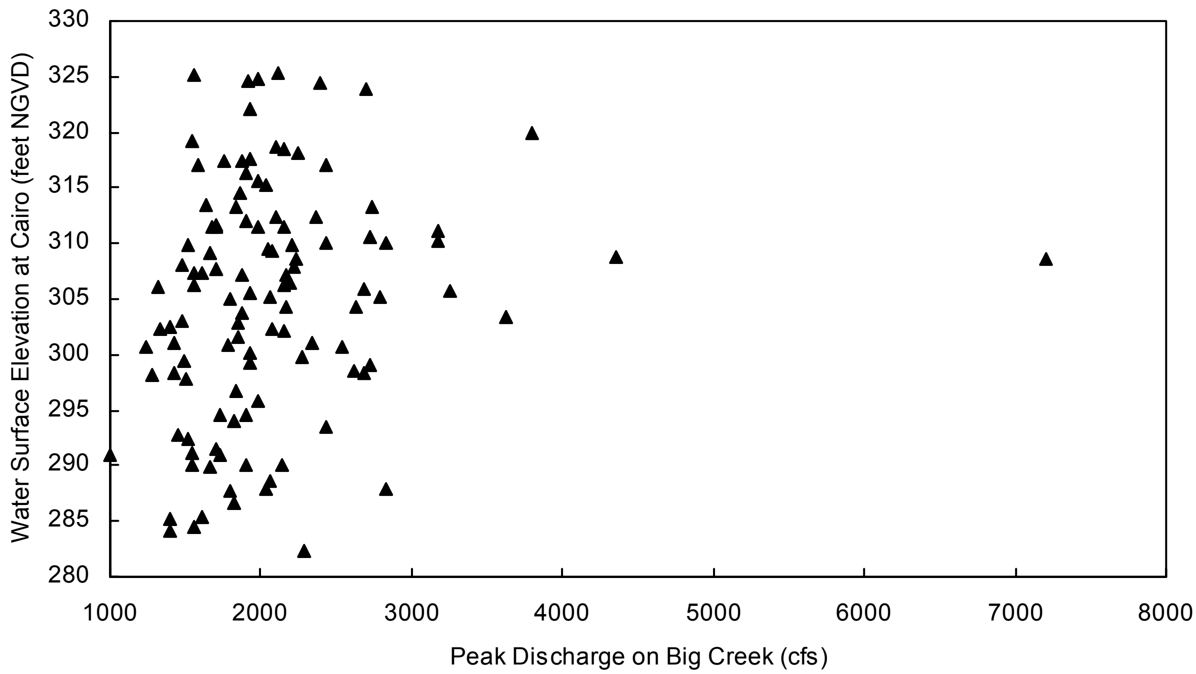


Figure 12. Annual peak discharges for Big Creek and concurrent river stage at Cairo

Alternatives Considered for Reducing or Eliminating Reverse Flows

Several alternatives were considered for reducing peakflows from the Big Creek watershed into the Lower Cache River, or causing some other change to reduce or eliminate the reverse flows that occur on the Cache River directly to the east of the Big Creek confluence. Two basic types of alternatives were considered for the analysis: detention storage of flood waters and the diversion of Big Creek. A total of 23 detention alternatives were considered, as described fully in appendix B. These alternatives included:

- a large number of small ponds located in the headwaters of the Big Creek watershed,
- detention created by weirs located in smaller subwatersheds of Big Creek,
- detention created by weirs located on the main stem of Big Creek,
- a large detention basin located in the Cache River valley near the confluence of Big Creek with the Cache River, and
- various combinations of the above detention options.

Two alternatives were examined relating to the possible diversion of Big Creek. The first alternative considers the case where all flow on Big Creek is diverted to the west when it reaches the floodplain of the Cache River. Hydrologic and hydraulic modeling were used to simulate the alternative where Big Creek is redirected to enter the Cache River downstream of the existing confluence, at a location west of Interstate 57 and east of Route 51. The proposed diversion channel was located far enough downstream of the existing Big Creek confluence such that there would be no backwater or reverse flow impact from the diversion channel into Buttonland Swamp. Figure 13 shows the proposed location of the diversion channel. More detailed design and analysis would be required to site such a diversion channel in the best possible location if this alternative is selected. The second type of diversion, termed split flow, maintains the present Big Creek channel for conveying low and medium flows to the Cache River, but most high flows are diverted to the diversion channel previously described.

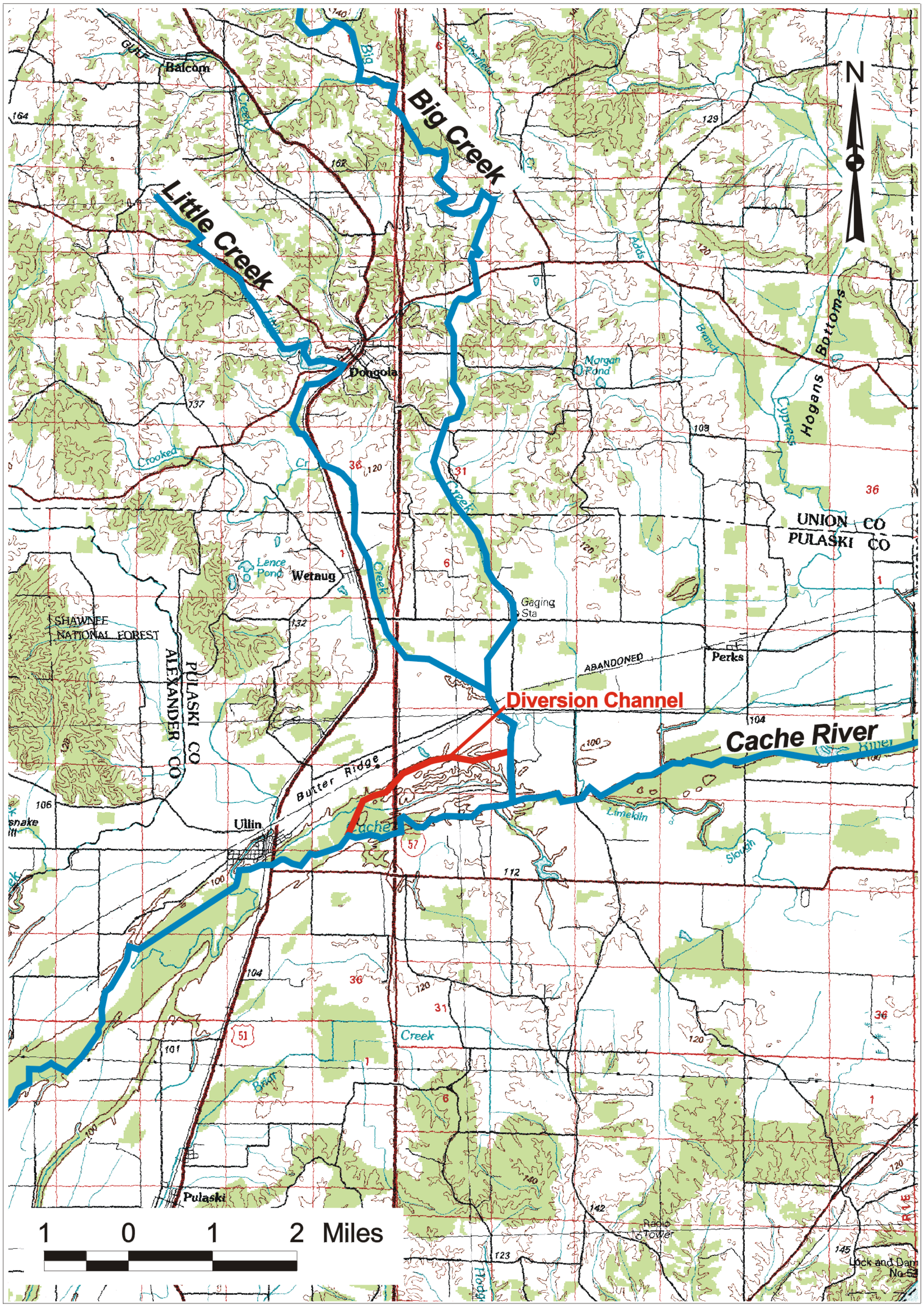


Figure 13. Location of the channel used for the diverted flow alternative

Precipitation-Runoff Modeling of the Big Creek Watershed

The first step in the analysis was to simulate the rainfall-runoff process in the Big Creek watershed and other tributaries to the Lower Cache River. The HEC-1 Flood Hydrology Package, developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center (HEC, 1990), was chosen as the hydrologic model for the watershed. In 1990, the Illinois State Water Survey (ISWS) applied the HEC-1 model to the portion of the Cache River watershed between Route 51 and the Cache River Levee (Demissie et al., 1990b). Figure 14 shows the location of the area modeled using the HEC-1 model, and figure 15 shows a schematic of the individual tributary areas simulated in that model. For the modeling of the Big Creek and Little Creek tributaries, the subwatersheds shown in figure 15 were subdivided into smaller watershed units, which are described in appendix B.

Based on the examination of the 1990 Cache River application of the HEC-1 model, and the availability of new data, it was decided to update and reevaluate the application. New precipitation and streamflow data were used for the update, certain model parameters were recalibrated, and the Big Creek and Little Creek tributary areas were subdivided. Subdividing these two tributaries was necessary to evaluate all of the detention storage alternatives discussed later in this report.

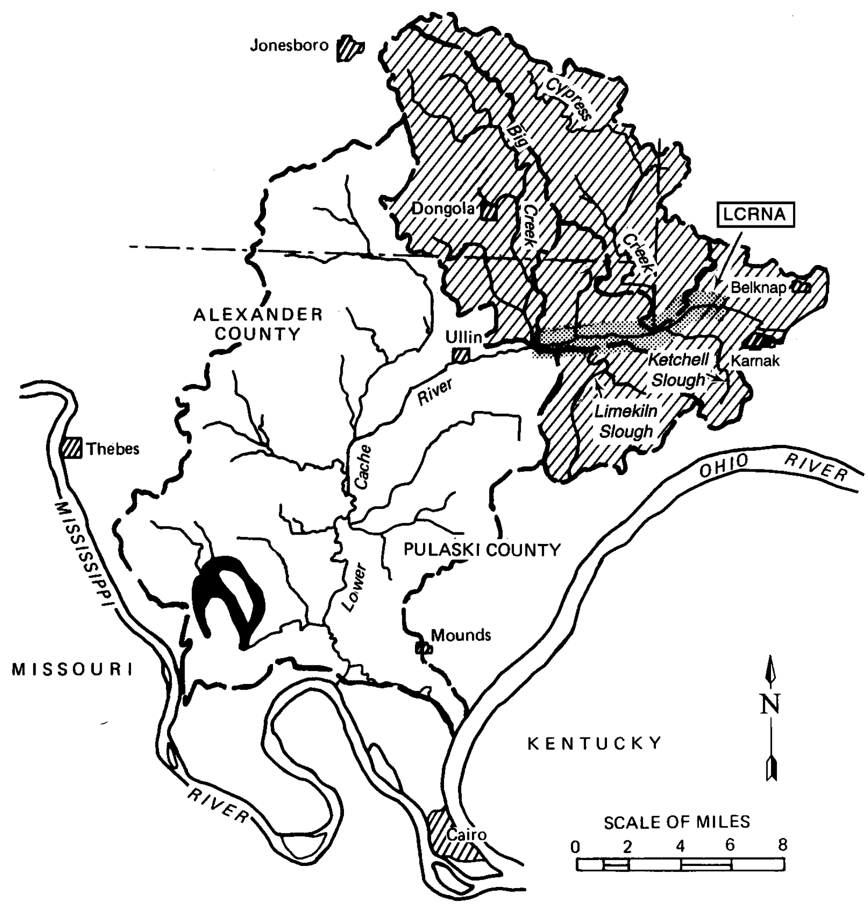


Figure 14. Subbasins of the Lower Cache River modeled using HEC-1

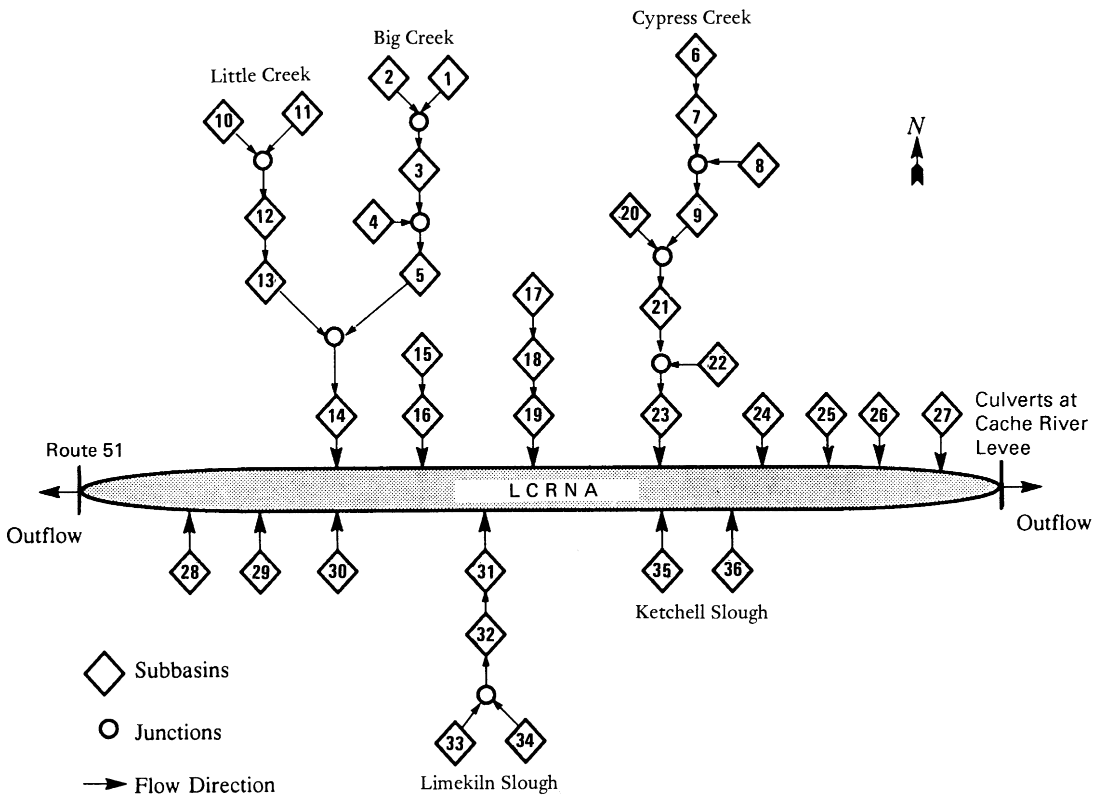


Figure 15. Schematic representation of the HEC-1 tributary areas and their interconnection in the Lower Cache River watershed

Table 3 shows some of the physical parameters for each tributary area identified in figure 15, as measured for use in the 1990 modeling study. There have not been any substantial changes in those watershed characteristics used by the model, those being the lengths and slopes of the overland and channel flow elements. Thus, there was no need to modify these parameters from the values used in the 1990 HEC-1 model. Other parameters used in the HEC-1 model, such as overland roughness, channel roughness, and the runoff curve number, are calibrated values that may change depending on both land-use changes and the data used for calibration.

Also shown in table 3 are some of the physical parameters for the tributary subdivisions of the Big Creek and Little Creek watersheds. The locations of these subdivisions are described in appendix B. In the modeling process these subdivisions replace the tributary areas used in the 1990 HEC-1 model. For example, subdivisions 2A, 2A1, 2B, 2B1, 2B2, 2B3, and 2C replace tributary area 2 in the model.

Model Recalibration

The HEC-1 model parameters were recalibrated for the Big Creek watershed. This watershed is of greatest interest for this study, and also has the most additional data from which to re-examine the model calibration. In the 1990 modeling effort, three storms were used for

Table 3. HEC-1 Characteristics of Tributary Areas in the Lower Cache River Watershed

		Main Channel		*Overland Plane #1*			*Overland Plane #2*		
Tributary unit	*Area (mi^2)*	*Length (ft)*	*Slope (ft/ft)*	*Length (ft)*	*Slope (ft/ft)*	*Percent*	*Length (ft)*	*Slope (ft/ft)*	*Percent*
1	7.98	32257	0.0062	6874	0.0135	42	8619	0.0168	58
2	8.46	37396	0.0061	5907	0.0142	70	2650	0.0254	30
3	4.83	26030	0.0012	4526	0.0039	40	3699	0.0066	60
4	4.09	20631	0.0078	7746	0.0129	100			
5	5.99	21063	0.0094	4817	0.0088	37	10132	0.0075	63
6	5.55	33650	0.0068	4479	0.0199	52	4296	0.0127	48
7	6.22	318684	0.0018	4869	0.0245	59	4140	0.0203	41
8	3.9	9730	0.0154	5223	0.0236	100			
9	8.65	22848	0.0008	8385	0.0115	54	9457	0.011	46
10	5.97	29045	0.0082	7187	0.0171	60	7703	0.0129	40
11	4.13	26972	0.0088	5281	0.0184	69	2167	0.038	31
12	2.74	11000	0.0016	3245	0.0153	33	4745	0.0189	67
13	3.5	8660	0.001	12651	0.0086	63	4918	0.0113	37
14	2.36	6474	0.0003	10364	0.0018	62	13547	0.0022	38
15	1.64	10265	0.0058	2705	0.0246	58	3028	0.019	42
16	1.95	10740	0.00093	3057	0.001	48	4280	0.00023	52
17	3.86	15052	0.0073	8214	0.0058	65	3380	0.0073	35
18	1.68	6752	0.00015	4833	0.00021	59	6733	0.00015	41
19	3.44	6933	0.0013	16008	0.00013	100			
20	8.14	37622	0.0027	4722	0.0168	51	5415	0.0196	49
21	7.3	27626	0.00054	4117	0.0054	29	8136	0.0058	71
22	5.21	19416	0.006	4321	0.0265	33	8299	0.011	67
23	1.37	7500	0.0008	7450	0.0008	100			
24	0.74	6381	0.0156	2545	0.015	62	2990	0.0216	38
25	2.58	12466	0.0056	6049	0.0132	41	6006	0.0182	59
26	0.86	8023	0.0086	4828	0.004	49	2964	0.0218	51
27	2.52	13629	0.0007	2792	0.059	25	10681	0.0009	75
28	0.58	5000	0.0144	1360	0.0051	100			
29	2.77	13975	0.0052	3665	0.0182	44	3826	0.0197	56
30	2.78	8060	0.0089	3378	0.0139	32	3391	0.0137	68
31	1.96	13781	0.00015	5052	0.0069	100			
32	2.74	12573	0.0055	10215	0.0041	100			
33	8.07	27347	0.0044	6628	0.0124	52	6215	0.0101	48
34	9.31	24609	0.0016	10461	0.0081	53	9111	0.0058	47
35	0.73	4808	0.0021	2995	0.015	100			
36	10.9	33552	0.0027	7982	0.0067	53	5845	0.0067	47

model calibration for Big Creek. For the current study, 17 storms were chosen at random from periods for which good rainfall and discharge data were available. All storms chosen for calibration occurred within the period 1987-1992, a time during which the ISWS was operating three precipitation gages in the vicinity along with the streamgage on Big Creek near Wetaug. Each selected storm event has a corresponding peakflow rate of at least 500 cfs, as measured at the Big Creek gage.

The recalibration of the Big Creek subwatershed in the HEC-1 model is described in greater detail in appendix C. The storms used for recalibration include a broad range of climatic and antecedent conditions, such as soil moisture, land cover, and baseflow, that exist in the watershed prior to the onset of each storm. Based on a comparison with the earlier calibration, the newer parameters values (overland roughness, curve number, and channel roughness) are expected to be superior for flow simulation.

Except for Cypress Creek, all other watersheds draining to the Cache River were ungaged. Because the flow record for the Cypress Creek gaging station is under development, these data were not available for modeling, and recalibration was limited to the Big Creek watershed. Two options were available for the application of the HEC-1 model to the remainder of the watersheds. The first option was to use the parameters applied to the 1990 version of the HEC-1 model. The second option was to adopt the parameters developed for Big Creek for use on all other watershed areas. The second approach was adopted because there was greater confidence in the recalibrated parameters. Full recalibration of Cypress Creek and other watersheds could be performed in the future as sufficient data and resources become available.

Simulation of Flood Flows for Big Creek and Other Cache River Tributaries

To estimate the relative impact of Big Creek flood flow on the Cache River hydraulics, it was also necessary to model the flood flows for all other tributaries that contribute to the flow dynamics of the Lower Cache River. The 1990 version of the HEC-1 model was used to simulate the flows of all tributaries to the Lower Cache River upstream of Route 51 for three flood conditions: the 2-, 5-, and 100-year floods. Appendices A and C present a detailed description of the precipitation values and parameters used in the HEC-1 model to develop these flood flows. Figure 16 presents the 2-, 5-, and 100-year hydrographs for Big Creek, as estimated by the model.

For the current study, it was also necessary to estimate inflows to the Cache River for tributaries located downstream of Route 51. For example, the 2-year inflow hydrograph for Mill Creek was assumed to be the same as the 2-year Big Creek hydrograph computed by the HEC-1 model. This type of assumption was considered acceptable for the current study since the primary area of concern is well upstream of these estimated inflows and a detailed analysis of the downstream portion of the Lower Cache River was not in the scope of the study.

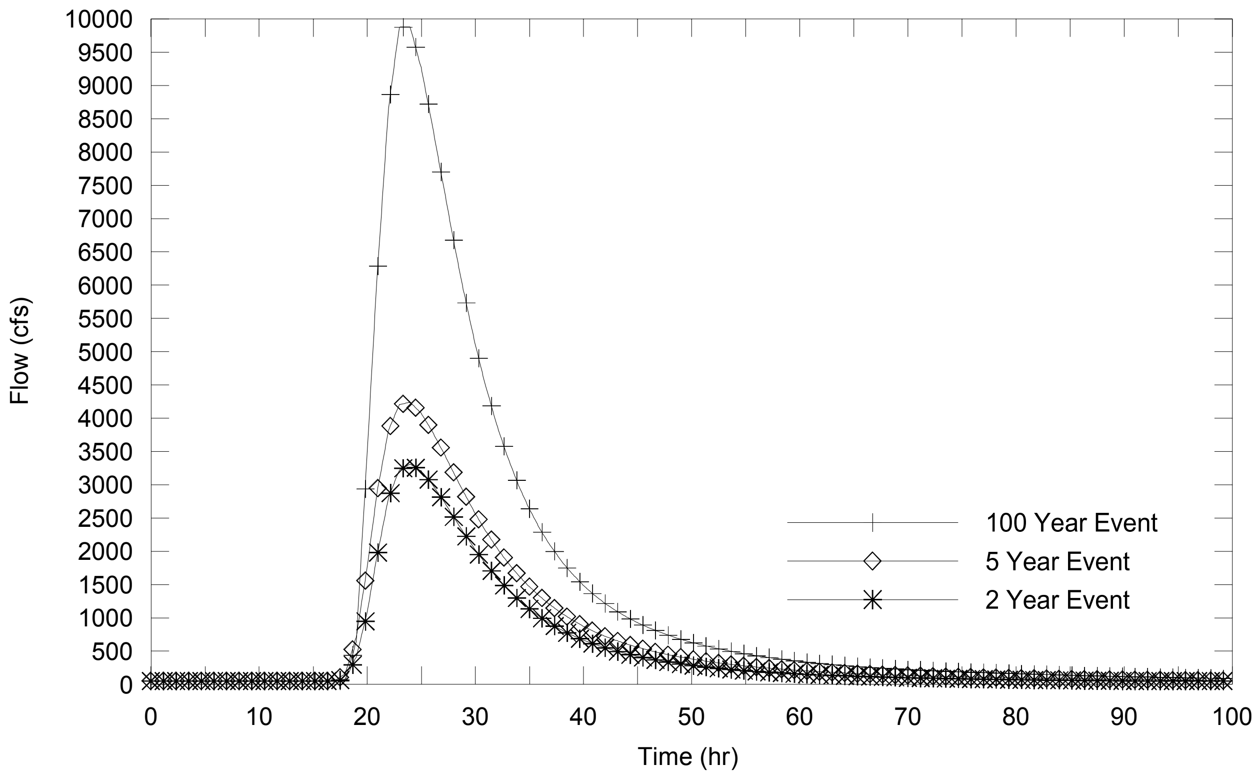


Figure 16. Simulated hydrographs for 2-, 5-, and 100-year floods at the mouth of Big Creek

Impact of Detention Storage on Big Creek Flows

The impacts of detention storage on the streamflow hydrographs from the Big Creek watershed were analyzed using the HEC-1 model. A total of 23 detention alternatives were examined, as discussed earlier in this report. The simulated impacts of all 23 alternatives on Big Creek flows are detailed in appendix B. Many of the detention alternatives examined in this study provide similar flood reduction impacts on Big Creek. Four alternatives, listed below, were selected for presentation and additional analysis. The alternatives selected are not necessarily the most desirable detention options, but rather provide examples of the range of impacts on the Big Creek flows.

- Alternative 10 (Big Creek detention) provides 825 acre-feet of storage on the mainstem of Big Creek.
- Alternative 16 (Cache valley detention) provides 810 acre-feet of storage in the Lower Cache River valley.
- Alternative 20 (Big Creek and Cache valley) combines alternatives 10 and 16.
- Alternative 23 (Many Ponds) provides up to 199 acre-feet of storage on 23 smaller ponds in the headwaters of Big Creek.

The primary focus of the analysis presented in this report was the reduction of peakflows at the mouth of Big Creek as it flows into the Lower Cache River. Figure 17 compares the Big Creek flow hydrographs associated with each of these four alternatives based on a simulation of the 2-year flood event. The simulations indicate that the four selected alternatives reduce the peak discharge at the outlet of Big Creek by 31 to 56 percent. The largest reduction in discharge is provided by the construction of two detention facilities on the mainstem of Big Creek and in the Lower Cache River valley. The smallest reduction in discharge, 31 percent, is provided by the 23 smaller detention ponds located in the headwaters of the watershed.

Other alternatives presented in appendix B address the combined impact of three to five medium-sized detention facilities located on various tributary streams. As indicated by those modeling results, it may be concluded that the ability of an individual facility to reduce peakflows immediately downstream is not directly related to its impact at locations farther downstream, such as at the mouth of Big Creek. In choosing locations for detention storage that will have the greatest downstream impact, it is very important to ascertain the expected timing of runoff from individual watersheds and the joint impacts of combinations of facilities.

The HEC-1 model was used to simulate the flood reduction impacts of the four alternatives on the 2-, 5-, and 100-year hydrographs at the mouth of Big Creek. Table 4 lists the peak discharge associated with each alternative and each of these flood events, as well as for the October 4, 1990 event. An examination of table 4 indicates that the reduction in peakflows ranges from 29 to 62 percent, depending on the alternative and size of the event, with an average

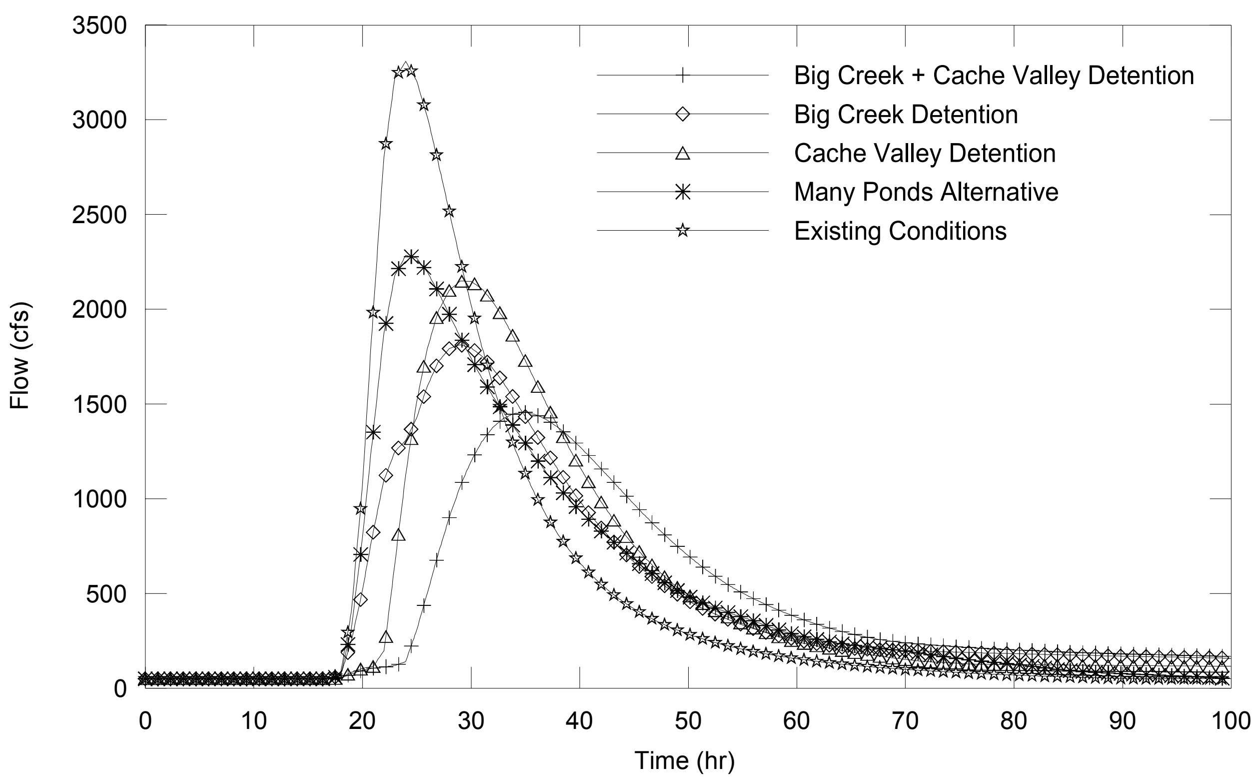


Figure 17. Simulated impact of four detention alternatives on flows at the outlet of Big Creek; 2-year simulated flow

Table 4. Impact of Detention Storage on the Peak Discharge for Various Flood Events at the Mouth of Big Creek

	Flood (cfs)			
Alternative	*10/04/1990*	*2-year*	*5-year*	*100-year*
Existing condition	2,060	3,306	4,237	9,876
Alternative 10	842	1,812	2,534	5,830
Alternative 16	1,202	2,147	2,819	5,046
Alternative 20	638	1,453	2,035	4,112
Alternative 23	1,466	2,283	2,907	5,011

reduction of 40 percent. For all alternatives, the absolute reduction in peakflows increases as the size of the flood event increases, i.e., from the 2-year event up to the 100-year event. However, the percentage reduction from the 2-year to the 100-year event varies depending on the detention alternative. For example, for the two alternatives that use Big Creek detention (alternatives 10 and 20), the percent reduction in peakflows decreases as the size of the event increases. Conversely, for alternatives 16 and 23, the percentage reduction in peakflows increases from the 2-year event to the 100-year event. For alternative 23, the percent reduction in peakflow increases from 29 percent for the October 4, 1990 event to 49 percent for the 100-year event. These relative changes in the effectiveness of all detention storage alternatives are in part related to the selected pond size, and to some degree can be altered through changes in pond design.

To determine the effects of the reduced peak inflows on the Cache River, additional analysis using an unsteady flow routing model was required. The results of this analysis are presented later in this report in the section "Impact of Alternatives on the Lower Cache River Flow Dynamics."

Unsteady Flow Modeling of the Lower Cache River

In situations where the flow hydraulics are complex, resulting in reverse flows, and where the channel slopes are very low, the hydraulics of flow were analyzed using an unsteady flow, dynamic wave routing model. The UNET model (HEC, 1997), developed and maintained by the U.S. Army Corps of Engineers, was chosen as the tool to analyze the flow dynamics in the Lower Cache River. The St. Louis District of the Army Corps of Engineers had previously developed several sets of data for use in UNET modeling on the Lower Cache River, including cross-sectional data of the channel and floodplain geometry (USCOE, 2000). No additional surveying was performed, and the channel and floodplain cross sections were not changed for the present modeling effort. The input files used for the present study were essentially the same as those obtained from the St. Louis District of the Army Corps of Engineers, with minor parameter adjustments so that the model's equations would yield a solution under a greater variety of inflow conditions. The UNET data files were modified to input hydrographs computed from the HEC-1 model. Table 5 shows the location of important features included in the Cache River UNET model.

Table 5. Locations of Major Features Included in the Cache River UNET Model

River Mile	*Feature*
0.000	Outflow to Mississippi River
4.500	Illinois Route 3
5.100	Estimated inflow for watershed below Mill Creek
13.200	Township Road at Sandusky
15.000	Estimated inflow for Mill Creek
20.500	Estimated inflow for Indian Creek w/ overflows from Mill Creek (sub 28)
20.600	Illinois Central Gulf RR
20.700	U.S. Route 51
21.677	Big Creek Diversion (split flow and diverted models only)
22.400	HEC-1 modeled inflow (sub 30)
22.407	Interstate 57
22.447	HEC-1 modeled inflow (sub 29)
24.100	Big Creek (split flow and existing models only)
24.838	Cache Chapel Road
25.100	HEC-1 modeled inflow (subs 15,16)
25.160	HEC-1 modeled inflow for Limekiln inflow (sub 31)
27.131	Perks Road
27.155	HEC-1 modeled inflow (subs 17,18,19)
29.400	Cypress Creek
29.976	HEC-1 modeled inflow for Ketchell Slough inflow (subs 35,36)
30.618	Illinois Route 37
31.399	HEC-1 modeled inflow (sub 24)
31.505	Chicago and Eastern Illinois RR
31.573	HEC-1 modeled inflow (sub 25)
32.959	HEC-1 modeled inflow (sub 26)
33.003	Bridge 0.5 mile west of NY Central RR
33.990	HEC-1 modeled inflow (sub 27)
35.900	Culverts at Cache River Levee

Evaluation of the detention storage alternatives using the UNET model involved changing the input hydrographs for the Big Creek inflows, but did not require any additional modification of the UNET model. Modification was required, however, for the evaluation of the diverted and split flow alternatives. In the diverted flow alternative, the lower end of the Big Creek channel was routed through a proposed channel to a point on the Cache River approximately midway between Route 51 and Interstate 57. In the split flow model, the existing Big Creek channel was maintained while the diversion channel was added. This allows the flow from Big Creek to separate and flow to the Cache River in two paths.

Model Assumptions and Limitations

This UNET modeling analysis should be used as a feasibility study with the results providing a general view of the flow dynamics under different conditions. Specific alternatives must be studied in greater detail for consideration in project designs. Aside from a general site visit, no additional fieldwork or surveying was performed by the Water Survey. Estimates of stage – surface area curves for use in the detention storage analyses were taken from 1:24,000 USGS topographic maps. The existing cross sections prepared by the U.S. Army Corps of Engineers were used for the hydraulic analysis. Areas in which changes in channel geometry may occur must be evaluated, and new cross-section data must be obtained if necessary.

The equation solutions in the UNET model may not easily converge when modeling certain situations; for example, when simulating low flow conditions or when flows and stages change rapidly. This model sensitivity is a typical characteristic of dynamic wave routing models. The UNET flow simulations required a minimum amount of flow in each tributary and each channel reach throughout the simulation. In real life, the Lower Cache River and its tributaries can have zero flow or very low flow at the onset of a flood. However, the UNET model cannot begin a simulation under these conditions.

A trial-and-error analysis was conducted to determine the amount of minimum flow required by UNET for simulation of the Lower Cache River. Minimum baseflow amounts were added for all tributary and lateral inflow points in the model. The top half of table 6 presents the baseflow used for each of 11 tributaries, which is the minimum flow used with the tributary hydrographs. Flow inputs were also required at various other channel locations in the model, for reaches where the model would otherwise have difficulty reaching a solution for all flow conditions being modeled. The bottom half of table 6 lists the total amount of additional flow required as input at various points in the model so that the model would run under all alternative conditions.

It is possible that some of this additional inflow is not needed simply for initial or low flow conditions, but may also provide a buffer in situations when the model might be unstable. Other potential modifications may reduce model instability and improve convergence, including modifications to the channel geometry and/or bridges, or a reduction in the time step used by the model. Given further study, these other characteristics could be adjusted to reduce the total amount of flow needed to run the model successfully.

Table 6. Additional Baseflows Needed in the UNET Model to Converge to a Solution (cfs)

Baseflow required for each inflow at start of simulation

	2-yr	*5-yr*	*100-yr*
Existing condition	50	50	50
Diverted flow alternative	41	41	41
Split flow alternative	40	40	40
Big Creek detention	40	40	40
Cache valley detention	40	40	40
Big/Cache detention	40	40	40
Many ponds detention	40	40	40

Note: There are ten inflow points in the model.

Total additional inflow required at various other model locations

	2-yr	*5-yr*	*100-yr*
Existing condition	421	421	421
Diverted flow alternative	411	411	411
Split flow alternative	411	411	411
Big Creek detention	411	411	411
Cache valley detention	411	411	411
Big/Cache detention	411	411	411
Many ponds detention	411	411	411

Note: Additional flows input at various locations between River Mile 20.630 and 33.990.

Given the need for additional flows, model output becomes less reliable for conditions when the flow magnitude is relatively low. For example, it may be difficult to conclude that reverse flow may be occurring in the field when the simulated magnitude of the reverse flow is only a few hundred cubic feet per second (cfs).

Flow Dynamics during Flood Events on the Lower Cache River

The following section describes of the general dynamics of flows and river stages for the Lower Cache River during the 2-, 5-, and 100-year floods. These descriptions were developed through examination of the output from the UNET model simulation of these flood events.

The 2-Year Flood

In the initial stages of the 2-year flood, the flows in the tributaries start rising and begin entering the Lower Cache River. Because the Lower Cache River has a low channel slope, the flow from each major tributary (Cypress Creek, Limekiln Slough, Big Creek, and Mill Creek) does not immediately go directly downstream, but instead spreads out from the point of confluence, some flowing west (downstream) and some flowing east (upstream). Flows heading to the east are described as reverse flows, and are presented herein as negative flow values.

Figure 18 shows the flow hydrograph for Big Creek as it enters the Cache River. Also shown are the flow hydrographs on the Cache River immediately upstream and downstream of the Big Creek confluence, with reverse flow occurring on the upstream side. In general, two-thirds of the Big Creek inflow heads downstream (west), while one-third of the flow heads upstream (east). Eventually, as the Big Creek inflow recedes, the reverse flow ends and the

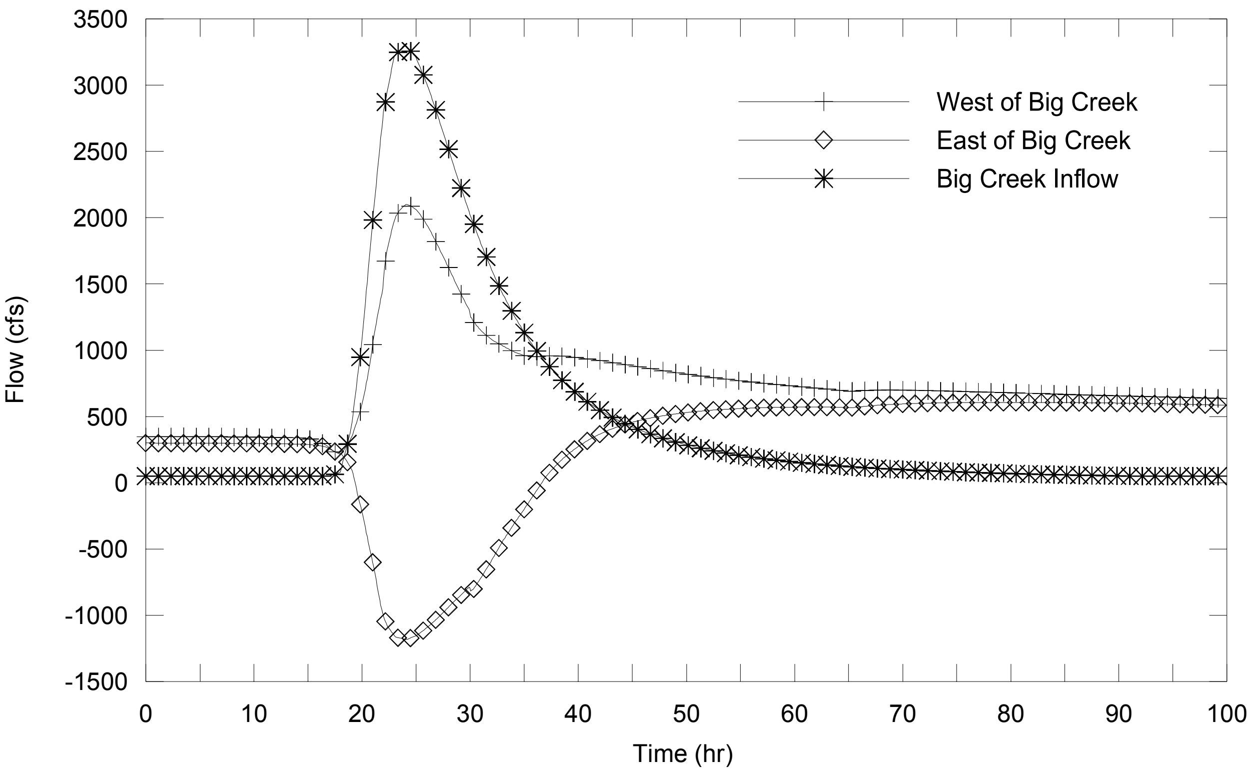


Figure 18. Flow hydrographs for Big Creek and the Cache River immediately west and east of Big Creek; 2-year flood

Cache River upstream of Big Creek slowly begins flowing to the west as Buttonland Swamp drains. As shown in figure 18, the peakflow rate directly east of the Big Creek confluence is noticeably greater during reverse flow conditions (-1184 cfs) than the highest flow rates in the downstream direction (605 cfs), which occur several days later during the flood event.

