United States General Accounting Office

GAO

Briefing Report to the Honorable David Pryor, U.S. Senate

August 1991

# WATER RESOURCES

# Corps' Management of 1990 Flooding in the Arkansas, Red, and White River Basins


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GAO

**United States**
**General Accounting Office**
**Washington, D.C. 20548**

**Resources, Community, and**
**Economic Development Division**

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August 1, 1991

The Honorable David Pryor
United States Senate

Dear Senator Pryor:

This briefing report responds to your May 14, 1990, request that we examine the U.S. Army Corps of Engineers' operation of its flood control structures (reservoirs) in the Arkansas, Red, and White River basins during the May 1990 flooding that caused severe damage in Arkansas, Texas, and Oklahoma.

On the basis of discussions with you and your staff, we agreed to determine whether the Corps had followed its operating procedures in capturing and releasing water from nine reservoirs in the three basins before, during, and after the flood. We briefed your office on the preliminary results of our work at seven of the nine reservoirs included in our review. As requested, we also summarized the preliminary results in correspondence to you dated March 14, 1991. This report presents our final detailed findings and conclusions concerning the Corps' management of the nine reservoirs from April 15 through June 30, 1990.

In summary, we found the following:

- The Corps generally operated the nine reservoirs in accordance with its operating procedures before, during, and after the May 1990 flooding. We found no evidence to indicate that the Corps released water from the Wister, Eufaula, Blue Mountain, Nimrod, Bull Shoals, and Norfork reservoirs contrary to its procedures.
- Most of the releases from the Tenkiller Ferry, Texoma, and Hugo reservoirs also complied with the Corps' procedures. However, in two cases—one at the Tenkiller Ferry reservoir and the other at the Texoma and Hugo reservoirs—the Tulsa District released water contrary to its operating procedures. Our analysis indicated that the releases prolonged the flooding of rural lands predominantly in Texas and Oklahoma. These cases are summarized below.

## Background

In March 1990, above-normal rainfall in the three river basins caused water levels in reservoirs to rise. Between late March and mid-April, the Corps released the water in its reservoirs so that by mid-April the Corps had available almost all of its flood control storage capacity. In late

April, two storm systems moved through Oklahoma and Arkansas. These storms saturated the ground and rapidly filled reservoirs in the three river basins. Because flooding was occurring downstream from the reservoirs, the Corps did not release this water before torrential rains fell on May 2, 3, and 4, 1990. These rains and resulting runoff caused the water levels in some reservoirs in the Arkansas and Red River basins to exceed their flood control storage capacity, thereby necessitating water releases, even though flooding was occurring downstream.

The Corps has established operating procedures for its reservoirs that are contained in its river basin manuals. Corps district offices are responsible for the day-to-day operation of the reservoirs in accordance with the applicable river basin manual and take direction from Corps division offices. However, in unusual circumstances, such as severe flooding, the district offices may, with the approval of the division office, deviate from their operating procedures.

## Tenkiller Ferry Reservoir

In the case of the Tenkiller Ferry reservoir, the Tulsa District obtained approval from the Southwestern Division to release water in excess of the amount allowed by its operating procedures in order to regain a portion of the reservoir's flood control storage capacity. However, for 12 days in May, the releases resulted in river levels (stages) at Gore, Oklahoma, about 1 foot above those allowed by the operating procedures. Neither the district's request nor the division's approval had provided the Tulsa District with the authority to release water from Tenkiller Ferry in volumes that would cause the prescribed river stage to be exceeded.

Southwestern Division officials acknowledged that the prescribed river stage at Gore was exceeded, but they believed that minimal additional flooding resulted and was confined primarily to rural lands in Oklahoma. They said that district personnel continually monitored the affected area and reported no structural damage.

## Texoma and Hugo Reservoirs

In the case of the Texoma and Hugo reservoirs, the Tulsa District did not obtain approval from the Southwestern Division to deviate from its operating procedures. For 23 days in May and June the district regulated water releases from the Texoma and Hugo reservoirs to maintain a Red River stage up to 1.3 feet higher than the standard 23.7-foot regulating stage at the De Kalb, Texas, monitoring station.

Tulsa officials told us that division approval of this action was not needed because their manual permits them to carry out reconnaissance to determine the effects of regulating to a higher river stage. The district performed aerial and field reconnaissance between June 11 and June 13, or 20 days after the standard river stage was first exceeded.

The district's decision to regulate releases to maintain a stage higher than the standard river stage of 23.7 feet prolonged the period during which some land remained flooded and delayed the start of cultivation of farmland, predominantly in Oklahoma and Texas. Southwestern Division officials agreed with us that any deviation needed by the district to perform such reconnaissance required prior division approval. On the basis of our discussions of this matter, the division has sent a letter to each of its districts clarifying the authority of the district when performing reconnaissance and will revise its operating procedures accordingly.

## Scope and Methodology

To assess whether the Corps had followed its flood control operating procedures, we obtained reservoir and river data maintained by the Corps' Southwestern Division in Dallas for nine reservoirs: Eufaula, Wister, Tenkiller Ferry, Blue Mountain, and Nimrod in the Arkansas River basin; Texoma and Hugo in the Red River basin; and Bull Shoals and Norfork in the White River basin. These nine reservoirs used the largest amount of flood control storage capacity and released the largest volume of water during the flood in their respective river basins.

We conducted our review from June 1990 to May 1991 in accordance with generally accepted government auditing standards. (See app. I for a more complete discussion of our scope and methodology.)

## Views of Agency Officials

We discussed the information in this report with officials responsible for flood control management at the Corps' headquarters and at its Southwestern Division. They generally agreed that the information presented in this report was accurate. However, as requested, we did not obtain written agency comments on a draft of this report.

We are sending copies of this briefing report to the appropriate congressional committees; interested Members of Congress; the Secretaries of Defense and the Army; the Chief, U.S. Army Corps of Engineers; and the

Director, Office of Management and Budget. We will make copies available to others upon request.

Please contact me at (202) 275-7756 if you or your staff have any questions concerning this report. Major contributors to this report are listed in appendix II.

Sincerely yours,

James Duffus III
Director, Natural Resources
Management Issues

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## Abbreviations

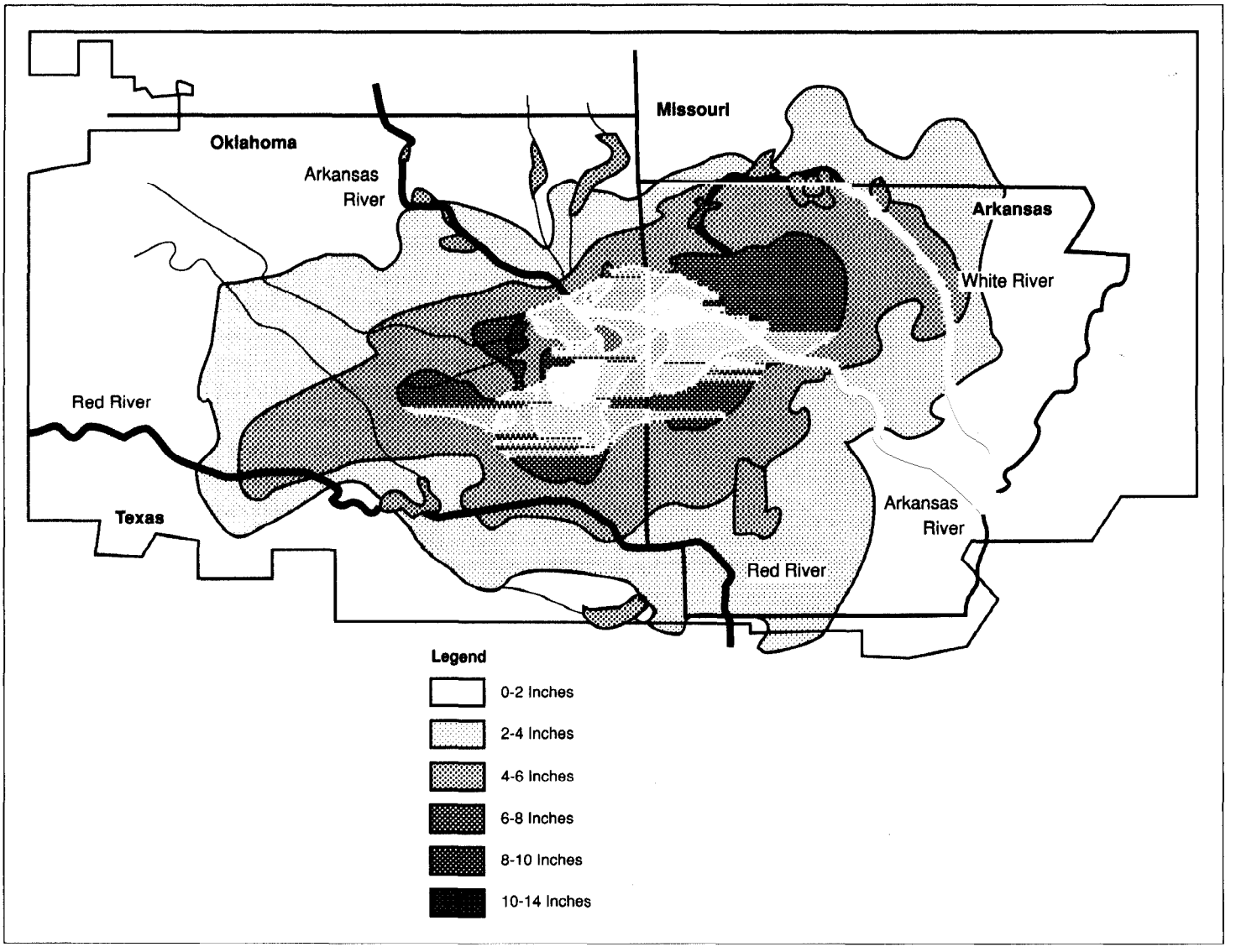
| | |
|---|---|
| cfs | cubic feet per second |
| GAO | General Accounting Office |
| msl | mean sea level |

# Meteorological Aspects of the May 1990 Flood

In March 1990, above-normal rainfall in the Arkansas, Red, and White River basins caused water levels in reservoirs to rise. Between late March and mid-April, the Corps evacuated the water captured by its reservoirs so that by mid-April the Corps had available almost all of its flood control storage capacity.

Cold fronts moving from west to east set off a series of storms in April and May of 1990. Storms began to move into Oklahoma and through Arkansas from April 19 to 21 and again from April 26 to 28. After the passage of these storms, the ground was saturated and reservoirs were rapidly filled in the three river basins. Additional heavy rains occurred on May 2, 3, and 4. Figure 1.1 shows the distribution of rainfall for the 3-day period in the three river basins. Four to 14 inches of rain fell on the saturated areas of the Arkansas River basin, 3 to 10 inches of rain fell on the Red River basin in Arkansas and Oklahoma, and 4 to 6 inches of rain fell over the upper portion of the White River basin. The average rainfall for the area depicted is 14.2 inches for the period from January 1 to May 4. In 1990, the rainfall for the area totaled 33.8 inches, or about 140 percent more than average.

**Figure 1.1: Distribution of Rainfall in the Arkansas, Red, and White River Basins** (May 2-4, 1990)




Source: U.S. Army Corps of Engineers.

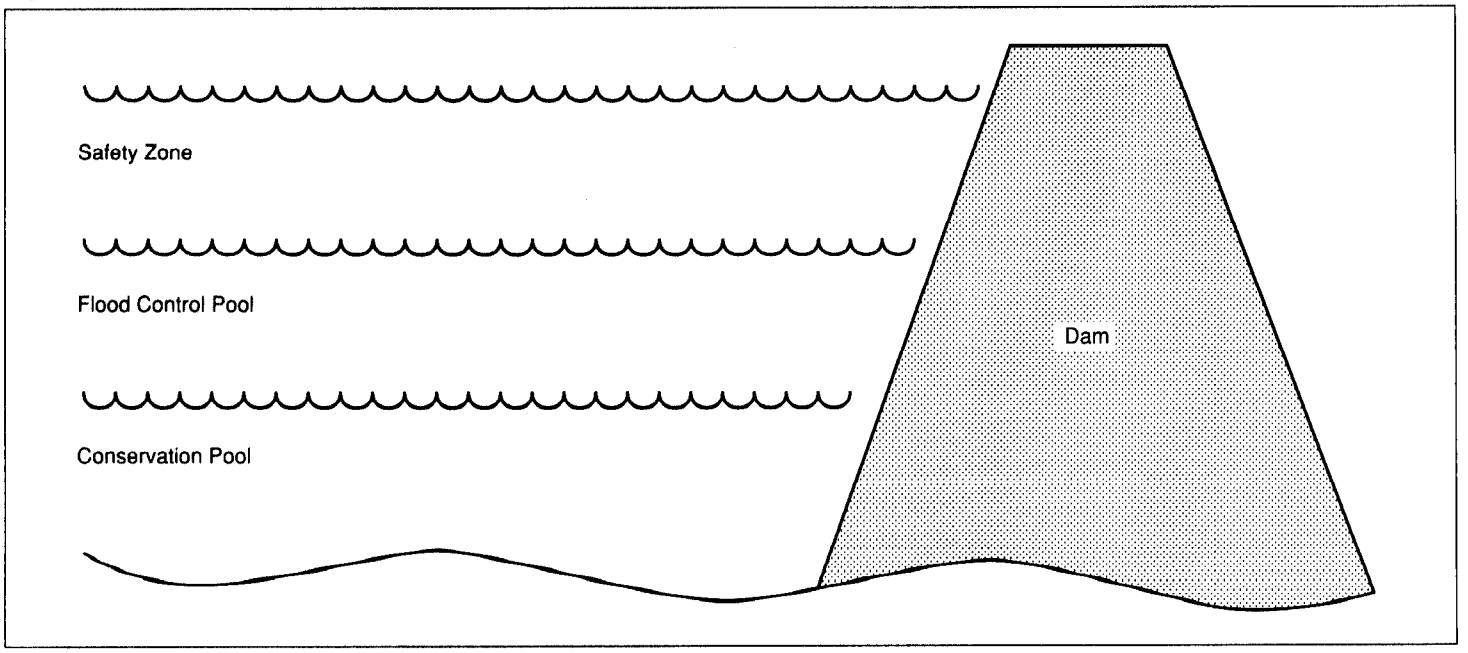
# Reservoir Operating Procedures

The Corps operates its dam and reservoir systems to help control a heavy influx of rain into a basin. Figure 2.1 is a diagram of a flood control reservoir. Its storage capacity includes a conservation pool, a flood control pool, and a safety zone. The normal level of water in the reservoir is within the conservation pool.[1] The flood control pool is used to capture and store water runoff from most rains so as to prevent flood damage downstream. Very heavy rainfall may cause the water to rise into the safety zone.

