DEPARTMENT OF THE ARMY
SOUTHWESTERN DIVISION, CORPS OF ENGINEERS
1100 COMMERCE STREET, SUITE 831
DALLAS, TEXAS 75242-1317

CESWD-RBT

14 DECEMBER 2015

MEMORANDUM FOR: Commander, Little Rock District, ATTN: CESWL-EC-H

SUBJECT: Bull Shoals & Norfork Dams Final Version Water Control Manual Approval

1. References:

   a. Email, CESWL-EC-H, 25 Aug 2014, subject as above

   b. Email, CESWL-EC-H, 19 November 2015, subject as above

   c. Email, CESWD-RBT-W, 14 December 2015, subject: Approval reference from Mike Sterling.

2. Review of the subject Bull Shoals & Norfork Dams Water Control Manual has been completed (Encl 1). The water control manual is approved as submitted subject to any minor editorial changes that were sent by email on 30 Nov 2015. Ensure that the Southwestern Division receives a copy of the final manual for our files. The manual is approved for distribution.

3. For additional information on this issue please contact Fred Jensen at (469) 487-7090.

For, Michael R. [signature] P.E.

Encl

PETE G. PEREZ, P.E.
Director, Regional Business Directorate

S: 19 November 2015

CESWL-EC-H (CESWD-RBT-W/12 September 2014) 4th End Himstedt/vew/501-324-6232

SUBJECT: Final Water Control Manual for Bull Shoals & Norfork Dams, White River, Arkansas

Little Rock District, Chief, HTS Branch, ATTN: CESWL-EC-H, P.O. Box 867, Little Rock, Arkansas 72203-0867 02 November 2015

FOR Commander, Southwestern Division, ATTN: CESWD-RBT-W, Dr.Mike Sterling, 1100 Commerce Street, Dalas, TX 75242

1. A revised Final Water Control Manual for Bull Shoals & Norfork Dams is transmitted for your final review and approval. Please review this draft and provide any comments by 19 November 2015.

2. We previously provided you two opportunities—July 2014 and September 2014—for your detailed review of this manual, and we have incorporated all of your comments. Your comments from the September 2014 review were very minor in depth. Therefore, I request your approval even should you find minor, editorial comments.

3. The draft manual that we submitted in August 2014 included changes incorporated from SWD, SWPA, SWL offices, and other offices. Most of those comments were accepted into the revision attached, which is dated September 2014. Our contractor made those changes. Since then, SWL staff has reviewed the text and plates page-by-page and made editorial or spelling corrections in several chapters and a few plates, yet none of the significant material was altered. We have included the printed plates in the paper version even though we received few comments to the plates; we did not provide electronic copies of the plates with the DVD.

4. Please use the separate endorsement format to reply with your approval so that we might properly track the approval process for future generations. Sample is attached.

5. POC is the undersigned.

Encl

H. HENRY HIMSTEDT, PE
Chief, HTS Branch

CESWL-EC-H 01 February 2016

MEMORANDUM FOR RECORD

SUBJECT: 3d Endorsement for the Review of the Draft water Control Manual for Bull Shoals & Norfork dams, White River, Arkansas

1. This MFR replaces the 3d endorsement from the Water Management & Infrastructure Safety Team at Southwestern Division (SWD) for the subject work, and serves to document the transmittal of the SWD comments. That endorsement transferred comments from the Water Management & Infrastructure Safety Team to Little Rock District (SWL) for inclusion in the water control manual. SWL included those comments in the revised manual, which was later re-submitted for review.

2. The 3d endorsement from the Water Management & Infrastructure Safety Team at SWD is missing from our files. The staffs from SWL and SWD searched their files and cannot find the memorandum. Files from FY14 and FY15 have become corrupted and are not available. By email dated, Monday, August 25, 2014 at 12:56 PM, the SWD staff indicated that an official SWD memorandum transmitting their review comments would be sent. The email reads:

"Mike B./Henry, I am sending you the official SWD Memo for the Bull Shoals & Norfork Dams WCM draft review comments. Also I am adding a few more minor grammatical comments that mostly deal with discrepancies with the Table of Contents and the body of the Water Control Manual. I will be sending these out as well this afternoon. Thanks, Fred Jensen – Water Management Team"

3. A copy of that email message is attached.

Encl

H. HENRY HIMSTEDT, PE
Chief, HTS Branch

-----Original Message-----
From: Jensen, Fred SWD
Sent: Monday, August 25, 2014 12:56 PM
To: Biggs, Mike L SWL; Himstedt, Henry SWL
Cc: Sterling, Michael C SWD; Jensen, Fred SWD
Subject: Memo for Bull Shoals/Norfork WCM draft review comments (enclosed) (UNCLASSIFIED)

Classification: UNCLASSIFIED
Caveats: NONE

Mike B./Henry, I am sending you the official SWD Memo for the Bull Shoals & Norfork Dams WCM draft review comments. Also I am adding a few more minor grammatical comments that mostly deal with discrepancies with the Table of Contents and the body of the Water Control Manual. I will be sending these out as well this afternoon. Thanks,

Fred Jensen - Water Management Team
(469) 487-7090 SWD

Classification: UNCLASSIFIED
Caveats: NONE

Classification: UNCLASSIFIED

CESWD-EC-H (CESWD-RBT-W/31 July 2014) 2nd End Himstedt/vew/501-324-6232

SUBJECT: Draft Water Control Manual for Bull Shoals & Norfork Dams, White River, Arkansas

Chief, HTS Branch, ATTN: CESWL-EC-H 25 August 2014

FOR Commander, Southwestern Division, ATTN: CESWD-RBT-W, Dr. Mike Sterling, 1100 Commerce Street, Dallas, TX 75242

1. A revised Draft Water Control Manual for Bull Shoals & Norfork Dams is transmitted for your approval. Please review this final draft and provide any final comments or your approval by 12 September 2014.

2. Little Rock District has revised the Draft Water Control Manual for Bull Shoals & Norfork Dams according to comments received from Southwestern Division, the Southwestern Power Administration, and our internal distribution. We have attached the file in which we captured all comments and our response to those comments. Most comments were accepted into this final draft as presented. However, please note that we did not adopt the recommended change in all cases; we may have adopted a modified change to best address similar comments, or we may have not adopted the change because we did not believe it improved the manual.

3. We are not resending the plates because we received very few comments regarding the plates, and the AE is already addressing those. The AE will address all formatting, pagination, and Table of Contents comments in the final draft, so any of those comments are not necessarily corrected in this draft.

Encl

HENRY HIMSTEDT, PE
Chief, HTS Branch

DEPARTMENT OF THE ARMY
SOUTHWESTERN DIVISION, CORPS OF ENGINEERS
1100 COMMERCE STREET, SUITE 831
DALLAS TX 75242-1317

CESWD-RBT-W

MEMORANDUM FOR Chief, HTS Branch, ATTN: CESWL-EC-H

SUBJECT: Draft Water Control Manual comments for Bull Shoals & Norfork Dams, White River, Arkansas

1. Southwestern Division's comments for the Water Control Manual for Bull Shoals & Norfork Dams were provided by email by Mr. Fred Jensen on 30 July 2014 and by Dr. Mike Sterling on 31 July 2014. These two electronic files constitute the SWD consolidated comments.

2. Please revise the draft Water Control Manual accordingly and re-submit for approval.

MICHAEL R. ZALESAK
Chief, Business Technical Division

DEPARTMENT OF THE ARMY
LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
POST OFFICE BOX 867
LITTLE ROCK, ARKANSAS 72203-0867
www.swl.usace.mil/

REPLY TO
ATTENTION OF

Suspense: 30 July 2014

CESWL-EC-H

07 July 2014

MEMORANDUM THRU

Chief, Engineering and Construction Division
Chief, Business Technical Division, ATTN: CESWD-RBT, Southwestern Division

FOR Lead Water Management, ATTN: CESWD-RBT-W, Dr. Mike Sterling

SUBJECT: Draft Water Control Manual for Bull Shoals & Norfork Dams, White River, Arkansas

1. Enclosed is the Draft water control manual for Bull Shoals & Norfork Dams.

2. Please provide your comments to H&TS Branch by 30 July 2014 so that we can meet the schedule established with our contractor for completing work this fiscal year. Pay particular attention to the changes included in Chapter 7 of the manual that document the implementation of White River Basin, Arkansas Minimum Flows Project at Bull Shoals and Norfork according to the Record of Decision dated 13 January 2009 and the FY2006 Energy and Water Resources Development Appropriations Act (PL 09-103).

3. If you have any questions concerning this report, please contact Mr. Mike Biggs in the Reservoir Control Section at 501-324-6235.

Encl (1 Copy)

HENRY HIMSTEDT, P.E.
Chief, Hydraulics and Technical
Services Branch

CF:
CESWL-EC-DI (Dan Smith)
CESWL-OP-OM (James Mckinnie)
CESWL-OP-MH-N (Mark Eddings)

BULL SHOALS DAM AND NORFORK DAM
WHITE AND NORTH FORK RIVERS
WHITE RIVER BASIN, AR

WATER CONTROL MANUAL
APPENDIX VIII
TO
WHITE RIVER BASIN
WATER CONTROL MASTER MANUAL

DEPARTMENT OF THE ARMY
LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
ARKANSAS

SEPTEMBER 2014

REVISED NOVEMBER 2015

BULL SHOALS DAM

NORFORK DAM

NOTICE TO USERS OF THIS MANUAL

Regulations specify that this Water Control Manual be used in loose-leaf form, and only those sections, or parts thereof; requiring changes will be revised and printed. Therefore, this copy should be preserved in good condition so that inserts can be made to keep the manual current. Changes to individual pages must carry the date of revision, which is Southwestern Division's approval date.

All elevations referred to in this manual, unless noted otherwise, are in feet, NGVD (National Geodetic Vertical Datum).

NOTE ON VERTICAL DATUM:

The project vertical datum for Bull Shoals and Norfork Dams was originally established referenced to the National Geodetic Vertical Datum of 1929 (NGVD29). In the interest of consistency with historic records, project structural elevations and pool elevations will continue to be referenced to the NGVD29 Legacy Datum. The relationship of the NGVD29 Legacy Datum to the most currently referenced vertical datum, North American Vertical Datum 1988 (NAVD88), is:

Bull Shoals	NAVD88 = NGVD29 Legacy Datum + 0.36
Norfork	NAVD88 = NGVD29 Legacy Datum + 0.34

All elevations in this manual are referenced to the NGVD29 Legacy Datum unless noted otherwise (e.g. NAVD88). In this manual the presence of any form of the mean sea level acronym (msl, MSL, m.s.l, or M.S.L) indicates a reference to the NGVD29 Legacy Datum.

EMERGENCY REGULATION ASSISTANCE PROCEDURES

[redacted]

[redacted]

[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted] [redacted]
[redacted]	[redacted]	[redacted] [redacted]

EMERGENCY PERSONNEL LIST

[redacted]	[redacted]	[redacted]
[redacted]		[redacted]
[redacted]	[redacted]	[redacted] [redacted]
[redacted]	[redacted]	[redacted] [redacted]
[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]

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[redacted]

BULL SHOALS DAM AND NORFORK DAM
WATER CONTROL MANUAL

I - INTRODUCTION

1-01. Authorization. This manual is submitted as required by ER 1110-2-240 “Water Control Management”, (October 1982, revised April 1987); and prepared in accordance with EM 1110-2-3600 “Management of Water Control Systems”, (November 1987) and ER 1110-2-8156 “Preparation of Water Control Manuals”, (August 1995).

1-02. Purpose and Scope. The purpose of this manual is to document the Bull Shoals Dam and Norfork Dam regulation plans, to present detailed information to higher authority, and to give guidance to personnel who will become concerned with or responsible for the regulation of Bull Shoals Dam and Norfork Dam during the life of the project. This manual includes data and information pertinent to the regulation of both Bull Shoals Dam and Norfork Dam. For more detailed information related to the water control plan for the White River, see the White River Basin Water Control Master Manual (March 1993).

1-03. Related Manuals and Reports. This manual is Appendix VIII to the White River Basin Water Control Master Manual (March 1993). The information in this manual supersedes the information that pertains to the Bull Shoals and Norfork projects in the October 1966 Reservoir Regulation Manual for Beaver, Table Rock, Bull Shoals and Norfork Reservoirs (Appendix III to the White River Basin Water Control Master Manual). Other reports and manuals related to the White River Basin are cited in the White River Basin Water Control Master Manual. Reports and manuals pertinent to Bull Shoals Dam and Norfork Dam are listed in Table 1-01.

1-04. Project Owner. Both Bull Shoals Dam and Norfork Dam are owned by the United States Government.

1-05. Operating Agency. The U.S. Army Corps of Engineers (Little Rock District) is the operating agency for both Bull Shoals Dam and Norfork Dam. The Operations Project Manager (OPM) at the Mountain Home Project Office supervises the superintendents for Bull Shoals Dam and Norfork Dam Power Stations and the Bull Shoals and Norfork lake managers. The hydropower facilities at Bull Shoals and Norfork are operated remotely from the Table Rock Powerhouse using the Supervisory Control and Data Acquisition (SCADA) System at Table Rock Dam. The Mountain Home Project Office is located in Mountain Home, Arkansas. Little Rock District personnel interact with Southwestern Power Administration (SWPA) personnel to coordinate hydropower release schedules at Bull Shoals and Norfork.

1-06. Regulating Agencies. The U.S. Army Corps of Engineers is the regulating agency for both Bull Shoals and Norfork Dams. The Reservoir Control Section, Hydraulics and Technical Services Branch, in the Little Rock District Office enforces the guidelines of the water control plan by monitoring pool levels, making hydrologic forecasts, and coordinating overall water management operations.

TABLE 1-01
PERTINENT REPORTS AND DESIGN MEMORANDA
FOR BULL SHOALS DAM AND NORFORK DAM

REGULATION MANUALS		**Date Approved**
White River Basin Water Control Master Manual		Mar 1993 rev Dec 1998
Clearwater Lake	Appendix I[1]	Jul 1995
Stream Flow Forecasting	Appendix II[1]	Jul 1956
Beaver, Table Rock, Bull Shoals, and Norfork Lakes Regulation Manual	Appendix III[1]	rev Oct 1966
Greers Ferry Lake	Appendix IV[1]	Nov 1966
Drought Contingency Plan	Appendix V[1]	Oct 1989
Beaver Lake Water Control Manual	Appendix VI	Oct 1998
Table Rock Lake WCM	Appendix VII	TBD
Bull Shoals & Norfork Lake WCM	Appendix VIII	TBD
Greers Ferry Lake WCM	Appendix IX	TBD
DESIGN MEMORANDA		
Norfork Lake – Definite Project Report, Design Memorandums[2] No. 1-4		Apr 1940
Bull Shoals Lake – Definite Project Report, Design Memorandums[2] No. 1-6		Feb 1942
Operation Maintenance Manual for Norfork Dam		Jun 1945
Operation of Spillway Gates, Norfork Dam		Jul 1951
Power Operations, Bull Shoals and Norfork Projects		Aug 1951
Plan of Flood Regulation, Bull Shoals and Norfork Reservoirs		Jun 1952
Seasonal Power Operation for Bull Shoals and Norfork		Jul 1952
Design Memorandum No. 8, Hydrology, Table Rock Dam and Reservoir (also refers to regulation of Bull Shoals Reservoir)		Aug 1952
Master Manual for Reservoir Regulation, White River Basin, Arkansas and Missouri		Dec 1954
Reservoir Regulation Manual for Bull Shoals and Norfork Reservoirs, Appendix III to Master Manual for Reservoir Regulation, White River Basin		Dec 1955
Stream Flow Forecasting, White River Basin, Arkansas and Missouri, Appendix II to Master Manual for Reservoir Regulation		Feb 1956
Operation and Maintenance Manual for Bull Shoals Dam and Power Plant		Feb 1957
Reservoir Regulation Manual for Table Rock, Bull Shoals, and Norfork Reservoirs, Appendix III (Revised) to Master Manual for Reservoir Regulation, White River Basin		Apr 1961
Area and Capacity Tables for Beaver, Table Rock, Bull Shoals, and Norfork		Nov 1963
Reservoir Regulation Manual for Beaver, Table Rock, Bull Shoals, and Norfork Reservoirs, Appendix III (Revised) to Master Manual for Reservoir Regulation, White River Basin		Oct 1966

TABLE 1-01
PERTINENT REPORTS AND DESIGN MEMORANDA
FOR BULL SHOALS DAM AND NORFORK DAM
continued

DESIGN MEMORANDA	**Date Approved**
White River Basin – Comprehensive Basin Study (Vol. I-IV)	Jun 1968
White River Rule Curve Studies – 1968 White River Hydroelectric System	Sep 1968
Basis of Design (Bull Shoals)	Feb 1942
Analysis of Design (Bull Shoals)	Oct 1946
Dam Safety, Hydrologic and Hydraulic Studies for Spillway Adequacies, Beaver, Table Rock, and Bull Shoals Lakes, White River, Arkansas and Missouri	Nov 1980
Dam Safety Assurance Program – Norfork Dam Reconnaissance Report	Nov 1982
White River Lakes Study – Arkansas and Missouri	1985
Norfork Lake – Operation and Maintenance Manual – Vol. II, Flood Emergency Plan	Apr 1982 rev Aug 88
Bull Shoals Lake – Operation and Maintenance Manual – Vol. II, Flood Emergency Plan	Jun 84 rev Aug 88
ER 500-1-1, Natural Disaster Procedures	Mar 1991
OM 500-1-1, Little Rock District Natural Disaster Response Plan, Operational Procedures under PL 84-99, PL 93-288, and Others (ER 500-1-1)	Jul 1991
Dam Safety, Hydrologic and Hydraulic Studies for Spillway Adequacies, Norfork Lake, White River, Arkansas and Missouri	May 2008
White River Basin, Arkansas Minimum Flows Report and Final EIS	Nov 2008
Dam Safety, Hydrologic and Hydraulic Studies for Spillway Adequacies, Bull Shoals Lake, White River, Arkansas and Missouri[3]	Feb 2013

1/ – Appendices to the White River Basin Water Control Master Manual (March 1993, rev. December 1998).

2/ – Where several design memorandums are listed together the date refers to the earliest one.

3/ – Report submitted February 2013. Approval is pending.

II - DESCRIPTION OF PROJECT

2-01. Location. Bull Shoals and Norfork dams are located in north central Arkansas. Bull Shoals Dam is on the White River at river mile 418.6 in Marion County, Arkansas, approximately 14 river miles upstream of the U.S. Highway 62 bridge near Cotter, Arkansas. Bull Shoals Dam, in combination with Beaver Dam and Table Rock Dam, regulates flow from 6,036 square miles of drainage area. Bull Shoals Lake extends into Baxter and Boone Counties in Arkansas as well as Taney and Ozark Counties in Missouri. Norfork Dam is on the North Fork River, 4.8 miles upstream from its confluence with the White River in Baxter County, Arkansas. Norfork Lake extends partially into Fulton County, Arkansas and Ozark County, Missouri and regulates flow from 1,806 square miles of drainage area. The project locations are shown on Plate 2-01(a) and Plate 2-01(b).

The White River Basin is divided into three sub-basins: the Upper White River Basin, the Black River Basin, and the Lower White River Basin. The Upper White River Basin encompasses the area from the headwaters of the White River to Newport, Arkansas. The Black River Basin extends from the headwaters of the Black River to the confluence with the White River near Newport, Arkansas. The Lower White River Basin extends from Newport, Arkansas to the confluence with the Mississippi River. Bull Shoals Dam and Norfork Dam are located in the Upper White River Basin. Plate 4-01 shows the White River Basin Map.

2-02. Purpose. Storage in both the Bull Shoals and Norfork projects is provided for flood control, hydropower, White River Minimum Flows (WRMF), and municipal and industrial water supply. Bull Shoals was authorized for flood control and hydroelectric power by the Flood Control Act approved 18 August 1941 (Public Law (P.L.) 228, 77th Congress, 1st session). The initial two power units began operating in September 1952, with additional units added in June 1953 (two units), January/February 1962 (two units), then August and October 1963 (final two units).

The Norfork project was authorized for flood control with provision for installing penstocks by the Flood Control Act approved 28 June 1938 (P. L. 761, 75th Congress, 3rd session). This Act was modified to provide facilities for generation of power by the Flood Control Act of 18 August 1941 (P. L. 228, 77th Congress, 1st session). Generation of power with one unit began in June 1944, and a second unit was placed in operation in February 1950. Temporary bulkheads were initially installed on the spillway crest and were replaced by crest gates in November 1950.

Both lakes have storage allocated for flood control, hydropower, WRMF, and municipal and industrial (M&I) water supply. The permanent conservation pool also provided for recreation and wildlife habitats. The lakes are components of the White and Lower Mississippi River Basins' flood control and water resources development plans. The water supply agreements for Bull Shoals Lake and

Norfork Lake are summarized in Tables 2-01 and 2-02, respectively.

TABLE 2-01
WATER SUPPLY CONTRACTS AND YIELD FOR BULL SHOALS LAKE

		WS Agreement Storage Space (ac-ft)				
User	Date of Agreement	Present	Future	Not Under Contract	Total	Yield (MGD)
MCRWD [1]	1988	1,698[2]	0	0	1,698	1.000
OMRPWA[3]	2010	10,035[4]	0	0	10,035	5.91
MCRWD	2010	1,698	0	0	1,698	1.000

[1] Marion County Regional Water District (MCRWD).

[2] Original contract of 880 acre-feet plus WRMF dependable yield mitigation storage of 818 acre-feet.

[3] Ozark Mountain Regional Public Water Authority (OMRPWA).

[4] Agreement for additional 153.5 acre-feet (0.09 mgd) is pending.

TABLE 2-02
WATER SUPPLY CONTRACTS AND YIELD FOR NORFORK LAKE

		WS Agreement Storage Space (ac-ft)				
User	Date of Agreement	Present	Future	Not Under Contract	Total	Yield (MGD)
City of Mountain Home	1969	1,151 [1]	0	0	1,151	1.000
Supplement	1971	2,301 [2]	0	0	2,301	2.000

[1] Original contracted storage of 800 acre-feet plus WRMF dependable yield mitigation storage of 351 acre-feet.

[2] Supplemental contracted storage of 1,600 acre-feet plus WRMF dependable yield mitigation storage of 701 acre-feet.

2-03. Physical Components.

a. Dams.

1. Bull Shoals. Bull Shoals Dam is a concrete gravity structure with a crest length of [redacted] and a maximum height of [redacted] above the streambed. The top of the dam (elevation 708.0) serves as a portion of Arkansas State Highway 178. The top of dam parapet wall is at [redacted]. The general layout plan is shown on Plate 2-02(a).

2. Norfork. Norfork Dam is a concrete gravity structure with a crest length of [redacted] and a maximum height of [redacted] above the streambed. The top of the Dam (elevation [redacted] serves as a portion of State Highway 177. The top of the dam parapet wall is at [redacted]. The general layout plan is shown on Plate 2-02(b).

b. Lakes.

1. Bull Shoals. Bull Shoals Lake covers an area of 71,240 acres at the top of flood control pool, elevation 695.0, and contains 5,408,000 acre-feet of total storage.

2. Norfork. Norfork Lake covers an area of 30,700 acres at the top of flood control pool, elevation 580.0, and contains 1,983,000 acre-feet of total storage.

c. Abutments.

1. Bull Shoals. The right abutment includes a [redacted]. Arkansas State Highway 178 crosses the bulkhead sections and dam. The overall crown of roadway width is approximately [redacted]. The left abutment, which includes the powerhouse facilities, is [redacted] in length. The upstream side is sloped on a [redacted] grade and the downstream side is graded at [redacted] The plan, elevation, and sections are shown on Plates 2-03(a) and 2-03(b), and pertinent data are given in Exhibit A.

2. Norfork. The right abutment includes a [redacted] bulkhead section at [redacted]. Arkansas State Highway 177 crosses the [redacted] The overall crown of roadway width is approximately 42 feet. The right abutment also includes the powerhouse facilities. The left abutment is [redacted] in length, and the operating tower is located on this side. The upstream side is sloped on a [redacted] grade and the downstream side is graded at [redacted]. The plan, elevation, and sections are shown on Plates 2-03(c) and 2-03(d), and pertinent data are given in Exhibit A.

d. Spillway.

1. Bull Shoals. The spillway is a gated ogee section with a gross length of [redacted] The spillway includes [redacted] controlled by [redacted] Rating curves for the spillway are shown on Plate 7-02. These spillway gates [redacted]. The [redacted] ssemblies. The gates are operated by [redacted]. A gate may be opened by [redacted] Each gate is equipped with a [redacted] which measures the vertical opening from the gate seat to the

bottom of the gate. [redacted] are provided at 1-foot intervals to the intermediate position. The spillway sill is level at [redacted] with a flat crest. The top of gates elevation in the closed position (and top of flood control pool) is [redacted]. The gates used to control the spillway discharge are a [redacted] with the [redacted] set at elevation [redacted]. Plates 2-03(a) and 2-03(b) show plan, elevation and typical spillway section. Additional spillway details are provided in Exhibit A, Supplementary Pertinent Data.

2. Norfork. The spillway is a gated ogee section with a gross length of [redacted]. The spillway includes [redacted], controlled by [redacted] Rating curves for the spillway are shown on Plate 7-07. Motors, controls, and dials are all similar to the installation at Bull Shoals. The gate [redacted] used to open the gates have been replaced with [redacted] assemblies. The crest elevation is [redacted] and the top of gates elevation in the fully closed position (and top of flood control pool) is [redacted] The gates used to control the spillway discharge are a [redacted] with a [redacted]. The gate [redacted] Plates 2-03(c) and 2-03(d) show plan, elevation and typical spillway section. Additional spillway details are provided in Exhibit A, Supplementary Pertinent Data.

e. Stilling Basin.

1. Bull Shoals. The spillway has a stilling basin [redacted] (normal to the dam axis) with floor elevations ranging from [redacted]. The stilling basin apron has side walls that extend to elevation [redacted] and a minimum elevation of [redacted] at the flowline of the flood control conduits. The end sill is set parallel to the spillway axis. The normal tailwater elevation is [redacted].

2. Norfork. The spillway has a horizontal stilling basin [redacted] (normal to the dam axis) with a [redacted]. The stilling basin apron has side walls that extend to elevation [redacted] and a bottom elevation of [redacted]. The end sill is set parallel to the spillway axis. The normal tailwater elevation is [redacted].

f. Hydropower.

1. Bull Shoals. The left abutment of the dam contains the hydropower facilities which include four 40 megawatt (MW) power units (units 1 through 4), and four 45 MW units (units 5 through 8). Since unit 3 has been de-rated to 35 MW the hydropower facilities total capacity is now 335 MW. The units and plant can generate above nameplate capacity when running on “overload” producing up to 370 MW. The [redacted] penstocks are [redacted] and the centerline elevations are [redacted] upstream and [redacted] downstream. The turbine discharge at rated capacity at the top of the conservation pool (elevation 659.0) for units 1, 2, and 4 is 2,578 cfs, for unit 3 is 2,296 cfs, and for units 5 through 8 is 2,873 cfs. The lowest elevation for rated capacity is 630.0. Plate 7-03 shows the turbine rating curves for the initial 40 MW units, while Plate 7-04 shows the turbine rating curves

for the 45 MW units (Units 5-8). The tailwater rating curve is shown on Plate 7-05. The Supervisor Controlled Data Acquisition (SCADA) system has been modified to allow [redacted] of the Bull Shoals turbines from Table Rock powerhouse.

2. Norfork. The right abutment of the dam contains the hydropower facilities which include two power units of 40.275 MW capacity each. The units and plant can generate above nameplate capacity when running on "overload" producing up to 90 MW. The penstocks are [redacted] and the centerline elevation is [redacted] on the upstream side and [redacted] on the downstream side. The dam has [redacted] penstocks, with only [redacted] currently in use. The turbine discharge at rated capacity at the original design top of the conservation pool (elevation 552.0) is 2,700 cfs. The lowest elevation for rated capacity is elevation 528.5. Plate 7-08 shows the turbine rating curves, and Plate 7-09 shows the tailwater rating curve. The SCADA system has been modified to allow [redacted] of the Norfork turbines from Table Rock powerhouse.

g. Conduits.

1. Bull Shoals. In addition to the spillway gates, Bull Shoals has [redacted] in section. Each conduit has a capacity at the top of power pool (elevation 659.0) of 3,500 cfs. The upstream flowline elevation is elevation [redacted] and the downstream flowline elevation is elevation [redacted]. Each conduit is controlled by [redacted] designed to operate at full openings. Plate 7-01 shows the conduit rating curves.

2. Norfork. In addition to the spillway gates, Norfork Dam has [redacted] in section. Each conduit has a capacity at the top of power pool (elevation 553.75) of 2,200 cfs. The upstream flowline elevation is elevation [redacted].0 and the downstream flowline elevation is [redacted]. Each conduit is controlled by [redacted] designed to operate at full openings.

[redacted]

h. Siphon System. A siphon system was installed at Norfork Dam in 2012 to provide an additional release to supplement house unit releases, hatchery releases, and leakage to meet a minimum flow of 300 cfs, as authorized by Section 132 of (P.L. 109-103). The minimum flow was designed to increase the downstream wetted perimeter to aid the trout fishery. The system is designed to be operated whenever hydropower generation is not underway. The siphon system includes a [redacted] to coincide with the U.S. Fish & Wildlife (USFW) fish hatchery intakes. The pipe was attached at the point where [redacted]. The system will discharge at elevation [redacted] on the downstream side of Norfork Dam. Using the SCADA system, the siphon system provides the ability to [redacted]. Plate 2-04 shows the siphon system. The siphon cannot be operated whenever the lake elevation drops below [redacted]. This is a physical limitation, and not an intended operational constraint.

2-04. <u>Related Control Facilities</u>. The White River Basin encompasses areas in both the Little Rock and Memphis Corps of Engineers districts. The White River and its tributaries from river mile 175.0 near Georgetown, Arkansas, downstream to river mile 10.0 are under the jurisdiction of the Memphis District, while all other portions are controlled by the Little Rock District (Corps).

The Corps interacts with the SWPA to coordinate hydropower release schedules at the five hydropower projects (Beaver, Table Rock, Bull Shoals, Norfork, and Greers Ferry) within the White River Basin system. There are also non-federal hydropower facilities at Ozark Beach Dam, downstream of Table Rock Lake, and at the three lock and dams on the White River near Batesville, Arkansas. Power production at these non-federal facilities is at the discretion of the owners. At river mile 0.5, the Montgomery Point Lock and Dam was completed in 2005 to insure adequate navigation depth for the first 10 miles of the White River Entrance Channel to the McClellan-Kerr Arkansas River Navigation System (MKARNS).

2-05. <u>Real Estate Acquisition</u>.

a. <u>Bull Shoals.</u> At the top of conservation pool (elevation 659.0 as raised from design 654.0 for compliance with the WRMF Project), Bull Shoals Lake has a surface area of 48,005 acres (75 square miles), has a shoreline which is approximately 780 miles long, and has a storage capacity of 3.281 million acre-feet. Reservoir lands were blocked out at the 700-foot contour which is five feet above the top of the spillway gates (in a closed position). The reservoir was cleared between elevation 620.0 and the top of the original power pool, elevation 654.0.

All state highways in the reservoir area were relocated or raised to or above the highest pool elevations that would occur as a result of a surcharge storage operation during floods equal to the maximum of record. These elevations range from about elevation 698.0 in the flat part of the pool to approximately elevation 701.0 in the backwater areas. County and special road district roads were acquired by fee or condemnation below the top of power pool, and flowage easements were obtained by the Government on roads between the top of power pool and the limits of Government-owned land. Lump-sum contracts were made with the counties and special districts for relocating and replacing affected roads which afforded access to tracts that were inhabited at the time. Increased travel distances were considered as a basis for relocation or replacement if the distances seemed excessive. Some of the old roads provided shorter routes, and they are still in use when passable. Some bridges on abandoned roads were left in-place to provide convenient access to the lake during periods of low pool stages and to serve as fishing piers.

Approximately 12,100 acres of land and water around the lake have been licensed to the Missouri Department of Conservation (MDC) for conservation and management of fish and wildlife. The Arkansas Game and Fish Commission (AGFC) has licenses for approximately 3,000 acres of land for the Jones Point Wildlife Management Area (WMA) along the lake and developed a fish nursery pond and WMA near the Lead Hill Boat Dock. The nursery pond dam is within the flood pool with the top of the nursery pond dam at elevation 683.83 and spillway crest at elevation 675.0.

b. Norfork. At the top of conservation pool (elevation 553.75, raised from 552.0 by Congress for the WRMF Project), Norfork Lake has a surface area of 22,454 acres (35.1 square miles), has a shoreline 388 miles long, and has a storage capacity of 1.29 million acre-feet. Reservoir lands were blocked out at the 580-foot contour which is at the level of the top of the spillway gates (in a closed position). The reservoir was completely cleared to elevation 555.0, which was three feet above the original top of power pool.

A lump-sum settlement based on the cost of relocating Arkansas State highways affected by Norfork Lake was made with the State. Modern concrete multi-span bridges, completed in 1934, were inundated by the lake. In lieu of relocations, the State provided free ferry crossings for these highways. These ferries for State Highway 101 and U.S. Highway 62 were eventually replaced with bridges in October 1983. County roads were acquired in fee below elevation 552.0. Flowage easements were obtained by the Government on roads between elevation 552.0 and the maximum expected pool elevations, or several feet above the top of spillway gates. Replacements for county roads provided complete or part-time access to all affected tracts inhabited at the time. The Pigeon Creek County Road is inundated by high-pool stages. It serves as a main access road for inhabitants living north of Mountain Home. The bridge floor over Pigeon Creek is at approximate elevation 569.0, and the lowest approach is elevation 567.0 as set by an agreement with Baxter County.

The AGFC leases over 2,100 acres of federal land around the lake for game management. In addition, the U.S. Fish and Wildlife Service (USFW) operates the Norfork National Fish Hatchery just downstream of the dam on the right bank on 43.9 acres.

2-06. Public Facilities.

a. Bull Shoals. Bull Shoals Lake has 20 developed parks and 11 marinas operated by the private concessionaires. The Corps operates 14 of the developed parks, all others are operated by Arkansas State Parks or other local agencies. The parks include 18 boat ramps, 15 campgrounds, and 6 designated swim areas. The Corps operated campgrounds are located in River Run, Beaver Creek, Buck Creek, Theodosia, Oakland, Lakeview, Highway 125, Lead Hill, and Tucker Hollow. Pontiac, Ozark Isle, and the Dam Site parks are operated by private concessionaires. Other primitive camping areas (by permit only) include Indian Point, Big Bend, Lowry Park, Yocum Creek, and West Sugarloaf. There are also three other lake access points located around the lake. See Table 2-03 for a summary of Public Facilities. Refer to Plate 2-05(a) for location of parks and access points.

TABLE 2-03
PUBLIC FACILITIES – BULL SHOALS LAKE

[redacted]

b. Norfork. Norfork Lake has 11 developed parks and 11 marinas with public facilities. The Corps operates 9 of the developed parks. All of the marinas are operated by private concessionaires. The parks include 18 boat ramps, 15 campgrounds, and 6 designated swim areas. The Corps operated campgrounds are located in Bidwell Point, Cranfield, Gamaliel, Henderson, Panther Bay, Quarry, Robinson Point, Tecumseh, and Udall parks. Howard Cove and Jordan parks are operated private concessionaires. See Table 2-04 for a summary of Public Facilities. Refer to Plate 2-05(b) for location of parks and access points.

TABLE 2-04
PUBLIC FACILITIES – NORFORK LAKE

[redacted]

c. White River Minimum Flows Impacts. Section 132(a) of the FY 2006 Energy and Water Development Appropriations Act (EWDAA) (P.L. 109-103) authorized and directed implementation of BS-3 (Bull Shoals) and NF-7 (Norfork) as described in the July 2004 White River Minimum Flow Reallocation Report. Due to storage reallocations from the flood pools at both Bull Shoals and Norfork, lakeside facility modifications were required for WRMF implementation. For a more detailed description of storage reallocation see paragraph 3-05. Modifications to Regulations (e) on page 3-6. Table 2-05 provides a summary of Bull Shoals lakeside facilities that have been modified, and Table 2-06 provides a summary of Norfork lakeside facilities that have been modified.

TABLE 2-05
BULL SHOALS LAKE FACILITY MODIFICATIONS FOR WHITE RIVER MINIMUM FLOWS

PARK	FEATURE	LENGTH	AREA	CONDITION	COMMENT
BEAVER CREEK	BOAT RAMP	30 FT	1,308 SQ FT	MODIFICATION	CORPS OWNED
BUCK CREEK	SWIM BEACH		17,482 SQ FT	RELOCATION	CORPS OWNED
BUCK CREEK	PARKING		1,501 SQ FT	MODIFICATION	CORPS OWNED
BUCK CREEK	PARKING LOT		5,221 SQ FT	MODIFICATION	CORPS OWNED
BUCK CREEK	BOAT RAMP	20 FT	589 SQ FT	MODIFICATION	CORPS OWNED
DAM SITE	BOAT RAMP	30 FT	1,285 s SQ FT	MODIFICATION	CORPS OWNED
HIGHWAY 125	PARKING		10,830 SQ FT	MODIFICATION	CORPS OWNED
HIGHWAY 125	SWIM BEACH		25,749 SQ FT	RELOCATION	CORPS OWNED
HIGHWAY 125	BOAT RAMP		1,044 SQ FT	MODIFICATION	CORPS OWNED
HIGHWAY K	ROAD		1,053 SQ FT	MODIFICATION	CORPS OWNED
LAKEVIEW	ROAD	140 FT	2,248 SQ FT	MODIFICATION	CORPS OWNED
LAKEVIEW	ROAD	275 FT	9,662 SQ FT	MODIFICATION	CORPS OWNED
LAKEVIEW	SWIM BEACH		27,891 SQ FT	MODIFICATION	CORPS OWNED
LAKEVIEW	BOAT RAMP	30 FT	914 SQ FT	MODIFICATION	CORPS OWNED
LEAD HILL	BOAT RAMP		4,888 SQ FT	MODIFICATION	CORPS OWNED
LEAD HILL	HANDICAP ACCESS		453 SQ FT	MODIFICATION	CORPS OWNED
LEAD HILL	SWIM BEACH		53,642 SQ FT	RELOCATION	CORPS OWNED
LEAD HILL	PARKING LOT		12,484 SQ FT	MODIFICATION	CORPS OWNED
LEAD HILL	BOAT RAMP	40 FT	1,178 SQ FT	MODIFICATION	CORPS OWNED
MARION CO ROAD 143	ROAD	193 FT	4,101 SQ FT	MODIFICATION	MARION CO.

TABLE 2-05
BULL SHOALS LAKE FACILITY MODIFICATIONS FOR WHITE RIVER MINIMUM FLOWS
continued

PARK	FEATURE	LENGTH	AREA	CONDITION	COMMENT
OAKLAND	BOAT RAMP	40 FT	1,536 SQ FT	MODIFICATION	CORPS OWNED
OAKLAND	PARKING LOT		2,595 SQ FT	MODIFICATION	CORPS OWNED
OAKLAND	PARKING		7,299 SQ FT	MODIFICATION	CORPS OWNED
POINT RETURN	PARKING LOT		13,628 SQ FT	MODIFICATION	CORPS OWNED
POINT RETURN	SWIM BEACH		18,979 SQ FT	RELOCATION	CORPS OWNED
POINT RETURN	BOAT RAMP	15 FT	254 SQ FT	MODIFICATION	CORPS OWNED
POINT RETURN	PARKING /LAUNCH		38,569 SQ FT	RELOCATION	PROPOSED MEGA RAMP
POINT RETURN	WATERBORNE TOILET		1,018 SQ FT	RELOCATION	PROPOSED MEGA RAMP
POINT RETURN	PARKING		118,304 SQ FT	RELOCATION	PROPOSED MEGA RAMP
POINT RETURN	BOAT RAMP	300 FT	38,943 SQ FT	RELOCATION	PROPOSED MEGA RAMP
POINT RETURN	STAGING AREA		5,911 SQ FT	RELOCATION	PROPOSED MEGA RAMP
POINT RETURN	PAVILION		2,338 SQ FT	RELOCATION	PROPOSED MEGA RAMP
PONTIAC	BOAT RAMP	50 FT	2,024 SQ FT	MODIFICATION	CORPS OWNED
PONTIAC	PARKING		5,070 SQ FT	MODIFICATION	CORPS OWNED
RIVER RUN	LIGHT POLE		NA	RELOCATION	LOCATE ABOVE 653
SLOUGH HOLLOW ROAD	ROAD	722 FT	17,775 SQ FT	MODIFICATION	TANEY CO.
SLOUGH HOLLOW ROAD	ROAD	1024 FT	25,030 SQ FT	MODIFICATION	TANEY CO.
THEODOSIA	PARKING LOT		9,301 SQ FT	MODIFICATION	CORPS OWNED
THEODOSIA	SWIM BEACH		14,284 SQ FT	RELOCATION	CORPS OWNED
THEODOSIA	BOAT RAMP		13,700 SQ FT	MODIFICATION	PROPOSED MEGA RAMP
THEODOSIA	ROAD		8,664 SQ FT	MODIFICATION	PROPOSED MEGA RAMP
THEODOSIA	PARKING LOT		32,639 SQ FT	MODIFICATION	PROPOSED MEGA RAMP
TUCKER HOLLOW	BOAT RAMP	50 FT	1,677 SQ FT	MODIFICATION	CORPS OWNED
TUCKER HOLLOW	ROAD		3,063 SQ FT	MODIFICATION	CORPS OWNED

TABLE 2-06
NORFORK LAKE FACILITY MODIFICATIONS FOR WHITE RIVER MINIMUM FLOWS

PARK	FEATURE	LENGTH	AREA	CONDITION	COMMENT
BIDWELL POINT	SWIM BEACH		32,536 SQ FT	RELOCATION	CORPS OWNED
CRANFIELD	SWIM BEACH		110,327 SQ FT	RELOCATION	CORPS OWNED
GAMALIEL	SWIM BEACH		22,669 SQ FT	RELOCATION	CORPS OWNED
GEORGES COVE	BOAT RAMP		1,752 SQ FT	MODIFICATION	CORPS OWNED
JORDAN	SWIM BEACH		34,226 SQ FT	RELOCATION	CORPS OWNED
PANTHER BAY	SWIM BEACH		48,248 SQ FT	RELOCATION	CORPS OWNED
PANTHER BAY	PARKING		3,040 SQ FT	MODIFICATION	CORPS OWNED
QUARRY	SWIM BEACH		37,890 SQ FT	RELOCATION	CORPS OWNED
ROBINSON POINT	SWIM BEACH		28,736 SQ FT	RELOCATION	CORPS OWNED
ROBINSON POINT	BOAT RAMP		1,042 SQ FT	MODIFICATION	CORPS OWNED
UDALL	PARKING		50,164 SQ FT	MODIFICATION	CORPS OWNED
UDALL	BOAT RAMP		25,831 SQ FT	MODIFICATION	CORPS OWNED

III - HISTORY OF PROJECTS

3-01. Authorization. In early 1937 extremely heavy rainfall occurred in eleven states along the Ohio and Mississippi river valleys. The United States Weather Bureau (NWS) estimated that there was enough rain to cover about 204,000 square miles to a depth of 11.2 inches. Arkansas recorded 12.61 inches of rain in January, which was 8.22 inches above normal. Arkansas's floodwaters came from tributary streams no longer able to drain effectively due to the cresting Mississippi River. The White River was one of these that spilled across agriculture terrain mostly bare of crops that time of year and already struggling from the effects of drought, the Great Depression, and the Dust Bowl.

In response, Congress enacted the Flood Control Act of 1938 which authorized the construction of six projects in the White River Basin, including Clearwater Lake in Missouri; Water Valley and Norfork Lakes in Missouri and Arkansas; and Lone Rock, Greers Ferry, and Bell Foley Lakes in Arkansas.

In August 1941, the Table Rock and Bull Shoals projects were authorized for flood control and hydroelectric power by the Flood Control Act approved 18 August, 1941 (Public Law 228, 77th Congress, 1st session). The Norfork project was authorized by the 1938 Flood Control Act with a provision for providing penstocks. This act was modified in 1941 to provide power generation facilities under the 1941 Flood Control Act. See Page 1-1 of the 1966 Bull Shoals, Norfork, Water Control Manual for more details.

The Reservoir Regulation Manual for Bull Shoals and Norfork Reservoirs, Appendix III to the Master Manual for Reservoir Regulation, was originally submitted to the Office, Chief of Engineers, by letter dated 28 December 1955. Appendix III was revised to include Table Rock Dam and submitted to the Office, Chief of Engineers, by letter dated 17 April 1961. Appendix III was again revised to include Beaver Dam and submitted to the Office, Chief of Engineers, by letter dated 31 December 1963.

3-02. Planning and Design. The Flood Control Acts of 1938 and 1941 authorized the construction of Norfork and Bull Shoals dams, respectively. A series of design memorandums and reports associated with the planning and construction of the dams resulted from these acts. The reports covered foundation explorations; stilling basins; spillways and embankments; geology at the dam sites; real estate acquisition; relocations of roads, utilities, and cemeteries; and hydropower facilities. A listing of design memorandums and related manuals and reports is provided in Table 1-01 (pages 1-3 through 1-4).

At the time of design of the Bull Shoals and Norfork projects, the 1927 flood (which was the maximum known) was used as the project design flood. Hydrographs of the project design floods at Bull Shoals and Norfork are shown on Plates 7-16 and 7-18, respectively. Statistics for the spillway design floods for Bull

Shoals and Norfork are given in the Pertinent Data. Hydrographs for spillway design floods for Bull Shoals and Norfork are shown on Plates 7-17 and 7-19, respectively.

3-03. Construction. Following the Flood of 1937, Congress enacted the Flood Control Act of 1938 which approved the White River Basin comprehensive plan for flood control and other purposes. In 1940, construction of Norfork Dam began. With the declaration of war in December 1941, work on civil projects was suspended. However, Congress then authorized the installation of hydroelectric power equipment at Norfork making it the Little Rock District's first war project and construction continued. At the same time, Congress also authorized Bull Shoals Dam for construction and power generation, but the war delayed the construction.

In 1946, construction began at Bull Shoals, while filling of the power pool began in July 1951. The construction of Bull Shoals placed Ozark Beach Dam and power plant (which are privately owned) within Bull Shoals' flood control pool. In 1954 a retaining wall was constructed 7 feet downstream of the Ozark Beach Dam to prevent inundation of the power facilities during high water.

A resume of construction activities for Bull Shoals Lake and Norfork Lake is presented in Table 3-01.

TABLE 3-01
RESUME OF CONSTRUCTION ACTIVITIES

Activity	Date
Norfork – Construction began	October 1940
Norfork – Filling began	June 1943
Norfork – 1st Hydropower Unit online	June 1944
Norfork – Filling ended, top of conservation pool reached	February 1945
Norfork – 2nd (final) Hydropower Unit online	February 1950
Norfork – Temporary bulkheads replaced by crest gates	November 1950
Norfork – Siphon for minimum flow	December 2012
Bull Shoals – Construction began	April 1946
Bull Shoals – Filling began	July 1951
Bull Shoals – First 2 of 4 Initial Hydropower Units came online	September 1952
Bull Shoals – Filling ended, top of conservation pool reached	March 1953
Bull Shoals – Hydropower Units 3 and 4 online	June 1953
Bull Shoals – Hydropower Units 5 and 6 online	Jan. & Feb. 1962
Bull Shoals – Final Hydropower Units 7 and 8 online	Aug. & Oct. 1963

3-04. Related Projects. Federal projects related to the Bull Shoals and Norfork water control objectives are Beaver and Table Rock Lakes on the main stem of the White River upstream of Bull Shoals Lake. The three main stem White River lakes (Beaver, Table Rock, and Bull Shoals) act as a subsystem of the overall White

River flood reduction system. The percentage of flood control storage remaining in the three lake subsystem is balanced with the percentage of flood control storage remaining in Norfork Lake when sizing the daily volume of flood reduction releases to meet the regulation point at Newport.

There are zero non-federal projects that impact the water control objectives of Bull Shoals and Norfork Lakes, but some power projects built in the basin include Ozark Beach Dam at Powersite, Missouri and the Independence County hydropower retrofits of three early twentieth century locks and dams on the White River near Batesville, Arkansas. Ozark Beach Dam is located between Table Rock and Bull Shoals and was completed in September 1913. It is owned and operated by Empire District Electric Company and is basically a run of river project dependent on releases from Table Rock Dam to sustain power generation. On the White River downstream of Bull Shoals and Norfork, there are three former federal locks and dams on the White River near Batesville, Arkansas that were built between 1903 and 1908 and later sold to Independence County Arkansas in 1951 when navigation was determined to be unfeasible. Independence County decided to modify and fit each with a four megawatt (MW) power plant. The construction for all 3 plants was completed in 2007.

TABLE 3-02
WHITE RIVER BASIN PROJECTS

Project	River	Year Completed
Beaver Dam	White	1966
Table Rock Dam	White	1958
Bull Shoals Dam	White	1951
Norfork Dam	North Fork	1943
Clearwater Dam	Black	1949
Greers Ferry	Little Red	1962
Montgomery Point Lock and Dam	White	2005
Non-Corps Projects:		
Ozark Beach Dam/Lake Taneycomo	White	1913
Taum Sauk	Black-East Fork	1963
Independence County Hydropower Dams 1-3	White	2007

3-05. Modifications to Regulations.

a. The initial regulation plan, dated June 1952, was issued for the operation of Bull Shoals and Norfork dams. In this plan, White River flow at Newport was regulated to 25 feet (70,000 cfs) from 01 December to 15 March and 21 feet (50,000 cfs) from 15 March to 01 May at all stages in the flood pool. From

01 May to 01 December, Newport was regulated to 21 feet when flood pool stages were above the Flood Control Rule Curve. When flood pool stages were below this curve, Newport was regulated to 18 feet (40,000 cfs).

Releases were restricted to continuous (firm) power (i.e., no secondary power generation) until 3 days after the crest had passed Newport if the stage at Newport was above the applicable regulating stage.

b. Significant complaints were generated by the sustained use of the 25-foot regulating stage in the initial plan. A drought in the early 1950s led to the clearing of low lands and their conversion to cultivated land. This added pressure to lower regulating stages. This led to the second regulation plan (dated December 1955) which was similar to the 1952 plan but had a couple of significant changes.

- First, the use of the 25-foot regulating stage was limited to periods not to exceed 10 days; thereafter, a 21-foot regulating stage was used.

- Second, a provision was added for regulating to the crest of the natural rise at Newport (unmodified by the reservoirs) if it was less than the applicable regulating stage. This was subject to a minimum regulating stage of 18 feet at any time of the year.

c. A flood in 1957, continued clearing of the low lands, and a drought in the early 1960s once again created public support for lowering the regulating stage from May to November. Following the completion of the Beaver and Table Rock projects, a regulation plan (dated November 1963 and revised in October 1966) was issued for the operation of the Beaver, Table Rock, Bull Shoals, and Norfork reservoir system. Features of this plan include:

- Regulating Newport to 21 feet from 01 December to 01 May; 18 feet from 01 May to 01 June; and 14 feet (30,000 cfs) from 01 June to 01 December.

- Allowing decreased releases from Bull Shoals and Norfork to firm power, and in extreme cases, zero if a significant reduction in critical downstream flood conditions is possible. Secondary releases from these projects are to be curtailed until 6 days after the crest at Newport and released at rates that assured a continued recession to the applicable regulating stage.

- Prorating releases from Bull Shoals and Norfork to maintain an equal percent of available flood control storage in the Norfork and the Beaver-Table Rock-Bull Shoals system.

- Releases of 15,000 cfs from Table Rock when its pool is between elevations 915.0 and 920.0 while Bull Shoals is below elevation 684.0 (66%fs); and up to 20,000 cfs when between elevations 920.0 and 931.0 while Bull Shoals is below elevation 684.0 (66%fs). Both of these conditions are subject to downstream channel capacity. With Bull Shoals above 684.0, Table Rock releases are limited to maintain equal amounts of remaining flood control storage in Table Rock and Bull Shoals, subject to the minimum release required for firm power.

- Restricting releases at Beaver to firm power when more than two feet of water is stored in the flood pools at Table Rock and/or Bull Shoals. When less than two feet is being utilized at these two reservoirs, the maximum release from Beaver is 15,000 cfs less the tributary inflow between Beaver and Table Rock, again subject to downstream channel capacity.

d. In 1993, the Little Rock District (Corps) solicited volunteers from various White River interest groups to form an Ad Hoc group to discuss potential changes to the regulation plan. The White River Ad Hoc Work Group worked through several different plans before submitting a compromise plan to the Corps 3.5 years later. The Corps then evaluated the plan and determined that it was both technically sound and within its authority to implement. A recommended plan was implemented on 01 December 1998, making changes to the regulating stages at Newport. Changes at Newport included the following:

- **Between 01 December and 14 April** - Regulate to 21 feet except, if a natural rise exceeding 21 feet occurs, regulate to the lesser of the observed crest or 24 feet. Spillway or conduit releases (non-power-producing releases) will be utilized as needed to maintain a 21 feet regulating stage, but will be used to maintain a 24-foot regulating stage only when the four-lake system (Beaver, Table Rock, Bull Shoals, Norfork) flood storage exceeds 50% full. During flood operations, the total project discharge from Bull Shoals (using turbine and non-turbine releases) will approximate up to the equivalent of 10 hydropower turbines (32,000 cfs), and the total project discharge at Norfork will approximate up to the equivalent of 3 hydropower turbines (11,000 cfs), unless emergency operations are required, subject to a maximum flow of 50,000 cfs at Batesville.

- **Between 15 April and 07 May** – Regulate to 14 feet except, regulate to 21 feet from 15 April through 30 April, and 18 feet from 01 May through 14 May, IF the four-lake system (Beaver, Table Rock, Bull Shoals, Norfork) flood storage exceeds 50% full.

In addition, at the request of the Southwestern Power Administration (SWPA), and after coordination with the Corps, hydropower releases for peak power demands in excess of those limited by the 14 feet regulating stage at Newport can be made providing:

(1) Newport stage does not exceed 16 feet;
(2) Increased releases do not occur for more than 3 consecutive days; and
(3) There will be a minimum of 7 days between requests.

- **Between 08 May and 30 November** – Regulate to 12 feet except, regulate to 14 feet from 15 May through 30 November, IF the four-lake system flood storage exceeds 70% full.

In addition, at the request of SWPA, and after coordination with the Corps, hydropower releases for peak power demands in excess of those limited by the 12 feet regulating stage at Newport can be made providing:

(1) Newport stage does not exceed 14 feet;
(2) Increased releases do not occur for more than 3 consecutive days; and
(3) There will be a minimum of 7 days between requests.

Note: In the event of a declared power emergency, regulating stages may be exceeded, on a case-by-case basis, according to the existing Memorandum of Understanding (MOU) between the SWPA and the Corps (see Exhibit B).

e. Another consideration to the regulation plan is the downstream cold water fisheries. Historically the White River provided a thriving warm water fishery. Construction of the hydropower projects and their associated cold water releases forced a need for a change. Since the water temperatures regime downstream of the hydropower projects changed the most drastically, downstream hatcheries were built at Table Rock, Norfork, and Greers Ferry to supply trout stock for a cold water "put and take" trout fishery in the White River. Initially it was thought that the power releases could sustain the cold water temperatures, but experiences in the 1950s and 1960s proved that additional releases would be required. During periods of lower power release in the summer, downstream temperatures rise to critical levels. Various minimum release plans were tried in the 1950s and 1960s, with each plan increasing the volume of daily releases. In the early 1970s, the minimum release plan was again increased at all the multipurpose lakes. Bull Shoals and Norfork releases were increased more than the other projects.

f. The White River Basin, Arkansas Minimum Flows Report and Final Environmental Impact Statement (2008), provides documentation in support of improved minimum flows for the benefit of tailwater fisheries below Bull Shoals and Norfork lakes. Bull Shoals Lake changes include the reallocation of five feet of flood control storage for the minimum flows release of 800 cfs. The minimum flow release of 800 cfs includes leakage and powerhouse station service units releases in addition to the minimum flow release from one of the main turbines. The top of conservation pool was raised five feet from elevation 654.0 to 659.0, and the top of the May through July seasonal pool for water temperature releases was also raised by five feet from elevation 657.0 to 662.0. The top of the flood control pool remains at the existing elevation of 695.0. The minimum flows releases are made through one of the main turbines, so no new release facilities were required. Norfork Lake changes includes the reallocation of 3.5 feet of storage to be evenly divided (50:50 split) between the conservation and flood control pools to provide for the minimum flows release of 300 cfs. A siphon system has been constructed at the dam and is operated in concert with the existing powerhouse station service unit as discussed in Section 2-03.h to provide the minimum flow. The minimum flows release of 300 cfs includes leakage, powerhouse station service unit releases, Norfork hatchery releases, and the minimum flow release from the siphon. The top of conservation pool is now 1.75 feet higher at elevation 553.75, and the top of the May through July seasonal pool for water temperature releases has also been raised by 1.75 feet from elevation 555.0 to 556.75. The top of the flood control pool remains at the existing elevation of 580.0. The Arkansas Game and Fish Commission (AGFC) had the responsibility to relocate parks and roads above levels impacted by the higher conservation pools at Bull Shoals and Norfork.

3-06. Principal Regulation Problems. As the White River basin has developed, the request for operations keyed to specific interests has intensified, and at times these requests are for conflicting operations. Flood control operation and storage must be coordinated and balanced between the four reservoir system in the Upper White River Basin. High pool elevations over long durations around the lakes impact recreation and access and the local economy. Lower pool elevations also impact boat ramp access as well as water supply, hydropower generation, and minimum flow releases.

Dissolved oxygen (DO) and temperature in the tailwater below each dam are also a concern for the trout fishery. Water released from the lower zones of the lakes are cold, but may have very low DO contents. Water released from the upper zones of the lakes may have adequate DO content, but be too warm during the summer months. The minimum State Water Quality Standard is 6 milligrams per liter (mg/l) DO levels in the tailwater, which cannot always be maintained. When the tailwater DO drops below 4 mg/l during hydropower generation, recommended maximum generation rates are provided to SWPA. Hub baffles and vacuum breakers have been installed on the turbines in order to try to increase the DO in the tailrace as well. See Chapter 7, paragraph 7-07.b. (Dissolved Oxygen) for more details on problems and solutions associated with DO downstream of both dams.

[redacted] in the conduits at Norfork Dam is also a concern and limits the use of these outlet structures during normal operations. During a 1989 stilling basin inspection, the [redacted] were used to flush the stilling basin. An engineer on site witnessed potential [redacted]. [redacted] should only be used with onsite engineering supervision and monitoring. More details are contained in the Memorandum for Record dated 05 October 1989 and included in Exhibit E.

The siphon was authorized as the outlet to increase the wetted area to fulfill the requirements of Section 132(a) of the FY 2006 Energy and Water Development Appropriation Act (EWDAA) (Public Law (P.L.) 109-103). There were initially some environmental and design problems with the operation of the siphon with periods that it was out of service. During these outages, the Corps has used spillway releases or “speed/no load” turbine releases to meet the minimum flow requirement. Warm lake water temperatures and low DO levels can limit the use of these alternatives.

IV - WATERSHED CHARACTERISTICS

4-01. General Characteristics. The White River rises in the Boston Mountains southeast of Fayetteville, Arkansas, at an elevation of approximately 2,100 feet, and flows northeast into Beaver Lake (approximate river mile 609.0). From Beaver Lake, the White River continues northeasterly into Table Rock Lake (river mile 528.8) in Missouri. Here the river turns southeasterly and flows through Lake Taneycomo and into Bull Shoals Lake (river mile 418.6), a distance of approximately 110 river miles. In combination with Beaver and Table Rock dams, Bull Shoals controls a watershed of 6,036 square miles, of which 67 percent is controlled by the upstream projects. From Bull Shoals Dam, the White River continues southeast to Batesville, Arkansas (river mile 299.8) past the confluences with the Buffalo River (river mile 387.7) and the North Fork River (river mile 376.4). Norfork Dam is located on the North Fork River 4.8 miles upstream of the confluence with the White River, and controls approximately 99 percent of the North Fork River's 1,806 square mile drainage area.

From Batesville, the White River leaves the Ozark foot hills and enters the alluvial valley to the city of Newport, Arkansas (river mile 257.6). Newport is just downstream of the confluence with the Black River (river mile 264.8) which nearly doubles the size of the contributing drainage area to approximately 19,900 square miles. The alluvial plain in this area contains several levee districts which protect the urban areas. Plate 4-01 provides a map of the White River watershed. Major tributaries to the White River watershed between Table Rock and Bull Shoals dams include Beaver Creek and the Little North Fork River. Plates 4-02(a) and 4-02(b) show the local watershed map for Bull Shoals and Norfork dams, respectively.

There are no major populated areas (cities with populations greater than 50,000) near the dam that could be affected by a high pool elevation of Bull Shoals Lake. Branson, Missouri (elev. 722.0), is the city lowest in elevation and is located on Lake Taneycomo, which is affected by backwater from Bull Shoals. The other towns located near Bull Shoals Lake are well above the maximum design water surface of 703.0. There are no major population areas near Norfork Lake, and the small towns in the vicinity are located well above the maximum design water surface of [redacted]

There are several highways in the vicinity of Bull Shoals and Norfork dams. U.S. Highway 412 is south of Bull Shoals Lake and crosses the White River about 16 river miles downstream of the dam. U.S. Highway 160 crosses the lake near Theodosia, Missouri. Arkansas State Highway 7 leads to the lake, as does State Highway 178 which crosses the spillway. State Highway 125 uses the Peel Ferry Service to connect the north and south sides of the lake. U.S. Highway 62/412 crosses Norfork Lake near Henderson, Arkansas. State Highway 177 crosses the spillway on the south side of the lake, and State Highway 101 crosses near the midpoint of the lake. State Highway 201 crosses a tributary on the west side of the lake just north of Mountain Home, Arkansas.

4-02. Topography. Bull Shoals and Norfork lakes lie along the reach of the White River between the Boston Mountains to the south and the Salem Plateau to the north. This area is characterized by steep limestone valleys with karst topography which provides little or no filtration of the runoff as it flows to the White River. The lakes are located in the highlands, but downstream of the North Fork River confluence, the White River leaves the plateaus and enters the Mississippi River's alluvial plain.

4-03. Geology & Soils.

a. Regional Geology. Bull Shoals and Norfork lakes are located in the Ozark Plateau Province, within the Interior Highlands Physiographic Division. The Ozark uplift consists of flat-lying rocks consisting predominantly of limestone, dolomitic limestone, sandstone, and shale with a natural dip of less than 2 degrees southward. The Ozark Plateaus encompasses the Salem Plateau, the Springfield Plateau, and the Boston Mountain Regions. These regions are dissected by steep valleys.

b. Geology of Dam Sites. The dams are located on the Salem Plateau. The Salem Plateau is underlain by dolostone, limestones, shales, and sandstones of Ordovician age or older. The Boston Mountains make up the highest elevations within the Ozark Plateau Province, and they are capped by resistant Pennsylvanian Age sandstone. Stream systems within the province generally consist of steep headwater streams occupied by gravel size material.

1. Bull Shoals. The Bull Shoals Dam site is located in the Ozark Mountains near the southern edge of the Salem Plateau which is an extensive plain developed during the interval between Pennsylvanian and Tertiary time. The mountains in this area have been formed by erosion rather than by folding and faulting. The land was base leveled by erosion and the main topographic features were the extensive meanders of the river and its principal tributaries and occasional isolated hills which are for the most part still in existence. These hills are the remnants of the higher Springfield Plateau. This comparatively flat plain was very extensive and sloped away from the St. Francois Mountains in Missouri which form the central core of the Ozarks. The entire Ozark area was later slowly uplifted, probably in Tertiary time, and since the uplift was very gradual the major streams started cutting downward in their sinuous courses.

The river at the present time has cut its channel about 325 feet below the level of the Salem Plateau. The hilltops in the area are remarkably accordant and have a uniform elevation of slightly over 775.0 except in the cases of isolated knobs, such as Bull Shoals Mountain, which are the remnants of the higher

Springfield Plateau and rise above the general level of the Salem Plateau. In a few instances erosion, assisted by solution activity, has formed narrow saddles, the lowest of which in the reservoir has a crest elevation of [redacted]

The overburden in the floor of the valley is principally a loamy soil composed of clay, silt and sand with a few pockets of gravel. It is usually underlain by a blanket of dirty gravel from 2 to 8 feet in thickness. The overburden has an average thickness of 25 feet and a maximum thickness of about 35 feet. Bedrock is generally exposed throughout the river area and talus slopes are present at the base of both abutments.

The abutments and foundations of the dam site are composed almost entirely of bedded dolostones. The un-weathered dolostone is generally a light gray, finely crystalline, hard, dense rock weighing about 165 pounds per cubic foot and having an average compressive strength of about 25,000 pounds per square inch. It occurs in beds ranging from 6 inches to 15 feet in thickness, the average bed being about 1.5 feet thick. On the whole the dolostone is solid and undisturbed although there are occasional fractured beds such as the one exposed on the left abutment at an elevation of [redacted]. Two horizons of dolostone containing small quartz-lined vugs are present at depths of 50 and 100 feet below river level. Some mineralized fractures and vugs, containing pyrite, marcasite, and sphalerite, have been encountered at various horizons.

2. Norfork. The Norfork Dam site is located on the southern flank of the Ozark Highland, a structural dome centering in the igneous St. Francois Mountains, 200 miles northeast. The relatively flat-lying strata has been gently folded, in some cases faulted, and eroded into deeply cut valleys with narrow uplands. The rivers follow a winding course through deeply entrenched post-Eocene meanders, with bluffs on the outside and moderate slopes to the uplands on the inside of the bends. The smaller streams usually follow fairly straight, narrow valleys. Most of the flat-topped ridges in the vicinity reach heights from 400 to 450 feet above river level, and represent the post-Eocene Salem Plateau. However, Matney Knob, Shipps Knob, and a few other knobs reach an elevation of over 800 feet above river level, and are the remnants of the still older Cretaceous-Tertiary Springfield Plateau.

The soil, a residuary of weathering, is relatively thin on the hills. In some places it is exceedingly stony, due to the disintegration of the cherty limestone; in others it is very sandy with sandstone fragments and boulders; and in still other localities it is composed of red clay, formed by the decomposition of limestone, intermingled with sand and chert fragments. The rivers flow on bedrock and have cut a meandering course through the well-developed narrow floodplains. The alluvial material in these floodplains is composed principally of silt and sand and seldom exceeds 30 feet in thickness.

Geologically, the rocks are very old and have had a complex history. The Calico Rock Sandstone is of Middle Ordovician Age and caps most of the hills in the vicinity. It is a soft, friable sandstone and uncomfortably overlies the Powell Limestone formation. This sandstone varies in thickness due to depositional and erosional irregularity; the thickest outcrop observed being about 110 feet, with the average approaching 50 feet.

A feature of this area as a whole is the evidence of widespread solution activity in the limestones. Several caves are known and numerous sinkholes, springs, and solution valleys indicate the existence of subterranean caverns. Some of the caves have their major development along joints, while others have developed along disconformities and bedding planes. In many of the caves the limestone is decomposing into a red clay in situ.

4-04. Sediment. The White River is a light sediment bearing stream. Most of the watershed upstream of Bull Shoals Lake is mountainous terrain with a large percentage of the coverage in dense woods, which greatly retard erosion. Additional information on the sediment ranges established for Bull Shoals Lake and Norfork Lake is given in paragraph 5-03.

4-05. Climate.

a. General. The climate of the Bull Shoals and Norfork dams' area is marked by exposure to all types of continental North American air masses. The Arkansas highlands' weather is also influenced by the Gulf of Mexico. The area generally has hot, humid summers and cold, slightly drier winters. Snowfall is fairly common, with the highlands usually experiencing several snowfalls in the winter. Table 4-01 provides the monthly normals of precipitation for Mountain Home, Arkansas.

b. Temperature. Temperatures in the Bull Shoals and Norfork dams' area are reflected by the National Weather Service (NWS) data collected in Mountain Home, Arkansas.

- Mean Annual at Mountain Home [1/]: 58.2°F
- Maximum Recorded at Mountain Home [2/]: 114°F (12 August 1934)
- Minimum Recorded at Mountain Home [2/]: -16°F (9 December 1917)

Temperature characteristics for other areas within the White River Basin are presented in the White River Basin Water Control Master Manual.

c. Precipitation. The mean annual precipitation over the watershed is

48.05 inches[1/]. Mountain Home recorded a maximum annual precipitation of 74.54 inches in 1927 and a minimum annual precipitation of 25.97 inches in 1953[2/].

Precipitation in the Mountain Home area is well distributed throughout the year. Summer precipitation is mostly from intense, short, isolated convective cells. The winter and spring are characterized by wide spread frontal events. Significant runoff is generally produced by this type of storm. The narrow valleys, steep gradients, and comparatively large channel capacities in the highland area result in rapid and transitory movement of rises on the streams. The highest recorded 24-hour precipitation in Mountain Home was 8.96 inches on 4 September 1985[2/].

Average monthly and annual rainfall totals for Mountain Home, Arkansas are presented in Table 4-01. Average annual precipitation for the basin is shown on Plate 4-03. Snowfall averages approximately 10.5 inches per year[3/] in the highlands and can contribute to flooding during snowmelt depending on the amount and distribution over the watershed. The warm front weather in the winter and early spring, characterized by shallow surface cold air flow from the north under warm moist Gulf air results in excellent conditions for freezing precipitation. Therefore, ice storms, while infrequent, can at times be severe.

[1/] National Oceanic and Atmospheric Administration's (NOAA) 1981-2010 Climate Normals for Mountain Home 1 NNW (Baxter Co.)

[2/] www.ktlo.com, National Weather Service (NWS) Cooperative Weather Observer

[3/] NWS Little Rock

TABLE 4-01
AVERAGE MONTHLY AND ANNUAL RAINFALL
MOUNTAIN HOME, ARKANSAS [1/]

Month	Average Rainfall (inches)	Percent of Yearly Total
January	3.16	6.58
February	3.27	6.81
March	4.62	9.61
April	4.71	9.80
May	4.84	10.07
June	3.62	7.53
July	3.58	7.45
August	3.17	6.60
September	4.26	8.87
October	3.81	7.93
November	5.14	10.70
December	3.87	8.05
AVERAGE ANNUAL	48.05	100.00

[1/] - NOAA's 1981-2010 Climate Normals for Mountain Home 1 NNW (Baxter Co.)

d. Evaporation. The mean annual lake evaporation, estimated to be 72% of the recorded pan evaporation for the region, is approximately 38 inches. The estimated monthly lake evaporations at Bull Shoals Dam and Norfork Dam are given in Table 4-02.

TABLE 4-02
ESTIMATED MONTHLY PAN EVAPORATION [1/]

	Evaporation(inches)	
Month	Bull Shoals	Norfork
January	0.9	0.9
February	1.2	1.2
March	2.1	2.1
April	2.8	2.8
May	3.1	3.2
June	3.7	3.7
July	4.3	4.3
August	3.8	3.8
September	2.0	2.0
October	1.8	1.9
November	1.4	1.3
December	0.8	0.7
ANNUAL	27.9	27.9

[1/] - Based on average monthly evaporation values. Period-of-record January 1989-December 2011.

e. Wind. The prevailing wind in the region is from the southwest with a mean hourly speed of 9.6 miles per hour. The wind speed is typically slightly higher (approximately 3 mph) in the winter months. Wind generally has little impact on the operation of the dam.

4-06 Storms and Floods. The storms which cause significant flows at both Bull Shoals and Norfork dams generally are of two to five day duration and occur over a widespread area of the basin in western Arkansas and southern Missouri in the spring or late fall. Generally these are frontal storms which are stalled in the area and fed by tropical moisture from the Gulf.

a. Flood of April/May 2011. April began with warm temperatures (record highs tied/broken) and below normal precipitation. However, the last two weeks of the month featured one of the busiest periods of severe weather and flash flooding in recent memory. Roughly four dozen tornadoes were spawned, and rainfall exceeded a foot in some areas, including much of the northern part of Arkansas and the White River Basin.

The Fayetteville (15.28") and Harrison (14.73") stations both reported precipitation amounts that were nearly 11 inches in excess of the normals. A powerful, damaging severe weather event occurred on 14-15 April with straight-line winds and even a few tornadoes. More rain fell in the northwest half of Arkansas on 23-27 April, with four to eight inches common, and in some places more than a foot.

Heavy rain again fell in May, and in combination with April runoff, combined with a high Mississippi River, resulted in record crests along the lower White River. Norfork reached elevation 580.95 (top of flood pool is 580.0) on 2 May 2011, and a peak discharge of 37,960 cfs. High water threatened homes and businesses early in the month, and even forced the closing of Interstate Highway 40. The weather was not as severe as April, but May featured the strongest tornado (EF5 rating) of the year at Joplin, Missouri.

Once again Fayetteville (11.50") and Harrison (9.51") recorded precipitation amounts near double the normals. This was common throughout the northern and central parts of the state. The White River crests exceeded those seen in 2008 (see paragraph 4-06(b)). The Newport gauge crested at 34.17 feet (292,000 cfs) on 4 May 2011, eclipsing the 21 March 2008 peak of 33.87 feet (266,000 cfs), and was well above the flood stage of 26 feet. This flow has an approximate recurrence interval of 25 to 50 years.

Around 20 May, cooler temperatures settled in the area. Then a cold front came in from the Plains and resulted in additional rainfall and severe weather. On 27 May Bull Shoals set a new pool of record at 696.52 feet, 1.52 feet above top of flood pool. The total release, spillway and hydropower, was over 58,775 cfs. Norfork reached elevation 579.4 (top of flood pool is 580.0).

b. Flood of March/April 2008. Excessive rainfall occurred across the Little Rock District watersheds beginning in early March 2008 through mid-April 2008. Some areas in western, northern, and central portions of Arkansas received six months of normal rainfall in a 6-week period, making this one of the wettest March and April periods on record for much of the state. Rainfall in January and February of 2008 had caused reservoirs to be at or near their top of conservation pool levels.

As in 2011, Fayetteville and Harrison had excessive rainfalls, records show 2008 was among the top 5 wettest years on record for those cities. Some locations in the north and west had surpluses of more than 20 inches of rainfall. It was the wettest or second wettest years on record for Mountain Home and Lead Hill (near Bull Shoals Lake).

A heavy rain occurred in western Arkansas on 3-4 March 2008, resulting in flash flooding. A heavy late snowfall occurred in western Arkansas on 06 March 2008, with two to six inches of snow in most areas and isolated amounts of up to 18 inches. The melting snow over the next few days left a wet antecedent soil moisture condition that was conducive to large amounts of runoff. Beginning on 17 March 2008, two to five inches of rainfall fell in western and northern Arkansas with local depths of eight inches over two days. The mainstem White River crested at 33.87 feet at the Newport gauge with a flow of 266,000 cfs on 21 March 2008. This flow has an approximate recurrence interval of 25 to 50 years.

Rains continued periodically over the next few weeks with another large storm event between 9 -10 April. This runoff pushed lake levels higher than top of flood pools. Beaver (+1.6'), Table Rock (+2.2'), and Norfork (+1.45') all exceeded flood pools shortly thereafter. Typical hydropower release of two units at overload (115% nameplate) capacity at Norfork is about 6,900 cfs. On 10 April, the dam was releasing up to 82,000 cfs, which created flooding along the North Fork River between the dam and the upper reaches of the White River. Bull Shoals reached top of flood pool on 14 April with the lake level at 695.03 and releases of 27,270 cfs.

c. Flood of May 1990. There were heavy rains in the upper part of the White River Basin in May 1990. Also, heavy rains in the Black River Basin raised the stage at Newport. The Black River (at Black Rock, Arkansas) peaked at 30,800 cfs on 05 May 1990. While there was not significant flash flooding in the White River Basin, the combination of factors created a situation in which Bull Shoals and Norfork dams could not release floodwaters due the regulating stage at Newport.

The regulation plans in place at the time governing both Norfork and Bull Shoals operation stated that the stage at Newport must be regulated to 21 feet (48,500 cfs) between 01 December and 01 May, then 18 feet (39,700 cfs) between 01 May and 01 June, followed by 14 feet (29,100 cfs) from 01 June through 01 December.

Beginning in March, heavy rains on the Black River Basin and the White River Basin downstream of Bull Shoals raised the stage at Newport above the regulating stage. On 06 May, Newport peaked at 104,000 cfs, or roughly 28.5 feet. Although Bull Shoals and the other highland lakes were filling, they did not release due to the downstream conditions at Newport. While the flood waters slowly receded throughout May and early June, the lower regulating stage in effect limited releases from Bull Shoals and Norfork. Bull Shoals peaked at 691.44 on 09 June before finally increasing its releases on 12 June when the stage at Newport finally dropped back below 14 feet. Norfork peaked at 576.35 feet on 11 June.

d. Flood of December 1982. The White River Basin experienced high precipitation in December of 1982. Near record rainfall occurred over the upper White River Basin in early December with widespread rainfall amounts of 7 inches to over 12 inches. The river crested at Newport with a stage of 34.0 feet and a flow of 330,000 cfs on 05 December. This was the highest flow at Newport since completion of Bull Shoals Dam in 1951. Bull Shoals peaked at 679.95 on 08 January 1983 and Norfork peaked at 567.26 on 06 January 1983.

e. Floods of April 1973. The White River Basin experienced high precipitation in March and April of 1973. Over 24 inches of rainfall fell in the three month period from March-May 1973 across northern Arkansas and southern Missouri. The river was swollen throughout much of the early part of 1973, and crested at 244,000 cfs at a stage of 32.7 feet at Newport on 25 April. Bull Shoals peaked at 690.93 on 15 June and Norfork peaked at 579.03 on 10 May. Newport flows were above 50,000 cfs from 10 March through 29 May.

4-07. Runoff Characteristics. The narrow valleys, steep gradients, and comparatively large channel capacities in the highland area result in rapid and transitory movement of rises on the streams. Monthly and annual runoff volumes for the White River at Bull Shoals Dam and Norfork Dam are shown in Table 4-03. Plate 4-04 shows the mean annual runoffs for the White River Basin. Plate 4-05 shows the discharge rating curve for the White River at Newport, Arkansas. Crest travel times along the White River and major tributaries for moderate and low flows are shown on Plates 4-06 (a) and 4-06 (b), respectively. Monthly and annual inflow duration curves for Bull Shoals Lake are shown on Plates 4-07 through 4-10. The annual inflow frequency curve for Bull Shoals Lake is shown on Plate 4-11. Monthly and annual inflow duration curves for Norfork Lake are shown on Plates 4-12 through 4-15. The annual inflow frequency curve for Norfork Lake is shown on Plate 4-16.

TABLE 4-03
AVERAGE RUNOFF VOLUMES AT WHITE RIVER [1/]

Average Runoff (acre-ft)		
Month	Bull Shoals	Norfork
January	399.3	126.9
February	445.7	144.0
March	607.8	209.6
April	653.0	245.1
May	605.2	214.1
June	363.3	88.8
July	309.8	57.5
August	244.6	43.5
September	219.3	64.6

TABLE 4-03
AVERAGE RUNOFF VOLUMES AT WHITE RIVER [1/]
continued

Average Runoff (acre-ft)		
Month	Bull Shoals	Norfork
October	201.1	63.8
November	283.8	103.9
December	327.4	103.3
ANNUAL	4,660.3	1,465.1

[1/] - Period-of-record January 1989-December 2011 inflows.

4-08. Water Quality. The quality of water in the White River should remain well within the state water quality standards since water quality or low flow releases are made on a regular basis from upstream reservoirs to help maintain water quality. Both Bull Shoals and Norfork lakes are among the clearest in the country. Storage is currently allocated in each project specifically for instream flow needs (minimum flows). Although water quality releases are made seasonally, no storage is currently allocated specifically for water quality. Seasonal storage is provided to assist in making the water quality releases; however, the releases are required even if the seasonally provided storage is not captured. Minimum releases are made as hydropower releases or gate controlled releases to accommodate downstream needs for fisheries and general instream flows requirements.

Real-time measurements of dissolved oxygen (DO) and temperature are made at the following locations relative to the Bull Shoals and Norfork projects: Bull Shoals Dam Penstocks 4 & 5; Bull Shoals Lake Tailwater (State Park); Bull Shoals Lake Tailwater (Right Bank, 300 yards downstream); White River at Fairview, Arkansas; Norfork Dam Penstock 1; Norfork Siphon Intakes T-Chain (elevations 423.0, 462.7, 502.4); Norfork Lake Tailwater; White River at Calico Rock, Arkansas; and White River at Sylamore, Arkansas. These sensors are operated from April until late December to monitor the downstream trout fishery conditions during the annual low DO and high temperature season. All information is transmitted via Data Collection Platforms (DCPs) and filed in the Water Control Data System (WCDS) computer for use in water management activities.

Under qualifying conditions, water is released daily from mid-spring to early-fall to help sustain cold temperatures downstream of Bull Shoals and Norfork dams. The requirement for fishwater is specified in paragraph 7-08. The requirement specifies the volume of water to be released during a 24-hour period; however, it is generally released over a 1- to 2-hour period when it can be conveniently applied to a power demand. This timing rarely coincides with the optimum needs of the fishery. The temperature maintenance release is supplemented by a combined 2,000 dsf 3-day running average release when air temperatures at Calico Rock are forecasted at or above 85 degrees Fahrenheit and pool elevations are above 649.0 at Bull shoals and 545.0 at Norfork. This non-power purposes release (water temperature) is separate and in addition to the minimum flow requirements that are detailed in paragraph 7-03.d.

The stream channels below both Bull Shoals and Norfork have many shallow shoal areas. During warmer weather, water temperature in these shoals may reach threatening levels for the trout. Once the need for additional releases is identified, there may be as much as 24 hours of travel time before the releases reach the problem areas. There are no official provisions for providing hydropower generation releases beyond the required minimum daily and 3-day minimum combined releases, and the minimum flow releases. Any additional desired releases are not required and are at the discretion of Southwestern Power Administration (SWPA) and to the extent practicable.

Water temperature gauges are located below Bull Shoals Dam and at Fairview, Cotter, Calico Rock, and Sylamore and must be monitored daily during warm weather to identify additional release needs. There are also water temperature gauges on the North Fork River immediately downstream of the dam at Salesville and Norfork Siphon DO and temperature gauges. The releases are targeted to prevent stream temperatures from exceeding 75 degrees Fahrenheit within the fishery reach as far downstream as Sylamore.

The White River Dissolved Oxygen Committee also closely monitors the water quality of the river. The committee is comprised of representatives from the federal and state agencies concerned with the water quality in the White River. The members include: the Little Rock District U.S Army Corps of Engineers (Corps), SWPA, Arkansas Game and Fish Commission (AGFC), Arkansas Department of Environmental Quality (ADEQ), Arkansas Natural Resources Commission (ANRC), Arkansas Department of Parks and Tourism, Missouri Department of Conservation (MDC), and Missouri Department of Natural Resources (MDNR).

4-09. Channel and Floodway Characteristics.

a. Table Rock Dam Site to Bull Shoals Dam Site: This reach is approximately 110 river miles in length (RM 528.8 to RM 418.6). The river channel downstream of Table Rock Dam to the headwater of Bull Shoals Lake (approximately 23 river miles) is largely occupied by Lake Taneycomo which extends from Ozark Beach Dam (also known as the Powersite Dam) at the head of the Bull Shoals Reservoir at river mile 506.1 to approximately 1.5 miles downstream of Table Rock Dam. Ozark Beach Dam was completed in 1913 and operates as a run-of-the-river hydropower project operated by the Empire District

Electric Company in Joplin, Missouri.

The combination of high bluffs on one bank and flood plain on the other typifies the river valley in this reach. Branson, Missouri lies in this reach and continues to develop as a resort community around Lake Taneycomo. This is also the reach where the White River turns toward the south and east and re-enters Arkansas within the Bull Shoals Lake pool.

b. Bull Shoals Dam Site to Batesville, Arkansas: This reach is [redacted]

c. North Fork River Reach: The North Fork River originates in the Ozark Highlands in southwestern Missouri and flows southward to north central Arkansas where it joins the White River at river mile 376.4. The headwater area of the North Fork River is on sedimentary rock with embedded limestone formations that contain numerous springs. Stream slopes above Norfork Lake are very steep, generally 8.3 feet per mile to Tecumseh, Missouri.

d. Water Surface Profiles. Backwater computed water surface profiles through the White River are shown on Plates 4-17 through 4-19. These data reflect conditions for various discharges and starting water surface elevations that are commonly pertinent to the operation of the project. These profiles are based on water surface elevations computed with HEC-RAS backwater models developed by the Corps. Since Norfork Dam is so close to the White River, the North Fork River profiles have been omitted. Discharge rating curves for various gauges in the watershed are shown on Plates 4-20 through 4-24.

e. Revetments and Dikes. Seven spur dikes were built along the White River between Jacksonport and Bull Shoals to aid navigation in 1879 and 1880. In 1899, the River and Harbor Act authorized construction of Lock and Dams 1, 2, and 3 near Batesville. Development of the railroads resulted in limited use of Lock and Dams 1, 2, and 3 and the abandonment of the plans to construct 7 other structures. No revetments were built as a result of this shift away from the upper White River as a transportation waterway. Ten bendway weirs were built in 2008, under Section 14 authority, to protect the Batesville wastewater plant lagoons from bank erosion. These weirs were designed and constructed to direct White River flows away from the toe of the banks near the lagoons and move the channel thalwag towards the center of the White River channel.

f. [redacted]

Patrolling begins on the Padgett Island Levee when the stage at Batesville reaches [redacted] (U.S. Hwy. 167 Bridge), and it overtops at [redacted]. Patrolling begins on the Bateman Levee when the stage at Newport reaches [redacted], and the approximate overtopping stage is [redacted]. The Jackson County Levee is patrolled at stages above [redacted] at Newport, with the approximate overtopping stage of [redacted] The Newport Levee is also patrolled at stages above [redacted] at Newport, with the approximate overtopping stage of [redacted].

4-10. Upstream Structures. Two Corps White River mainstem projects, Beaver Dam and Table Rock Dam (river miles 609.0 and 528.8, respectively), control approximately 67 percent of Bull Shoals' 6,036 square mile watershed. More information on these projects is located in the White River Basin Water Control Master Manual and their individual project manuals.

Immediately upstream of Bull Shoals (and nearly within backwater limits) is Ozark Beach Dam, also known as Powersite Dam. This is the control structure for Lake Taneycomo. It is located at river mile 506.1 and is owned by the Empire District Electric Company based in Joplin, Missouri. The electric company in 2012 replaced the flash boards and [redacted] of damaged operable gates with a [redacted] across the full length of the spillway. With the gates down and a pool elevation of [redacted] the spillway is able to pass approximately 20,000 cfs with no turbine releases and 26,000 cfs with turbine releases. There is no flood control storage at Lake Taneycomo.

