KEYSTONE LAKE
ARKANSAS RIVER, OKLAHOMA
WATER CONTROL MANUAL

APPENDIX M
TO
WATER CONTROL MASTER MANUAL
ARKANSAS RIVER BASIN

PREVIOUS EDITION – NOVEMBER 1989
REVISED EDITION – AUGUST 2012

DEPARTMENT OF THE ARMY
TULSA DISTRICT, CORPS OF ENGINEERS
OKLAHOMA

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. All elevations referred to in this manual, unless noted otherwise, are in feet, NGVD29 (National Geodetic Vertical Datum 1929).

EMERGENCY REGULATION ASSISTANCE PROCEDURES

In the event that unusual conditions arise during duty hours and at various hours during weekends and holidays, contact can be made by telephone to the Water Management Section, Tulsa District (918) 669-7085. If the above office cannot be contacted, assistance can be achieved by contacting, in the order listed, one of persons shown below. Section VII of this manual contains detailed instructions for emergency regulations. All project personnel associated with regulation of the project must be thoroughly familiar with the procedure outlined in this section.

EMERGENCY

PERSONNEL

ROSTER

TITLE AND NAME	RESIDENCE TELEPHONE
Coordinator (b) (6)	(b) (6)
Backup Coordinator (b) (6)	(b) (6)
Chief, Water Management Section (b) (6)	(b) (6) (b) (6)
Chief, Hydrology-Hydraulics Branch (b) (6)	(b) (6) (b) (6)

LOOKING SOUTHWEST AT KEYSTONE DAM AND LAKE

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PERTINENT DATA

LOCATION:
Keystone Dam is located in Tulsa County, OK, RM 538.8 on the Arkansas River, about 15 miles west of Tulsa, OK.

DRAINAGE AREA:
74,506 square miles above dam, of which 22,351 are contributing
One inch of runoff = 1,191,308 acre-feet

DAM:
Type: Rolled Earth fill Embankment
Length: 4,600 feet (including spillway)
Max Height: 121 feet above streambed
Top Width of Embankment: 44 feet

SPILLWAY:
Crest Elevation: 719.0 feet, NGVD29
Length: 856 feet gross, 720 feet net overflow length
Type: Gate controlled concrete, gravity Ogee weir
Control: 18 - 35' wide by 40' high tainter gates

LAND ACQUISITION:

	Guide Contour Elevation (NGVD29)	Area (acres)
Fee Simple	754.0 plus backwater	49,182
Easement	759.0 plus backwater	24,503

OUTLET WORKS:

Type and size: 9 – 5'8" x 10'0"sluices
Location: Through alternate intermediate piers in spillway
Control: Hydraulic, vertical-lift gates
Invert elevation: 657.0 feet, NGVD29

POWER FEATURES:

Capacity: 70,000 kW
(approximately 12,000 c.f.s.)
No. of units 2 Penstock
Invert elevation: 659.5 feet, NGVD29

Feature	Elevation Feet, NGVD29	Area (acres) [1]	Lake Capacity			Spillway Capacity (c.f.s.) 18 gates	Outlet Works Capacity (c.f.s.)
			Accumulative (acre-feet) [1]	Runoff (inches)	Incremental (acre-feet) [1]		
Top of Dam	771.0	79,535	2,703,355	2.27	344,225	--	
Maximum Pool	766.5	72,370	2,359,130	1.95	798,570	854,030	36,250 [2]
Top of Flood Control Pool	754.0	53,030	1,560,560	1.31	1,128,640	557,280	35,000 [3]
Top of Conservation pool	723.0	16,740	431,920	0.36	64,380	18,180	30,800
Spillway Crest	719.0	15,420	367,540	0.31	170,380	0	29,800
Bottom of Conservation pool	706.0	11,100	197,160	0.17	197,160	0	26,000
Flood Control Storage	723.0 - 754.0	--	1,128,640	0.95			
Conservation storage	706.0 - 723.0	--	234,760	0.20			
Streambed at dam	650.0	--	--	--	--	--	--

(1) Based on 2005 bathymetric survey and 2008 LiDAR survey.
(2) Based on an assumption of the spillway operating. Free flow curve, gates fully open, with no spillway operating is 40,500 c.f.s.
(3) Based on an assumption of the spillway operating. Free flow curve, gates fully open, with no spillway operating is 37,900 c.f.s.

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I - INTRODUCTION

1-01. Authorization. This manual is submitted in accordance with ER 1110-2-240 and prepared in accordance with EM 1110-2-3600 and ER 1110-2-8156.

1-02. Purpose and Scope. The purpose of this manual is to document the plan of water control; to present detailed information to higher authority; and to give guidance to personnel who will become concerned with, or responsible for, regulation of the lake during the life of the project.

1-03. Related Manuals. This manual is Appendix M to the Arkansas River Basin Water Control Master Manual. Other related manuals important to the regulation of Keystone Lake are:

Appendix A - Great Salt Plains
Appendix B - Heyburn
Appendix D - Hulah
Appendix E - Fort Gibson
Appendix F - Birch
Appendix G - Tenkiller
Appendix J - Wister
Appendix L - Oologah
Appendix N - Eufaula
Appendix S - Navigation System
Appendix T - Kaw
Appendix W - Copan
Appendix Y - Skiatook

The locations of existing and authorized projects are shown on Plate 1-1. Design memoranda important to the regulation of Keystone Lake are shown in Table 1-1. Supplementary Pertinent Data is given in Exhibit A of this manual.

1-04. Project Owner. Keystone Lake is owned by the U.S. Government.

TABLE 1-1

PERTINENT REPORTS AND DESIGN MEMORANDA
FOR KEYSTONE DAM AND LAKE

Memorandum No.	Title	Date Submitted
	Preliminary Hydrology for Definite Project Report	Jul 1950
1	Site Selection and Alternative Projects Considered	Feb 1954
2	Hydrology	Jul 1954
3	Economic Studies	Nov 1955
2	Hydrology Revision I	Jan 1956
4	General Design	Jan 1956
3	Economic Studies Revision	Aug 1956
5	Real Estate for Dam Site Area	Aug 1956
2	Hydrology Revision II	Nov 1956
2	Hydrology - Part II	Aug 1957
4	Supplement to General Design – Evaluation of River Discharges	Dec 1959
54	Pumping Stations at Cleveland, Oklahoma	Jun 1960
18	Construction of Embankment and Spillway	Aug 1961
80	Hydroelectric Power	Jan 1962
	Letter Report – Stop Logs for Power Intake	Sep 1962
12B	Master Plan – Appendix Drawings	Dec 1962
12B	Master Plan for Keystone Reservoir	Dec 1962

TABLE 1-1 (continued)

Memorandum No.	Title	Date Submitted
	Letter Report – Yale Water Supply Facilities	Dec 1965
12B	Supplement No. 3 to Master Plan	July 1971
-	Keystone Dam Operation and Maintenance Manual Part I -- Revised	1980
-	Mid-Arkansas River, Oklahoma – Arkansas River Basin for Keystone Lake, Kaw Lake, Great Salt Plains Lake, Heyburn Lake, Drought Contingency Plan -- Revised	Nov 2005
-	Keystone Lake Operation and Maintenance Manual Volume II	Aug 2008

1-05. Operating Agency. The U.S. Army Corps of Engineers, Tulsa District, is the operating agency for Keystone Lake. The Lake Manager, Keystone Lake, operating through the Operations Project Manager, Northern Area, and the Operations Division, Tulsa District, has the responsibility for project operations. The project is manned 24 hours a day when the lake level is above elevation 744.0 feet, National Geodetic Vertical Datum of 1929 (NGVD29). Between elevations 744.0 feet and 734.0 feet, the project will be manned during normal work hours each day. Below elevation 734.0 feet, the project will be manned for the normal 5-day work week. However, when the project is in a flood control regulation, operation personnel will closely monitor the project and the downstream river reaches. The project is furnished a list of the Water Management Section personnel to contact when necessary. The Lake Manager will furnish the Water Management Section a list of project personnel, giving their office and home telephones and addresses. The Lake Manager resides as close to the project as is considered prudent to carry out his official duties.

1-06. Regulating Agencies. The regulating agency for Keystone Lake is the Corps of Engineers, with the lake's regulation being the responsibility of the Water Management Section, Hydrology-Hydraulics Branch, Tulsa District. Regulation of Keystone Lake's hydropower releases is coordinated with the Southwestern Power Administration (SWPA), which is the responsible Federal agency for marketing hydroelectric power and energy from the project. SWPA schedules hydropower releases from the project on a daily basis in coordination with the Water Management Section.

II - DESCRIPTION OF PROJECT

2-01. Location. Keystone Dam is located at mile 538.8 on the Arkansas River, approximately 15 miles west of the City of Tulsa, Oklahoma. The lake itself is situated in Tulsa, Osage, Pawnee, and Creek Counties in Oklahoma. The project location is shown on Plate 2-1.

2-02. Purpose. Keystone Lake is a multi-purpose project for flood control, water supply, hydropower, navigation, fish and wildlife, and recreation. The project was designed to provide maximum benefits on the Arkansas River when operated in conjunction with the Arkansas River Basin System.

2-03. Physical Components.

a. Embankment. The embankment is a rolled, earth fill structure with approximately one-half of the structure being impervious material and the other half composed of random material. The top of the dam is at elevation 771.0 feet and is 121 feet above the stream bed. The embankment is 4,600 feet long and at the crest is 44 feet wide, with 24 feet of width being roadway paving. A cutoff trench with a bottom width of 25 feet is provided for the full length of the embankment. The upstream slope of the embankment is protected by 24-inch riprap on backing material and the downstream slope is grass covered. The general plans, sections and elevations of the structures are shown on Plate 2-2.

b. Spillway. The spillway is a gated, concrete, gravity ogee weir type structure with a gross length of 856 feet, a net overflow length of 720 feet, and a crest elevation of 719.0 feet. The structure is located near the left abutment. Flows over the spillway are controlled by eighteen 40 feet by 35 feet tainter gates operated by individual electric powered hoists. The rate of travel for each gate is approximately one foot of arc per minute. An emergency diesel powered generating unit is located at the project to provide electricity in case normal electric service is interrupted. The concrete slab stilling basin has 2 rows of baffles and a 6-foot high end sill. The spillway plan view is shown on Plate 2-2.

c. Outlet Works. The outlet works consist of nine (9) 5'8” x l0' sluices which pass through the spillway along the centerline of alternate intermediate piers. The sluice outlets are equipped with tetrahedral type deflectors and the flow is controlled by hydraulically operated gates. The invert elevation is 657.0 feet. A section of the spillway and outlet works is shown on Plate 2-2.

d. Water Quality. There are no physical water quality facilities built into the project. However, releases are occasionally made to alleviate dissolved oxygen deficiency or pollution downstream.

e. Water Supply. The water supply facility consists of a 72-inch circular conduit with a blind flange in the left non-overflow section of the spillway. The invert elevation of the water supply pipe is 698.28.

f. Sedimentation and Degradation Ranges. A combination range and contour survey method is used for measuring sediment deposition in Keystone Lake. Seventy-nine (79) sediment ranges have been established in and upstream of the lake. The end of each range is marked by permanent monuments with known vertical and horizontal positions. Twenty-eight (28) degradation ranges across the flood plain downstream of the dam have also been established. Sediment surveys of the ranges are performed periodically by Tulsa District personnel or by contract for the purpose of computing sediment deposition and new lake area and capacity data. The locations of the sedimentation and degradation ranges are shown on Plates 2-3 through 2-5.

g. Hydroelectric Power. Hydroelectric power is generated at the dam and marketed by SWPA. The powerhouse is located between the spillway and the left abutment and contains two 35,000 kilowatt (kW) generators. Two 27-foot diameter penstocks at an invert elevation of 659.5 feet and controlled by two 14-foot by 30-foot gates provide the water for the power units. The power head is 86 feet with full conservation pool (one unit online) and is 66 feet when the conservation pool is empty (two units online). The annual firm energy output as based on calendar year 1956 original capacity was 43 million kilowatt-hours (kWh) of primary energy and 185 million kWh of secondary energy.

2-04. Related Control Facilities. A levee has been built to protect portions of Cleveland, Oklahoma from inundation caused by high pool levels. Downstream of Keystone Dam, levees were constructed to protect Sand Springs, Tulsa (west side), and Jenks, Oklahoma. The downstream levees are designed to provide protection from flows up to 350,000 cubic feet per second (c.f.s.).

2-05. Real Estate Acquisition. The fee taking line for Keystone Lake is a semi-blocked perimeter to elevation 754.0 feet, which is the top of the flood control pool. Flowage easements were acquired in the flat pool area above the fee taking line to elevation 759.0 feet. In the upper reaches the flowage easement is to elevation 759.0 feet, or the elevation of the envelope curve of backwater effects of the 50-year flood after 50 years of sedimentation, whichever is higher. The envelope curves of backwater effects for the Arkansas and Cimarron Rivers are shown on Plates 2-6 through 2-9. The initial conditions are shown on Plates 2-6 and 2-7. Plates 2-8 and 2-9 show the effects after 50 years of sedimentation. There are 49,182 acres in fee simple title and 24,503 acres in easement.

2-06. Public Facilities. A public overlook shelter and park are located on the upstream side of the right abutment. The Corps of Engineers maintains fourteen (14) parks and two (2) access points; the State of Oklahoma maintains three (3) parks; the city of Cleveland, Oklahoma, maintains one (1) park and one (1) access point; and the city of

Sand Springs, Oklahoma, maintains a park downstream of the dam. The Public Use Sites are shown on Plate 2-10.

III - HISTORY OF PROJECT

3-01. Authorization. Keystone Lake was authorized for construction by the Flood Control Act approved 17 May 1950 (Public Law 516, 81st Congress, 2nd session).

3-02. Planning and Design. The comprehensive report of possible plans of development of the Arkansas River and tributaries for flood control and other uses was published in 1936 as House Document 308, 74th Congress, 1st session. It was concluded that construction of a reservoir on the Cimarron River near Mannford, Oklahoma, would furnish the most economical means of control of the Cimarron River. The Mannford Reservoir was included in a system of reservoirs recommended for control of floods in the Arkansas River Basin in the report "Comprehensive Flood Control Plan for Ohio and Lower Mississippi Rivers," dated 6 Apr 1937, published as committee Document No. 1, 75th Congress, 1st session. The general plan of improvement recommended by this published document was approved by the Flood Control Act of 1938. A definite project report was submitted to the Chief of Engineers 15 Jul 1944. The Mannford Reservoir as proposed would have been located at mile 20.4 on the Cimarron River.

Several changes to the plan presented were suggested by the Division Engineer, Southwestern Division (SWD), with the major suggestion being an increase in lake capacity. The Chief of Engineers concurred in general with the suggestion and requested that the necessary revisions be made to the report. Since the Keystone site had been developed as a possible project during the period of review of the Mannford definite project report, the Chief of Engineers, by 6th endorsement dated 2 Feb 1945, gave approval for deferment of further studies for revisions to the Mannford report, pending the results of preliminary investigations for the Keystone site. The survey report, "Arkansas River and Tributaries, Mannford Reservoir (Keystone Site)," published as Senate Document No. 107, 81st Congress, 1st session, 17 Aug 1949, was a review of the report published in House Document 308, 74th Congress, 1st session. This report concluded that the most desirable modification would be the substitution of Keystone Reservoir for Mannford Reservoir. The report also found that Keystone Reservoir would replace the authorized Blackburn and Taft reservoirs. Storages for Keystone Reservoir were reallocated subsequent to completion of the project document studies to provide for an increase in power installation and to provide for municipal water supply. A series of design memoranda have been prepared covering hydrology, structural features of the plan, relocation of roads and utilities, hydroelectric power, and real estate.

3-03. Construction. A resume of construction activities for Keystone Lake is presented in Table 3-1.

TABLE 3-1

RESUME OF CONSTRUCTION ACTIVITIES

Activity	Date
Construction began	Jan 1957
Date of diversion	13 Feb 1963
Final storage scheduled	11 Sep 1964
Conservation pool filling	20 Nov 1964

3-04. Related Projects. Keystone Lake is a component of the multi-purpose Arkansas River Basin flood control and navigation system. Included in this system are completed projects in the Verdigris, Walnut, Ninnescah, Canadian, North Canadian, Grand, Caney, Illinois, and Poteau River Basins. The Arkansas River system is operated for the control of floods, navigation, and other beneficial uses.

3-05. Modification to Regulations. The regulation of Keystone Lake has been modified to coincide with the present Arkansas River System Operating Plan as discussed in the Arkansas River Basin Water Control Master Manual.

3-06. Principal Regulation Problems. There have been no significant structural problems at the Keystone Lake project related to the regulation of the lake. Flooding and inundation of access roads to recreation areas occurs when the pool reaches elevation 730.0 feet. At elevation 732.0 feet, the slide gates on the Cleveland Levee ponding areas are closed, the pumps are set on automatic, and personnel on duty monitor the levee area. Twenty-four hour flood surveillance at the dam begins at elevation 752.0 feet. During the Oct 1986 flood operation, releases were made that would have flooded the power house without construction of sand bag dikes (300,000 c.f.s. would be approximately 3.5 feet deep in the powerhouse lobby). A removable bulkhead was constructed for the powerhouse bay door to prevent high flows from entering the powerhouse.

The endangered Interior Least Terns nest on islands below Keystone each year and are a water management concern between late May and the end of August. Further information concerning the water management for the Least Tern information is in Para 7-08 and 8-05. Also an Interim Risk Reduction Management Plan (IRRMP) has been completed for Keystone Dam. Water management may be affected as individual issues are addressed through further studies and remedies. The importance of being current on the developments as they occur is stated in Para 7-03.b.

IV - WATERSHED CHARACTERISTICS

4-01. General Characteristics. The Arkansas River begins in the Rocky Mountains near Leadville, Colorado (river mile 1440.0) and flows southeasterly through the states of Colorado, Kansas, Oklahoma, and Arkansas and joins the Mississippi River at a point near river mile 581.5. The total length of the Arkansas River is approximately 1,460 miles. The elevation at the source of the stream is about 11,500 feet and the elevation at the mouth is approximately 106 feet. The slope of the river ranges from 110 feet per mile near the source to about 2.2 feet per mile at Keystone Dam and 0.4 foot per mile near the mouth of the river.

The watershed upstream from Hutchinson, Kansas, is essentially non-contributing to floods at Keystone Dam. The channel from Hutchinson, Kansas, to the Kansas-Oklahoma state line averages about 400 feet in width with banks about five feet high. Between the Kansas-Oklahoma state line and Keystone Dam, the width of the channel ranges from 600 to 2,500 feet and the banks are from 10 to 12 feet high. Downstream of Keystone Dam, the width of the channel ranges from 600 to 3,000 feet. The banks are from 10 to 20 feet high upstream from the Grand (Neosho) River and 20 to 40 feet high from there to the mouth. The Cimarron River is the major tributary to the Arkansas River upstream of Keystone Dam. It begins in Colfax County in northeastern New Mexico and flows about 698 miles in an easterly direction to its confluence with the Arkansas River.

The watershed upstream from Waynoka, Oklahoma, is essentially non-contributing to floods at Keystone Dam. Smaller tributaries of the Arkansas River upstream of Keystone Dam are: Little Arkansas River with a drainage area of 1,343 square miles; Ninnescah River with a drainage area of 2,295 square miles; Walnut River with a drainage area of 1,955 square miles; and Salt Fork of the Arkansas River with a drainage area of 6,764 square miles. Stream profiles for the Arkansas and Cimarron Rivers are shown on Plates 4-1 and 4-2, respectively. Large towns along the Arkansas River downstream of Keystone Dam include: Sand Springs, Tulsa, Bixby, and Muskogee, Oklahoma, and Van Buren, Arkansas.

4-02. Topography. The terrain of the Arkansas River watershed varies from rolling to hilly and is characterized by sandstone hills, streams, and valleys with broad alluvial plains. Throughout Kansas and parts of Oklahoma the course of the river is crooked and meandering and is subject to frequent changes. From the confluence of the Verdigris River near Muskogee, Oklahoma, to its confluence with the Mississippi River, the Arkansas River's course has been stabilized and controlled to facilitate commercial navigation. Land use consists of crop production, ranching, and oil and gas production.

4-03. Geology and Soils. Keystone Lake is located in the interior lowlands physiographic province. The bedrock strata are sedimentary rocks, mostly sandstone of Pennsylvanian age. The tertiary alluvial deposits consist of terrace deposits, dune sand, and loess.

4-04. Sediment. The lake inflow carries a large amount of sediment which comes mostly from the Cimarron River. During periods of low flow, the channel meanders over a wide sandy bed between banks that are easily eroded. During periods of high flows, bank caving and erosion occur at many locations. Four sediment surveys have been conducted (1964, 1977, 1988, 2005) since completion of the project. There was also a 2008 LiDAR survey of the bottom of the flood pool to the top of the dam. It is estimated that the sediment deposition would be 12,035 acre-feet annually, with 78 percent being deposited below the top of conservation pool. This storage is distributed as follows: 22 percent flood pool (62,355 ac-ft deposited, with 1,128,642 ac-ft remaining), 40 percent conservation pool (116,957 ac-ft deposited, with 234,758 ac-ft remaining), and 38 percent inactive pool (109,539 ac-ft deposited, with 197164 ac-ft remaining). According to the 2005 and 2008 surveys, the total sediment deposited since the 1964 survey is 288,851 acre-feet.

4-05. Climate. The climate in the general project area is characterized by moderate winters and long summers with high temperatures. Rainfall usually occurs in the form of high intensity, local thunderstorms which occur primarily during the late spring and early fall months. These storms are frequently accompanied by high winds, hail, and occasional tornadoes. Climatic characteristics for the basin are shown in the following tabulation.

a. Temperature. (Period of Record is Jan 1905 through Dec 2011)

Mean annual	60 degrees F
Maximum recorded (Tulsa, Oklahoma, 10 Aug 1936)	115 degrees F
Minimum recorded (Nowata, Oklahoma, 10 Feb 2011)	-31 degrees F

b. Rainfall.

Mean Annual (Jan 1905 – Dec 2011)	33 inches
Maximum annual (1973)	69.88 inches
Minimum annual (1956)	16.10 inches
Percent during growing season (Apr through Sep)	62 %

The average monthly and annual rainfall and runoff data are shown in Table 4-1.

c. Snowfall. (Period of Record is Jan 1905 through Dec 2011)

Maximum month (Feb 2011)	22.5 inches
Minimum (Several years)	Zero
Mean Annual	12 inches

TABLE 4-1

AVERAGE MONTHLY AND ANNUAL RAINFALL
AND RUNOFF UPSTREAM OF KEYSTONE DAM

Month	Average rainfall (inches)[1]	Percentage of average annual Rainfall	Average Runoff [2] [3]		Percent of average annual runoff
			(acre-feet)	(inches)	
Jan	0.93	2.8	231,220	0.19	3.9
Feb	1.16	3.5	289,250	0.24	4.9
Mar	2.01	6.1	542,640	0.46	9.2
Apr	2.78	8.4	657,860	0.55	11.2
May	4.42	13.4	910,470	0.76	15.4
Jun	4.12	12.5	836,440	0.70	14.2
Jul	2.99	9.1	617,470	0.52	10.5
Aug	2.93	8.9	345,520	0.29	5.9
Sep	3.38	10.2	333,640	0.28	5.7
Oct	3.63	11.0	453,280	0.38	7.7
Nov	2.39	7.2	369,190	0.31	6.3
Dec	2.26	6.8	309,210	0.26	5.2
Total	33.00	100.0	5,896,190	4.94	100.0

(1) Period of Record is Jan 1930 through Dec 2009 (from Annual Report)
(2) Contributing drainage area upstream of Keystone Dam is 22,351 square miles
(3) Period of Record is Jan 1940 through Dec 2009 (from Annual Report)

d. Evaporation. Following the construction of Keystone Dam, evaporation data was collected from an evaporation pan on site. In 1996, the Tulsa District migrated from physical evaporation measurements to using an empirical formula based on meteorology data collected on site. The formula incorporates electronically collected data for solar radiation, wind speed, air temperature and relative humidity. The

estimated monthly pan evaporation figures are shown in Table 4-2 for the period Jan 1980 through Dec 2010.

TABLE 4-2

ESTIMATED MONTHLY EVAPORATION
KEYSTONE LAKE

Month	Evaporation (inches) [1]
Jan	2.1
Feb	2.6
Mar	4.5
Apr	6.4
May	6.7
Jun	7.8
July	9.6
Aug	6.0
Sep	6.3
Oct	4.5
Nov	3.0
Dec	2.2
Annual Total	64.7

[1] National Weather Service (NWS) Class "A" pan. Period of Record is Jan 1980 through Dec 2010. On-site pan evaporation from Jan 1980 through Dec 1996, and empirical formula from Jan 1997 through December 2010.

e. Wind. The prevailing wind is from a southerly direction, with the greatest wind movements occurring in the spring months. A study of available wind velocity data indicates that for 1-minute and 1-hour durations, the highest wind velocities that can reasonably be expected are 75 and 53 miles per hour, respectively.

4-06. Storms and Floods. Most of the flood producing storms in the Keystone Lake drainage basin have occurred during April through June and during September through November. Thunderstorms and the remnants of hurricanes are the type of storms that produce most high runoff events in the basin. The largest storm in the 81 years of record was the 13 Jun – 3 Jul 2007 storm which produced an average of 11.42 inches of rainfall over the basin. Time of year and antecedent soil moisture conditions are major factors that determine the amount of runoff from a given storm. Thus, some lesser rainfall storms have resulted in runoff as great as or greater than storms of higher rainfall. Major storms that have occurred in the Keystone Lake watershed are listed in Table 4-3. The top twenty annual peak flows at major gages are listed in Table 4-4.

TABLE 4-3

KEYSTONE DAM SITE MAJOR STORMS
OCT 1935 THROUGH JUL 2010
ARKANSAS RIVER BASIN

Date of storm	Average rainfall (inches)	Date of storm	Average rainfall (inches)
6 -11 Jun 1923	4.11	1 - 9 May 1961	3.11
13 - 20 Sep 1923	4.39	13 May 1961	2.51
10 - 16 Oct 1923	3.33	12 - 14 Sep 1961	4.85
25 Sep – 4 Oct 1926	6.14	14 - 19 Nov 1964	4.30
7 - 19 Apr 1927	4.61	1 - 14 Jun 1965	4.78
14 - 18 Nov 1928	4.20	16 - 21 Sep 1965	4.58
29 May – 8 Jun 1929	3.82	22 - 28 Apr 1969	2.00
2 - 11 May 1930	4.02	20 - 28 Jun 1969	2.01
10 - 17 Nov 1931	3.32	15 - 19 Apr 1970	3.00
12 - 21 May 1935	5.92	1 - 11 Mar 1973	4.90
18 - 23 May 1938	3.83	27 Mar – 03 Apr 1973	2.12
15 - 17 Aug 1938	3.43	21 - 28 Sep 1973	5.80
2 - 6 Sep 1940	1.96	10 - 11 Oct 1973	3.80
19 - 26 Nov 1940	3.58	8 - 11 Mar 1974	2.90
6 - 11 Jun 1941	3.36	20 - 26 May 1974	3.13
14 - 26 Oct 1941	5.33	2 - 09 Jun 1974	3.22
16 - 27 Apr 1942	4.60	27 Oct – 04 Nov 1974	5.60
3 - 16 Aug 1942	3.71	9 - 14 May 1975	2.37
6 - 11 May 1943	2.58	4 - 11 Jun 1975	2.00
13 - 20 May 1943	3.72	16 - 21 May 1977	4.10
19 - 27 Apr 1944	3.04	24 - 26 Apr 1980	2.33
10 - 16 Apr 1945	4.05	12 - 17 May 1982	5.87
21 - 30 Sep 1945	7.55	17 - 24 Mar 1984	3.10
8 - 15 Apr 1947	4.86	20 - 24 Feb 1985	2.96
15 - 20 May 1947	3.00	26 - 30 Apr 1985	2.25
20 - 28 Jun 1948	6.00	8 - 15 Oct 1985	2.25
6 - 15 Aug 1948	4.34	27 Sep – 04 Oct 1986	9.80
14 - 21 May 1949	4.16	22 - 29 May 1987	4.58
28 Jul – 2 Aug 1950	3.75	27 - 28 Sep 1987	2.05
14 - 23 May 1951	5.18	2 - 6 Mar 1988	2.24
28 Jun – 5 Jul 1951	3.08	29 Mar – 2 Apr 1988	2.61
19 – 21 May 1955	2.74	14 - 25 Sep 1988	5.70
17 – 23 Apr 1957	2.82	27 - 31 Mar 1989	2.79
9 – 18 May 1957	4.31	12 - 20 May 1989	3.02
9 – 18 Jun 1957	3.06	1 - 14 Jun 1989	5.72
22 - 26 Jun 1957	2.50	29 Jul – 9 Aug 1989	2.44
16 - 22 Jun 1958	2.82	11 - 26 Aug 1989	3.55
12 - 24 Jun 1959	3.82	28 Aug – 6 Sep 1989	2.53
23 - 26 Sep 1959	3.21	9 - 17 Sep 1989	2.53
30 Sep – 5 Oct 1959	5.51	10 - 15 Mar 1990	2.82

TABLE 4-3 (continued)

Date of storm	Average rainfall (inches)	Date of storm	Average rainfall (inches)
17 - 22 Sep 1990	2.37	30 Sep – 5 Oct 1998	4.59
8 - 13 Oct 1990	3.30	28 Oct – 3 Nov 1998	5.55
20 - 25 May 1991	2.12	29 - 31 Jan 1999	2.04
28 Aug – 5 Sep 1991	2.44	22 - 27 Apr 1999	3.58
28 Oct – 9 Nov 1991	2.19	19 - 26 Jun 1999	3.49
14 - 22 Nov 1991	2.66	2 - 10 Dec 1999	3.66
19 - 23 Dec 1991	2.21	25 - 28 May 2000	2.49
1 - 12 Jun 1992	3.28	10 - 30 Jun 2000	4.66
25 - 30 Jun 1992	2.36	20 - 22 Jul 2000	2.23
13 - 22 Jul 1992	2.55	21 - 29 Oct 2000	3.44
1 - 15 Aug 1992	4.94	16 - 22 May 2001	2.32
17 - 26 Nov 1992	4.42	28 - 31 May 2001	2.60
28 Apr - 3 May 1993	3.68	15 - 21 Sep 2001	2.28
5 - 12 May 1993	3.75	11 - 15 Aug 2002	2.48
12 - 15 Jul 1993	2.18	17 - 20 Mar 2003	2.17
9 - 12 Apr 1994	2.28	14 - 17 May 2003	2.21
28 Apr – 3 May 1994	3.56	27 Aug – 3 Sep 2003	2.84
12 - 23 Jul 1994	2.71	3 - 5 Mar 2004	3.47
3 - 9 Oct 1994	2.04	16 - 22 Jun 2004	3.26
19 - 21 Nov 1994	3.18	28 Jun – 7 Jul 2004	2.72
13 - 15 Mar 1995	2.06	4 - 12 Oct 2004	2.49
29 Apr – 1 May 1995	2.16	4 - 14 Jun 2005	3.25
6 - 8 May 1995	2.15	20 - 29 Aug 2005	3.65
23 - 27 May 1995	2.27	27 - 31 Mar 2007	3.39
30 May – 11 Jun 1995	7.13	6 - 12 May 2007	3.44
20 - 24 Jul 1995	2.12	22 May – 2 Jun 2007	4.00
1 - 6 Aug 1995	4.92	13 Jun – 3 Jul 2007	11.42
13 May – 2 Jun 1996	3.93	10 - 11 Apr 2008	2.29
5 - 12 Jul 1996	2.13	6 - 9 May 2008	2.59
29 Jul – 3 Aug 1996	2.11	23 - 29 May 2008	3.17
14 - 16 Sep 1996	2.16	9 - 10 Jun 2008	2.77
13 - 20 Nov 1996	2.11	16 - 20 Jun 2008	2.66
19 - 22 Feb 1997	2.56	9 - 13 Jul 2008	2.54
8-14 Apr 1997	2.78	9 - 14 Sep 2008	3.93
26 Jun – 1 Jul 1997	2.61	26 Apr – 6 May 2009	3.66
15 - 22 Jul 1997	4.01	15 - 21 Aug 2009	4.08
17 - 23 Aug 1997	2.77	8 - 9 Oct 2009	2.42
19 - 25 Sep 1997	3.10	19 - 20 May 2010	2.25
21 - 26 Dec 1997	2.30	13 - 17 Jun 2010	3.06
15 - 21 Mar 1998	3.72	3 - 10 Jul 2010	3.18
26 - 29 Apr 1998	2.58		

TABLE 4-4

TOP TWENTY ANNUAL PEAK FLOWS AT STREAM GAGES

Tulsa Gage			Ralston Gage			Haskell Gage		
DATE	FLOW (c.f.s.)	STAGE	DATE	FLOW (c.f.s.)	STAGE	DATE	FLOW (c.f.s.)	STAGE
5 Oct 1986	307,000	25.21	11 Jun 1923	200,000	23.00	21 May 1943	700,000	48.20
13 Jun 1923	244,000 (1)	22.80	13 Oct 1973	211,000	22.98	May 1898	384,000	39.50
5 Oct 1959	246,000	22.00	25 Apr 1944	179,000	22.82	26 May 1957	366,000	39.03
21 May 1957	235,000	21.53	18 Nov 1964	171,000	22.60	31 Oct 1941	304,000	37.23
14 May 1993	149,000	17.48	4 Oct 1986	174,000	22.20	18 Apr 1945	326,000	36.65
9 May 1961	164,000	17.32	5 Oct 1959	158,000	21.62	6 Oct 1926	325,000	36.50
26 Apr 1944	172,000	17.00	3 Jul 1951	135,000	21.45	Jun 1923	295,000	34.70
1 Oct 1945	165,000	16.70	20 May 1957	120,000	21.41	7 Oct 1959	286,000	34.00
20 May 1943	173,000	16.50	8 May 1961	165,000	21.22	21 Apr 1941	248,000	32.72
4 Sep 1940	143,000	16.20	12 May 1993	139,000	19.76	9 May 1961	295,000	32.70
16 Apr 1947	151,000	15.94	19 Apr 1945	124,000	19.55	15 May 1929	249,000	31.50
12 Jun 1995	127,000	15.90	2 Oct 1945	110,000	19.48	15 Apr 1927	248,000	31.40
4 Jul 1951	149,000	15.70	12 Mar 1973	121,000	19.41	17 Jul 1951	240,000	31.40
18 Apr 1945	140,000	15.40	6 Oct 1926	108,000	18.70	9 Jun 1935	243,000	30.80
25 Jun 1942	139,000	15.20	5 Nov 1974	111,000	18.62	1 Oct 1945	231,000	30.67
4 Nov 1998	106,000	14.70	3 Nov 1998	113,000	18.51	24 Jun 1948	224,000	30.25
4 Nov 1961	114,000	14.53	16 Apr 1947	114,000	18.50	5 Oct 1986	259,000	22.82
20 May 1949	123,000	14.44	3 Jul 2007	105,000	18.11	6 Nov 1974	108,000	17.30
13 Apr 1927	114,000	14.40	30 Sep 1986	103,000	17.87	1 Jul 2007	91,200	15.52
6 Nov 1974	101,000	13.63	4 Nov 1961	103,000	17.83	9 Jun 2008	86,300	15.21
Flood Stage = 15.0 feet Period of Record is 3 Jun 1905 – Present			Flood Stage = 16.0 feet Period of Record is 11 Jun 1923 – Present			Flood Stage = 18.0 feet Period of Record is 6 Oct 1926 - Present With a break from 1986-2004 Slightly different location from 2005 to the present time		

(1) Estimated Peak Flow
(2) Data Not Available
(3) Lock & Dam No. 13 Pool Elevation

Note: Annual Peak Flows are the highest flow during a given water year (1 Oct to 30 Sep of following calendar year) and are based on published data from the USGS website.
Flows Regulated by Keystone Dam since Sep 1964 for Tulsa, Haskell, Muskogee and Van Buren gages.

TABLE 4-4 (continued)

Muskogee Gage			Van Buren Gage		
DATE	FLOW (c.f.s.)	STAGE	DATE	FLOW (c.f.s.)	STAGE
21 May 1943	700,000	48.20	12 May 1943	850,000	38.00
May 1898	384,000 (1)	39.50	17 Apr 1945	650,000	(2)
26 May 1957	366,000	39.03	28 May 1957	510,000	35.97
31 Oct 1941	304,000	37.23	2 Nov 1941	485,000	(2)
18 Apr 1945	326,000	36.65	19 Jun 1935	418,000	34.10
15 Apr 1927	325,000	36.50	7 Oct 1959	418,000	32.55
Jun 1923	295,000 (1)	34.70	13 May 1950	402,000	30.90
7 Oct 1959	286,000	34.00	5 May 1990	401,000	401.75 (3)
21 Apr 1941	248,000	32.72	19 Feb 1938	375,000	32.71
9 May 1961	295,000	32.70	9 Oct 1986	357,000	400.32 (3)
7 Jul 2007	176,000	31.62	25 Jun 1948	330,000	30.61
15 May 1929	249,000	31.50	22 May 1949	323,000	29.03
15 Jul 1951	242,000	30.83	16 May 1929	315,000	29.00
9 Jun 1935	243,000	30.80	22 Apr 1941	311,000	30.58
10 Jun 2008	153,000	30.72	15 Jun 1995	294,000	397.05 (3)
1 Oct 1945	231,000	30.67	2 Oct 1945	287,000	29.42
24 Jun 1948	224,000	30.25	11 May 1993	267,000	396.87 (3)
20 May 1949	208,000	28.27	13 Dec 1946	262,000	27.80
22 Jun 1928	197,000	27.90	25 Nov 1973	259,000	397.72 (3)
2 May 2009	124,000	27.73	6 Jul 1951	250,000	26.76
Flood Stage = 28.0 feet Period of Record is 7 Sep 1926 - Present			Flood Stage = 22.0 feet Period of Record is 3 Oct 1927 – Present		

(1) Estimated Peak Flow
(2) Data Not Available
(3) Lock & Dam No. 13 Pool Elevation

Note: Annual Peak Flows are the highest flow during a given water year (1 Oct to 30 Sep of following calendar year) and are based on published data from the USGS website.
Flows Regulated by Keystone Dam since Sep 1964 for Tulsa, Haskell, Muskogee and Van Buren gages.

4-07. Runoff Characteristics. Tributaries to the Arkansas River upstream of Hutchinson, Kansas, are relatively small and do not significantly contribute to river flows at Keystone Lake. Tributaries to the Arkansas River downstream of Hutchinson, Kansas, are large and numerous and contribute significantly to inflows to Keystone Lake. Flows from storm-water runoff are highly variable in magnitude and duration and channel losses are small. The portion of the Cimarron River basin west of Waynoka, Oklahoma, is similar in character to the upper Arkansas River. Flows from this area contribute to floods in the lower Cimarron River basin, but do not contribute materially to major floods on the Arkansas River. Downstream from Waynoka, Oklahoma, the Cimarron River watershed is a well-developed drainage with relatively large, rapid, runoff volumes. Because of these characteristics, the normally contributing drainage area for Keystone Lake is considered to be that area downstream of Waynoka, Oklahoma, on the Cimarron River and Hutchinson, Kansas, on the Arkansas River. This amounts to a total contributing drainage area of 22,351 square miles. Prior to Keystone Dam being placed into operation, flows in the Arkansas River at Tulsa (15.1 miles downstream from Keystone Dam) fluctuated over a wide range, with extended periods of low flow during dry seasons and rapid rises of relatively short duration following heavy rains. During design studies it was determined that the time to peak inflow into Keystone Lake is about 3-1/2 days, however this time is highly dependent on the storm pattern. Storm studies indicate that 1 to 2 inches of rainfall generally were needed to satisfy initial losses before significant runoff began. Pertinent data for stream gaging stations in the system are shown in Table 4-5. The estimated monthly and annual flows at Keystone Dam site modified by Kaw, El Dorado, Cheney, and Great Salt Plains Lakes for the period 1940 through 2010 are shown in Table 4-6, located in the Supplemental Tables Section. The modified inflow volume frequency (volume by months) is shown on Table 4-7. Flow duration curves using modified flows are shown on Plate 4-3.

Peak inflows taken from monthly inflow computation records at the dam site for the period Jan 1940 through Dec 2008 were used to compute the maximum annual peak inflow probability. The inflow probability was derived in accordance with Bulletin 17B, "Guidelines for Determining Flood Flow Frequency," dated September 1981. The peak inflow probability curve is shown on Plate 4-4.

4-08. Water Quality. The water impounded by Keystone Dam is too highly mineralized to be suitable for most industrial or municipal uses without extensive treatment. Concentrations of chemical constituents such as chloride, sodium, and the total dissolved solids often exceed the maximum limits recommended by the U. S. Environmental Protection Agency in Quality Criteria for Water, EPA 440/9-76-023, and the Oklahoma Water Resources Board in Oklahoma's Water Quality Standards, Publication 79.

TABLE 4-5

PERTINENT DATA FOR STREAM GAGING STATIONS

STATION	STREAM	MILES ABOVE MOUTH	GAGE ZERO (ft.,NGVD29)	FLOOD STAGE (ft.) [1]	DRAINAGE AREA [2] (sq. mi.)	MAXIMUM FLOOD OF RECORD		
						DATE	STAGE (ft.)	FLOW (c.f.s.)
Tulsa, OK	Arkansas River	523.7	615.23	15.0	62,074	5 Oct 1986	25.21	307,000
Ralston, OK	Arkansas River	594.0	776.70	16.0	46,850	11 Jun 1923	23.00	200,000
Haskell, OK	Arkansas River	483.7	530.00	28.0	62,932	5 Oct 1986	22.82	259,000
Muskogee, OK	Arkansas River	457.8	471.38	28.0	84,133	21 May 1943	48.20	700,000
Van Buren, AR	Arkansas River	308.9	372.36	22.0	127,736	12 May 1943	38.00	850,000

STATION	STREAM	2nd LARGEST FLOOD OF RECORD			3rd LARGEST FLOOD OF RECORD			PERIOD OF RECORD
		DATE	STAGE (ft.)	FLOW (c.f.s.)	DATE	STAGE (ft.)	FLOW (c.f.s.)	(FLOW AND/OR STAGE)
Tulsa, OK	Arkansas River	13 Jun 1923	22.80	244,000	5 Oct 1959	22.00	246,000	3 June 1905 to present
Ralston, OK	Arkansas River	13 Oct 1973	22.98	211,000	25 Apr 1944	22.82	179,000	11 Jun 1923 to present
Haskell, OK	Arkansas River	14 May 1993	19.28	150,000	11 Jun 1995	18.49	142,000	6 Oct 1926 - present
Muskogee, OK	Arkansas River	6 Oct 1986	39.60	375,000	May 1898	39.50	384,000	6 Oct 1926 to 30 Sep 1987, 2005 – present (4)
Van Buren, AR	Arkansas River	17 Apr 1945	(3)	650,000	28 May 1957	35.97	510,000	3 Oct 1927 to present

(1) Regulating Flood Stages
(2) Contributing Area
(3) Not Determined
(4) Slightly Different Location

NOTE: Flow and stage data taken from published information shown on the USGS website.

TABLE 4-7

INFLOW VOLUME FREQUENCY (Jan 1940 - Dec 2009)
MONTHLY INFLOW VOLUME IN 1,000s of ACRE-FEET

	Frequency of Occurrence in Years					
Month	2	5	10	25	50	100
Jan	162	331	490	794	1,020	1,340
Feb	133	416	654	835	1,500	1,600
Mar	328	873	1,360	2,020	2,700	3,350
Apr	423	1,010	1,560	2,053	3,200	4,090
May	652	1,350	1,970	2,203	3,810	4,810
Jun	588	1,220	1,810	2,151	3,710	4,800
Jul	413	919	1,390	2,030	2,860	3,690
Aug	185	538	846	1,441	1,770	2,250
Sep	180	500	804	1,318	1,530	1,620
Oct	197	630	1,150	1,990	2,350	3,340
Nov	188	550	862	1,600	2,300	3,290
Dec	163	427	686	842	1,510	1,610

4-09. Channel and flooding characteristics. The regulating channel capacities on the Arkansas River downstream of Keystone Dam are estimated to be: (1) 105,000 c.f.s. at Sand Springs, Oklahoma, (2) 105,000 c.f.s. at Tulsa, Oklahoma, and (3) a flood stage of 22.0 feet (150,000 c.f.s.) at Van Buren, Arkansas. Rating curves for the Ralston, Tulsa, Haskell, Muskogee and Van Buren gages on the Arkansas River are shown on Plates 4-5, through 4-9, and rating curves for the Dover, Guthrie and Ripley gages on the Cimarron River are shown on Plates 4-10 through 4-12. A gage that previously existed at Perkins was replaced by the gage on State Highway 33 near Ripley after sufficient measurements were taken to establish a rating curve. Rating curves used by the Water Management Section are adjusted to changing conditions and are maintained in current status. The channel between the Kansas-Oklahoma state line and Keystone Dam ranges in width from 600 to 2,500 feet and the banks are 10 to 12 feet high. Downstream of Keystone Dam the width of the channel ranges between 600 and 3,000 feet and the banks are 10 to 20 feet high. Crest travel time from Keystone Dam to Van Buren, Arkansas is about 45 hours. A simplified diagram showing crest travel time is shown on Plate 4-13. Travel time varies with the magnitude of the flood; therefore this diagram should be used as a guide only.

4-10. Upstream Structures. Operational structures upstream of Keystone Dam are: (1) Great Salt Plains Lake in Oklahoma on the Salt Fork of the Arkansas River; (2) Kaw Lake in Oklahoma on the Arkansas River; (3) John Martin Reservoir in Colorado on the Arkansas River; (4) El Dorado Lake in Kansas on the Walnut River; and (5) Cheney Reservoir in Kansas on the North Fork of the Ninnescah River.

4-11. Downstream Structures. Structures located downstream of Keystone Lake in the Arkansas River Basin include the following:

Arkansas River

Webbers Falls Lock & Dam #16 and Reservoir
Robert S. Kerr Lock & Dam #15 and Reservoir
W. D. Mayo Lock and Dam #14

Verdigris River Basin

Toronto Lake
Fall River Lake
Elk City Lake
Pearson-Skubitz Big Hill Lake
Oologah Lake
Skiatook Lake
Birch Lake
Copan Lake
Hulah Lake
Newt Graham Lock and Dam #18
Chouteau Lock and Dam #17

Grand (Neosho) River Basin

Council Grove Lake
Fort Gibson Lake
Marion Reservoir
John Redmond Dam & Reservoir
Grand Lake O' The Cherokees
Lake Hudson

Canadian River Basin

Optima Lake
Lake Meredith
Lake Thunderbird
Fort Supply Lake
Canton Lake
Eufaula Lake
Arcadia Lake

Illinois River Basin

Tenkiller Ferry Lake

Polecat Creek

Heyburn Lake

Poteau River Basin

Wister Lake

Also, the City of Tulsa constructed the Zink Lake low water dam near river mile 522.0 on the Arkansas River.

4-12. Economic Data.

a. Population. The population of counties traversed by the Arkansas River downstream of Keystone Dam and the larger cities in those counties are shown in Table 4-8.

b. Agriculture. Agriculture has long been an important factor in the economy of the Arkansas River Basin. The climate, topography, and soil are all suitable for diversified farming, with the uplands used principally for grazing livestock and for hay production. Principal cash crops grown in the region are wheat, soybeans, sorghums, corn, pecans, and garden truck. Production and annual value of the major crops in the flood plain downstream of Keystone Dam are shown in Table 4-9.

c. Industry. Manufacturing is the largest industry in the region followed by retail and wholesale trade. Tables 4-10A, 4-10B, and 4-10C display the major industries in the City of Tulsa and Wagoner and Muskogee counties along with corresponding data on number of establishments, sales, annual payroll, and employees.

d. Flood Damages. The estimated average annual flood damages prevented by Keystone Dam on the Arkansas River are presented in Table 4-11. The top five flood events, in terms of flood damages prevented, to pass through Keystone Dam are presented in Table 4-12. Plates 4-14 through 4-17 show structural loss and area curves for reaches along the Arkansas River from Keystone Dam downstream to the vicinity of Fort Smith, Arkansas.

TABLE 4-8

POPULATION OF COUNTIES AND CITIES
DOWNSTREAM OF KEYSTONE DAM

County	Major Cities	U.S. Census Population			% Change (2000-2010)
		1990	2000	2010	
OKLAHOMA					
Tulsa County		503,341	563,299	603,403	7.12
	Tulsa	367,302	393,049	391,906	-0.29
	Jenks	7,493	9,557	16,924	77.08
	Bixby	9,502	13,336	20,706	55.26
Wagoner County		47,883	57,491	73,085	27.12
	Coweta	6,159	7,139	9,943	39.28
Muskogee County		68,078	69,451	70,990	2.22
	Haskell	2,143	1,765	2,007	13.71
	Muskogee	37,708	38,310	39,223	2.38
Haskell County		10,940	11,792	12,769	8.29
	Stigler	2,574	2,731	2,685	-1.68
Sequoyah County		33,828	38,972	42,391	8.77
	Sallisaw	7,122	7,989	8,880	11.15
1990 Census, 2000 Census, 2010 Census http://factfinder2.census.gov					

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TABLE 4-9

ANNUAL VALUE OF CROPS
ARKANSAS RIVER
DOWNSTREAM OF KEYSTONE DAM

Crops	Keystone D.S. to Verdigris River		Verdigris River to Illinois River		Illinois River to Ft. Smith		Total	
	Acres	**Value ($)**	**Acres**	**Value ($)**	**Acres**	**Value ($)**	**Acres**	**Value ($)**
Corn	1,800	375,100	-	-	-	-	1,800	375,100
Alfalfa	5,900	1,312,840	3,320	783,350	9,630	2,272,190	18,850	4,368,380
Garden Truck	4,100	4,165,600	1,280	1,300,480	3,720	3,779,520	9,100	9,245,600
Soybeans	28,920	3,785,560	11,670	1,623,570	34,020	4,732,990	74,610	10,142,120
Grain Sorghum	1,800	409,990	-	-	-	-	1,800	409,990
Pecans	4,250	3,242,750	-	-	-	-	4,250	3,242,750
Wheat	29,810	3,563,040	12,810	1,640,350	37,330	4,780,180	79,950	9,983,570
Other	2,250	409,990	750	456,430	2,180	1,337,220	5,180	2,203,640
Total	**78,830**	**17,264,870**	**29,830**	**5,804,180**	**86,880**	**16,902,100**	**195,540**	**39,971,150**

Yield Rates from Oklahoma State University Crop Enterprise Budgets 2009
2009 Current Normalized Prices, Acres maintained from WCM

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TABLE 4-10A

2002 ECONOMIC CENSUS FOR TULSA COUNTY, OK

NAICS Code	Industry Description	Number of Establishments	Sales, Shipments, Receipts, or Revenue ($1,000's)	Annual Payroll ($1,000's)	Number of Employees
31-33	Manufacturing	1,103	9,713,750	1,530,587	41,309
42	Wholesale trade	1,341	9,859,729	690,015	16,650
44-45	Retail trade	2,458	7,298,312	709,855	36,958
51	Information	374	N	D	j
53	Real estate & rental & leasing	849	740,897	156,760	5,733
54	Professional, scientific, & technical services	2,294	1,752,442	716,907	16,900
56	Administrative & support & waste management & remediation service	981	1,256,713	550,487	27,828
61	Educational services	123	102,506	38,859	1,561
62	Health care & social assistance	1,766	3,088,367	1,254,084	37,415
71	Arts, entertainment, & recreation	224	186,942	48,538	3,278
72	Accommodation & food services	1,337	962,292	280,883	24,653
81	Other services (except public administration)	1,194	696,915	183,439	7,744

Source: U.S. Bureau of the Census, 2002 Economic Census, * 2006 County Business Patterns

Key to Table:
D = Withheld to avoid disclosing data for individual companies; data are included in higher totals
j = 10,000 to 24,999 employees
N = Not available or not comparable

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TABLE 4-10B

2002 ECONOMIC CENSUS FOR WAGONER COUNTY, OK

NAICS Code	Industry Description	Number of Establishments	Sales, Shipments, Receipts, or Revenue ($1,000's)	Annual Payroll ($1,000's)	Number of Employees
31-33	Manufacturing	81	262,262	52,896	1,661
42	Wholesale trade	38	73,525	4,885	150
44-45	Retail trade	109	202,504	16,108	1,049
51	Information	4	N	D	a
53	Real estate & rental & leasing	32	8,238	1,313	75
54	Professional, scientific, & technical services	46	9,120	3,312	201
56	Administrative & support & waste management & remediation service	42	17,441	9,167	586
61	Educational services	3	D	D	b
62	Health care & social assistance	59	31,909	12,498	631
71	Arts, entertainment, & recreation	11	7,662	2,539	134
72	Accommodation & food services	48	22,360	5,805	628
81	Other services (except public administration)	42	9,455	1,951	102

Source: U.S. Bureau of the Census, 2002 Economic Census

Key to table:
a = 0 – 19 employees
b = 20 – 99 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher totals
N = Not available or not comparable

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TABLE 4-10C

2002 ECONOMIC CENSUS FOR MUSKOGEE COUNTY, OK

NAICS Code	Industry Description	Number of Establishments	Sales, Shipments, Receipts, or Revenue ($1,000's)	Annual Payroll ($1,000's)	Number of Employees
31-33	Manufacturing	78	1,185,528	184,242	4,867
42	Wholesale trade	81	332,276	29,674	1,139
44-45	Retail trade	316	655,782	61,118	3,475
51	Information	28	N	13,146	424
53	Real estate & rental & leasing	61	30,471	6,246	287
54	Professional, scientific, & technical services	93	42,764	16,274	604
56	Administrative & support & waste management & remediation service	74	46,258	24,114	1,069
61	Educational services	4	D	D	a
62	Health care & social assistance	201	330,642	145,783	5,551
71	Arts, entertainment, & recreation	19	22,379	3,706	291
72	Accommodation & food services	134	70,746	19,603	2,151
81	Other services (except public administration)	99	32,390	9,089	493

Source: U.S. Bureau of the Census, 2002 Economic Census
Key to table:

a = 0 – 19 employees
D = Withheld to avoid disclosing data for individual companies; data are included in higher totals
N = Not available or not comparable

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TABLE 4-11

AVERAGE ANNUAL FLOOD DAMAGES PREVENTED
DOWNSTREAM OF KEYSTONE DAM

Average Annual Flood Damages Prevented by Keystone Dam		
Years in Operation	**Cumulative Damages Prevented (2008 $1,000's)**	**Average Annual Damages Prevented (2008 $1,000's)**
43	1,395,080	32,440

TABLE 4-12

TOP FIVE FLOOD EVENTS
DOWNSTREAM OF KEYSTONE DAM

Top Five Flood Events [1]		
Year	**Damages Prevented ($1,000's)**	**Damages Prevented (2008 $1,000's)**
1987	266,940	503,460
1974	33,270	136,880
1975	32,560	122,320
2007	101,530	105,900
1986	28,290	54,740

(1) The years of 1993 and 1995 were also significant, with flood damages prevented of $52.7 million and $50.5 million (in year 2008 dollars), respectively.

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V - DATA COLLECTION AND COMMUNICATION NETWORKS

5-01. Hydrometeorological Stations.

a. Facilities. The Water Management Section, Hydrology-Hydraulics Branch, Tulsa District; the NWS; and the U.S. Geological Survey (USGS) cooperate to collect data and maintain a reliable communication network. All pertinent reporting observation stations are shown on Plate 5-1. Pool elevation data are provided by a bubbler gage connected to a digital recorder and wired to a transmitting type Data Collection Platform (DCP). This equipment is located in a gage house on the dam.

All stream gaging stations are automated gages consisting of float wells or bubbler gages connected to digital recorders and DCPs. The following stream gages are key stations used in forecasting inflows to Keystone Lake: Tonkawa on the Salt Fork of the Arkansas River; Blackwell on the Chikaskia River; Pawnee on Black Bear Creek; Ralston on the Arkansas River; and Dover, Guthrie, and Ripley Highway 33 Bridge on the Cimarron River. The following gages have been designated as key stations for regulation: Tulsa, Haskell, and Muskogee in Oklahoma and Van Buren, Arkansas. Stream flow measurements downstream of Keystone Dam are made by the USGS at the 11th Street Bridge in Tulsa. Automated stream gaging stations are equipped with automated rain gages that provide precipitation data transmitted along with stage data. The NWS also maintains a network of local observer stations throughout Tulsa District. Precipitation and stream gaging stations are shown on Plate 5-1.

b. Reporting. The reporting procedures for precipitation and stream gaging stations are on a cooperative basis with the NWS and the USGS. The reporting of data from pool elevation and stream gaging stations has been automated by using DCPs that record data hourly and transmit the data every hour or when a threshold value is exceeded. The data are transmitted via Geostationary Operational Environmental Satellite (GOES) to a downlink and computer facility owned and operated by the National Oceanic and Atmospheric Administration (NOAA) near Washington, D.C. The data are then transmitted to a domestic satellite (DOMSAT) that passes the data to the Tulsa District's Receive Only Terminal (DROT). The data from the NOAA computer facility may also be transferred via the Internet. When received, the river stage is converted to flow and lake elevation is converted to storage. All the data are then stored in a database on the Tulsa District Water Control Data System (WCDS) for access when needed. DCPs also report rainfall data in the same way.

In addition to the DCP data, observer rainfall data are collected and stored in the computer system for use in forecasting. Observers telephone the NWS offices in this region and the NWS then encodes the data into a Standard Hydrologic Exchange Format (SHEF). The data are then transferred to the WCDS by electronic data transmission from the Arkansas-Red Basin River Forecast Center. Once the data are received, they are decoded and handled similarly to the DCP data. Informative display

of all data is possible by using several versatile computer programs developed for use on the WCDS. Table 5-1, located in the Supplemental Tables Section, contains a list of automated stream gage and rainfall stations. Detailed instructions on reporting criteria are presented in Exhibit B, Standing Instructions to Lake Manager.

c. Maintenance. Maintenance and repair of stream gages are the responsibility of the administering agency. Both the Corps of Engineers and the USGS have stream-gaging equipment in the Arkansas River Basin. The Water Management Section, Hydrology-Hydraulics Branch, Tulsa District, is charged with the responsibility for the equipment placed by the Corps of Engineers.

5-02. Water Quality Stations.

a. Facilities. Water quality samples have been taken at Tulsa and Haskell, Oklahoma. Water quality sample data have not been recorded for Keystone Lake with any regularity. These data are reported directly to the Tulsa District.

b. Reporting. Water quality samples taken by Corps of Engineers personnel will be reported directly to the Tulsa District.

c. Maintenance. There are no permanent facilities to maintain.

5-03. Sediment Stations.

a. Facilities. Tulsa District has established seventy-nine (79) sedimentation ranges upstream of Keystone Dam and twenty-eight (28) degradation ranges downstream of Keystone Dam to be used for sedimentation and degradation measurements (paragraph 4-04). Keystone Lake bathymetry is surveyed periodically to compute sediment deposition and to compute updated lake area/capacity data. The sedimentation and degradation ranges are shown on Plates 2-3 through 2-5.

b. Reporting. Sediment surveys are periodically made for Keystone Lake. The last re-surveys were done in 2005 (conservation pool bathymetric survey) and 2008 (flood pool LIDAR survey).

c. Maintenance. Maintenance on the sediment data is performed by Tulsa District.

5-04. Recording Hydrologic Data. Hydrologic information is recorded as it is received by the Water Management Section as follows:

a. Stages and Discharges. The raw data that the Water Management computer retrieves from the central computer are stored as they are received. These raw data are then sorted by station and stored again. Several computer programs convert the raw data into stage/pool elevation data and the corresponding flow/storage values as determined from rating curves. These processed data are then stored in two databases.