The Corps determines reservoir releases on the basis of the amount of storage utilized and the volume of runoff flowing into both the reservoir and the river downstream from the dam. The Corps' operating procedures generally prohibit release of water from a reservoir if flooding is occurring downstream unless predicted inflow indicates that the water will rise into the safety zone. If the water is predicted to, or does, rise into the safety zone, releases at less than the inflow rate are made regardless of downstream flooding. Once the water rises above the top of the safety zone, releases are made to protect the structural integrity of the dam at the lesser of the inflow rate or the maximum discharge capacity. The Corps' regulations permit its districts to modify these operating procedures if prior approval has been obtained from the cognizant Corps division. During an emergency, however, such as a drowning or failure of operation facilities, the district is not required to obtain prior approval but is required to notify the division of its actions as soon as possible.

[1]The water maintained in a reservoir's conservation pool may be used for authorized purposes, such as hydropower, navigation, water supply, and recreation.

**Figure 2.1: Diagram of a Flood Control Reservoir**




Source: U.S. Army Corps of Engineers.

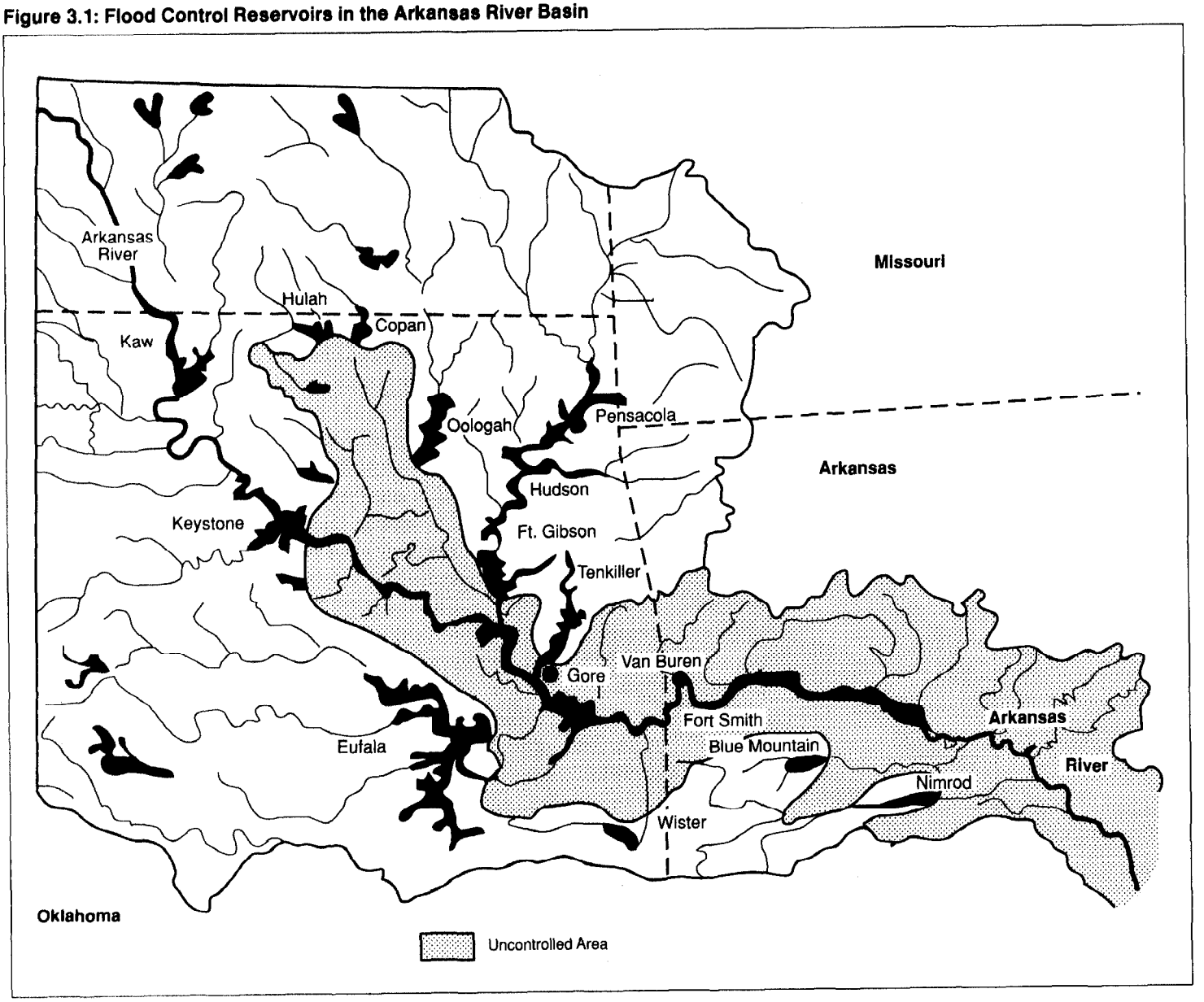
# Arkansas River Basin

The Arkansas River basin comprises about 138,000 square miles of contributing drainage area. Figure 3.1 depicts the portion of the Arkansas River basin in the states of Oklahoma and Arkansas and the location of 13 flood control reservoirs. The Corps uses 11 major flood control reservoirs within the state of Oklahoma to modify flows of the rivers where the reservoirs are located and flows of the main stem of the Arkansas River. The two reservoirs in the state of Arkansas are generally operated independently of the Arkansas River main stem to control flooding in their respective rivers. The Corps' Tulsa District has operational responsibility for the 11 reservoirs in Oklahoma, while the Little Rock District has operational responsibility for the two reservoirs in Arkansas.

The Corps uses a stream gauge located near Van Buren, Arkansas, to monitor the volume of water flowing into the state of Arkansas. Above Van Buren are about 128,000 square miles of drainage area, which includes an uncontrolled area of about 7,600 square miles depicted as the shaded area in figure 3.1. The Corps cannot regulate runoff within this uncontrolled area because the water does not drain into any flood control reservoir. By monitoring river flows within the uncontrolled area and synchronizing releases from the 11 upstream reservoirs, the Corps tries to maintain target flows at the Van Buren monitoring station. Releases require varying periods of time, ranging from a few hours to 3 days to arrive at the Van Buren monitoring station. Target flows at Van Buren vary according to the season of the year and the percent of basin flood control storage capacity being utilized.

We reviewed the Corps' operations at 5 of the 13 flood control reservoirs shown on figure 3.1 - Eufaula on the Canadian River, Wister on the Poteau River, Tenkiller Ferry on the Illinois River, Blue Mountain on the Petit Jean River, and Nimrod on the Fourche LaFave River. We found that the Corps generally operated the five flood control reservoirs in accordance with its river basin master manuals, which provide guidance and regulations for operating the reservoirs. However, in one case, the Corps' releases of water at Tenkiller Ferry reservoir, combined with runoff from the uncontrolled area, caused the Illinois River to rise up to 1 foot above the 17-foot flood stage at the Gore, Oklahoma, monitoring station for 12 days in May. We believe that the Tulsa District did not have authority to release water from Tenkiller in volumes that would cause the 17-foot Gore regulating stage to be exceeded.

**Figure 3.1: Flood Control Reservoirs in the Arkansas River Basin**




Source: U.S. Army Corps of Engineers.

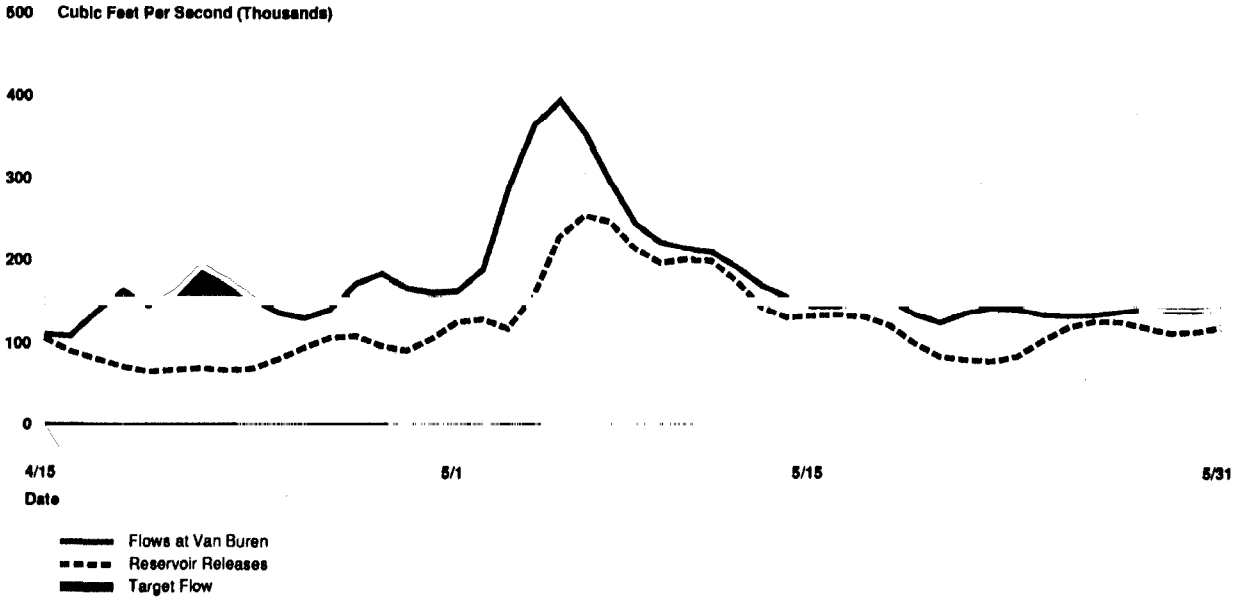
## Impact of Reservoir Releases on Arkansas River Flow at Van Buren

Figure 3.2 depicts, for the period April 15 to May 31, 1990, the daily (1) Arkansas River flows at the Van Buren monitoring station, (2) total volume of water released from Corps reservoirs that flowed through the Van Buren area, and (3) target flow of 150,000 cubic feet per second (cfs), which the Corps attempts to maintain. The difference between the reservoir releases and the river flow at Van Buren represents the runoff from the uncontrolled area above the Van Buren monitoring station.

Figure 3.2 shows that from April 15 to 30, the Corps reduced releases when heavy rainfall and resulting runoff from the uncontrolled area increased the flows at the Van Buren monitoring station. As the flow at Van Buren receded, the Corps increased its reservoirs' releases. According to Corps officials, releases from reservoirs closest to a flooded area are usually started soon after flood waters begin to recede to prevent sediment from building up in the river bed and river banks from eroding. From May 1 to 5, flows at Van Buren increased significantly because of heavy rainfall and resulting runoff from the uncontrolled area. Reservoir releases also increased significantly, primarily because Eufaula and Wister had water in their safety zones that mandated large releases. The combined releases from all reservoirs that impacted the flows at Van Buren increased from about 124,000 cfs on May 1 to 228,075 cfs on May 5. These releases made up about 58 percent of the peak average daily flow of 390,000 cfs at Van Buren on May 5. Runoff from the uncontrolled area made up the difference.

Figure 3.2 shows that releases reaching Van Buren peaked on May 6 at about 253,000 cfs and extended the period during which flows at Van Buren exceeded the 150,000 cfs target flow. On May 4, the Tulsa District implemented a modification approved by the Southwestern Division to evacuate its reservoirs' flood control pools by releasing larger amounts of water than the applicable basin manual permits. The modification hastened the emptying of the flood control pools above Van Buren but slowed the reduction of flows at Van Buren. The Corps' rationale for the modification was that the system of flood control reservoirs in the Arkansas River basin was vulnerable to subsequent storms. The National Weather Service forecast for May called for additional above-normal rains. Under normal procedures, the flow at Van Buren would have been allowed to recede to 150,000 cfs, and releases would have sustained that rate until most of the system's flood control pools had been evacuated. The lower Arkansas River regulating unit supervisor said the modification extended the length of time that flows remained above 150,000 cfs at Van Buren by about 2 days. On May 15, the flow dipped to 143,000 cfs and remained below 150,000 cfs for the rest of May.

**Figure 3.2: Arkansas River Basin Reservoir Releases and Flows at Van Buren** (April 15 to May 31, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Eufaula Reservoir

Figure 3.3 depicts water elevations in the Eufaula reservoir from April 15 to June 30, 1990. The flood control pool extends from 585 feet mean sea level (msl) to 597 msl. Figure 3.4 shows the volume of water that flowed into, and releases made from, Eufaula for the same period.

On April 16, about 92 percent of Eufaula's flood control storage capacity was available to capture rainfall and runoff. From April 19 to 22, water flowing into Eufaula ranged from 74,700 cfs to 186,900 cfs. During the same period, the Corps increased releases from about 12,700 cfs to about 25,000 cfs. As a result of the large inflows, the water in the reservoir rose about 6 feet.

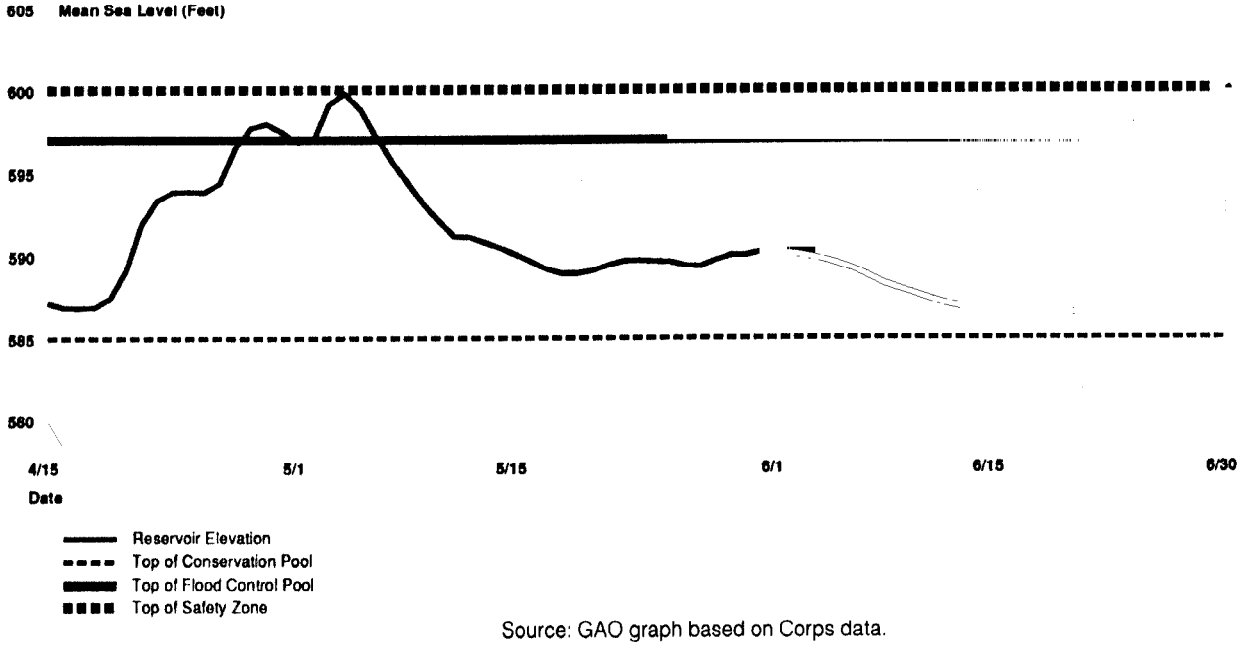
Additional rainfall from April 26 to 28 produced inflows ranging from 177,100 cfs to 86,500 cfs. The Corps increased releases to about 80,000 cfs on April 30 because on April 29 the water had risen 1 foot into the reservoir's safety zone.