As long as the Big Creek inflow is high, it effectively acts as a dam for the upstream reaches of the Cache River, such that the Cache River to the east of Big Creek cannot drain to the west. This "damming effect" is illustrated by figure 19, which shows the bed profile of the Cache River along with a profile view of the peak stages for the 2-, 5-, and 100-year floods. The peak stage that occurs for the 2-year flood at the Big Creek confluence, River Mile 24, is almost 2 feet higher than the peak stages one mile to the east in Buttonland Swamp.

The magnitude and duration of the reverse flow depends upon location, the amount of tributary inflow, and the initial rate of flow in the Cache River. In locations where the channel slope is greater, such as near Route 51, the reverse flow may be short-lived, lasting 1 or 2 hours (figure 20). Route 51 is directly upstream of the Indian Camp Creek confluence, where the Mill Creek overflow enters the Cache River. In other locations where the tributary inflows go into floodplain storage, such as in Buttonland Swamp near Limekiln Slough, the reverse flow may last up to 24 hours, as the inflow from the tributary slowly fills the floodplain along the river. The magnitude of the reverse flow is greatest directly east of the Limekiln Slough confluence with the Cache River, where both the Big Creek and Limekiln Slough inflows contribute to the reverse flow condition. Farther to the east, in Buttonland Swamp east of Perks Road and west of the Cypress Creek inflow (figure 20), the flow oscillates westward and eastward at relatively low

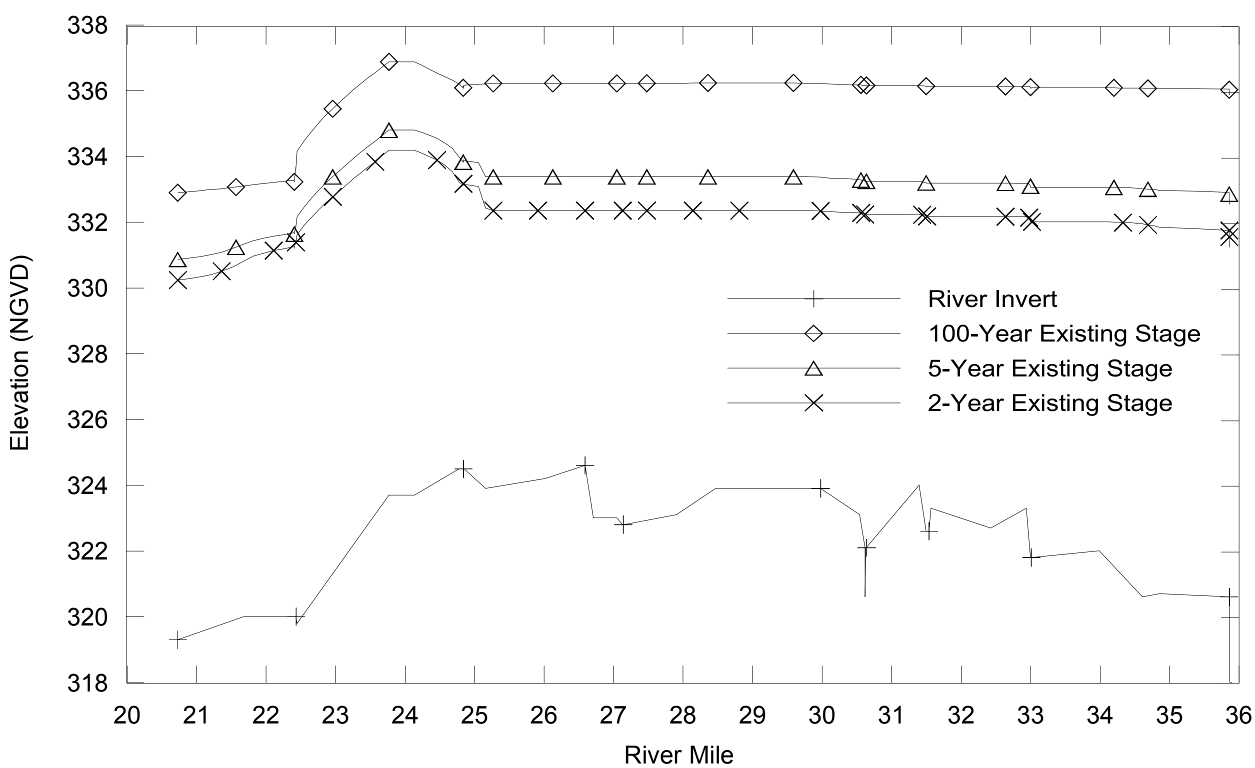


Figure 19. Peak stage for 2-, 5-, and 100-year floods; existing condition

magnitude; however, there are periods during the 2-year event when a definite westward flow is established. Because there is little reverse flow at this latter location, it can be concluded that much of the reverse flow from Big Creek and Limekiln Slough are detained within Buttonland Swamp. According to the UNET model results, that portion of Buttonland Swamp located east of Cypress Creek continues to flow to the east for almost the entire duration of the 2-year flood (figure 20).

Peakflow velocities for the 2-year flood were computed at various locations, and (table 7). In general, the velocities within Buttonland Swamp, between Cache-Chapel Road and Route 37 are very low, generally less than 0.2 foot per second (fps). Velocities at bridge locations, such as Perks Road, Cache Chapel Road, and Interstate 57, are noticeably higher (greater than 1 fps) because of flow constrictions at these bridges.

The 5-Year Flood

Figure 21 shows the 5-year hydrographs for the Big Creek inflow and the Cache River flows immediately east and west of the Big Creek confluence. The dynamics and timing of flow in the Cache River area for the 5-year flood and the 2-year flood generally appear to be very similar, although the magnitude of flows is higher (figure 22). The peak stages of a 5-year event are roughly 1 foot higher than for the 2- year flood, as shown in figure 19. As with the 2-year flood, the region of the river between Cypress Creek and the Cache River Levee flow to the east for most of the duration of the 5-year flood (figure 22).

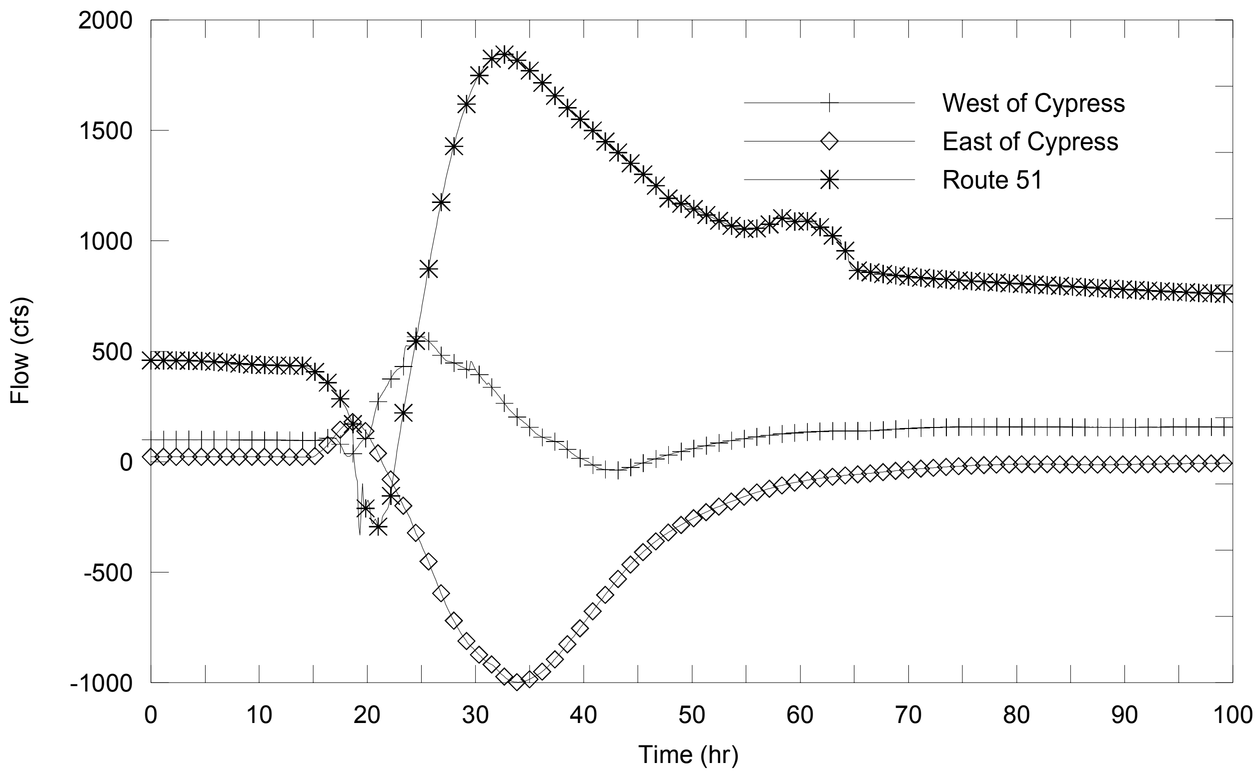


Figure 20. Flow hydrographs for the Cache River at Route 51, west of Cypress Creek (east of Perks Road), and east of the Cypress Creek confluence; 2-year flood

Table 7. Average Velocities during Peakflow Conditions: 2-, 5-, and 100-Year Floods

		Velocity (fps)		
River mile	*Location description*	*2-year*	*5-year*	*100-year*
30.6	Illinois Route 37	0.80	1.00	1.29
29.4	East of Cypress Creek	0.10	0.12	0.16
28.5	West of Cypress Creek	0.10	0.14	0.31
27.4	East of Perks Road	0.41	0.43	0.43
27.1	Perks Road	1.02	1.26	1.02
27.0	West of Perks Road	0.09	0.11	0.24
26.0	East of Limekiln Slough	0.07	0.09	0.20
24.8	Cache Chapel Road	1.59	1.92	3.22
24.1	East of Big Creek	1.71	1.83	2.10
23.8	West of Big Creek	2.35	2.73	2.86
22.4	Interstate 57	4.73	5.68	8.57
18.2	Downstream of Indian Camp Creek	1.28	1.25	1.43

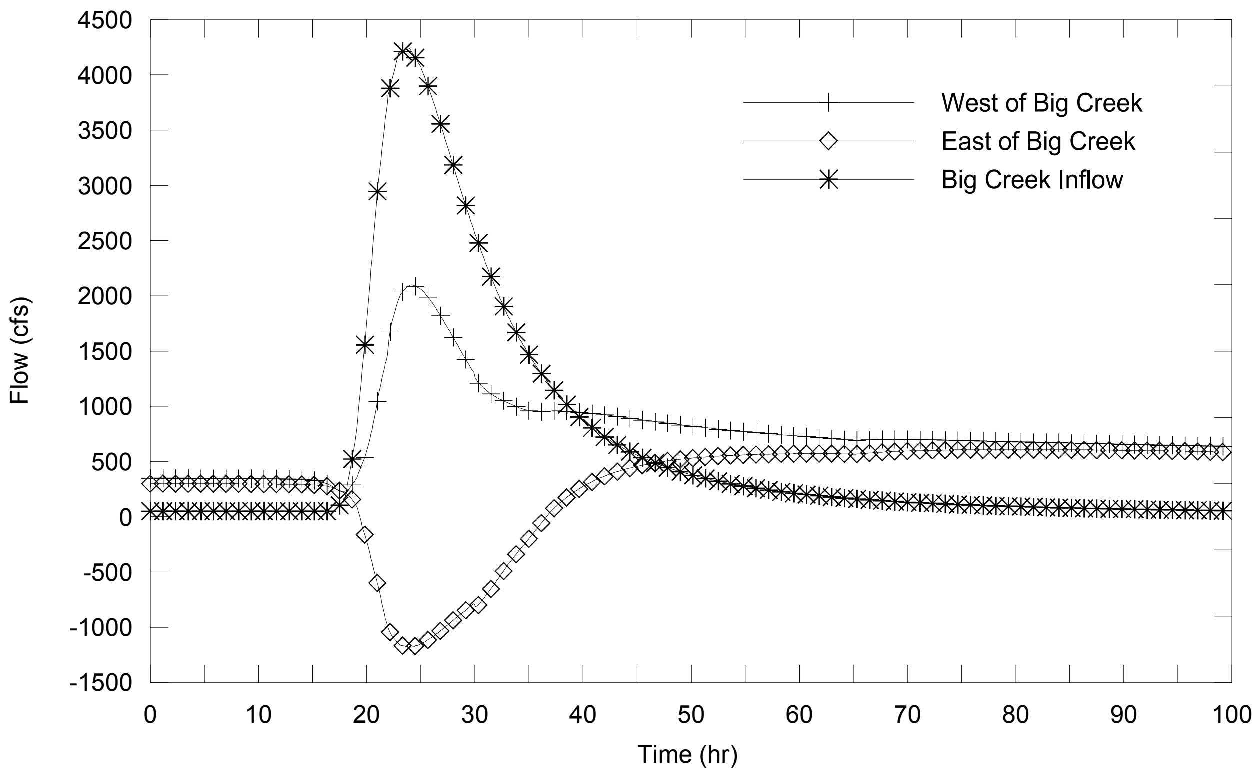


Figure 21. Flow hydrographs for Big Creek and the Cache River immediately west and east of Big Creek; 5-year flood

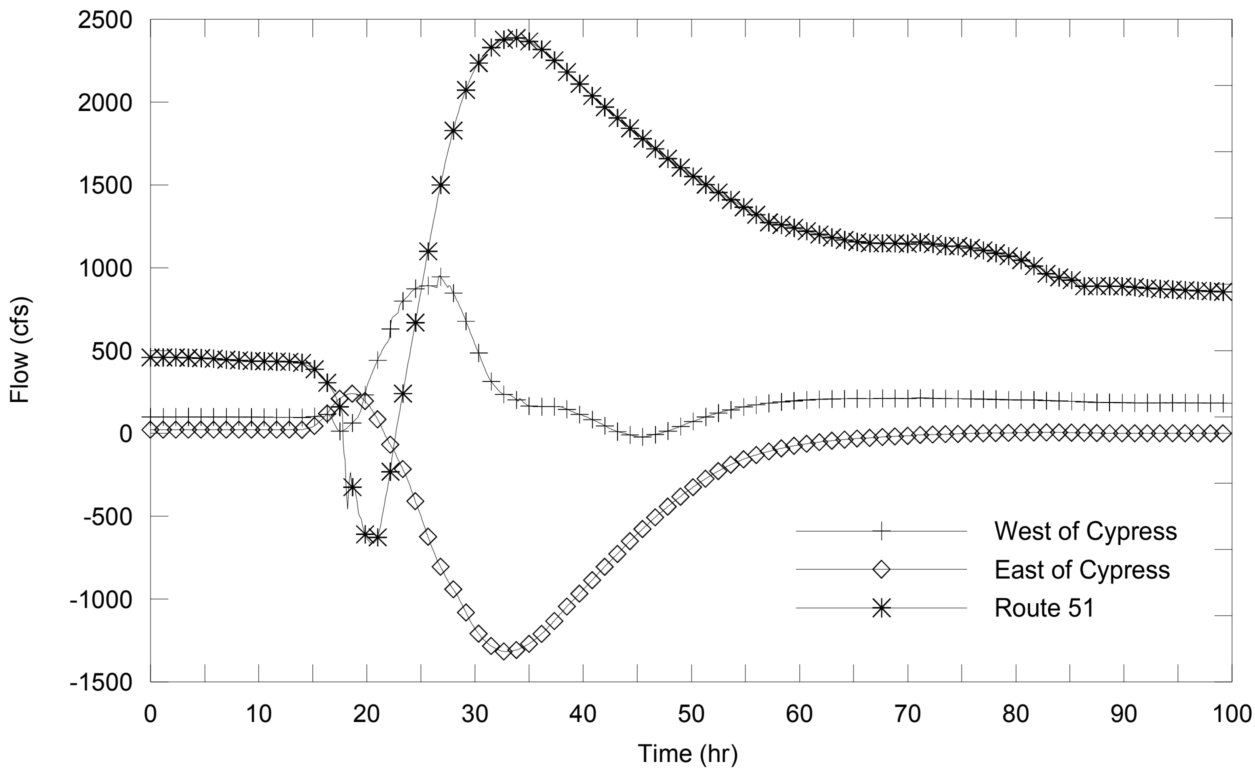


Figure 22. Flow hydrographs for the Cache River at Route 51, west of Cypress Creek (east of Perks Road), and east of the Cypress Creek confluence; 5-year flood

Peakflow velocities for a 5-year flood are given in table 7. As with a 2-year flood, the velocities within Buttonland Swamp, between Cache-Chapel Road and Route 37, are very low.

The 100-Year Flood

Figure 23 shows the inflow hydrographs for Big Creek and for the Cache River upstream and downstream of the Big Creek confluence. The dynamics of flows along the Cache River area for the 100-year flood are roughly similar to those of the 2- and 5-year floods, with the following differences. The volume of water entering Buttonland Swamp during the 100-year event is sufficient to cause water levels to rise to a much higher elevation, estimated by the UNET model to be 336.07 feet NGVD (figure 19). Although this is lower than the peak stages at the Big Creek confluence (336.88 feet NGVD), the difference in peak stage between these two locations is much less than for the 2- and 5-year events. A gradient of flow from the east to the west is established before the Big Creek inflow fully recedes, and the reverse flow condition east of Big Creek lasts only about 13 hours (figure 23). Nevertheless, the peakflow rate of reverse flow is 4,000 cfs, accounting for roughly 40 percent of the peak inflow from Big Creek. There are no reverse flows near the center of Buttonland Swamp, west of Cypress Creek (figure 24), with the flows maintaining a consistent westward direction with a peakflow rate near 2,500 cfs. East of Cypress Creek, a westward flow was established in the later stages of the 100-year flood hydrograph.

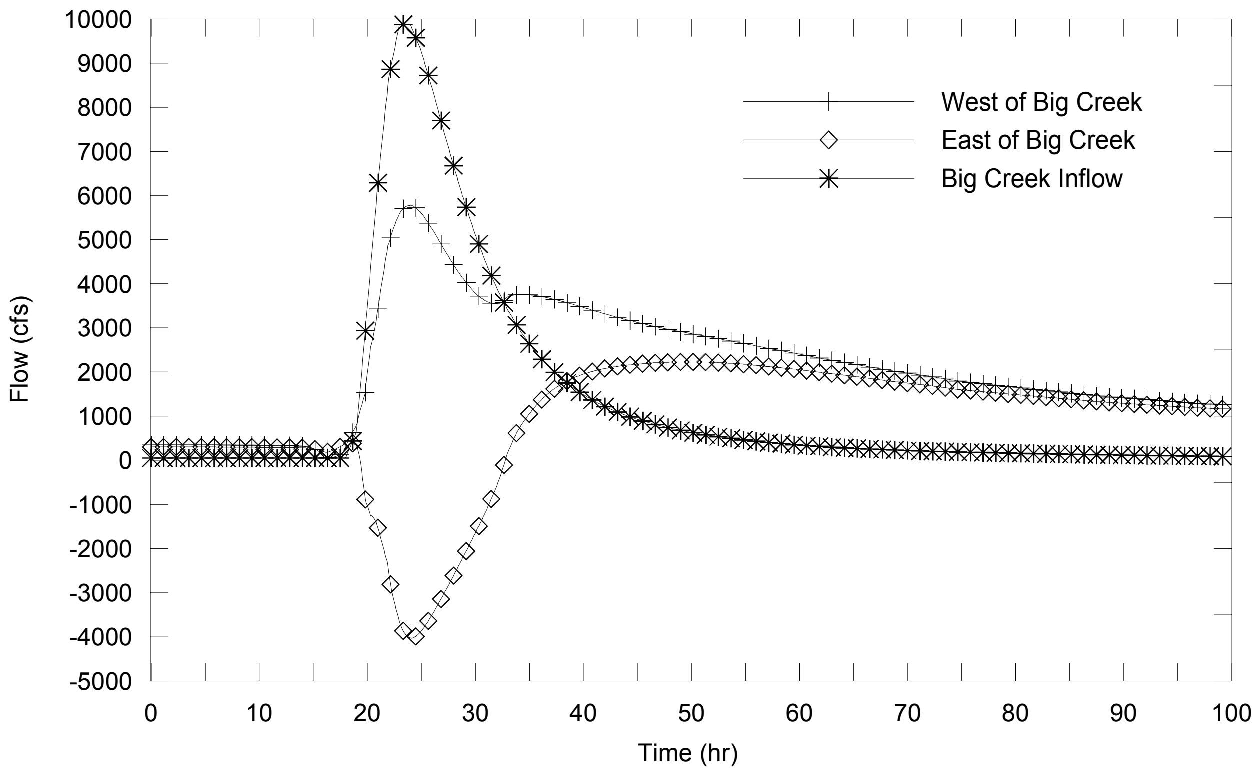


Figure 23. Flow hydrographs for Big Creek and the Cache River immediately west and east of Big Creek; 100-year flood

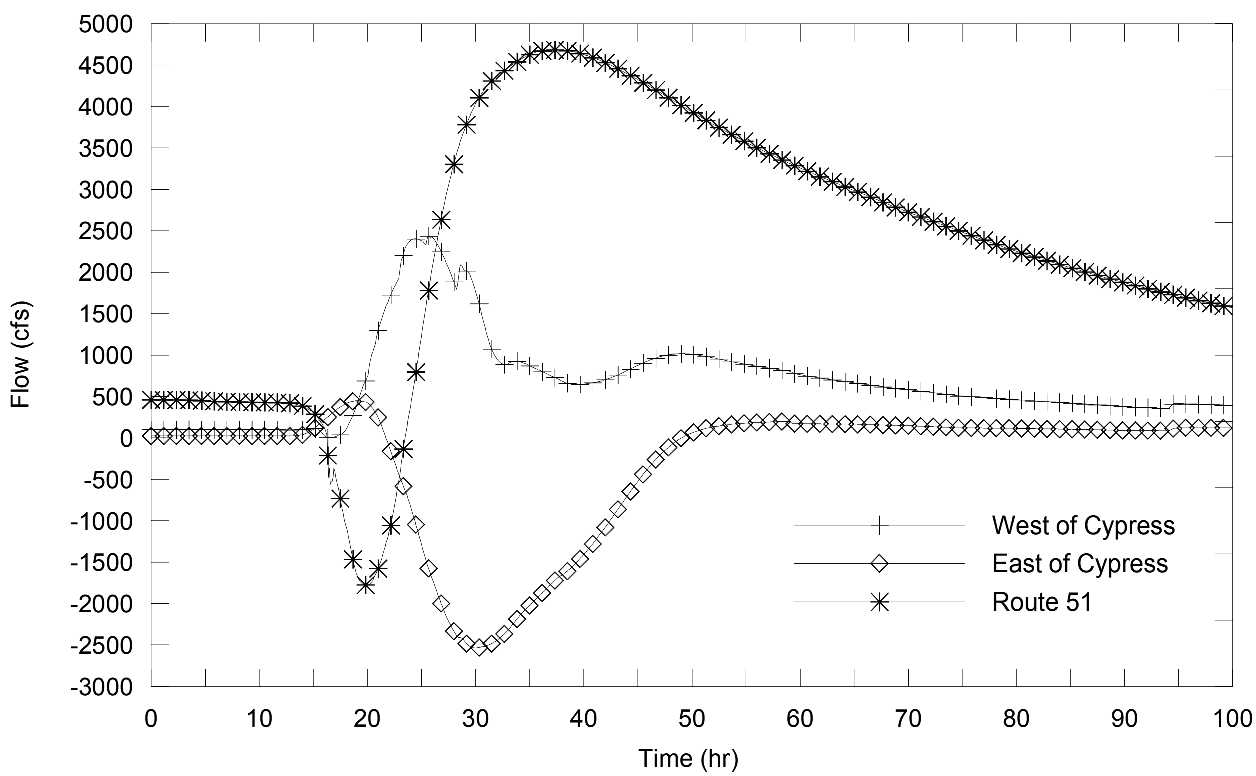


Figure 24. Flow hydrographs for the Cache River at Route 51, west of Cypress Creek (east of Perks Road), and east of the Cypress Creek confluence; 100-year flood

Impact of Alternatives on the Lower Cache River Flow Dynamics

Nine different alternative conditions were examined in the UNET model analysis of the Cache River: four detention storage alternatives, the diverted flow alternative, and the split flow alternative, and three combinations of split flow and detention storage. The flow hydrographs computed by the UNET model for five locations on the Cache River will be presented and discussed in this section. These locations are

- immediately east of Route 51, at River Mile 20.7
- immediately west of the existing Big Creek confluence
- immediately east of the existing Big Creek confluence
- in Buttonland Swamp (east of Perks Road) at River Mile 28.5
- east of the Cypress Creek confluence

The 2-Year Flood

Figures 25-29 show the impact of the nine different alternatives on the 2-year flood hydrographs at the five locations on the Lower Cache River. Four alternatives are based on detention storage: the Big Creek detention (alternative 10), Cache River valley detention (alternative 16), the combination of the Big Creek and Cache River valley detentions (alternative 20), also called the Big/Cache detention alternative, and the use of many smaller ponds throughout the watershed (alternative 23). The direct influence of detention storage is to reduce the rate of inflow entering the Cache River from Big Creek. The impact of the detention on the Big Creek hydrograph was presented earlier.

Figure 27 shows the impact of the alternatives on the Cache River flows directly east of the confluence with Big Creek. Of the four detention alternatives shown in figure 27a, the Cache valley and many ponds alternatives have the least impact on the amount of reverse flow that occurs for the 2-year flood, with a 26 percent reduction in flow. The Big Creek detention reduces the peak magnitude of the reverse flow by roughly 42 percent and Big/Cache detentions together reduce the peak magnitude of the reverse flow by roughly 61 percent. When the reverse flows are reduced, there is a greater tendency for the Buttonland Swamp area to flow to the west. This is illustrated in figure 28a, which shows a 75 percent increase in peakflow in the swamp for the Big/Cache detention alternative.

The detention alternatives also reduce the amount of flow to the west of the Big Creek confluence, as shown in figure 26a. The many ponds alternative reduces these peakflows west of Big Creek by 30 percent, the Cache valley detention reduces peakflows by 38 percent, and the Big Creek and Big/Cache detention alternatives reduce peakflows by 45 and 50 percent, respectively. As the detention basins drain, which occurs as flows recede in the days following peakflow conditions, the presence of the detention alternatives will result in an increase in downstream flows. The detention alternatives produce comparatively less change in the peakflow rates farther downstream at Route 51 (figure 25a) with reductions in the range of 17 to 30 percent.

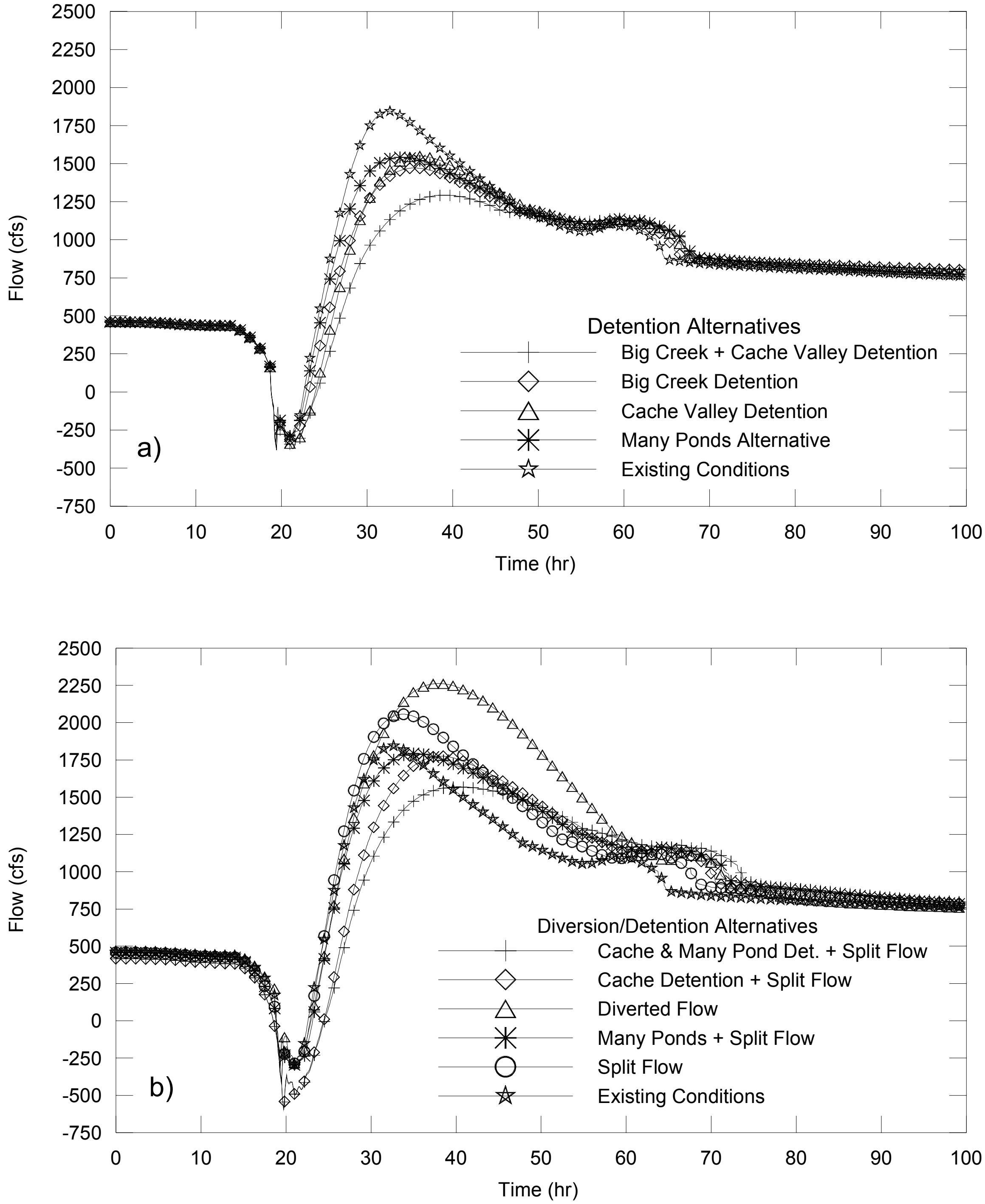


Figure 25. Simulated 2-year flood hydrographs for existing conditions and nine alternatives; Cache River at Route 51

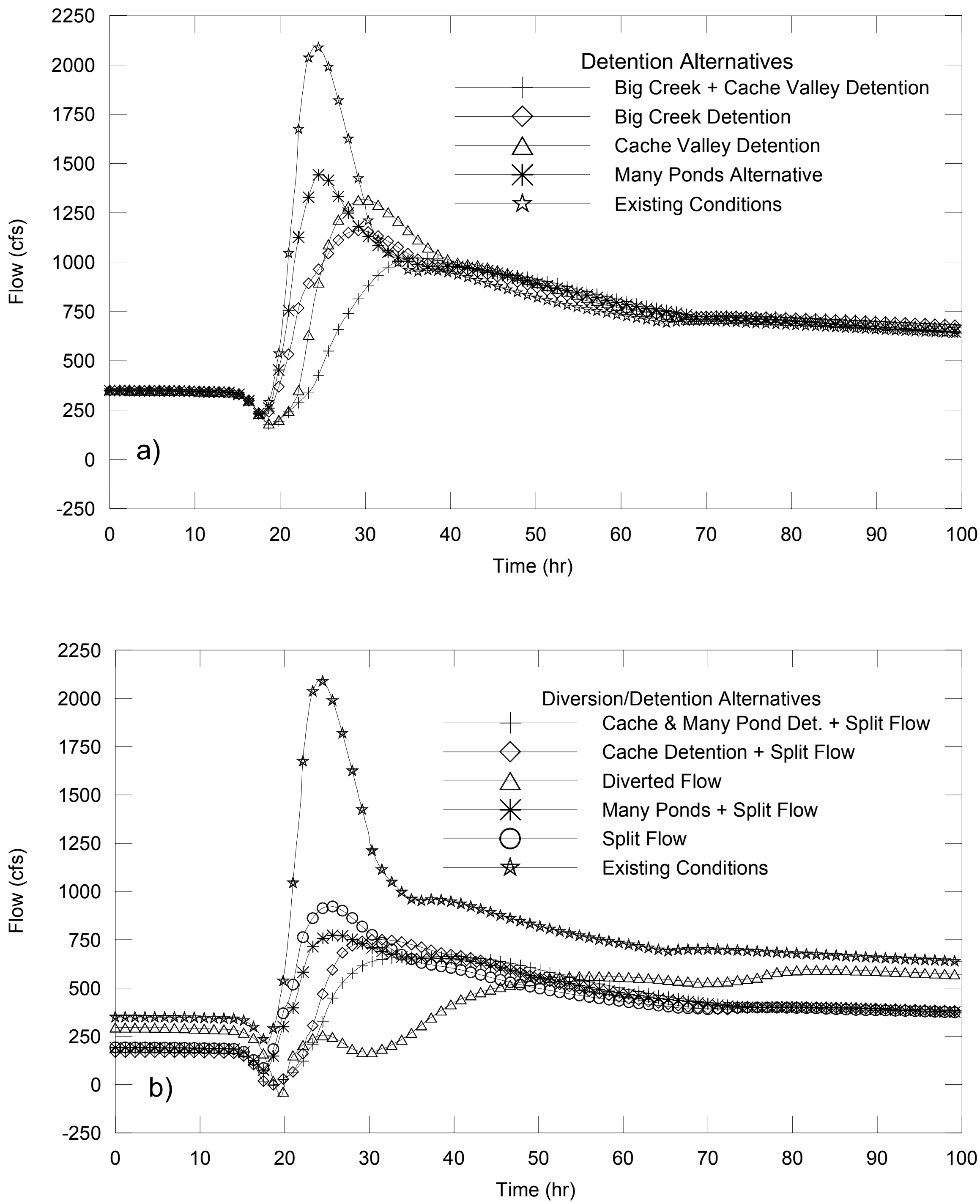


Figure 26. Simulated 2-year flood hydrographs for existing conditions and nine alternatives; Cache River west of Big Creek

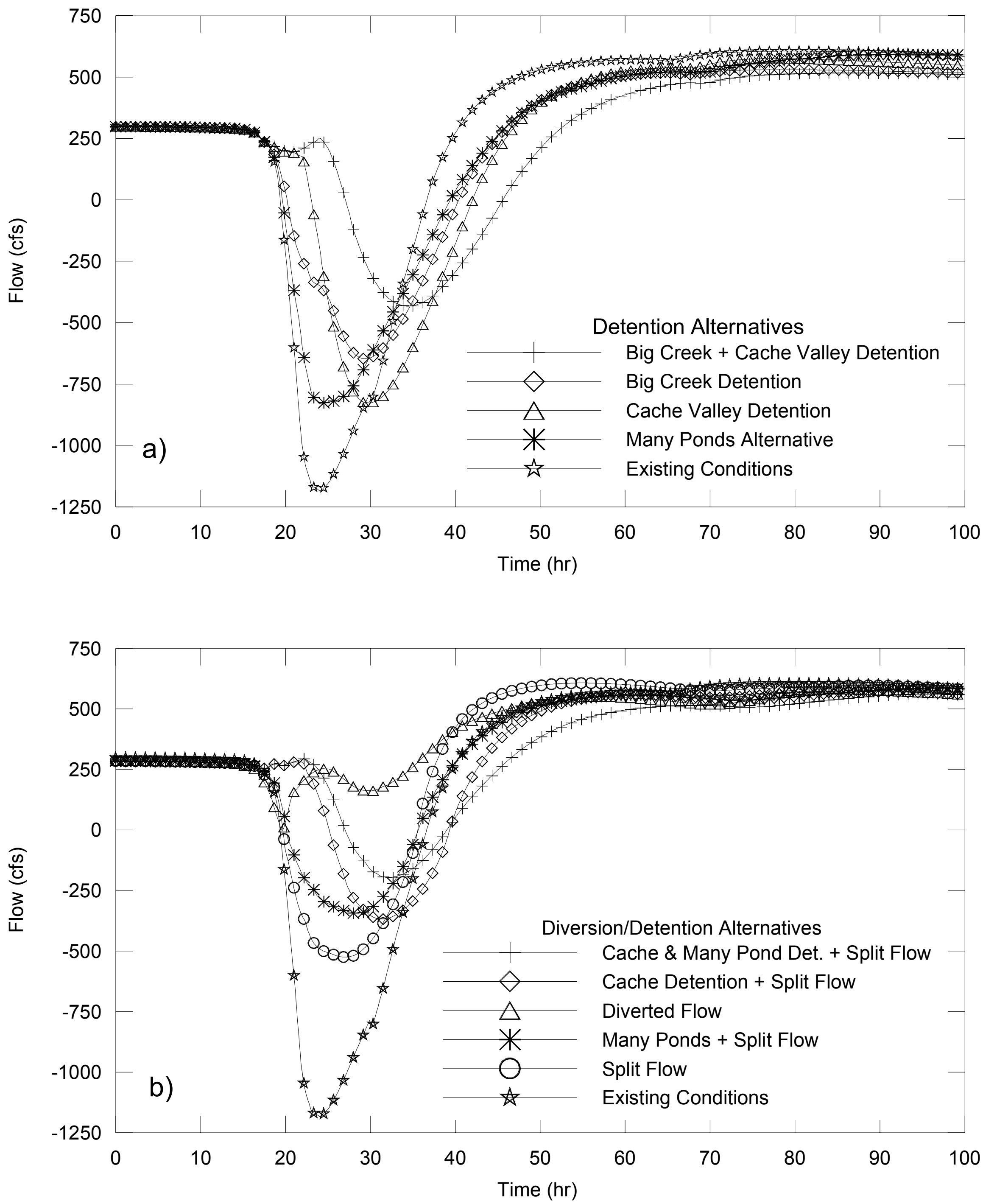


Figure 27. Simulated 2-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Big Creek