4-11. Downstream Structures. Norfork Lake is downstream of Bull Shoals Lake, but since it is located on the North Fork River it is not immediately affected by flood releases. Norfork Dam and Bull Shoals Dam both regulate to Newport stages.

U.S. Highway 412 is south of Bull Shoals Lake and crosses the White River about 16 river miles downstream of the spillway. Lock and Dams 1, 2 and 3 were built in 1908 but later abandoned. These three dams are located at river miles 299.5, 308.3, and 320.1, respectively, near Batesville, Arkansas. These three dams cause minor backwater flooding during small rises, but their effects are insignificant during large events. In the early 2000's, the dams were retrofitted with turbines by Independence County to produce hydroelectric power. There is one unit in each of the former lock chambers at Lock and Dams 1, 2, and 3. A small impoundment was created by the dams above each hydropower plant. The power is produced generally in a "run of river" style of operation without routinely drawing down the pools below the crest of the structures. Given that the flow rate of the White River can fall below 4,000 cfs, the turbines are capable of drawing down these impoundments below the crest of these dams and to even lower levels. For more detail on Locks 1, 2, and 3, see paragraph 4-09.b.

Independence County hydropower personnel drew down the pool at Batesville on 01 June 2012 to clean out the hydropower intake. It appears that proper coordination efforts were not taken and serious impacts were narrowly avoided. Both the Batesville and Southside municipal water intakes were almost de-watered and local irrigation pumps along the river cavitated. While the basin was experiencing a serious drought, the SWPA was conserving water in Bull Shoals and Norfork Lakes and releases were held to low levels. As a result, the flow rate of the White River at Batesville was in the 2,000 to 3,000 cfs range. As the pool was lowered, the stage of the Batesville gauge dropped below 3 feet. Many misunderstood the situation having never seen the pool at Batesville drawn down this low and most thought some Corps actions were to blame. The White River system engineer made some quick coordination with SWPA of additional power generation from both Bull Shoals and Norfork. The pools were recovered the following day with routine generation and the cooperation of the Independence County Hydropower personnel. The run-of-river Independence County hydro plants can be contacted at the following numbers: Independence County Hydro 870-251-2223; John Stacy, Project Manager 870-613-7231.

4-12. Economic Data.

a. Population. The population by states and principal cities in the White River Basin is contained in the White River Basin Water Control Master Manual. They are taken from the United States Census figures available at the time of publication. The population of counties adjacent to or immediately downstream of Bull Shoals and Norfork Dams are shown in Table 4-04.

TABLE 4-04
POPULATION OF COUNTIES IN THE
VICINITY OF BULL SHOALS DAM AND NORFORK DAM

County	1970 [1/]	1980 [1/]	1990 [1/]	2000 [1/]	2010 [1/]	Percent Change 2000-2010
Baxter, AR	15,319	27,409	31,186	38,386	41,513	+8.1
Marion, AR	7,000	11,334	12,001	16,140	16,653	+3.2
Boone, AR	19,073	26,067	28,297	33,948	36,903	+8.7
Fulton, AR	7,699	9,975	10,037	11,642	12,245	+5.2
Izard, AR	7,381	10,768	11,364	13,249	13,696	+3.4
Stone, AR	6,838	9,022	9,775	11,499	12,394	+7.8
Howell, MO	23,521	28,807	31,447	37,238	40,400	+8.5
Ozark, MO	6,226	7,961	8,598	9,542	9,723	+1.9
Taney, MO	13,023	20,467	25,561	39,703	51,675	+30.2

[1/] - U. S. Bureau of the Census, Census of Housing and Population.

b. Agriculture. The primary crops in the White River Basin are corn, rice, and soybeans. They are primarily grown in the Coastal Plain bottomlands. Livestock production is also a major economic value in the region, and principally in the Ozark Plateaus regions where Bull Shoals and Norfork Dams are located. Similarly, timber production is a significant industry in the Ozarks. Due to the nature of the flood control lakes and the fact that flowage easements surround the lakes to their maximum flood pool, only the acreage devoted to each crop and the approximate annual value of areas downstream of the dams are included in Table 4-05.

TABLE 4-05
ANNUAL VALUE OF CROPS

	Baxter County	Boone County	Marion County	Fulton County	Izard County	Stone County
Geographic Area (acres)						
County Area	354,790	378,355	382,528	395,622	371,635	388,218
Land in Farms	103,255	283,879	143,272	249,516	241,662	164,113
Cropland Harvested	12,076	36,288	14,668	24,228	20,167	21,535
Timber	221,101	173,220	213,856	206,581	225,537	332,188
Revenue (in millions)						
All Crops	$0.7	$1.7	$0.6	$1.6	$1.0	$1.3
All Livestock	$34.1	$87.3	$32.2	$29.1	$38.8	$52.6
Other Farm Income	$1.6	$8.8	$1.7	$2.9	$2.1	$2.9
Timber (delivered value)	$1.1	$0.8	$1.9	$0.4	$3.4	$6.3

c. Industry. A brief description of the industrial and commercial activities in the White River Basin in Arkansas is contained in the White River Basin Water Control Master Manual. Major industries in the area include: poultry production, lumbering, mining, processing of farm products and natural resources, and tourism. A significant portion of the livestock estimates in Table 4-05 are from broilers and turkeys. While the White River is used for transporting goods and commodities, the ports only extend upstream as far as Newport, Arkansas.

d. Flood Damages. Prior to development of the extensive flood control system in the upper reaches of the White River Basin, frequent flooding caused extensive property damage and occasional loss of life. Since the construction of the projects, the damage caused annually in Arkansas has been drastically reduced. Through fiscal year 2011, the White River Basin reservoirs and levees under control by the Corps have prevented $1.13 billion in damages ($959.7 million for the reservoirs and $170.1 million for the levees).

In fiscal year 2011 alone, the White River Basin flood control system within the Little Rock District prevented $113.2 million in damages ($83.7 million for the reservoirs and $29.5 million for the levees). Table 4-06 shows the annual damages prevented within the White River Basin.

TABLE 4-06
BULL SHOALS AND NORFORK DAMS ANNUAL DAMAGES PREVENTED
(FY 2002 THROUGH FY 2011)

	BULL SHOALS		NORFORK	
Fiscal Year [1/] (FY)	LOSSES PREVENTED IN FY	CUMULATIVE LOSSES PREVENTED	LOSSES PREVENTED IN FY	CUMULATIVE LOSSES PREVENTED
Pre-2002	n/a	$152,026,800	n/a	$49,635,700
2002	$5,153,200	$157,180,000	$1,460,400	$51,096,100
2003	$1,360,900	$158,540,900	$475,200	$51,571,300
2004	$23,075,000	$181,615,900	$5,330,100	$56,901,400
2005	$3,022,600	$184,638,500	$1,073,000	$57,974,400
2006	$2,312,300	$186,950,800	$154,700	$58,129,100
2007	$3,032,800	$189,983,600	$1,243,900	$59,373,000
2008	$25,307,700	$215,291,300	$6,265,000	$65,638,000
2009	$10,231,900	$225,523,200	$2,718,700	$68,356,700
2010	$7,364,000	$232,887,200	$3,176,000	$71,532,700
2011	$35,108,000	$267,995,000	$9,269,000	$80,802,000

[1/] - The Fiscal Year is from October through September.

e. Recreation. Upper White River Basin recreation has become a vital part of the area's economy, in attracting both tourists and the retirement population. The Corps has developed several parks around both lakes (Plate 2-05 (a) and Plate 2-05 (b)). These parks offer public use areas that include picnicking and camping facilities, boat launching ramps, and swim beaches. A listing of lake elevations that impact public use facilities is given in Tables 3-03 and 3-04. Also located on the lakes are commercial boat dock concessions where boat rental, boat storage, and other recreational supplies are available. Based on Corps information for 2013, the most common recreation uses at Bull Shoals Lake and Norfork Lake are recreational fishing, camping, sightseeing, boating, swimming, water skiing, and picnicking.

V - DATA COLLECTION AND COMMUNICATION NETWORKS

5-01. Hydrometeorological Stations.

a. Facilities. The Little Rock District Corps of Engineers (Corps), the National Weather Service (NWS), and the Arkansas and Missouri offices of the U.S. Geological Survey (USGS) cooperate in the collection and dissemination of hydrologic data in the Upper White River Basin. The Cooperative Stream Gauging Program is discussed further in paragraph 9-02.c. Tables 5-01 and 5-02 present a listing of the gauging stations and the parameters they measure pertinent to Bull Shoals Lake and Norfork Lake, respectively. The primary means used in transmission of data is the Data Collection Platform (DCP). DCPs are owned, operated and maintained by both the Corps and the USGS. The locations of key stream discharge stations and rainfall reporting stations within the White River Basin are shown on Plate 5-01. Data from the DCPs are relayed via the Geostationary Orbiting Environmental Satellite (GOES) to the Wallops Island, Virginia downlink and into the National Oceanic and Atmospheric Administration (NOAA) computer. The data are processed and then retransmitted over the Domestic Satellite System (DOMSAT). Data are received at the Little Rock District Office by the Data Acquisition Server (DAS), which is part of the Water Control Data System (WCDS) network. The data are processed and stored in data files on the WCDS server for use by the Reservoir Control Section (RCS) in routine and emergency water management activities.

b. Reporting

1. Real-time data from the NWS rainfall stations are reported by observers to the NWS. The reports are then obtained by the RCS from a NOAAPort ground receive station. In 1999 the Automated Field Observation Service (AFOS) was replaced with the NOAAPort satellite system for disseminating data. The NOAA Advanced Weather Interactive Processing System (AWIPS) Network Control Facility (NCF) sends thousands of types of data each day over this signal consisting of items such as observer and automated rainfall reports, river summaries and forecasts, flood warnings, severe weather statements, graphical display of weather patterns and precipitation, and point source DCP environmental data from the NOAA Data Collection System (DCS) Automated Processing System (DAPS). The NOAAPort is the primary data link between the Corps and the NWS. In addition to NWS rainfall data, the Corps stream gauging stations are also equipped with tipping bucket rainfall gauges that automatically transmit via DCP. These hourly data values are received by the WCDS at one-hour intervals. Rainfall data from the stream gauging stations are used as an early indicator of rainfall amounts and timing.

2. River stages, headwater and tailwater, turbine releases at Bull Shoals and Norfork Dams and siphon data at Norfork are collected and reported via [redacted] at these stations are furnished by and maintained by the Corps or USGS to assure reliable transmission of real-time data. The [redacted]. The USGS operates and maintains the river stage stations under the Corps/USGS Cooperative Streamgage Program. Tables 5-03 and 5-04 show the pertinent USGS streamflow gauging stations for Bull Shoals and Norfork projects, respectively. Hourly data are normally received at 1-hour transmission intervals from all stations. At some locations random transmissions are allowed in response to sudden changes in water surface measurements. Spillway and conduit gate openings are [redacted].

TABLE 5-01
BULL SHOALS LAKE BASIN GAUGING STATIONS AND PARAMETERS

		Parameter Measured						
Station	Type	Stage	Precip	Headwater	Tailwater	Temp	DO	Turbine Release & Generation
[redacted]	[redacted]	[redacted]	[redacted]					
[redacted]	[redacted]	[redacted]	[redacted]					
[redacted]	[redacted]	[redacted]	[redacted]					
[redacted]	[redacted]	[redacted]						
[redacted]	[redacted]		[redacted]	[redacted]	[redacted]			[redacted]
[redacted]	[redacted]					[redacted]	[redacted]	
[redacted]	[redacted]					[redacted]	[redacted]	
[redacted]	[redacted]					[redacted]	[redacted]	
[redacted]	[redacted]					[redacted]	[redacted]	

[redacted] Owned and operated by the Arkansas USGS.
2/ - Owned and operated by the Missouri USGS.
3/ - Owned and operated by the Corps.

TABLE 5-02
NORFORK LAKE BASIN GAUGING STATIONS AND PARAMETERS

		Parameter Measured							
Station	Type	Stage	Precip	Head water	Tailwater	Temp	DO 4/	Turbine Release & Generation	Siphon Discharge (cfs)
[redacted]	[redacted]	[redacted]							
[redacted]	[redacted]	[redacted]							
[redacted]	[redacted]		[redacted]	[redacted]	[redacted]			[redacted]	
[redacted]	[redacted]					[redacted]	[redacted]		
[redacted]	[redacted]					[redacted]	[redacted]		
[redacted]	[redacted]					[redacted]	[redacted]		
[redacted]	[redacted]					[redacted]	[redacted]		[redacted]
[redacted]	[redacted]					[redacted]	[redacted]		
[redacted]	[redacted]					[redacted]	[redacted]		
[redacted]	[redacted]	[redacted]				[redacted]			
[redacted]	[redacted]					[redacted]			

[redacted] Owned and operated by the Arkansas USGS.
2/ - Owned and operated by the Missouri USGS.
3/ - Owned and operated by the Corps.
4/ - Dissolved Oxygen

TABLE 5-03
STREAMFLOW GAUGING STATION DATA (BULL SHOALS)

Station Number	Station Name	Drainage Area (square miles)	Streamflow Period of Record		Discharges for Period of Record		
					Max	Min	Avg
			From	To	cfs		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

TABLE 5-04
STREAMFLOW GAUGING STATION DATA (NORFORK)

Station Number	Station Name	Drainage Area (square miles)	Streamflow Period of Record		Discharges for Period of Record		
					Max	Min	Avg
			From	To	cfs		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

3. The rainfall, project data, and river stage data from the above sources are automatically processed and stored in data files within the [redacted] and used by the [redacted]. Once in these files, the data are then utilized for checking project status, defining basin conditions, forecasting river flows, and disseminating information to other Corps elements. Data from these files serve as a historical record of stages and discharges from which Reservoir Control functions are carried out. The data are stored in two separate databases. The current production database is Data Storage System (DSS) developed by the Corps of Engineers Hydrologic Engineering Center (HEC) at Davis, California. Transformation, validation, generation of reports, and

manual data entry which utilize the DSS database are performed using computer software programs also developed by HEC. Unchecked, raw data are also being stored in the Corps Water Management System (CWMS) Oracle database. The CWMS is an Enterprise level system that represents the next generation of software and hardware for Corps of Engineers water management functions. Implementation of this system is currently taking place. In time, all Water Management functions will be migrated to CWMS.

c. Maintenance

1. As part of the FC-16 observer network program in the National Corps/NWS Cooperative Program, the NWS rainfall stations that provide the bulk of rainfall data are maintained by NWS personnel. The Corps provides funding by interagency transfer to the NWS to help support the cost of operation of the system. The funding is provided through the National Corps/NWS Cooperative Program. Any problems detected within the program from a NWS Cooperative Program station or observers are reported to the NWS Weather Forecast Office (WFO) or NWS River Forecast Center (RFC). Each WFO and RFC has a specific geographical area for which they are responsible. In the Little Rock District that includes WFOs: Little Rock (LZK), Springfield (SGF), Tulsa (TSA), Shreveport (SHV), Memphis (MEG), and Paducah (PAH). The Lower Mississippi River Forecast Center (LMRFC) forecasts the White River.

2. [redacted] The funding for maintenance of USGS gauges is provided through interagency funding with the Corps/USGS.

5-02. Water Quality Stations.

a. Facilities

1. Real-time measurements of temperature and dissolved oxygen (DO) are made at Bull Shoals Dam in Penstocks 4 and 5, at two locations in the tailwater just below the dam and at Fairview on the White River downstream of the dam. Measurements at Norfork are made at each siphon intake, Penstock 1, at the siphon discharge, and at two locations in the tailwater below the dam. These gauges are in the immediate tailwater, one on the left bank and one on the right bank, of the dam and are used for operational decisions related to DO. All of these gauges are operated from May until late December to help monitor downstream trout fishery conditions during the annual low DO season. Additional temperature sensors are located at Calico Rock and Sylamore on the White River, and are operated year-round to monitor water temperatures in the put and take trout fisheries. All water quality information is transmitted via DCP and stored in the WCDS server for use in water

management activities. Tables 5-01 and 5-02 provide a list of the gauging stations and parameters that are measured at each site.

2. In addition to real-time data collection, approximately twenty DO profiles, distributed across the five lakes in the White River system, are collected by the USGS during low DO season, typically June through December. The number of profiles was reduced by about 40% in FY12 due to budget constraints. Of the twenty DO profiles, eight to ten are taken at Bull Shoals and Norfork as conditions warrant. These profiles are used to quantify the depletion of oxygen in the hypolimnion and to estimate the DO concentration entering the penstocks in the coming weeks. The profiles are taken at a point approximately 1,000 feet upstream of the dam. This is generally in the area of the log boom. Readings of temperature, specific conductance, DO, and pH are made at depth intervals of 10 feet. At points where a parameter is changing rapidly, a smaller interval is used. In addition to the profile, a monthly measurement is made below the dam, preferably while turbine releases are being made.

b. Reporting. Water quality data are stored and available from the U.S. Environmental Protection Agency (EPA) and USGS, via the STORET and WATSTORE data files, respectively, and published in the USGS Water Resources Data annual publication for Arkansas. Water quality data may also be obtained from the Arkansas Department of Environmental Quality (ADEQ).

c. Maintenance. Maintenance of water quality instrumentation is the responsibility of the agency involved in collection of the data.

5-03. Sediment Stations. Sediment ranges were established in each of the White River reservoirs at the time of construction. The inflow to the White River reservoirs has not historically had a major sediment load; therefore, initial sediment ranges for the lakes were established as index ranges to be surveyed only on a spot basis every 10 years unless a sedimentation problem was identified. Thus far, no major sediment deposits have been identified with the sedimentation surveys. Therefore, many of the ranges have never been resurveyed.

There are 86 sediment ranges at Bull Shoals Lake. Of these, 38 ranges are on the mainstem and 48 are located on tributaries. There are 72 sediment ranges at Norfork Lake. Of these, 34 ranges are on the mainstem and 38 are located on tributaries. Plates 5-02 and 5-03 show the locations of the ranges at Bull Shoals and Norfork lakes, respectively. The Hydrology and Hydraulics Section personnel implemented a DSS database for all of the sediment ranges for all projects in the District in 1997. This database simplifies the analysis of the data and determination of possible sedimentation problems. The Operations Project Manager (OPM) inspects all monuments connected to the sediment ranges at least once a year. The Hydrology and Hydraulics (H&H) Section of the Corps coordinates with the Survey and Data Section to ensure that the ranges are re-surveyed as needed depending on their location, sedimentation rates, and available funding.

5-04. Recording Hydrologic Data.

a. Project Data.

1. At Bull Shoals and Norfork Dams all project data are collected and reported by a system known as the [redacted] The system consists of an interactive display terminal with interfaces to communicate with monitoring equipment, record it internally, and transmit the required data via the satellite system at its designated time.

At Bull Shoals Dam, headwater and tailwater elevations are read from digital [redacted] and precipitation is read from a tipping bucket rain gauge. In addition, values from the powerhouse [redacted] system programmable logic controller (PLC) are collected via a [redacted]e. The values monitored from the PLC ar [redacted]

At Norfork Dam, headwater and tailwater elevations are read from digital [redacted], and precipitation is read from a tipping bucket rain gauge. In addition, values from the powerhouse [redacted] system PLC are collected via a [redacted] The values monitored from the powerhouse PLC are [redacted] The values monitored are siphon intakes 1-3 DO, siphon discharge DO, siphon intakes 1-3 water temperature, siphon discharge water temperature, and siphon discharge in cfs.

Data collected by the [redacted] are automatically transmitted to the [redacted] every hour. These data are stored for approximately 180 days on the [redacted]. Upon receipt of that data, the hourly values are decoded into engineering units and written to a temporary (26-day database) DSS file identified as [redacted] on the [redacted]. The data in the [redacted] file is checked and corrected by regulation personnel as necessary for quality control. The corrected hourly data and processed daily parameters are then moved into the respective project historical DSS files, identified as [redacted] and [redacted] for archiving. Data not available via [redacted] such as mean daily nonpower release and evaporation, are manually entered in the project DSS file.

2. The data recording system described above was developed around the automated data system known as the [redacted] Development began in March 1987 and historical data, where available, have been added to the files to

provide a complete historical record for the project data.

3. The project office is responsible for maintaining records of gate settings, time of gate changes, and the headwater and tailwater elevations at the time of change.

b. River Station Data. Hourly stage data from the White River and the tributaries identified in Tables 5-01 and 5-02 are received via [redacted] and processed into the DSS file identified as [redacted] described above. Additionally, hourly discharge data are determined from the stage data via a stage-discharge rating table and written to [redacted]. After the data are checked and corrected, hourly stage and flow data are archived into a DSS file identified as [redacted]. In addition to these [redacted] computer files, some going back as far as 1940, the USGS maintains a permanent hard copy file of some of these stations within their station reporting procedures. Other than the data contained in these computer data files, Reservoir Control has no permanent records of these stations.

c. Precipitation Data. The [redacted] file stores precipitation data from the [redacted] stations (Corps and USGS operated). This hourly [redacted] rainfall is transferred from [redacted] to another DSS file, [redacted], after being checked and corrected by regulation personnel for quality control. After one year, this file is archived and renamed as [redacted] (where [redacted] is the last two digits of the year being archived). Precipitation data received through the [redacted] are also stored in a DSS file, [redacted]. After one year, it too is archived and renamed as [redacted] (where [redacted] is the last two digits of the year being archived). All files are kept for a period of 5 years. The NWS also records the data from its observer network permanently within its standard climatological records. Prior to archiving, both the [redacted] rainfall data are written to sequential daily files for use in real-time operations such as a rainfall contouring program.

5-05. Communication Network. [redacted]

<u>TABLE 5-05</u>
<u>BULL SHOALS AND NORFORK COMMUNICATIONS</u>
<u>TELEPHONE AND FACSIMILE</u>

Office	Telephone Number	Facsimile Number
[redacted]	[redacted]	[redacted]

5-06. Communication with the Project. [redacted]

a. Reservoir Control Section with Southwestern Power Administration. [redacted]

b. <u>Table Rock Powerhouse with Southwestern Power Administration Dispatch Center.</u> [redacted]

[redacted]

c. Reservoir Control Section with Table Rock Powerhouse. [redacted]

d. Reservoir Control Section with Bull Shoals and Norfork. [redacted]

e. Between Project Office and Others. [redacted]

5-07. Project Reporting Instructions.

a. Routine Project Reporting. [redacted]

[redacted]

[redacted]

b. Non-routine Project Reporting. [redacted]

5-08. Warnings. [redacted]

[redacted]

TABLE 5-06
EMERGENCY CONTACTS

Office	Telephone Number	Facsimile Number
[redacted]	[redacted]	[redacted]
[redacted]		
[redacted]		

[redacted]

[redacted]

[redacted]

5-09. Routine Information for Public Release. Information on current lake elevations, flow conditions, and selected stream stages are made available to the public via the Little Rock District website (www.swl-wc.usace.army.mil/). See links and descriptions below for helpful reports. Current hydropower generation conditions at Bull Shoals and Norfork dams are made available to the public via telephone (870-431-5311).

- Current conditions at all projects – http://www.swl-wc.usace.army.mil/pages/reports/remote/curcond.htm
- Real time information for lakes and stream gauges – http://www.swl-wc.usace.army.mil/pages/real_time_data.htm.
- Daily lake forecasts – http://www.swl-wc.usace.army.mil/pages/reports/remote/lakfcst.htm.

VI - HYDROLOGIC FORECASTS

6-01. General. Streamflow forecasts are needed on the White River and its major tributaries for real-time project operations, planning and scheduling future operations, and hydropower scheduling. Stage forecasts are generally needed in conjunction with high flow situations where high stages are expected to cause flooding. The coordination of daily release volumes with the National Weather Service (NWS) is highly encouraged for consistency of stage forecasts. Reservoir Control Section (RCS) routinely prepares hydrologic forecasts for the White River Basin system. These forecasts are prepared for the short-term (4-day) and the long-term (30-day) execution of the water control plan discussed in Chapter VII.

The short-term forecast is used on a day to day basis for regulating the system to meet authorized project purposes and for predicting conditions at the lakes and downstream projects, particularly during flood control operations. The coordination of daily release volumes with the NWS is highly encouraged for consistency of stage forecast. The long-term forecast is a more gross approximation of future conditions and is based on historical flows and statistical data. Long-term forecasts are used at Bull Shoals and Norfork Dams primarily for determining the time required to empty the flood control pool.

The manual “Streamflow Forecasting, White River Basin, Appendix II of the Master Manual for Reservoir Regulation, January 1956”, herein referred to as Appendix II, explains the streamflow forecasting methods in detail. Further discussion of the role of the Corps in making hydrologic forecasts for the White River System is presented in Chapter VI of the White River Basin Water Control Master Manual (WRWCMM).

a. Role of Corps of Engineers. The Little Rock District Corps of Engineers (Corps) responsibility in hydrologic forecasting is generally limited to those parameters necessary to follow the mandate for operation outlined in the White River Water Control Master Manual. Such parameters routinely forecast include reservoir inflows and releases based on observed rainfall, (water on the ground), along with reservoir headwaters and downstream river control point stages. Corps river forecasts are for internal use only, and should not be substituted for official NWS river forecasts. The Corps produces a 3-day forecast of lake levels in the White River Basin each workday. During periods while lake levels are in the flood pool, a crest or empty date is also provided. Reservoir pool elevation forecasts are available on the Corps home page on the Internet (www.swl-wc.usace/.army.mil) to notify project office personnel and other lake users of impending conditions. The pool forecast is used in determining the need for flood control releases, which impacts downstream projects and river streamflow, and can impact Southwestern Power Administration (SWPA) operations. The Corps provides the Lower Mississippi River Forecast Center (LMRFC) with pool release forecasts from Bull Shoals and Norfork Dams for use in NWS river forecasts.

b. Role of Other Agencies.

1. Role of the National Weather Service. The NWS is the federal agency charged with the responsibility of river stage forecasting (ER 1110-2-240) and issuing flood warnings and other hydrologic data to the public. Forecasts for key locations within the White River Basin are prepared by the LMRFC in Slidell, Louisiana. Five-day stage forecasts for key river stations for the White River basin are forecasted by the NWS and include: North Fork River near Tecumseh, MO; Buffalo River near Saint Joe, AR; Black River at Black Rock, AR; and White River mainstem locations at Calico Rock, Batesville, Newport, Augusta, Georgetown, Des Arc, and Clarendon, AR. These forecasts are usually available around 11:00 a.m. and are transmitted by text product and graphically via the internet through its Advanced Hydrologic Prediction Service (AHPS). Updates are prepared in the afternoon if rapidly changing conditions dictate a revision. The Corps utilizes the NWS forecasts during flood events to respond to public inquiries and as additional information for forecasting project inflows and releases.

2. Role of the Southwestern Power Administration. The SWPA is a federal agency within the Department of Energy which is responsible for the marketing of hydropower generated at the Corps dams. SWPA meets monthly with the Corps and provides an outlook on expected power to be generated in the subsequent month. Factors such as inflow, channel capacity, power plant capabilities, and pool drawdowns are taken into consideration.

6-02. Flood Condition Forecasts. Whenever runoff producing precipitation occurs in the basin, personnel in the RCS make forecasts of inflows and reservoir stages for the upper White River System Lakes including Beaver, Table Rock, Bull Shoals, and Norfork Lakes. These four lakes are operated as a subsystem to the White River system plan. All forecasts are made during normal working hours except in emergencies, when personnel are available in the RCS on a 24 hour basis. The NWS Weather Prediction Center makes quantitative precipitation forecasts (QPF) twice daily in 6-hour, 12-hour, and 24-hour increments for a total of 5 and 7 days into the future. Graphical QPF forecast maps can be found at the following site: http://www.hpc.ncep.noaa.gov/. The Little Rock District White River system engineer (system engineer) uses these forecasts for awareness of potential flooding or high runoff situations and contingency forecasting for internal use only. QPF forecasts are not used for daily operational decisions.

a. Requirements. Daily forecasts of inflow, pool elevation, and downstream channel capacity are needed for the upper White River basin to determine necessary reservoirs operations and system conditions. These time-distributed forecasts are used primarily to determine the daily volume of water to be released from the reservoirs without exceeding guidelines as described in the WRWCMM. Instructions for required releases are furnished to SWPA and the

NWS each day for the current day, and the next three days. The system engineer forecasts tributary flows for the Bull Shoals and Norfork Lake sub-basins using 6-hour unit hydrographs. Bull Shoals forecasts also must include experienced and forecasted pool releases from Table Rock. The key control points for forecasting Bull Shoals Lake are Table Rock Lake releases and the Bull Shoals pool elevation. The key control point for forecasting Norfork Lake is the pool elevation. The key control point downstream for determining the releases from both reservoirs is the White River stage at Newport, Arkansas. This downstream control point may at times move upstream to Batesville, Arkansas and downstream to Augusta, Arkansas. Moving the control point is dependent on flow rate and rainfall patterns. These forecasts are generally completed by 10 a.m. The tributaries and routing reaches used in the forecasts are shown on Plate 6-01 for Bull Shoals Lake and 6-02 for Norfork Lake.

b. Methods. Runoff-index curves and surface runoff hydrographs are used to compute river stages and intervening area inflows into each lake. The intervening flow for Bull Shoals is added to the experienced and forecasted releases from Table Rock Lake to derive the total inflow into Bull Shoals Lake. Methods for forecasting lake levels are found within Appendix II. For more detailed guidance with examples, refer to this document. Currently, all basin runoff and pool elevation calculations are computed using excel spreadsheets.

1. The forecasting of runoff from a particular event begins with the development of an average basin rainfall for each sub-basin affected. Bull Shoals Lake basin is divided into four sub-basins (shown on Plate 6-01) and Norfork Lake is divided into two sub-basins (shown on Plate 6-02). Bull Shoals four sub-basins include: Bull Creek and other tributaries into Lake Taneycomo designated as A1; Swan and Beaver Creeks designated as A2; Bear Creek designated A3; and the Little North Fork River designated A4. The two Norfork Lake sub-basins include the North Fork River and Bryant Creek above Tecumseh, MO designated A1 and the remaining area downstream of Tecumseh designated A2. Rainfall data is collected as described in Chapter V, Section 5-04.c, and RCS uses the rainfall contouring program ViewRain (to be replaced by MetVue in Fiscal Year (FY) 2015) to determine average basin rainfall amounts for each sub-basin using isohyetal methods.

2. The procedure for estimating surface runoff from rainfall is based on the observed or estimated ground water discharge at the index station at the start of a storm, the season of the year, antecedent rain that has not affected the ground water discharge, and the rainfall for which the surface runoff is sought. The method for estimating runoff for Bull Shoals sub-basins A1, A2, and A4 is determined using the surface runoff index curve for the James River above Galena initial groundwater discharge. For sub-basin A3, use the surface runoff index curve for the Buffalo River near St. Joe initial groundwater discharge. The surface runoff index curve used to estimate surface runoff for

Norfork is the initial groundwater discharge for the Piney Fork above Evening Shade. Each of these surface runoff index plates, found in Appendix II, contains step-by-step outlines for their use.

3. Surface runoff volumes are distributed by means of unit hydrographs. Table 6-01 presents the one inch runoff hydrographs for the four sub-basins for Bull Shoals Lake and Table 6-02 presents the one inch runoff hydrographs for the two sub-basins for Norfork Lake. Multiply experienced rainfall by values in the tables for corresponding runoff values. Table Rock releases must also be added to the sub-basin inflows to Bull Shoals Lake to obtain the total inflow.

TABLE 6-01
BULL SHOALS SUB-BASINS 6 HOUR HYDROGRAPH ORDINATES
FOR 1" OF RUNOFF

Bull Creek		Swan and Beaver		Bear Creek		Little North Fork R.	
A1		A2		A3		A4	
Period #	1000 cfs	Period #	1000 cfs	Period #	1000 cfs	Period #	1000 cfs
1	0	1	0.1	1	1.3	1	3.2
2	6.7	2	1.5	2	8.5	2	9.4
3	11	3	8.6	3	12.1	3	14.4
4	8.6	4	16	4	8.9	4	13
5	5.2	5	13	5	5	5	8.1
6	2.2	6	7.5	6	2.8	6	5
7	1.2	7	4.6	7	1.9	7	3.6
8	0.7	8	3.2	8	1.4	8	2.6
9	0.5	9	2.4	9	1.1	9	2
10	0.3	10	1.8	10	0.9	10	1.6
11	0.2	11	1.5	11	0.8	11	1.4
12	0.1	12	1.3	12	0.6	12	1.2
13	0.1	13	1	13	0.5	13	0.9
14	0	14	0.9	14	0.4	14	0.8
15	0	15	0.7	15	0.3	15	0.6
16	0	16	0.6	16	0.2	16	0.4
17	0	17	0.5	17	0.1	17	0.2
18	0	18	0.4	18	0.1	18	0.1
19	0	19	0.4	19	0.1	19	0.1
20	0	20	0.3	20	0	20	0
21	0	21	0.2	21	0	21	0
22	0	22	0.1	22	0	22	0
23	0	23	0.1	23	0	23	0
24	0	24	0	24	0	24	0

TABLE 6-02
NORFORK SUB-BASINS 6 HOUR HYDROGRAPH ORDINATES
FOR 1" OF RUNOFF

North Fork Above Tecumseh (A1)		North Fork Below Tecumseh (A2)	
Period #	1000 cfs	Period #	1000 cfs
1	1.6	1	7.7
2	7.3	2	21.9
3	14.6	3	14.4
4	23	4	7
5	21.4	5	4.2
6	13.2	6	3
7	8.5	7	2.4
8	6.6	8	2
9	5.5	9	1.7
10	4.7	10	1.4
11	3.9	11	1.2
12	3.3	12	1
13	2.7	13	0.7
14	2.3	14	0.5
15	1.9	15	0.3
16	1.5	16	0.2
17	1.1	17	0.1
18	0.8	18	0.1
19	0.5	19	0
20	0.3	20	0
21	0.2	21	0
22	0	22	0
23	0	23	0
24	0	24	0

4. A 2.0 foot increment elevation-area-capacity table for Bull Shoals is given in Table 6-03. A 2.0 foot increment elevation-area-capacity table for Norfork is given in Table 6-04. Area and capacity curves for Bull Shoals are shown on Plate 6-03. Area and capacity curves for Norfork are shown on Plate 6-04. The Average Groundwater Recession Curve upstream of Bull Shoals is shown on Plate 6-05. The Average Groundwater Recession Curve upstream of Norfork Dam is shown on Plate 6-06.

5. The H&H Section staff is developing a Corps Water Management System (CWMS) model for the White River System that will include operations for Bull Shoals and Norfork. The model will be available in FY 2016

for beta testing and operational for use in FY 2017. This model will provide an additional tool to the system engineer primarily for flood forecasting although the model may provide benefits for other operations.

TABLE 6-03
BULL SHOALS RESERVOIR WHITE RIVER
ARKANSAS AND MISSOURI AREA AND CAPACITY OF RESERVOIR

Elev.	Area	Volume	Elev.	Area	Volume	Elev.	Area	Volume
Feet			[redacted]			[redacted]		
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

TABLE 6-03
BULL SHOALS RESERVOIR – WHITE RIVER,
ARKANSAS AND MISSOURI, AREA AND CAPACITY OF RESERVOIR
continued

Elev.	Area	Volume	Elev.	Area	Volume	Elev.	Area	Volume
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]			

[redacted]

TABLE 6-04
NORFORK RESERVOIR – NORTH FORK RIVER,
ARKANSAS AND MISSOURI, AREA AND CAPACITY OF RESERVOIR

Elev.	Area	Volume	Elev.	Area	Volume	Elev.	Area	Volume
Feet [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

TABLE 6-04
NORFORK RESERVOIR – NORTH FORK RIVER,
ARKANSAS AND MISSOURI, AREA AND CAPACITY OF RESERVOIR
continued

Elev.	Area	Volume	Elev.	Area	Volume	Elev.	Area	Volume
Feet [redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

c. Example Forecast. A generalized example for forecasting hydrologic inflows into Bull Shoals is presented below. The original curves, tables and methods from Appendix II were used as the basis for use in spreadsheet applications. See Appendix II for more detailed guidance. A similar process for Norfork Lake can also be found in Appendix II. A general overview is detailed below.

1. Determine average basin rainfall for the current event, one value for each of the sub-basins as defined in Appendix II.

2. Use the corresponding surface runoff index curves to estimate the percent of the rainfall that will result in runoff, see Table 6-05 example for Bull Shoals Lake. For this example assume ½ inch basin average runoff from all four sub-basins and an initial Bull Shoals Lake elevation of 666.0

feet.

3. Bull Shoals is restricted to firm power release of 3,750 cfs. There is a constant release from Table Rock Dam of 6,000 cfs. Apply the ½ inch runoff to the hydrograph ordinates for the sub-basins shown in Table 6-01. Add the Table Rock release; subtract the Bull Shoals release; and convert the total inflow to a volume in acre-feet. For the initial pool elevation of 666.0 feet, add the total inflow of 249,850 acre-feet. Bull Shoals pool crest is 675.0 feet for this example.

4. For subsequent storms, the process is repeated and resulting hydrographs added in the additional 6-hour time steps.

TABLE 6-05
BULL SHOALS FORECAST SPREADSHEET

Forecast Period	Initial Inflow	Sub-basin A1	Sub-basin A1	Sub-basin A1	Sub-basin A1	Table Rock Release	6 hour Inflow	Total Inflow*
1	200	0	50	650	1,600	6,000	8,500	4,750
2	200	3,350	750	4,250	4,700	6,000	19,250	24,000
3	200	5,500	4,300	6,050	7,200	6,000	29,250	53,250
4	200	4,300	8,000	4,450	6,500	6,000	29,450	82,700
5	200	2,600	6,500	2,500	4,050	6,000	21,850	104,550
6	200	1,100	3,750	1,400	2,500	6,000	14,950	119,500
7	200	600	2,300	950	1,800	6,000	11,850	131,350
8	200	350	1,600	700	1,300	6,000	10,150	141,500
9	200	250	1,200	550	1,000	6,000	9,200	150,700
10	200	150	900	450	800	6,000	8,500	159,200
11	200	100	750	400	700	6,000	8,150	167,350
12	200	50	650	300	600	6,000	7,800	175,150
13	200	50	500	250	450	6,000	7,450	182,600
14	200	0	450	200	400	6,000	7,250	189,850
15	200	0	350	150	300	6,000	7,000	196,850
16	200	0	300	100	200	6,000	6,800	203,650
17	200	0	250	50	100	6,000	6,600	210,250
18	200	0	200	50	50	6,000	6,500	216,750
19	200	0	200	50	50	6,000	6,500	223,250
20	200	0	150	0	0	6,000	6,350	229,600
21	200	0	100	0	0	6,000	6,300	235,900
22	200	0	50	0	0	6,000	6,250	242,150
23	200	0	50	0	0	6,000	6,250	248,400
24	200	0	0	0	0	6,000	6,200	249,850

*For the total inflow, subtract Bull Shoals release of 3,750 from each period.

For Norfork Lake, use a similar method with the two sub-basins. There will be no upstream releases to add to the inflow for Norfork Lake.

6-03. Conservation Condition Forecasts. Forecasts of daily inflow, releases, and pool levels during non-flood periods will be accomplished using similar methods to periods of flooding. Estimated flows under natural conditions for the damsite and the inflow duration curves (Plates 4-07 through 4-09 for Bull Shoals and 4-12 through 4-14 for Norfork) for the damsite are considered in conjunction with NWS forecasts in making conservation forecasts for non-flood conditions. Forecasts are developed for runoff, project pool elevations, and downstream flow to assist in the operation of the White River Basin projects.

a. Requirements. The forecasts are required each workday and are used in conjunction with the guidelines of the White River Water Control Master Plan. They consist of a four-day intervening inflow forecast provided to SWPA and a three-day pool elevation forecast.

1. Hydropower. Production of hydropower at the projects must meet the constraints defined in authorizing legislation, coordinate with other project purposes, and satisfy any other requirements outlined in memorandums of understanding with other federal, state, or local agencies. SWPA, the federal power marketing agency for the Little Rock District (Corps) projects, determines the distribution of power within the limits set forth by the Corps. Power scheduled should not exceed available downstream channel capacity, safe yield of the reservoir, or cause short term over drafting of the reservoir to drop the lake level over the 7-day and 28-day limits in Exhibit B.

2. Fish and Wildlife. The system engineer must ensure daily fishwater releases are made from 1 May through 15 October to maintain the downstream cold water trout fishery. The release plan is discussed in paragraph 7-07.a.

3. Water Quality Forecasting. During the low dissolved oxygen (DO) season, typically occurring from as early as June to as late as December, the system engineer monitors in-lake and downstream DO levels, reports changing conditions, and recommends maximum generation rates based on observed downstream DO levels. The forecasts of DO concentrations in releases from the dams can be based on historic Intake DO (IDO) plots and used to anticipate impacts to hydropower generation.

b. Methods.

1. Hydropower. [redacted]

[redacted]

2. Fish and Wildlife. NWS publishes ambient air temperature forecasts at Calico Rock, Arkansas, that the system engineer uses in determining water release requirements for non-power purposes. RCS provides the air temperature forecast electronically to SWPA in the 4-day reservoir inflow forecast for use in scheduling hydropower releases to meet the fishwater requirements.

3. Water Quality Forecasting. Periodic lake profiles are taken by the U.S. Geologic Survey (USGS) to help determine the IDO and the rate of change as the low DO season progresses. Information on the collection of the profile data by USGS, and the methods for reporting and processing the data by Corps personnel can be found in Paragraph 5-02a.2. These data, in conjunction with historical data, are used to forecast IDO concentrations. Forecasts of DO concentrations in the releases from the dams are not analytically possible using mathematical methods. The best existing method to forecast DO in the short term is use of historic traces of DO and IDO and extrapolating the most recent trends.

6-04. Long-Range Forecasts. Reliable methods for long range runoff forecasts are not presently available, as they are only as reliable as long-range predictions of precipitation. Long-term forecasts are used at Bull Shoals and Norfork Lakes primarily for estimating the time required to empty flood control pools. However, based on historical data, long range inflow volume can be determined on a statistical basis. Although not a meteorologically based forecast, it is adequate to assist in the decision-making process for long term actions. The NWS also publishes an Average Monthly Weather Outlook semi-monthly that may be used as an estimate for the trend of weather patterns but should not be given too much weight for a forecast, especially for a specific point.

a. Requirements.

1. Hydropower Allocation. The Corps and SWPA meet monthly to determine the next month's power allocation. Power is scheduled within the capability of the projects and the system constraints as identified by SWPA and RCS. RCS defines power generation as a requirement during flood conditions or as available during conservation conditions.

2. Dissolved Oxygen. Long-range forecasting for IDO is helpful to RCS to provide an outlook of the power producing releases that may be used for lowering flood pools and to SWPA for planning requirements for power generation marketing.

b. Methods.

1. Hydropower Allocation. Each month Corps and SWPA representatives meet to agree on the next month's use of the hydropower projects in the system. This meeting is alternately held at the SWPA offices in Tulsa, Oklahoma and by teleconference. At this meeting, Corps personnel provide the SWPA with the amount of energy that is estimated to be available for the next month. This information consists of a minimum, maximum, and recommended amount of energy available for use. The amount of energy available is based on the existing energy in storage, time of year, forecasts of project inflows and downstream conditions, mechanical condition of the power equipment, allowable drawdown criteria, and required flood control operations. In addition to agreeing on hydropower generation for the month, the meeting's participants discuss the available energy in storage, repair/maintenance outage schedules, shortages, transmission limitation, anticipated energy needs, and any special operations requested for the next month.

2. Dissolved Oxygen. Accurate long range forecasts for DO cannot be made because of the number of variables involved. Historic plots may be used as a reasonable method to anticipate DO trends.

6-05. Drought Forecasts. During drought conditions, guidance for monitoring conditions and the actions to be taken can be found in the Drought Contingency Plan, Appendix V to the Master Water Control Manual, White River Basin, Arkansas and Missouri, October 1989.

a. Requirements. Appendix V establishes the four levels of drought, and defines the RCS responsibilities during each. The most important drought indicator for Bull Shoals and Norfork is lake elevation, which is indicative of the inflow and consumption, and the system engineer must monitor daily and report as required.

b. Methods. The two major indicators of drought are the Palmer Drought Severity Index (PDSI) and lake elevations. PDSI's are indicators of the relative dryness or wetness effecting water sensitive economies and can also indicate prolonged and abnormal moisture deficiencies. They are updated weekly and posted on the NWS Climate Prediction Center website at http://www.cpc.ncep.noaa.gov/products/analysis_monitoring/cdus/palmer_drought/ . RCS personnel monitor and maintain a listing of the monthly PDSI's for the appropriate regions in Arkansas and Missouri. In addition, lake elevations are monitored and evaluated along with the number of months that the PDSI has been below zero to determine the appropriate drought level. Using these tools, RCS personnel initiate the actions as defined in Appendix V, (see Table 6-06).

TABLE 6-06
DROUGHT LEVELS
BULL SHOALS AND NORFORK LAKES

Drought Level	PDSI less than zero Duration In months	Bull Shoals Elevation	Norfork Elevation
1	0-12	654-640	552-538
2	12-24	640-635	538-530
3	24-36	635-632	530-515
4	>36	<632	<515

VII - WATER CONTROL PLAN

7-01. General Objectives. By Congressional authorization the water control plans for Bull Shoals and Norfork dams provides for flood control, hydropower, water supply, and minimum flows. The water control plan allows for seasonal flood control releases based on conditions at downstream locations and agricultural practices along the White River. A permanent conservation pool at each project meets hydropower, water supply, and minimum flow requirements. Seasonal releases are provided for the downstream fisheries based on monitored and forecasted ambient air temperatures. In addition to the authorized purposes of the projects, the impoundments support recreation and fish and wildlife habitat. The overall water control plan also provides procedures to respond to emergency, unplanned, and planned deviations.

7-02. Constraints.

a. Bull Shoals.

1. Pool Elevations – In-Lake Concerns.

(a) Flood Control Storage. The top of flood control pool at Bull Shoals Lake is elevation 695.0. The flood control pool extends from elevation 659.0 to 695.0 (2,127,000 acre-feet) from 01 October to 30 April; from a transition line between elevation 660.0 to 662.0 up to 695.0 from 01 May to 15 May; elevation 662.0 to 695.0 (1,980,000 acre-feet) from 16 May to 15 June; from a transition line between elevation 662.0 to 661.0 up to 695.0 from 16 June to 15 July; and elevation 661.0 to 695.0 (2,029,500 acre-feet) from 16 July to 30 September. Plate 7-10 shows the Zonal Rule Curve for Bull Shoals Lake. Table 7-15 (page T7.15-1) provides detailed elevation-capacity data for Bull Shoals. The White River Minimum Flows (WRMF) project reallocation did not change the top of the flood control pool.

Beaver, Table Rock, and Bull Shoals are operated as a 3-lake subsystem. The percentage of flood storage in use in the 3-lake subsystem is balanced with flood storage in use at Norfork when practicable. The regulating plan further allows for the evacuation of Table Rock's flood pool before the flood pool at Bull Shoals is completely evacuated. Due to these features of the plan, in-lake users at Beaver and Bull Shoals experience higher pool elevations of longer duration giving the appearance that Table Rock Lake is "favored". Although high pool levels may cut off some marina primary access roads, such as the Lead Hill Causeway at elevation 672.0, all marinas have alternate means of access. Table 7-01 lists areas subject to flooding within the flood control pool at Bull Shoals Lake.

TABLE 7-01
AREAS SUBJECT TO FLOODING AT BULL SHOALS LAKE

Area	Location	Critical Elevation (feet, NGVD)
Upstream		
Lead Hill Park	Road to dock	661.0
Lead Hill Park	Causeway	672.0
Oakland	Road to swim beach	675.0
Ozark Isle	Causeway	680.0
Highway 125	Main Road	681.0
Tucker Hollow	Causeway	681.0
Downstream		
No damages expected up to bankfull conditions, 32,500 cfs.		

(b) Conservation Storage. The conservation pool at Bull Shoals Lake was originally designed for elevation 654.0. Following the September 1968 Rule Curve Study, a seasonal pool was created that raised the conservation pool as high as elevation 657.0 from 01 May through 30 September to provide storage for water temperature maintenance releases. In July 2013, the conservation pool was raised 5 feet to 659.0 as part of the congressionally authorized White Rriver Minimum Flow (WRMF) project reallocation of storage. The seasonal pool was raised to a maximum elevation of 662.0 during the May through September period as a consequence of the WRMF reallocation.

The Arkansas Game and Fish Commission (AGFC) relocated or modified public facilities at Bull Shoals Lake identified within the WRMF Study Report and Environmental Impact Statement to allow for *reasonable continued use* of *lakeside facilities* because of the reallocation of storage. Some AGFC boat launches and the associated parking areas were not modified or relocated. The minimum flow conservation pool was first captured in July 2013. Facilities that were not moved were noted by the local residents as the impacts of this higher pool were clearly illustrated. No relocation or modification of private facilities such as marinas, concessions, or docks was required. The boat ramp design elevation at Bull Shoals Lake is elevation 634.0. Most commercial dock operators, however, view lake fluctuations in excess of 10 feet from conservation pool as unacceptable.

(c) Hydropower Drawdown Limits. When the pool elevation falls to within Zones III or IV, hydropower generation cannot lower the pool more than 1.5 feet per seven consecutive days or 4.5 feet in any 28 consecutive days. However, in emergency situations, these limits may be exceeded with an approved deviation.

2. Releases.

(a) Large Flood Releases. The non-damaging channel capacity, using a combination of hydropower and non-power releases, is [redacted]. This is also limited to a total flow not to exceed 50,000 cfs at Batesville.

The highest sustained releases occurred in May 2011 with a peak discharge of over 58,600 cfs. Other significant releases include 35,500 cfs in April 2008 and 30,000 cfs in January 1985.

(b) Maximum and Minimum Generation and Turbine Releases. The power plant at Bull Shoals was designed to run at or near its rated capacity. When sufficient channel capacity is available eight units can run up to 115% of nameplate capacity to evacuate flood storage, but maintenance and overheating issues may cause the powerplant staff to restrict individual units to nameplate capacity or derate the units. Testing units in 2001 for minimum flow release of less than 10 MW did not reveal any immediate problems. For minimum flow purposes, one unit is routinely operated at generation rates at about 7 MW. Plates 7-03 and 7-04 show the turbine rating curves. Plate 7-05 shows the tailwater rating curve.

(c) Non-Power Releases with Hydropower Plant Outages. The power plant is in excess of 50 years old, and turbine and line outages are becoming more frequent. In order to meet the flood operation requirements, conduit releases and/or spillway releases may be needed to evacuate flood control storage. Spillway releases will be used first to supplement power releases. Spillway releases are limited to pool elevations above 667.0. When the pool elevation is between 659.0 and 667.0, use conduit releases to supplement power releases. A deviation from the flood control plan to limit releases to the available hydropower units is not advisable and is counter to the flood control mission.

3. Conflict Between In-Lake and Downstream Users. Stakeholders concerned with the regulation of the lake are the in-lake recreation and hydropower industries, and the downstream flood control, recreation, navigation, and environmental beneficiaries. Many users prefer lower lake levels in the fall and winter in advance of anticipated late winter and spring rains because it decreases the likelihood of high pool levels in late spring. Downstream interests desire the pools as low as possible prior to the winter and spring rains to reduce the need for sustained flood pool evacuation releases in late spring and summer. Interests diverge in the spring. The agricultural stakeholders want the water off their fields as early as possible, which requires a lower regulation stage and a correspondingly slower evacuation of the stored flood water. The in-lake recreation users want the water out of the lakes quickly, which requires a higher regulating stage, to recover access and parking at facilities and to have the pool elevation stabilized during the fish spawn in March, April, and May.

4. Coldwater Fishery Maintenance. A specified daily volume of hydropower releases is provided for the downstream fisheries from 01 May through 15 October based on the forecasted ambient air temperatures at Calico Rock, Arkansas. During this time period, daily hydropower releases are required regardless of power demand. Paragraph 7-07.a. further discusses the coldwater fishery maintenance.

5. Dissolved Oxygen. Because of low dissolved oxygen (DO), the Little Rock District White River system engineer (system engineer) may recommend reduced hydropower generation rates. The effect of low concentrations of DO on the White River trout fishery was first noticed during the fall of 1990. The cause of low DO in the turbine releases at Bull Shoals was naturally occurring lake stratification. An operational plan was developed and is reviewed annually to maintain the trout fishery during the low DO season while continuing to operate the system according to its authorized purposes of flood control and hydropower production. The plan includes blocking open vacuum breaker vents and recommending maximum generation rates to Southwestern Power Administration (SWPA). Both actions impact SWPA's generation capabilities and efficiency. Paragraph 7-07.b. further discusses operations for DO maintenance. Due to seasonal low DO levels in Bull Shoals' tailwater, the White River immediately downstream of Bull Shoals was placed on Arkansas' 2004 List of Water Quality Limited Waterbodies, commonly referred to as the 303(d) list, by the Arkansas Department of Environmental Quality (ADEQ).

b. Norfork.

1. Pool Elevations – In-Lake Concerns.

(a) Flood Control Storage. The top of flood control pool at Norfork Lake is elevation 580.0. The WRMF project reallocation did not change the top of the flood control pool. The flood control pool extends from elevation 553.75 to 580.0 from 01 October to 30 April (692,900 acre-feet); from a transition line between elevation 554.75 to 556.75 up to 580.0 from 01 May to 15 May; elevation 556.75 to 580.0 from 16 May to 15 June (624,400 acre-feet); from a transition line between elevation 556.75 to 555.75 up to 580.0 from 16 June to 15 July; and elevation 555.75 to 580.0 from 16 July to 30 September (647,500 acre-feet). Plate 7-11 shows the Zonal Rule Curve for Norfork Lake. The percent flood storage in use at Norfork is balanced, when practicable, with the 3-lake subsystem of Beaver, Table Rock, and Bull Shoals. Table 7-02 lists areas subject to flooding within the flood control pool at Norfork Lake. Table 7-16 (page T7.16-1) provides the Norfork Lake detailed elevation-capacity data.

[redacted]

[redacted]

TABLE 7-02
AREAS SUBJECT TO FLOODING AT NORFORK LAKE

Area	Location	Critical Elevation (feet, NGVD)
Upstream		
Quarry Marina Parking Lot	Quarry Park	560.0
Mallard Point Subdivision	Mountain Home	580.0
Downstream		
No damages are expected up to bankfull conditions, 10,500 cfs.		

(b) Conservation Storage. The conservation pool at Norfork Lake was originally designed for elevation 552.0. Following the September 1968 Rule Curve Study, a seasonal pool was created that raised the conservation pool as high as elevation 555.0 from 01 May through 30 September to provide storage water temperature maintenance releases. In November 2012, the conservation pool was raised 1.75 feet to 553.75 as part of the congressionally authorized Minimum Flows project reallocation of storage. The seasonal pool was raised to a maximum elevation of 556.75 during the May through September period as a consequence of the WRMF reallocation.

Raising the conservation pool at Norfork Lake resulted in a conservation pool level above the spillway crest of 552.0. The WRMF project included a bulkhead to allow for gate maintenance and repair work when the lake is at or above the spillway crest. The AGFC relocated or modified public facilities at Norfork Lake identified within the White River Minimum Flows Study Report and Environmental Impact Statement to allow for *reasonable continued use* of *lakeside facilities* because of the reallocation of storage. No relocation or modification of private facilities such as marinas, concessions, or docks was required. The recreation industry prefers that the lake level not recede below elevation 545.0, but this is in conflict with the operational range for hydropower generation. Rapidly rising pool levels at Norfork Lake cause the majority of the problems for marina operators, with fewer impacts down to approximately elevation 533.0. The Mountain Home water intake in Norfork Lake was constructed with the lowest inlet at elevation 525.0, which is 15 feet above the bottom of the conservation pool.

(c) Hydropower Drawdown Limits. When the pool elevation falls to within Zones III or IV, hydropower generation cannot lower the pool more than 1.5 feet per seven consecutive days or 5 feet in any 28 consecutive days. However, in emergency situations, these limits may be exceeded with an approved deviation.

2. Releases.

(a) Large Flood Releases. The non-damaging channel capacity, using a combination of hydropower and non-power releases, is [redacted] This is also limited to a total flow not to exceed 50,000 cfs at Batesville.

The highest sustained releases occurred in April 2008 with a peak release of 81,700 cfs. Another significant release was the 37,900 cfs release in May 2011. During the 2008 release, water leaked into the lower level of the powerhouse.

(b) Maximum and Minimum Generation and Turbine Releases. The power plant at Norfork was designed to run at or near its rated capacity. When sufficient channel capacity is available eight units can run up to 115% of nameplate capacity to evacuate flood storage, but maintenance and overheating issues may cause the powerplant staff to restrict individual units to nameplate capacity or derate the units. The system engineer should not plan to run the power plant in excess of nameplate capacity. The units are not routinely operated at rates less than 10 MW except to meet the minimum flows requirement when the siphon is non-operational. Plate 7-08 shows the turbine rating curve for Norfork Dam. A tailwater rating curve is shown on Plate 7-09.

(c) Non-Power Releases with Hydropower Plant Outages. The power plant is in excess of 50 years old at Norfork Dam, and turbine and line outages are becoming more frequent. In order to meet the flood operation requirements spillway or conduit releases may be needed to evacuate flood control storage. The system engineer may use spillway and/or conduit releases to supplement power releases. Use onsite monitoring by Hydrology & Hydraulics Engineers when using conduits. A deviation from the flood control plan to limit releases to the available hydropower capacity is not advisable and is counter to the flood control mission.

3. Siphon Operation. A 42-inch siphon was added at Norfork to make the additional 185 cfs release required for minimum flow. Construction was completed and siphon discharges were initiated in September 2013. During operational testing engineers discovered that at least two of the siphon intakes are

required to be open to obtain 185 cfs discharge without cavitation occurring. The minimum elevation that the siphon can operate without cavitation is 546.0.

The minimum flow has been made using other outlets due to operational issues with the siphon. The system engineer will coordinate preferred operational alternatives on a case by case basis.

4. Conflict Between In-Lake and Downstream Users. Stakeholders concerned with the regulation of the lake are the in-lake recreation and hydropower industries, and the downstream flood control, recreation, navigation, and environmental beneficiaries. Many users prefer lower lake levels in the fall and winter in advance of anticipated late winter and spring rains because it decreases the likelihood of high pool levels in late spring. Downstream interests desire the pools as low as possible prior to the winter and spring rains to reduce the need for sustained flood pool evacuation releases in late spring and summer. Interests diverge in the spring. The agricultural stakeholders want the water off their fields as early as possible, which requires a lower regulation stage and a correspondingly slower evacuation of the stored flood water. The in-lake recreation users want the water out of the lakes quickly, which requires a higher regulating stage, to recover access and parking at facilities and to have the pool elevation stabilized during the fish spawn in March, April, and May.

5. Coldwater Fishery Maintenance. A specified daily volume of hydropower releases is provided for the downstream fisheries from 01 May through 15 October based on the forecasted ambient air temperatures at Calico Rock, Arkansas. During this time period, daily hydropower releases are required regardless of power demand. Paragraph 7-07.a. contains further discussion of the coldwater fishery maintenance.

6. Dissolved Oxygen. The low DO operational plan is implemented annually to maintain the trout fishery during the low DO season while continuing to operate the system according to its authorized purposes of flood control and hydropower production. The plan includes blocking open vacuum breaker vents and recommending maximum generation rates to SWPA. Both actions impact SWPA's generation capabilities and efficiency. Paragraph 7-07.b contains further discussion of operations for DO maintenance. Due to seasonal low DO levels in Norfork's tailwater, the North Fork of the White River immediately downstream of Norfork was placed on Arkansas' 2004 List of Water Quality Limited Waterbodies, commonly referred to as the 303(d) list, by the ADEQ.

7. [redacted]

[redacted].

7-03. Overall Plan for Water Control. The water control plan presented herein meets the authorized purposes of flood control, hydropower, water supply, and minimum flows. It also recognizes the many other uses and demands that have arisen in the basin, particularly those based on the recreation industry. The water control plan for Bull Shoals and Norfork Lakes includes all aspects of the management of lake levels and releases from the projects. The primary aspects and those dealt with in the most detail are flood control, hydropower, and minimum flows. The water control plan also provides operational considerations for water supply withdrawals through a drought contingency plan, in-lake recreation by imposing drawdown limitations, downstream DO concerns from hydropower releases, downstream recreation interests by limiting start up generation rates, and the cold water trout fishery by the temperature maintenance release requirements.

a. Pool Zones. As authorized multi-purpose projects within the White River System, Bull Shoals and Norfork Lakes have operational objectives and controls for stored lake water that varies by zone. The zoned divisions for Bull Shoals and Norfork are shown on Plates 7-10 and 7-11, respectively, and Table 7-03 (pages T7.3-1 through T7.3-6) outlines the operational objectives and constraints for each zone.

1. **Zone I** is the "Flood Control Zone" of the project's flood pool. Primary objectives for this zone are to reduce the peak stage at downstream flood damage areas, restore flood control capability as soon as practicable, and minimize damages within the lake area as much as possible.

2. **Zone II** is the lower portion of the flood control pool and serves as the transition zone between the flood control pool and the conservation pool. When the pool is in this zone, releases are typically limited to a maximum daily volume equal to about 12 hours of full powerplant generation. When the lake has risen into Zone I, limiting the release to the equivalent volume of 12-hour rated capacity generation produces a flow taper in the river from the higher flood pool release rates to those that will occur under normal power releases in the conservation pool to reduce downstream bank caving. Zone II provides a means to control minor rises into the flood pool without initiating short duration high releases. During the summer months, Zone II is used as a seasonal conservation pool as shown on the shaded portions of the plates. This seasonal pool is operated under the conditions specified in Zone III, the flexible conservation storage zone.

3. **Zone III** is the flexible conservation storage zone and provides for energy production in excess of firm energy amounts. The zone encourages the

full use of power production potential and supplements flood control potential if available. Other water users also own a portion of conservation storage within this zone for municipal water supply and for supplying the minimum flows release.

4. **Zone IV** **i**s the storage zone for the production of firm energy. The firm energy zone contains the storage required to sustain firm energy generation through each project's drought of record.

5. **Zone V** is the emergency storage zone. In the event of a drought more severe than the drought of record, storage in this zone may be used to meet emergency situations at the discretion of the District Engineer. Refer to the Drought Contingency Plan, Appendix V, to the White River Basin Master Water Control Manual for guidance.

b. Flood Control Operations. The White River System of Reservoirs is operated using a "closing" strategy. After heavy rains occur, the outlet works are closed to capture and store the flood water in their flood pools. After the downstream peak has occurred and rivers begin receding, water is released in a controlled fashion following guidelines of the water control plan. With the dams in place, flood peaks are reduced. The dams do not eliminate the flood threat downstream. Impounded water stored in the flood pool must be evacuated in preparation for the next storm as quickly as downstream conditions allow without creating additional flooding.

The objective of the flood-control portion of the plan is to reduce flood damages downstream and reduce stage heights at key downstream gauges. This requires the storage and controlled release of floodwaters. The controlled release requires an extended duration of a pre-determined, lower flow rate than what would have naturally occurred. One of the primary beneficiaries of the flood control system is the agricultural stakeholders. Since most farming operations have varying seasonal requirements, it is possible to adjust the acceptable control point stages, or regulating stages, to roughly correspond with the agricultural seasonal requirements. Lower stages are needed in the spring for planting, the summer months for crop growth, and through the fall for harvest. Higher stages can be used the remainder of the year when much of the ground lays fallow. Bull Shoals and Norfork are operated for benefit of the White River valley.

c. Hydropower Operations. SWPA markets power from the hydroelectric projects that is in excess of the needs of the project. When releases from Bull Shoals and Norfork are required and/or allowed, they are made from the powerplant in order to meet the authorized hydropower purpose of the project. SWPA's control on the quantity and timing of hydropower releases depends on pool elevation, release rules that are in effect at Bull Shoals and Norfork, and available channel capacity at the downstream control point at Newport. Refer to the Zonal Rule Table, Table 7-03, for more information. Section 7-06 contains further discussion of hydropower operations during both flood control and conservation operations.

d. Minimum Flow Operations. Bull Shoals and Norfork have a requirement to make minimum flow releases. A Record of Decision (ROD) signed by the Assistant Secretary of the Army for Civil Works in January 2009 completed the congressionally authorized reallocation of storage for minimum flow releases, which added this as an authorized project purpose at Bull Shoals and Norfork lakes. The reallocation of storage from conservation and flood pools to provide minimum flow releases is discussed in paragraph 7-02. Minimum flow releases, whose purpose is to provide an increased wetted perimeter to enhance the habitat for the cold water fisheries in the projects' tailwaters, are made whenever the project is not otherwise generating. The flow consists of a combination of house unit releases, leakage, trout hatchery releases (at Norfork only), and a supplemental release to provide the required total minimum flow. The study shows that the reallocated storage will yield minimum flows about 80% of the time.

1. Bull Shoals. The required minimum flow at Bull Shoals is 800 cfs. The minimum flows consists of 50 cfs from the house unit, 160 cfs leakage, and 590 cfs from one of the main turbines generating at a low rate of about 6-9 MW. The required storage was captured and minimum flow releases began in July 2013. Total reallocated storage from the flood pool was 233,000 acre-feet, or 11.9%, with 121,729 acre-feet available to provide the minimum flow releases and 111,271 acre-feet used to maintain the yields of existing stakeholders with conservation pool allocations.

When SWPA ceases generation, the Corps operator selects one unit for minimum flow releases and sets the generation rate to attain the required 590 cfs. There are physical limitations to attain the 590 cfs release due to the turbine discharge rates at fixed whole MW outputs and the varying head pressure as the pool rises and falls. Actual releases in the 6 to 9 MW range vary from 600 and 650 cfs.

2. Norfork. The required minimum flow at Norfork is 300 cfs. It consists of 20 cfs from the house unit, 55 cfs leakage, 40 cfs from the fish hatchery discharge, and 185 cfs from the siphon. The transition to minimum flow operation at Norfork began in November 2012, the required storage was captured in April 2013, and minimum flow releases began in September 2013. Total storage reallocated included 38,900 acre-feet (5.6%) from the flood pool and 29,200 acre-feet (3.9%) from the conservation pool for a total of 68,100 acre-feet. Of the 68,100 acre-feet reallocated to the minimum flow, 46,219 acre-feet is available to provide the minimum flow releases and 21,881 acre-feet is used to maintain the yields of existing stakeholders with conservation pool allocations.

The siphon is automatically operated via a programmable logic controller (PLC) in the Norfork powerhouse. When generation ceases, the PLC begins siphon flow, and when generation starts up the PLC stops the siphon flow.

7-04. Standing Instructions to Damtender. See Exhibit C.

7-05. Flood Control.

a. Regulation Criteria for Bull Shoals and Norfork. The Corps regulates Bull Shoals and Norfork lakes as part of a four-lake system of reservoirs that includes Beaver, Table Rock, Bull Shoals, and Norfork. These lakes are regulated to reduce peak flood stages on the lower White River. The water control plan provides that when the flood control storage remaining in Bull Shoals is reduced to 760,000 acre-feet or less (corresponding approximately to elevation 684.0 in the pool), releases from Table Rock will be reduced to maintain equal amounts of remaining storage in acre-feet in Table Rock and Bull Shoals insofar as practicable, subject to the minimum flood control release at Table Rock, which is equivalent to firm power generation. The water control plan provides for prorating the permissible flood-control releases between the Beaver-Table Rock-Bull Shoals subsystem on the White River and the Norfork project on the North Fork River according to the percent of flood-control storage in use at the time. Plate 7-24 shows the four-lake system balance curve.

The system engineer will restrict releases from Bull Shoals and Norfork to the minimum flood control releases, which is equivalent to firm power, when the regulating stage at Newport is exceeded. The release of flood storage from Zones I and II made by Bull Shoals and/or Norfork, and the volume of their combined release is controlled by the Newport Guide Curve, Plate 7-26. The system engineer determines the size and timing of the flood control releases based upon downstream conditions at Newport. During the evacuation of flood storage, as well as during normal conservation operations, releases from the projects are routinely set to maintain the downstream regulating stage or meet other downstream constraints. Table 7-04 summarizes the criteria for regulation of releases from Bull Shoals and Norfork dams.

The system engineer adjusts releases at Bull Shoals and Norfork on the basis of unused regulating capacity up to the regulating stage forecasted two days in the future at Newport, as this is the approximate travel time from these projects to Newport. Power plant releases are used as the first priority release mechanism unless they are incapable of supporting the required release. **When the hydropower plant is incapable of releasing the volume available at the Newport gage, the system engineer will direct the use of non-power releases to fulfill the flood control release requirements.**

b. Regulating Stage at Newport. Newport is the primary regulating control point for Bull Shoals and Norfork. It was selected as a control point because it is as far downstream as flood forecasts permit positive regulation by curtailing releases to prevent combination with unregulated peak flows. The Black River (8,558 square miles) has its confluence with the White River just upstream of Newport. The travel time from the gauge at Black Rock to the gauge at Newport is about 2 days.

The Buffalo River (1,340 square miles) has its confluence with the White River upstream from Norfork Dam, and the travel time from the gauge near St. Joe is about 2 days to Newport. This is approximately the same travel time the releases from Bull Shoals and Norfork take to reach the Newport gauge. Therefore, the Newport control point allows for effective reservoir operations to prevent releases from coinciding with rises originating on the Black and Buffalo Rivers. Newport is also located at the head of a long and agriculturally important damage center which extends to Georgetown. While Newport is the designated regulation point, regulation can be shifted upriver to Batesville or down to Augusta if these locations are nearer to a localized flood damage area. It is not feasible to shift regulation further downstream as releases cannot be effectively synchronized with the uncontrolled flow over such an extended travel time.

The minimum flood control release rate is that required for generation of firm power. In extreme cases to save human life, mitigate major property damage, or if a significant reduction in critical downstream flood conditions is possible, the minimum rate may be reduced to zero by declaring a flood emergency.

In the event that flood storage is fully depleted or forecasted to be fully depleted at either project, the release from a surcharge operation may prevail over the rule curve release restrictions and channel capacities downstream from the dams.

TABLE 7-04
CRITERIA FOR FLOOD CONTROL RELEASES

Dates	Elevation	Criteria
1 December to 14 April	Any elevation in flood pool	Regulate Newport to 21 feet. If the natural crest exceeds 21 feet, regulate to the lower of 24 feet or the natural crest.
15 April to 30 April	Any elevation in flood pool	Regulate Newport to 14 feet. If the 4-lake system has 50% or more flood storage in use, regulate to 21 feet.
1 May to 7 May	Any elevation in flood pool	Regulate Newport to 14 feet. If the 4-lake system has 50% or more flood storage in use, regulate to 18 feet.
8 May to 14 May	Any elevation in flood pool	Regulate Newport to 12 feet. If the 4-lake system has 50% or more flood storage in use, regulate to 14 feet.
15 May to 30 November	Any elevation in flood pool	Regulate Newport to 12 feet. If the 4-lake system has 70% or more flood storage in use, regulate to 14 feet.
1 October to 30 September	Any elevation in flood pool	Release a minimum of firm power. Prorate flood control releases between Bull Shoals and Norfork to maintain equal percentages of available flood control storage in Norfork and the Beaver-Table Rock-Bull Shoals subsystem, insofar as practicable. Release a maximum of 32,500 cfs from Bull Shoals and 10,500 cfs from Norfork, subject to a 50,000 cfs flow limit at Batesville. Curtail secondary power generation until 6 days after the crest at Neport (secondary power releases should provide that stages above the regulating stage continue to recede until the regulating stage is reached). NOTE: In extreme cases release zero if a significant reduction in critical downstream flood conditions is possible.
1 October to 30 September	Above or predicted to exceed the top of spillway gates	Regulate to obtain the most effective flood modification with the designated surcharge to storage space.

c. Regulating Stages Versus Season. The flood-control plan for Bull Shoals and Norfork uses seasonal adjustments of regulation stages at Newport. Regulated releases are generally at much lower rates during the agricultural season. The seasonal stages are set to maximize the flood-control benefits by providing lower stages during the agricultural season and higher stages during the remainder of the year. The system engineer adjusts releases to transition to the seasonal stage within three (3) days of the change to new stage criteria. Plate 7-26 shows the stage guide curve for Newport, and Table 7-04 contains the criteria for flood control releases.

Regulating stage is a target used to size and time combined flood control releases from Bull Shoals and Norfork. These releases plus the naturally occurring runoff from the basins downstream from the dams approximate the seasonal regulating stage. When the lakes are within their conservation pools, regulating stage is used to determine the allowable maximum daily hydropower release. Plate 7-20 shows the rating curve for the White River at Newport, Arkansas. Plates 7-21 through 7-23 show rating curves at other locations on the White River.

d. Firm Power as a Flood Control Release. When flood control storage is in use, the minimum flood control release is firm power. Also termed "Firm Energy", Table 7-05 lists the minimum daily hydropower release volumes. If flood conditions warrant greater restrictions, the Corps will notify SWPA according to the guidelines set forth in the draft Operating Arrangement; see Appendix B. When restricted to firm power during the course of the day, the firm power remaining for that day is computed by prorating the number of hours left in the day.

The 1942 Basis of Design for Definite Project Report included studies that showed that the minimum flood control release was essential to continually restore flood storage even when downstream stages exceed regulating or flood stages. The impacts from the minor increase in stage from firm power are already accounted.

TABLE 7-05
DAILY FIRM ENERGY RELEASES ALLOWABLE DURING FLOOD CONDITIONS [1/]

	Allowable Daily Release	
Reservoir	Volume (DSF)[2/]	Approximate Energy (MWh)
Bull Shoals	3,750	1,352
Norfork	1,300	410

[1/] - Energy values represent the energy produced by the daily release volume with the pool at conservation level.

[2/] - On the first day of limitation in releases to firm energy, the allowable daily release is computed as the number of hours remaining in the day, at the time of notification, times the above values divided by 24. The allowable daily releases for subsequent days are taken from above.

e. Routine Regulation for Flood Control.

1. Allowable Flood Control Releases from Bull Shoals and Norfork. Releases are made from the flood control pools at Bull Shoals and Norfork according to the channel capacity available in the White River at Newport, the regulating station, as detailed in paragraph 7-05.a. When determining the total release from the dams, the system engineer forecasts the flow at Newport gauge two days in advance to allow for the travel time from Bull Shoals and Norfork. Available channel capacity is determined by the applicable seasonal regulating stage and the forecasted flow. The system engineer uses: flow from the Buffalo River using the St. Joe gauge, flow from the Black River and tributaries using the Black Rock and Poughkeepsie gauges, flow from the White River using the Batesville gauge, and any other information deemed reasonable to predict the Newport stage. [redacted] Should the official NWS river forecast differ from the Corps river forecast, the process should be repeated with a new set of forecasted reservoir releases. It is possible that the seasonal regulation stage may be exceeded during periods when releases are restricted to the minimum flood control release, the equivalent volume of firm power.

2. Newport Flow Increasing. If the lakes are in their conservation pools, Zones III or IV, and forecast to remain in their conservation pools, limit releases to a *maximum* of firm power. If the lakes are in their conservation pools, Zones III or IV, and pool forecast indicates a rise into the flood pool, Zones I or II, or when the lakes are currently in their flood pools, *target* a release equal to the minimum flood control release, which is the equivalent of firm power.

3. Newport Flow Receding. As the Newport flow recedes, it is important to increase releases in a timely manner to transition to regulation stage. The Newport stage should not fluctuate due to improperly sizing the releases. The travel time from Bull Shoals and Norfork dams is approximately 2 days, the same as the flow on the Black River at Black Rock. Travel time for the flow at Batesville to reach the Newport gauge is approximately 1 day. Primary factors in determining the two-lake total releases are: the flow at Batesville; the flow at Black Rock; the Strawberry River; and the runoff from the area between Newport, Batesville, and Black Rock. The stream flow forecasting methodology found in Appendix II to the 1956 Master Manual for Reservoir Regulation has been transferred to spreadsheets and simplified with graphical tools. A basic example follows.

(a) Secondary Power Releases Six Days after Newport Crest. During floods on the White River when the stage at Newport is above the regulating stage, no secondary power release should be scheduled until 6 days after the crest at Newport. Then, secondary power releases should be limited to maintain continuous falling stages at Newport until the regulating stage is reached; the rate for the continuous falling stage at Newport will vary based upon the hydrometeorological conditions.

(b) Allocation of Flood Releases Between the BV-TR-BS Sub-system and Norfork. The combined storage in the Beaver-Table Rock-Bull Shoals 3 lake flood control subsystem and the storage in Norfork should be kept in approximate balance by making flood control releases from the system or reservoir having the greatest percentage of flood control storage in use. Knowing the current combined storage remaining below the top of flood control pools at Beaver, Table Rock, and Bull Shoals and knowing the current pool elevation at Norfork, the reservoir from which to make the flood control release may be obtained from Plate 7-25, (Bull Shoals and Norfork Allocation of Releases). In so far as practicable, secondary energy should be generated to the full capacity of the turbines before making supplemental non-power releases to complete the total allowable release. In cases where excess power cannot be marketed or the power plant capacity is insufficient, make equivalent non-power releases to complete the total allowable release.

[redacted]

[redacted]

[redacted]

f. Flood Control Release Methods.

1. Hydropower. After hydrologic conditions are determined, the system engineer calculates the required and/or allowable releases from Bull Shoals and Norfork as described in paragraph 7-05.b. When flood control releases from Bull Shoals and Norfork are required and/or allowed, they are made from the hydropower plant as a first priority in order to meet the authorized hydropower purpose of the project. If the required release exceeds plant capacity or during periods of generator outage, non-power releases will be made to supplement the turbine releases. [redacted] See section 5-06 for a more detailed description of communications with SWPA and the Table Rock power house. The system engineer must monitor hydropower production to ensure that SWPA does not exceed the allowable daily volume release shown in Table 1, Exhibit B when the release is restricted to firm power.

2. Non-Power Releases. Spillway and/or conduit releases are made to supplement turbine releases if the required release exceeds turbine capacity. The system engineer gives instructions for spillway and conduit releases to the Bull Shoals and/or Norfork power plant maintenance superintendent, or designee. [redacted]

(a) Bull Shoals. Non-power releases required to supplement turbine releases from the Bull Shoals flood control pool should be made from the conduits when reservoir stages are below the spillway crest, elevation 667.0, and through the spillway when stages are above the spillway crest. It will be necessary to supplement spillway releases with conduit releases when the reservoir level is just above the spillway crest or to maintain the temperature of the White River below 70 degrees for trout. At such times the gates in the spillway bays adjacent to an open conduit should be closed to permit proper aeration of the conduit. The conduit gates should always be operated in fully open position. To prevent excessive use of any of the conduits, they should be operated in rotation according to Table 7-08, which shows their order of use by cycles. Conduit rating curves for Bull Shoals Dam are shown in Plate 7-01. Spillway rating curves at Bull Shoals Dam are provided in Plate 7-02.

TABLE 7-08
SCHEDULE FOR OPENING BULL SHOALS CONDUITS

[redacted]

*

[redacted]

A

[redacted]

[redacted]

TABLE 7-09
SCHEDULE FOR OPENING
BULL SHOALS SPILLWAY GATES [1/]

[redacted]	[redacted]											
	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
	[redacted]											
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

TABLE 7-10
SCHEDULE FOR OPENING
NORFORK SPILLWAY GATES[1/]

[redacted]	[redacted]									
[redacted]	[redacted]									
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]						
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
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[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

Locations	Hours
[redacted]	[redacted]

(a) Bull Shoals. [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

Revised Nov 2015

Date	6-hour Period of The Day	Estimated inflow 1,000 cfs	Table Rock Release 1,000 cfs	Accumulated inflow 1,000 cfs
[redacted]	[redacted]	[redacted]	[redacted]	[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

EXAMPLE 7-06
SPILLWAY & CONDUIT GATE OPERATION FOR NORFORK

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

g. Emergency Regulation. See Exhibit C.

h. Regulations for Mississippi River Flood Conditions. In general, operation of Bull Shoals and Norfork do not consider Mississippi River conditions, yet regulation of floods on the White River would tend to reduce the contribution of flood flow to the Mississippi River. The time of crest travel of major floods on the Mississippi River from Cairo to the mouth of the White River is about 10 days, and the travel time from Bull Shoals to the mouth of the White River is about 10 days. Therefore, considerable advance warning of floods on the Mississippi River will be required to regulate floods at Bull Shoals and Norfork directly for the Mississippi River. During critical floods on the Mississippi River, the Lower Mississippi Valley Division is furnished reports of conditions on the White River, including Bull Shoals and Norfork. Any special regulation of the reservoirs for the Mississippi River must be based on the specific combination of circumstances at the time and would require a deviation approved by Southwest Division.

7-06. Hydroelectric Power.

a. General. SWPA is the agency responsible for scheduling and marketing the hydroelectric power generated at the Bull Shoals and Norfork powerhouses. The system engineer provides guidance for hydropower releases.

b. Operation. The Outline of Regulation Criteria, Table 7-03 (pages T7.3-1 through T7.3-6), indicates the degree to which the Corps and SWPA exercise control on the size and timing of these hydropower releases. After flood conditions are forecast, the system engineer determines the extent to which curtailment of secondary power is necessary to comply with the plan of regulation and notifies SWPA. SWPA arranges the actual curtailment of generation.

1. Flood Control Pool. The flood control pool includes Zones I and II. When the lakes are in either of these zones, the Corps has absolute control on the quantity and timing of the hydropower releases. The one exception is the daily volume needed for minimum flood control release, which is the equivalent of firm power. [redacted] When in the flood control pool, the primary objective of generation is to provide releases for recovery of flood storage within the criteria given in paragraph 7-05. The system engineer will use non-power releases when SWPA notifies the system engineer that they cannot meet daily requirements. The intentional release of less than regulating stage capacity when in Zones I and II of the flood control pool requires a deviation to the Water Control Plan.

When the pool enters Zone II, flood control releases are set to the equivalent of 12 hours of the project's power plant releases when operating at nameplate capacity. Release rates, volumes, and the timing of the releases are at the discretion of the system engineer. Normal operation requirements are forwarded to the SWPA each weekday and as needed during critical flood operations.

2. Conservation Pool. The conservation pool includes all of Zones III and IV, and seasonally from 01 May to 30 September, Zone II is converted operationally into Zone III, which provides storage to offset hydropower losses during water quality releases for cooler water temperatures in the tailwater. When in conservation pool, SWPA determines the quantity and timing of the hydropower releases based on hydropower needs unless there is an overriding project need. Zone III provides storage which allows secondary generation above firm power amounts during droughts which are as severe as the project design drought. Zone IV provides storage to allow continued generation at firm power during design drought conditions. Zone V provides storage below the conservation pool for storage of sediment, as head for hydropower generation, and for emergency water supply. Its use as a reserve water source for conservation purposes is controlled by the Corps as provided in the White River Basin Drought Contingency Plan, Appendix V to the White River Basin Master Water Control Manual. Hydropower releases are established at rates which will not exceed the flood control criteria given in paragraph 7-05, and must also satisfy the water quality requirements of paragraph 7-07.

3. Constraints. Table 7-12 shows the minimum time required for Bull Shoals and Norfork powerhouses to respond to generation changes for both normal and emergency operations. An emergency operation exists when SWPA loads the plant rapidly in response to a sudden power demand that cannot be shifted to other power sources. The maximum time-loading sequence attempts to dampen the rapid tailwater fluctuation caused by a sudden onset of high-rate generation.

TABLE 7-12
BULL SHOALS AND NORFORK DAMS RESPONSE TIME CRITERIA FOR HYDROPOWER OPERATIONS[1/]

[redacted]

4. Limit of 7-Day and 28-Day Drawdowns. Table 7-13 presents project drawdown limits and applies to consecutive 7-day and 28-day periods as a moving time window. The drawdown limits apply only within the conservation pool, and the system engineer monitors the limits by maintaining records of pool elevations. The drawdown rates were adopted as a general practice to allow dock operators time to move their facilities out of the coves and into the deeper channels as the lake level falls. The limits were established after a period of extremely cold weather and heavy hydropower generation in the mid-1970s during which the lakes receded at near record rates while the docks were essentially frozen in place damaging many dock facilities. They also form a basis for the maximum recommended energy allocation presented by the Corps at the monthly power meeting. Exceeding these limits requires an approved deviation.

TABLE 7-13
MAXIMUM DRAWDOWN RATES IN CONSERVATION POOL

Project	7-Day Period Maximum Drawdown, ft.	28-Day Period Maximum Drawdown, ft.
Bull Shoals	1.5	4.5
Norfork	1.5	5.0

5. System Allocations. A monthly hydropower meeting is held on or before the last Thursday of each month to develop the hydropower operating plan for the following month. At this meeting, system and project power allocations are agreed upon for the following month. The system engineer furnishes SWD and SWPA the maximum, minimum, and recommended energy requirements for each project. Energy requirements are developed using rule-curves, drawdown limits, energy in storage, downstream hydrologic considerations, water quality requirements, and equipment outages. SWPA will provide, with input from its customers, its anticipated needs. During the meeting, an agreement will be reached on the monthly allocations at each project. Also discussed will be any special operations anticipated during the upcoming month. Once agreed upon, SWPA will schedule power production to meet the allocations. In the event that unforeseen power conditions require changes, SWPA will coordinate the change with the District prior to scheduling.

7-07. Water Quality. Water quality regulation is considered in the maintenance of the downstream cold water fishery by scheduling and monitoring releases to help maintain temperature and DO levels. Although not an authorized project purpose, the District, SWPA, and State agencies developed a plan of operation to sustain the put-and-take cold-water-trout fishery. During the period from early summer through mid-December, thermal stratification of Bull Shoals and Norfork lakes occurs that result in a temperature and DO concentration gradient from the lake's surface to the bottom. For both parameters, the gradient typically has higher values at the surface and lower values at the bottom. It is from these lower depths, where water temperatures are low and DO levels drop to near zero, that hydropower generation draws water into the penstocks. The cold water supports the fishery while the poorly oxygenated water poses a threat. No specific regulation is required for in-lake water quality, but it should be considered in any pool level drawdown. To monitor lake stratification and provide data necessary for DO computations, the USGS takes lake profiles at the log boom upstream from the penstocks from June to December. Details of the specific regulation activities for temperature and DO in the downstream areas are discussed in the following paragraphs.

a. Water Temperature. To maintain cooler water temperatures sufficient to sustain the trout fishery, this plan specifies daily volume releases for 01 May through 15 October from storage created by seasonal conservation pools. Seasonal conservation pools start on 01 May and end on 01 October. During a period when there is a need for flood control releases, there can be a three day period of lesser releases, subject to a minimum of firm energy, to transition from the conservation pool on 30 April up to the 01 May higher seasonal conservation pool. It is also allowable to make adjustments to the releases to allow a smooth transition down in the pool elevation from the end of seasonal conservation pool on 01 October to the conservation pool at the end of the required period of fishwater releases on 15 October. These transitions will be guided by engineering judgment and with consideration to the prevailing climatic conditions.