On May 1, the water in the reservoir receded to just below the top of the flood control pool and the Corps reduced the releases to 70,000 cfs. Heavy rains that fell between May 2 and 4 generated inflows ranging from about 192,000 cfs to 311,100 cfs. Beginning on May 2, releases were continually increased until they peaked on May 4 at about 235,000 cfs. The water crested on the morning of May 4, 0.23 feet from the top of the reservoir's safety zone. The water remained in the safety zone through May 6.

Under normal operating procedures, releases from Eufaula would have been reduced to the greater of 40,000 cfs or the inflow average of the preceding 12-hour period on May 7 when the reservoir receded into the flood control pool. However, the Tulsa District obtained approval from the Southwestern Division to modify the normal operating procedures by maintaining larger releases in order to hasten the flood control pool's evacuation. The Corps continued to release more than 40,000 cfs through May 11.

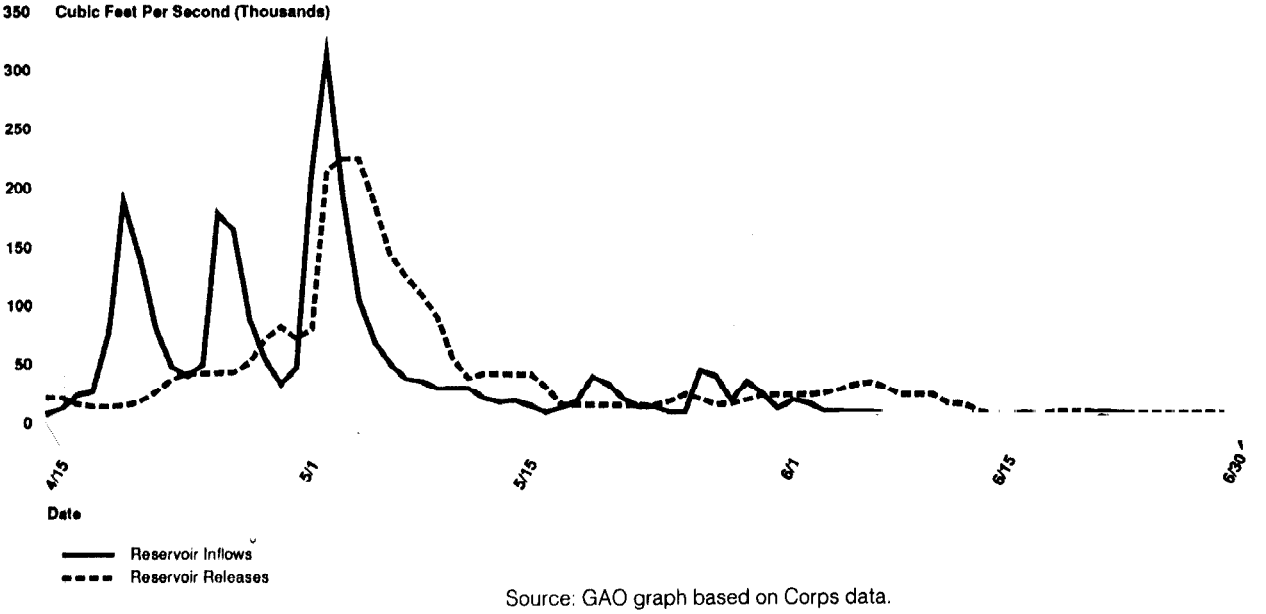
From May 13 to 18, Eufaula's releases were generally reduced from about 40,000 cfs to 13,400 cfs and maintained at that rate until May 20. The water in the reservoir continued to recede until May 19 when intermittent rain began to fall, causing the water to rise about 1 foot by May 31. Between May 21 and June 11, releases ranged from about 12,700 cfs to 30,600 cfs while the water in the reservoir continued to recede. By June 30, the water was utilizing about 7 percent of the flood control pool.

**Figure 3.3: Eufaula Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 3.4: Eufaula Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Wister Reservoir

Figure 3.5 depicts water elevations in the Wister reservoir from April 15 to June 30, 1990. The flood control pool extends from 474.6 msl to 502.5 msl. Figure 3.6 shows the volume of water that flowed into, and releases made from, Wister for the same period.

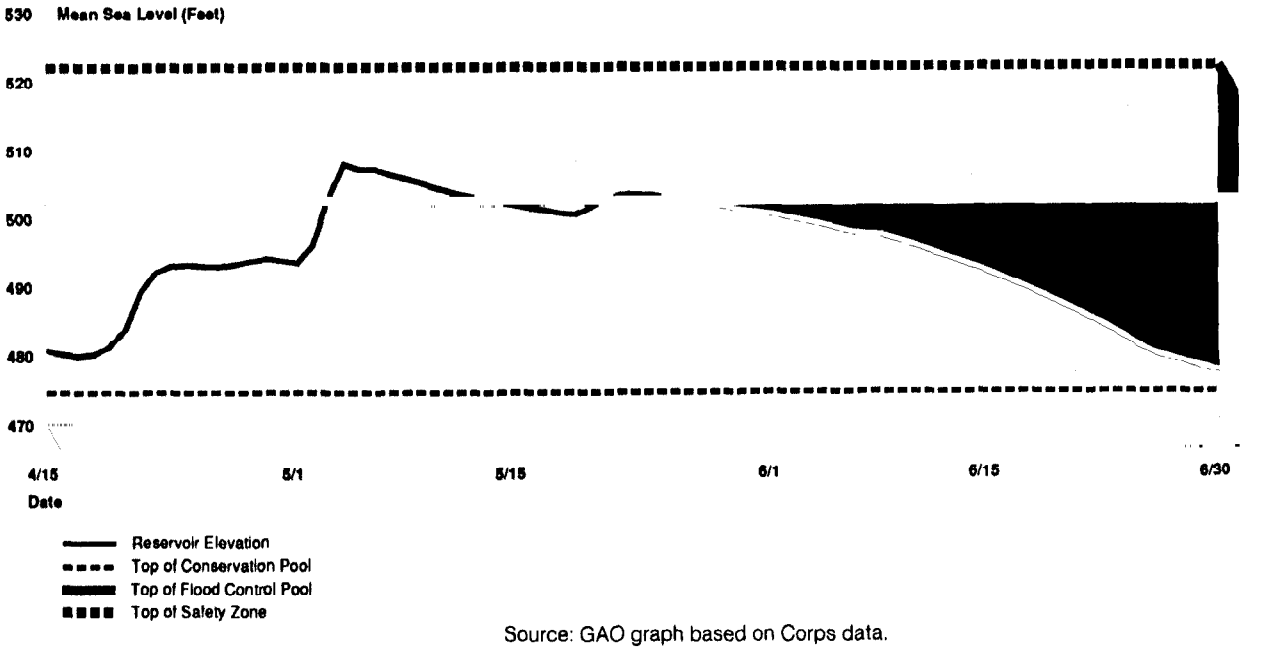
On April 16, about 91 percent of Wister's flood control storage capacity was available to capture rainfall and runoff. Inflows from April 18 to 22 significantly exceeded releases as the Corps attempted to minimize flooding along the Poteau River. Inflows ranged from 3,450 cfs to 30,250 cfs, while releases were about 200 cfs. As a result, the water in the reservoir rose about 12 feet and used about 50 percent of the flood control pool.

Because heavy rains that began on May 1 caused flooding downstream, the Corps discontinued Wister's releases in accordance with its operating procedures. From May 1 to 3, Wister recorded 10.13 inches of rain, and the water in the reservoir rose about 9 feet. Wister's flood control pool was filled on May 3. By May 4, the water had risen an additional 5 feet in the safety zone. From May 1 to 5, inflow ranged from 7,000 cfs to 92,300 cfs, while releases peaked at 23,110 cfs.

On May 4, the Tulsa District obtained approval from the Southwestern Division to modify normal operating procedures because water had risen into the reservoir's safety zone. Beginning on May 8, the Tulsa District opened release gates to maintain releases larger than normal operating procedures allow. The larger releases were continued until May 17 and ranged from about 6,650 cfs to about 13,400 cfs.

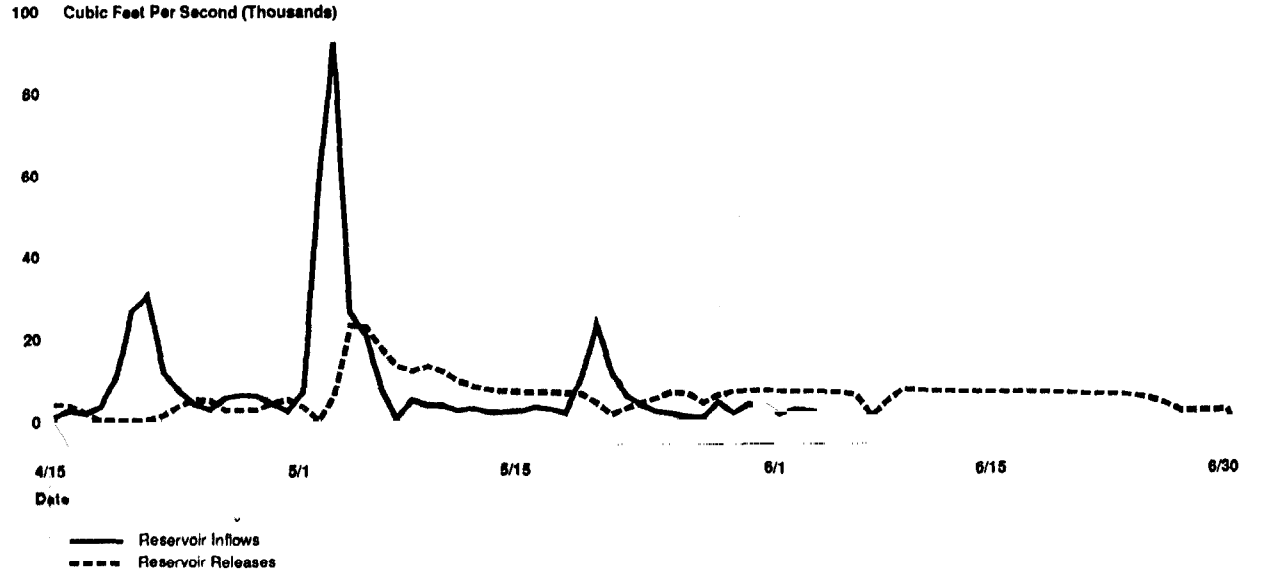
By May 19, the Corps had lowered the water in the reservoir about 2 feet below the top of the flood control pool. However, additional rainfall caused the water to rise again into the safety zone on May 21. Gate releases, which had been discontinued on May 20, were resumed on May 22. Releases were generally less than 6,500 cfs for the remainder of May and June. The water receded so that by June 30 it was about 3 feet above the top of the conservation pool.

**Figure 3.5: Wister Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 3.6: Wister Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Tenkiller Ferry Reservoir

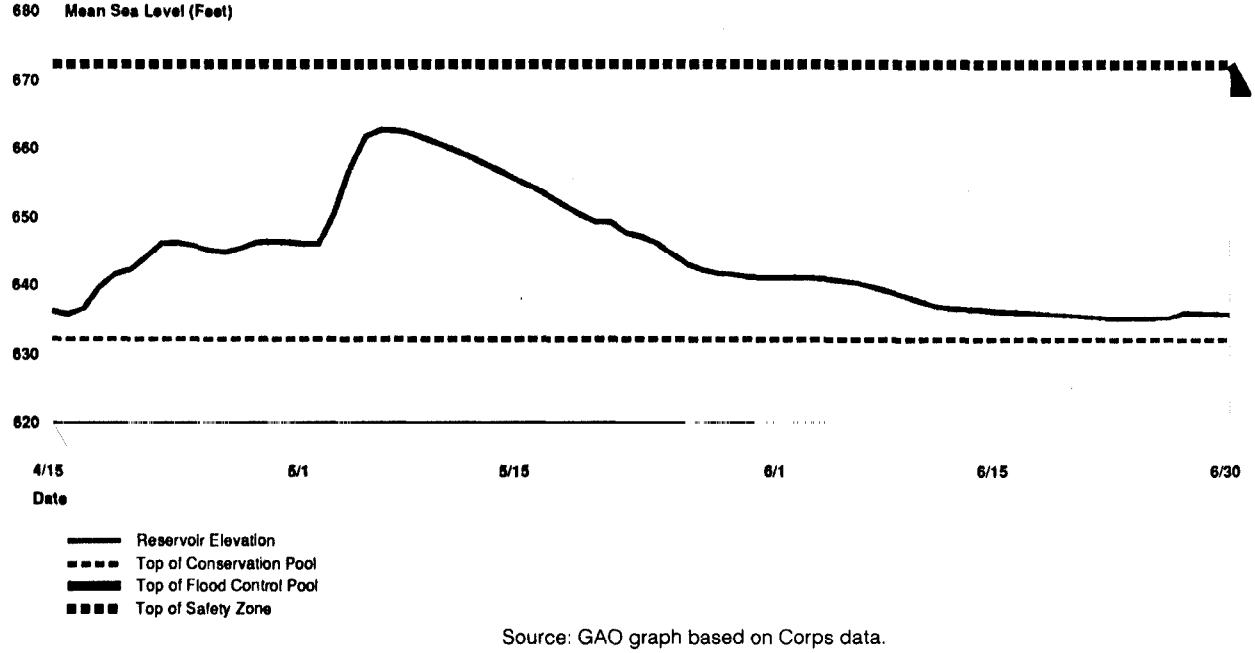
Figure 3.7 depicts water elevations in the Tenkiller Ferry reservoir from April 15 to June 30, 1990. The flood control pool extends from 632.0 msl to 667.0 msl. Figure 3.8 shows the volume of water that flowed into, and releases made from, Tenkiller Ferry for the same period.