To prevent the databases from filling, they are periodically archived on tape for permanent storage. Stream flow measurements made by the USGS are reported to the Hydrology and Hydraulics Section. The measurements are entered into the database for storage.

b. Precipitation. Precipitation data from the DCPs and the Keystone Lake project office are combined with NWS observer precipitation data that can then be used by computer programs for plotting distribution, determining basin rainfall, and forecasting runoff (see Section VI).

c. Water Quality Data. Water quality data have not been recorded with regularity for Keystone Lake.

5-05. Communication Network. Wire facilities at the Keystone Lake project office consist of local and long-distance telephone service. Radio communication is by a VHF-FM fixed station (call signal WUI-321) capable of reaching local mobile stations, the Tulsa District, stations on the local loop of the Tulsa District and other stations on the north and south loop of the Tulsa District via repeater relay. Maintenance of the telephone lines is the responsibility of the company leasing the lines to the Government. The Tulsa District radio technician makes quarterly inspections of the project's fixed equipment and makes repairs as conditions warrant. To alert the public of impending gate changes, warning horns are located on the conduit gate tower, on the downstream end of the conduit, and on the spillway. Control buttons for these devices are found on the gate control panels.

5-06. Communication with Project.

a. Water Management Section With Project Office. Instructions for the storage and release of water from the lake will be communicated by the Water Management Section to the responsible project operating personnel for the implementation of the provisions set forth in Section IX of this manual. This communication will normally be made by telephone but could on occasion be made by VHF-FM radio. The reports by the project office, described in paragraph 5-07. and Exhibit B of this manual, will be communicated directly to the Water Management Section. Should communication between the project and Tulsa District be disrupted, the Lake Manager will, on his or her own initiative, direct regulation of the lake according to emergency regulations as required in Section VII and Exhibit B of this manual. A chart, "Organization For Flood Control Regulation" is shown on Plate 5-2.

b. Between Project Office and Others. Communications between project personnel and other Federal, State, and local agencies will be sufficient to facilitate the coordination described in Section IX of this manual.

5-07. Project Reporting Instructions. Hydrologic data items affecting release of water, confirmation of change in releases as instructed, complaints, operating machinery failure, or out-of service times for maintenance shall be reported to the Water Management Section as they occur.

The following data should be included in the daily report to the Water Management Section from all flood control storage projects with hydropower. Data are typically reported by telephone, fax, and email. Data collected will be reviewed and input into the Water Management Section's data base before 10 a.m. and published to the lake data morning report located at http://www.swt-wc.usace.army.mil/old_resvrept.htm. See plate 5-3 for lake data reporting details.

a. As of 8 a.m. Each Weekday.

1) Pool elevations at 12 noon, 4 p.m., and 12 midnight of the previous day and the current 8 a.m. pool elevation and tailwater elevation (if available).

2) The total precipitation amounts for the previous 24-hour period (7 a.m. to 7 a.m. time period).

3) The current wind direction and wind speed (Beaufort scale).

4) Water supply withdrawal or release for previous day (if available).

5) The average power discharge in day second feet (d.s.f.) for the previous 24-hour period (midnight to midnight).

6) The net power generation in megawatt hours (MWh) for the previous 24-hour period (midnight to midnight.)

7) The total discharge in d.s.f. for the previous 24-hour period (midnight to midnight).

8) The 8 a.m. instantaneous power discharge in c.f.s.

9) The 8 a.m. instantaneous total discharge in c.f.s.

10) The total hourly discharge in c.f.s. for the previous 24-hour period (midnight to midnight).

11) The current gate setting and any gate changes made during the past 24-hour period including the time and pool elevation (and tailwater elevation if necessary) when the change was made.

b. As of 8 a.m. Each Monday.

1) The same data from the weekend as required in 5-07.a. above.

2) The current pool elevation readings from the pool gage, the recording chart or tape, the shaft encoder or data logger, and the wire weight or staff gage. If wind or weather prevents readings on Monday, then these readings can be taken on the next day that weather permits.

c. Weekends and Holidays.

1) Daily reports are not required to be submitted on weekends and holidays except during flood periods.

d. During Flood Periods.

1) During flood periods, weekend and holiday reports should include the same data as required in 5-07.a. above as well as the 8 a.m. pool elevation from the pool gage.

2) In addition to the data in 5-07.a., 5-07.b., and 5-07.c. above, additional reports of lake elevations may be requested by Water Management Section personnel.

5-08. Warnings. It is the responsibility of the Lake Manager to initiate a warning to the Tulsa District and local law enforcement agencies if emergency situations develop. They have the responsibility to properly recognize emergency situations and to seek assistance from supervisory offices, if time permits. They must be knowledgeable of conditions that constitute an emergency such as a dam failure possibility. The downstream population should be notified as early as possible of a potential problem. Initial notification by project personnel will include (listed by priority), Chief of Operations, Chief of Operations Technical Support, Chief of Engineering and Construction, Chief of Emergency Management, as set forth in the Operations and Maintenance Manual Volume II, Keystone Lake, Flood Emergency Plan, dated Mar 2010. The Keystone Lake project personnel have compiled a list of downstream contacts for use in emergency situations.

5-09. Frequency of Gate Changes. During flood periods, gate changes may be directed by the Water Management Section at any time. The initial transition to flood releases or vice versa may require gate changes every hour. When floodwater has significantly risen into the flood control pool, gate changes can be expected two or more times daily. Only under the most unusual circumstances will changes be ordered more frequently than once every hour.

VI - HYDROLOGIC FORECASTS

6-01. General. Hydrologic forecasts are necessary in predicting stream flow upstream and downstream of Keystone Lake to determine if and when releases should be made.

a. Role of Corps of Engineers. Hydrologic forecasts are made by the Water Management Section, Tulsa District, for use in the regulation of lakes for flood control and other authorized purposes and for the benefit of Corps of Engineers' construction projects and flood management activities. As distinguished from the NWS, who furnishes weather and flood forecasts to the public, the Tulsa District furnishes information on current and forecasted lake levels and lake releases, along with technical advice. The Water Management Section lake levels recording, telephone number (918) 669-7521, is listed in the Tulsa telephone directory to provide the public a means of obtaining current lake information such as pool levels and discharges. General news releases are made by the Public Affairs Office which is kept fully informed of the hydrologic situation as appropriate. Further discussion of the role of the Corps of Engineers in hydrologic forecasts is presented in Section V of the Arkansas River Basin Water Control Master Manual.

b. Role of Other Agencies. The NWS, Tulsa, Oklahoma, is the official agency making flood forecast information available to the public. This information is distributed by the NWS Automation of Field Operations and Services (AFOS) network to subscribing government agencies and the various news media. The NWS issues routine scheduled reports containing the following forecasts:

(1) Weather forecasts (daily, severe weather, and 5-day extended).

(2) National weather summaries and additional details for the five south-central states (four times daily).

(3) Quantitative precipitation forecasts (four times daily – one 24-hour and one 48-hour quantitative precipitation forecast and two 6-hour quantitative precipitation forecasts).

(4) Three-day river stage forecasts (when available).

(5) Rainfall required to produce bank full stages (weekly).

(6) Urgent priority messages such as severe weather warnings, watches, forecasts and statements, and instructions from Civil Defense during emergency conditions are transmitted immediately, regardless of scheduled traffic. Unscheduled traffic, including the following, is sent when appropriate.

(a) Damage reports.
(b) Road information and winter weather conditions.

(c) River and flood warning bulletins, forecasts, and statements.
(d) Thirty-day forecast.
(e) Road information and winter weather conditions.

(7) Percent chance of precipitation (twice daily).

6-02. Flood Conditions Forecasts.

a. Requirements. Flood condition forecasts are necessary whenever substantial rainfall has occurred on the basin upstream of or downstream of Keystone Dam. Personnel in the Water Management Section have developed a flood-forecasting model for Keystone Lake. This model was calibrated to historical flood events. Basin subdivisions contained in the forecasting model are presented on Plate 6-1. To use this model the following data are required:

(1) Rainfall for stations listed in Table 5-1.

(2) Keystone Lake pool elevation for time of forecast.

(3) Flood hydrographs for stream gages listed in Table 5-1.

(4) Releases from Keystone Lake, including projected releases, from time of forecast until the end of the forecast period.

b. Methods. Inflow forecasts are made using a slightly modified HEC-1 computer program. Precipitation data are received from the NWS observers, the DCPs by the water control computer, the Oklahoma Mesonet, and also the NWS Stage III digital radar. The average precipitation over the project basin is computed by a computer program called VIEWRAIN. The VIEWRAIN program takes the DCP data and plots isohyetal maps of 24-hour rainfall. The VIEWRAIN program also computes the basin and subbasin average rainfalls for input into the HEC-1 forecasting model. The HEC-1 program uses the hourly DCP rainfalls to distribute the subbasin average rainfalls. Beginning loss rates are chosen based upon historical storm reproductions. Rainfall excess is computed by subtracting the applicable losses from the incremental rainfall amounts. One-hour unit hydrographs are computed using Snyder's coefficients or are entered directly into the data file for each subarea. Flood hydrographs are computed by applying the rainfall excess to the unit hydrographs. Computed flood hydrographs are compared with observed flood hydrographs for gages listed in Table 5-1. Loss rates are adjusted and the HEC-1 model is rerun until the computed and observed hydrographs converge. Calibrated loss rates are applied to un-gaged subareas and flood hydrographs are combined and routed to compute an inflow hydrograph. Using projected releases from Keystone Lake, the inflow hydrograph is routed through the lake to determine elevations. Flood control releases are projected based upon conditions on the Arkansas River System and following procedures described in section V of the Arkansas River Basin Water Control Master Manual. Unit hydrographs are presented on Plates 6-2 through 6-6.

6-03. Conservation Purpose Forecasts.

a. Requirements. Conservation forecasts may be requested by Project personnel for endangered species protection, hydropower, to predict pool levels during fish spawning season, for special recreation events, and for water supply. Forecasts may also be requested for water quality.

b. Methods. Forecasts for conservation purposes during non-flood periods would rely largely on statistical interpretation of historical data. The flow duration curve, Plate 4-3, and the peak inflow probability curve, Plate 4-4, would be considered with NWS forecasts in making conservation forecasts during non-flood periods.

6-04. Long-Range Forecasts.

a. Requirements. The regulatory decision involved in evacuating stored floodwater, sustaining yield during low flow periods, and maintaining constant or slowly changing pool levels for conservation purposes is dependent on accurate estimates of the water volume that will pass through the lake.

b. Methods. Reliable methods for long range runoff forecasts are not presently available. The NWS publishes an "Average Monthly Weather Outlook" semi-monthly, which may be used as an estimate of the trend of the weather but should not be given too much weight for one forecast, especially for a specific point. The NWS forecasts described in paragraph 6-01.b. are more useful in a shorter range.

6-05. Drought Forecasts. Droughts can be forecast when runoff is dependent upon snowmelt by measuring snow pack in the mountains. However, on projects where runoff is a result of a rainfall event, as in the Tulsa District, no techniques are available at this time to forecast droughts. Future pool drawdowns can be forecast by estimating water supply usage and evaporation rates forecast by estimating water supply usage, hydropower production, and evaporation rates.

VII - WATER CONTROL PLAN

7-01. General Objectives. The primary objectives of the Keystone Lake project are flood control, water supply, hydropower production, navigation, recreation, and fish and wildlife. Keystone Lake is operated as a unit in a multi-purpose system for optimal flood control providing benefits in the Arkansas River Basin. Flood releases from Keystone Lake will be made in accordance with the predicted runoff from the uncontrolled area downstream, the allowable stage for the downstream control points, the predicted volume of inflow into the lake, and the proportion of available storage remaining in the various lakes in the system. All of the flood control storage will be utilized to provide optimal benefits, categorized as method "A" in paragraph 3-3.c.(2)(b) of EM 1110-02-3600, dated 30 Nov 1987.

7-02. Major Constraints. The channel capacity downstream of Keystone Dam is currently estimated at 105,000 c.f.s. while the spillway and outlet works are capable of discharging 592,280 c.f.s. at the top of the flood control pool (elevation 754.0 feet). The invert of the outlet works is at elevation 657.0 feet which is the lowest elevation from which water can be released from the dam. The recession of floodwaters on the lower Arkansas River is to be monitored so that releases from the dam will coincide with the natural recession of the river to below bank full. The limiting non-damaging flows at the Tulsa and Haskell gages on the Arkansas River are currently estimated at 105,000 and 135,000 c.f.s. (stages of 15 and 18 feet), respectively. The navigation taper, as described in paragraph 7-03. of the Arkansas River Basin Water Control Master Manual, is to be followed.

7-03. Overall Plan for Water Control.

a. General. Keystone Lake is regulated as a unit in a multi-purpose system for the benefit of water resources in the Arkansas River Basin. Development of these water resources is discussed in the Arkansas River Basin Water Control Master Manual, while the specific purposes of each of the various projects are detailed in the appropriate Appendices. The Keystone Lake watershed contains many farm ponds, city lakes, storm water detention facilities, etc. that hold water for the benefit of flood control, agriculture, recreation, and other uses. However, these structures do not significantly affect flood operations in the Keystone Lake watershed. Cheney Reservoir and Great Salt Plains, Kaw, and El Dorado Lakes all influence the operation of Keystone Lake.

b. System Regulation. Keystone Lake will be regulated in a system with Kaw Lake for control of floods on the Arkansas River from Keystone Dam to Muskogee, Oklahoma and in the total Arkansas River system for control of floods on the Arkansas River from Muskogee, Oklahoma to Van Buren, Arkansas. When floodwaters are being accumulated in the system, each lake shall be regulated to retain equivalent flood control capabilities. Priority for releases will be given to the lakes with the least amount of flood storage available, considering predicted inflow into the lake, conditions downstream, and curve classification in the Master Manual. Keystone Lake is classified

as curve “B” on plate 7-54 of the Master Manual. Before any floods operations commence, it is the responsibility of the water manager to review Interim Risk Reduction Measures (IRRM) or other deviations that may affect the system regulation plan. Section VII of the Arkansas River Basin Water Control Master Manual provides detailed information on the Arkansas River System operation. In addition, Keystone Lake will be regulated for fish and wildlife, water quality, water supply, navigation, and hydroelectric power.

c. Kaw and Keystone Lakes Subsystem Regulation. The Arkansas River system regulation plan discussed in the previous paragraph will be used in determining a release schedule for Keystone Lake. This release schedule will be the evacuation rate for the total flood control storage (storage volume plus inflow) in Keystone and Kaw Lakes. When Keystone Lake is forecast to have a greater percent of flood storage utilized than Kaw Lake and the release schedule for Keystone Lake is set as described above, a release schedule for Kaw Lake would be determined that will strive to equalize the flood control storage in the projects. If Kaw Lake has or is forecasted to have a greater percent of flood control storage utilized, the releases from Kaw Lake will be at channel capacity or at a rate which will strive to balance the subsystem. The releases as determined by the Arkansas River System regulation for Keystone Lake will not be reduced solely to achieve a balance between the two lakes. When a reasonable subsystem balance is achieved, releases from Kaw Lake will be at a rate which will continue the balance and empty the subsystem at approximately the same time. The release schedule shown on Plate 7-1 (Seasonal Guide Curve for Release Rates) will be used as a guide in determining Keystone Lake releases if the releases are not controlled by the Arkansas River system regulation plan.

7-04. Standing Instructions to Lake Manager. During flood periods, Keystone Lake will be regulated in accordance with the normal flood control regulations as directed in subparagraph 7-05.a. and Exhibit B of this manual. Instructions for the storage and discharge of flood water are to be issued by the Water Management Section. In the event communication with Tulsa District is disrupted, the lake regulation is the responsibility of the Lake Manager and is to be regulated in accordance with subparagraph 7-05.b. and Exhibit B of this manual. In addition, the Lake Manager will immediately make every effort to re-establish communications with Tulsa District. The Lake Manager will make daily observations of the weather station and pool level data and report those observations as directed in paragraph 5-07.a. through 5-07.d., and also repeated in Exhibit B. Should an emergency situation occur, in which communication is not lost, such as inoperable gates, a drowning accident, excessive trash in gates, a broken buoy line, or power outage, the Water Management Section will be notified immediately.

7-05. Flood Control.

a. Normal Flood Control Regulations. Keystone Lake will be regulated for optimal flood reductions on the Arkansas River from the dam to Van Buren, Arkansas. The following regulations, as shown in Table 7-1, will govern releases from Keystone Lake.

During flood control regulation the tainter gates are to be operated at uniform settings with no more than a 1-foot difference in opening between any gates.

TABLE 7-1

NORMAL FLOOD CONTROL REGULATION SCHEDULE
KEYSTONE LAKE
ARKANSAS RIVER, OKLAHOMA

LAKE STAGE	POOL CONDITIONS	REGULATION
Below 723.0	Rising	Releases will be made to maintain elevation 723.0 feet or meet demand for hydroelectric power.
723.0 - 754.0 and forecasted not to exceed 754.0	Rising	Make releases using the following schedule as a guide, except that the release, when combined with intervening flow downstream, shall not exceed a 15.0 foot stage on the Arkansas River at the Tulsa gage (currently estimated 105,000 c.f.s.), an 28-foot stage at the Muskogee gage (currently estimated flow of 120,000 c.f.s.), or a 22.0 foot stage at the Van Buren gage (currently estimated 150,000 c.f.s.) unless superseded by the requirements in Chapter 7 of the Arkansas River Basin Water Control Master Manual. If the flows exceed any of those listed above, no release will be made until the flows recede below flood stage. NOTE: Verify that channel has not changed such that Haskell, 18.0 foot stage (currently estimated 135,000 c.f.s.), is not the controlling gage upstream of Van Buren gage.

TABLE 7-1 (continued)

Release Schedule

Pool Stages	Maximum Allowable Release Rates (c.f.s.) [1]
723.0 – 725.4 [2]	12,000
725.4 – 734.1 [2]	60,000
734.1 – 754.0	105,000

[1] Releases may be modified to meet requirements of the Arkansas River system operating plan.

[2] Follow the Seasonal Guide Curve shown on Plate 7-1.

LAKE STAGE	POOL CONDITIONS	REGULATION
754.0 - 757.0 or forecasted to exceed 754.0	Rising	Releases shall be made such that the pool elevation will not exceed 757.0 feet, if possible. If the forecasted inflow will cause the pool to exceed elevation 757.0 feet (top of induced surcharge pool) releases shall be directed by the District Commander, his/her designated representative, or the highest ranking official available in the Engineering and Construction Division, after coordinating the situation with Southwestern Division (SWD). Plate 7-2, Spillway Gate Regulation Schedule – Inflow Parameter, can be used as a guide for determining releases. If the pool rises to elevation 757.0 feet, releases will be made equal to the inflow. Releases will be made by operating all the spillway gates at uniform openings.
757.0 or above	Rising	Gates shall be opened to maintain elevation 757.0 feet or until the gates are in the full opened position.

TABLE 7-1 (continued)

LAKE STAGE	POOL CONDITIONS	REGULATION
757.0 or above	Falling	The maximum gate opening attained shall be held until the pool elevation recedes to elevation 757.0 feet.
757.0 - 754.0	Falling	The maximum gate opening attained shall be held until the pool level recedes an amount sufficient to permit lowering the spillway gates one-half foot without lowering the discharge below inflow. A margin of not less than one-fourth foot between the lake level and the top of the spillway gates shall be maintained at all times. This regulation shall be repeated until the lake level nears elevation 754.0 feet, at which time the outflow shall be made equal to the inflow or the maximum release permissible (as stated below), whichever is greater.
754.0 - 723.0	Falling	Make releases according to the following schedule, except that the release, when combined with intervening area flows downstream, shall not exceed those stages listed under the above rising pool conditions.

Release Schedule

Pool Stages	Maximum Allowable Release Rates (c.f.s.) [1]
754.0 – 734.1	105,000
734.1 – 725.4 [2]	60,000 + Inflow [3]
725.4 – 723.0 [2]	12,000 + Inflow [3]

[1] Releases may be modified to meet requirements of the Arkansas River system Operating Plan.
[2] Follow the Seasonal Guide Curve shown on Plate 7-1.
[3] Forecasted inflow over a 2- to 5-day period.

b. Emergency Flood Control Regulations. When communication with Tulsa District is disrupted, the Lake Manager will, on his or her own initiative, direct regulation of the lake in accordance with the schedule shown in Table 7-2 until communication is

restored. In addition, the Lake Manager will make every effort to re-establish communication with Tulsa District. Plate 7-3 (Inflow vs. Rate of Rise Nomograph) will be used by the Lake Manager during emergency flood operations to determine the 6-hour inflow. The spillway gates shall be operated at uniform openings as discussed in paragraph 7-05.a.

c. Constraints. The regulation schedules provide that the channel capacity of 105,000 c.f.s. downstream of the dam is not to be exceeded insofar as practicable. Floodwaters will be released as rapidly as practicable with consideration given to minimizing flooding of low-water crossings and low-lying farmland while maximizing benefits to authorized purposes. The significance of the stages or discharges is shown on the stage-damage curves at the control points (see Plates 4-14 through 4-17).

d. Operational Curves. As previously noted, the Seasonal Guide Curve for Release Rates is shown on Plate 7-1, the Spillway Gate Regulation Schedule-Inflow Parameter is shown on Plate 7-2, and the Inflow vs. Rate of Rise Nomograph is shown on Plate 7-3. The Spillway Rating Curves for Partial and Full Gate Openings are shown on Plate 7-4 and the Sluice Gate Rating Curves are on Plate 7-5. Evaporation curves are shown on Plate 7-6. Elevation-area-capacity curves are shown on Plate 7-7. Table 7-3, shown in the Supplemental Tables Section of this report, shows the elevation vs. area and capacity data. Plate 7-8 shows the tail water rating curve. Rating curves used by the Water Management Section are adjusted for changing conditions and are maintained in current status.

TABLE 7-2

EMERGENCY FLOOD CONTROL REGULATION SCHEDULE
KEYSTONE LAKE
ARKANSAS RIVER, OKLAHOMA

LAKE STAGE	POOL CONDITIONS	REGULATION
Below 723.0	Rising	Continue the releases being made.
723.0 - 748.0	Rising	Maintain releases being made until communication is restored or 12 hours have elapsed. After 12 hours, if communication has not been restored continue the release being made at the time communication was lost. Should the lake level rise above elevation 748.0 feet (approximately 75% of flood pool) during the 12-hour period, releases in accordance with the minimum discharge curve on the "Spillway Gate Regulation - Inflow Parameter" (Plate 7-2), shall be started immediately.
748.0 - 754.0	Rising	(1) Releases shall be made in accordance with the minimum discharge curve on the "Spillway Gate Regulation Schedule – Inflow Parameter" (Plate 7-2). (2) At no time when the lake level is above 748.0 feet and rising shall releases be decreased
754.0 - 757.0	Rising	Releases shall be made every hour in accordance with the inflow curves on Plate 7-2, “Spillway Gate Regulation Schedule - Inflow Parameter”. The previous 6-hour time interval shall be used to compute the inflow as shown on Plate 7-3 (use present pool elevation and pool elevation 6-hours earlier). NOTE: At no time when the lake level is above 754.0 feet and rising shall releases be decreased.
757.0 or above	Rising	Releases shall be increased by raising the spillway gates to maintain elevation 757.0 feet or until all gates are fully open.

TABLE 7-2 (continued)

LAKE STAGE	POOL CONDITIONS	REGULATION
757.0 or above	Falling	Maximum spillway gate openings attained shall be maintained until the lake level recedes to elevation 757.0 feet.
757.0 - 754.0	Falling	The maximum spillway gate opening attained shall be held until the lake level recedes an amount sufficient to permit lowering the spillway gates one-half foot without lowering the release below inflow. A margin of not less than one-fourth foot between the lake level and the top of the spillway gates shall be maintained at all times. This operation shall be repeated until the lake level recedes to elevation 754.0 feet. The minimum release rate shall be 105,000 c.f.s.
754.0 - 734.0	Falling	Releases shall be made equal to the previous 6-hour inflow or 105,000 c.f.s. whichever is greater. (See Plate 7-3 for inflow computation example.)
734.0 - 733.0	Falling	Begin a gradual reduction of the release rate (Not to exceed 15,000 c.f.s. per 3-hour period) until the releases are equal to 60,000 c.f.s. or the previous 6-hour inflow, whichever is greater. (See Plate 7-3 for inflow computation example.)
733.0 - 727.0	Falling	Releases shall be made equal to the previous 6-hour inflow or 60,000 c.f.s. whichever is greater. (See Plate 7-3 for inflow computation example.)
727.0 - 725.0	Falling	Begin a gradual reduction of the release rate (Not to exceed 15,000 c.f.s. per 3-hour period) until the releases are equal to 12,000 c.f.s.
725.0 - 723.0	Falling	Maintain releases of 12,000 c.f.s. At elevation 723.0 feet, reduce releases to that of inflow.

7-06. Recreation. Recreation is included as a project purpose; however, there is no storage or releases specifically designated for recreation.

7-07. Water Quality. Keystone Lake has no storage allocated to water quality. However, small short term releases shall be made as necessary to alleviate emergency conditions such as fish kills in the stilling basin. The requirement for a minimum release as stated in the previous manual was removed by the Operation Plan for SWD Hydropower (see Exhibit D) which was adopted in 2010.

7-08. Fish and Wildlife. Fish and wildlife is included as a project purpose; however, there is no authorized storage or releases specifically for this purpose. Operations are occasionally modified (via increased or decreased releases) to protect endangered species and to alleviate conditions such as fish kills. Deviations are sometimes requested for seasonal pool variations to allow higher releases early in the nesting season of the Interior Least Terns. The higher releases encourage the endangered fowl to nest at higher elevations so the nests are less likely to be inundated by uncontrolled runoff during summer rainstorms, and to discourage predators from crossing shallow water and/or land bridges and ravaging the nests.

7-09. Water Supply.

a. General. Keystone Lake has water supply storage of 20,000 acre-feet with a dependable yield of 20 million gallons per day (m.g.d.). Public Service Company of Oklahoma (PSO) has a contract for 18,000 acre-feet. The remaining 2,000 acre-feet has not been contracted (see Table 7-4).

TABLE 7-4

KEYSTONE LAKE WATER SUPPLY

User	Total User Storage (Acre-Feet)
Public Service Company	18,000
Not Under Contract	2,000
Total	20,000

b. Accounting Procedure for Water Supply. Accounting procedures for conservation storage in multipurpose projects have been developed by the Tulsa District and approved by SWD to account for the withdrawal of water from lakes by each

water supply user. Losses are charged to each user in proportion to his average remaining storage. Inflows, after deductions for downstream water rights and vested rights, are credited to the storage account of the user in proportion to his contracted storage. Inflows occurring when the lake is above the conservation pool are passed through the lake, and even though they may be satisfying an annual water right, they will not affect the conservation pool accounting procedure. When conservation storage falls to 75%, monthly accounting of water supply usage is initiated. Each user will periodically be notified of his remaining water supply storage, and when a user's storage is depleted, no withdrawals from storage are made for that user. No accounting is necessary where all conservation storage is contracted for by one user or when the Corps is not the contracting agency.

7-10. Water Rights.

a. General. The Oklahoma Water Resources Board (OWRB) has issued water rights on the Arkansas River downstream of Keystone Lake. These water rights locations and amounts are shown in Table 7-5, located in the Supplemental Tables Section.

b. Regulation Procedure for Water Rights. Releases from inflows to satisfy downstream water rights are made at the request of OWRB which will inform the Water Management Section as to the amount and time distribution of the required release. No withdrawal from storage in the lake is made for downstream water rights unless the water-right holder has contracted storage available in the lake.

7-11. Hydroelectric Power.

a. General. The storage in Keystone Lake between elevations 706.0 feet and 723.0 feet (less 20,000 acre-feet for water supply) has been allocated for hydroelectric power generation. Keystone Dam has two 35,000 kW generators for a total installed capacity of 70,000 kW. The discharge from the two turbines at full power production is about 12,000 c.f.s. at elevation 723 feet. The turbines are used in conjunction with the spillway and outlet works for flood control releases. Flood control releases of 12,000 c.f.s. or less are made through the turbines, if operable. The Water Management Section will notify the Southwestern Power Administration (SWPA) of the required turbine release. The release of water from the conservation storage (below elevation 723.0 feet) will normally be for the production of hydroelectric power as required by SWPA. The turbines (if operable), spillway or outlet works may be used to meet downstream water rights or to alleviate fish distress in the stilling basin.

b. Hydroelectric Power Constraints. In accordance with the Operating Plan for SWD COE Hydropower (Exhibit D) required by North American Electric Reliability Corporation (NERC), the following are hydropower constrains at Keystone Lake. Per the Operating Plan, allowable firm power release is 1,500 c.f.s., or 216 MWh per day. The maximum hydropower drawdown rate in the conservation pool is limited to 1.0 foot per week, and 3.0 feet in any consecutive 4-week period. Response time to changes in

hydropower generation is limited to 20 minutes under normal operating conditions, and to 5 minutes under emergency operating conditions. Maximum fluctuation downstream is 7.0 feet.

7-12. Navigation. Keystone Lake is regulated for flood control in conjunction with the other lakes in the navigation system to help provide a tapered recession of flows along the Arkansas River navigation channel. The coordinated regulation of the lakes is discussed in Chapter VII of the Arkansas River Basin Water Control Master Manual.

7-13. Sedimentation. There are no regulation procedures for sediment. However, Keystone Lake does provide sediment storage for the benefit of the McClellan-Kerr Arkansas River Navigation System.

7-14 Drought Contingency Plans. The Drought Contingency Plan for the Mid-Arkansas River, Oklahoma including Keystone Lake, Revised Nov 2005, was prepared by the Water Management Section.

7-15. Flood Emergency Action Plans. A flood emergency action plan is outlined in the document "Operation and Maintenance Manual, Volume II, Keystone Dam, Flood Emergency Plan", updated Mar 2010. The purpose of the manual is to specify procedures to protect the public from possible property damage or loss of life as a result of uncontrolled releases of water due to failure, or severe damage to the dam appurtenant works.

7-16. Deviation From Normal Flood Control Regulation. Deviation from normal flood control regulation of the lake is occasionally necessary. Prior approval for a deviation is obtained from SWD, except as noted in subparagraph 7-16.a., shown below. Deviation requests fall into the following categories:

a. Emergencies. The water control plan is subject to temporary modification by the Corps if found necessary in time of emergency. Request for and actions on such modifications may be made by the fastest means of communication available. Also, the Lake Manager may temporarily deviate from the water control plan in the event an immediate short-term departure is deemed necessary for emergency reasons to avoid serious hazards. The Lake Manager may deviate from the water control plan whenever necessary to protect the safety of the dam. Such actions shall be immediately reported to the Water Management Section by the fastest means of communication available. Actions shall be confirmed in writing as soon as possible to the Water Management Section and shall include justification for the action. Continuation of the deviation will require the express approval of SWD. A written confirmation showing the deviation and conditions will be furnished by the Water Management Section to SWD.

b. Unplanned Minor Deviations. There are unplanned instances that create a temporary need for minor deviations from the normal regulations of the reservoir, although they are not considered emergencies. Construction accounts for the major portion of the incidents and include utility stream crossings, bridge work, and major

construction contracts. Changes in releases are sometimes necessary for maintenance and inspection. Requests for changes of release rates are generally from a few hours to a few days. Each request is analyzed on its own merits. Consideration is given to upstream watershed conditions, potential flood threat, conditions of the lakes, and possible alternative measures. In the interest of maintaining good public relations, the requests are complied with providing there are no adverse effects on the overall operation of the project (or projects) for the authorized purposes. Approval for these minor deviations will normally be obtained by the Water Management Section from SWD by telephone or email. Normally, SWD is advised by telephone of these minor deviations with written follow-up to confirm the deviation.

c. Unplanned Major Deviations There are unplanned instances that create a temporary need for major deviations from the normal regulation plan and may be considered, but are not, emergencies. Flood control releases account for the major portion of these incidents and typical examples include project pre-releases or exceeding downstream channel capacity, incidents that have a short window of opportunity in an effort to minimize damages or optimize benefits. Requests for changes in release rates generally involve time periods ranging from a few hours to a few days. Each request is analyzed on its own merits. In evaluating the proposed deviation, consideration must be given to upstream watershed conditions, potential flood threat, and condition of the lake, and alternative measures that can be taken. Approval for these major deviations normally will be obtained from SWD by telephone or email. Written confirmation explaining the deviation and its cause will be furnished to the SWD water control manager.

d. Planned Deviations. Advance approval of the SWD water control manager is required prior to any deviation from the plan of regulation prescribed or approved by the Corps in the interest of flood control, except in emergency conditions provided for in subparagraph 7-16.a. Each condition will be analyzed on its own merits. When conditions appear to warrant a prolonged deviation from the approved plan, the Water Management Section will investigate and evaluate the proposed deviation to insure that the overall integrity of the plan would not be unduly compromised. Approval of prolonged deviations will not be granted unless such investigation and evaluations have been conducted to the extent deemed necessary by the SWD water control manager.

7-17. Rate of Release Change. The increase and decrease in releases from Keystone Lake shall be accomplished in a manner which minimizes damage to the reservoir area and downstream channel as shown in Table 7-6. Every reasonable precaution will be made, if possible, to eliminate bank sloughing, undercutting, excessive erosion, and danger to human and animal lives. Situations will arise which will not allow an orderly increase and/or decrease in releases. Examples of these situations are large flood releases, as described in paragraph 7-05., and drownings which occur downstream of the dam.

TABLE 7-6

RELEASE RATE CHANGES

INCREASING RELEASES TO CHANNEL CAPACITY [1]

Current Release Range (c.f.s.)	Maximum Increase (c.f.s.)	Minimum Time Between Changes (hours) [2]
0 - 105,000	15,000	2

DECREASING RELEASES BELOW CHANNEL CAPACITY [1]

Current Release Range (c.f.s.)	Maximum Increase (c.f.s.)	Minimum Time Between Changes (hours) [2]
105,000 - 0	15,000	3

[1] See paragraph 7-05.a. for releases that will exceed channel capacity and also decrease in releases above channel capacity

[2] Maximum of 3 gate changes per day

VIII - EFFECT OF WATER CONTROL PLAN

8-01. General. The effects of emergency flood control regulations (communication between Tulsa District and the Keystone Project Office is disrupted) on the spillway design flood and the standard project flood and examples of the normal and emergency regulations of a historical major flood are presented in the following paragraphs. The floods were selected to show the effects of the flood control regulations for Keystone Lake on a variety of possible flood conditions.

8-02. Flood Control.

a. Probable Maximum Flood. The original Probable Maximum Flood (PMF) was generated by applying the probable maximum precipitation (PMP) from Hydrometeorological Report (HMR) No. 52 through the HEC-1 runoff model to the Keystone Lake drainage basin. The flood has a volume of 8,940,000 acre feet with a peak inflow to Keystone Lake of 1,117,200 c.f.s. The resulting maximum release was 989,000 c.f.s.at the maximum pool elevation of 766.5 feet. Plate 8-1 shows the operational hydrographs for the original PMF routed through Keystone Lake by emergency regulations on both an empty and full flood control pool.

In 2008, an updated PMF was generated by applying the probable maximum storm from HMR 51 through the HEC-HMS runoff model using updated criteria. The updated PMF had a volume of 8,959,900 acre feet with a peak inflow to Keystone Lake of 1,573,500 cfs. The maximum pool elevation of 766.5 feet can pass 74.6% of the updated PMF

b. Standard Project Flood. The Standard Project Flood (SPF) was considered to be one half of the PMF. The resulting flood has a volume of 4,470,000 acre feet with a peak inflow of 556,000 c.f.s. The flood was routed through Keystone Lake using emergency regulations which resulted in a peak discharge of 551,400 c.f.s. at the peak pool elevation of 757.0 feet. Plate 8-2 shows the operational hydrographs for the SPF routed by emergency regulations.

c. Flood of Sep – Oct 1986. This flood was the result of a stalled cold front followed by the remnants of a hurricane that resulted in basin average rainfall of 9.8 inches from 27 Sep to 4 Oct 1986. The flood had a volume of 4,444,000 acre feet with a peak inflow into Keystone Lake of 344,000 c.f.s. The maximum pool elevation was 755.83 feet and the peak outflow was 300,000 c.f.s. This flood is a significant historical flood for the Keystone Lake drainage basin. Plate 8-3 shows the operational hydrographs for Keystone Lake for both experienced and emergency regulations.

d. Flood of Jun - Jul 2007. The Jun-Jul 2007 flood was the result of an Arkansas River basin rainfall of 11.42 inches upstream of Keystone Dam. The flood had a peak inflow into Keystone Lake of 190,500 c.f.s and a volume of 3,156,840 acre-feet. The maximum pool elevation was 755.22 feet and the peak outflow was 75,340 c.f.s. The

pool elevation stayed above 740.0 feet through 2 Aug 2007 and it stayed above 730.0 feet through 20 Aug 2007. The maximum pool elevation when operated under emergency regulations was 754.10 feet and the peak outflow was 110,000 c.f.s. Plate 8-4 shows the operational hydrographs for both experienced and emergency regulations for this flood at Keystone Lake.

8-03. Recreation. Low lying areas begin to be affected at elevation 727. Access roads to recreation areas begin to be inundated at elevation 729. Recreation will be affected by hydroelectric power generation during high-demand periods when generation will draw the pool level well below normal.

8-04. Water Quality. See paragraph 7-07.

8-05. Fish and Wildlife. Keystone Lake provides an improved fishery over the natural river, allowing some species of sport fish to flourish in contrast to previous natural river conditions. The regular generation schedule at Keystone allows fish and wildlife to exist in the Arkansas River below the dam. Generation schedules are sometimes manipulated in response to requests from US Fish and Wildlife Service for protection of the endangered interior least terns which nest on islands downstream of the dam. During periods when generation is limited, minimum releases can be made to relieve emergency conditions such as oxygen deficiency. Some wildlife habitat was inundated due to impoundment; however, wildlife management of lake perimeter lands strives to replace these losses.

8-06. Water Supply. Presently the only contract for water from Keystone Lake is with Public Service Company of Oklahoma. No municipal use is made of water from Keystone Lake as the water quality is marginal.

8-07. Hydroelectric Power. During normal operations releases will be made primarily through the turbines to maintain the pool at elevation 723.0 feet. The conservation storage from elevation 723.0 feet to 706.0 feet (less 20,000 acre-feet for water supply) is allocated to hydroelectric power generation. The generation of power during high-demand periods will draw the pool significantly below the top of the conservation pool (elevation 723.0 feet).

8-08. Navigation. The coordination of releases from Keystone Lake with other reservoirs (discussed in Chapter VII of the Arkansas River Basin Water Control Master Manual) will significantly benefit navigation along the McClellan-Kerr Navigation system by providing a tapered recession of flows along the system. This controlled recession will enable navigation to continue while shoals are removed from the navigation channel. Another benefit from Keystone Lake is sediment storage that will reduce the incidence of shoaling.

8-09. Frequencies.

a. Peak Inflow Probability. Estimated natural flows taken from "Riverware" run 2010-01 at the dam site for the period January 1940 through December 2008 were used to

compute the maximum annual peak inflow probability. The inflow probability was derived in accordance with Bulletin 17B, "Guidelines for Determining Flood Flow Frequency," dated June 2006. The peak inflow probability curve (natural conditions) is shown on Plate 4-4.

b. Pool Elevation Duration and Probability. The pool elevation hydrographs resulting from the Arkansas River system routing of the computed flows at the dam site were used to compute maximum and minimum annual pool elevations which were converted to partial duration series. The computations were made using the general procedures presented in ER 1110-2-1450, dated 10 Oct 1962. The annual series was converted to a partial duration series by Langbein's Conversion Table described in "Transactions American Geophysical Union," Volume 30, Dec 1949. Plate 8-5 shows the pool elevation probability curve and Plate 8-6 shows the pool elevation duration curve. Plates 8-7 through 8-13 show pool elevations from simulated and actual operational hydrographs for the period of record Jan 1940 through Dec 2011.

c. Key Control Points. Discharge rating curves used in the regulation of Keystone Lake are shown on Plates 4-5 through 4-12.

8-10. Other Studies.

a. Examples of Regulation. Studies are in progress to improve the forecasting techniques presented in Section VI of this manual. Computer programs have been developed to forecast inflows into the lake, the resulting pool elevations, and the effects of releases at the downstream gage. Use of these programs has greatly shortened the reaction time in preparing regulation schedules.

b. Channel and Floodway Improvement. A flood insurance study has been made for Tulsa County. The Arkansas River is covered by this study. This report includes profiles of the 500- 100-, 50-, and 10-year floods. There have been several discharge profiles developed in addition to those that do not have frequency. Channelization projects exist below Keystone Lake with the majority related to the Arkansas River navigation system. Ground and aerial reconnaissance are made as required to determine if revised channel capacities and maximum discharge limits are warranted.

c. Dam Safety Studies. Keystone dam has been screened by a national cadre as part of the FY 2006 Screening for Portfolio Risk Analysis (SPRA). Based on the initial project risk screening, which noted the large downstream population center, an Interim Risk Reduction Measure Plan was formulated and put into to place to temporarily reduce Dam Safety risks while long-term solutions are being investigated.

An Issue Evaluation Study has been started for Keystone Dam but is on hold due to prioritization and funding issues. An Issue Evaluation Study is a study of failure modes, identification of risks, and investigation of the need to pursue or not to pursue a Dam Safety Modification study.

IX - WATER CONTROL MANAGEMENT

9-01. Responsibilities and Organizations.

a. Corps of Engineers. Keystone Lake is a Corps of Engineers project, with the Tulsa District prescribing and directing the flood control releases. Operation and Maintenance, as well as regulation of the conservation storage, is the responsibility of the Corps. Project reporting instructions and an organization chart are presented in Section V, and project regulating instructions are presented in Section VII of this manual.

(1) Responsibilities and Duties During Normal Operations. The Water Management Section, Hydrology-Hydraulics Branch, Tulsa District, is charged with the following responsibilities and duties under general supervision of the Engineering and Construction Division.

(a) Routine regulation of lakes and distribution of routine data.

(b) Investigations and refinement of regulation procedures.

1). Analysis of past floods.

2). Reconnaissance to determine channel capacities.

3). Improvement of forecasting techniques.

4). Plan and coordinate the hydrologic reporting network with the NWS and the USGS.

(c) Train personnel in flood control duties.

1). Make periodic visits to projects by Section personnel to familiarize themselves with regulation facilities, become acquainted with the operating personnel, discuss emergency regulation procedures with operating personnel, and provide the background for improving facilities and methods.

2). Instruct personnel of the Hydrology-Hydraulics Branch in flood control procedures to supplement the Water Management Section during flood emergencies, when necessary.

(d) Prepare reports on lake regulation.

1). Recurring reports.

2). Water control manuals.

3). Post-flood reports.

(2) Responsibilities and Duties During Flood Emergencies. During flood emergencies, the Water Management Section is responsible for the following:

(a) Evaluation of current hydrologic, hydraulic, and meteorological data.

(b) Performing or obtaining reservoir forecasts.

(c) Presentation of storm and flood analysis to the District Commander and other interested Tulsa District personnel.

(d) When necessary, furnish personnel to help project operating personnel in flood regulations.

(e) Regulation of lakes according to flood control regulation schedules.

(f) Furnish information to higher authority.

1). Provide initial reports to SWD and the Office of the Chief of Engineers by telephone.

2). Provide hydrologic data for situation reports.

(g) Furnish information to the Reservoir Information Control Center (RICC). The duties of the Lake Manager under flood conditions are set forth in Section VII of this manual. The details of the overall procedures of the Tulsa District under emergency conditions are set forth in Tulsa District Supplement A, Natural Disaster Activities, to ER 500-1-1.

(3) Assignment of Personnel. During non-flood periods, the Water Management Section accomplishes the routine regulation of the lake. However, during flood periods, assistance of other personnel may be required to maintain effective regulation of the lake. Plate 5-2 shows the organization of the Water Management Section during a major flood. The area and size of the flood will determine the number of people engaged in each activity.

(4) Provision for 24-hour Alert. The NWS and project personnel are provided with a list of names, addresses, and telephone numbers of key personnel of the Engineering Division with instructions to provide warning if unusual conditions occur. Responsible personnel will be on duty at the Tulsa District 24 hours a day whenever basin and/or project conditions warrant and during flood emergencies. Responsible personnel will be on duty at the project office or on call at all times.

(5) Role of Lake Manager. The Lake Manager will regulate the lake during flood periods according to instructions issued by personnel of the Water Management Section. The instructions follow the "Normal Regulations for Flood Control," included in Section VII. If the Lake Manager loses communication with the Tulsa District, he/she will immediately attempt to reestablish communication with the Tulsa District while following the instructions outlined in the Section “Emergency Regulations for Flood Control” included in Section VII and Exhibit B of this manual. The Lake Manager will make daily observations as directed in paragraph 5-07.

b. Other Federal Agencies. The NWS and the USGS cooperate with the Water Management Section, Hydrology-Hydraulics Branch, Tulsa District, to accumulate rainfall and stream flow data. The Environmental Protection Agency (EPA), together with the State of Oklahoma, establishes the standards for water quality releases. SWPA cooperates with the Corps of Engineers to market hydropower produced by the project..

c. State Agencies. Management of the fish and wildlife resources of the Keystone Lake project is the responsibility of the Oklahoma Department of Wildlife Conservation.

d. Private Organizations. Presently, there are no privately owned flood control protection facilities at Keystone Lake whose regulation is coordinated with the Corps of Engineers.

9-02. Interagency Coordination. Cooperative arrangements with other Federal agencies, State agencies and local interests are discussed in the following subparagraphs.

a. Local Press and Corps Bulletins. The Corps of Engineers, the NWS, and USGS coordinate in forecasting flood stages, stream flow, and pool elevations. The NWS is officially responsible for issuing flood warnings to the public. This information will be supplemented by the Corps of Engineers bulletins from the Public Affairs Office (PAO) on observed conditions and with technical advice to enable local interests, within the limits of their capabilities, to obtain optimal flood protection and to perform rescue and relief functions. The Corps of Engineers further assists in flood control through the office of the Emergency Operations Manager, who furnishes sandbags and other necessary equipment based on equipment on hand and need. To facilitate the distribution of these data, the RICC is in operation when conditions warrant.

b. National Weather Service. The Tulsa District and the NWS’s Arkansas-Red Basin River Forecast Center exchange hydrometeorological data and reports to prevent duplication of effort in obtaining and distributing data. This exchange of data is discussed in greater detail in Section VI of this manual. The NWS is the responsible agency for issuing public forecasts of stream stages.

c. U.S. Geological Survey. The Corps of Engineers and the USGS cooperate in a program for the construction, maintenance, and operation of stream gaging stations

throughout the Tulsa District. During floods, the Corps of Engineers and the USGS coordinate field activities to maximize the number of stream discharge measurements.

d. Power Marketing Agency. The SWPA is responsible for the sale and delivery of all electric power and energy generated at Keystone Dam to municipalities and rural electric cooperatives. Close coordination is maintained between the Tulsa District and SWPA. The Tulsa District provides SWPA with daily inflow forecasts to Keystone Lake. SWPA provides the Tulsa District with daily, weekly, and monthly power generation schedules.

e. Other Federal, State, or local agencies. The Tulsa District exchanges information with State government officials, the State Department of Transportation, State Highway Patrol, and others during flood emergencies. Tulsa District also coordinates with State agencies concerning fish and wildlife throughout normal operations.

9-03. Interagency Agreements. Exhibit C is a Memorandum of Understanding (MOU) between The US Department of Energy (via SWPA) and the Corps of Engineers detailing hydropower operations at Keystone Lake, dated 23 Jul 1980.

9-04. Commissions, River Authorities, Compacts, and Committees.

There are no commissions or a river authority on the Arkansas River. Arkansas River Basin compacts have been established between the states of Arkansas and Oklahoma, and Kansas and Oklahoma. The major purposes of these compacts are:

a. To promote interstate comity between Arkansas and Oklahoma, and Kansas and Oklahoma.

b. To provide for an equitable apportionment of the waters of the Arkansas River between Arkansas and Oklahoma, and Kansas and Oklahoma, and to promote the orderly development thereof.

c. To provide an agency for administering the water apportionment agreed to in the compacts.

d. To encourage the maintenance of an active pollution abatement program in each of the three states and to seek the further reduction of both natural and manmade pollution in the waters of the Arkansas River basin.

e. To facilitate the cooperation of the water administration agencies of Arkansas and Oklahoma and Kansas and Oklahoma in the total development and management of the water resources of the Arkansas River basin.

9-05. Reports.

a. Daily Reports. In accordance with Tulsa District policy, this report is prepared following procedures outlined by the Water Management Section on a daily basis, except Saturday, Sunday, and holidays, to cover a period of 24-hours. The report provides data for use by personnel, whose work requires knowledge about the regulation of reservoirs, field investigations, stream gaging, and construction of flood control projects affected by releases from reservoirs, answering public inquiries, and preparing public releases. The report includes information on pool elevation, flood control storage, releases, inflow and rainfall. The report is completed and dispatched from the Hydrology-Hydraulics Branch by 10:00 a.m. daily under normal conditions.

b. Monthly Lake Reports. The Water Management Section prepares monthly reports in accordance with EM 1110-2-3600 and ER 1110-2-240. These reports are records for all flood control, navigation, and multiple-purpose storage lakes under supervision of or of direct interest to the Tulsa District. Supplemental information on the regulation of the reservoirs, such as explanation of deviations from approved schedules, is added as a note on the reports or as an attachment. These tabulations 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. The monthly lake reports are also available on the Tulsa District Web Page from 1994 to the present at http://www.swt-wc.usace.army.mil/KEYScharts.html.

c. Flood Situation Reports. The Water Management Section provides daily information to the Readiness and Security Branch for situation reports during floods in accordance with ER 500-1-1 and OM 500-1-6. The report contains various types of information about the floods. Pertinent data specifically required for reservoirs are as follows: name of reservoir, reservoir stage, predicted maximum stage, rates of inflow and outflow in c.f.s., percent of flood control storage used to date and at predicted maximum stage, and any special information particularly pertinent to the flood situation.

d. Post Flood Reports. This report is prepared according to ER 500-1-1 and OM 500-1-6 when practicable after a flood that had caused major damages. The report describes flood emergency operations by the Corps of Engineers and others. Included in summary form are: available hydrologic information, damage estimates, and other engineering data as are considered essential for flood control and flood plain studies or in the review or possible claims against the United States for damages. The Tulsa District Planning Division personnel, using data compiled and prepared by the Water Management Section, prepare the report. The report should be completed within approximately three months of the time of flooding, including a statement of final damages.

e. Annual Reports. The Water Management Section prepares this report. The report contains a summation of the general conditions of the river basins and the individual projects in the Tulsa District for the preceding fiscal year. The report also presents the activities and accomplishments of the Water Management Section for the

past year. The report is forwarded to the SWD Water Management Section for inclusion in SWD's annual report.

f. Summary of Reports. Table 9-1 is a summary of the reports required in the regulation of the lakes in the Tulsa District.