Table 7-14 shows the required release for water temperature purposes that are contained in the MOU between the Corps and the SWPA (Exhibit B). The release requirements provide a daily volume of water, which at times needs to be supplemented by additional generation. The temperature maintenance release is supplemented by a combined 2,000 dsf 3-day running average release when air temperatures at Calico Rock are forecasted at or above 85 degrees Fahrenheit and pool elevations are above 649.0 at Bull shoals and 545.0 at Norfork. This water temperature release is separate and in addition to the WRMF requirements that are detailed in paragraph 7-03.d.

The water temperature releases for the fisheries are based on forecasted ambient air temperatures at Calico Rock, Arkansas. Water temperatures need to remain below 75° Fahrenheit to support the trout. The system engineer must monitor the water temperature sensors below Bull Shoals and Norfork hydropower plants, and at Fairview, Calico Rock, and Sylamore. The releases are targeted to prevent stream temperatures from exceeding 75 degrees Fahrenheit within the fishery reach as far downstream as Sylamore when practicable. Extended periods of water temperatures above 75° Fahrenheit can be fatal. As with any dynamic system, the extent of the cold water fishery will fluctuate because these water temperature releases may not keep water temperatures below 75 degrees to Sylamore under all circumstances.

b. Dissolved Oxygen. The state standard for DO in rivers with trout fisheries is a minimum of 6.0 milligrams per liter (mg/l). The Corps strives to meet the standard through the framework and criteria for interagency cooperation and actions detailed in the White, North Fork, and Little Red Rivers Operational Action Plan for Low Dissolved Oxygen Season, to the extent reasonably possible while preserving the flood control and hydropower benefits of the project. This action plan is updated yearly; see paragraph 9-04.

When tailwater DO concentrations are at 6 mg/l and receding, as measured at the first downstream monitoring station, the turbine vents on the hydropower units are blocked open and the required power load spread across all units to assure maximum aspiration capability for the remainder of the low DO season. When tailwater DO concentrations are at 4 mg/l and receding, as measured at the first downstream monitoring station, the system engineer will determine a Recommended Maximum Generation Rate (RMGR) for the available generating units that will prevent the tailwater DO from receding below 4 mg/l if possible, and advise SWPA of the total RMGR at the project. More details of the plan, communications, and reporting requirements can be found in the White, North Fork, and Little Red Rivers Operational Action Plan for Low Dissolved Oxygen Season for the current year.

7-08. Fish and Wildlife.

a. General. Bull Shoals and Norfork lakes support in-lake and downstream fisheries that provide an important economic base for tourism. Construction and operation of the hydropower features at each dam resulted in changes to the native warm water fishery because of the cold water hydropower releases. As part of the mitigation measures for these projects, a federally funded fish hatchery was constructed at Norfork. This resulted in the development of a put-and-take cold water fishery downstream of both Bull Shoals and Norfork dams. The White River coldwater fishery extends about 78 river miles from Bull Shoals Dam to Sylamore. The trout fishery depends on cool water temperatures and sufficient DO concentrations. This can impact hydropower operations as discussed in paragraph 7-06.

b. Hatchery. The Norfork National Fish Hatchery is located below Norfork Dam and is managed by the U.S. Fish and Wildlife Service (USFW). Although there is no special reservoir regulation for the hatchery, intakes for water withdrawal were built to supply it in conjunction with dam construction to provide for approximately a 40 cfs withdrawal rate.

c. White River Fisheries Partnership. The White River Fisheries Partnership group may propose a water level plan for one lake per year to increase the probability of successful fish spawning. Discussions are held to develop a list of objectives with consideration of the opportunities created by the existing hydrological conditions of the target reservoir. The partners understand that raising the elevation of any lake is dependent upon favorable hydrological conditions and approval of a deviation. Since this would be a Planned Deviation, entities making such a request must provide measureable, quantified benefits before the District can consider their request, and there is no implied guarantee that the request will be favorably considered. Also, the partners recognize that to enact such a plan permanently would constitute a change to the Water Control Plan that would require detailed engineering, economic, and environmental analysis.

d. Required Water Temperature Maintenance Releases. See 7-07 Water Quality. a. Water Temperature.

7-09. Water Supply. The storage required to meet water supply withdrawals is included within the conservation pools. The conservation pool co-mingles the contracted storage volume for the following uses: 1) Municipal & Industrial (M&I) water supply, 2) AGFC (Minimum Flow), and 3) SWPA hydropower. Reservoir Control staff performs a storage accounting procedure when the lake levels are below the top of the conservation pools to determine the storage used by each. Each month the M&I water supply purveyors submit a monthly usage report to the Planning Office. A copy of this report is furnished to the Reservoir Control Section (RCS) to use along with minimum flows and hydropower withdrawals in preparing the monthly storage accounting report. Based on the water supply agreements, as a percent of total conservation storage, inflow and losses to the project are distributed among the accounts. Inflow is credited to the storage account for each user in proportion to their contracted storages. If a user's inflow share is greater than his storage deficit, the surplus inflow is distributed to the other users in proportion to their contracted storages.

[redacted]

7-10. Recreation. The water control plan recognizes recreation as an important secondary project purpose. Provisions for recreation are, in part, accomplished by meeting authorized project purposes through drawdown limits and plant loading limits as discussed in paragraph 7-06. Regulation considerations for recreation fall into two categories: in-lake and downstream. The sytem engineer monitors the drawdowm limits shown in Table 7-02 to mitigate in-lake impacts. Downstream recreation affected by project releases includes fishing and boating, especially wade fishing. Table 7-13 shows the minimum time required for the powerplant to respond to generation changes to mitigate sudden surges of water from the powerhouses. In addition, special operations are sometimes coordinated to benefit downstream recreational events as summarized in paragraph 7-15.

7-11. Navigation. Navigation is not an authorized purpose.

7-12. Drought Contingency Plans. The District developed a Drought Contingency Plan for the White River Basin, entitled Drought Contingency Plan, Appendix V to the White River Basin Master Water Control Manual. This plan provides a basic reference for water management decisions and coordination at Corps lakes in response to drought. Table 7-17 shows the pool elevations and duration for each drought action level. Refer to the Drought Contingency Plan for details.

[redacted] el

[1] Duration refers to the number of consecutive months that PDSI values have been below zero

7-13. [redacted]

[redacted]

7-14. Other. Not Applicable.

[redacted]

a. Emergencies. [redacted]

b. [redacted]

[redacted]

c. Planned Deviations [redacted] The system engineer staffs the [redacted]

7-16. Rate of Release Change. The normal rate for increasing or decreasing flood control releases from Bull Shoals and Norfork dams should be limited to 5,000 cfs per hour. This rate of change limit should help prevent sudden drops/rises of river levels and bank sloughing. This limitation does not apply to induced surcharge operations. Hydropower generation limits are provided in paragraphs 7-06 and 7-10. Changes in outflow from the dams should not be made at such a rate as to create a hazard downstream. The more common situations that will be encountered are increases in flood-control releases at Bull Shoals and Norfork dams to maintain the downstream regulating stage, a decrease in releases from these reservoirs when a downstream rise occurs (or is forecast), and the subsequent increase in releases if the rise is smaller than expected, or a decrease in release when the flood-control pool is empty.

TABLE 7-14
WATER QUALITY RELEASE REQUIREMENTS FOR NONPOWER PURPOSES [1/]

		90°F or below		91-95°F		96-104°F		105°F or above	
Project	Period of Time in Effect	Generation (MWh)	Discharge (DSF)	Generation (DSF)	Discharge (DSF)	Generation (MWh)	Discharge (DSF)	Discharge (DSF)	Discharge (DSF)
Bull Shoals[2/]	1 May – 15 Oct	80	250	120	375	160	500	240	750
Norfork[2/]	1 May – 15 Oct	40	145	60	218	80	290	100	360

[1/] - This low flow release criteria along with the seasonal pool operational criteria were approved for use in SWD's 7th endorsement dated 11 February 1980 to an SWLED-H letter dated 22 January 1978; Subject: Policy for Encouragement vs. Releases for Flow Maintenance Downstream from SWD Dams.

[2/] - The minimum combined operation at Bull Shoals and Norfork shall not be less than a 3-day summation of 6,000 day-second-feet (DSF). Any 3-day daily average shall not be less than 2,000 DSF. This applies for all air temperatures conditions above 85°F and pool elevations above 649.0 at Bull Shoals and 545.0 at Norfork.

VIII - EFFECT OF WATER CONTROL PLAN

8-01 General. The purpose of the water control plan for Bull Shoals and Norfork dams is to provide flood damage reduction, hydropower generation, fish and wildlife habitat, and water supply. Navigation and recreation have benefitted from the water control plan because of the reliability of water depths and lake surface area. The effects of the Bull Shoals and Norfork Dams water control plan were evaluated for the spillway design flood and the project design flood using original design criteria. These effects are discussed below. The effects of the plan during other floods and droughts over the period-of-record were evaluated using the reservoir simulation computer model, RiverWare©. In the RiverWare model, the projects were operated in as realistic a manner as possible using historical stream flows for the period 1940-2011. Tables 8-01(a) and 8-01(b) provide a summary of the period of record floods as simulated by RiverWare at Bull Shoals and Norfork dams, respectively. Tables 8-02(a) and 8-02(b) show the simulated use of surcharge storage during the period of record at Bull Shoals and Norfork dams, respectively.

8-02. Flood Control. Flood control on the White River is provided by flood control reservoirs (including Bull Shoals and Norfork dams) operated by the Little Rock District (Corps) and levees along the White River mainstem between Batesville and Newport.

a. [redacted]

1. Bull Shoals. [redacted]

2. Norfork. [redacted]

b. Inflow Design Flood.

1. Bull Shoals. [redacted]

(a) Antecedent Conditions. According to Section 8.f of ER 1110-8-2(FR), an antecedent flood should be [redacted]

(b) Inflow Design Flood. [redacted]

[redacted]

(c) Hydrologic Adequacy. [redacted]

(d) Summary for Bull Shoals Dam.

- [redacted]

2. Norfork. [redacted]

[redacted]

[redacted]

(b) Inflow Design Flood. [redacted]

(c) Hydrologic Adequacy. [redacted]

[redacted]

(d) Summary for Norfork Dam.

- [redacted]

8-03. Recreation. The permanent pool created by the projects greatly enhanced the opportunity for flat-water related recreation. The Corps operates numerous parks along the lakes and downstream reaches of the White River. Camping, picnicking, boating, fishing and sightseeing are recreational activities attracting the public to the parks serving this area. In 2012, more than 2.6 million visitors enjoyed the Corps-provided facilities at Bull Shoals and 1.2 million visitors enjoyed Norfork facilities.

8-04. Water Quality. The only established water quality operations at Bull Shoals and Norfork are for releases to provide temperature control and to mitigate dissolved oxygen (DO) impacts in the downstream fisheries.

a. Seasonal Pools. Seasonal pools were authorized and established to assist in providing water for meeting seasonal fish water requirements related to water temperature. During the 1960s and 1970s the trout fisheries that had been established below Bull Shoals and Norfork were expanding, and studies showed a need for cold water releases for the trout fisheries. The dependence of these trout upon hydropower releases requires consideration of downstream water temperatures when scheduling releases. These considerations resulted in the development of the minimum fishwater release requirements shown in Table 7-15. The requirements for temperature maintenance (fishwater releases) are specified in paragraph 7-08.

b. Dissolved Oxygen. In 1991 an operational plan was developed and implemented that resulted in a network of downstream monitoring stations, modifications to the ventilation system of the turbines (vacuum breaker bypass and hub baffle modifications on all units at all projects have been completed), and operational constraints. The operational constraints consist of Federal actions to block open the hydropower turbine vents, reduce generation rates at each plant, and spread the plant load equally to all available units. The operational plan continues to be implemented each year, and although it has undergone minor adjustments over the years, it has proven to be extremely effective in meeting the established goal to sustain DO concentrations in the releases at or above 6 milligrams per liter (mg/l) as long as possible and to prevent DO concentrations from receding below 4 mg/l, if possible. The White, North Fork, and Little Red Rivers Operational Action Plan for Low Dissolved Oxygen Season is published each year by the White River DO Committee.

TABLE 8-01(a)
Computer simulated data
PERIOD OF RECORD FLOODS AT BULL SHOALS DAM [1/]
(1940-2011)

Year	Month	Maximum Elevation (feet, NGVD)	Percent Flood Storage in Use	Maximum Inflow (cfs)	Maximum Discharge (cfs)
1940	April	663.49	65%	41,801	17,331
1941	April	666.78	68%	51,591	26,705
1941	November	667.99	69%	35,848	21,070
1942	April	662.00	63%	32,044	25,600
1942	December	668.94	70%	54,873	35,790
1943	May	694.45	99%	87,947	23,016
1945	April	697.45	103%	162,115	140,877
1946	May	676.28	78%	55,114	11,100
1946	December	663.67	65%	35,855	35,790
1947	April	666.35	67%	30,015	24,313
1948	June	666.31	67%	40,711	18,752
1949	January	669.13	70%	52,988	24,298
1950	January	668.65	70%	45,518	15,673
1950	May	687.50	91%	72,061	10,292
1951	February	667.41	68%	53,584	35,790
1951	July	678.36	80%	43,411	23,753
1951	November	670.09	71%	39,722	23,517
1952	April	667.12	68%	56,141	15,819
1957	April	695.63	101%	96,174	37,276
1958	March	667.66	69%	63,818	29,867
1960	May	671.78	73%	63,842	24,723
1961	May	690.30	94%	105,358	20,329

TABLE 8-01(a)
Computer simulated data
PERIOD OF RECORD FLOODS AT BULL SHOALS DAM [1/]
(1940-2011)
continued

Year	Month	Maximum Elevation (feet, NGVD)	Percent Flood Storage in Use	Maximum Inflow (cfs)	Maximum Discharge (cfs)
1966	May	670.55	72%	48,746	22,846
1968	March	666.16	67%	52,678	35,300
1969	January	669.90	71%	75,699	35,790
1969	April	666.61	68%	48,624	26,209
1970	May	669.01	70%	39,484	24,031
1970	November	664.54	66%	59,239	35,790
1973	November	678.24	80%	102,301	34,874
1974	June	686.31	89%	90,905	23,969
1974	November	674.66	76%	97,121	35,790
1975	March	676.12	77%	46,244	28,335
1976	June	668.72	70%	30,282	24,311
1978	March	665.78	67%	80,424	35,790
1979	April	672.94	74%	54,372	4,254
1983	April	661.53	63%	56,767	31,843
1984	April	669.97	71%	32,715	15,824
1984	December	680.30	82%	147,683	35,790
1985	November	676.71	78%	97,641	35,790
1986	June	664.71	66%	21,675	17,461
1987	December	669.33	70%	75,595	35,790
1988	April	672.16	73%	61,674	24,302
1989	February	662.41	64%	48,824	32,921
1990	May	693.78	98%	114,155	26,008
1991	January	666.13	67%	34,993	35,790
1991	April	675.02	76%	42,082	23,006
1992	June	670.79	72%	45,883	25,566
1993	January	664.75	66%	81,044	35,790
1993	September	675.34	77%	129,942	18,821
1994	April	677.05	78%	31,201	20,253
1995	June	684.52	87%	54,806	19,804
1996	May	662.25	64%	32,381	4,258
1996	November	671.93	73%	59,967	34,318
1997	April	662.33	64%	38,250	21,784
1998	March	671.62	73%	47,052	32,080
1999	May	667.40	68%	32,422	21,180
2002	May	688.64	92%	77,515	18,045
2004	April	678.08	80%	155,491	20,792
2005	January	667.59	69%	47,742	35,790

TABLE 8-01(a)
Computer simulated data
PERIOD OF RECORD FLOODS AT BULL SHOALS DAM [1/]
(1940-2011)
continued

Year	Month	Maximum Elevation (feet, NGVD)	Percent Flood Storage in Use	Maximum Inflow (cfs)	Maximum Discharge (cfs)
2008	March	695.41	101%	133,374	30,040
2009	May	675.58	77%	33,537	22,148
2010	May	669.74	71%	46,914	20,071
2011	April	696.31	102%	250,486	61,572

[1/] Source: White River model, Run W12N01 (2012)

TABLE 8-01(b)
Computer simulated data
PERIOD OF RECORD FLOODS AT NORFORK DAM [1/]
(1940-2011)

Year	Month	Maximum Elevation (feet, NGVD)	Percent Flood Storage in Use	Maximum Inflow (cfs)	Maximum Discharge (cfs)
1940	April	557.03	69%	23,100	3,325
1941	November	557.28	69%	26,250	10,885
1942	April	558.94	71%	13,420	5,128
1942	December	563.66	77%	45,200	10,885
1943	May	576.70	95%	53,600	7,250
1945	April	580.89	101%	76,570	40,760
1946	February	558.80	71%	29,360	10,885
1946	May	569.28	84%	37,860	8,290
1946	December	558.04	70%	22,610	10,885
1947	May	559.35	72%	6,150	6,284
1948	June	556.98	69%	22,340	3,386
1949	January	562.86	76%	58,500	10,885
1949	July	561.38	74%	25,100	10,885
1950	January	562.92	76%	62,300	10,885
1950	May	572.24	89%	41,055	10,679
1951	February	559.14	71%	24,800	10,885
1951	July	566.29	80%	21,700	5,347
1951	November	562.34	75%	17,400	10,885
1952	March	559.82	72%	27,000	10,885
1956	May	547.09	58%	37,500	1,710
1957	April	579.62	99%	55,185	4,050
1958	March	560.15	73%	23,875	10,885

TABLE 8-01(b)
Computer simulated data
PERIOD OF RECORD FLOODS AT NORFORK DAM [1/]
(1940-2011)
continued

Year	Month	Maximum Elevation (feet, NGVD)	Percent Flood Storage in Use	Maximum Inflow (cfs)	Maximum Discharge (cfs)
1958	November	556.07	68%	25,350	10,885
1960	May	559.87	72%	20,355	5,329
1961	May	573.37	90%	70,165	3,720
1963	May	550.48	61%	24,325	3,327
1966	February	552.47	64%	48,680	2,801
1966	May	567.47	82%	18,920	10,885
1968	March	559.01	71%	24,770	10,885
1969	February	565.76	80%	47,550	10,885
1969	April	561.96	75%	6,830	10,627
1970	April	563.51	77%	31,080	9,153
1972	April	556.81	69%	21,810	1,888
1972	November	553.71	65%	15,903	2,163
1973	November	569.21	84%	54,973	10,885
1974	April	575.24	93%	43,827	10,449
1974	November	557.63	70%	13,194	10,885
1975	March	565.43	79%	20,381	10,027
1976	June	557.73	70%	9,871	1,450
1977	March	551.78	63%	42,741	1,408
1978	March	558.90	71%	29,892	10,885
1979	April	575.76	94%	31,831	10,885
1982	December	563.47	77%	104,196	10,885
1983	April	564.91	79%	32,823	6,388
1984	May	561.99	75%	10,600	4,544
1985	February	566.18	80%	80,906	10,885
1985	November	567.81	82%	96,904	10,885
1987	December	559.30	72%	31,301	10,885
1988	April	561.15	74%	22,399	10,885
1988	November	549.08	60%	17,793	2,123
1989	February	563.05	76%	25,197	10,885
1989	May	557.74	70%	19,315	4,567
1990	May	576.32	94%	46,303	5,198
1991	January	558.90	71%	13,049	10,885
1991	April	568.22	83%	20,701	4,844
1991	December	555.91	68%	8,588	10,885
1992	June	559.17	71%	6,797	4,737
1993	January	561.41	74%	55,309	10,885
1993	September	567.73	82%	69,505	9,850

TABLE 8-01(b)
Computer simulated data
PERIOD OF RECORD FLOODS AT NORFORK DAM [1/]
(1940-2011)
continued

Year	Month	Maximum Elevation (feet, NGVD)	Percent Flood Storage in Use	Maximum Inflow (cfs)	Maximum Discharge (cfs)
1994	April	569.21	84%	26,035	7,322
1994	November	554.00	65%	36,314	2,992
1995	May	567.76	82%	17,705	9,958
1996	April	559.54	82%	16,232	10,885
1996	November	560.04	72%	20,492	10,885
1997	April	558.00	70%	21,918	10,885
1998	March	563.61	77%	22,237	10,885
1999	May	559.05	71%	11,832	3,827
2002	May	576.89	95%	46,089	9,816
2004	April	568.09	83%	60,979	6,417
2005	January	560.04	72%	13,287	10,885
2006	May	547.44	58%	18,135	1,888
2006	November	539.22	50%	48,794	2,976
2008	March	580.04	100%	100,730	33,798
2009	October	570.69	86%	41,975	10,885
2010	May	560.61	73%	15,230	6,374
2011	April	580.09	101%	111,740	12,895

[1/] Source: White River model, Run W12N01 (2012).

TABLE 8-02(a)
PERIOD OF RECORD USE OF SURCHARGE
STORAGE AT BULL SHOALS DAM [1/]

[redacted]

TABLE 8-02(b)
PERIOD OF RECORD USE OF SURCHARGE
STORAGE AT NORFORK DAM
(1940-2011)

[redacted]

8-05. Fish and Wildlife. The water control plan satisfies all the current requirements for fish and wildlife purposes. Special operations to benefit fish and wildlife needs are frequently accomplished at Bull Shoals and Norfork Lakes on a case by case basis through coordination with stakeholders. The FY 2006 Energy and Water Development Appropriations Act (EWDAA) (Public Law (P.L.) 109-103) authorized and directed the Corps to reallocate storage at Bull Shoals and Norfork for the purpose of making a minimum release during non-hydropower producing periods. The guide curve at Bull Shoals was raised 5-feet and at Norfork it was raised 1.75 feet in order to provide storage for meeting the minimum flow requirements. The minimum flow target release at Bull Shoals is 800 cfs and at Norfork it is 300 cfs. The target releases provide a minimum wetted perimeter that is beneficial to the tailwater fisheries.

8-06. Water Supply. Current water supply contracts and yields for Bull Shoals and Norfork lakes are shown in Tables 2-01 and 2-02. The water control plan satisfies all requirements for water supply.

8-07. Hydroelectric Power. The RiverWare™ model determined hydropower production based on power loads provided by the Southwestern Power Administration (SWPA). The model was operated to satisfy the power load (firm energy) through power produced by the hydropower plant. If the power load could not be met by the hydropower plant, power (thermal energy) was purchased to satisfy the power load. Any power produced by the hydropower plant above the power load amount was excess. Based on the period of record, 1940 through 2011, Bull Shoals Lake, on an average annual basis, produced a total of 655.4 gigawatt-hours (GWh) satisfying the power load of 285.1 GWh while producing 370.3 GWh of excess energy. Thermal energy average purchase was 12.4 GWh. Norfork Lake, on an average annual basis, produced a total of 169.3 GWh satisfying the power load of 96.2 GWh while producing 73.1 GWh of excess energy. Thermal energy average purchase was 6.5 GWh.

8-08. Navigation. Not applicable.

8-09. Drought Contingency Plans. The Corps has developed a Drought Contingency Plan for the White River Basin (Appendix V to the White River Basin Water Control Master Manual). The plan's purpose is to provide a reference for water management decisions and coordination at Corps lakes and dams in response to drought induced water shortages. The plan addresses the foreseeable operational and physical problems that would be caused by a drought and would provide guidance as a drought worsens. Recommendations for operational changes and deviations to the Water Control Plan are specified in the Drought Contingency Plan, along with other actions that the Corps can take to improve regulation during low flow periods. Additional information on droughts is given in paragraphs 6-06 and 7-12, and the Drought Contingency Plan, Appendix V, to the White River Basin Water Control Master Manual.

8-10. Emergency Action Plans (EAP). [redacted].

8-11. Frequencies and Durations. Durations and frequencies for Bull Shoals and Norfork lakes, as determined by the RiverWare model, are shown in Plates 8-05 through 8-24. Specifically, monthly elevation duration curves for Bull Shoals Lake are shown on Plates 8-05 through 8-07, and for Norfork Lake on Plates 8-15 through 8-17. The annual elevation duration curve for Bull Shoals Lake is shown on Plate 8-08 and is shown on Plate 8-18 for Norfork Lake. The maximum and minimum annual elevation frequency curves for Bull Shoals and Norfork lakes are shown on Plates 8-09 and 8-19, respectively. Monthly discharge duration curves for Bull Shoals are shown on Plates 8-10 through 8-12, and for Norfork are shown on Plates 8-20 through 8-22. The annual discharge duration curves for Bull Shoals and Norfork lakes are shown on Plates 8-13 and 8-23, respectively. The annual discharge frequency curves for Bull Shoals and Norfork lakes are shown on Plates 8-14 and 8-24, respectively. Plates 8-25 through 8-32 show the experienced versus simulated pool hydrographs for Bull Shoals Lake. Plates 8-33 through 8-40 show the experienced versus simulated pool hydrographs for Norfork Lake. Additional hydrologic data for Bull Shoals and

Norfork lakes may be found in the White River Basin Water Control Master Manual.

8-12. Other Studies.

a. Examples of Regulation. There have been numerous studies related to the regulation of Bull Shoals and Norfork dams over the years. In 1942, the Basis of Design for Definite Project Report was developed, which included the original studies for the method of operation for Bull Shoals and Norfork. This report helped establish the size of the flood and conservation pools in each lake. In 1952, the Plan of Flood Regulation for Bull Shoals and Norfork Reservoirs was developed. This report described the proposed plan of regulation for Bull Shoals and Norfork dams. In 1954, the Master Manual for Reservoir Regulation of the White River Basin was first developed. This described the operating criteria for Bull Shoals, Norfork, and Greers Ferry. In 1963, the Reservoir Regulation Manual for Beaver, Table Rock, Bull Shoals, and Norfork Reservoirs was developed and revised in 1966. In 1993, the Master Manual for Reservoir Regulation for the White River Basin was developed. No changes to the Water Control Plan were made, only basin conditions were updated. In 1998, after years of additional study, a revision to the water control plan was made that lowered the regulating stages on the White River at Newport. In January 2009, a record of decision for the White River Basin Minimum Flows Project was issued. Further details related to this record of decision are provided in paragraph 8-12(d).

b. Water Supply Reallocation Studies. Water Supply reallocation studies have been conducted at both Bull Shoals and Norfork since 1969. The most recent study was completed and resulted in a reallocation action of 11,887 acre-feet from Bull Shoals Lake for use by the Ozark Mountain Regional Public Water Authority (OMRPWA) and Marion County Regional Water District (MCRWD). Previously, MCRWD had obtained a reallocation of 880 acre-feet in 1988. These reallocations actions total 12,767 acre-feet for water supply at Bull Shoals Lake.

Norfork has only one water supply user that consists of 2,400 acre-feet for the City of Mountain Home. This reallocation was completed in 1969.

c. Flood Insurance Studies. The Federal Emergency Management Agency (FEMA) has a detailed Flood Insurance Study (FIS) for the areas around Bull Shoals and Norfork lakes. The current Baxter County study was approved in December 2010. Both Bull Shoals and Norfork 1% annual chance exceedance (100-year) pool elevations are shown as Zone A (no detailed study) on the Baxter and Marion Counties Flood Insurance Rate Maps. There are segments of Zone AE (detailed study) floodplain along the White River below Bull Shoals and Norfork dams downstream to Newport.

d. White River Minimum Flows Study. The White River Basin, Arkansas Minimum Flows Project was authorized in Section 132(a) of the Fiscal Year 2006

Energy and Water Resources Development Appropriations Act (P.L. 109-103), which directed implementation of Bull Shoals and Norfork lakes' alternatives to provide for minimum flow releases and reallocation of storage for downstream fish and wildlife interests as described in the July 2004 White River Minimum Flows Reallocation Report. The WRMF study determined that the tailwater fishery below Bull Shoals and Norfork dams would benefit from an increased wetted perimeter provided by the increased minimum flows. There would be an increase in downstream recreation benefits associated with the improved trout fishery. No change would occur with respect to the water supply use of the two lakes. A small reduction to flood-control benefits would result due to raising of the top of the conservation pool at Bull Shoals and Norfork lakes.

e. White River Comprehensive Study. Section 729 of the 1986 Water Resources Development Act (WRDA) and Section 202 of WRDA 2000 authorized and established cost sharing for the White River Basin Comprehensive study. The study area includes the White River Basin which is comprised of approximately 28,000 square miles in northeastern Arkansas and southern Missouri. The basin contains five large multi-purpose reservoirs and one reservoir primarily for flood control; over 150 miles of flood control levees along the White River and its tributaries; 2 major national wildlife refuges; and the largest remaining concentration of seasonally flooded bottomland hardwoods in the Mississippi Valley. The study will identify water resources needs and opportunities with potential study outputs addressing needs for water supply, flood control, waste water management, navigation, recreation, power generation, and other water resource related needs identified by the comprehensive study. Cost-sharing sponsors include the Arkansas Natural Resources Commission (ANRC), Arkansas Game and Fish Commission (AGFC), Arkansas Natural Heritage Commission (ANHC), Arkansas Waterways Commission, Missouri Department of Conservation (MDC), Missouri Department of Natural Resources (MDNR), and The Nature Conservancy. The study is managed primarily by the Memphis District, with input from Little Rock District team members.

IX - WATER CONTROL MANAGEMENT

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]
- [redacted]

(2) Reservoir Control Section/Hydraulics and Technical Services Branch (Flood Emergencies). During flood emergencies, RCS personnel will do the following:

- [redacted]
- [redacted]
- [redacted]
- [redacted]

- [redacted]

[redacted]

(3) Reservoir Control Section/Hydraulics and Technical Services Branch (Drought Management). The responsibilities and duties of the Reservoir Control Section during a drought period are as follows:

- Evaluate and consolidate the Corps' position, [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

(4) Mountain Home Project Office (Routine Regulation). The Mountain Home Project Office's responsibilities as they pertain to routine regulation are as follows:

- [redacted]

[redacted]

[redacted]

[redacted].

- [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

(5) [redacted]). [redacted]

- [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

[redacted] [redacted]

- [redacted]

(6) Operations Division. The responsibilities and duties of the Operations Division are as follows:

- [redacted]

[redacted]

[redacted]

(7) [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

b. Other State and Federal Agencies.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

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[redacted] [redacted]

[redacted]

[redacted]

[redacted]

[redacted]

d. Other Organizations.

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

[redacted]

9-06. Reports. Table 9-01 summarizes reports issued by the Corps, specifying their authorization and frequency.

a. Daily Reservoir Report. This report is prepared daily by the RCS, except, Saturday, Sunday, and holidays. The White River lakes daily report provides morning elevation at the projects, percent of storage in use, 24-hour change in elevation, and mean daily release. The report also provides historical elevations for the current date. In addition to the lake data, morning stage, 24-hour change in stage, and morning discharge is provided for downstream USGS White

River streamflow gauges. Historical stages are also provided for reference. The report is completed and made available on the Corps Water Management website under normal conditions. The report is available on the Internet at the Corps Water Management daily reports webpage: http://www.swl-wc.usace.army.mil/pages/reports/remote/white.htm .

b. Daily Pool Forecast Report. This report is prepared by the RCS daily, except Saturday, Sunday, and holidays, to cover a period of 3 days. The report provides data for the 7:00 a.m. forecasted pool elevations for the next 3 days, and when appropriate, the forecasted pool crest elevation and date or the forecasted flood pool empty date. The report is completed and made available on the Corps Water Management website by noon daily, under normal conditions. The report is available on the Internet at the Corps Water Management daily reports webpage: http://www.swl-wc.usace.army.mil/pages/reports/remote/lakfcst.htm .

c. Monthly Report. The RCS prepares the monthly lake reports in accordance with paragraph 6-04 of EM 1110-2-3600 and paragraph 13(c) of EC 1110-2-208. These reports are a tabular record of regulation for all flood control, navigation, or multiple-purpose storage reservoirs that are under supervision of, or of direct interest to, the Corps. Supplemental information on the regulation of the reservoirs, such as explanation of deviations from approved schedules, are added as a note on the report or as an attachment. These reports are promptly prepared each month and maintained in such form as to be readily available for transmittal to the Chief of Engineers, or others, upon request, and is available on the Internet http://www.swl-wc.usace.army.mil/pages/mcharts.htm .

d. Flood Situation Report. [redacted]

e. Post Flood Report. This report is prepared in accordance with ER 500-1-1 as soon as practical after a flood causing major damage. The report describes flood emergency operations by the Corps and others. Included in summary form are: available hydrologic information, damage estimates, and other engineering data considered to be essential for flood control and flood plain studies or for the review of possible claims against the United States. Typically, the report is prepared by the Corps' Office Planning Division. Information derived from field investigations by personnel of the Hydraulics and Technical Services Branch along with information compiled by the RCS are also included. The report should be completed within approximately three months of the time of flooding, including statement of final cost.

f. Annual Report. This report is prepared by the RCS. The report contains a summation of the general conditions of the river basins and the individual projects in the Little Rock District for the preceding fiscal year. The report also presents the activities and accomplishments of the RCS for the past year. The report is forwarded to SWD Water Management for inclusion in the Division's Annual Report.

g. Monthly Hydropower Allocation Report. While not a formal report, near the end of the month the power production data for the following month are calculated relative to the subsequent starting month's pool elevation. These power production values are presented to the SWPA for discussion during the monthly hydropower meeting. During this monthly meeting, pool drawdown limits, special operations requests, water quality conditions and concerns, and any other pertinent business are also discussed.

h. Seasonal Water Quality Report. Not applicable.

i. End Year Water Quality Report. Data from the previous year's low DO and water temperature season are accumulated and presented to the White River DO Committee at the spring meeting. There is no set format. Plots and tables are provided as needed.

j. Seasonal Water Supply Accounting Reports. Not applicable.

TABLE 9-01
TABULATION OF REPORTS

Name of Report	Sent to	Due out of Sender's Office	Authorization
Daily Reservoir Report			
Daily Pool Forecast Report		Mornings	
Monthly Lake Report		Monthly	EM 1110-2-3600 EC 1110-2-208
Flood Situation Report	Emergency Operation Center		ER 500-1-1
Post Flood Report		Within 3 months of event	ER 500-1-1
Monthly Hydropower Allocation Report		Monthly	
End of Year Water Quality Report		Annually Spring	
Seasonal Water Supply Accounting Report			
Annual Reports		Annually Spring	Annual Letter from CESWD-RBT-W

Exhibit A

[redacted]

Exhibit B

EXHIBIT B:

Corps/SWPA Memorandum of Understanding

"EXHIBIT A"

Projects of the Corps

(Completed and Under Construction)

Projects for which the Division Engineer, Southwestern Division is responsible:

- Beaver Lake
- Broken Bow Lake
- Bull Shoals Lake
- Dardanelle
- Denison Dam - Lake Texoma
- Eufaula Lake
- Ft. Gibson Lake
- Greers Ferry Lake
- Robert S. Kerr Lake
- Keystone Lake
- Norfork Lake
- Ozark Lake
- Sam Rayburn Dam and Reservoir
- Table Rock Lake
- Tenkiller Ferry Lake
- Webbers Falls Lake
- Whitney Lake

Projects for which the Division Engineer, Missouri River Division is responsible:

- Stockton Lake
- Harry S. Truman Dam and Reservoir

Projects for which the Division Engineer, Lower Mississippi Valley Division is responsible:

- Clarence Cannon Dam and Reservoir
- Blakely Mountain Dam - Lake Ouachita
- DeGray Lake
- Narrows Dam - Lake Greeson

EXHIBIT A

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EXHIBIT "B" OF

CONTRACT NO. DE-GMIS-80 SW 00058

OPERATING ARRANGEMENT

BETWEEN THE SOUTHWESTERN DIVISION

OF THE CORPS OF ENGINEERS AND THE

SOUTHWESTERN POWER ADMINISTRATION

EXHIBIT "B"

OPERATING ARRANGEMENT

TABLE OF CONTENTS

TABLES

TABLE 2

WATER RELEASE REQUIREMENTS
FOR INTSTREAM FLOW NEEDS

Project	Period of Time in Effect	Forecast Air Temperature (Degrees Fahrenheit)							
		90 or Below		91 - 95		96 - 104		105 and above	
		Generation (MWH)	Discharge (DSF)	Generation (MWH)	Discharge (DSF)	Generation (MWH)	Discharge (DSF)	Generation (MWH)	Discharge (DSF)
Beaver1/	May 1 - Oct 15	29	85	43	125	56	165	68	200
Table Rock	May 1 - Dec 1	34	100	48	140	60	175	68	200
Bull Shoals	May 1 - Oct 15	80	250	120	375	160	500	240	750
Norfork	May 1 - Oct 15	40	145	60	218	80	290	100	360
Greers Ferry2/	May 1 - Oct 15	35	115	45	150	54	175	69	225
Keystone	Jan - Dec	Minimum release is 140 MWH, 1,000 DSF three times/week. Example: Monday, Wednesday, and Friday; Tuesday, Thursday, and Saturday.							
Broken Bow	Jan - Dec	Maintain 100 CFS from re-regulation structure, require minimum of 250 MWH, 750 DSF twice a week (separate by 3 days).							

1/ If feasible, minimum one hour morning and afternoon.

2/ Increase required release by 50 percent on one day of a 3-day period.

Exhibit C

Exhibit D

Exhibit E

Tables

TABLE 7-3
OPERATIONAL RULES FOR WHITE RIVER BASIN MULTIPURPOSE PROJECTS

ZONE I

1. Description. Flood control zone.

2. Operational Objectives.

   a. Reduce downstream peak stages at flood damage areas.
   b. Restore flood control capability as soon as practicable.
   c. Maintain an equal percent of available flood control storage between the Beaver, Table Rock, Bull Shoals system and Norfork.
   d. Provide firm power.
   e. Minimize damages within the lake area as much as practicable.

3. Operational Constraints.

   a. Spillway and power releases are limited by the downstream regulating stages at Newport or by other damage centers on the lower White River, as may be determined to control releases.
   b. Releases are prorated to maintain an equal percent of available flood control storage as stated in paragraph 2.c. above.
   c. Minimum daily release is firm power, except in extreme cases where significant reduction in critical downstream flood conditions will result from curtailing generation.
   d. Peaking capability may be limited to minimize downstream effects.
   e. Maximum routine release rates are specified in Table 7-05.

4. Declaration of Energy Available.

   i. Downstream limiting.
      1. Above regulating stage at control point.
         a. Required release when operating for a gradually falling stage.
         b. Firm power.
         c. Zero in extreme cases.
   ii. Downstream not limiting.
      1. 24 hours per day at plant capacity or overload.

Note: The required release may be given as a combined release for Bull Shoals and Norfork.

5. Frequency of Contact with SWPA.

   a. Daily – furnish SWPA pertinent reservoir data, 4-day inflow forecasts, operating constraints and required releases for next 1 to 2 days.
   b. Provide SWPA 48 hours' notice of the following conditions:
      i. Changes in required releases.
      ii. When pool will fall into Zone II.

6. Degree of Corps Control. Absolute.

ZONE II

1. Description. Transition zone within the flood control pool.

2. Operational Objectives.

   a. Provide a transition from large flood control releases to moderate power releases.
   b. Minimize damage to banks because of rapid stage reduction when banks are saturated.
   c. Control minor rises in the flood control pool without short duration releases at high flood control release rates.
   d. Reduce downstream peak stages at flood damage areas.
   e. Provide firm power.
   f. Protect downstream cold water fishery.

3. Operational Constraints.

   a. Bull Shoals and Norfork.
      i. Release a minimum of a 12-hour operation at turbine capacity subject to the operational constraints for each project as stated in paragraph 3, Zone I.
      ii. Release minimum fishwater, as required seasonally.

4. Declaration of Energy Available.

   a. Bull Shoals.
      i. Downstream limiting.
         1. Required release (usually not less than firm power).
      ii. Downstream not limiting.

1. Release firm power plus Table Rock releases plus tributary inflow between Table Rock and Bull Shoals not less than 12 hours per day at turbine capacity.

iii. Release minimum fishwater, as required seasonally .

b. Norfork.

i. Downstream limiting.

1. Required release (usually not less than firm power).

ii. Downstream not limiting.

1. Release firm power plus inflow not less than 12 hours per day at plant capacity.

iii. Release minimum fishwater.

5. Frequency of Contact with SWPA.

a. Daily – furnish SWPA pertinent reservoir data, 4-day inflow forecasts, operating constraints and required releases for next 1 to 2 days.

b. Provide SWPA 48 hours notice of the following conditions:

i. When pool will rise into Zone I or fall into Zone III.

ii. Change in required releases.

6. Degree of Corps Control. Absolute.

Note: Releases will be coordinated for Beaver, Table Rock and Bull Shoals so that operations at an upstream project do not force downstream projects into a higher zone. Therefore, operations to empty Zones I or II at Beaver or Table Rock may be require additional generation from Table Rock and/or Bull Shoals.

ZONE III

1. Description. Flexible conservation storage zone.

2. Operational Objectives.

a. Exercise best judgment in achieving conservation storage benefits.
b. Encourage full utilization of power production potential.
c. Supplement flood control potential, if possible.
d. Monitor competitive uses of conservation storage to assure equity.
e. Protect downstream flood damage areas.
f. Protect downstream cold water fishery.

3. Operational Constraints.

a. Bull Shoals.

i. Maximum drawdown is limited to not more than 1.5 feet per 7-days up to 4.5 feet in 28-days.
ii. Flood control operations are subject to the operational constraints as stated in paragraph 3, Zone I.
iii. Release minimum fishwater, as required seasonally.

b. Norfork.
i. Maximum drawdown is limited to not more than 1.5 feet per 7-days up to 5.0 feet in 28-days.
ii. Flood control operations are subject to the operational constraints as stated in paragraph 3, Zone I.
iii. Release minimum fishwater.

4. <u>Declaration of Energy Available.</u>

a. Monthly – furnish monthly hydropower allocations to SWD about 2 weeks before the first of the month.

5. <u>Frequency of Contact with SWPA.</u>

a. Daily – furnish SWPA pertinent reservoir data, 4-day inflow forecasts, operating constraints and required releases for next 1 to 2 days.
b. Monthly – meet with SWPA to discuss recommended monthly hydropower allocations and production plans at monthly meeting.
c. As needed to coordinate special operations.

6. <u>Degree of Corps Control.</u>

a. On power production.
i. Firm energy – advisory.
ii. Supplemental energy – advisory, subject to drawdown limitations.

b. On flood control operations – absolute.
c. On fishwater releases – absolute.

<u>ZONE IV</u>

1. <u>Description.</u> Conservation storage zone for the production of firm power.

2. <u>Operational Objectives.</u>

a. Assure that all authorized project purposes are met according to design or latest approved water control plan.
b. Monitor competitive uses of conservation storage to assure equity.

c. Maintain a relatively balanced condition between Beaver, Norfork, and Greers Ferry Lakes and between Table Rock and Bull Shoals Lakes based on percent of conservation storage available.
d. Reduce peak stages at downstream flood damage areas.
e. Protect downstream cold water fishery.

3. Operational Constraints.

a. Bull Shoals.
   i. Maximum drawdown is limited to not more than 1.5 feet per 7-days up to 4.5 feet in 28-days.
   ii. Maintain a balance as stated in paragraph 2.c. above within 5 percent.
   iii. Flood control operations are subject to the operational constraints as stated in paragraph 3, Zone I.
   iv. Release minimum fishwater, as required seasonally.

b. Norfork.
   i. Maximum drawdown is limited to not more than 1.5 feet per 7-days up to 5.0 feet in 28-days.
   ii. Maintain a balance as stated in paragraph 2.c. above within 5 percent.
   iii. Flood control operations are subject to the operational constraints as stated in paragraph 3, Zone I.
   iv. Release minimum fishwater.

4. Declaration of Energy Available.

a. Monthly – furnish monthly allocation to SWD about 2 weeks before first of month.

5. Frequency of Contact with SWPA.

a. Daily – furnish SWPA pertinent reservoir data, 4-day inflow forecasts, operating constraints and required releases for next 1 to 2 days.
b. Weekly – set loading priorities as necessary to maintain the subsystem balances as in 2.c. above.
c. Monthly – furnish SWD an allocation of energy available.
d. Monthly – meet with SWPA to discuss cumulative deviations, power allocations, power operations, etc., at the monthly power conference.

6. Degree of Corps Control.

a. To rectify over production – absolute.
b. To rectify under production – negotiable.
c. Flood control operation – absolute.

Note: Cumulative production in Zone IV may vary from subsystem firm because of short-term extremes in weather, equipment failures or declared electrical energy emergencies, etc. However, during extended periods in Zone IV, actual production should approximate firm energy.

ZONE V

1. Description. Emergency storage.

2. Operational Objectives.

   a. In the event of an emergency drawdown, the storage will be evacuated as fast as possible through all available outlets including the turbines.
   b. In the event of a severe drought, storage in Zone V may be used to meet emergency situations at the discretion of the District Engineer. Resources will be managed as described in Appendix V to the White River Basin Water Control Master Manual, “Drought Contingency Plan.”

3. Operational Constraints. Depend on the situation.

4. Declaration of Energy Available. Declare on basis of emergency faced and confine to designated amount except when emptying as in 2.a. above.

5. Frequency of Contact with SWPA.

   a. Daily – furnish SWPA project data and 4-day inflow forecasts.
   b. Daily – declare energy available.

6. Degree of Corps Control. Absolute.

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Plates

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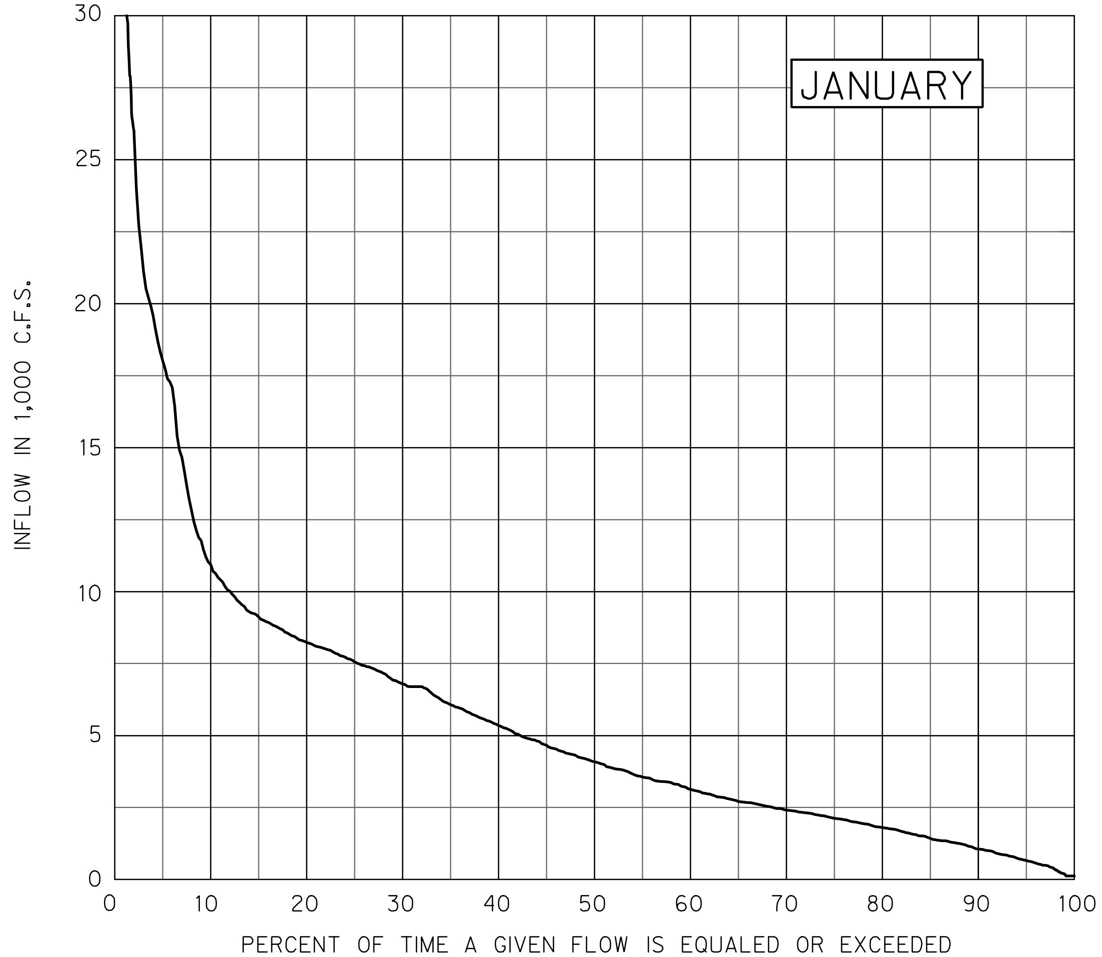
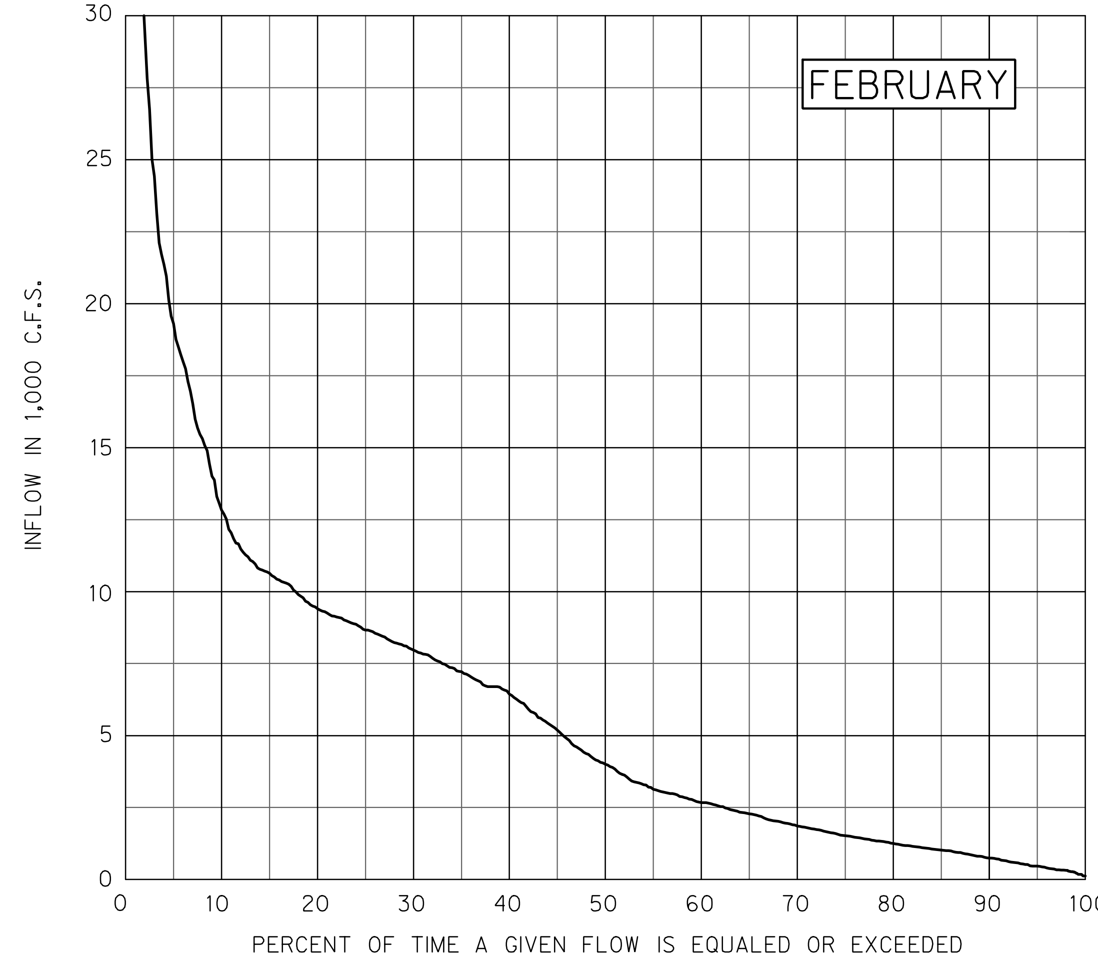
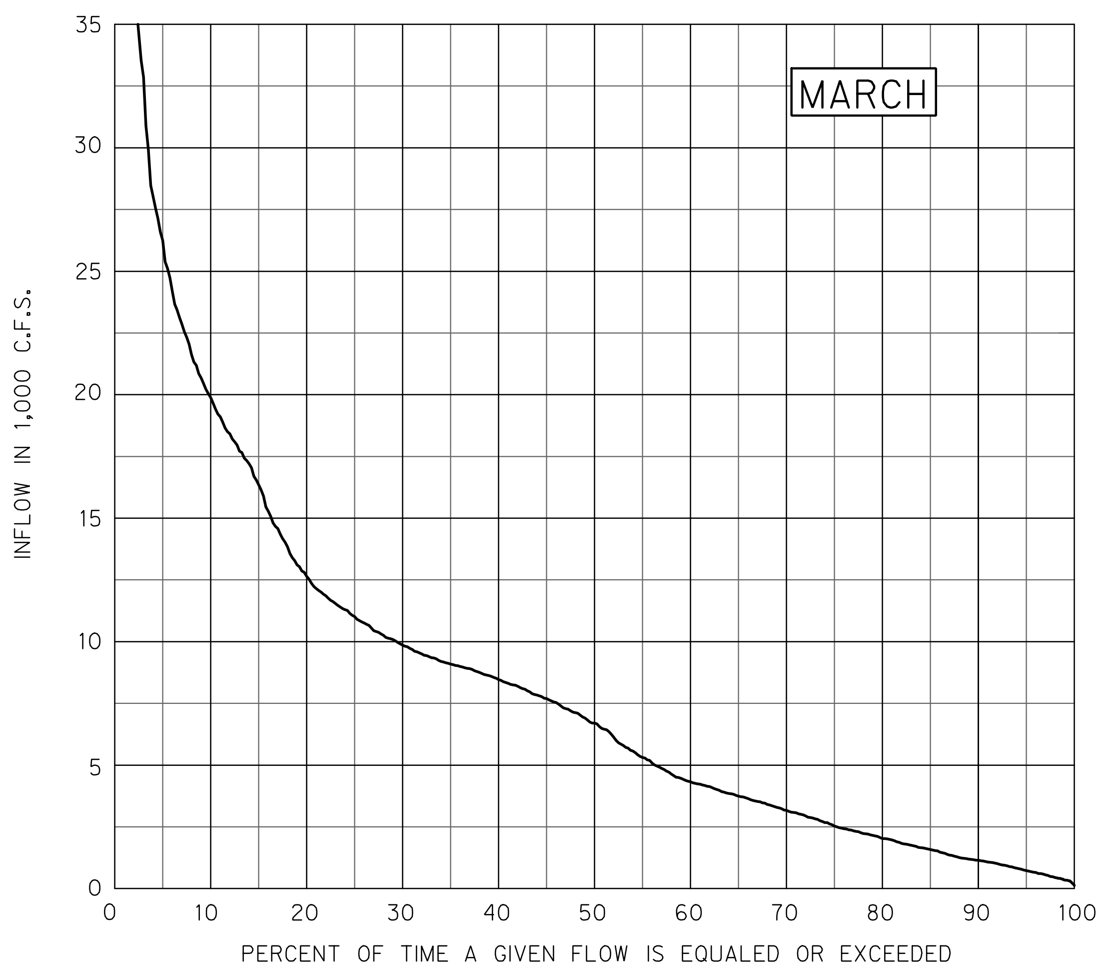
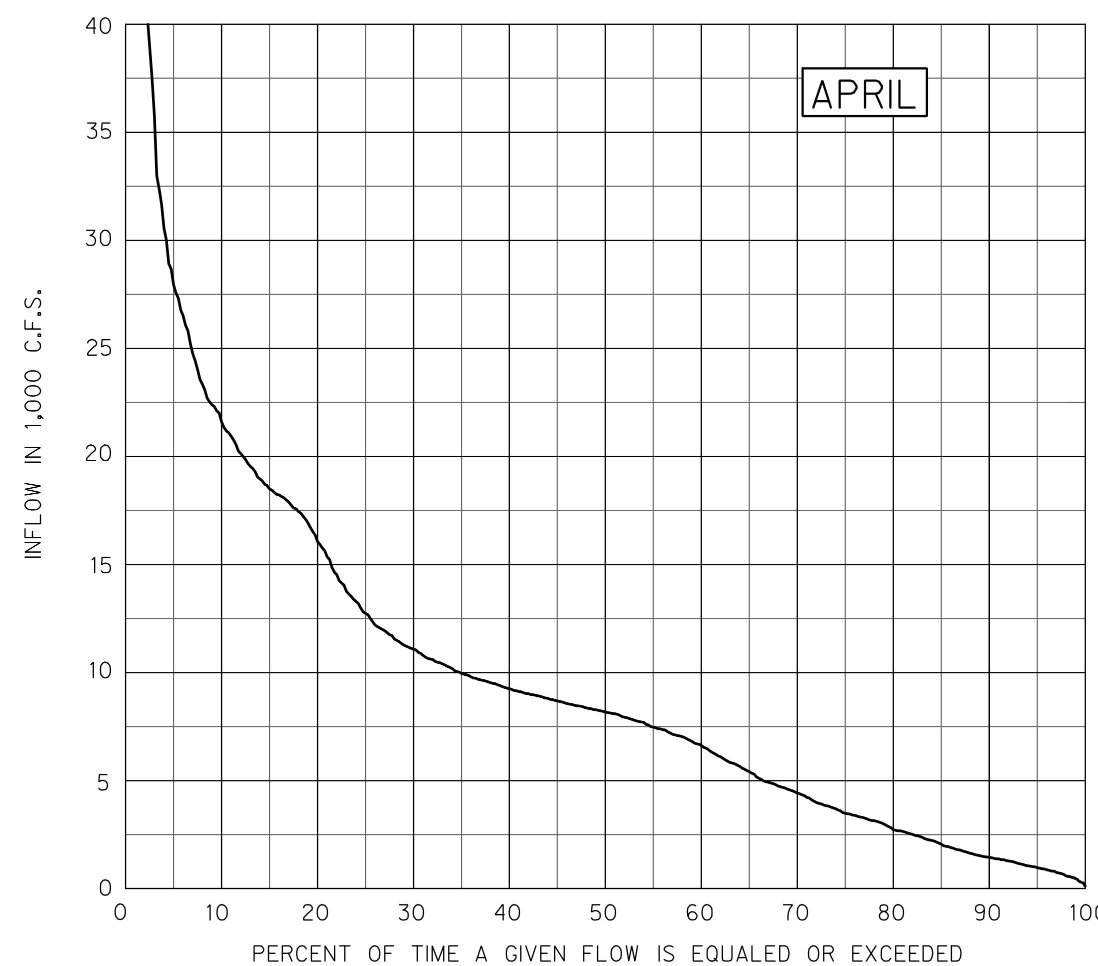








NOTE:

2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

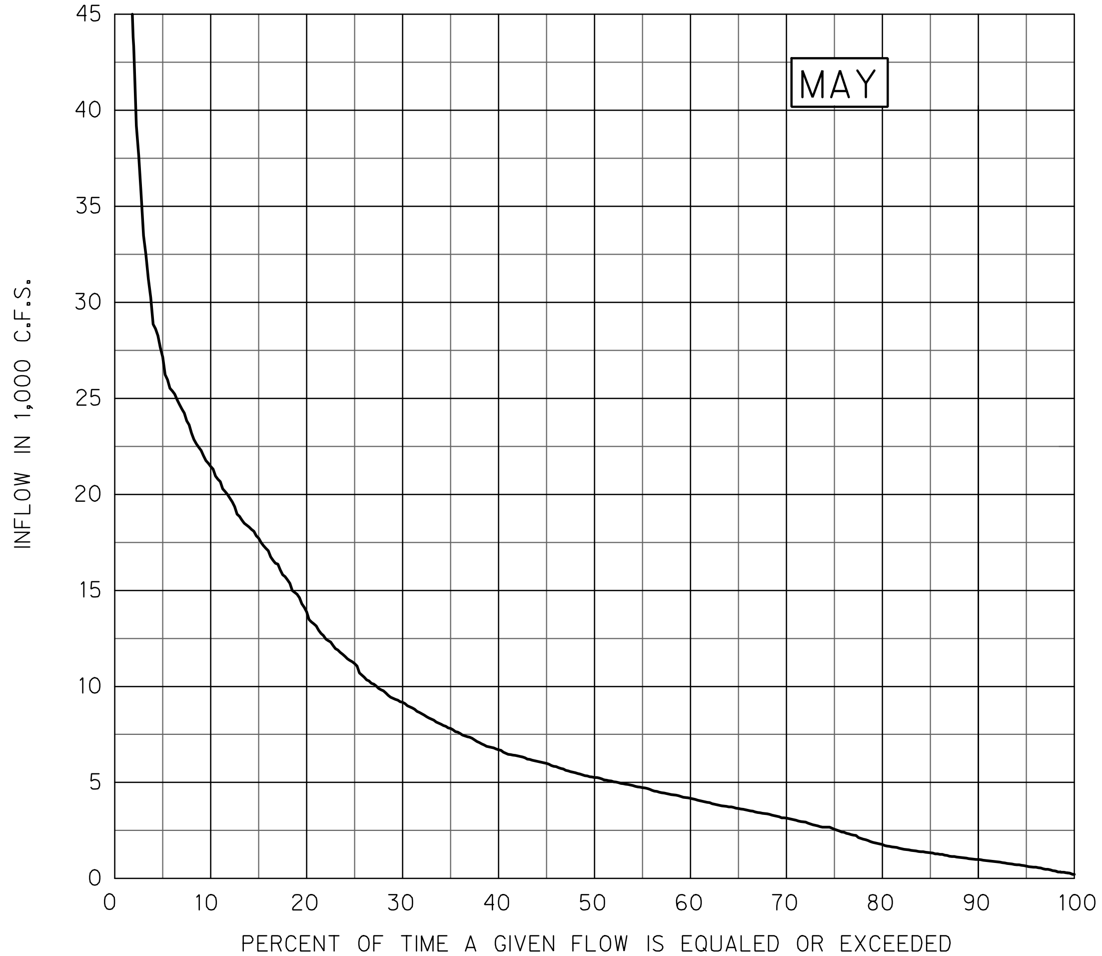
WHITE RIVER BASIN ARKANSAS AND MISSOURI

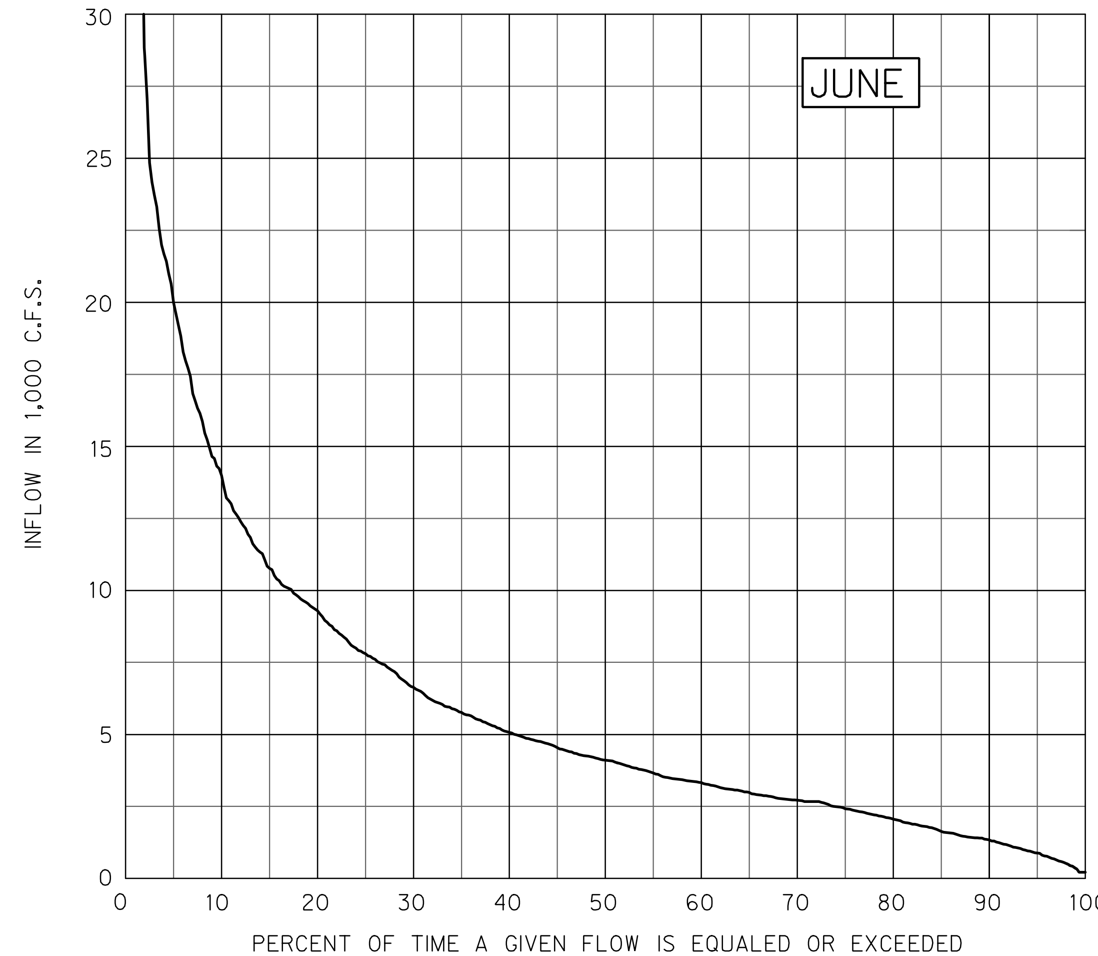
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

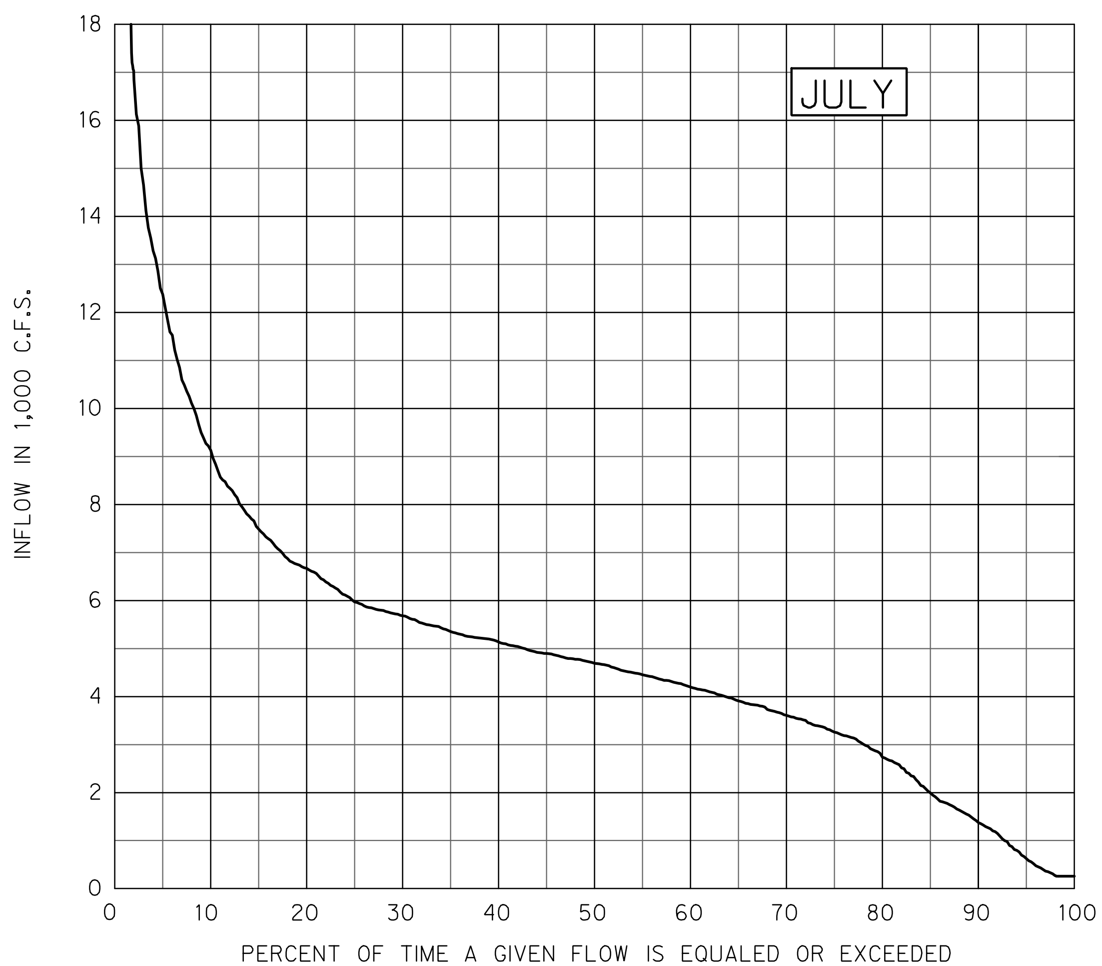
MONTHLY
INFLOW DURATION CURVES
BULL SHOALS LAKE
JANUARY-APRIL
1940 -2011

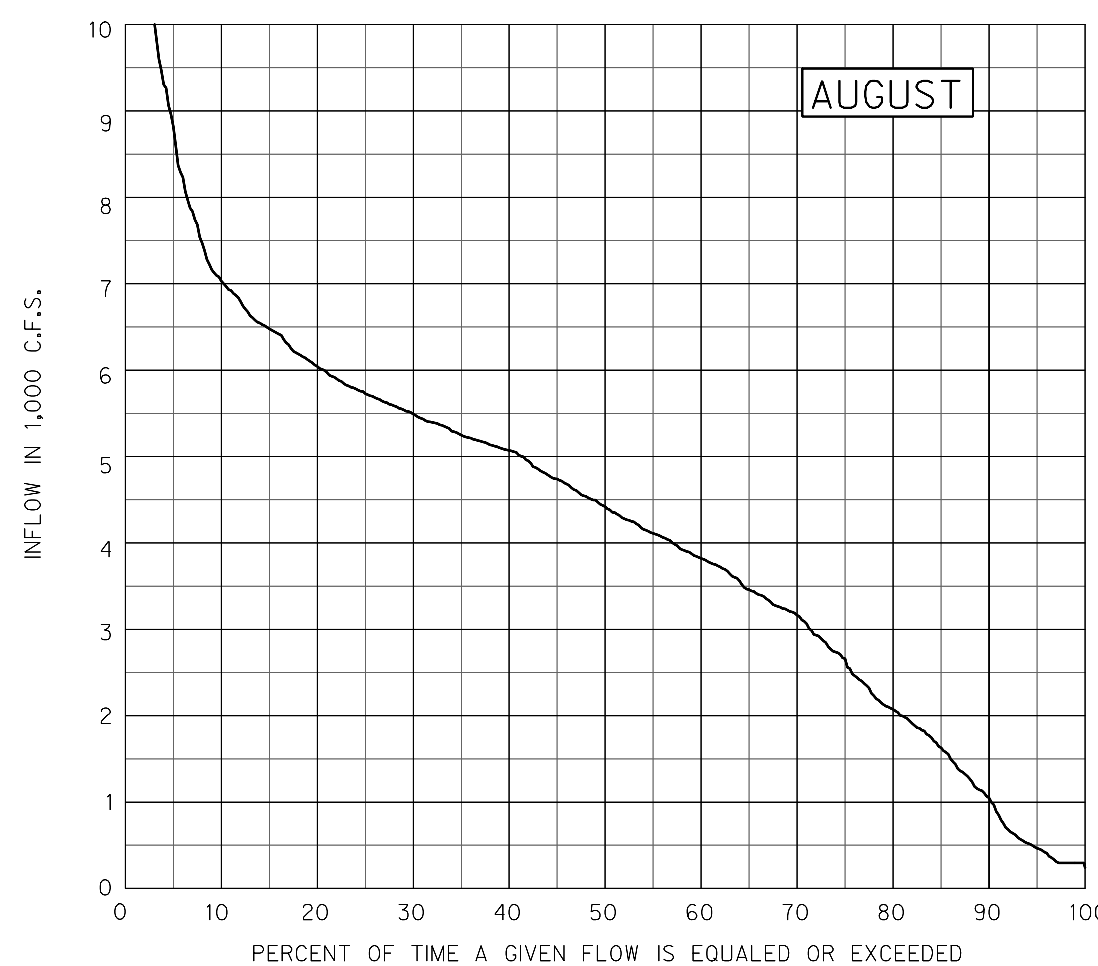
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

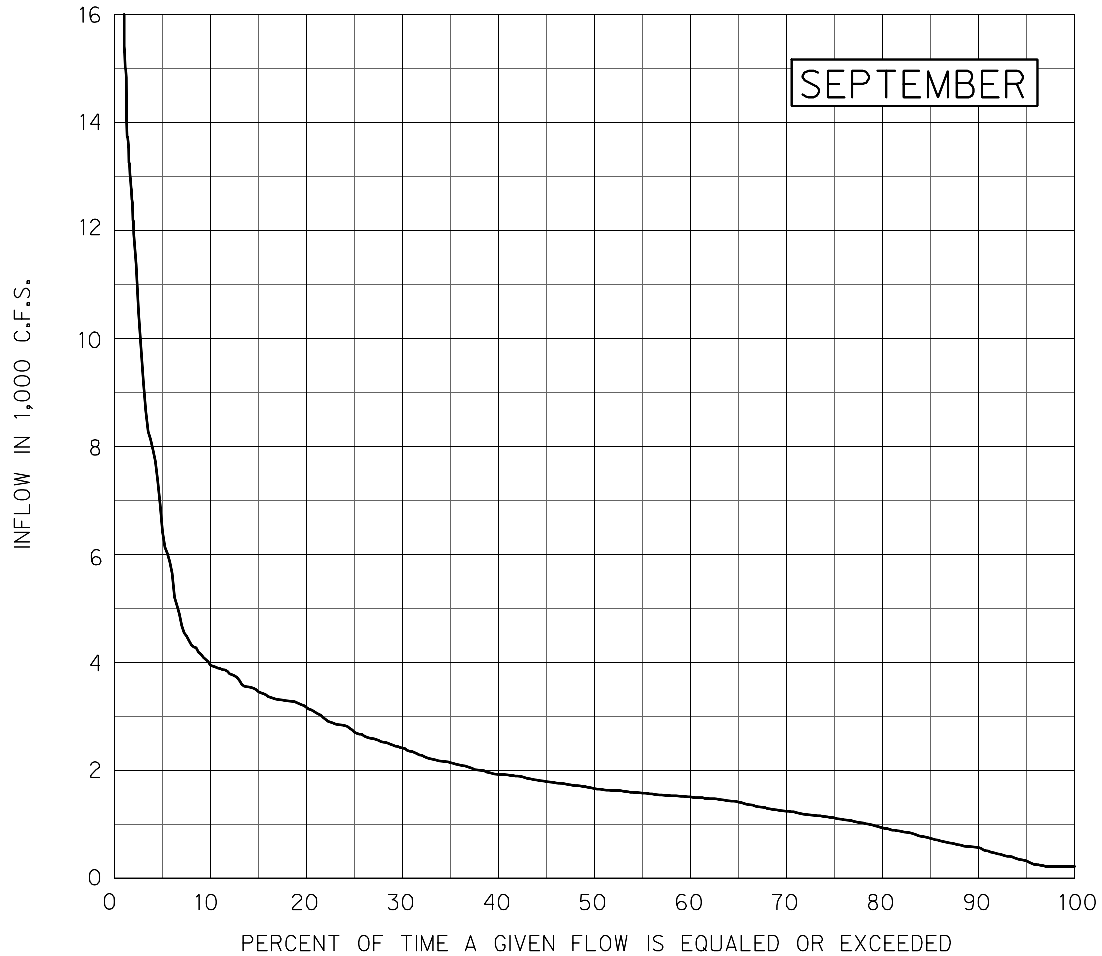
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

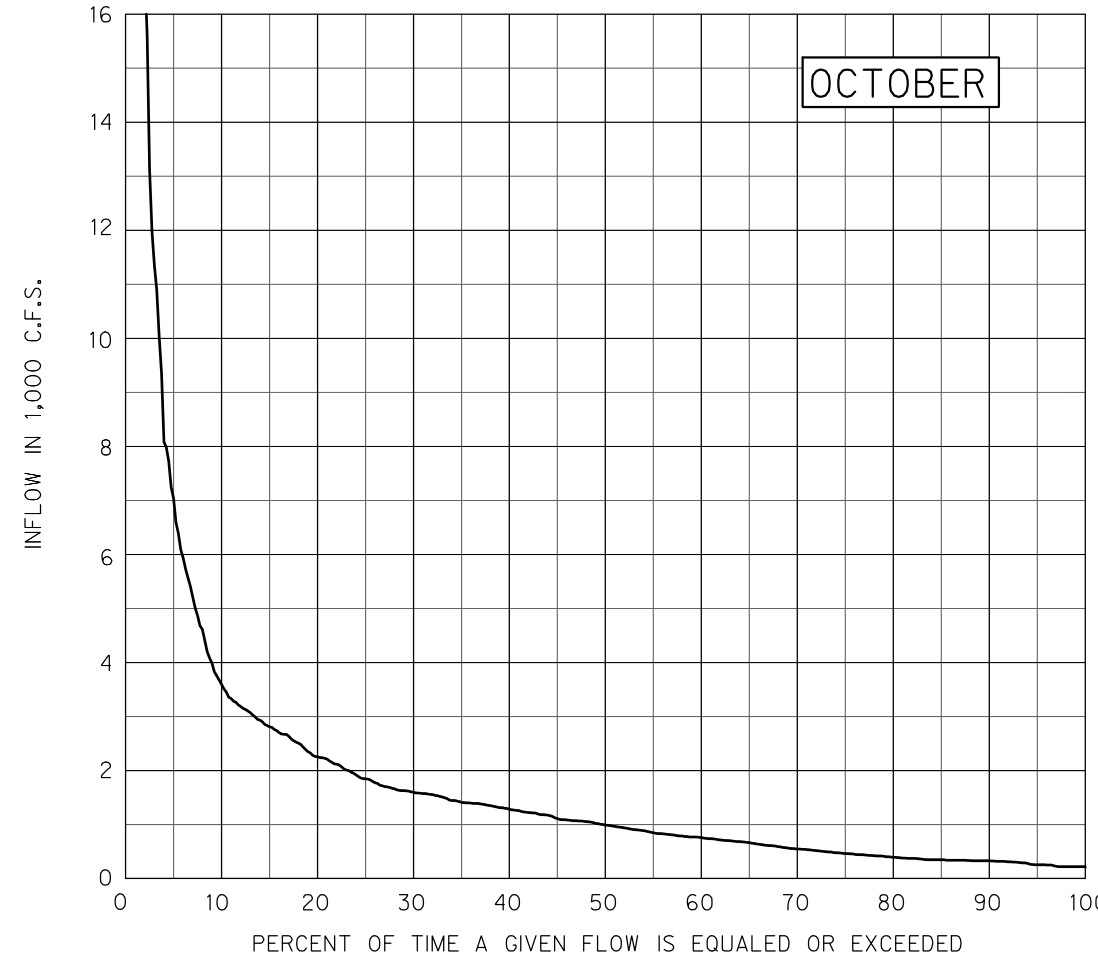
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

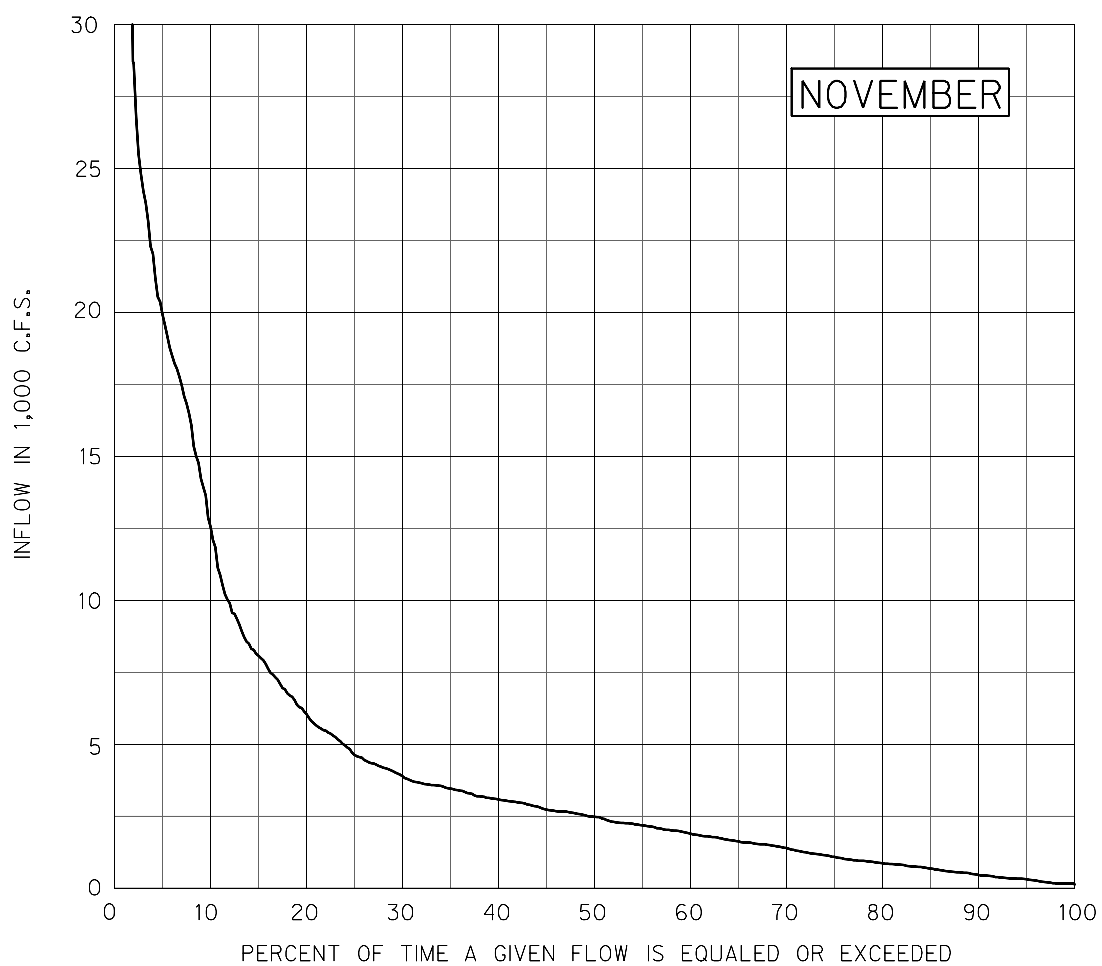
MONTHLY
INFLOW DURATION CURVES
BULL SHOALS LAKE
MAY-AUGUST
1940 -2011

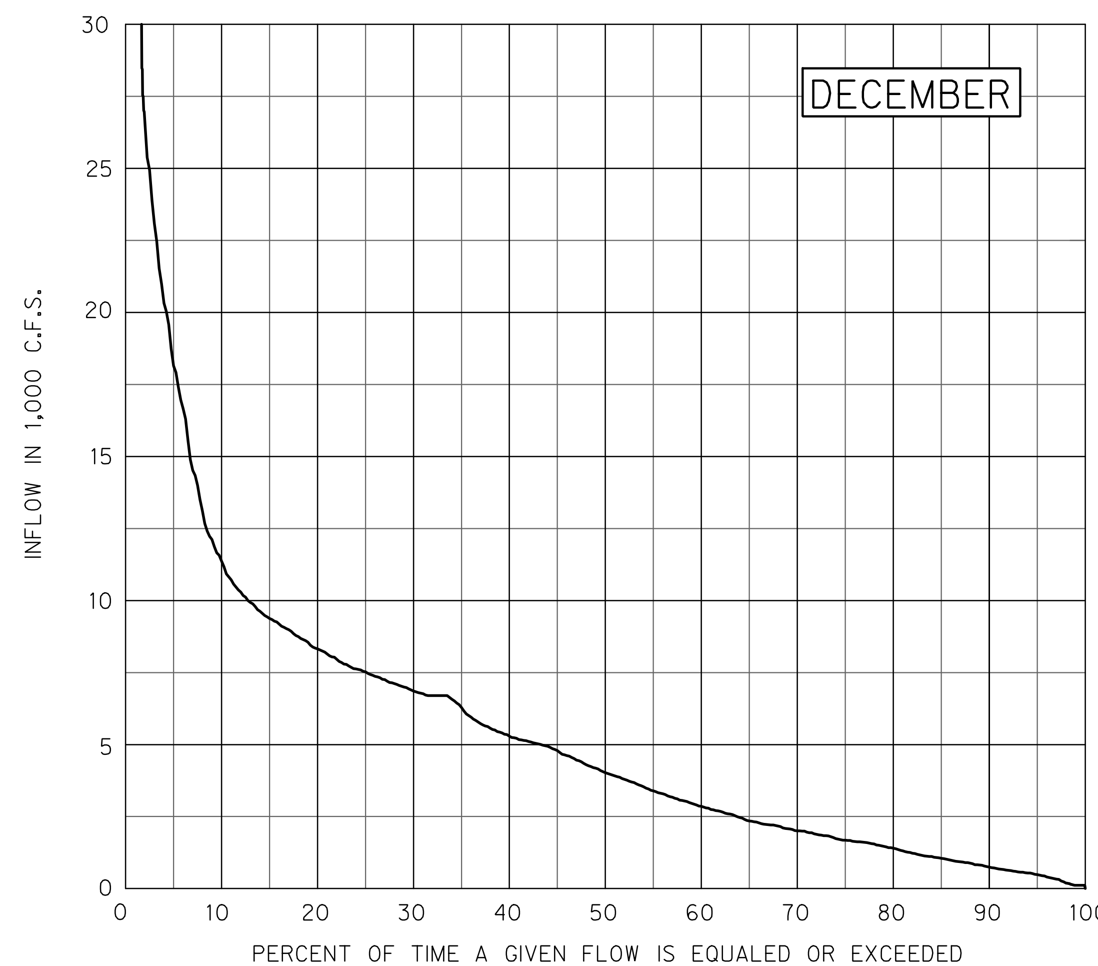
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