On April 16, about 89 percent of the reservoir's flood control storage capacity was available to capture rainfall and runoff. From April 17 to 22, inflows ranged from 14,200 cfs to 27,000 cfs, while releases varied between 3,900 cfs and 9,000 cfs. During this period, the water in the reservoir rose almost 10 feet. The runoff from rain that fell from May 2 to 5 raised the level of the water in the reservoir 16 feet in 5 days so that about 84 percent of the flood control storage pool was utilized on May 6. Inflows ranged between 13,300 cfs and 61,000 cfs. Because of flooding at Van Buren, releases were suspended on May 3. However, the Tulsa District expressed concern on May 4 that the flood control pool would fill completely if releases were not made. Therefore, as required by Corps regulations, the district requested and received approval from the division to modify normal operating procedures, and it released water, despite the flooding at Van Buren. The request stated that the district planned to make releases until 25 percent of Tenkiller's flood control pool had been evacuated. Between May 4 and 8, releases ranged from 5,000 cfs and 13,200 cfs.

From May 9 to 19 and on May 25, the Tulsa District made releases from Tenkiller, raising the Illinois River about 1 foot above its regulating stage of 17 feet at a monitoring station on the Illinois River near Gore, Oklahoma. The river basin manual requires that Tenkiller's releases, combined with local runoff below the dam, not exceed a 17-foot river stage, which coincides with a flow of about 13,800 cfs at the Gore monitoring station. The releases made during the 12 days ranged from about 13,900 cfs to about 15,200 cfs. According to the lower Arkansas River regulating unit supervisor, Corps personnel surveyed the area between the dam and the Arkansas River and reported minimal flooding, which was confined primarily to rural areas, and no structural losses.

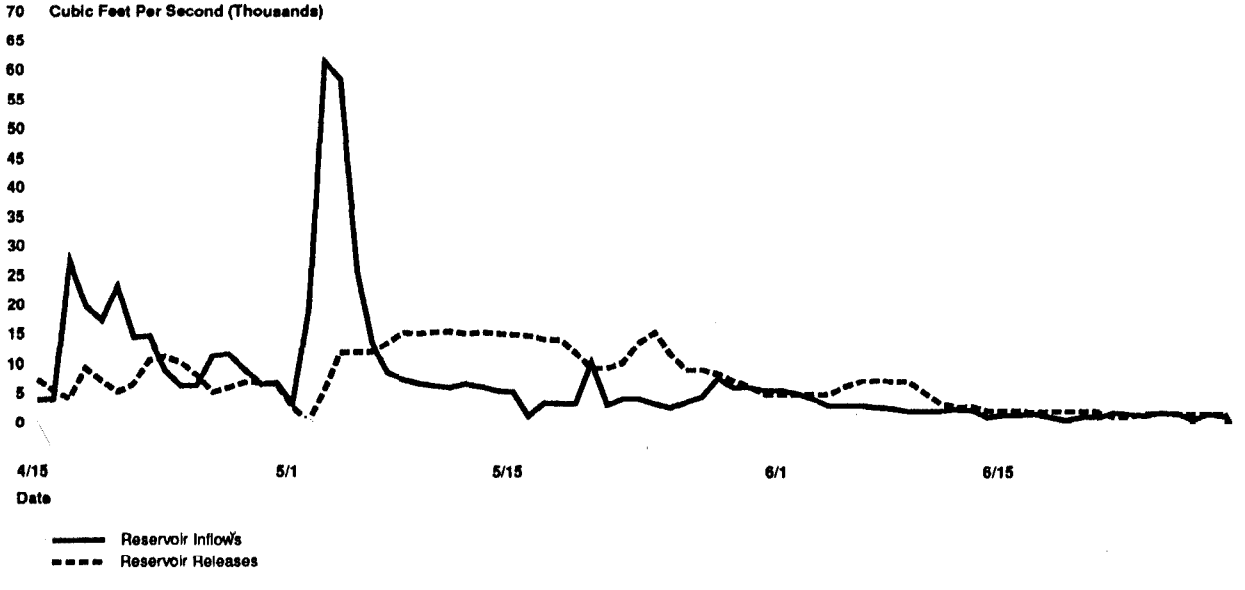
Division officials stated that even though the division did not authorize the district to exceed the 17-foot stage at Gore, the district did not violate the authorized modification because the area between the dam and the Arkansas River was closely monitored, the 17-foot stage was exceeded by less than a foot and resulted in minimal flooding, and no structural damage occurred. We believe that the Tulsa District did not operate Tenkiller Ferry in accordance with the applicable river basin manual because the 17-foot regulating stage was exceeded.

**Figure 3.7: Tenkiller Ferry Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 3.8: Tenkiller Ferry Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Blue Mountain Reservoir

Figure 3.9 depicts water elevations in the Blue Mountain reservoir from April 15 to June 30, 1990. The flood control pool extends from 384 msl to 419 msl. Figure 3.10 shows the volume of water that flowed into, and releases made from, Blue Mountain for the same period.

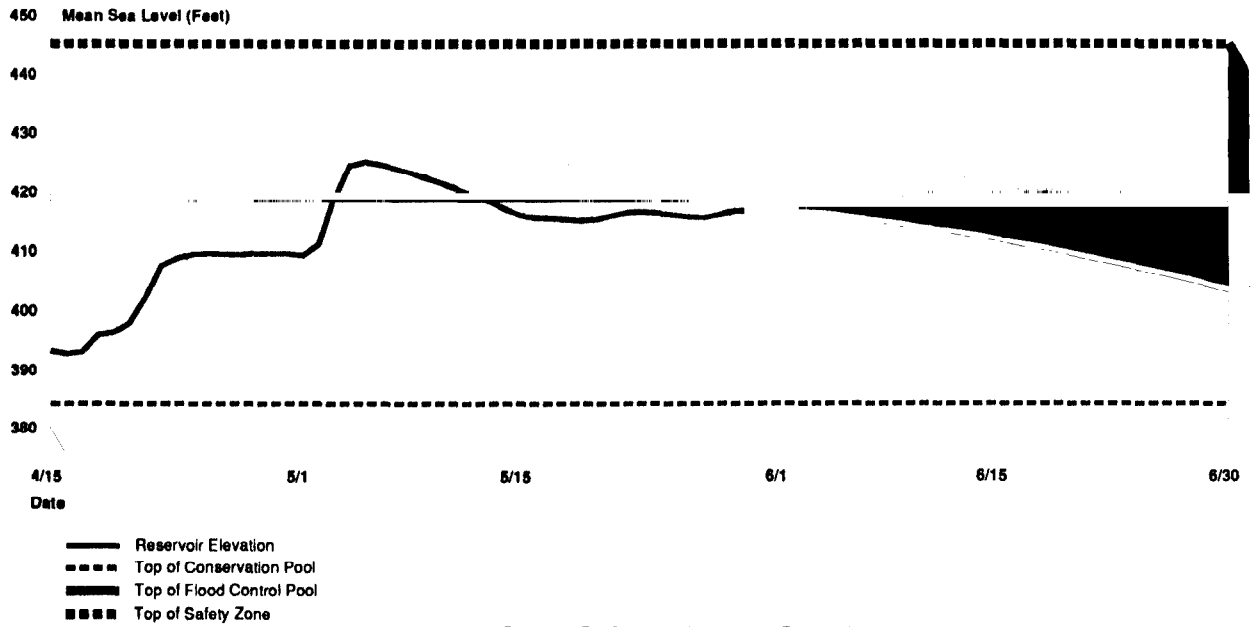
On April 16, about 90 percent of Blue Mountain's flood control storage capacity was available to capture rainfall and runoff. On 6 of the 7 days from April 17 to 23, the Corps released less than 1,000 cfs because flooding was occurring downstream of the dam. Rainfall and resulting runoff generated inflows ranging from about 3,000 cfs to 23,000 cfs. As a result of these events, the reservoir rose almost 16 feet and used 55 percent of the flood control storage pool on April 23.

On May 1, the Corps reduced releases from Blue Mountain to 1,726 cfs because flooding was occurring downstream. Rain that fell on May 1 to 3 generated inflows ranging from about 2,700 cfs to about 48,000 cfs, causing the water in the reservoir to rise above the flood control pool on May 3. On May 5, the water crested 6 feet into the safety zone. From May 4 to 12, the water remained in the safety zone. Releases made during these 9 days ranged from about 6,200 cfs to about 7,600 cfs.

From May 13 to 15, the Little Rock District, with the approval of the Southwestern Division, modified normal operating procedures by maintaining releases greater than 2,500 cfs in order to evacuate 15 percent of the Blue Mountain flood control pool as quickly as possible.

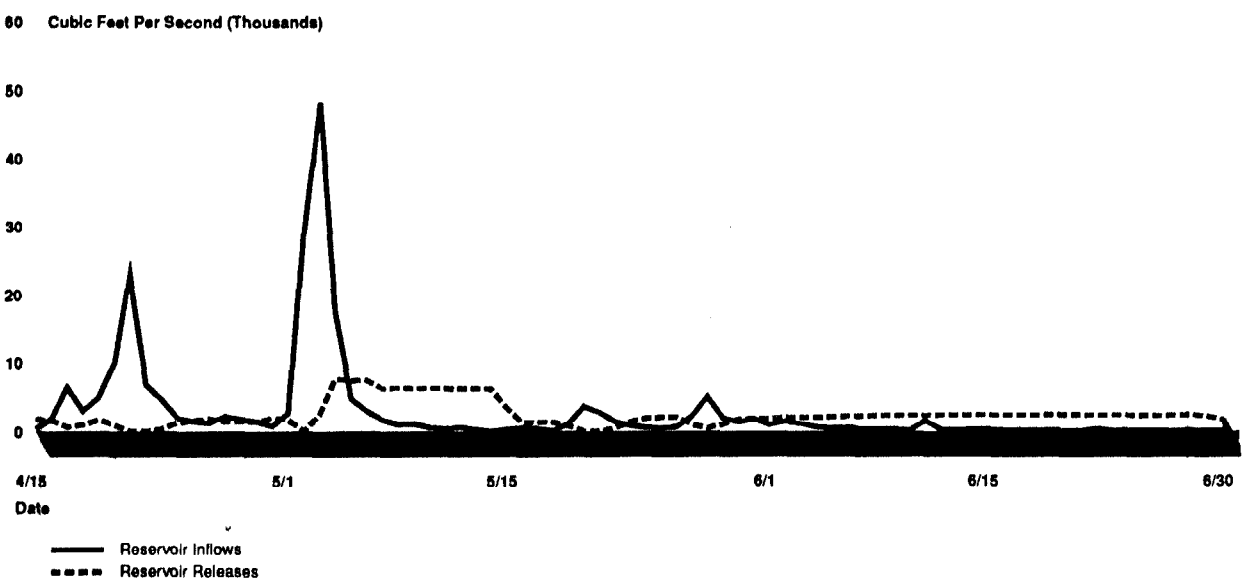
During the remainder of May, the Corps' efforts to evacuate the flood control pool were hampered by rain that fell on May 20, 21, and 28. Thereafter, the water in the reservoir receded to 403.49 msl, utilizing 37 percent of the flood control pool on June 30.

**Figure 3.9: Blue Mountain Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 3.10: Blue Mountain Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Nimrod Reservoir

Figure 3.11 depicts water elevations in the Nimrod reservoir from April 15 to June 30, 1990. The flood control pool extends from 342 msl to 373 msl. Figure 3.12 shows the volume of water that flowed into, and releases made from, Nimrod for the same period.

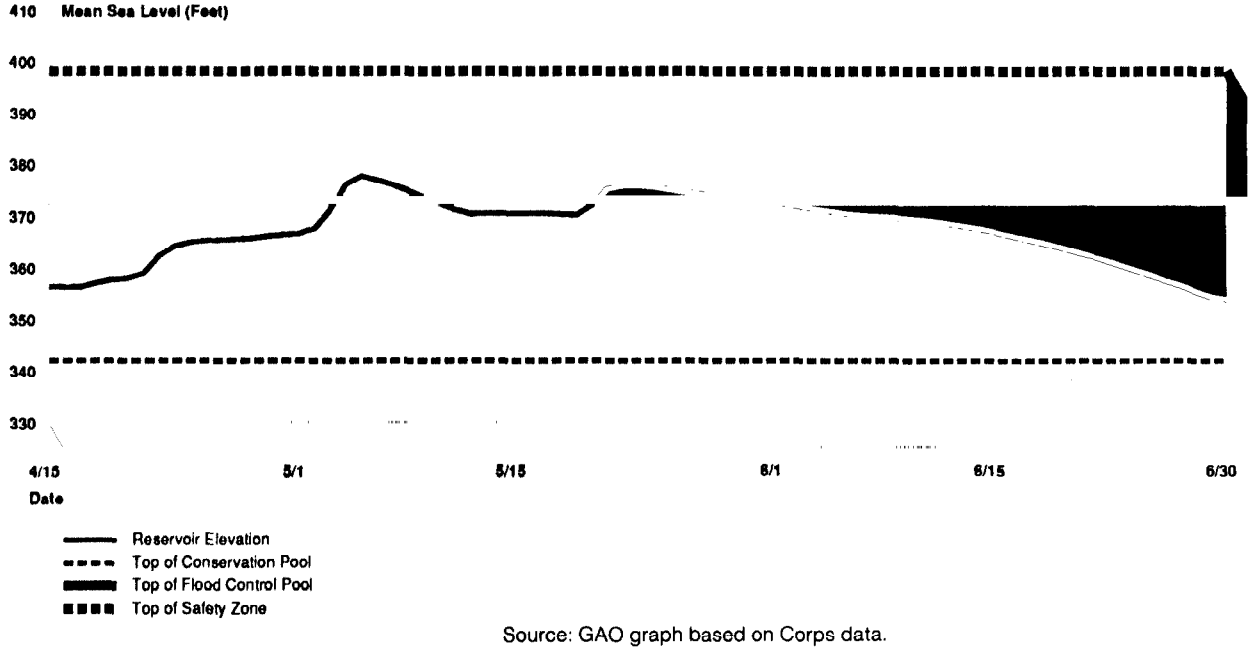
On April 15, about 74 percent of Nimrod's flood control storage capacity was available to capture rainfall and runoff. Rain that fell on April 16 and 17 generated inflows ranging from about 1,000 cfs to 3,000 cfs. Additional rainfall from April 21 to 23 generated inflows as large as 16,542 cfs (on April 22). Releases on 6 of the 8 days from April 16 to 23 were limited to 20 cfs because of flooding occurring downstream. As a result, the water in the reservoir rose almost 8 feet and utilized about 54 percent of the flood control pool on April 23. The water rose an additional 2 feet by April 30 and utilized about 64 percent of the flood control pool.