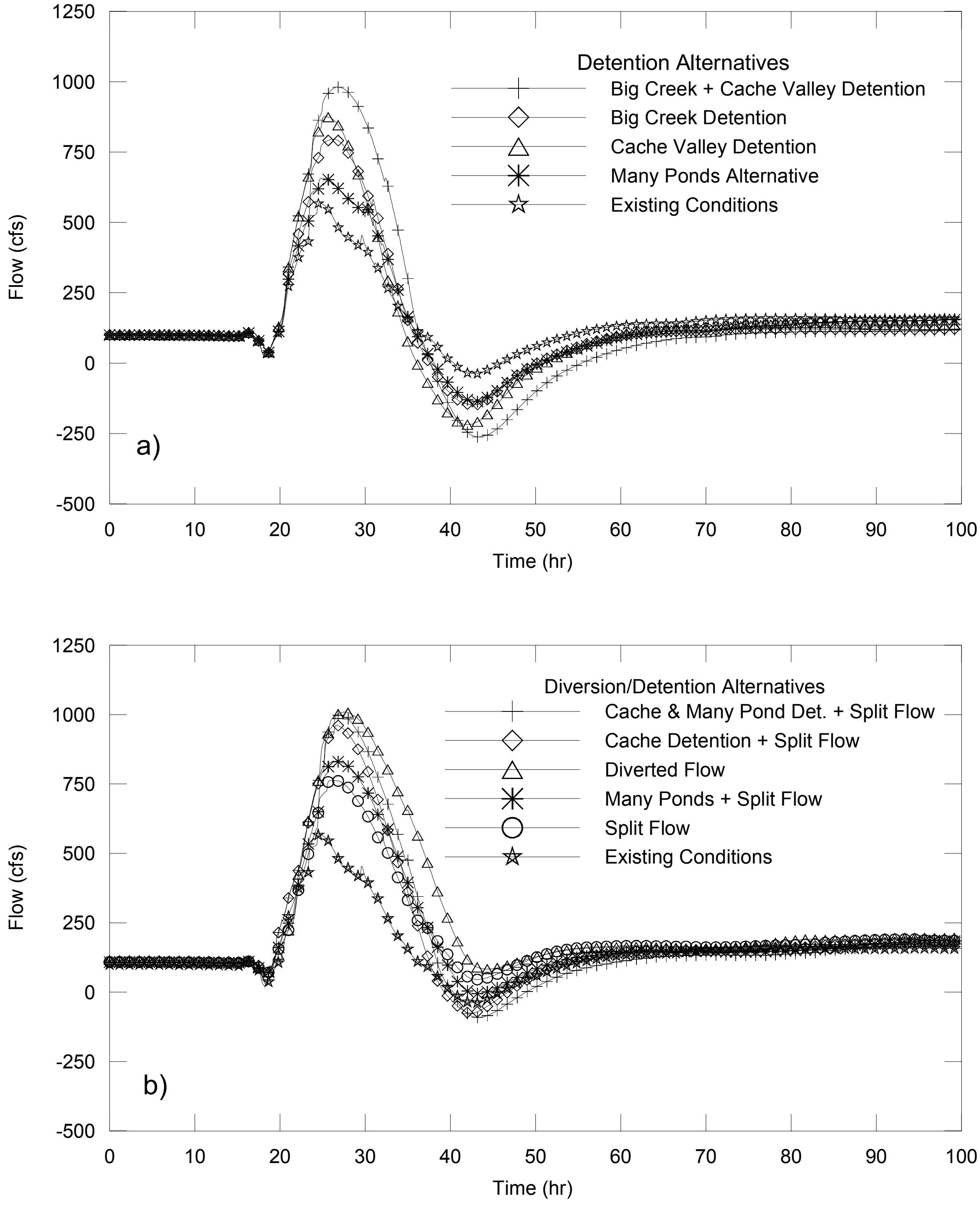


Figure 28. Simulated 2-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Perks Road

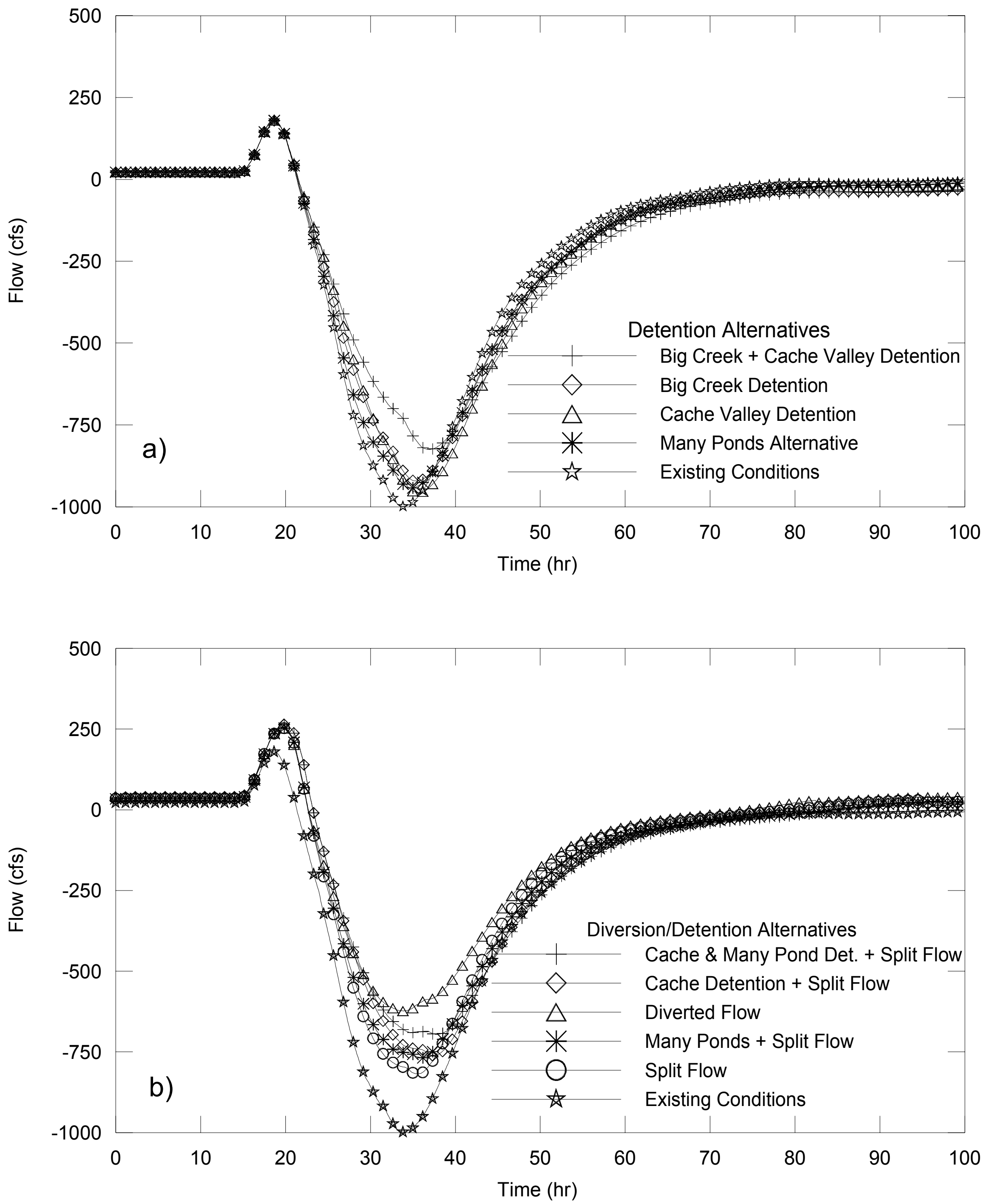


Figure 29. Simulated 2-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Cypress Creek

Figure 27b shows the impact of the diverted flows and split flow alternatives on the reverse flow east of Big Creek. The diverted flow alternative would eliminate the occurrence of reverse flow at this location. By itself, the split flow alternative would reduce the peak of the reverse flow by 52 percent. When combined with various detention alternatives, the split flow approach can reduce the reverse flow by 67 to 81 percent. All alternatives also increase the westward movement of flow in Buttonland Swamp, as shown in figure 28b.

The diverted flow and split flow alternatives greatly reduce the flow in the Cache River directly west of Big Creek (figure 26b). Diverting all of the Big Creek flows away from this location causes the greatest reduction in the Cache River flows at this location. But farther west, downstream of the confluence of the diversion channel with the Cache River, the situation is considerably different (figure 25b). The diverted flow alternative increases the peakflow at Route 51 by roughly 22 percent, and the split flow alternative increases the peakflows by 10 percent. Only when detention storage is used in combination with either the diverted flow or split flow can the Cache River flows be kept at or below the existing peakflow condition.

Figure 30 shows the impact of four alternatives on the 2-year flood peak stages along the lower Cache River. All alternatives greatly reduce the peak stages near the Big Creek confluence and farther upstream in Buttonland Swamp. However, downstream, between Interstate 57 and the town of Ullin, the peak flood stage is increased by 0.1 foot for both the split flow and

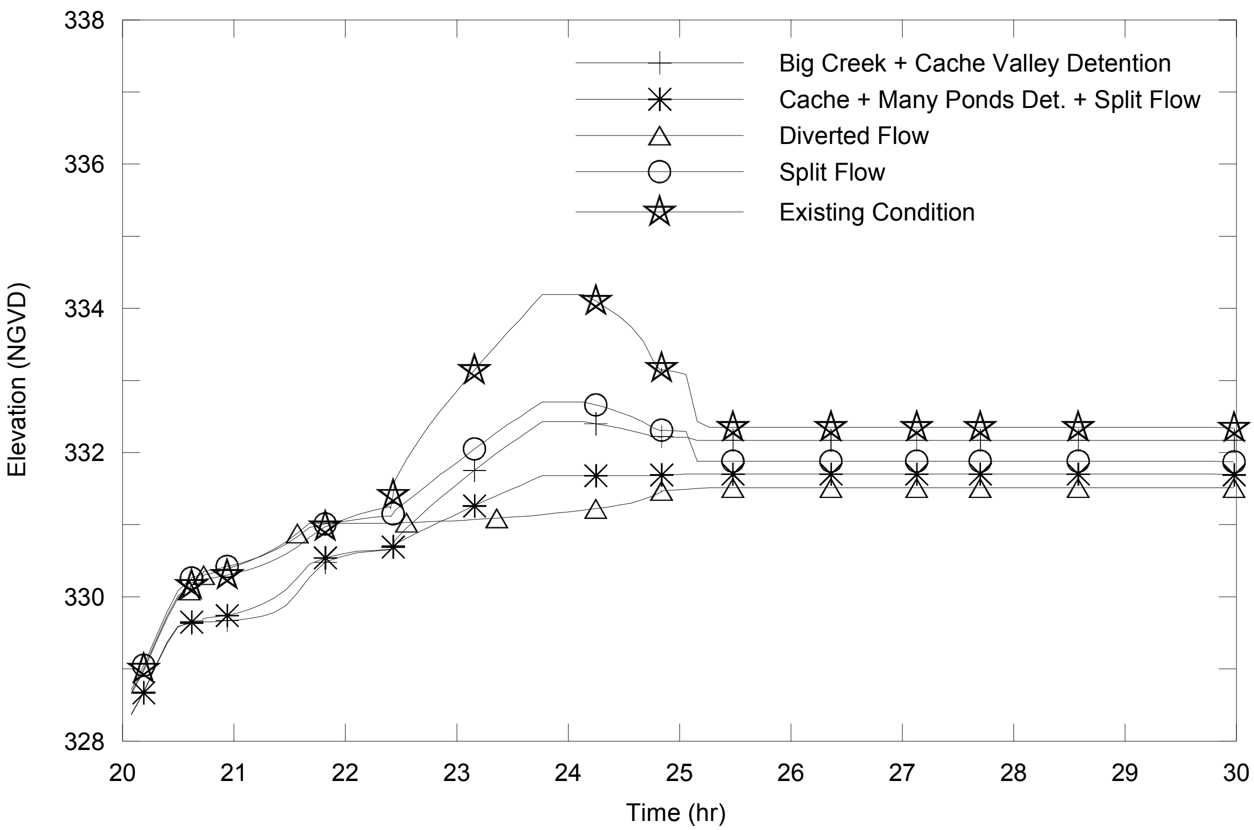


Figure 30. Peak stages on the Cache River for the 2-year flood; existing condition, diverted flow, and Big Creek/Cache detention storage alternatives

diverted flow alternatives. If the split flow alternative is combined with significant detention storage, in the combined form of many headwater ponds and a Cache valley detention facility, then peak stages can potentially be reduced along all of the Lower Cache River.

The 5-Year Flood

Figures 31-35 show the impact of the nine different alternatives on the 5-year flood hydrographs at the five locations on the Lower Cache River. As compared to the 2-year flood, the detention storage for the 5-year flood produces a relatively greater reduction in reverse flows east of Big Creek (figure 33a). The reductions in reverse flows east of Big Creek associated with the four detention storage alternatives (Many Ponds, Cache valley, Big Creek, and Big/Cache) are 30, 30, 37, and 52 percent, respectively. The split flow alternative reduces the reverse flow peak by 54 percent (figure 33b), and the reduction is in the range of 70 to 85 percent when combined with detention storage alternatives. As expected, the diverted flow option eliminates the reverse flow condition east of Big Creek.

The amount of westward flow in the Buttonland Swamp area is increased for all alternatives, as seen in figure 34. The overall reduction in peakflows west of Big Creek for the four detention alternatives (figure 32a) is substantial, with decreases in the range of 35 to 50 percent.

As with the 2-year flood, the peakflow rate downstream at Route 51 has the potential to be increased by the diverted flow and split flow alternatives (figure 31b). The use of sufficient detention storage with the split flow alternative can eliminate the potential for such an increase.

Figure 36 shows the estimated peak stages for a 5-year flood for the Lower Cache River, with the estimated impacts of four alternatives. As shown previously for the 2-year event, the diverted flow and split flow (without storage) alternatives cause an increase in peak stages in the vicinity of the Lower Cache River downstream of Interstate 57, including at the town of Ullin. The addition of detention storage with the split flow has the potential to decrease peak stages along the entire length of the Lower Cache River in the study area.

The 100-Year Flood

Figures 37-41 show the impact of the nine different alternatives on the 100-year flood hydrographs at the five locations on the Lower Cache River. Figure 39a shows the estimated flows directly east of the Big Creek confluence using the four detention alternatives. For the 100-year event, the many ponds alternative (57 percent reduction) is nearly as effective as the Cache valley alternative (60 percent reduction) in reducing the reverse flow. The reduction caused by the split flow alternative (figure 39b) is 69 percent, and the combination of the split flow and many ponds alternatives reduces the peak reverse flow by 80 percent.

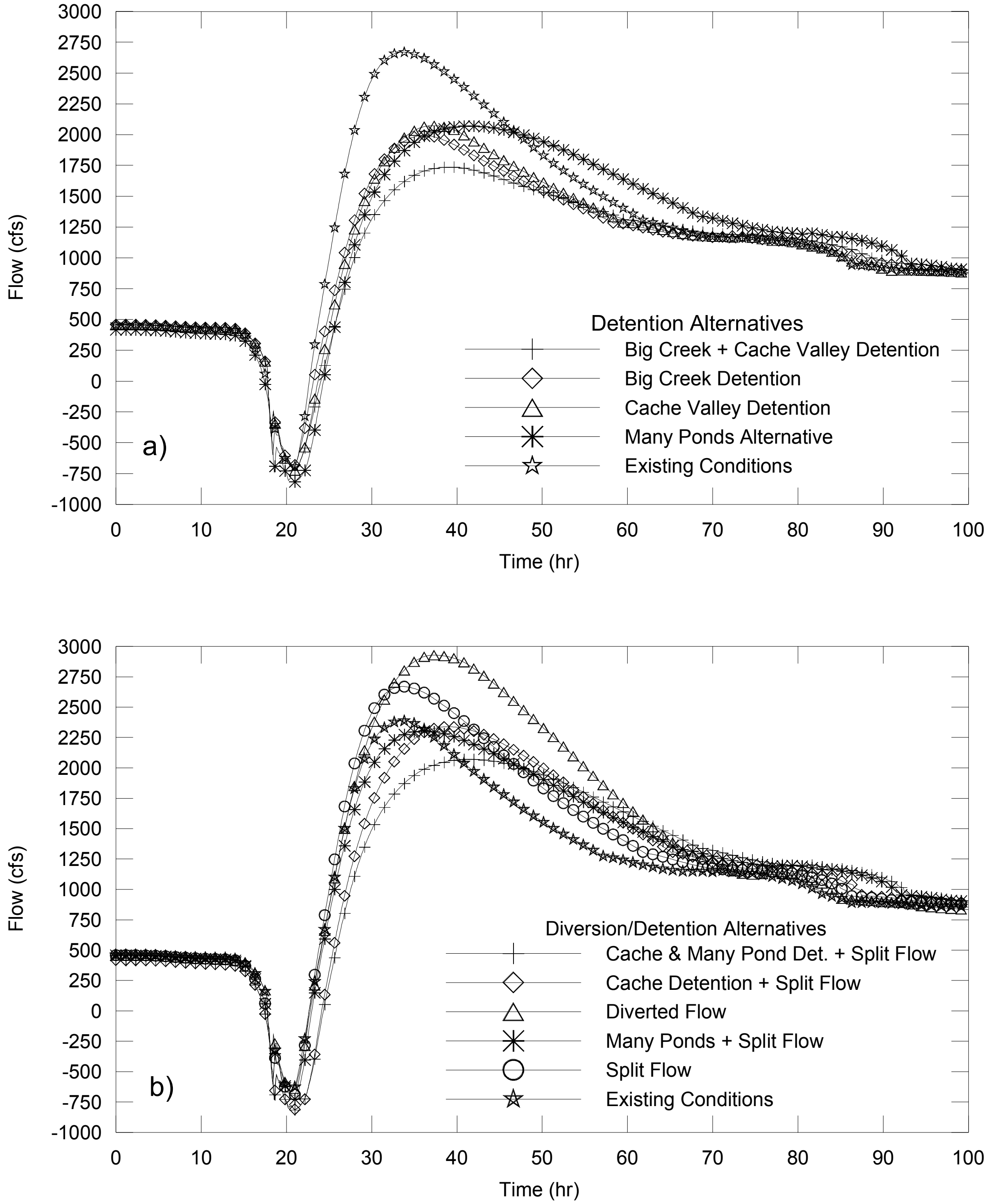


Figure 31. Simulated 5-year flood hydrographs for existing conditions and nine alternatives; Cache River at Route 51

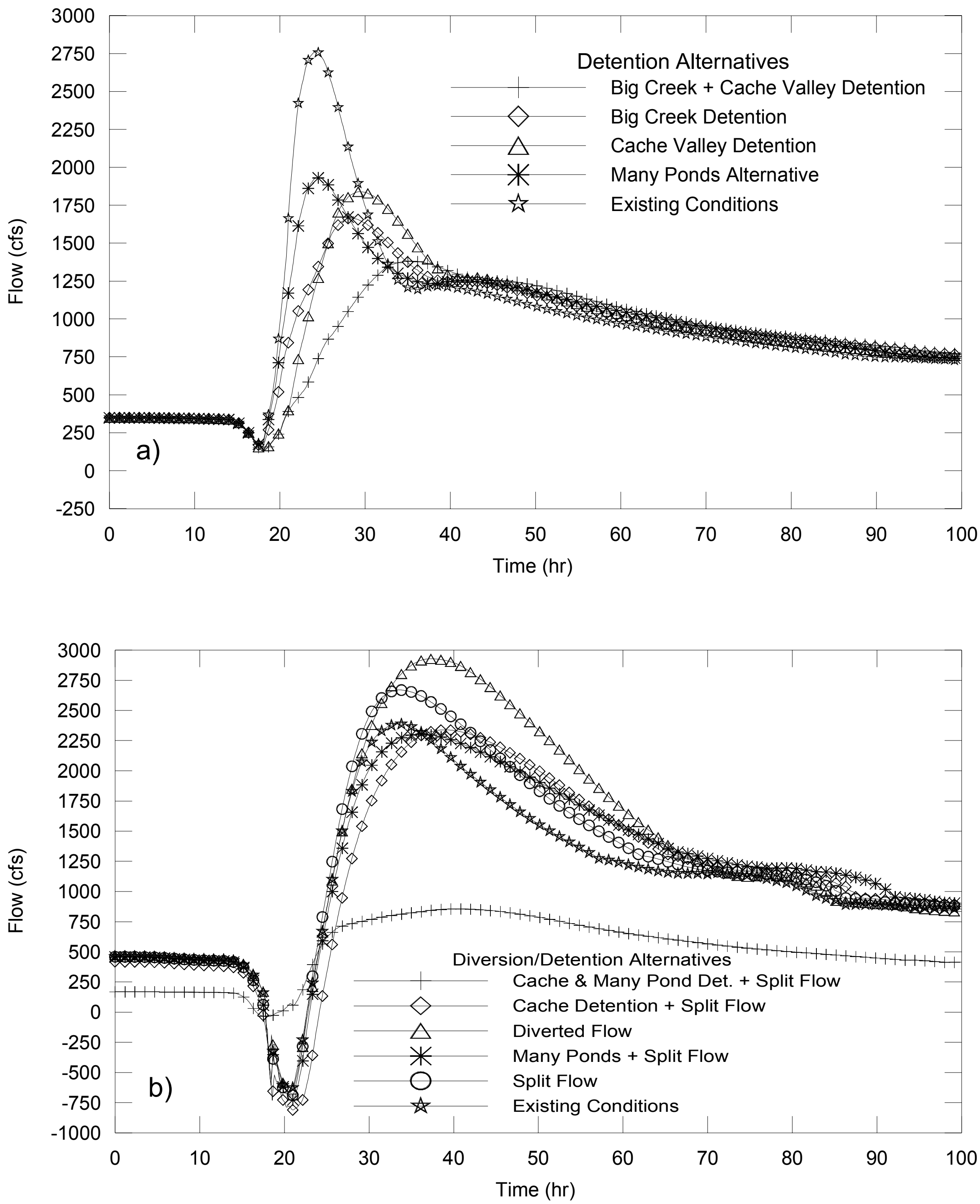


Figure 32. Simulated 5-year flood hydrographs for existing conditions and nine alternatives; Cache River west of Big Creek

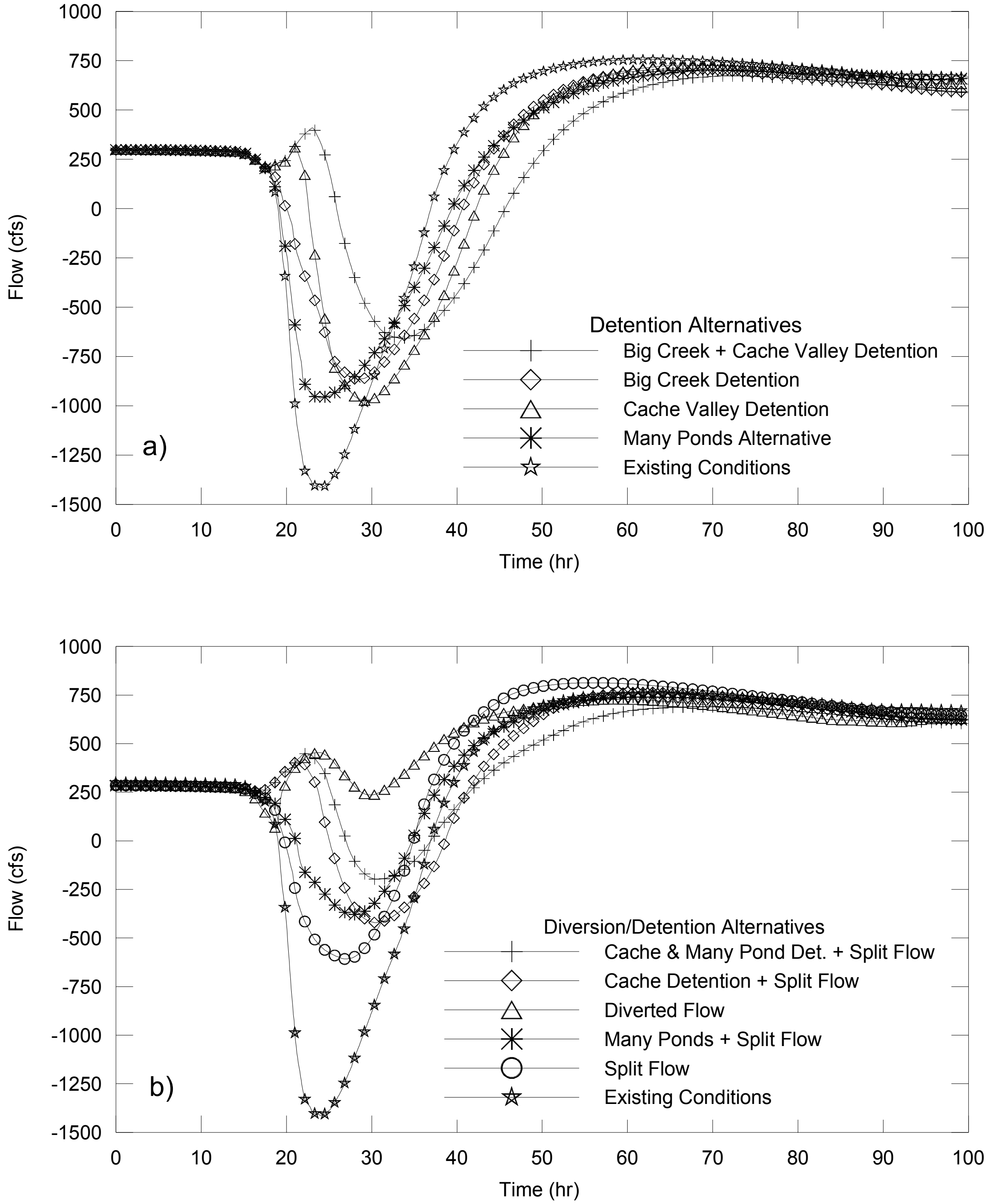


Figure 33. Simulated 5-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Big Creek

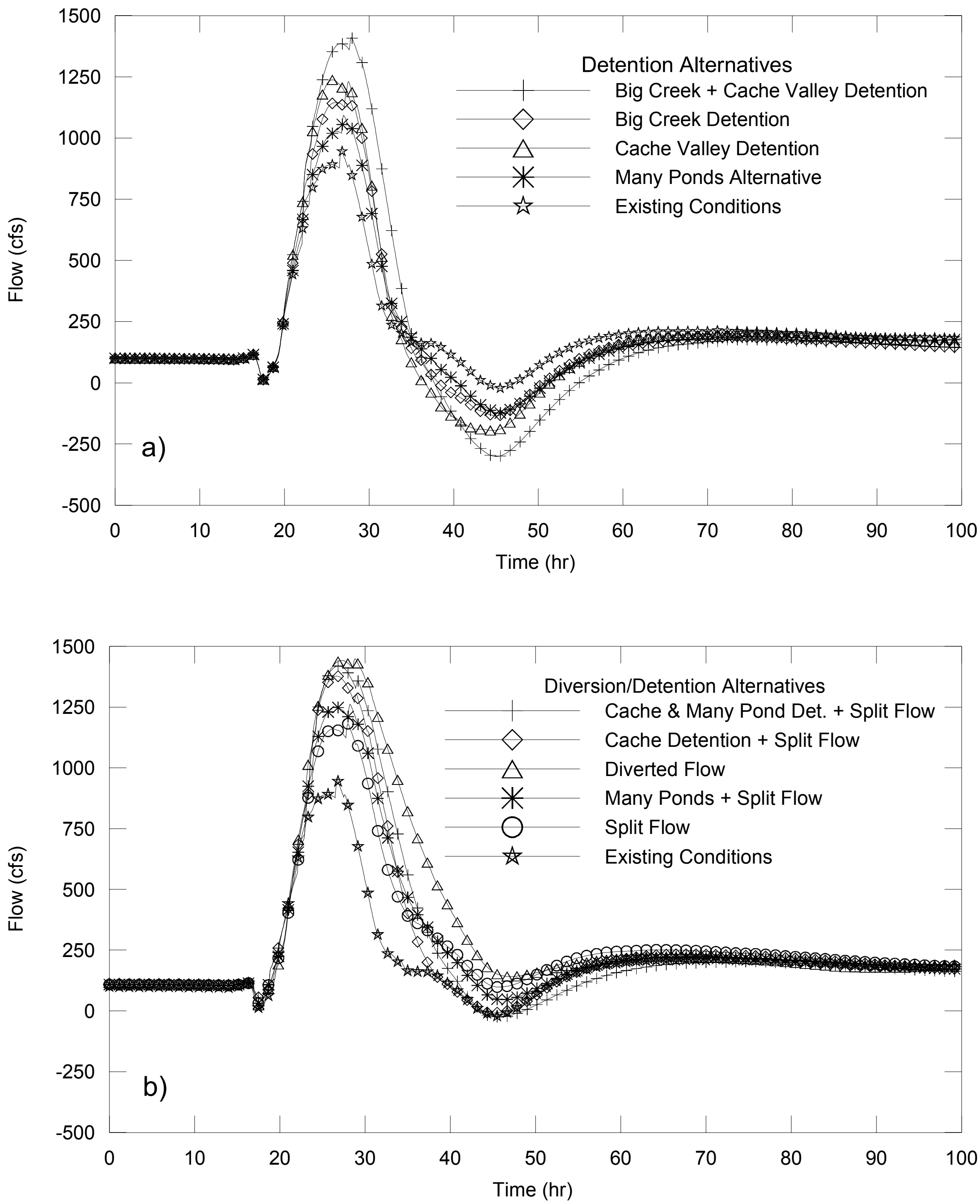


Figure 34. Simulated 5-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Perks Road

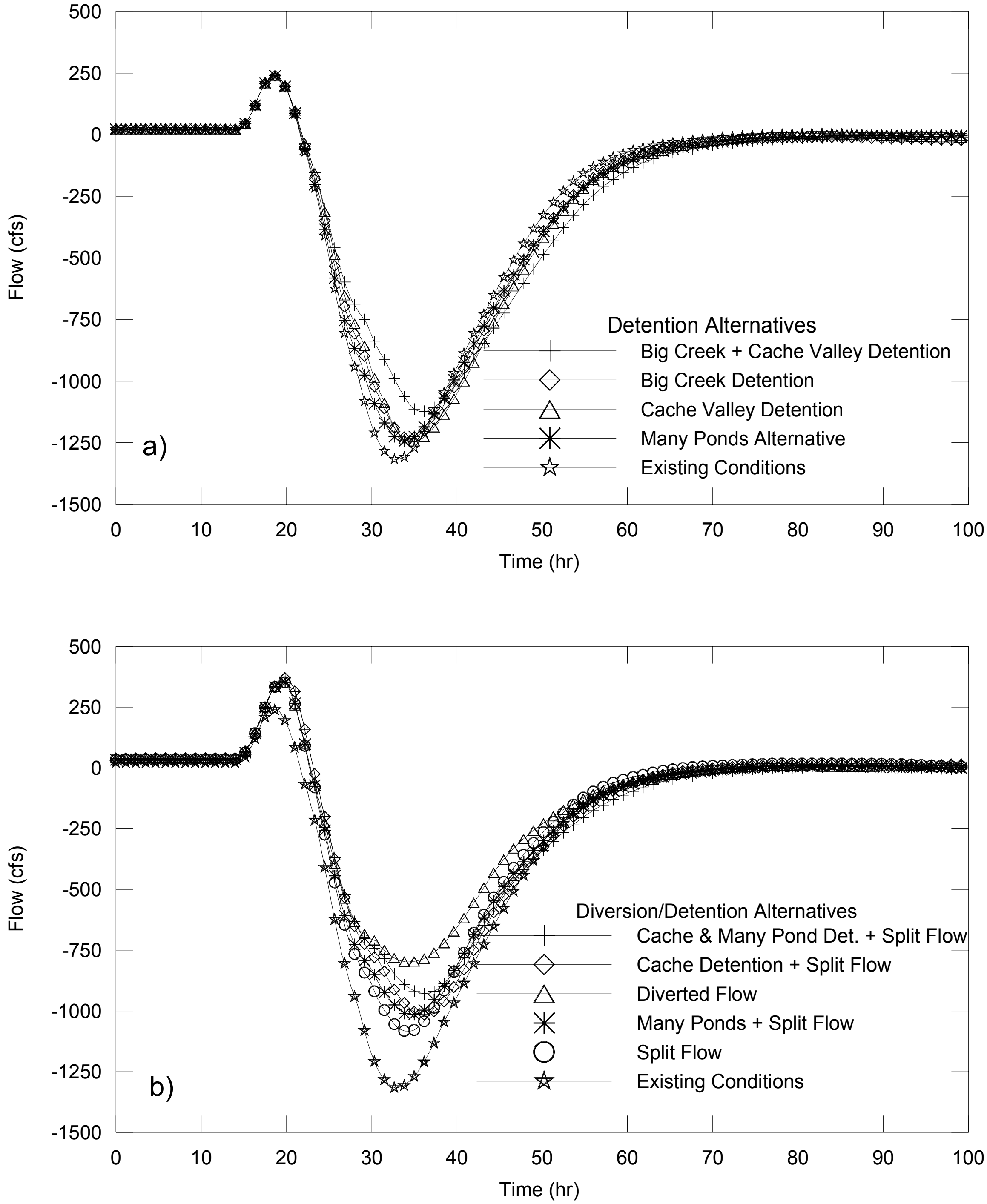


Figure 35. Simulated 5-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Cypress Creek

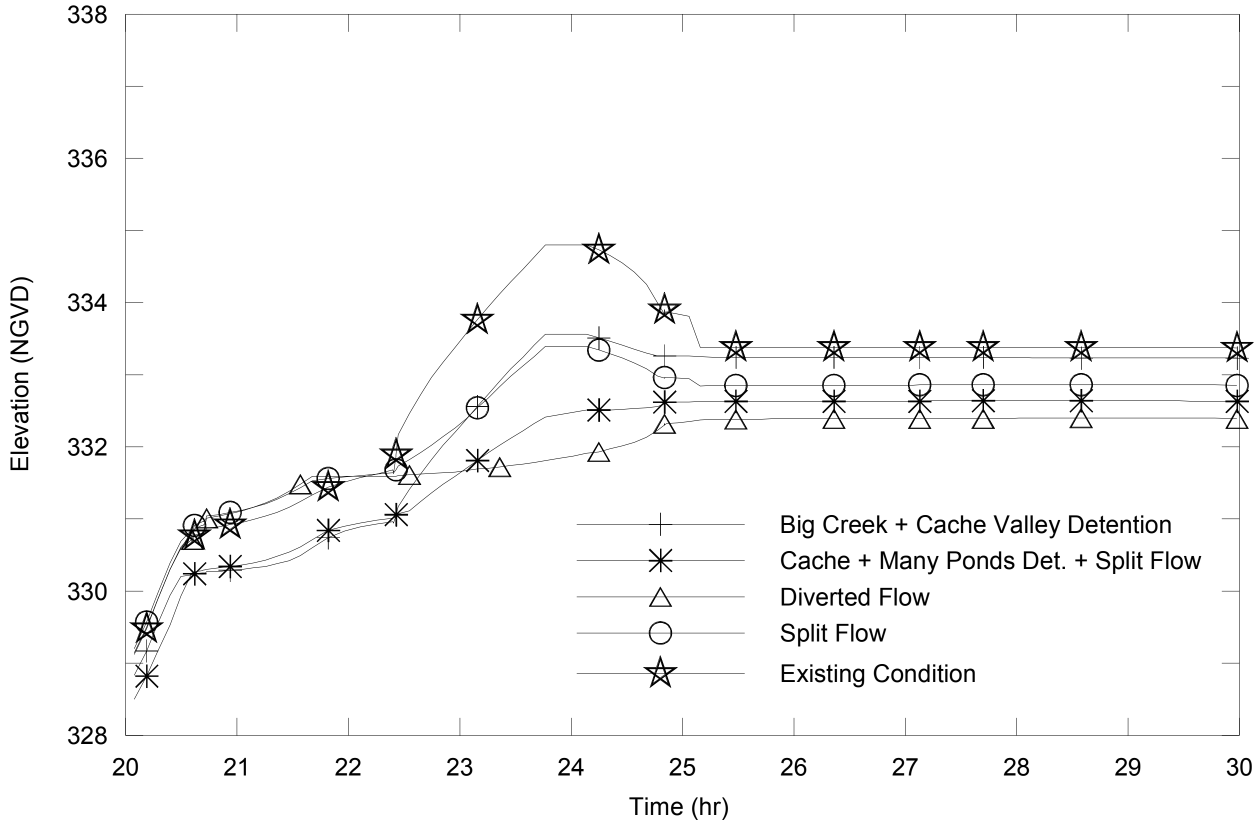


Figure 36. Peak stages on the Cache River for the 5-year flood; existing condition, diverted flow, and Big Creek/Cache detention storage alternatives

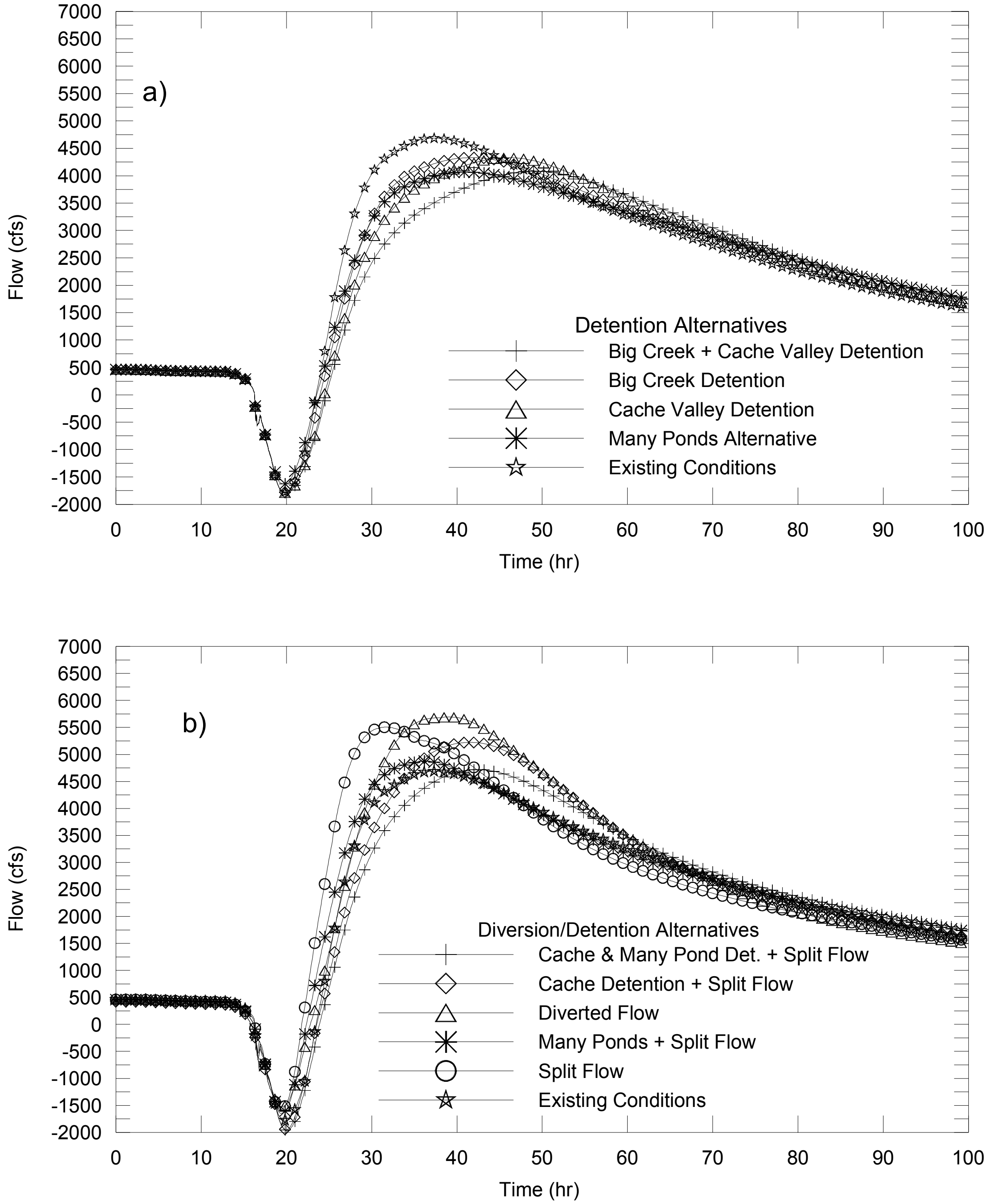


Figure 37. Simulated 100-year flood hydrographs for existing conditions and nine alternatives; Cache River at Route 51