TABLE 9-1

TABULATION OF REPORTS

Name of Report	**When Required**	**Regulation Requiring Reporting**
Daily Report	Daily, except Saturday, Sunday, and holidays	Tulsa District Policy
Monthly Lake Report	Monthly	ER 1110-2-3600 EM 1110-2-240
Flood Situation Report	During Floods	OM 500-1-6 ER 500-1-1
Post flood Report	Following a flood causing major damage	OM 500-1-6 ER 500-1-1
Annual Report	Annually	ER 1110-2-1400

KEYSTONE LAKE, ARKANSAS RIVER, OKLAHOMA
WATER CONTROL MANUAL
APPENDIX M
TO
WATER CONTROL MASTER MANUAL
ARKANSAS RIVER BASIN

SUPPLEMENTAL TABLES

TABLE 4-6

KEYSTONE DAM SITE
MONTHLY INFLOWS (acre-feet)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1940	3,400	18,200	15,400	117,000	293,400	233,700	183,700	90,100	465,800	35,100	156,500	113,500	1,725,800
1941	123,200	120,400	156,400	477,800	919,200	888,300	415,400	171,500	199,700	1,333,300	863,500	497,600	6,166,300
1942	220,500	249,500	289,100	1,838,500	1,314,200	1,347,500	861,600	513,900	671,100	565,600	240,700	363,300	8,475,500
1943	379,400	237,800	154,400	157,900	1,685,700	799,300	333,000	125,000	60,800	162,300	66,200	76,900	4,238,700
1944	90,000	95,700	662,300	1,632,200	1,789,200	842,200	471,600	200,100	299,500	618,500	258,600	829,100	7,789,000
1945	350,600	186,700	560,400	1,655,400	1,308,700	646,900	595,000	281,700	548,800	1,548,500	171,600	124,700	7,979,000
1946	274,400	235,100	292,600	208,900	247,100	115,700	155,800	23,900	50,100	128,500	169,500	148,200	2,049,800
1947	113,800	71,400	163,900	1,971,600	1,480,500	806,400	502,000	138,400	44,500	27,800	33,700	83,800	5,437,800
1948	53,600	70,300	547,800	210,600	195,800	524,600	1,896,000	1,403,100	328,400	93,300	266,700	209,100	5,799,300
1949	655,500	1,615,000	934,800	529,500	2,124,400	1,681,200	551,300	399,800	519,000	319,300	165,800	125,800	9,621,400
1950	88,500	190,500	125,800	90,500	358,700	289,400	963,000	2,031,500	767,800	315,600	137,300	131,500	5,490,100
1951	131,900	201,500	200,600	249,900	2,155,400	2,111,700	3,289,000	1,124,300	1,119,900	444,800	499,700	279,700	11,808,400
1952	277,700	198,500	652,200	558,900	410,800	409,400	73,200	70,500	29,500	13,900	31,600	51,200	2,777,400
1953	62,600	59,000	120,300	177,800	181,400	129,200	238,600	99,900	30,100	18,200	72,600	74,800	1,264,500
1954	39,400	41,000	42,600	41,000	292,600	160,100	10,400	7,000	5,200	10,100	3,800	3,300	656,500
1955	5,800	7,600	15,100	7,700	939,900	738,200	316,800	45,700	23,200	891,000	50,800	36,700	3,078,500
1956	36,200	48,000	37,200	32,200	30,100	33,500	31,600	9,900	3,100	5,700	7,700	4,900	280,100
1957	4,300	5,600	7,900	704,300	2,975,000	3,347,200	2,419,100	354,400	343,100	287,900	199,000	184,400	10,832,200
1958	154,700	130,200	760,300	725,400	403,000	487,200	1,128,400	576,900	489,400	250,300	108,100	103,600	5,317,500
1959	101,600	114,800	48,700	318,700	578,400	314,000	1,021,200	334,900	665,200	3,356,400	501,100	283,400	7,638,400
1960	323,100	702,900	892,200	670,300	811,000	676,900	696,800	639,100	550,900	381,900	362,100	225,100	6,932,300
1961	147,500	154,800	317,700	475,800	1,737,400	882,400	675,400	573,400	1,477,200	1,092,600	1,544,000	489,200	9,567,400
1962	313,000	579,300	314,300	253,200	144,400	825,500	635,600	373,200	358,200	310,600	146,100	191,100	4,444,500
1963	127,900	149,000	221,700	166,500	128,300	323,200	485,500	138,600	399,900	175,100	83,700	54,400	2,453,800
1964	73,700	86,300	71,500	152,900	274,100	158,000	93,600	186,300	237,200	120,500	1,189,500	684,800	3,328,400
1965	271,000	123,600	194,200	554,800	356,100	1,058,700	905,300	212,900	953,800	422,800	145,700	184,300	5,383,200
1966	127,000	166,000	187,200	112,900	163,300	156,400	98,300	101,400	149,500	22,500	33,200	29,600	1,347,300

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TABLE 4-6 (continued)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1967	53,800	45,500	43,100	69,900	125,900	358,800	983,300	431,200	311,000	293,200	139,400	49,300	2,904,400
1968	118,000	125,700	237,000	424,400	551,500	393,100	253,500	389,000	285,700	285,700	422,700	301,300	3,787,600
1969	164,900	261,800	572,900	707,300	1,467,400	1,110,700	464,200	228,200	446,300	351,100	158,900	151,500	6,085,200
1970	126,500	115,800	105,500	1,422,300	432,400	413,100	374,300	43,500	153,500	194,400	125,900	46,600	3,553,800
1971	101,200	84,200	262,500	126,600	153,200	376,600	229,200	102,000	393,000	128,200	319,000	412,800	2,688,500
1972	116,400	103,500	85,100	96,800	218,300	110,500	190,700	63,500	173,200	66,200	301,300	196,600	1,722,100
1973	756,500	751,600	2,505,900	2,696,100	1,365,200	412,800	243,500	206,900	629,700	2,408,500	1,187,100	758,400	13,922,200
1974	574,500	581,500	1,572,500	615,200	1,151,900	954,000	357,200	413,000	599,700	584,100	2,185,000	572,900	10,161,500
1975	511,000	926,300	1,014,700	426,500	1,464,400	1,902,200	425,200	200,800	106,500	82,800	84,500	117,100	7,262,000
1976	88,000	88,300	121,700	213,400	571,400	219,300	617,100	36,300	43,200	44,800	54,400	38,100	2,136,000
1977	36,100	61,500	78,300	83,600	873,700	667,700	446,700	413,200	606,400	143,900	217,000	101,700	3,729,800
1978	62,200	333,100	421,400	293,100	623,700	586,600	146,900	25,200	24,600	33,500	112,300	39,500	2,702,100
1979	94,100	96,200	820,500	462,600	594,300	472,600	330,300	245,000	187,600	33,800	889,500	255,700	4,482,200
1980	192,200	216,600	316,100	1,153,600	935,900	837,600	89,300	85,400	18,900	50,000	23,600	49,200	3,968,400
1981	74,400	39,700	47,700	37,000	205,500	296,700	216,100	136,900	108,100	185,000	568,500	128,500	2,044,100
1982	126,200	312,900	388,800	130,300	1,894,700	1,697,100	759,200	181,000	46,300	35,100	47,500	74,800	5,693,900
1983	135,500	211,700	442,100	1,281,300	1,010,200	707,100	520,100	60,100	81,100	386,300	104,100	454,800	5,394,400
1984	107,900	169,000	1,175,200	1,637,800	676,400	351,900	135,700	32,900	15,900	68,200	85,100	454,800	4,910,800
1985	383,400	704,300	741,300	606,000	586,500	722,800	278,900	240,200	354,800	1,466,100	796,300	452,000	7,332,600
1986	299,300	182,100	170,500	272,500	746,200	649,200	453,100	227,100	404,100	4,440,800	1,111,200	511,900	9,468,000
1987	522,400	1,027,600	2,308,300	979,000	1,406,500	1,181,600	1,086,100	317,600	362,400	377,300	192,400	522,600	10,283,800
1988	717,000	284,800	1,119,700	1,711,100	463,300	181,500	165,200	56,100	272,400	82,600	122,400	90,200	5,266,300
1989	131,300	119,400	278,280	206,280	307,640	987,370	516,100	564,890	1,309,090	365,950	198,940	112,070	5,097,310
1990	280,860	324,690	1,730,780	1,122,840	713,850	362,970	162,640	82,110	73,190	59,500	52,170	41,850	5,007,450
1991	94,810	62,280	57,720	199,740	270,350	307,040	64,460	35,900	128,730	60,690	190,020	507,770	1,979,510

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TABLE 4-6 (continued)

YEAR	JAN	FEB	MAR	APR	MAY	JUN	JUL	AUG	SEPT	OCT	NOV	DEC	ANNUAL
1992	209,850	112,460	153,620	187,240	166,910	1,049,260	589,680	948,100	320,730	82,910	938,180	929,160	5,688,100
1993	957,570	1,164,300	897,020	1,061,060	5,402,480	1,550,680	1,484,030	818,880	358,410	155,110	146,180	152,930	14,148,650
1994	134,970	192,500	261,720	862,610	1,207,140	276,490	190,810	168,790	72,200	73,588	523,446	258,252	4,222,516
1995	171,771	115,043	764,441	475,048	1,690,339	4,179,929	1,181,373	1,725,050	293,558	158,085	99,770	126,944	10,981,351
1996	136,465	118,613	89,258	97,588	129,721	253,590	125,343	613,467	778,127	462,840	1,017,238	594,951	4,417,201
1997	271,442	705,233	453,924	1,440,269	723,928	735,184	1,390,731	895,203	565,992	617,712	249,376	695,266	8,744,260
1998	966,659	468,156	1,958,409	1,404,368	912,710	248,880	313,492	93,373	73,390	1,121,273	3,172,489	760,890	11,494,089
1999	448,370	859,252	1,098,165	2,147,040	1,570,337	2,432,069	1,826,407	444,701	328,666	231,074	165,322	790,710	12,342,113
2000	279,277	288,520	1,835,571	992,147	724,374	882,062	729,928	162,012	29,951	180,697	439,147	114,448	6,658,134
2001	256,566	881,567	1,020,610	389,559	787,152	736,573	188,631	62,084	186,449	61,489	66,745	55,538	4,692,963
2002	144,796	117,175	77,952	132,121	475,544	754,345	255,951	285,029	264,867	841,953	305,663	154,135	3,809,531
2003	173,901	186,347	1,007,454	703,834	790,512	632,429	173,058	90,744	430,909	656,529	107,802	124,562	5,078,081
2004	286,066	313,884	1,704,693	703,239	723,659	556,066	1,082,221	432,327	91,884	112,036	458,092	245,930	6,710,097
2005	790,611	543,223	460,661	278,281	269,018	1,605,222	484,215	748,958	376,264	156,198	81,174	50,578	5,844,403
2006	79,537	120,297	107,107	204,942	523,041	139,636	108,198	51,312	70,760	14,122	23,603	41,107	1,483,662
2007	49,785	111,173	428,092	1,434,148	2,031,528	3,128,428	3,123,033	822,605	329,950	444,198	112,494	255,392	12,270,826
2008	204,565	549,044	752,449	1,252,085	1,610,240	2,600,399	954,168	227,583	1,395,470	740,786	390,892	170,836	10,848,517
2009	201,818	316,661	310,512	1,217,117	1,885,368	541,487	465,560	550,701	460,582	536,777	447,511	158,073	7,092,167
2010	197,712	452,003	539,256	330,565	860,072	1,425,698	934,611	347,286	160,324	70,433	67,339	61,785	5,447,084
MIN	3,400	5,600	7,900	7,700	30,100	33,500	10,400	7,000	3,100	5,700	3,800	3,300	280,100
MEAN	228,454	290,026	536,805	645,609	899,380	833,681	613,776	341,550	340,814	443,383	362,961	250,138	5,786,576
MAX	966,659	1,615,000	2,505,900	2,696,100	5,402,480	4,179,929	3,289,000	2,031,500	1,477,200	4,440,800	3,172,489	929,160	14,148,650

T4-6-3

TABLE 5-1

AUTOMATED GAGES

Station	Operating Agency	Tulsa ID	USGS ID	SHEF ID	LATITUDE NORTH (Deg Min Sec)	LONGITUDE WEST (Deg Min Sec)
Automated Stream Gages						
Arkansas River at Arkansas City, KS	USGS	AARK	07146500	ARKCK1	37 03 23	97 03 28
Salt Fork Arkansas River nr Alva, OK	USGS	ALVA	07148400	AVAO2	36 48 54	98 38 52
Cimarron River nr Ames, OK		AMES	N/A	AMCO2	36 13 07	98 15 16
Turkey Creek nr Bison, OK		BISO	N/A	BTCO2	36 11 19	97 57 43
Chikaskia River nr Blackwell, OK	USGS	BLAC	07152000	BLKO2	36 48 41	97 16 37
Caney River nr Cedar Vale, KS	USGS	CEDA	07171600	CDVK1	37 06 37	96 29 21
Chikaskia River nr Corbin, KS	USGS	CORB	07151500	CBNK1	37 07 44	97 36 06
Cimarron River nr Dover, OK	USGS	DOVE	07159100	DOV02	35 57 06	97 54 51
North Canadian River nr El Reno, OK	USGS	ELRE	07239500	ELNO2	35 33 47	97 57 26
Skeleton Creek at Enid, OK	USGS	ENID	07160350	ESCO2	36 22 34	97 48 00
Cimarron River nr Guthrie, OK	USGS	GUTH	07160000	GTRO2	35 55 14	97 25 32
Hominy Creek nr Hominy, OK	USGS	HOMI	07176950	HMYO2	36 28 25	96 22 43
Arkansas River at Ponca City, OK	USGS	KAWA	07148140	PCYO2	36 41 36	96 55 48
Medicine Lodge River nr Kiowa, KS	USGS	KIOW	07149000	KIOK1	37 02 20	98 28 14
Arkansas River nr Larned, KS	USGS	LARN	07141220	LRDK1	38 12 13	99 00 07
Skeleton Creek nr Lovell, OK	USGS	LOVE	07160500	LVLO2	36 03 36	97 35 05
Rattlesnake Creek nr Macksville, KS	USGS	MACK	07142300	MACK1	37 52 18	98 52 33
South Fork Ninnescah River nr Murdock, KS	USGS	MURD	07145200	MDKK1	37 33 42	97 51 10
Crooked Creek nr Englewood, KS	USGS	NYEC	07157500	ENWK1	37 01 57	100 12 39
North Canadian River bl Lake Overholser nr OKC, OK	USGS	OKC1	07241000	OLBO2	35 28 43	97 39 47
Ninnescah River nr Peck, KS	USGS	PECK	07145500	PECK1	37 27 25	97 25 25

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TABLE 5-1 (continued)

Station	Operating Agency	Tulsa ID	USGS ID	SHEF ID	LATITUDE NORTH (Deg Min Sec)	LONGITUDE WEST (Deg Min Sec)
Automated Stream Gages (continued)						
Black Bear Creek nr Pawnee, OK	USGS	PAWN	07153000	PAWO2	36 20 37	96 47 57
South Fork Ninnescah River nr Pratt, KS	USGS	PRAT	07144910	PTTK1	37 38 16	98 43 14
Arkansas River at Ralston, OK	USGS	RALS	07152500	RLSO2	36 30 15	96 43 41
Cimarron River nr Ripley, OK	USGS	RIPL	07161450	RIPO2	35 59 09	96 54 43
North Canadian River nr Seiling, OK	USGS	SEIL	07238000	SEIO2	36 11 00	98 55 15
Cottonwood Creek nr Seward, OK	USGS	SEWA	07159750	SWDO2	35 48 49	97 28 40
Stillwater Creek nr Stillwater, OK		STILL	N/A	SFRO2	36 05 44	96 59 52
Salt Fork Arkansas River at Tonkawa, OK	USGS	TONK	07151000	TONO2	36 40 19	97 18 33
Arkansas River at Tulsa, OK	USGS	TULA	07164500	TLSO2	36 08 26	96 00 22
North Canadian River nr Watonga, OK	USGS	WATO	07239300	WATO2	35 48 43	98 25 14
Arkansas River near Haskell, OK	USGS	HASK	07165570	HSKO2	35 49 22	95 38 16
Arkansas River near Muskogee, OK	USGS	MUSK	07194500	MKGO2	35 46 10	95 17 49
Arkansas River at Ft. Smith, AR	USGS	FSMI	07249455	FSAA4	35 23 30	94 25 56
Cimarron River nr Waynoka, OK	USGS	WAYN	07158000	WANO2	36 31 02	98 52 45
Slate Creek at Wellington, KS	USGS	WELI	07145700	WELK1	37 14 58	97 24 12
North Canadian River at Woodward, OK	USGS	WOO2	07237500	WDGO2	36 26 12	99 16 41
Automated Pool Gages						
Arcadia Lake Dam	COE	ARCA	07242340	ACDO2	35 38 54	97 21 47
Canton Lake Dam	COE	CANT	07238500	CNLO2	36 04 54	98 36 07
Fort Supply Lake Dam	COE	FSUP	07236500	FSLO2	36 33 14	99 34 16
Great Salt Plains Lake Dam	COE	GSAL	07150000	GSPO2	36 44 40	98 08 08
Kaw Lake Dam	COE	KAWL	07148130	KAWO2	36 41 58	96 55 18
Sooner Power Plant [1]	OG&E	N/A	N/A	N/A	36 26 58	97 01 02

T5-1-2

TABLE 5-1 (continued)

Station	Operating Agency	Tulsa ID	USGS ID	SHEF ID	LATITUDE NORTH (Deg Min Sec)	LONGITUDE WEST (Deg Min Sec)
Automated Rainfall Gages						
Keystone Lake Dam	COE	KEYS	07164200	KEYO2	36 09 02	96 15 08
Precipitation Gage nr Hallett, OK		HALL	N/A	HLTO2	36 13 05	96 38 38
Precipitation Gage nr Hardy, OK		HARD	N/A	HARO2	36 56 30	96 48 00
Precipitation Gage nr Harper, KS		HARP	N/A	HRPK1	37 16 30	98 02 30
Precipitation Gage at Lahoma, OK		LAHO	N/A	LHMO2	36 24 00	98 06 00
Precipitation Gage at Perry, OK		PERR	N/A	PERO2	36 17 00	97 18 00
Oklahoma MESONET Sites						
7.2 miles SSW of Alva, OK		AVSO2	N/A	AVSO2	36 42 29	98 42 35
0.5 miles SW of Buffalo, OK		BFSO2	N/A	BFSO2	36 49 52	99 38 27
4 miles SSE of Blackwell, OK		BLSO2	N/A	BLSO2	36 45 15	97 15 16
5 miles E of Orlando, OK		CBSO2	N/A	CBSO2	36 08 50	97 17 09
0.5 miles SSW of Cherokee, OK		CRSO2	N/A	CRSO2	36 44 43	98 21 45
6 miles ESE of Oilton, OK		DRSO2	N/A	DRSO2	36 01 52	96 29 50
3 miles SE of Breckinridge, OK		ENSO2	N/A	ENSO2	36 24 43	97 41 38
5 miles WNW of El Reno, OK		ERSO2	N/A	ERSO2	35 32 54	98 02 11
3 miles SSW of Freedom, OK		FDSO2	N/A	FDSO2	36 43 32	99 08 32
7 miles SW of Burbank, OK		FFSO2	N/A	FFSO2	36 38 04	96 48 37
1 mile W of Fairview, OK		FVSO2	N/A	FVSO2	36 15 48	98 29 51
4 miles WDW of Guthrie, OK		GTSO2	N/A	GTSO2	35 50 56	97 28 47
1 miles W of Kingfisher, OK		KFSO2	N/A	KFSO2	35 51 15	97 57 15
1 Mile WSW of Lahoma, OK		LHSO2	N/A	LHSO2	36 23 03	98 06 41

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TABLE 5-1 (continued)

Station	Operating Agency	Tulsa ID	USGS ID	SHEF ID	LATITUDE NORTH (Deg Min Sec)	LONGITUDE WEST (Deg Min Sec)
Oklahoma MESONET Sites (continued)						
1 mile SW of Medford, OK		MFSO2	N/A	MFSO2	36 47 32	97 44 44
4 miles SSE of Marshall, OK		MSSO2	N/A	MSSO2	36 07 00	97 36 24
16 miles NNE of Freedom, OK		MYSO2	N/A	MYSO2	36 59 13	99 00 39
8 miles E of Newkirk, OK		NKSO2	N/A	NKSO2	36 53 53	96 54 37
6.1 miles N of Oklahoma City, OK		OCSO2	N/A	OCSO2	35 33 20	97 30 38
3 miles ENE of Pawnee, OK		PNSO2	N/A	PNSO2	36 21 40	96 46 11
2 miles NNW of Perkins, OK		PRSO2	N/A	PRSO2	35 59 55	97 02 53
7 miles SSE of Red Rock, OK		PYSO2	N/A	PYSO2	36 21 21	97 09 11
7 miles WNW of Seiling, OK		SESO2	N/A	SESO2	36 11 25	99 02 25
4 miles NW of Skiatook, OK		SKSO2	N/A	SKSO2	36 24 55	96 02 13
2 miles W of Stillwater, OK		SRSO2	N/A	SRSO2	36 07 15	97 05 42
7 miles W of Watonga, OK		WNSO2	N/A	WNSO2	35 50 30	98 31 34
2 miles S of Wynona, OK		WYSO2	N/A	WYSO2	36 31 05	96 20 31

(1) OG&E has a staff gage in their pump station wet well. No rating curve exists for this station, but stage data can be obtained from OG&E in a flood emergency.

T5-1-4

TABLE 7-3
ELEVATION – AREA – CAPACITY DATA
KEYSTONE LAKE, OKLAHOMA
2000 CONSERVATION POOL SURVEY AND 2008 POOL LIDAR SURVEY

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	657	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
		0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000	0.000
	658	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001	0.002	0.002
		0.000	0.000	0.000	0.000	0.000	0.001	0.001	0.001	0.001	0.001
	659	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.003	0.004	0.004
		0.001	0.001	0.002	0.002	0.002	0.003	0.003	0.003	0.003	0.004
	660	0.004	0.005	0.005	0.006	0.006	0.007	0.007	0.008	0.008	0.009
		0.004	0.005	0.005	0.006	0.007	0.008	0.008	0.009	0.010	0.010
	661	0.009	0.010	0.011	0.012	0.013	0.015	0.016	0.017	0.018	0.019
		0.011	0.012	0.014	0.015	0.012	0.018	0.019	0.020	0.021	0.023
	662	0.020	0.022	0.025	0.027	0.030	0.032	0.034	0.037	0.039	0.042
		0.024	0.027	0.030	0.033	0.036	0.040	0.043	0.046	0.049	0.052
	663	0.044	0.049	0.053	0.058	0.062	0.067	0.072	0.076	0.081	0.085
		0.055	0.061	0.068	0.074	0.081	0.087	0.093	0.100	0.106	0.113

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29		0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
	664	0.090	0.097	0.104	0.111	0.118	0.126	0.133	0.140	0.147	0.154
		0.119	0.132	0.144	0.157	0.169	0.182	0.194	0.207	0.219	0.232
	665	0.161	0.171	0.180	0.190	0.200	0.210	0.219	0.229	0.239	0.248
		0.244	0.264	0.285	0.305	0.326	0.346	0.366	0.387	0.407	0.428
	666	0.258	0.270	0.270	0.295	0.307	0.319	0.331	0.343	0.356	0.368
		0.448	0.480	0.512	0.543	0.575	0.607	0.639	0.671	0.702	0.734
	667	0.380	0.391	0.403	0.414	0.426	0.437	0.448	0.460	0.471	0.483
		0.766	0.810	0.854	0.897	0.941	0.985	1.029	1.073	1.116	1.160
	668	0.494	0.509	0.523	0.538	0.552	0.567	0.581	0.596	0.610	0.625
		1.204	1.260	1.317	1.373	1.429	1.486	1.542	1.598	1.654	1.711
	669	0.639	0.657	0.676	0.694	0.713	0.731	0.749	0.768	0.786	0.805
		1.767	1.840	1.912	1.985	2.057	2.130	2.202	2.275	2.347	2.420
	670	0.823	0.842	0.861	0.881	0.900	0.919	0.938	0.957	0.977	0.996
		2.492	2.584	2.676	2.768	2.860	2.953	3.045	3.137	3.229	3.321
	671	1.015	1.036	1.057	1.078	1.099	1.121	1.142	1.163	1.184	1.205
		3.413	3.525	3.637	3.750	3.862	3.974	4.086	4.198	4.311	4.423

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
672	1.226	1.249	1.272	1.294	1.317	1.340	1.363	1.386	4.945	1.431
	4.535	4.669	4.803	4.937	5.071	5.205	5.339	5.473	5.607	5.741
673	1.454	1.477	1.500	1.524	1.547	1.570	1.593	1.616	1.640	1.663
	5.875	6.032	6.189	6.347	6.504	6.661	6.818	6.975	7.133	7.290
674	1.686	1.708	1.729	1.751	1.772	1.794	1.815	1.837	1.858	1.880
	7.447	7.627	7.806	7.986	8.165	8.345	8.525	8.704	8.884	9.063
675	1.901	1.922	1.943	1.965	1.986	2.007	2.028	2.049	2.071	2.092
	9.243	9.444	9.645	9.847	10.048	10.249	10.450	10.651	10.853	11.054
676	2.113	2.132	2.151	2.170	2.189	2.208	2.227	2.246	2.265	2.284
	11.255	11.476	11.696	11.917	12.138	12.359	12.579	12.800	13.021	13.241
677	2.303	2.322	2.341	2.361	2.380	2.399	2.418	2.437	2.457	2.476
	13.462	13.702	13.942	20.908	14.423	14.663	14.903	15.143	15.384	15.624
678	2.495	2.513	2.532	2.550	2.568	2.587	2.605	2.623	2.641	2.660
	15.864	16.123	16.381	16.640	26.467	17.157	17.416	17.674	17.933	18.191
679	2.678	2.699	2.721	2.742	2.763	2.785	2.806	2.827	2.848	2.870
	18.450	18.728	19.006	19.285	19.563	19.841	20.119	20.397	20.676	20.954

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
680	2.891	2.916	2.941	2.965	2.990	3.015	3.040	3.065	3.089	3.114
	21.232	21.533	21.835	22.136	22.437	22.739	23.040	23.341	23.642	23.944
681	3.139	3.164	3.189	3.214	3.239	3.264	3.288	3.313	3.338	3.363
	24.245	24.571	24.898	25.224	25.551	25.877	26.203	26.530	26.856	27.183
682	3.388	3.418	3.449	3.479	3.509	3.540	3.570	3.600	3.630	3.661
	27.509	27.862	28.215	28.569	28.922	29.275	29.628	29.981	30.335	30.688
683	3.691	3.724	3.757	3.790	3.823	3.857	3.890	3.923	3.956	3.989
	31.041	31.427	31.813	32.199	32.585	32.972	33.358	33.744	34.130	34.516
684	4.022	4.050	4.078	4.106	4.134	4.162	4.190	4.218	4.246	4.274
	34.902	35.318	35.734	36.151	36.567	36.983	37.399	37.815	38.232	38.648
685	4.302	4.330	4.358	4.386	4.414	4.443	4.471	4.499	4.527	4.555
	39.064	39.508	39.952	40.396	40.840	41.284	41.728	42.172	42.616	43.060
686	4.583	4.615	4.648	4.680	4.712	4.745	4.777	4.809	4.841	4.874
	43.504	43.978	43.978	44.927	45.402	45.876	46.350	46.825	47.299	47.774
687	4.906	4.933	4.960	4.987	5.014	5.041	5.067	5.094	5.121	5.148
	48.248	48.753	49.258	49.762	50.267	50.772	51.277	51.782	52.286	52.791

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
688	5.175	5.199	5.222	5.246	5.269	5.293	5.316	5.340	5.363	5.387
	53.296	53.825	54.354	54.883	55.412	55.941	56.469	56.998	57.527	58.056
689	5.410	5.434	5.458	5.483	5.507	5.531	5.555	5.579	5.604	5.628
	58.585	59.138	59.691	60.244	60.797	61.350	61.902	62.455	63.008	63.561
690	5.652	5.680	5.707	5.735	5.762	5.790	5.817	5.845	5.872	5.900
	64.114	64.693	65.272	65.850	66.429	67.008	67.587	68.166	68.744	69.323
691	5.927	5.955	5.983	6.010	6.038	6.066	6.094	6.122	6.149	6.177
	69.902	70.508	71.115	71.721	72.328	72.934	73.540	74.147	74.753	75.360
692	6.205	6.244	6.282	6.321	6.359	6.398	6.437	6.475	6.514	6.552
	75.966	76.605	77.245	77.884	78.523	79.163	79.802	80.441	81.080	81.720
693	6.591	6.626	6.661	6.697	6.732	6.767	6.802	6.837	6.873	6.908
	82.359	83.037	83.714	84.392	85.069	85.747	86.425	87.102	87.780	88.457
694	6.943	6.971	6.999	7.028	7.056	7.084	7.112	7.140	7.169	7.197
	89.135	89.844	90.552	91.261	91.969	92.678	93.387	94.095	94.804	95.512
695	7.225	7.255	7.857	7.315	7.345	7.376	7.406	9.362	7.466	7.496
	96.221	96.958	97.695	98.433	99.170	99.907	100.644	101.381	102.119	102.856

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
696	7.526	7.558	7.590	7.622	7.654	7.687	7.719	7.751	7.783	7.815
	103.593	104.361	105.130	105.898	106.667	107.435	108.203	108.972	109.740	110.509
697	7.847	7.883	7.918	7.954	7.989	8.025	8.061	8.096	8.132	8.167
	111.277	112.079	112.882	113.684	114.487	115.289	116.091	116.894	117.696	118.499
698	8.203	8.245	8.287	8.329	8.371	8.413	8.455	8.497	8.539	8.581
	119.301	120.141	120.982	121.822	122.662	123.503	124.343	125.183	126.023	126.864
699	8.623	8.664	8.705	8.746	8.787	8.828	8.868	8.909	8.950	8.991
	127.704	128.587	129.471	130.354	131.238	132.121	133.004	133.888	134.771	135.655
700	9.032	9.070	9.107	9.145	9.182	9.220	9.257	9.295	9.332	9.370
	136.538	137.460	138.382	139.304	140.226	141.149	142.071	142.993	143.915	144.837
701	9.407	9.441	9.475	9.509	9.543	9.577	9.610	9.644	9.678	9.712
	145.759	146.717	147.674	148.632	149.589	150.547	151.504	152.462	153.419	154.377
702	9.746	9.784	9.821	9.859	9.896	9.934	9.971	10.009	10.046	10.084
	155.334	156.328	157.321	158.315	159.308	160.302	161.295	162.289	163.282	164.276
703	10.121	11.168	12.215	13.262	14.309	15.356	16.402	17.449	18.496	19.543
	165.269	166.298	167.328	168.357	169.387	170.416	171.445	172.475	173.504	174.534

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
704	10.469	10.503	10.537	10.571	10.605	10.640	10.674	10.708	10.742	10.776
	175.563	176.628	177.692	178.757	179.821	180.886	181.951	183.015	184.080	185.144
705	10.810	10.839	10.868	10.897	10.926	10.955	10.983	11.012	11.041	11.070
	186.209	187.305	188.400	189.496	190.591	191.687	192.782	193.878	194.973	196.069
706	11.099	11.127	11.155	11.182	11.210	11.238	11.266	11.294	11.321	11.349
	197.164	198.288	199.412	200.535	201.659	202.783	203.907	205.031	206.154	207.278
707	11.377	11.406	11.435	11.464	11.493	11.523	11.552	11.581	11.610	11.639
	208.402	209.554	210.706	211.859	213.011	214.163	215.315	216.467	217.620	218.772
708	11.668	11.698	12.298	11.758	11.788	11.818	11.848	11.878	11.908	11.938
	219.924	221.106	222.287	223.469	224.650	225.832	227.014	228.195	229.377	230.558
709	11.968	11.997	12.026	12.056	12.085	12.114	12.143	12.172	12.202	12.231
	231.740	232.952	234.163	235.375	236.586	237.798	239.009	240.221	241.432	242.644
710	12.260	12.291	12.321	12.352	12.383	12.414	12.444	12.475	12.506	12.536
	243.855	245.096	246.337	247.579	248.820	250.061	251.302	252.543	253.785	255.026
711	12.567	12.597	12.627	12.657	12.687	12.717	12.747	12.777	12.807	12.837
	256.267	257.539	258.811	260.082	261.354	262.626	263.898	265.170	266.441	267.713

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
712	12.867	12.897	12.928	12.958	12.989	13.019	13.049	13.080	13.110	13.141
	268.985	270.287	271.589	272.890	274.192	275.494	276.796	278.098	279.399	280.701
713	13.171	13.203	13.235	13.266	13.298	13.330	13.362	13.394	13.425	13.457
	282.003	283.336	284.668	286.001	287.333	288.666	289.999	291.331	292.664	293.996
714	13.489	13.526	13.562	13.599	13.635	13.672	13.709	13.745	13.782	13.818
	295.329	296.696	298.062	299.429	300.796	302.163	303.529	304.896	306.263	307.629
715	13.855	13.893	13.930	13.968	14.005	14.043	14.081	14.118	14.156	14.193
	308.996	310.401	311.805	313.210	314.615	316.020	317.424	318.829	320.234	321.638
716	14.231	14.271	14.311	14.352	14.392	14.432	14.472	14.512	14.553	14.593
	323.043	324.485	325.928	327.370	328.813	330.255	331.697	333.140	334.582	336.025
717	14.633	14.674	14.715	14.756	14.797	14.838	14.878	14.919	14.960	15.001
	337.467	338.951	340.435	341.920	343.404	344.888	346.372	347.856	349.341	350.825
718	15.042	15.080	15.118	15.155	15.193	15.231	15.269	15.307	15.344	15.382
	352.309	353.832	355.355	356.878	358.401	359.924	361.447	362.970	364.493	366.016
719	15.420	15.456	15.492	15.528	15.564	15.601	15.637	15.673	15.709	15.745
	367.539	369.100	370.660	372.221	373.781	375.342	376.902	378.463	380.023	381.584

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
720	15.781	15.813	15.845	15.877	15.909	15.941	15.973	16.005	16.037	16.069
	383.144	384.738	386.332	387.926	389.520	391.115	392.709	394.303	395.897	397.491
721	16.101	16.133	16.165	16.196	16.228	16.260	16.292	16.324	16.355	16.133
	399.085	400.711	402.337	403.962	405.588	407.214	408.840	410.466	412.091	413.717
722	16.419	16.451	16.483	16.515	16.547	16.579	16.611	16.643	16.675	16.707
	415.343	417.001	418.659	420.317	421.975	423.633	425.290	426.948	428.606	430.264
723	16.739	16.772	16.805	16.838	16.871	16.904	16.936	16.969	17.002	17.035
	431.922	433.612	435.303	436.993	438.684	440.374	442.064	443.755	445.445	447.136
724	17.068	17.419	17.769	18.120	18.470	18.821	19.171	19.522	19.872	20.223
	448.826	450.708	452.590	454.472	456.354	458.237	460.119	462.001	463.883	465.765
725	20.573	20.732	20.890	21.049	21.208	21.367	21.525	21.684	21.843	22.001
	467.647	469.898	472.148	474.399	476.650	478.901	481.151	483.402	485.653	487.903
726	22.160	22.255	22.349	22.444	22.539	22.634	22.728	22.823	22.918	23.012
	490.154	492.441	492.441	492.441	492.441	492.441	492.441	492.441	492.441	492.441
727	23.107	23.277	23.447	23.617	23.787	23.957	24.126	24.296	24.466	24.636
	513.028	515.622	518.216	520.810	523.404	525.999	528.593	531.187	533.781	536.375

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
728	24.806	24.964	25.121	25.436	25.436	25.594	25.751	25.909	26.066	39.139
	538.969	541.624	544.279	546.934	549.589	552.244	554.899	557.554	560.209	562.864
729	26.381	26.479	26.578	26.676	26.774	26.873	26.971	27.069	27.167	27.266
	565.519	568.241	570.962	573.684	576.405	579.127	581.849	584.570	587.292	590.013
730	27.364	27.481	27.599	27.716	27.834	27.951	28.068	28.186	28.303	28.421
	592.735	595.585	598.435	601.284	604.134	606.984	609.834	612.684	615.533	618.383
731	28.538	28.624	28.710	28.795	28.881	28.967	29.053	29.139	29.224	29.310
	621.233	624.145	627.057	629.968	632.880	635.792	638.704	641.616	644.527	647.439
732	29.396	29.487	29.578	29.668	29.759	29.850	29.941	30.032	30.122	30.213
	650.351	653.351	656.350	659.350	662.350	665.350	668.349	671.349	674.349	677.348
733	30.304	30.393	30.482	30.571	30.660	30.749	30.837	30.926	31.015	31.104
	680.348	683.480	686.613	689.745	692.877	696.010	699.142	702.274	705.406	708.539
734	31.193	31.273	31.353	31.433	31.513	31.594	31.674	31.754	31.834	31.914
	711.671	714.840	718.009	721.179	724.348	727.517	730.686	733.855	737.025	740.194
735	31.994	32.124	32.254	32.385	32.515	32.645	32.775	32.905	33.036	33.166
	743.363	746.790	750.217	753.644	757.071	760.498	763.925	767.352	770.779	774.206

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
736	33.296	33.380	33.464	33.548	33.632	33.716	33.800	33.884	33.968	34.052
	777.633	781.028	784.422	787.817	791.212	794.607	798.001	801.396	804.791	808.185
737	34.136	34.217	34.298	34.380	34.461	34.542	34.623	34.704	34.786	34.867
	811.580	815.039	818.499	821.958	825.417	828.877	832.336	835.795	839.254	842.714
738	34.948	35.121	35.293	35.466	35.638	35.811	35.984	36.156	36.329	36.501
	846.173	850.138	854.103	858.068	862.033	865.999	869.964	873.929	877.894	881.859
739	36.674	36.767	36.860	36.952	37.045	37.138	37.231	37.324	37.416	37.509
	885.824	889.574	893.324	897.074	900.824	904.575	908.325	912.075	915.825	919.575
740	37.602	37.710	37.819	37.927	38.036	38.144	38.252	38.361	38.469	38.578
	923.325	927.212	931.098	934.985	938.871	942.758	946.644	950.531	954.417	958.304
741	38.686	38.780	38.873	38.967	39.061	39.155	39.248	39.342	39.436	39.529
	962.190	966.108	970.025	973.943	977.860	981.778	985.695	989.613	993.530	997.448
742	39.623	39.713	39.804	39.894	39.984	40.075	40.165	40.255	40.345	40.436
	1001.365	1005.403	1009.441	1013.479	1017.517	1021.555	1025.592	1029.630	1033.668	1037.706
743	40.526	40.638	40.749	40.861	40.972	41.084	41.195	41.307	41.418	41.530
	1041.744	1045.930	1050.116	1054.301	1058.487	1062.673	1066.859	1071.045	1075.230	1079.416

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
744	41.641	41.749	41.857	41.965	42.073	42.181	42.288	42.396	42.504	42.612
	1083.602	1087.830	1092.058	1096.287	1100.515	1104.743	1108.971	1113.199	1117.428	1121.656
745	42.720	42.831	42.941	43.052	43.163	43.274	43.384	43.495	43.606	43.716
	1125.884	1130.247	1134.611	1138.974	1143.338	1147.701	1152.064	1156.428	1160.791	1165.155
746	43.827	43.938	44.050	44.161	44.273	44.384	44.495	44.607	44.718	44.830
	1169.518	1173.981	1178.445	1182.908	1187.372	1191.835	1196.298	1200.762	1205.225	1209.689
747	44.941	45.050	45.158	45.267	45.376	45.485	45.593	45.702	45.811	45.919
	1214.152	1218.750	1223.347	1227.945	1232.543	1237.141	1241.738	1246.336	1250.934	1255.531
748	46.028	46.128	46.229	46.329	46.430	46.530	46.630	46.731	46.831	46.932
	1260.129	1264.808	1269.487	1274.167	1278.846	1283.525	1288.204	1292.883	1297.563	1302.242
749	47.032	47.135	47.239	47.342	47.446	47.549	47.652	47.756	47.859	47.963
	1306.921	1311.684	1316.446	1321.209	1325.971	1330.734	1335.497	1340.259	1345.022	1349.784
750	48.066	48.176	48.285	48.395	48.505	48.615	48.724	48.834	48.944	49.053
	1354.547	1359.457	1364.368	1369.278	1374.188	1379.099	1384.009	1388.919	1393.829	1398.740
751	49.163	49.306	49.448	49.591	49.734	49.877	50.019	50.162	50.305	50.447
	1403.650	1408.879	1414.107	1419.336	1424.564	1429.793	1435.021	1440.250	1445.478	1450.707

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
752	50.590	50.708	50.825	50.943	51.060	51.178	51.295	51.413	51.530	51.648
	1455.935	1461.114	1466.292	1471.471	1476.650	1481.829	1487.007	1492.186	1497.365	1502.543
753	51.765	51.892	52.018	52.145	52.271	52.398	52.524	52.651	52.777	52.904
	1507.722	1513.006	1518.290	1523.575	1528.859	1534.143	1539.427	1544.711	1549.996	1555.280
754	53.030	53.155	53.280	53.405	53.530	53.656	53.781	53.906	54.031	54.156
	1560.564	1565.949	1571.334	1576.718	1582.103	1587.488	1592.873	1598.258	1603.642	1609.027
755	54.281	54.436	54.591	54.746	54.901	55.056	55.211	55.366	55.521	55.676
	1614.412	1620.014	1625.615	1631.217	1636.818	1642.420	1648.022	1653.623	1659.225	1664.826
756	55.831	55.962	56.093	56.225	56.356	56.487	56.618	56.749	56.881	57.012
	1670.428	1676.098	1681.767	1687.437	1693.106	1698.776	1704.445	1710.115	1715.784	1721.454
757	57.143	57.275	57.408	57.540	57.672	57.805	57.937	58.069	58.201	58.334
	1727.123	1732.947	1738.770	1744.594	1750.418	1756.242	1762.065	1767.889	1773.713	1779.536
758	58.466	58.646	58.826	59.005	59.185	59.365	59.545	59.725	59.904	60.084
	1785.360	1792.045	1798.731	1805.416	1812.102	1818.787	1825.472	1832.158	1838.843	1845.529
759	60.264	60.427	60.589	60.752	60.914	61.077	61.239	61.402	61.564	61.727
	1852.214	1858.653	1865.091	1871.530	1877.968	1884.407	1890.846	1897.284	1903.723	1910.161

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
760	61.889	62.038	62.186	62.335	62.484	62.633	62.781	62.930	63.079	63.227
	1916.600	1922.919	1929.238	1935.557	1941.876	1948.195	1954.514	1960.833	1967.152	1973.471
761	63.376	63.547	63.718	63.888	64.059	64.230	64.401	64.572	64.742	64.913
	1979.790	1986.387	1992.984	1999.582	2006.179	2012.776	2019.373	2025.970	2032.568	2039.165
762	65.084	65.253	65.422	65.591	65.760	65.929	66.097	66.266	66.435	66.604
	2045.762	2052.579	2059.396	2066.213	2073.030	2079.847	2086.664	2093.481	2100.298	2107.115
763	66.773	66.925	67.078	67.230	67.383	67.535	67.687	66.925	66.925	66.925
	2113.932	2120.747	2127.562	2134.377	2141.192	2148.007	2154.822	2120.747	2120.747	2120.747
764	68.297	68.456	68.615	68.773	68.932	69.091	69.250	69.409	69.567	69.726
	2182.082	2188.989	2195.896	2202.803	2209.710	2216.617	2223.524	2230.431	2237.338	2244.245
765	69.885	70.041	70.198	70.354	70.510	70.667	70.823	70.979	71.135	71.292
	2251.152	2258.270	2265.388	2272.506	2279.624	2286.742	2293.859	2300.977	2308.095	2315.213
766	71.448	71.633	71.818	72.003	72.188	72.374	72.559	72.744	72.929	73.114
	2322.331	2329.686	2337.040	2344.395	2351.749	2359.104	2366.458	2373.813	2381.167	2388.522
767	73.299	73.457	73.615	73.773	73.931	74.090	74.248	74.406	74.564	74.722
	2395.876	2403.317	2410.757	2418.198	2425.639	2433.080	2440.520	2447.961	2455.402	2462.842

TABLE 7-3 (continued)
ELEVATION – AREA – CAPACITY DATA

AREA IN 1000'S OF ACRES
CAPACITY IN 1000'S OF ACRE-FEET

ELEVATION NGVD29	0	0.1	0.2	0.3	0.4	0.5	0.6	0.7	0.8	0.9
768	74.880	75.042	75.204	75.366	75.528	75.691	75.853	76.015	76.177	76.339
	2470.283	2477.895	2485.506	2493.118	2500.729	2508.341	2515.953	2523.564	2531.176	2538.787
769	76.501	76.653	76.805	76.957	77.109	77.262	77.414	77.566	77.718	77.870
	2546.399	2554.185	2561.970	2569.756	2577.541	2585.327	2593.113	2600.898	2608.684	2616.469
770	78.022	78.173	78.325	78.476	78.627	78.779	78.930	79.081	79.232	79.384
	2624.255	2632.165	2640.075	2647.985	2655.895	2663.805	2671.715	2679.625	2687.535	2695.445
771	79.535									
	2703.355									

TABLE 7-5

STREAM WATER RIGHTS DOWNSTREAM OF KEYSTONE DAM TO WEBBERS FALLS LOCK & DAM
AS OF 17 MAR 2011

PERMIT #	NAME	1/4	1/4	1/4	SEC	TWN	RNG	COUNTY	AMT (AF/YR)	PURPOSE	DATE FILED	DATE ISSUED
19850005	Oklahoma State Industries	SW	SW	SW	07	15N	17E	Muskogee	500.0	Irrigation	17 Jan 1985	14 May 1985
19850005	Oklahoma State Industries	SW	NW	SE	07	15N	17E	Muskogee	500.0	Irrigation	17 Jan 1985	14 May 1985
19810036	(b) (6)	SW	SE	NW	25	15N	19E	Muskogee	120.0	Irrigation	13 Feb 1981	12 May 1981
19660457	(b) (6)			S2	25	15N	19E	Muskogee	180.0	Irrigation	26 Jul 1966	13 Sep 1966
20060046	Georgia-Pacific Consumer Products LP	NW	NW	NW	34	15N	19E	Muskogee	19593.0	Industrial	17 Aug 2006	13 Feb 2007
19750026	Georgia-Pacific Consumer Products LP			NW	34	15N	19E	Muskogee	15842.0	Industrial	14 Apr 1975	10 Jun 1975
19700297	Public Service Co of Okla	SE	NW	SE	32	18N	13E	Tulsa	13035.0	Power	27 Aug 1970	8 Dec 1970
19930027	Public Service Co of Okla	SE	SW	SW	13	19N	12E	Tulsa	3645.0	Power	24 Jun 1993	14 Sep 1993
19640878	Public Service Co of Okla	SE	SW	SW	13	19N	12E	Tulsa	313.0	Power	19 Oct 1964	8 Dec 1964
19640878	Public Service Co of Okla	SE	NW	NW	24	19N	12E	Tulsa	313.0	Power	19 Oct 1964	8 Dec 1964
19930027	Public Service Co of Okla	SE	NW	NW	24	19N	12E	Tulsa	3645.0	Power	24 Jun 1993	14 Sep 1993

EXHIBIT A

SUPPLEMENTARY PERTINENT DATA

KEYSTONE LAKE

EXHIBIT A

SUPPLEMENTARY PERTINENT DATA

KEYSTONE LAKE

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EXHIBIT A
SUPPLEMENTARY PERTINENT DATA
KEYSTONE LAKE

1 - GENERAL INFORMATION

Other names for project	None
Location	Arkansas River Basin, Arkansas River, at river mile 538.8, State of Oklahoma
Type of project	Dam and Lake
Objectives of regulation	Multipurpose – Flood control, hydropower, water supply, navigation, recreation, and fish and wildlife
Project owner	US Government
Operating agency	US Army Corps of Engineers. The normal working hours of operation for weekdays are 7:00 a.m. to 4:30 p.m. Working hours for weekends, holidays and nights vary. Working hours under flood emergency conditions are 24 hours.
Regulating agency	US Army Corps of Engineers.
Code of Federal Regulations, Title 33 (applies to Section 7 Projects)	Does not apply
Federal power distributing and marketing	Southwestern Power Administration (SWPA).
Other inter-agency agreement	Memorandum of Understanding (MOU) between the Corps of Engineers and SWPA, dated 23 Jul 1980
Water rights	57,686 acre-feet per year
Project cost through FY 2010	$139,159,652.65

Closure date	Lake -- Sep 1964 Power Unit #1 – 21 May 1968 Power Unit #2 – 2 May 1968
Special project features	Levee near city of Cleveland, OK for urban protection
Other	None

TABLE A-1

WATER SUPPLY AGREEMENTS

User Name	Present Storage (ac-ft) (1)	Future Storage (ac-ft)	Total User Storage (ac-ft)	Yield (m.g.d.)	Approval Date
Public Service Company	18,000	0	18,000	18.0	5 Apr 1971
Not under	2,000	0	2,000	2.0	
TOTAL	**20,000**	**0**	**20,000**	**20.0**	

Yield for total conservation pool storage of 234,740 ac-ft = 234.7 m.g.d.
Yield for current water supply agreements (not including hydropower) of 18,000 ac-ft = 18.0 mgd

2 - LAKE INFORMATION

ELEVATIONS, AREAS, AND STORAGES

Feature	Elevation (feet, NGVD29)	Lake area (acres)	Storage	
			Accumulative (Acre-feet) [1]	Runoff Inches [2]
Top of dam	771.0	79,535	2,703,355	2.27
Maximum pool	766.0	71,450	2,322,330	1.95
Top of surcharge	757.0	57,140	1,727,120	1.45
Top of flood control pool	754.0	53,030	1,560,560	1.31
Top of conservation pool	723.0	16,740	431,920	0.36
Spillway crest	719.0	15,420	367,540	0.31
Bottom of conservation pool	706.0	11,100	197,160[3]	0.17
Flood control storage	723.0 – 754.0	-	1,128,640	0.95
Conservation storage	706.0 – 723.0	-	234,760[4]	0.20
24 hour surveillance begins	744.0			
Streambed at upstream toe of dam	650.0	0	0	

(1) Storage yield of approximately 234.74 m.g.d. for water supply
(2) From 22,351 square miles of contributing drainage area
(3) Provides for sediment storage and minimum head for hydropower generation
(4) Includes 20,000 acre-feet for water supply

NOTE: Area and Storage based on 2010 re-survey.

Remaining sediment storage: 1,128,642 Ac-Ft in the Flood Pool
234,758 Ac-Ft in the Conservation Pool
197,164 Ac-Ft in the Inactive Pool

Real estate taking for land fee title	The fee taking line is a semi-blocked perimeter to elevation 754.0 feet, and contains 49,182 acres
Real estate taking for Easement	Flowage easements were acquired in the flat pool area above the fee taking line to elevation 759.0 feet. In the upper reaches the flowage easement is to elevation 759.0 feet or to the elevation of the backwater envelope curve for a 50-year flood after 50 years of sedimentation, whichever is higher. This contains 24,503 acres.
Range of clearing	The lower limit is 712.7 feet. The upper limit of clearing is elevation 726.0 feet.
Channel capacity downstream of dam	Non-damaging channel capacity immediately downstream of Keystone Dam is estimated at 105,000 c.f.s.
Reservoir length at top of conservation pool	28 miles -- Arkansas River arm; 35 miles – Cimarron River arm
Shoreline length at top of conservation pool	330 miles
Safety aspects, possibly requiring warning	Low lying picnic tables and adjoining facilities will be inundated at elevation 727.0 feet (about 1 year flood frequency). At elevation 729.0 feet (about 2 year flood frequency), access roads to recreation areas would be inundated. The Lake Manager will make every effort to inform campsite users when roads and campsites are closed. When water is released for power or flood control purposes, a horn will sound and red lights located on the power house will begin flashing.

Emergency drawdown	Keystone Lake has eighteen 40’ x 35’ tainter gates with a spillway crest at elevation 719.0 feet. The dam also has nine 5’8” x 10’ sluices, controlled by vertical lift gates, with an invert elevation of 657.0 feet. All water in the reservoir can be emptied through the sluices. The minimum time required to empty when the water level is at the top of the conservation pool is 14 days. The total time required to empty the lake from the top of flood control pool would be 41 days.

3 – HYDROLOGY

Drainage area	74,506 square miles, of which 22,351 contribute to runoff

Probable Maximum Flood

Maximum water surface elev.	766.5 feet, NGVD29
Peak inflow (into full pool)	1,117,200 c.f.s.
Total storm runoff	7.50 inches
Volume (into full pool)	8,940,000 acre-feet
Maximum outflow	989,000 c.f.s.
Duration of flood	11 days
Seasonal distinction	All Seasons

Standard Project Flood

Maximum water surface elev.	757.0 feet, NGVD29
Peak inflow (into full pool)	556,000 c.f.s.
Total storm runoff	3.75 inches
Volume (into full pool)	4,470,000 acre-feet
Maximum outflow	551,400 c.f.s.
Duration of flood	11 days
Seasonal distinction	All seasons

Climate	Moderate
One inch of runoff	1,191,308 acre-feet
Storm types	Primarily Thunderstorms

Flood seasons	Mar through Jul and Sep through Nov, although records show floods can occur at any time during the year.
Low flow season	Aug, Sep, and Dec through Feb, but low flow can occur during any time of the year.
Minimum daily inflow and date of occurrence*	13 c.f.s. on 11 Oct 1956
Minimum monthly inflow and date*	3,100 c.f.s. (Sep 1956)
Minimum annual inflow and year*	280,100 acre-feet in 1956 Period of record 1940-2010
Average annual inflow*	5,891,055 acre-feet Period of record 1940-2010
Maximum annual inflow and year*	14,148,650 acre-feet in 1993 Period of record 1940-2010
Maximum monthly inflow and date*	4,440,800 acre-feet in Oct 1986
Maximum daily inflow and date*	310,910 c.f.s. on 5 Oct 1986
Maximum instantaneous inflow and date	344,000 c.f.s. on 5 Oct 1986
Maximum flood volume and date	4,443,800 acre-feet for 29 Sep – 6 Oct 1986

*Based on 1940 - 2010 Period of Record with Kaw, El Dorado, Cheney, and Great Salt Plains Lakes in operation

Name and location of key stream flow stations for Keystone Dam	Arkansas River: Ralston, OK (river mile 594.0) Tulsa, OK (river mile 523.7) Haskell, OK (river mile 483.7) Van Buren, AR (river mile 316.5) Cimarron River: Dover, OK (river mile 160.6) Perkins, OK (river mile 87.3) through Oct 1986 Ripley, OK (river mile 79.2) Since Oct 1987
Type of hydrometeorological data recorded at dam site	Maximum and minimum air temperature Precipitation (recording and non-recording) Pool elevation (recording and staff) Tailwater elevation (recording and staff) Wind at 8 a.m.
Number of precipitation stations used in hydrologic forecasting inflow	6 recording and 27 Mesonet gages, plus 37 stream gages and 6 pool gages.
Number of snow courses	None
Number of sediment ranges	79
Number of degradation ranges	28

4 – EMBANKMENT

Location	Arkansas River at river mile 538.8
Purpose	Flood control, hydropower, water supply, recreation, navigation, and fish and wildlife.
Type	Non-overflow embankment
Type of fill	Rolled earth fill with impervious core
Slope protection	Riprap on upstream face; grassed on

	downstream face.
Height	121 feet above streambed
Length	4,600 feet
Top elevation	771.0 feet, NGVD29
Design flood	Maximum Probable Flood
Freeboard	5.0 feet above maximum pool
Used for roadway	Yes. Oklahoma Highway 151 crosses the embankment and spillway with a 24-foot wide asphalt roadway
Elevation of stream bed	Approximately 650.0 feet, NGVD29

5 – SPILLWAY

Location	Near left abutment
Type	Gated controlled spillway, gravity ogee weir
Crest elevation	719.0 feet, NGVD29
Net overflow length	720 feet
Number, type, and size of gates	Eighteen 40’ x 35’ tainter gates operated by individual electric powered hoists
Top of gate elevation	754.0 feet, NGVD29
Induced surcharge	3 feet
Design head	47 feet
Maximum discharge capacity	49,280 c.f.s. with one gate operating 887,040 c.f.s. with eighteen gates operating (elevation 769.0 feet, NGVD29)

Type of energy dissipater	Concrete slab stilling basin with 2 rows of baffles and a 6 foot high end sill
Time required to open/close gates	45 to 60 minutes from top to bottom positions for tainter gates
Type emergency closure	Diesel powered generating unit is located at project
Spillway activation	The tainter gates and sluices, except for periodic maintenance, are activated only during flood conditions. During normal conditions, all discharges including low flow requirements are released through the penstocks and turbines.

6 – LEVEE

Location	South and east sides of Cleveland, OK
Purpose	Urban protection
Type	Non-overflow, rolled earth levee.
Type of fill	Impervious (river side) and random.
Slope protection	Riprap on river side and grass on city side.
Height (maximum)	43 feet
Length	12,915 feet
Top elevation	763.50 feet, NGVD29
Design flood	Standard project flood with backwater effects from Keystone after 50 years of sedimentation
Freeboard	3.50 feet
Flood closure structure	None

Drainage structures	Area 1: Two 36-inch diameter C.M.P. gravity drains with flap gates. One 12-inch diameter steel pump line with two 1,850-g.p.m., 40-hp pumps. Area 2: One 36-inch diameter C.M.P. gravity drain with flap gate. One 8-inch diameter steel pump line with two 600-g.p.m.,10-hp pumps. Area 3: Two 36-inch diameter C.M.P. gravity drains with flap gates. One 10-inch diameter steel pump line with two 1,000-g.p.m., 20-hp pumps. Area 4: One 36-inch diameter C.M.P. gravity drain with flap gate. One 14-inch diameter steel pump line with two 2,600 g.p.m., 50-hp pumps.

7 – OUTLET FACILITIES

Sluices

Location	Through alternate intermediate piers in spillway
Purpose	Low flow and drawdown releases
Type of outlet	Rectangular
Number and size of gates	Nine 5’8” wide x 10’0” high
Type of service gates	Hydraulically operated lift gates
Entrance invert elevation	657.0, feet NGVD29

Discharge at pertinent elevations	Bottom of conservation pool – 26,000 c.f.s. (elev. 706.0 feet) Top of conservation pool – 30,800 c.f.s. (elev. 723.0 feet) Top of flood control pool – 35,000 c.f.s. with spillway operating and 37,900 c.f.s. with no spillway operating (elev. 754.0 feet) Top of maximum pool – 36,200 c.f.s. with spillway operating and 40,400 c.f.s. with no spillway operating (elev. 766.0 feet)
Minimum pool elevation when inoperative	657.0 feet, NGVD29
Minimum time required to open or close service gates	Average time is 25 minutes from completely closed to completely opened positions
Type of emergency closure	Auxiliary gates similar to operating gates
Type energy dissipater	Tetrahedral deflectors

8 – HYDROELECTRIC POWER FACILITIES

Location	Near left abutment
Type	Storage
Installed capacity	70,000 kilowatts
Number, type, capacity	Two 35,000 kilowatt Kaplan units
Power online date	May 1968 (both units)

Plant factor	37.2% average annual
Load factor	During the four demand months the load factor would be 9.1 percent, and for the critical drawdown period it would be 6.3 percent
Number and size of penstocks	Two (2) 27-foot diameter
Turbine discharge	Top of conservation pool: 5,840 c.f.s. with one unit running, 5,950 c.f.s. per unit when both running. At design head: 6,150 per unit.
Design head (net head)	74.0 feet
Maximum gross head for power	87 feet
Average net head	Conservation pool full (1 unit) - 86.0 feet Conservation pool empty (2 units) - 66.0 feet
Firm Energy	216 MWh/day (1,500 d.s.f.)
Drawdown	17 feet (depth of power pool)
Critical Drawdown	May 1956 to Apr 1957
Minimum peaking capability	63.5 MW at bottom of conservation pool
Dependable capacity	72,000 kW
Estimated Annual Energy	
Primary	43,000,000 kWh
Secondary	185,000,000 kWh
Total	228,000,000 kWh

Conservation Storage	234,920 acre-feet at top of conservation pool (includes 20,000 acre-feet for water supply), remaining amount for hydroelectric power.
Critical tailwater elevation	637.7 feet, NGVD29 (elevation of 0 c.f.s. discharge
Physical Constraints	Downstream channel capacity is 105,000 c.f.s. Maximum fluctuation caused by start-up of generators downstream, is 7 feet.
Operational Constraints	Response time change, normal operations is 20 minutes Response time change, emergency operation is 5 minutes Drawdown limit is 1.0 foot per week, or 3.0 feet for any consecutive 4-week period.

9 - CONTROL POINTS/RIVER REACHES

a. Tulsa Gage (Arkansas River)

Location	At river mile 523.7 on Arkansas River, near left bank on downstream side of bridge on Oklahoma Highway 66 in Tulsa
Purpose	Measure discharge and serve as control point for flood releases from Keystone Lake
Channel description	Meandering over wide sandy bed
Drainage area	74,615 square miles of which 12,541 square miles is probably non-contributing (USGS estimate)
NWS flood stage	18.0 feet (for a minor flood)
Corps regulating stage	Bank full stage is 15.0 feet, 105,000 c.f.s.
Time of water travel Keystone Dam to gage	Approximately 8 hours
Description of equipment	Water-stage recorder
Zero of gage	Elevation 615.23 feet
Maximum stage of record	25.21 feet, 5 Oct 1986
Maximum flow of record	307,000 c.f.s., 5 Oct 1986

9 - CONTROL POINTS/RIVER REACHES (continued)

b. Haskell Gage (Arkansas River

Location	At river mile 483.7 on Arkansas River, near right bank on downstream side of bridge on Oklahoma State Highway No. 104 bridge, two miles east of Haskell.
Purpose	Measure discharge and serve as control point for flood releases from Keystone Lake
Channel description	Meandering over wide sandy bed
Drainage area	75,473 square miles, of which 12,541 square miles is probably noncontributing (USGS estimate)
NWS flood stage	19 feet
Corps Regulating Stage	18 feet
Time of water travel Keystone Dam to gage	26 hours
Description of equipment	Water-stage recorder
Zero of gage	530.0 feet, NGVD29
Maximum stage of record	26.02 feet 1 Jan 1980
Maximum flow of record	259,000 c.f.s. on 5 Oct 1986

c. **Muskogee Gage (Arkansas River)**

Location	At river mile 457.8 on Arkansas River, about 1.7 miles downstream of Grand River. Located on downstream side of left pier of bridge on State Highway 62, 3.5 miles northeast of Muskogee.
Purpose	Measure discharge and serve as control point for flood releases from Keystone Lake
Channel description	Channelized and stabilized
Drainage area	96,674 square miles of which 12,541 square miles is probably non-contributing (USGS estimate)
NWS regulating stage	28.0 feet (for a minor flood)
Corps regulating stage	Bank full stage is 28.0 feet, 120,000 c.f.s. (current rating curve)
Time of water travel Keystone Dam to gage	Approximately 30 hours
Description of equipment	Water-stage recorder
Zero of gage	Elevation 471.38
Maximum stage of record	48.20 feet, 21 May 1943
Maximum flow of record	700,000 c.f.s., 21 May 1943

9 - CONTROL POINTS/RIVER REACHES (continued)

d. **Van Buren Gage (Arkansas River)**

Location	At river mile 308.7 on Arkansas River, in Dam No. 13 control house on right bank
Purpose	Measure discharge and provide river stage data for flood control
Channel description	Channelized and stabilized
Drainage area	149,977 square miles of which 22,241 square miles is probably non-contributing (USGS estimate)
NWS regulating stage	22.0 feet (for a minor flood)
Corps regulating stage	Bankfull stage is 22.0 feet, 150,000 c.f.s. (current rating curve)
Time of water travel Keystone Dam to gage	Approximately 45 hours
Description of equipment	Water stage recorder and gate position recorder
Zero of gage	Elevation 372.36 feet
Maximum stage of record	38.00 feet, 12 May 1943
Maximum flow of record	850,000 c.f.s., 12 May 1943

EXHIBIT B

STANDING INSTRUCTIONS TO LAKE MANAGER

KEYSTONE LAKE

EXHIBIT B

STANDING INSTRUCTIONS TO LAKE MANAGER

KEYSTONE LAKE

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TABLE INDEX

EXHIBIT B
STANDING INSTRUCTIONS TO LAKE MANAGER
KEYSTONE LAKE

I - GENERAL

1. Operation. The lake will be regulated in accordance with the normal regulations for flood control as directed in Section VII of this Manual or Paragraph II-1.a. of this Exhibit. Instructions for the storage and discharge of floodwater will be issued by the Water Management Section. In the event communications with the Tulsa District Office are disrupted, the lake will be regulated in accordance with the schedule of emergency regulations for flood control (see Section VII of this Manual or paragraph II-1.b. of this Exhibit). In addition, the Lake Manager will immediately make every effort to re-establish communications with the Tulsa District.

2. Project Reporting Instructions. Hydrologic data items affecting release of water, confirmation of change in releases as instructed, complaints, operating machinery failure, or out-of service times for maintenance shall be reported to the Water Management Section as they occur.

The following data should be included in the daily report to the Water Management Section (Hydrology-Hydraulics Branch, Tulsa District) from all flood control storage projects with hydropower. Data are typically reported by telephone, fax, or email. Data collected will be reviewed and input into the Water Management Section's data base before 10 a.m. and published to the lake data morning report located at http://www.swt-wc.usace.army.mil/old_resvrept.htm by 10 a.m. See Plate 5-3 for lake data reporting details.

a. As of 8 a.m. Each Weekday.

1) Pool elevations at 12 noon, 4 p.m., and 12 midnight of the previous day and the current 8 a.m. pool elevation and tailwater elevation (if available).

2) The total precipitation amounts for the previous 24-hour period (7 a.m. to 7 a.m. time period).

3) The current wind direction and wind speed (Beaufort scale).

4) Water supply withdrawal or release for previous day (if available).

5) The average power discharge in day second feet (d.s.f.) for the previous 24-hour period (midnight to midnight).

6) The net power generation in megawatt hours (MWh) for the previous 24-hour period (midnight to midnight.)

7) The total discharge in d.s.f for the previous 24-hour period (midnight to midnight).

8) The 8 a.m. instantaneous power discharge in c.f.s.

9) The 8 a.m. instantaneous total discharge in c.f.s.

10) The total hourly discharge in c.f.s for the previous 24-hour period (midnight to midnight).

11) The current gate setting and any gate changes made during the past 24-hour period including the time and pool elevation (and tailwater elevation if necessary) when the change was made.

b. As of 8 a.m. Each Monday.

1) The same data from the weekend as required in I - 2.a. above.

2) The current pool elevation readings from the pool gage, the recording chart or tape, the shaft encoder or data logger, and the wire weight or staff gage. If wind or weather prevents readings on Monday, then these readings can be taken on the next day that weather permits.

c. Weekends and Holidays.

1) Daily reports are not required to be submitted on weekends and holidays except during flood periods.

d. During Flood Periods.

1) During flood periods, weekend and holiday reports should include the same data as required in I - 2.a. above as well as the 8 a.m. pool elevation from the pool gage.

2) In addition to the data in I - 2.a., I - 2.b., and I - 2.c. above, additional reports of lake elevations may be requested by Water Management Section personnel.

3. Reporting Unusual Events. Events or conditions not normally encountered in the routine operation of the dam and lake which might endanger the dam or necessitate temporary or permanent revision of the operating procedures such as settlement, movement, or cracking of the earth embankment or abutments; unusual change in seepage rates, or development of new seepage areas; mechanical malfunction or failure; structural settlement, movement, cracking, or vibration; landslides, rockslides, or indications of an impending movement; or an occurrence indicating any degree of jeopardy to the safety of the dam, or to the safety of the public shall be reported promptly to the Water Management Section, Hydrology-Hydraulics Branch.

4. Warnings. It is the responsibility of the Lake Manager and project personnel authorized to make gate changes to maintain a list in current status of residents and/or property which might be endangered or inconvenienced by large and/or prolonged releases. If damaging releases are expected to occur, notification will be made by telephone, or oral warning by Corps employees. Notification will be made in accordance with the Tulsa District supplements to ER 500-1-1. This would include media such as radio, television, telephone, citizens band radio, use of law enforcement and civil defense agencies and their communication system, National Guard and reserve units, supplemented by oral warning by Corps employees. Studies have been made to determine the possible downstream flood conditions that could exist in the event of a maximum spillway release or failure of the dam at maximum pool. Approximate water surface profiles and flooded area maps giving the results of these studies are kept in the Keystone Lake Operation and Maintenance Manual, Volume II, Contingency Plan for Emergencies. In every case, when a gate change is made a horn is blown to give warning to people immediately downstream of Keystone Dam.