From May 2 to 4, rainfall and runoff generated inflows ranging from about 23,000 cfs to about 43,000 cfs. By May 4, the water had risen into the reservoir's safety zone and continued to rise until it crested almost 5 feet into the safety zone on May 5. From May 1 to 5, releases ranged from 20 cfs to 13,500 cfs.

From May 6 to 9, the Corps released about 12,000 cfs in order to lower the water into the flood control pool. When the water receded into the flood control pool on May 10, the Little Rock District continued to release more water than its operating procedures allowed because the Southwestern Division had approved a modification to permit evacuation of 15 percent of Nimrod's flood control pool. By May 12, the district had evacuated 15 percent of the flood control pool and reduced releases to about 460 cfs.

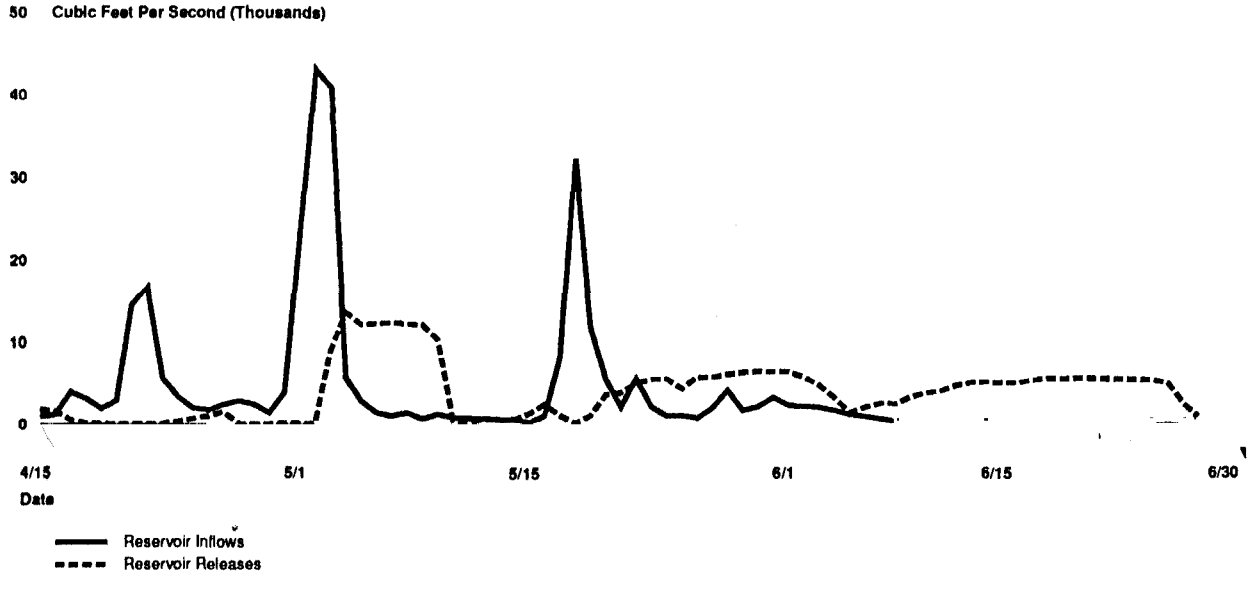
The water level in the reservoir remained fairly constant from May 12 to 19. Rainfall from May 19 to 21 raised the water about 3 feet into the safety zone by May 23. The inflows ranged from 2,158 cfs to 32,257 cfs, while releases ranged from 142 cfs to 3,850 cfs. The water receded into the flood control pool on May 31. By June 30, about 19 percent of its flood control pool was being utilized.

**Figure 3.11: Nimrod Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 3.12: Nimrod Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

# Red River Basin

Figure 4.1 depicts the portion of the Red River basin that lies within the states of Oklahoma, Texas, and Arkansas and the location of flood control reservoirs in the basin. The Corps operates four major reservoirs as a system to regulate water in the Red River basin: Texoma, Hugo, Pat Mayse, and Millwood. The other reservoirs in the basin empty into these reservoirs.

The Corps uses four stream gauges on the Red River as monitoring stations. The gauges are located near Arthur City, Texas; De Kalb, Texas; Index, Arkansas; and Fulton, Arkansas. The shaded area represents the uncontrolled area of the Red River basin above the Fulton gauge—about 6,640 square miles. The Corps cannot regulate runoff within this uncontrolled area because the water does not drain into any flood control reservoir. The Red River Basin Manual requires that, insofar as possible, water released from the four reservoirs, combined with local inflow below the dams, should not exceed the river stages of 20.0 feet at Arthur City, 23.7 feet at De Kalb, 19.8 feet at Index, and 25.0 feet at Fulton.

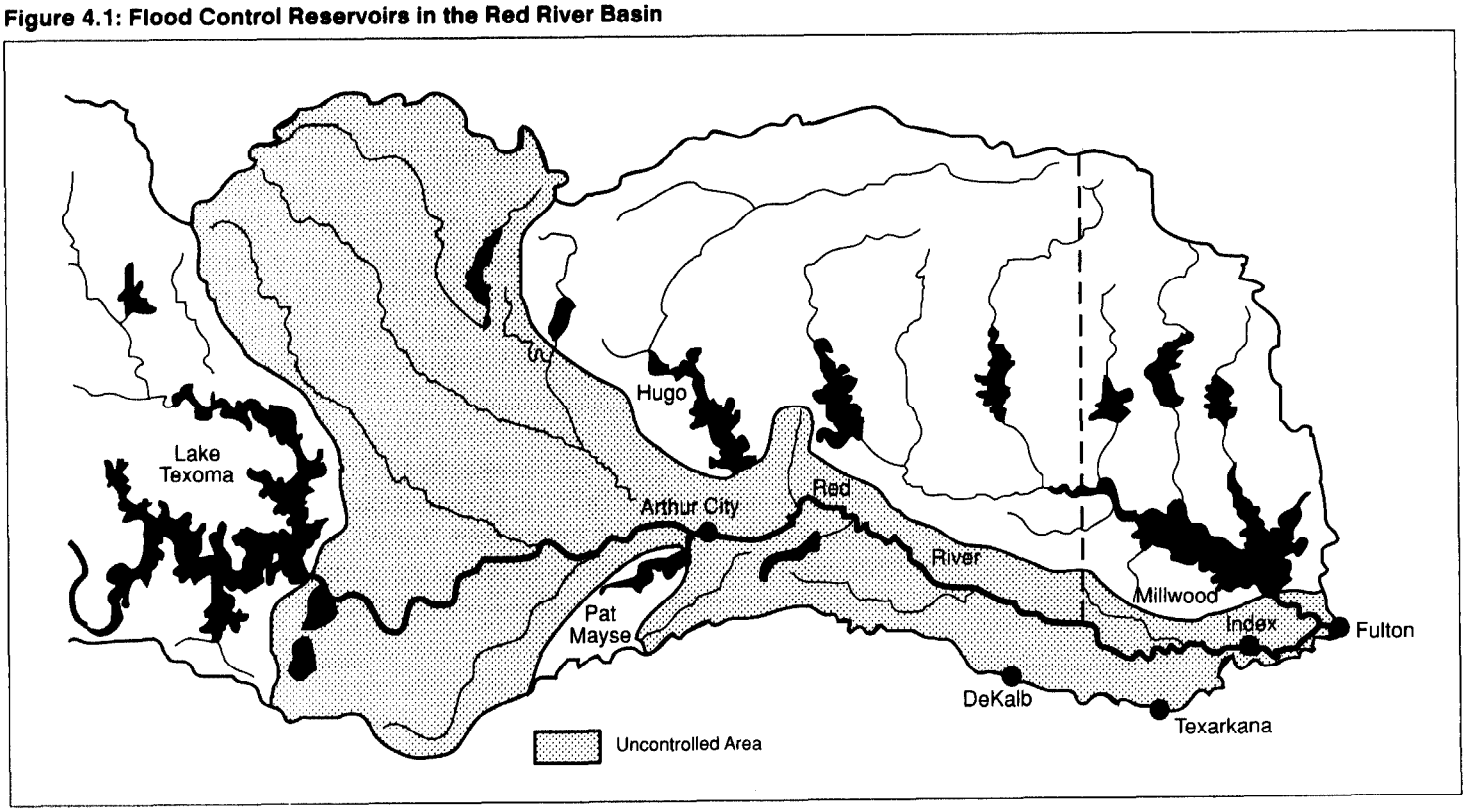
We reviewed the Corps' operations of two of the flood control reservoirs shown on figure 4.1 - Texoma on the Red River and Hugo on the Kiamichi River. We found that except for the period from May 22 through June 13, the Corps generally operated the two flood control reservoirs in accordance with its river basin manuals, which provide guidance and regulations for operating the reservoirs. During these 23 days, the Tulsa District regulated water releases to maintain a river stage between 23.7 feet and 25 feet at the De Kalb monitoring station without obtaining approval from the Southwestern Division. Tulsa District officials told us that division approval was not needed because their manual permits them to carry out reconnaissance to determine the effects of regulating to a higher river stage.

Tulsa District personnel conducted aerial and field reconnaissance of the Red River between De Kalb and Texarkana, Texas, from June 11 to 13. District officials told us that they could not perform the reconnaissance before this time because intermittent rain was falling in the area. On June 14, the district resumed regulating to a 23.7 foot river stage at De Kalb.

District officials acknowledged that although their actions did not cause any structural damage, they did prolong the period during which some land remained flooded, and they did delay the start of cultivation of

farm land, predominantly in Oklahoma and Texas. Southwestern Division officials agreed with us that any deviation needed by the district to perform such reconnaissance required prior division approval. On the basis of our discussions of this matter, the division has sent a letter to each of its districts clarifying the authority of the district when performing reconnaissance and will revise its operating procedures accordingly.

**Figure 4.1: Flood Control Reservoirs in the Red River Basin**




Source: U.S. Army Corps of Engineers.

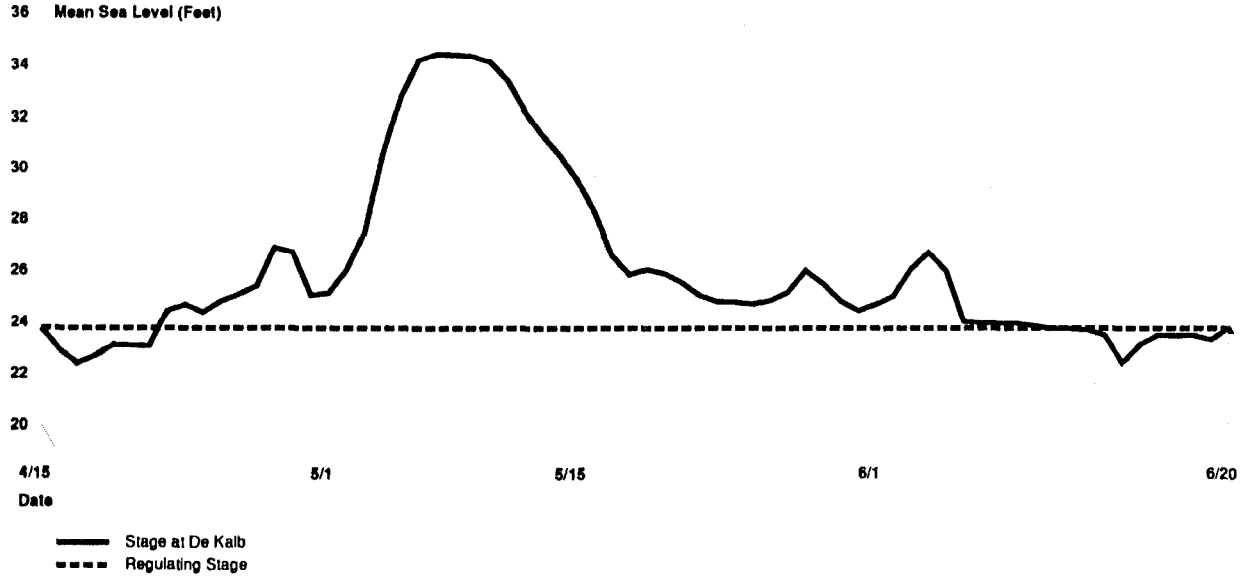
## Impact of Texoma and Hugo Reservoir Releases on Red River Stage and Flow at De Kalb

Figure 4.2 shows the regulating stage of 23.7 feet and the actual river stage at the De Kalb monitoring station for the period from April 15 to June 20, 1990. Figure 4.3 depicts the actual river flow at De Kalb, the combined releases from Texoma and Hugo reservoirs, and the regulating flow of 70,000 cfs for the same period. The difference between the reservoirs' releases and the river flow represents the runoff from the uncontrolled area above the De Kalb monitoring station. Releases from Texoma take about 3 to 4 days to reach the De Kalb monitoring station, while releases from Hugo take about 2 days.

Figure 4.2 shows that the regulating stage of 23.7 feet was exceeded from April 22 to June 10, 1990. Rainfall and the resulting runoff in the uncontrolled area accounted for a significant portion of the river flow at De Kalb from April 22 to May 7. On May 7, the river stage peaked at 34.28 feet with a flow of 248,771 cfs. Figure 4.3 shows that on that day, the combined releases from Texoma and Hugo of 95,810 cfs accounted for 39 percent of the flow. The remaining 61 percent came from the uncontrolled area. Combined releases significantly increased from May 4 to 10 because both Texoma and Hugo had water in their safety zone and large releases were therefore mandated, even though flooding was occurring.