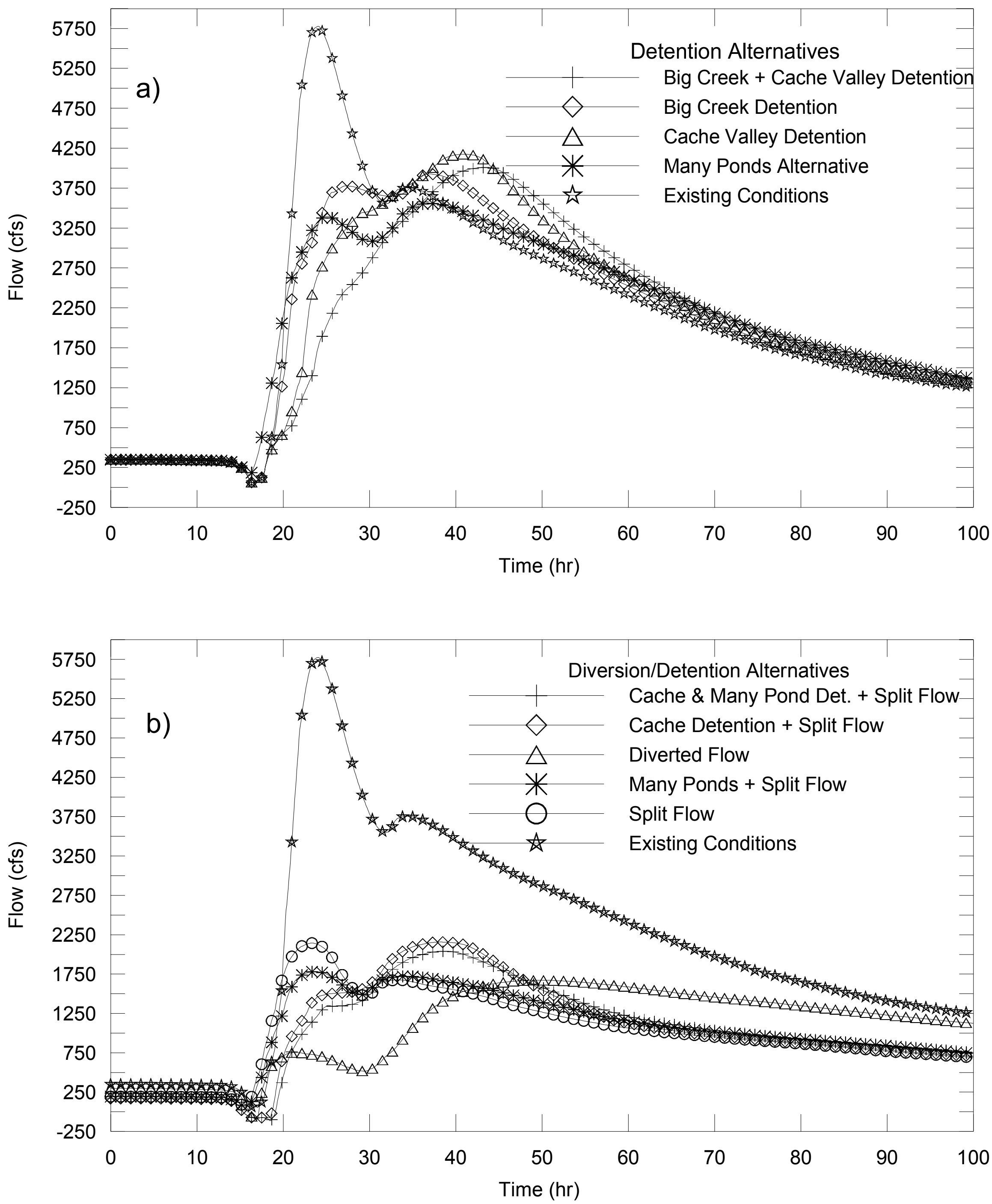


Figure 38. Simulated 100-year flood hydrographs for existing conditions and nine alternatives; Cache River west of Big Creek

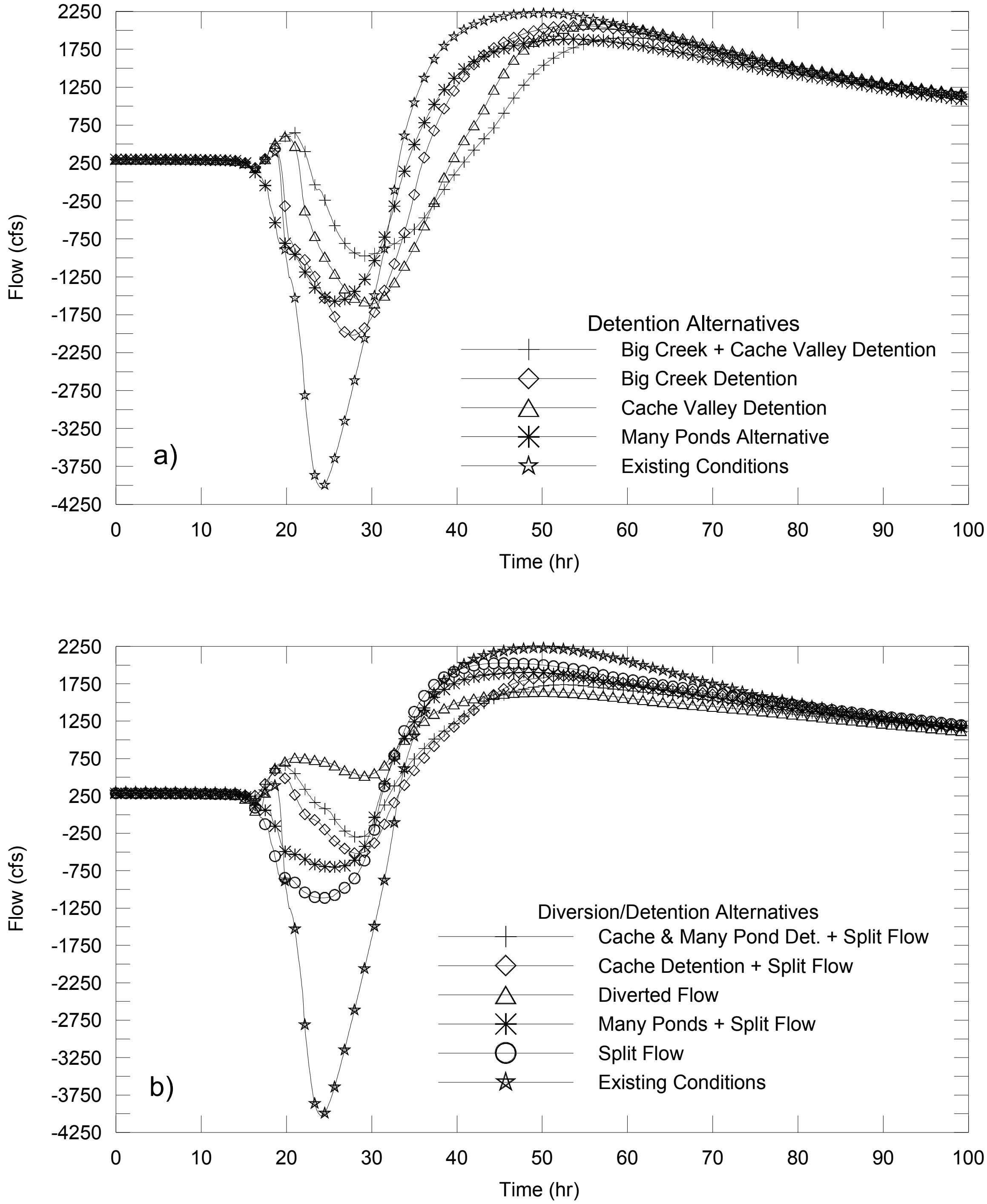


Figure 39. Simulated 100-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Big Creek

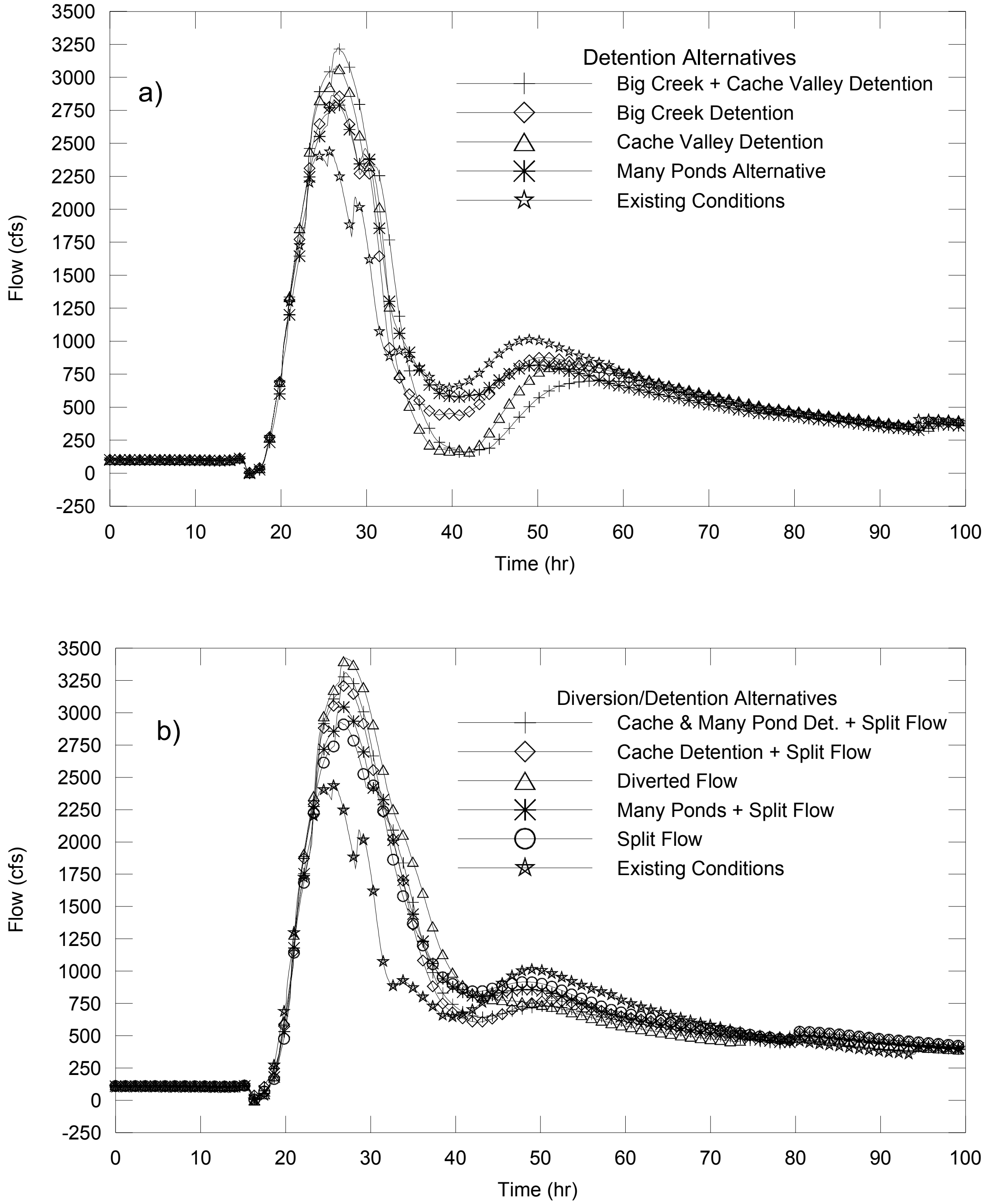
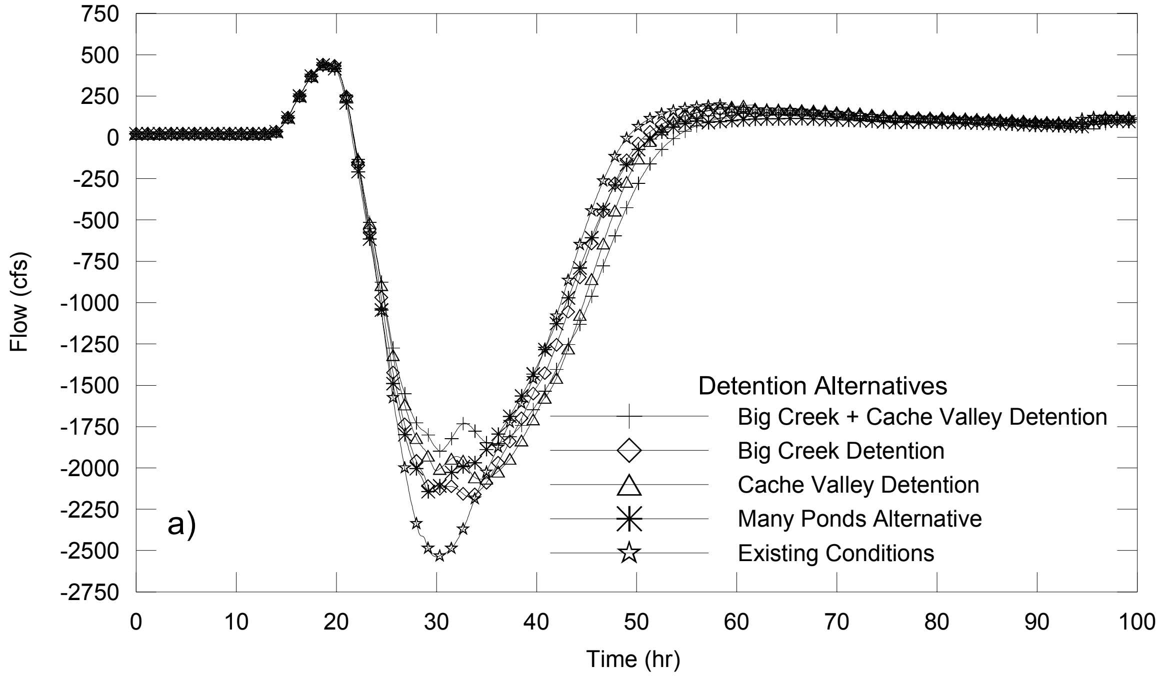


Figure 40. Simulated 100-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Perks Road



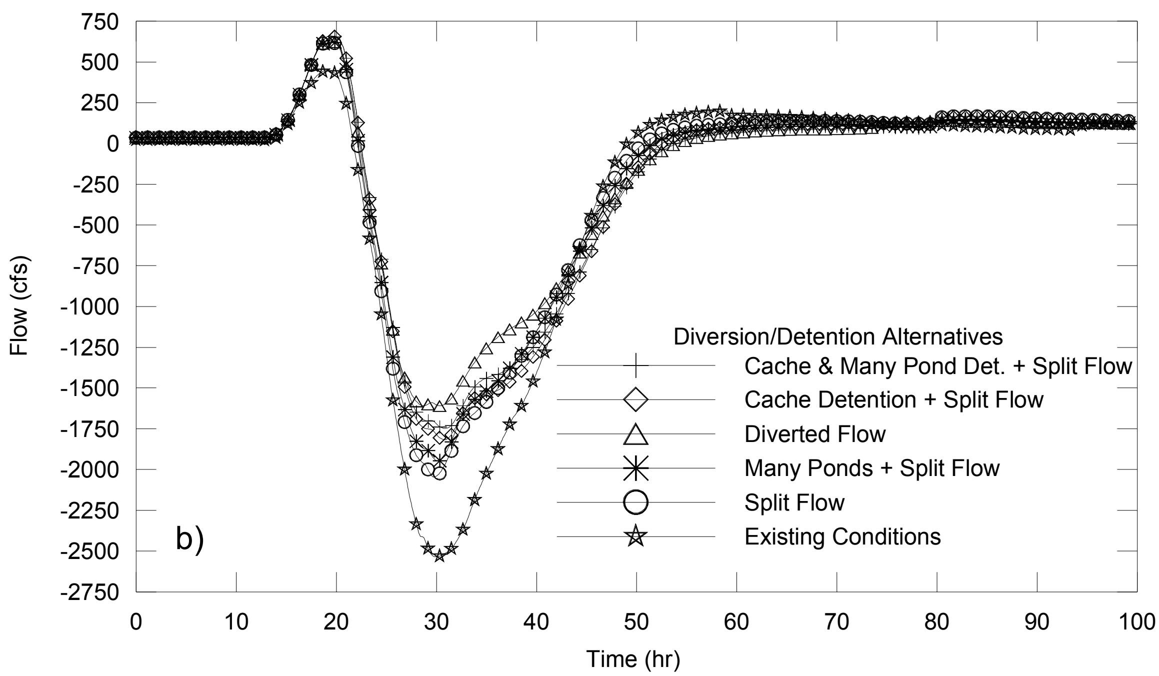


Figure 41. Simulated 100-year flood hydrographs for existing conditions and nine alternatives; Cache River east of Cypress Creek

Upstream in Buttonland Swamp (figure 40), the presence of the detention storage causes a 20-40 percent increase in the magnitude of westward flow during the early part of the flood hydrograph, but causes a decrease in the westward flow later in the hydrograph, such that over the duration of the entire flood there is little change in the total volume of flow.

For the 100-year event, the peakflows at Route 51 occur only after the Buttonland Swamp area has reached its peak stages and the entire Lower Cache River is flowing to the west (figure 37). Thus the magnitude of the flow downstream of the Big Creek confluence is related more to the total volume of floodwater in Buttonland Swamp and less to the inflow characteristics from the Big Creek watershed. Nevertheless, the use of either the split flow or diverted flow alternatives causes roughly a 20 percent increase in peakflow rates at Route 51. Detention storage, using both the many ponds and Cache valley alternative, is required to counteract the increase in flow caused by the split flow.

Figure 42 shows the estimated 100-year flood peak stages on the Lower Cache River from mile 20 to mile 29. In the Buttonland Swamp area, all four alternatives produce a reduction in peak stage, but the alternatives involving diverted flow and split flow provide the greatest amount of reduction. At Route 51 near Ullin, the diverted flow and split flow alternatives are estimated to produce a 0.4 to 0.8 foot increase in peak stage, respectively, as compared to the

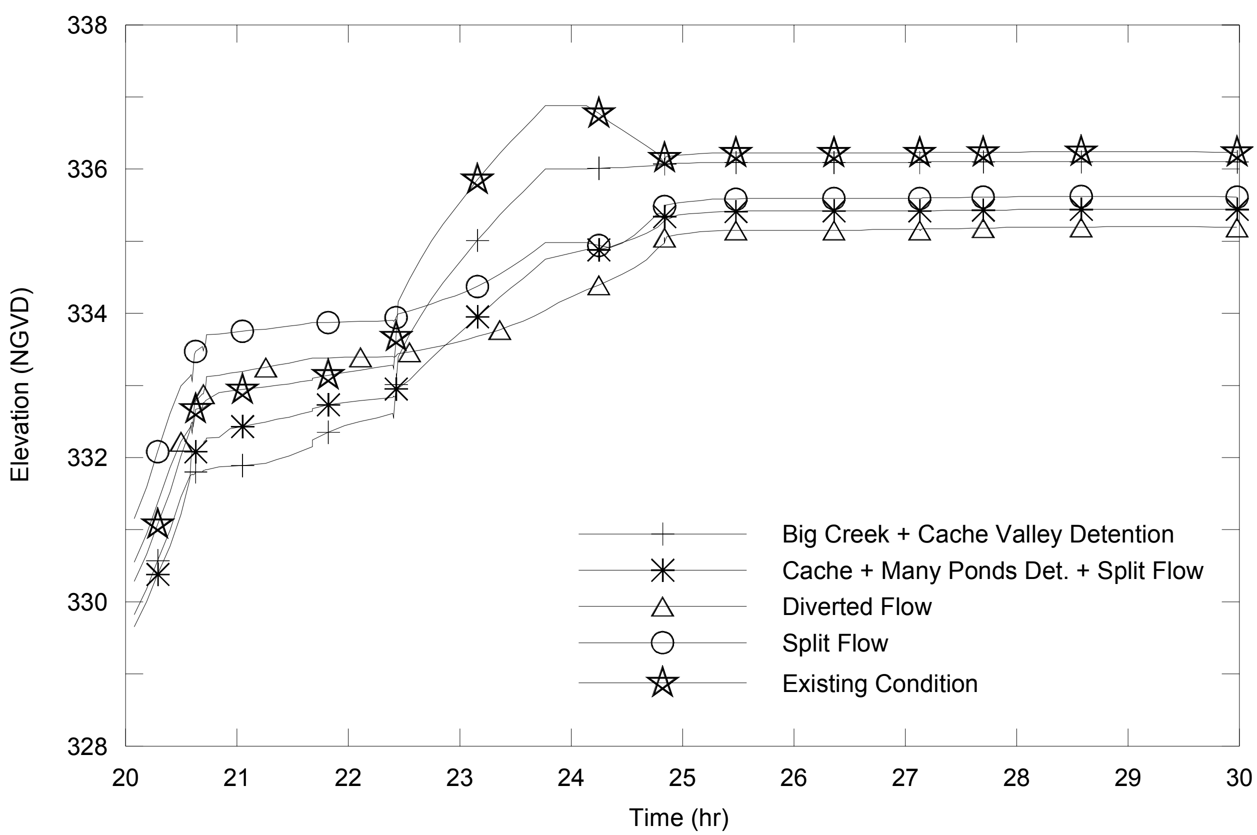


Figure 42. Peak stages on the Cache River for the 100-year flood; existing condition, diverted flow, and Big Creek/Cache detention storage alternatives

existing condition. When the split flow is combined with both headwater storage in Big Creek and the detention facility in the Cache valley, there is a 0.5 foot reduction in the peak stage near Ullin and an overall 0.5-1.0 foot reduction in stage at all locations in the study area.

Discussion

The simulated flow indicates that the detention storage alternatives, which detain flows from the Big Creek watershed, reduce the reverse flow condition that exists on the Cache River immediately to the east of the Big Creek confluence. The detention alternatives examined are comparatively more successful in reducing the reverse flows associated with large flood events, such as the 100-year flood, with decreases in the peak reverse flow of 48-76 percent. With the more common 2-year flood event the detention storage alternatives reduce the peak reverse flow by 26-61 percent, and there is a 30-51 percent reduction associated with the 5-year flood event.

The diverted flow alternative appears to eliminate reverse flows for all sizes of floods. However, this alternative also causes higher flood stages at locations farther downstream (to the west) on the Cache River. Therefore, it is believed that this would be an unacceptable alternative unless detention storage was also created so that the downstream flood stages would not surpass that associated with the existing condition.

The simulated split flow alternative significantly reduces but does not eliminate reverse flows. It also has the disadvantage of increasing downstream flood stages. However, when the split flow approach is combined with sufficient detention storage in the Big Creek watershed, reverse flows to the east of Big Creek can be eliminated without increasing flood peaks in the vicinity of Ullin and Interstate 57.

Summary

The hydrology of the Big Creek watershed and its influence on the hydraulics of the Lower Cache River were investigated using two models. The HEC-1 model was initially used to simulate rainfall-runoff processes for the Big Creek watershed. This model was initially created in the 1980s using limited hydrologic data for calibration and verification. The present model was extensively calibrated using additional hydrologic data collected after the initial model was developed. It is therefore expected that the present model simulates the hydrology of the Big Creek watershed much better than the older model. The newly calibrated model for the Big Creek watershed also was used to improve the estimates of hydrologic parameters for other tributary watersheds that drain into the Lower Cache River.

The HEC-1 model was then used to evaluate the impacts of detention basins in the Big Creek watershed on the flood hydrograph of Big Creek before it enters the Lower Cache River. A total of 23 detention alternatives were considered. The alternatives considered different sizes and locations of detention basins within the Big Creek watershed. Detention basin locations along the main stem of Big and Little Creeks, on smaller tributaries of Big Creek, and in the Lower Cache valley near the confluence of Big Creek with Lower Cache River were considered. The different combinations of locations and sizes of detention basins affect the Big Creek flood hydrograph in different ways. Most of the alternatives reduce the peakflow and shift the time for the flood peak, while a few increase the flood peak by changing the timing of flood peaks from tributary streams.

The UNET model was then used to evaluate the influence of the flows from Big Creek under different assumptions on the flows in the Lower Cache River. The primary purpose is to evaluate how the reverse flow, defined as flow in an easterly direction, in the Lower Cache River east of the Big Creek junction is affected by the different alternatives considered for Big Creek. The impacts were evaluated for 2-, 5-, and 100-year floods.

Under existing conditions, the UNET model shows that reverse flow occurs in the Lower Cache River east of Big Creek junction during all the flood events considered. For the 2-year flood, about 31 percent of the flow from Big Creek flows eastward for a period of about 20 hours. For the 5-year flood, about 28 percent of the flow from Big Creek flows eastward for a period of 13 hours. For the 100-year flood, about 27 percent of the flow from Big Creek flows eastward for a period of 10 hours. The portion of Big Creek discharge that flows east and the duration of the reverse flow decreases as the return period of the flood increases. The model results indicate that during extreme flood, the reverse flows are relatively less significant while during moderate and more frequent floods the reverse flows are more significant and last for longer durations.

Two types of alternatives for minimizing the frequency and magnitude of reverse flow in the area immediately east of Big Creek were evaluated using the UNET model. The first type involves some form of detention structure in the Big Creek watershed or in the Cache River valley while the second type involves partial or full diversion of the flow from Big Creek to a point further downstream (west) in the Lower Cache River. Table 8 summarizes some of the impacts of these alternatives on peak flows and stages at selected locations.

Table 8. Impacts of Selected Alternatives on Peakflows and Stages

	Peakflow reduction at Big Creek outlet (%)			*Reduction in peak reverse flow east of Big Creek (%)*			*Change in peak flood elevation at Rt. 51 (ft)*		
Event	*2-year*	*5-year*	*100-year*	*2-year*	*5-year*	*100-year*	*2-year*	*5-year*	*100-year*
Existing	0	0	0	0	0	0	0	0	0
Big Creek Detention	45	40	41	42	37	48	-0.4	-0.4	-0.5
Cache valley Detention	35	33	48	26	30	60	-0.4	-0.4	-0.8
Big + Cache Detention	56	52	58	61	52	76	-0.6	-0.6	-1.0
Many Ponds	31	31	49	26	30	57	-0.2	-0.7	-0.5
Diverted	100	100	100	106	112	105	0.1	0.1	0.4
Split	57	60	67	52	54	69	0.1	0.2	0.8
Split+Many	67	70	75	26	71	80	-0.1	-0.1	0.2
Split +Cache valley	66	69	74	66	68	80	-0.4	-0.4	0.8
Split+Many+Cache	74	77	83	81	85	92	-0.6	-0.6	-0.5

For the 2-year flood, the detention alternatives reduce the peak of the reverse flow east of Big Creek by 26 to 61 percent with the combination of detentions on Big Creek and Cache River valley being the most effective. The detention alternatives also reduce the peakflows and stages to the west of Big Creek and thus will have a positive impact farther downstream with respect to flooding. For the 5-year flood, the detention alternatives reduce the peak of the reverse flow east of Big Creek by 30 to 52 percent with the combination of detention on Big Creek and the Cache River valley being the most effective. The detention alternatives also reduced peak stages along the Lower Cache River to a similar extent as compared to the 2-year flood. For the 100-year flood, the detention alternatives reduce the peak reverse flow east of Big Creek by 48 to 76 percent, the combination of detention on Big Creek and Cache River valley removing 76 percent of the reverse flow. The reduction on peak stages farther downstream is generally greater for the 100-year flood than for the 2- and 5-year floods.

The other alternatives considered were to totally or partially divert the Big Creek flow from its present inflow point farther west past the I-57 bridge. The alternative to totally divert the Big Creek flow eliminates reverse flow in the area immediately east of Big Creek outlet for all the flood conditions considered. The total diversion also reduces flood peaks east of Big Creek by 0.4 to 2 feet, resulting in increased flows westward from the Buttonland Swamp area. This alternative, however, increases peak flood stages farther downstream west of the I-57 bridge by 0.1 to 0.4 foot for the 2-year and 100-year flood events, respectively.

The alternative to divert only a portion of the Big Creek flow (split flow) appears to be similar to the detention alternatives where peak reverse flows east of Big Creek are reduced by 52 percent for the 2-year flood to 69 percent for the 100-year flood. The partial diversion alternative reduces flood stages to the east of Big Creek greater than the detention alternatives but not as great as the total diversion alternative. For locations farther west on the Lower Cache

River, the UNET model indicates that the partial diversion alternative increases the peak flood stages to a greater extent than the total diversion alternative, although to some degree this result seems counterintuitive. Changes to the design of the diverted and split flow channels could affect the comparative impacts of these alternatives.

To eliminate most of the reverse flow east of Big Creek and at the same time not increase flood stages farther west on the Lower Cache River, it may be necessary to use a combination of detention storage and either partial or total diversion of the lower portion of Big Creek. The use of the split flow alternative in combination with the many ponds and Cache valley detention alternatives reduces the peak reverse flows east of Big Creek by 81 percent for the 2-year flood and 92 percent for the 100-year flood. This combined alternative also accomplishes a reduction in the peak stages farther downstream west of I-57 by approximately 0.5 foot.

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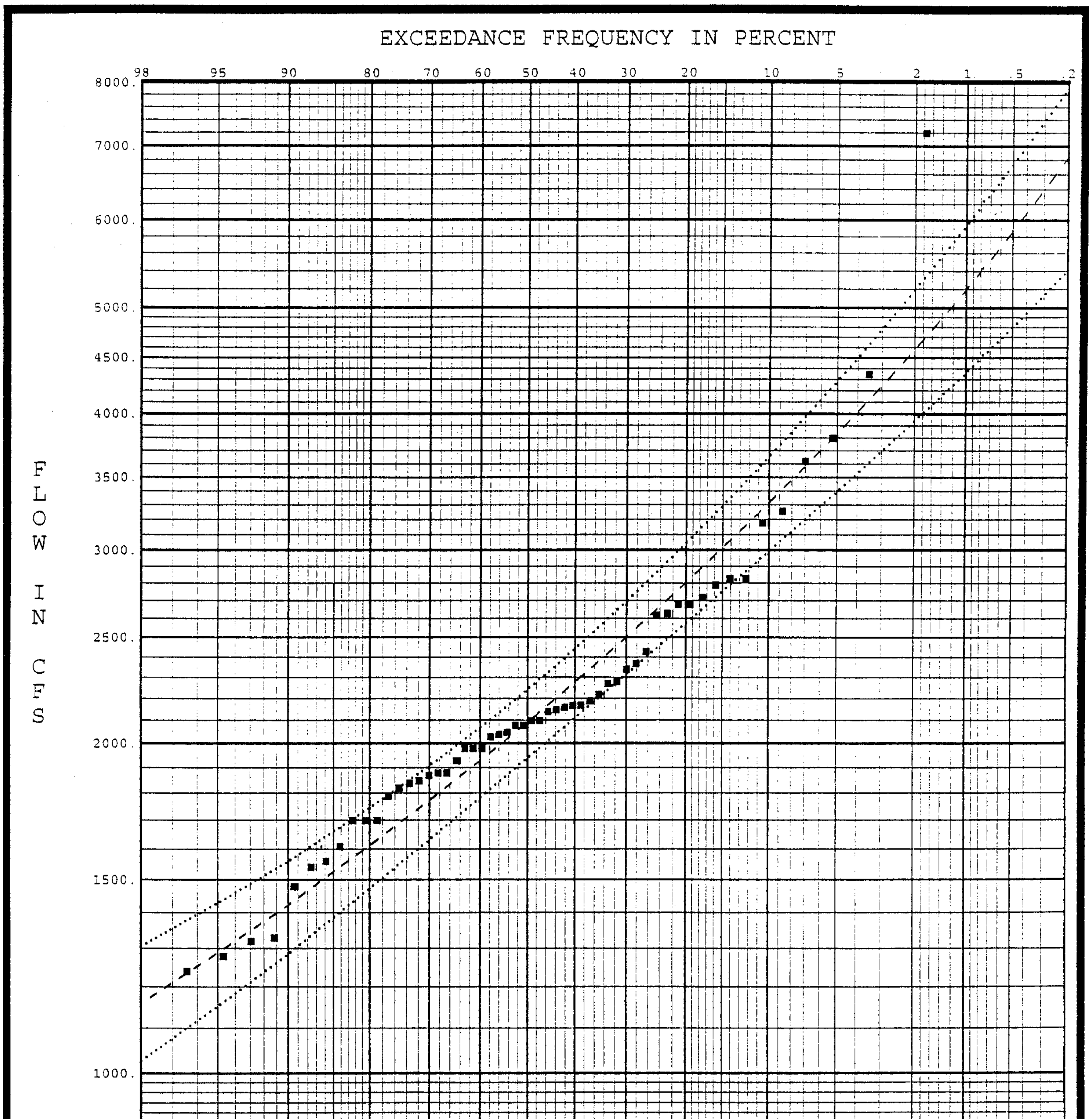
Appendix A. Design Rainfall Determination

Design events were modeled to give a frequency to the magnitude of flows modeled. The 24-hour storm duration was chosen, and it was necessary to determine the 2-, 5-, and 100-year rainfall events and flows. From Bulletin 70 (Huff and Angel, 1989) the point values of the total rainfall amounts were chosen, and these values were reduced by a factor of 0.93 due to the area modeled being 155 square miles. The total amount of rainfall was therefore 3.37 inches for the 2-year storm and 4.19 and 7.69 inches, respectively, for the 5- and 100-year storm events. The rainfall for each hypothetical event was distributed according to the third quartile distribution for areas of 50 to 400 square miles (table A-1).

To determine the peakflow rates for each design event, a frequency analysis was performed using the Flood Frequency Analysis software (HEC-FFA) from the U.S. Army Corps of Engineers (figure A-1). The 2-, 5-, and 100-year peakflows calculated were 2,100, 2,800, and 5,200 cfs, respectively. In order to estimate a volume of runoff for each of the design events, historical data were examined. To estimate the 100-year volume, the three highest annual flows were selected. Their corresponding volumes were determined by determining the baseflow and dividing by the basin area at the gage site. The average amount of runoff for the 100-year storm was 4.2 inches. To estimate a runoff volume for the 5-year event, seven storms in the period of record with peakflows between 2,600 and 3,000 cfs were chosen with an average runoff of 2.2 inches. To estimate a runoff volume for the 2-year event, ten storms with peakflows between 2,000 and 2,200 cfs were chosen with an average runoff of 1.6 inches.

Table A-1. Design Event Rainfall Distributions (inches)

Hour	*2-year*	*5-year*	*100-year*
1	0.07	0.08	0.15
2	0.03	0.04	0.08
3	0.07	0.08	0.15
4	0.10	0.13	0.23
5	0.07	0.08	0.15
6	0.07	0.08	0.15
7	0.07	0.08	0.15
8	0.03	0.04	0.08
9	0.07	0.08	0.15
10	0.10	0.13	0.23
11	0.10	0.13	0.23
12	0.20	0.25	0.46
13	0.27	0.34	0.62
14	0.40	0.50	0.92
15	0.40	0.50	0.92
16	0.37	0.46	0.85
17	0.30	0.38	0.69
18	0.20	0.25	0.46
19	0.13	0.17	0.31
20	0.10	0.13	0.23
21	0.07	0.08	0.15
22	0.07	0.08	0.15
23	0.03	0.04	0.08
24	0.03	0.04	0.08
Total	3.37	4.19	7.69



--- FLOW Frequency (with Exp. Prob.)
■ Weibull Plotting Positions
······· 5% and 95% Confidence Limits

FREQUENCY STATISTICS

LOG TRANSFORM OF FLOW, CFS		NUMBER OF EVENTS	
MEAN	3.3299	HISTORIC EVENTS	0
STANDARD DEV	.1411	HIGH OUTLIERS	1
SKEW	.8765	LOW OUTLIERS	0
REGIONAL SKEW	-.3500	ZERO OR MISSING	0
ADOPTED SKEW	.4000	SYSTEMATIC EVENTS	56
		HISTORIC PERIOD(1942-1997)	56

Figure A1. Flow frequency for Big Creek at Perks Road (HEC-FFA output)

Appendix B. Analysis of Detention Storage Alternatives

Detention Storage Approaches

Main Channel Options

This analysis focuses on the impacts of detention storage within the Big Creek watershed on the flow rates of Big Creek. A primary purpose of this analysis was the reduction or elimination of the reverse flow condition in the Lower Cache River that provides the means for water and sediment from Big Creek to flow into Buttonland Swamp. Three basic types of detention storage facilities were evaluated for this purpose: 1) in-channel detention sites along Big Creek and Little Creek, 2) a detention facility located in the floodplain area of the Lower Cache River near the mouth of Big Creek, and 3) numerous smaller detention ponds located near the headwaters of the Big Creek and Little Creek watersheds.

In-Channel Detention

Eight potential in-channel detention storage sites were identified for use in determining the impacts of detention storage on the Big Creek flows. The locations of these potential detention storage sites are described in table B-1 and shown in figure B-1. All sites correspond to the outflow point of a particular subwatershed within the Big Creek basin, as modeled using HEC-1, and are identified by the identification number of that subwatershed. Thus, detention site 10 is located at the outflow point of watershed number 10, as identified in table 3 and figure 15 in the main report and in figure B-1. The conceptual design of the detention storage approach uses low-head weirs. Weir heights of 10 feet were used for all locations except site number 5 for which a 15-foot detention structure also was examined. The key hydrologic attributes of the detention facilities, including volume of storage and surface area at the top elevation of the weir, are given in table B-1. For most cases, the weirs are not contained entirely within the stream channel, and would extend out into the floodplain. For most sites, the simulated detention facility would inundate less than 30 acres of land behind the weir during flood events. The exceptions are site number 12 on Little Creek and the use of a 15-foot weir at site number 5 on Big Creek.

It is expected that the low-head weirs have a culvert outlet that is used to drain the detained water, and during low and normal flow conditions also permits streamflow to pass underneath the weir without being detained. The simulated diameter of the culverts was 3 feet for all detention storage sites. At the maximum level of detention storage, the outflow from the culverts is roughly 125 cubic feet per second (cfs). Making the size of the culverts larger or smaller will change the inflow-outflow relationship of the detention storage, and can have a variable, but generally small impact on the flood discharges farther downstream on Big Creek, as will be shown later. All detention structures are assumed to have an overflow spillway that is 75 feet wide, which is used when the detention storage has been filled.

Cache Valley Detention

The use of a detention facility in the floodplain of the Lower Cache River valley provides another alternative for reducing the peakflow rate from Big Creek to the Lower Cache River, and thus potentially reducing reverse flows in the river. The proposed site would be close to the mouth of Big Creek at the outflow point of subwatershed area 14, as shown in figure B-1 and described in table B-1. Detention site 14 was modeled with the assumption that a 10-foot or 15-foot embankment would be constructed with storage capacities of 313 and 1523 acre-feet, respectively, to contain the excess high flows from Big Creek. Outflow from the detention facility would be through a 3-foot diameter culvert.

Headwater Detention

The use of small detention (or farm) ponds in the headwaters of the Big Creek and Little Creek watersheds also was examined for use in reducing peakflows on Big Creek. These ponds potentially would be located on small streams draining catchment areas of generally less than one square mile.

In order to evaluate the impact of these ponds and obtain meaningful results, it was necessary to modify the hydrologic model (HEC-1) to simulate flows on smaller watershed areas. A total of 44 watershed subdivisions were defined in this process, as shown in figure B-2. Watershed characteristics for these areas are presented in table B-2. As simulated by the HEC-1 model, a farm pond was located at the outflow point of 23 of these smaller watersheds. The locations and detention storage characteristics of the 23 ponds are presented in table B-3. In modeling the smaller ponds, the height of all the embankments was set at 5 feet, and the diameter of all culverts was set at 2 feet. This means that due to placement and drainage area, some ponds may not be optimally efficient, while other ponds may have significant amounts of storage atypical of a normal farm pond. Individually these ponds do not capture a sufficient amount of water to cause a meaningful reduction in the Big Creek flows. However, it is expected that collectively the 23 ponds may have a significant impact on these flows.

Description of Detention Alternatives

Twenty-three detention alternatives were defined, in which each alternative represents the impacts of either one detention pond or a collection of ponds. The detention components associated with each alternative are described by the two left columns in tables B-4 and B-5. For example, alternative 12 represents the collective impact of detention storages at sites 1, 2, 4, and 5, and in which a 15-foot detention structure is used at site 5. Alternative 23, hereafter described as the “many ponds” alternative, represents the collective impact of all 23 headwater farm ponds at locations described in table B-3 and figure B-2.

Inflow/Outflow Characteristics of Individual Detention Facilities

The impact of the individual detention facilities on the runoff from the subwatershed units was modeled using rainfall data from the storm event of October 4, 1990 and a 5-year design storm. The peakflow of the October 1990 event, as measured at the Big Creek gage near Wetaug, was 1,520 cfs. This event is a common flood event having a recurrence interval of less than 2 years. For comparison, the peakflow of the 2-year event was estimated to be 2,100 cfs. All results are presented for flow conditions farther downstream at the mouth of Big Creek. The simulated outflow of the October 4, 1990 event at the mouth of Big Creek for existing conditions was 2,060 cfs. The simulated outflows for the 5-year design flood at the Wetaug gage and the mouth of Big Creek were 2806 and 4237 cfs, respectively.

Tables B-4 and B-5 describe various flow and storage characteristics as taken from the hydrologic modeling results for the alternatives studied. In this section, we will initially discuss only the inflow-outflow relationships for individual ponds. Alternatives 1-3 and 6-9 present the impacts of the in-channel 10-foot detention structures at locations 10-12, 1, 2, 4, and 5, respectively. Alternative 10 presents the impact of a 15-foot weir at location 5. Alternatives 16 and 17 represent the impact of the Cache River floodplain detention (location 14).

In-Channel Detention

Figures B-3 through B-10 show the inflow and outflow hydrographs of a 5-year storm event for detention sites 1, 2, 4, 5 (10- and 15-foot weirs), and 10-12. For detention sites 1, 2, 4, 10, and 11, the 10-foot weir causes little or no reduction in the 5-year flood peak. For detention sites 5 and 12, which inundate a greater area, the 10-foot weir reduces the 5-year peakflows by roughly 10 percent. When a 15-foot weir is used at site 5, the amount of reduction in the peak flood is increased to 40 percent. The increase from a 10- to 15-foot weir at site 5 increases the maximum amount of inundated land from 145 to 301 acres.