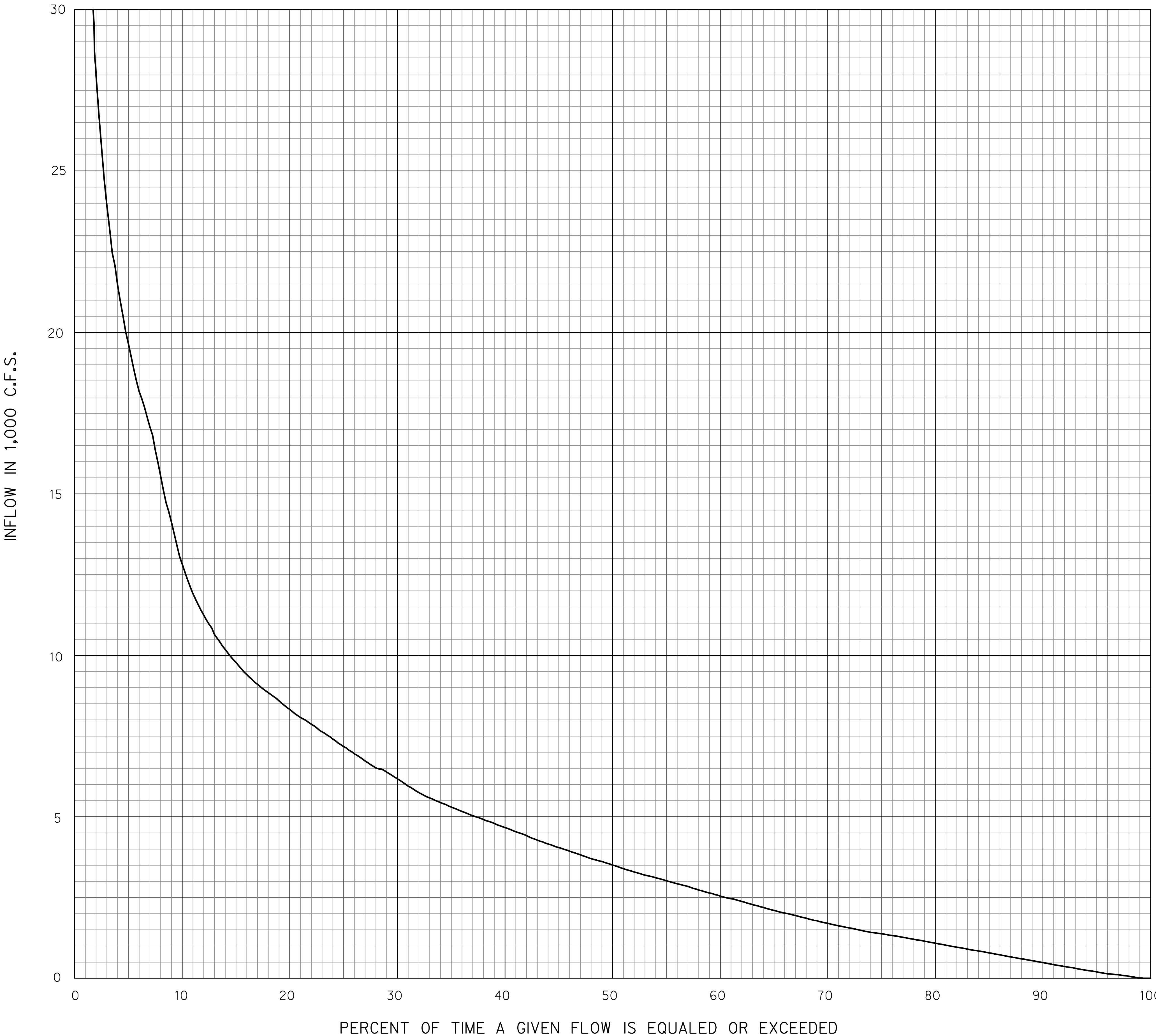
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

MONTHLY
INFLOW DURATION CURVES
BULL SHOALS LAKE
SEPTEMBER - DECEMBER
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

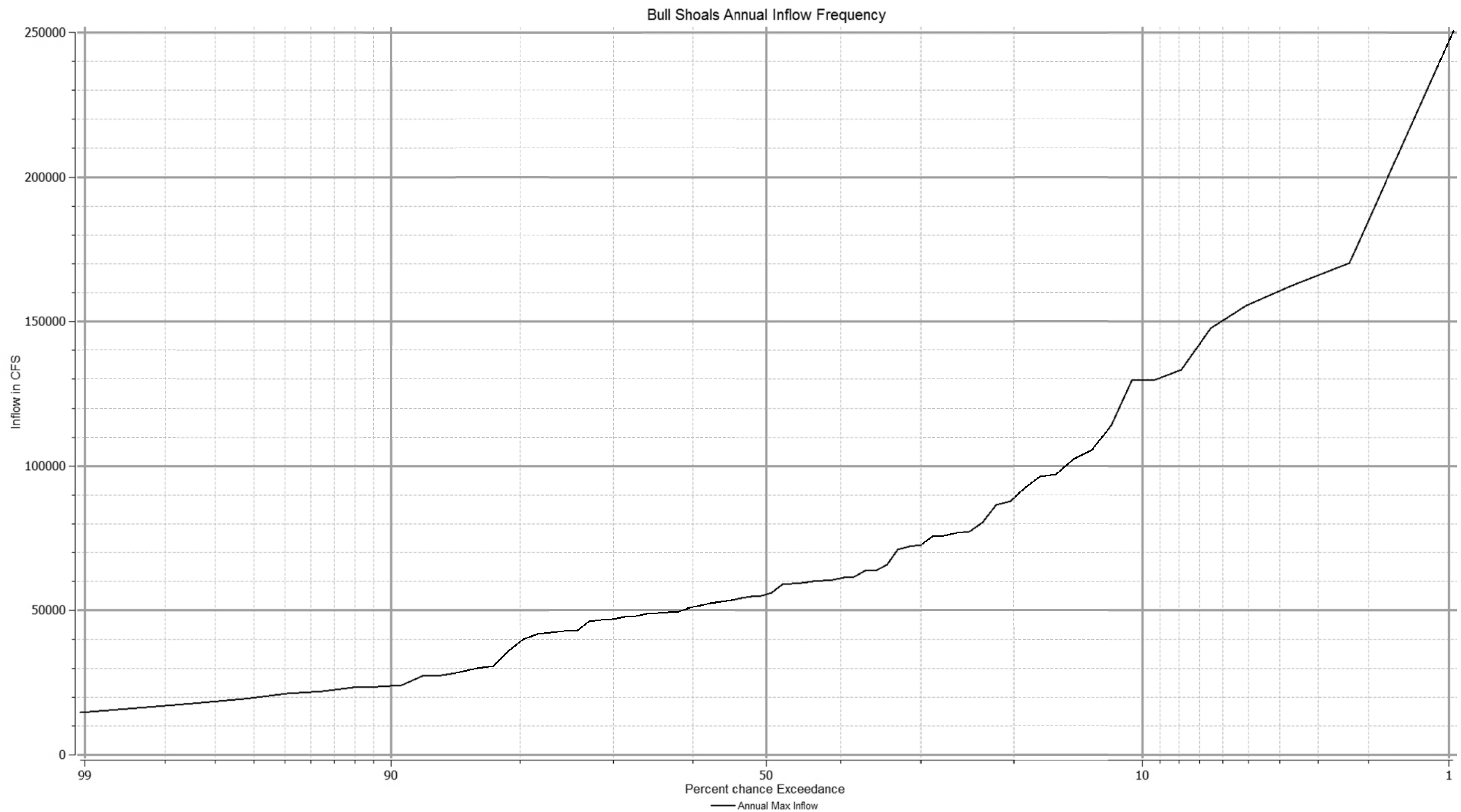
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

ANNUAL INFLOW DURATION CURVE
BULL SHOALS LAKE
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

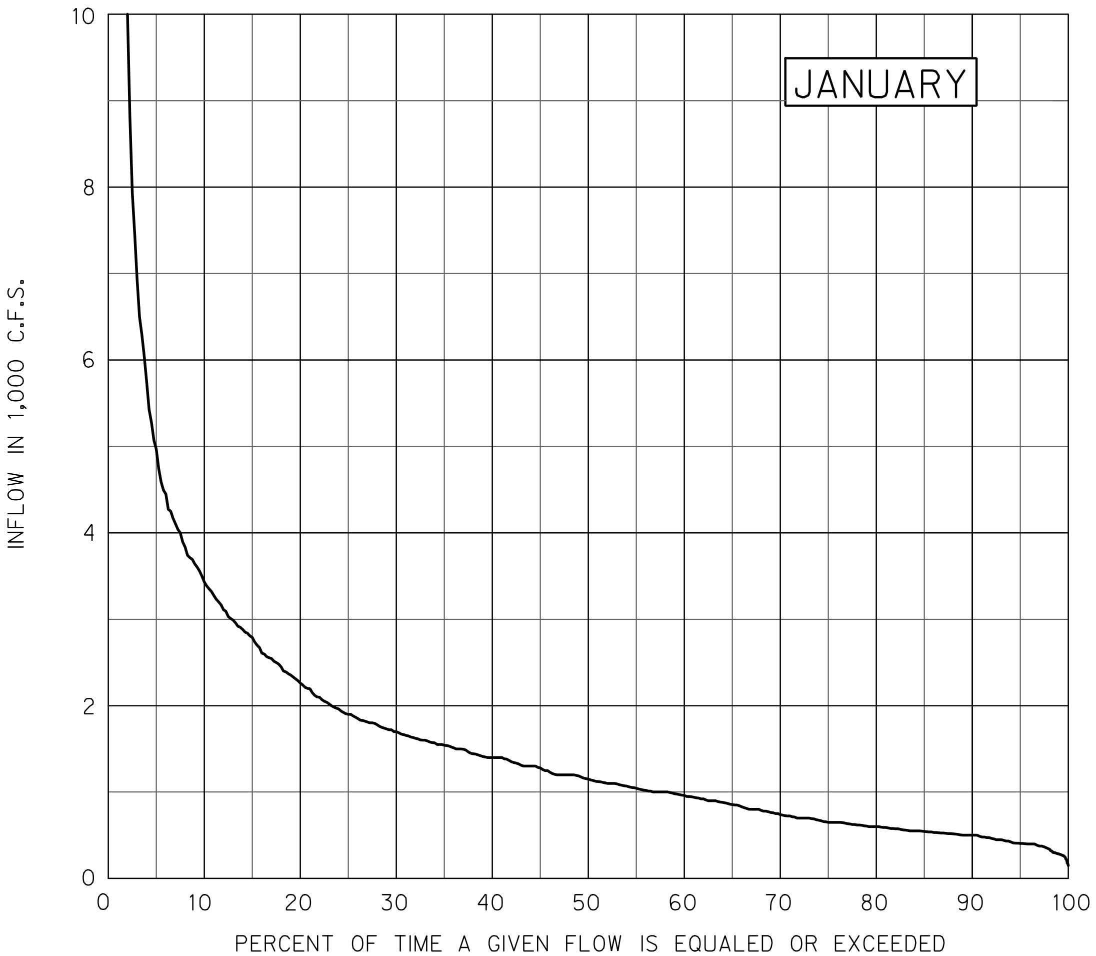
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

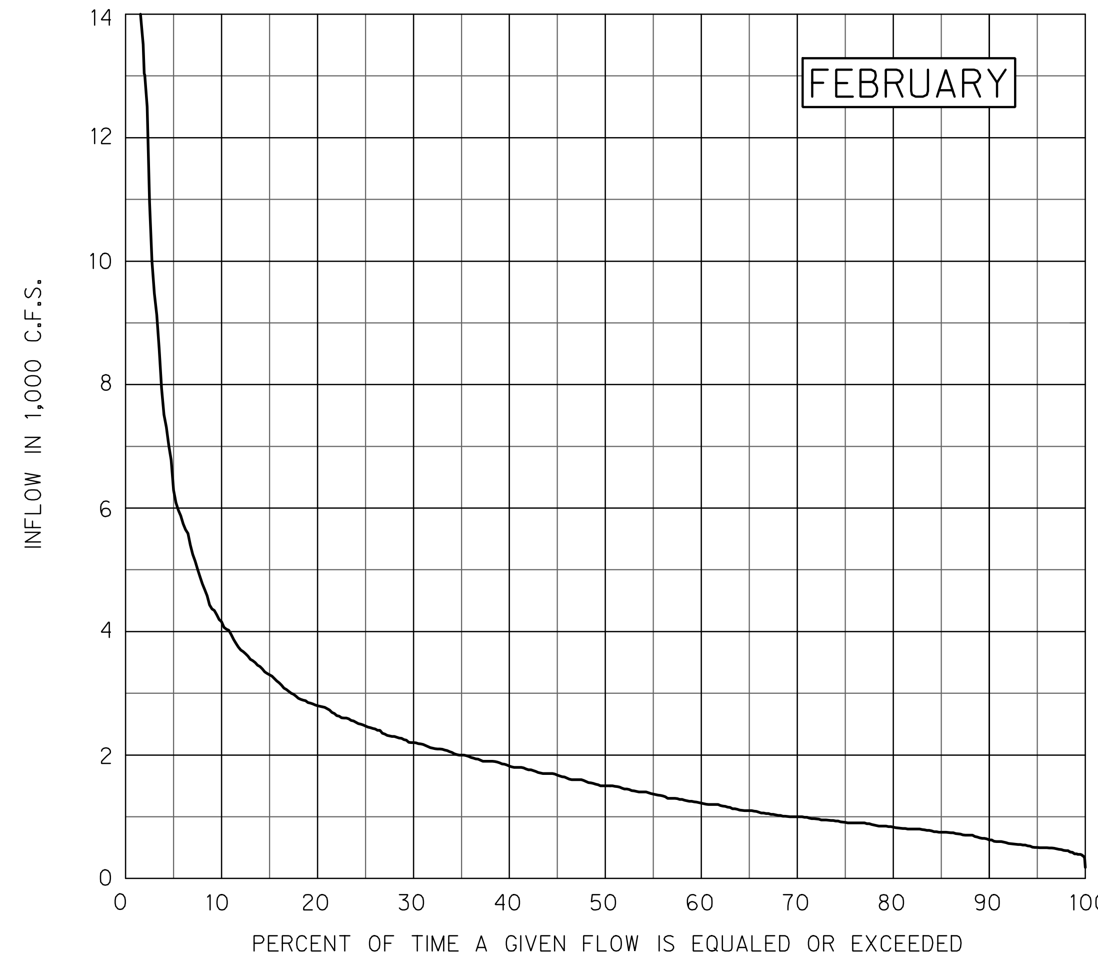
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

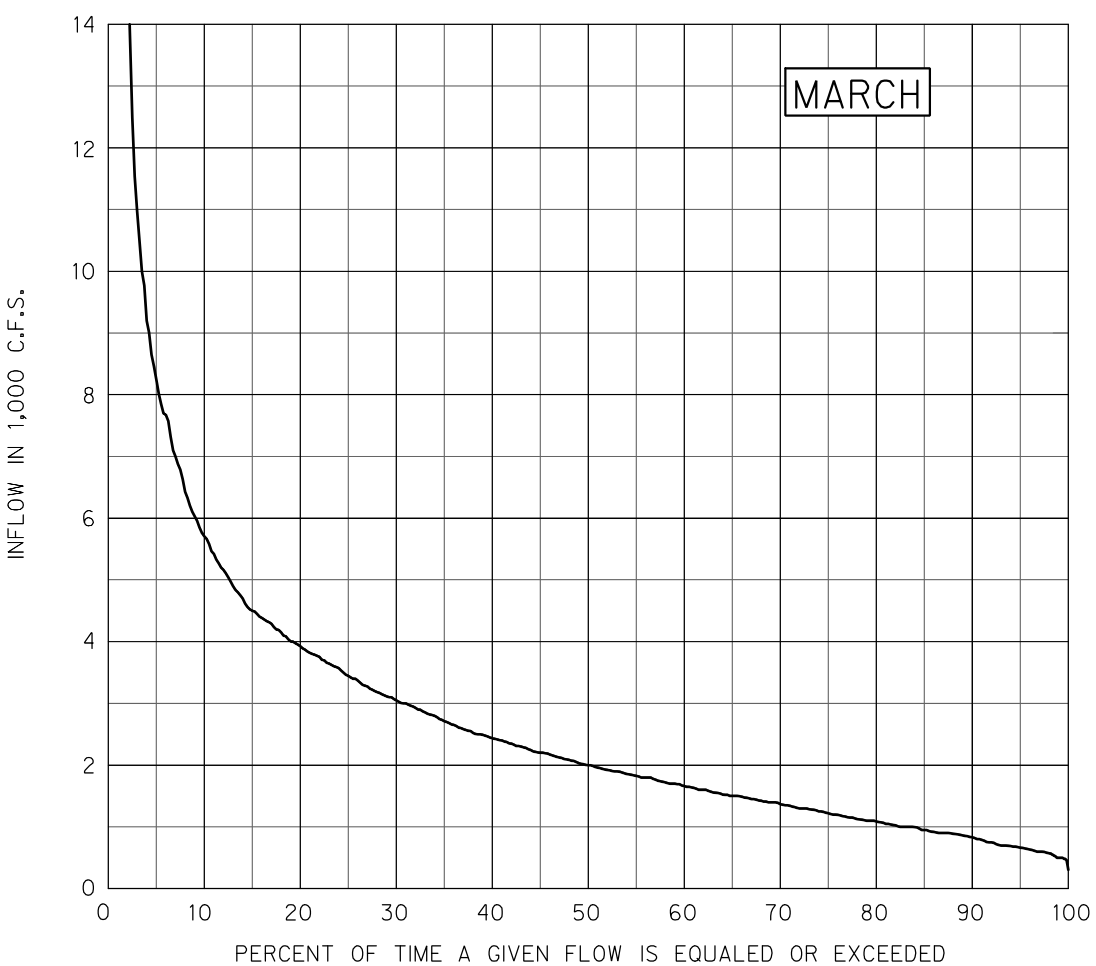
ANNUAL INFLOW FREQUENCY CURVE BULL SHOALS LAKE

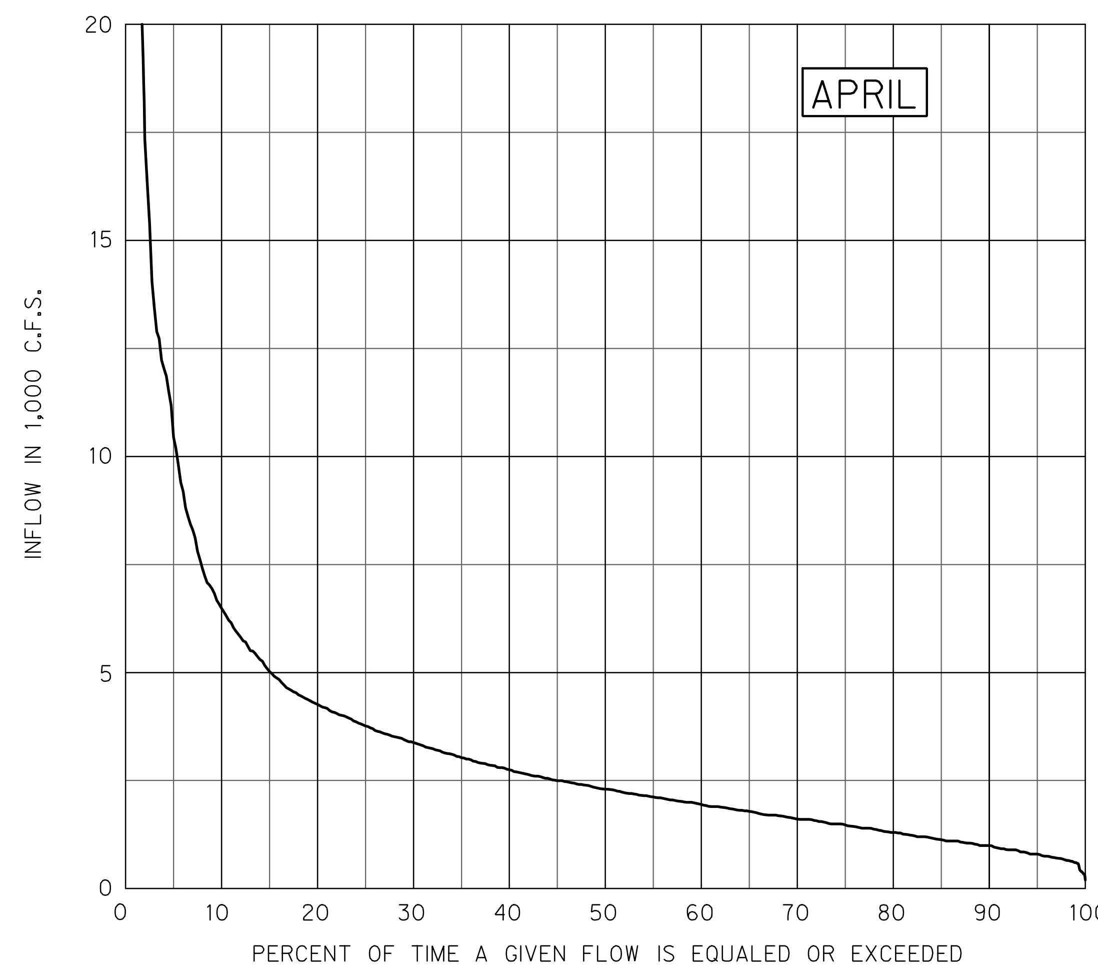
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

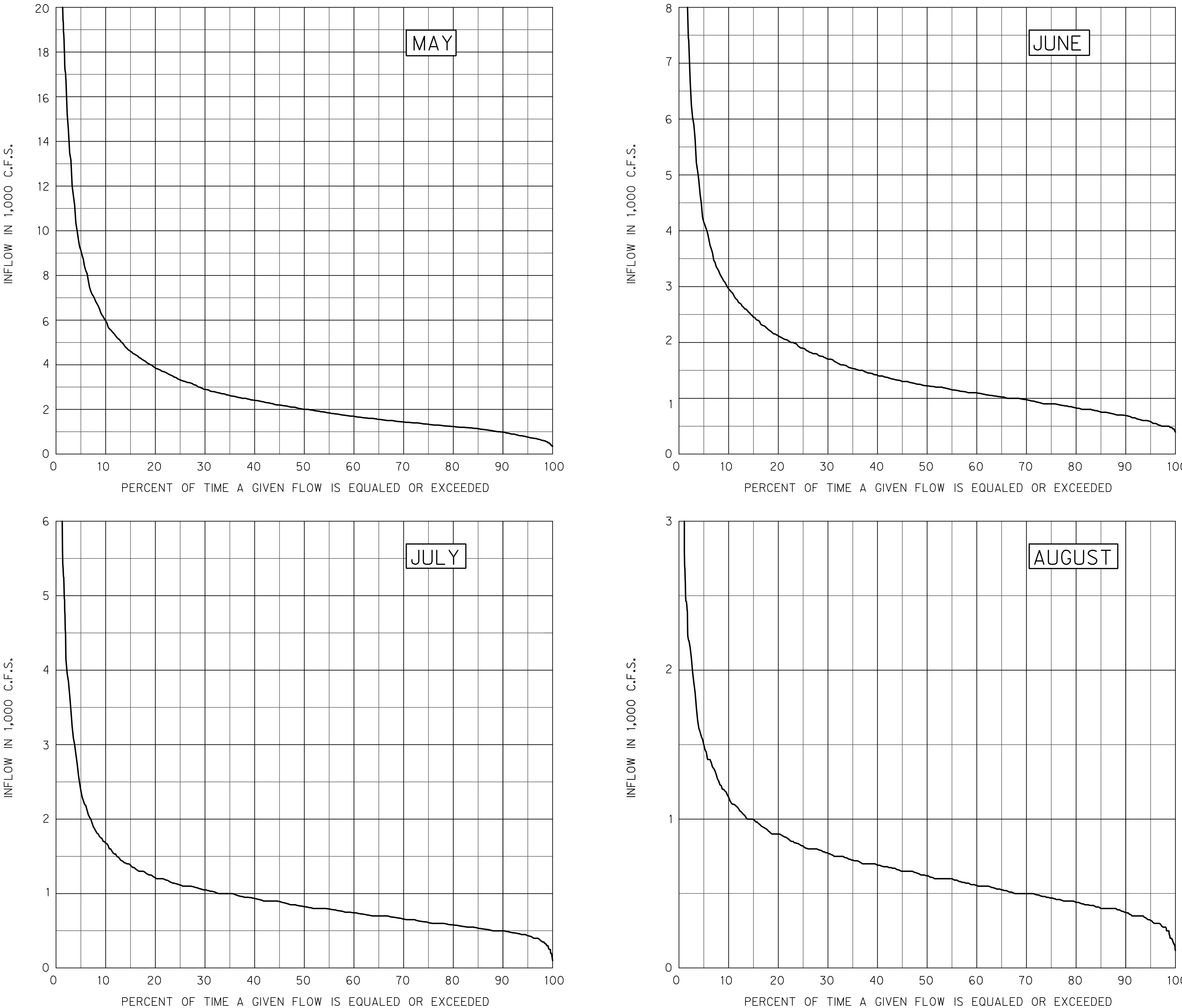
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

MONTHLY
INFLOW DURATION CURVES
NORFORK LAKE
JANUARY - APRIL
1940 -2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



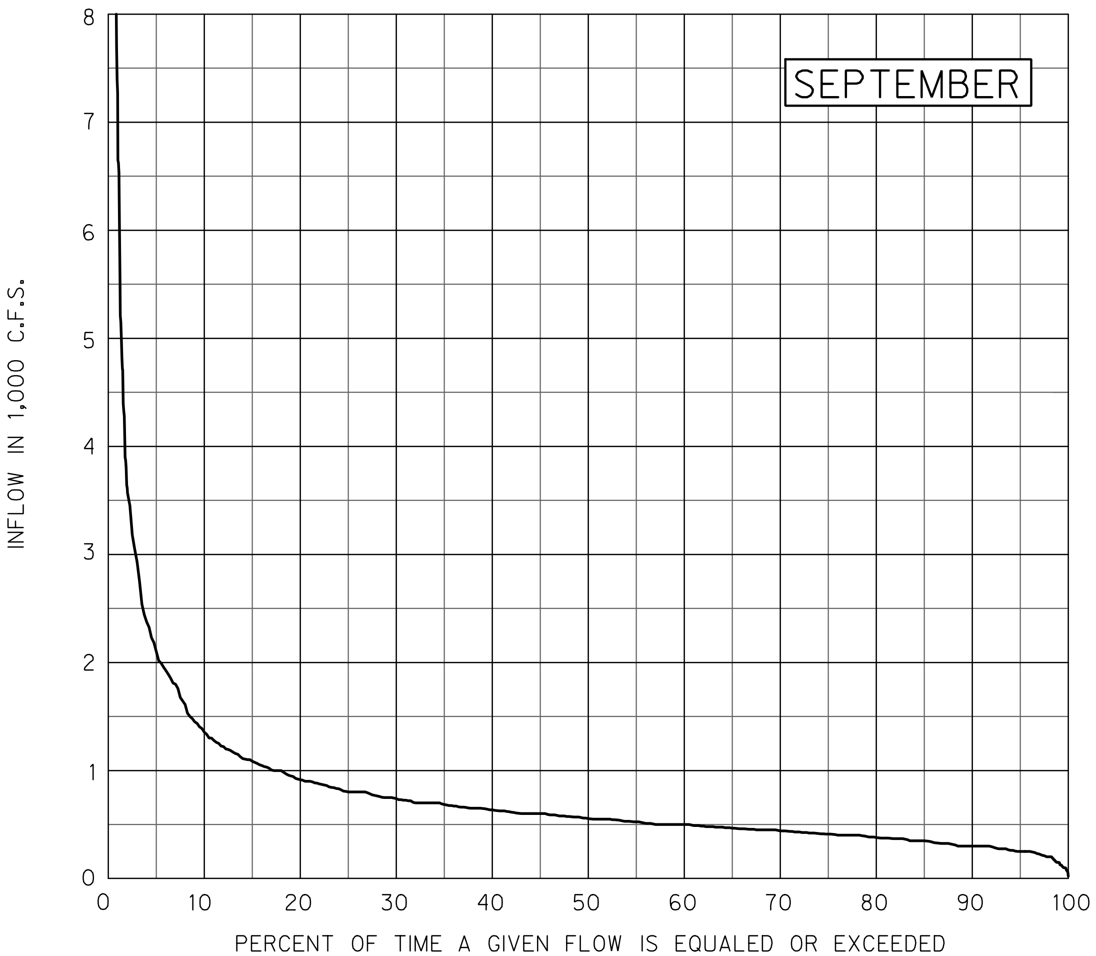
NOTE:

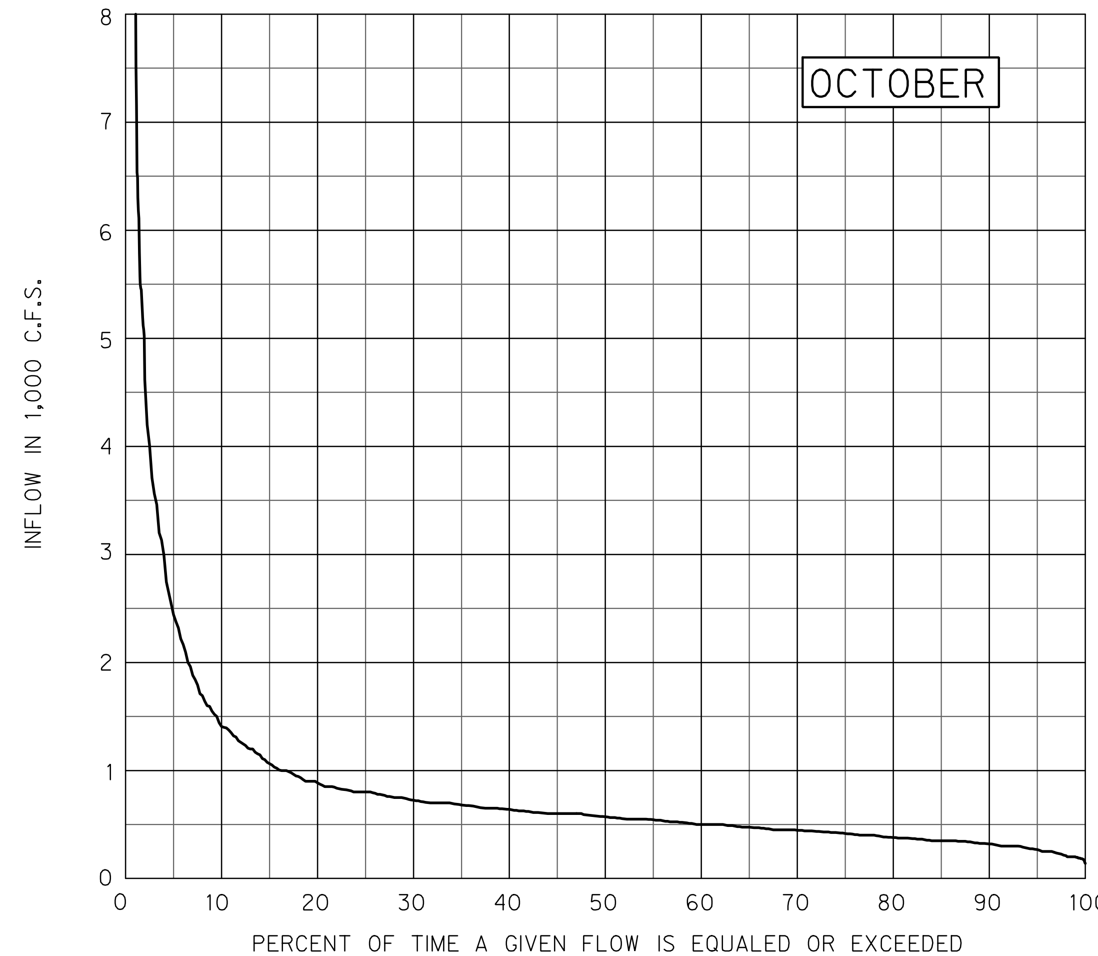
2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

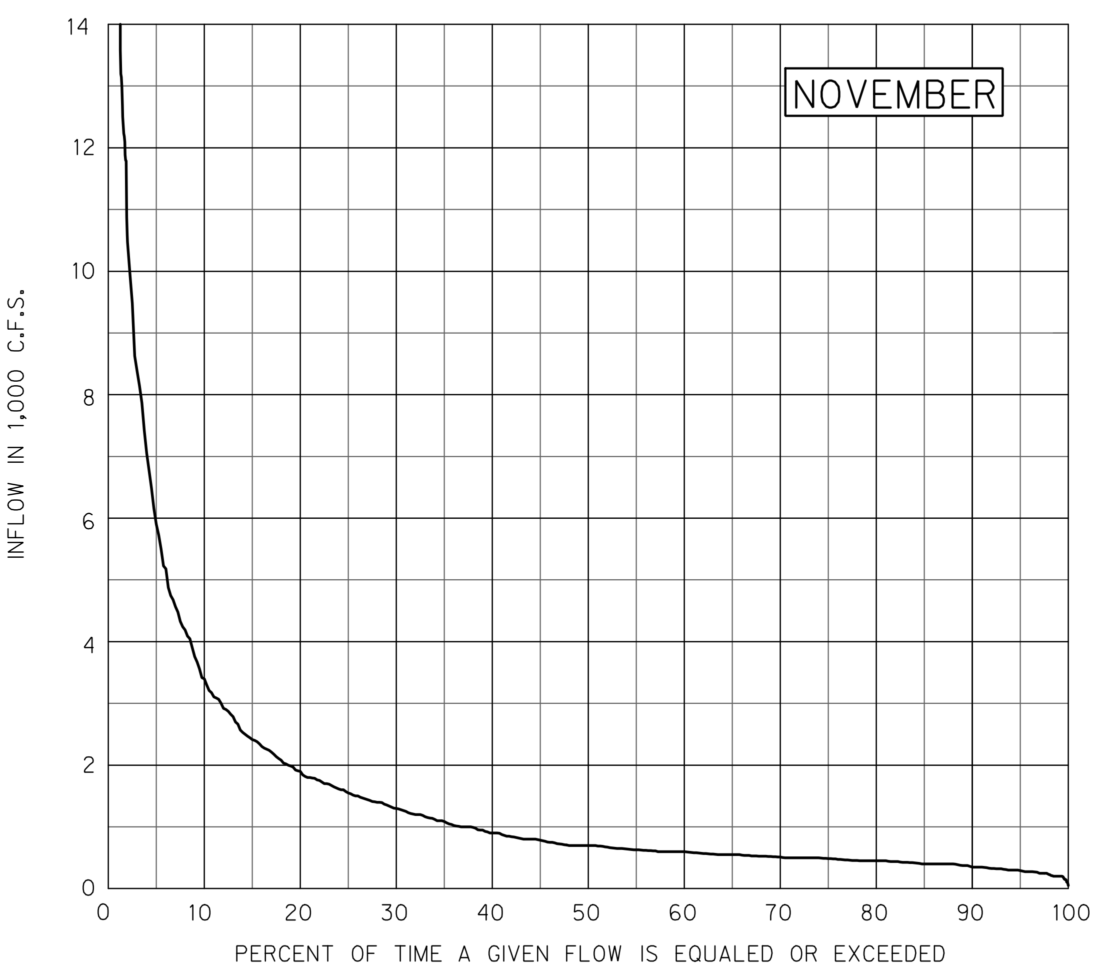
WHITE RIVER BASIN ARKANSAS AND MISSOURI

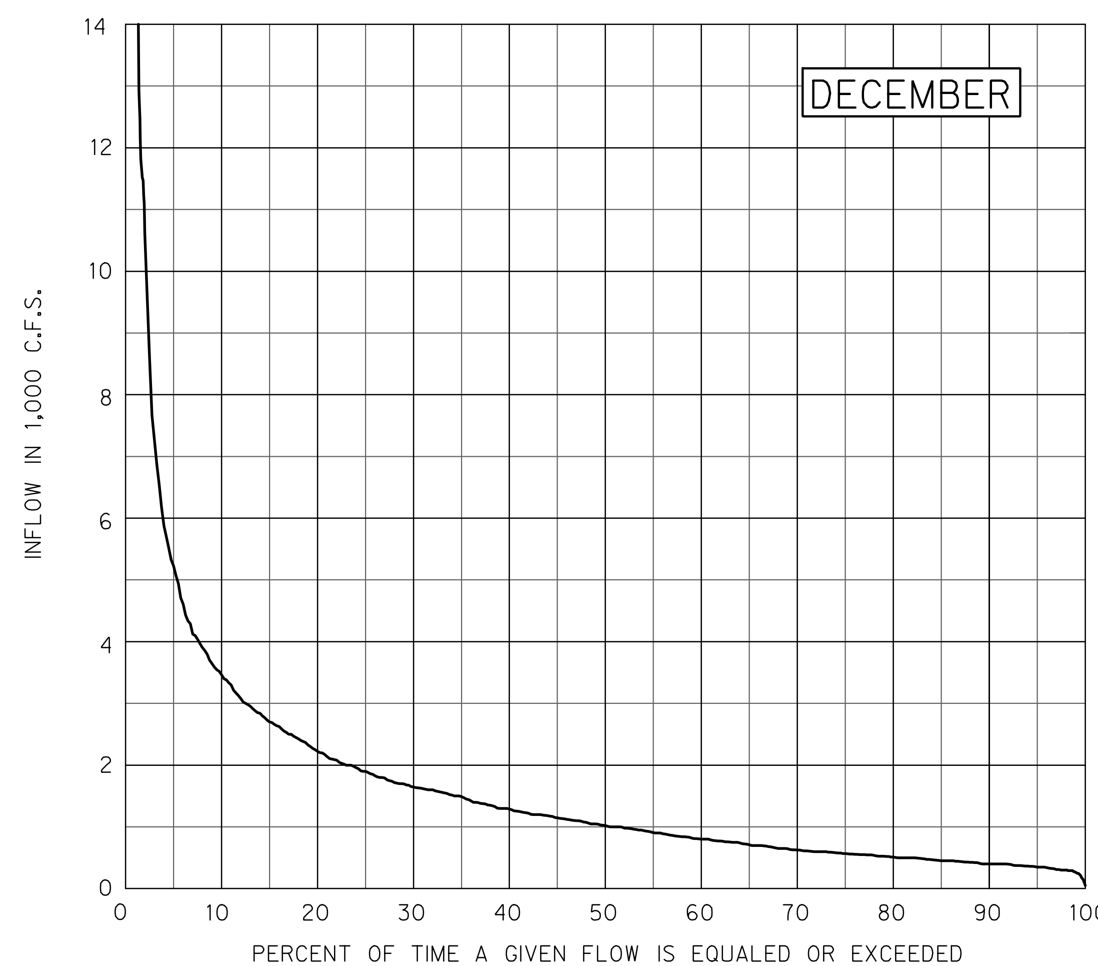
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
INFLOW DURATION CURVES
NORFORK LAKE
MAY-AUGUST
1940 -2011
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

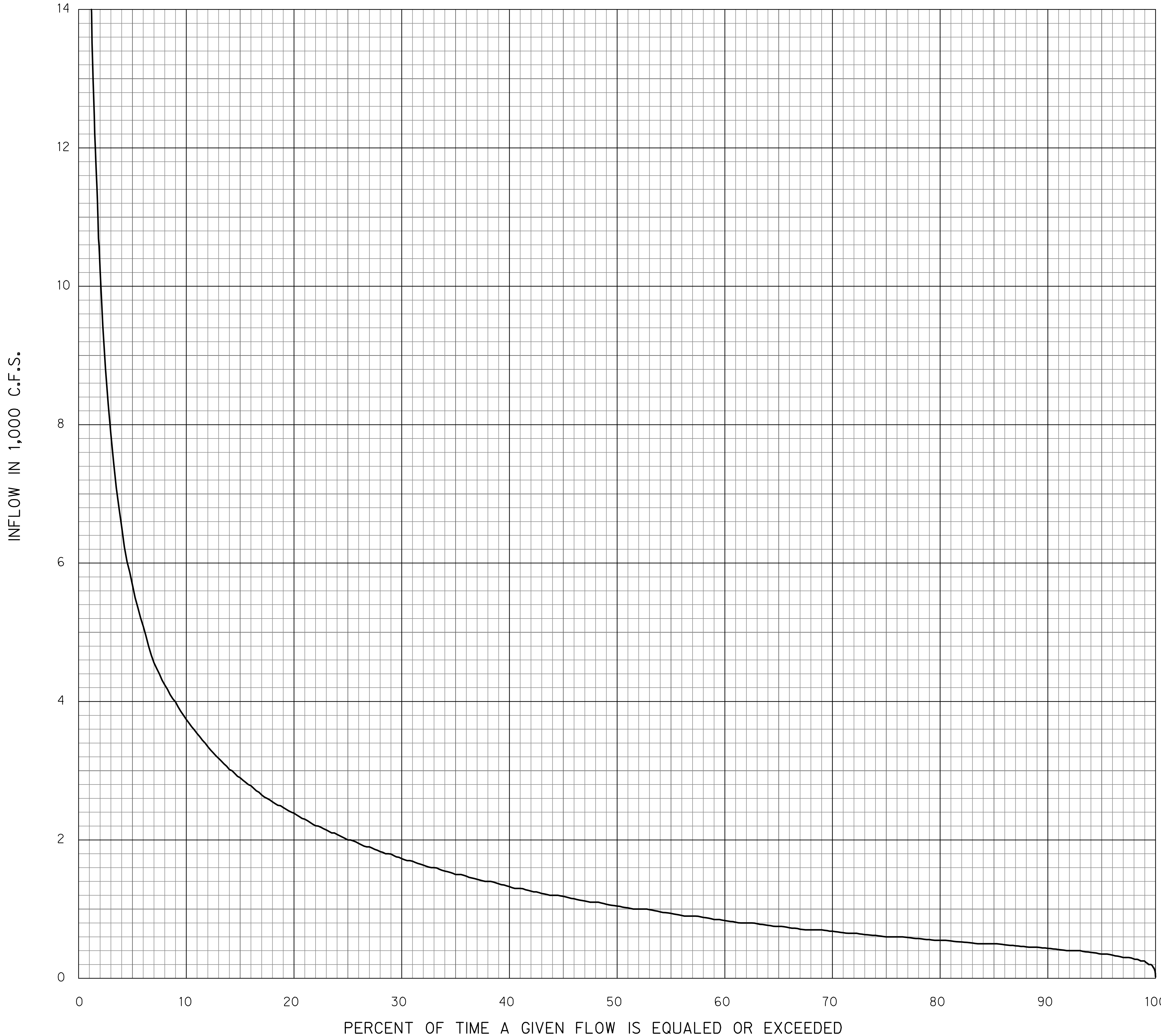
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

MONTHLY
INFLOW DURATION CURVES
NORFORK LAKE
SEPTEMBER - DECEMBER
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

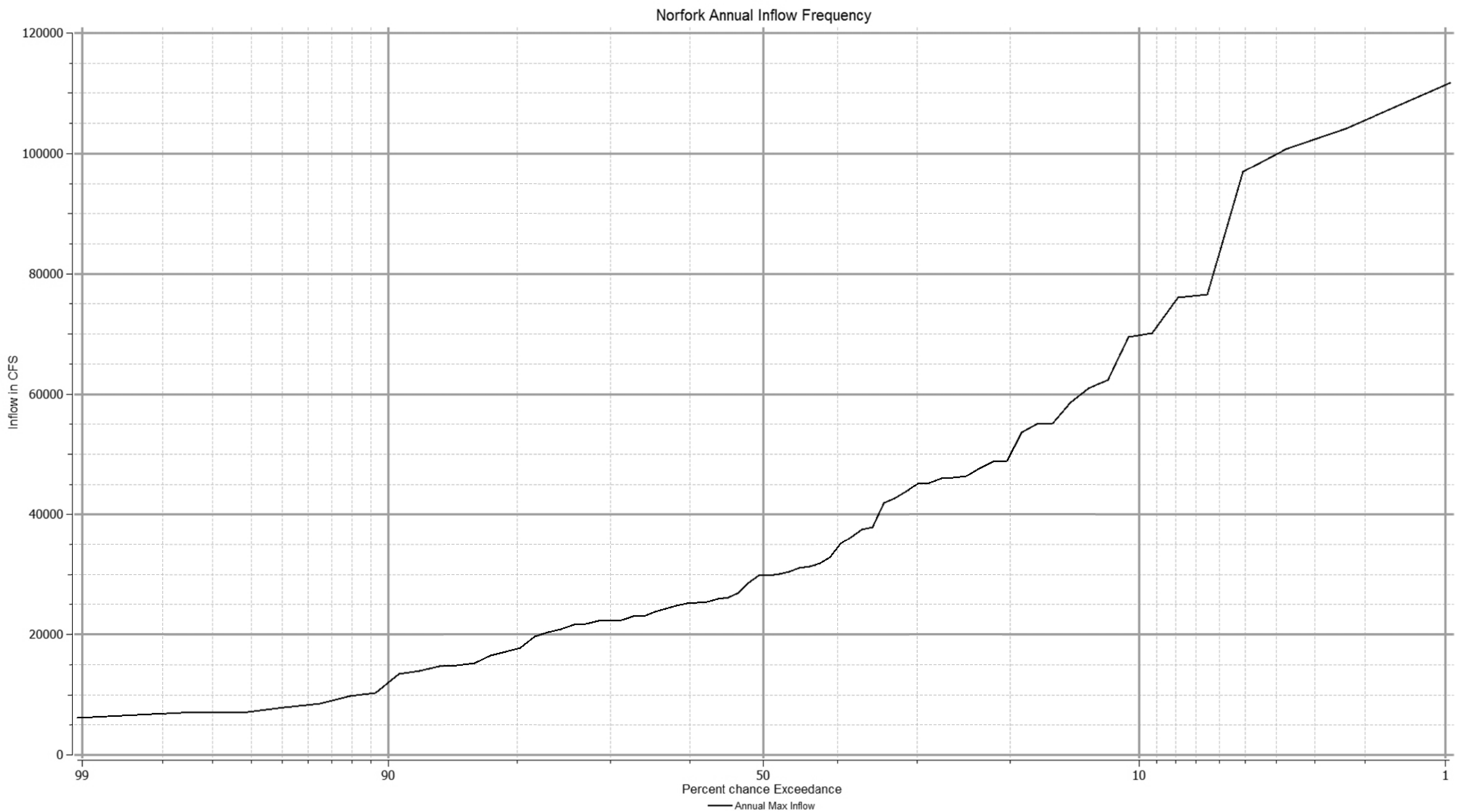
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

ANNUAL INFLOW DURATION CURVE NORFORK LAKE 1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

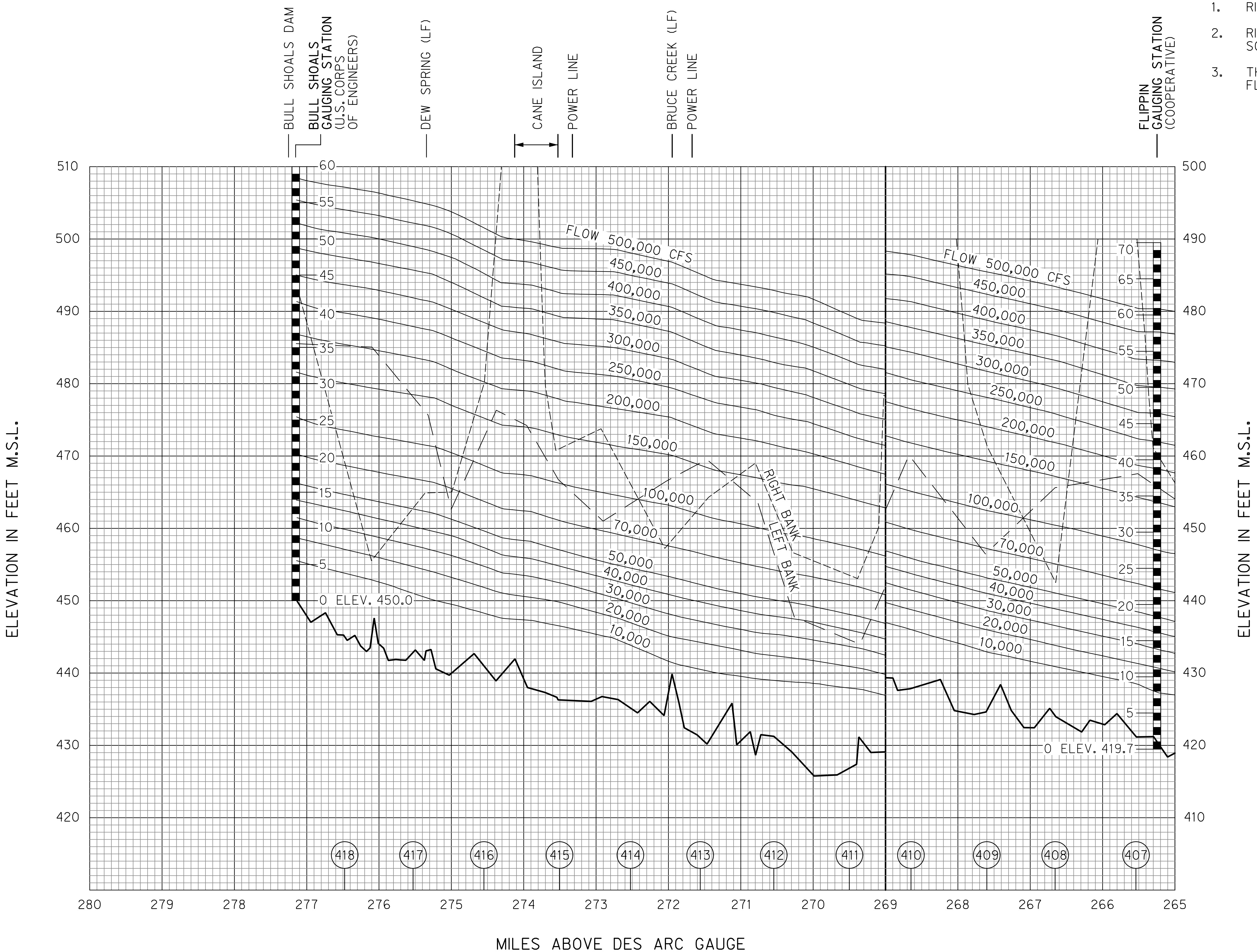
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

ANNUAL INFLOW
FREQUENCY CURVE
NORFORK LAKE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTES:

1. RIVER MILES ARE 1945 BELOW BATESVILLE AND 1942 ABOVE.
2. RIVER MILES ABOVE DES ARC ARE MID-BANK DISTANCES SCALED FROM LATEST 7.5 MINUTE QUAD MAPS AS OF 1978.
3. THE WATER SURFACE PROFILES ARE COMPUTED STEADY FLOW BASED ON FIELD SURVEYS OF 1978 CONDITIONS.

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

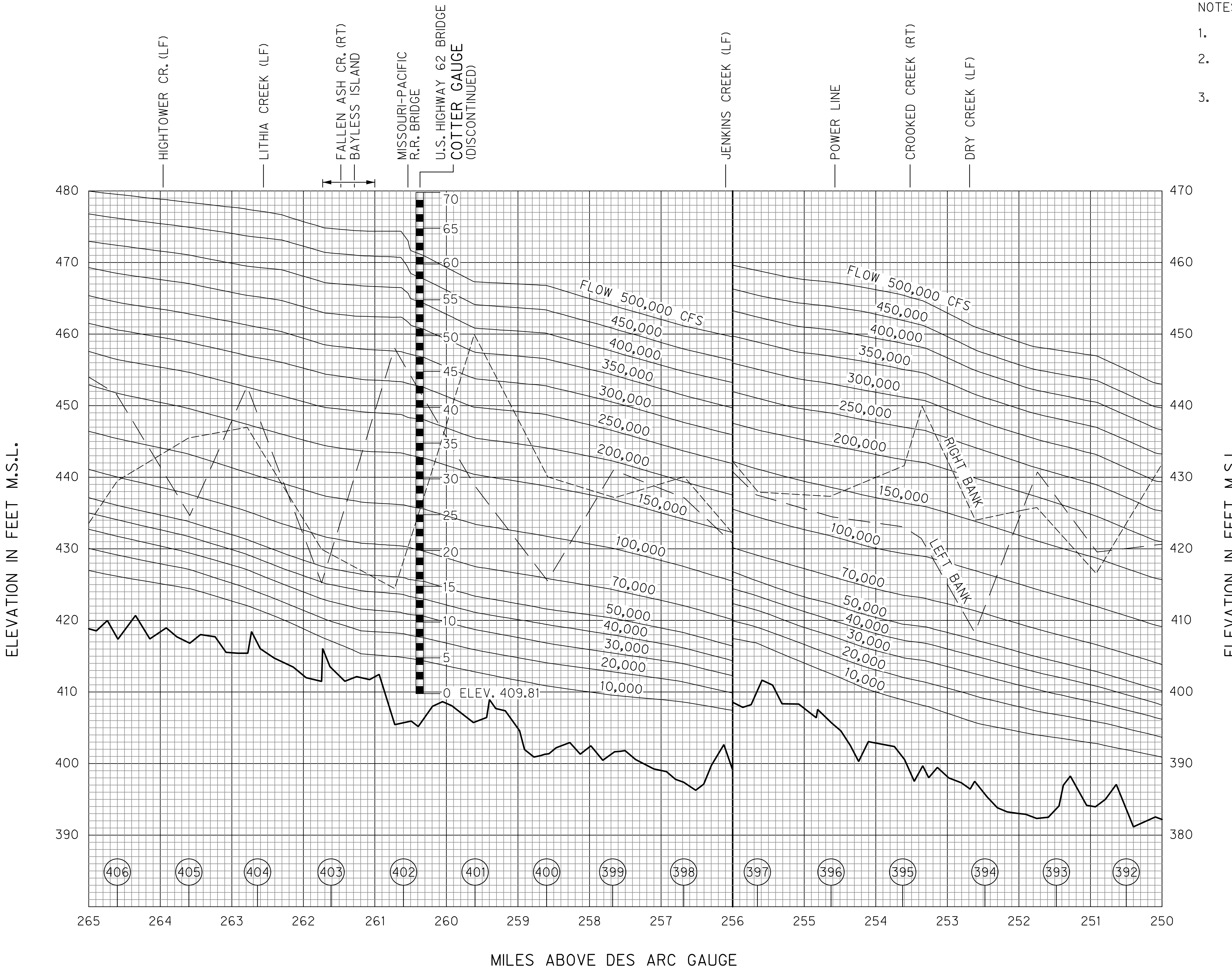
WHITE RIVER PROFILE
RIVER MILE 406.4 TO 418.4

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014

NOTES:

1. RIVER MILES ARE 1945 BELOW BATESVILLE AND 1942 ABOVE.
2. RIVER MILES ABOVE DES ARC ARE MID-BANK DISTANCES SCALED FROM LATEST 7.5 MINUTE QUAD MAPS AS OF 1978.
3. THE WATER SURFACE PROFILES ARE COMPUTED STEADY FLOW BASED ON FIELD SURVEYS OF 1978 CONDITIONS.



WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

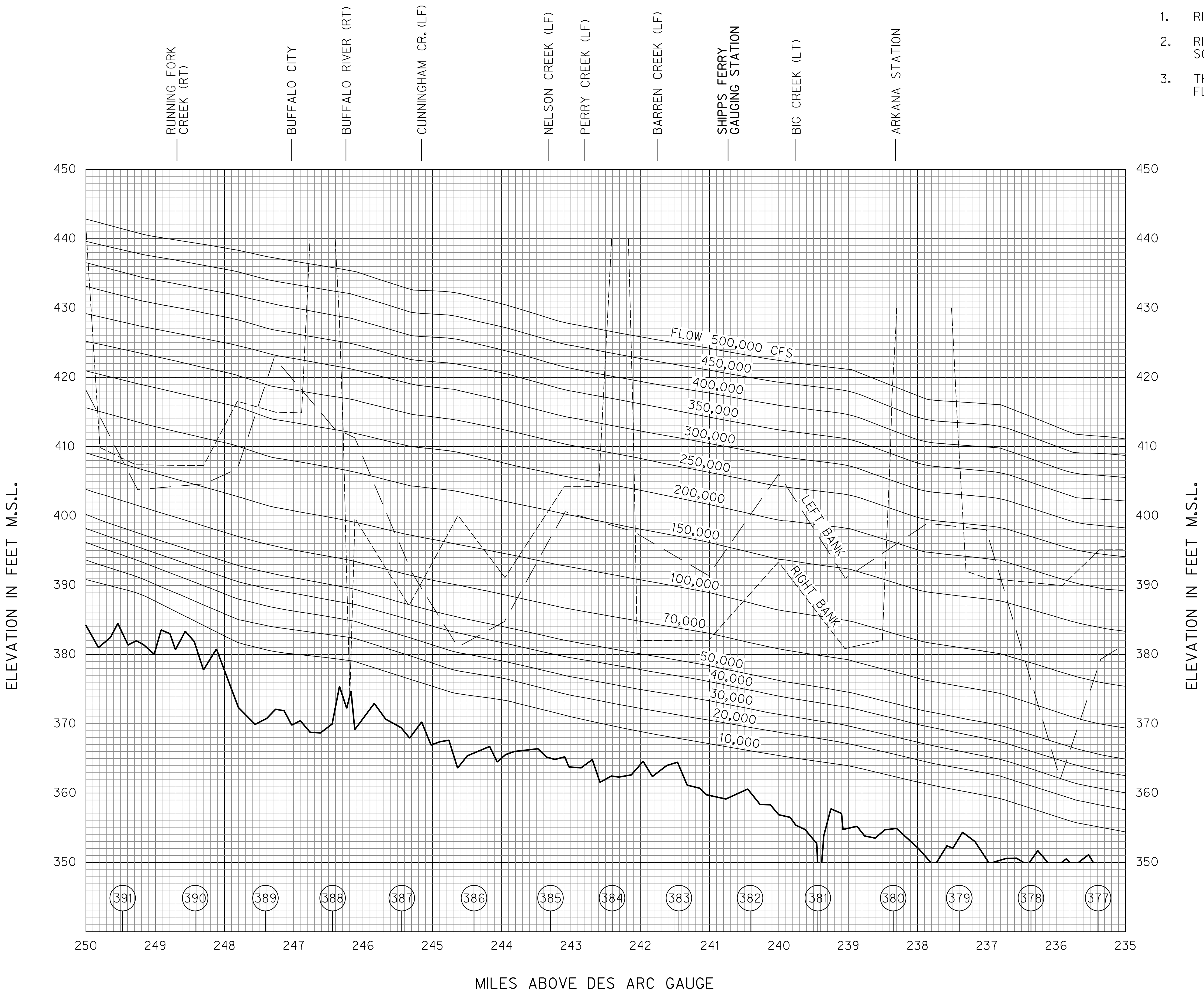
WHITE RIVER PROFILE
RIVER MILE 391.6 TO 406.4

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014

NOTES:

1. RIVER MILES ARE 1945 BELOW BATESVILLE AND 1942 ABOVE.
2. RIVER MILES ABOVE DES ARC ARE MID-BANK DISTANCES SCALED FROM LATEST 7.5 MINUTE QUAD MAPS AS OF 1978.
3. THE WATER SURFACE PROFILES ARE COMPUTED STEADY FLOW BASED ON FIELD SURVEYS OF 1978 CONDITIONS.



WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

WHITE RIVER PROFILE
RIVER MILE 376.6 TO 391.6

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014

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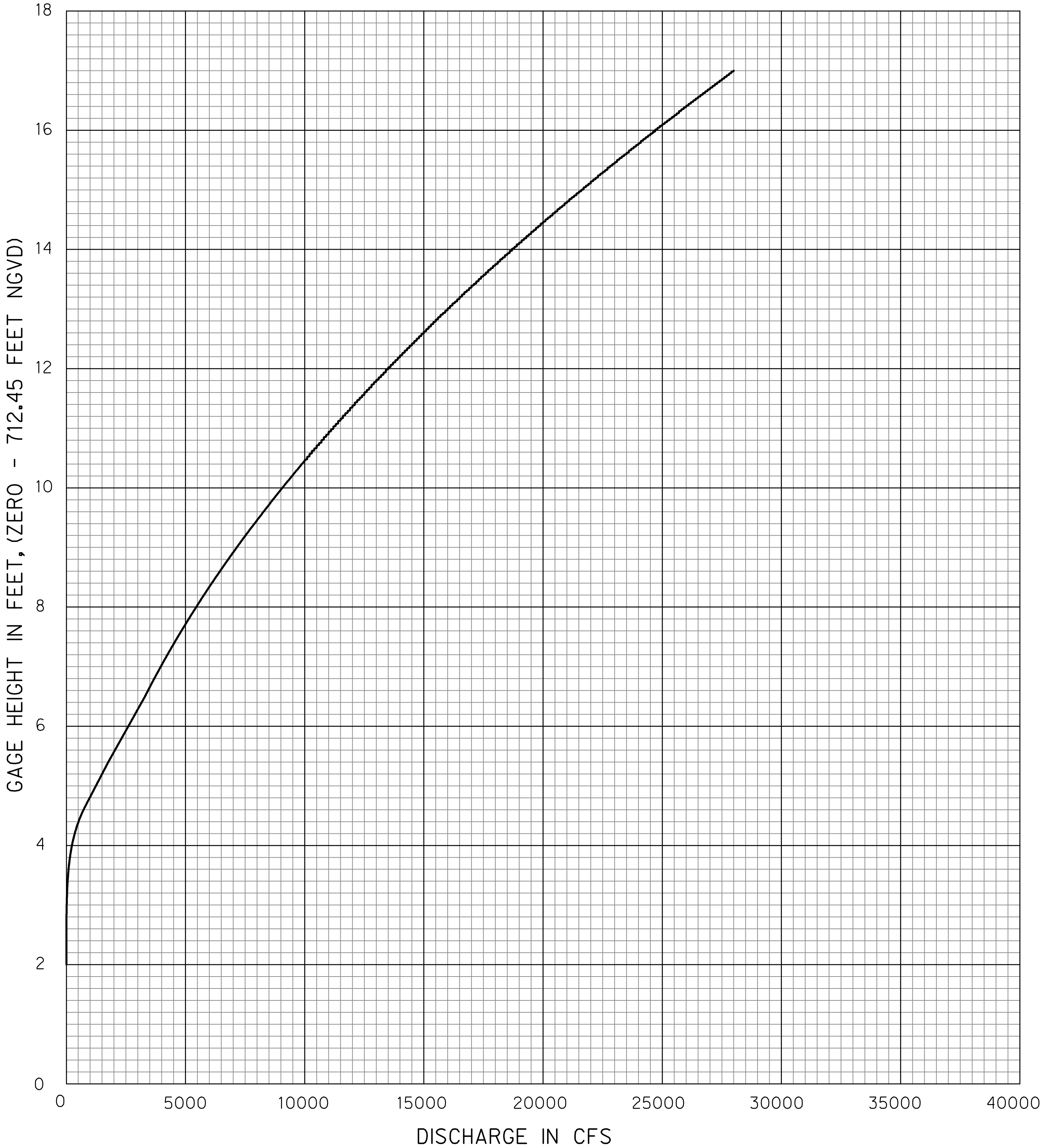


USGS OCTOBER 2011 RATING

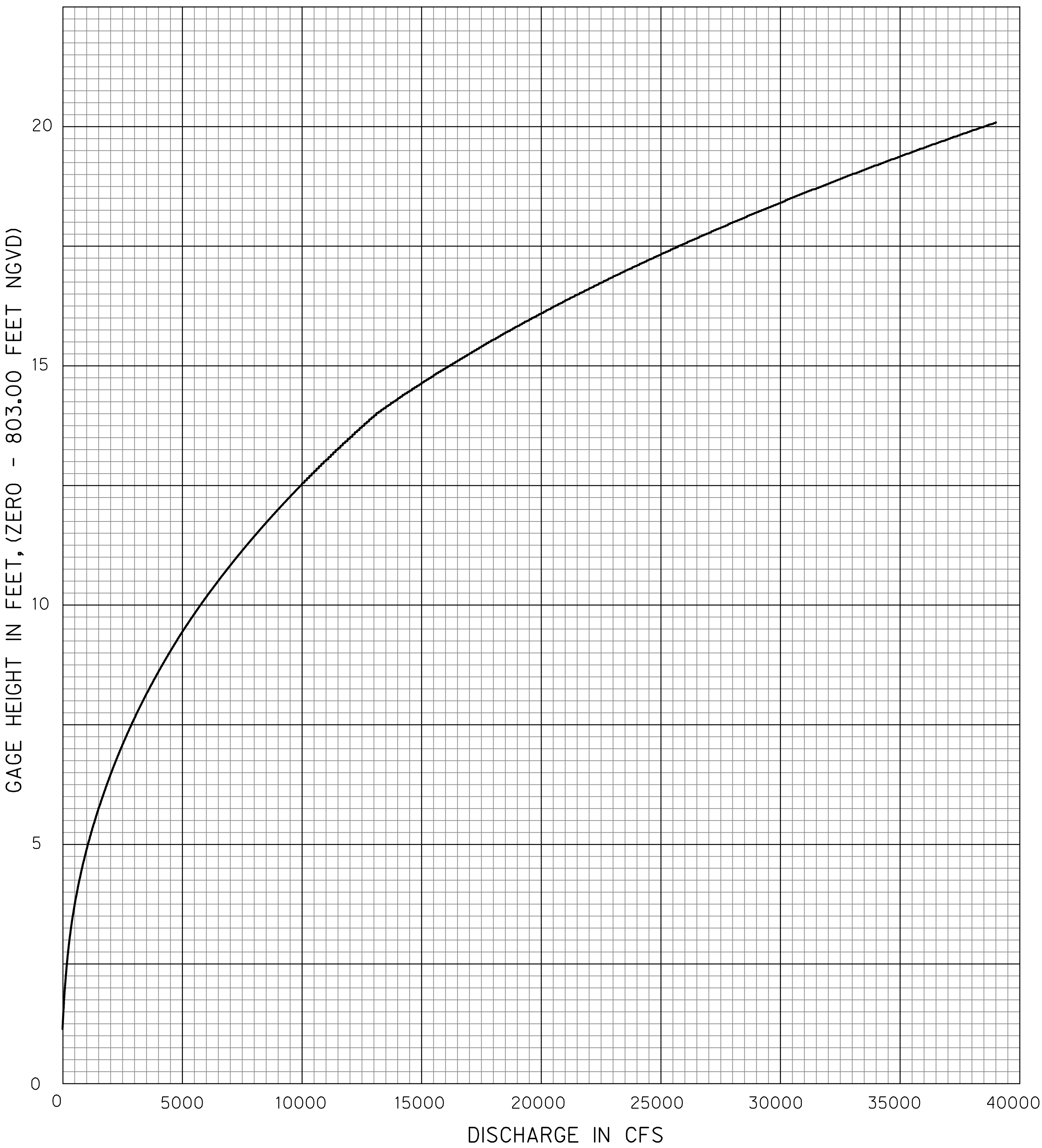
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
BULL CREEK NEAR WALNUT SHADE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



USGS OCTOBER 2011 RATING

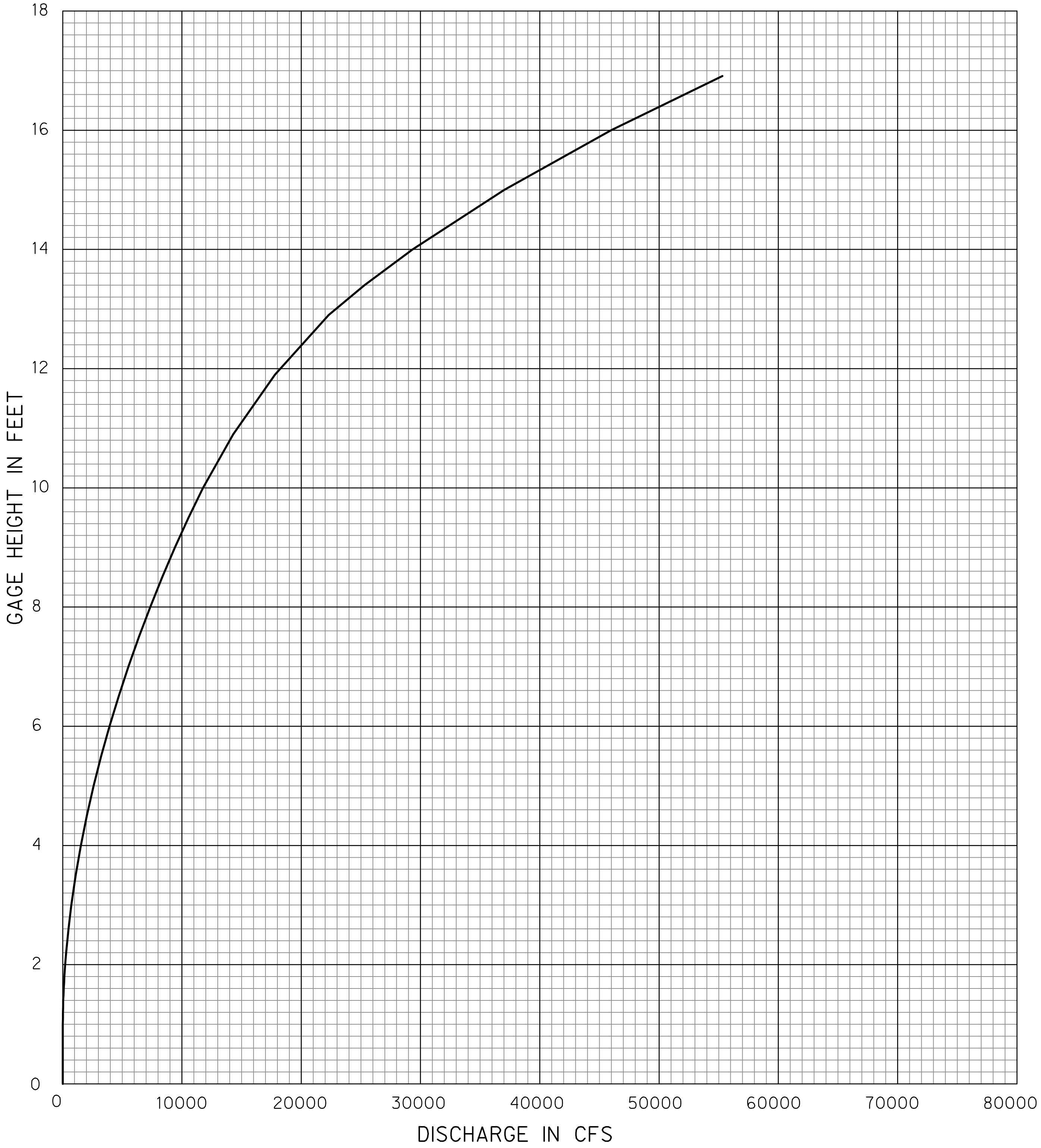
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
BEAVER CREEK AT BRADLEYVILLE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



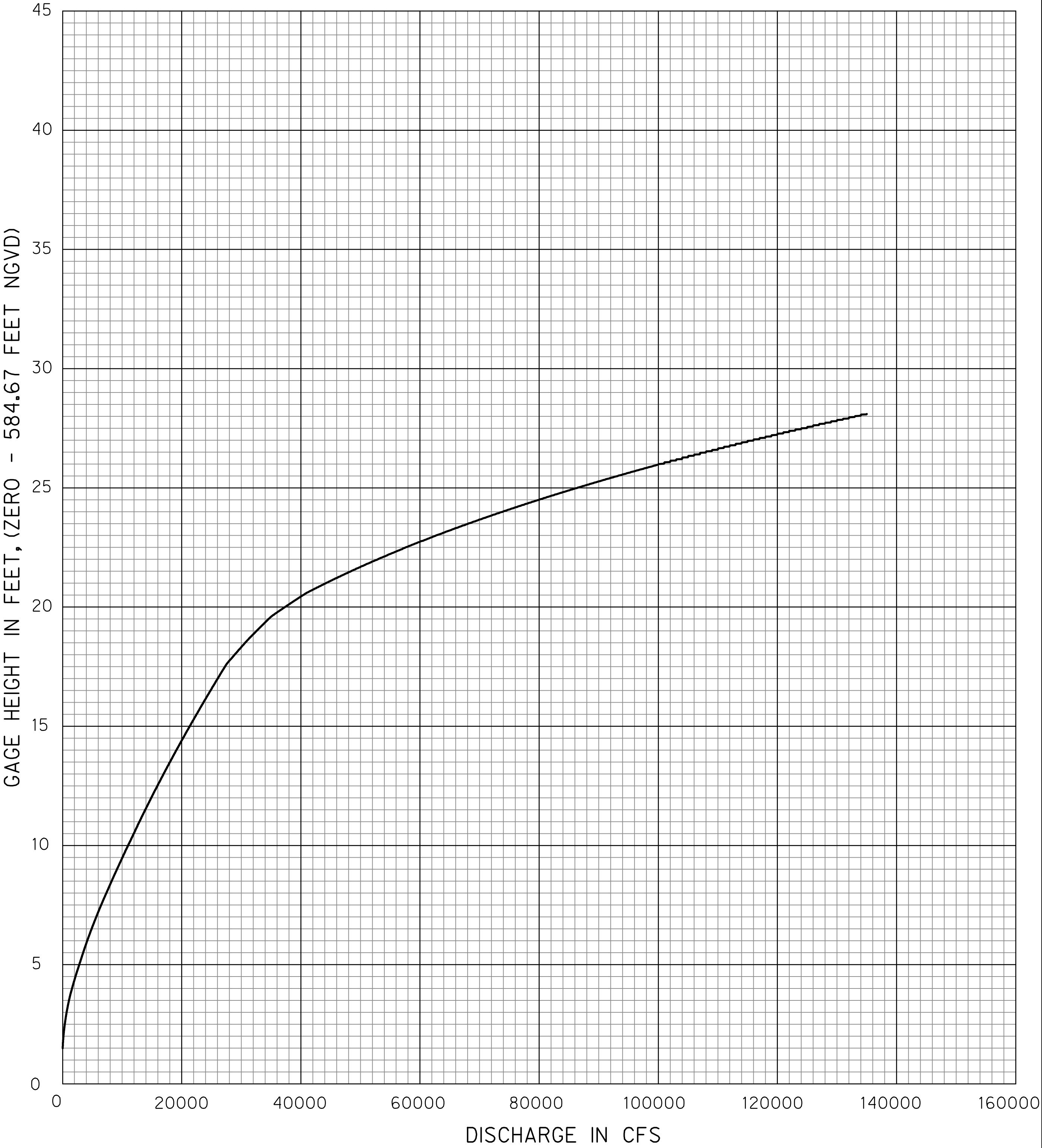
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
BEAR CREEK NEAR OMAHA

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



USGS AUGUST 2011 RATING

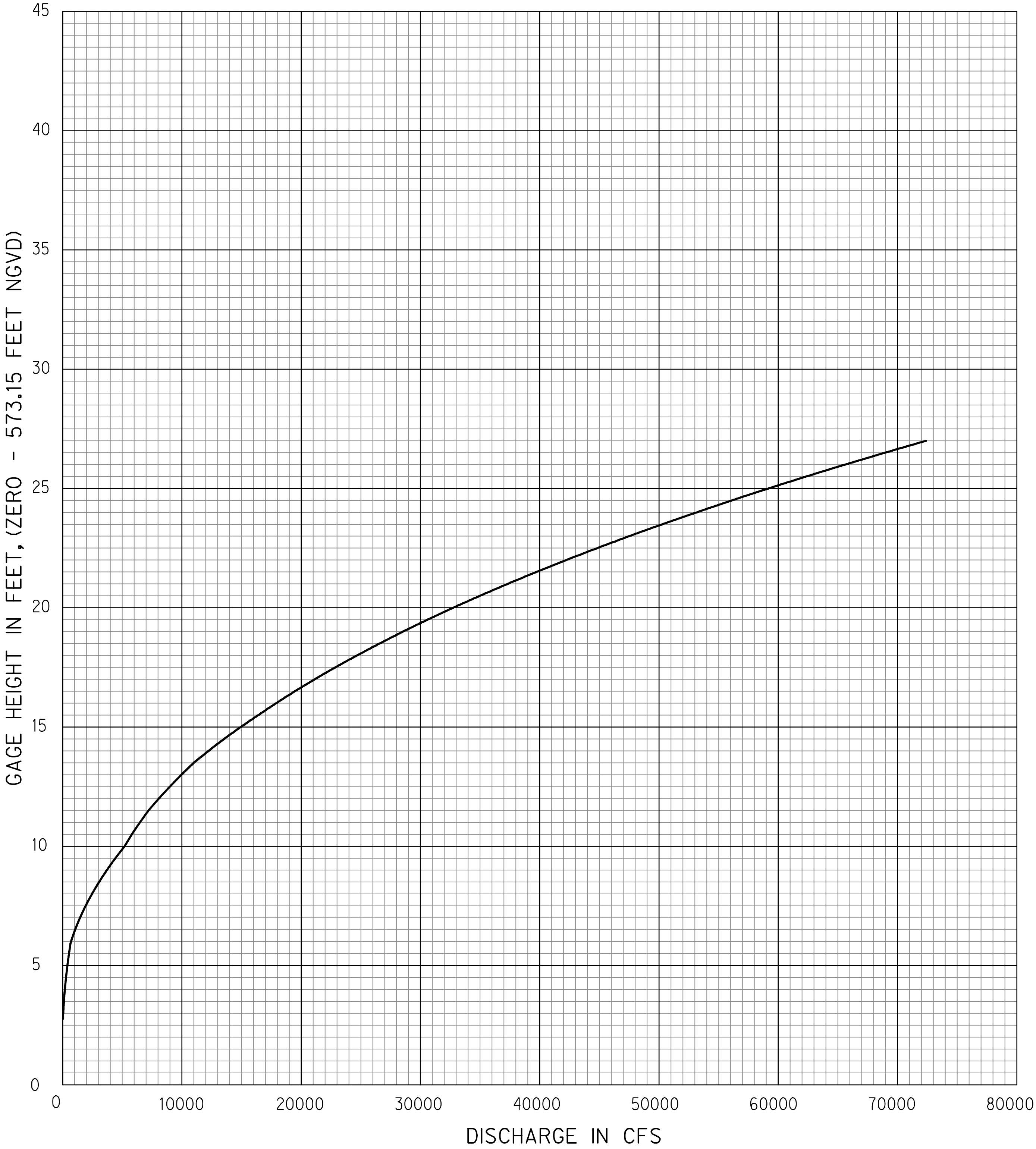
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
NORTH FORK RIVER NEAR TECUMSEH

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



USGS AUGUST 2011 RATING

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
BRYANT CREEK NEAR TECUMSEH

SCALE: AS SHOWN

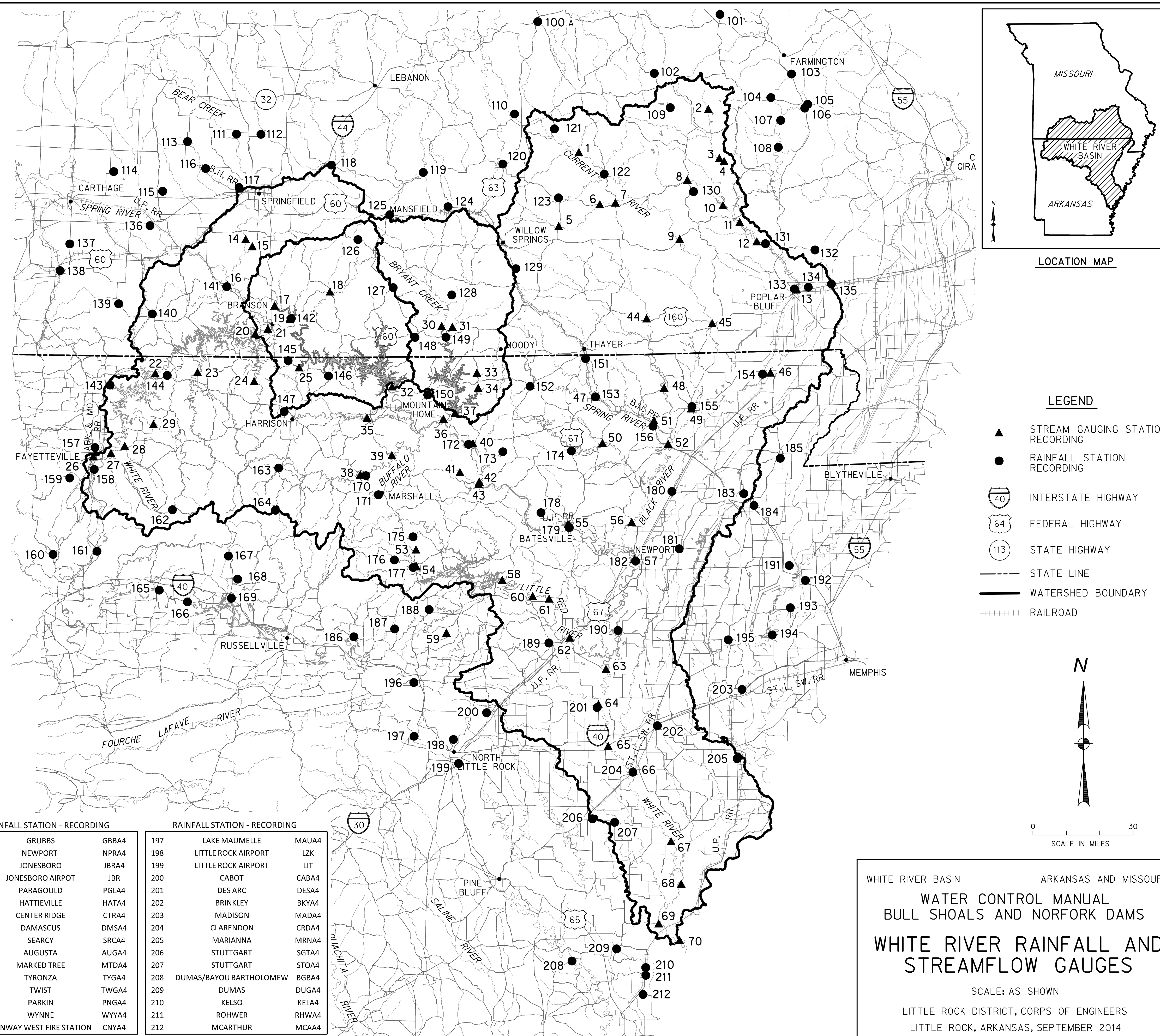
LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014

STREAM GAUGING STATION - RECORDING		
1	AKERS	AKFM7
2	LESTERVILLE	JSIM7
3	ANNAPOLIS	ANZM7
4	HIGHWAY	KBANM7
5	MOUNTAIN VIEW	JFKM7
6	ALLEY SPRING	ALYM7
7	EMINENCE	EMCM7
8	ELLINGTON	ELLM7
9	C.R. VAN BUREN	VNBM7
10	CLEARWATER	CLZM7
11	LEEPER	LPRM7
12	WILLIAMSVILLE	WLMM7
13	POPLAR BLUFF	PPBM7
14	BOAZ	JAMM7
15	RIVERDALE	FINM7
16	GALENA	GLNM7
17	WALNUT SHADE	BBCM7
18	BRADLEYVILLE	BRADL
19	OZARK BEACH	PSZM7
20	TABLE ROCK	TRZM7
21	SCHOOL OF THE OZARKS	SOGM7
22	BEAVER	BVGA4
23	BERRYVILLE	BRYA4
24	DENVER	DENVE
25	OMAHA	OMBA4
26	TOWN BRANCH	FYHA4
27	FAYETTEVILLE	FYGA4
28	GOSHEN	GSHA4
29	HINDSVILLE	HDGA4
30	B.C. TECUMSEH	TBCM7
31	N.F. TECUMSEH	TNZM7
32	BULL SHOALS	BSGA4
33	VIDETTE	BNRA4
34	ELIZABETH	MBCA4
35	YELLVILLE	YEGA4
36	HIGHWAY 341	WRNA4
37	NORFORK	NFDA4
38	ST. JOE	SJOA4
39	HARRIETT	HRRA4
40	CALICO ROCK	CLRA4
41	FIFTY SIX	FSXA4
42	SYLAMORE	SYGA4
43	ALLISON	ALLA4
44	BARDLEY	EPGM7
45	DONIPHAN	DNZM7
46	CORNING	CRGA4
47	HARDY	HDYA4
48	RAVENDEN	RVSA4
49	POCAHONTAS	POCA4
50	POUGHKEEPSIE	PKGA4
51	IMBODEN	IMBA4
52	BLACK ROCK	BKRA4
53	SHIRLEY	SRGA4
54	CLINTON	CIGA4
55	BATESVILLE	BAGA4
56	ELGIN FERRY	EFGA4
57	NEWPORT	NPTA4
58	GREERS FERRY	GRRA4
59	AUGUSTA	AGGA4
60	PANGBURN	PAGA4
61	DEWEY	DEWA4
62	JUDSONIA	JUDA4
63	GEORGETOWN	GEOA4
64	DES ARC	DSCA4
65	DE VALLS BLUFF	DBGA4
66	CLARENDON	CLDA4
67	ST. CHARLES	SCHA4
68	ELAINE	GBPA4
69	L & D 1	NOGA4
70	MPLD	MPDA4