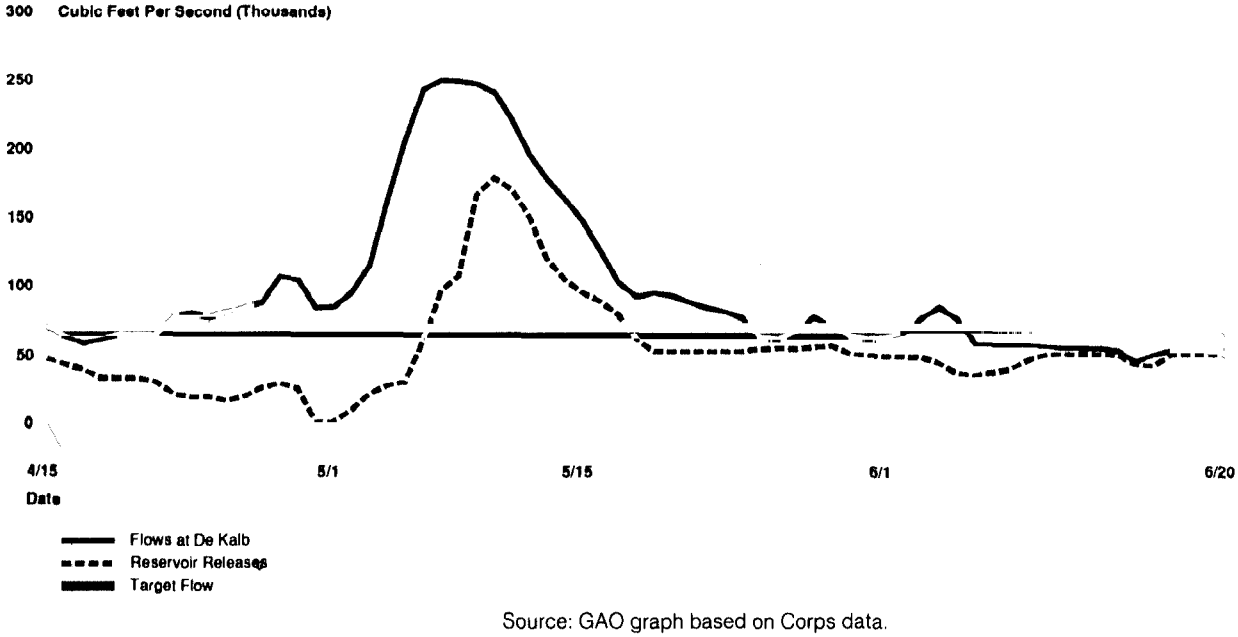
From May 8 to June 10, 1990, releases from Texoma and Hugo significantly contributed to maintaining a river stage greater than 23.7 feet. The combined releases were more than 70,000 cfs until May 18, primarily because Texoma had water in its safety zone until May 14. From May 19 to 21, the Corps maintained releases at about 52,000 cfs to prevent river bank erosion.

**Figure 4.2: Comparison of Actual and Target River Stage at De Kalb** (April 15 to June 20, 1990)




Source: GAO graph based on Corps data.

**Figure 4.3: Texoma and Hugo Reservoir Releases and Flows at De Kalb** (April 15 to June 20, 1990)




Source: GAO graph based on Corps data.

As previously mentioned, from May 22 to June 13, the Tulsa District regulated releases from Texoma and Hugo to maintain a river stage between 23.7 feet and 25 feet. Releases made between May 22 and June 13 affected De Kalb between May 24 and June 15. Figure 4.2 shows that from May 25 to June 10 the regulating stage of 23.7 feet was exceeded, even though the 70,000 cfs target flow was exceeded on only 5 days, as shown on figure 4.3. According to Corps officials, characteristics of the Red River, such as the channel depth and bank heights, were changed by the May flood so that a smaller volume of water generated a higher river stage.

During the 23 days from May 22 to June 13, the river stage exceeded 25 feet on 6 days (because rain fell on May 26 and 27 and between May 29 and June 3), ranged between 23.7 and 25 feet on 12 days, and was below the 23.7 foot regulating stage for 5 days. According to the lower Red River regulating unit supervisor, the 23.7-foot stage was not exceeded from June 11 to 15 because the runoff from the uncontrolled area was not large enough when combined with releases to produce a river stage greater than 23.7 feet.

## Corps Operation of Texoma Reservoir

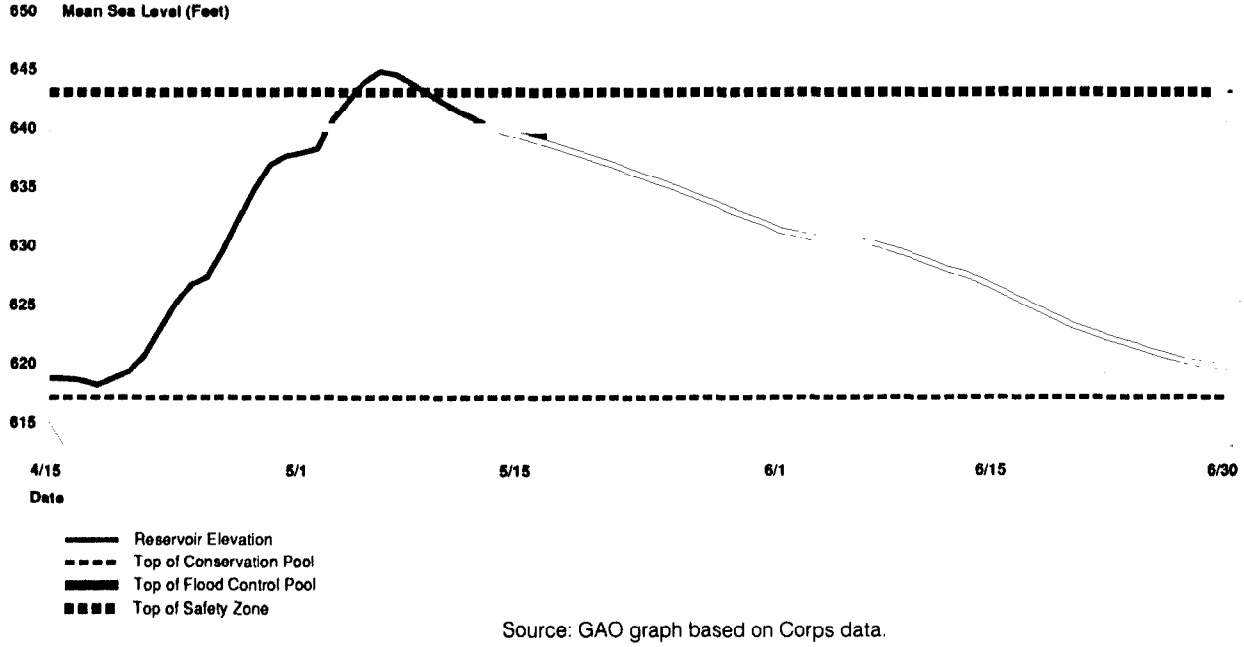
Figure 4.4 depicts the water elevation in the Texoma reservoir from April 15 to June 30, 1990. The flood control pool extends from 617 msl to 640 msl. Figure 4.5 shows the volume of water that flowed into, and releases made from, Texoma for the same period.

On April 15, about 94 percent of Texoma's flood control storage capacity was available to capture rainfall and runoff. Rain that fell between April 15 and 30 generated inflows of 100,000 cfs or more on 7 of the 16 days, while average daily releases ranged from about 28,200 cfs to 20 cfs. Within 2 weeks, the water in the reservoir had risen about 19 feet, 2.42 feet below the top of the flood control pool.

Torrential rains in early May generated inflows of over 150,000 cfs from May 2 to 6, causing the water in the reservoir to crest at 1.73 feet above the top of the safety zone on May 6. The water remained above the top of the safety zone until May 8 and then gradually receded into the flood control pool on May 14. At midday on May 2, the Corps realized that future releases could be minimized by increasing releases to 60,000 cfs, even though downstream flooding was occurring. From May 3 to 13, the Corps made releases ranging from about 61,000 cfs on May 3 to about 144,000 cfs on May 6 because the water in the reservoir was in or above the safety zone. These releases were consistent with Texoma's operating procedures, which permit releases larger than 60,000 cfs while the water is in or above the safety zone. On May 14, the Corps reduced the releases to less than 60,000 cfs. From May 15 to 21, releases remained constant at about 45,000 cfs.

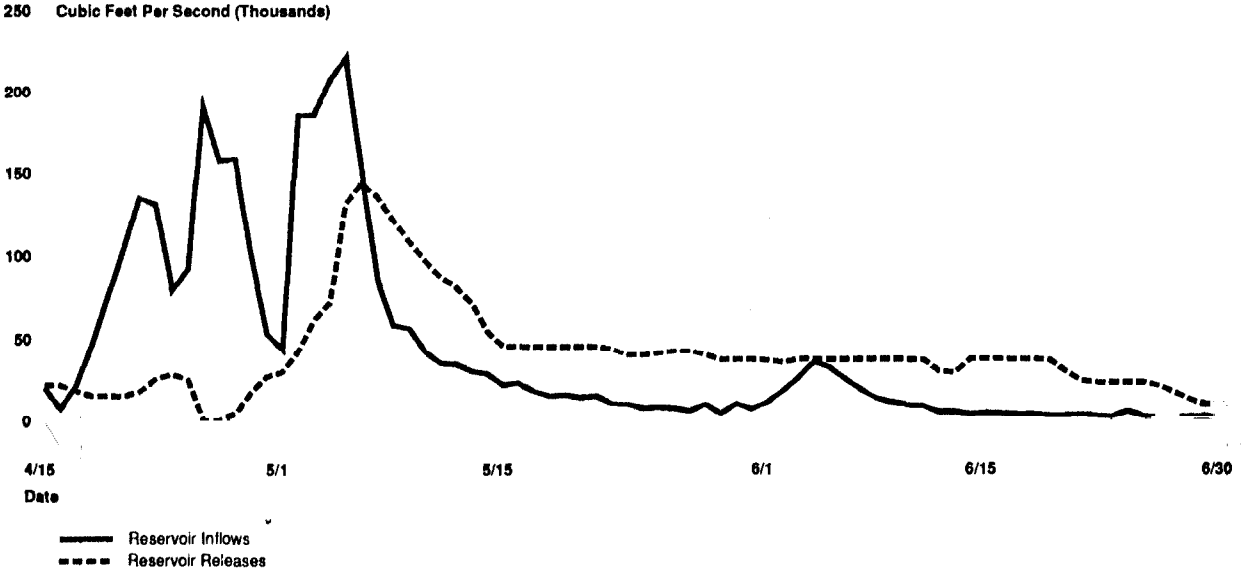
As previously mentioned, the Tulsa District did not follow its operating procedures in regulating releases from Texoma from May 22 to June 13. During the remainder of June, the Corps did regulate Texoma's releases in accordance with its operating procedures, and the regulating stages were not exceeded. By June 30, 9 percent of the flood control pool was being utilized.

**Figure 4.4: Texoma Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 4.5: Texoma Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Hugo Reservoir

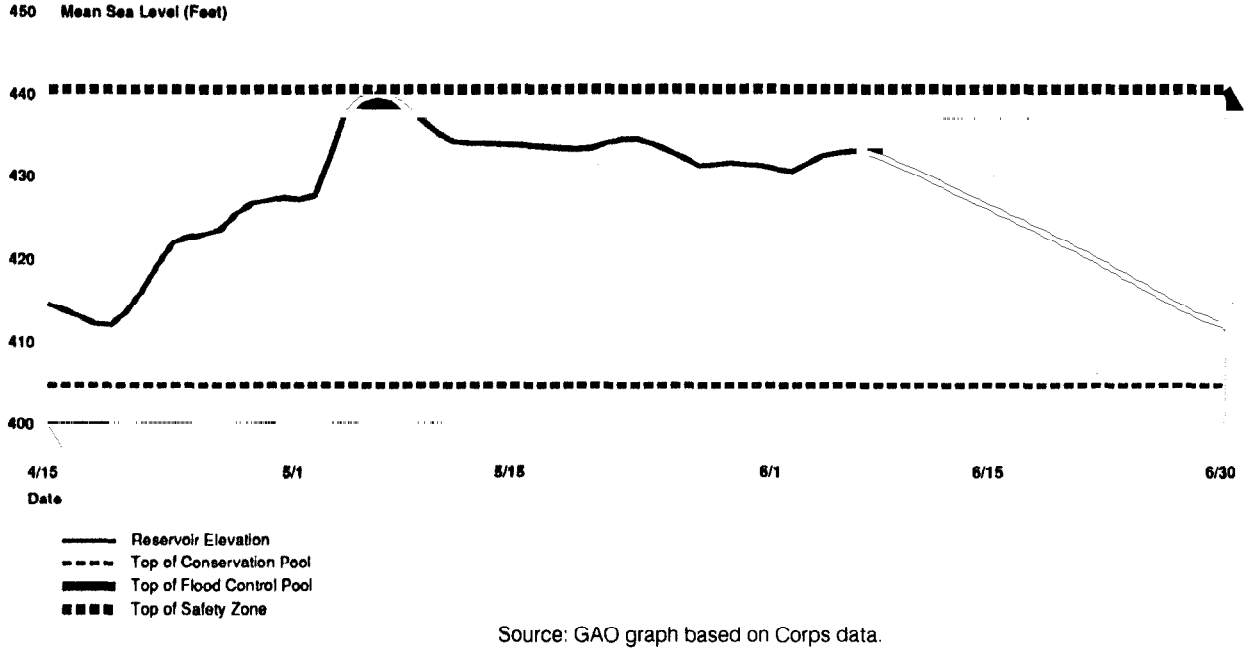
Figure 4.6 depicts water elevations in the Hugo reservoir between April 15 and June 30, 1990. The flood control pool extends from 404.5 msl to 437.5 msl. Figure 4.7 shows the volume of water that flowed into, and releases made from, Hugo for the same period.

On April 19, about 91 percent of Hugo's flood control storage capacity was available to capture rainfall and runoff. Rain that fell from April 17 to 22 generated inflows ranging from a high of 41,850 cfs on April 21 to a low of 15,900 cfs on April 22, while releases were decreased from 10,833 cfs on April 17 to 4,064 cfs on April 22. On April 25 and 26, more rain fell, generating inflows of over 21,000 cfs. Releases were about 80 cfs on these 2 days. By April 30, about 58 percent of the flood control pool was filled. Within 11 days, the water in the reservoir had risen about 15 feet. Early May rains caused the water in the reservoir to rise almost 13 feet and crest about half a foot below the top of safety zone on May 6. From May 1 to 6, the average daily inflows ranged from about 12,300 cfs to about 92,000 cfs. On May 2, the Corps again reduced Hugo's releases to less than 200 cfs and maintained low releases until May 4 when the water rose into the reservoir's safety zone. On May 5, releases were increased to 34,700 cfs. Releases of over 34,000 cfs were made through May 8. The releases made between May 5 and 8 were in accordance with Hugo's operating procedures, which permit releases larger than 20,000 cfs when the water is above the flood control pool.

When the water receded into the flood control pool on May 9, the Tulsa District implemented a modification to the normal operating procedures that the Southwestern Division had approved on May 5. The modification permitted large releases to continue until 15 percent of the flood control pool had been evacuated. Releases of over 33,200 cfs were made until May 10 when the division rescinded the modification; nevertheless, on May 11, 15 percent of the flood control pool was evacuated. From May 12 to 21, the Corps maintained releases of 7,250 cfs so that the water in the Hugo reservoir and the river stage at De Kalb would continue to recede.