5. Frequency of Gate Changes. During flood periods, gate changes may be directed by the Water Management Section at any time. When the floodwaters have significantly risen into the flood control pool, gate changes can be expected two or three times daily. When the pool level is at or above the top of the flood control pool, gate changes may occur every hour. Only under the most unusual circumstances will changes be ordered more frequently than once every hour. Frequency of gate changes during low flow operation will generally be less than once a day.

II - REGULATION PROCEDURES

1. Regulating River Stages and Discharges. The regulation schedules provide that the channel capacity of 105,000 c.f.s. is not to be exceeded insofar as practicable. Flood waters will be released as rapidly as practicable with consideration given to minimizing flooding of low-water crossings and low-lying farmland. Factors considered in the determination of releases are: maximum inflow into the reservoir during a rise, general climatic conditions, season of the year with respect to the probability of floods, status of crops in low-lying farmlands, and minimum stages or discharges.

a. Normal Flood Control Regulations. Under normal procedures, instructions for storage and release of water for conservation and flood control will be issued by the Tulsa District, Water Management Section. The implementation of the instructions is to be confirmed back to the Water Management Section as soon as the required action is completed. Instructions originating from any other source should not be processed. Keystone Lake will be regulated for optimal flood reductions on the Arkansas River. The regulations shown in Table B-1 will govern releases from Keystone Lake.

b. Emergency Flood Control Regulations. When communication with the Tulsa District Office is disrupted, the Lake Manager will, on his or her own initiative, direct regulation of the lake in accordance with the rules of regulation shown in Table B-2 until communication is restored. In addition, the Lake Manager will immediately make every effort to re-establish communication with the Tulsa District Office. The spillway gates will be operated at uniform openings.

2. During Emergency Events. The Lake Manager may temporarily deviate from the current release rates in the event an immediate short-term departure is deemed necessary for emergency reasons to protect the safety of dam, or to avoid serious hazards to life. Such actions shall be immediately reported by the fastest means of communication available. Actions shall be confirmed in writing the same day to the Water Management Section and shall include justification for the action. Continuation of the deviation will require the express approval of the Water Management Section and the Southwestern Division (SWD) office.

TABLE B -1

NORMAL FLOOD CONTROL REGULATION SCHEDULE
KEYSTONE LAKE
ARKANSAS RIVER, OKLAHOMA

LAKE STAGE	POOL CONDITIONS	REGULATION
Below 723.0	Rising	Releases will be made to maintain elevation 723.0 feet or meet demand for hydroelectric power.
723.0 - 754.0 and forecasted not to exceed 754.0	Rising	Make releases using the following schedule as a guide, except that the release, when combined with intervening flow downstream, shall not exceed a 15.0 foot stage on the Arkansas River at the Tulsa gage (currently estimated 105,000 c.f.s.), an 28-foot stage at the Muskogee gage (currently estimated flow of 120,000 c.f.s.), or a 22.0 foot stage at the Van Buren gage (currently estimated 150,000 c.f.s.) unless superseded by the requirements in Chapter 7 of the Arkansas River Basin Water Control Master Manual. If the flows exceed any of those listed above, no release will be made until the flows recede below flood stage. NOTE: Verify that channel has not changed such that Haskell, 18.0 foot stage (currently estimated 135,000 c.f.s.), is not the controlling gage upstream of Van Buren gage.

RELEASE SCHEDULE

Pool Stages	Maximum Allowable Release Rates (c.f.s.) [1]
723.0 – 725.4 [2]	12,000
725.4 – 734.1 [2]	60,000
734.1 – 754.0	105,000

(1) Releases may be modified to meet requirements of the Arkansas River system operating plan.

(2) Follow the seasonal guide curve shown on Plate 7-1.

TABLE B -1 (continued)

LAKE STAGE	POOL CONDITIONS	REGULATION
754.0 - 757.0 or forecasted to exceed 754.0	Rising	Releases shall be made such that the pool elevation will not exceed 757.0 feet, if possible. If the forecasted inflow will cause the pool to exceed elevation 757.0 feet (top of induced surcharge pool) releases shall be directed by the District Commander, his/her designated representative, or the highest ranking official available in the Engineering and Construction Division, after coordinating the situation with SWD. Plate 7-2, Spillway Gate Regulation Schedule - Inflow Parameter, can be used as a guide for determining releases. If the pool rises to elevation 757.0 feet, releases will be made equal to the inflow. Releases will be made by operating all the spillway gates at uniform openings.
757.0 or above	Rising	Gates shall be opened to maintain elevation 757.0 feet or until the gates are in the full opened position.
757.0 or above	Falling	The maximum gate opening attained shall be held until the pool elevation recedes to elevation 757.0 feet.

TABLE B -1 (continued)

LAKE STAGE	POOL CONDITIONS	REGULATION
757.0 - 754.0	Falling	The maximum gate opening attained shall be held until the pool level recedes an amount sufficient to permit lowering the spillway gates one-half foot without lowering the discharge below inflow. A margin of not less than one-fourth foot between the lake level and the top of the spillway gates shall be maintained at all times. This regulation shall be repeated until the lake level nears elevation 754.0 feet, at which time the outflow shall be made equal to the inflow or the maximum release permissible (as stated below), whichever is greater.
754.0 - 723.0	Falling	Make releases according to the following schedule, except that the release, when combined with intervening area flows downstream, shall not exceed those stages listed under the above rising pool conditions.

Release Schedule

Pool stages	Maximum Allowable Release Rates (c.f.s.) (1)
754.0 – 734.1	105,000
734.1 – 725.4 (2)	60,000 + Inflow (3)
725.4 – 723.0 (2)	12,000 + Inflow (3)

(1) Releases may be modified to meet requirements of the Arkansas River system operating plan.

(2) Follow the Seasonal Guide Curve shown on Plate 7-1.

(3) Forecasted inflow over a 2- to 5-day period.

NOTE: Do not exceed 105,000 c.f.s.

TABLE B – 2

EMERGENCY FLOOD CONTROL REGULATION SCHEDULE
KEYSTONE LAKE
ARKANSAS RIVER, OKLAHOMA

LAKE STAGE	POOL CONDITIONS	REGULATION
Below 723.0	Rising	Continue the releases being made.
723.0 - 748.0	Rising	Maintain releases being made until communication is restored or 12 hours have elapsed. After 12 hours, if communication has not been restored continue the release being made at the time communication was lost. Should the lake level rise above elevation 748.0 feet (approximately 75% of flood pool) during the 12-hour period, releases in accordance with the minimum discharge curve on the "Spillway Gate Regulation - Inflow Parameter" (Plate 7-2), shall be started immediately.
748.0 - 754.0	Rising	(1) Releases shall be made in accordance with the minimum discharge curve on the "Spillway Gate Regulation Schedule – Inflow Parameter" (Plate 7-2). (2) At no time when the lake level is above 748.0 feet and rising shall releases be decreased
754.0 - 757.0	Rising	Releases shall be made every hour in accordance with the inflow curves on Plate 7-2, “Spillway Gate Regulation Schedule - Inflow Parameter”. The previous 6-hour time interval shall be used to compute the inflow as shown on Plate 7-3 (use present pool elevation and pool elevation 6-hours earlier). NOTE: At no time when the lake level is above 754.0 feet and rising shall releases be decreased.
757.0 or above	Rising	Releases shall be increased by raising the spillway gates to maintain elevation 757.0 feet or until all gates are fully open.

TABLE B - 2 (continued)

LAKE STAGE	POOL CONDITIONS	REGULATION
757.0 or above	Falling	Maximum spillway gate openings attained shall be maintained until the lake level recedes to elevation 757.0 feet.
757.0 - 754.0	Falling	The maximum spillway gate opening attained shall be held until the lake level recedes an amount sufficient to permit lowering the spillway gates one-half foot without lowering the release below inflow. A margin of not less than one-fourth foot between the lake level and the top of the spillway gates shall be maintained at all times. This operation shall be repeated until the lake level recedes to elevation 754.0 feet. The minimum release rate shall be 105,000 c.f.s.
754.0 - 734.0	Falling	Releases shall be made equal to the previous 6-hour inflow or 105,000 c.f.s. whichever is greater. (See Plate 7-3 for inflow computation example.)
734.0 - 733.0	Falling	Begin a gradual reduction of the release rate (Not to exceed 15,000 c.f.s. per 3-hour period) until the releases are equal to 60,000 c.f.s. or the previous 6-hour inflow, whichever is greater. (See Plate 7-3 for inflow computation example.)
733.0 - 727.0	Falling	Releases shall be made equal to the previous 6-hour inflow or 60,000 c.f.s. whichever is greater. (See Plate 7-3 for inflow computation example.)
727.0 - 725.0	Falling	Begin a gradual reduction of the release rate (Not to exceed 15,000 c.f.s. per 3-hour period) until the releases are equal to 12,000 c.f.s.
725.0 - 723.0	Falling	Maintain releases of 12,000 c.f.s. At elevation 723.0 feet, reduce releases to that of inflow.

EXHIBIT C

MEMORANDUM OF UNDERSTANDING

CONTRACT NUMBER
DE-(AM)75-80SW00058

COPY

This MEMORANDUM OF UNDERSTANDING is entered into by and between the United States Department of Energy, Southwestern Power Administration (hereinafter called "the Administrator"), and the United States Department of the Army, Corps of Engineers (hereinafter called "the Corps"),

WITNESSETH:

WHEREAS certain statutes provide that various projects constructed in the States of Arkansas, Missouri, Oklahoma, Kansas, Texas, and Louisiana, by the Department of the Army shall be operated and maintained under the direction and supervision of the Corps of Engineers and

WHEREAS the projects set forth in Exhibit A of this memorandum ("Projects") have been or are being constructed and, as shown on Exhibit A, the Division Engineer of either the Missouri River, Lower Mississippi Valley, or Southwestern Division (hereinafter called "the Division Engineer"), is responsible for the operation and maintenance of said Projects; and

WHEREAS the Division Engineer, Southwestern Division, has been delegated authority by the Director of Civil Works to negotiate and sign this memorandum as the representative of the Corps of Engineers; and

WHEREAS the Administrator recognizes the Corps' responsibility to operate the projects to serve all authorized functions including power; and

WHEREAS the Administrator is authorized by Section 5 of PL 534, 78th Congress dated December 22, 1944, to dispose of the electric energy generated from said Projects, surplus to the energy required for their operation and maintenance and to recover the cost of producing and transmitting this energy, including the amortization of capital investment allocated to power over a reasonable period of years; and

WHEREAS the Corps recognizes the Administrator's responsibility for marketing and transmission of the power generated at the projects; and

WHEREAS the Administrator coordinates and schedules the hydroelectric generation at the Projects that constitute the Southwestern Federal Power System; and

WHEREAS the Corps and the Administrator desire to meet the above recited obligations and desire that certain procedures be implemented to maintain an effective working relationship between the staff elements of the Corps and of the Administrator.

NOW, THEREFORE, the parties hereto mutually agree as follows:

1. Term of Memorandum. This memorandum shall be effective commencing on the date of execution and shall remain in effect until terminated upon 90 days prior written notice by either party.

2. Availability of Hydroelectric Generation.

(a) The Division Engineer, during the term of this memorandum, shall make available to the Administrator all of the hydroelectric generation available at the Projects listed in Exhibit A (attached hereto and hereby made a part of this memorandum), in excess of the amounts reserved for use by the projects in accordance with schedules provided by the Administrator and mutually agreed upon by the Administrator and the Division Engineer. The parties hereto agreed to supersede said Exhibit A with a new Exhibit A whenever it becomes necessary to do so as a result of any changes occurring with respect to an existing Project or Projects, or the addition of a new project or projects.

(b) Subject to temporary interruption or reduction in the availability of hydroelectric generation which, in the opinion of the Division Engineer, is necessary for the purpose of maintenance, replacement, installation of equipment, or investigation and inspection, and subject to emergencies, or other extraordinary conditions, the Corps shall operate the Projects so as to schedule and to make available hydroelectric generation as requested by the Administrator, provided that, in the opinion of the Division Engineer, compliance with such request in the operation of the Projects:

(1) Would not require the safe limits of the generating, transforming and switching facilities, and appurtenant equipment of said Projects to be exceeded, or otherwise cause damage to the same;

(2) Would not conflict with the statutory requirements for the operation of said Projects with regard to authorized purposes such as flood control, navigation, irrigation, water supply, and recreation, etc;

(3) Would avoid, insofar as practicable, harmful effects on the environment, including established fish and wildlife resources and recreation;

(4) Would not infringe upon the vested property rights of third parties;

(5) Would not be inconsiderate of the effect on any major downstream construction or maintenance activities being undertaken by public or private entities.

(c) The use by the Corps of hydroelectric generation and the outages contemplated by subsection (b) of this section, shall be scheduled in advance, so far as is practicable, to the end that there will be a minimum

of interference with the availability of hydroelectric generation to the Administrator in accordance with subsection (a) of this section.

3. Emergency. It is recognized that the Administrator has obligations to its customers, the Southwest Power Pool, and the regional power industry to maintain its reliability and prevent power failures and brownouts. In the event that conditions arise which require power and energy in excess of the amount which the Division Engineer and Administrator have mutually agreed to be available from hydro sources, and in excess of that normally available from thermal sources, the Administrator will act to acquire needed power and energy from other sources. If this is not sufficient, the Administrator, after advising the Division Engineer, may declare a power emergency. The Division Engineer's concurrent declaration of operating limits will be based on relaxation of the five limitations contained in the preceding subsection 2(b) to the maximum extent that the emergency justifies and considering any unusual situations that may exist at that time.

4. Detailed Operating Arrangements. The Division Engineer, responsible for particular projects as shown on Exhibit A, and the Administrator will establish mutually satisfactory detailed operating arrangements to be followed in the coordination of their respective responsibilities. Such detailed operating arrangements will be prepared as needed to insure effective coordination between operations for power generation, other authorized project purposes, and protection of the environment. Such detailed operating arrangements when approved by the appropriate Division Engineer and Administrator, will be attached to this Memorandum of Understanding under Exhibit B (attached hereto and hereby made a part of this memorandum) and shall be subject to amendment with the prior written approval of the appropriate Division Engineer and Administrator.

5. License for Lines and Facilities. During the term of this Memorandum the Division Engineer will permit use by the Administrator of land under jurisdiction of the Corps in connection with the operation of the Projects necessary for the location of electric power transmission lines, control and communications lines and cables, substations, switching stations, radio stations, and appurtenances constructed or found necessary by the Administrator for construction in connection with the marketing of electric power and energy produced at said Projects. Before commencement of any construction on lands under the jurisdiction of the Corps, the Administrator will submit to the Division Engineer copies of his layout, plans, and designs, and construction activities will not be started until the Division Engineer has furnished a permit or letter to the Administrator approving the construction and the location thereof. The Administrator will provide any environmental impact statement required for proposed construction.

6. Cooperation. The Division Engineer and the Administrator will make available to each other all the information necessary for the Administrator and the Division Engineer to meet their responsibilities

pursuant to law. The timely interchange of certain data and information will be necessary to insure efficient operation for all purposes. Accordingly, such interchange will be made promptly as pertinent data and information become available. Any equipment shall be installed in such a way that there will be no adverse effect on the existing equipment of the other party. The specific information interchanged between the Administrator and the Division Engineer shall include, but not be limited to, the following:

(a) The Division Engineer will furnish data on power resources available at the Projects and data which have a bearing on loading of the plants and limitations of operation.

(b) The Administrator will furnish data on estimated Federal system load requirements, and other pertinent information as are needed to permit the Division Engineer to carry out his responsibilities for multiple-purpose operation at the Projects.

(c) The Division Engineer and the Administrator will discuss plans for adding or changing power projects, transmission facilities, and control and communication facilities in the preliminary planning phases to ensure effective coordination.

(d) The Division Engineer will furnish the Administrator with Reservoir Regulation Manuals for information and comment prior to final approval.

(e) The Administrator will furnish the Division Engineer power sales contracts for information. In addition, those contracts providing for the sale of power generation from Projects not integrated with the SWPA System, will be furnished to the Division Engineer for comment prior to final approval.

(f) The Division Engineer will furnish the Administrator summarized financial statements and operating reports with respect to construction and operation of the Projects. The financial statements will include costs as incurred under the Corps' GAO approved accounting system. The Administrator will furnish the Division Engineer like statements and reports with respect to the marketing of and accounting for revenues from power and energy made available to it from the Projects. Such statements and reports for each Project will be furnished promptly after the close of each governmental fiscal year following commencement of generation and for such other periods during each year and in such form as may be mutually agreed upon from time to time.

IN WITNESS WHEREOF, the parties hereto have executed this Memorandum as of 23 July 1980.

UNITED STATES OF AMERICA

Department of Energy

By _____
Administrator
Southwestern Power Administration

Approved as to Legal Form and Sufficiency

_____
Chief Counsel
Southwestern Power Administration

Department of the Army

By _____
Division Engineer, Southwestern Division
Corps of Engineers

Projects of the Corps

(Completed and Under Construction)

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

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

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

DEPARTMENT OF THE ARMY
SOUTHWESTERN DIVISION, CORPS OF ENGINEERS
1114 COMMERCE STREET
DALLAS, TEXAS 75242-0216

REPLY TO ATTENTION OF

October 30, 1986

SWPA OFFICIAL COPY

From/Date: SD 11/03/86		
Assigned to:	ORG	DATE
No Action Req.	INITIAL	DATE
Copies to:		
SURNAME	DATE	Route Code
W	11/5	100
	11/6	101
	11-7	~~300~~
	11/13	330

Water Management Branch
Engineering Division

Mr. Ronald H. Wilkerson
Administrator
Southwestern Power Administration
Post Office Box 1619
Tulsa, Oklahoma 74101

Dear Mr. Wilkerson:

In your letter transmitted to me on 23 October 1986, you referred to the meeting between our staffs of 22 October 1986. As expressed by my staff in that meeting, there is a safety hazard created downstream during rapid hydropower generation changes and the safety of the people in the downstream areas must be considered during start up of the hydropower units. Therefore, Table 5, title "Response time to change in generation" defining these limitations cannot be deferred as requested by your staff.

I do understand that there is a meeting next week among you, your customer, and the Little Rock District to discuss these issues as they pertain to Bull Shoals and Table Rock projects. However, I must reemphasize from a safety standpoint that those criteria and responsibilities contained in the Draft Operating Arrangement are considered SWD operating policies and will be used until these differences are resolved.

I have included a copy of the Draft Operating Arrangement dated 20 October 1986 for your reference. I am also looking forward to the formal signing of this document in the near future.

Sincerely,

J. B. Hilmes
Major General, U. S. Army
Division Engineer

Enclosure

Copies Furnished:

Commander, Little Rock District
Commander, Tulsa District
Commander, Fort Worth District

Department of Energy
Southwestern Power Administration
Post Office Box 1619
Tulsa, Oklahoma 74101

OCT 23 1986

Major General Jerome B. Hilmes
Division Engineer
Southwestern Division
U.S. Army Corps of Engineers
1114 Commerce Street
Dallas, TX 75242-0216

Dear General Hilmes:

In accordance with the meeting between our staffs in Dallas yesterday, it was recommended you and I delay signing the Operating Arrangement on Monday, October 27, 1986, as previously scheduled. A customer has expressed concerns about some operational criteria that appear to be in conflict with provisions in his power sales contract. Southwestern Power Administration, Little Rock District Corps of Engineers, and this particular customer have previously scheduled a meeting next week in Arkansas where this issue among others will be discussed and hopefully resolved. If we are successful, I would anticipate signing the Operational Arrangement in the near future. I will contact you to arrange a convenient time for that signing.

Sincerely,

Ronald H. Wilkerson

Ronald H. Wilkerson
Administrator

20 OCT 86

DRAFT

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

Exhibit "B"

OPERATING ARRANGEMENT
(Reservoir Regulation and Power Scheduling)

1. Authority. This Arrangement states the principles and procedures relating to reservoir regulation and power scheduling of Corps of Engineers Hydroelectric Projects within the Southwestern Division (SWD) and the Southwestern Power Administration (SWPA). This Arrangement was developed in compliance with Paragraph 4 of the Memorandum of Understanding (MOU) dated 23 July 1980 and the authority therein.

2. Revision or Termination. This Operating Arrangement shall be effective commencing on the date of execution and shall remain in effect until terminated upon 90 days prior written notice by either party. It is provided further, that this Operating Arrangement may be amended with the mutual written consent of both parties.

3. Obligations. SWD and SWPA agree on the following obligations:

a. Obligations of SWPA:

(1) The marketing and transmission of surplus (in excess of project requirements) power.

(2) The preparation of monthly estimates of generation requirements for each SWD project.

(3) The scheduling of power plants to meet system requirements.

(4) To contract for the sale of power generated at SWD projects.

b. Obligations of SWD:

(1) The regulation of SWD projects for authorized purposes and in accordance with Presidential directives.

(2) The daily operation and maintenance of electric generation and switchyard facilities at each SWD power plant.

(3) The planning of hourly, daily and monthly regulations of SWD projects.

(4) The preservation of project integrity.

c. SWD and SWPA agree to consult on load and resource requirements.

d. SWD and SWPA agree to undertake improvements in their respective computer facilities.

4. Procedures.

a. Power Allocations and Monthly Meetings.

(1) A monthly hydropower meeting will be held by SWPA on or before the last Thursday of each month to develop a 30-day operational plan, including allocations for the next month, and to review current operations, planned outages, transmission limitations, reservoir conditions (current and projected), and other items of mutual concern. The meeting may be conducted by telephone conference, providing each party approves.

(2) SWD will furnish SWPA recommended monthly available energy along with maximum and minimum energy quantities for their projects for the following month. Recommended monthly hydropower energies will consider the individual project rule curve, system guide curve, projected reservoir condition, and other beneficial reservoir uses. This information will be provided formally within four (4) working days prior to the monthly hydropower meeting.

(3) SWPA will furnish SWD its anticipated energy needs for the following month from SWD projects. Monthly hydropower needs will consider load requirements, the condition of the interconnected reservoir system, system guide curve, projected reservoir conditions, available capacity, inflow trends and the ability to obtain energy at a reasonable cost from other sources. This data will be available for two (2) days before the monthly hydropower meeting.

(4) Prior to each month's operations, an agreement between SWPA and SWD as to the proposed generation (hydropower allocation) to be accomplished at each SWD project will be obtained. A written confirmation of that agreement will be provided to SWD by SWPA. In the event that an agreement cannot be obtained at the monthly meeting, negotiations between the Administrator and Division Commander will commence.

b. Operation.

(1) General.

(a) SWPA will schedule the monthly hydropower production in accordance with the monthly agreement. However, in the event of special conditions or unforeseen events, SWPA may schedule hydropower production differently than specified in the monthly agreement, provided that these changes are arranged with the responsible SWD District Office prior to scheduling.

(b) Operation of SWD projects for hydropower operations within approved regulations will be handled between SWPA and the appropriate SWD District Office. Only in cases of disagreement concerning operations, will SWD become involved in the day-to-day operations described herein.

(c) Energy generation will commence or be adjusted when the dispatcher makes a request to the power plant operator. The power plant operator will verify that the request is within the limits agreed to between the two agencies and that it does not violate any special instructions issued by the District office. If these conditions are satisfied, the operator will commence generation to the requested limits as rapidly as conditions and equipment will permit. If the request exceeds the limits or violates the conditions previously established, the power plant operator will advise the dispatcher as to what generation is available from the power plant. It is the intent that, to the extent possible, dispatchers and power plant operators relay all problems to the respective control offices.

(d) Daily (prior to 10.00 a.m.), SWD District Offices will provide SWPA a 4-day forecast of inflow, pool elevations and any limiting constraints for each project.

(2) Flood Control Operations.

(a) During flood control operations, SWD District Office will furnish to SWPA a weekly statement of flood control objectives for the next seven days relative to individual pool regulations and planned release volumes. The release schedule will be furnished by phone until adequate computer interconnections are available.

(b) SWPA will plan its weekly generation schedule compatible with stated flood control release schedules for the week.

(c) SWD District Offices will make a daily declaration to SWPA of energy available or required releases. The minimum hydropower releases are listed in Table 1. Only under flood conditions as defined in paragraph 4(b)(4)(e) herein may generation be limited to less than shown in Table 1.

(d) SWD District Offices will provide SWPA, when possible, 48-hour notice of a change in operation that will affect power production.

(e) SWPA will reschedule generation between projects and/or obtain non-hydropower to meet its needs as expeditiously as possible to effect any reductions in project releases required by SWD District Offices for flood control needs.

(3) Conservation Operation.

(a) Each day prior to 3.30 p.m., SWPA will furnish the SWD District Offices updated hourly generation schedules for each project for the remainder of the current day and for the following day. Weekend and holiday generation schedules will be furnished by 3.30 p.m., on the last working day prior to the weekend or holiday and will also include the schedule for the next working day.

(b) SWPA will be responsible for daily hydropower operations to meet the needs of their customers and downstream release requirements shown in Table 2. Table 3 shows desirable downstream release requirements to be accomplished providing hydrologic conditions are favorable. Favorable hydrologic conditions are included in Table 3.

(c) SWPA will furnish SWD a weekly statement of their generation plans and objectives relative to pool manipulations, balancing operations, thermal purchases and other details which will provide an understanding of scheduling and generation patterns and the effects to be expected at each project. The weekly statement will be provided, if possible, by 2:00 p.m., on the preceding Friday and will include an estimate of daily release volumes from each project. This will be by telephone until such time as adequate computer interconnections are available.

(d) Release schedules by SWPA and the districts will consider project and system guide curves, pool zone criteria, drawdown limits, current and projected pool conditions, downstream needs, and the needs of other authorized uses of the project.

(e) Table 4 shows maximum drawdown rates within the conservation pool for applicable Corps projects.

(4) Special Operations.

(a) General. Normally, special operations will be coordinated by SWD Districts and documentated in the minutes of the monthly hydropower meeting. Those special operations which have significant impacts on SWPA will be coordinated by SWD. If an emergency does not exist, SWD will consult with SWPA on alternatives and the impacts of these alternatives on the economics and reliability of the federal hydropower system. SWD will notify SWPA of the special operating limits which are necessary for the operation of its projects. Notification will be provided as soon as each special operating limit is determined. Written or teletype confirmation of each special operation limit will be transmitted by SWD to SWPA. Such notifications and confirmations will include the nature of the limit, the firmness of the limit, its probable duration, and the reason for the limit.

(b) Short Term Power Emergency. It is recognized that certain situations which adversely affect system reliability may occur. Such circumstances demand a rapid response to prevent deterioration of the system reliability. The necessary response may involve a deviation from previously agreed to schedules. These situations (short term emergencies) typically involve overloaded facilities and/or low voltage and may arise slowly, as when due to high power demands, or suddenly, as when due to the loss of a line, station, or generator on the SWPA or a neighboring system. When possible, the response deemed necessary by the SWPA dispatcher will be coordinated prior to scheduling with the appropriate SWD District Office.

When the required response time does not permit prior coordination the power plant operator will follow the direction of the SWPA dispatcher within limits specified in Table 5 and the safe operating limits of the generating, transforming and switching equipment, and the necessary coordination will begin as soon as practical. Table 5 lists the minimum time required for each project to respond to a generation change under normal and emergency conditions.

(c) Declared Power Emergency. It is recognized that SWPA has obligations to its customers, the Southwest Power Pool, and the regional power industry to maintain its reliability and prevent power failures and brownouts. In the event that conditions arise which require power and energy in excess of the amount which the Division Commander and Administrator have mutually agreed to be available from hydro sources, and in excess of that normally available from thermal sources, the Administrator will act to acquire needed power and energy from other sources. If this is not sufficient, the Administrator, after advising the Division Commander, may declare a power emergency. The Division Commander's concurrent declaration of operating limits will be based on relaxation of the five limitations listed in this paragraph to the maximum extent that the emergency justifies and considering any unusual situations that may exist at that time.

(i) Would not require the safe limits of the generating, transforming and switching facilities, and appurtenant equipment of said projects to be exceeded or otherwise cause damage to the same.

(ii) Would not conflict with the statutory requirements for the operation of said projects with regard to authorized purposes such as flood control, navigation, irrigation, water supply, and recreation, etc,

(iii) Would avoid, insofar as practicable, harmful effects on the environment, including established fish and wildlife resources and recreation.

(iv) Would not infringe upon the vested property rights of third parties.

(v) Would not be inconsiderate of the effect on any major downstream construction or maintenance activities by public or private entities.

(d) Short Term Emergency. Short term emergencies requiring a reduction in releases such as for drowning, imminent loss of life or property, emergency maintenance or to preserve the

integrity of the project may be coordinated directly between SWD powerhouse personnel and SWPA dispatcher. Information documenting the emergency and the actions taken shall be forwarded to SWPA at the earliest possible time.

(e) Flood Constraints. SWPA recognizes that the SWD has the responsibility to minimize flooding to the extent possible by the regulation of Federal projects. Hydropower generation will be constrained to the extent possible during flood periods to prevent reservoir releases from adding to downstream flood damages. Normally, the constraints on power generation at SWD projects during flood periods will not be less than the minimum hydropower releases as shown on Table 1. However, conditions may occur where it is desirable for reservoir releases to be reduced below the Table 1 values to prevent or reduce downstream flooding. In this event, the SWD district office will notify SWPA of the restriction and its estimated duration. SWPA, if possible, will take action to reschedule generation such that the restriction can be accomplished. If this proposed restriction of power generation results in a determination by SWPA that a significant economic loss to the Federal Government or to SWPA customers would result, SWPA shall report that impact to the SWD district. Upon receipt of the SWPA finding of significant economic impact, the district shall increase the permissible release to the Table 1 value or request SWD to formally establish the constraint with documentation to SWPA describing the need, duration, and impacts of the constraint. If under such constraints as established by SWD, SWPA determines there is not enough power and energy available to maintain electric service to consumers in the marketing area, the Division Commander, based on the information provided by the respective SWD district offices and SWPA, will declare sufficient energy available by project to meet minimum needs.

(5) Individual Project Regulation and System Hydropower Operation. To enhance the working relationship between SWD and SWPA and to form a basis for general concurrence on how the individual projects and the power system will be operated, the following will be undertaken:

(a) SWD will provide Water Control Manuals to SWPA for information and comment before final adoption. Table 6 is a list of applicable projects.

(b) SWD will provide operating guide curves and pool zone criteria for each of the SWD hydroelectric projects within the SWPA marketing area. Subsequent changes of and addition to operating guide curves will be transmitted by letter from the Division Commander to SWPA. The SWPA will comment by letter.

(c) The parties will undertake cooperative effort to establish a system guide curve that will reflect SWPA and SWD needs, including defining the periods that supplemental power may be purchased to offset the power demands.

(d) SWD will provide any update of plant efficiency curves (included in this agreement by reference) for maximizing power performance at individual projects as shown in Table 7.

(e) The Administrator will furnish SWD power sales contract for information. In addition, those contracts providing for the sale of power generation from Projects listed by name in the contracts will be furnished to the Division Commander for comment prior to final approval.

(6) Generation Scheduling. Request for actual generation at a power plant will be given to the power plant operator by the SWPA dispatcher or dispatcher designated in writing by SWPA. To the maximum extent possible, these directions will conform with the generation guidelines agreed to by the appropriate representatives of SWPA and the SWD.

(7) Generating Equipment Maintenance Schedule. The planned outage schedule will be prepared by the SWD in January each year and will be furnished to SWPA by February 1. The SWD will make every effort to avoid scheduling outages during power system peak load periods (Jun 15 - Sep 15 and Dec 15 - Mar 15). SWPA requests for schedule changes shall be submitted to SWD in writing within 30 days after receipt of the schedule. SWD will accommodate the requests to the maximum extent practicable within available resources, including manpower resources. SWPA requests for rescheduling during the course of the year due to unanticipated load requirements or water conditions, shall be transmitted to the SWD by letter. SWD will furnish a timely response. Changes to the schedule initiated by SWD during the course of the year will be coordinated with SWPA. A revised schedule will be pre-pared and distributed if any significant changes are made during the year. The SWD will give SWPA as much advance notice as possible in the event of unplanned or forced outages.

(8) Switching Activities. All switching at SWD power plants which may affect the high-voltage transmission system or the availability of a unit will be coordinated with each party. Detailed procedures governing clearance and hold orders will be developed and included as a part of the Arrangement.

c. Reporting. The following summary of reporting requirements is not intended to include all aspects of data and information exchange needed between the SWPA and SWD elements.

(1) Daily observed hydrologic data, forecasts, flood control release requirements and schedules will be supplied by telephone between SWPA and SWD District Offices. Summary confirmations will be supplied on the computer data file program to the extent possible.

(2) Weekly plans and schedules will be exchanged by SWPA and SWD District Offices by telephone until adequate computer interconnections are available. At that time, these will be furnished through the interconnected facilities.

(3) Notifications of constraints, emergencies or revisions will be furnished by telephone with computer data file confirmation. All elements will be included in the notification for coordinated approvals and actions. Follow-up teletypes or letters may be required for official documentation.

(4) Special needs or operations will be furnished by telephone with follow-up teletype or letter between SWPA and SWD with copies to appropriate SWD District Office. When possible these may be covered in monthly hydropower meetings and documented in the meeting minutes without additional correspondence.

(5) Monthly hydropower meeting minutes (including pre-meeting summaries, agenda, needs, recommendations and follow-up allocations) will be furnished by teletype or letter to all elements.

(6) Record of actual hydropower generated during the previous month will be provided for each project by SWPA by mail until adequate computer connections are available.

(7) Records of hourly generation and water releases for each power plant will be furnished to SWPA.

TABLE 1
MINIMUM HYDROPOWER RELEASES
DURING FLOOD CONDITIONS

Reservoir	Allowable Daily Release Volume (DSF)	Energy (MWH) (1)
Beaver	950	332
Broken Bow	850	290
Bull Shoals	3,750	1,352
Denison	2,300	429
Eufaula	2,150	358
Fort Gibson	1,800	197
Greers Ferry	1,200	404
Keystone	1,500	216
Norfork	1,300	410
Sam Rayburn	1,150	161
Table Rock	2,550	943
Tenkiller Ferry	600	160
Whitney	500	86

(1) Energy values represent the energy produced by the daily release volume when pool elevation is at top of power pool.

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)	Discha. (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.

TABLE 3

DESIRABLE
WATER RELEASE REQUIREMENTS
FOR INSTREAM FLOW NEEDS

PROJECT	PERIOD OF TIME IN EFFECT	WATER RELEASE REQUIREMENTS	FAVORABLE HYDROLOGIC CONDITIONS
Dardanelle	Jan - Dec	Maximum 50-hour down time (minimum generation is 1,750 MWH 1/ per week, or inflow, whichever is less). Use at least 25 percent weekly total on Monday and Friday when minimum weekly generation scheduled.	Not restricted.
Denison	Jan - Dec	Generate at least one hour with one unit every fourth day, or as needed to replenish oxygen content of water in the tailrace and stilling basin.	Above elevation 612.0
Eufaula	Jan - Dec	Generate at least one hour with one unit every fourth day, or as needed to replenish oxygen content of water in the tailrace and stilling basin.	Not restricted.
Tenkiller Ferry	Oct 16 - May 31 Jun 1 - Oct 15	One Hour 10 MW Morning and Afternoon. One Hour 10 MW Morning and Afternoon.	Not restricted.
Bull Shoals	May 1 - Oct 15	The minimum combined operation at Bull Shoals and Norfork shall not be less than a 3-day summation of 6,000 DSF (approximately 2,000 MWH). This applies for all air temperature conditions at or above 85 .	Above elevation 649.0
Norfork	May 1 - Oct 12	Same as above.	Above elevation 545.0

1/ Minimum generation is based on 3,000 DSF.

TABLE 4

MAXIMUM DRAWDOWN
RATES IN CONSERVATION POOL

Project	Maximum Drawdown Per Week (ft)	Maximum Drawdown In Any Consecutive 4-Week Period (ft)
Beaver	2.0	6.0
Norfork	1.5	5.0
Greers Ferry	1.0	4.0
Table Rock	1.5	4.5
Bull Shoals	1.5	4.5
Keystone	1.0	3.0
Tenkiller Ferry	1.5	4.5
Eufaula	1.0	3.0
Denison	1.0	3.0
Broken Bow	2.0	6.0
Sam Rayburn	1.0	2.0
Whitney	1.0	3.0

TABLE 5
RESPONSE TIME TO CHANGE IN GENERATION

PROJECT	TIME	
	NORMAL	EMERGENCY
FORT WORTH DISTRICT		
Sam Rayburn	20 Minutes	5 Minutes
Whitney	20 Minutes	5 Minutes
LITTLE ROCK DISTRICT		
Beaver	10 Minutes	5 Minutes
Bull Shoals	10 Minutes 1/	5 Minutes
Table Rock	10 Minutes 2/	5 Minutes
Norfork	10 Minutes	5 Minutes
Greers Ferry	10 Minutes	5 Minutes
Dardanelle	10 Minutes	5 Minutes
Ozark	10 Minutes	5 Minutes
TULSA DISTRICT		
Broken Bow	20 Minutes	5 Minutes
Denison	20 Minutes	5 Minutes
Eufaula	20 Minutes	5 Minutes
Fort Gibson	20 Minutes	5 Minutes
Keystone	20 Minutes	5 Minutes
Robert S. Kerr	20 Minutes 3/	5 Minutes
Tenkiller Ferry	20 Minutes	5 Minutes
Webbers Falls	20 Minutes	5 Minutes

Notes:

General. Indicated Emergency Start Up and Loading times assume the powerplant control room operator is starting and loading only the local units. If the operator is starting and loading remote units, response times could be as much as twice as long for starting and loading the local units. Exact Emergency Start Up and Loading times for remote plants will depend greatly upon how many units, both local and remote, the control room operator is attempting to start and load.

1/ During normal operations, the initial start up and final shutdown should not exceed 100 megawatts per hour. Additional changes should not exceed 100 megawatts per 30 minutes.

2/ During normal operations, the initial start up and final shutdown should not exceed 115 megawatts per hour.

3/ First two units may start simultaneously. A lag of 1/2 hour between third and fourth units or a lag of one hour if third and fourth are started simultaneously.

TABLE 6

WATER CONTROL MANUALS

TITLE	DATE
Lake Regulation Manual, Broken Bow Lake	Oct 1973
Water Control Manual, Lake Texoma	May 1975
Reservoir Regulation Manual for Eufaula Reservoir	Sep 1962
Reservoir Regulation Manual for Pensacola, Markham Ferry and Fort Gibson Reservoirs	Sep 1964
Reservoir Regulation Manual for Keystone Reservoir	Nov 1963
Reservoir Regulation Manual, Robert S. Kerr Lock and Dam and Reservoir	Apr 1971
Lake Regulation Manual, Tenkiller Ferry Lake	Jul 1976
Reservoir Regulation Manual, Webbers Falls Lock and Dam	May 1972
Sam Rayburn	Jan 1982
Whitney	Apr 1975
Reservoir Regulation Manual for Greers Ferry Reservoir	Mar 1963 Revised Nov 1966
Reservoir Regulation Manual for Beaver, Table Rock, Bull Shoals and Norfork Reservoirs	Mar 1963 Revised Oct 1966
Regulation Manual for Ozark Lake and Pool No. 13	Oct 1974
Regulation Manual for Pool No. 9 and Lake Dardanelle	Feb 1976
Master Water Control Manual, Arkansas River	Jul 1980

TABLE 7

PROJECTS WITH PLANT EFFICIENCY CURVES

Beaver

Broken Bow

Bull Shoals (1)

Dardanelle

Denison

Eufaula

Fort Gibson

Greers Ferry

Keystone

Norfork (1)

Ozark

Sam Rayburn

Table Rock

Tenkiller Ferry (1)

Webbers Falls

Whitney

(1) Curves developed before units were rewound

IN WITNESS WHEREOF, the parties have executed this Memorandum as of _____, 1986.

UNITED STATES OF AMERICA
Department of Energy

By _____
Administrator
Southwestern Power Administration

Approved as to Legal
Form and Sufficiency

_____
Chief Counsel
Southwestern Power Administration

UNITED STATES OF AMERICA
Department of the Army

By _____
Division Commander
Southwestern Division
Corps of Engineers

Approved as to Legal
Form and Sufficiency

_____
Division Counsel
Southwestern Division
Corps of Engineers

EXHIBIT D

OPERATING PLAN FOR SOUTHWESTERN DIVISION (SWD) CORPS OF ENGINEERS (COE) HYDROPOWER

OPERATING PLAN FOR SOUTHWESTERN DIVISION (SWD) CORPS OF ENGINEERS (COE) HYDROPOWER

OPERATING PLAN

TABLE OF CONTENTS

ENCLOSURES

OPERATING PLAN

(Reservoir Regulation and Power Scheduling)

1. Purpose To outline processes and procedures for coordination of operations, maintenance, regulation of our power plant generation equipment and schedules. The goal is to operate projects within the authorized purposes. This document does not supersede any information or requirements, contained in water control manuals (see Table 6 for list of manuals and latest revisions), or other legal determinations. Also this document does not supersede or replace the 1986 Operating Arrangement between the Corps of Engineers (COE) and Southwestern Power Administration (SWPA).

2. Activities. SWD and SWPA activities include:

2.1 Activities of SWD:

2.1.1 The regulation of SWD District projects in accordance with authorized purposes and in accordance with approved water control plans and approved deviations.

2.1.2 The daily operation and maintenance of electric generation equipment and project facilities, including scheduling of outages at each SWD power plant.

2.1.3 The determination of hourly, daily and monthly water release requirements at SWD projects.

2.1.4 The preservation of project integrity.

2.2 Activities of SWPA:

2.2.1 The marketing and transmission of surplus (in excess of project requirements) power.

2.2.2 The preparation of monthly estimates of generation requirements for each SWD project.

2.2.3 The hourly, daily and monthly scheduling of power plants to meet system requirements.

2.2.4 To contract for the sale of power and energy generated at SWD projects.

2.3 SWD and SWPA will consult on load and resource requirements.

3. Procedures.

3.1 Power Allocations and Monthly Meetings.

3.1.1 A monthly hydropower meeting will be held by SWPA each month to develop a 30-day operational plan, including allocations for the next month, and to review current operations, planned outages, transmission limitations, reservoir conditions (current and projected), and other items of mutual concern. The meeting may be conducted by telephone conference or in person.

3.1.2 SWD may furnish SWPA recommended monthly available energy along with maximum and minimum energy quantities for their projects for the following month. Development of recommended monthly hydropower energies will consider the individual project rule curve, projected reservoir condition, water quality, endangered species, fish and wildlife and any authorized reservoir uses. This information will be provided formally via email prior to the monthly hydropower meeting.

3.1.3 SWPA will furnish SWD its anticipated energy needs for the following month from SWD projects. These monthly hydropower needs will consider SWPA system guide curve, load requirements, the condition of the interconnected reservoir system, projected reservoir conditions, available capacity, inflow trends and the ability to obtain energy from other sources. This information will be available to each SWD district via email prior to the monthly hydropower meeting.

3.1.4 During the monthly operational meeting, both SWPA and each SWD District will agree on the proposed generation (hydropower allocation) at each SWD project. The agreed upon releases will be documented in the final monthly operations meeting minutes prepared by SWPA which will be transmitted via email.

3.2 Operation.

3.2.1 General.

3.2.1.1 SWPA will schedule the monthly hydropower production in accordance with the monthly agreement. However, in event of special conditions or unforeseen events, SWPA may schedule hydropower production differently than specified in monthly agreement, provided that these changes are arranged with the responsible SWD District Office prior to scheduling.

3.2.1.2 Operation of SWD projects for hydropower operations within approved regulations will be handled between SWPA and the appropriate SWD District Office. Occasionally SWD will become involved in regional and special day-to-day operations described herein.

3.2.1.3 Power plant system controller shall begin or adjust generation in accordance with SWPA schedule as requested. The power plant system controller will verify that the request is within the limits agreed to between the two agencies and that it does not violate any special instructions issued by the District Office. If these conditions are satisfied, the controller will commence generation to the requested limits in a manner consistent with the system needs (normally across the hour in a ten-minute period). If the request exceeds the limits or violates the conditions previously established, the power plant system controller will advise the dispatcher as to what generation is available from the power plant.

3.2.1.4 Daily, SWD District Offices will make available to SWPA 4-day forecast of inflow, pool elevations and any limiting constraints for each project.

3.2.1.5 If it is determined that a turbine is operating in a rough zone, either the load will be changed or the unit will be shutdown to prevent damage to equipment. Power Plant System controller will contact the SWPA Dispatcher to facilitate the reliability of the bulk power system.

3.2.1.6 Notification of all scheduled and unscheduled outages shall be made using the attached unit un-availability for (Form 2) or revision thereto. The report shall be used to notify SWPA, internal Corps Offices and SWD. Notifications will be given when unit is removed and returned to service.

3.2.2 Flood Risk Management Operations.

3.2.2.1 During flood risk management operations, SWD H&H District Offices will furnish to SWPA a statement of flood control objectives for the next four days relative to individual pool regulations and planned release volumes. The release schedule will be furnished via email.

3.2.2.2 SWPA will plan its generation schedule consistent with flood releases.

3.2.2.3 SWD District Offices will coordinate daily if necessary with SWPA and provide required releases. The firm power hydropower releases are listed in Table 1. Generation may be limited to less than that shown in Table 1 for conditions described in para 3.2.4.5

3.2.2.4 SWPA will reschedule generation between projects and/or obtain other resources to meet its needs to effect any changes in project releases required by SWD District Offices for flood risk management needs to the extent possible. In the event SWPA is unable to reschedule generation or obtain sufficient resources to meet its needs,

SWPA may declare a power emergency in accordance with Section 3.2.4.3 Declared Power Emergency.

3.2.3 Conservation Operation.

3.2.3.1 Each day prior to 3:30 p.m., SWPA will furnish the SWD District Offices updated hourly generation schedules for each project for the remainder of the current day and for the following day. Weekend and holiday generation schedules will be furnished by 3:30 p.m., on the last working day prior to the weekend or holiday and will also include the schedule for the next working day.

3.2.3.2 SWPA will be responsible for daily hydropower operations to meet needs of their customers and downstream release requirements shown in Table 2. Table 3 shows desirable downstream release requirements to be accomplished providing hydrologic conditions are favorable. Favorable hydrologic conditions are included in Table 3.

3.2.3.3 SWPA will furnish SWD a weekly statement of their generation plans and objectives relative to pool manipulations. The weekly statement will be provided, if possible by 2:00 p.m., on the preceding Friday and will include an estimate of daily release volumes from each project.

3.2.3.4 Release schedules by SWPA and the Districts will consider project and system curves, pool zone criteria, drawdown limits, current and projected pool conditions, downstream needs, and the needs of other authorized uses of the project.

3.2.3.5 Table 4 shows maximum drawdown rates within the conservation pool for applicable Corps projects.

3.2.4 Special Operations

3.2.4.1 General. Normally, special operations will be coordinated by SWD Districts and SWPA. These operations will be documented in the minutes of the monthly hydropower meeting. If these special operations arise after the scheduled monthly meeting the SWD District will email the completed special operations form (Form 1) to SWPA. SWD Districts will coordinate with SWD those special operations which have significant impacts on SWPA. SWD Districts will notify SWPA of the special operating limits which are necessary for the operation of its projects. SWPA will be notified of planned special operations by email using the special operations form. SWD Districts will notify SWPA as soon as each special operating schedule is determined.

3.2.4.2 Short Term Power Emergency. It is recognized that certain situations which adversely affect system reliability may occur. Such circumstances demand a rapid response to prevent deterioration of the system reliability. The necessary response may involve a

modification from previously agreed to schedules. These situations (short term emergencies) typica1ly involve overloaded facilities and/or low voltage and may arise slowly, as when due to high power demands, or suddenly, as when due to the loss of a line, station, or generator on the SWPA or a neighboring system. When possible, the response deemed necessary by the SWPA will be coordinated prior to scheduling with the appropriate SWD District Office. When the required response does not permit prior coordination, the power plant system controller will follow the direction of the SWPA dispatcher within limits specified in Table 5 and the safe operating limits of the generating, transforming and switching equipment, and the necessary coordination will begin as soon as practical. Table 5 lists the minimum time required for project to respond to a generation change under normal and emergency conditions.

3.2.4.3 Declared Power Emergency. It is recognized that SWPA has an obligation to its customers, the Southwest Power Pool (SPP), and various regulatory bodies to adhere to mandatory reliability standards and requirements in an effort to minimize power system disturbances. In the event of a declared power emergency, the power plant system controller can make limited excursions beyond normal operation limits provided that equipment rating is not exceeded. For all operations, either normal or emergency, the power plant system controller shall operate his equipment in accordance with the listed criteria below.

(a) Would not require the safe limits of the generating, transforming and switching facilities, and appurtenant equipment of said projects to be exceeded or otherwise cause damage to the same.

(b) Would not conflict with the statutory requirements for the operation of said projects with regard to authorized purposes.

(c) Would avoid, insofar as practicable, harmful effects on the environment, including established fish and wildlife resources and recreation.

(d) Would not infringe upon the vested property rights of third parties.

(e) Would not be inconsiderate of the effect on any major downstream construction or maintenance activities by public or private entities.

3.2.4.4 Short Term Emergency. Short term emergencies requiring a reduction in releases such as for drowning, imminent loss of life, emergency maintenance or to preserve the integrity of the project may be coordinated directly between SWD powerhouse personnel and SWPA

dispatcher. Information documenting the emergency and the actions taken shall be forwarded by the power plant system controller to SWPA, and District H&H staff at the earliest possible time. Depending on circumstances, initial notification by power plant system controller may be by telephone and then followed up with an email.

3.2.4.5 Flood Constraints. SWD has the responsibility to minimize flooding to the extent possible by the regulation of Federal projects. Hydropower generation may be constrained during flood periods to prevent reservoir releases from adding to downstream damages. For any changes to scheduled generation, the District H&H staff will notify SWPA and power plant system controller. The actual request for generation load change will be confirmed and initiated by the SWPA dispatcher to the power plant system controller.

3.2.5 Generation Scheduling. Request for actual generation at a power plant will be given to the power plant system controller by the SWPA dispatcher or dispatcher designated in writing by SWPA. To the maximum extent possible, these requests will conform to the weekly schedules.

3.2.6 Generating Equipment Maintenance Schedule. The planned routine outage schedule will be prepared by SWD Districts and will be furnished to SWPA by February 1. The Planned routine outages should avoid the agreed to seasonal power peak load periods when practical. Changes to the scheduled outages should be provided to SWPA prior to the monthly scheduled operational meeting or as soon as practical. SWPA requests for rescheduling during the course of the year due to unanticipated load requirements or water conditions shall be transmitted to SWD Districts via email. Changes to the schedule initiated by a District during the course of the year will be coordinated with SWPA.

3.2.7 Unplanned Outages. The Districts will notify SWPA as soon as possible in the event of forced outages.

3.2.8 Switching Activities. Switching operations which affect the high-voltage transmission system or the availability of a unit will be coordinated with SWPA.

TABLE 1

FIRM POWER RELEASES

RESERVOIR	ALLOWABLE VOLUME (DSF)	DAILY RELEASE ENERGY (MWH) (1)
BEAVER	950	332
BROKEN BOW	850	290
BULL SHOALS	3,750	1,352
DENISON	2,300	429
EUFAULA	2,150	358
FORT GIBSON	1,800	197
GREERS FERRY	1,200	404
KEYSTONE	1,500	216
NORFORK	1,300	410
SAM RAYBURN	1,150	161
TABLE ROCK	2,550	943
TENKILLER FERRY	600	160
WHITNEY	500	86

(1) Energy values represent the energy produced by the daily release volume when pool elevation is at top of the power pool.

TABLE 2

WATER RELEASE REQUIREMENTS FOR INSTREAM FLOW NEEDS

Project	Period of Time in Effect	Forecast Air Temperature (Degrees Fahrenheit)							
		90 or Below		91 - 95		96 - 104		105 & Above	
		Generation (MWH)	Discharge (DSF)	Generation (MWH)	Discharge (DSF)	Generation (MWH)	Discharge (DSF)	Generation (MWH)	Discharge (DSF)
Beaver 1/	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 Ferry 2/	May 1 – Oct 15	35	115	45	150	54	175	69	225
Broken Bow	Jan - Dec	Maintain 100 CFS from re-regulation structure.							

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

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

TABLE 3

DESIRABLE
WATER RELEASE REQUIREMENTS
FOR INSTREAM FLOW NEEDS

Project	Period of Time in Effect	Water Release Requirements	Favorable Hydrologic Conditions
Dardanelle	Jan - Dec	Maximum 50-hour down time (minimum generation is 1,750 MWH 1/ per week, or inflow, whichever is less). Use at least 25 percent weekly total on Monday and Friday when minimum weekly generation scheduled.	Not Restricted.
Denison	Jan - Dec	Generate at least one hour with one unit every fourth day, or as needed to replenish oxygen content of water in the tailrace and stilling basin.	Above elevation 612.0
Eufaula	Jan - Dec	Generate at least one hour with one unit every fourth day, or as needed to replenish oxygen content of water in the tailrace and stilling basin.	Not Restricted.
Bull Shoals	May 1 – Oct 15	The minimum combined operation at Bull Shoals and Norfork shall not be less than a 3-day summation of 6,000 DSF (approximately 2,000 MWH). This applies for all air temperature conditions at or above 85.	Above elevation 649.0
Norfork	May 1 – Oct 12	Same as above.	Above elevation 545.0

1/ Minimum generation is based on 3,000 DSF.

TABLE 4

MAXIMUM DRAWDOWN RATES IN CONSERVATION POOL

PROJECT	MAXIMUM DRAWDOWN PER WEEK (FT)	MAXIMUM DRAWDOWN IN ANY CONSECUTIVE 4-WEEK PERIOD (FT)
BEAVER	2.0	6.0
NORFORK	1.5	5.0
GREERS FERRY	1.0	4.0
TABLE ROCK	1.5	4.5
BULL SHOALS	1.5	4.5
KEYSTONE	1.0	3.0
TENKILLER FERRY	1.5	4.5
EUFAULA	1.0	3.0
DENISON	1.0	3.0
BROKEN BOW	2.0	6.0
SAM RAYBURN	1.0	2.0
WHITNEY	1.0	3.0

TABLE 5

RESPONSE TIME TO CHANGES IN GENERATION

PROJECT	TIME	
	NORMAL	EMERGENCY
FORT WORTH DISTRICT		
SAM RAYBURN	10 minutes	5 minutes
WHITNEY	10 minutes	5 minutes
LITTLE ROCK DISTRICT		
BEAVER	10 minutes	5 minutes
BULL SHOALS	10 minutes 1/	5 minutes
TABLE ROCK	10 minutes 2/	5 minutes
NORFORK	10 minutes	5 minutes
GREERS FERRY	10 minutes	5 minutes
DARDANELLE	10 minutes	5 minutes
OZARK	10 minutes	5 minutes
TULSA DISTRICT		
BROKEN BOW	10 minutes	5 minutes
DENISON	10 minutes	5 minutes
EUFAULA	10 minutes	5 minutes
FORT GIBSON	10 minutes	5 minutes
KEYSTONE	10 minutes	5 minutes
ROBERT S. KERR	10 minutes 3/	5 minutes
TENKILLER FERRY	10 minutes	5 minutes
WEBBERS FALLS	10 minutes	5 minutes

Notes:

General. Indicated Emergency Start Up and Loading times assume the power plant control room operator is starting and loading only the local units. If the operator is starting and loading remote units, response times could be as much as twice as long for starting and loading the local units. Exact Emergency Start Up and Loading times for remote plants will depend greatly upon how many units, both local and remote, the control room operator is attempting to start and load.

1/ During normal operations, the initial start up and final shutdown should not exceed 100 megawatts per hour. Additional changes should not exceed 100 megawatts per 30 minutes.

2/ During normal operations, the initial start up and final shutdown should not exceed 115 megawatts per hour.

3/ First two units may start simultaneously. A lag of ½ hour between third and fourth units or a lag of one hour if third and fourth are started simultaneously.