The flood reduction impacts of the in-channel detention are comparatively greater for smaller floods, as indicated for the October 1990 event in table B-4. For detention sites 2, 4, 5, and 12, the 10-foot weir reduces the flood peaks by 8-17 percent and delays the peak by 1-4 hours. The 15-foot weir at detention site 5 reduces the flood peak of the October 1990 event by almost 60 percent.

Obviously, if the storage volume were increased at any location, such as with a higher weir extending into the floodplain area, there would be both an additional reduction in the flood peak and a greater amount of inundated land. It is also possible that the culvert sizes at any of the eight detention storage sites could be altered to further reduce the peak outflows from the site. However, the simulated results give a range of expected storage impacts from “general-purpose” weir design as simulated without detailed channel/floodplain geometry information.

Based on the above results, some of the detention sites may appear to be ineffective in reducing peakflows. However, as will be shown in the following section, the reduction in peak outflow at some detention sites does not always provide the best indication of the overall benefit of the site in reducing flood peaks farther downstream.

Cache Valley Detention

Figures B-11 and B-12 show the potential impact of a Cache valley detention facility on the 5-year flood hydrograph using 10-foot and 15-foot structures, respectively. The impact of a larger detention facility in the Lower Cache River floodplain, near the mouth of Big Creek, has the potential to reduce Big Creek outflow to a greater extent than individual structures located farther upstream. As shown in these figures, a 10-foot detention structure has the potential to reduce the 5-year peak outflow by 33 percent, and a 15-foot structure could reduce peak outflows by 77 percent. For the October 1990 event, the relative impact of the 10- and 15-foot structures is even greater, resulting in 42 percent and 90 percent reductions in peak outflows, respectively.

The peak storage and number of acres flooded with the 10-foot and 15-foot structures at this location (alternatives 16 and 17) are relatively large when compared to the detention structures examined at other sites. Potential alterations to the design of a Cache valley detention structure, such as an increase in the size of the outlet culvert, would significantly affect these results.

Impacts of Detention Storage Alternatives on Big Creek Outflow

Tables B-4 and B-5 also list detention storage alternatives that use a variety of combinations of different detention sites. Details on the inflow-outflow relationship and peak storage for each combination of detention sites are included in this table, as simulated for the October 1990 flood event (table B-3) and the 5-year flood event (table B-4). Also listed for this storm event is the simulated peakflow rate on Big Creek as it enters the Lower Cache River, which can be compared to the existing (no detention) peakflow rates. The impacts of the 23 detention alternatives on the 5-year outflow hydrograph of Big Creek are shown in figures B-13 to B-35.

Table B-6 compares the simulated impact of the individual detention storage facilities on the peakflow reduction at two locations: the detention site and downstream at the mouth of Big Creek. In most cases, the detention storage causes a larger impact on the peakflow farther downstream than it does at the detention site. This is particularly true for the smaller event of October 1990. The reason this occurs is that the detention storage not only reduces the peakflow at the detention site, but also delays the outflow by 1-4 hours. The lag in the outflow is often the most important factor in reducing flows downstream, because the peak outflow from the detention storage may no longer coincide with the peak outflow from other portions of the watershed.

In certain circumstances, creation of detention storage on a tributary has the potential to exacerbate the flooding problem farther downstream. This can happen when the runoff time of concentration of that tributary occurs earlier than the time of concentration on the mainstem of the stream. In these cases, a lag in the tributary outflow can cause its peakflow to coincide with the peakflow of the stream's mainstem. Notice, for example, that the site 11 detention storage (alternative 2) provides essentially no reduction in the peakflow at the mouth of Big Creek for the October 1990 event, even though the peak outflow from the detention facility is 66 cfs (15%) less than its peak inflow. Thus, in choosing locations for detention storage, it can be very important to evaluate the expected timing of runoff from individual watersheds.

Impacts of the In-Channel and Cache Valley Detention Alternatives

An examination of tables B-4 and B-5 indicates that there are 11 alternatives that provide a reduction in peakflow of at least 30 percent for both the October 1990 and 5-year flood events, these being alternatives 10, 12, 15, and 16-23. Each of these alternatives involves either detention storage near the mouth of Big Creek in the Cache River floodplain (site number 14) or a larger 15-foot weir, extending into the floodplain of Big Creek, at site number 5. These alternatives would use a minimum of 810 acre-feet of storage for the October 1990 event and 1312 acre-feet for the 5-year event. As a general rule, there is a greater reduction of peak discharge with increasing detention storage; however, there are several exceptions.

Three alternatives involve the combined use of at least three smaller detention units, these being alternatives 5, 11, and 13. For the October 1990 event, each of these alternatives provides a 15-22 percent reduction in the peakflow rates at the mouth of Big Creek. In contrast, for the 5-year event, only alternative 5 provides much of a reduction in the peakflow rates. However, it should be noted that alternatives 3, 9, and 14 also provide nearly the same degree of flood peak reduction with fewer detention units. This suggests that a few well-placed detention storage sites may potentially be nearly as effective for flood reduction on Big Creek as the widespread use of a number of units. However, the many ponds option (alternative 23) indicates that the widespread use of a number of detention units can be effective, as described later in this section.

Impacts of Varying Culvert Size

Figures B-36 and B-37 show examples of the impact of culvert size on the inflow-outflow relationships for the October 1990 storm event at detention sites 1 and 10, respectively. At detention site number 1, the use of the larger, 4-foot diameter culvert produces an additional 10 percent reduction in the peak discharge immediately downstream of the facility. At detention site number 10, there is little difference in the peak discharge immediately downstream, regardless of culvert size. In both cases, the peak outflow occurs after the detention storage is filled up, and the excess inflow overflows the weir. However, in the case of site number 1, the weir overflow does not occur until after the peak inflow has arrived and the inflows are receding. For the 5-year flood event, the detention weirs are overtopped early in the flood, such that culvert size has little impact on the outflow of this larger flood event.

Figures B-38 and B-39 show the impact the culvert size on the streamflow at the mouth of Big Creek, again for the October 1990 event. For both detention site 1 (figure B-38) and detention site 10 (figure B-39), an increase in the culvert size from 3 to 4 feet causes a corresponding increase in the peakflow on Big Creek. As discussed earlier, the expected timing of runoff from each detention facility is a key consideration in its impact farther downstream. At the time when the Big Creek flow is cresting, the contributing flow from both detention sites 1 and 10 comes primarily from the culvert outflow, and the maximum outflow through the 4-foot culverts (roughly 225 cfs) is greater than that through the 3-foot culverts (roughly 125 cfs). Given a different detention location and runoff response, it is possible that an increase in culvert size could reduce flood levels on Big Creek. Thus, a detailed analysis of expected watershed runoff amount and timing would be needed to determine the optimal detention characteristics for any individual facility or combination of detention facilities. For larger flood events, it is not expected that culvert size has much of an impact on the Big Creek outflow.

Impact of the Many Ponds Alternative

Alternative 23, or the "many ponds" alternative, examines the collective flood reduction impact of 23 ponds located in the headwaters of the watershed. One advantage to having a number of detention units is that they potentially can provide distributed flood reduction throughout the watershed, and not have benefits limited to a few selected stream reaches. As shown in tables B-4 and B-5, this alternative reduces the peakflow downstream at the mouth of Big Creek by roughly 29 percent for the October 1990 event and 38 percent for the 5-year flood event. All the "ponds" were assumed to have a 5-foot embankment above normal pool level and a 2-foot diameter culvert for outflow. The area that would be inundated for each facility was determined from topographic mapping. When fully inundated, most of the ponds would flood an area of less than 10 acres. However, eight of the detention ponds have listed a potential storage of more than 100 acre-feet, which suggests that they should not be considered "farm ponds." In general, only a small amount of the available storage (338 acre-feet) is used for the October 1990 event, and it is possible that many of these larger ponds could be downsized and still maintain the same flood reduction for moderate flood events. However, for the larger 5-year event, a significant amount of storage (2086 acre-feet) in the larger ponds is used.

Table B-1. Description of Potential In-Channel and Cache Valley Structures

Location ID	*Location*	*Storage available (ac-ft)*	*Surface area (ac)*	*Weir height (ft)*	*Culvert diameter (ft)*	*Channel invert (ft)*	*Drainage area (mi^2)*
In-Channel Detention							
1	Big Creek - approximately 1/10 mi. U/S of Little Creek #1, approximately 1 mile upstream of the I-57 bridge	79.0	20.7	10	3	399.0	7.98
2	Little Creek #1 - approximately 1/10 mi. U/S of Big Creek	63.8	17.3	10	3	398.3	8.46
4	Trib to Big Creek - approximately 1/2 mi. U/S of Dongola	46.0	13.8	10	3	380.0	16.44
5A*	Big Creek - approximately 3/4 mi. upstream of Perks Road	106.0	31.8	10	3	340.0	25.36
5B*	Big Creek - approximately 3/4 mi. upstream of Perks Road	543.7	159.6	15	3	340.0	25.36
10	Crooked Creek - approximately 1/3 mi. upstream of U.S. 51 Bridge	24.1	7.2	10	3	360.0	5.97
11	Little Creek #2 - approximately 1 mi. upstream of Dongola	44.0	13.2	10	3	400.0	4.13
12	Little Creek #2 - approximately 1/10 mi. upstream of Wetaug Bridge	134.3	59.0	10	3	343.8	12.84
Cache Valley Floodplain Detention							
14A*	Big Creek – upstream of the confluence with the Cache River	313.1	128.5	10	3	324.8	50.05
14B*	Big Creek – upstream of the confluence with the Cache River	1522.7	377.1	15	3	324.8	50.05

Note: *Two weir heights were examined for location 5, with locations 5A and 5B representing weir heights of 10 and 15 feet, respectively. In a similar manner, locations 14A and 14B represent weir heights of 10 and 15 feet, respectively, for the Cache valley floodplain detention site.

Table B-2. HEC-1 Model Watershed Characteristics for the Big Creek Watershed Subdivisions

			Main Channel				*Right Plane (1)*			*Left Plane (2)*			
Big Creek	*Sub-watershed*	*Basin area (mi^2)*	*Main channel length (ft)*	*Down-stream elev. (ft)*	*Up-stream elev. (ft)*	*Main channel slope*	*Portion of basin (%)*	*Avg max overland length (ft)*	*Avg overland slope*	*Portion of basin (%)*	*Avg max overland length (ft)*	*Avg overland slope*	*Raingage*
12	12	3.00	12425			0.0016	72	3245	0.0153	28	4745	0.0189	AES
13	13	2.77	7273			0.0010	26	12651	0.0086	74	4918	0.0113	AES
10	10A	0.19	1898	357	361	0.0021	65	1560	0.0449	35	1730	0.0116	AES
	10A1	0.61	9233	370	453	0.0090	61	1530	0.0294	39	1155	0.0173	Tripps
	10A2	1.81	13348	361	402	0.0031	31	1440	0.0278	69	2360	0.0403	AES
	10A3	1.42	15732	402	610	0.0132	55	1765	0.0113	45	1416	0.0643	Anna
	10B	0.06	2061	402	405	0.0015	53	690	0.0551	47	880	0.0511	Tripps
	10B1	0.70	10270	405	540	0.0131	53	1465	0.0478	47	1040	0.0385	Tripps
	10B2	0.29	4029	405	440	0.0087	25	780	0.0321	75	1640	0.0457	Tripps
	10B3	0.42	6933	440	587	0.0212	49	1220	0.0287	51	1360	0.0294	Tripps
	10C	0.53	7701	440	605	0.0214	31	1200	0.0017	69	1450	0.0345	Anna
11	11A	0.15	3895	361	374	0.0033	40	970	0.0124	60	830	0.0084	AES
	11A1	0.51	6542	374	508	0.0205	59	1620	0.0494	41	1300	0.0346	Tripps
	11A2	1.98	17136	374	440	0.0039	50	2300	0.0422	50	2250	0.0342	Tripps
	11A3	0.88	9949	440	635	0.0196	51	2455	0.0163	49	1750	0.0286	Anna
	11B	0.54	6812	440	635	0.0286	51	1590	0.0283	49	1600	0.0375	Tripps
1	1A	0.26	3441	400	409	0.0026	52	1820	0.0396	48	1200	0.0442	Tripps
	1A1	1.18	8726	409	570	0.0185	75	2060	0.0583	25	1510	0.0497	Tripps
	1A2	0.08	1072	409	410	0.0009	29	453	0.0640	71	2260	0.0372	Tripps
	1A3	0.54	10119	410	610	0.0198	58	1825	0.0515	42	840	0.0690	Tripps
	1A4	0.26	4026	410	440	0.0075	33	1300	0.0477	67	1380	0.0703	Tripps
	1A5	0.90	10697	440	602	0.0151	63	1500	0.0387	37	1720	0.0570	Tripps
	1B	0.52	5048	440	455	0.0030	50	1360	0.0441	50	1530	0.0660	Tripps
	1B1	1.03	11974	455	641	0.0155	72	2100	0.0571	28	976	0.0615	Anna

Table B-2. Concluded

Big Creek	Sub watershed	Basin area (mi^2)	*Main Channel* Main channel length (ft)	Down-stream elev. (ft)	Up-stream elev. (ft)	Main channel slope	*Right Plane (1)* Portion of basin (%)	Avg max overland length (ft)	Avg overland slope	*Left Plane (2)* Portion of basin (%)	Avg max overland length (ft)	Avg overland slope	Raingage
	1C	1.20	5254	455	490	0.0067	25	2440	0.0348	75	3400	0.0294	Anna
	1C1	0.72	7363	490	621	0.0178	36	1275	0.0235	64	1900	0.0211	Anna
	1D	1.73	12911	490	637	0.0114	72	2280	0.0175	28	1700	0.0424	Anna
2	2A	1.42	8468	400	440	0.0047	50	2400	0.0417	50	3260	0.0534	Tripps
	2A1	0.50	8152	440	645	0.0251	57	872	0.0917	43	1320	0.0530	Tripps
	2B	0.59	2613	440	465	0.0096	27	1530	0.0490	73	2595	0.0385	Tripps
	2B1	0.32	2911	465	490	0.0086	86	2370	0.0316	14	570	0.0789	Tripps
	2B2	1.24	11544	465	660	0.0169	21	2090	0.0100	79	3115	0.0257	Anna
	2B3	0.71	9388	490	601	0.0118	74	2030	0.0493	26	980	0.0306	Anna
	2C	3.15	22633	490	620	0.0057	40	1715	0.0274	60	3730	0.0214	Anna
3	3A	1.68	8750	371	380	0.0010	72	4470	0.0179	28	1905	0.0525	Tripps
	3B	0.92	10336	380	390	0.0010	64	2560	0.0465	36	2240	0.0366	Tripps
	3B1	0.82	7647	390	516	0.0165	38	2790	0.0190	62	2470	0.0336	Tripps
	3C	1.17	7155	390	400	0.0014	75	3000	0.0517	25	1630	0.0491	Tripps
4	4A	1.72	10874	371	405	0.0031	65	3560	0.0337	35	1070	0.0654	Tripps
	4A1	0.91	10927	405	580	0.0160	52	1810	0.0304	48	1280	0.0508	Tripps
	4B	1.47	10095	405	460	0.0054	64	2490	0.0245	36	2290	0.0293	Tripps
5	5A	1.03	12170	340	350	0.0008	24	1480	0.0270	76	2640	0.0227	AES
	5A1	1.57	13308	350	470	0.0090	77	4410	0.0181	23	850	0.0588	AES
	5B	1.43	7771	350	360	0.0013	50	3950	0.0152	50	1800	0.0394	AES
	5B1	1.05	10880	360	407	0.0043	40	1580	0.0443	60	2930	0.0276	AES
	5C	1.03	6446	360	371	0.0017	24	1375	0.0727	76	4360	0.0275	Tripps

Table B-3. Description of Potential Headwater Ponds

Location	*Storage available (ac-ft)*	*Channel invert (ft)*	*Drainage area (mi^2)*
1D	25.09	490.0	1.73
1C1	28.61	490.0	0.72
1B1	92.17	430.0	1.03
1A5	45.37	440.0	0.90
1A3	19.13	410.0	0.54
1A1	22.85	405.0	1.18
2B3	58.46	480.0	0.71
2C	77.37	480.0	3.15
2B2	157.85	465.0	1.24
2A1	14.07	440.0	0.50
3B1	58.48	390.0	0.82
4A1	171.02	405.0	0.91
4B	283.10	405.0	1.47
5B1	131.23	360.0	1.05
5A1	503.16	350.0	1.57
10B3	28.87	440.0	0.42
10C	19.87	440.0	0.53
10B1	23.47	405.0	0.70
10A3	152.34	402.0	1.42
10A1	210.97	370.0	0.70
11A3	36.57	450.0	0.88
11B	29.66	450.0	0.54
11A1	300.48	374.0	0.51

Note: Weir height and culvert diameter at all locations were 5 feet and 2 feet, respectively.

Table B-4. Performance of Detention Alternatives for October 4, 1990 Event

Cache River inflow properties				*Pond design properties*			*Hydrograph properties*			
Alternative	*Location ID*	*Peakflow to Cache (cfs)*	T_p *Cache (hr)*	*Peak storage (ac-ft)*	*Peak stage (ft)*	*Acres flooded*	Q_p *in (cfs)*	Q_p *out (cfs)*	T_p *in (hr)*	T_p *out (hr)*
Existing		2060	8							
Little Creek Detention Options										
1	10	2006	8	27	370.3	10	179	175	10	11
2	11	2057	9	59	411.0	15	453	387	4	6
3	12	1708	10	195	354.7	77	584	335	5	12
4	10	2002	9	27	370.3	10	179	175	10	11
	11			59	411.0	15	453	387	4	6
5	10	1644	9	27	370.3	10	179	175	10	11
	11			59	411.0	15	453	387	4	6
	12			185	354.6	74	315	291	7	15
Big Creek Detention Options										
6	1	1820	8	103	410.0	25	411	393	10	11
7	2	1932	9	94	409.8	22	628	579	6	7
8	4	1960	8	52	390.5	15	225	203	10	11
9	5A	1738	11	281	352.9	93	1528	1323	8	11
10	5B	842	16	825	356.5	217	1528	604	8	17
11	1	1635	11	103	410.0	25	411	393	6	7
	2			94	409.8	22	628	579	10	11
	4			52	390.5	15	225	203	10	11
12	1	708	7	103	410.0	25	411	393	6	7
	2			94	409.8	22	628	579	10	11
	4			52	390.5	15	225	203	10	11
	5B			772	356.3	207	1233	496	11	21
Big Creek & Little Creek Detention Options										
13	1	1623	11	103	410.0	25	411	393	6	7
	2			94	409.8	22	628	579	10	11
	4			52	390.5	15	225	203	10	11
	10			27	370.3	10	179	175	10	11
	11			59	411.0	15	453	387	4	6
14	5A	1657	12	281	352.9	93	1520	1323	8	11
	12			185	354.6	74	584	335	5	12
15	5B	902	16	825	356.5	217	1528	604	8	17
	12			185	354.6	74	584	335	5	12
Cache Valley Detention Options										
16	14A	1202	15	810	337.5	246	2060	1202	8	15
17	14B	211	32	1685	340.2	404	2060	211	8	32
Combination of Big Creek, Little Creek, and Cache Valley Detention Options										
18	12	1082	16	185	354.6	74	584	338	5	12
	14A			760	337.3	236	1708	1082	10	16
19	5A	1113	17	281	352.9	93	1528	1323	8	11
	14A			773	337.3	239	1113	1738	11	17
20	5B	638	22	772	356.3	207	1528	604	8	17
	14A			576	336.4	195	842	638	16	22
21	5A	1026	18	281	352.9	93	1528	1323	8	11
	12			185	354.6	74	584	355	5	12
	14A			736	337.2	231	1657	1026	12	18
22	5B	611	24	825	356.5	217	1528	604	8	19
	12			185	354.6	74	584	335	4	5
	14A			565	336.4	193	902	611	16	24
Many Ponds Detention										
23		1466	.	338		335				

Note: Location IDs 5A and 14A represent detention weir heights of 10 feet. Location IDs 5B and 14B represent 15-feet weirs.

Table B-5. Performance of Detention Alternatives for 5-Year Flood Event

Cache River inflow properties				*Pond design properties*			*Hydrograph properties*			
Alternative	*Location ID*	*Peakflow to Cache (cfs)*	*T_p Cache (hr)*	*Peak storage (ac-ft)*	*Peak stage (ft)*	*Acres flooded*	*Q_p in (cfs)*	*Q_p out (cfs)*	*T_p in (hr)*	*T_p out (hr)*
Existing		4237	24							
Little Creek Detention Options										
1	10	4246	24	23	369.89	6.45	737	750	21	22
2	11	4237	24	29	408.66	11.03	458	460	22	23
3	12	3840	25	346	356.26	114.69	1355	1072	22	26
4	10	4247	24	23	369.89	6.45	737	750	21	22
	11			29	408.66	11.03	458	460	22	23
5	10	3760	25	23	369.89	6.45	737	750	21	22
	11			29	408.66	11.03	458	460	22	23
	12			341	356.22	114.69	1301	1050	23	26
Big Creek Detention Options										
6	1	4201	24	75	408.75	20.01	941	928	21	21
7	2	4193	24	53	407.61	15.26	705	701	21	22
8	4	4237	24	28	388.49	10.75	411	406	22	23
9	5A	3757	25	487	354.59	145.43	2816	2526	23	26
10	5B	2534	28	1312	358.38	301.39	2816	1665	23	30
11	1	4148	24	75	408.75	20.01	941	928	21	21
	2			53	407.61	15.26	705	701	21	22
	4			28	388.49	10.75	411	406	22	23
12	1	2405	29	75	408.75	20.01	941	928	21	21
	2			53	407.61	15.26	705	701	21	22
	4			28	388.49	10.75	411	406	22	23
	5B			1300	358.34	301.39	2711	1639	24	31
Big Creek & Little Creek Detention Options										
13	1	4068	25	75	408.75	20.01	941	928	21	21
	2			53	407.61	15.26	705	701	21	22
	4			28	388.49	10.75	411	406	22	23
	10			23	369.89	369.89	737	750	21	22
	11			29	408.66	408.66	458	460	22	23
14	5A	3674	26	487	354.59	145.43	2816	2526	23	26
	12			346	356.26	114.69	1355	1072	22	26
15	5B	2688	29	1312	358.38	301.39	2816	1665	23	30
	12			346	356.26	114.69	1355	1072	22	26
Cache Valley Detention Options										
16	14_{10}	2819	24	1518	339.74	373.34	4237	2819	24	29
17	14_{15}	973	24	3273	342.03	530.11	4237	973	24	39
Combination of Big Creek, Little Creek, and Cache Valley Detention Options										
18	12	2674	30	346	356.26	114.69	1355	1072	22	26
	14A			1452	339.58	363.41	3840	2674	25	30
19	5A	2686	31	487	354.59	145.43	2816	2526	23	26
	14A			1457	339.59	364.03	3757	2684	25	31
20	5B	2035	34	1312	358.38	301.39	2816	1665	23	30
	14A			1163	338.75	314.05	2534	2035	28	34
21	5A	2620	32	487	354.59	145.43	2816	2526	23	26
	12			346	356.26	114.69	1355	1072	22	26
	14A			1427	339.51	359.11	3674	2620	26	32
22	5B	2039	35	1312	358.38	301.39	2816	1665	23	30
	12			346	356.26	114.69	1355	1072	22	26
	14A			1174	338.78	315.78	2688	2059	29	35
Many Ponds Detention Option										
23		2630	26	2086						

Note: Location IDs 5A and 14A represent detention weir heights of 10 feet. Location IDs 5B and 14B represent 15-feet weirs.

Table B-6. Impact of Detention Storage on Peakflow Reduction at Detention Site and Downstream at Mouth of Big Creek

October 4, 1990 Event

Detention storage site	*Reduction in peakflow at detention site (cfs)*	*Reduction in peakflow at mouth of Big Creek (cfs)*
1	18	240
2	49	128
4	22	100
5A (10-foot weir)	205	322
5B (15-foot weir)	924	1218
10	4	54
11	66	3
12	249	352
14A (10-foot weir)	858	858
14B (15-foot weir)	1849	1849

5-Year Design Storm

Detention storage site	*Reduction in peakflow at detention site (cfs)*	*Reduction in peakflow at mouth of Big Creek (cfs)*
1	13	36
2	4	44
4	5	0
5A (10-foot weir)	290	480
5B (15-foot weir)	1151	1703
10	-13	-9
11	-2	0
12	283	397
14A (10-foot weir)	1418	1418
14B (15-foot weir)	3264	3264

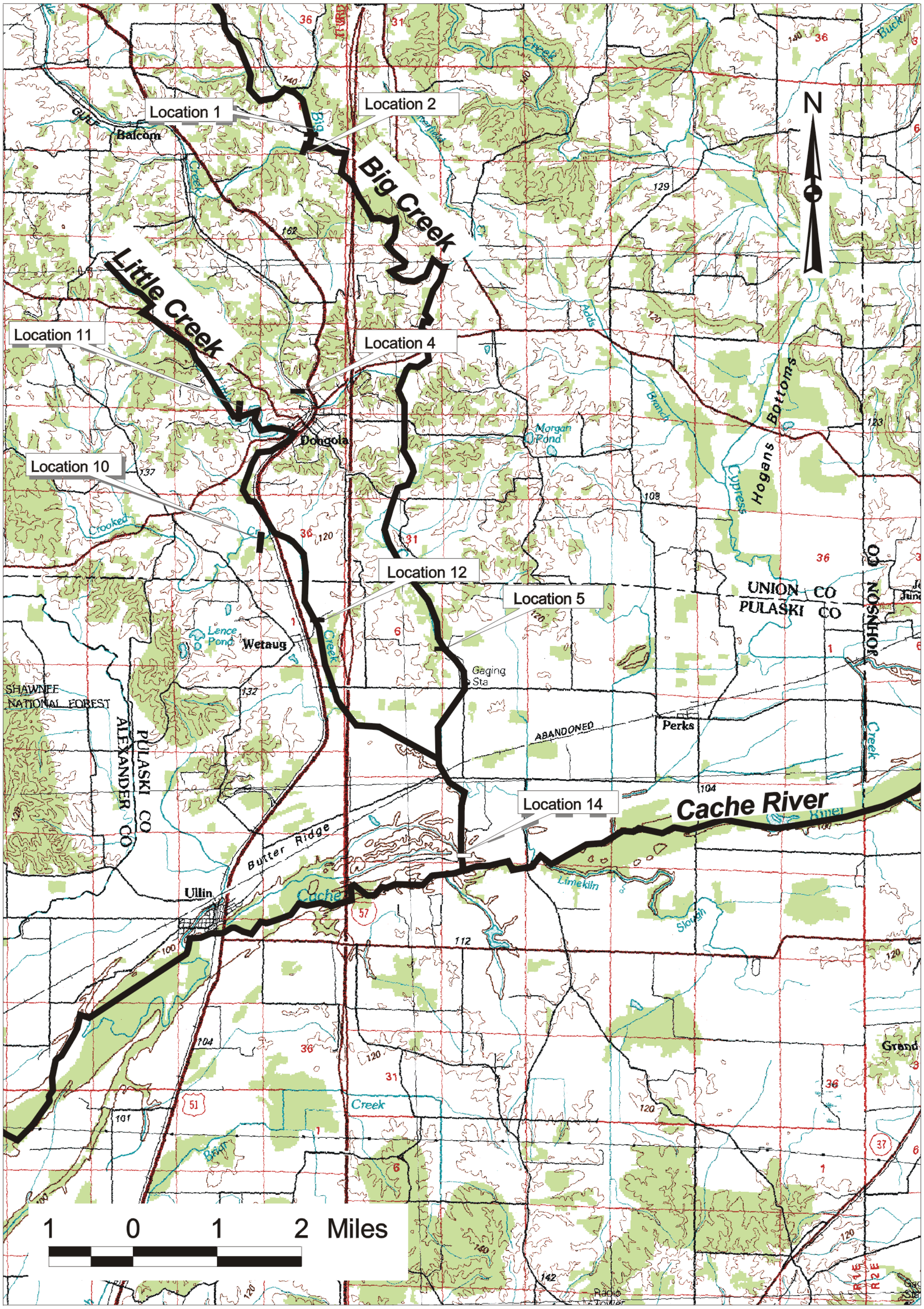


Figure B-1. Locations of the in-channel and Cache Valley detention sites considered in the analysis

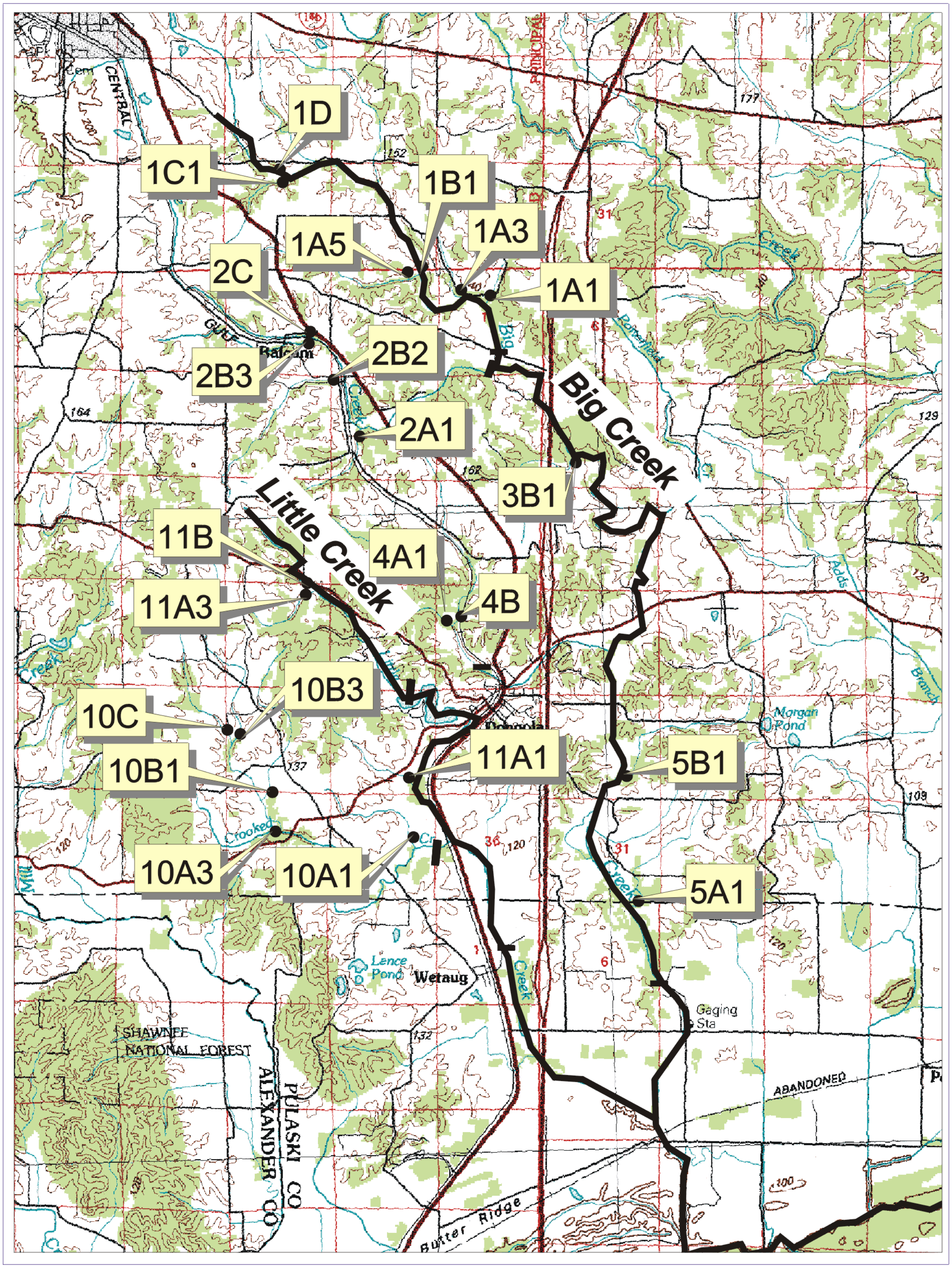


Figure B-2. Locations of the Big Creek watershed subdivisions and the 23 pond detection units

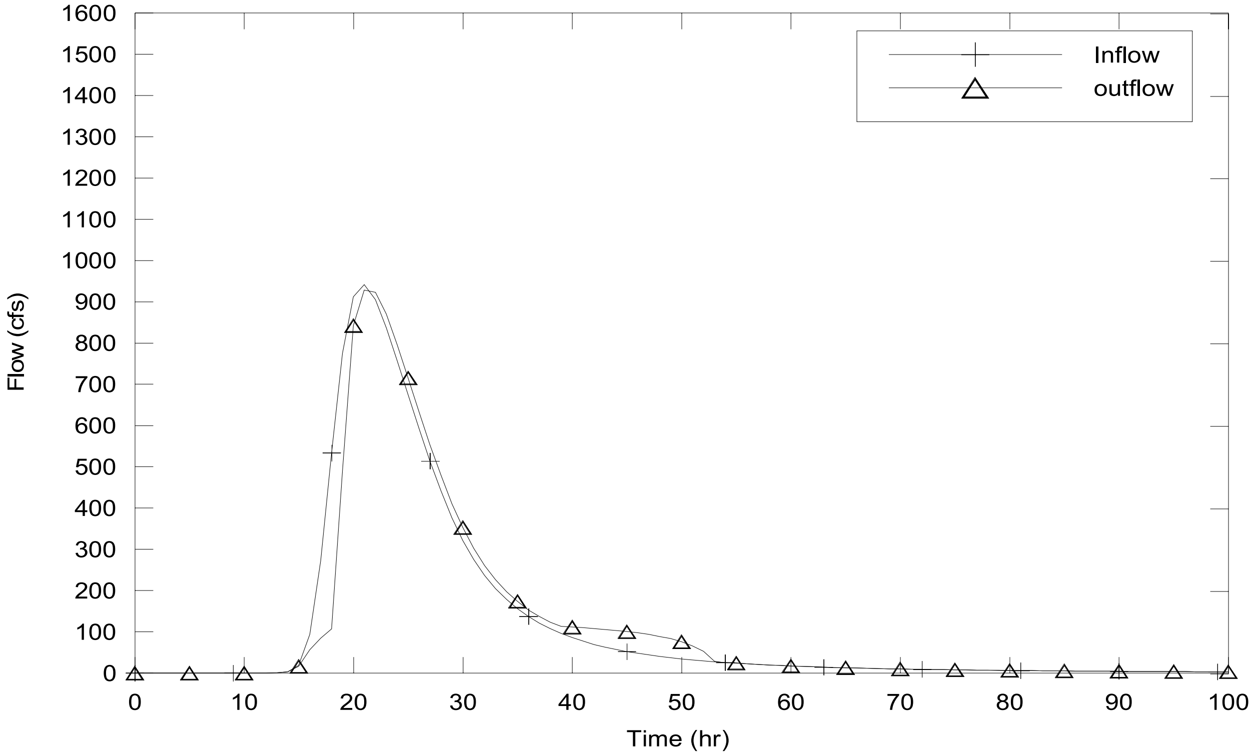


Figure B-3. Simulated inflow and outflow for detention site 1; 5-year modeled storm event

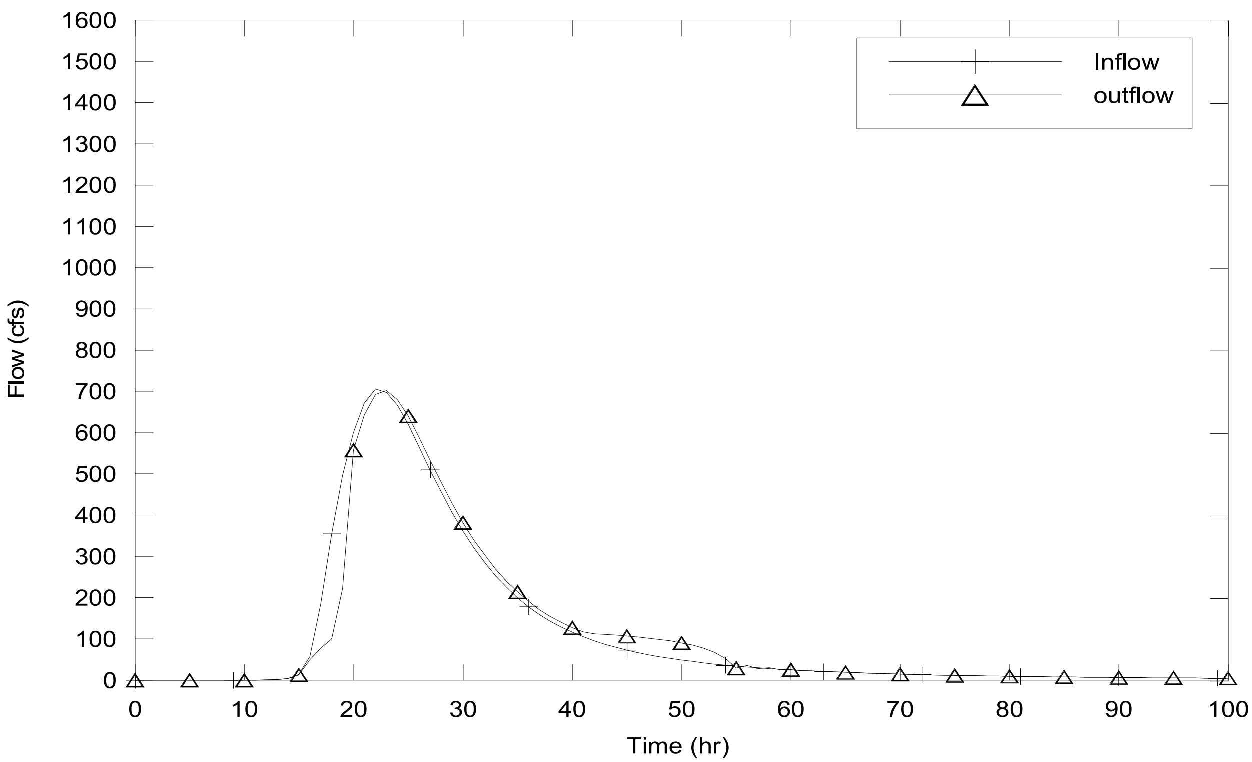


Figure B-4. Simulated inflow and outflow for detention site 2; 5-year modeled storm event

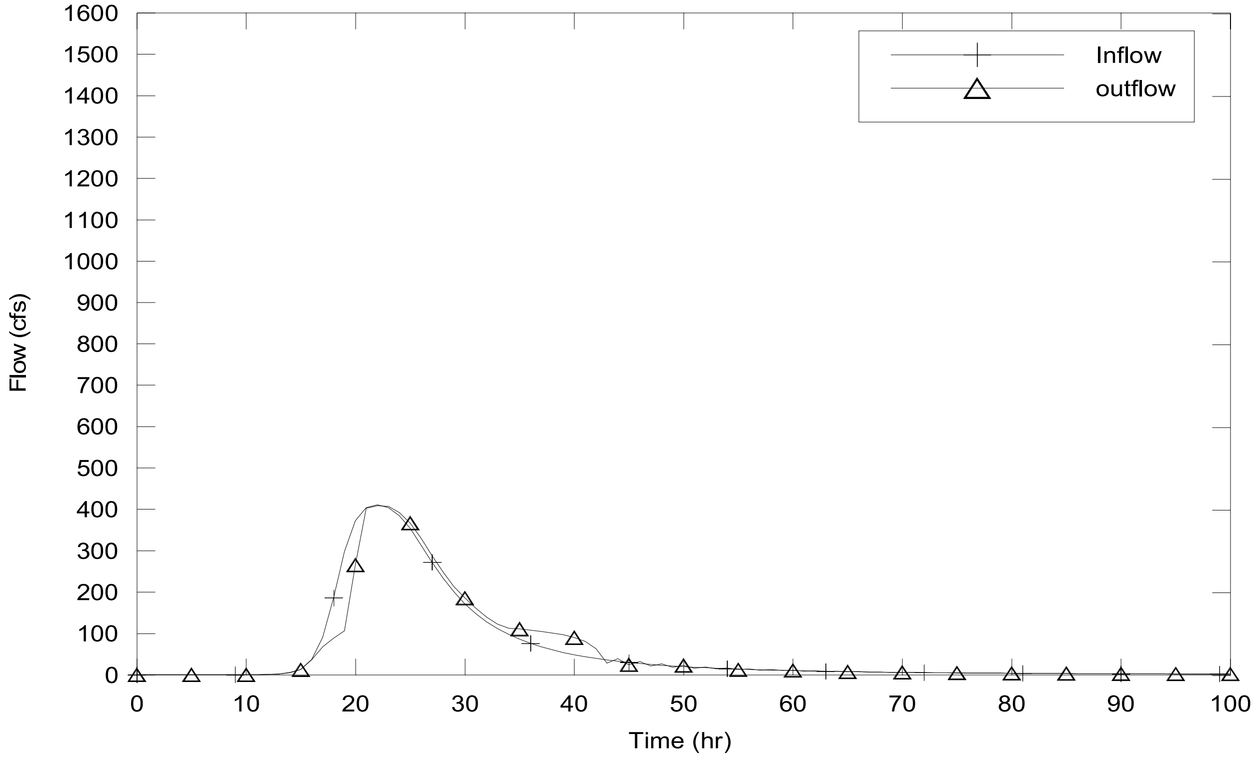


Figure B-5. Simulated inflow and outflow for detention site 4; 5-year modeled storm event