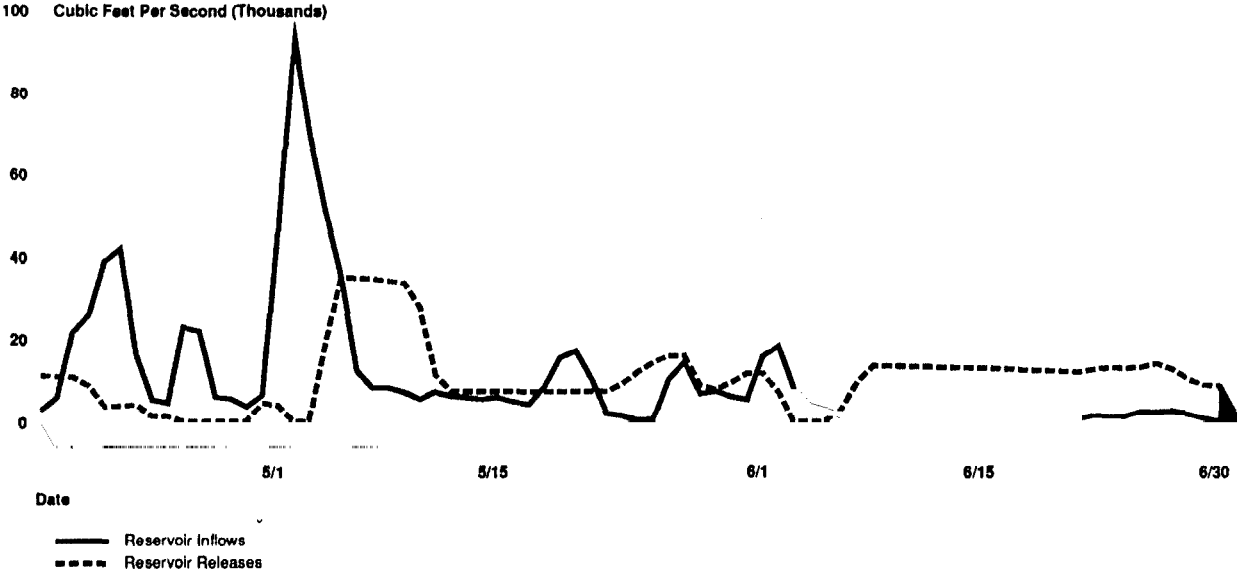
As previously mentioned, the district departed from its operating procedures in regulating Hugo releases from May 22 to June 13. Without having obtained approval from the division, the district regulated to a river stage higher than 23.7 feet at De Kalb. During the remainder of June, the Corps regulated Hugo's releases in accordance with its operating procedures, and the regulating stages were not exceeded. By June 30, about 7 feet of the reservoir's flood control pool was filled.

**Figure 4.6: Hugo Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 4.7: Hugo Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

# White River Basin

Figure 5.1 represents the White River basin located in Arkansas and Missouri. The basin contains about 28,000 square miles of drainage area, of which 10,000 square miles drain into Corps reservoirs. The shaded area represents the uncontrolled area of the river basin.

The Corps has six flood control reservoirs in the White River basin whose releases are regulated by three monitoring stations. We reviewed the operations of the Norfork and Bull Shoals reservoirs, whose releases are regulated by the stream gauge at Newport, Arkansas. Corps procedures require that releases from Bull Shoals and Norfork be managed so that both flood control pools remain in balance during evacuation periods and, insofar as possible, releases combined with inflow below the dams do not exceed a seasonal regulating river stage at Newport. The Corps has set seasonal regulating stages to accommodate the needs of the agricultural industry. The seasonal regulating stages and the corresponding flows at Newport are shown in table 5.1.

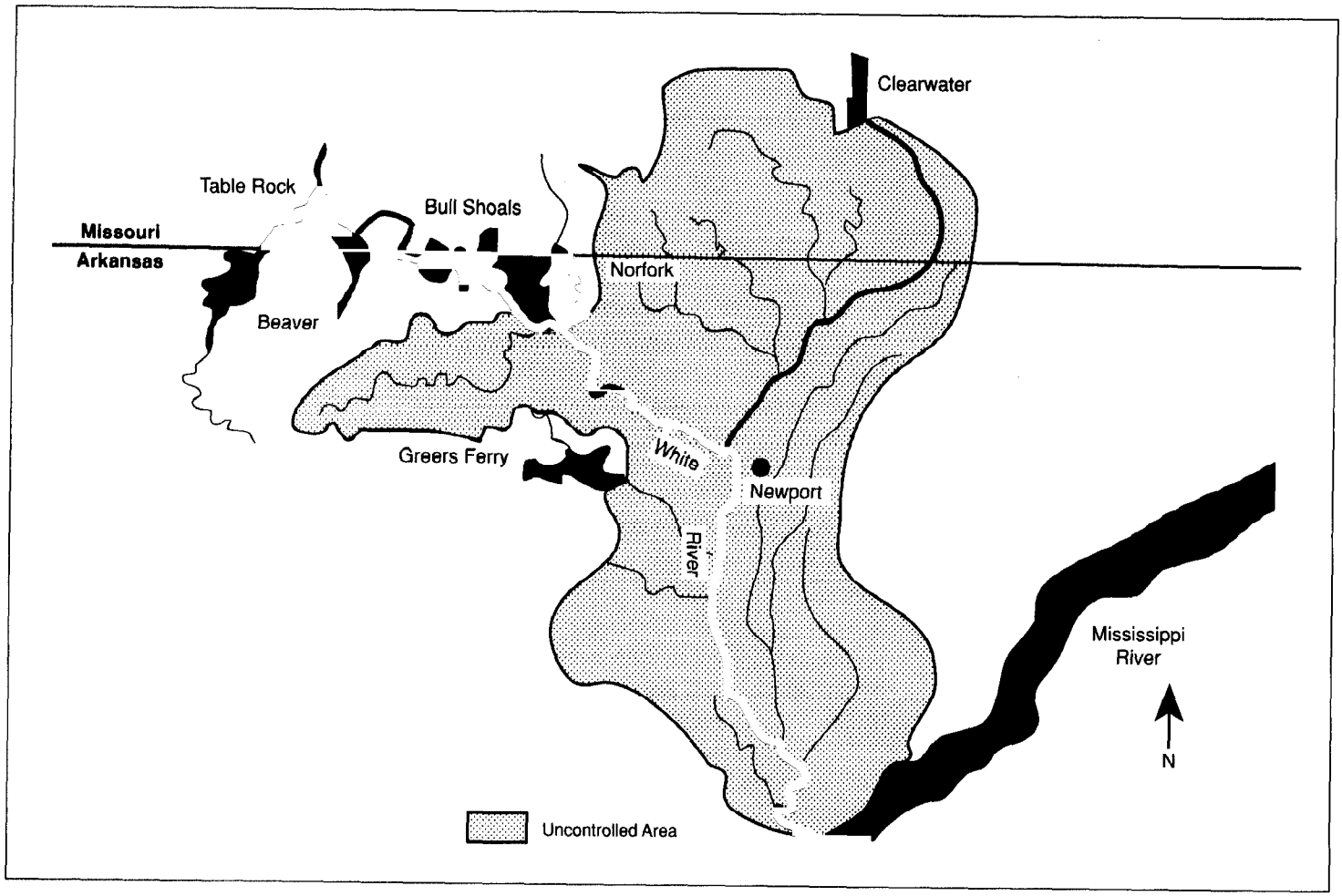
**Table 5.1: Seasonal Regulating Stages at Newport**

| Time of year | Regulating stage | Corresponding flow |
|---|---|---|
| Dec. 1 - April 30 | 21 feet | 50,000 cfs |
| May 1 - May 31 | 18 feet | 40,000 cfs |
| June 1 - Nov. 30 | 14 feet | 30,000 cfs |

Source: U.S. Army Corps of Engineers.

We found no evidence to indicate that the Corps had released water from Bull Shoals and Norfolk reservoirs contrary to its operating procedures.

**Figure 5.1: Flood Control Reservoirs in the White River Basin**




Source: U.S. Army Corps of Engineers.

## Impact of Bull Shoals and Norfork Reservoir Releases on White River Stages and Flows at Newport

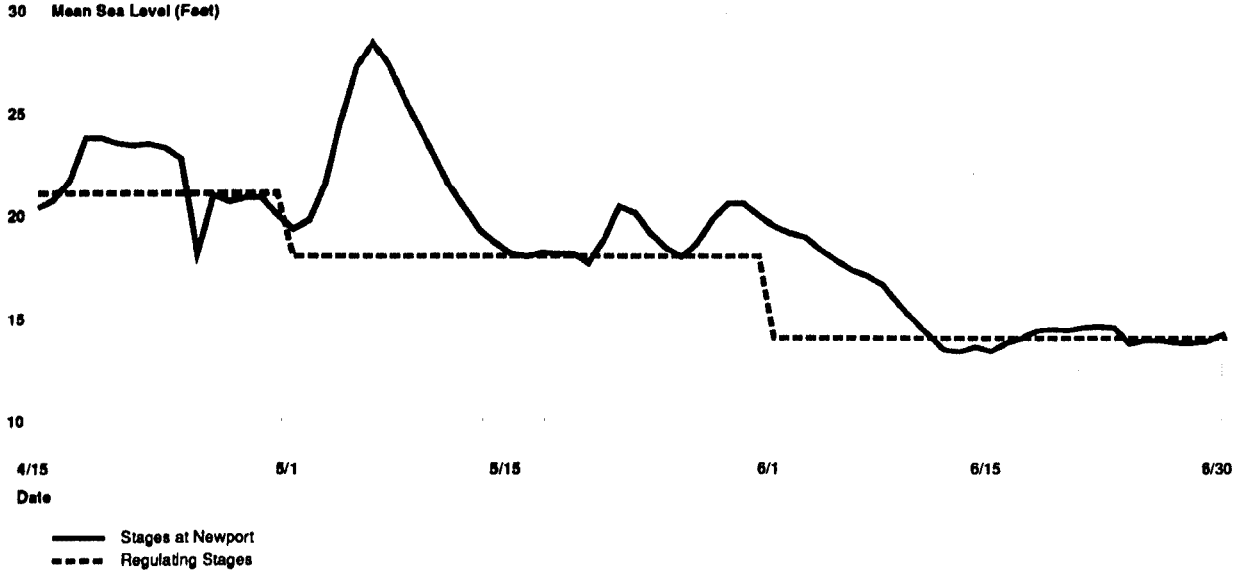
Figure 5.2 shows the White River stage and the seasonal regulating stages at the Newport monitoring station from April 15 to June 30. Figure 5.3 depicts the actual river flow at Newport, the combined volume of water released from the Bull Shoals and Norfork reservoirs that flowed past the Newport monitoring station, and the seasonal regulating flows for the same period. The area on figure 5.3 between the releases from the two Corps reservoirs and the river flow represents runoff from the uncontrolled area. Releases from Norfork and Bull Shoals take about 2 days to arrive at Newport.

Because the White River stage exceeded the regulating stage at Newport from April 17 through 24, the Corps attempted to lower the stage by reducing water releases from Bull Shoals and Norfork from a high of 27,400 cfs on April 18 to 5,050 cfs on April 24. Combined releases from these reservoirs contributed only 9 percent of the Newport flow on April 24, and the remaining 91 percent came from the uncontrolled area.

Between May 2 and 4, 4 to 6 inches of rain fell in the upper two-thirds of the White River basin. The peak stage of about 28 feet and a corresponding flow of 104,625 cfs at Newport occurred on May 6. The Corps again reduced its reservoir releases from a high of 15,620 cfs on May 1 to 1,780 cfs on May 6. The 1,780 cfs flow accounted for only 2 percent of the Newport flow on May 6, and the remaining 98 percent came from the uncontrolled area.

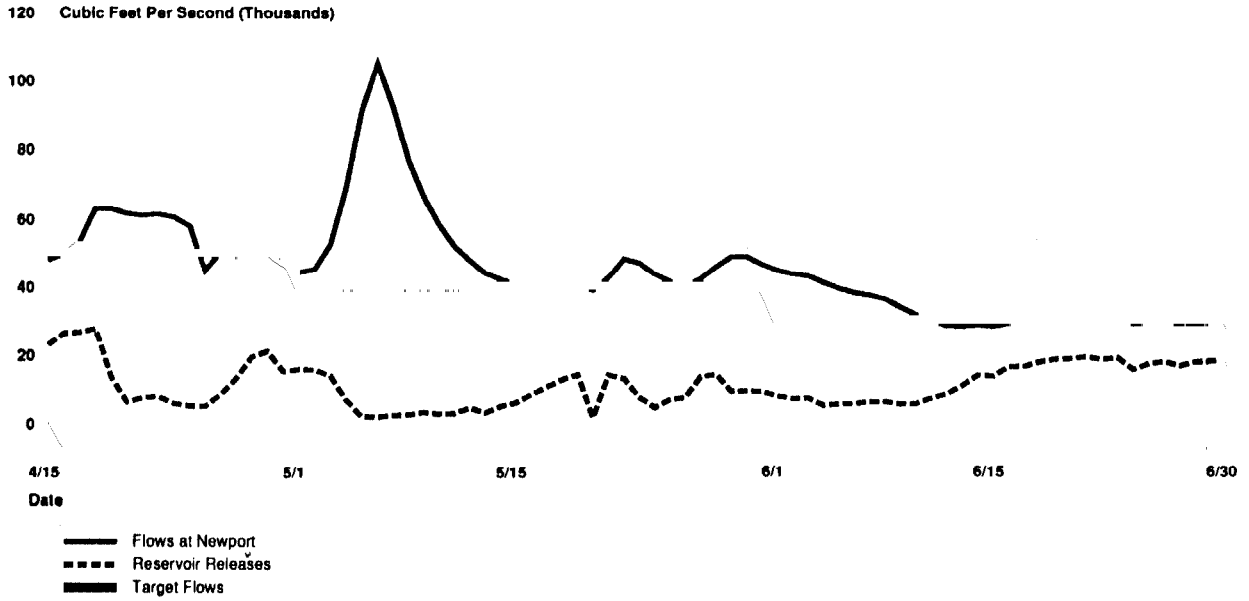
Corps procedures allow for combined releases of not more than 5,050 cfs to be made until 6 days after flood waters peak at Newport—in this case, May 12. The Corps followed its procedures by not increasing releases above this level until May 13, at which time it released 5,940 cfs. Intermittent rainfall between May 17 and 31 resulted in the Corps' exceeding its regulating stage of 18 feet. Similarly, as the Corps was making the transition to the 14-foot stage between June 1 and 11, its efforts were hampered by intermittent rain, which fell after releases had been made. The regulating stage of 14 feet was exceeded from June 17 to 23 and again on June 30 because the runoff from the uncontrolled area was greater than anticipated.

**Figure 5.2: Comparison of Actual and Target River Stages at Newport** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 5.3: Bull Shoals and Norfork Reservoir Releases and Flows at Newport** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Bull Shoals Reservoir

Figure 5.4 depicts water elevations in the Bull Shoals reservoir from April 15 to June 30, 1990. The flood control pool extends from 654.0 msl to 695.0 msl. Figure 5.5 shows the volume of water that flowed into, and releases made from, Bull Shoals for the same period.