TABLE 6

WATER CONTROL MANUALS

TITLE	DATE
Lake Regulation Manual, Broken Bow Lake	Feb 2000
Lake Texoma Water Control Manual,	Apr 1993
Reservoir Regulation Manual for Eufaula Reservoir	Jan 1994
Reservoir Regulation Manual for Pensacola, Markham Ferry and Fort Gibson Reservoirs	Nov 1992
Reservoir Regulation Manual for Keystone Reservoir	Jan 1990
Reservoir Regulation Manual, Robert S. Kerr Lock And Dam Reservoir	Dec 1998
Lake Regulation Manual, Tenkiller Ferry Lake	Mar 1977
Reservoir Regulation Manual, Webbers Falls Lock And Dam	Dec 1997
Sam Rayburn Reservoir Water Control Manual	Jan 1982
Whitney Lake Water Control Manual	Apr 1975
Dam B Reservoir (R.D. Willis)	Mar 1956
Reservoir Regulation Manual for Greers Ferry Reservoir	Mar 1963 Revised Nov 1966
Reservoir Regulation Manual for Beaver Lake	Oct 1998
Reservoir Regulation Manual for Table Rock,	Mar 1963
Bull Shoals, and Norfork Reservoirs	Revised Oct 1966
Regulation Manual for Ozark L&D and Pool No. 13	Oct 1974
Regulation Manual for Lake Dardanelle and Pool No. 9	Feb 1976
Arkansas River Master Water Control Manual	Oct 1980 Revised Oct 2007, (- Chapter 7)

FORM 1

Special Hydropower Operations Request
Southwestern Power Administration

Project: Date prepared:

Submitter
Name/District:
Phone: Cell Email:

Purpose:

Units affected/Proposed
Operation:

From: hours Month: Day:
To: hours Month: Day:

On-site contact
Person(s):
Agency/Organization:
Phone Number:
Cell Phone Number:

Comments:

Emailed to:

FORM 2

CORPS OF ENGINEERS (TULSA) **UNIT UNAVAILIBILITY REPORT**	
STATION:	
UNITS	TYPE OF OUTAGE:
GDFO: Generator Delayed Forced Outage. GFO: Generator Forced Outage. GSO: Generator Scheduled Outage. NGDF: Non-Generator Delayed Forced Outage. NGFO: Non-Generator Forced Outage NGSO: Non-Generator Scheduled Outage	
RELAYS OPERATED:	
BREAKERS TRIPPED:	
ESTIMATED TIME TO RETURN TO SERVICE: HRS.	
REPAIRS OR CORRECTIONS MADE	

RESTORED	DATE	TIME:
TOTAL UNAVAILABLE TIME: HOURS MINUTES		
POWER PLANT:		

Name

Signature **Date**

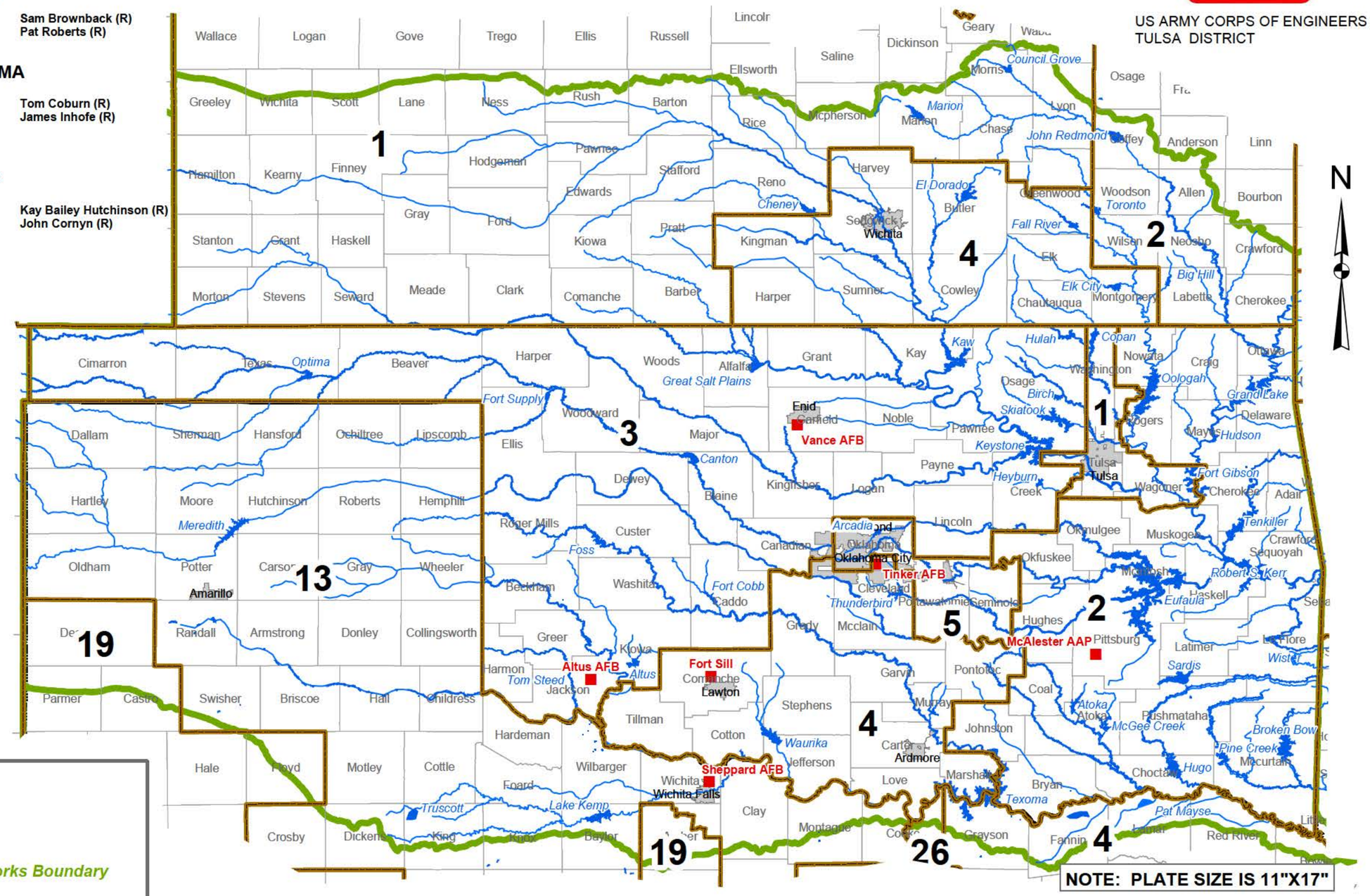
Title

PLATES AND DRAWINGS

KEYSTONE LAKE

US ARMY CORPS OF ENGINEERS
TULSA DISTRICT

U.S. Representative	U.S. Senator
KANSAS	
1 Jerry Moran (R)	Sam Brownback (R)
2 Lynn Jenkins (R)	Pat Roberts (R)
4 Todd Tiahirt (R)	
OKLAHOMA	
1 John Sullivan (R)	Tom Coburn (R)
2 Dan Boren (D)	James Inhofe (R)
3 Frank Lucas (R)	
4 Tom Cole (R)	
5 James Lankford (R)	
TEXAS	
4 Ralph M. Hall (R)	Kay Bailey Hutchinson (R)
13 Mac Thornberry (R)	John Cornyn (R)
19 Randy Neugebauer (R)	
26 Michael C. Burgess (R)	



Lakes

Military Installations

Tulsa District Civil Works Boundary

111th Congressional Boundaries

NOTE: PLATE SIZE IS 11"X17"

Arkansas River

Hominy

Osage County

Skiatook Lake

Cleveland

64

Pawnee County

Hallett

412

Keystone Lake

Mannford

51

Cimarron River

Payne County

48

Creek County

Lincoln County

97

4

64

Tulsa County

Tulsa

Sand Springs

0 2 4 8 Miles

N

Keystone Lake Basin

KANSAS

KEYSTONE LAKE

TEXAS

Tulsa

Oklahoma City

OKLAHOMA

VICINITY MAP

NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

PROJECT LOCATION AND VICINITY MAP

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 1

(b) (7)(F)

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

GENERAL PLANS, SECTIONS AND ELEVATIONS

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 2

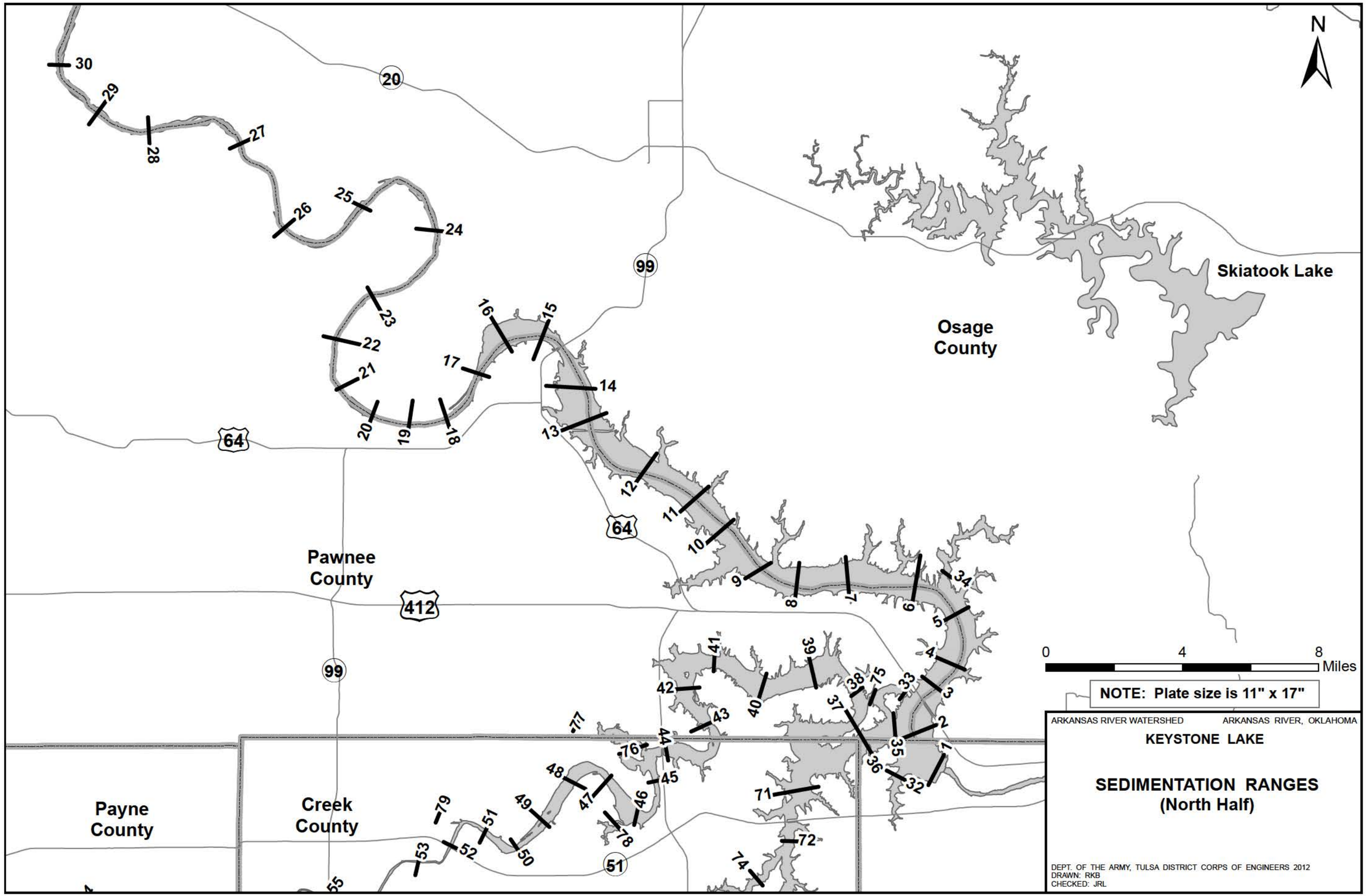

N
Skiatook Lake
Osage
County
Pawnee
County
Payne
County
Creek
County
20
99
64
412
51
0
4
8
Miles
NOTE: Plate size is 11" x 17"
ARKANSAS RIVER WATERSHED
ARKANSAS RIVER, OKLAHOMA
KEYSTONE LAKE
SEDIMENTATION RANGES
(North Half)
DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 3

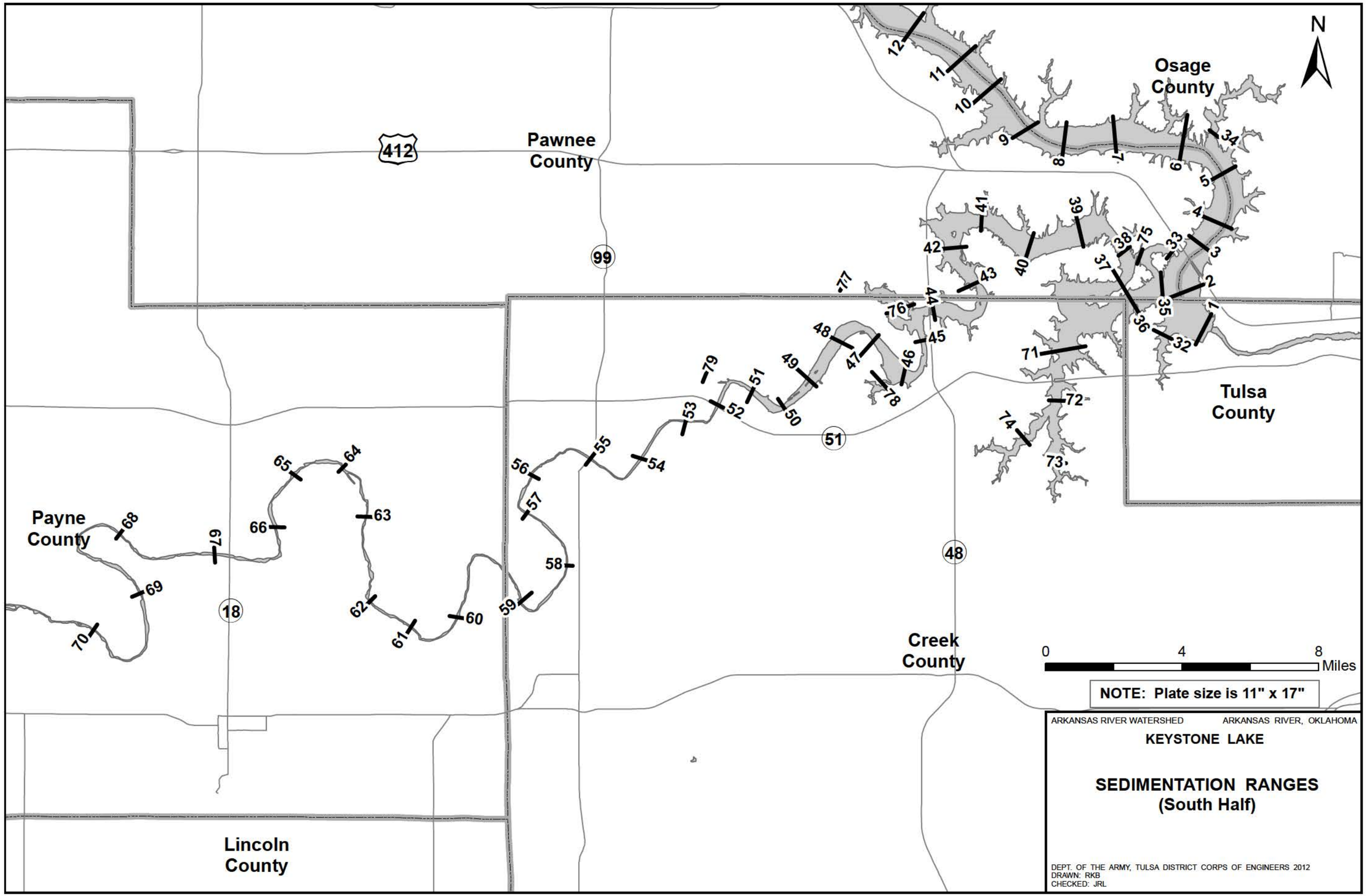
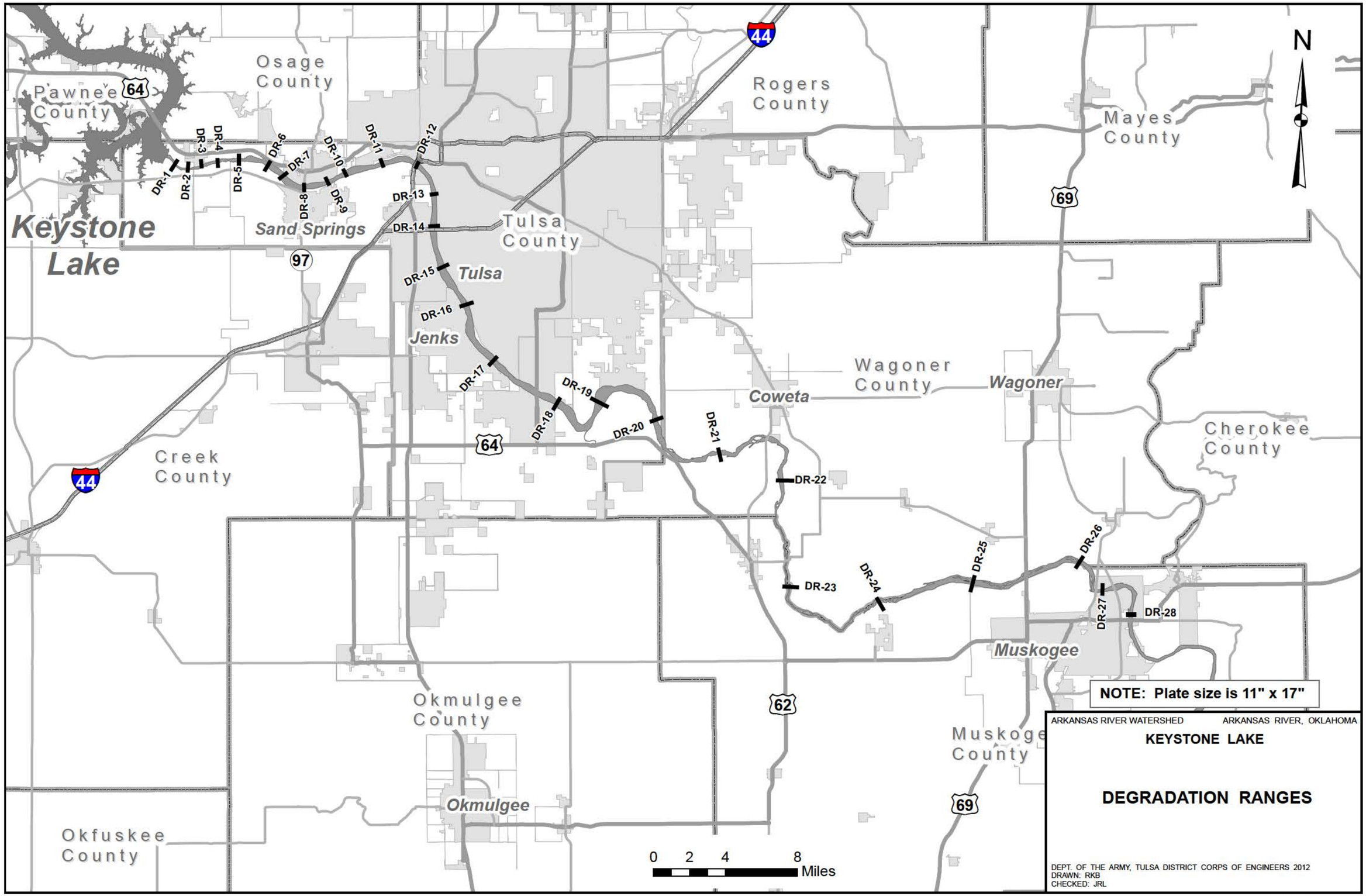

N
Osage County
Pawnee County
412
99
51
48
18
Tulsa County
Creek County
Payne County
Lincoln County
0
4
8
Miles
NOTE: Plate size is 11" x 17"
ARKANSAS RIVER WATERSHED
ARKANSAS RIVER, OKLAHOMA
KEYSTONE LAKE
SEDIMENTATION RANGES
(South Half)
DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 4



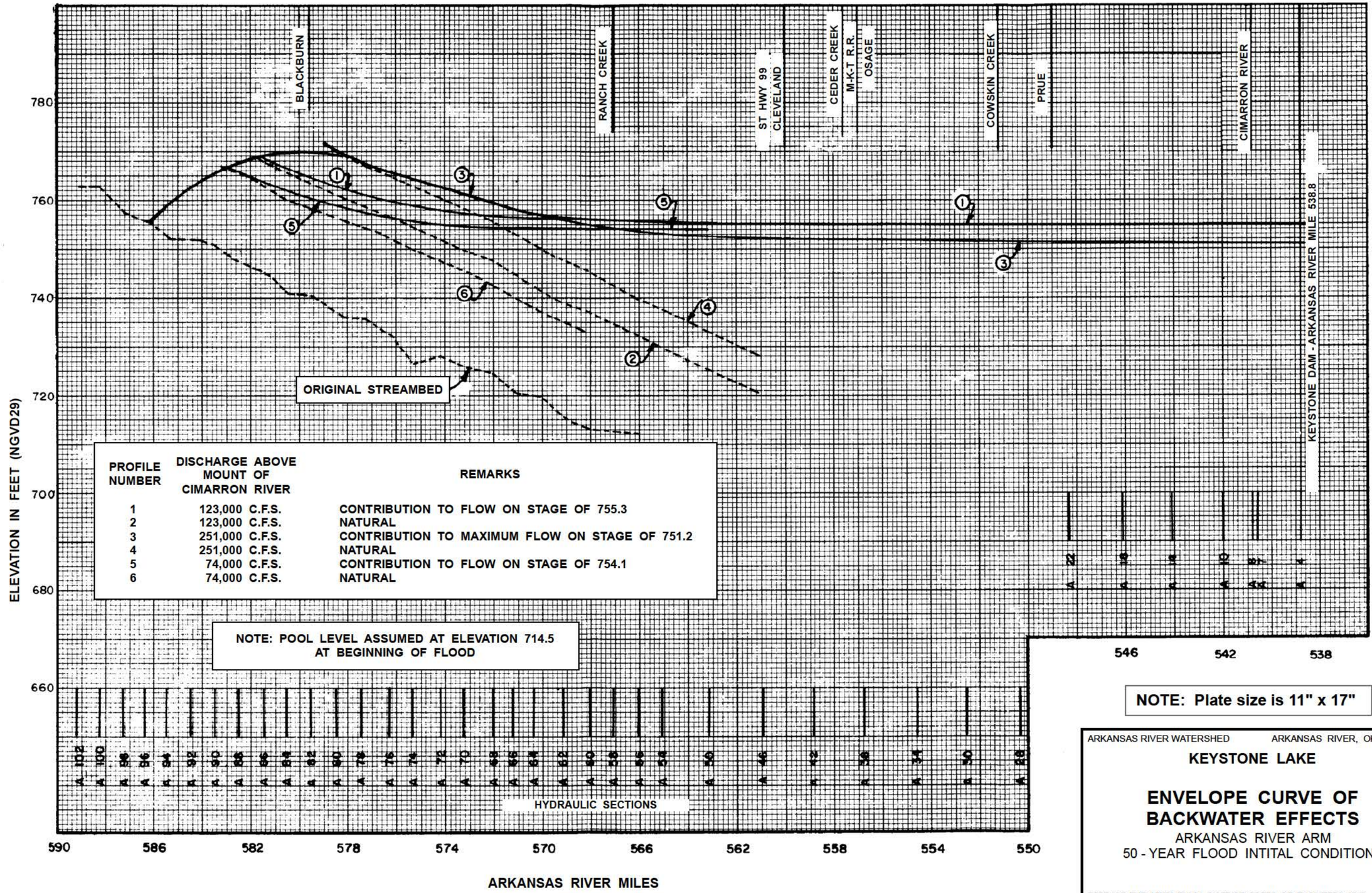
NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DEGRADATION RANGES

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL



PROFILE NUMBER	DISCHARGE ABOVE MOUNT OF CIMARRON RIVER	REMARKS
1	123,000 C.F.S.	CONTRIBUTION TO FLOW ON STAGE OF 755.3
2	123,000 C.F.S.	NATURAL
3	251,000 C.F.S.	CONTRIBUTION TO MAXIMUM FLOW ON STAGE OF 751.2
4	251,000 C.F.S.	NATURAL
5	74,000 C.F.S.	CONTRIBUTION TO FLOW ON STAGE OF 754.1
6	74,000 C.F.S.	NATURAL

NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

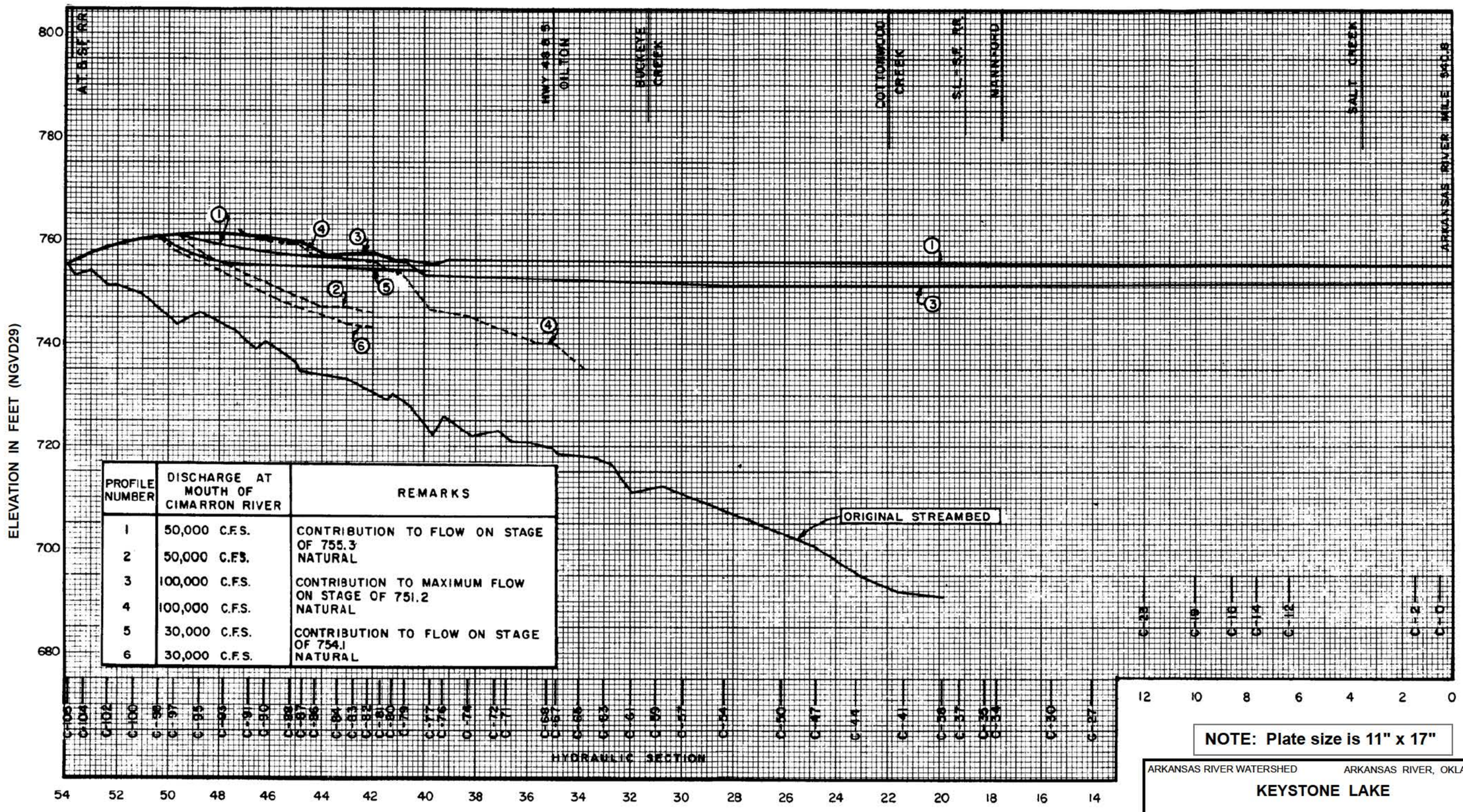
KEYSTONE LAKE

ENVELOPE CURVE OF BACKWATER EFFECTS

ARKANSAS RIVER ARM
50 - YEAR FLOOD INTITAL CONDITIONS

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 6



PROFILE NUMBER	DISCHARGE AT MOUTH OF CIMARRON RIVER	REMARKS
1	50,000 C.F.S.	CONTRIBUTION TO FLOW ON STAGE OF 755.3
2	50,000 C.F.S.	NATURAL
3	100,000 C.F.S.	CONTRIBUTION TO MAXIMUM FLOW ON STAGE OF 751.2
4	100,000 C.F.S.	NATURAL
5	30,000 C.F.S.	CONTRIBUTION TO FLOW ON STAGE OF 754.1
6	30,000 C.F.S.	NATURAL

NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

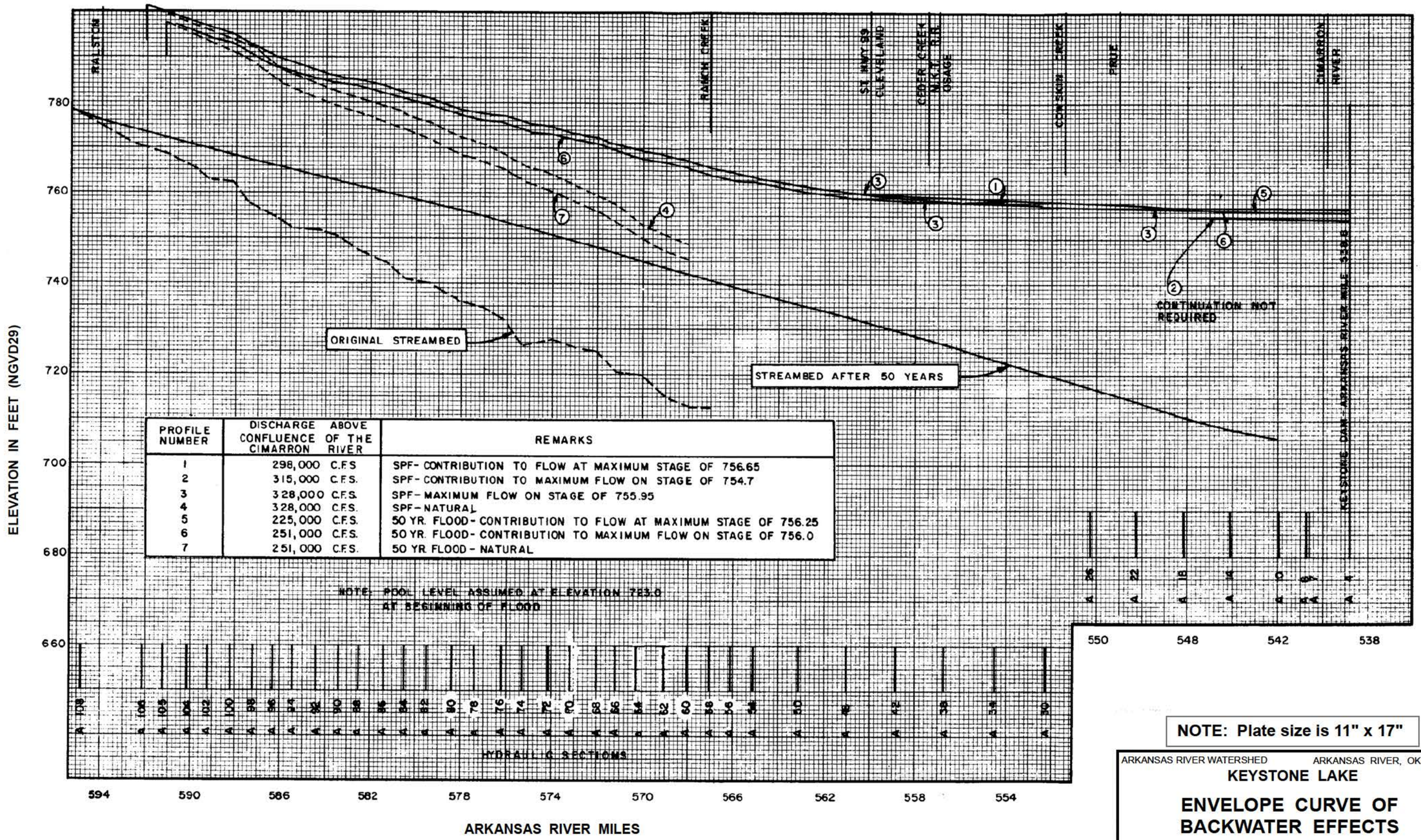
KEYSTONE LAKE

ENVELOPE CURVE OF BACKWATER EFFECTS

CIMARRON RIVER ARM
50 - YEAR FLOOD INITIAL CONDITIONS

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 7



PROFILE NUMBER	DISCHARGE ABOVE CONFLUENCE OF THE CIMARRON RIVER	REMARKS
1	298,000 C.F.S.	SPF- CONTRIBUTION TO FLOW AT MAXIMUM STAGE OF 756.65
2	315,000 C.F.S.	SPF- CONTRIBUTION TO MAXIMUM FLOW ON STAGE OF 754.7
3	328,000 C.F.S.	SPF- MAXIMUM FLOW ON STAGE OF 755.95
4	328,000 C.F.S.	SPF- NATURAL
5	225,000 C.F.S.	50 YR. FLOOD- CONTRIBUTION TO FLOW AT MAXIMUM STAGE OF 756.25
6	251,000 C.F.S.	50 YR. FLOOD- CONTRIBUTION TO MAXIMUM FLOW ON STAGE OF 756.0
7	251,000 C.F.S.	50 YR. FLOOD - NATURAL

NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

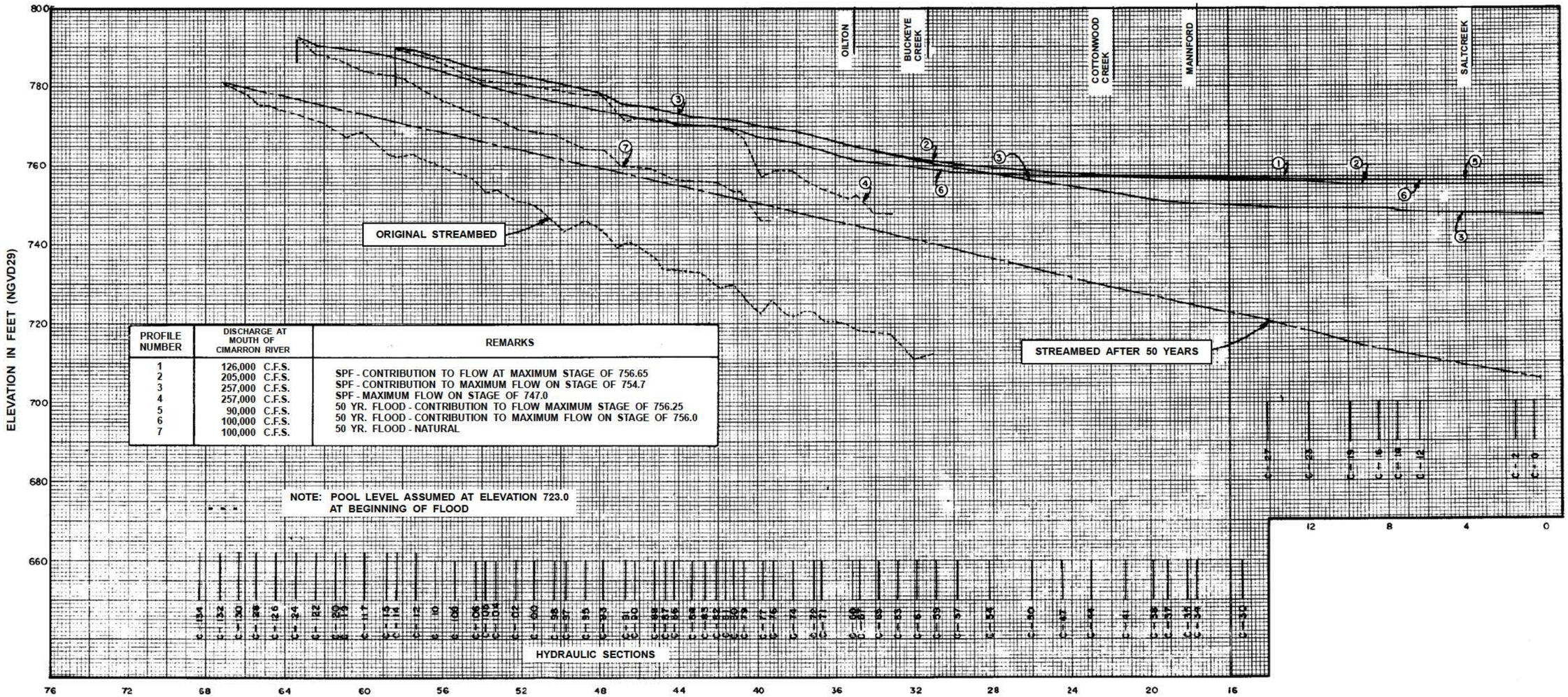
KEYSTONE LAKE

ENVELOPE CURVE OF BACKWATER EFFECTS

ARKANSAS RIVER ARM
50 - YEAR AND S.P. FLOODS
UNLTIMATE CONDITIONS

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 8



PROFILE NUMBER	DISCHARGE AT MOUTH OF CIMARRON RIVER	REMARKS
1	126,000 C.F.S.	SPF - CONTRIBUTION TO FLOW AT MAXIMUM STAGE OF 756.65
2	205,000 C.F.S.	SPF - CONTRIBUTION TO MAXIMUM FLOW ON STAGE OF 754.7
3	257,000 C.F.S.	SPF - MAXIMUM FLOW ON STAGE OF 747.0
4	257,000 C.F.S.	50 YR. FLOOD - CONTRIBUTION TO FLOW MAXIMUM STAGE OF 756.25
5	90,000 C.F.S.	50 YR. FLOOD - CONTRIBUTION TO MAXIMUM FLOW ON STAGE OF 756.0
6	100,000 C.F.S.	50 YR. FLOOD - NATURAL
7	100,000 C.F.S.	

NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

ENVELOPE CURVE OF BACKWATER EFFECTS

CIMARRON RIVER ARM
50 - YEAR AND S.P. FLOODS
UNLTIMATE CONDITIONS

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 9

KEYSTONE LAKE

PUBLIC HUNTING AREA

PUBLIC USE AREAS

1. Brush Creek
2. Washington Irving Cove (S)
3. Washington Irving Cove (N) -Closed
4. Walnut Creek Peninsula
5. Osage Point
6. Osage Ramp
7. East Levee
8. Cedar Creek Bay
9. Feyodi Creek
10. Cowskin (N)-Access Point
11. Cowskin (S)
12. Cimarron Park
13. Appalachia Bay
14. Sandy Park
15. Pawnee Cove (N)-Access Point
16. Pawnee Cove (S)-Closed
17. Mannford Ramp
18. New Mannford Ramp
19. Salt Creek Cove (N)
20. Salt Creek Cove (S)
21. Keystone Ramp
22. Keystone Park
23. White Water Park
24. River City Park

LEGEND

- Paved Road
- Improved Road
- Project Boundary
- Corps Areas Open For Hunting
- State Areas Open For Hunting
- See Restrictions

Scale of Miles 1 0 1 2

RESERVOIR DATA
Top of conservation pool El. 723.0
Total project land & water acreage 58671

NOTE: Plate size is 11" x 17"

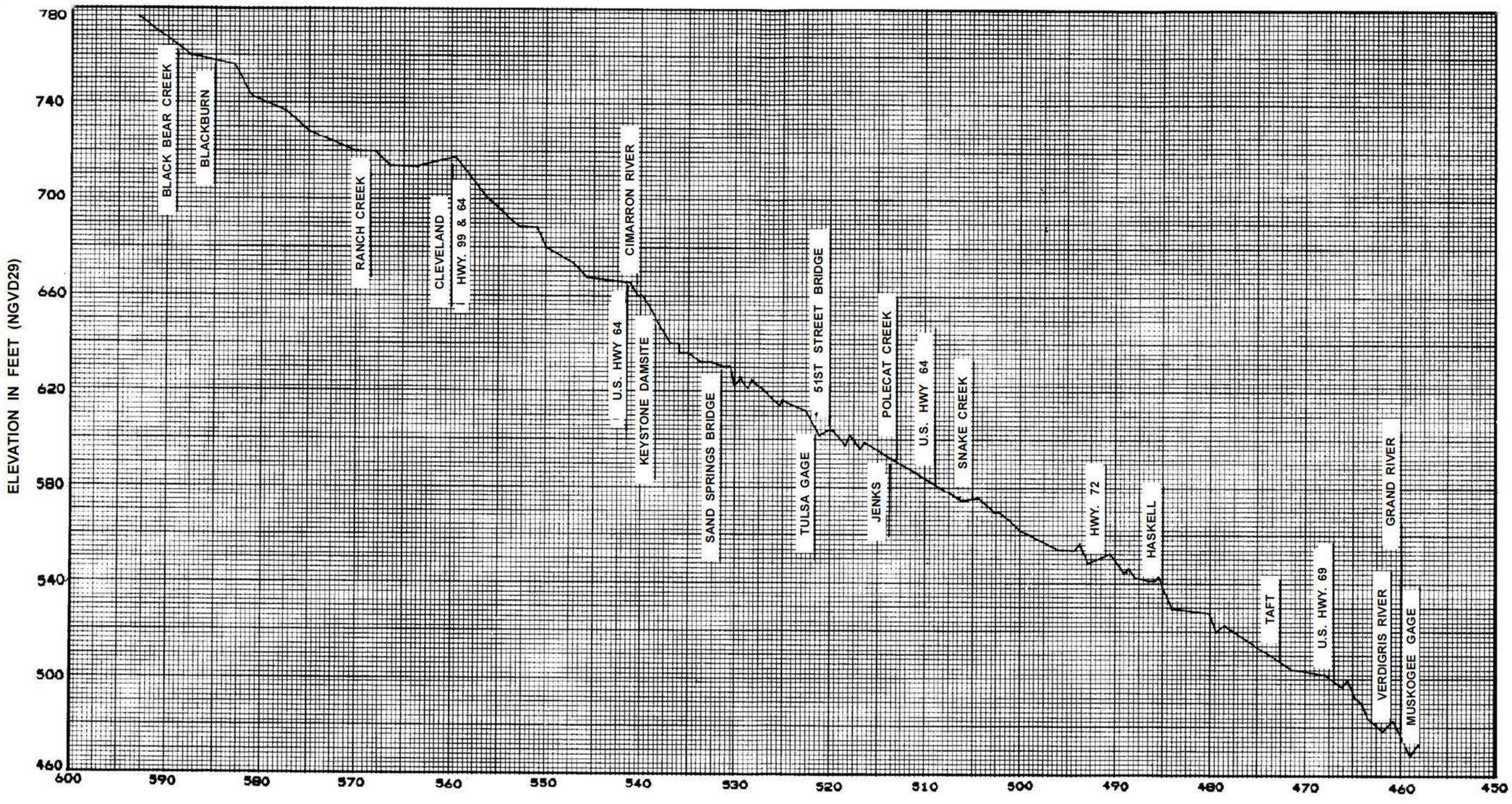
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

PUBLIC USE SITES

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 2 - 10



NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

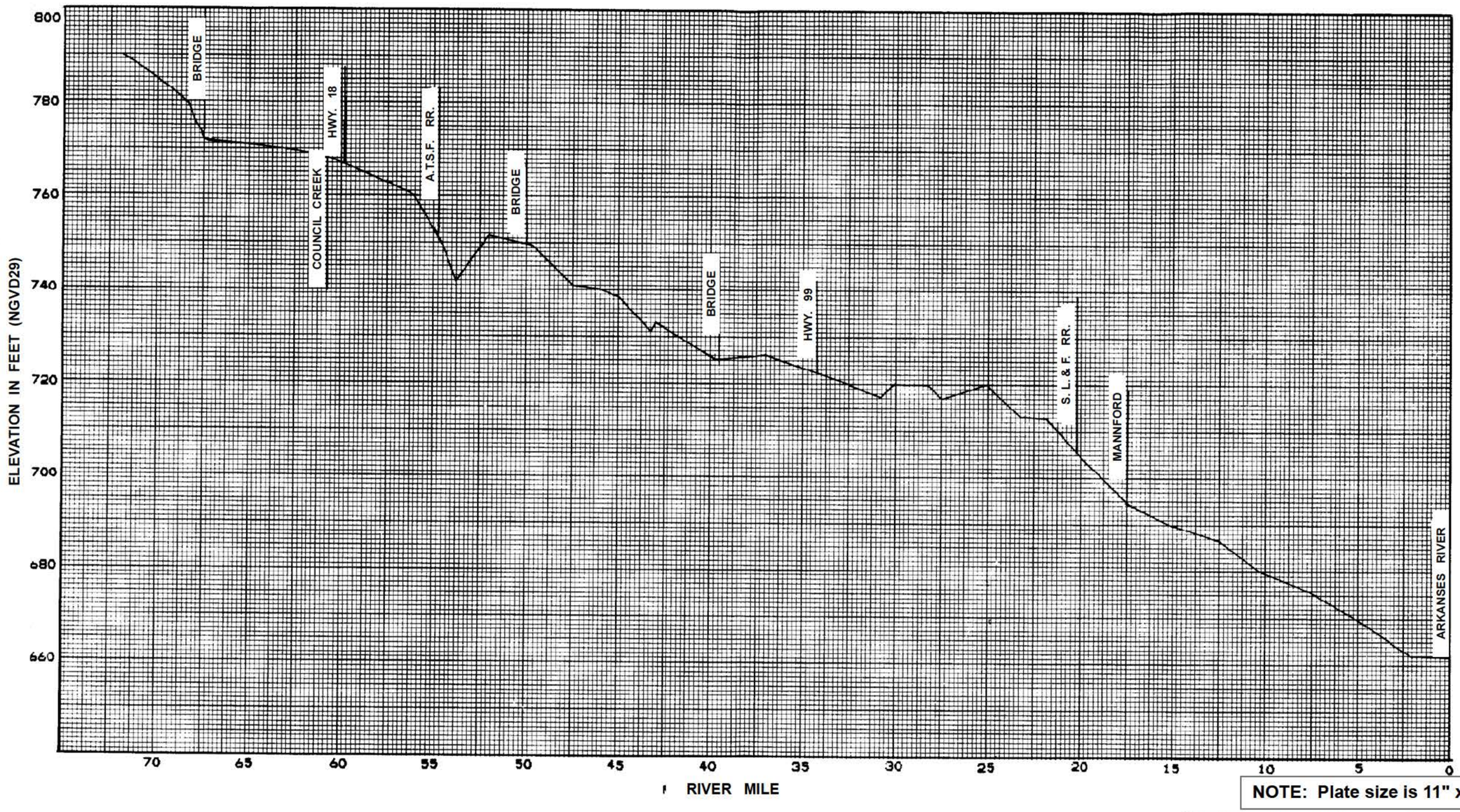
KEYSTONE LAKE

ARKANSAS RIVER STREAMBED PROFILE

(1977)

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 1



NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

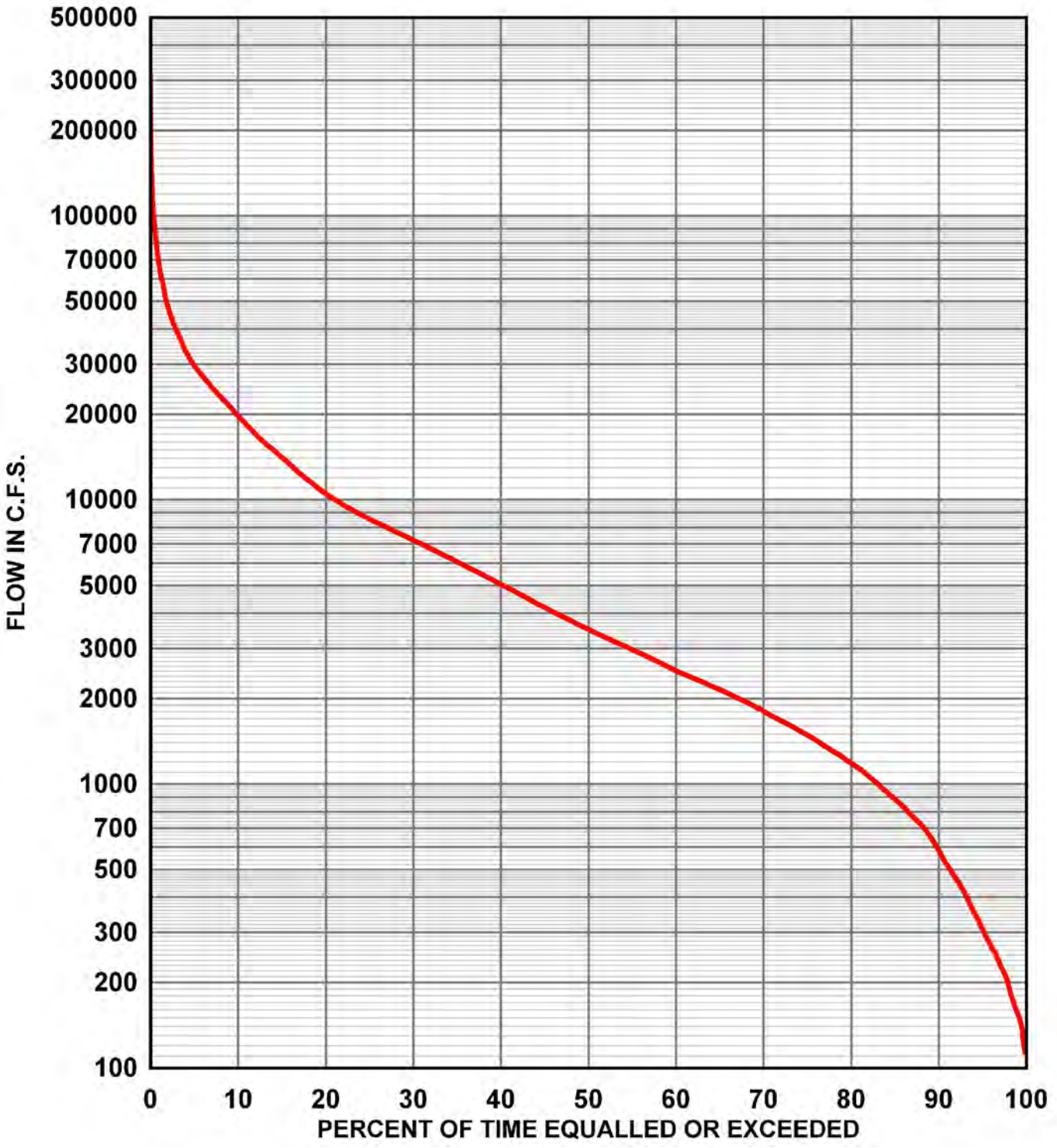
KEYSTONE LAKE

CIMARRON RIVER STREAMBED PROFILE

(1977)

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 2



ARKANSAS RIVER WATERSHED

ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

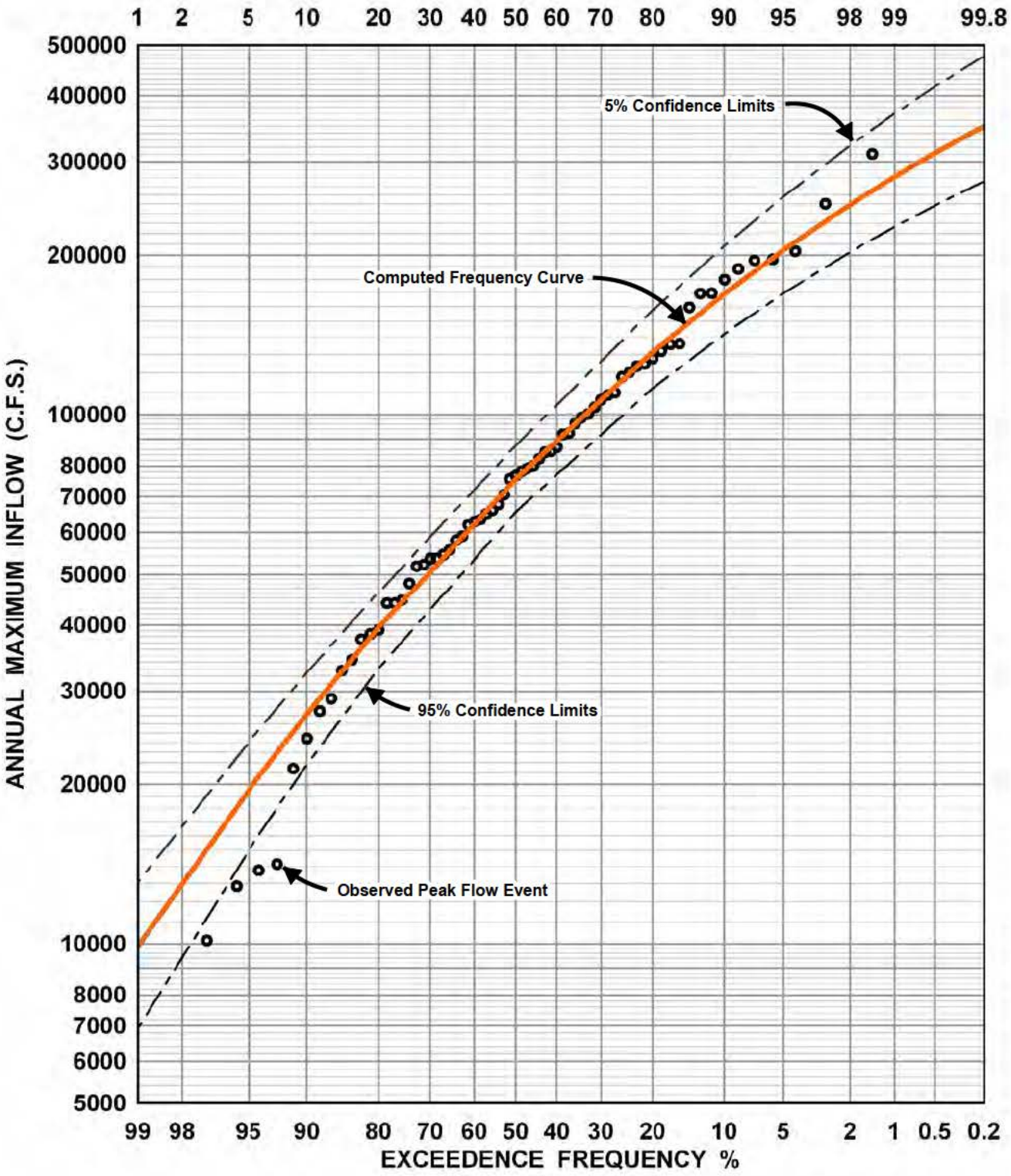
FLOW DURATION CURVE

NOTE:

BASED ON PERIOD OF RECORD JAN 1940 THRU DEC 2008 FROM RIVERWARE COMPUTER MODEL

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 3



NOTE:

1. **BASED ON PERIOD OF RECORD JAN 1940 THRU DEC 2008 FROM RIVERWARE COMPUTER RUN**
2. **BULLETIN NO. 17B FLOOD FLOW FREQUENCY GUIDELINES WERE USED**

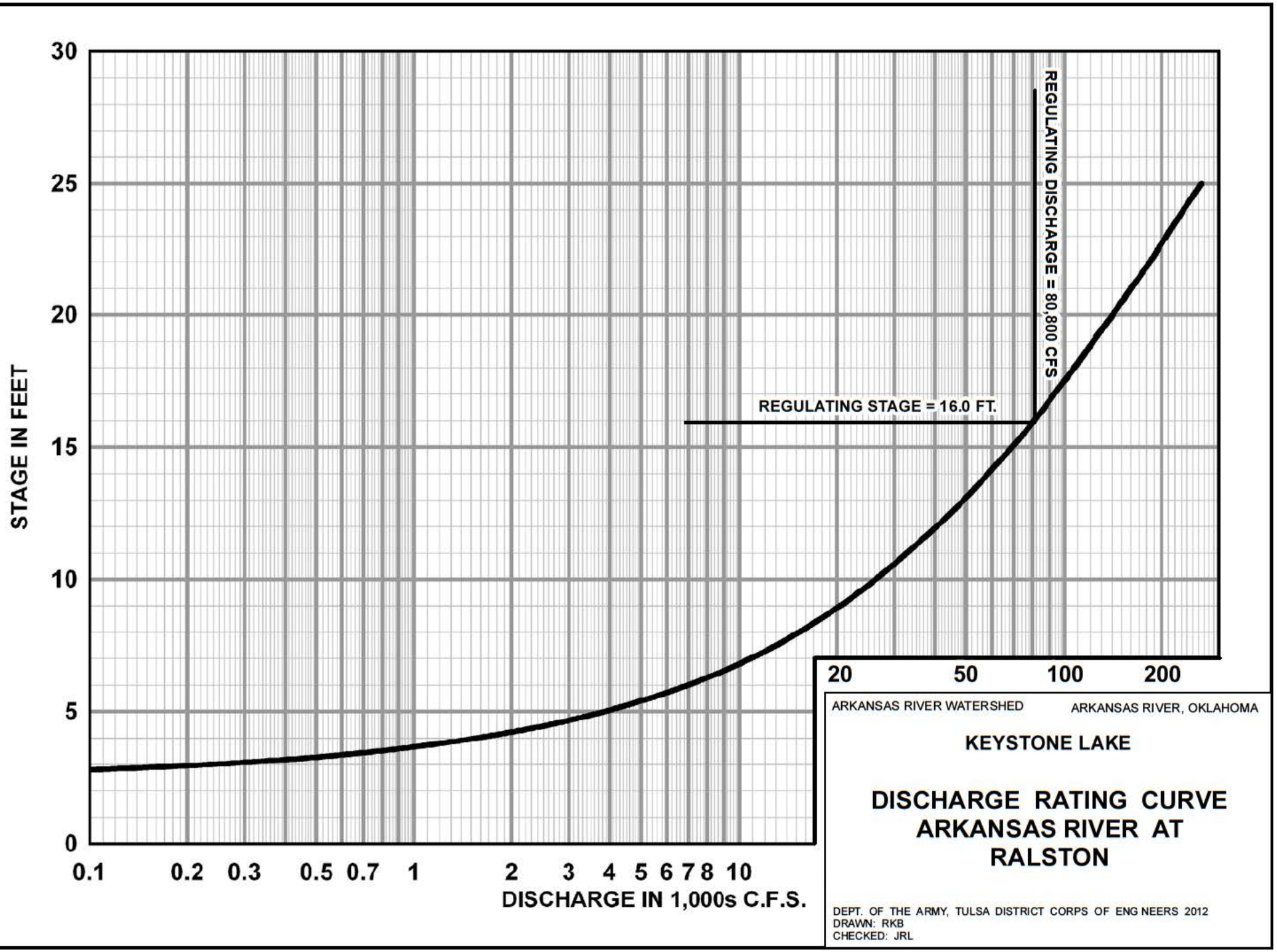
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

INFLOW PROBABILITY CURVE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 4



ARKANSAS RIVER WATERSHED

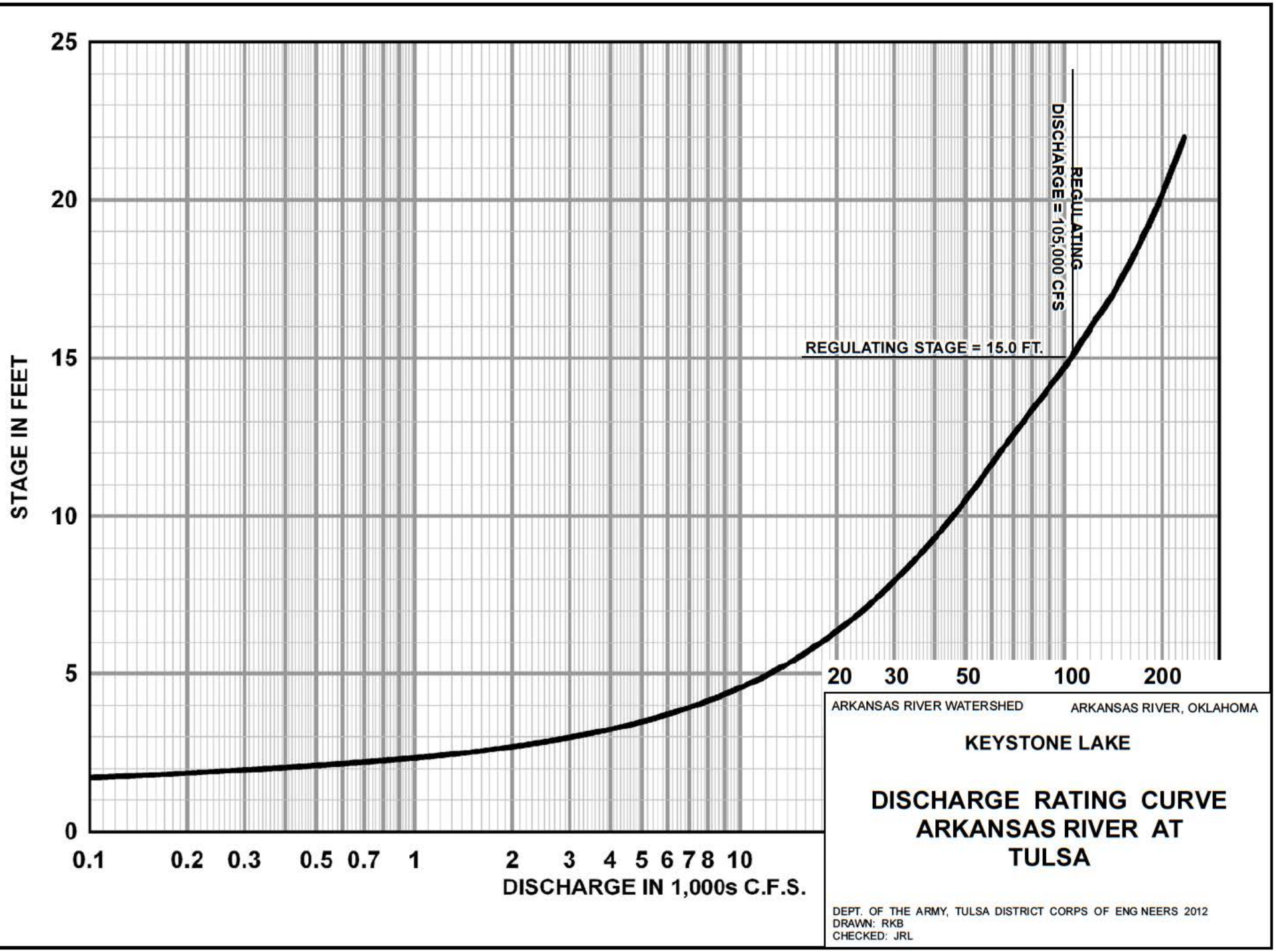
ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DISCHARGE RATING CURVE ARKANSAS RIVER AT RALSTON