RAINFALL STATION - RECORDING		
100	ROLLA	RRGM7
101	POTOSI	PTSM7
102	VIBURNUM	VBRM7
103	FARMINGTON	FARM7
104	ROSELLE	ROZM7
105	FREDERICKTOWN	FRDM7
106	FREDERICKTOWN	FRZM7
107	MILLCREEK	MLCM7
108	SACO	SAZM7
109	OATES	OATM7
110	LICKING	LCKM7
111	MORRISVILLE	MRRM7
112	PLEASANT HOPE	PLNM7
113	DADEVILLE	DDVM7
114	GOLDEN CITY	GLBDM7
115	MILLER	MLRM7
116	ASH GROVE	ASGM7
117	SPRINGFIELD AIRPORT	SGF
118	MARSHFIELD	MRFM7
119	HARTVILLE	HRTM7
120	HOUSTON	HOSM7
121	MONTAUK STATE PARK	MNTM7
122	ROUND SPRING	RNDM7
123	SUMMERSVILLE	SMMM7
124	MOUNTAIN GROVE	MTGM7
125	MANSFIELD	MNFM7
126	AVA	AVVM7
127	WASOLA	WASM7
128	DORA	DORM7
129	WEST PLAINS	WPLM7
130	ELLINGTON	ELLM7
131	WILLIAMSVILLE	WLLM7
132	WAPPAPELLO DAM	WPPM7
133	POPLAR BLUFF	PPBM7
134	POPLAR BLUFF AIRPORT	POF
135	FISK	FSKM7
136	MOUNT VERNON	MVRM7
137	DIAMOND	DMDM7
138	NEOSHO	NEOM7
139	BERRYVILLE	BRVA4
140	CASSVILLE	CASM7
141	GALENA	GALM7
142	OZARK BEACH	OZRM7
143	ROGERS AIRPORT	ROG
144	EUREKA SPRINGS	EURA4
145	OMAHA	OMHA4
146	LEAD HILL	LDHA4
147	HARRISON AIRPORT	HRO
148	ISABELLA	ISBM7
149	TECUMSEH	TCMM7
150	MOUNTAIN HOME	MHMA4
151	MAMMOTH SPRING	MMMA4
152	SALEM	SLMA4
153	HARDY	HRDA4
154	CORNING	CRNA4
155	POCAHONTAS	PCHA4
156	BLACK RIVER AT BLACK ROCK	BLKA4
157	FAYETTEVILLE EXP STA	FYVA4
158	FAYETTEVILLE AIRPORT	FYV
159	PRAIRIE GROVE	PRGA4
160	NATURAL DAM	NLDA4
161	MOUNTAINBURG	MTBA4
162	ST PAUL	STPA4
163	JASPER	JASA4
164	DEER	DEEA4
165	OZARK	OZAA4
166	COAL HILL	CHLA4
167	OZONE	OZOA4
168	CLARKSVILLE	CKVA4
169	CLARKSVILLE	CLAA4
170	GILBERT	GLBA4
171	MARSHALL	MSHA4
172	CALICO ROCK	CARA4
173	MELBOURNE	MELA4
174	STRAWBERRY R. AT EVE. SHADE	EVSA4
175	BOTKINBURG	BTKA4
176	CHIMES	CHMA4
177	CLINTON	CTNA4
178	BATESVILLE	BTSA4
179	BATESVILLE L & D	BATA4
180	ALICIA	ALCA4

RAINFALL STATION - RECORDING		
181	GRUBBS	GBBA4
182	NEWPORT	NPRA4
183	JONESBORO	JBRA4
184	JONESBORO AIRPOT	JBR
185	PARAGOULD	PGLA4
186	HATTIEVILLE	HATA4
187	CENTER RIDGE	CTRA4
188	DAMASCUS	DMSA4
189	SEARCY	SRCA4
190	AUGUSTA	AUGA4
191	MARKED TREE	MTDA4
192	TYRONZA	TYGA4
193	TWIST	TWGA4
194	PARKIN	PNGA4
195	WYNNE	WYYA4
196	CONWAY WEST FIRE STATION	CNYA4

RAINFALL STATION - RECORDING		
197	LAKE MAUMELLE	MAUA4
198	LITTLE ROCK AIRPORT	LZK
199	LITTLE ROCK AIRPORT	LIT
200	CABOT	CABA4
201	DES ARC	DESA4
202	BRINKLEY	BKYA4
203	MADISON	MADA4
204	CLARENDON	CRDA4
205	MARIANNA	MRNA4
206	STUTTGART	SGTA4
207	STUTTGART	STOA4
208	DUMAS/BAYOU BARTHOLOMEW	BGBA4
209	DUMAS	DUGA4
210	KELSO	KELA4
211	ROHWER	RHWA4
212	MCARTHUR	MCAA4



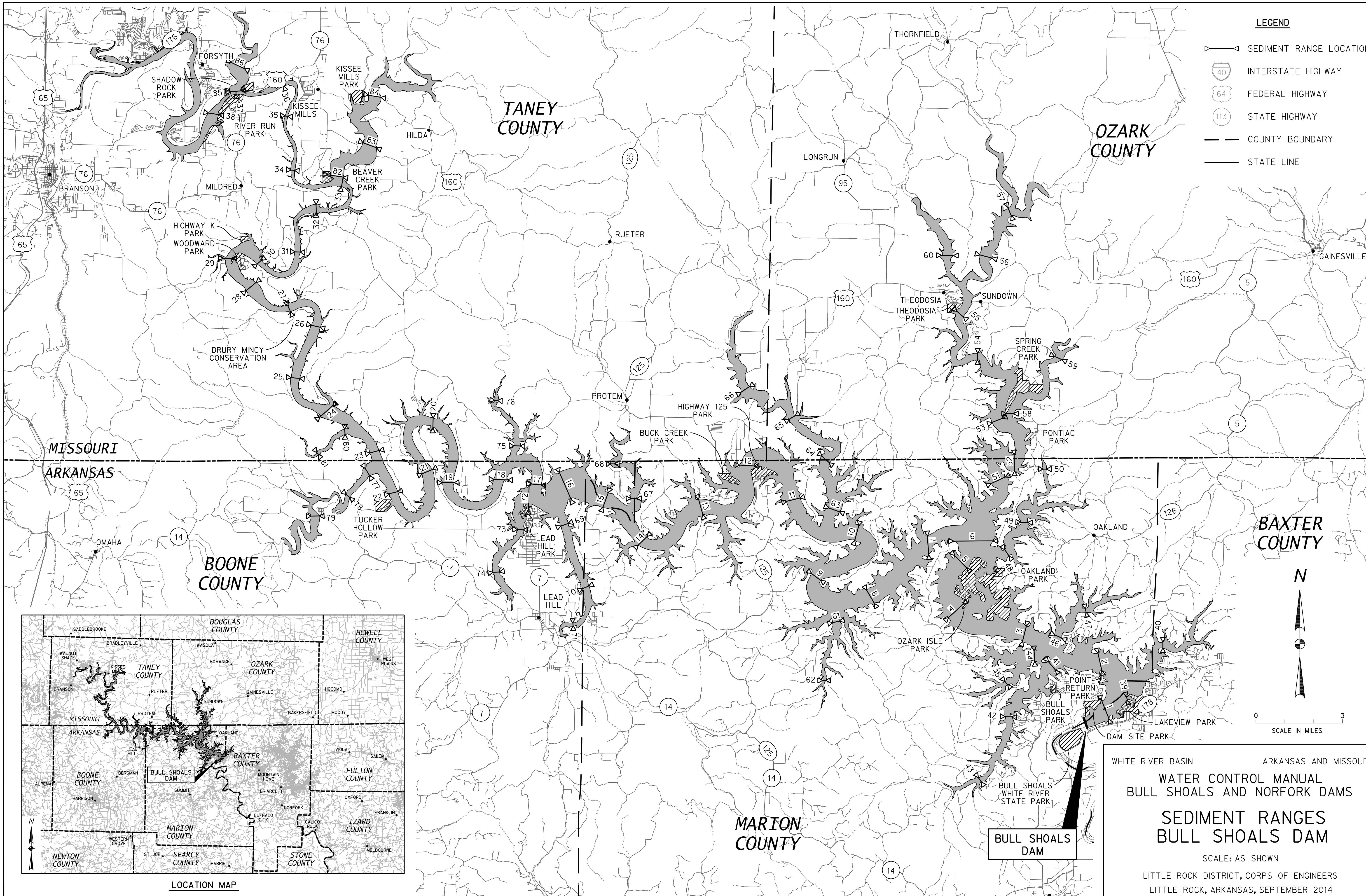
WHITE RIVER BASIN ARKANSAS AND MISSOURI

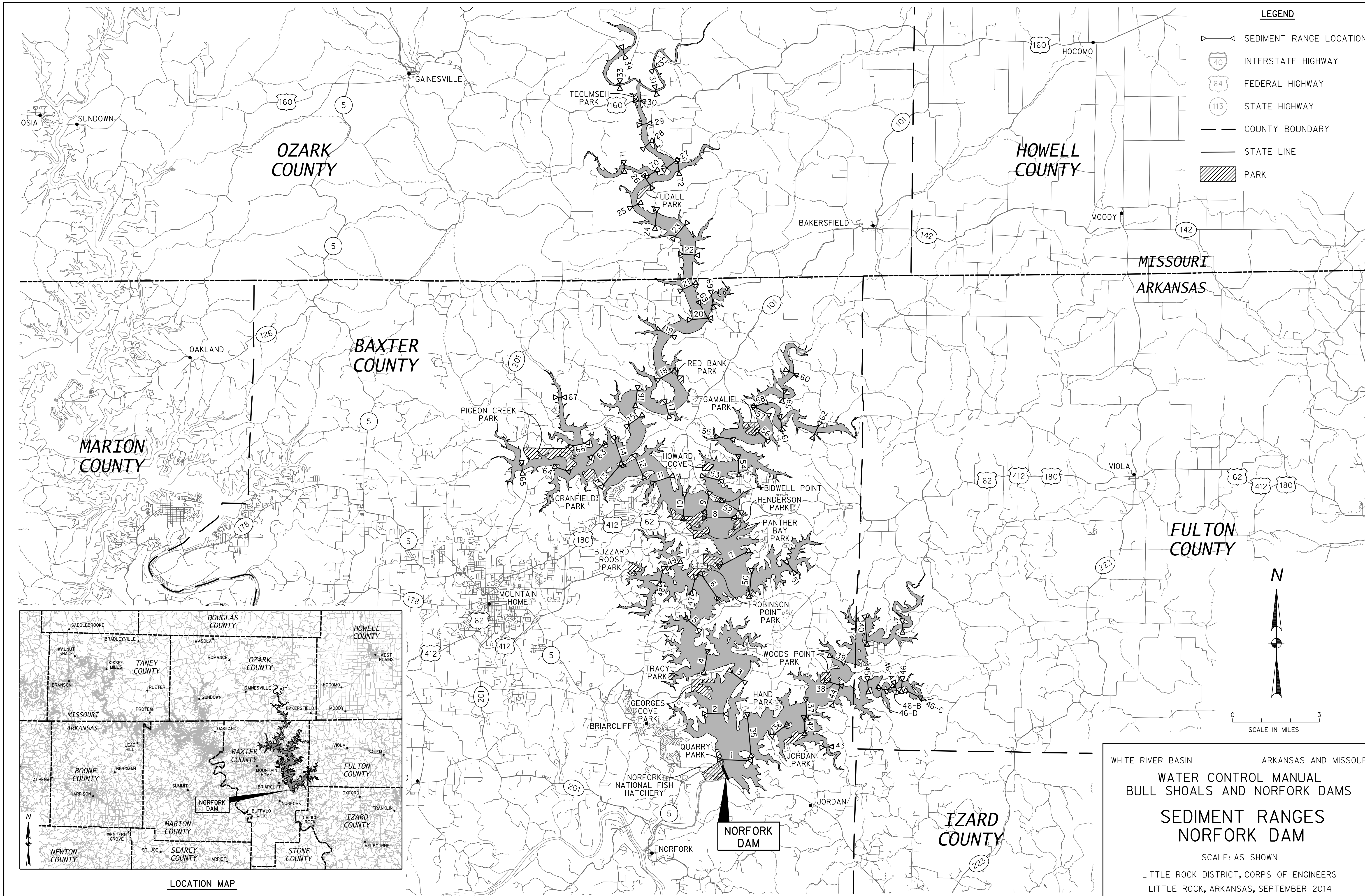
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

WHITE RIVER RAINFALL AND STREAMFLOW GAUGES

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014


LEGEND
SEDIMENT RANGE LOCATION
INTERSTATE HIGHWAY
FEDERAL HIGHWAY
STATE HIGHWAY
COUNTY BOUNDARY
STATE LINE
TANEY COUNTY
OZARK COUNTY
BOONE COUNTY
MARION COUNTY
BAXTER COUNTY
MISSOURI
ARKANSAS
FORSYTH
SHADOW ROCK PARK
KISSEE MILLS PARK
KISSEE MILLS
RIVER RUN PARK
HILDA
BRANSON
MILDRED
BEAVER CREEK PARK
HIGHWAY K PARK
WOODWARD PARK
DRURY MINCY CONSERVATION AREA
TUCKER HOLLOW PARK
OMAHA
LEAD HILL PARK
LEAD HILL
PROTEM
RUETER
HIGHWAY 125 PARK
BUCK CREEK PARK
THORNFIELD
LONGRUN
THEODOSIA
THEODOSIA PARK
SUNDOWN
SPRING CREEK PARK
PONTIAC PARK
GAINESVILLE
OAKLAND
OAKLAND PARK
OZARK ISLE PARK
POINT RETURN PARK
BULL SHOALS PARK
LAKEVIEW PARK
DAM SITE PARK
BULL SHOALS WHITE RIVER STATE PARK
BULL SHOALS DAM
N
0
3
SCALE IN MILES
LOCATION MAP
WHITE RIVER BASIN
ARKANSAS AND MISSOURI
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
SEDIMENT RANGES
BULL SHOALS DAM
SCALE: AS SHOWN
LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



WHITE RIVER BASIN

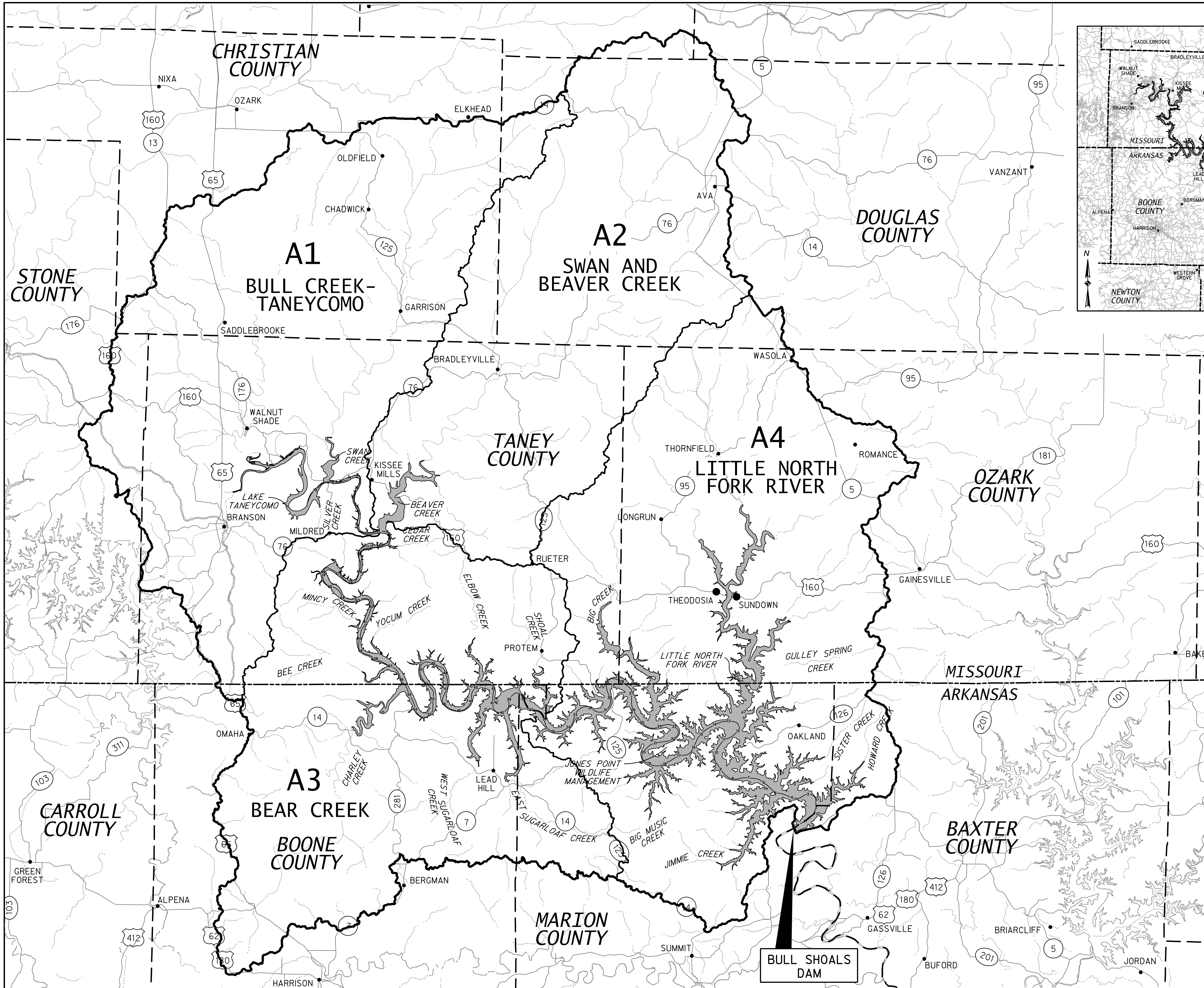
ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

SEDIMENT RANGES
NORFORK DAM

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



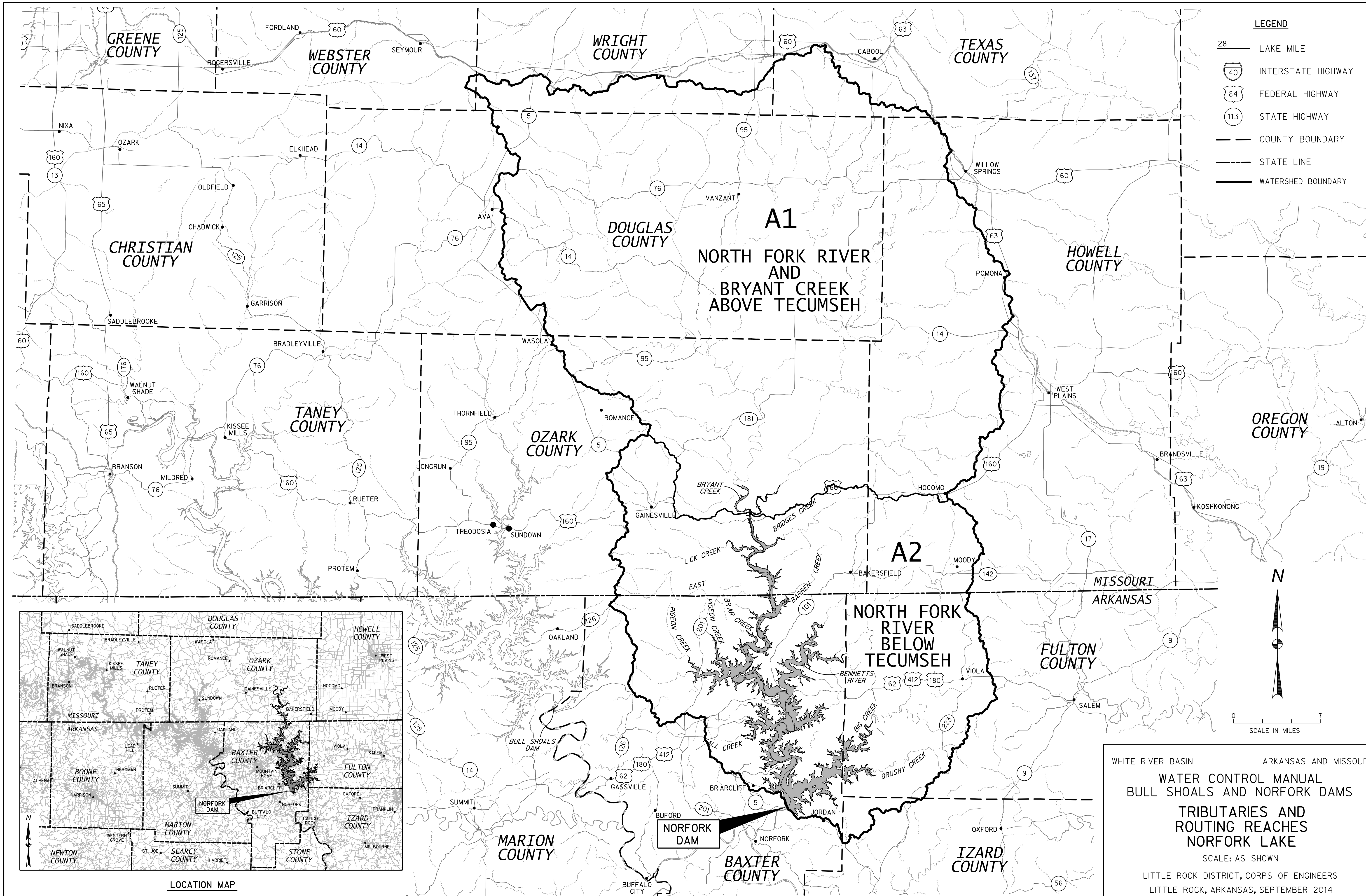
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

TRIBUTARIES AND
ROUTING REACHES
BULL SHOALS LAKE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

TRIBUTARIES AND
ROUTING REACHES
NORFORK LAKE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014

PLATE 6-02

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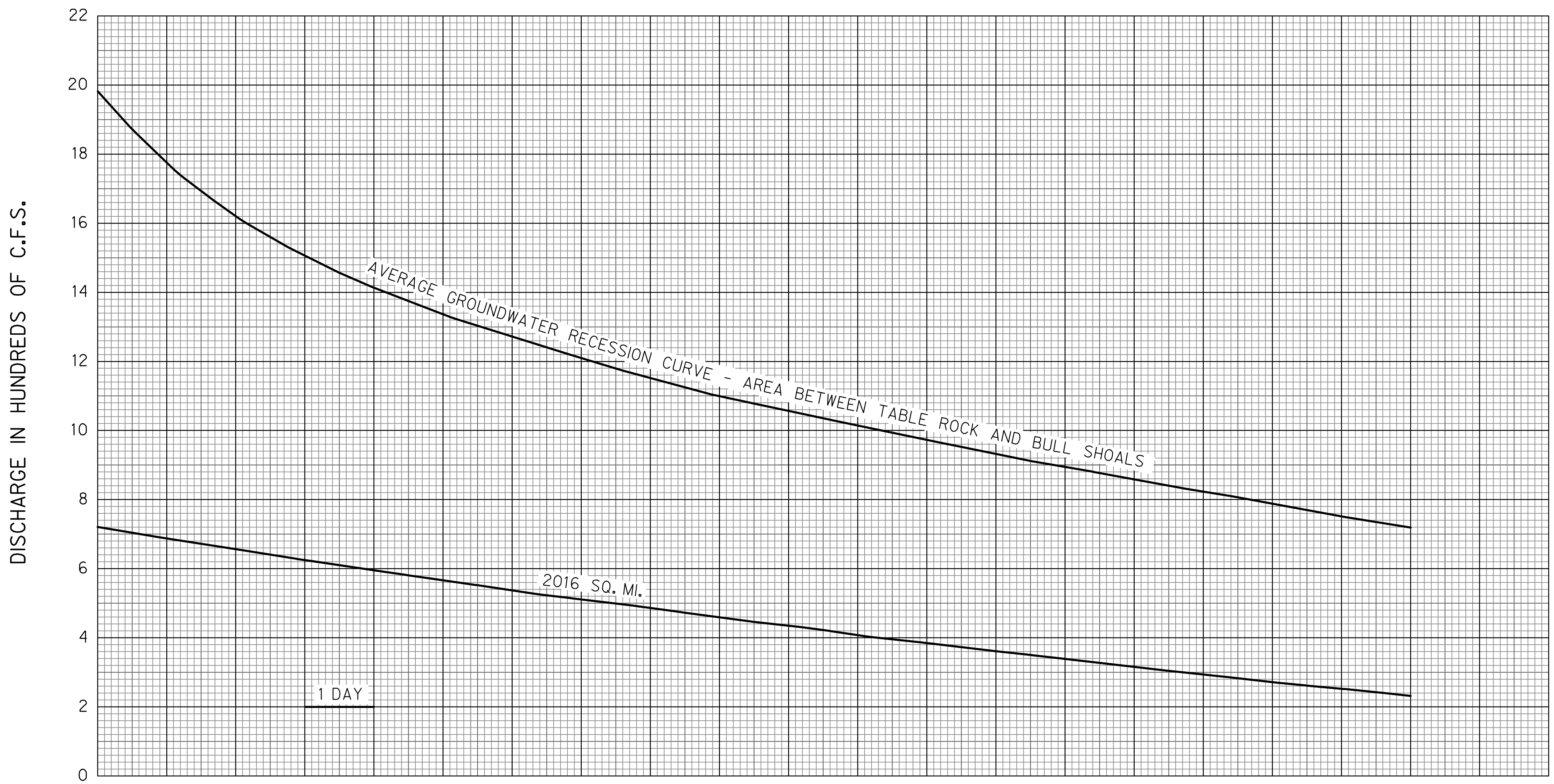


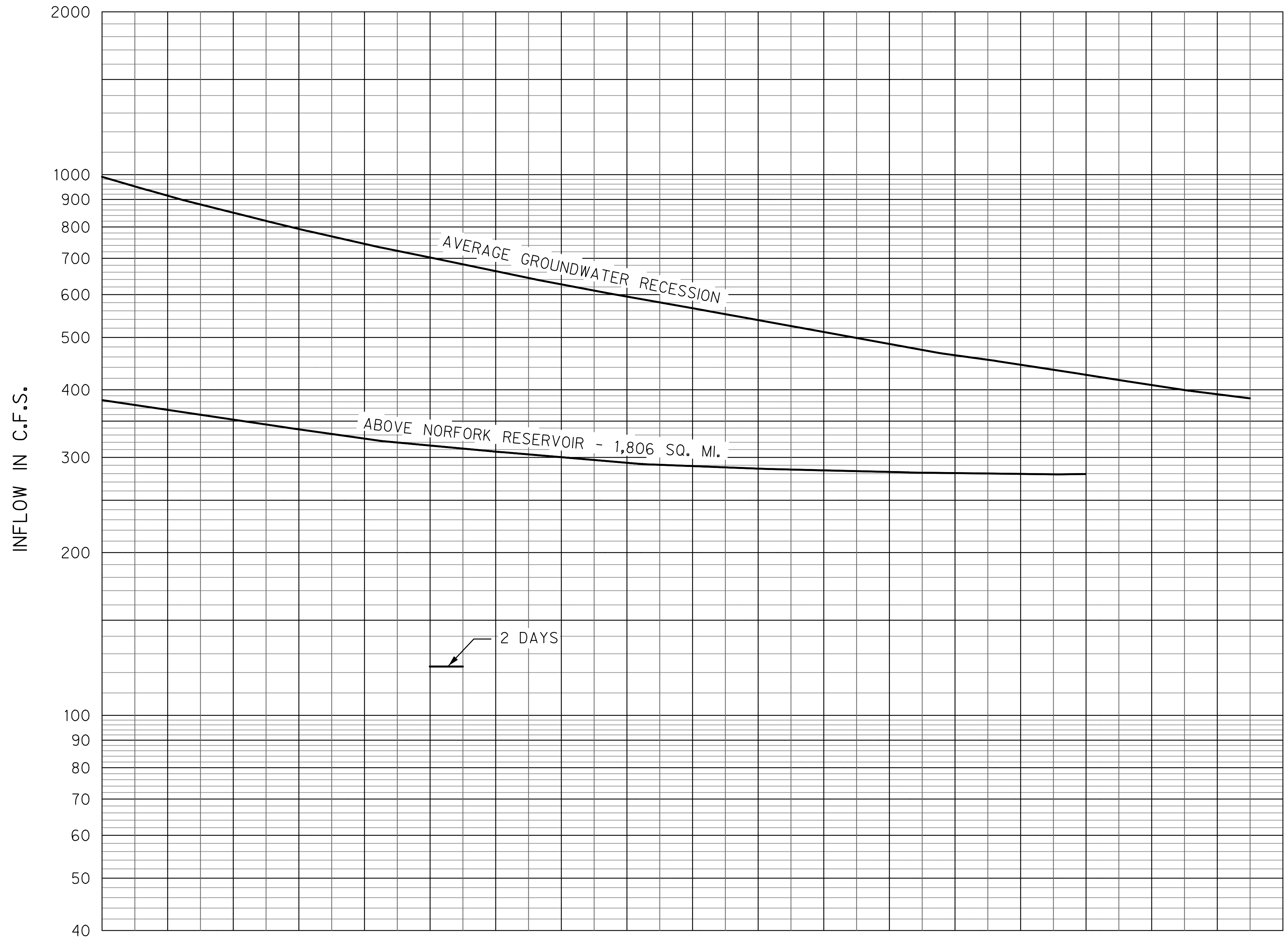
WHITE RIVER BASIN | ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

AVERAGE GROUNDWATER RECESSION CURVES BULL SHOALS DAM

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



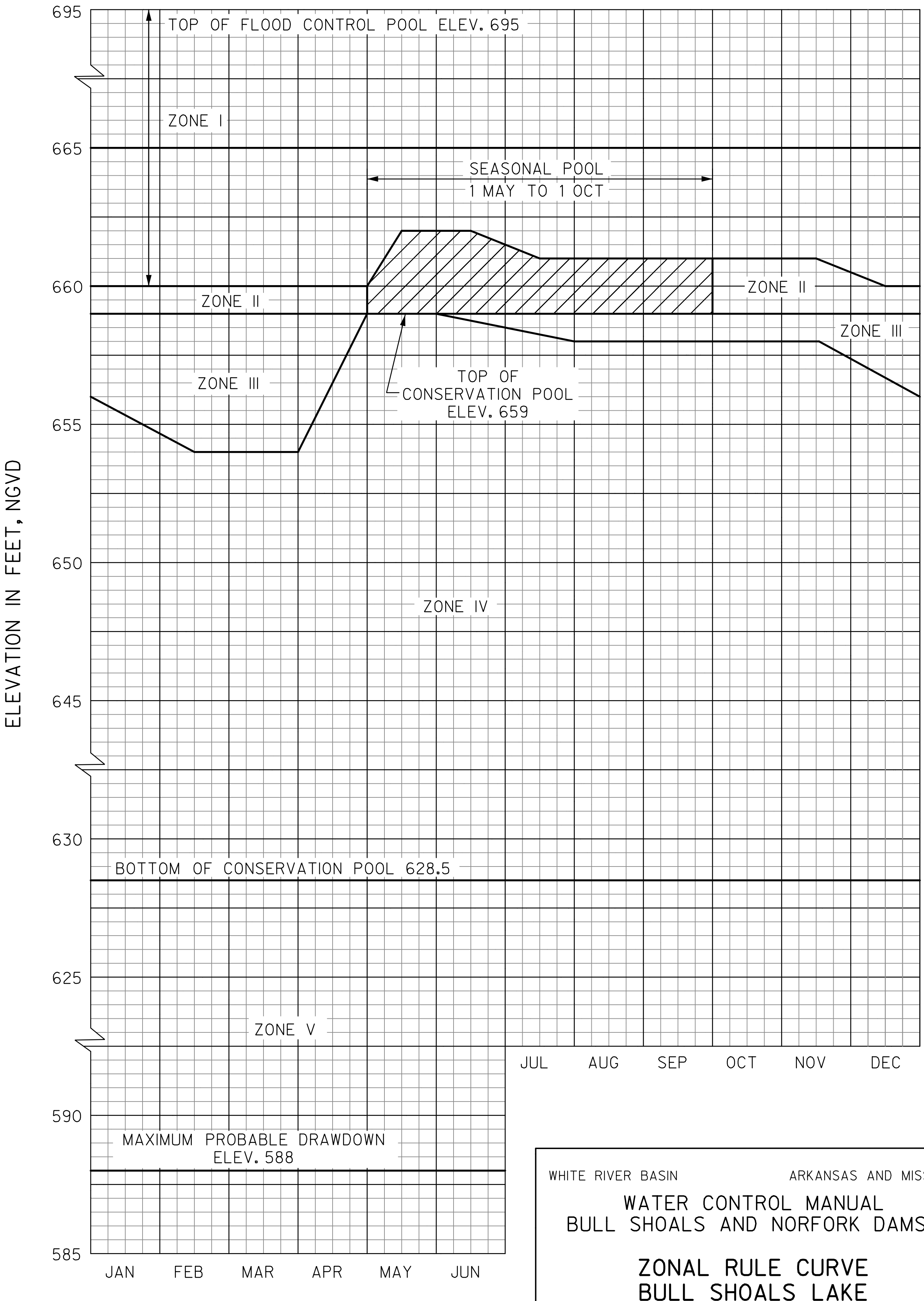
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

AVERAGE GROUNDWATER RECESSION CURVES NORFORK DAM

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE: CONDUIT INVERT ELEV. 477.06

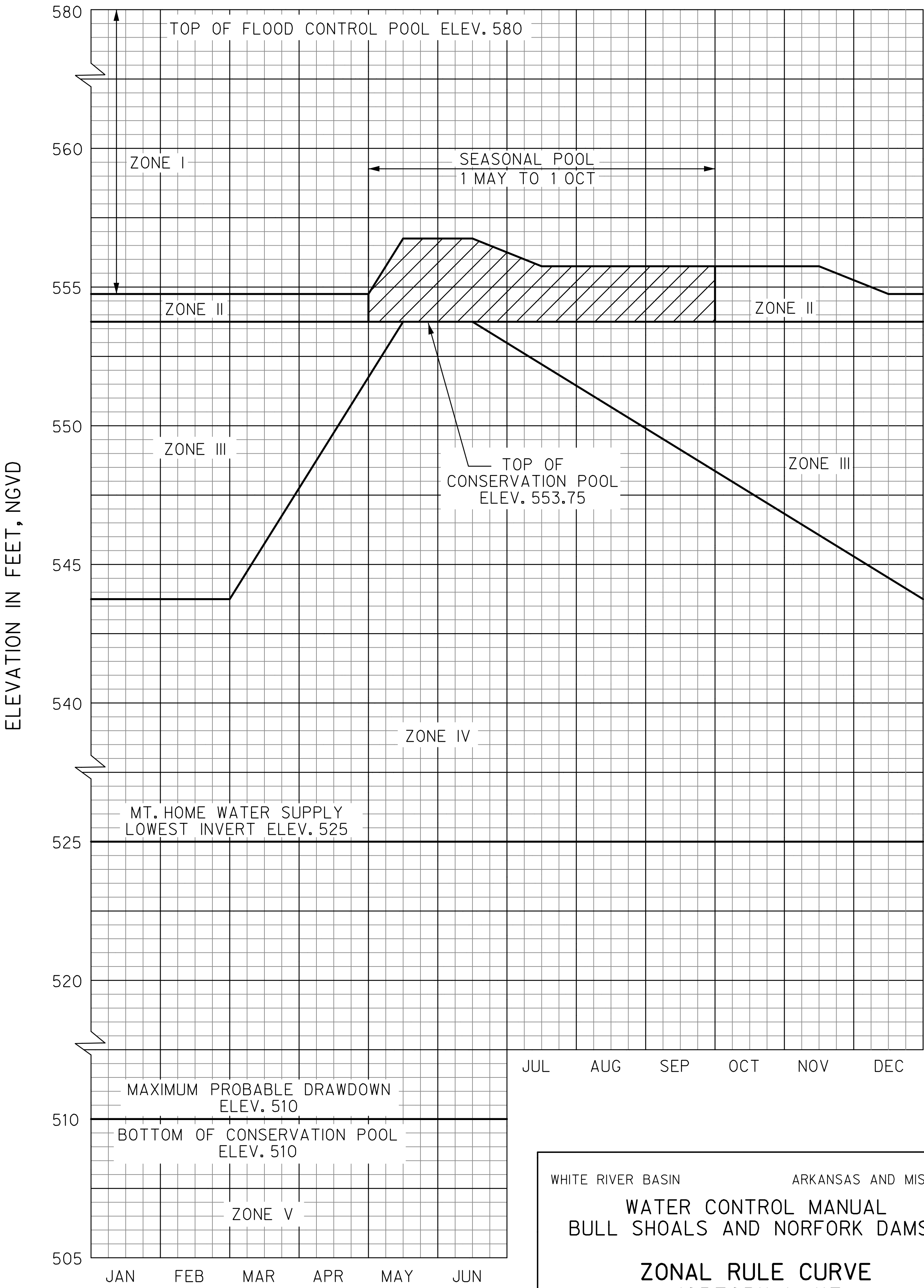
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

ZONAL RULE CURVE
BULL SHOALS LAKE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE: CONDUIT INVERT ELEV. 395.0

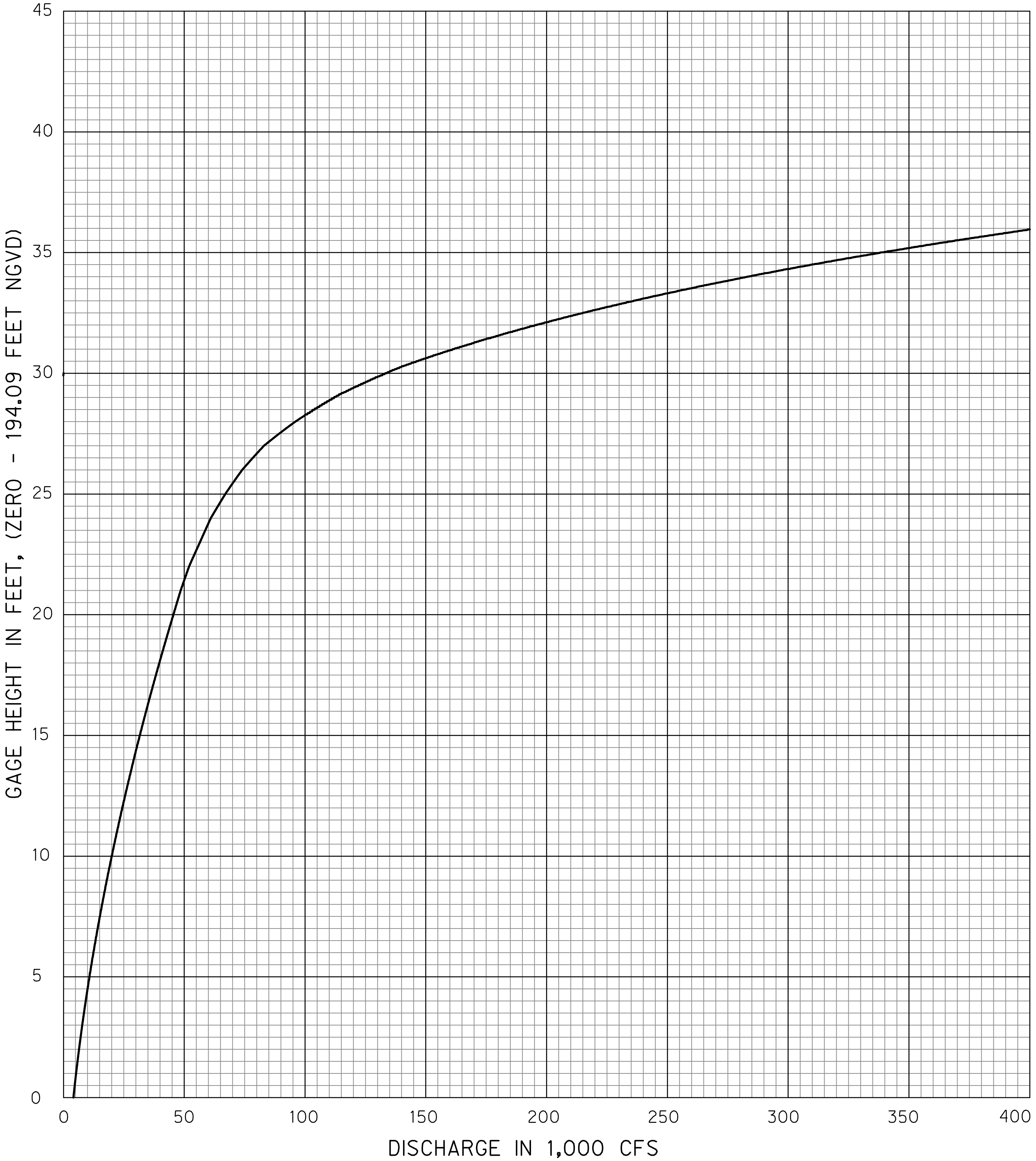
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

ZONAL RULE CURVE
NORFORK LAKE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



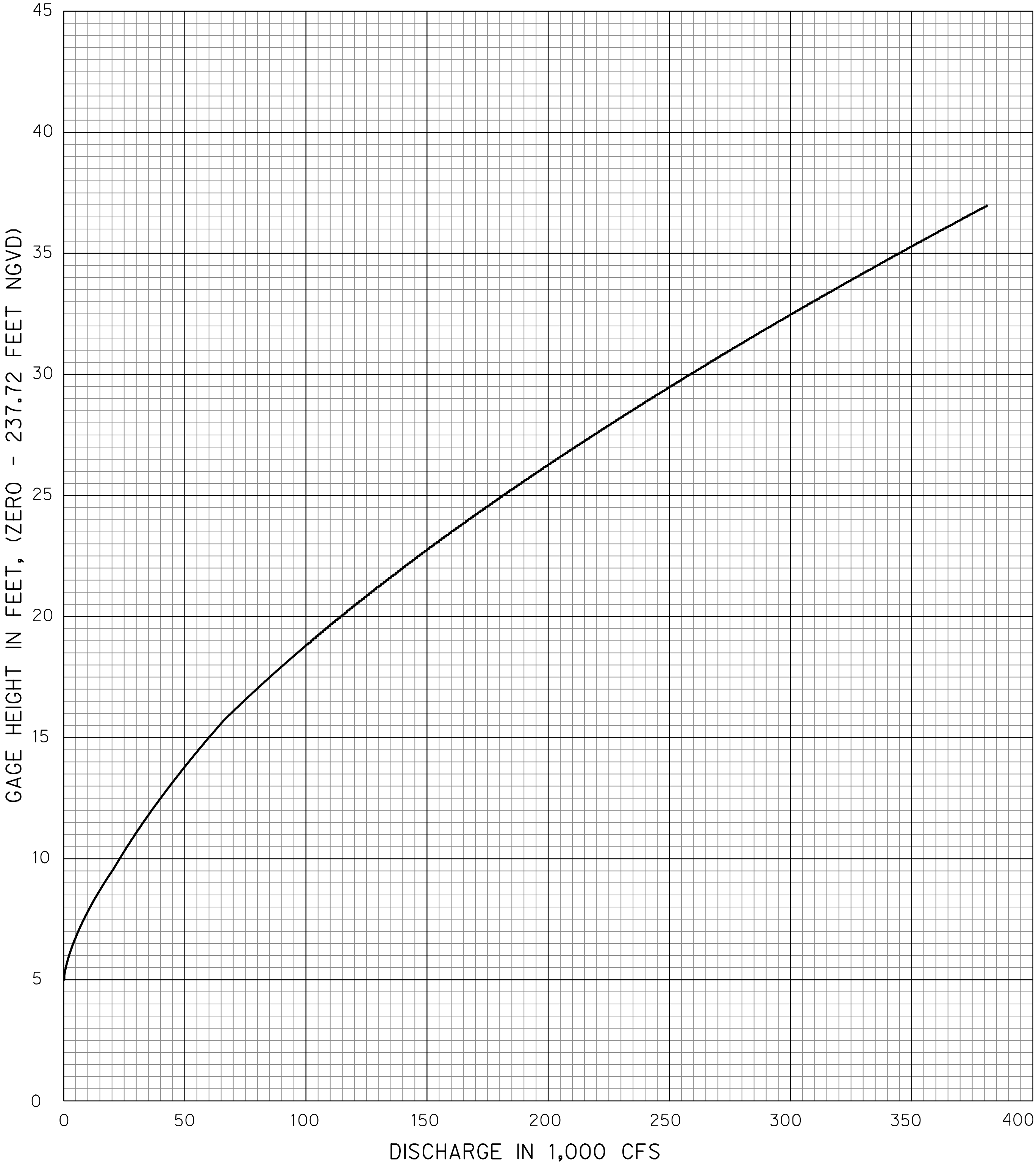
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
WHITE RIVER AT NEWPORT, ARKANSAS

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



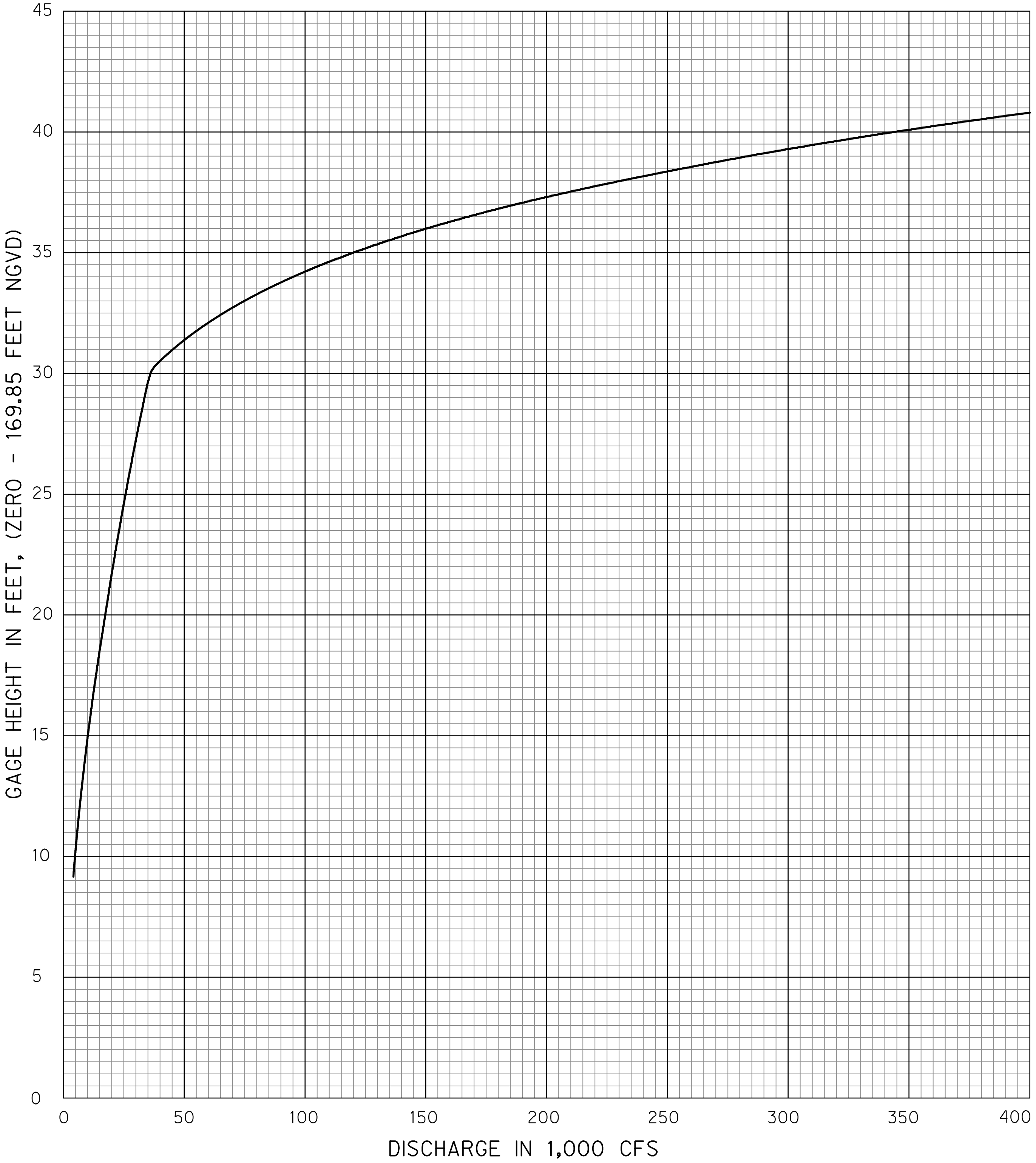
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
WHITE RIVER AT BATESVILLE, ARKANSAS

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



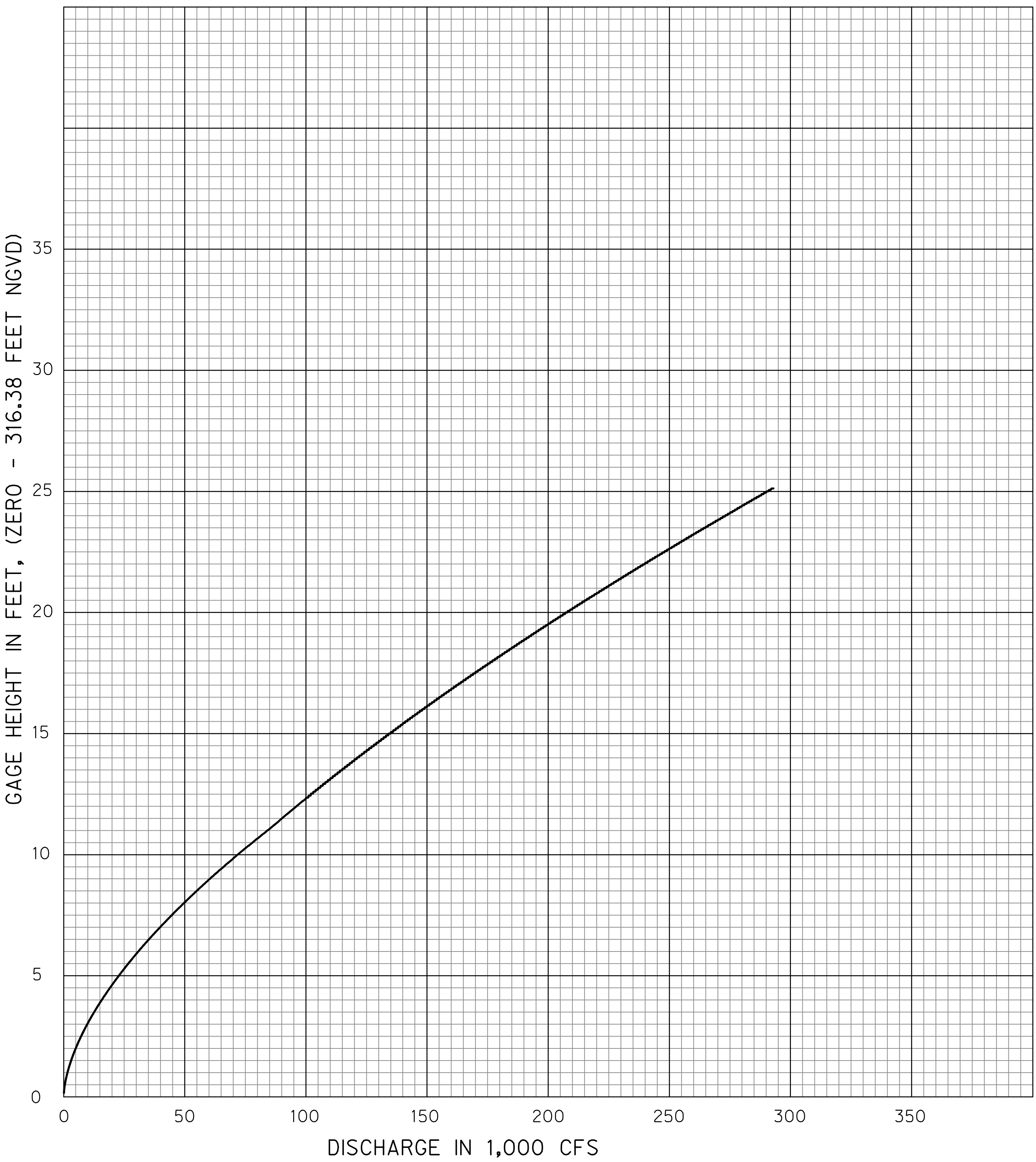
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
WHITE RIVER AT AUGUSTA, ARKANSAS

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



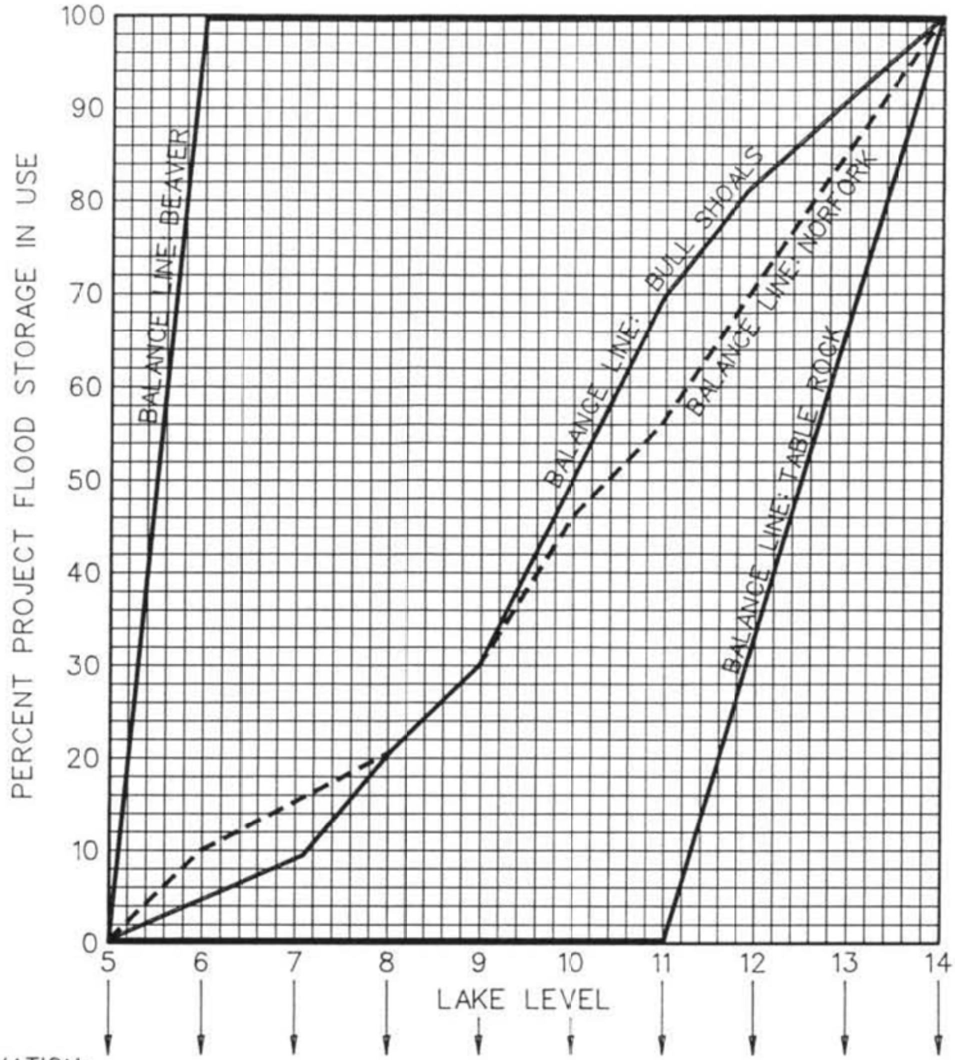
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

DISCHARGE RATING CURVE
WHITE RIVER AT
CALICO ROCK, ARKANSAS

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



LAKE ELEVATION:

Beaver	1120.00	1130.00	1130.00	1130.00	1130.00	1130.00	1130.00	1130.00	1130.00	1130.00
Table Rock	915.00	915.00	915.00	915.00	915.00	915.00	915.00	920.69	926.01	931.00
Bull Shoals	659.00	656.07	659.06	663.84	668.39	667.80	684.04	688.14	691.64	695.00
Norfork	553.75	555.27	556.85	558.40	561.43	565.77	568.55	572.54	576.35	580.00

PERCENT FULL:

Beaver	0.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0	100.0
Table Rock	0.0	0.0	0.0	0.0	0.0	0.0	0.0	33.3	66.7	100.0
Bull Shoals	0.0	4.0	10.0	20.0	30.0	50.0	68.7	80.0	90.0	100.0
SYSTEM	0.0	11.5	15.7	22.6	29.5	43.3	56.2	71.4	85.7	100.0
Norfork	0.0	10.0	15.0	20.0	30.0	45.0	55.0	70.0	85.0	100.0

NOTE:

The lakes are considered to be balanced when they are all at the same level. For example, if they are all in balance at Level 12, Beaver will be 100 percent full, Table Rock one-third full, Bull Shoals eighty percent full (making the 3-lake system 71.4 percent full) and Norfork seventy percent full.

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

BEAVER/TABLE ROCK/ BULL SHOALS/NORFORK SUBSYSTEM BALANCE CURVE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014

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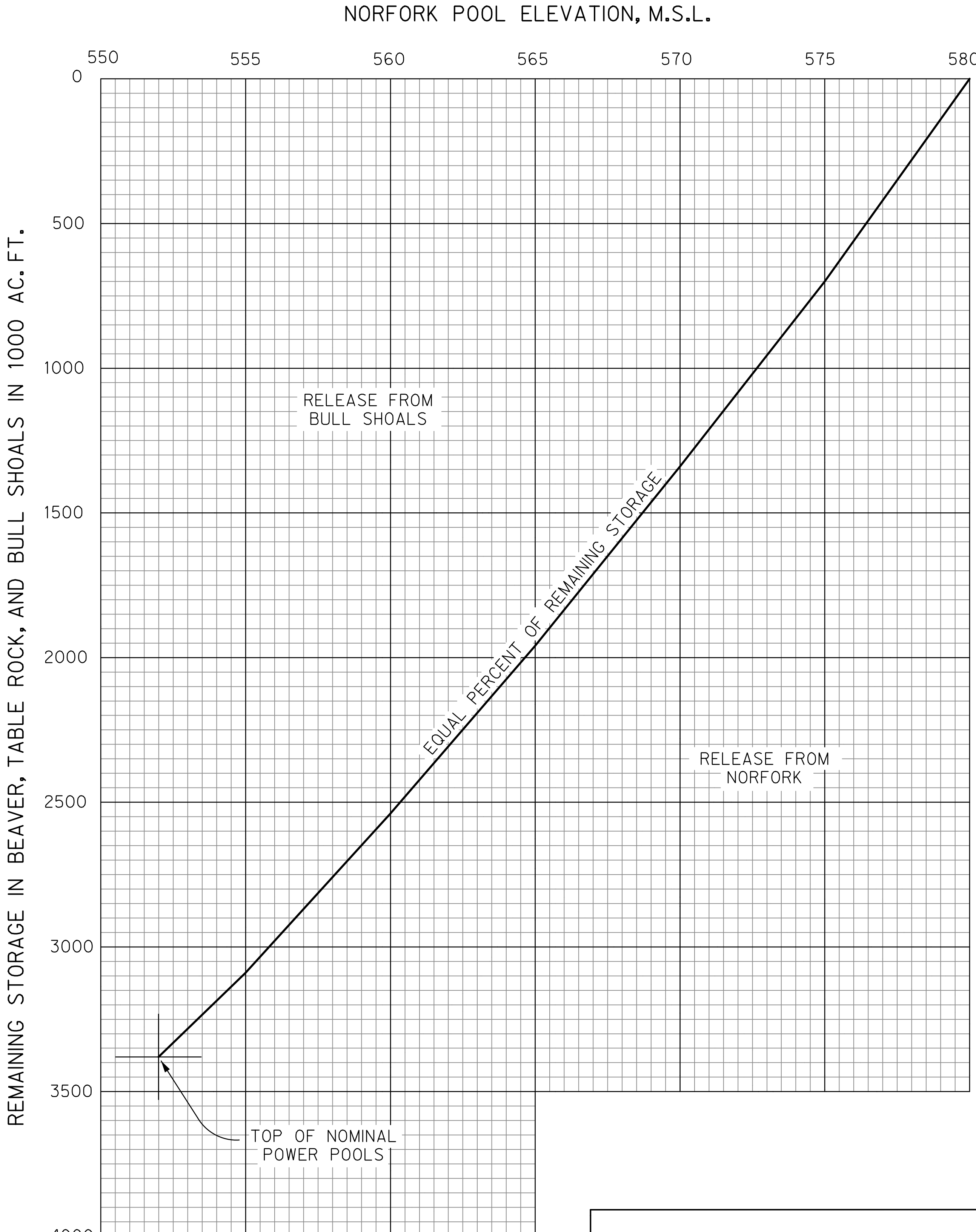


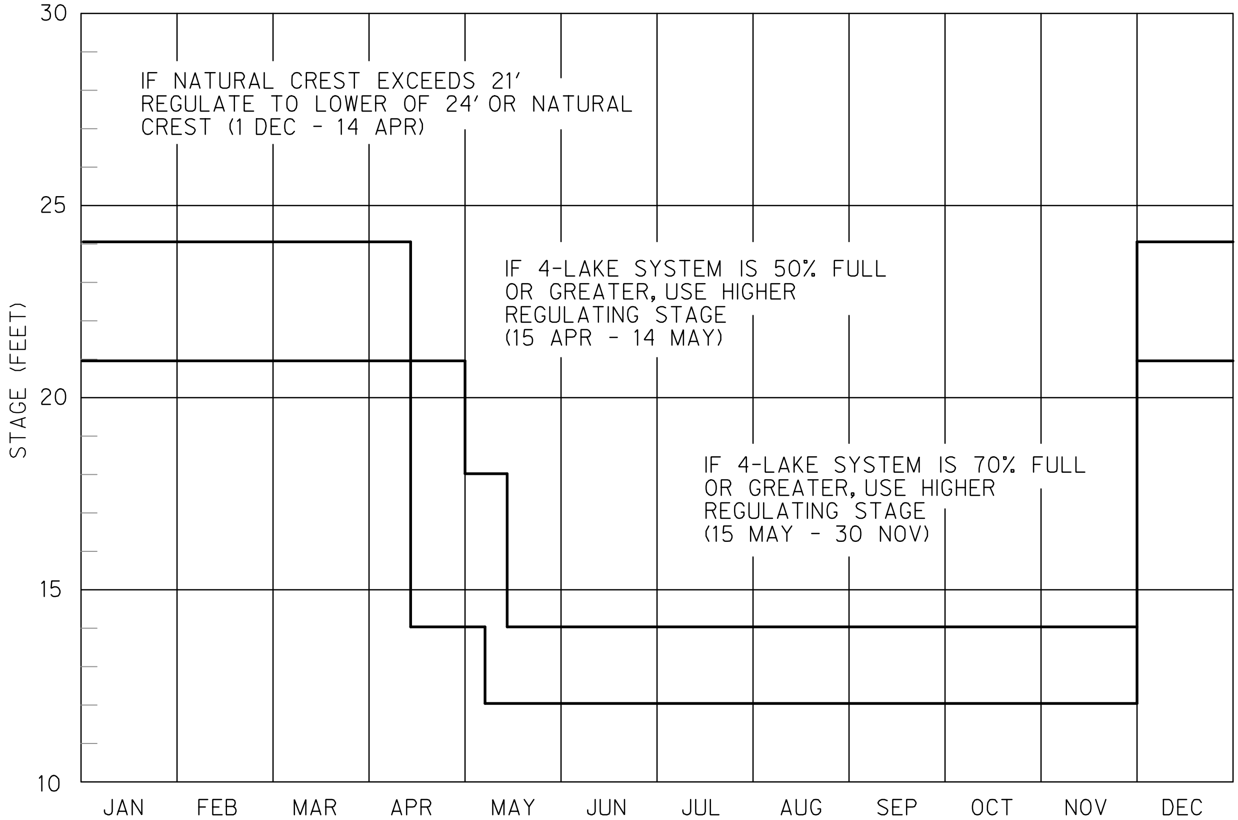
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

ALLOCATION OF RELEASES
BULL SHOALS DAM &
NORFORK DAM

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



REGULATION NOTES:

1. MAXIMUM ROUTINE PROJECT RELEASE RATES ARE AS FOLLOWS:

   BULL SHOALS 32,500 CFS
   NORFORK 10,500 CFS

   THESE ARE SUBJECT TO A 50,000 CFS FLOW LIMIT AT BATESVILLE.

2. DISCHARGE IS FOR 1990 RATING CURVE AND MAY VARY WITH TIME.

NEWPORT

DISCHARGE (CFS)	STAGE (FT)
60,000	24
50,000	21
40,000	18
30,000	14
25,000	12

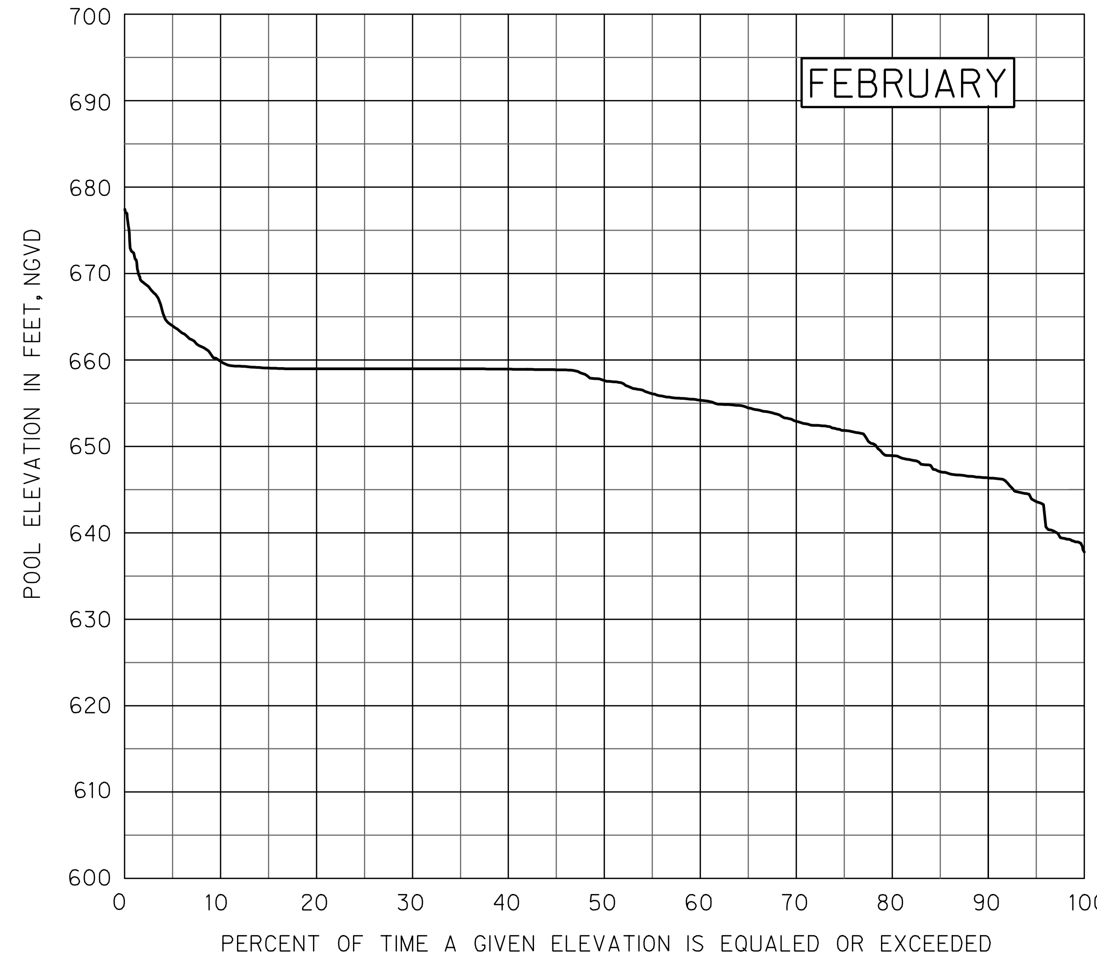
WHITE RIVER BASIN ARKANSAS AND MISSOURI

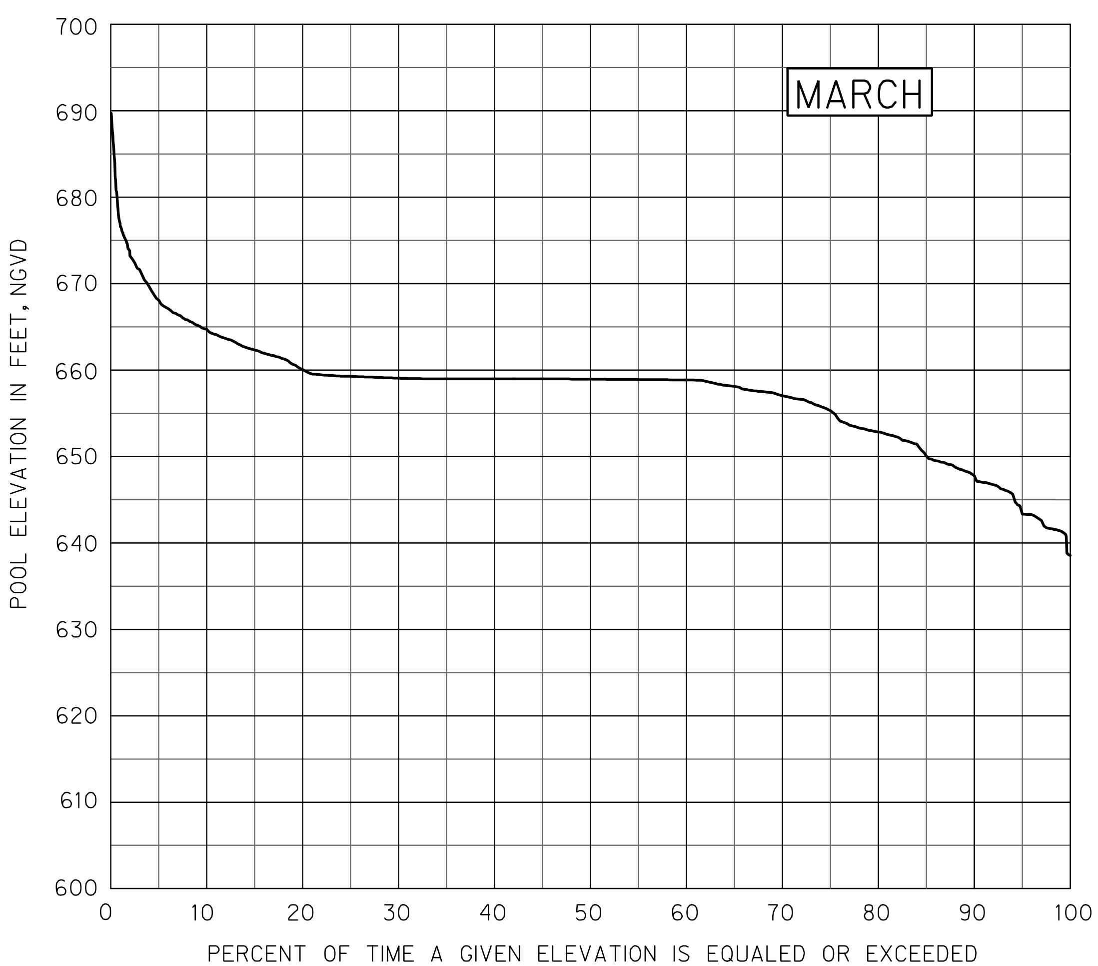
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

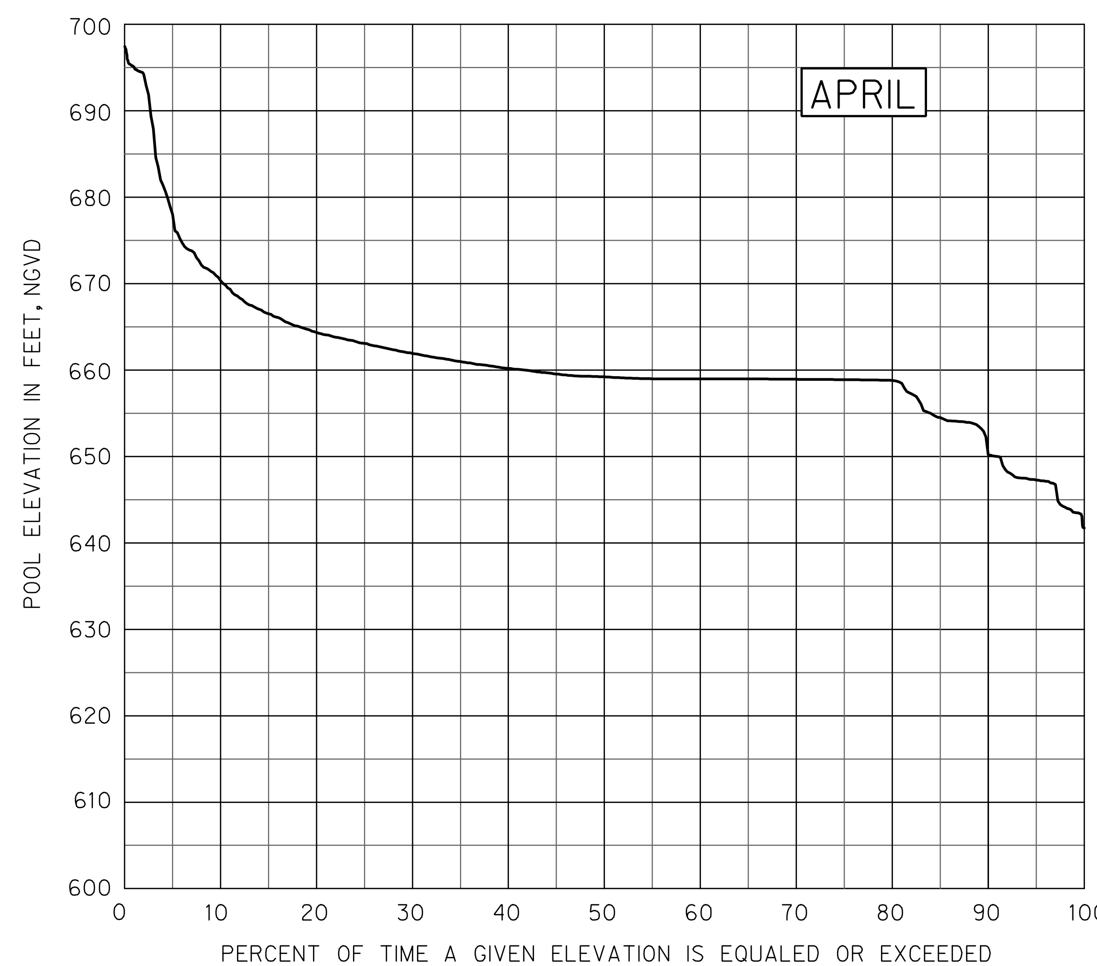
NEWPORT GUIDE CURVE FOR REGULATING DISCHARGE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







NOTE:

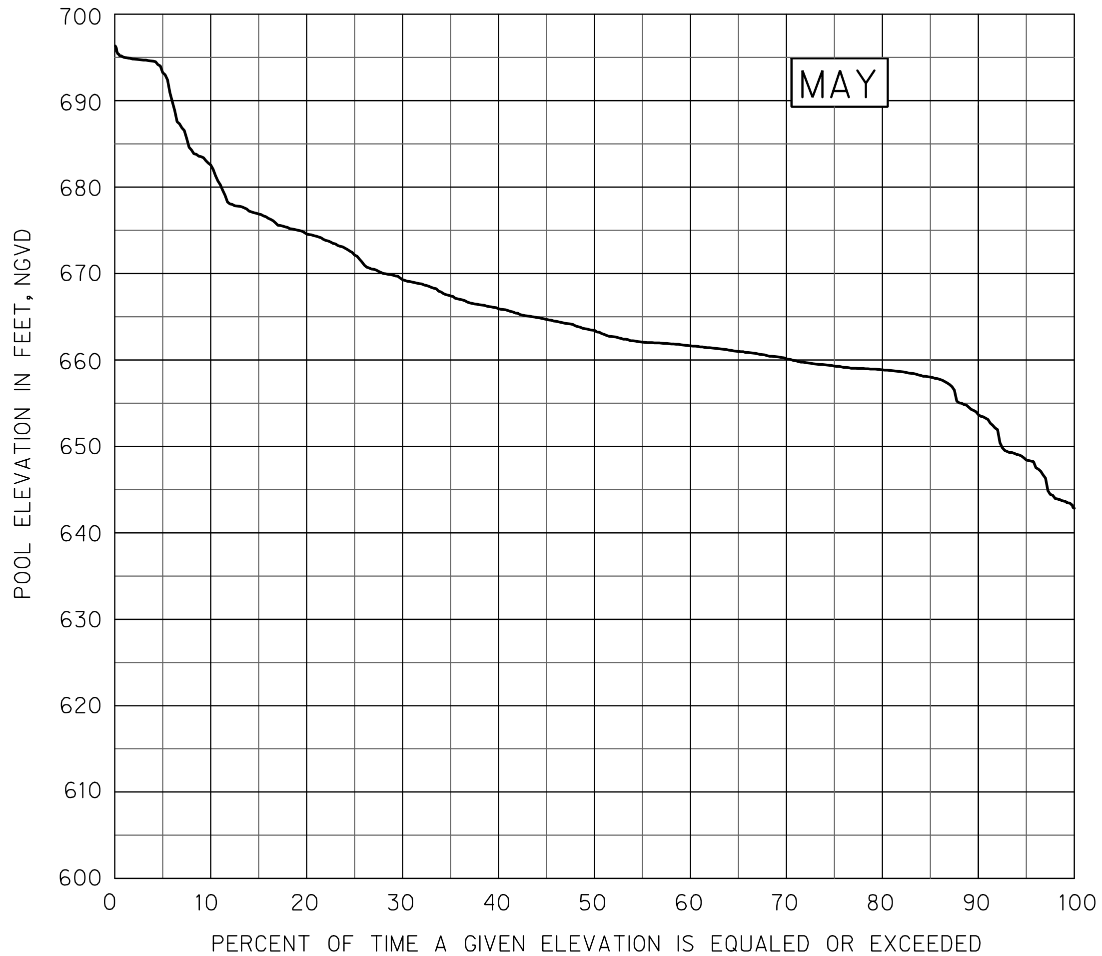
2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

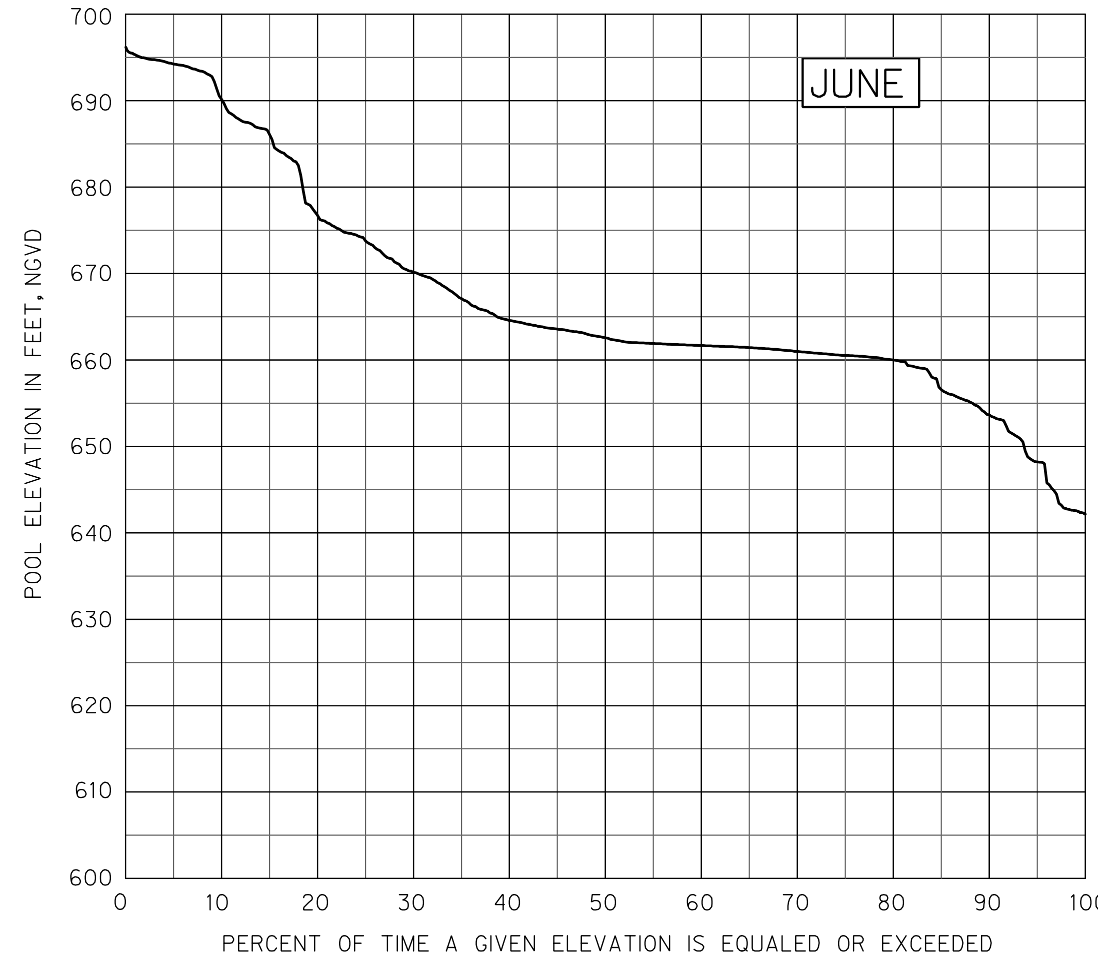
WHITE RIVER BASIN ARKANSAS AND MISSOURI

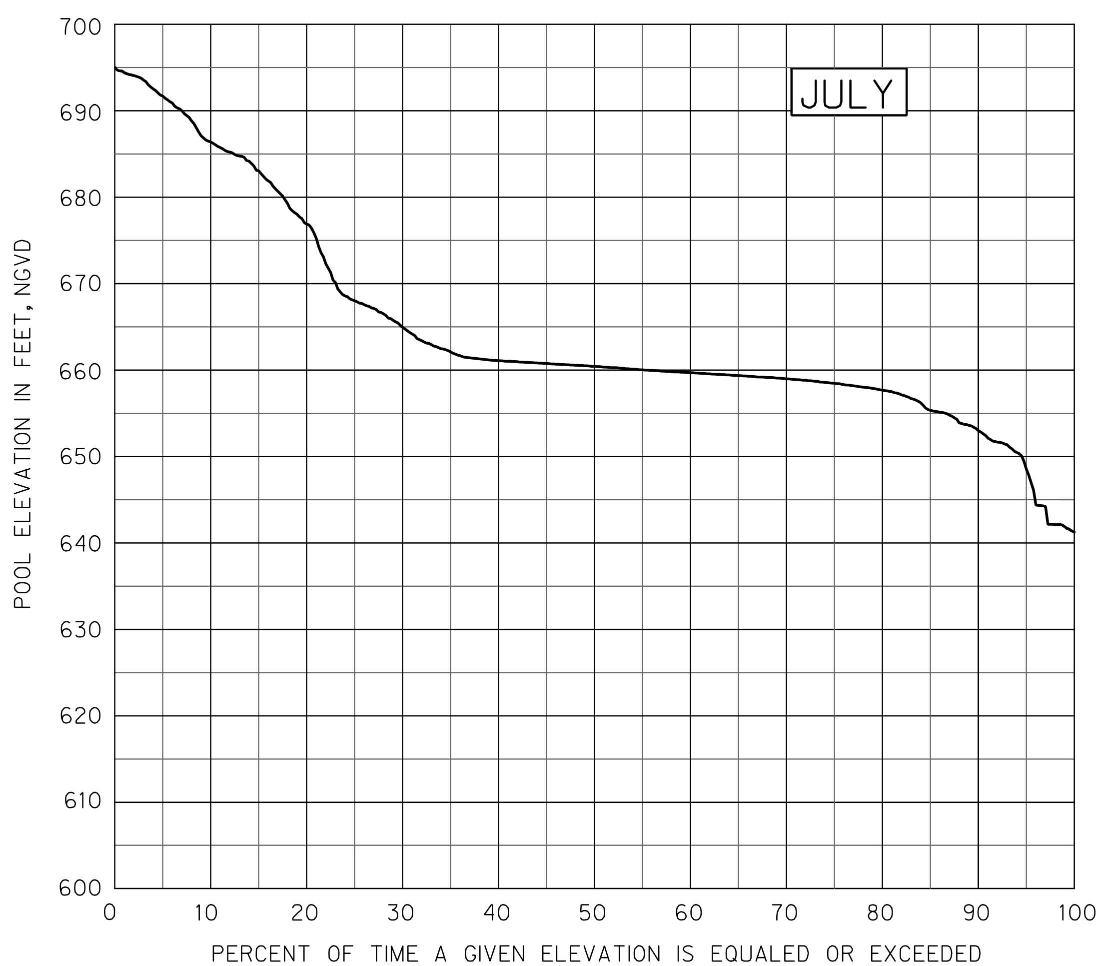
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
ELEVATION DURATION CURVES
BULL SHOALS LAKE
JANUARY - APRIL
1940 - 2011

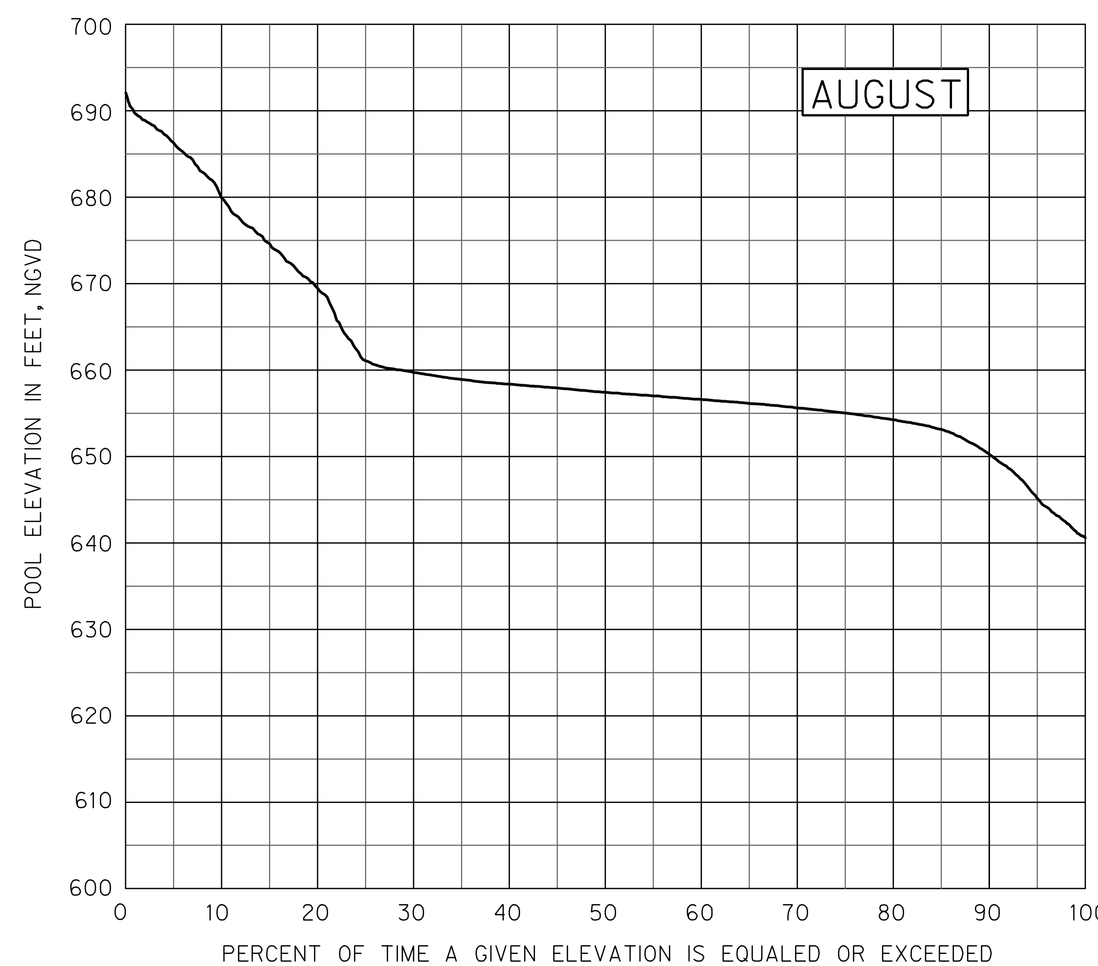
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