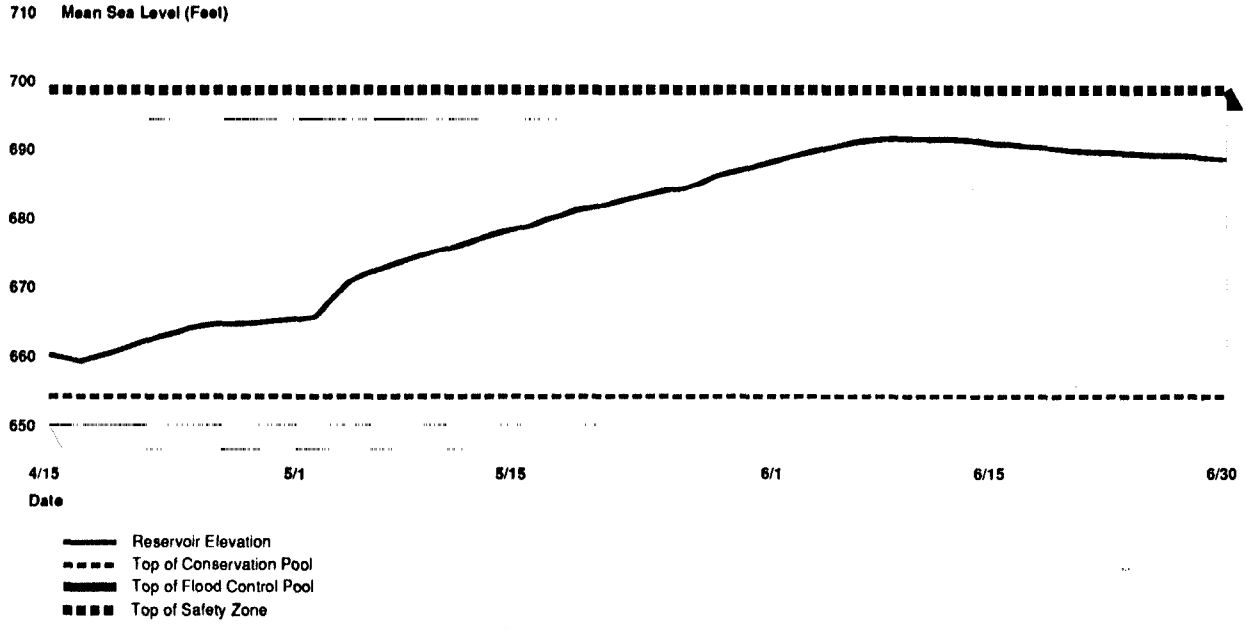
On April 15, about 12 percent of Bull Shoals' flood control storage capacity was being used. From April 15 to 30, inflows ranged between 9,700 cfs and 22,300 cfs, while releases ranged between 3,400 cfs and 24,850 cfs. During this period, the water in the reservoir rose almost 5 feet, utilizing about 23 percent of the flood control storage capacity by April 30.

During the first 3 days of May, the Corps reduced Bull Shoals' releases to about 1,200 cfs. Inflows during this period ranged from about 18,000 cfs to 103,000 cfs. From May 3 through 12, the Corps maintained releases of less than 3,700 cfs so that when combined with Norfork's releases, the total releases would not exceed the Corps' upper limit of 5,050 cfs until 6 days after flood waters had peaked at Newport. Inflows greater than 23,000 cfs occurred on 7 of the 10 days from May 3 to 12. During the first 12 days of May, the water in the reservoir rose about 11 feet, utilizing about 47 percent of the reservoir's flood control storage capacity.

The Corps increased Bull Shoals' releases until May 18 when releases were reduced to 800 cfs to facilitate the location of a drowning victim. Between May 19 and 26, releases were adjusted in response to varying river stages at Newport. From May 27 to June 9, the releases were reduced from about 7,000 cfs to about 5,600 cfs to make the transition to a regulating flow of 30,000 cfs at Newport. (See fig. 5.3.) However, efforts to reach the regulating flow were hampered by runoff from the uncontrolled area.

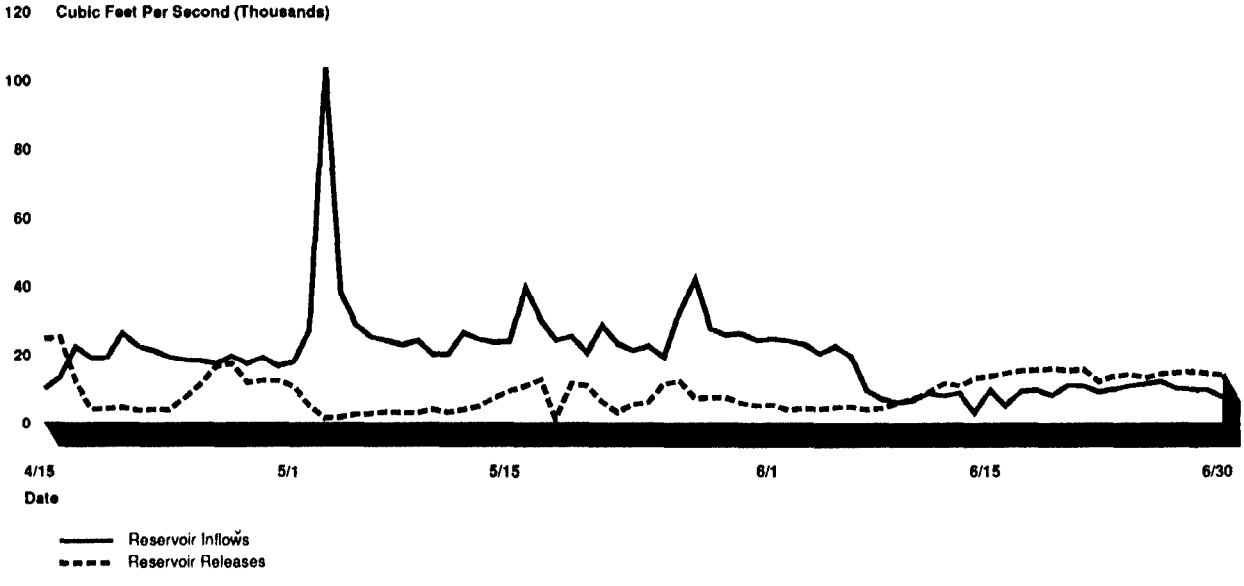
The water in the reservoir peaked on June 9 at elevation 691.44 msl, utilizing 89 percent of flood control pool. By June 30, the water had gradually receded about 3 feet until it was utilizing about 80 percent of its flood control pool.

**Figure 5.4: Bull Shoals Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 5.5: Bull Shoals Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

## Corps Operation of Norfork Reservoir

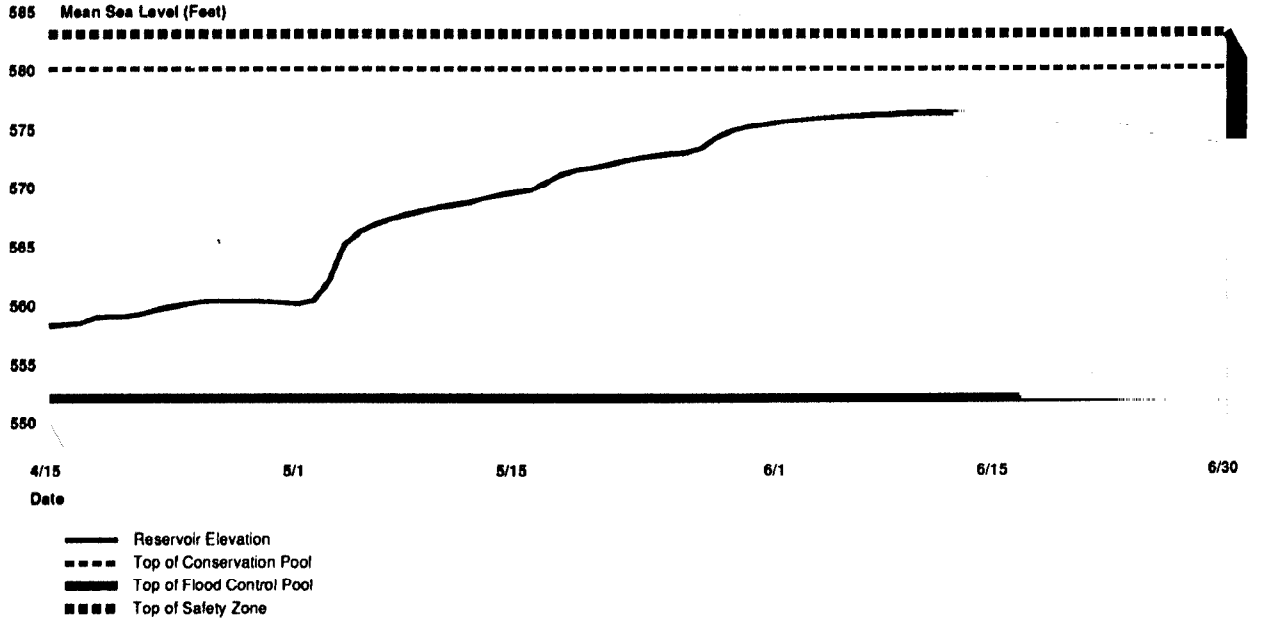
Figure 5.6 depicts water elevations in the Norfork reservoir from April 15 to June 30, 1990. The flood control pool extends from 552 msl to 580 msl. Figure 5.7 shows the volume of water that flowed into, and releases made from, Norfork for the same period.

Between April 15 and 30, the water in Norfolk rose about 2 feet, utilizing about 26 percent of the reservoir's flood control storage capacity. Inflows ranged from about 7,000 cfs to about 2,600 cfs, while releases varied from 3,680 cfs to 1,320 cfs.

The early May rains caused the water in the reservoir to rise to elevation 566.78 msl by May 6 and to utilize 47 percent of the flood control storage pool. Rainfall and resulting runoff produced a peak average daily inflow of 46,302 cfs on May 3. From May 3 to 12, releases ranging from 60 cfs to 1,300 cfs were made so that when combined with Bull Shoals' releases, the total releases would not exceed the Corps' upper limit of 5,050 cfs until 6 days after flood waters had peaked at Newport. The Corps generally increased Norfork's releases until May 18 when the releases were lowered to 770 cfs to facilitate the location of a drowning victim. Releases of less than 3,000 cfs were made between May 19 and June 13, while inflows generally ranged between 7,700 cfs and 3,600 cfs.

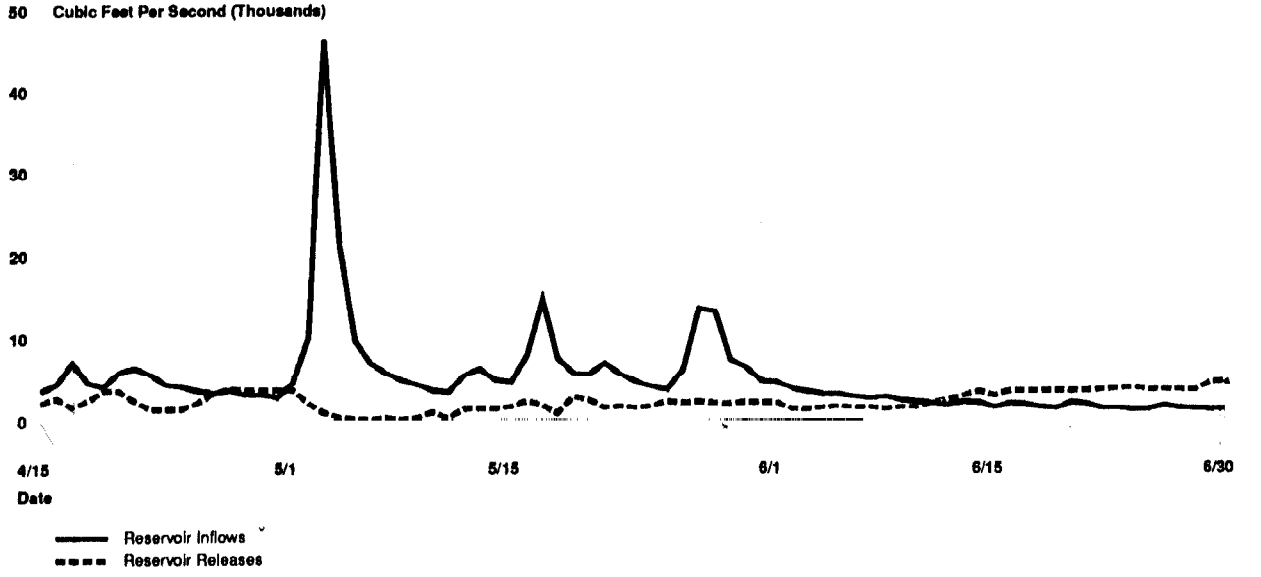
The water in the reservoir crested on June 11 at elevation 576.35, utilizing 83 percent of the flood control pool. By June 30, it had receded to elevation 573.67 msl and was utilizing 72 percent of the flood control pool.

**Figure 5.6: Norfork Reservoir Flood Control Pool Utilized** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

**Figure 5.7: Norfork Reservoir Inflows and Releases** (April 15 to June 30, 1990)




Source: GAO graph based on Corps data.

# Scope and Methodology

To assess whether the Corps had followed its flood control operating procedures, we obtained reservoir and river data maintained by the Corps' Southwestern Division in Dallas for nine reservoirs and 12 monitoring stations. The nine reservoirs reviewed were Eufaula, Wister, Tenkiller Ferry, Blue Mountain, and Nimrod in the Arkansas River basin; Texoma and Hugo in the Red River basin; and Bull Shoals and Norfork in the White River basin. We compared the actual reservoir releases and actual river flows and stages that occurred from April 15 to June 30, 1990, with recommended releases and river flows and stages in the Southwestern Division's river basin master manuals. We did not verify the accuracy of the division's data, nor did we evaluate the adequacy of the Corps' operating procedures for controlling flood events.

We selected the nine flood control reservoirs for review on the basis of the portion of the flood control pool utilized and the volume of water released during the flood. We selected the period from April 15 to June 30 in order to cover the Corps' responses to events that occurred before, during, and after the May flood.

We interviewed officials and hydrologic engineers at the Corps' Little Rock and Tulsa Districts to obtain their rationale for operating decisions affecting reservoir releases during the period covered by our review. When it was available, we obtained documentation that supported the oral information provided by Corps personnel. We also reviewed post-flood evaluation reports prepared by the Little Rock, Tulsa, and Vicksburg Districts.

We conducted our review from June 1990 to May 1991 in accordance with generally accepted government auditing standards. We discussed the information in this report with officials responsible for flood control management at the Corps' headquarters and at its Southwestern Division and incorporated their comments where appropriate.

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