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 5



ARKANSAS RIVER WATERSHED

ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DISCHARGE RATING CURVE ARKANSAS RIVER AT TULSA

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 6

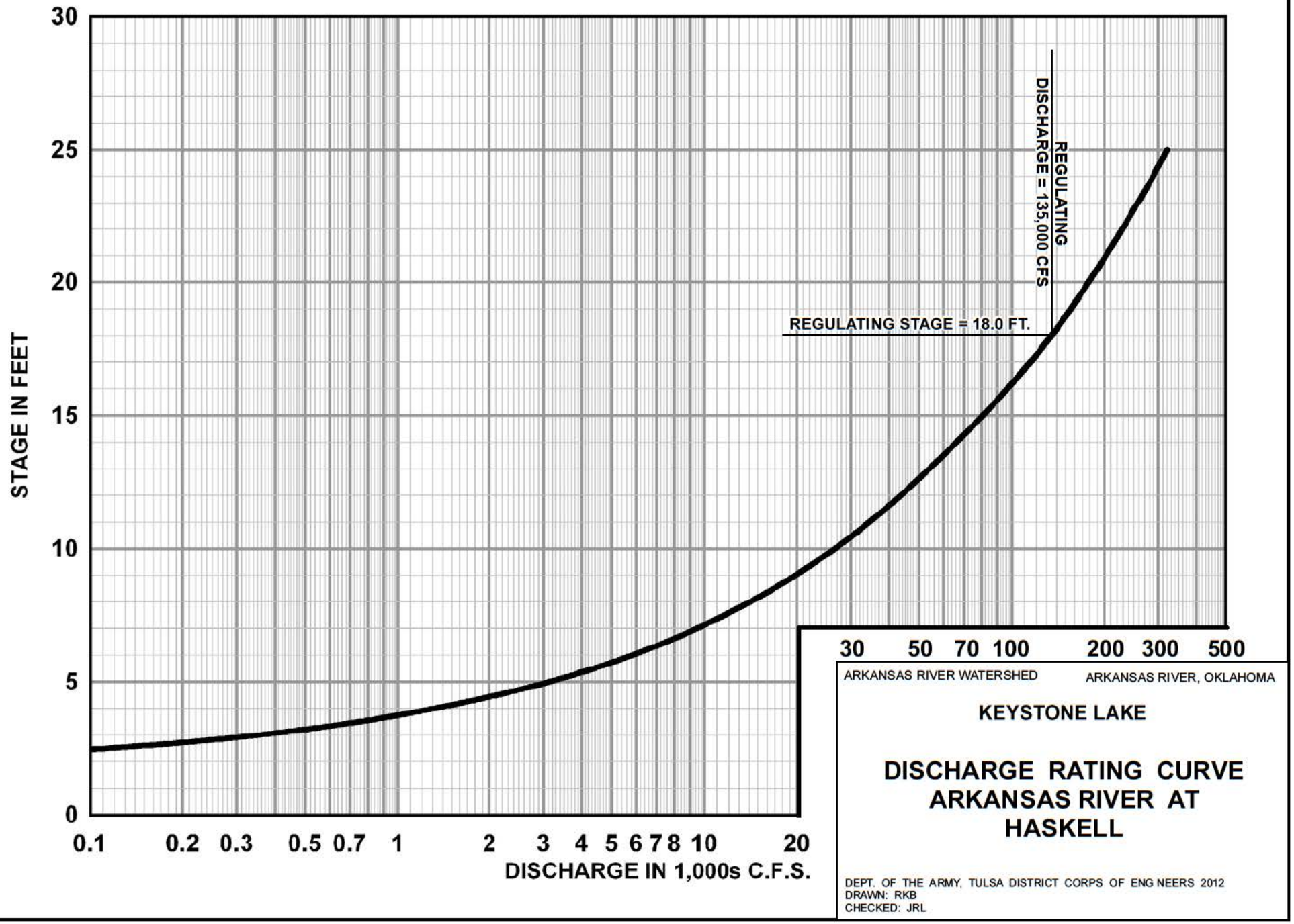
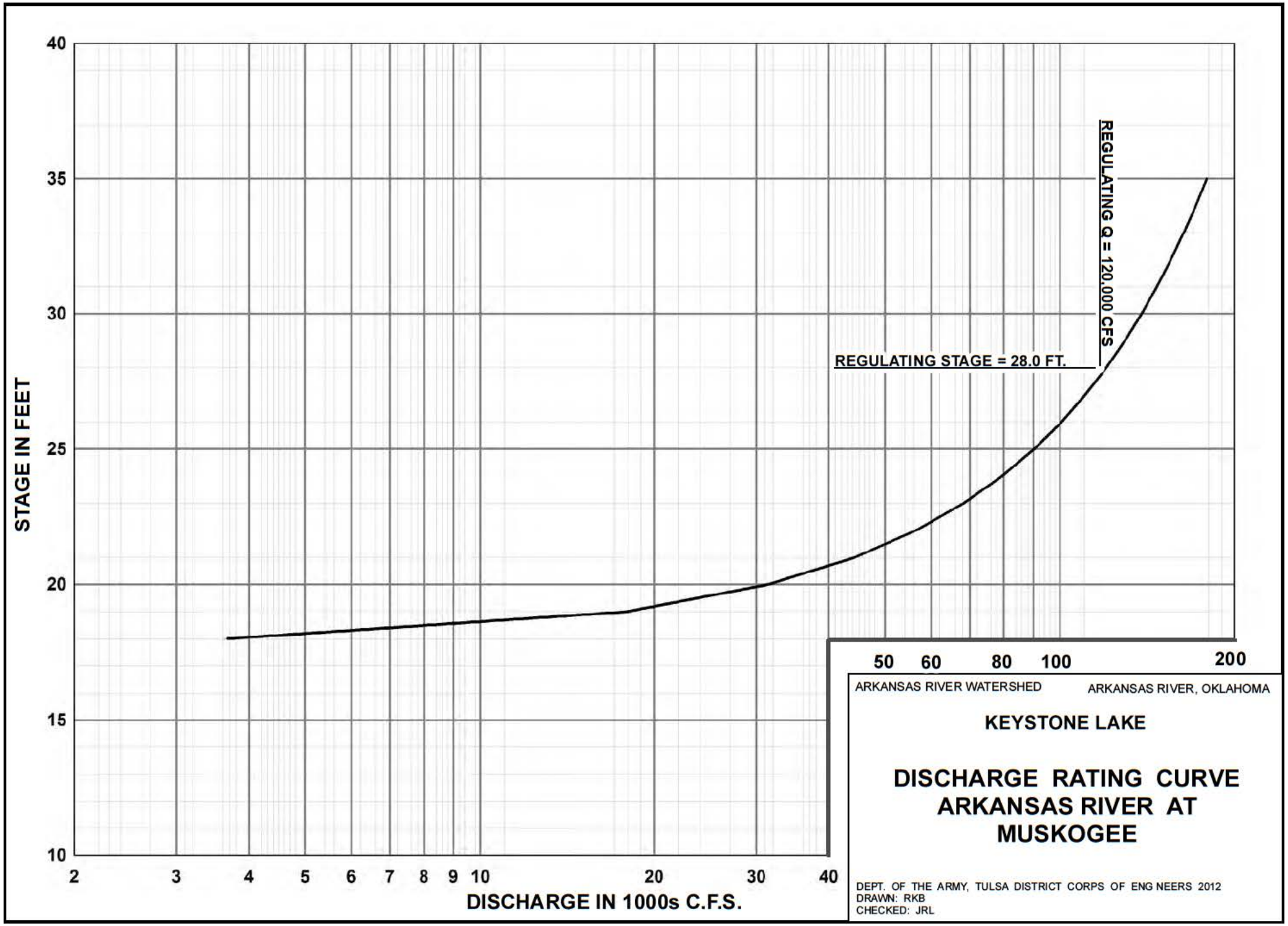

30
25
20
15
10
5
0
STAGE IN FEET
REGULATING
DISCHARGE = 135,000 CFS
REGULATING STAGE = 18.0 FT.
0.1
0.2
0.3
0.5
0.7
1
2
3
4
5
6
7
8
10
20
30
50
70
100
200
300
500
DISCHARGE IN 1,000s C.F.S.
ARKANSAS RIVER WATERSHED
ARKANSAS RIVER, OKLAHOMA
KEYSTONE LAKE
DISCHARGE RATING CURVE
ARKANSAS RIVER AT
HASKELL
DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 7



ARKANSAS RIVER WATERSHED

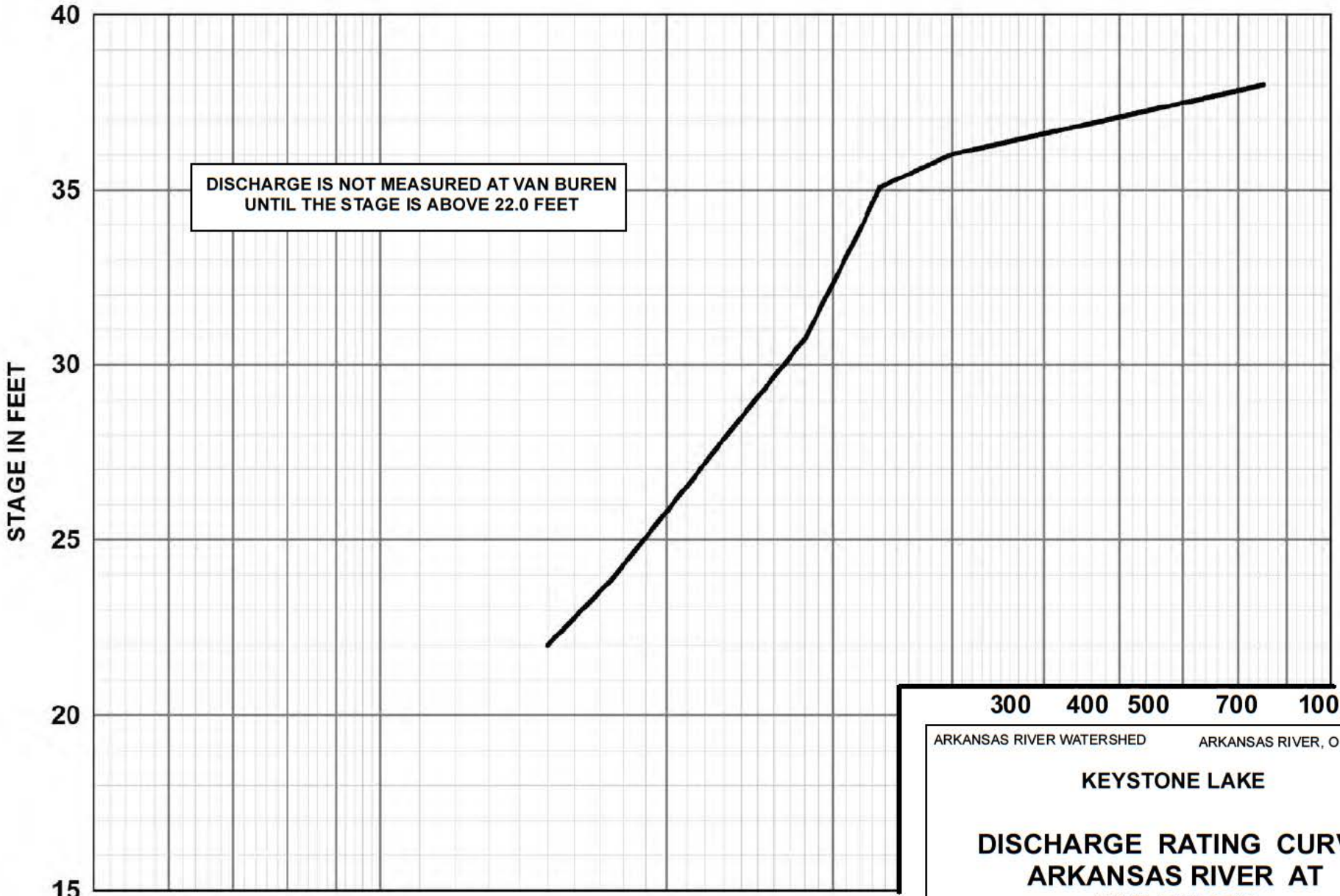
ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DISCHARGE RATING CURVE ARKANSAS RIVER AT MUSKOGEE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 8



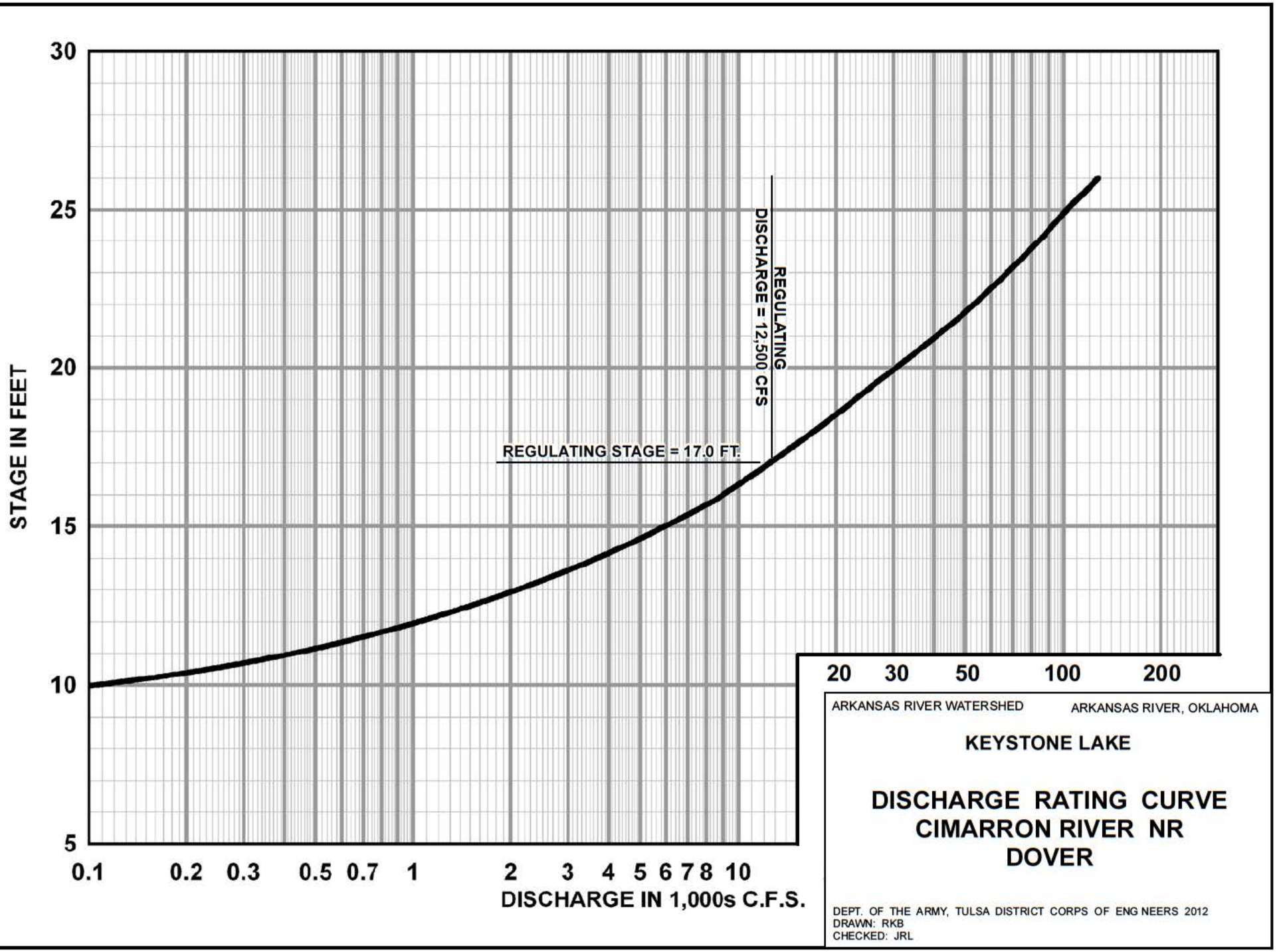
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DISCHARGE RATING CURVE ARKANSAS RIVER AT VAN BUREN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 9



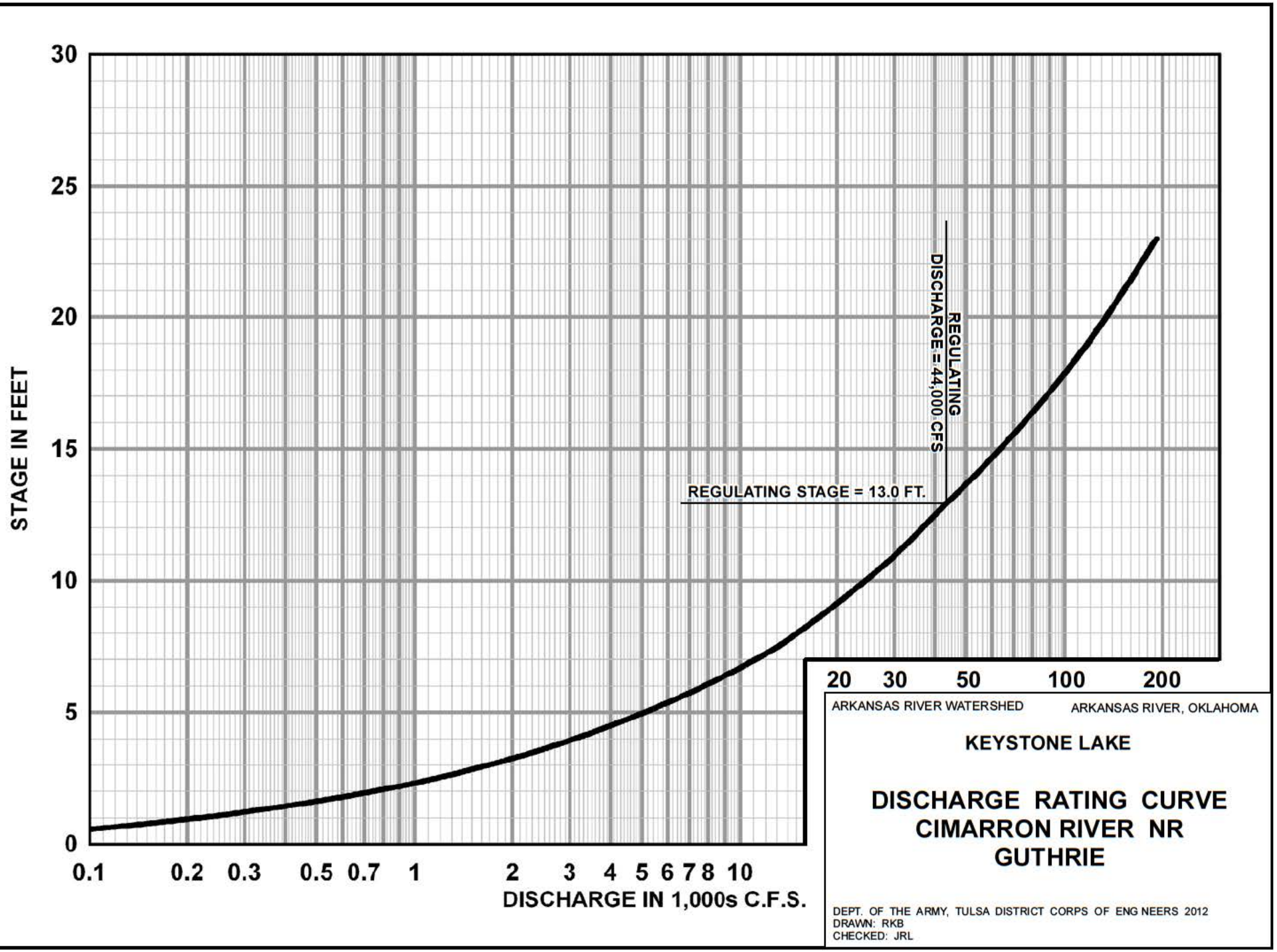
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DISCHARGE RATING CURVE CIMARRON RIVER NR DOVER

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 10



ARKANSAS RIVER WATERSHED

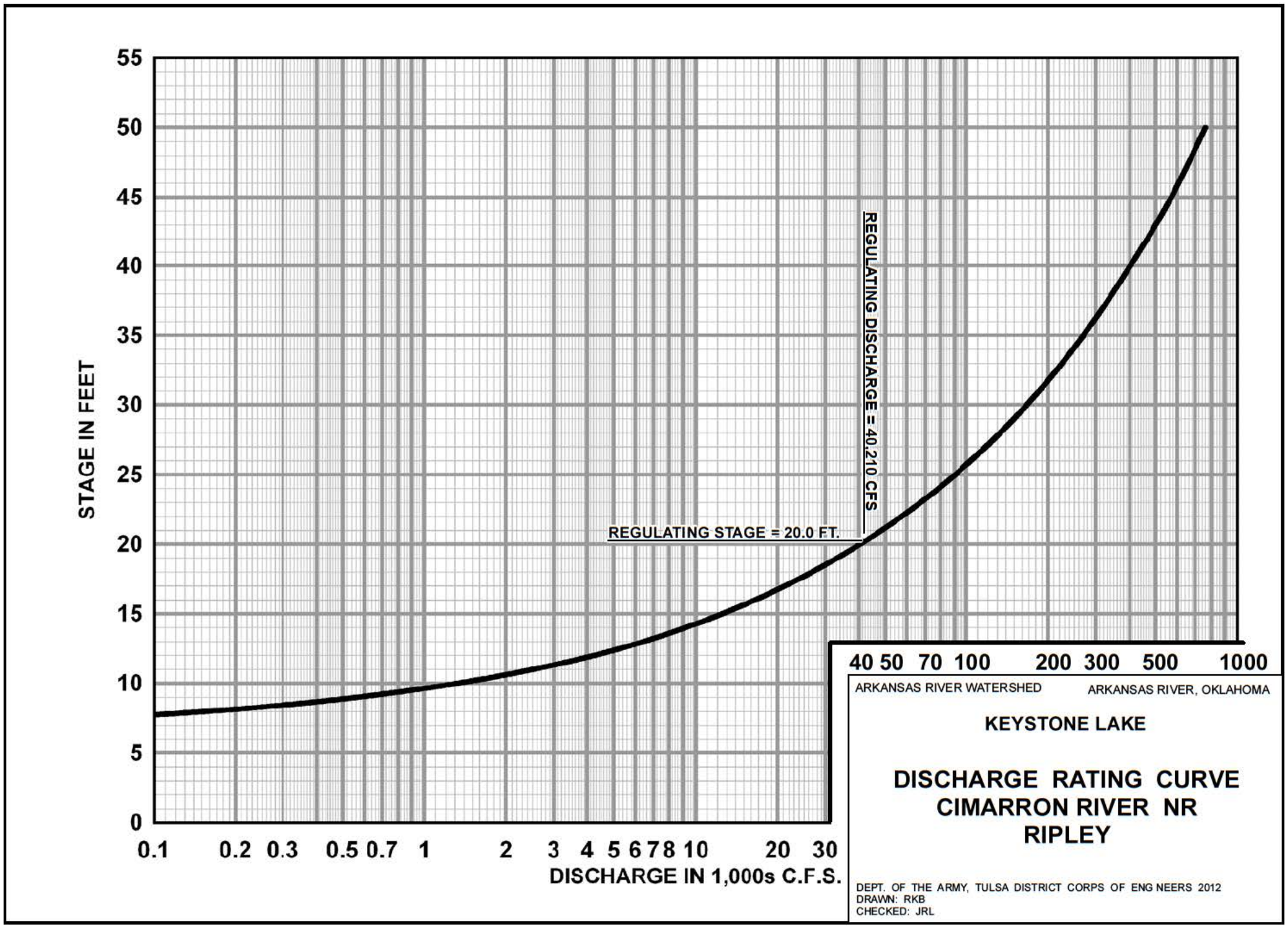
ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DISCHARGE RATING CURVE CIMARRON RIVER NR GUTHRIE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 11



ARKANSAS RIVER WATERSHED

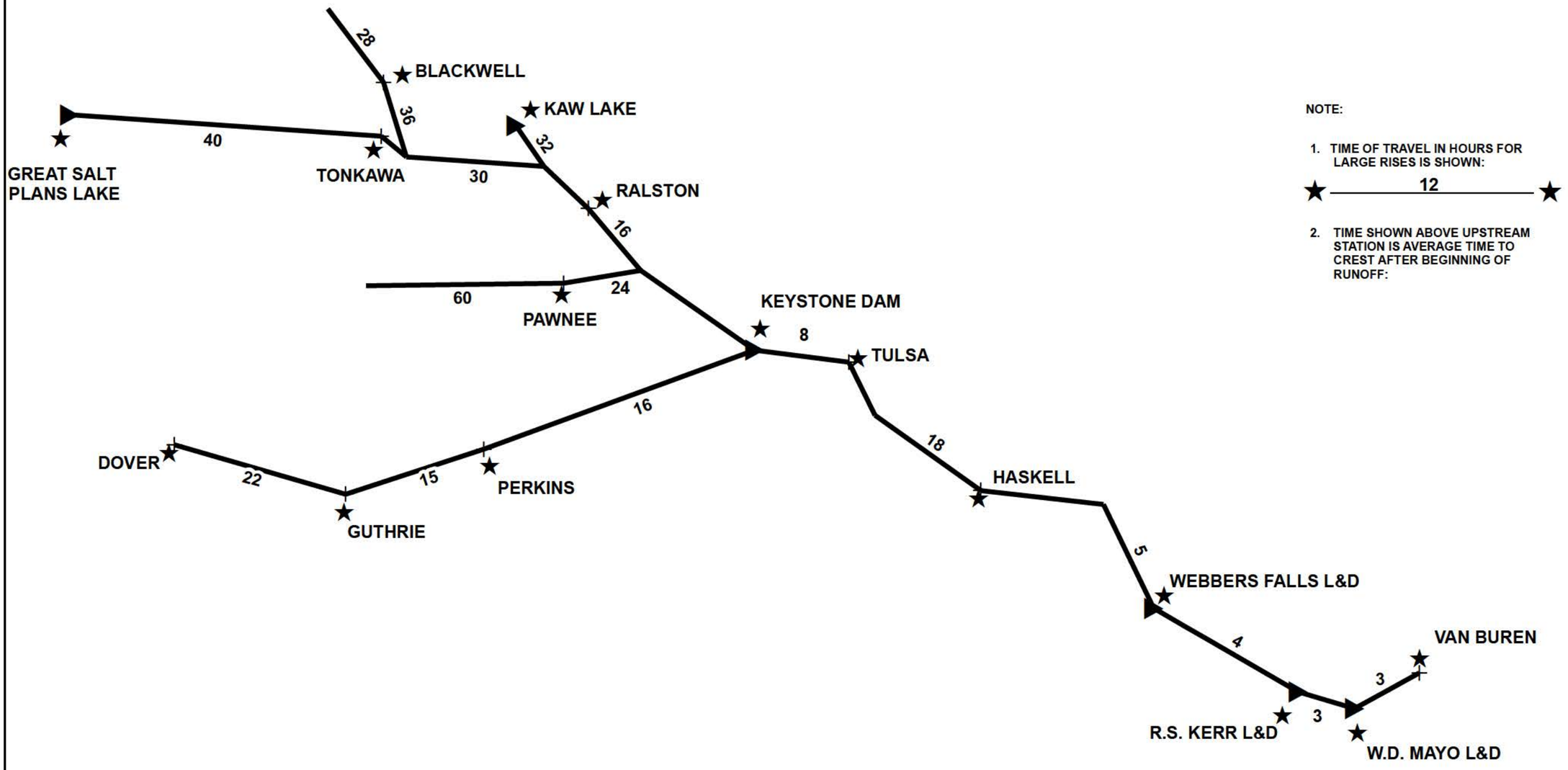
ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

DISCHARGE RATING CURVE CIMARRON RIVER NR RIPLEY

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 12



NOTE:

1. TIME OF TRAVEL IN HOURS FOR LARGE RISES IS SHOWN:

★ 12 ★

2. TIME SHOWN ABOVE UPSTREAM STATION IS AVERAGE TIME TO CREST AFTER BEGINNING OF RUNOFF:

NOTE: USE AS A GUIDE ONLY. ACTUAL TRAVEL TIMES VARY ACCORDING TO MAGNITUDE OF FLOW

NOTE: Plate size is 11" x 17"

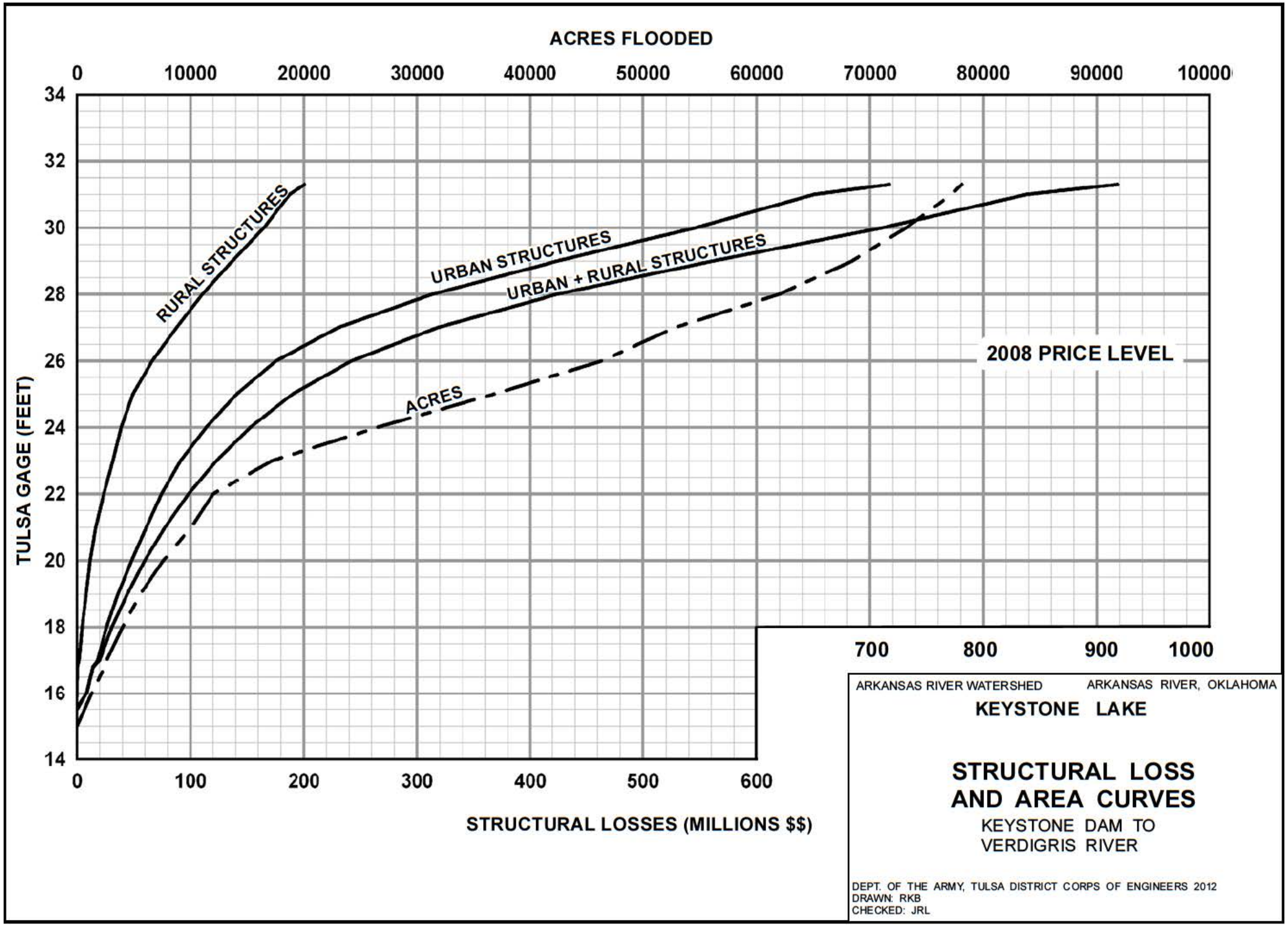
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

TIME OF CREST TRAVEL

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 13



ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

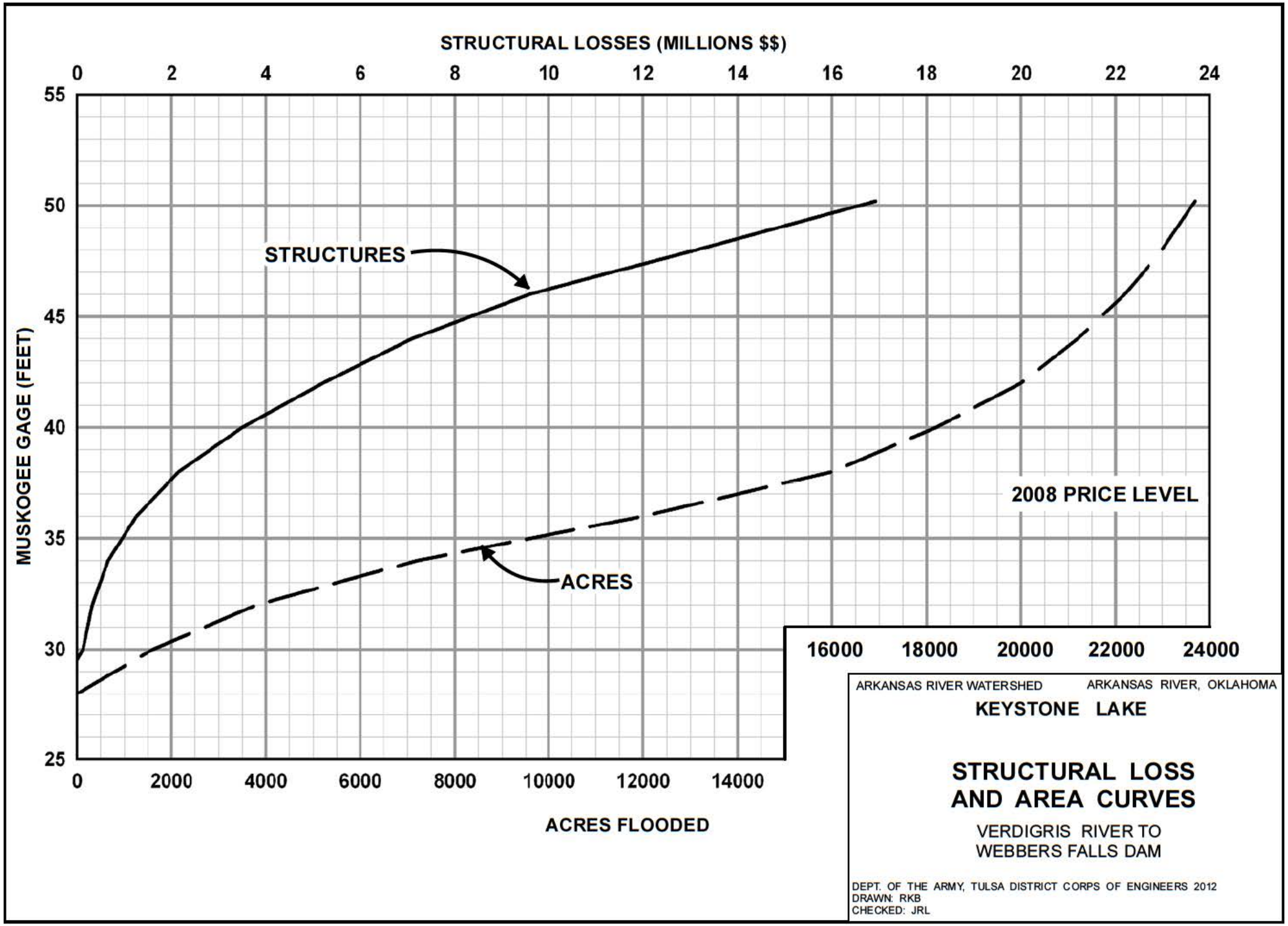
KEYSTONE LAKE

STRUCTURAL LOSS AND AREA CURVES

KEYSTONE DAM TO VERDIGRIS RIVER

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 14



ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

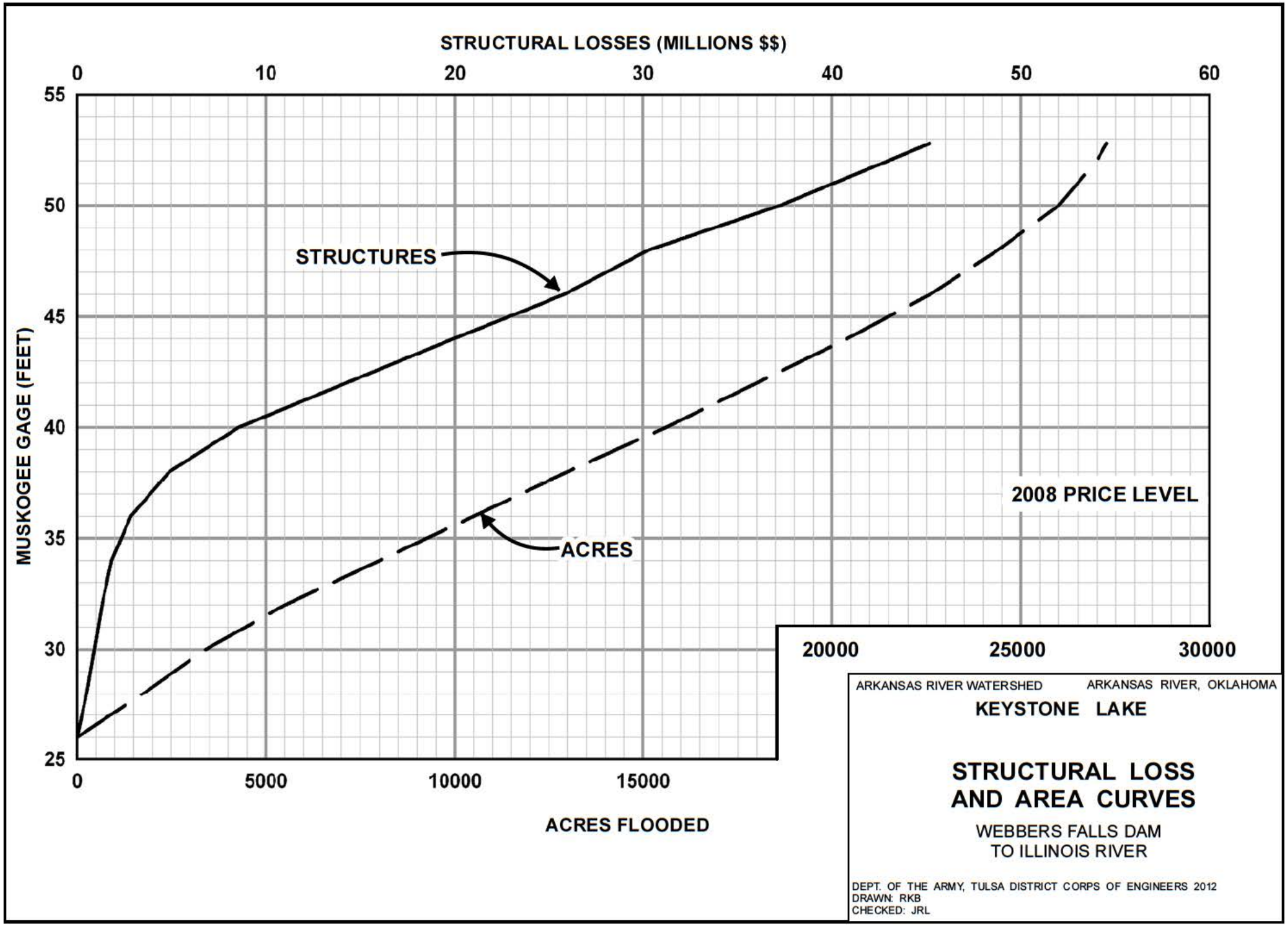
KEYSTONE LAKE

STRUCTURAL LOSS AND AREA CURVES

VERDIGRIS RIVER TO WEBBERS FALLS DAM

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 15



ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

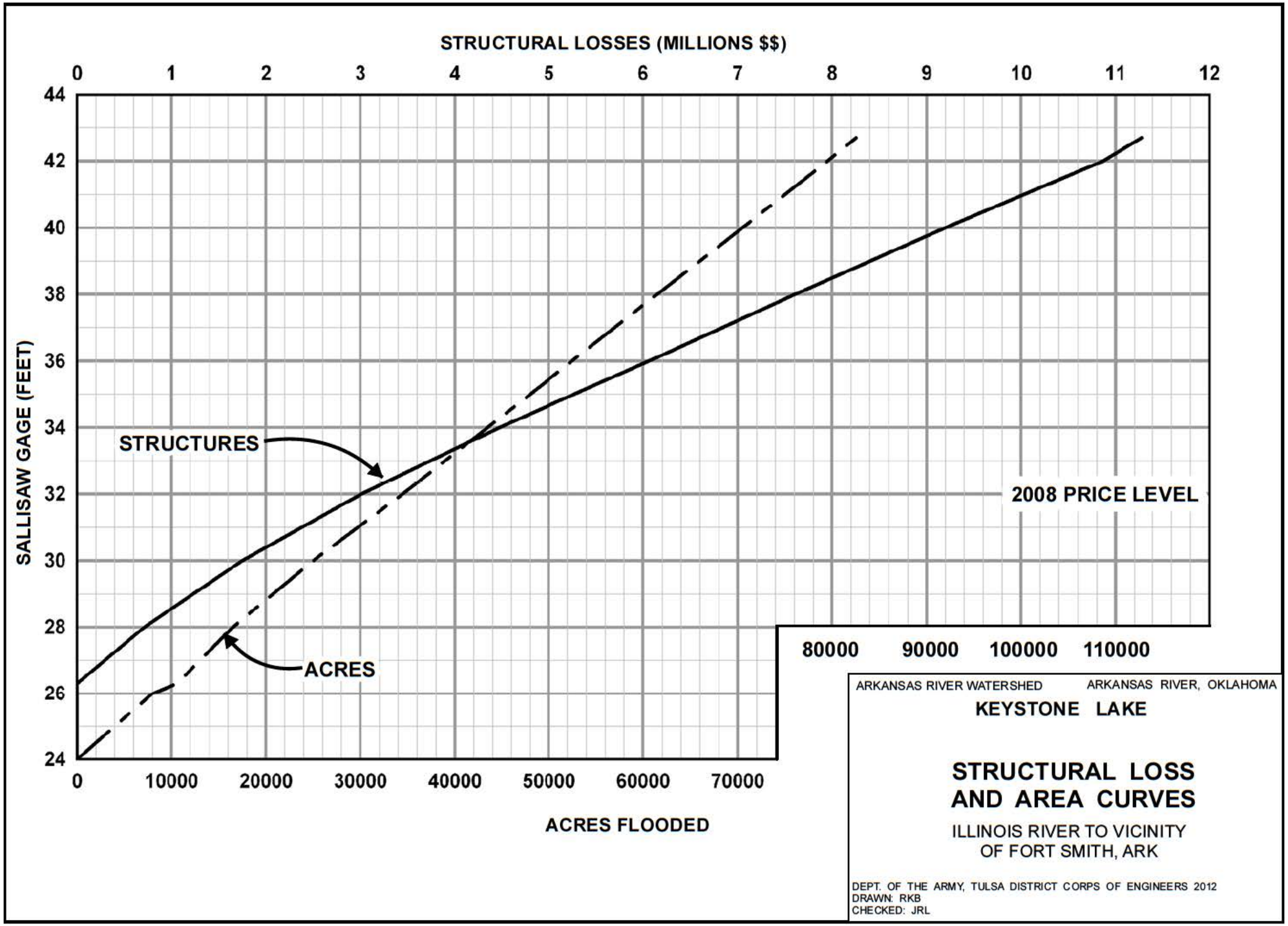
KEYSTONE LAKE

STRUCTURAL LOSS AND AREA CURVES

WEBBERS FALLS DAM
TO ILLINOIS RIVER

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 16



ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

STRUCTURAL LOSS AND AREA CURVES

ILLINOIS RIVER TO VICINITY OF FORT SMITH, ARK

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 4 - 17

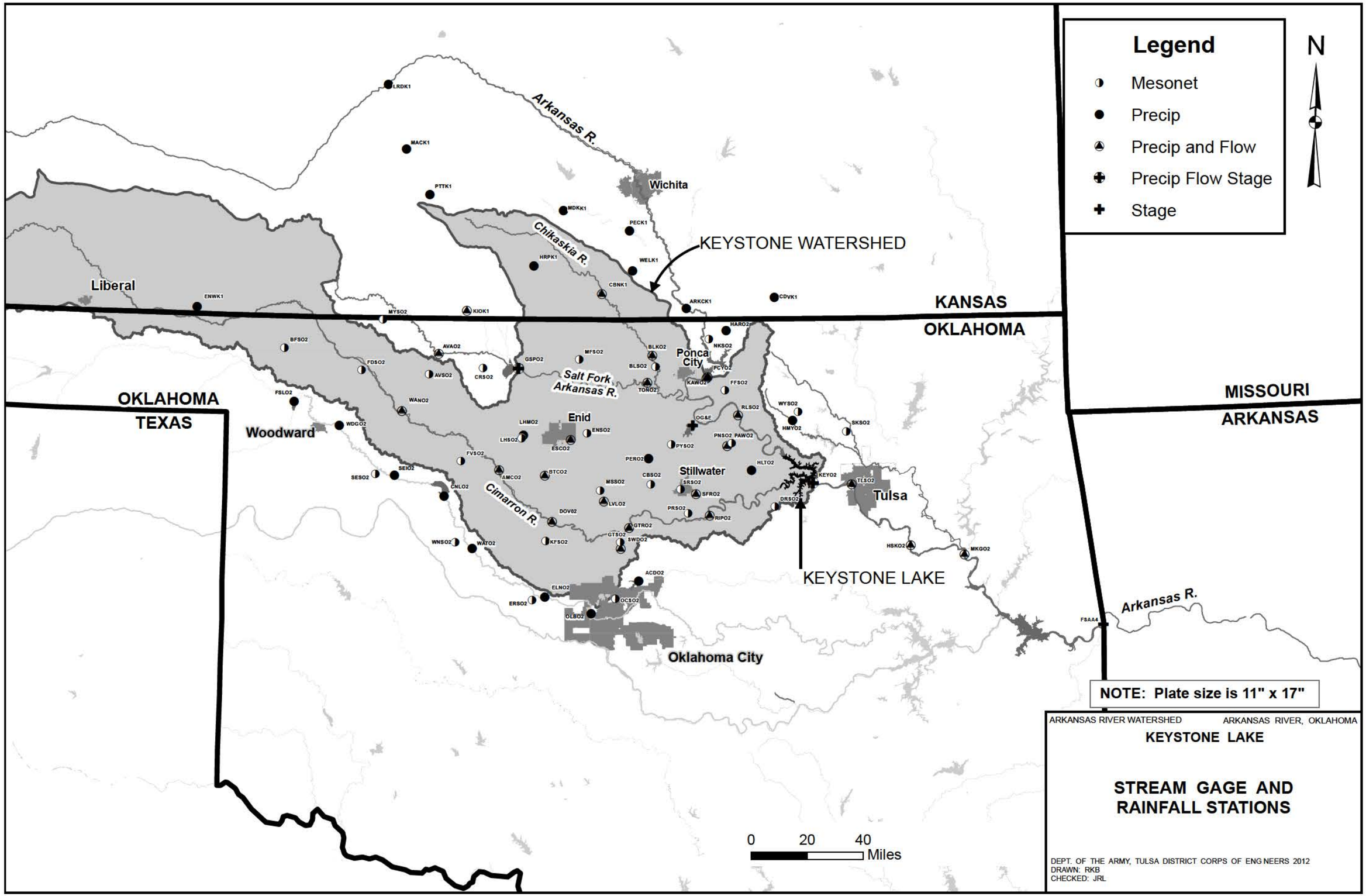
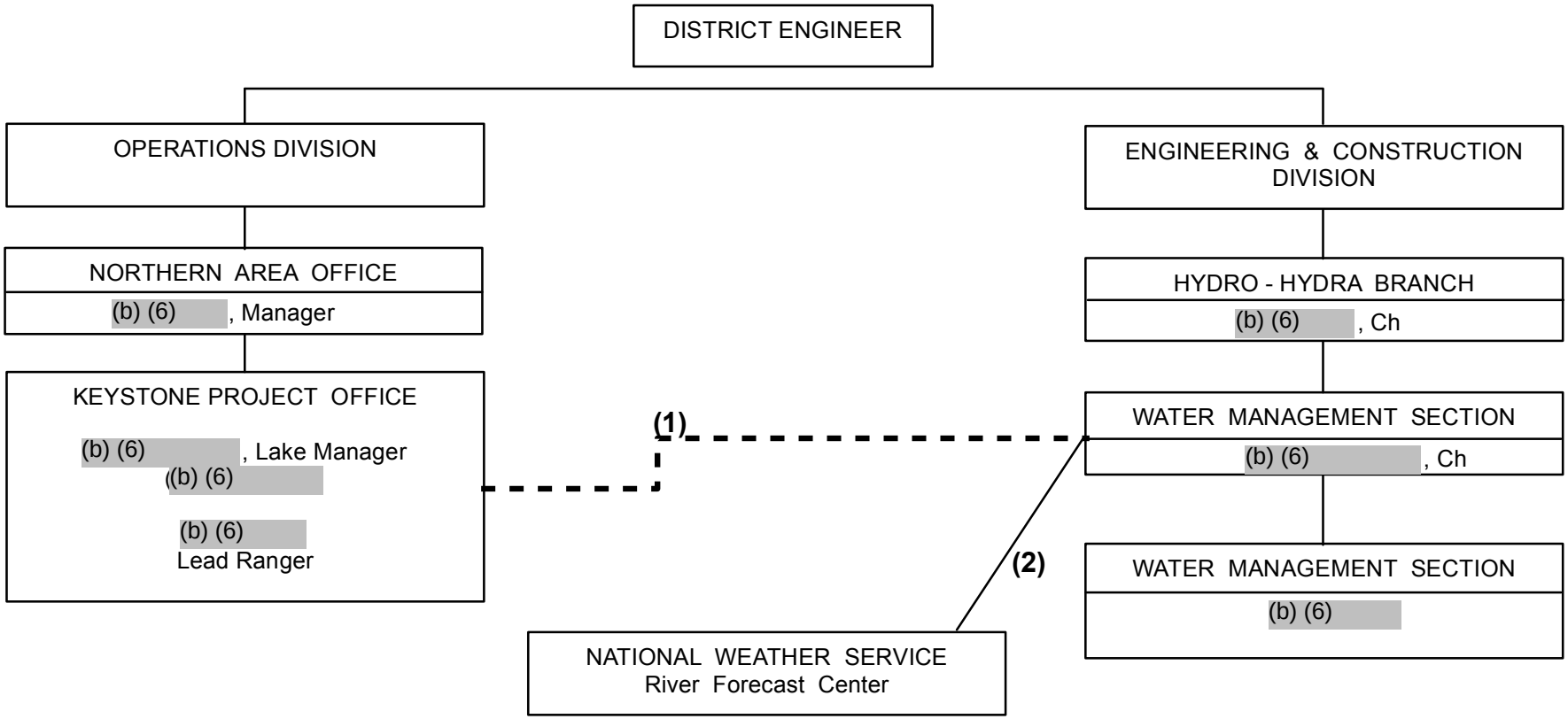

Legend
Mesonet
Precip
Precip and Flow
Precip Flow Stage
Stage
N
Arkansas R.
Wichita
Chikaskia R.
KEYSTONE WATERSHED
Liberal
KANSAS
OKLAHOMA
Ponca City
Salt Fork Arkansas R.
OKLAHOMA
TEXAS
MISSOURI
ARKANSAS
Woodward
Enid
Stillwater
Cimarron R.
Tulsa
KEYSTONE LAKE
Arkansas R.
Oklahoma City
LRDK1
MACK1
PTTK1
MDKK1
PECK1
HRPK1
WELK1
CBNK1
ARKCK1
CDVK1
ENWK1
MYSO2
KIOK1
HARO2
NKSO2
BFSO2
AVAO2
MFSO2
BLKO2
GSPO2
BLSO2
PCYO2
FDSO2
CRSO2
KAWO2
TONO2
FFSO2
FSLO2
WANO2
RLSO2
WYSO2
WDGO2
LHMO2
OG&E
HMYO2
SKSO2
ENSO2
LHSO2
ESCO2
PNSO2
PAWO2
PYSO2
FVSO2
PERO2
HLTO2
SEIO2
SESO2
AMCO2
BTCO2
CBSO2
KEYO2
TLSO2
CNLO2
MSSO2
SRSO2
SFRO2
LVLO2
DRSO2
DOV02
PRSO2
RIPO2
GTRO2
GTSO2
SWDO2
WNSO2
WATO2
KFSO2
HSKO2
MKGO2
ACDO2
ELNO2
ERSO2
OCSO2
OLBO2
FSAA4
0
20
40
Miles
NOTE: Plate size is 11" x 17"
ARKANSAS RIVER WATERSHED
ARKANSAS RIVER, OKLAHOMA
KEYSTONE LAKE
STREAM GAGE AND RAINFALL STATIONS
DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 5 - 1

U.S. ARMY CORPS OF ENGINEERS
TULSA DISTRICT



1. DIRECT COMMUNICATIONS ARE MAINTAINED BETWEEN KEYSTONE PROJECT OFFICE AND THE WATER MANAGEMENT SECTION FOR TRANSMISSION OF RESERVOIR DATA, REGULATIONS AND INSTRUCTIONS.