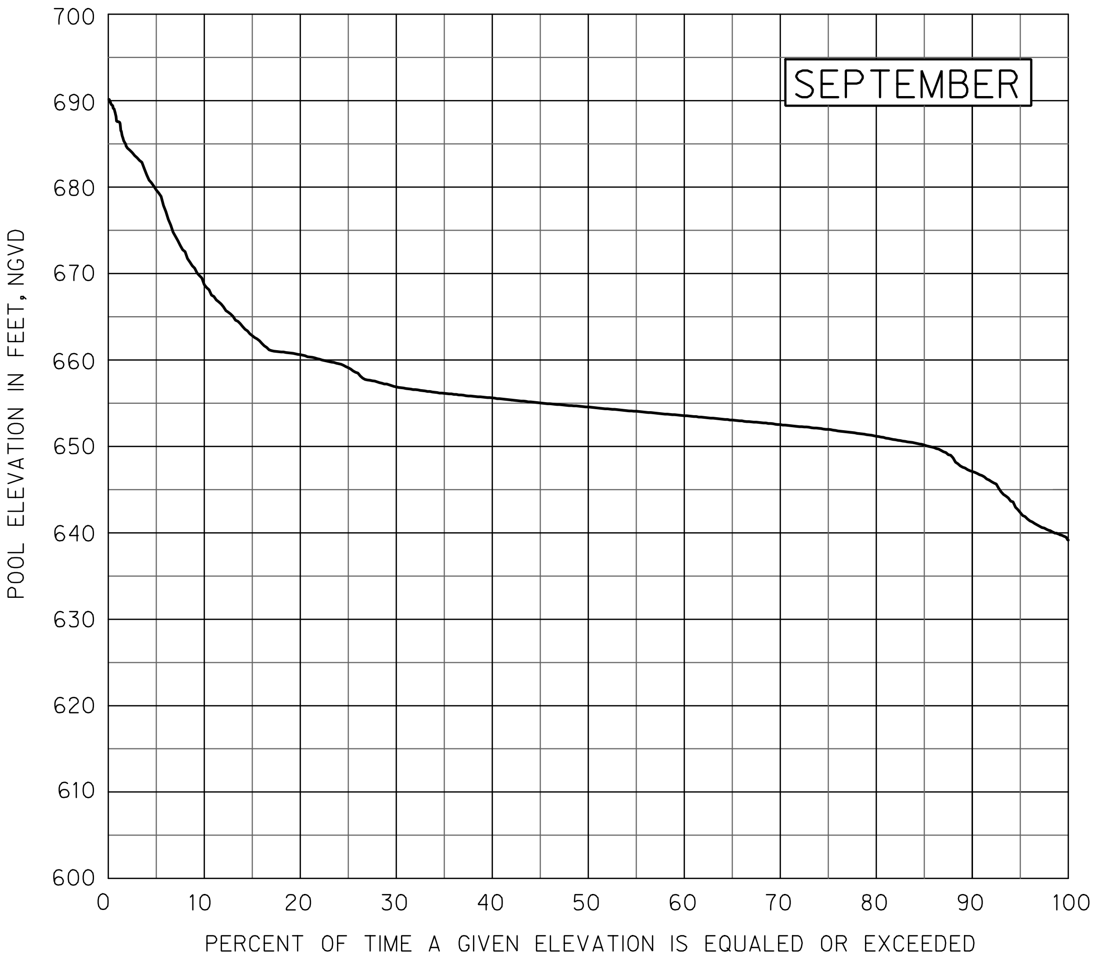
NOTE:

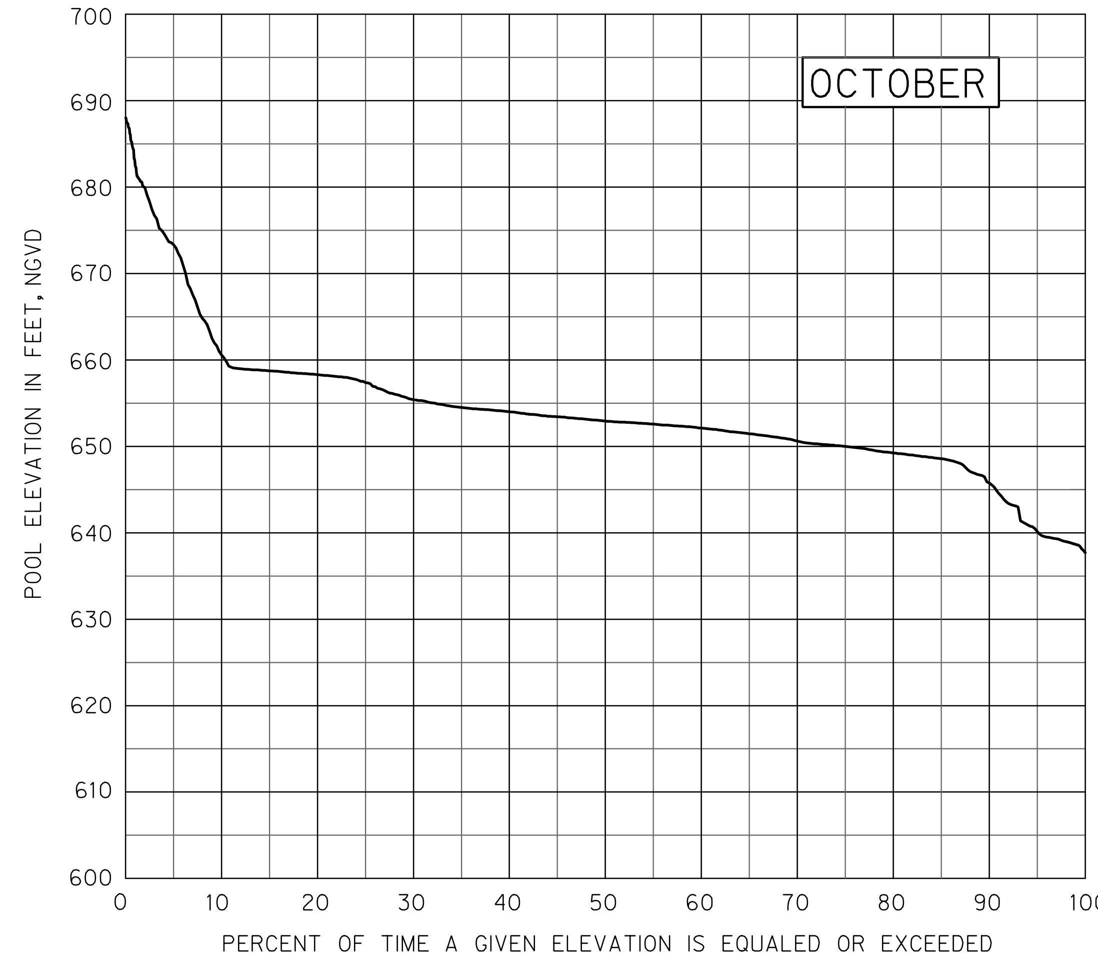
2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

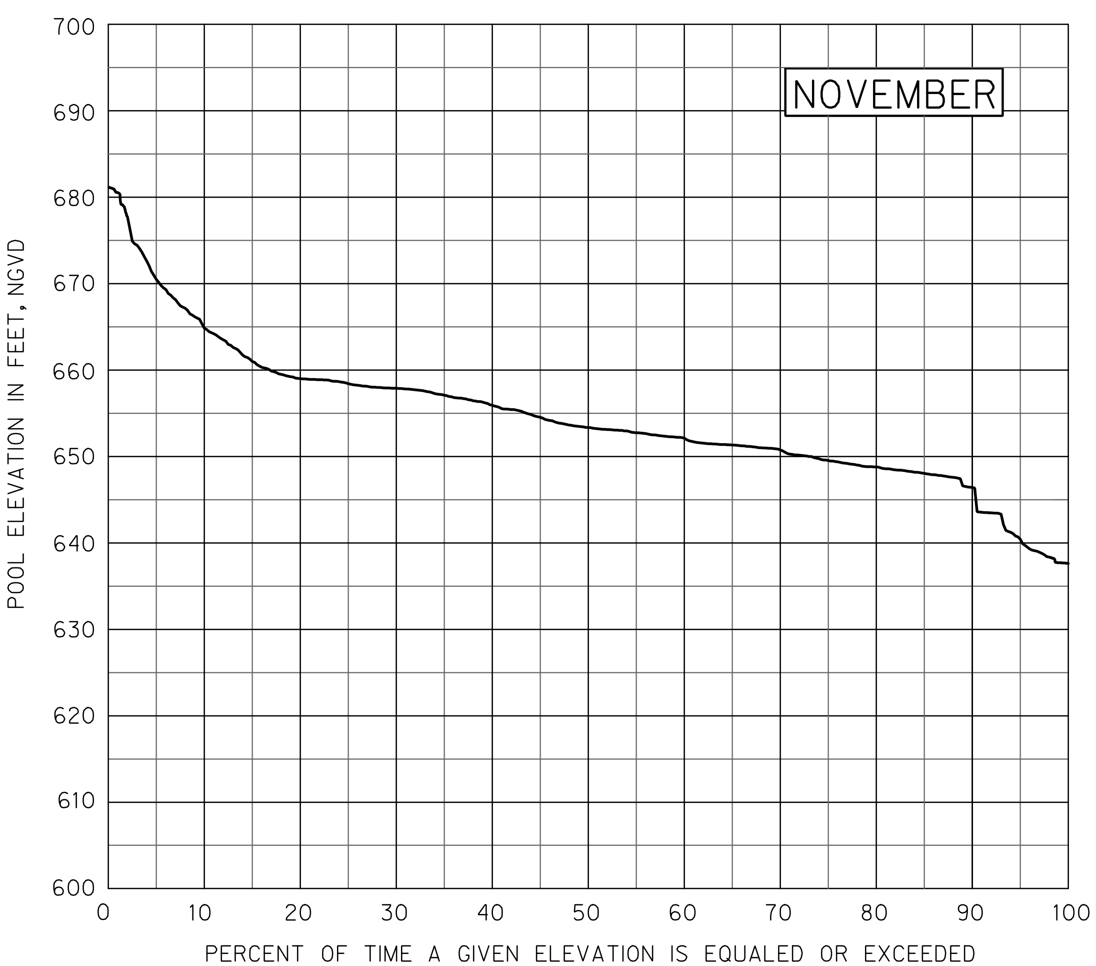
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

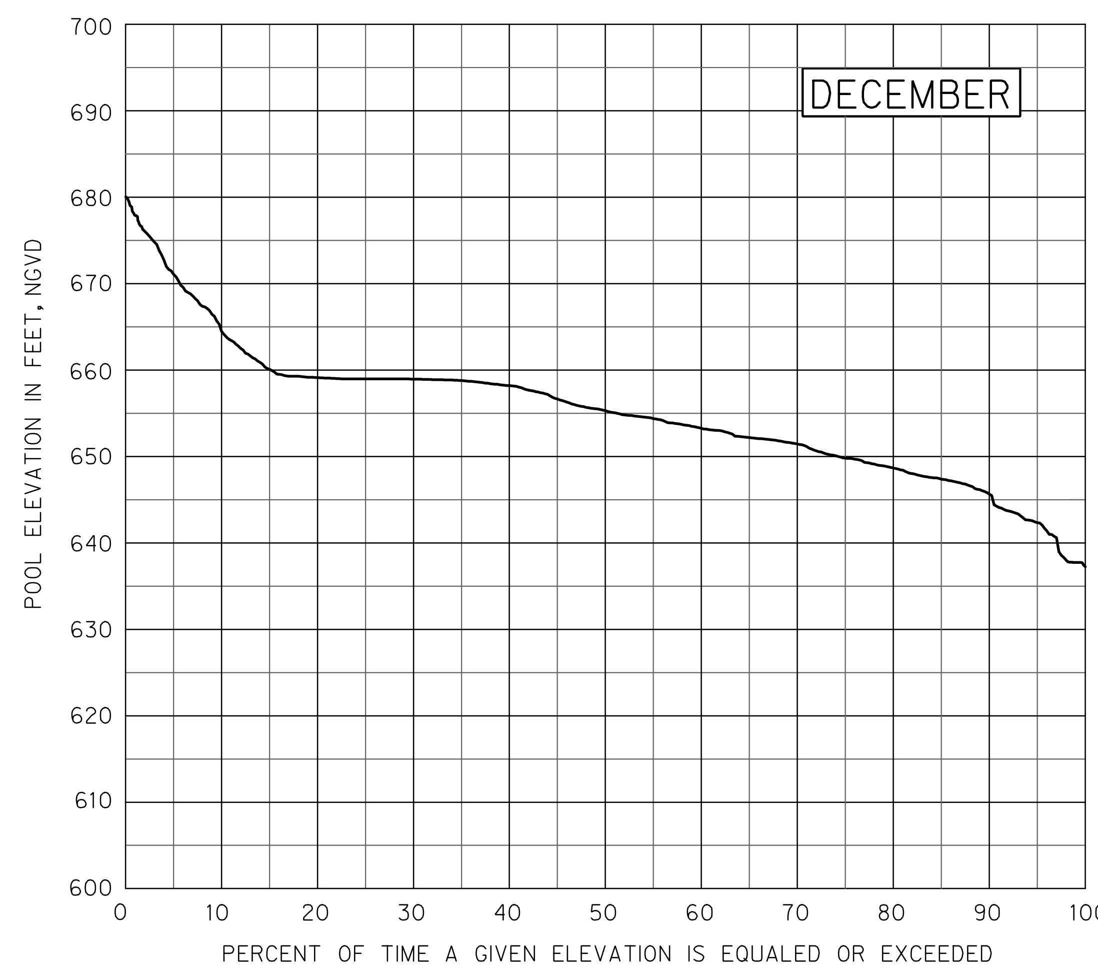
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
ELEVATION DURATION CURVES
BULL SHOALS LAKE
MAY - AUGUST
1940 - 2011
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

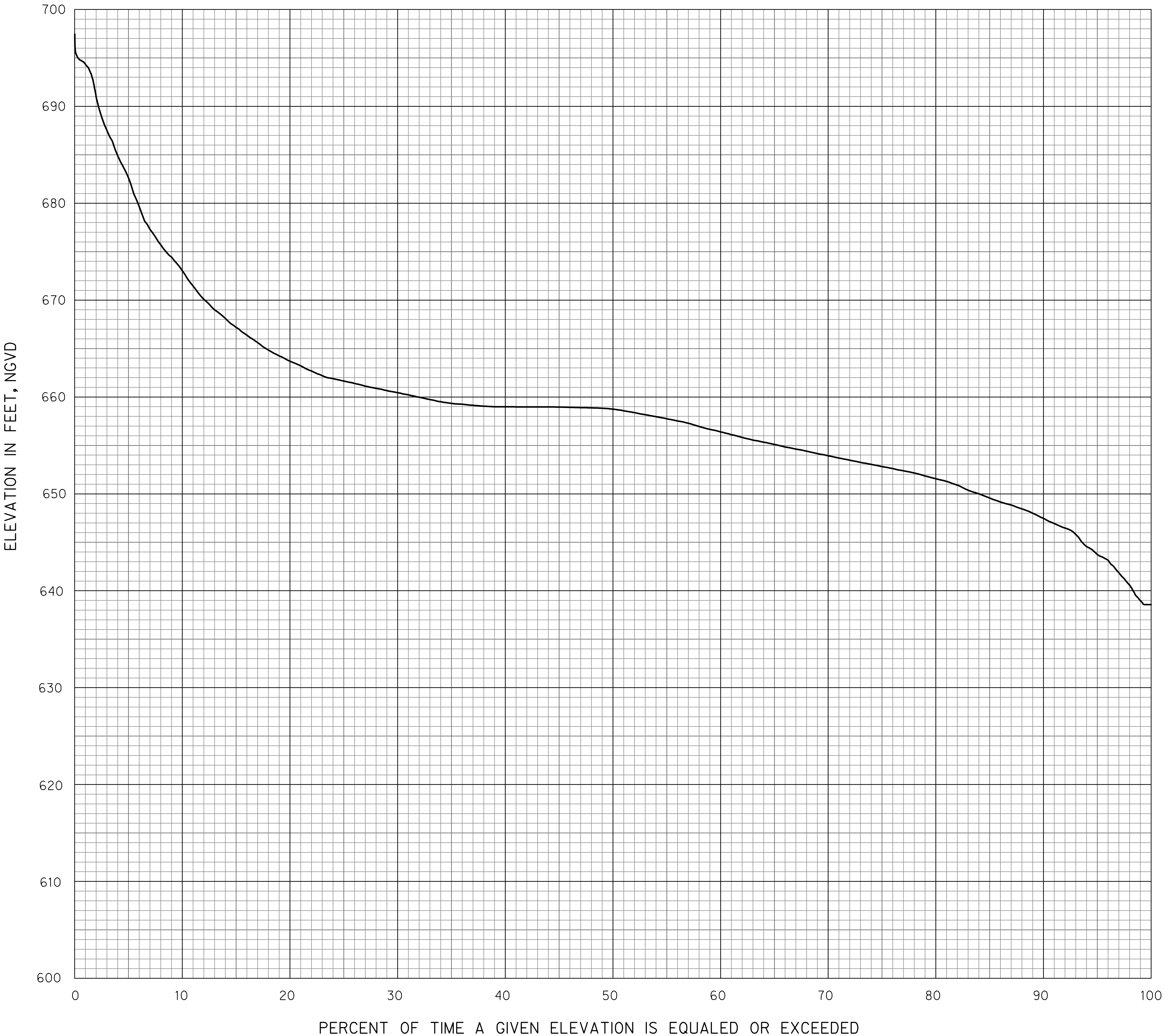
2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
ELEVATION DURATION CURVES
BULL SHOALS LAKE
SEPTEMBER - DECEMBER
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE:

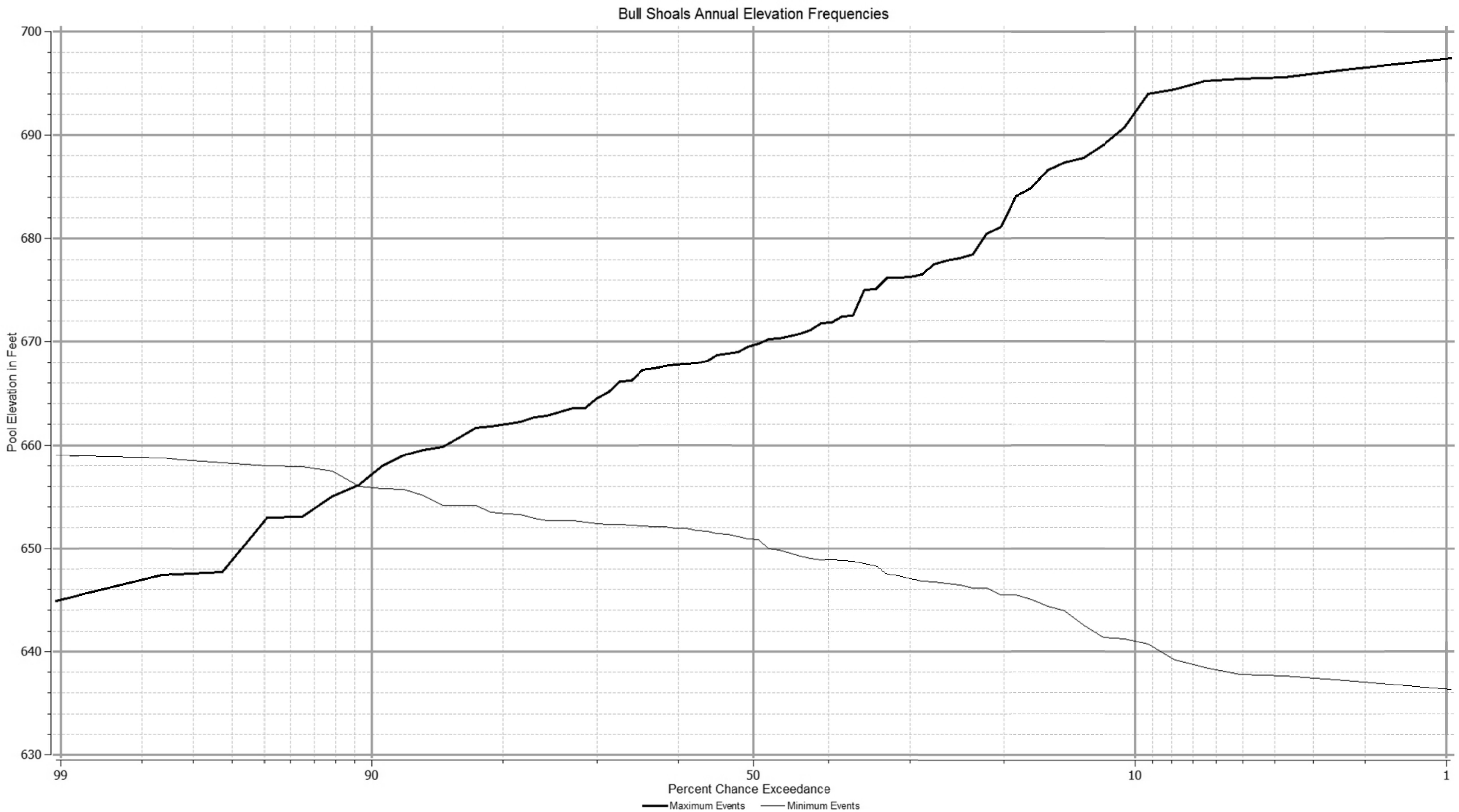
2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

WHITE RIVER BASIN — ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
ANNUAL
ELEVATION DURATION CURVE
BULL SHOALS LAKE
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



Bull Shoals		
Chance Exceedance	Max Elevation	Min Elevation
1%	697.42	636.34
2%	696.59	637.00
5%	695.42	637.74
10%	692.22	640.99
25%	678.00	646.50
50%	669.67	650.90

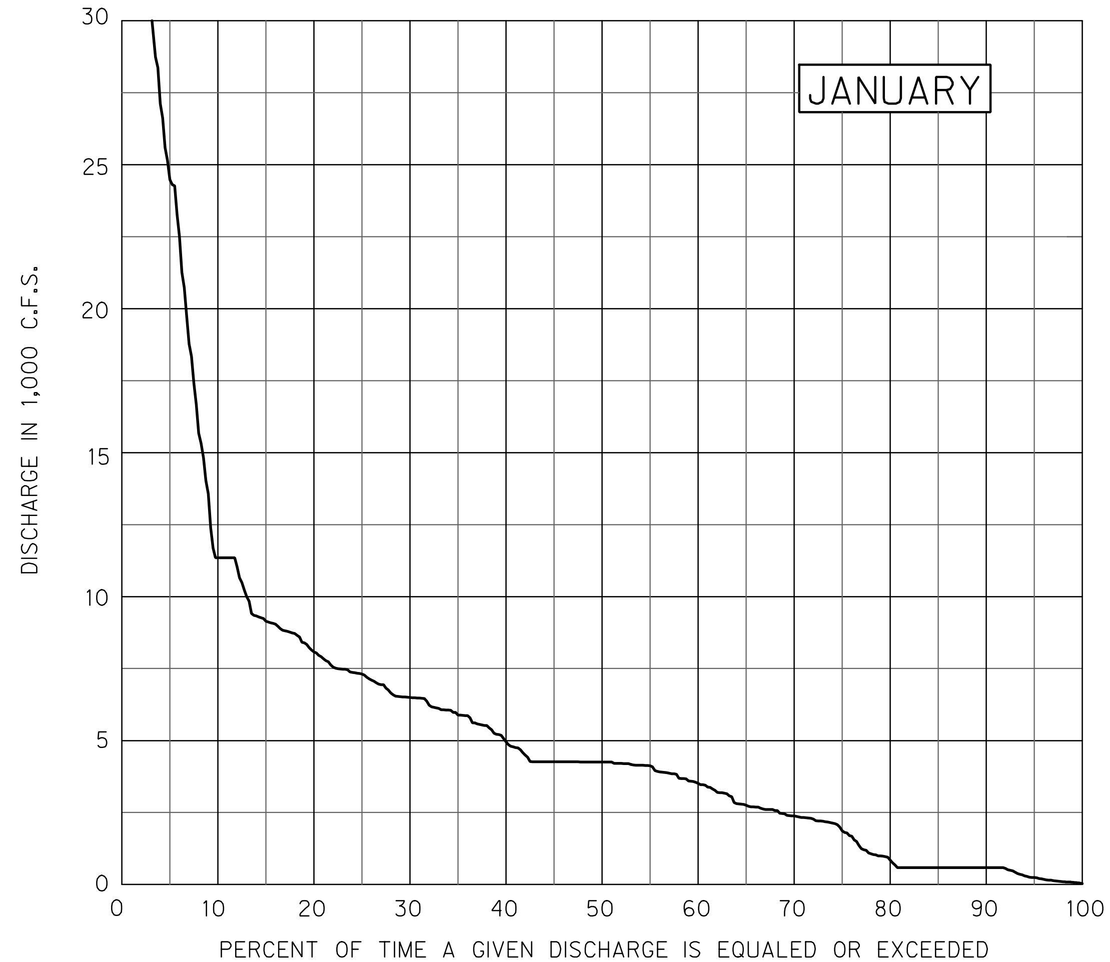
WHITE RIVER BASIN ARKANSAS AND MISSOURI

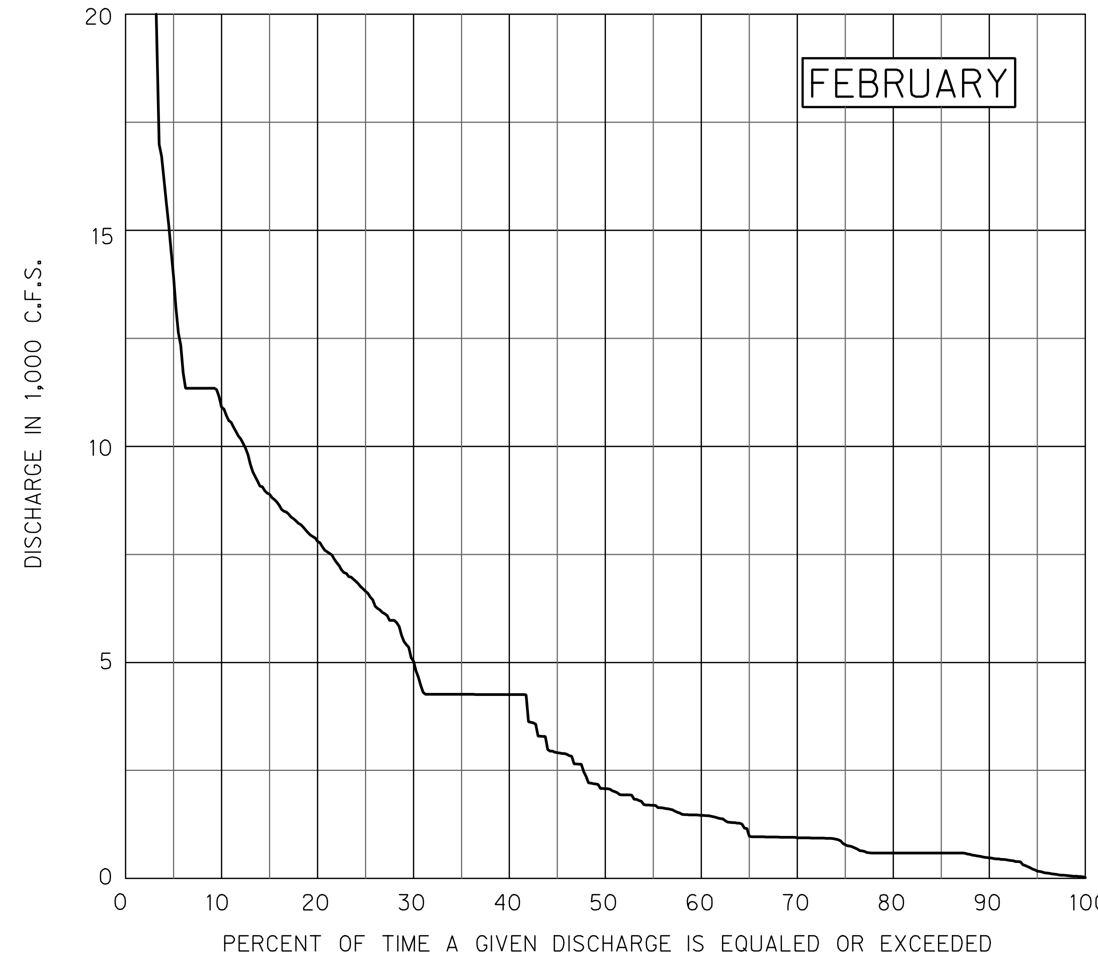
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

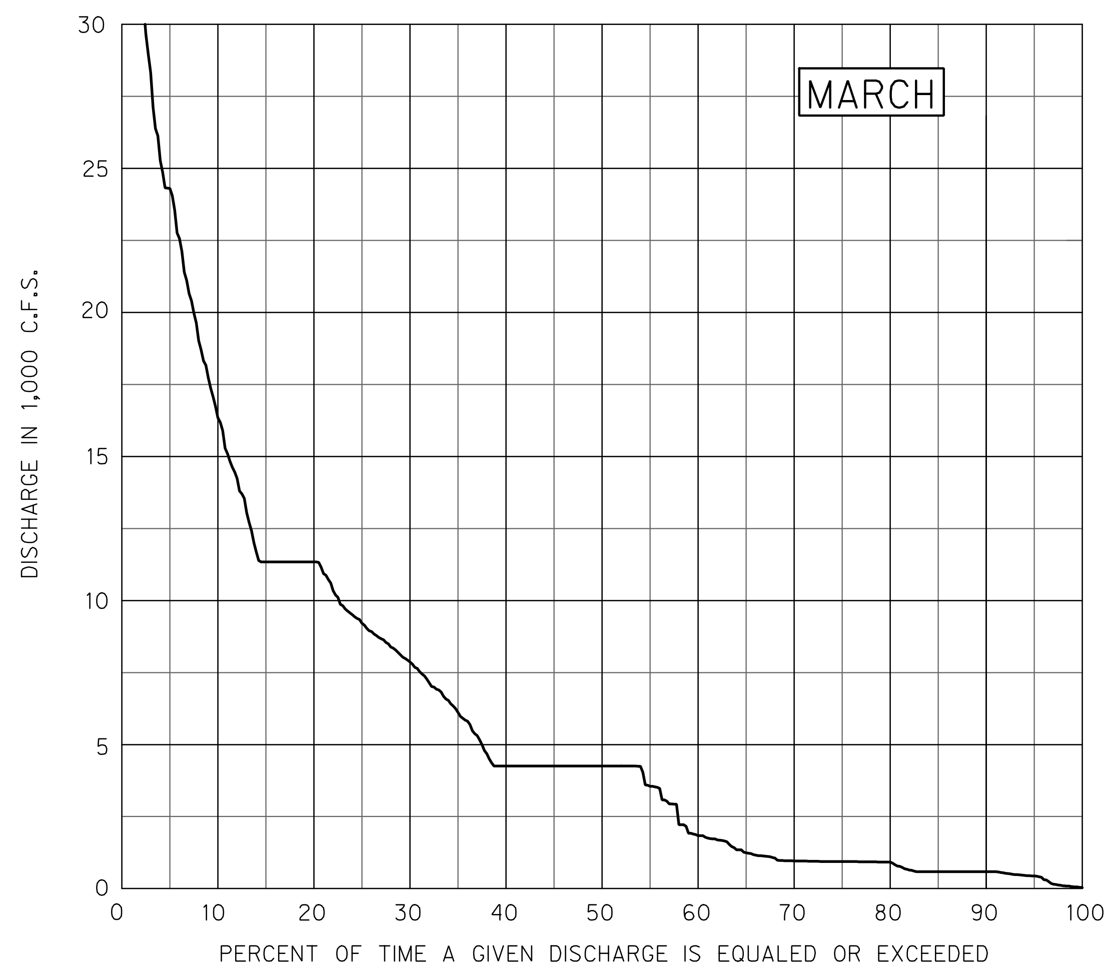
ANNUAL ELEVATION
FREQUENCY CURVES
BULL SHOALS LAKE

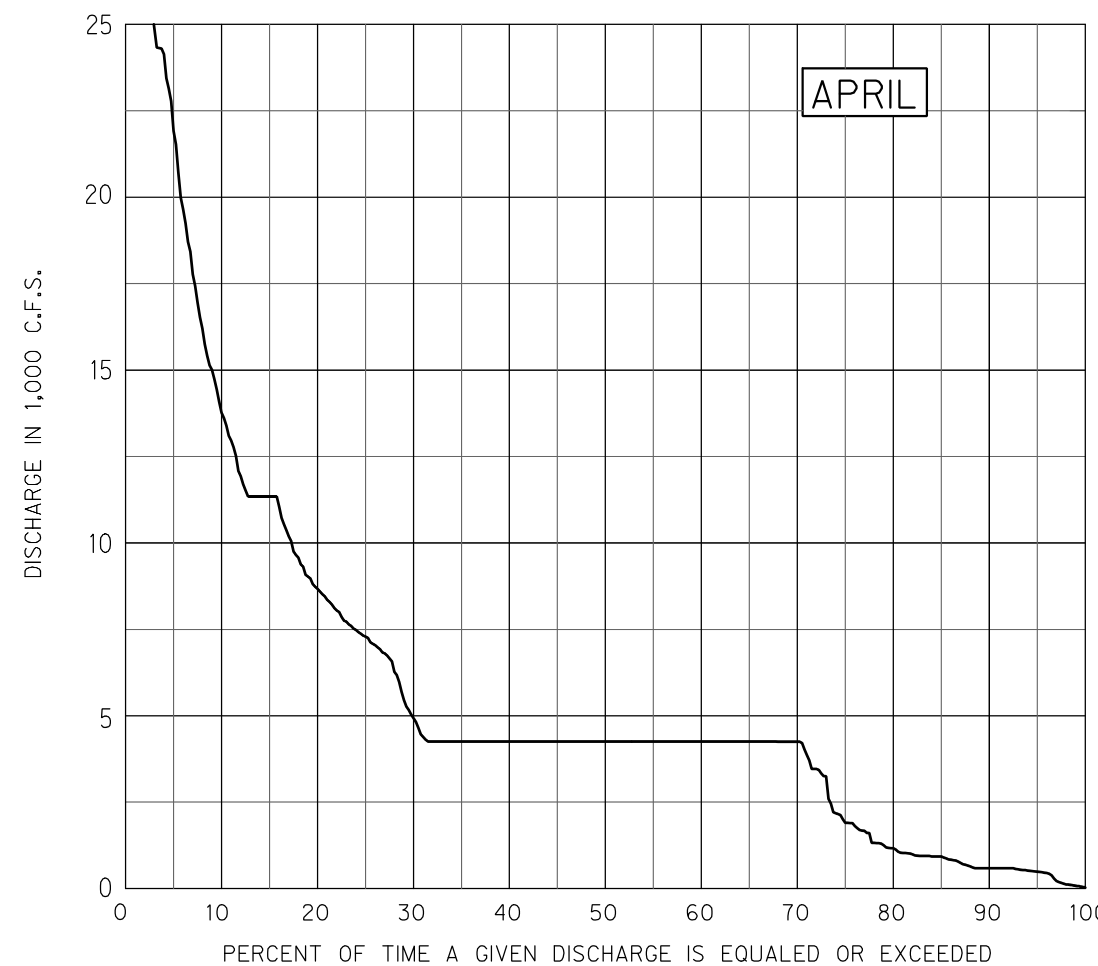
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









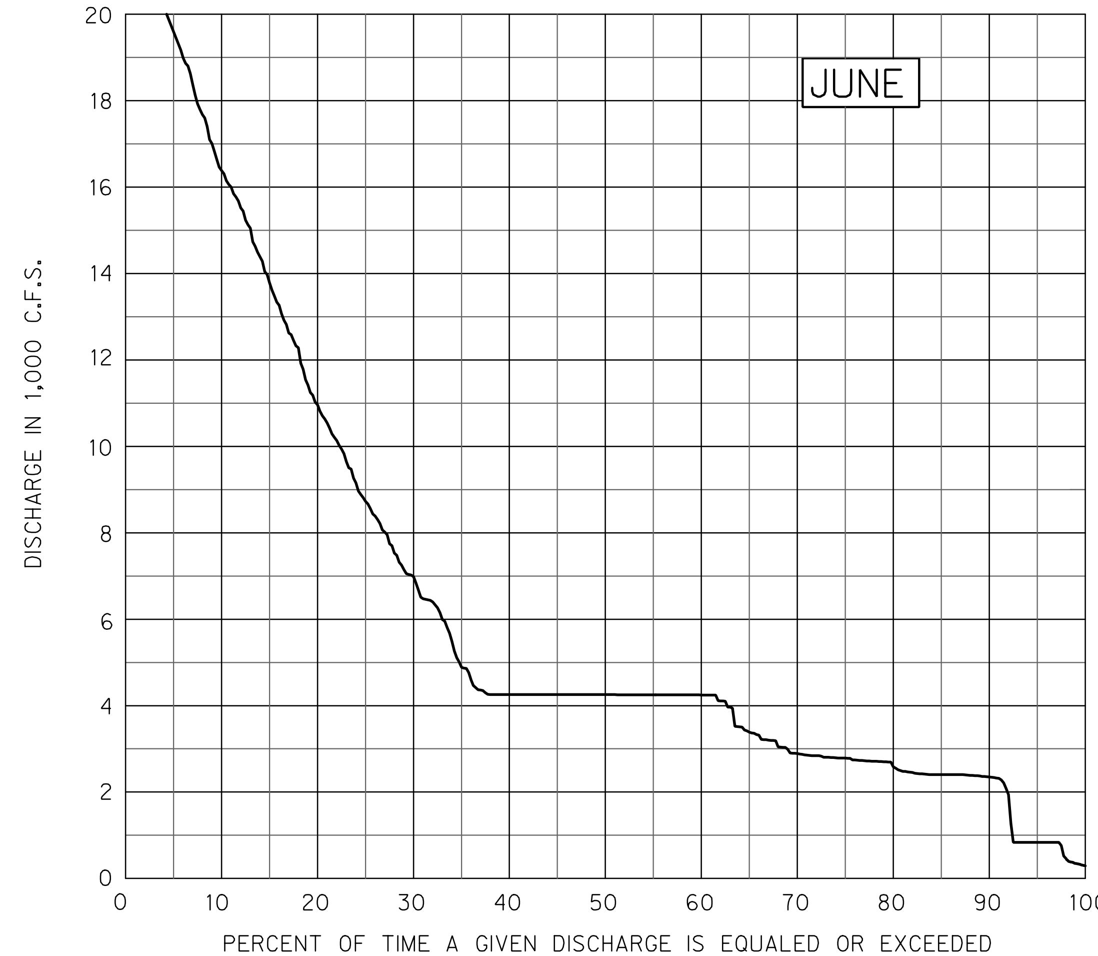
NOTE:

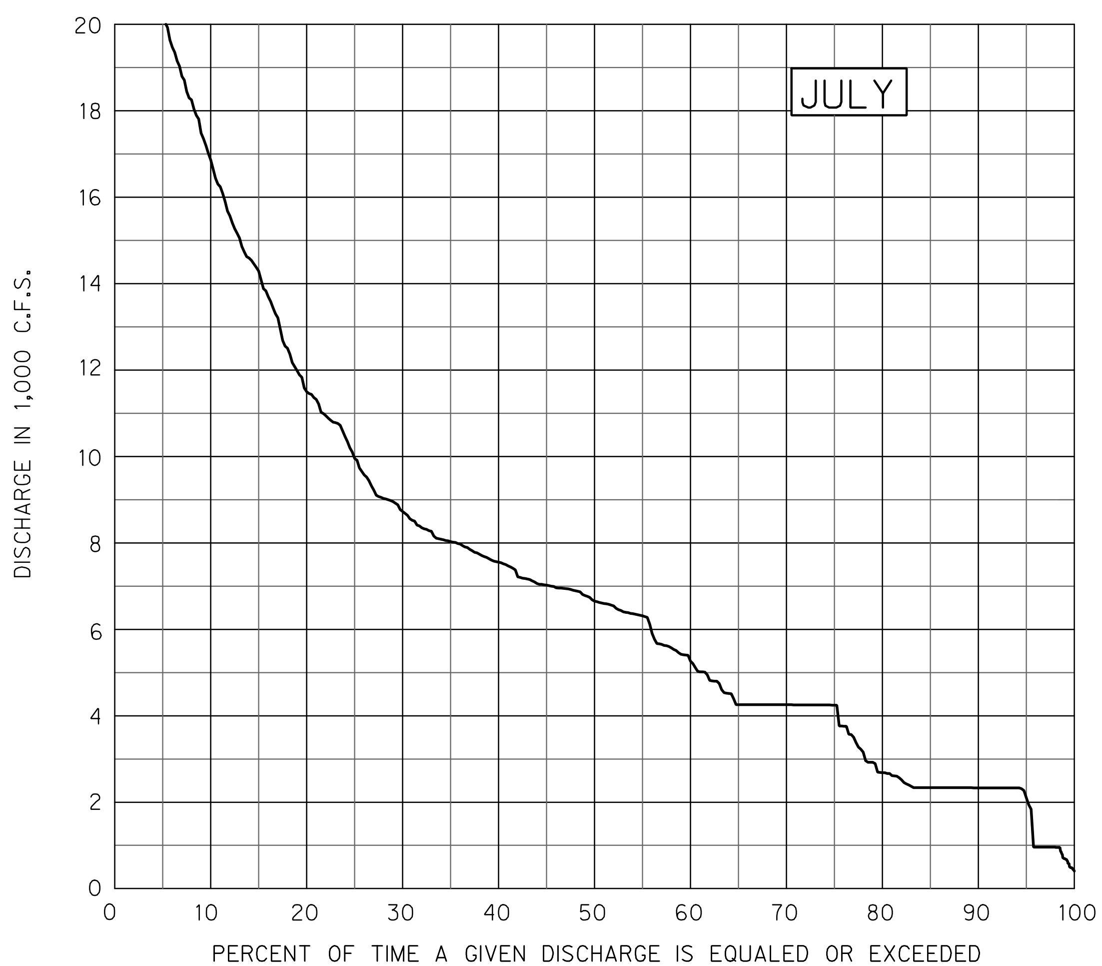
2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

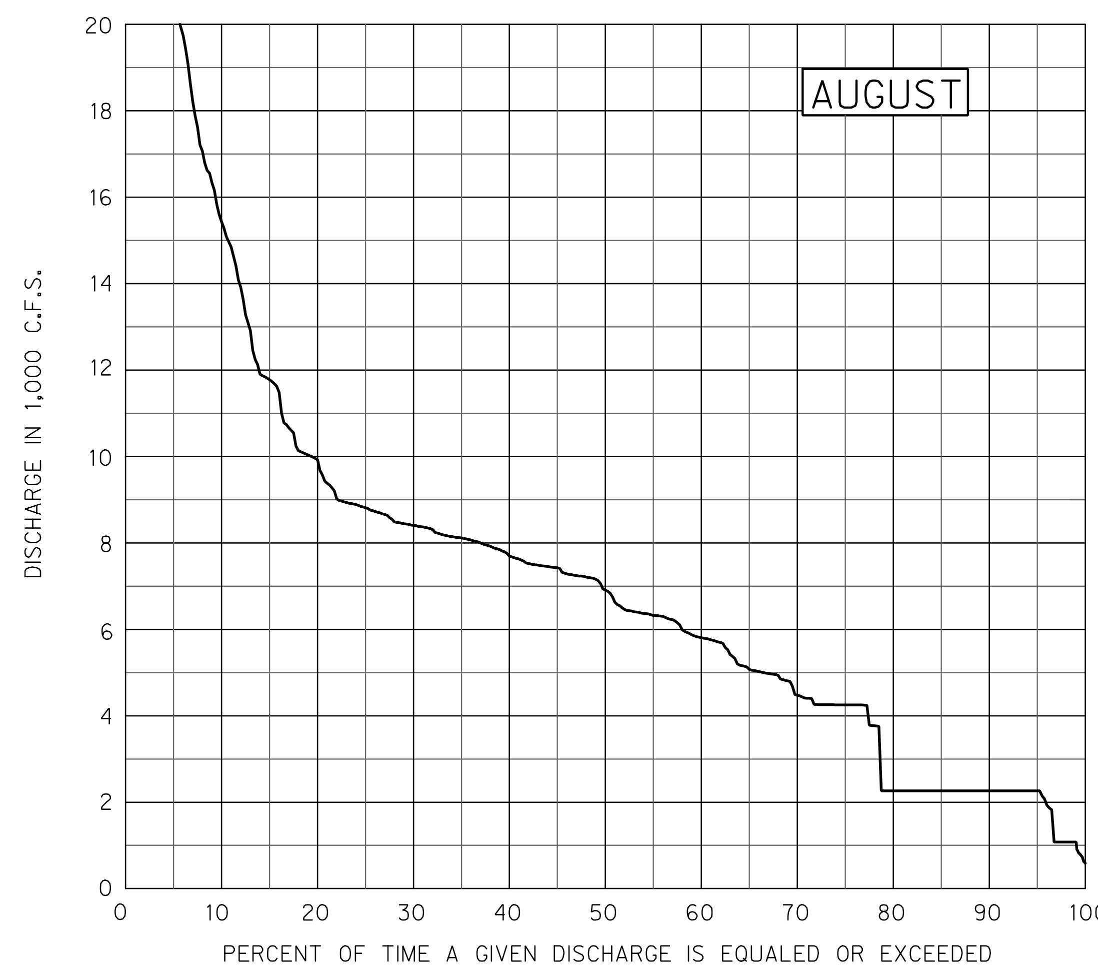
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
DISCHARGE DURATION CURVES
BULL SHOALS LAKE
JANUARY - APRIL
1940 - 2011
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

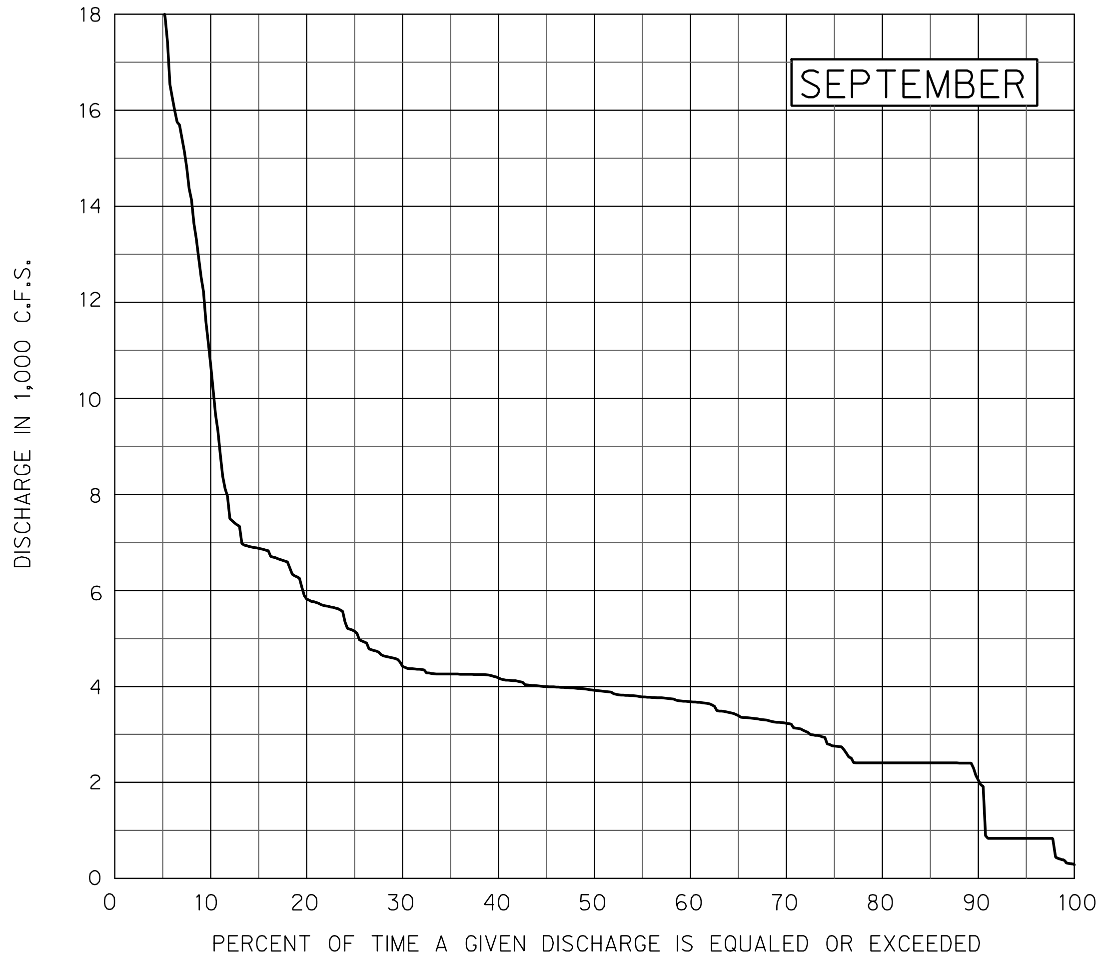
WHITE RIVER BASIN ARKANSAS AND MISSOURI

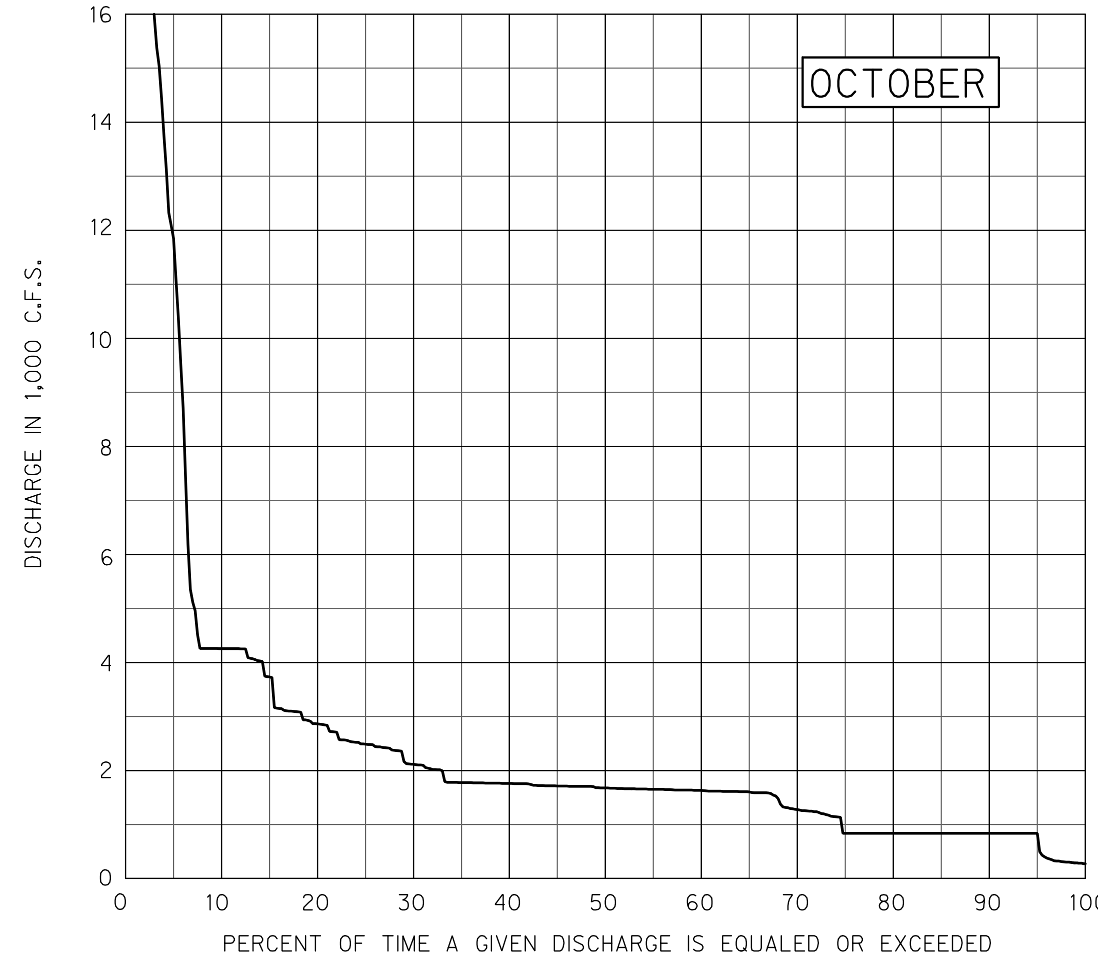
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

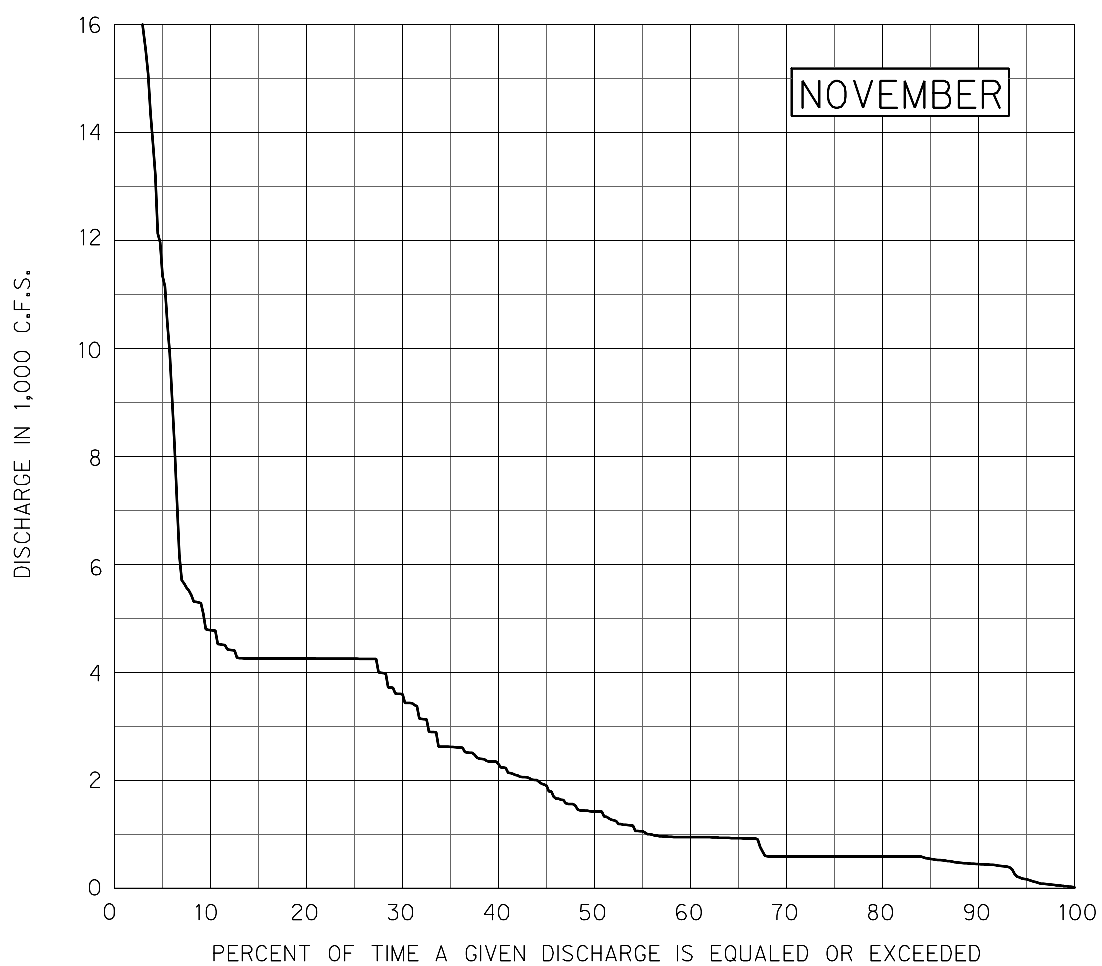
MONTHLY
DISCHARGE DURATION CURVES
BULL SHOALS LAKE
MAY - AUGUST
1940 - 2011

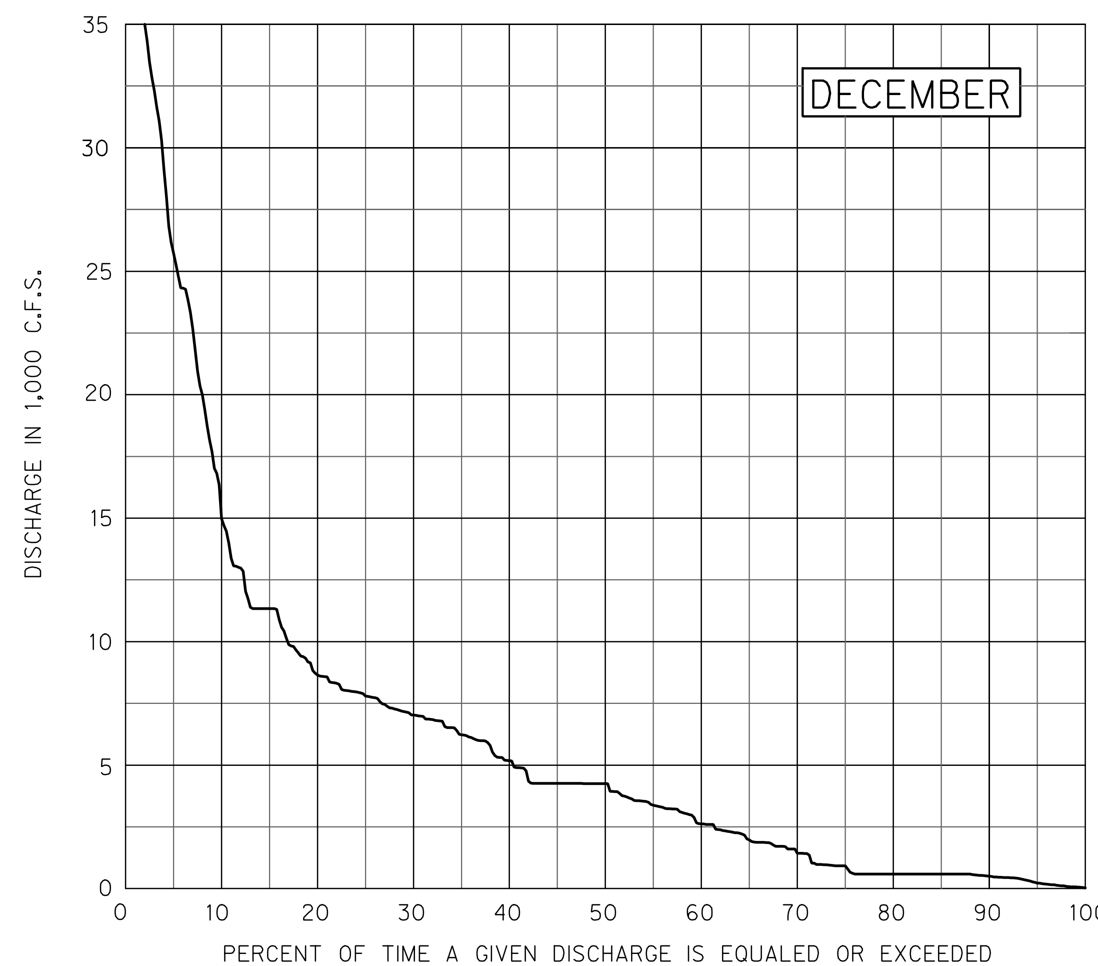
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

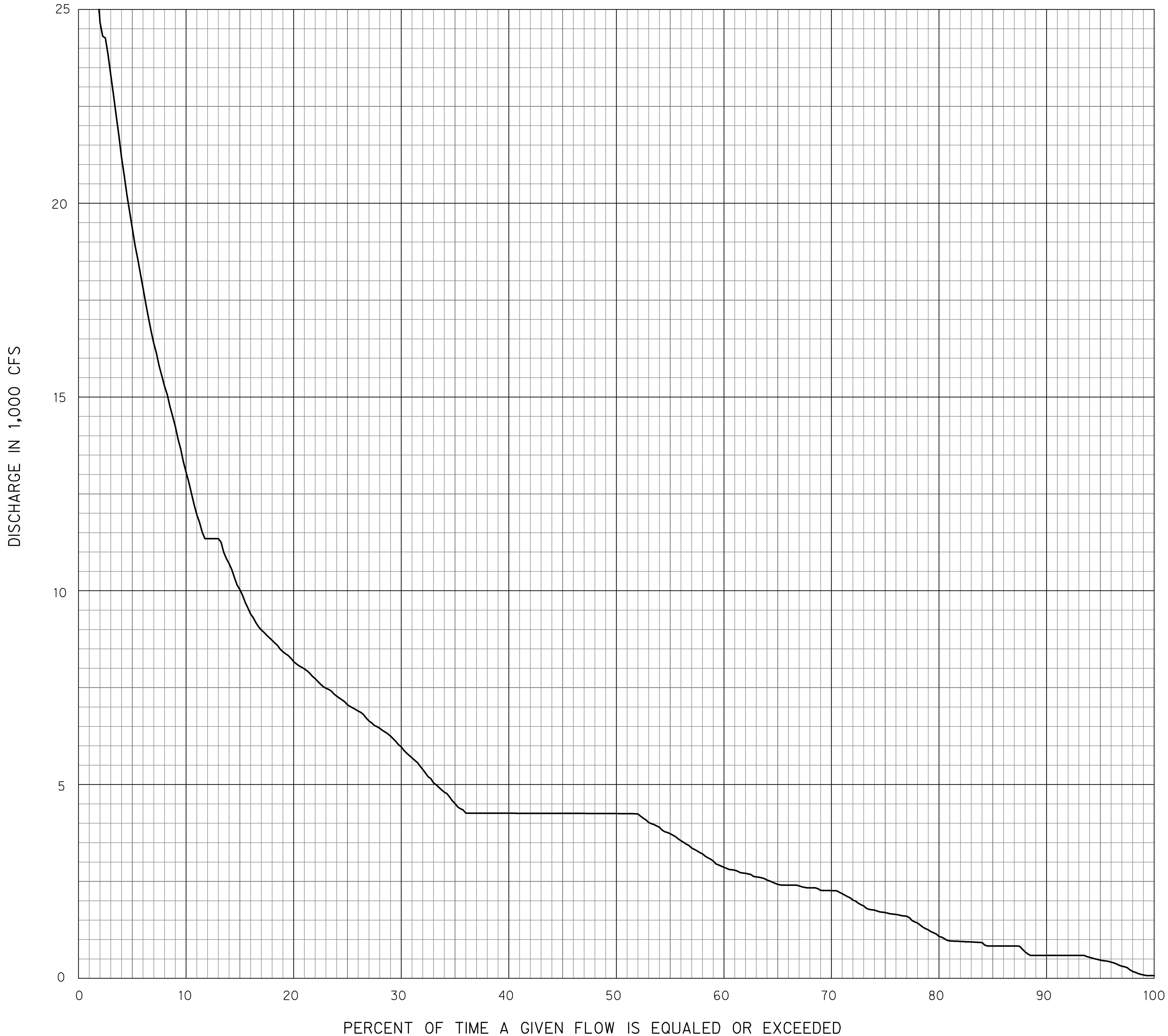
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

MONTHLY
DISCHARGE DURATION CURVES
BULL SHOALS LAKE
SEPTEMBER - DECEMBER
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE:

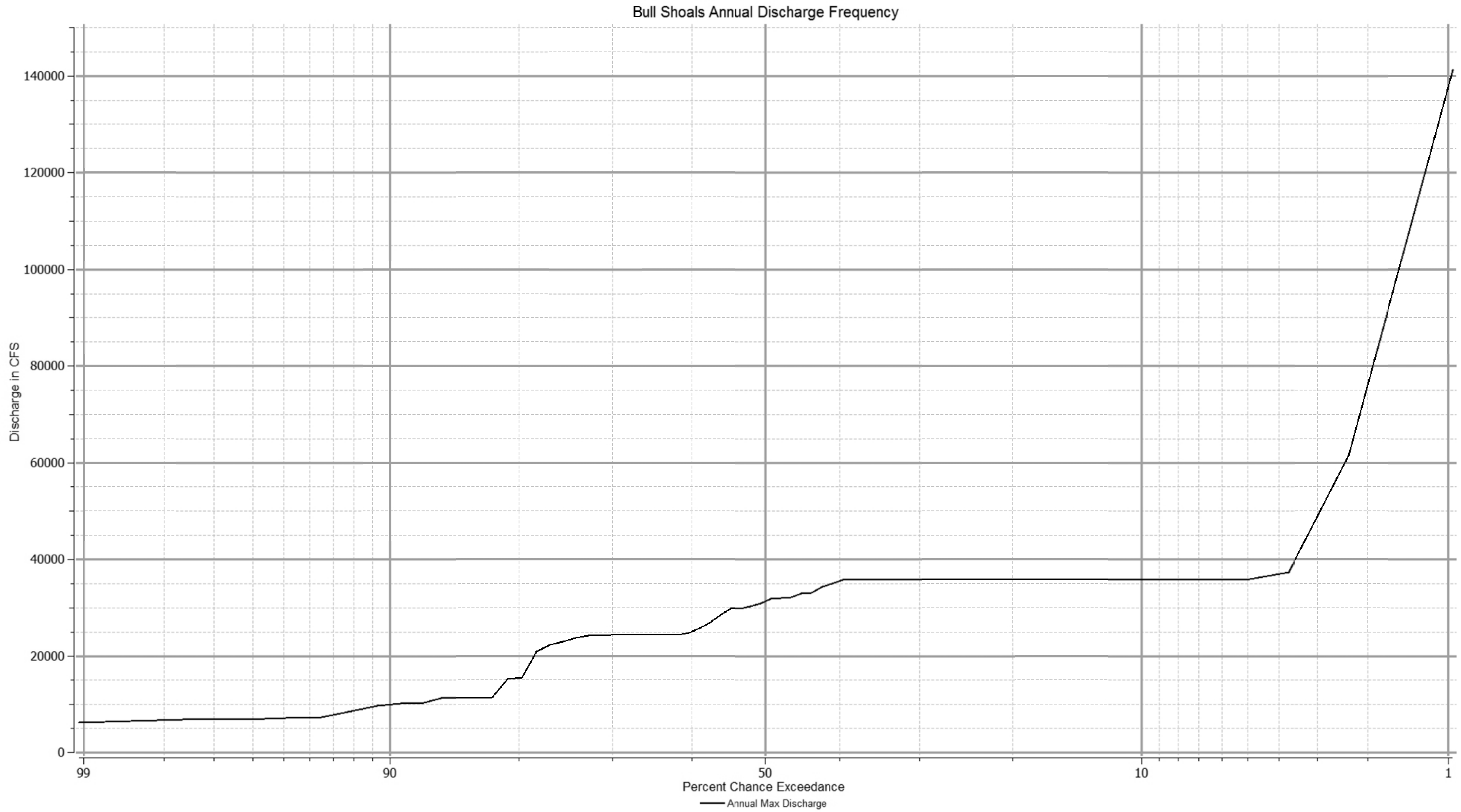
2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
ANNUAL
DISCHARGE DURATION CURVE
BULL SHOALS LAKE
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

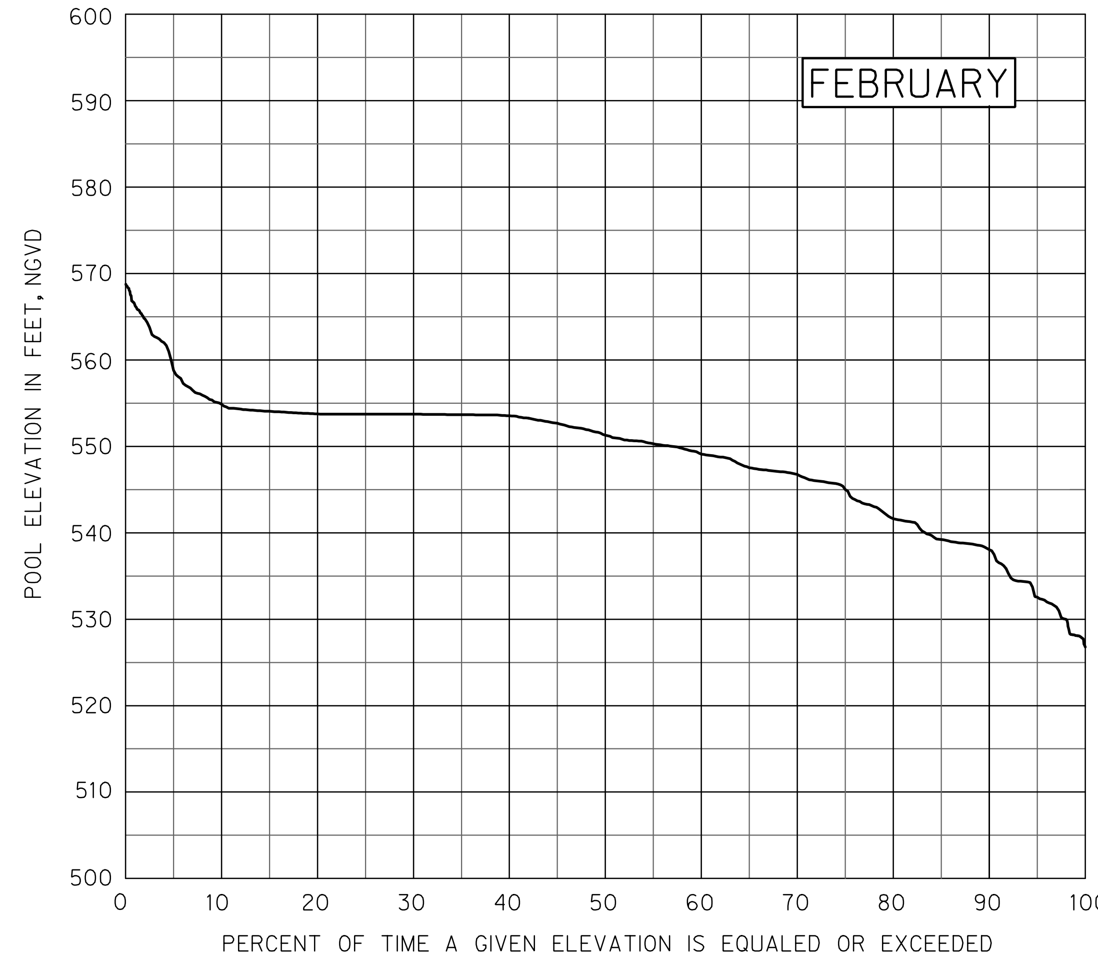
WHITE RIVER BASIN ARKANSAS AND MISSOURI

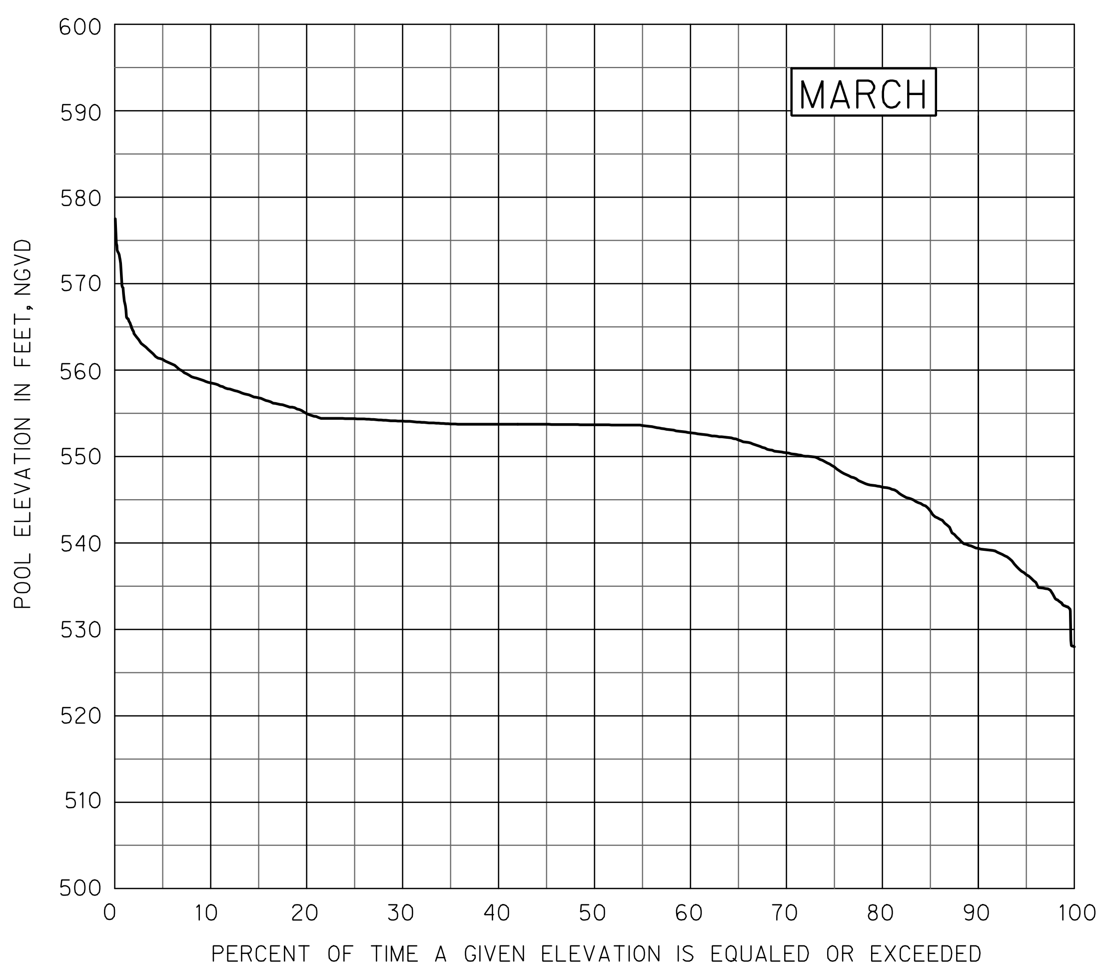
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

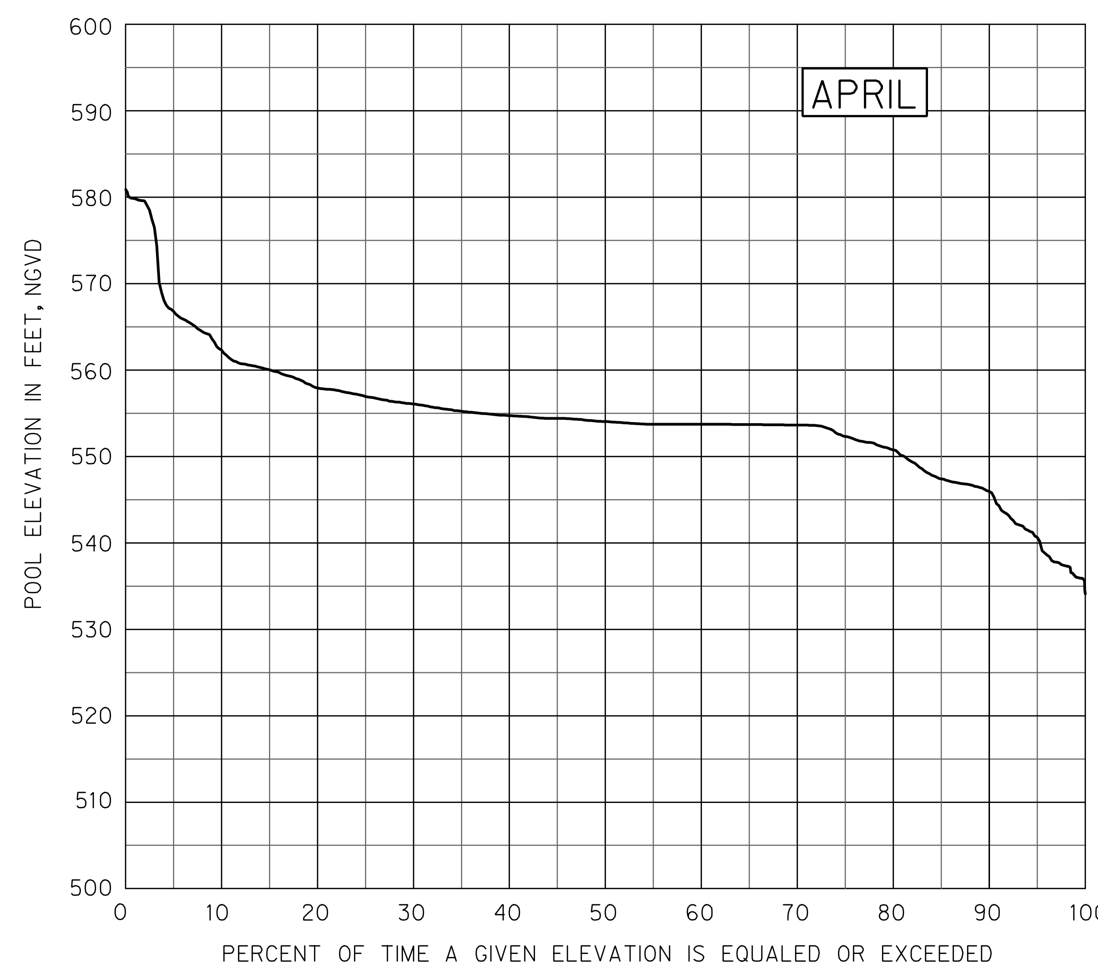
ANNUAL DISCHARGE FREQUENCY CURVE BULL SHOALS LAKE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







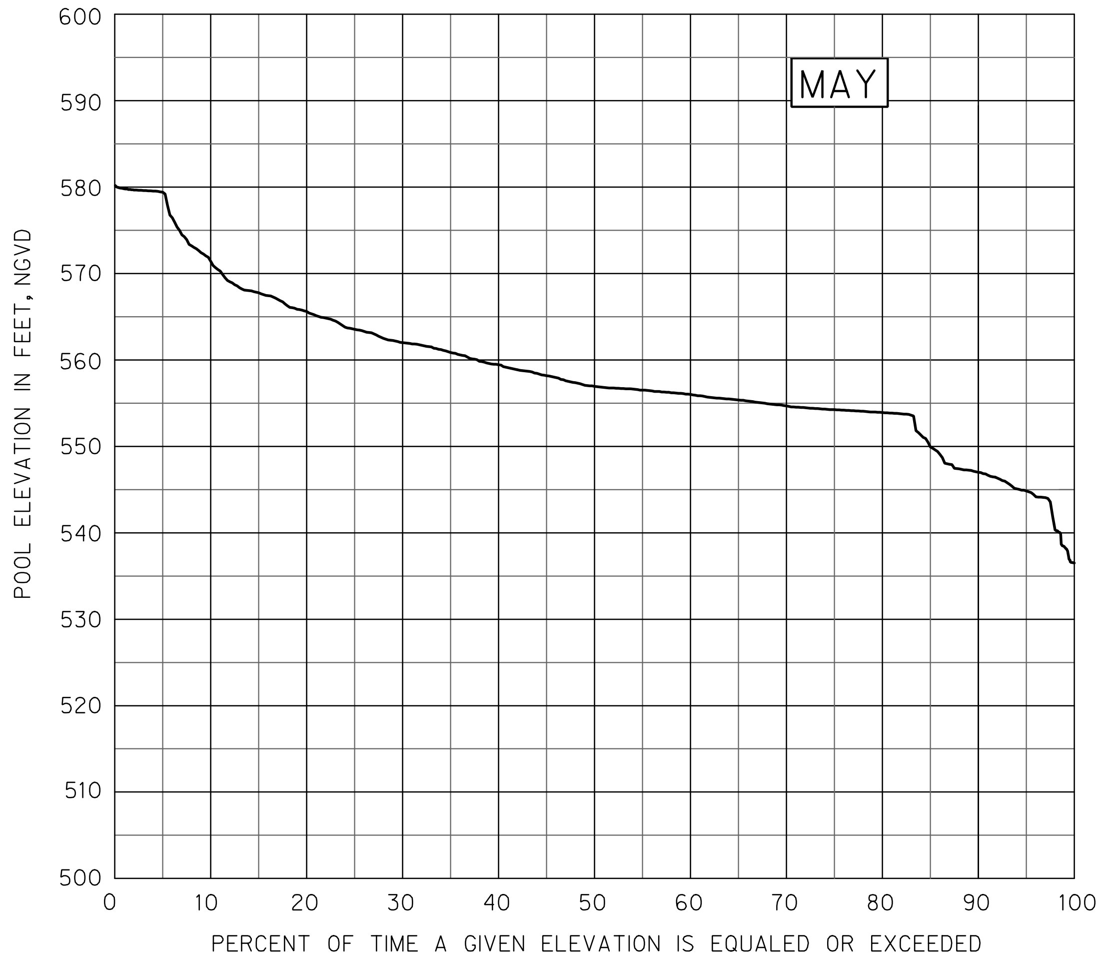
NOTE:

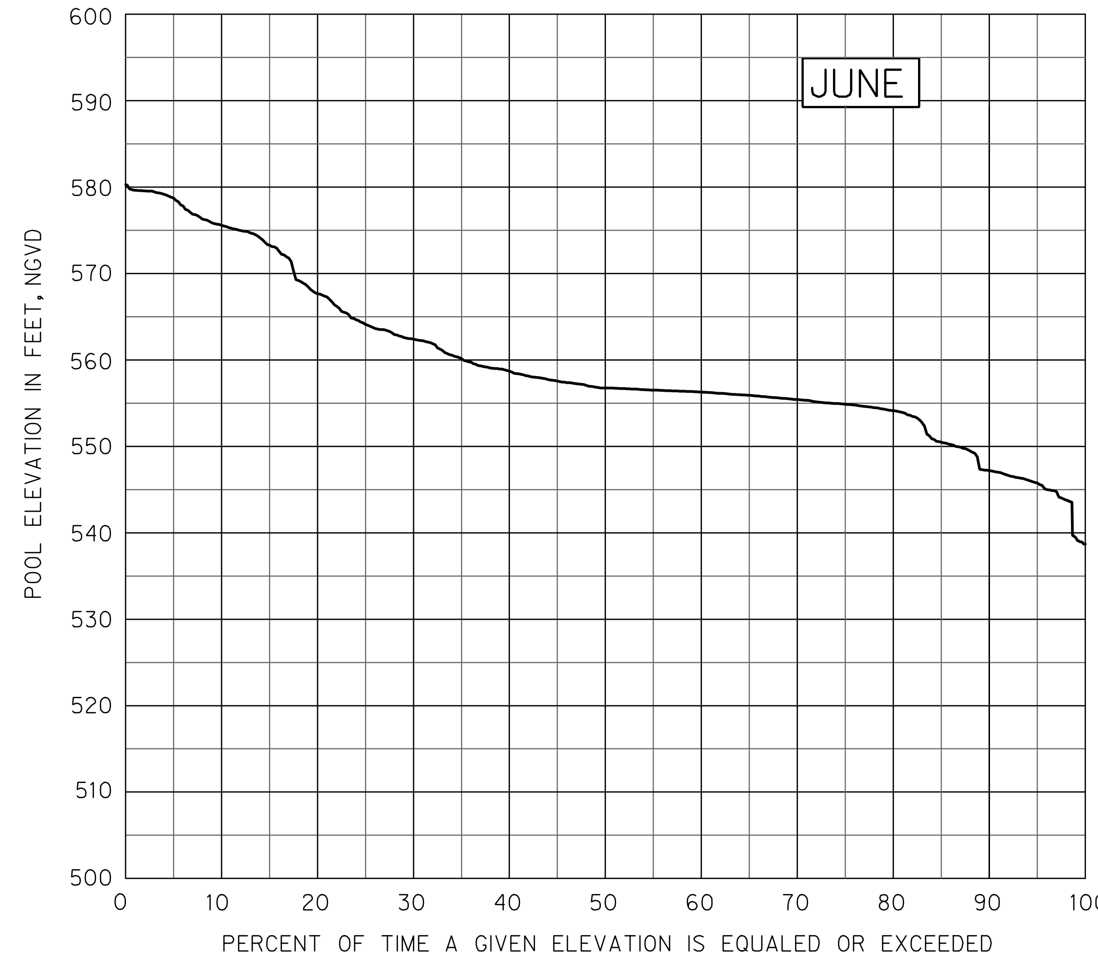
2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

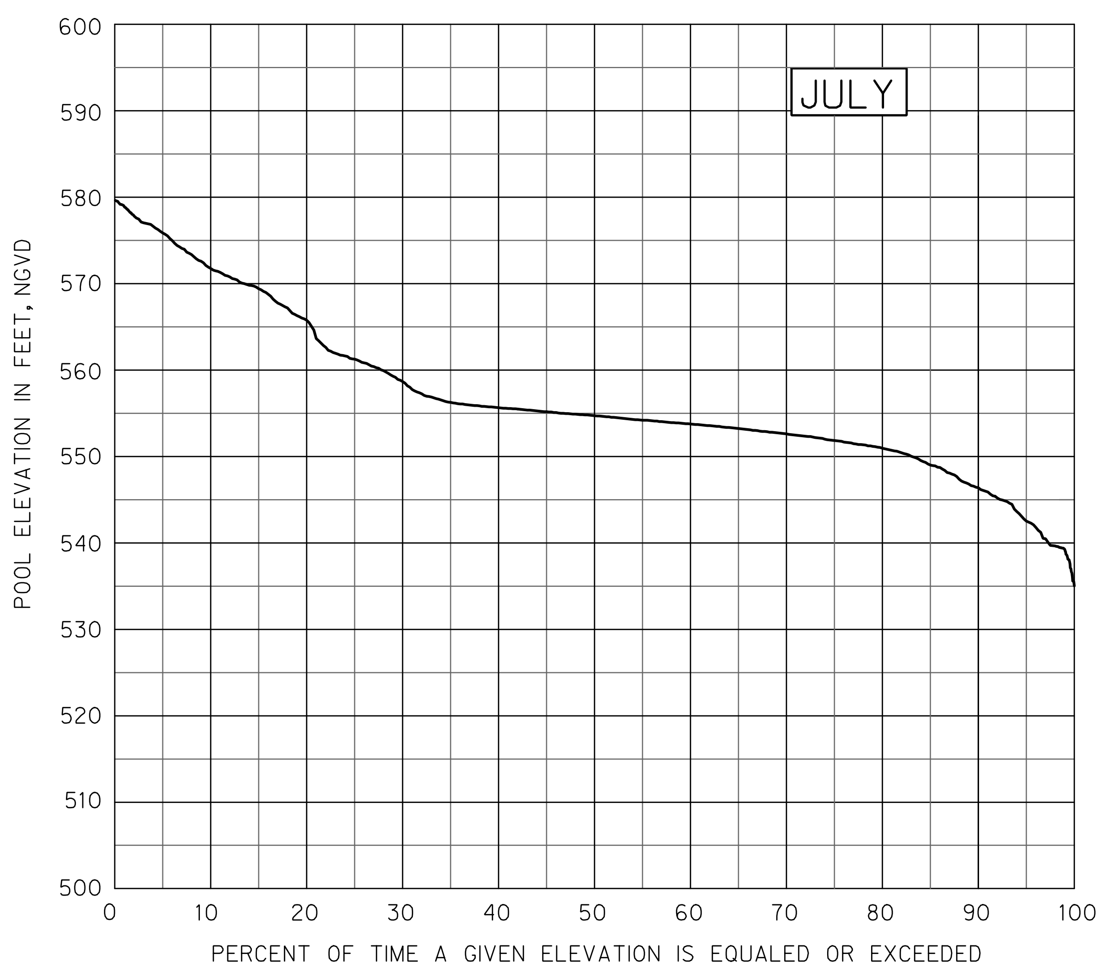
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