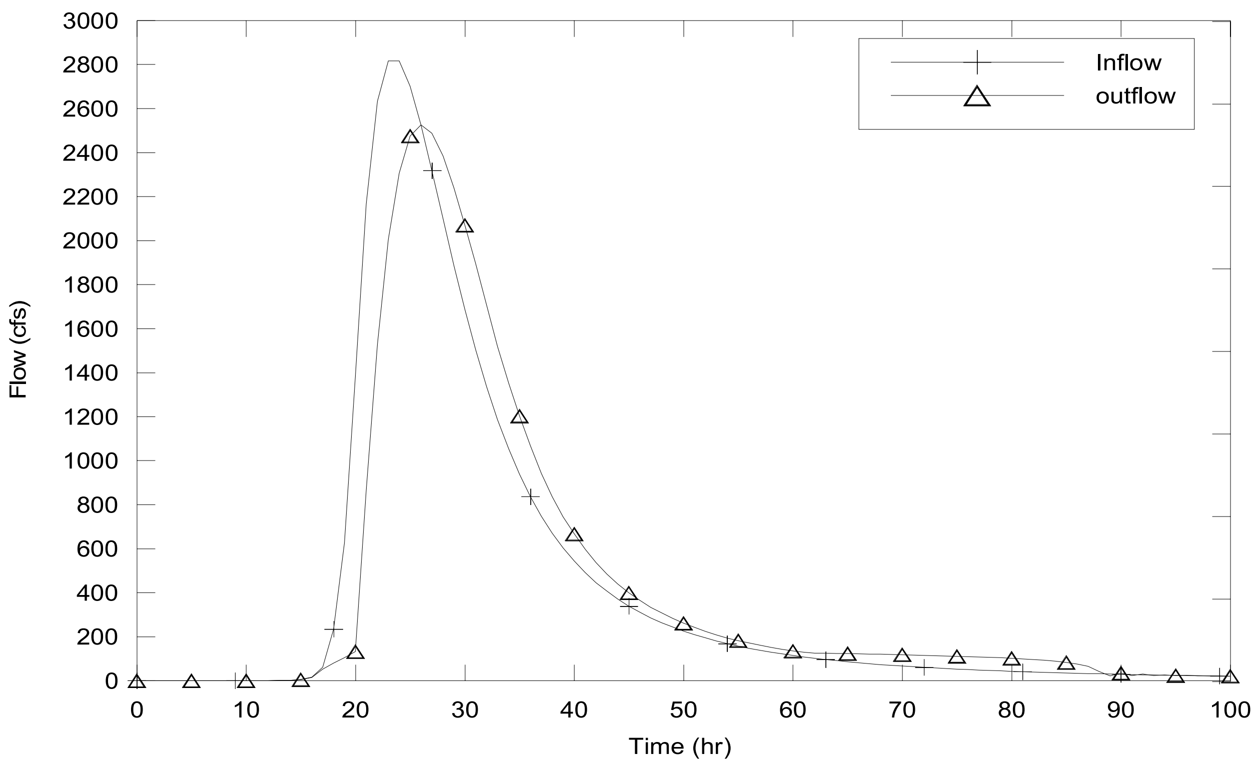


Figure B-6. Simulated inflow and outflow for detention site 5 at 10 feet; 5-year modeled storm event

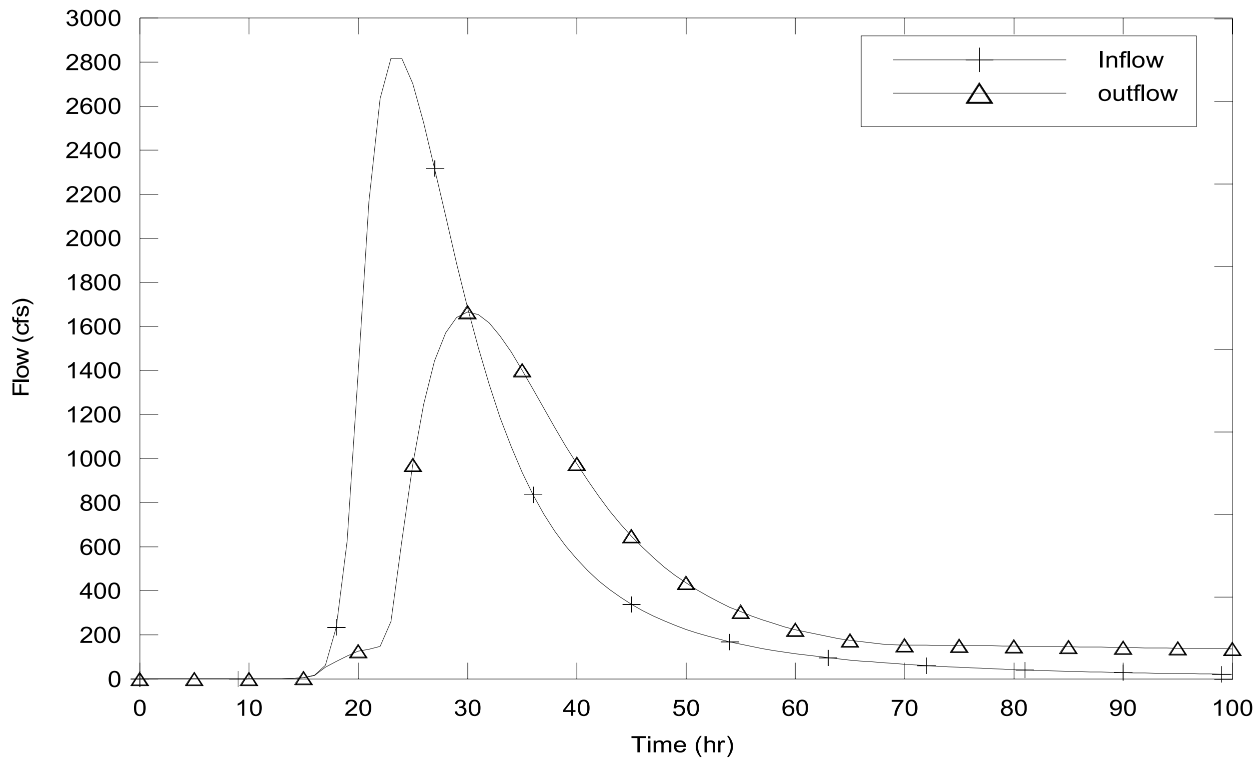


Figure B-7. Simulated inflow and outflow for detention site 5 at 15 feet; 5-year modeled storm event

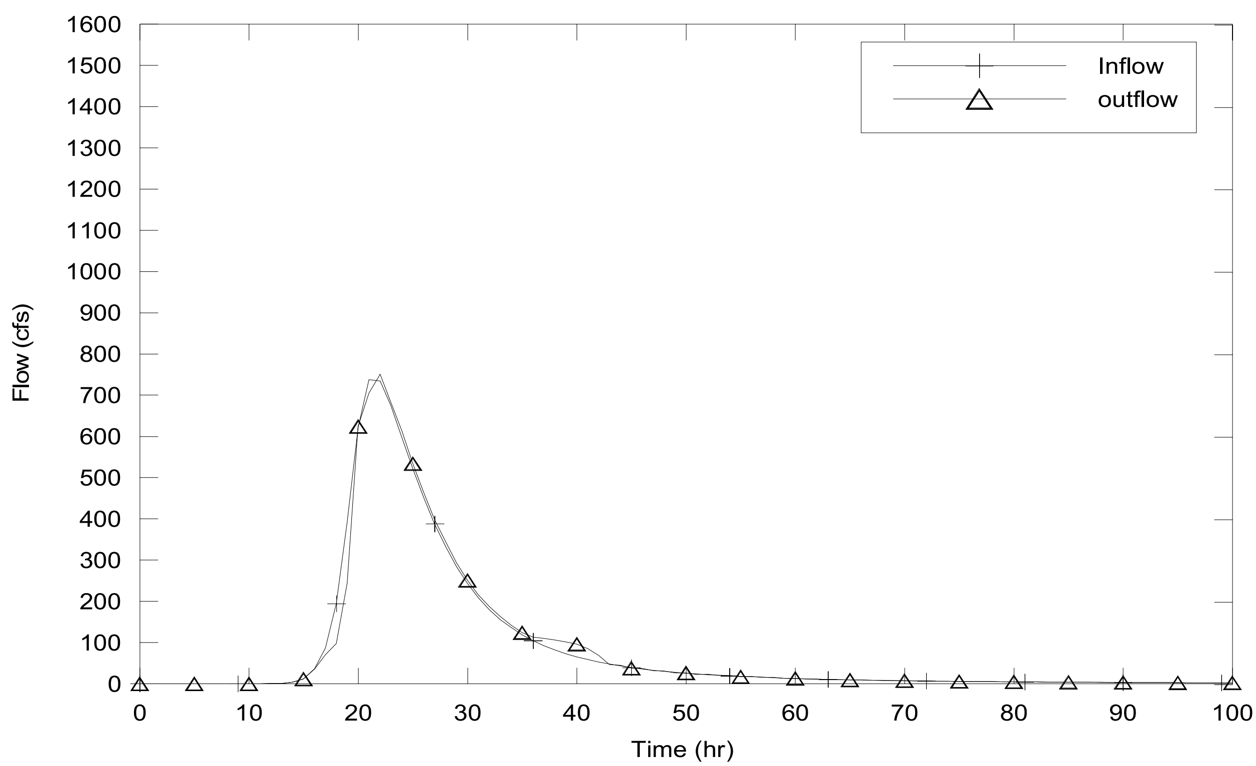


Figure B-8. Simulated inflow and outflow for detention site 10; 5-year modeled storm event

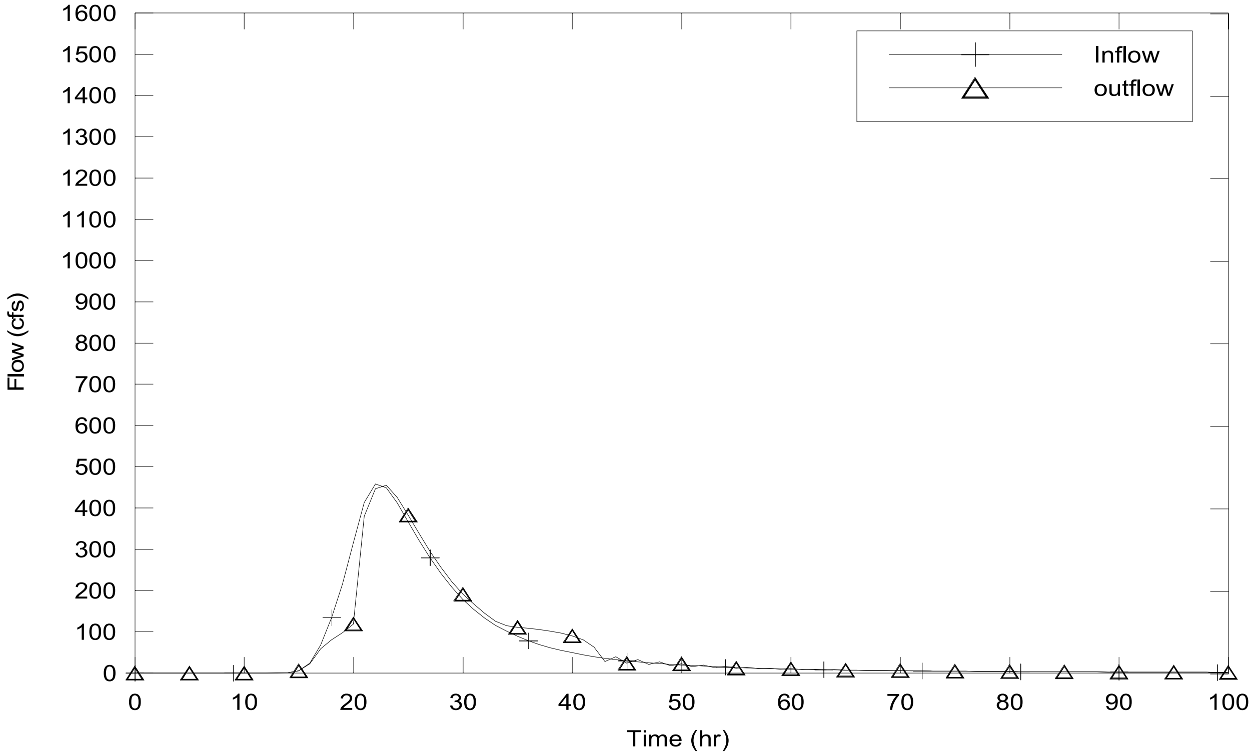


Figure B-9. Simulated inflow and outflow for detention site 11; 5-year modeled storm event

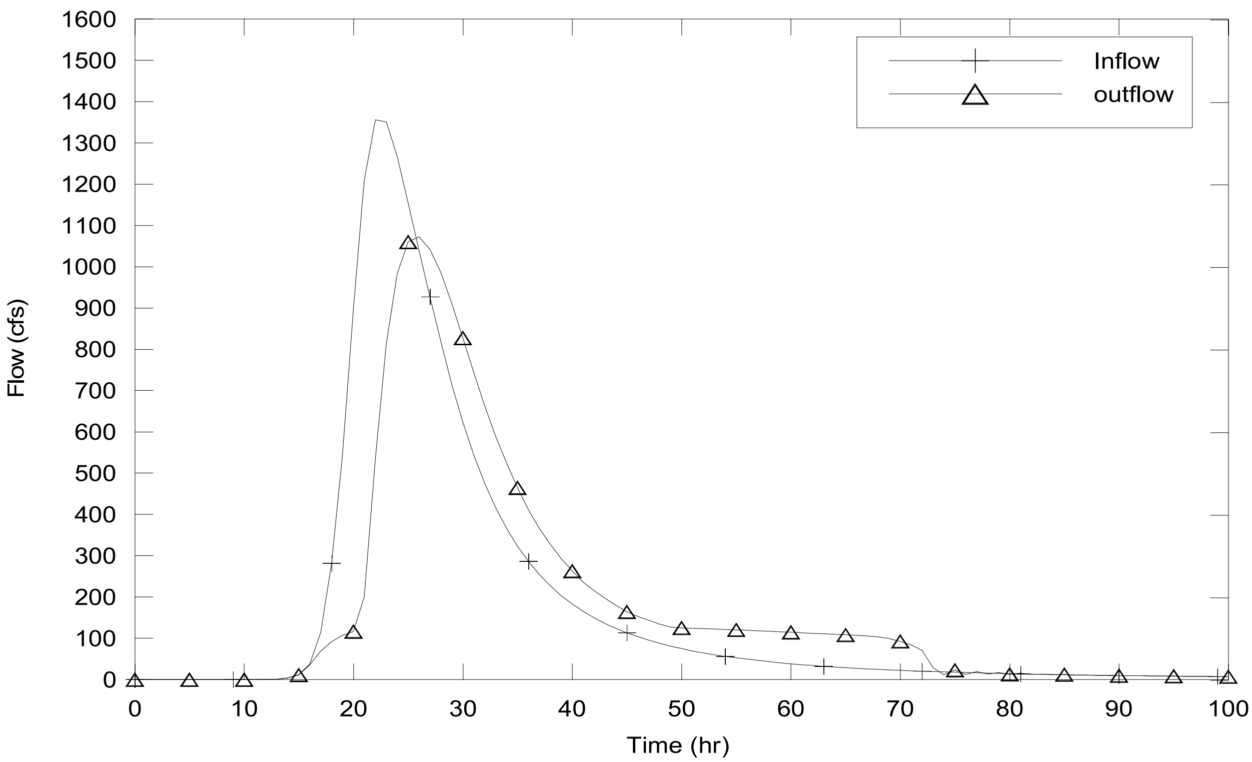


Figure B-10. Simulated inflow and outflow for detention site 12; 5-year modeled storm event

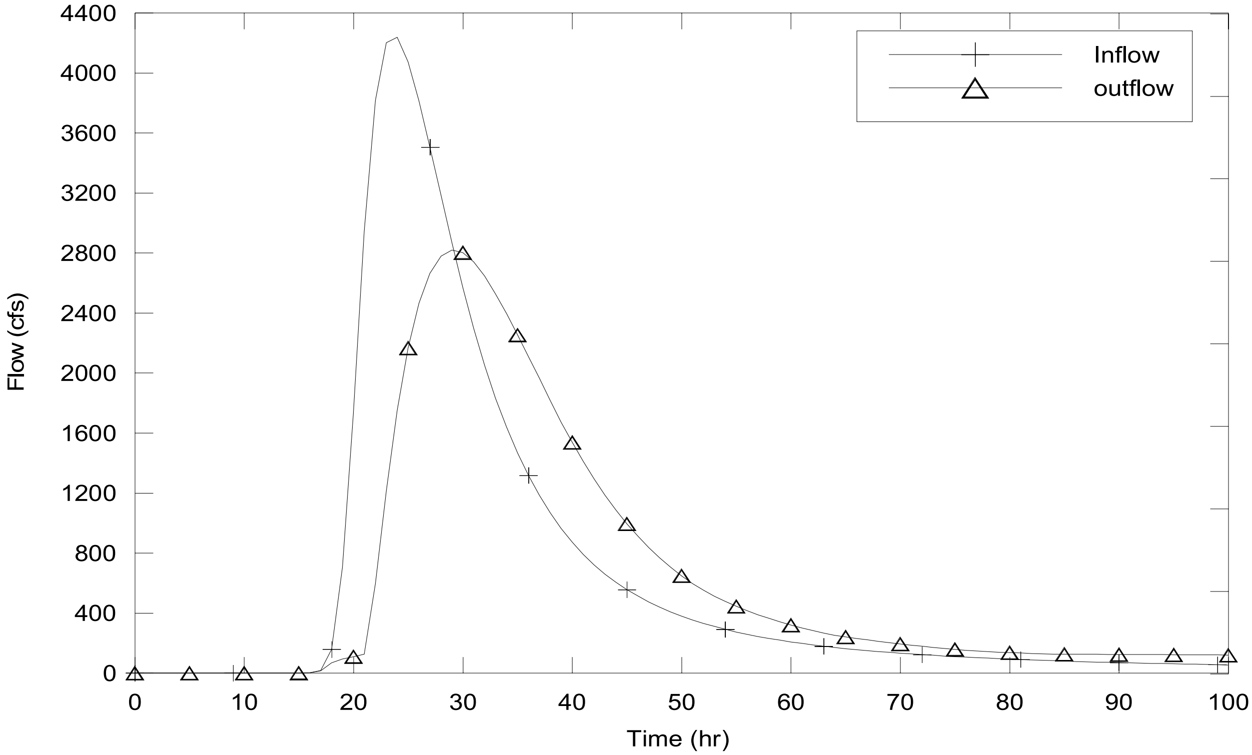


Figure B-11. Simulated inflow and outflow for detention site 14 at 10 feet; 5-year modeled storm event

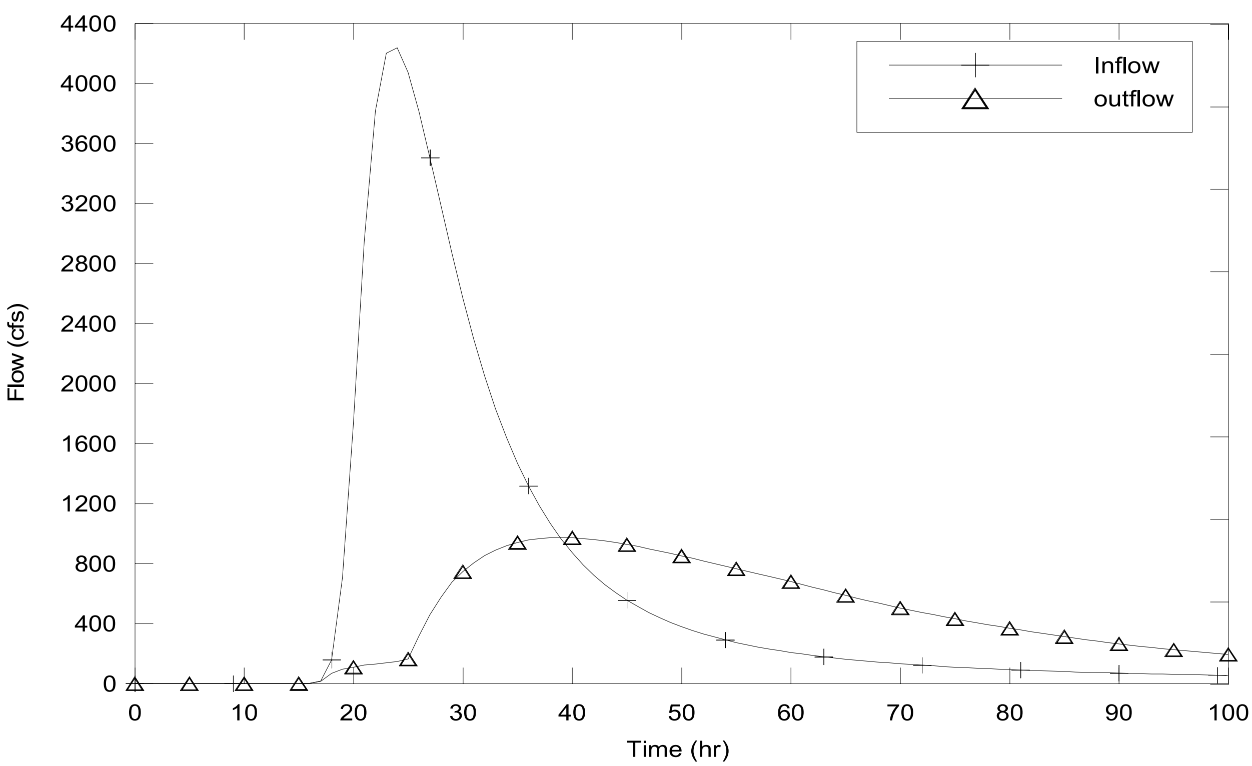


Figure B-12. Simulated inflow and outflow for detention site 14 at 15 feet; 5-year modeled storm event

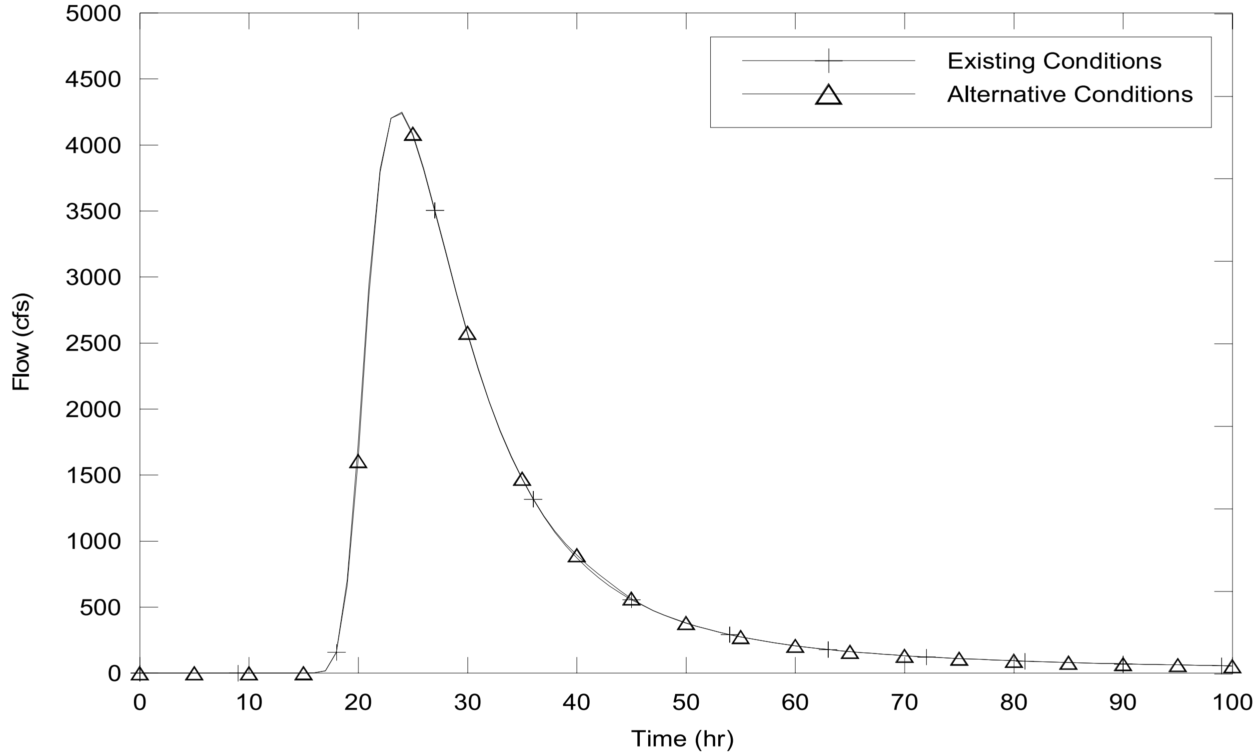


Figure B-13. Impact of detention alternative 1 on the flow at the mouth of Big Creek; 5-year modeled storm event

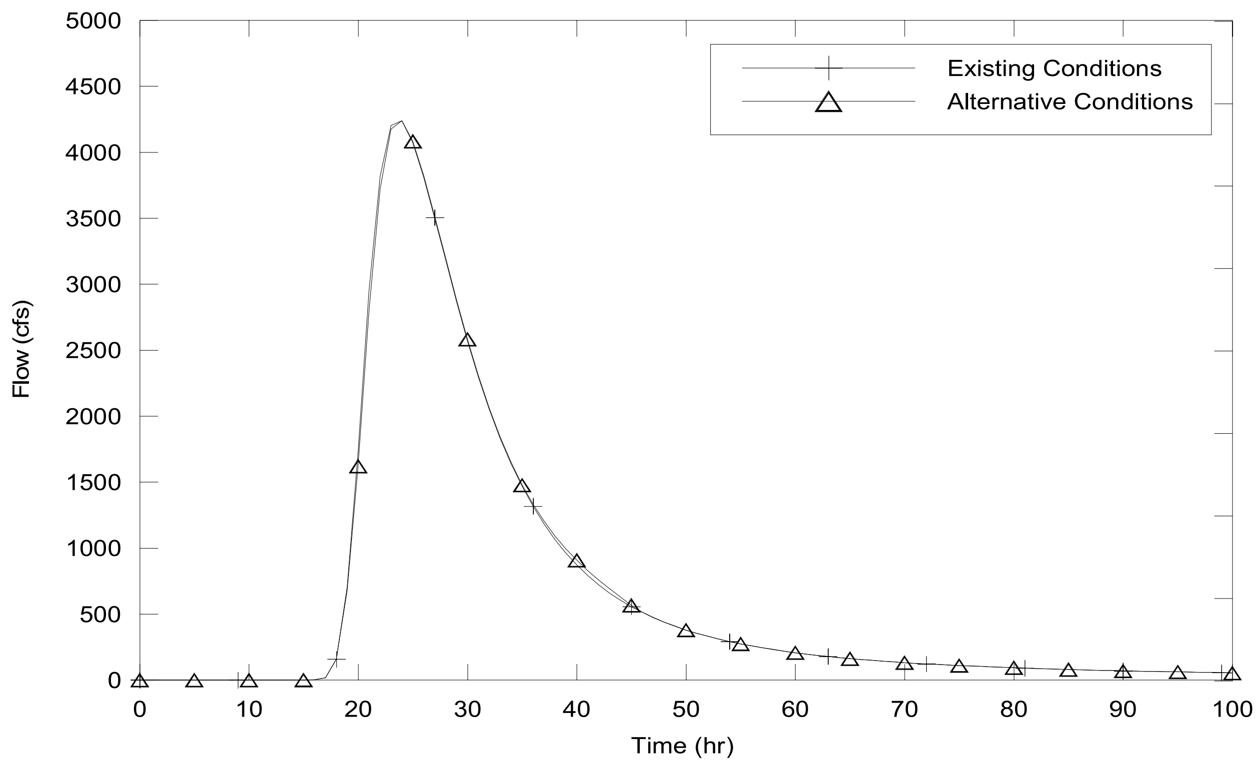


Figure B-14. Impact of detention alternative 2 on the flow at the mouth of Big Creek; 5-year modeled storm event

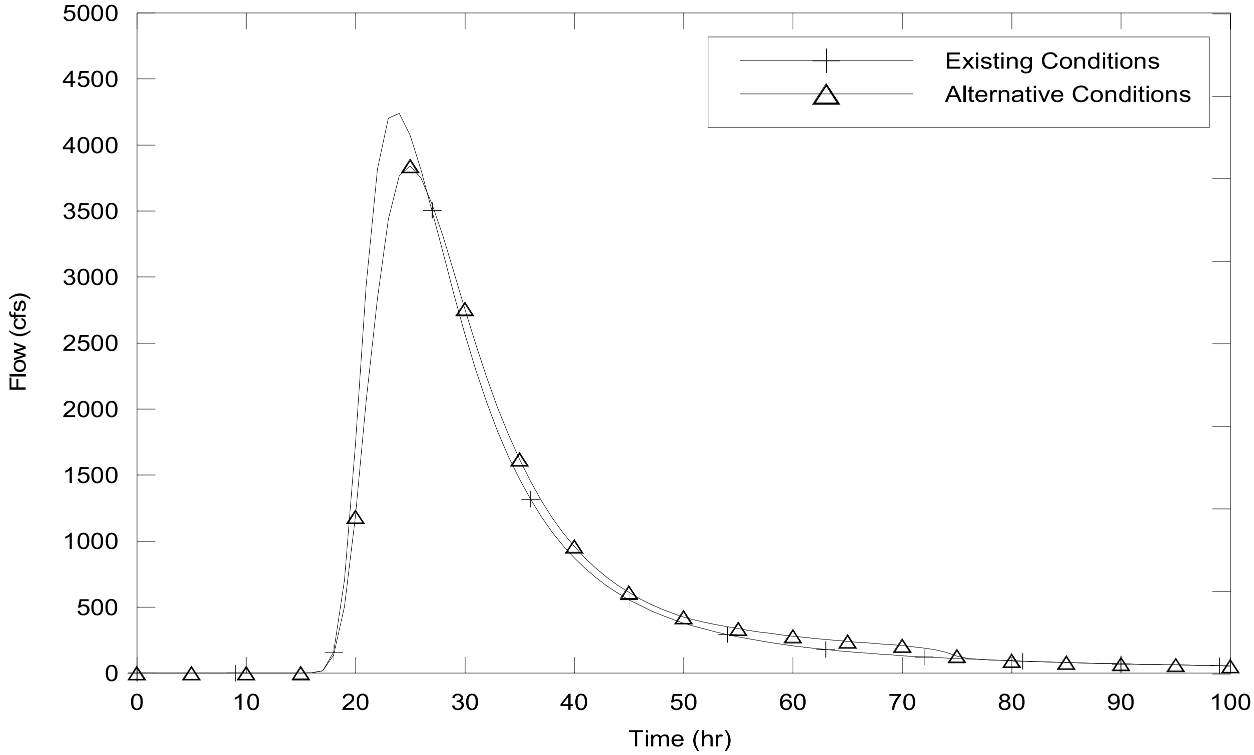


Figure B-15. Impact of detention alternative 3 on the flow at the mouth of Big Creek; 5-year modeled storm event

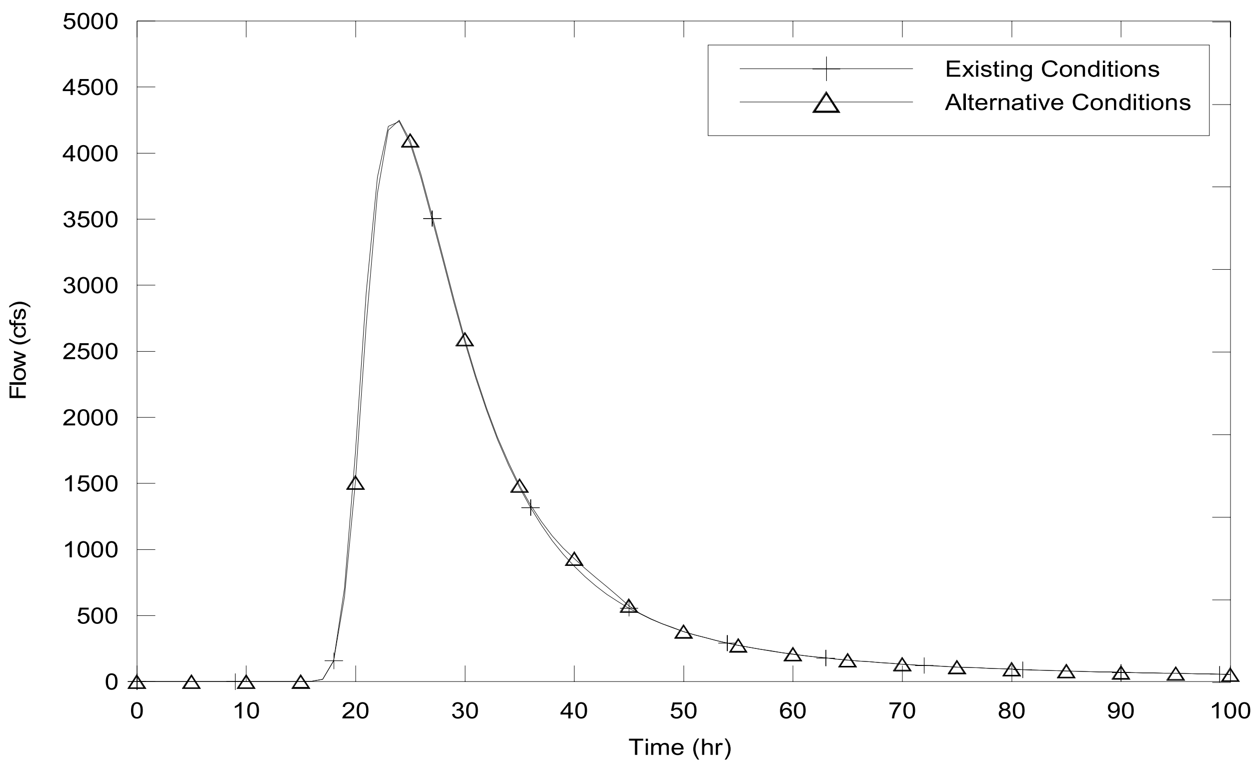


Figure B-16. Impact of detention alternative 4 on the flow at the mouth of Big Creek; 5-year modeled storm event

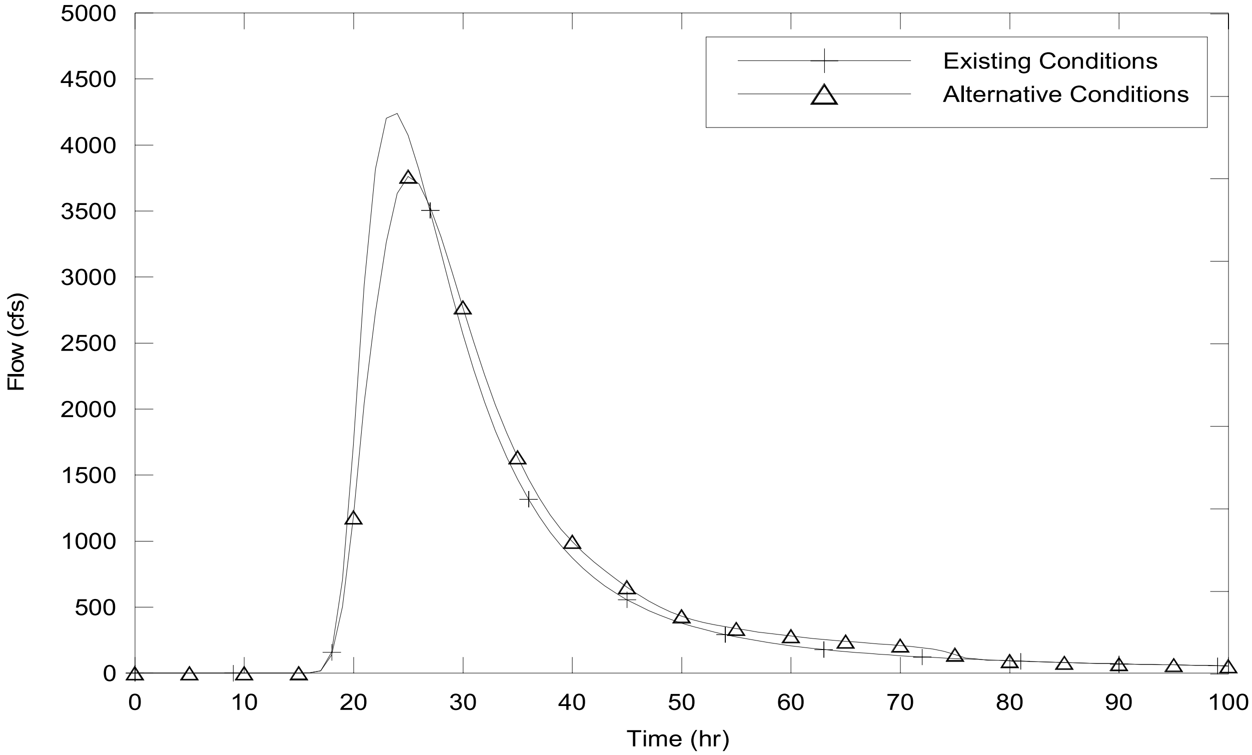


Figure B-17. Impact of detention alternative 5 on the flow at the mouth of Big Creek; 5-year modeled storm event

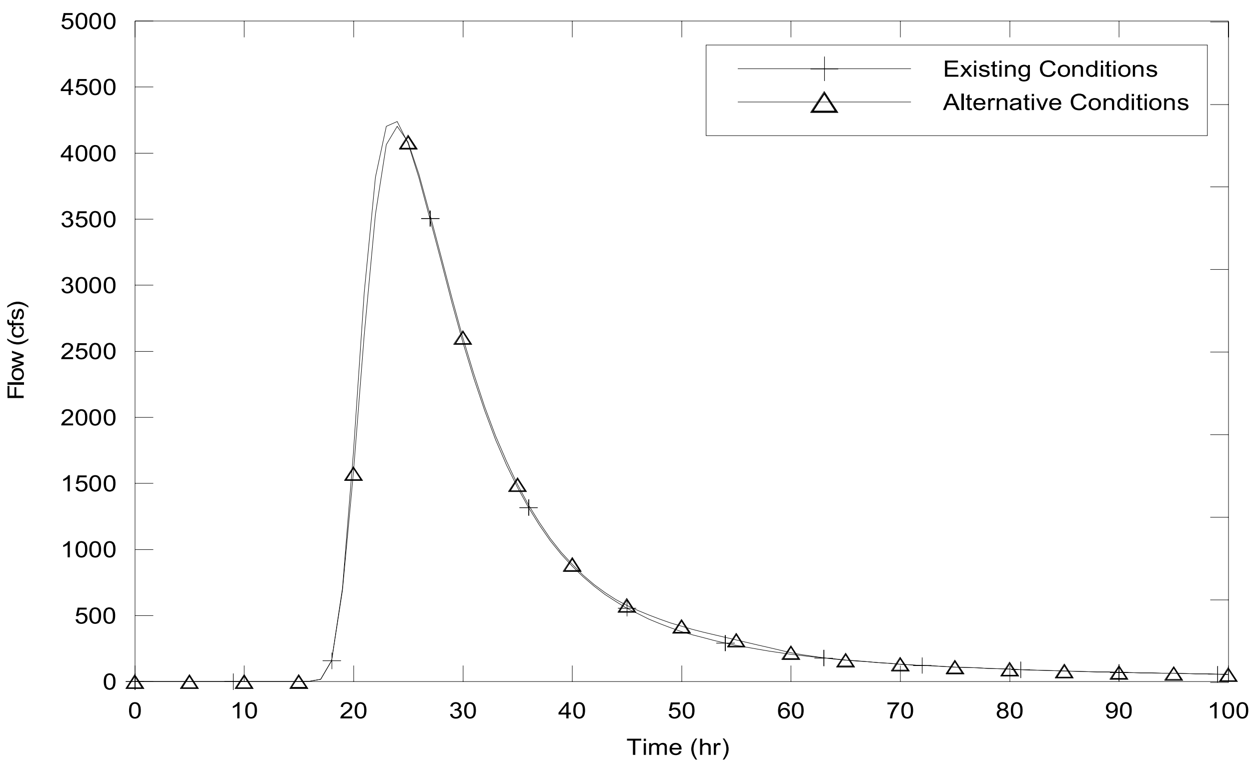


Figure B-18. Impact of detention alternative 6 on the flow at the mouth of Big Creek; 5-year modeled storm event