2. PRECIPITATION AND STREAM GAGE DATA ARE SHARED BY THE NATIONAL WEATHER SERVICE, RIVER FORECAST CENTER.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

ORGANIZATION FOR FLOOD CONTROL REGULATION

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RAB
CHECKED: JRL

PLATE 5 - 2

PROJECT **SKIA # 42** **LAKE DATA** **DATE :**

LINE #	ITEM		TIME									
1	POOL ELEVATION		12N									
2	POOL ELEVATION		4PM									
3	POOL ELEVATION		12M									
4	POOL ELEVATION		8AM									
5	TAILWATER ELEVATION		8AM									
6	24 HR AVG POWER DISCHARGE		12M									
7	24 HR AVG TOTAL DISCHARGE		12M									
8	NET POWER GENERATION		12M									
9	GEN#1 HRS OF USE		12M									
	GEN#2 HRS OF USE		12M									
	GEN#3 HRS OF USE		12M									
	GEN#4 HRS OF USE		12M									
10	INSTANTANEOUS POWER DISCHARGE		8AM									
11	INSTANTANEOUS TOTAL DISCHARGE		8AM									
12/13	LAKE	WEATHER	8AM									
14	TOTAL PRECEDING 6 HR PRECIPITATION ENDING AT		1PM									
			7PM									
			1AM									
			7AM									
15	TOTAL 24 HOUR PRECIPITATION		7AM									
16	COMMENTS ON PRECIP. DIST.											
17	EVAPORATION 24 HOURS		8AM									
18/19	WIND DIRECTION AND VELOCITY		8AM		B-		B-		B-		B-		B-		B-		B-
20	WATER SUPPLY											
21	GATE SETTINGS NO. TYPE AND OPENING		8AM									
22	GATE CHANGES	DATE TIME										
23	POOL ELEVATION											
24	FROM	GATE SETTING										
25	TO	GATE SETTING										
26	GATE CHANGES	DATE TIME										
27	POOL ELEVATION											
28	FROM	GATE SETTING										
29	TO	GATE SETTING										
30	GATE CHANGES	DATE TIME										
31	POOL EVEVATION											
32	FROM	GATE SETTING										
33	TO	GATE SETTING										

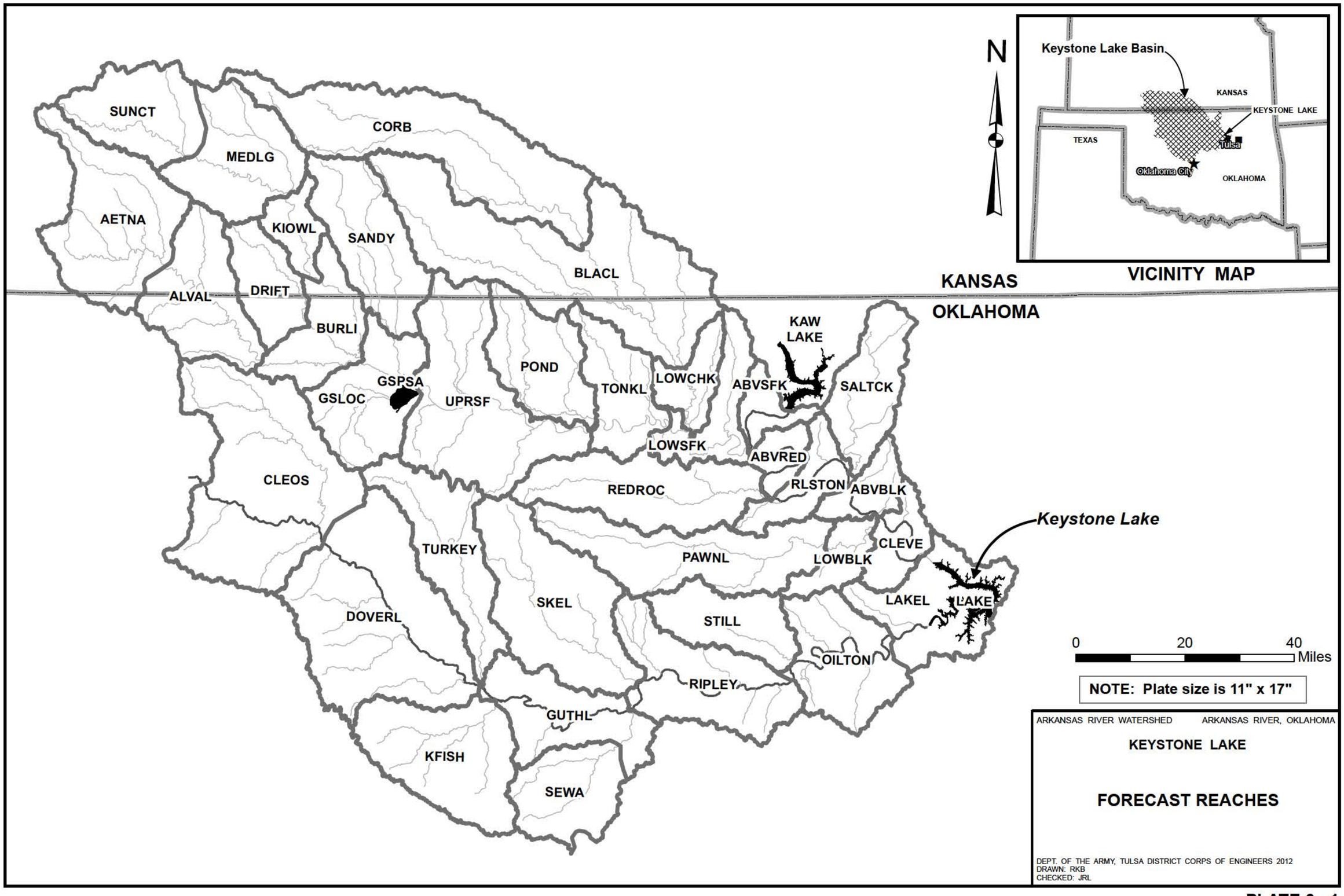
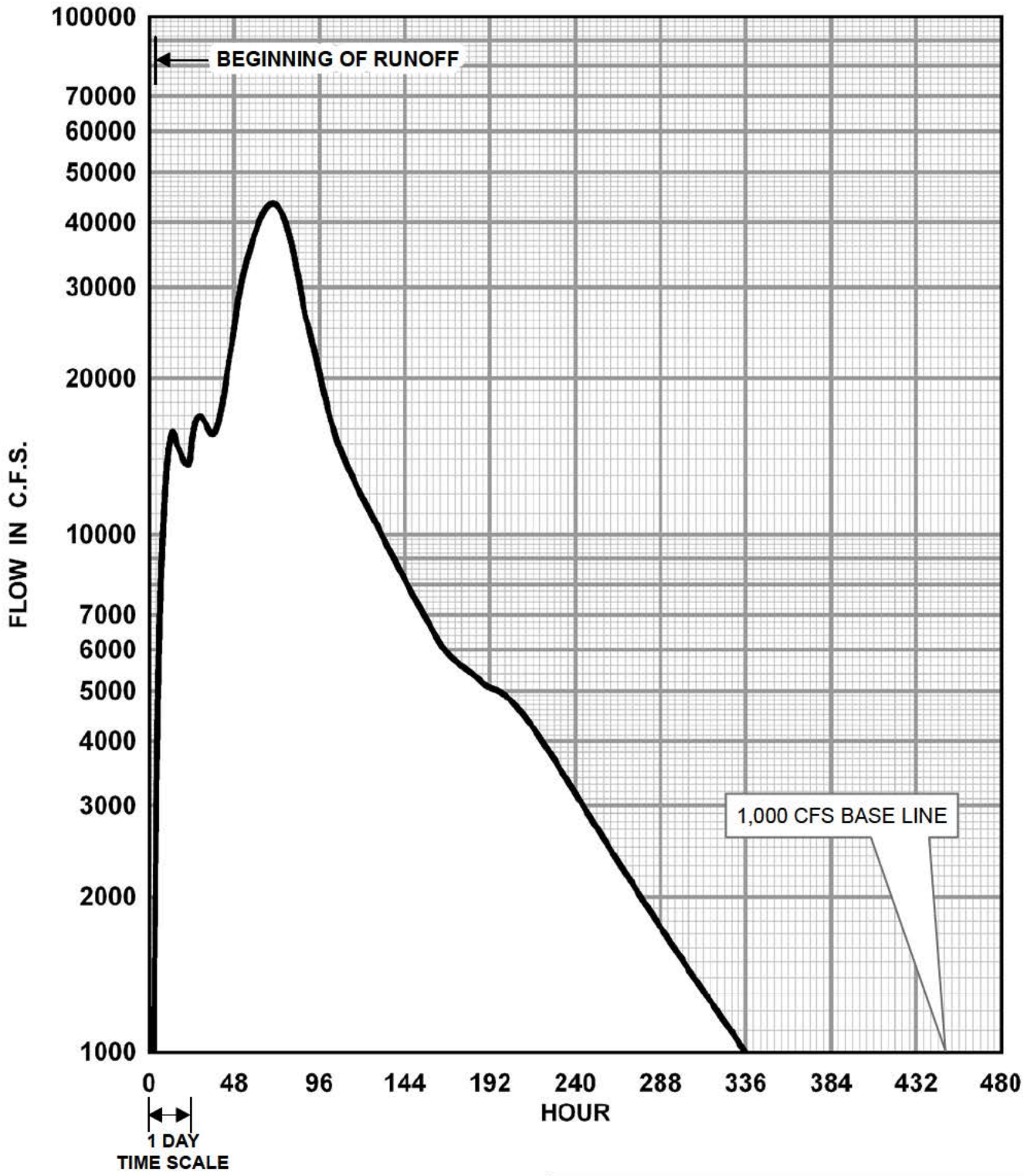

N
Keystone Lake Basin
KANSAS
KEYSTONE LAKE
TEXAS
Tulsa
Oklahoma City
OKLAHOMA
VICINITY MAP
KANSAS
OKLAHOMA
SUNCT
CORB
MEDLG
AETNA
KIOWL
SANDY
BLACL
ALVAL
DRIFT
BURLI
KAW LAKE
POND
GSPSA
GSLOC
UPRSF
TONKL
LOWCHK
ABVSFK
SALTCK
LOWSFK
ABVRED
CLEOS
REDROC
RLSTON
ABVBLK
Keystone Lake
TURKEY
PAWNL
CLEVE
LOWBLK
SKEL
LAKEL
LAKE
DOVERL
STILL
OILTON
RIPLEY
GUTHL
KFISH
SEWA
0
20
40
Miles
NOTE: Plate size is 11" x 17"
ARKANSAS RIVER WATERSHED
ARKANSAS RIVER, OKLAHOMA
KEYSTONE LAKE
FORECAST REACHES
DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 6 - 1



ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

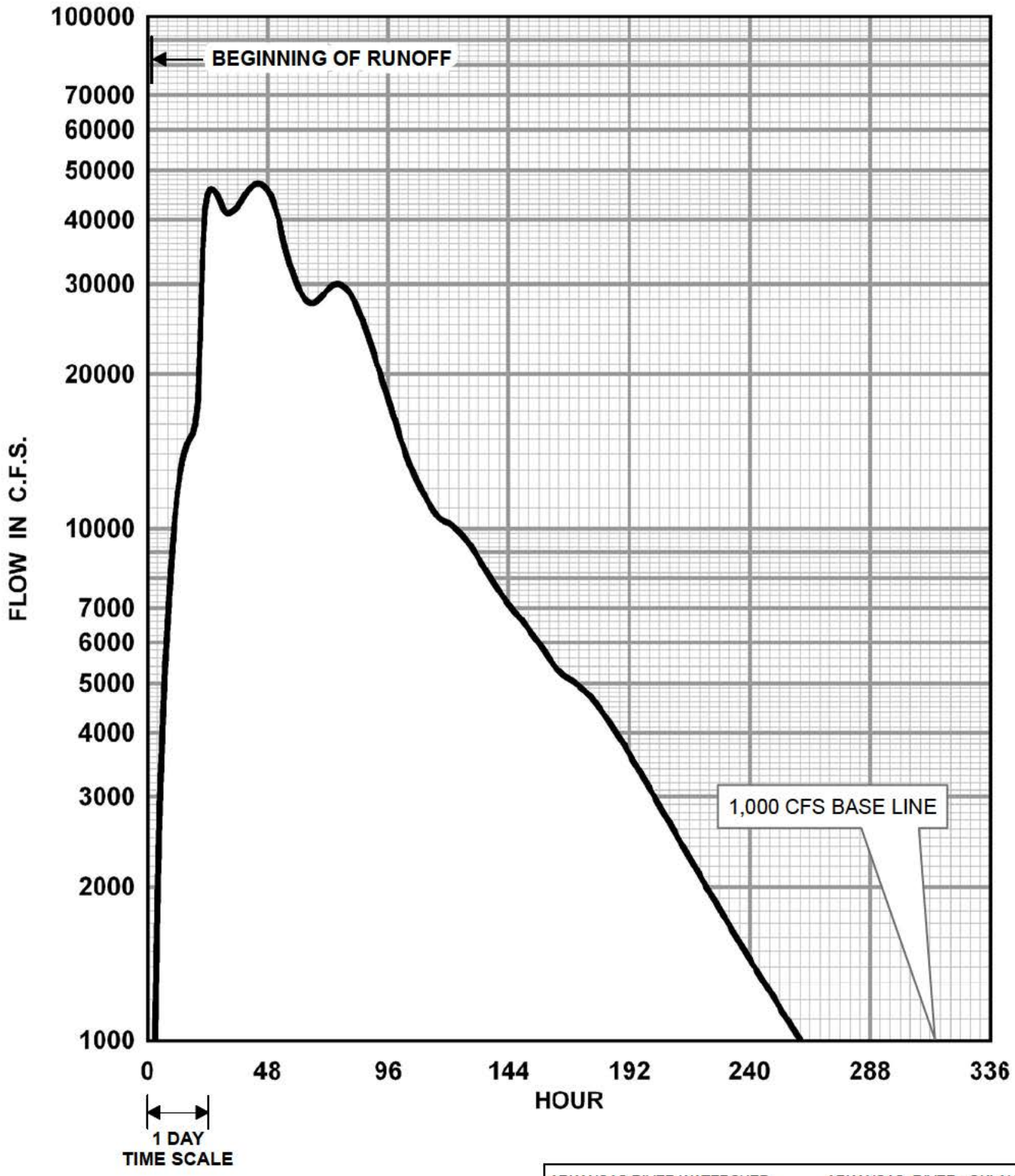
KEYSTONE LAKE

UNIT HYDROGRAPH FOR AREA DOWNSTREAM OF KAW AND GREAT SALT PLAINS DAMS AND UPSTREAM OF RALSTON GAGE ON ARKANSAS RIVER

DRAINAGE AREA = 4,074 SQ. MI.
1" RUNOFF = 217,144 AC.FT.
PEAK FLOW = 47,200 C.F.S.

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 6 - 2



ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

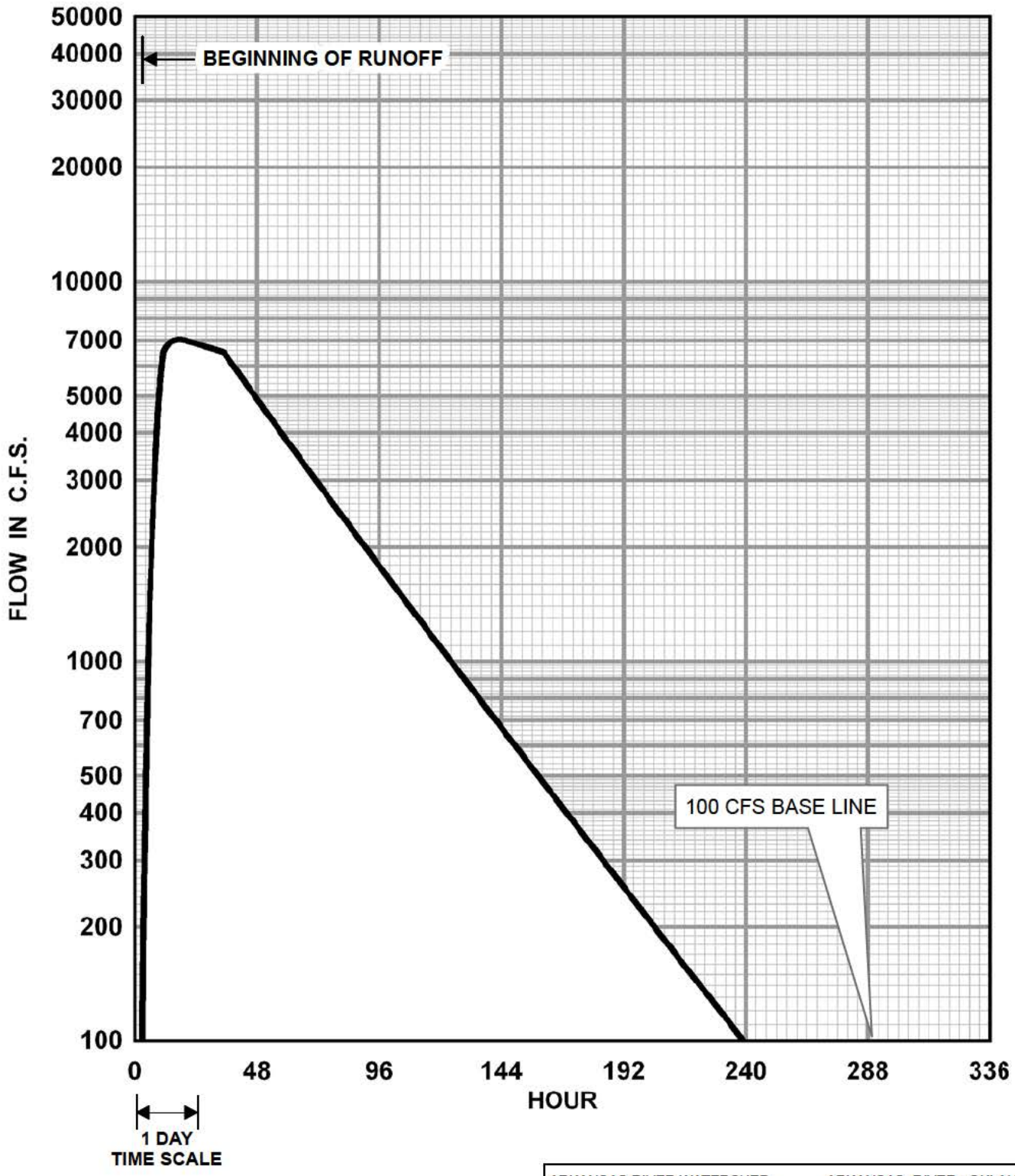
KEYSTONE LAKE

UNIT HYDROGRAPH FOR AREA DOWNSTREAM OF WAYNOKA GAGE AND UPSTREAM OF RIPLEY GAGE ON CIMARRON RIVER

DRAINAGE AREA = 4,589 SQ. MI.
1" RUNOFF = 244,593 AC.FT.
PEAK FLOW = 47,200 C.F.S.

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 6 - 3



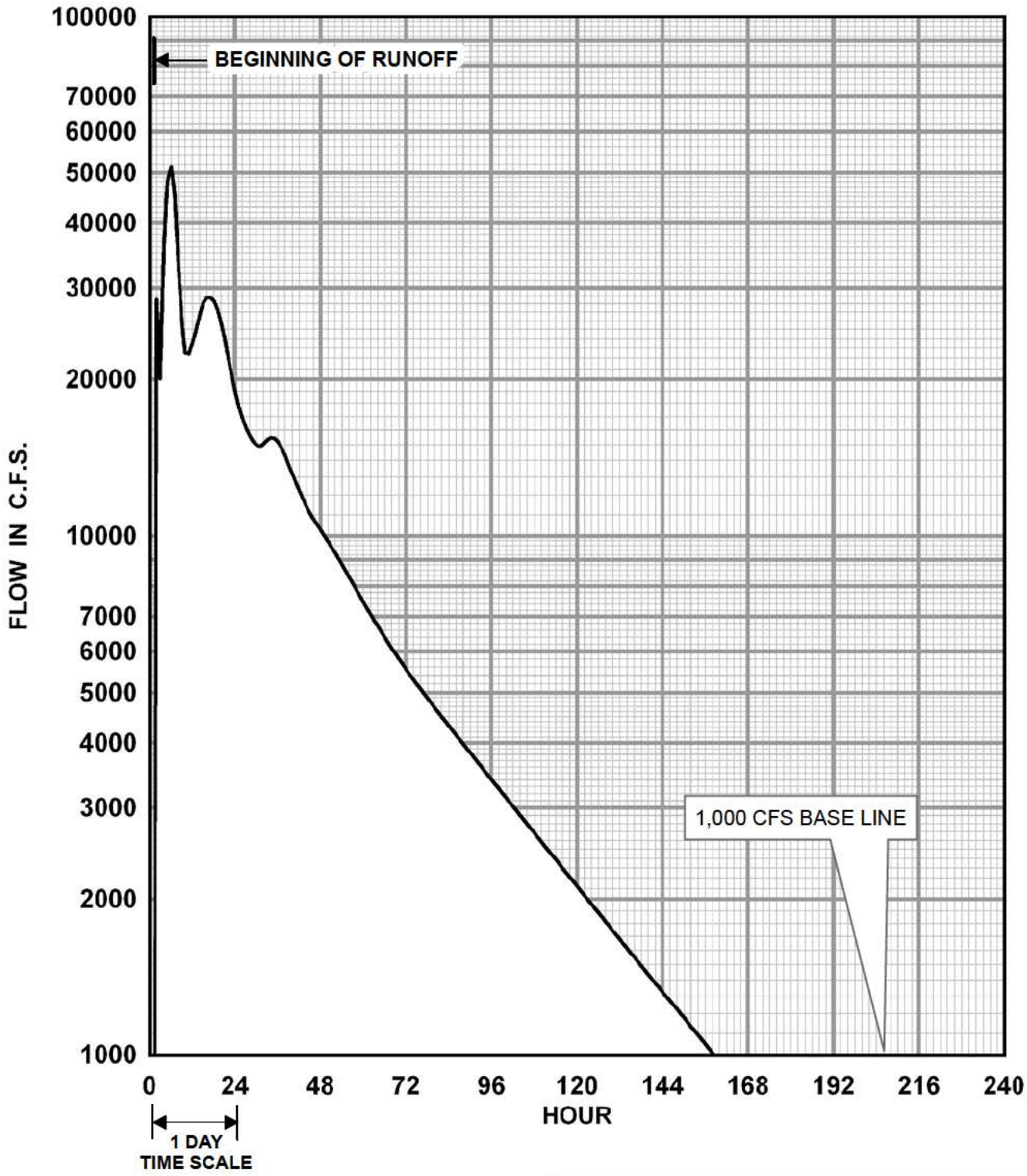
DRAINAGE AREA = 522 SQ. MI.
1" RUNOFF = 27,822 AC.FT.
PEAK FLOW = 7,046 C.F.S.

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

UNIT HYDROGRAPH FOR AREA UPSTREAM OF PAWNEE GAGE ON BLACK BEAR CREEK

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL



DRAINAGE AREA = 1,454 Q. MI.
1" RUNOFF = 77,500 AC.FT.
PEAK FLOW = 51,472 C.F.S.

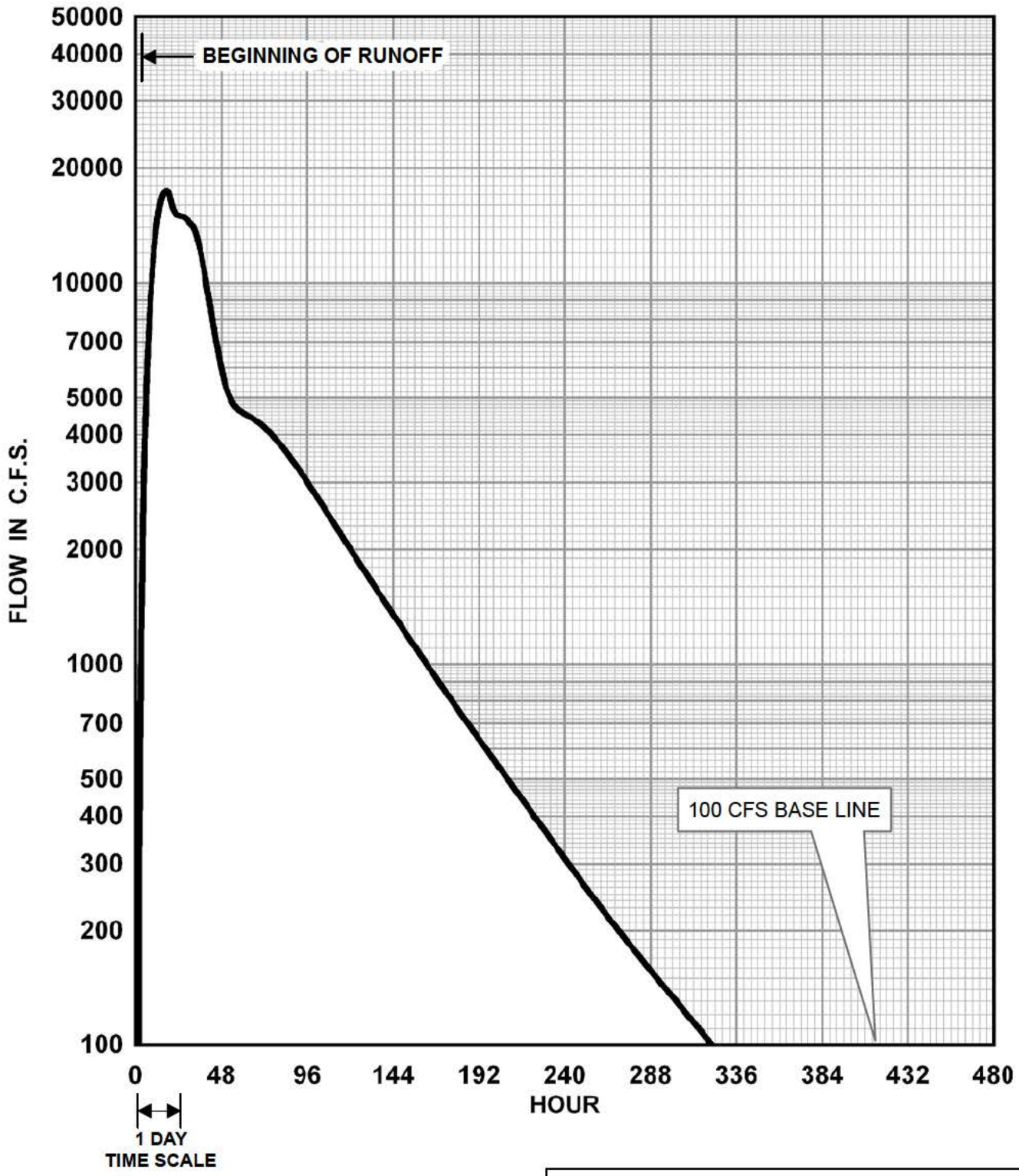
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

UNIT HYDROGRAPH FOR AREA DOWNSTREAM OF RALSTON, PAWNEE AND RIPLEY GAGES AND UPSTREAM OF KEYSTONE DAM

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 6 - 5



ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

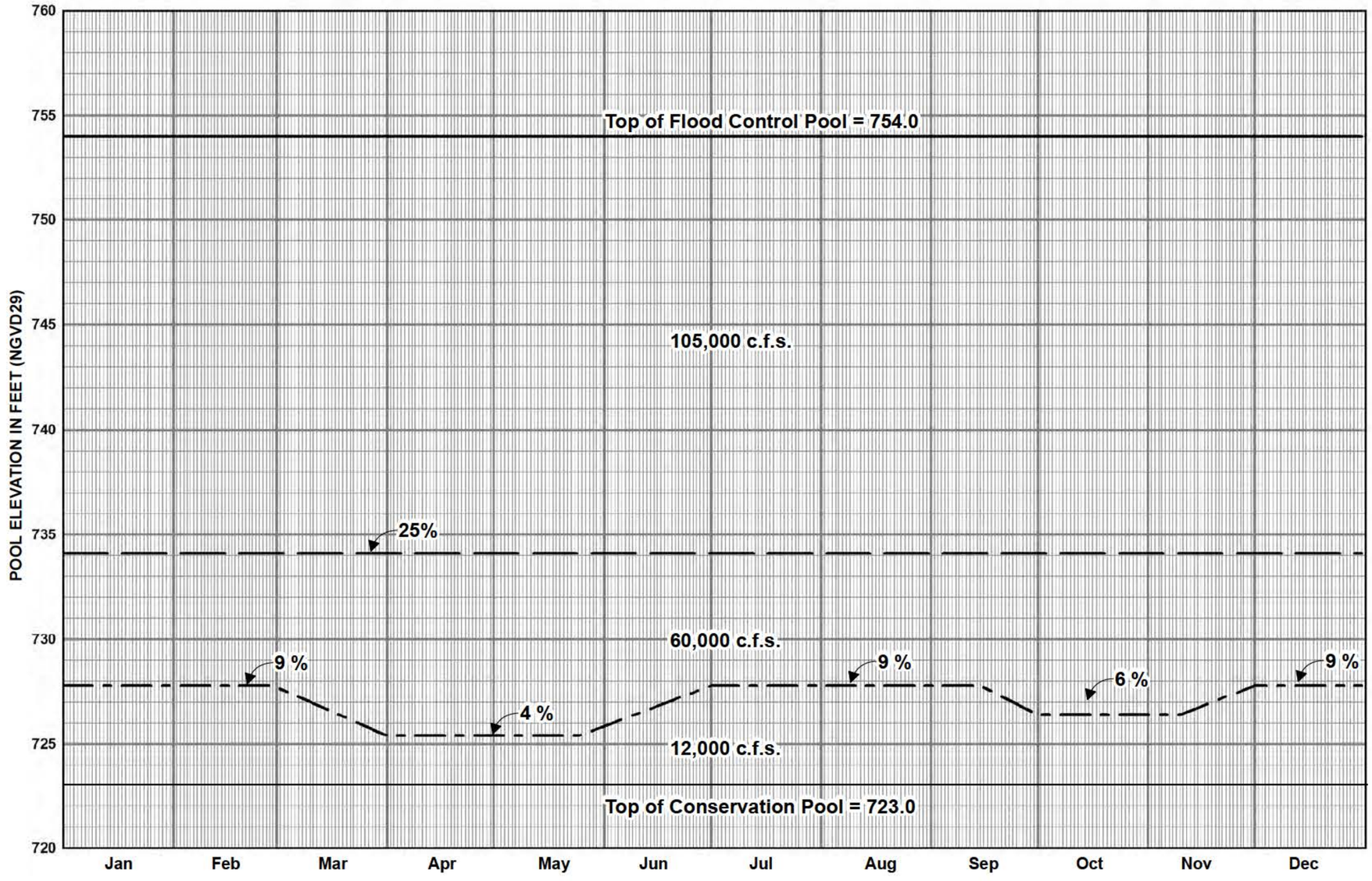
KEYSTONE LAKE

UNIT HYDROGRAPH FOR AREA DOWNSTREAM OF KEYSTONE DAM AND UPSTREAM OF HASKELL GAGE ON ARKANSAS RIVER

DRAINAGE AREA = 967 SQ. MI.
1" RUNOFF = 51,541 AC.FT.
PEAK FLOW = 17,468 C.F.S.

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 6 - 6



NOTE: Plate size is 11" x 17"

NOTE:

RELEASE RATES SHOWN FOR HIGHER ZONES ARE THE MAXIMUM EXPECTED.

RELEASE RATES FOR LOWER ZONES ARE THE AVERAGE RATES.

RELEASE RATES IN ALL ZONES MAY BE MORE OR LESS DEPENDING ON UPSTREAM AND/OR DOWNSTREAM FLOW CONDITIONS.

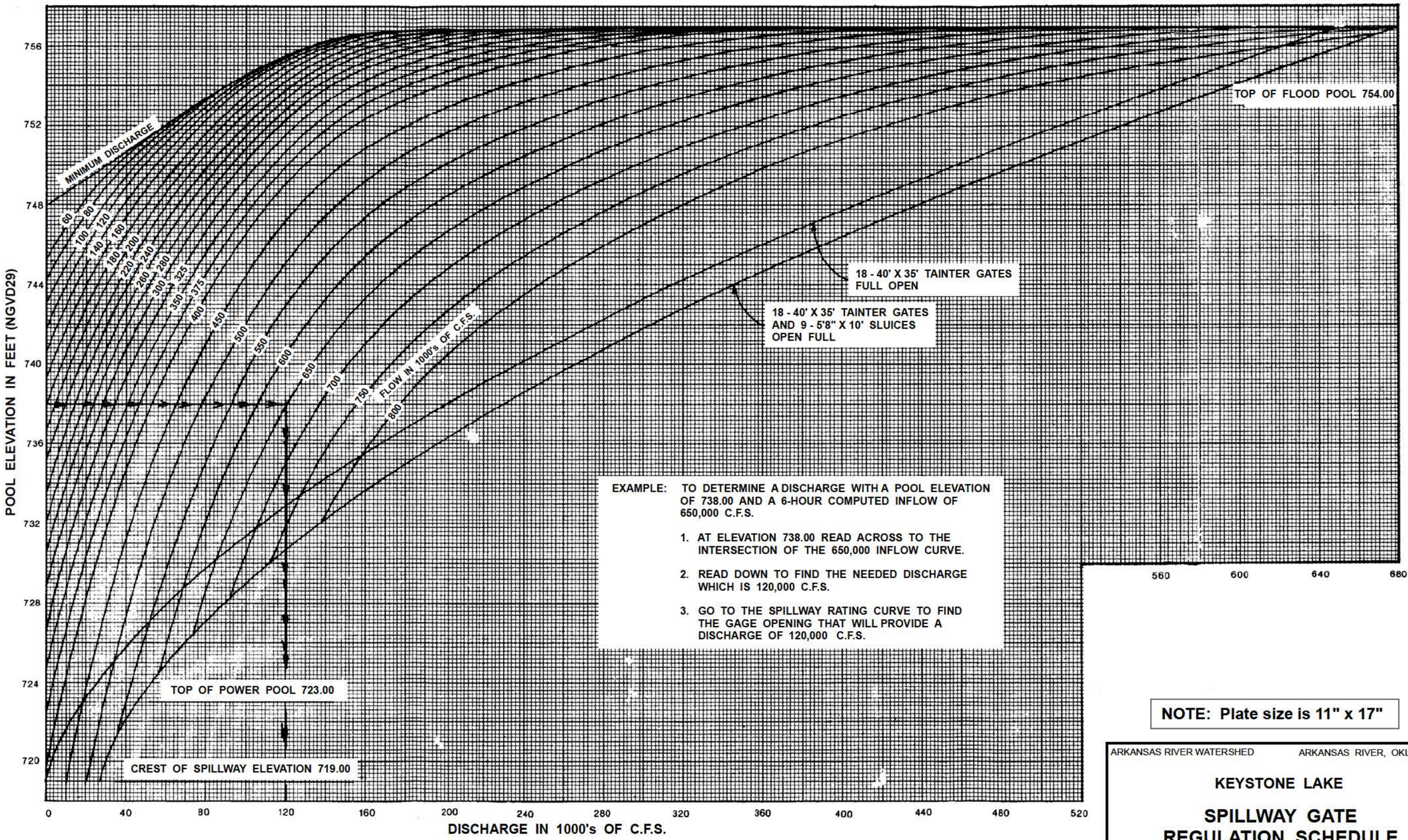
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

SEASONAL GUIDE CURVE FOR RELEASE RATES

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 7 - 1



EXAMPLE: TO DETERMINE A DISCHARGE WITH A POOL ELEVATION OF 738.00 AND A 6-HOUR COMPUTED INFLOW OF 650,000 C.F.S.

1. AT ELEVATION 738.00 READ ACROSS TO THE INTERSECTION OF THE 650,000 INFLOW CURVE.
2. READ DOWN TO FIND THE NEEDED DISCHARGE WHICH IS 120,000 C.F.S.
3. GO TO THE SPILLWAY RATING CURVE TO FIND THE GAGE OPENING THAT WILL PROVIDE A DISCHARGE OF 120,000 C.F.S.

NOTE: Plate size is 11" x 17"

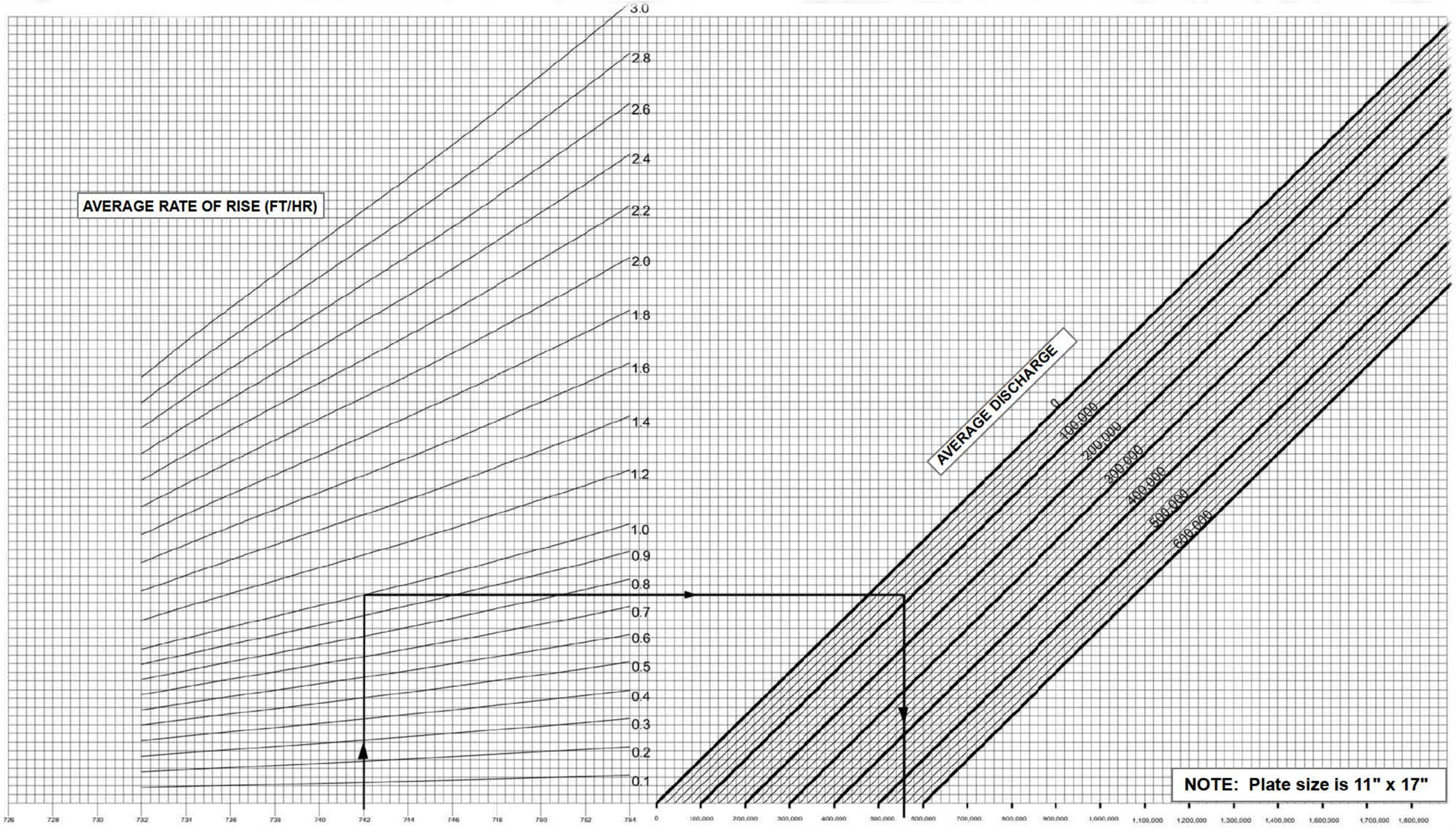
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

SPILLWAY GATE REGULATION SCHEDULE INFLOW PARAMETER

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 7 - 2



NOTE: Plate size is 11" x 17"

Example computations

1. Begin with a lake elevation of 742.0 ft. Six hours ago the elevation was 736.0 ft.
2. Rate of rise = (742.0-736.0)/6 hours = 1 ft/hr.
3. Releases for last 6 hours were
   2.0 hours at 60000 = 2 x 60000 = 120000 cfs
   4.0 hours at 100000 = 4 x 110000 = 440000 cfs

   Total for 6 hours = 560000 cfs
   Average release = 560000cfs/6 hours = 93,333 cfs/hr.
4. The resulting inflow in about 570,000 cfs.

Instructions
To determine the 6-hour inflow

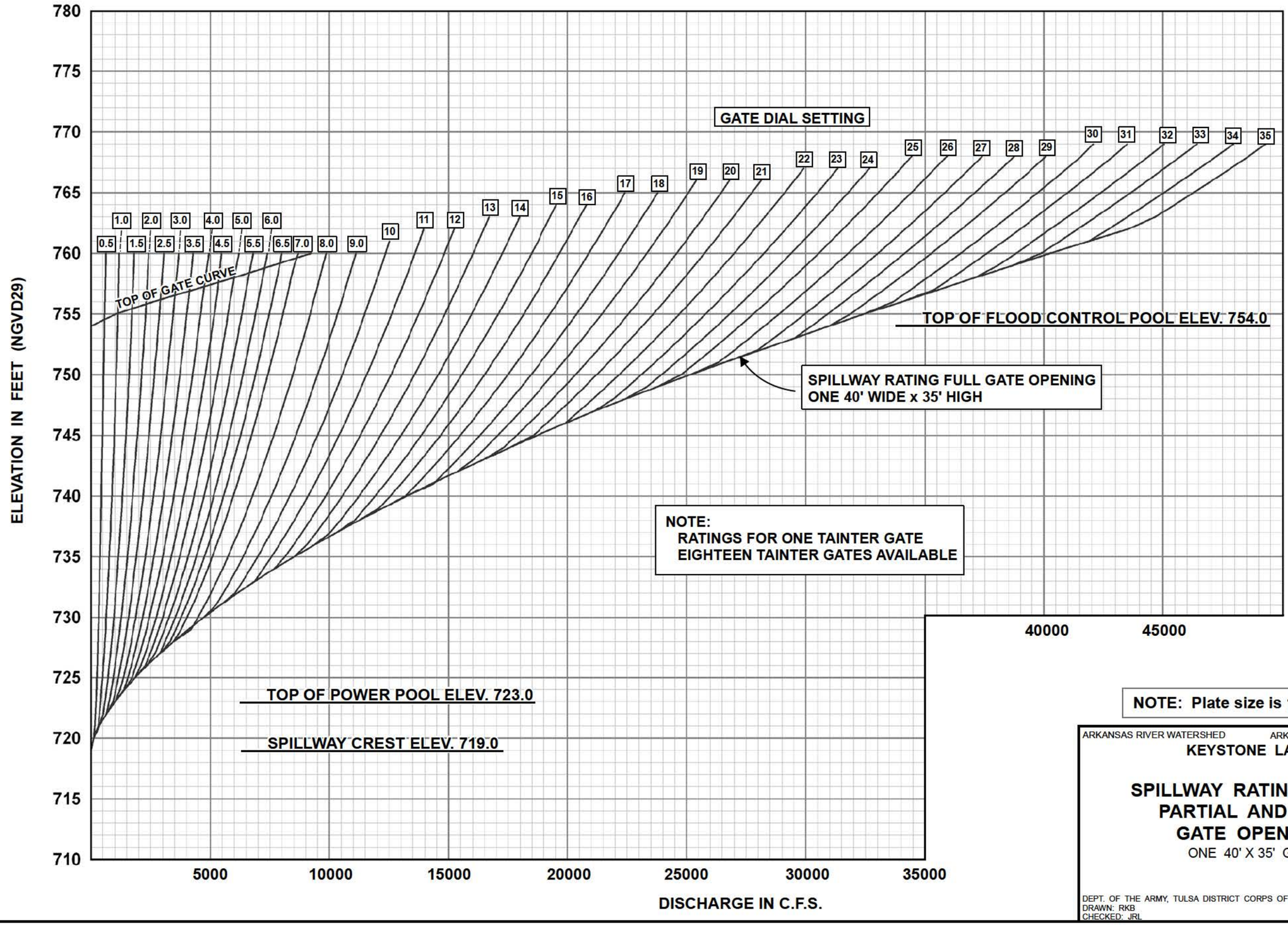
1. Locate the pool elevation at the end of the 6-hour period on the lower left portion of this chart.
2. Determine the rate of rise by subtracting the pool elevation at the beginning of the 6 hour period from the pool elevation at the end of the period and dividing by 6. Move straight up until you intersect the appropriate rate of rise curve.
3. Determine the 6 hour average discharge by
   (a) Multiply the discharge for each gate setting used during the 6 hour period by the time in hours each setting was in effect during the 6 hour period.
   (b) Sum those products and divide by 6 hours. (see sample computations to the left)
4. Move straight across until you intersect the appropriate average discharge curve.
5. Move straight down to the bottom of the chart to read the average inflow for the 6 hour period. Go to plate 7-4 to determine the appropriate gate settings for the discharge for the next period.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

INFLOW vs. RATE OF RISE NOMOGRAPH

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL



NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

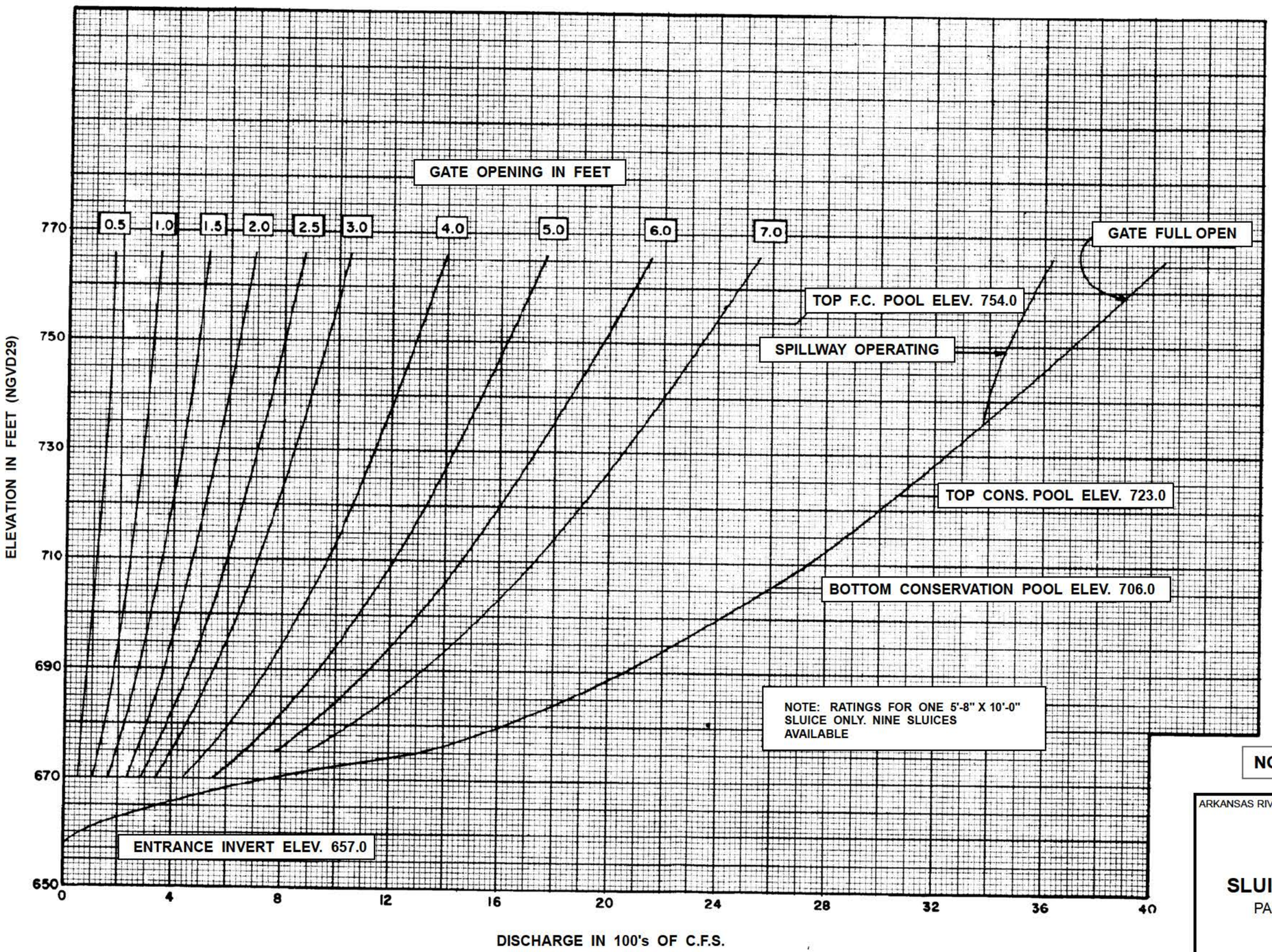
KEYSTONE LAKE

SPILLWAY RATING CURVE PARTIAL AND FULL GATE OPENING

ONE 40' X 35' GATE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 7 - 4



NOTE: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

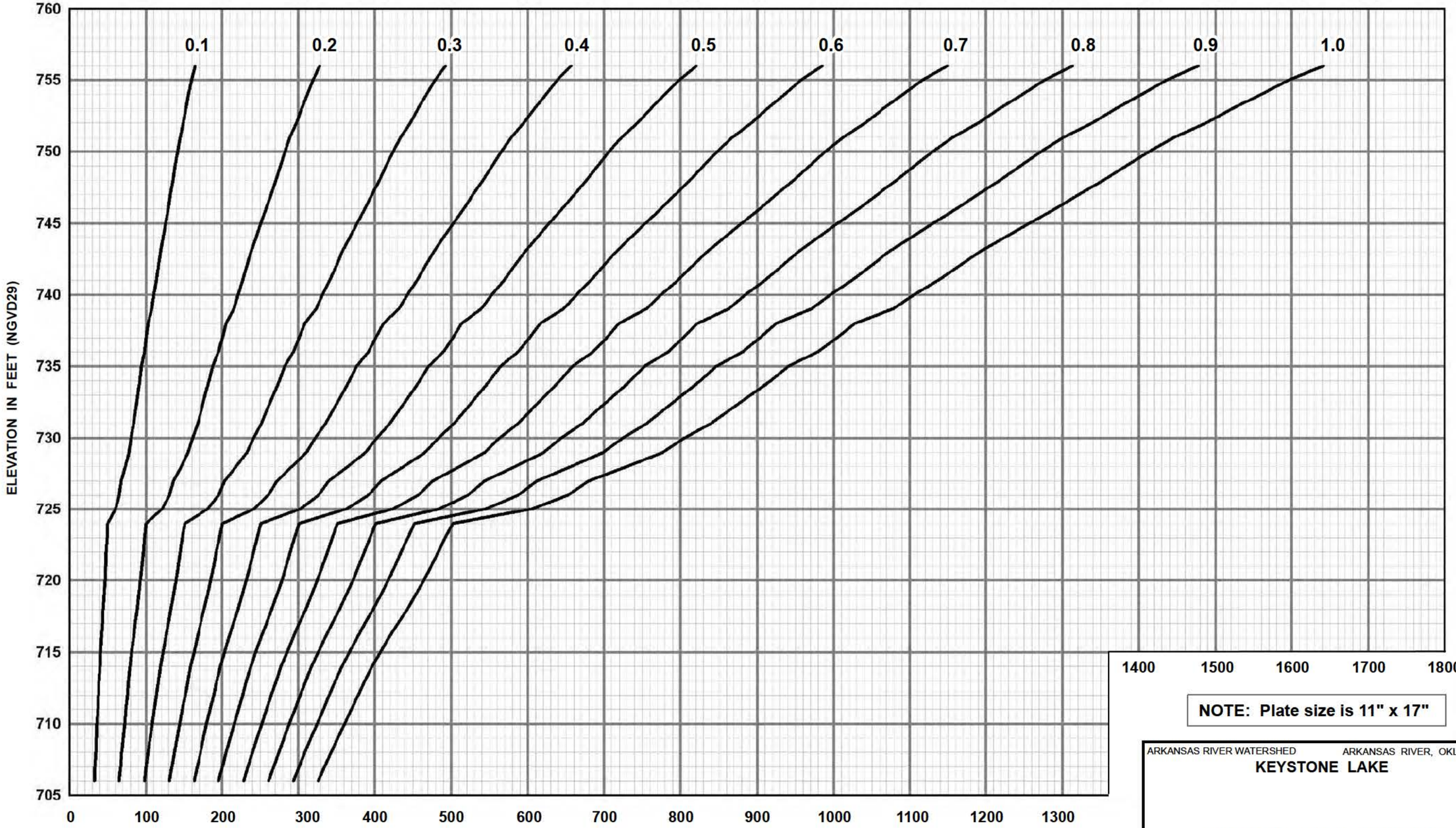
KEYSTONE LAKE

SLUICE GATE RATING CURVE

PARTIAL AND FULL GATE OPENING
(ONE GATE)

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 7 - 5



NOTE: CURVES COMPUTED FOR 70% OF CLASS A PAN EVAPORATION

NOTE: Plate size is 11" x 17"

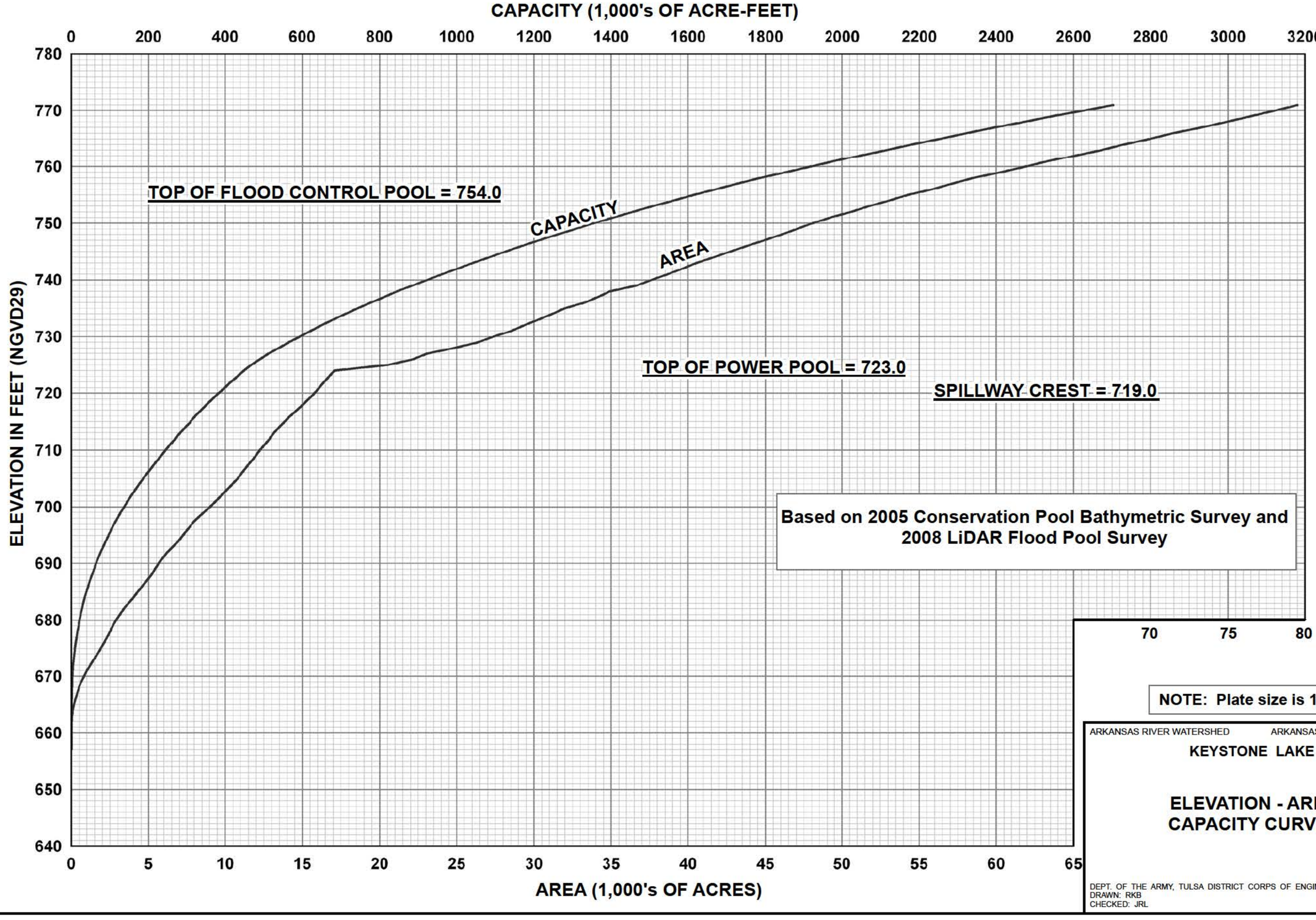
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

EVAPORATION CURVES

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 7 - 6



NOTE: Plate size is 11" x 17"

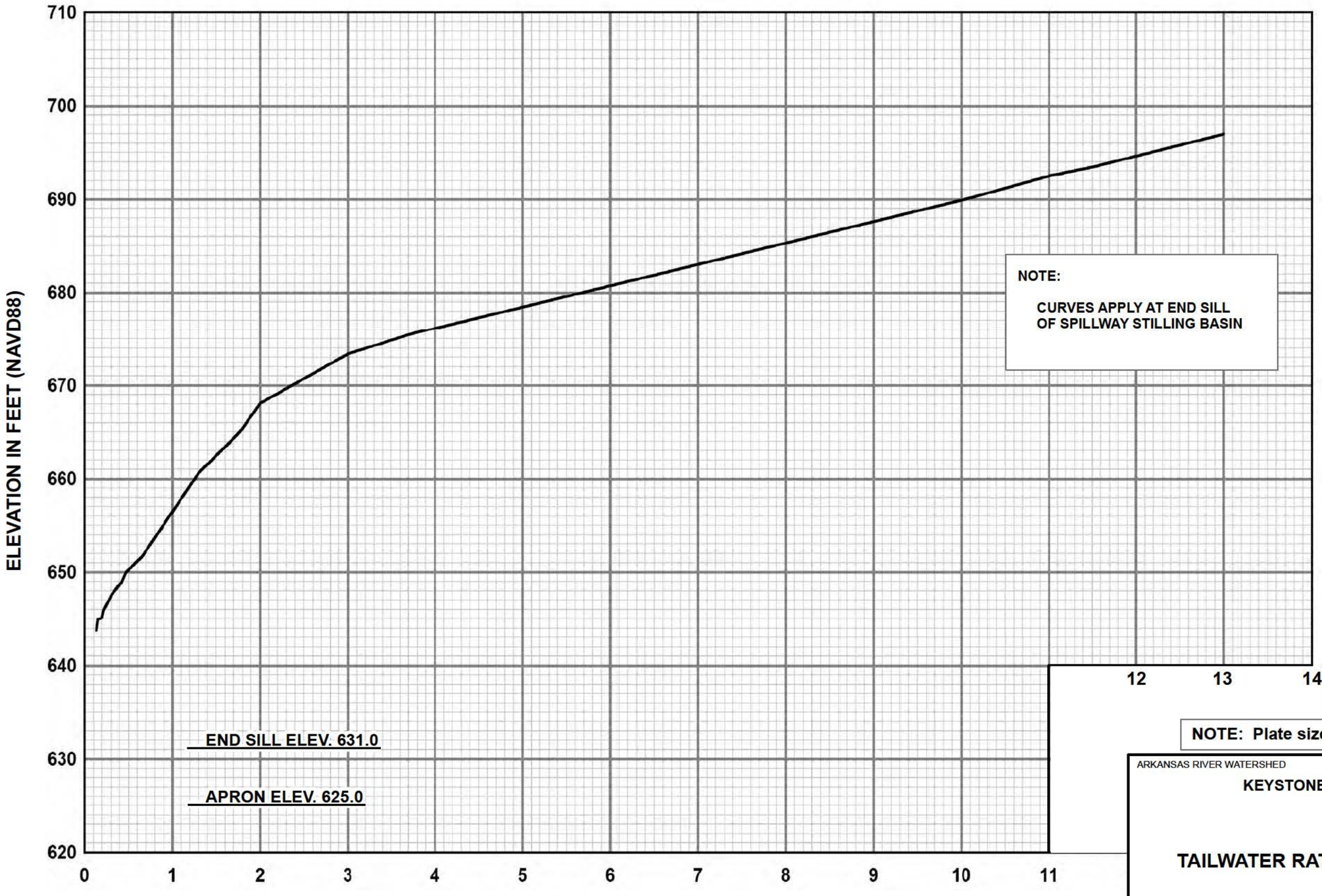
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

ELEVATION - AREA CAPACITY CURVES

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 7 - 7



NOTE: Plate size is 11" x 17"

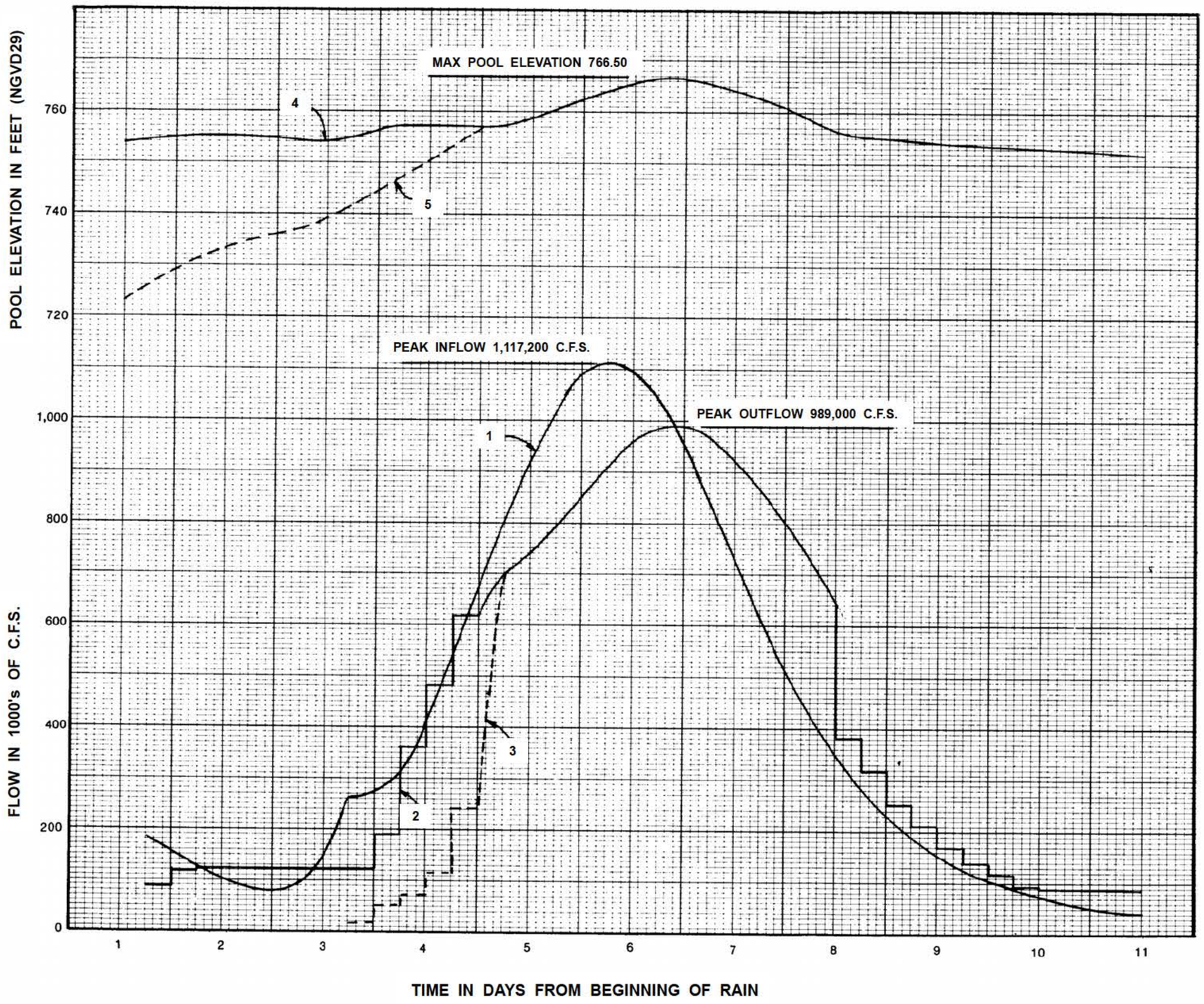
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

TAILWATER RATING CURVE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 7 - 8



NOTES: EMERGENCY OPERATIONS

1. **INFLOW HYDROGRAPH**
2. **OUTFLOW - FLOOD ON FULL POOL**
3. **OUTFLOW - FLOOD ON EMPTY POOL**
4. **POOL STAGE - FLOOD ON FULL POOL**
5. **POOL STAGE - FLOOD ON EMPTY POOL**