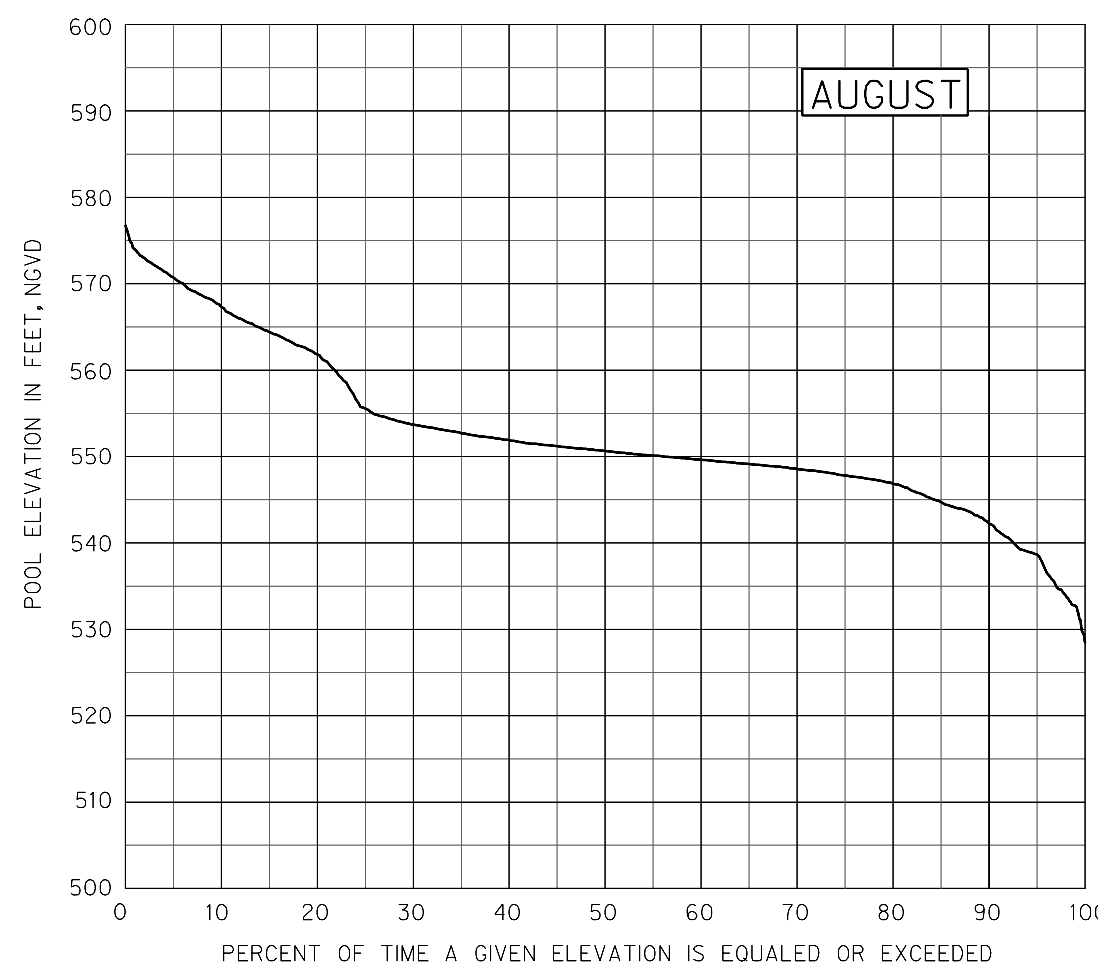
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
ELEVATION DURATION CURVES
NORFORK LAKE
JANUARY - APRIL
1940 - 2011
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









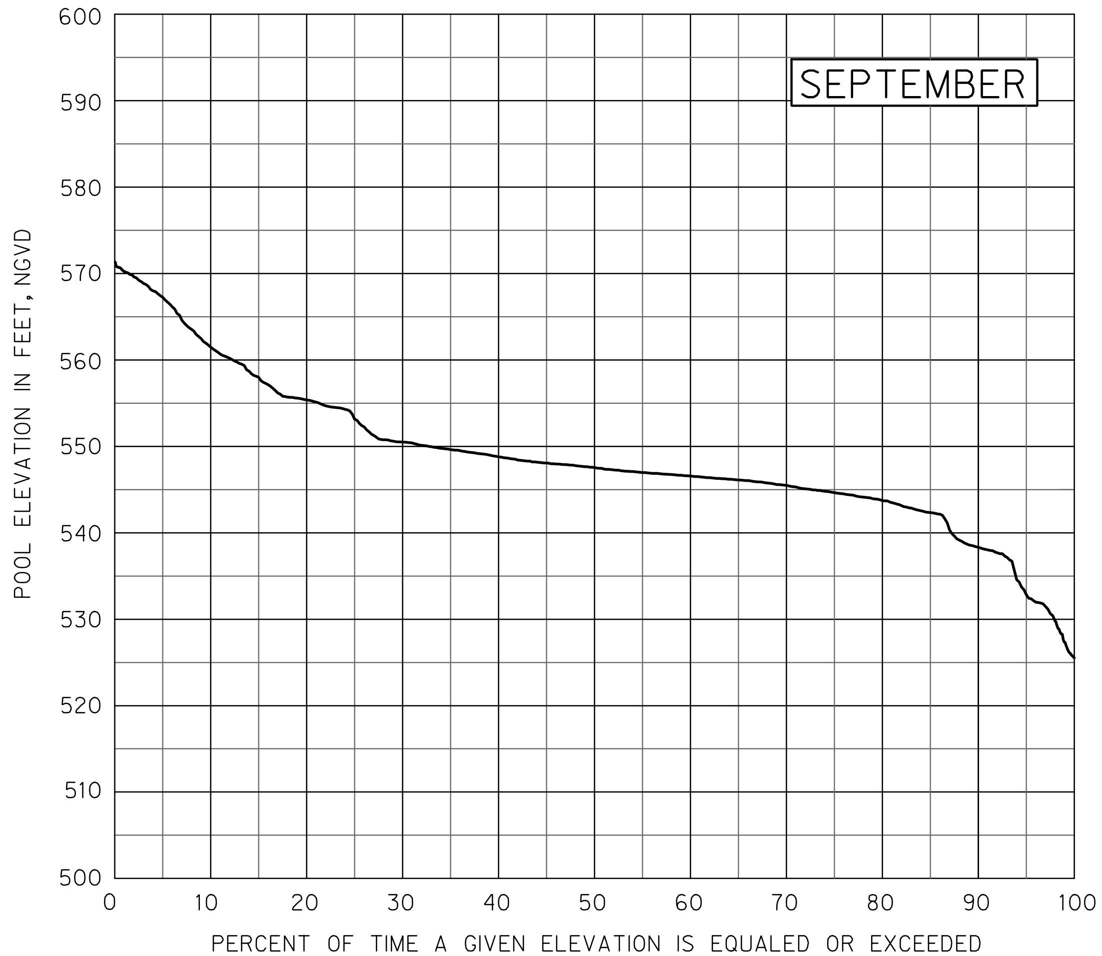
NOTE:

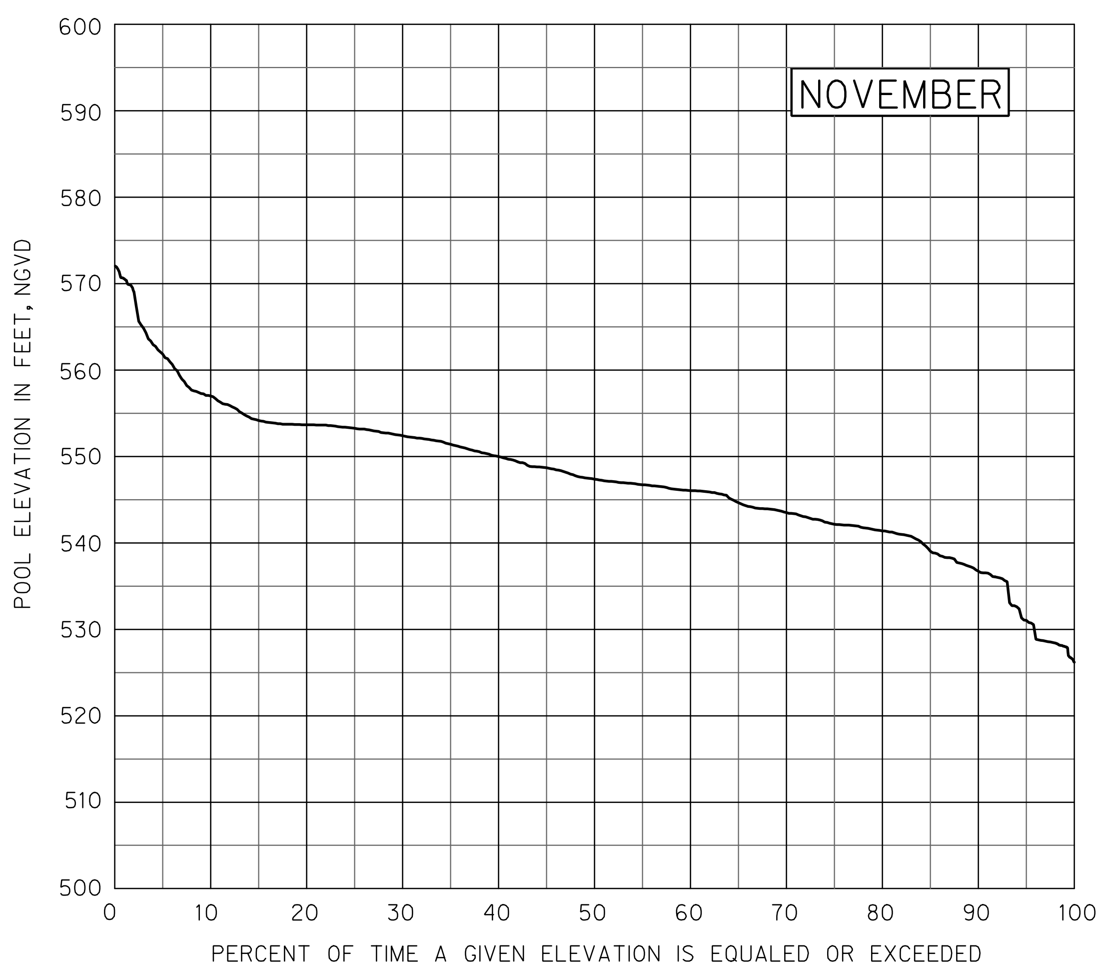
2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

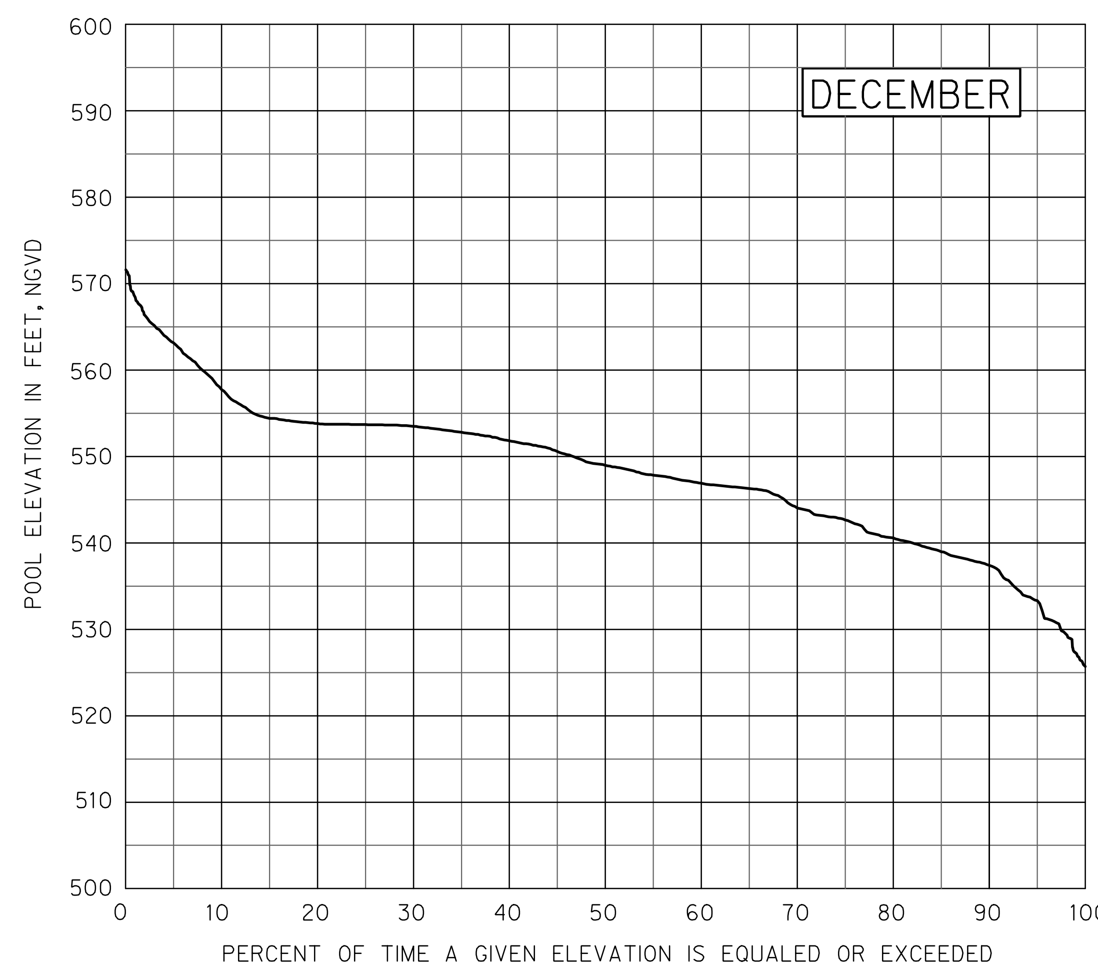
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
ELEVATION DURATION CURVES
NORFORK LAKE
MAY - AUGUST
1940 - 2011
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







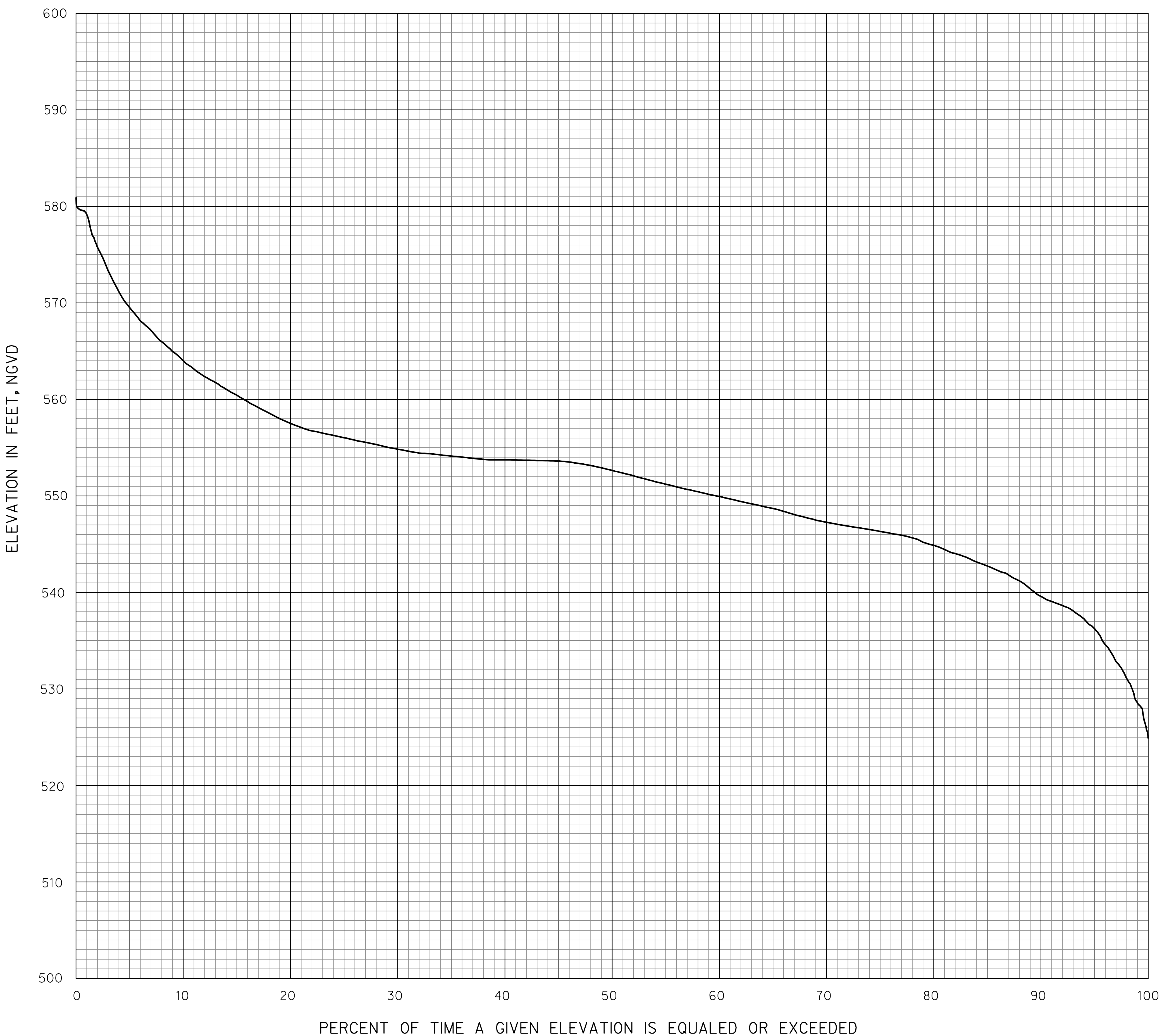
NOTE:

2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
ELEVATION DURATION CURVES
NORFORK LAKE
SEPTEMBER - DECEMBER
1940 - 2011
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE:

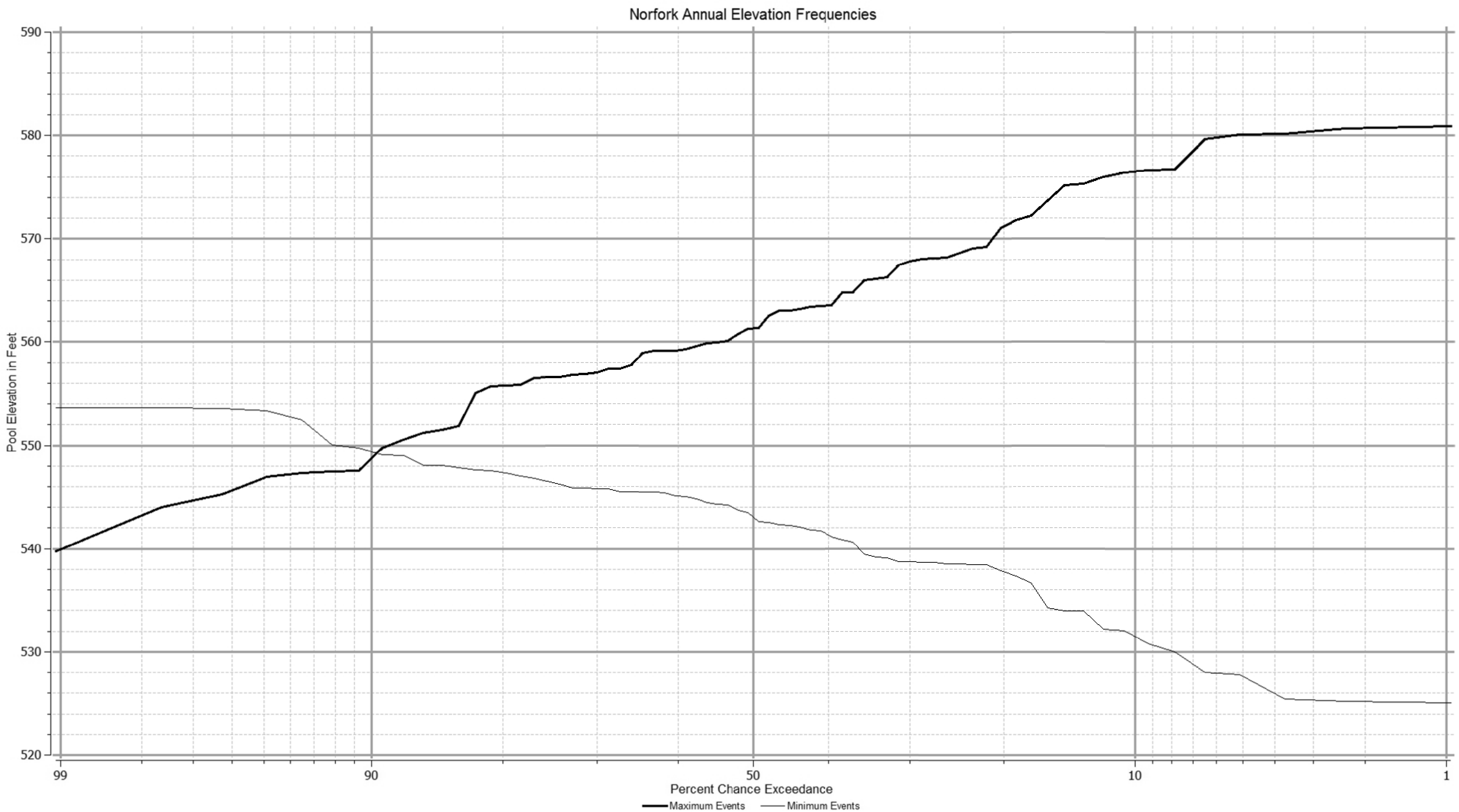
2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
ANNUAL
ELEVATION DURATION CURVE
NORFORK LAKE
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



Norfork		
Chance Exceedance	Max Elevation	Min Elevation
1%	580.88	525.07
2%	580.75	525.16
5%	580.10	527.6
10%	576.50	531.50
25%	568.48	538.51
50%	561.34	543.08

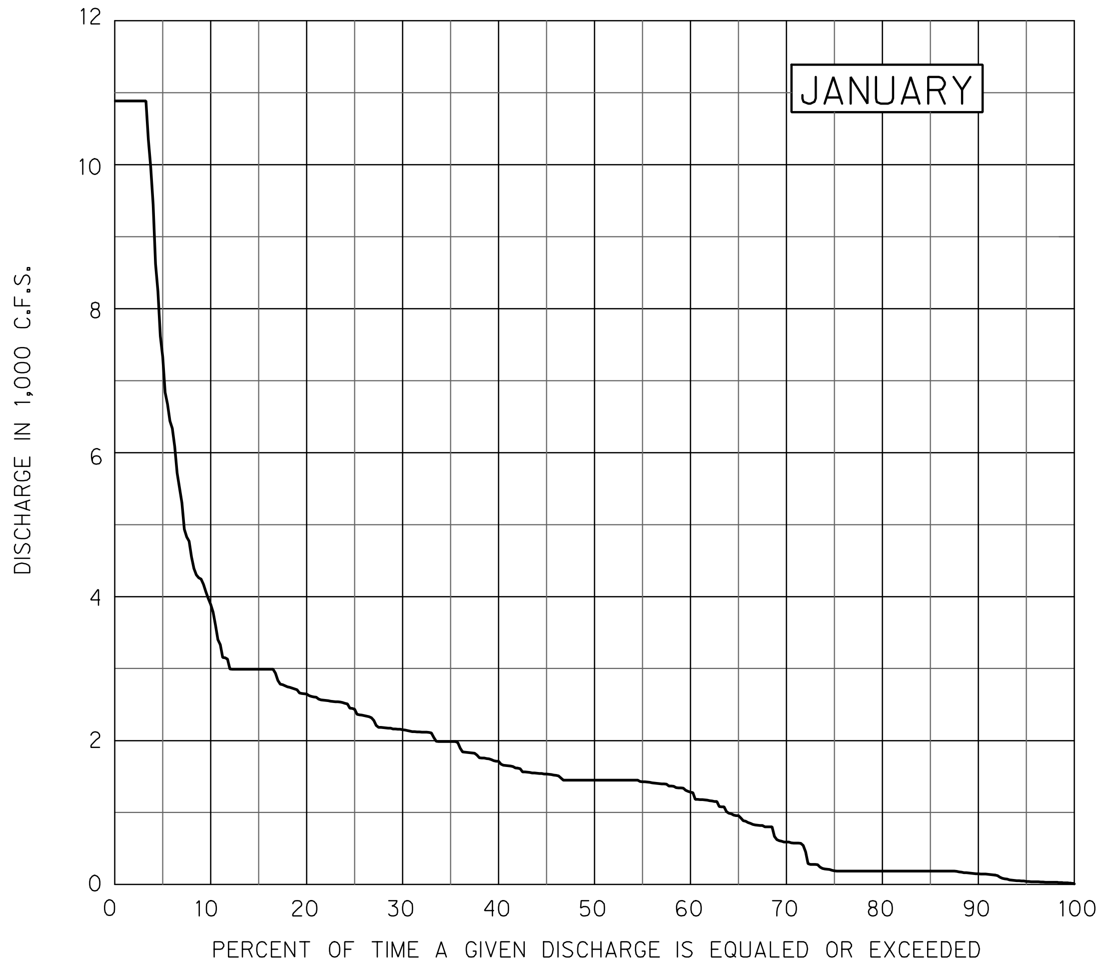
WHITE RIVER BASIN ARKANSAS AND MISSOURI

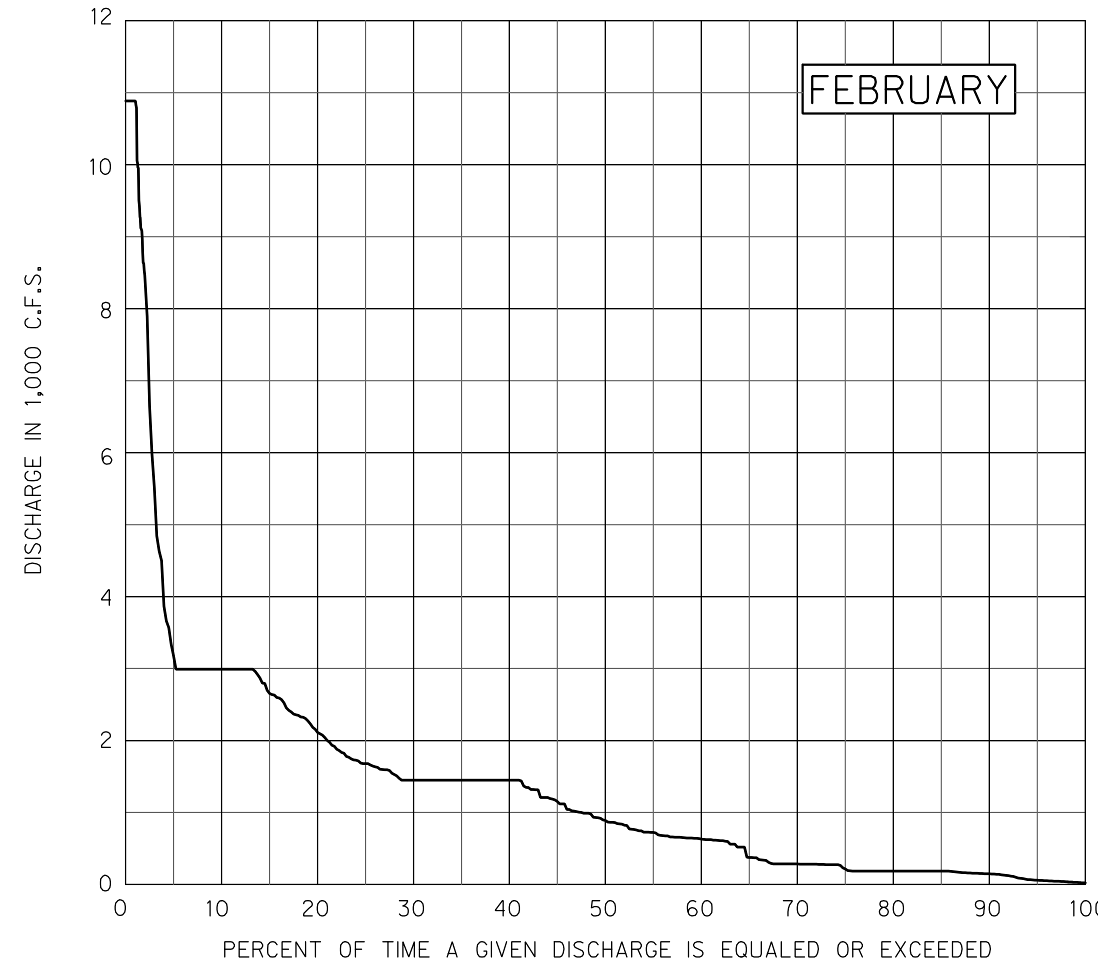
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

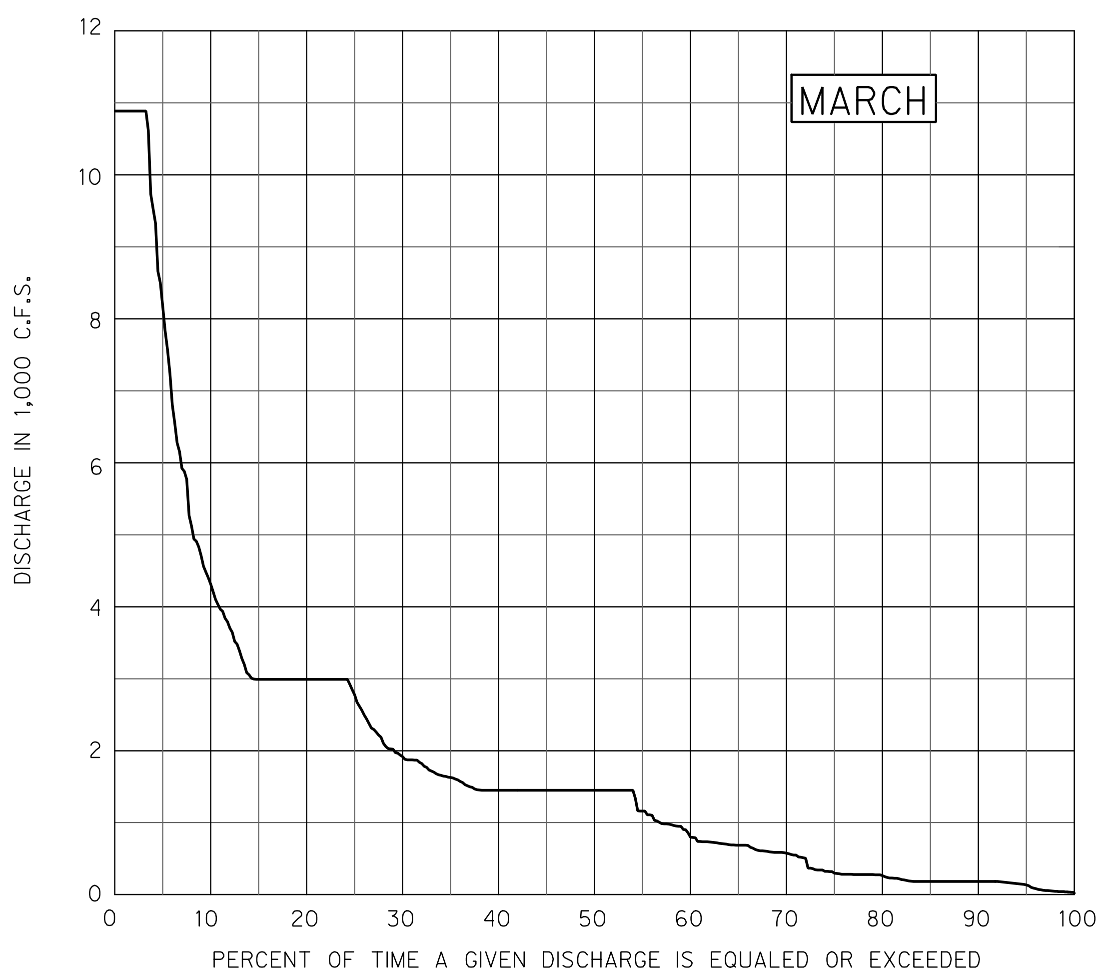
ANNUAL ELEVATION FREQUENCY CURVES NORFORK LAKE

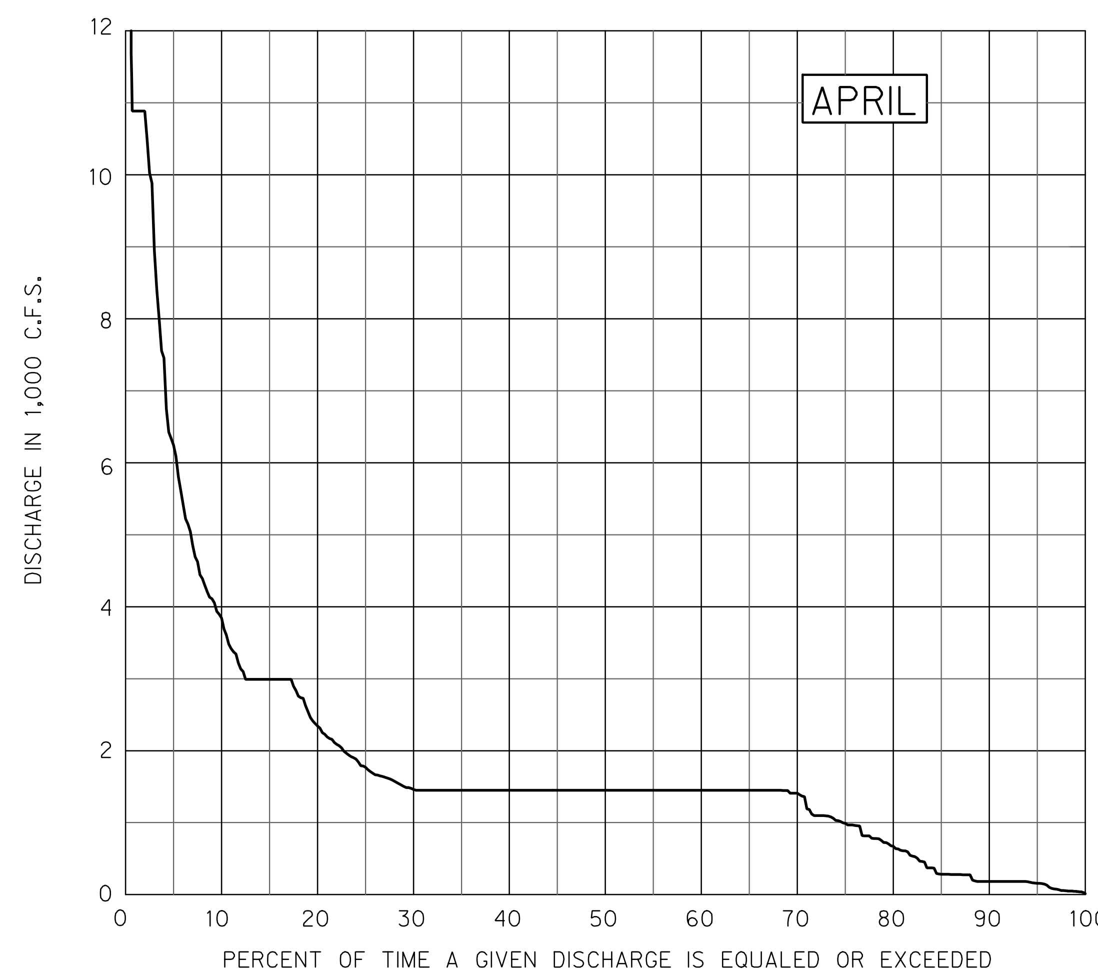
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

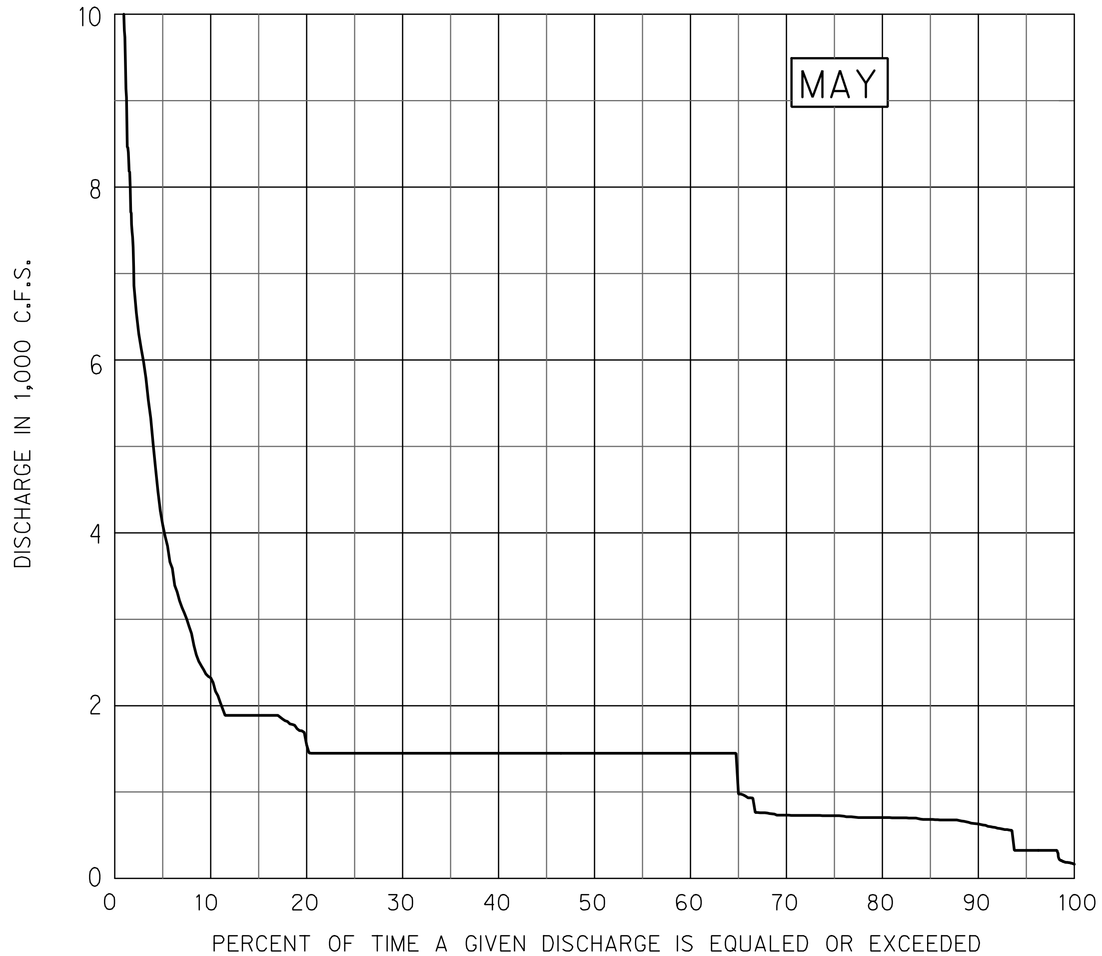
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

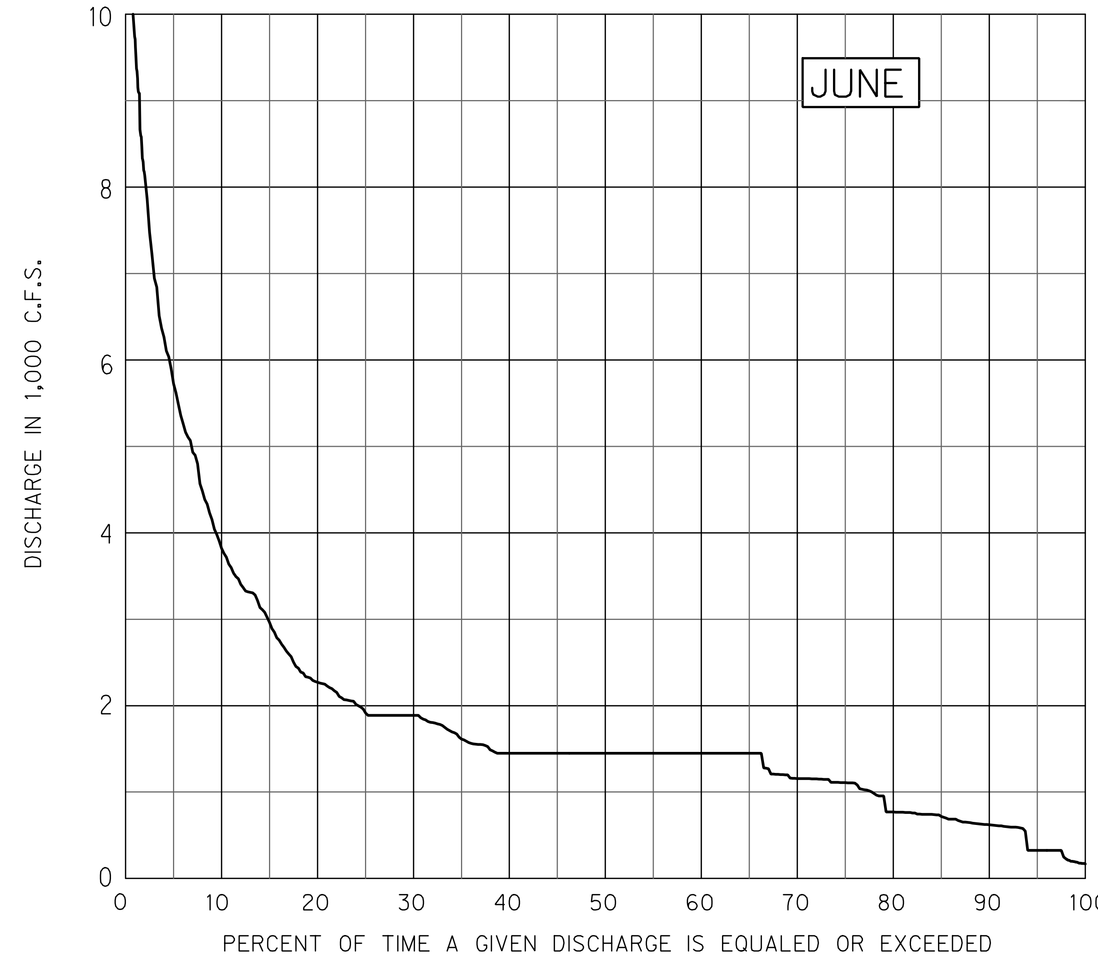
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

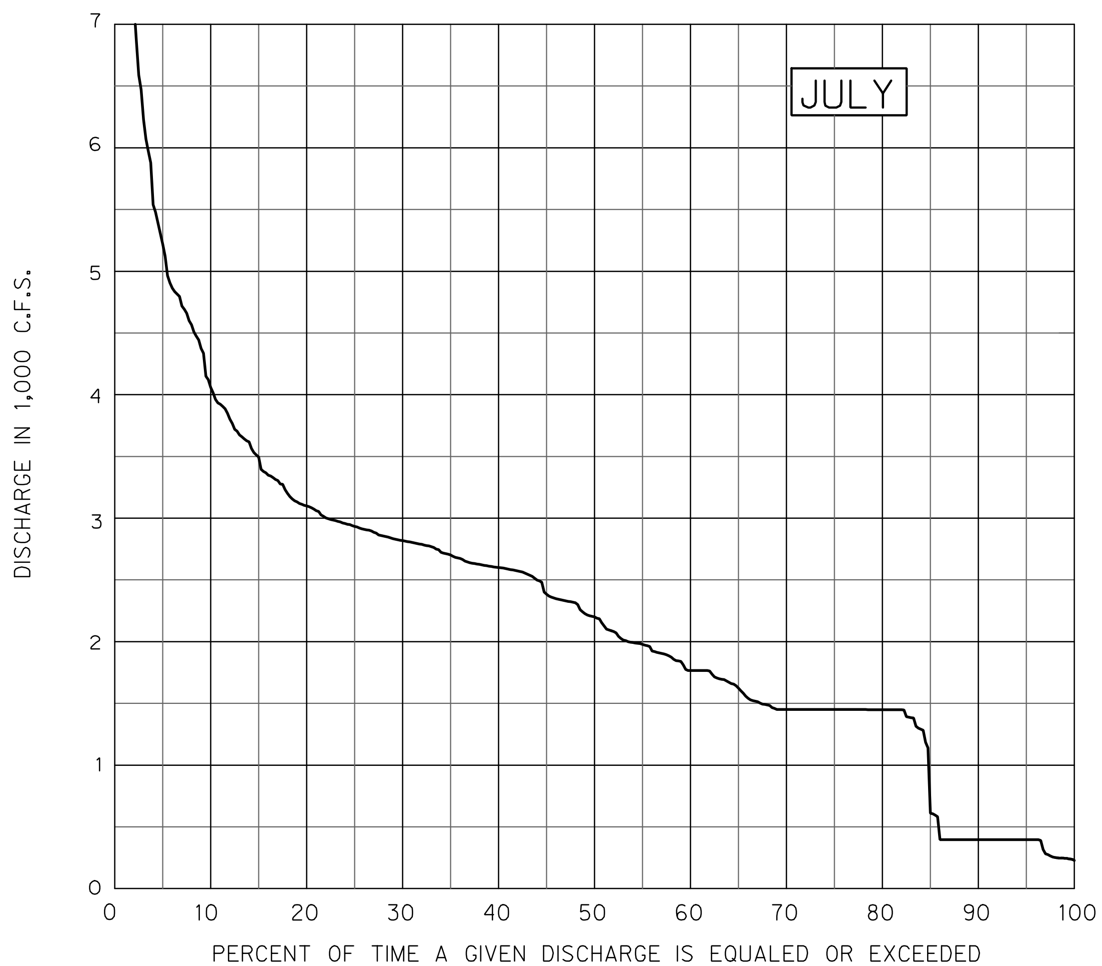
MONTHLY
DISCHARGE DURATION CURVES
NORFORK LAKE
JANUARY - APRIL
1940 - 2011

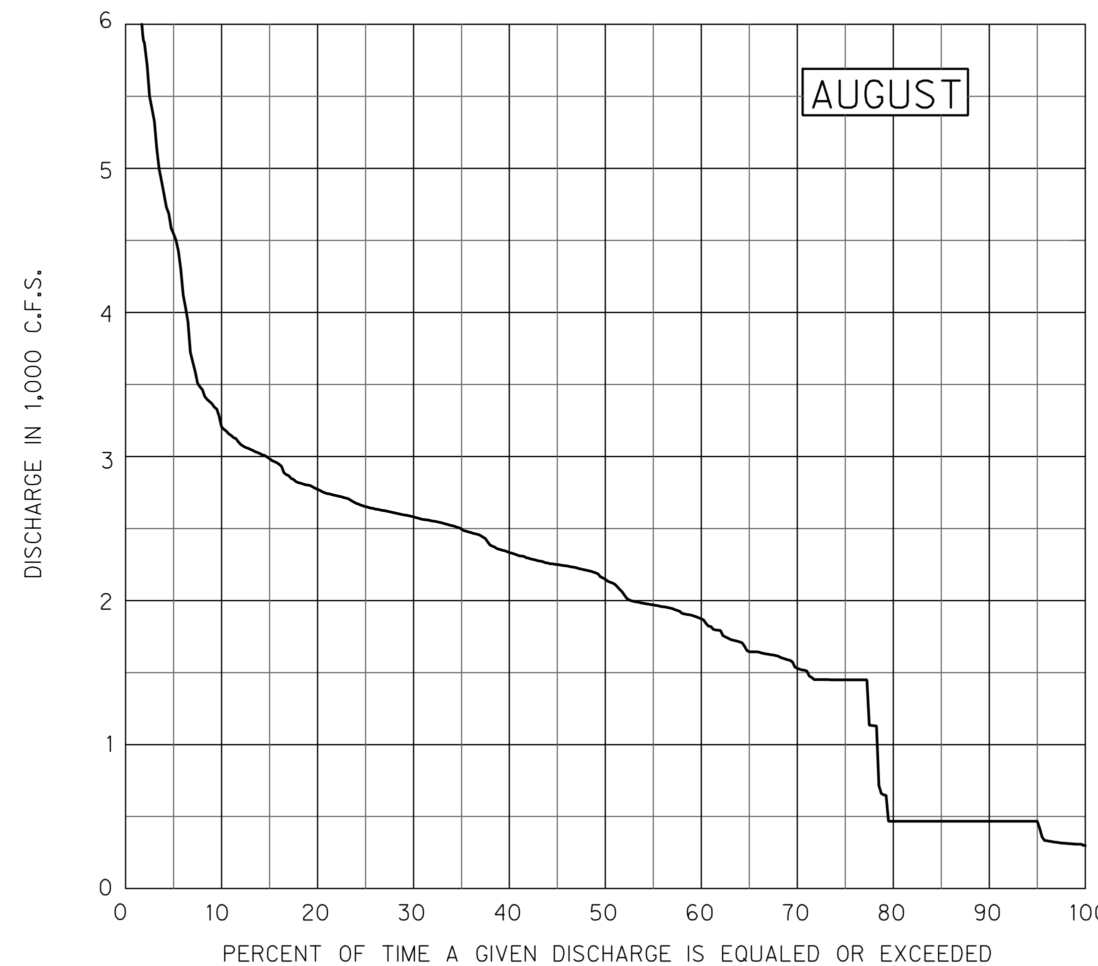
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

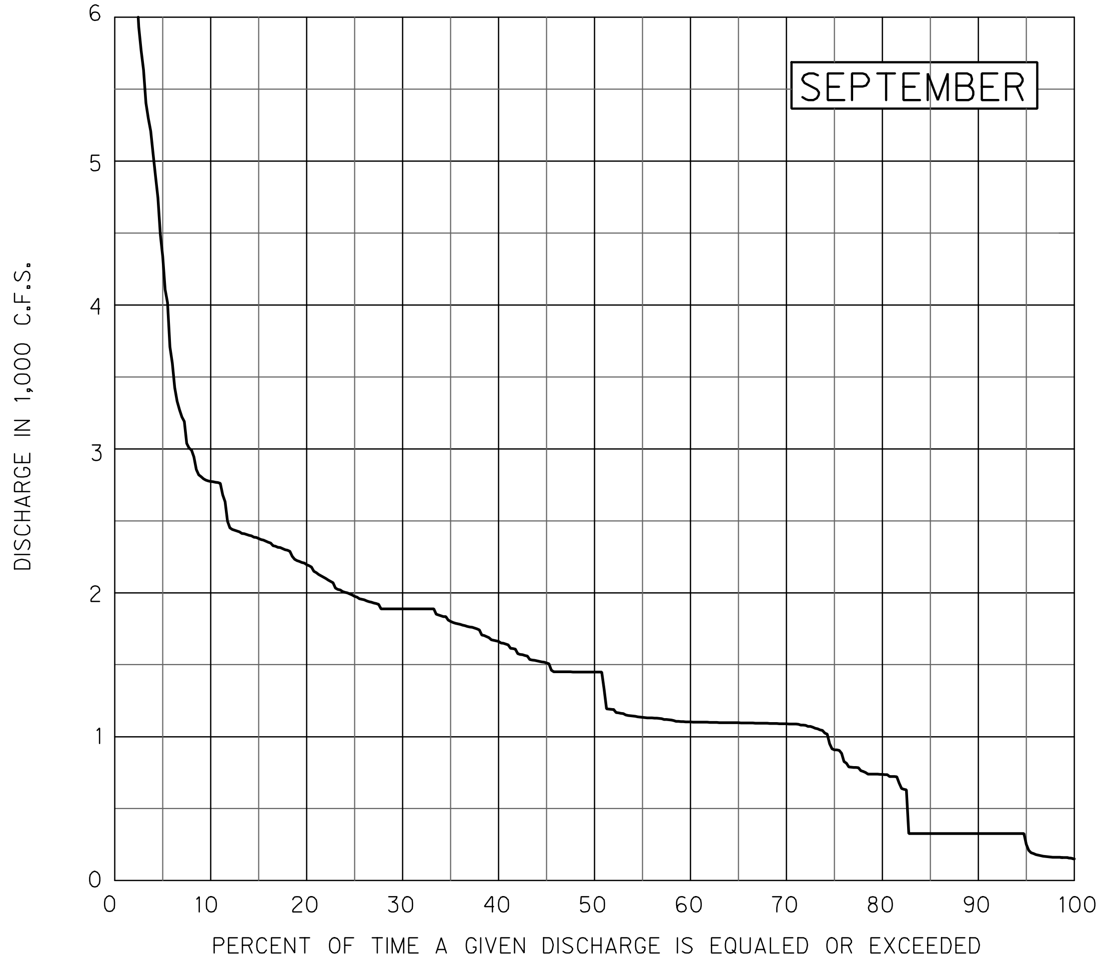
2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

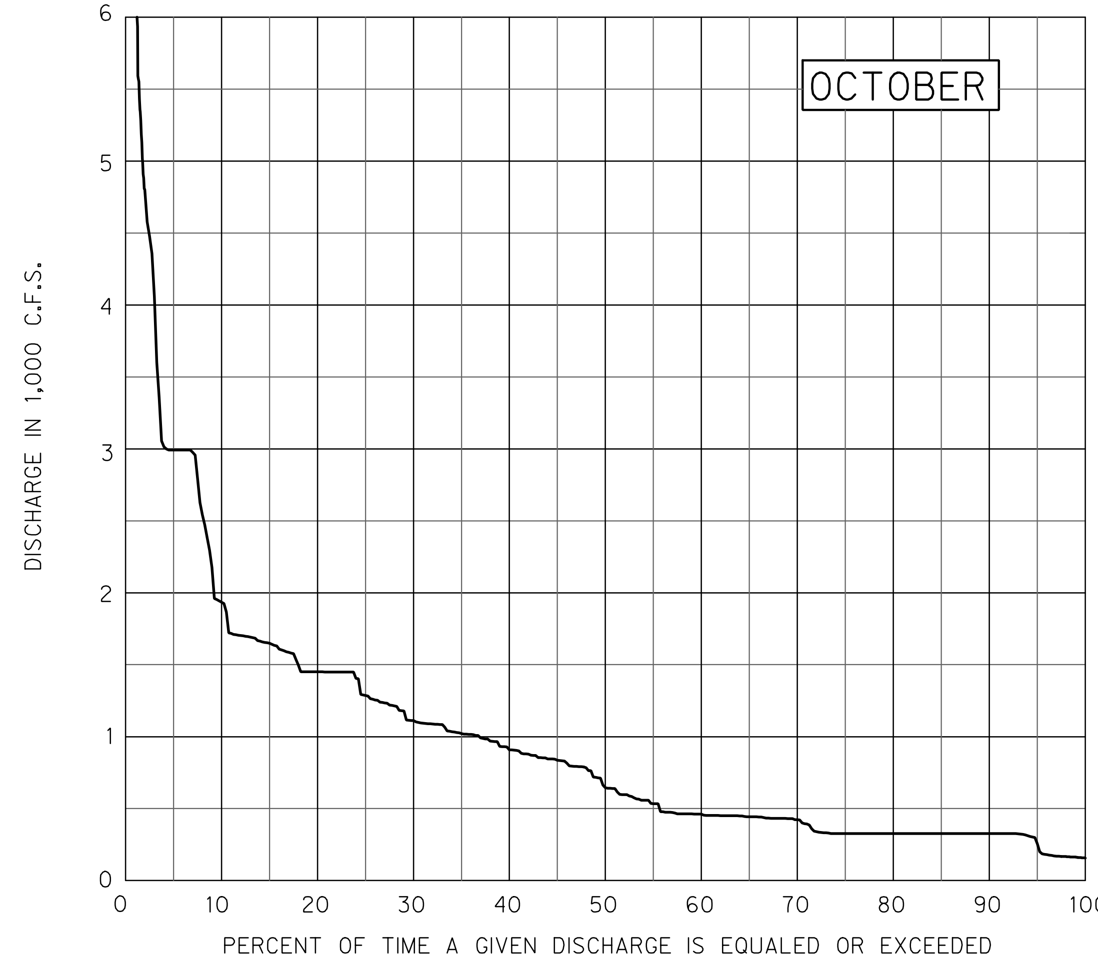
WHITE RIVER BASIN ARKANSAS AND MISSOURI

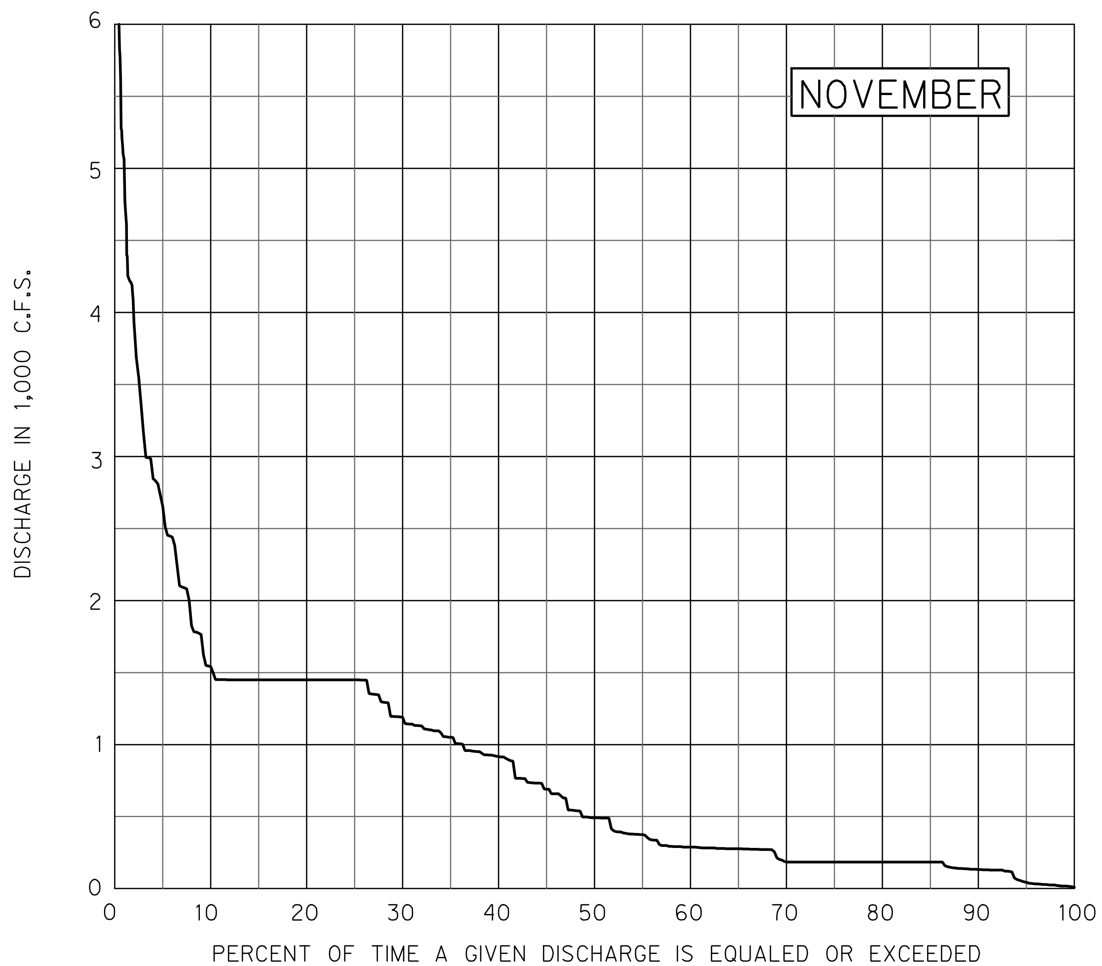
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
MONTHLY
DISCHARGE DURATION CURVES
NORFORK LAKE
MAY - AUGUST
1940 - 2011

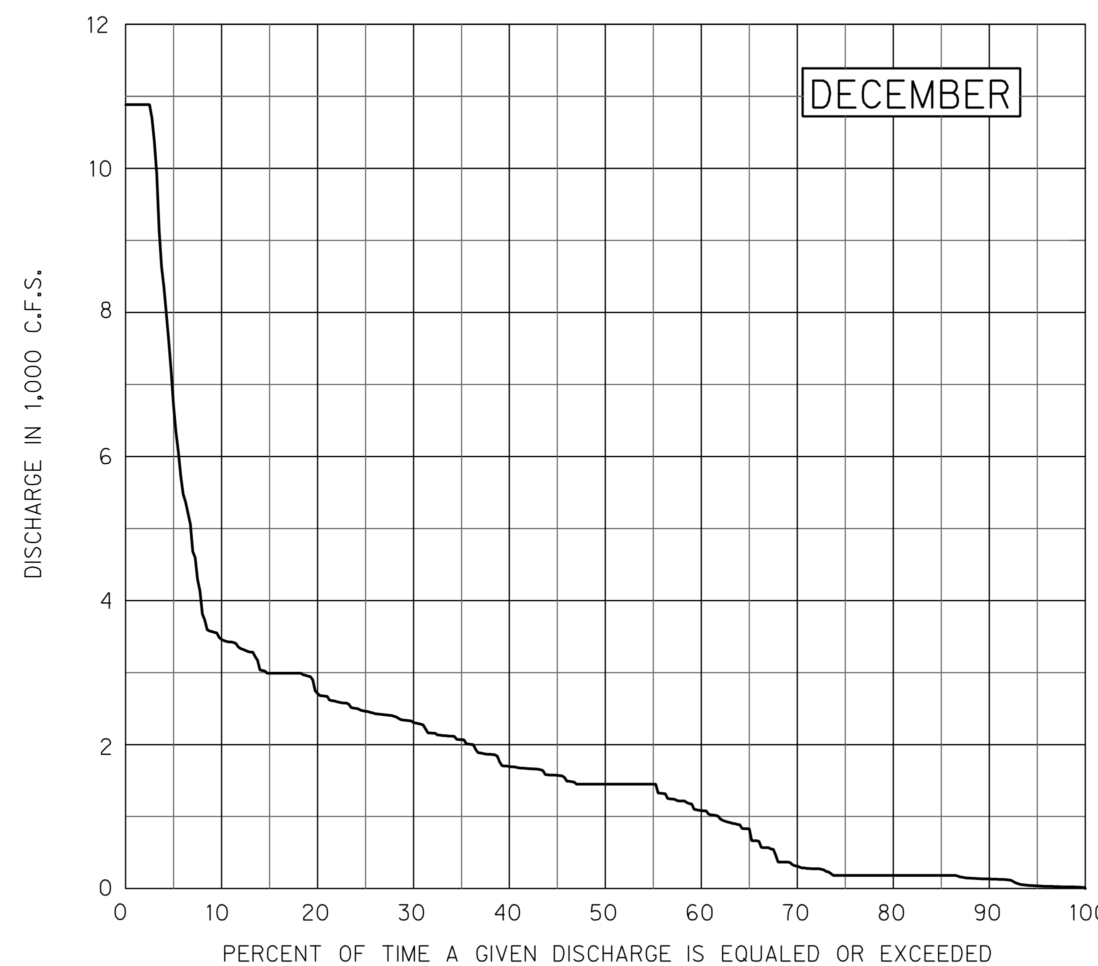
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014









NOTE:

2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

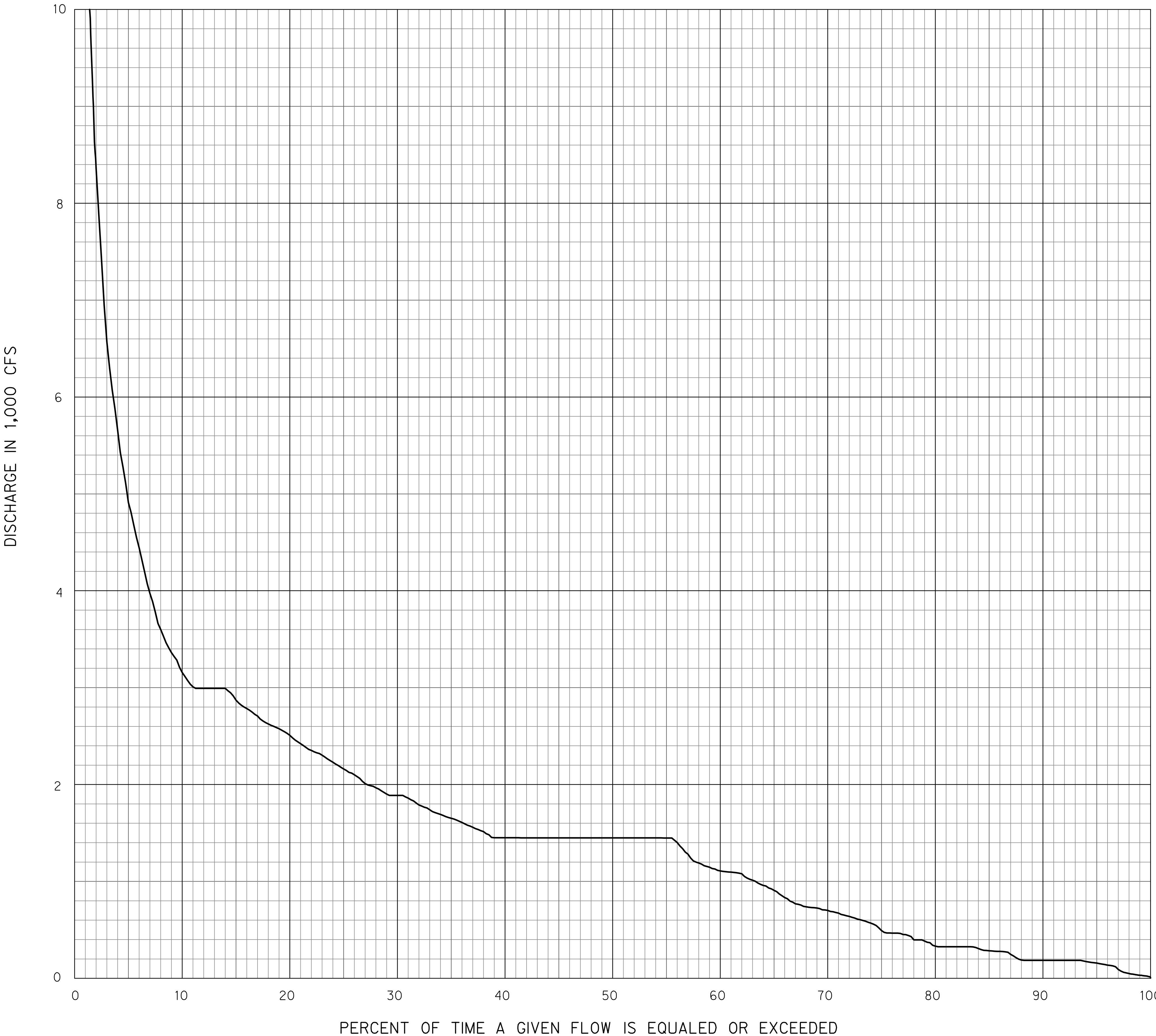
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

MONTHLY
DISCHARGE DURATION CURVES
NORFORK LAKE
SEPTEMBER - DECEMBER
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



NOTE:

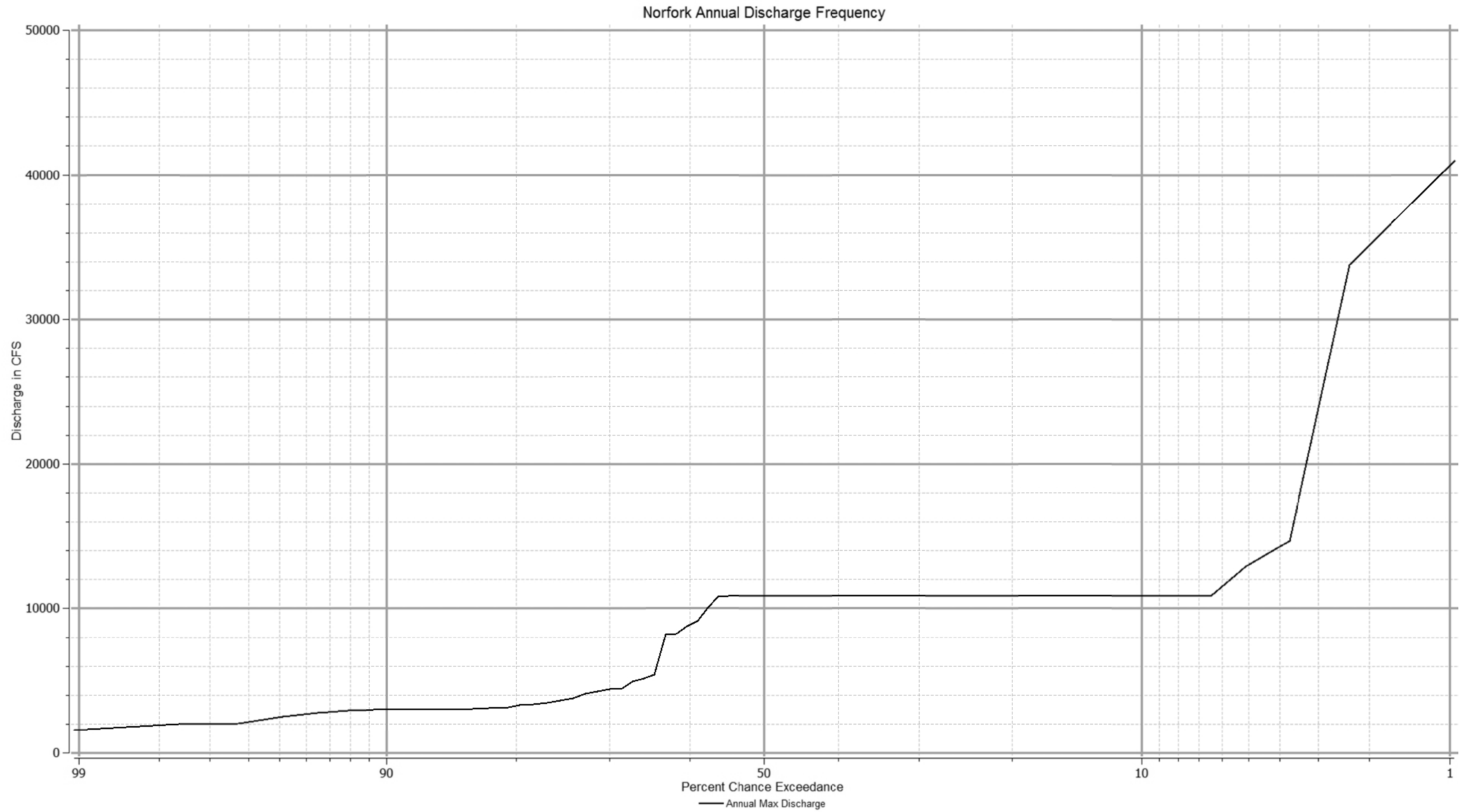
2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

WHITE RIVER BASIN	ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
ANNUAL
DISCHARGE DURATION CURVE
NORFORK LAKE
1940 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



2014 USACE RIVERWARE MODEL
FOR WHITE RIVER (1940-2011).
RUN RW-W14X02.

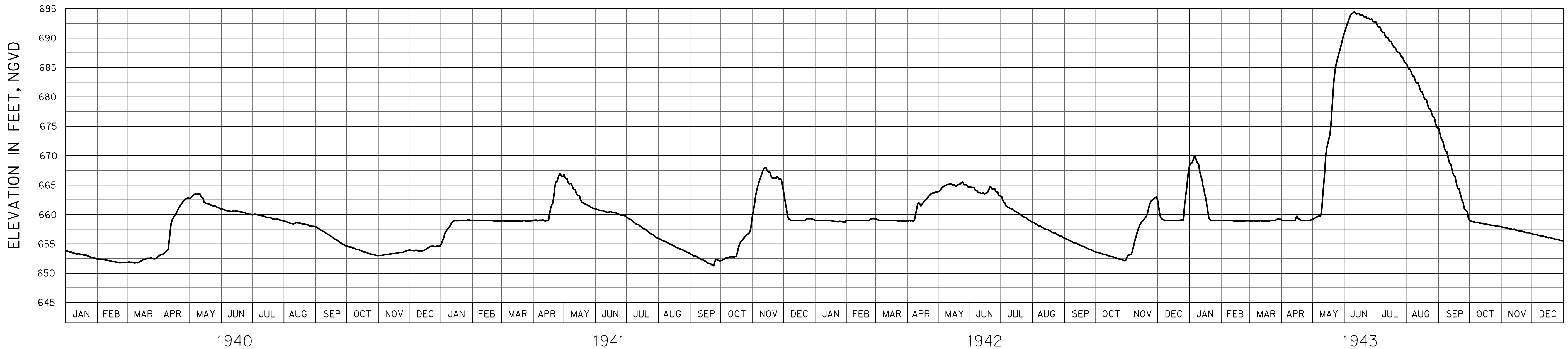
WHITE RIVER BASIN ARKANSAS AND MISSOURI

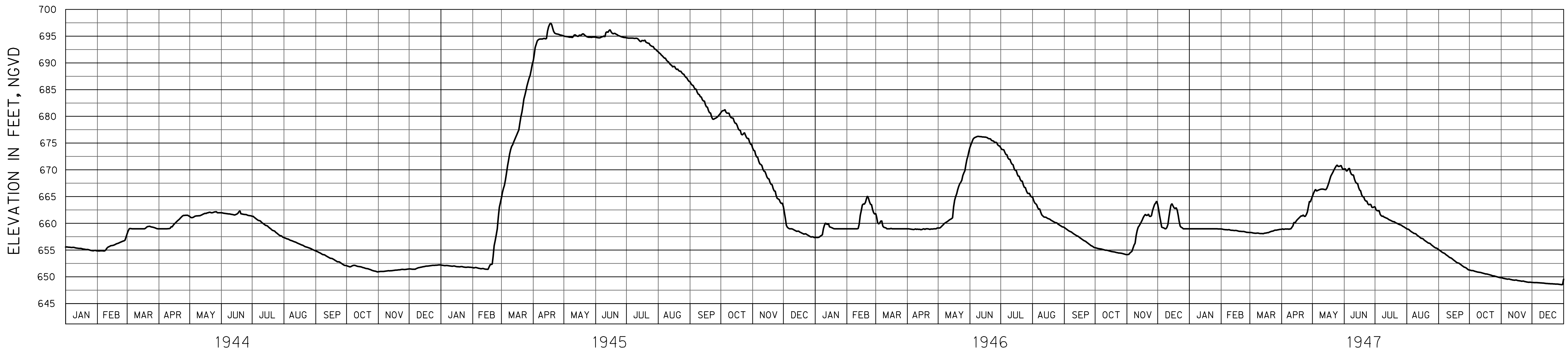
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

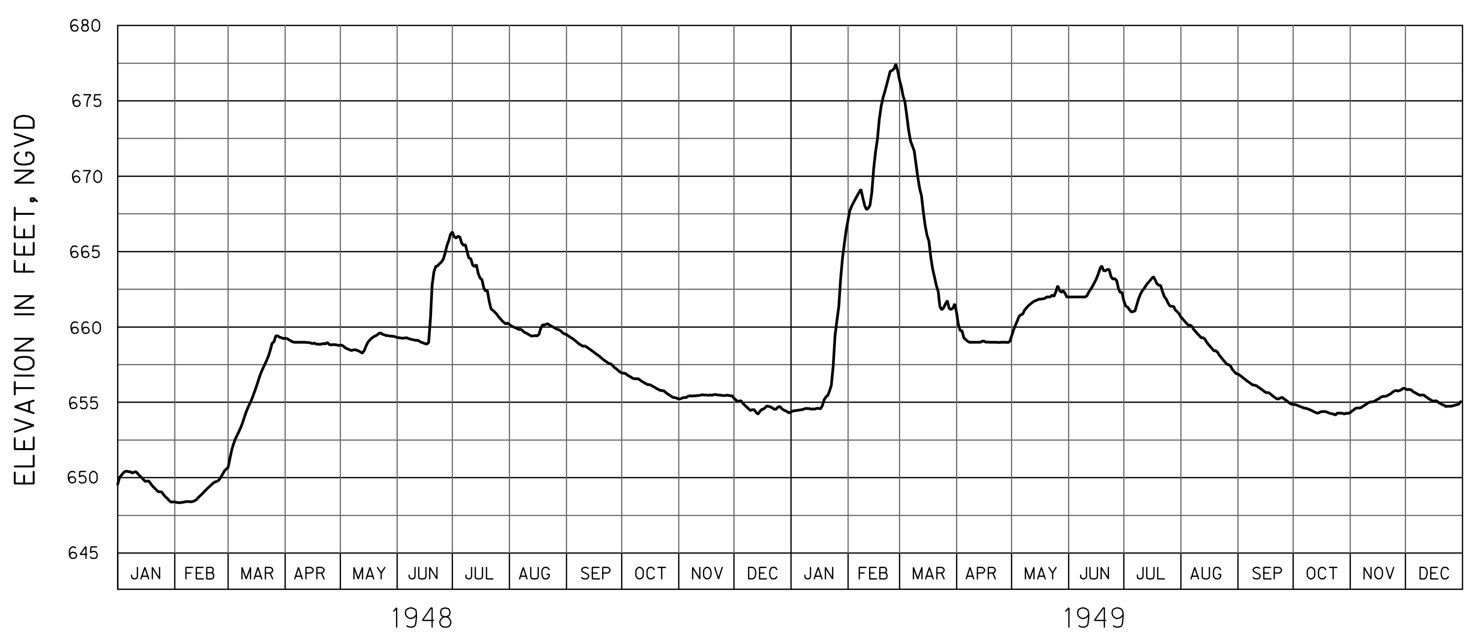
ANNUAL DISCHARGE
FREQUENCY CURVE
NORFORK LAKE

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







NOTES:

1. TOP OF CONSERVATION POOL: 654.0 FEET, NGVD (1951-06/30/2013); 659.0 FEET, NGVD (07/01/2013)
   TOP OF FLOOD CONTROL POOL: 695.0 FEET, NGVD
2. LAKE BEGAN FILLING IN JULY 1951 AND REACHED CONSERVATION POOL (654.0 FEET, NGVD) ON 03/21/1953. PRIOR TO 1951 ONLY SIMULATED DATA EXISTS.
3. SOURCE OF SIMULATED DATA: 2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

LEGEND

——— SIMULATED

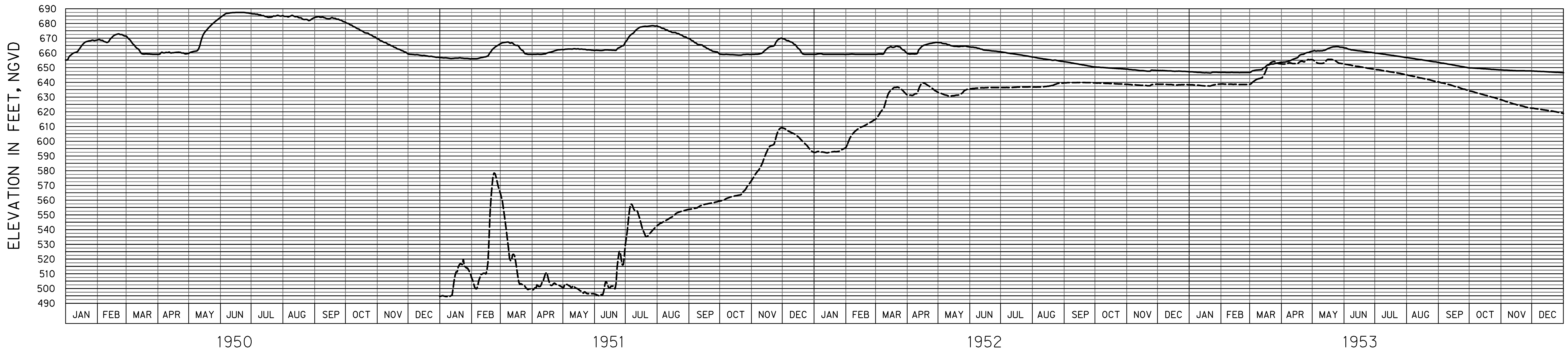
WHITE RIVER BASIN ARKANSAS AND MISSOURI

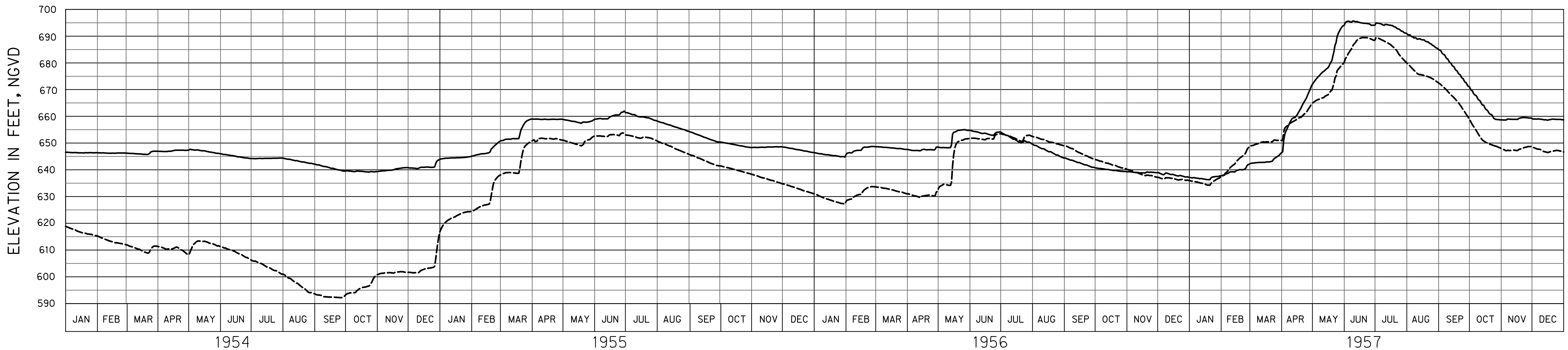
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

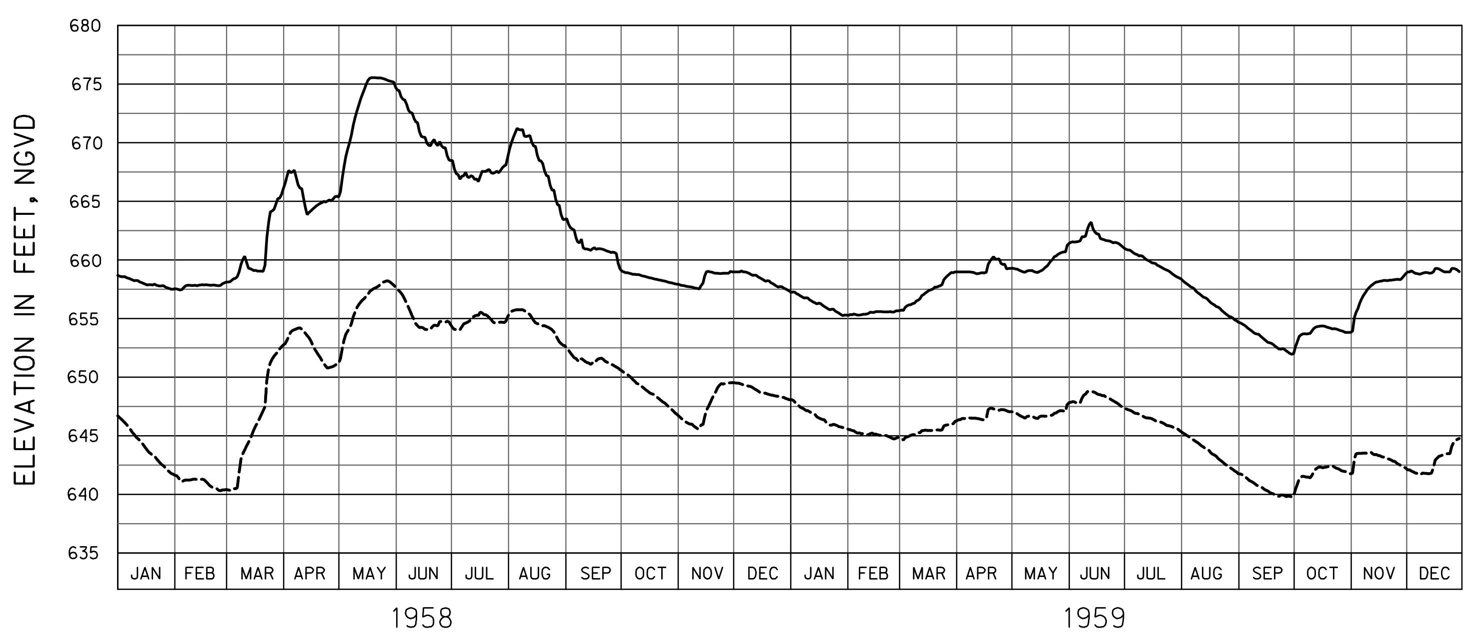
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
1940 - 1949

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







NOTES:

1. TOP OF CONSERVATION POOL: 654.0 FEET, NGVD (1951-06/30/2013);
   659.0 FEET, NGVD (07/01/2013)
   TOP OF FLOOD CONTROL POOL: 695.0 FEET, NGVD

2. LAKE BEGAN FILLING IN JULY 1951 AND REACHED CONSERVATION POOL (654.0 FEET, NGVD) ON 03/21/1953. PRIOR TO 1951 ONLY SIMULATED DATA EXISTS.