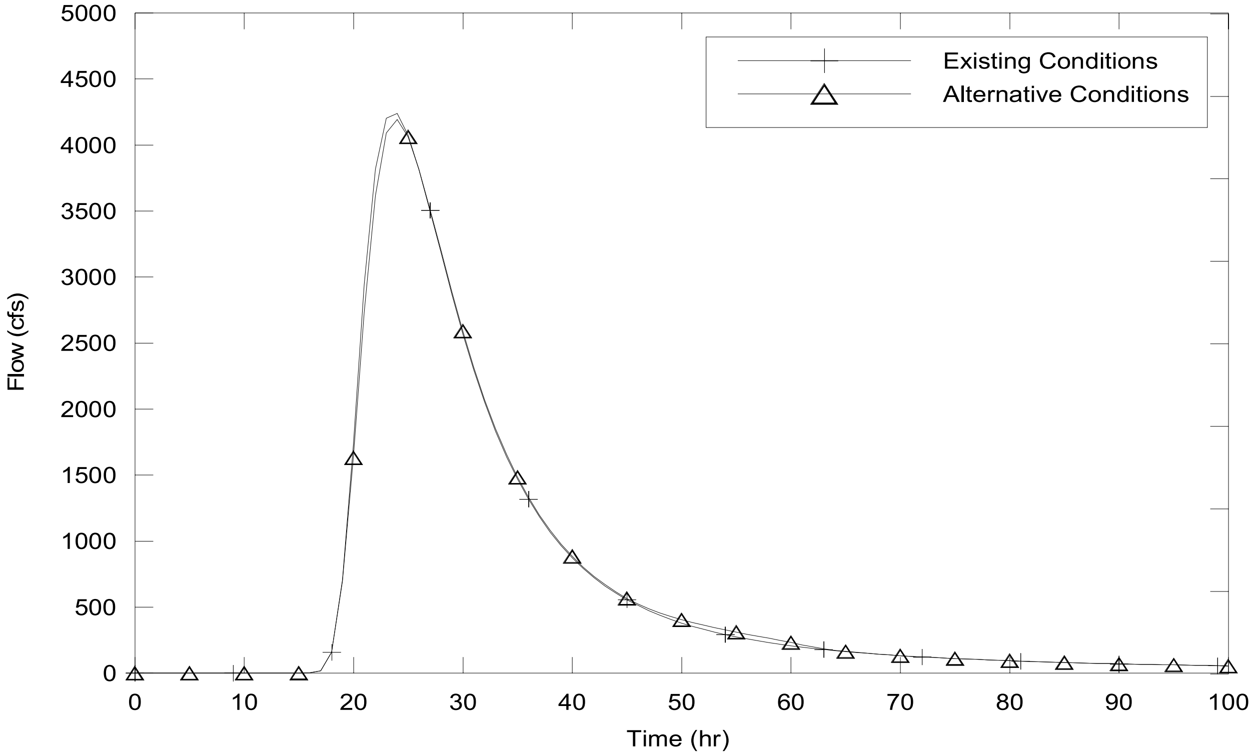


Figure B-19. Impact of detention alternative 7 on the flow at the mouth of Big Creek;
5-year modeled storm event

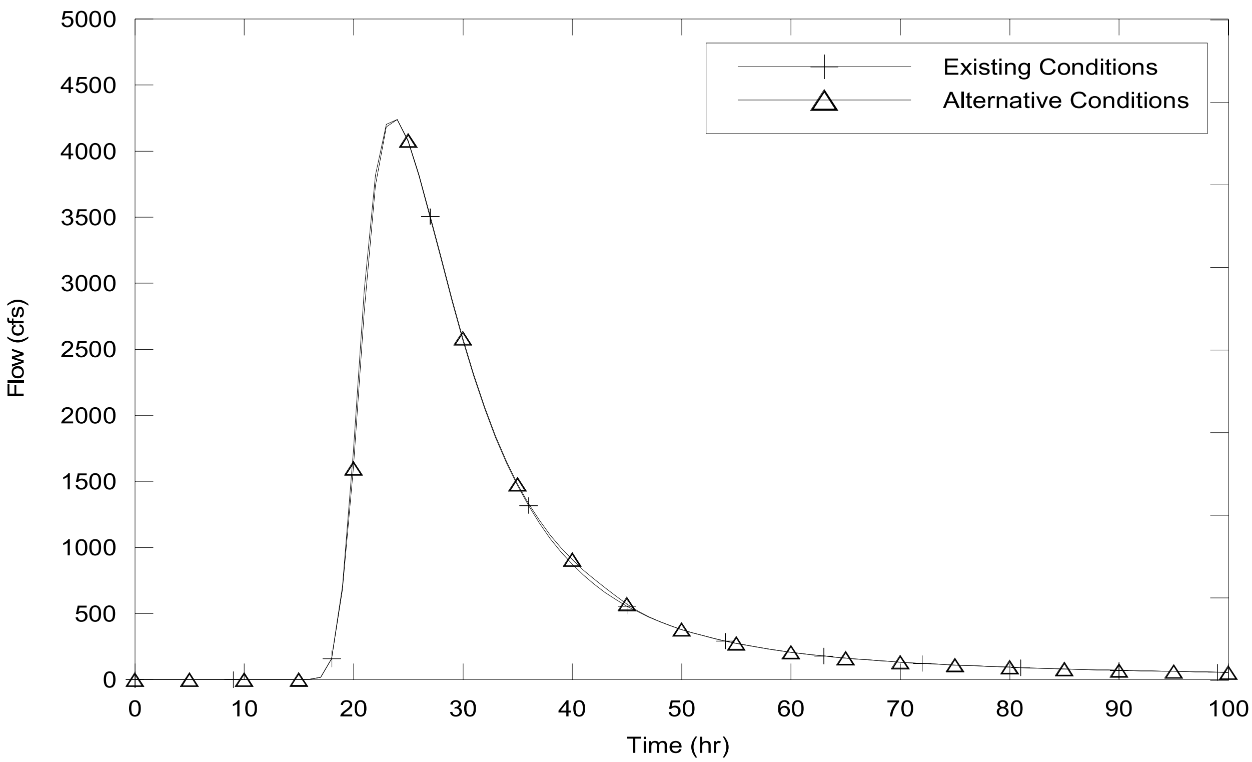


Figure B-20. Impact of detention alternative 8 on the flow at the mouth of Big Creek;
5-year modeled storm event

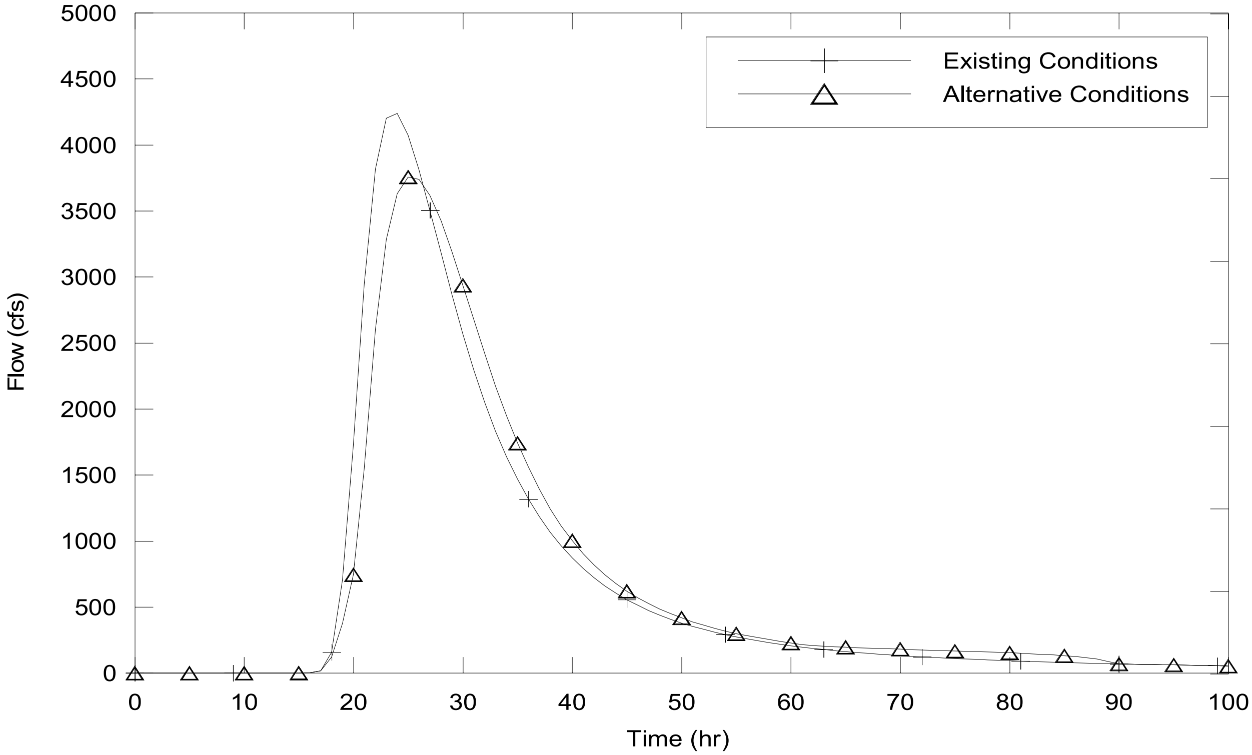


Figure B-21. Impact of detention alternative 9 on the flow at the mouth of Big Creek;
5-year modeled storm event

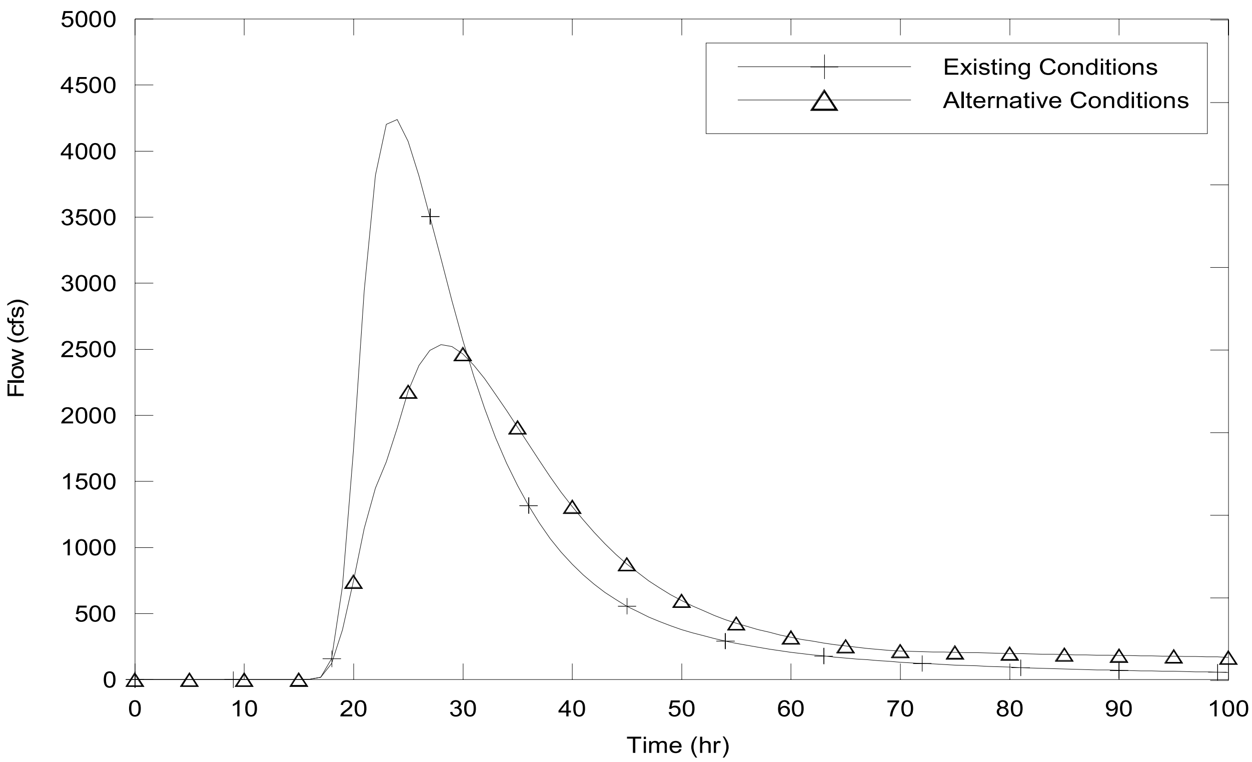


Figure B-22. Impact of detention alternative 10 on the flow at the mouth of Big Creek;
5-year modeled storm event

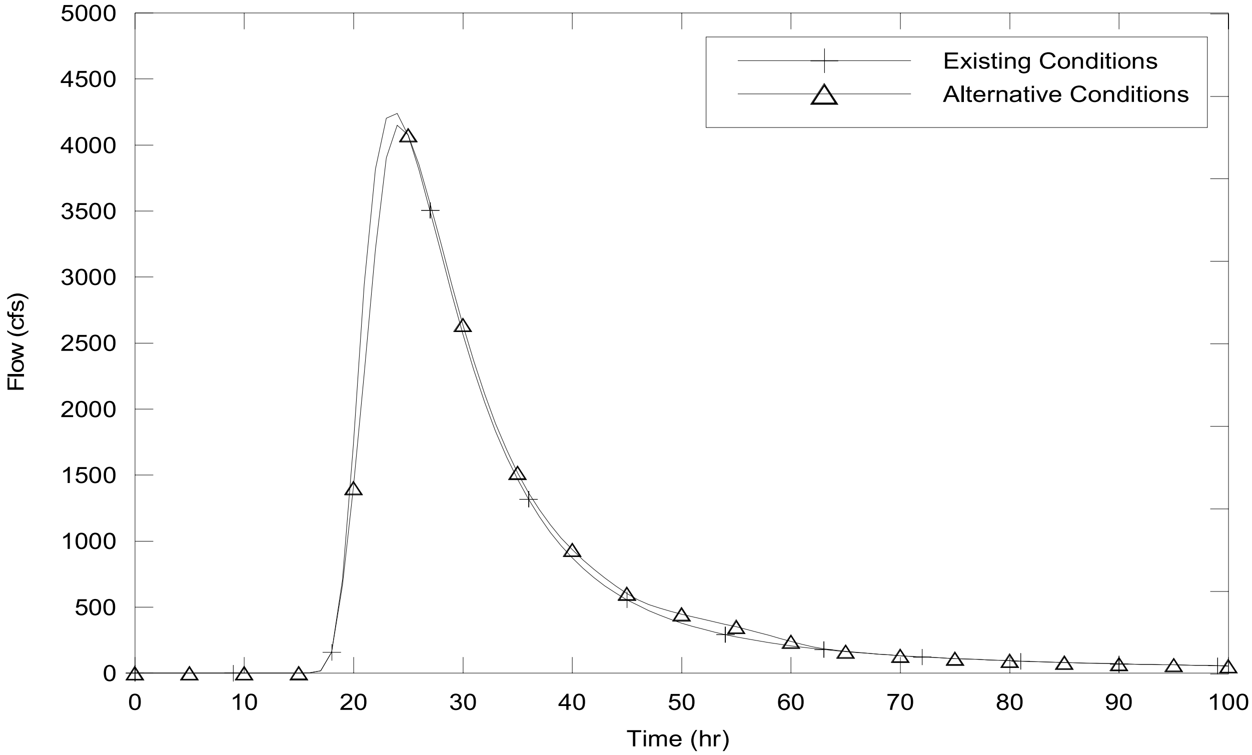


Figure B-23. Impact of detention alternative 11 on the flow at the mouth of Big Creek; 5-year modeled storm event

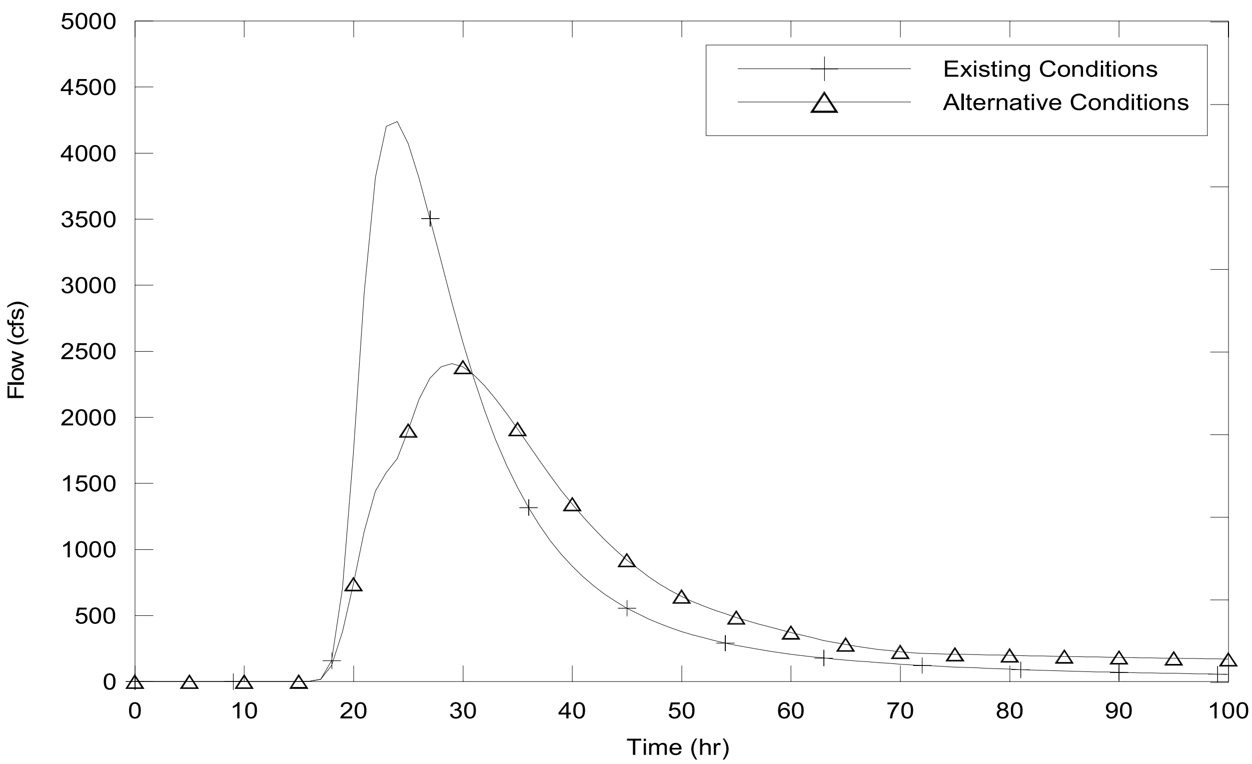


Figure B-24. Impact of detention alternative 12 on the flow at the mouth of Big Creek; 5-year modeled storm event

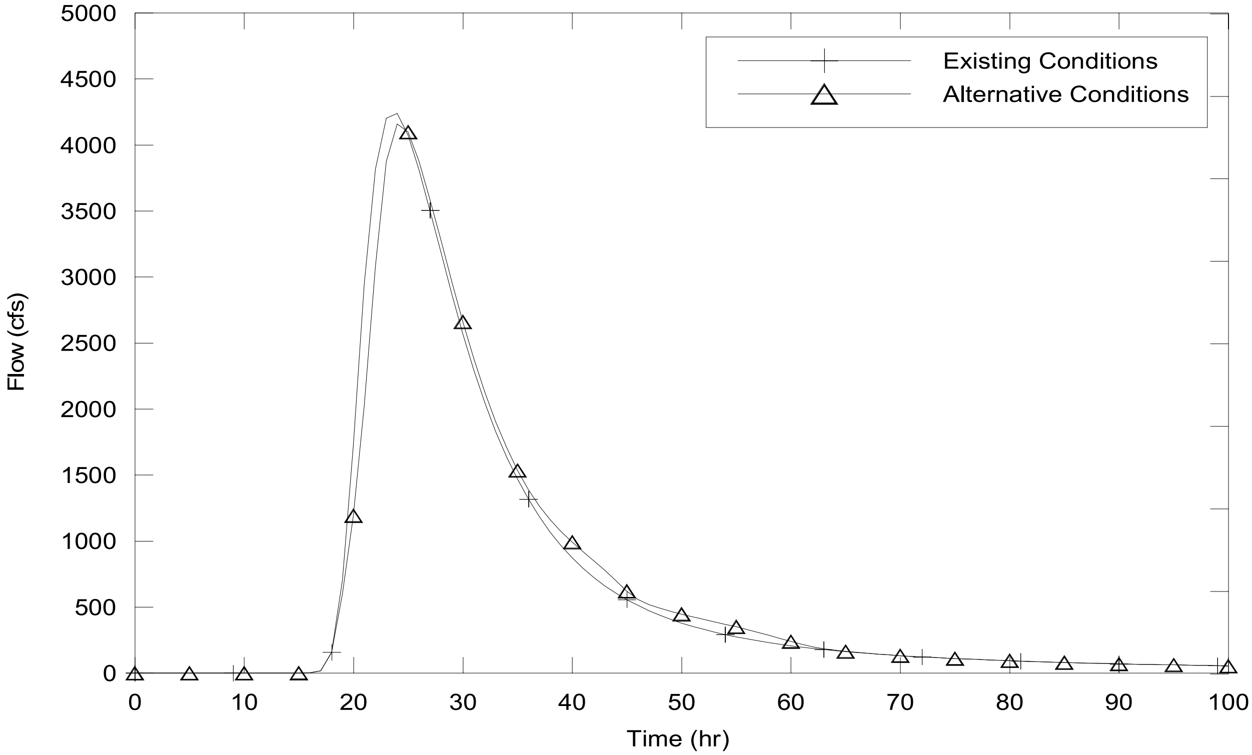


Figure B-25. Impact of detention alternative 13 on the flow at the mouth of Big Creek; 5-year modeled storm event

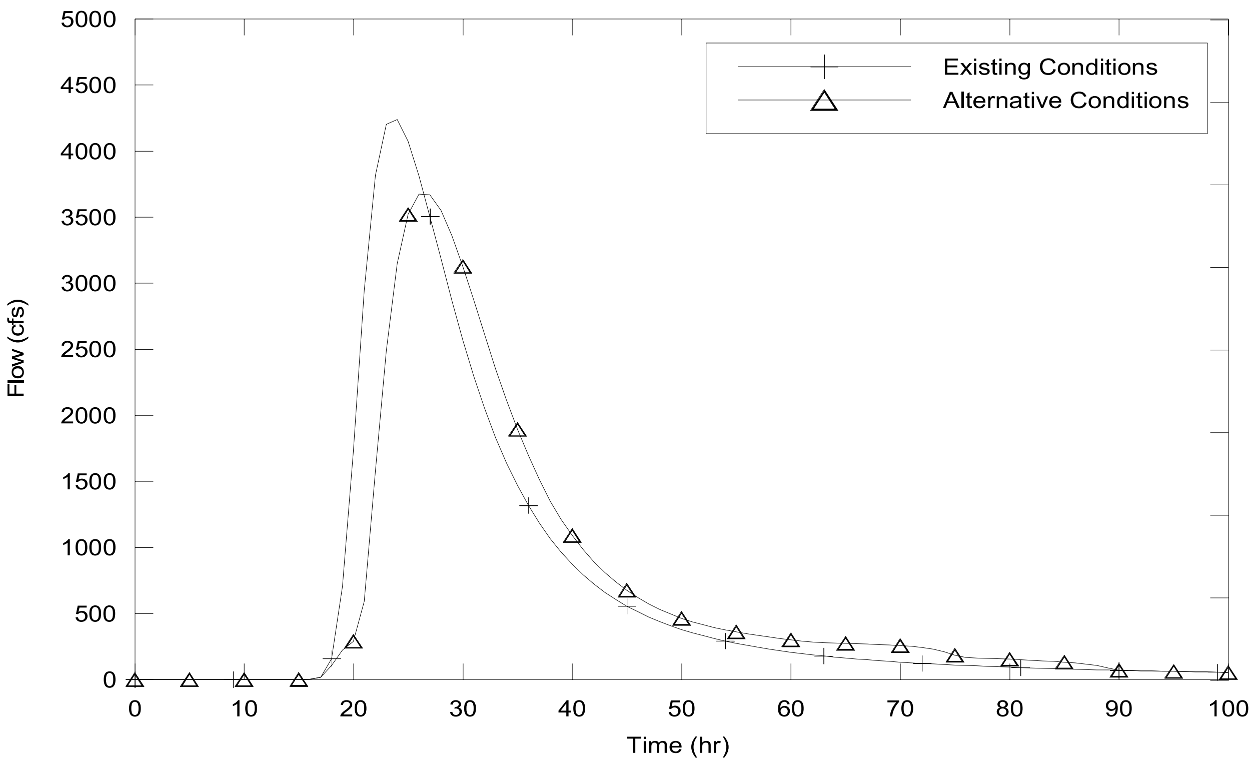


Figure B-26. Impact of detention alternative 14 on the flow at the mouth of Big Creek; 5-year modeled storm event

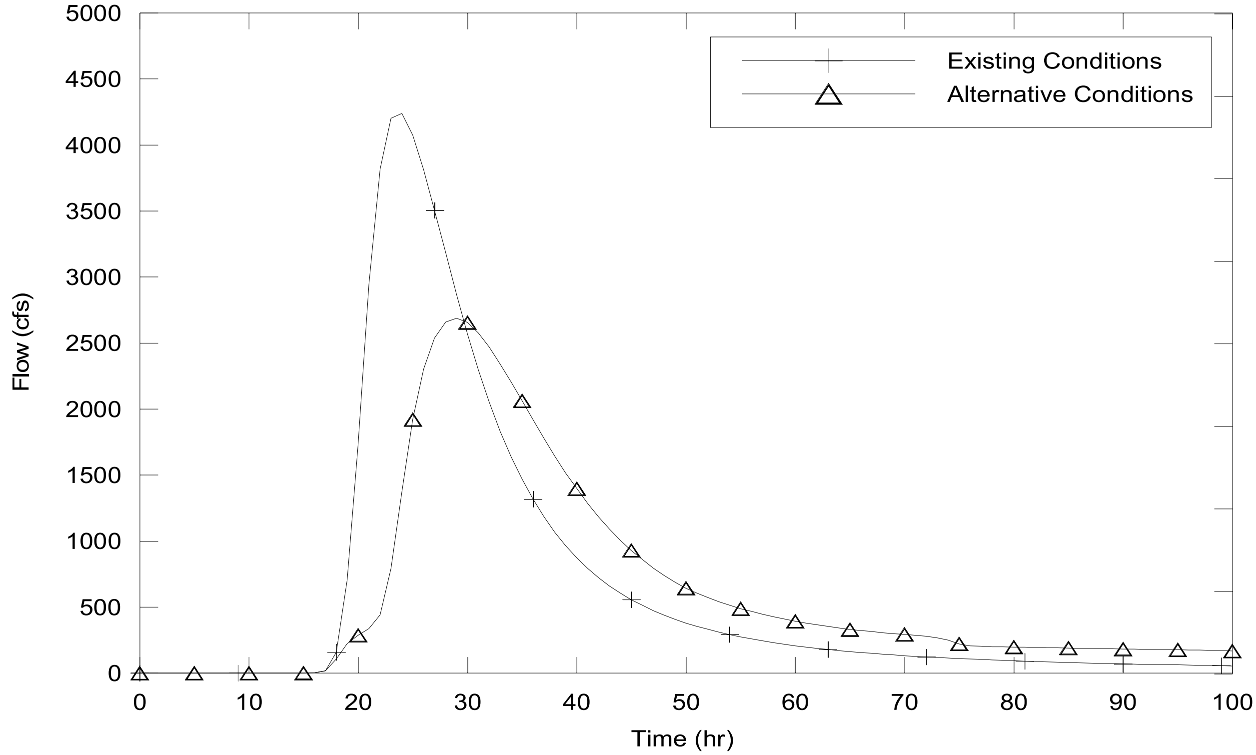


Figure B-27. Impact of detention alternative 15 on the flow at the mouth of Big Creek;
5-year modeled storm event

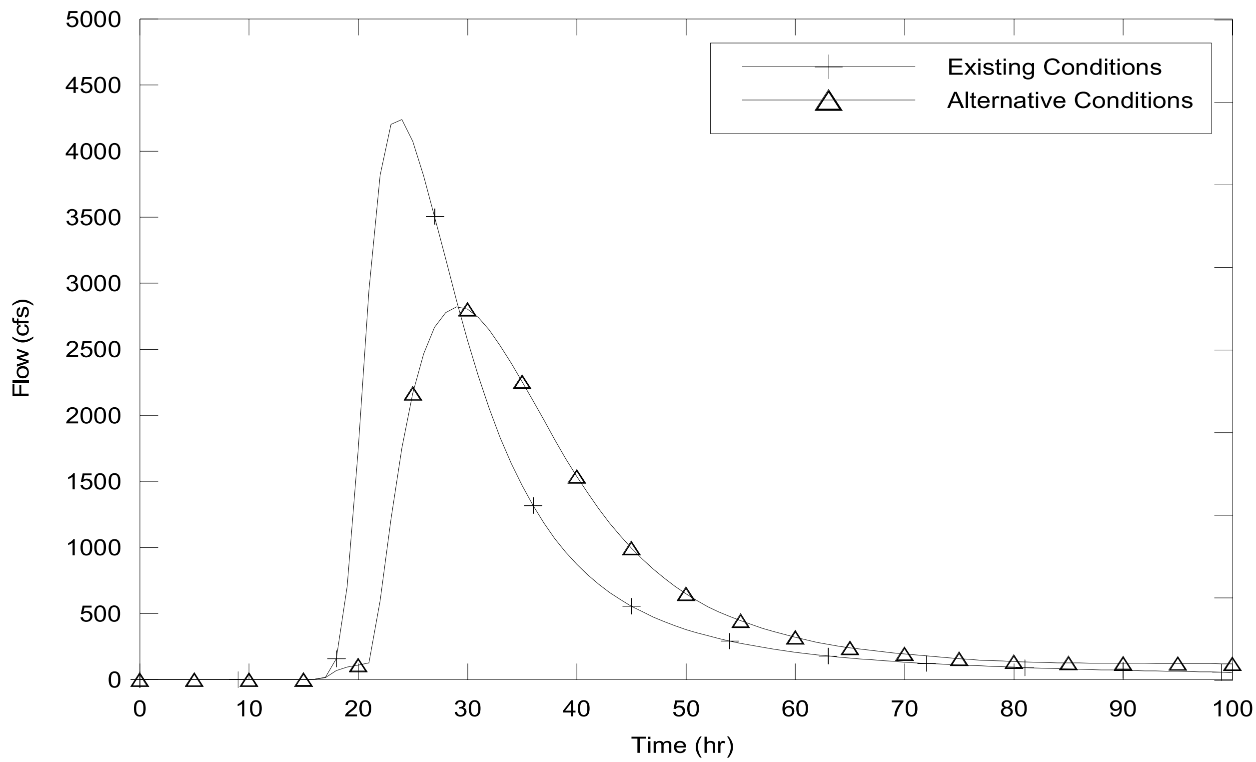


Figure B-28. Impact of detention alternative 16 on the flow at the mouth of Big Creek;
5-year modeled storm event

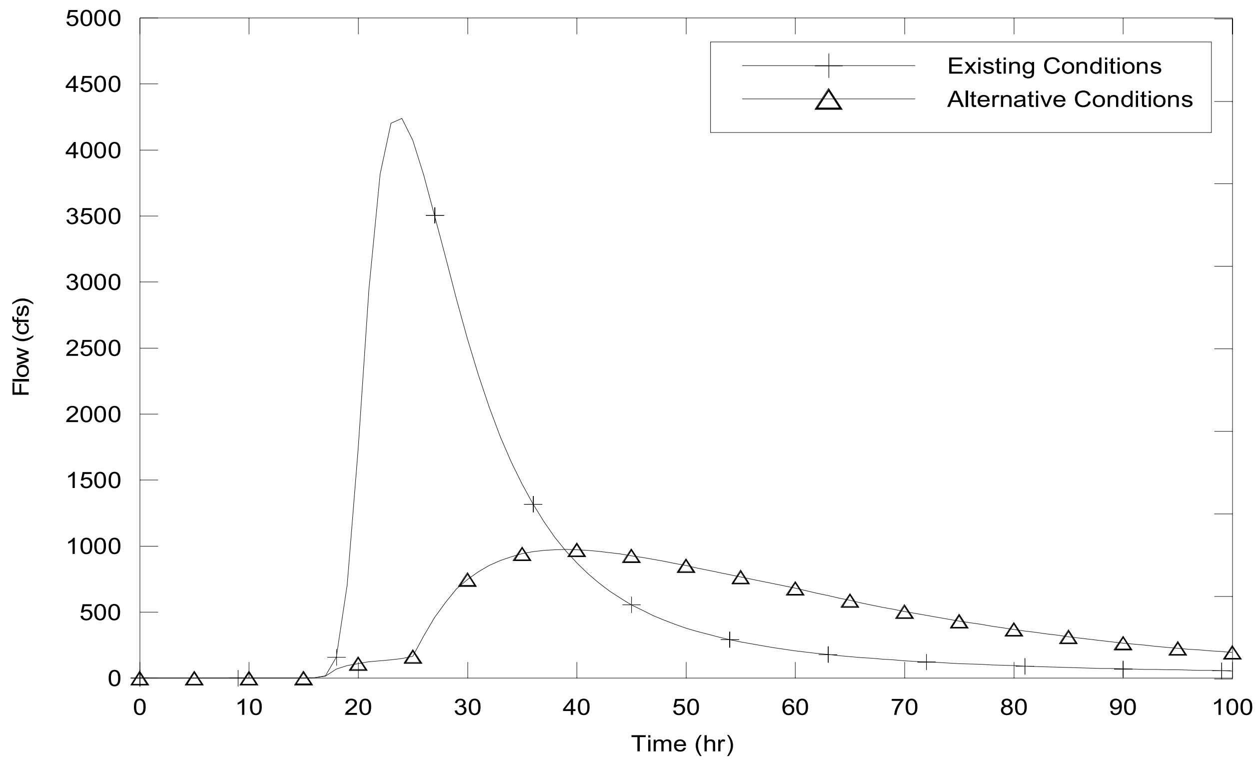


Figure B-29. Impact of detention alternative 17 on the flow at the mouth of Big Creek;
5-year modeled storm event

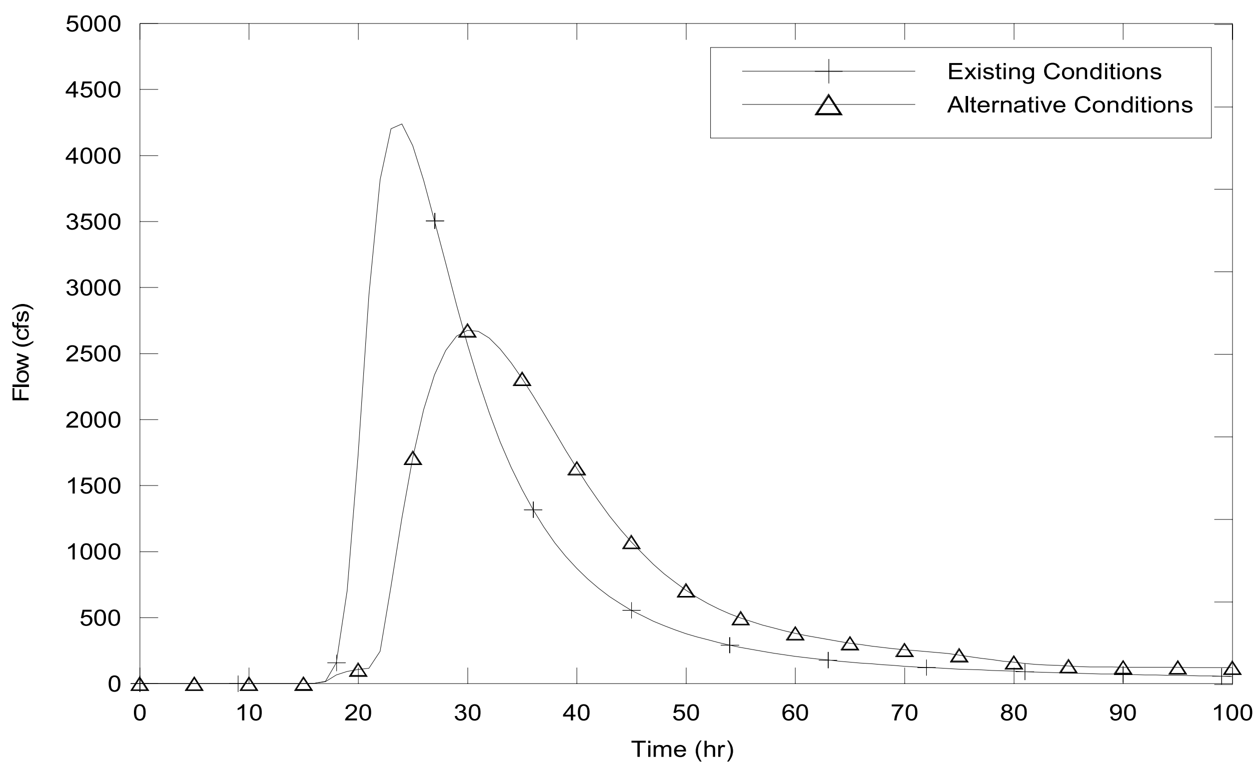


Figure B-30. Impact of detention alternative 18 on the flow at the mouth of Big Creek;
5-year modeled storm event

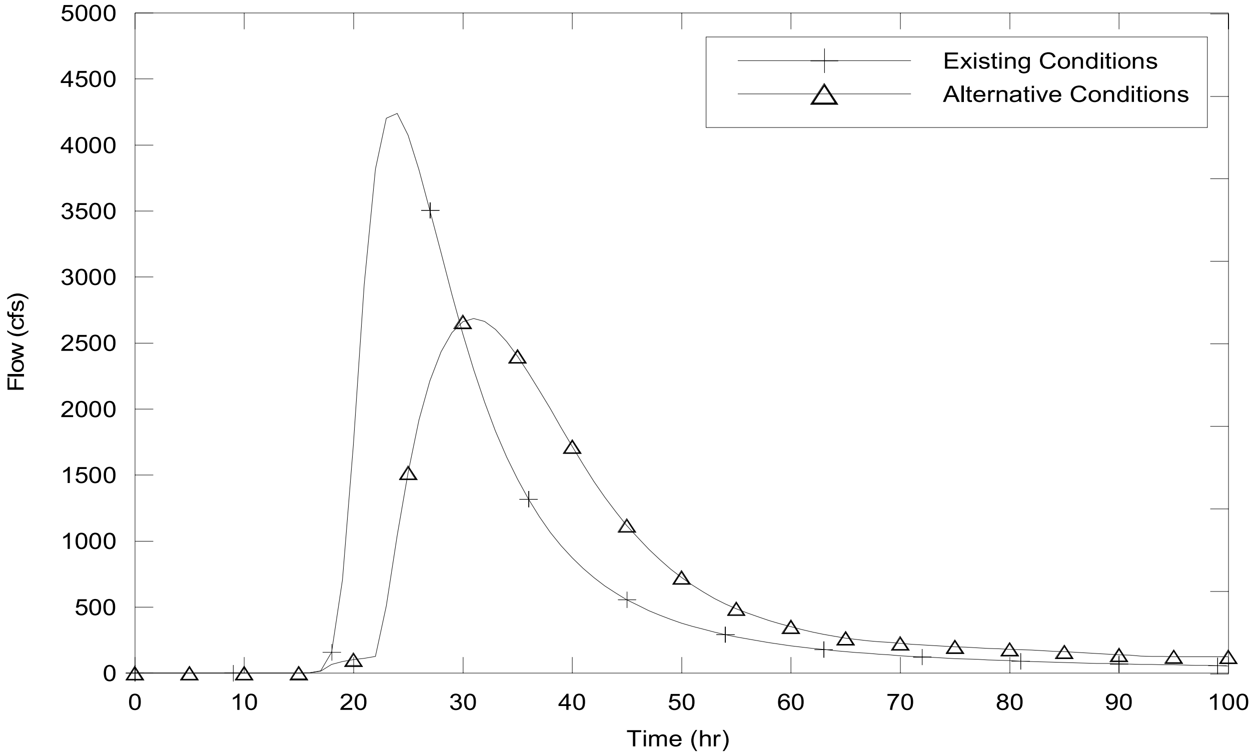


Figure B-31. Impact of detention alternative 19 on the flow at the mouth of Big Creek;
5-year modeled storm event