NOTE:
OUTFLOWS WERE REGULATED WHILE POOL ELEVATION REMAINED BELOW 757.00

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

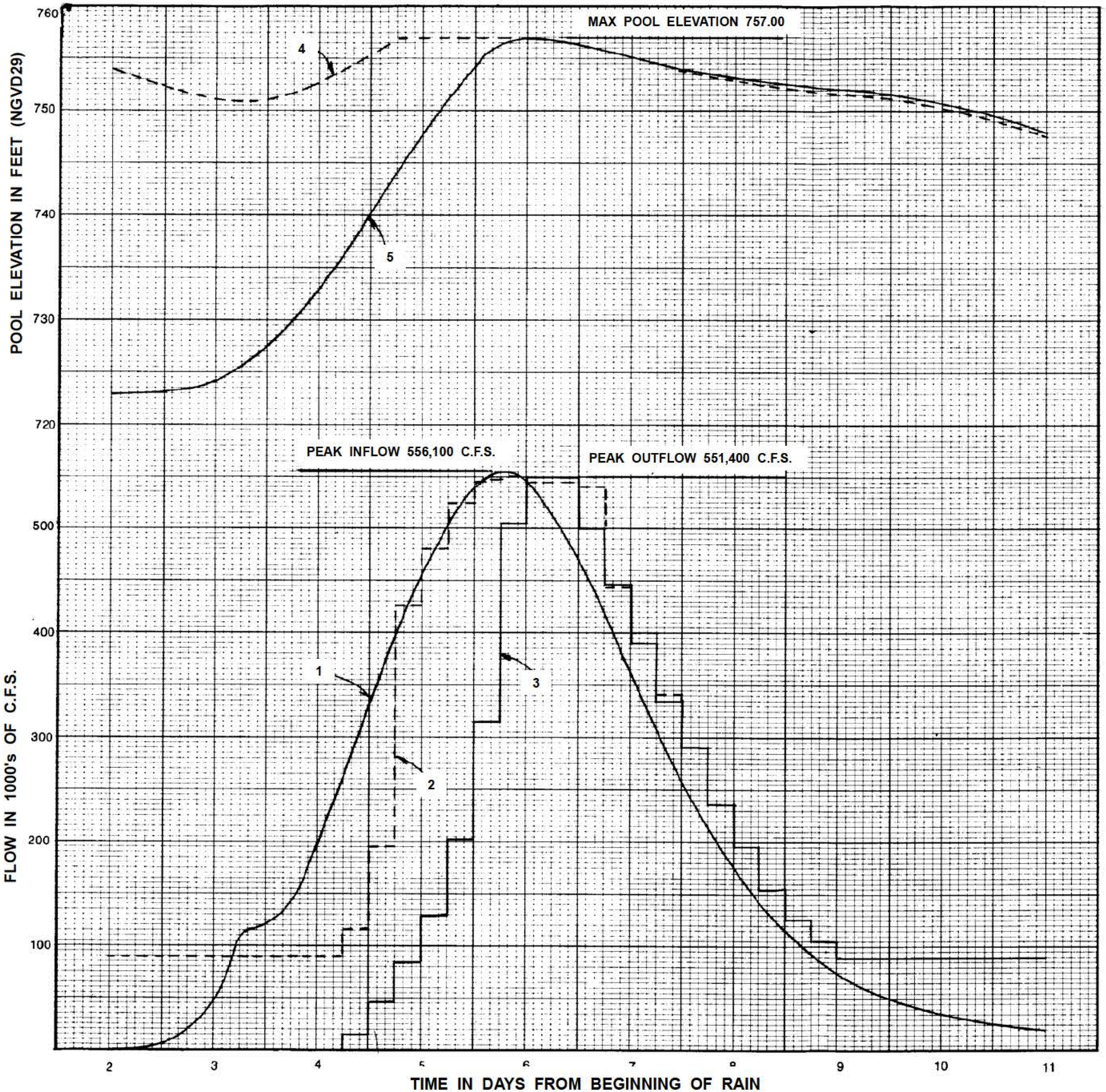
KEYSTONE LAKE

OPERATIONAL HYDROGRAPHS

PROBABLE MAXIMUM FLOOD

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 8 - 1



NOTES: EMERGENCY OPERATIONS
1. INFLOW HYDROGRAPH
2. OUTFLOW - FLOOD ON FULL POOL
3. OUTFLOW - FLOOD ON EMPTY POOL
4. POOL STAGE - FLOOD ON FULL POOL
5. POOL STAGE - FLOOD ON EMPTY POOL

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

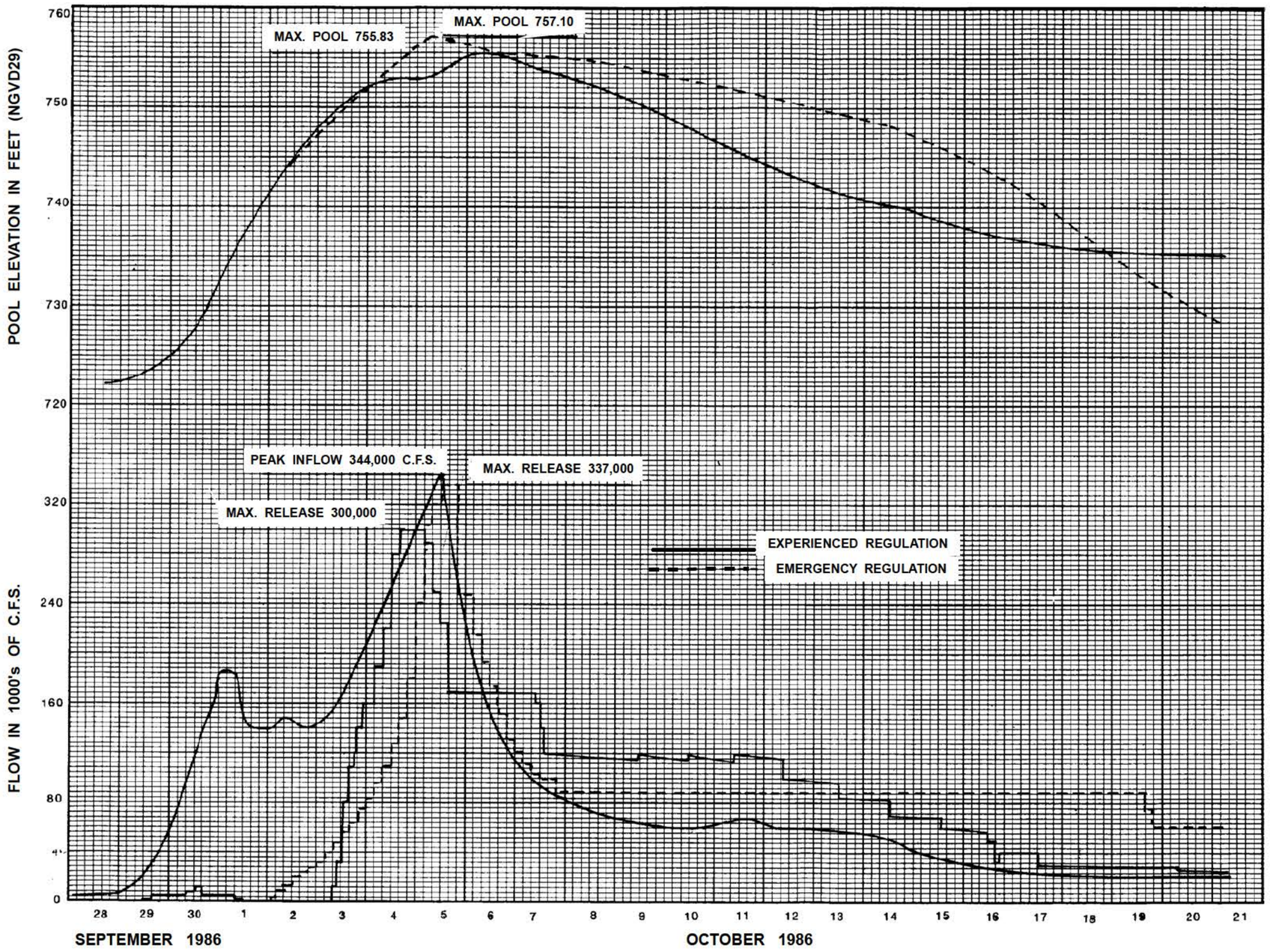
KEYSTONE LAKE

OPERATIONAL HYDROGRAPHS

STANDARD PROJECT FLOOD

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 8 - 2



NOTE:

'Normal' operations would be dictated by the Arkansas River evacuation plan, which prioritizes flood releases from eleven system reservoirs

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

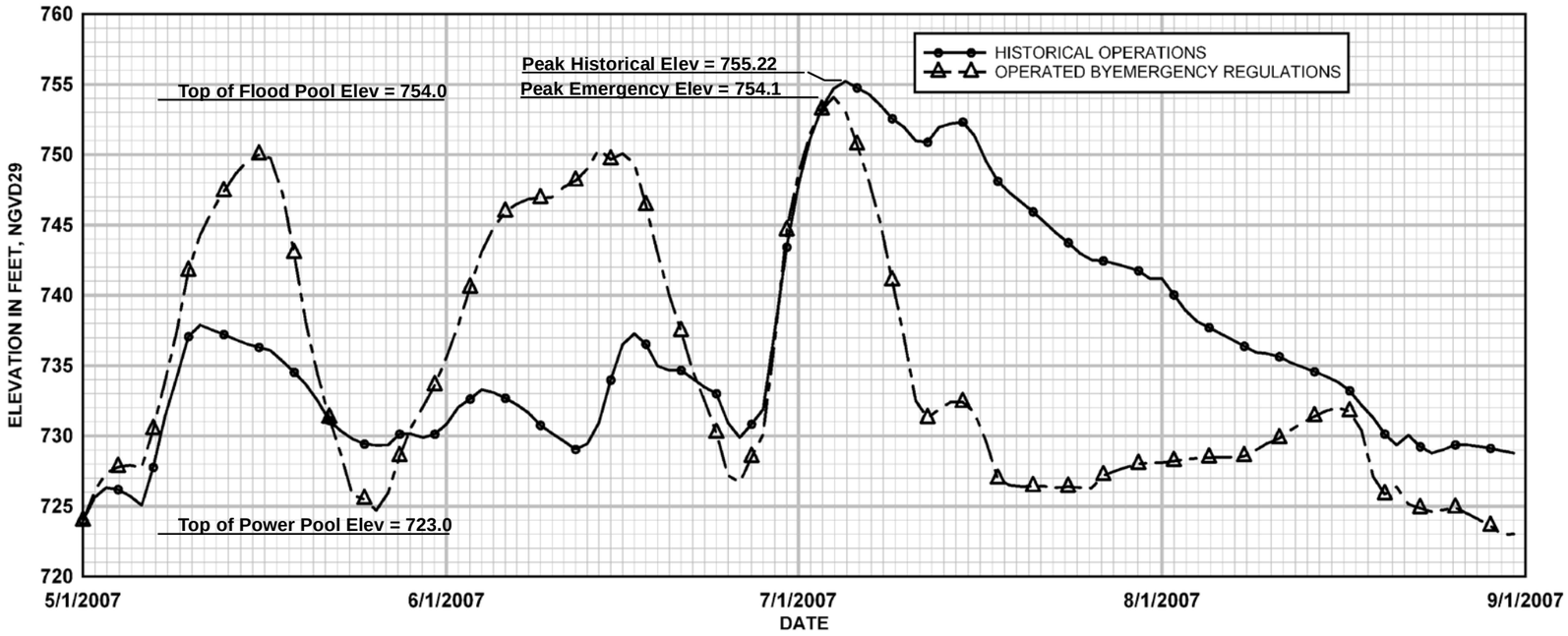
KEYSTONE LAKE

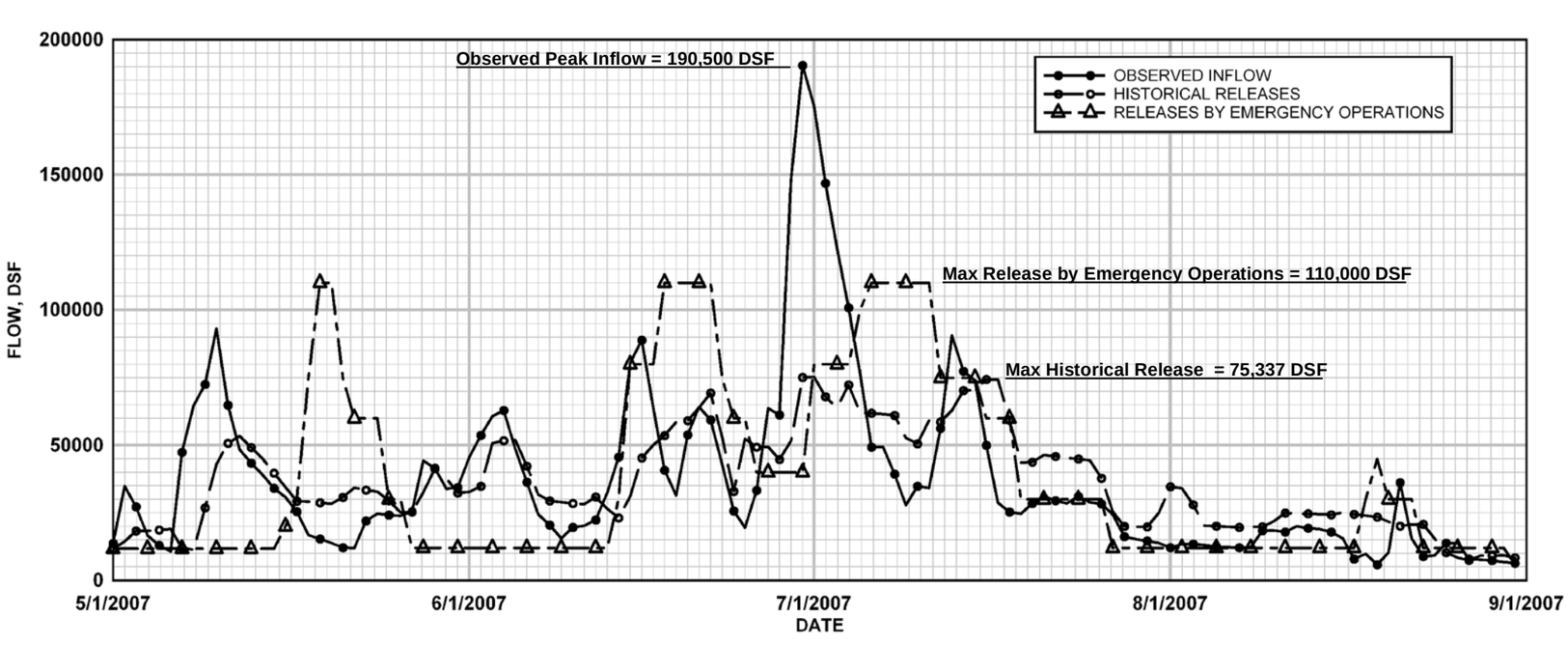
OPERATIONAL HYDROGRAPHS

FLOOD OF OCTOBER 1986
AT KEYSTONE DAM SITE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 8 - 3





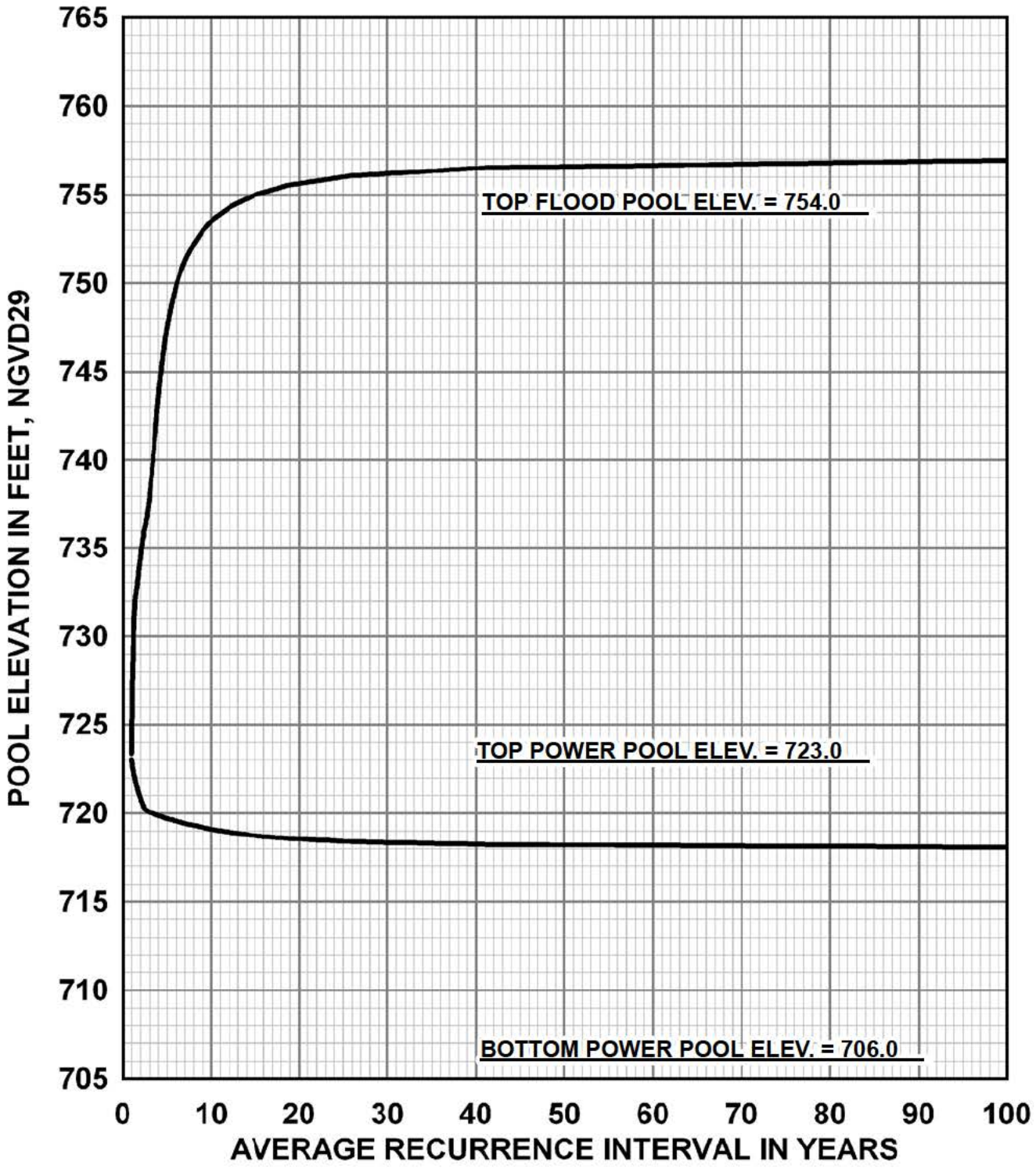
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

OPERATIONAL HYDROGRAPHS

FLOOD OF MAY - AUG 2007
AT KEYSTONE DAM SITE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL



NOTE:

**BASED ON PERIOD OF RECORD
JAN. 1940 THRU DEC. 2008
FROM RIVERWARE RUN
WITH 2008 SEDIMENT CONDITIONS**

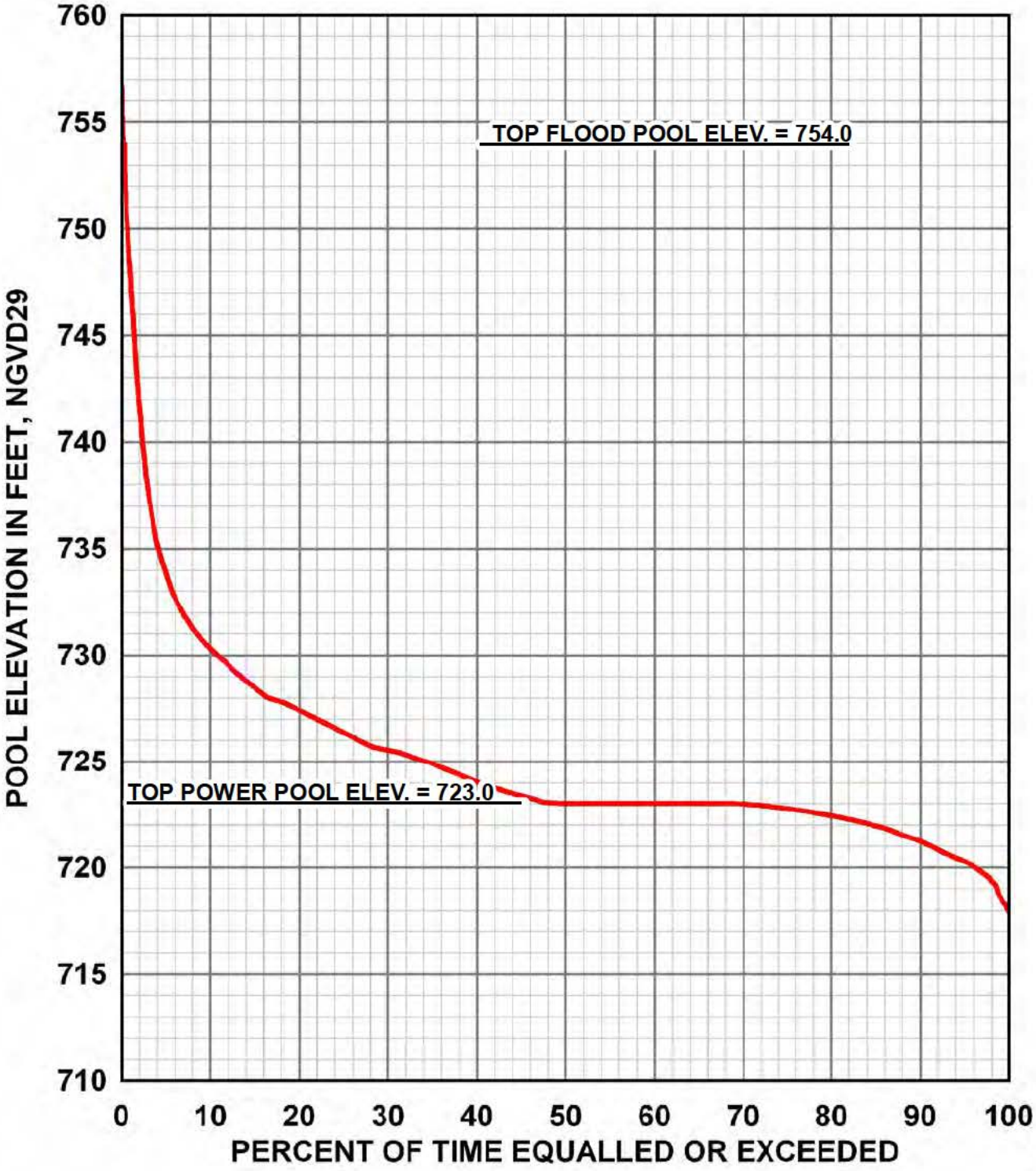
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

POOL ELEVATION PROBABILITY CURVE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 8 - 5



NOTE:

BASED ON PERIOD OF RECORD
JAN. 1940 THRU DEC. 2008
FROM RIVERWARE RUN
WITH 2008 SEDIMENT CONDITIONS

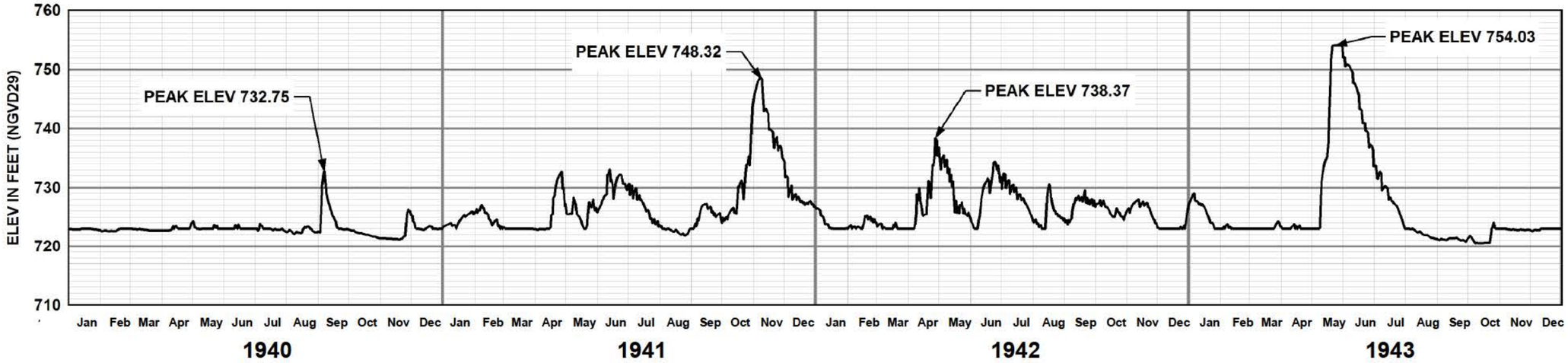
ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

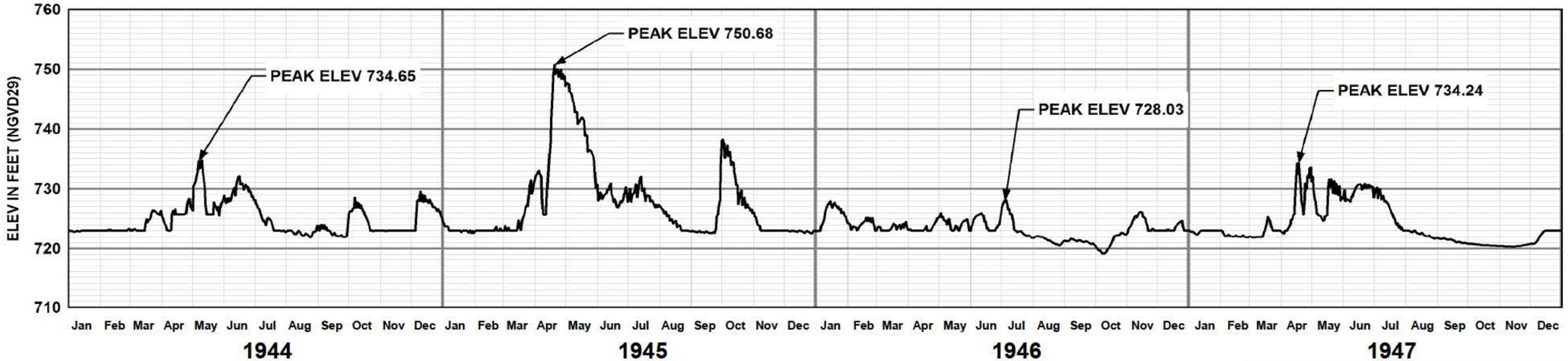
KEYSTONE LAKE

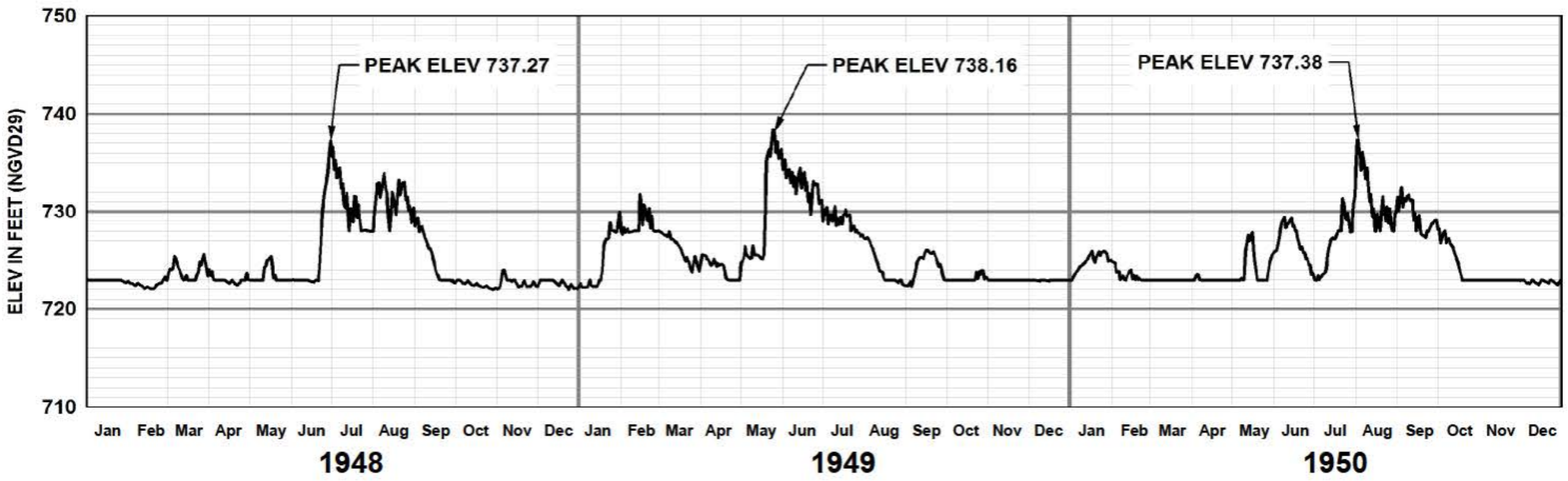
POOL ELEVATION DURATION CURVE

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 8 - 6







NOTE: Pool elevations for Jan 1940 through 22 May 1965 are based on a simulation using the RiverWare computer program. Elevations for 23 May 1965 through 31 Dec 2011 are actual historical values.

Note: Plate size is 11" x 17"

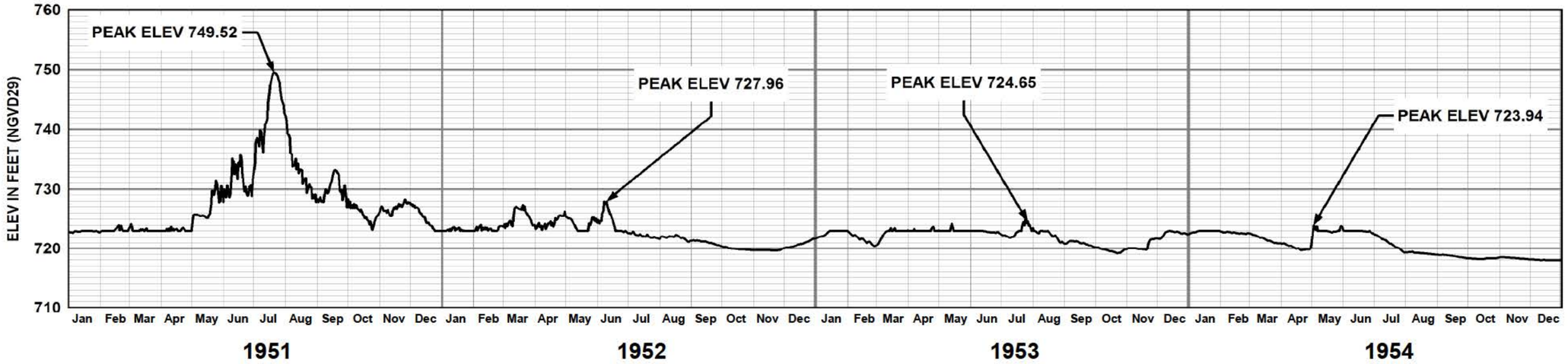
ARKANSAS RIVER WATERSHED

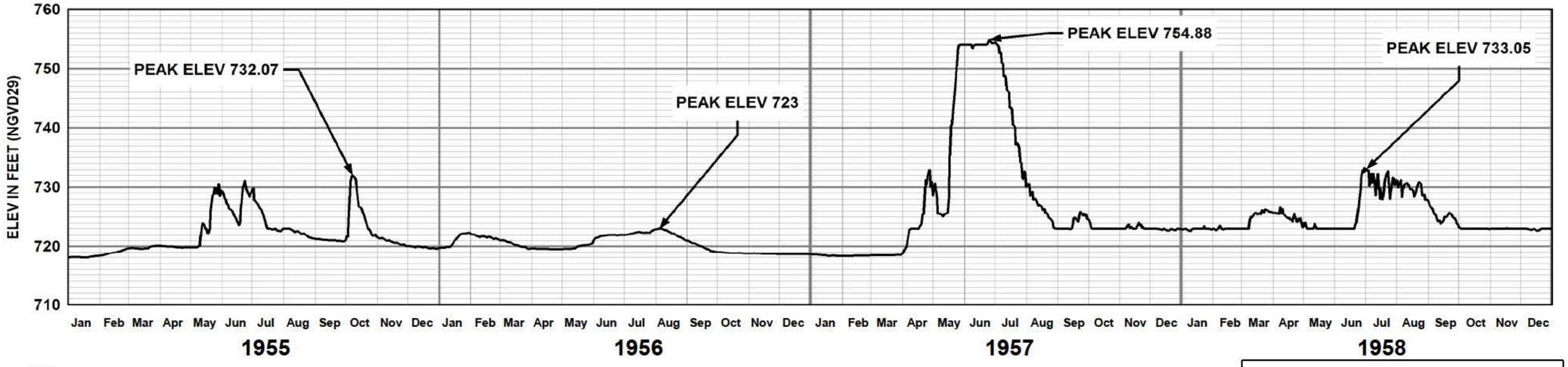
ARKANSAS RIVER, OKLAHOMA

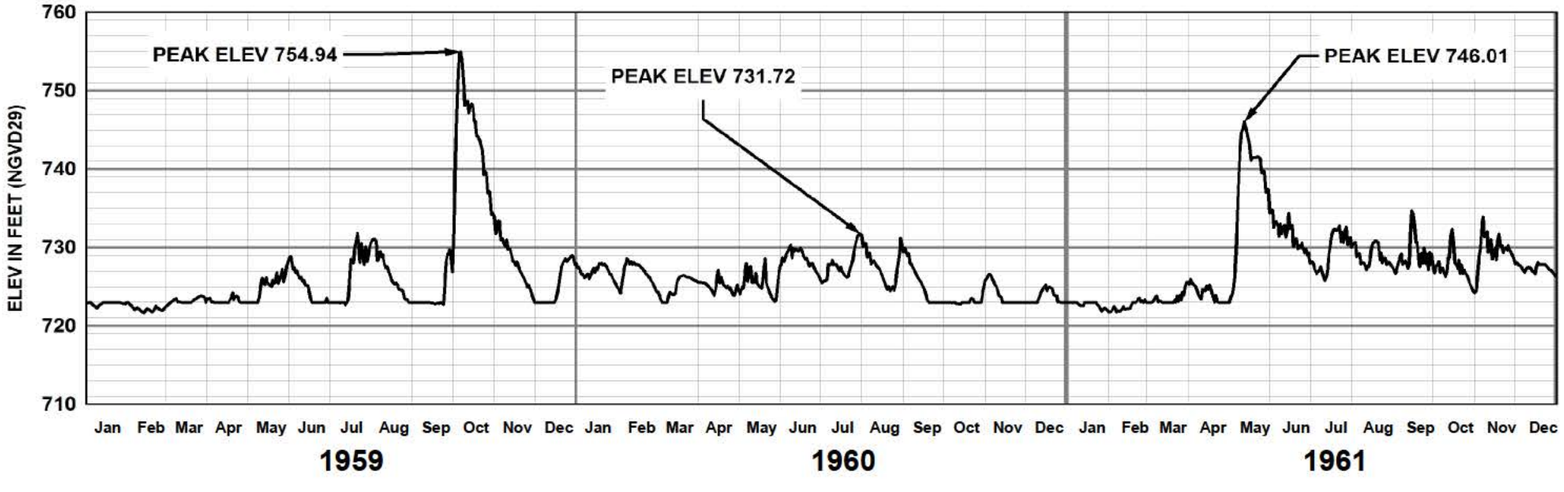
KEYSTONE LAKE

POOL ELEVATION HYDROGRAPHS 1940 - 1950

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL







NOTE: Pool elevations for Jan 1940 through 22 May 1965 are based on a simulation using the RiverWare computer program. Elevations for 23 May 1965 through 31 Dec 2011 are actual historical values.

Note: Plate size is 11" x 17"

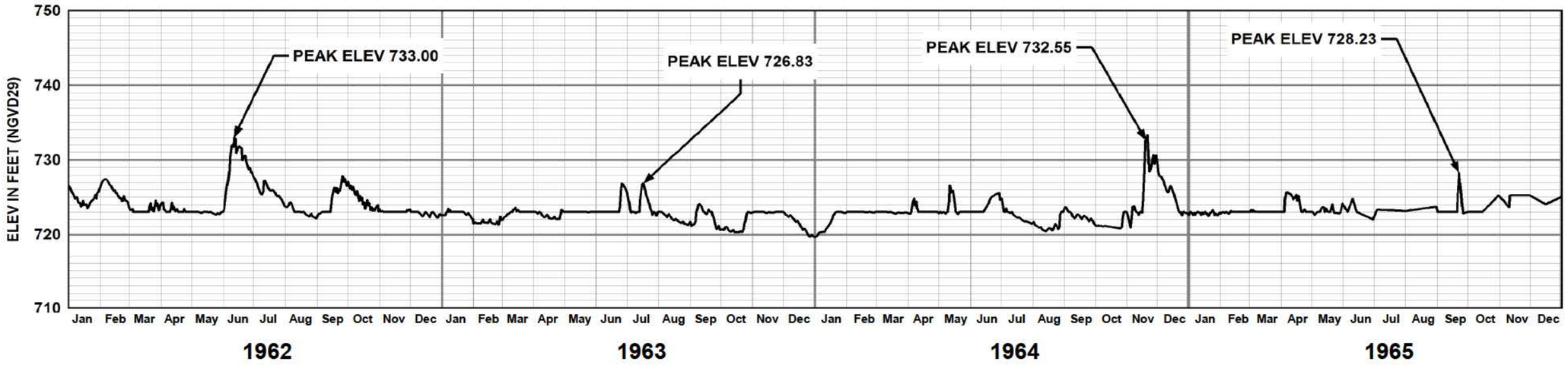
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

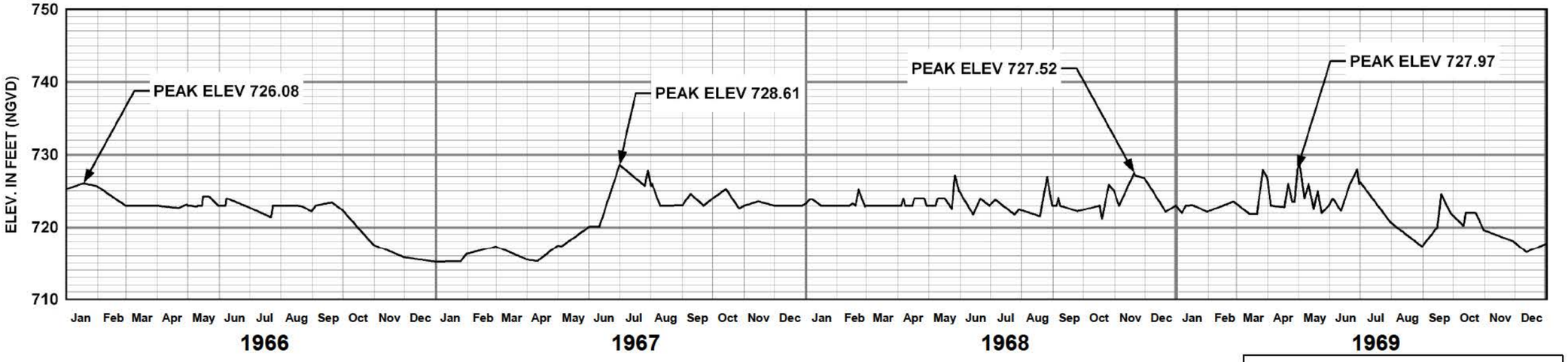
KEYSTONE LAKE

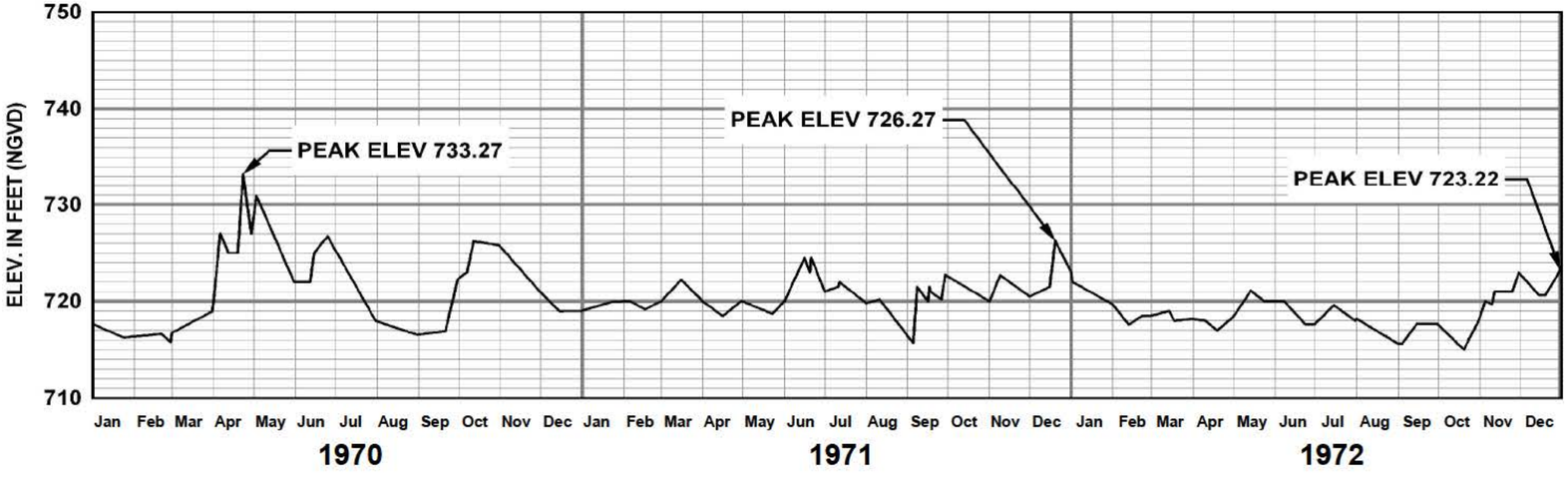
POOL ELEVATION HYDROGRAPHS 1951 - 1961

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 8 - 8







NOTE: Pool elevations for Jan 1940 through 22 May 1965 are based on a simulation using the RiverWare computer program. Elevations for 23 May 1965 through 31 Dec 2011 are actual historical values.

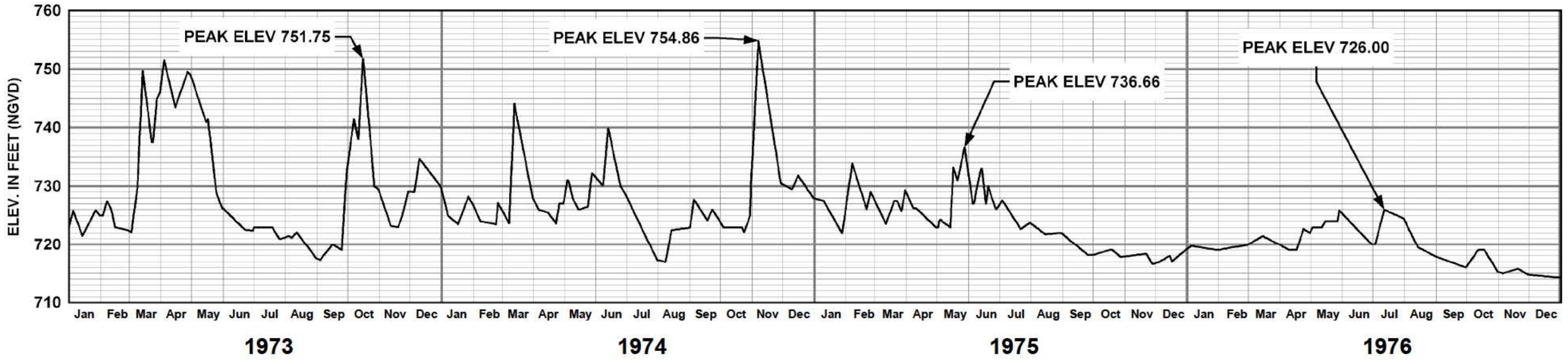
Note: Plate size is 11" x 17"

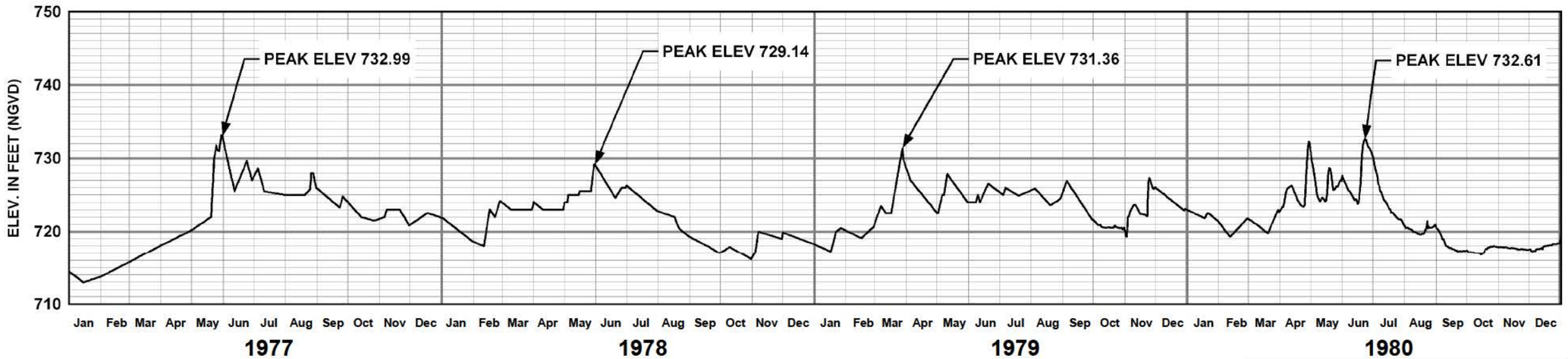
ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

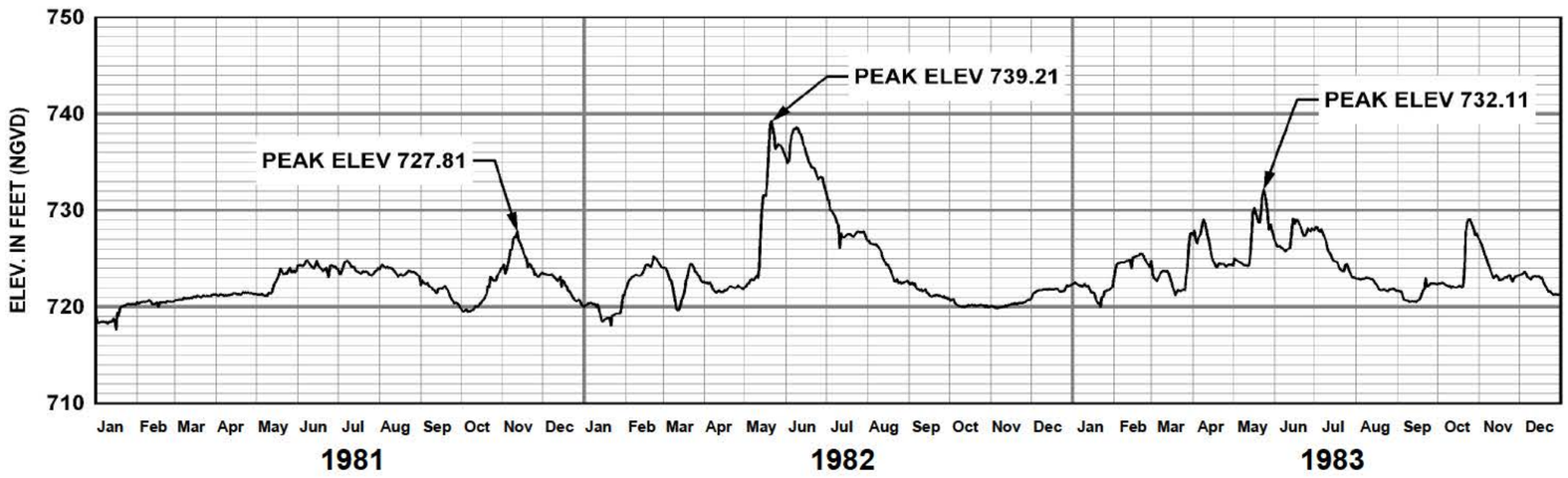
KEYSTONE LAKE

POOL ELEVATION HYDROGRAPHS 1962 - 1972

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL







NOTE: Pool elevations for Jan 1940 through 22 May 1965 are based on a simulation using the RiverWare computer program. Elevations for 23 May 1965 through 31 Dec 2011 are actual historical values.

Note: Plate size is 11" x 17"

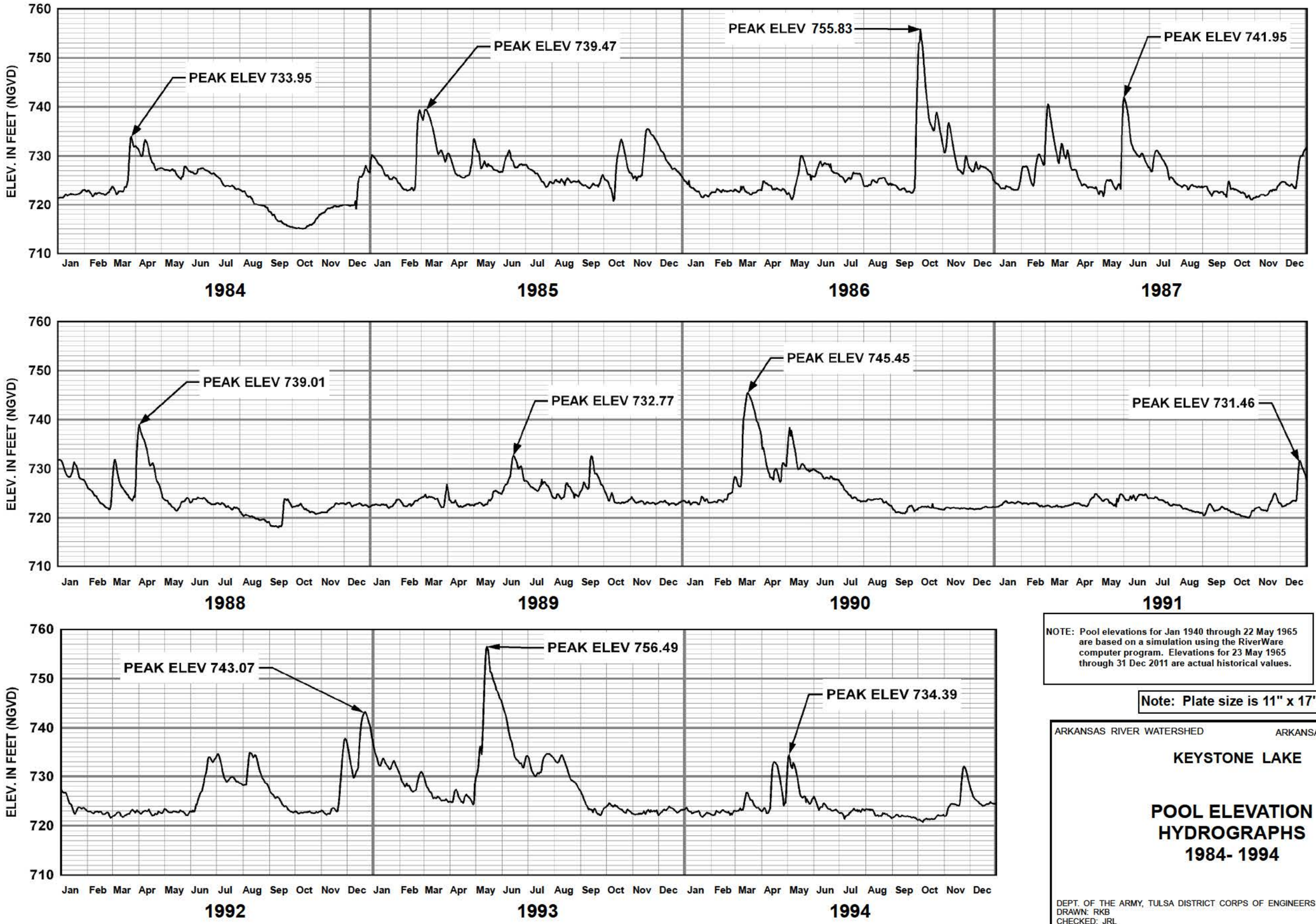
ARKANSAS RIVER WATERSHED

ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

POOL ELEVATION HYDROGRAPHS 1973 - 1983

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL



NOTE: Pool elevations for Jan 1940 through 22 May 1965 are based on a simulation using the RiverWare computer program. Elevations for 23 May 1965 through 31 Dec 2011 are actual historical values.

Note: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED

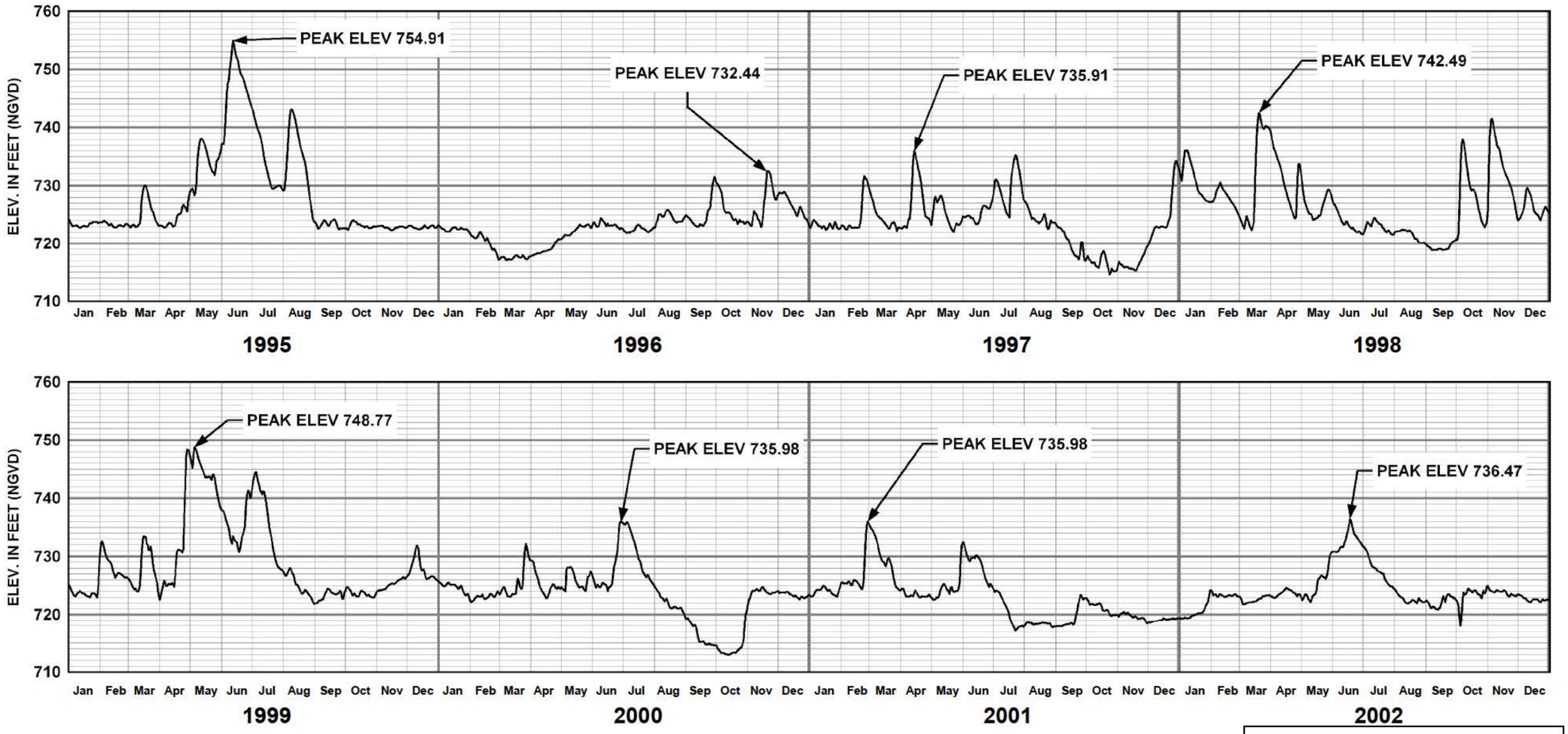
ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

POOL ELEVATION HYDROGRAPHS 1984- 1994

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2012
DRAWN: RKB
CHECKED: JRL

PLATE 8 - 11



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Note: Plate size is 11" x 17"

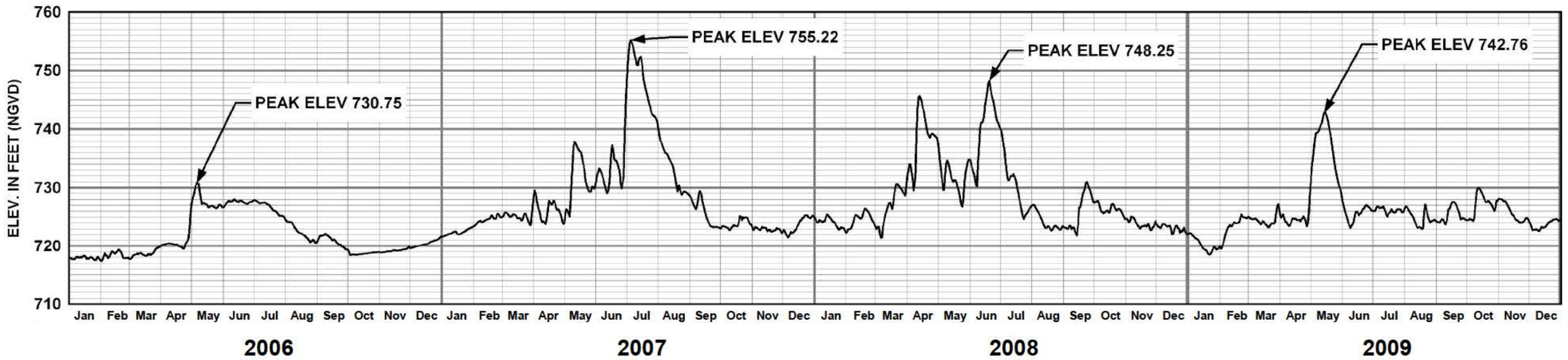
ARKANSAS RIVER WATERSHED

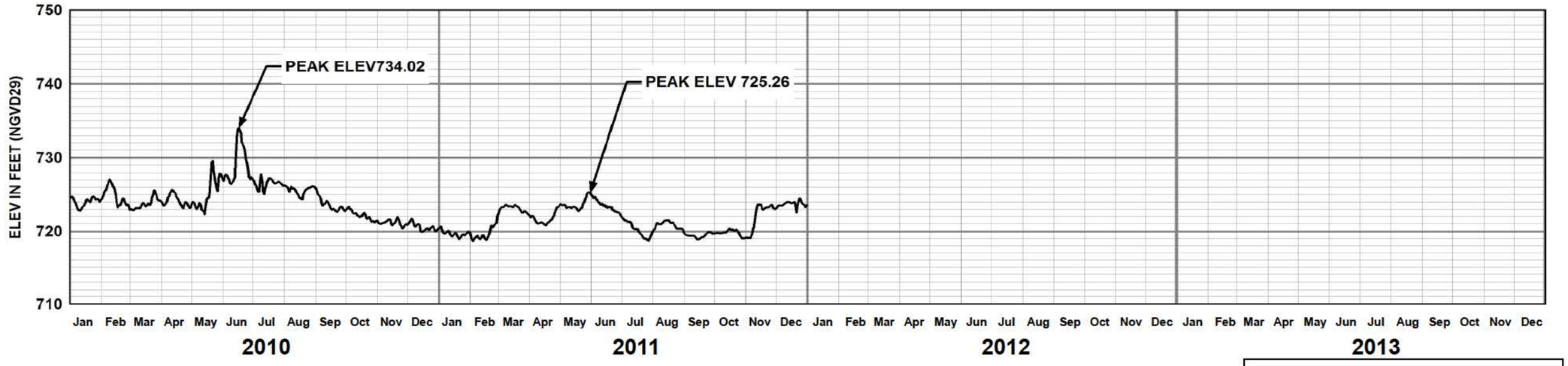
ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

POOL ELEVATION HYDROGRAPHS 1995- 2005

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2011
DRAWN: RKB
CHECKED: JRL





NOTE: Pool elevations for Jan 1940 through 22 May 1965 are based on a simulation using the RiverWare computer program. Elevations for 23 May 1965 through 31 Dec 2011 are actual historical values.

Note: Plate size is 11" x 17"

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

KEYSTONE LAKE

POOL ELEVATION HYDROGRAPHS 2006 - 2011

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2011
DRAWN: RKB
CHECKED: JRL