3. SOURCE OF SIMULATED DATA: 2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

LEGEND

SIMULATED (solid line)
EXPERIENCED (dashed line)

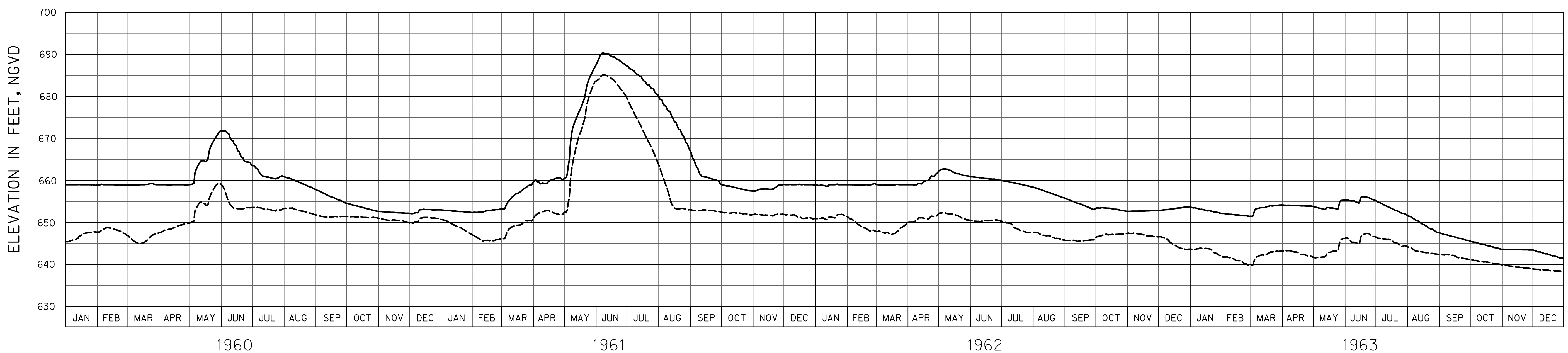
WHITE RIVER BASIN ARKANSAS AND MISSOURI

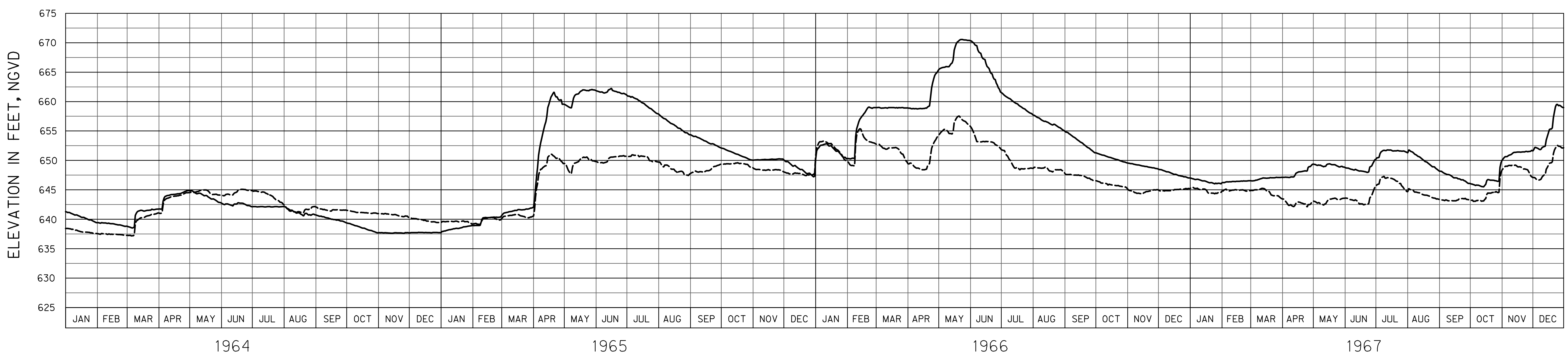
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

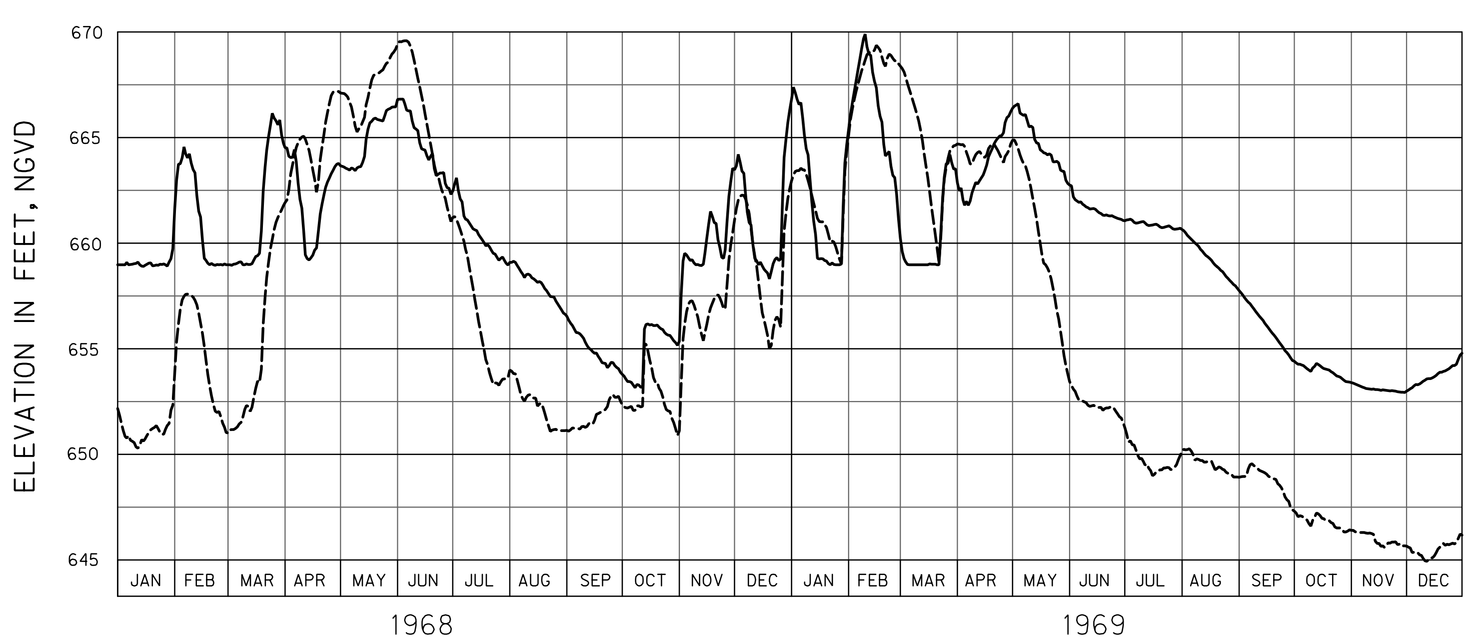
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
1950 - 1959

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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1. TOP OF CONSERVATION POOL: 654.0 FEET, NGVD (1951-06/30/2013);
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   TOP OF FLOOD CONTROL POOL: 695.0 FEET, NGVD
2. LAKE BEGAN FILLING IN JULY 1951 AND REACHED CONSERVATION POOL (654.0 FEET, NGVD) ON 03/21/1953. PRIOR TO 1951 ONLY SIMULATED DATA EXISTS.
3. SOURCE OF SIMULATED DATA: 2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

LEGEND

———	SIMULATED
– – – –	EXPERIENCED

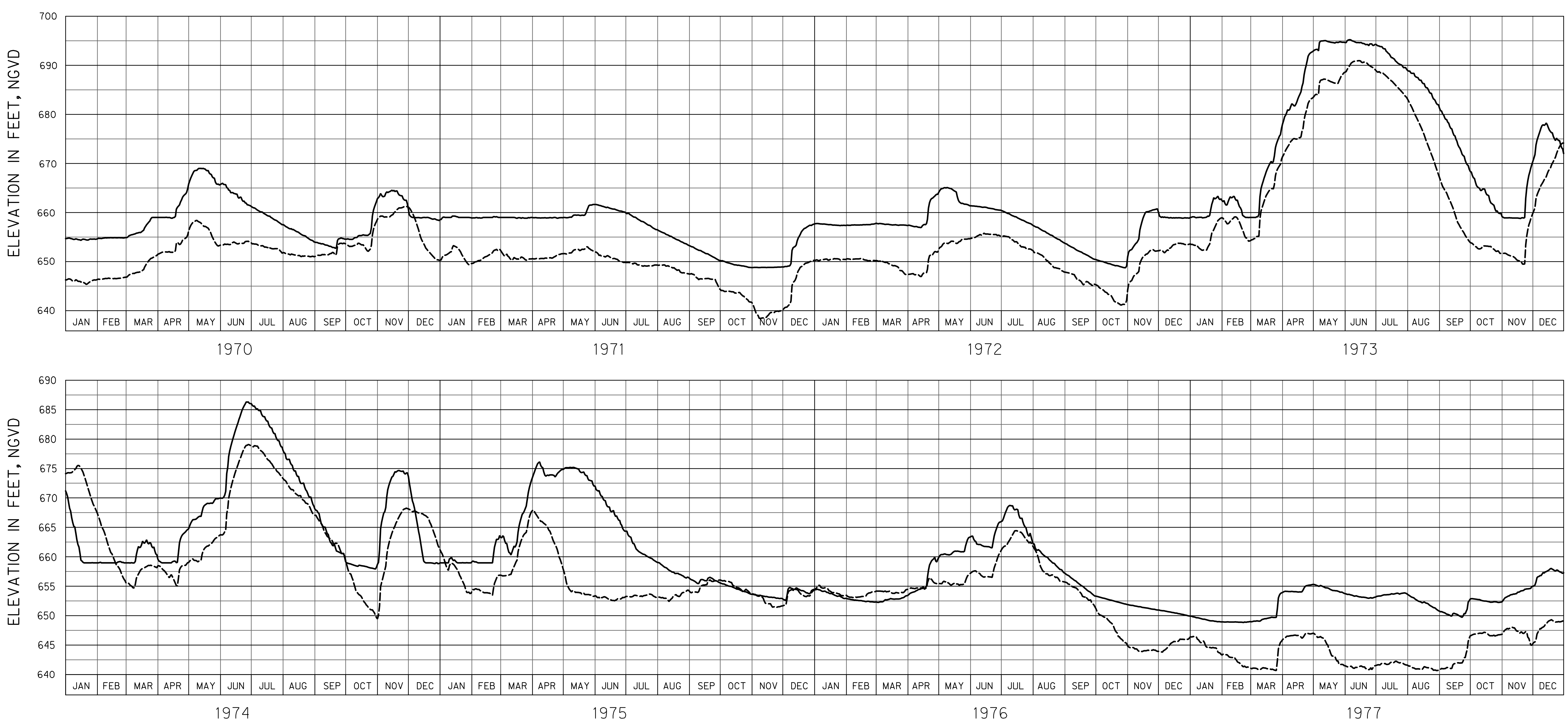
WHITE RIVER BASIN ARKANSAS AND MISSOURI

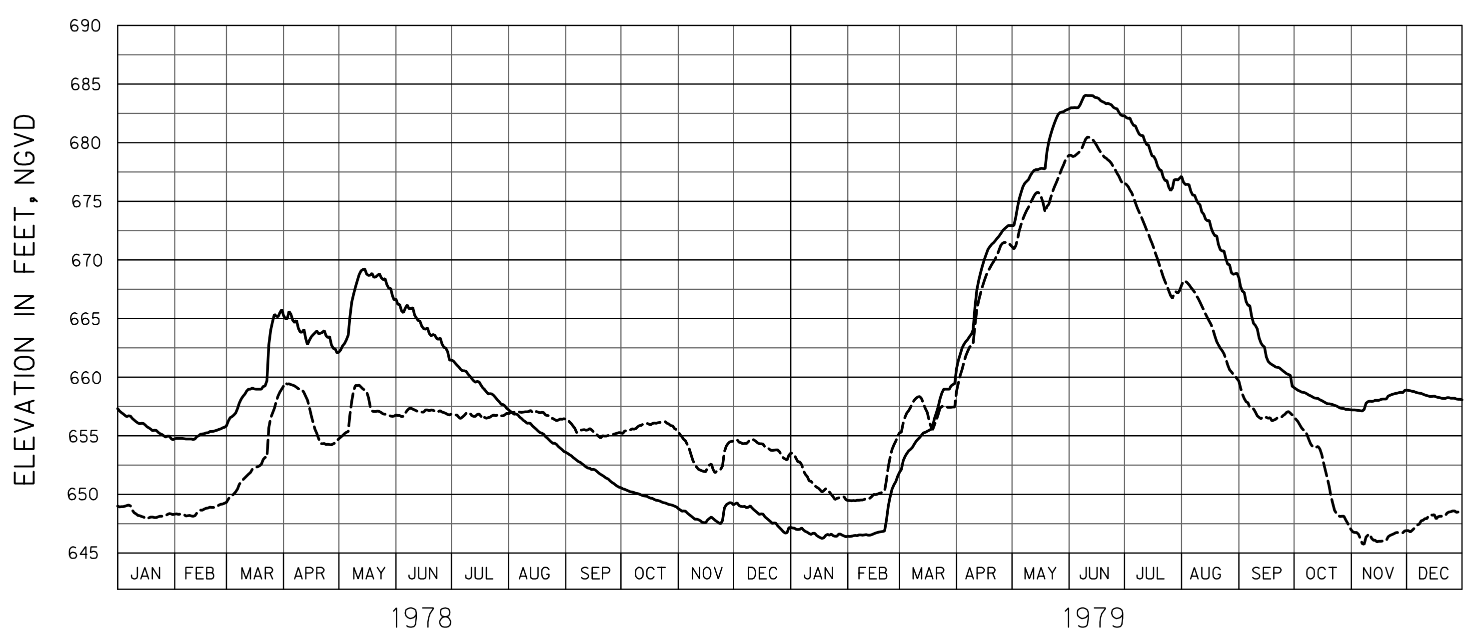
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
1960 - 1969

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014





NOTES:

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3. SOURCE OF SIMULATED DATA: 2014 USACE RIVERWARE MODEL FOR WHITE RIVER (1940-2011). RUN RW-W14X02.

LEGEND

————	SIMULATED
– – – –	EXPERIENCED

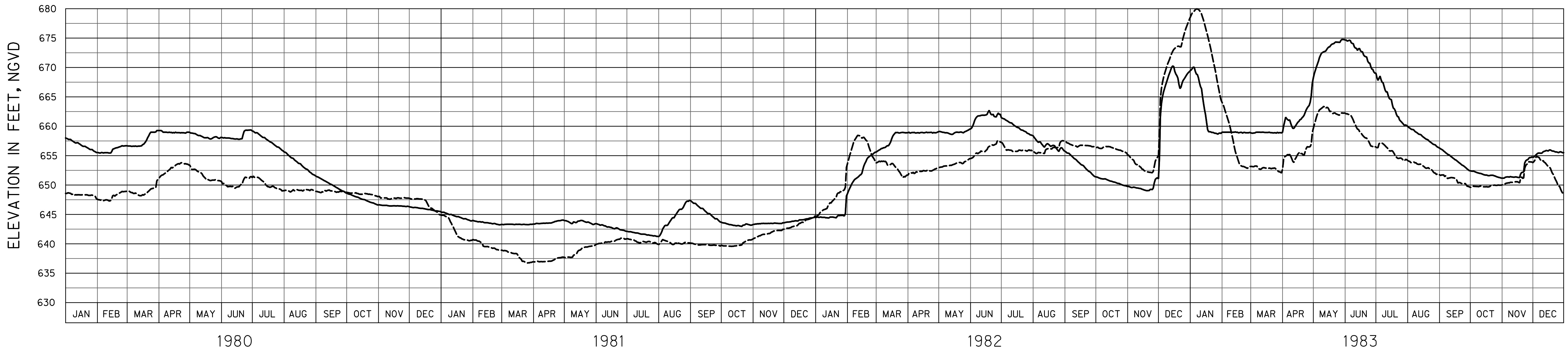
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

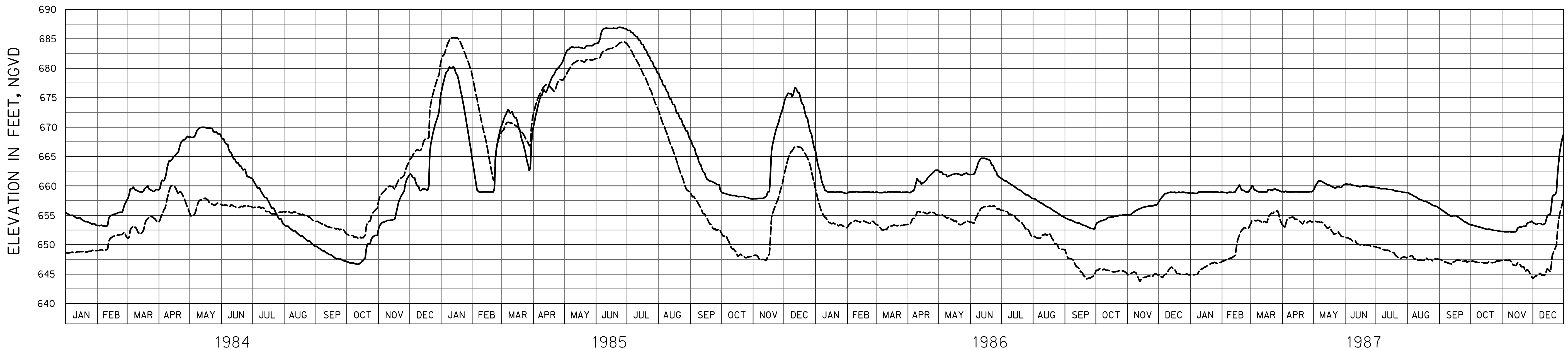
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

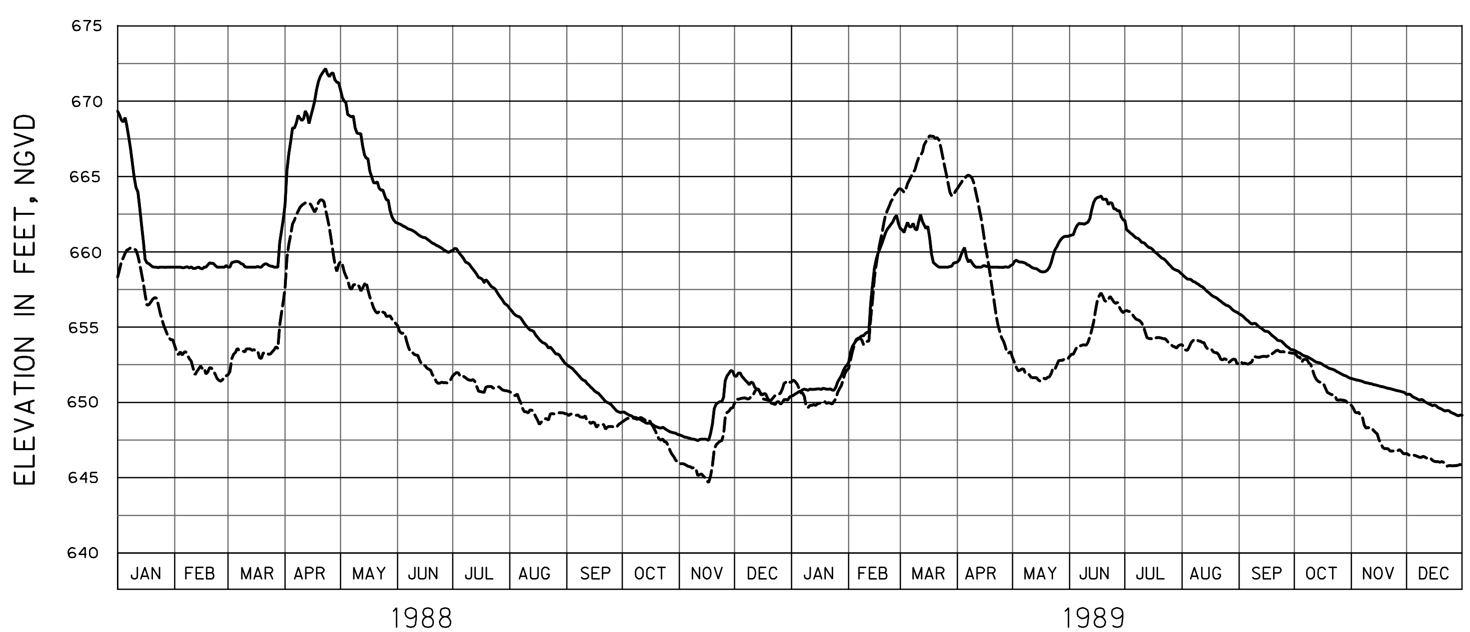
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
1970 - 1979

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

———— SIMULATED
– – – – EXPERIENCED

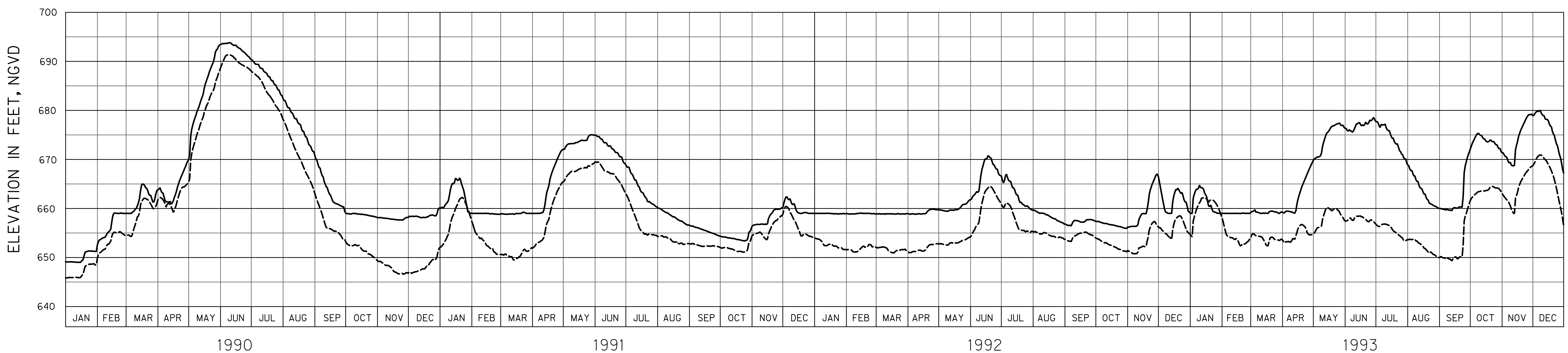
WHITE RIVER BASIN ARKANSAS AND MISSOURI

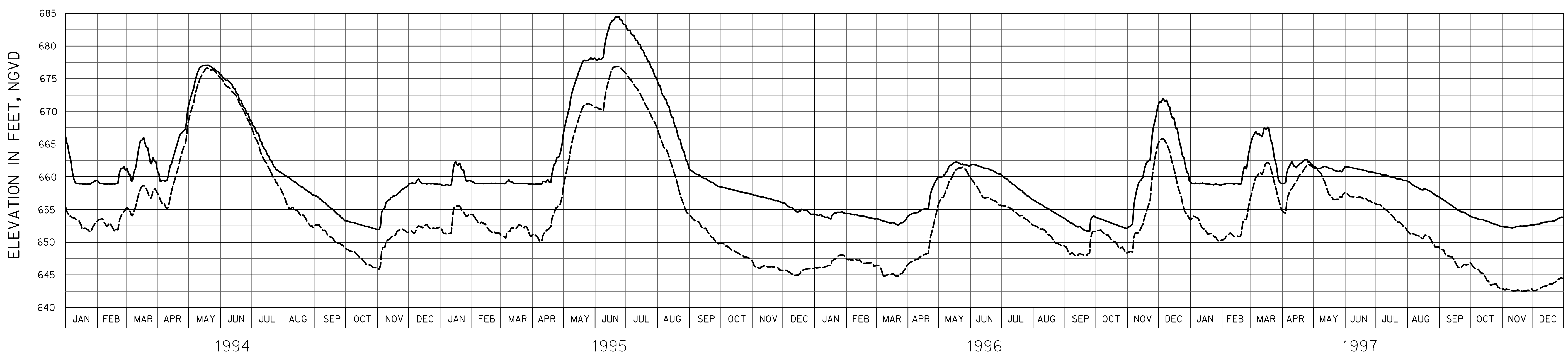
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

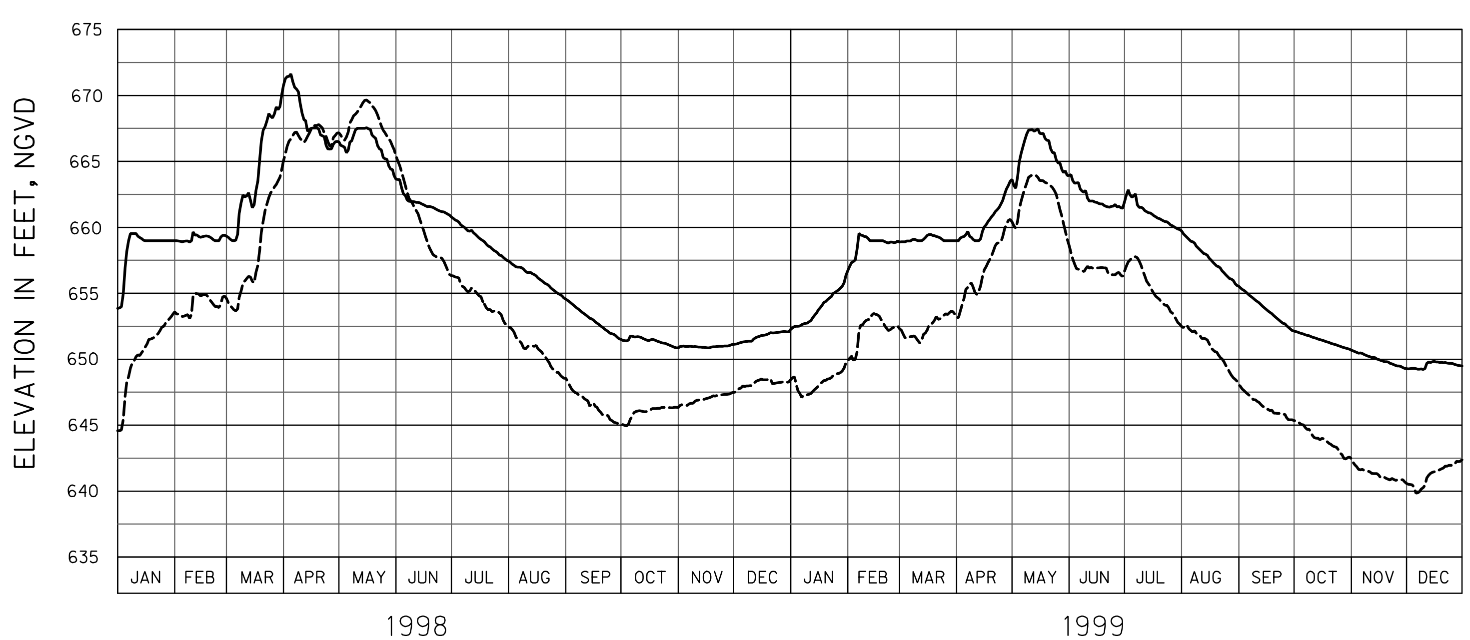
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
1980 - 1989

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

———— SIMULATED
– – – – EXPERIENCED

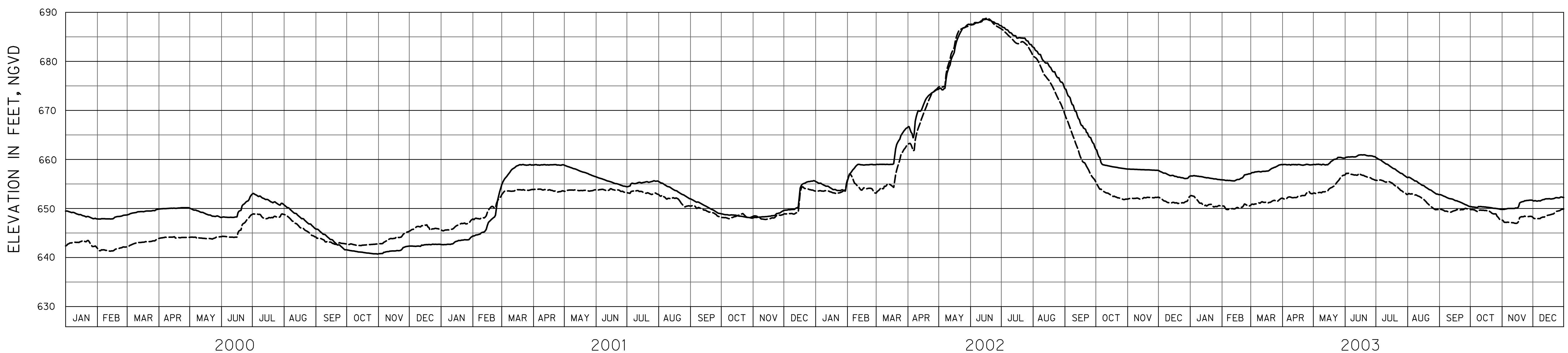
WHITE RIVER BASIN ARKANSAS AND MISSOURI

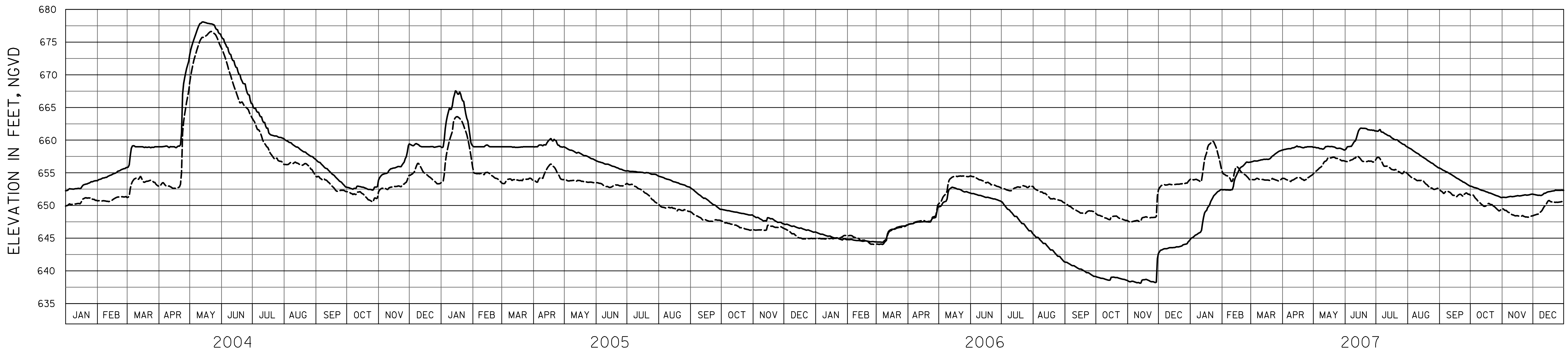
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

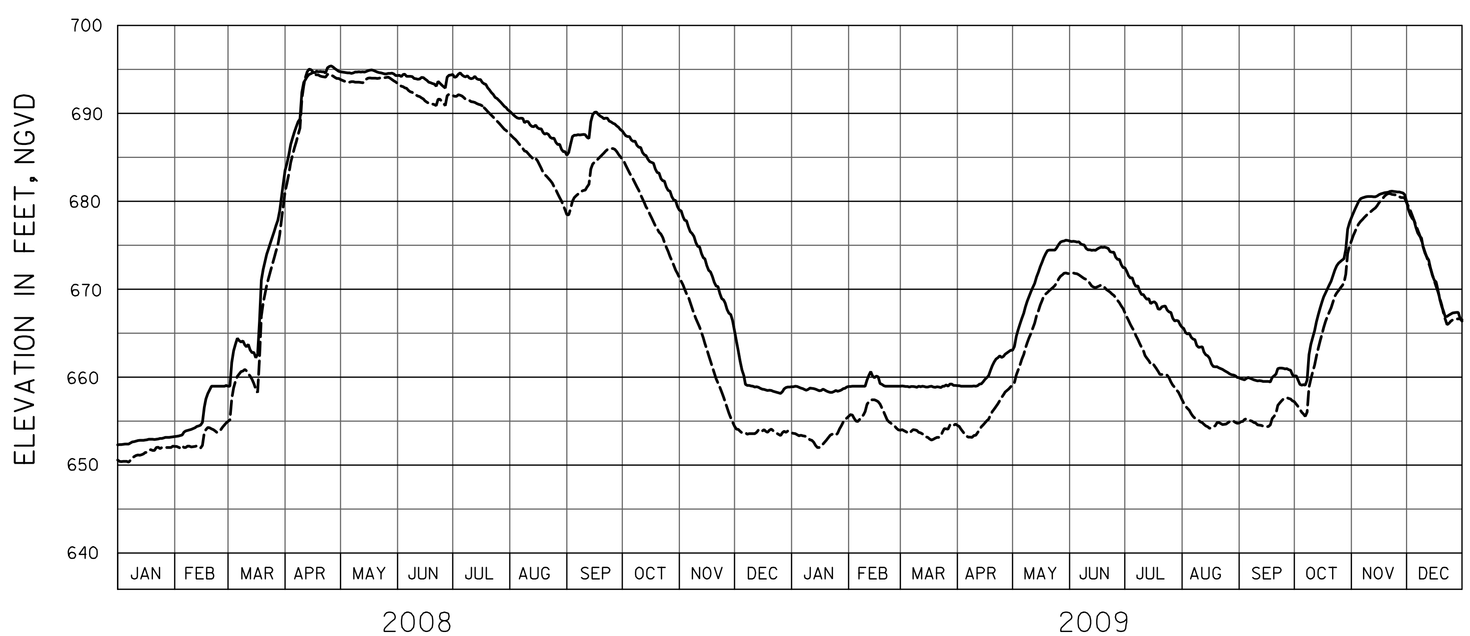
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
1990 - 1999

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

——— (solid)	SIMULATED
– – – (dashed)	EXPERIENCED

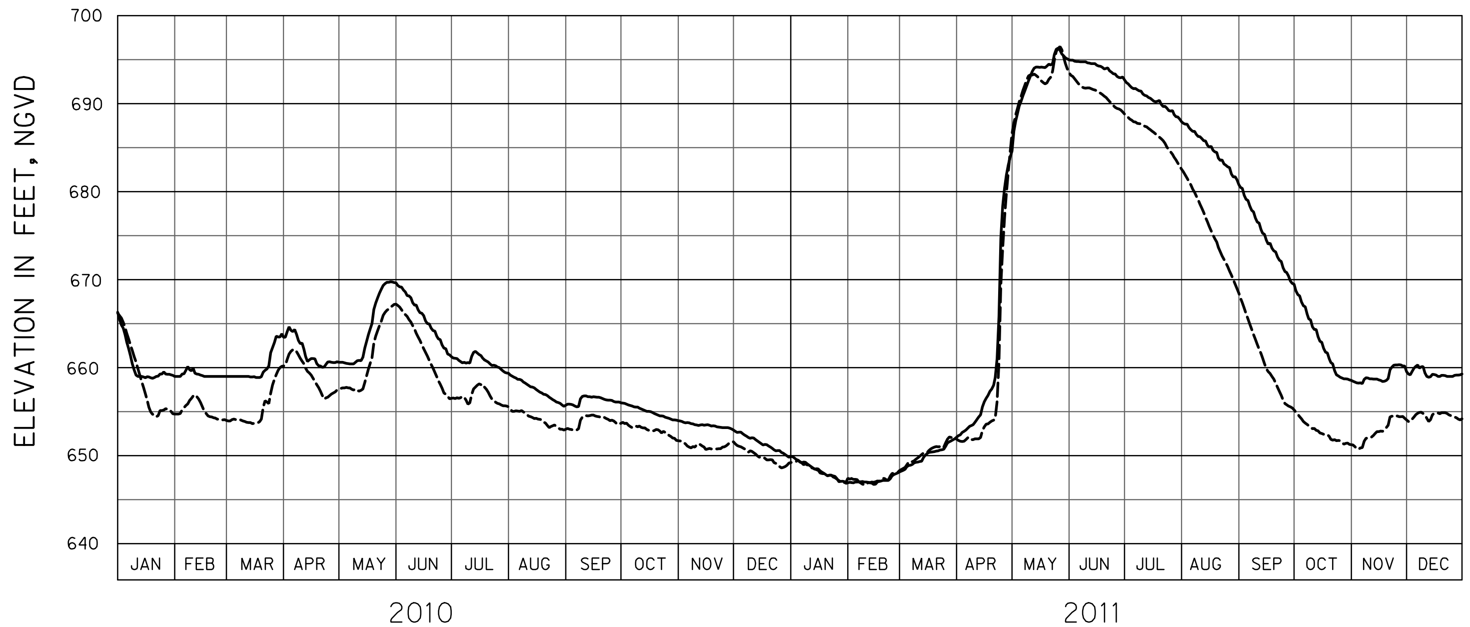
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
2000 - 2009

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



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LEGEND

——— SIMULATED
------ EXPERIENCED

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
BULL SHOALS LAKE
2010 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014

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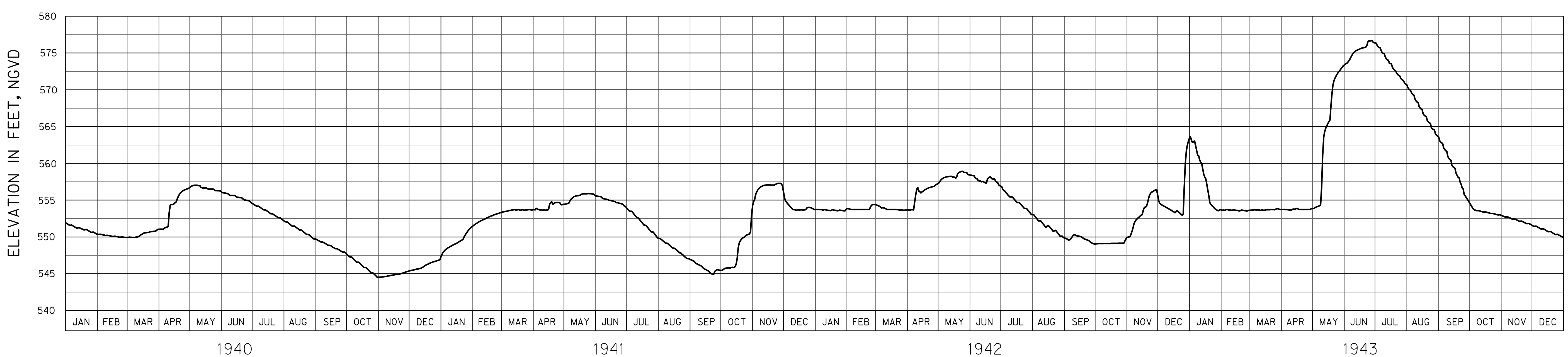

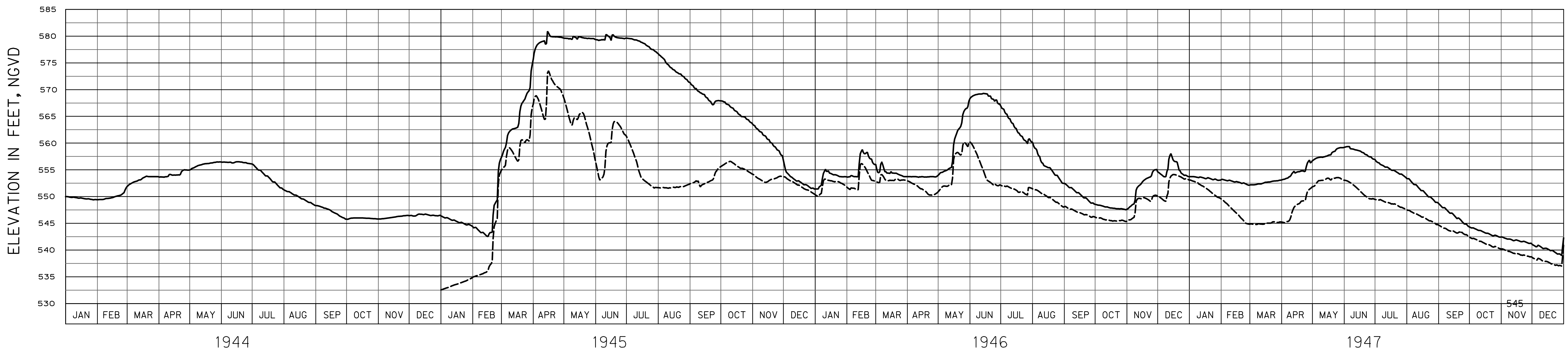

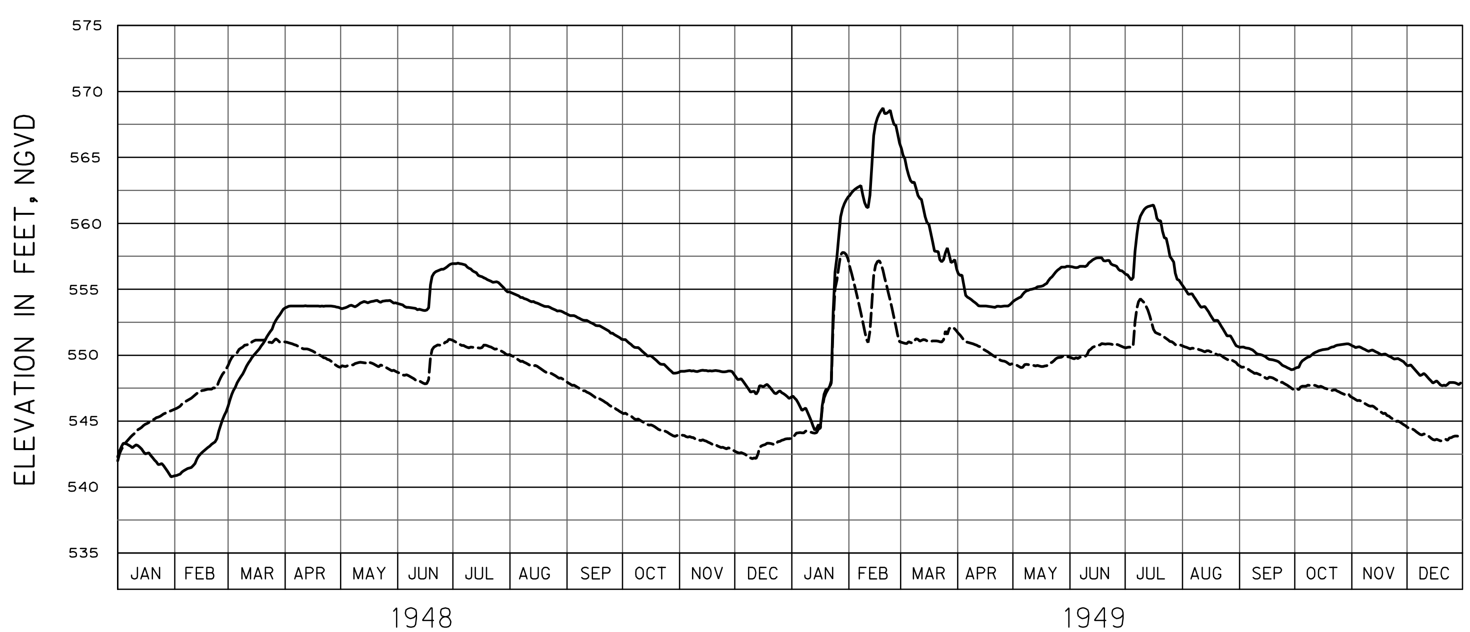

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LEGEND

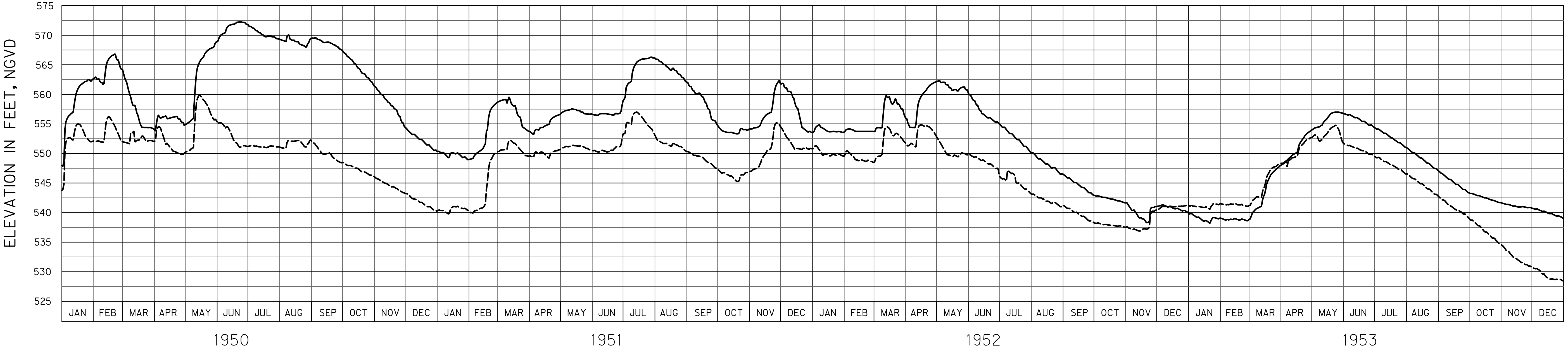
SIMULATED (solid line)

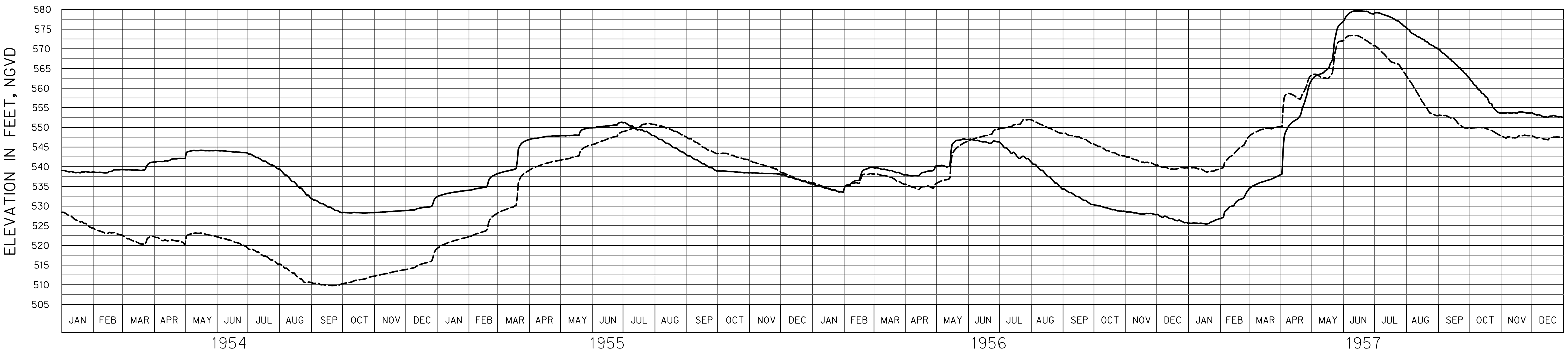
EXPERIENCED (dashed line)

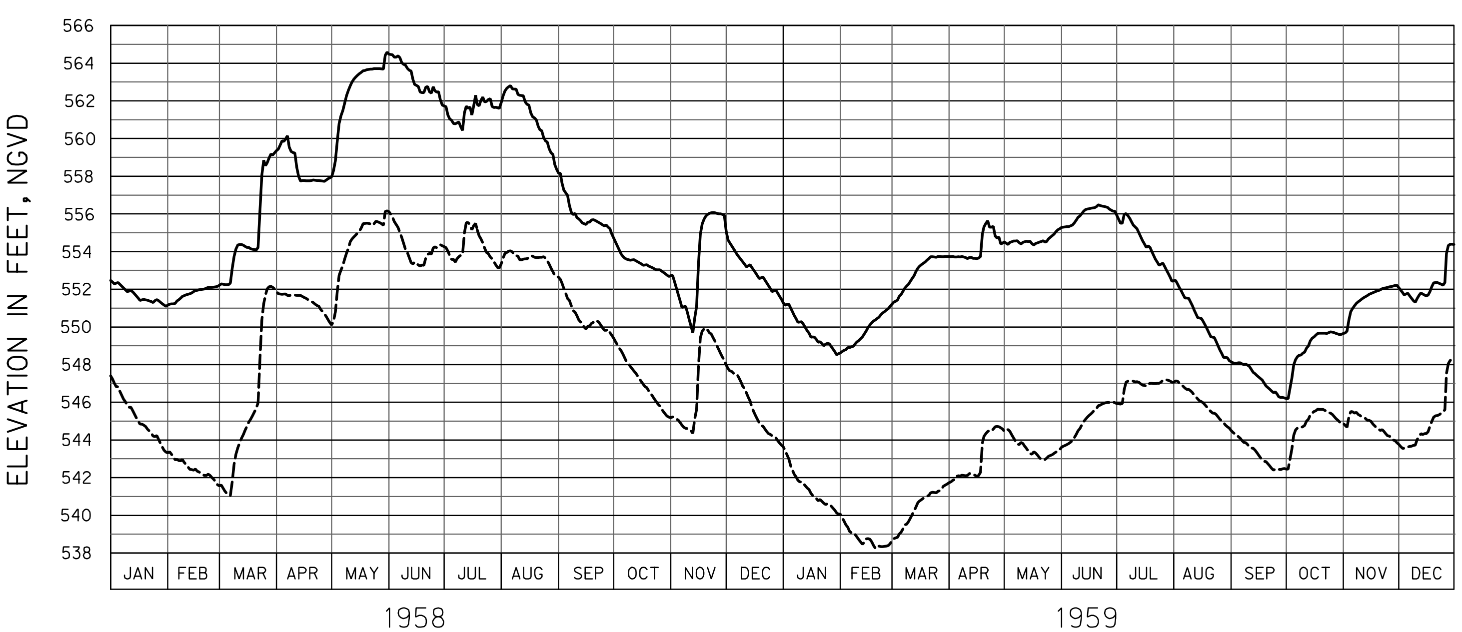
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
1940 - 1949
SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

———	SIMULATED
– – – –	EXPERIENCED

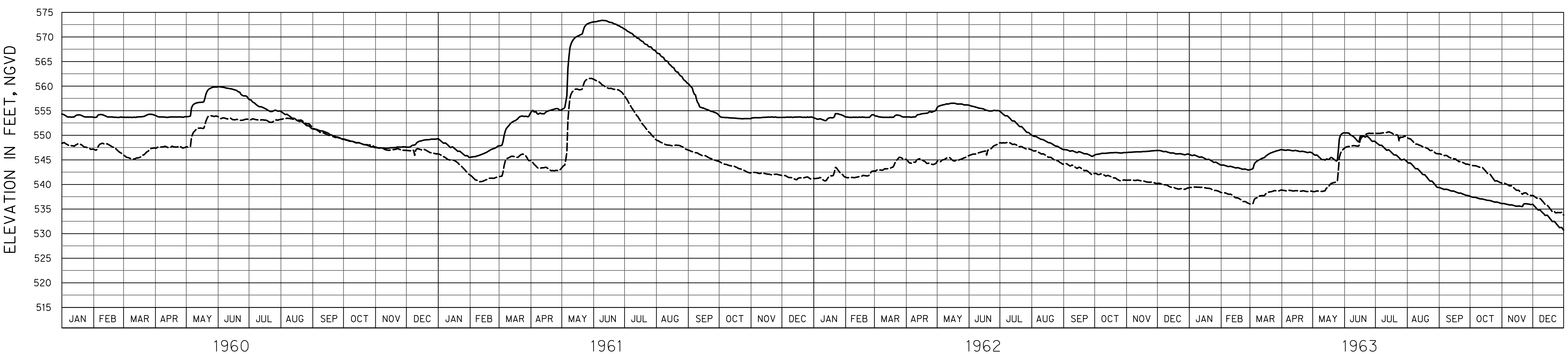
WHITE RIVER BASIN ARKANSAS AND MISSOURI

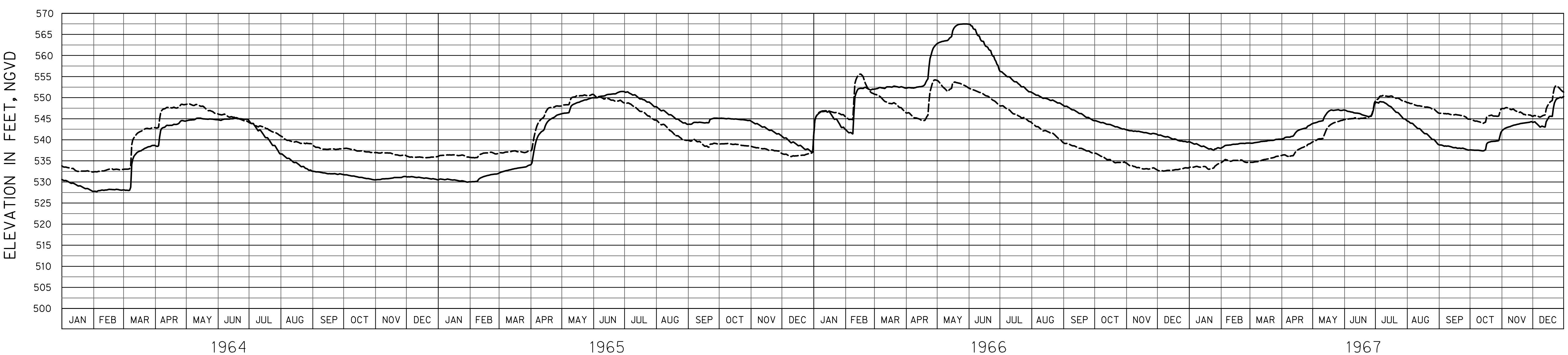
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

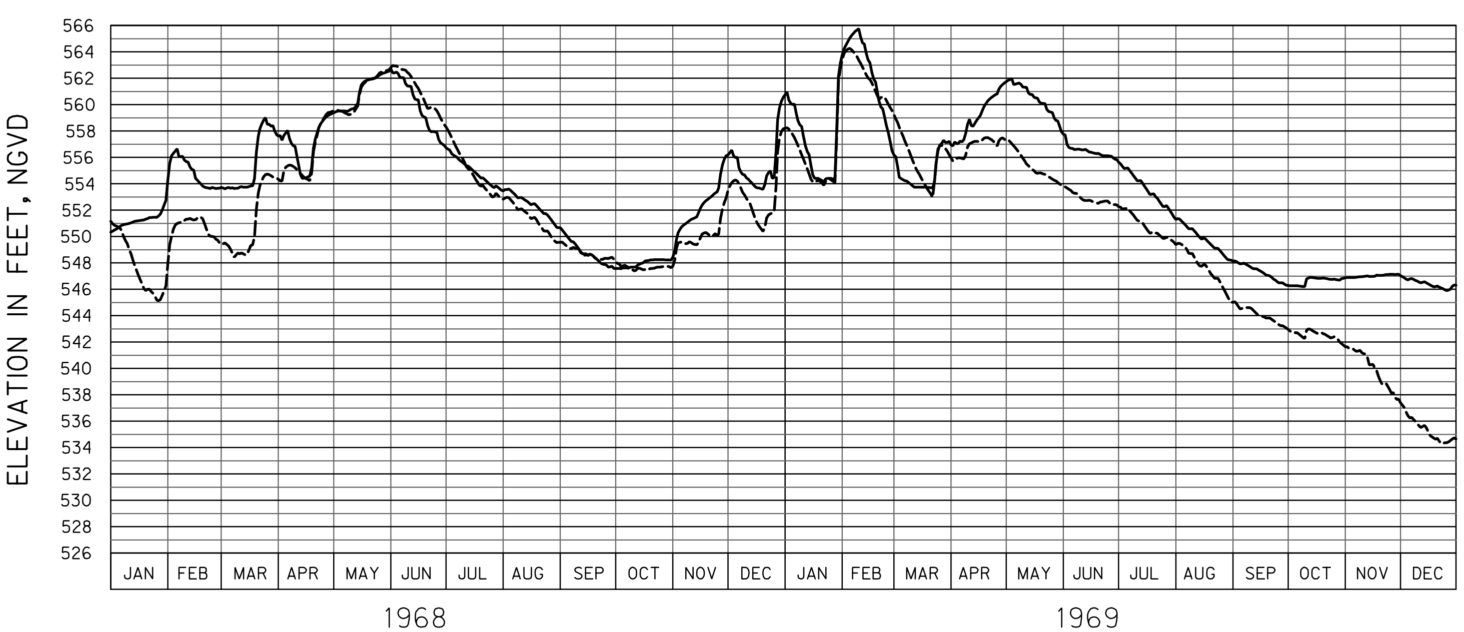
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
1950 - 1959

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

——— SIMULATED

- - - - EXPERIENCED

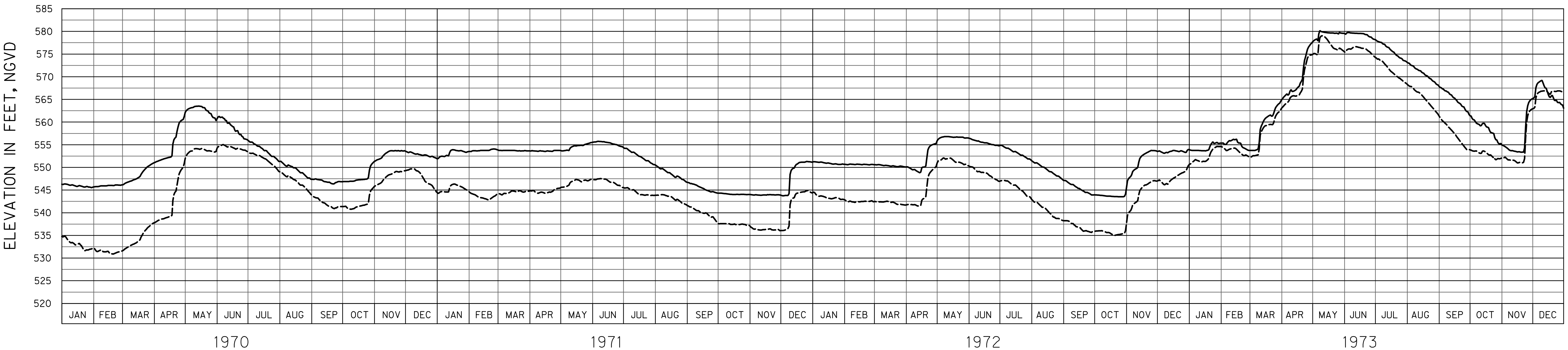
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

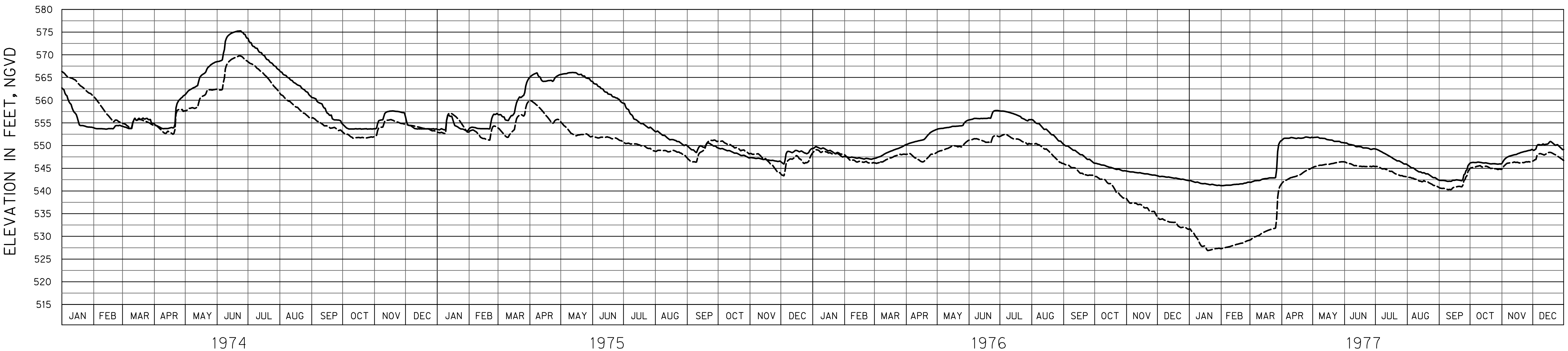
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

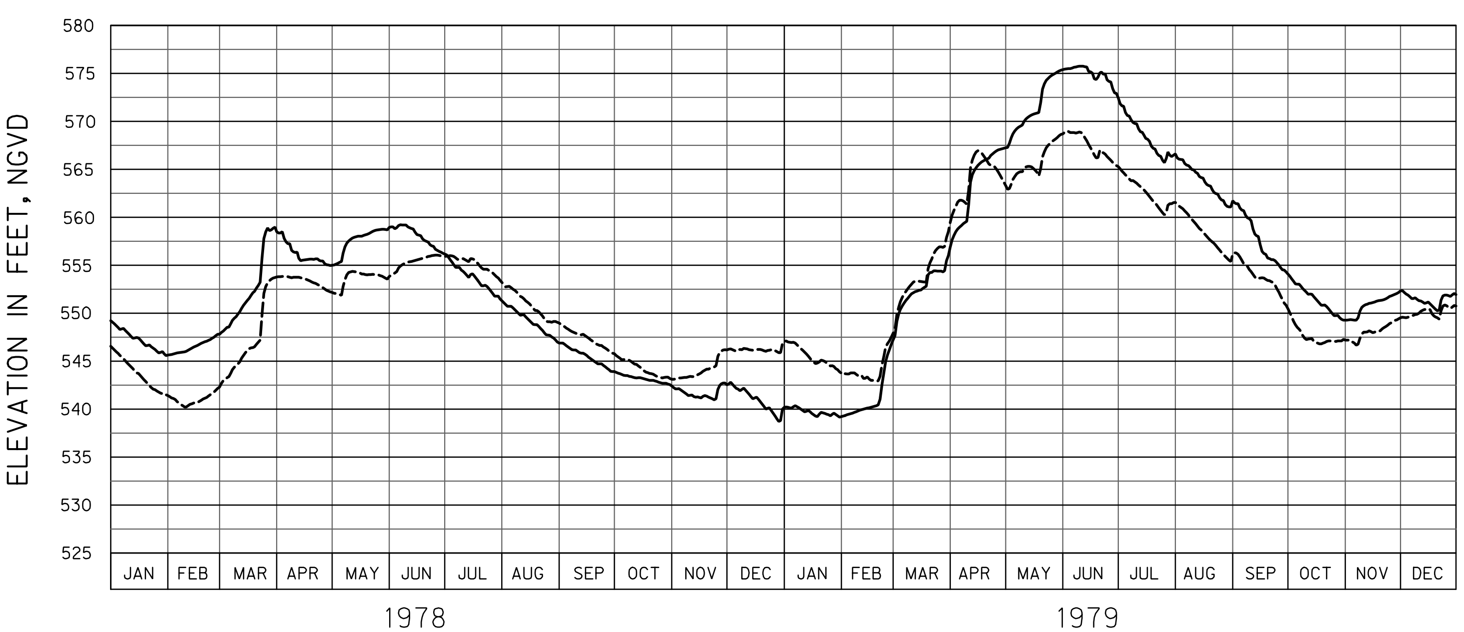
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
1960 - 1969

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

——— SIMULATED
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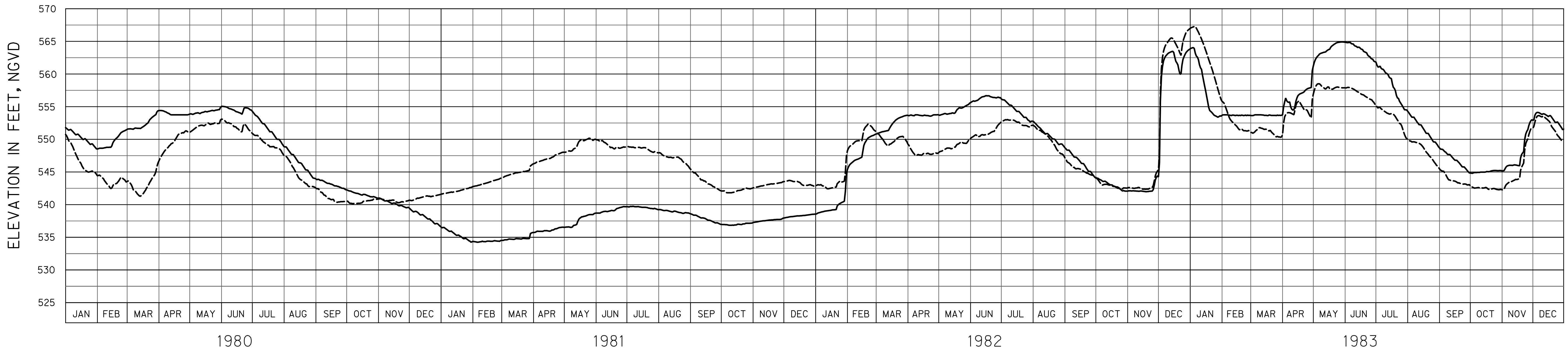
WHITE RIVER BASIN — ARKANSAS AND MISSOURI

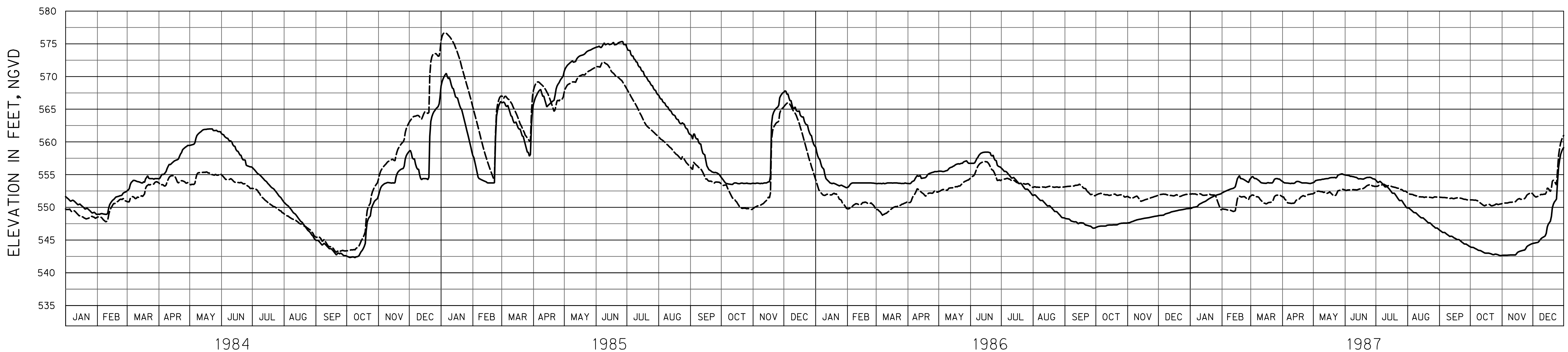
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

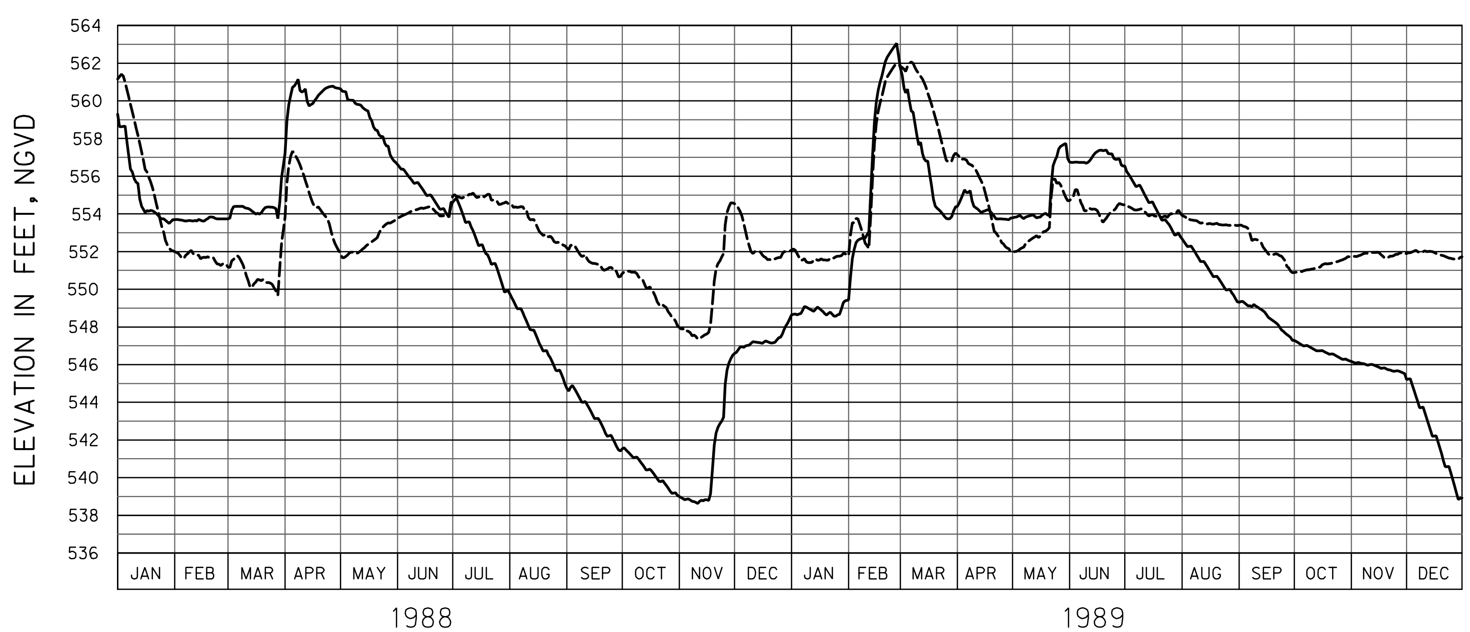
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
1970 - 1979

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

——— SIMULATED

- - - - EXPERIENCED

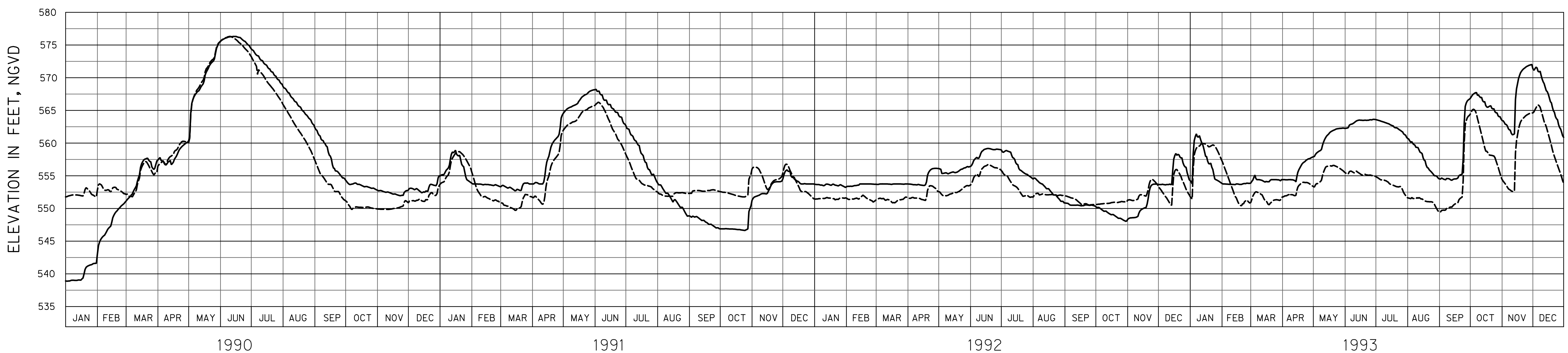
WHITE RIVER BASIN ARKANSAS AND MISSOURI

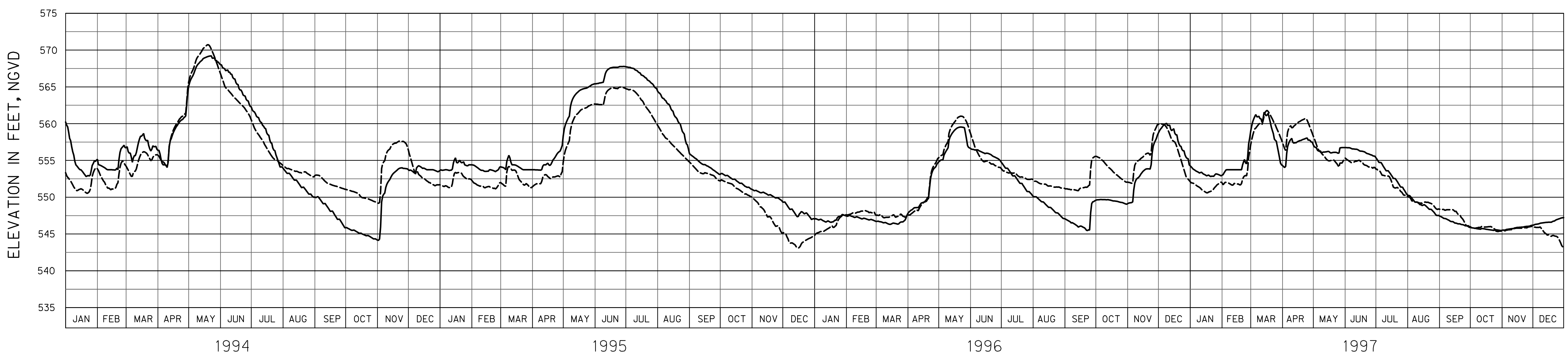
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

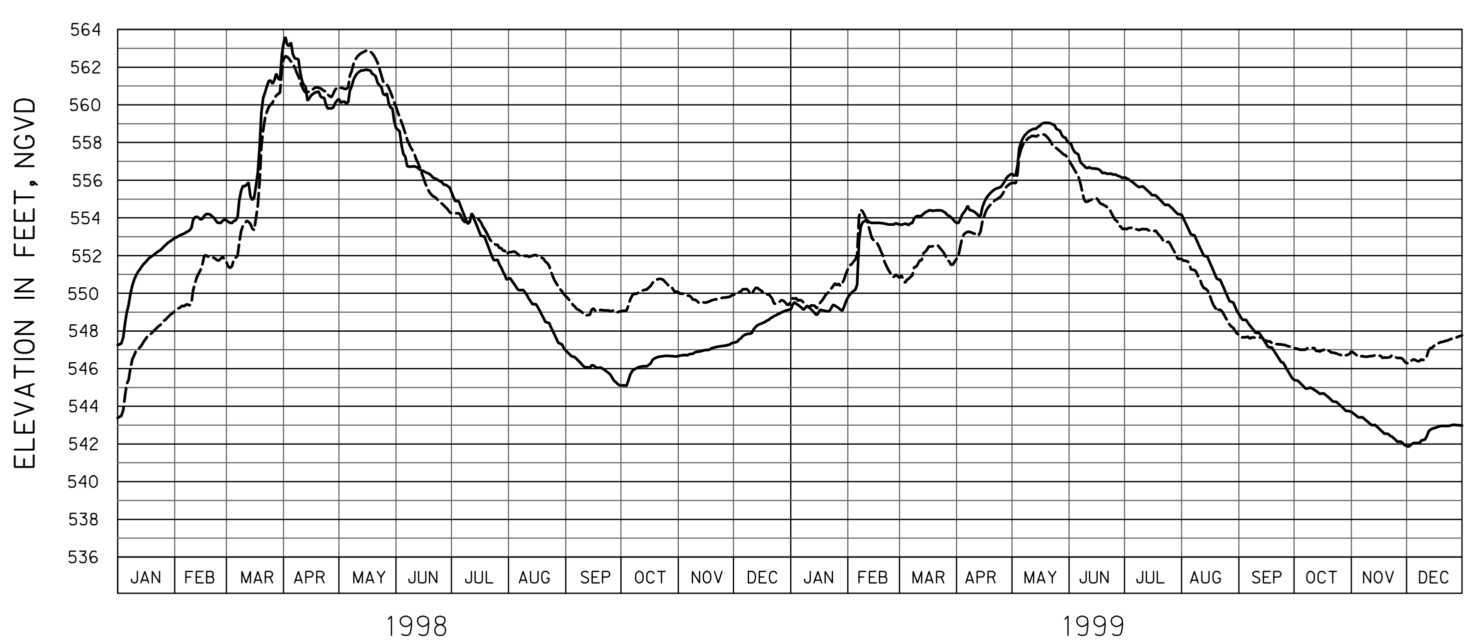
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
1980 - 1989

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

———— SIMULATED

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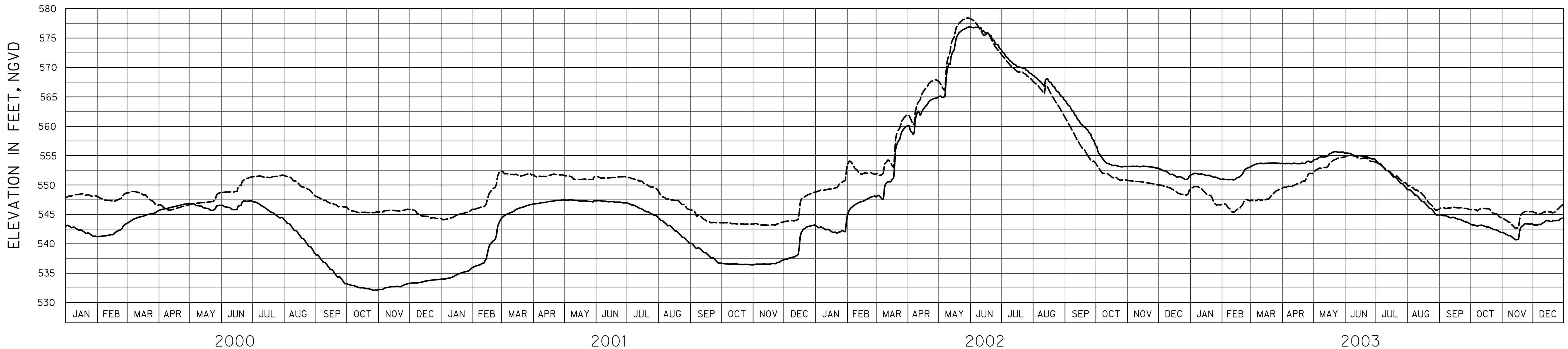
WHITE RIVER BASIN ARKANSAS AND MISSOURI

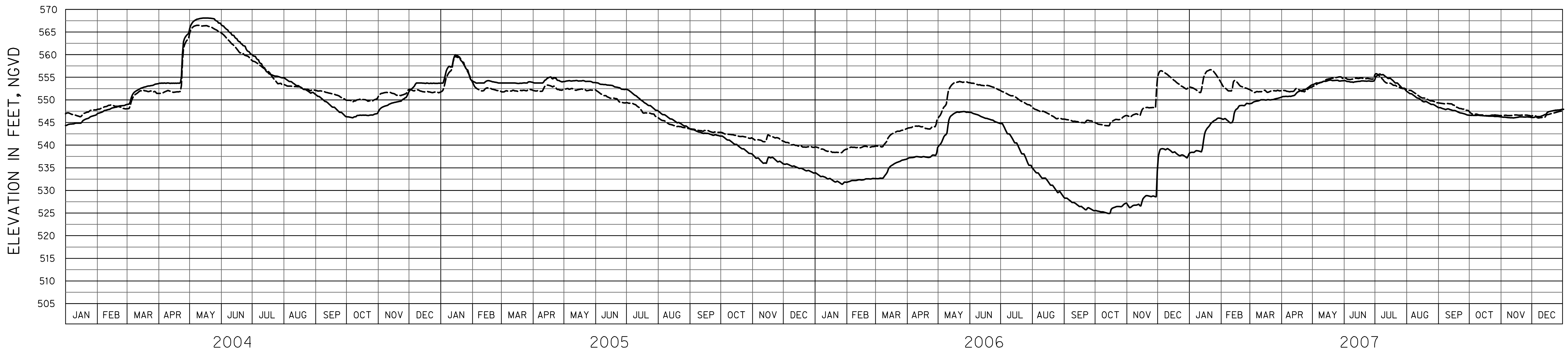
WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

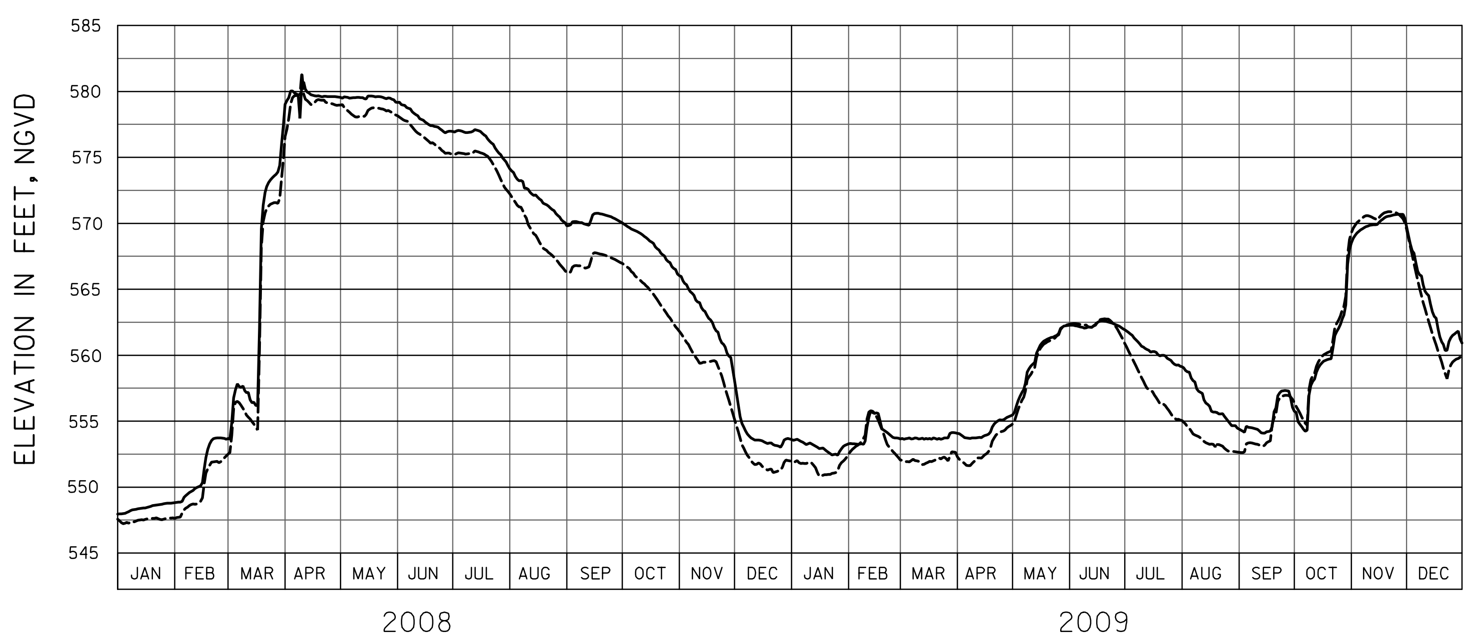
POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
1990 - 1999

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014







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LEGEND

——— SIMULATED
– – – – EXPERIENCED

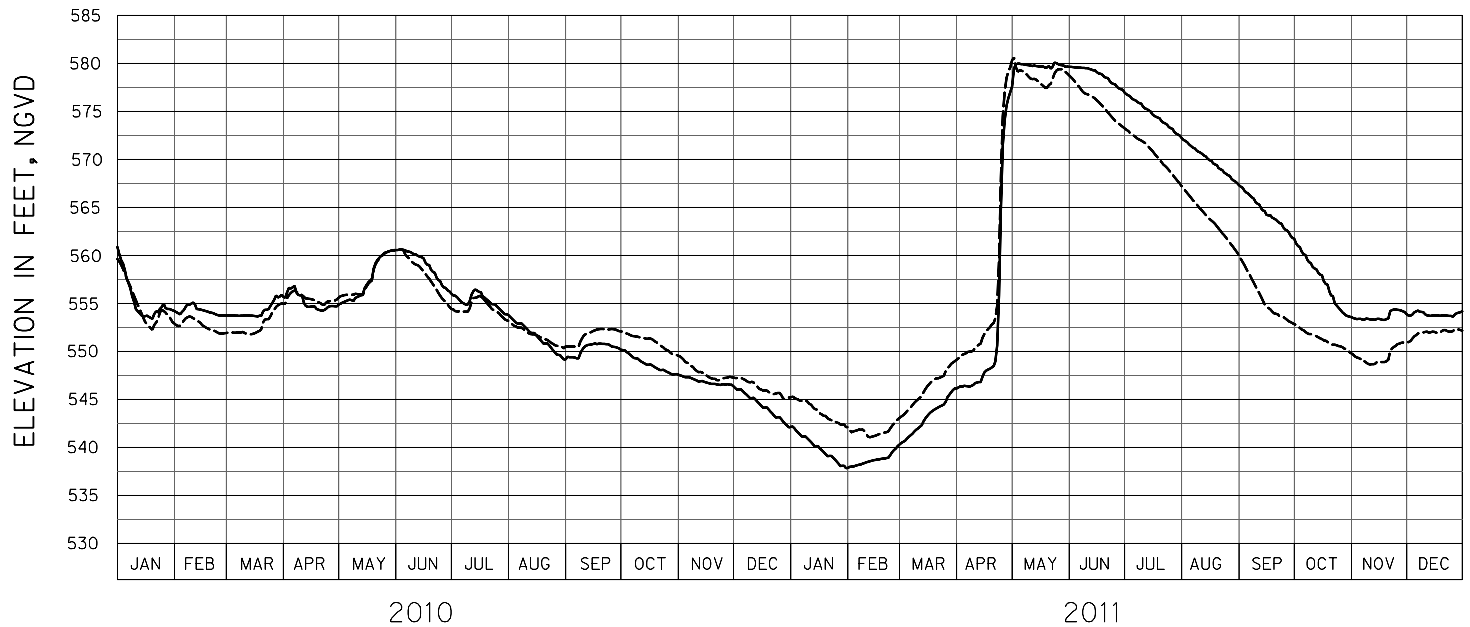
WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
2000 - 2009

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014



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LEGEND

——— SIMULATED
- - - - - EXPERIENCED

WHITE RIVER BASIN ARKANSAS AND MISSOURI

WATER CONTROL MANUAL
BULL SHOALS AND NORFORK DAMS

POOL ELEVATION HYDROGRAPHS
EXPERIENCED VS SIMULATED
NORFORK LAKE
2010 - 2011

SCALE: AS SHOWN

LITTLE ROCK DISTRICT, CORPS OF ENGINEERS
LITTLE ROCK, ARKANSAS, SEPTEMBER 2014