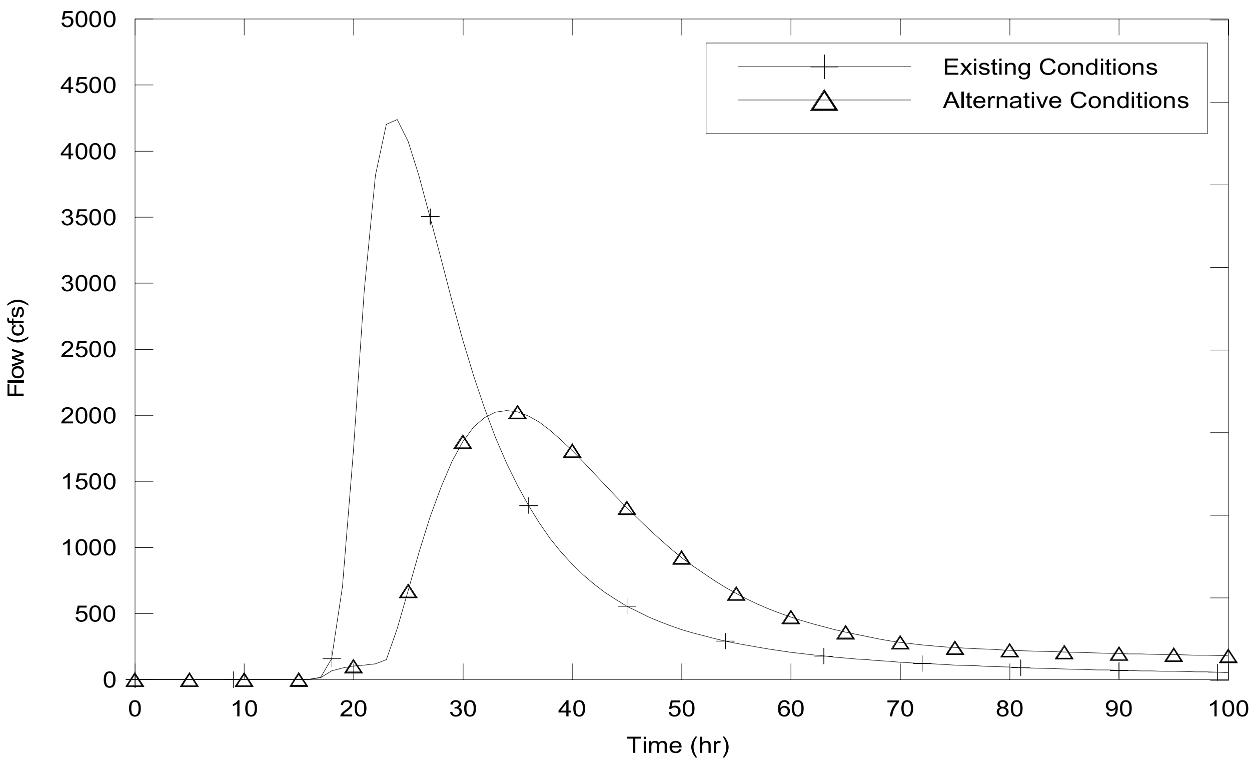


Figure B-32. Impact of detention alternative 20 on the flow at the mouth of Big Creek;
5-year modeled storm event

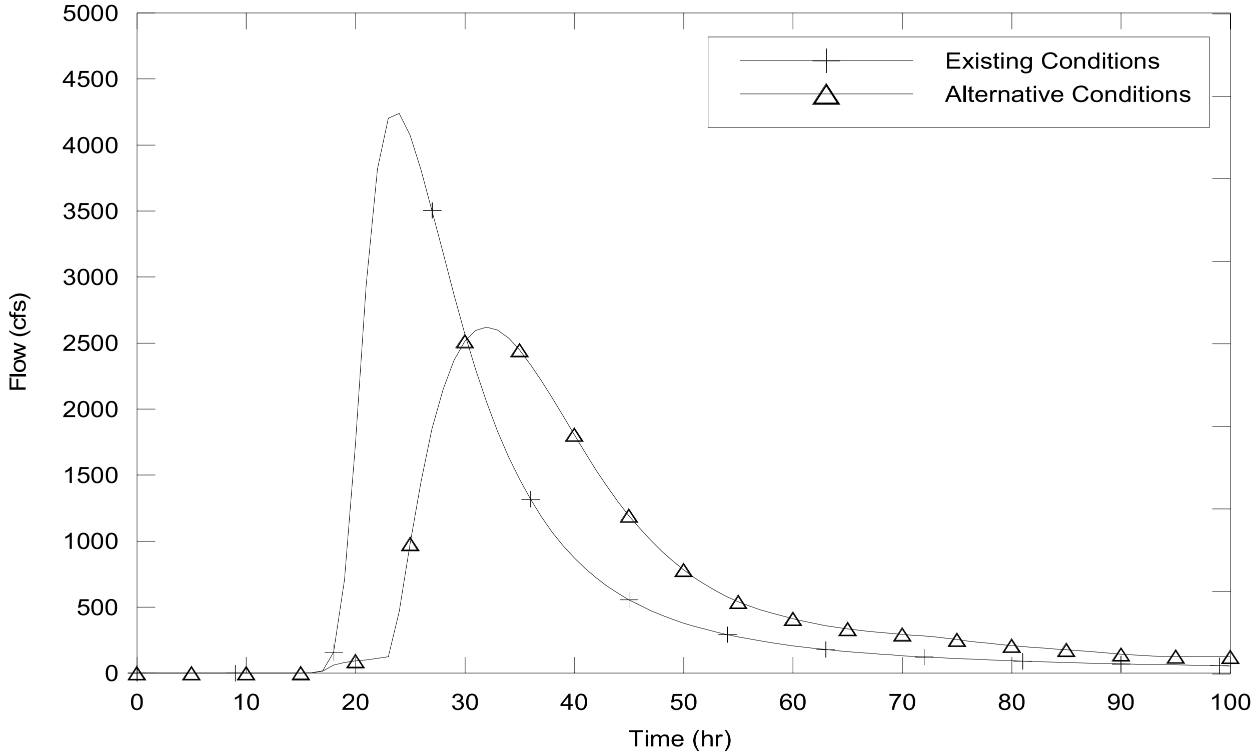


Figure B-33. Impact of detention alternative 21 on the flow at the mouth of Big Creek; 5-year modeled storm event

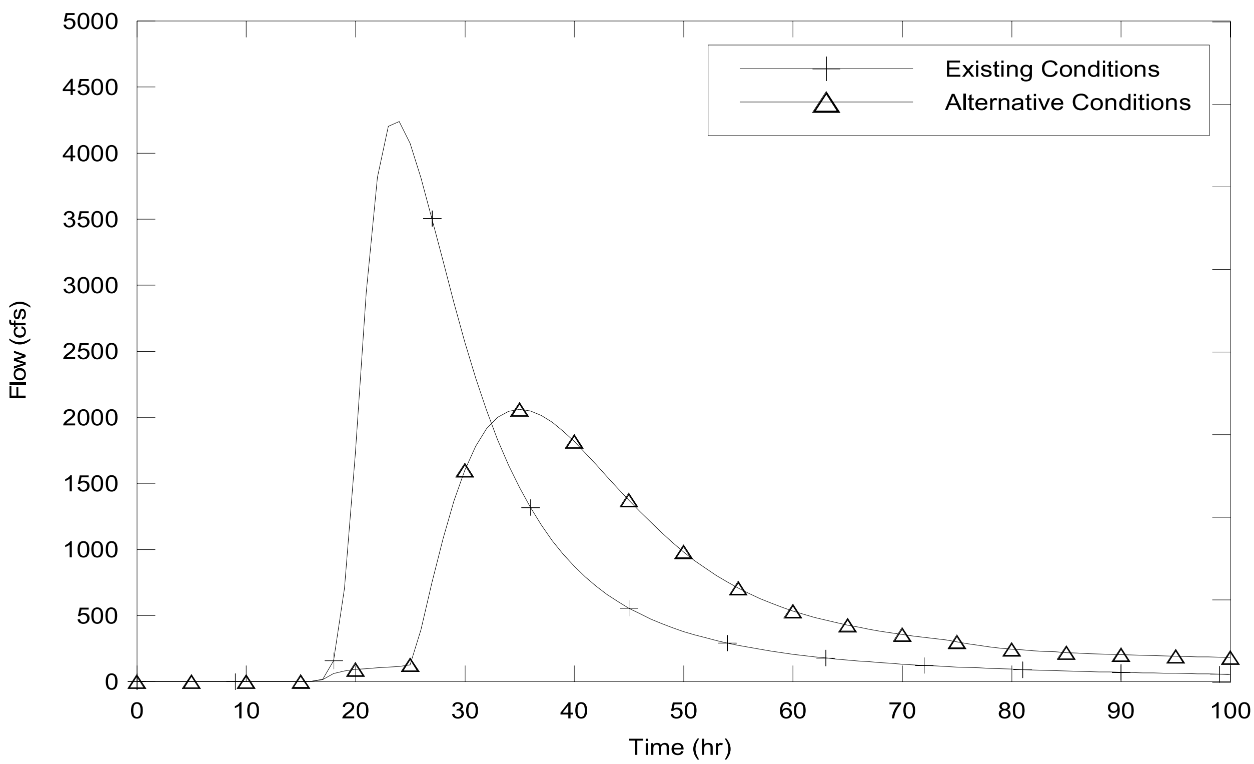


Figure B-34. Impact of detention alternative 22 on the flow at the mouth of Big Creek; 5-year modeled storm event

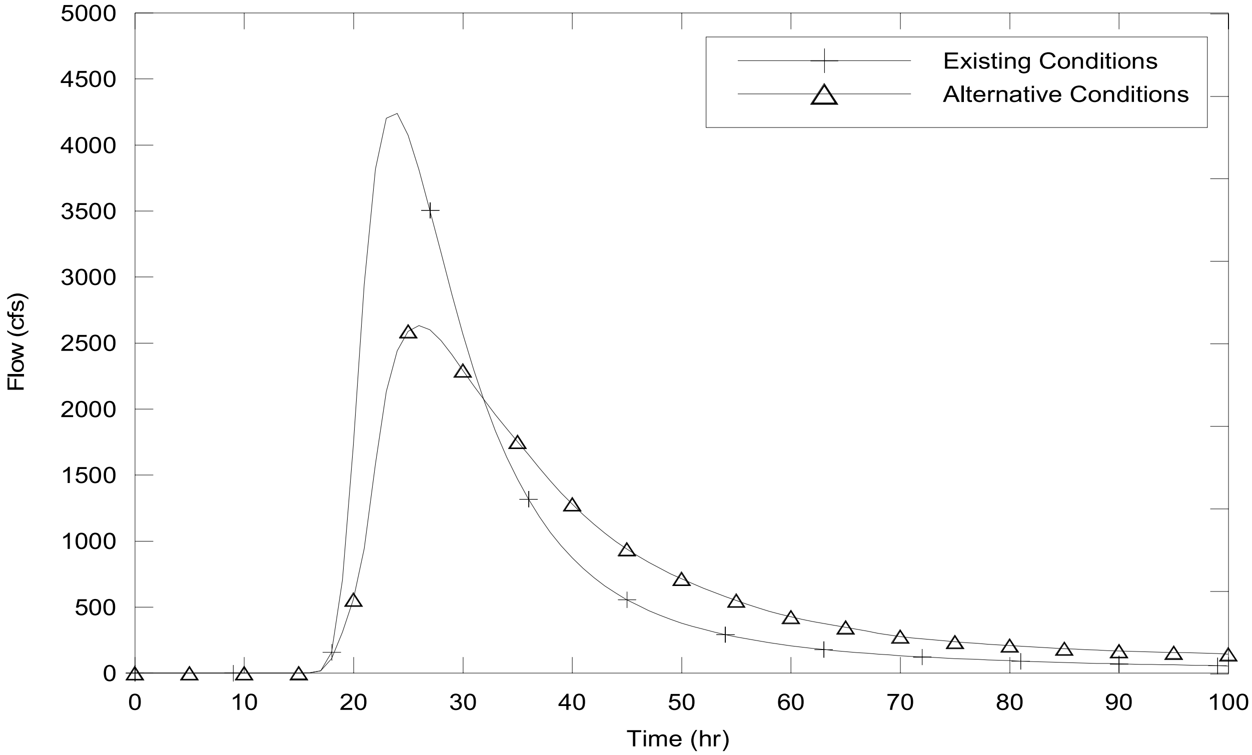


Figure B-35. Impact of detention alternative 23 on the flow at the mouth of Big Creek;
5-year modeled storm event

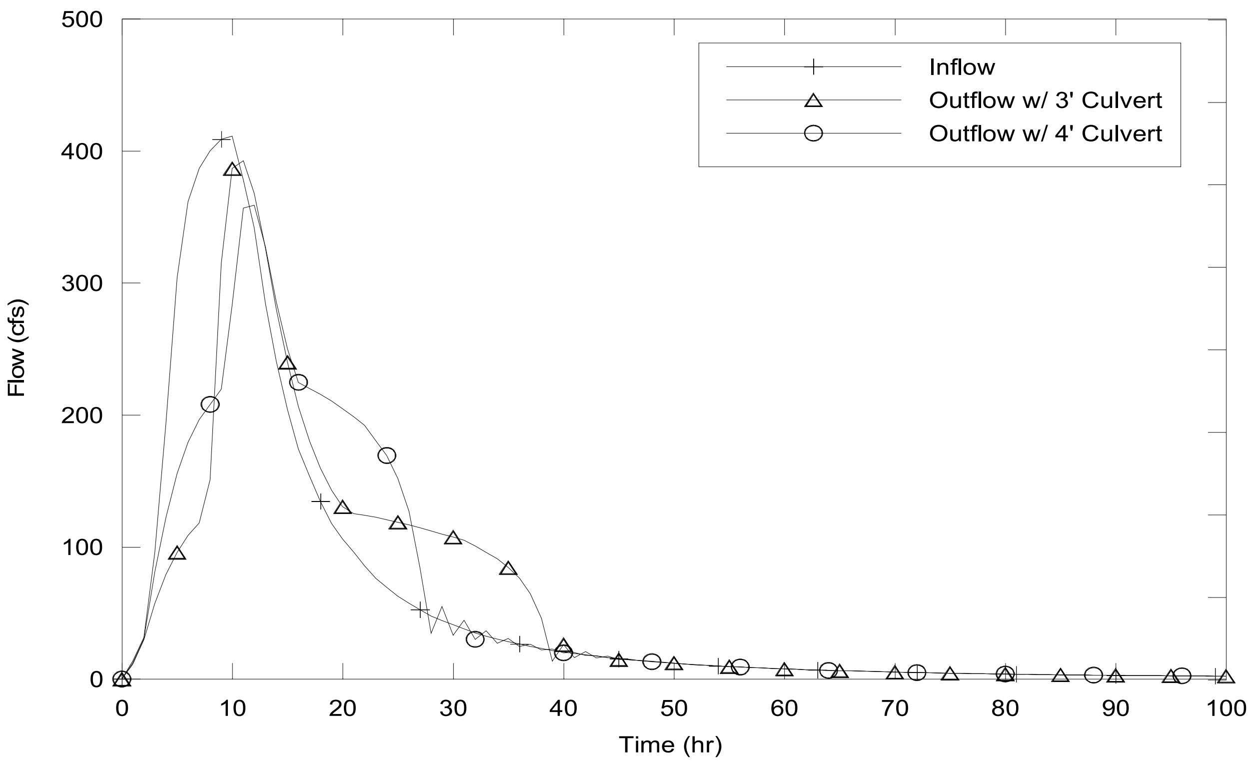


Figure B-36. Simulated inflow and outflow for detention site 1 using two different culvert sizes;
October 4, 1990 storm event

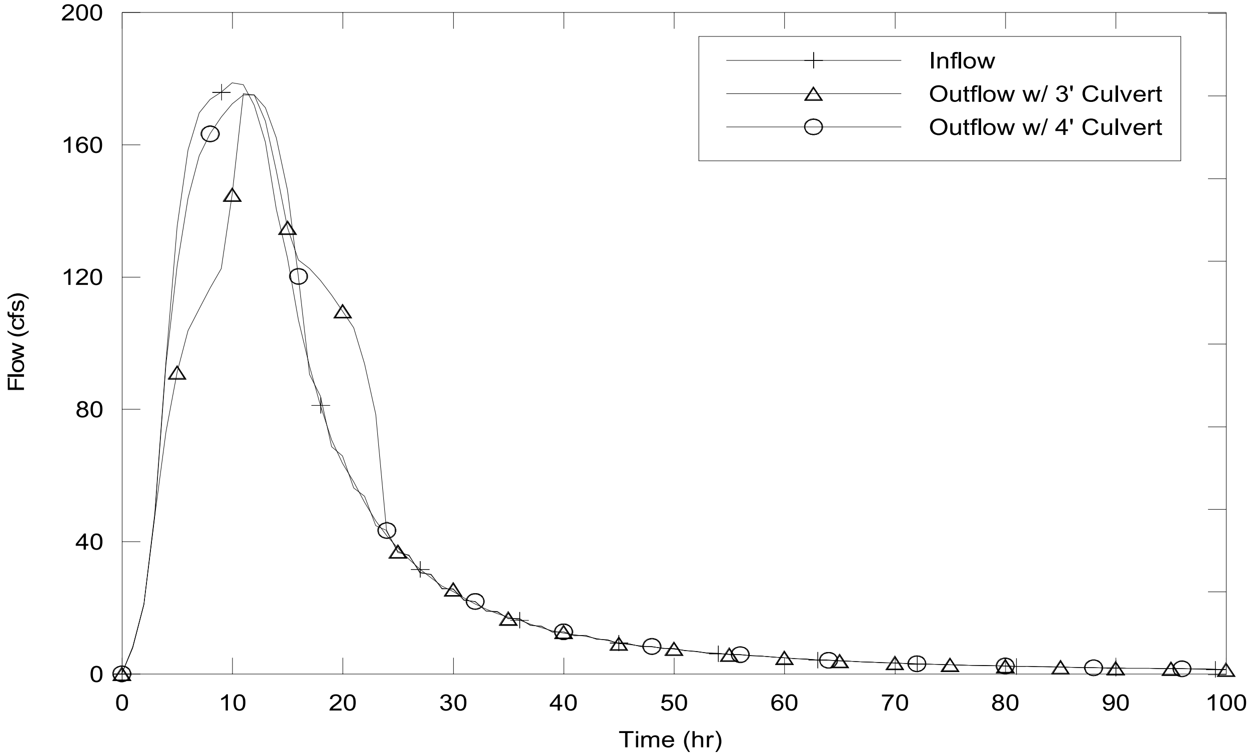


Figure B-37. Simulated inflow and outflow for detention site 10 using two different culvert sizes; October 4, 1990 storm event

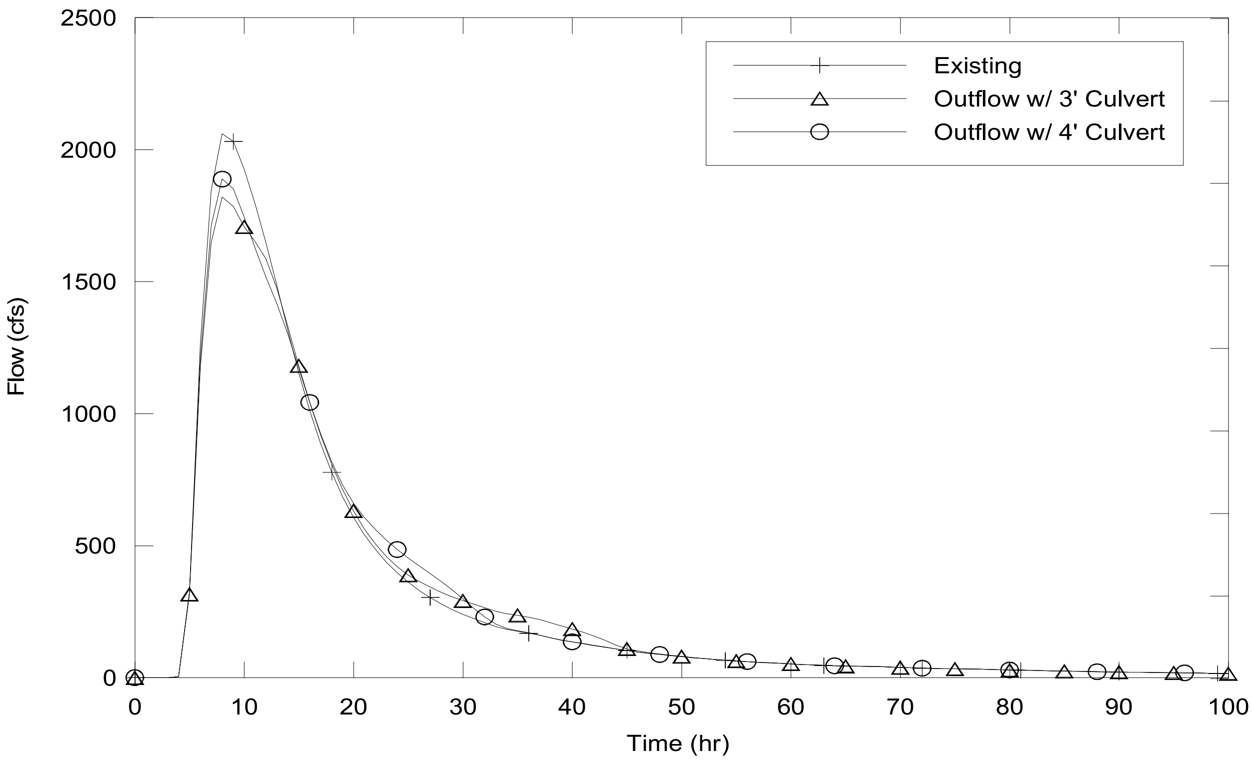


Figure B-38. Impact of culvert size at detention site 1 on Big Creek outflow; October 4, 1990 storm event

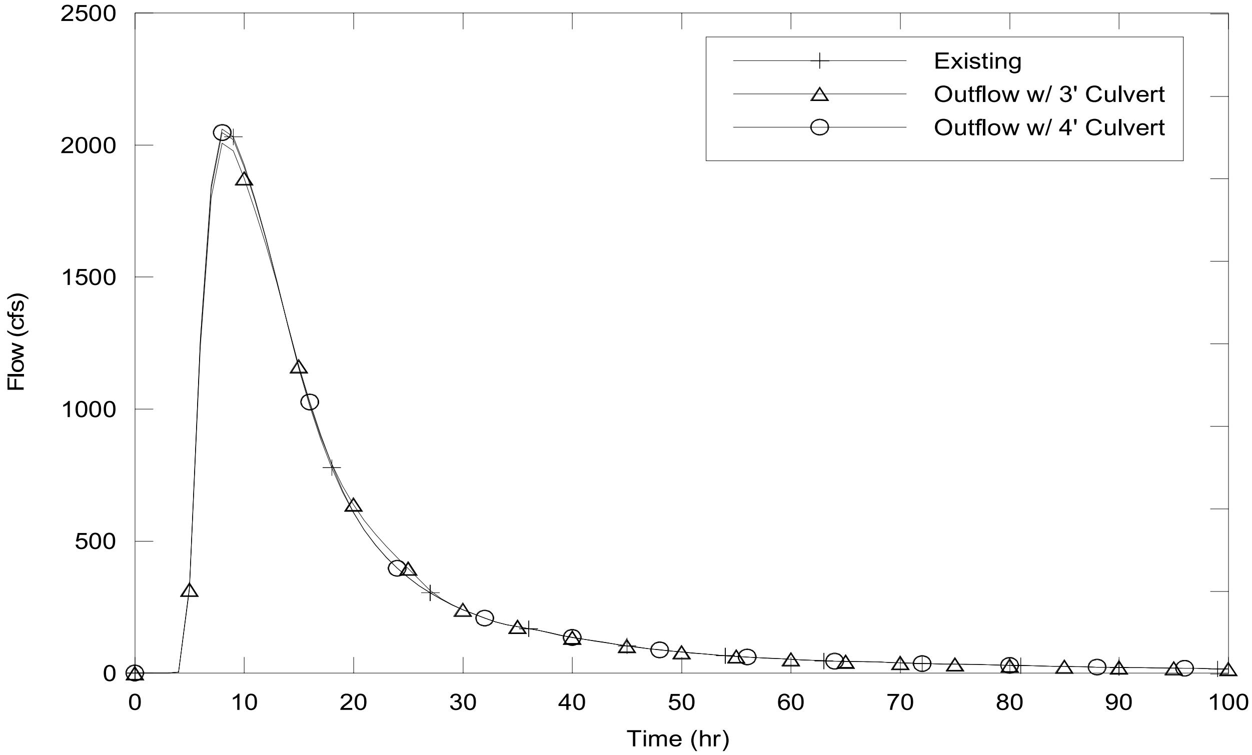


Figure B-39. Impact of culvert size at detention site 10 on Big Creek outflow; October 4, 1990 storm event

Appendix C. Calibration of HEC-1 Model to Big Creek Watershed

The model was calibrated to recorded and design events using updated precipitation and discharge records. Seventeen storms with peaks greater than 500 cfs were chosen at random from periods in which good rainfall and discharge data were available. Rainfall was taken from the three ISWS gages, which were in operation from 1986 to 1993. Discharge data were taken from the ISWS gage at Big Creek at Perks Road, which was previously operated by the USGS. The storms used for calibration are listed in Table C-1. The models were calibrated to best match the peak flow and runoff volume of each storm event.

The SCS Curve Number (CN) was used to calculate precipitation losses, and the Kinematic Wave option was chosen to model overland and stream routing. Parameters such as channel slope, channel length, channel shape, and drainage area were measured and were not modified in calibration. The parameters used to calibrate the models were the curve number, overland roughness coefficient, and channel roughness coefficient.

The channel roughness coefficient (Manning's n) was the easiest parameter to determine. A value between 0.08 and 0.11 worked well in all storms. It was determined that a value of 0.10 could be used for all events with no loss of accuracy in predicting volume and peak flow. This value of Manning's n is higher than would normally be used for hydraulic routing but works well with the HEC-1 hydrologic routing and probably accounts for errors in other aspects of the modeling process. If a hydraulic analysis was needed to match observed stages in the stream, channel roughness would be a more important parameter in calibration and it is likely that a different volume of channel roughness would result from that analysis.

The rainfall and discharge data were gathered for the events, and the HEC-1 model was run for each storm. For each storm the curve number and overland roughness values were modified until, by trial and error, the computed hydrograph matched the observed hydrograph to the best of the model's capabilities. Summaries of these values are given in table C-1 for each storm.

The calibrated values of the curve number and overland roughness for each individual storm have a high degree of variability. An examination of table C-1 indicates the calibrated curve number is most closely related to the season during which the storm occurred. High values of CN above 90 are normally associated with spring months when the soil is near saturation, whereas lower values of CN are associated with other seasons of the year. The calibrated value of the overland flow roughness is closely correlated with the size of the flood event, with the highest roughness values being associated with runoff volumes above one inch and peak flow rates above 1300 cfs.

The volume and peak were highly sensitive to the curve number, and the peak was sensitive to the overland roughness chosen. Figures C-1, C-2, and C-3 are examples that show the computed and observed shapes for three of the hydrographs. The data show that given the peakflow and volume of total runoff, a combination of overland roughness and a curve number can be chosen such that the peak and volume match while the computed hydrograph's shape matches reasonably well with the observed data.

Next, the model was calibrated to the design events determined in appendix A. Once the rainfall, peakflow, and volume were known for the design events, the same calibration procedure described earlier was used. The results of calibrating to the design events are seen in table C-2. These three models were then used to model what may occur on Big Creek as a result of modifying the watershed.

As a result of the recalibration study, it was found that with a given set of rainfall and discharge data, the peakflow and volume of direct runoff for any observed storm event can be simulated closely by adjusting the curve number and overland roughness coefficient by trial and error. The calibrated values of overland roughness coefficient are high compared to typical values expected for most watershed conditions. It is possible that some of the physical parameters of the watershed, such as overland slope and length as measured from topographic maps, do not fully represent the flow paths within the watershed, and the high values for the overland roughness coefficient may be compensating for the shortcomings in the parameters and associated modeling structure. Nevertheless, the calibrated model is effective for modeling the rainfall-runoff process of watersheds, any particular event may be studied, and modifications such as placing weirs along the channel may be modeled to determine their effects on the particular event being modeled.

Table C-1. Big Creek Observed Data Calibration Summary

	Observed		*Computed*		*Parameters*		
Event date	*Volume (in.)*	*Peak (cfs)*	*Volume (in.)*	*Peak (cfs)*	*Overland roughness*	*Channel roughness*	*CN*
2/28/87	0.615	993	0.621	993	0.13	0.10	90
6/30/87	0.282	746	0.287	723	0.05	0.10	77
11/19/88	0.386	663	0.374	664	0.06	0.10	78
11/20/88	0.388	719	0.376	707	0.04	0.10	91
2/3/89	1.532	1661	1.508	1651	0.37	0.10	82
3/31/89	0.607	1203	0.581	1200	0.10	0.10	92
4/4/89	0.829	1230	0.804	1224	0.23	0.10	97
1/20/90	0.898	1376	0.926	1376	0.18	0.10	75
2/15/90	1.012	1246	0.992	1240	0.13	0.10	83
5/12/90	0.536	1236	0.547	1260	0.11	0.10	80
5/17/90	1.139	1693	1.148	1692	0.29	0.10	91
10/4/90	1.027	1520	0.991	1521	0.27	0.10	87
4/13/91	0.780	1114	0.759	1093	0.08	0.10	90
4/29/91	0.406	1038	0.395	1098	0.03	0.10	91
3/30/92	0.442	558	0.432	559	0.06	0.10	93
11/12/92	0.386	575	0.383	570	0.13	0.10	68
11/22/92	0.277	731	0.275	746	0.01	0.10	86
Average	0.679	1077	0.671	1077	0.13	0.10	85.35

Table C-2. Big Creek Design Event Calibration Summary

	Design		*Computed*		*Parameters*		
Design event	*Volume (in.)*	*Peak (cfs)*	*Volume (in.)*	*Peak (cfs)*	*Overland roughness*	*Channel roughness*	*CN*
2-year	1.600	2100	1.599	2055	0.34	0.10	82
5-year	2.200	2800	2.180	2806	0.39	0.10	80
100-year	4.200	5200	4.269	5237	0.70	0.10	72

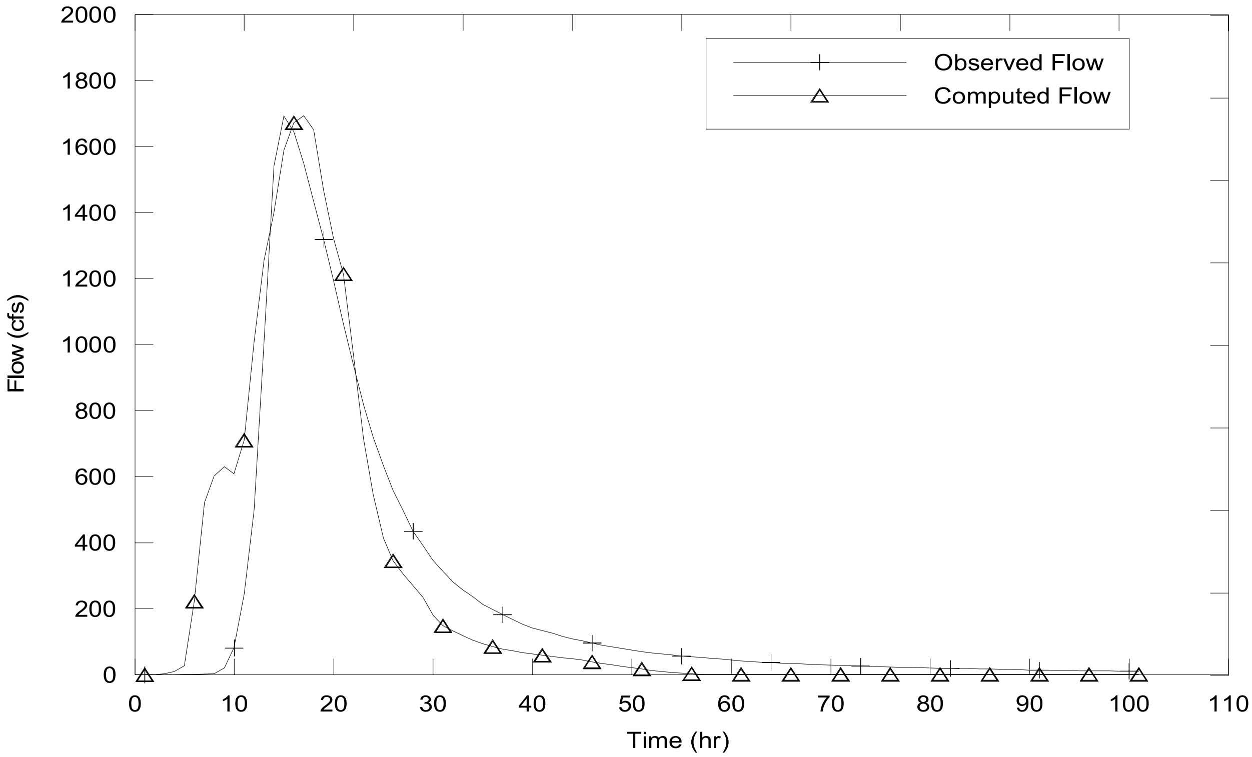


Figure C-1. Calibration, May 17, 1990

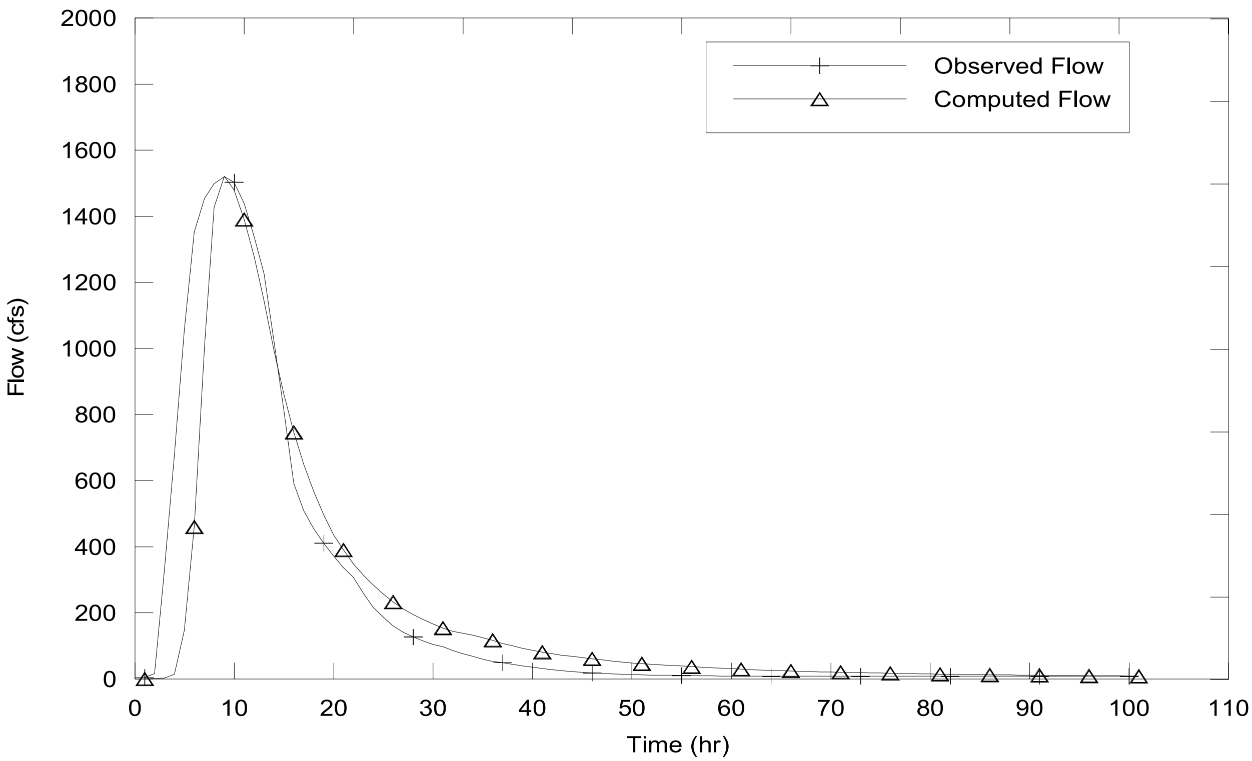


Figure C-2. Calibration, October 4, 1990

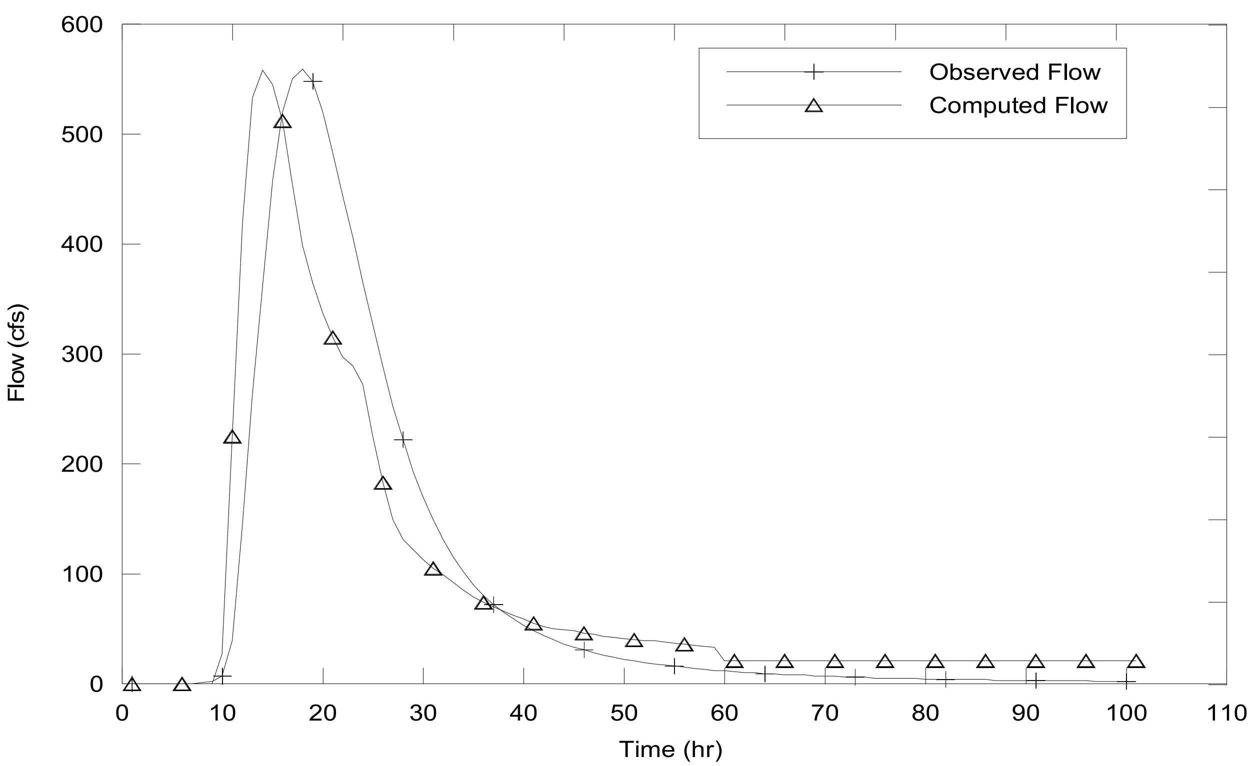


Figure C-3. Calibration, March 30, 1992

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