ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA

APPENDIX A

HYDROLOGIC AND HYDRAULIC ANALYSIS

RIVER FLOW MANAGEMENT

BY
TULSA DISTRICT HYDROLOGY AND HYDRAULICS BRANCH
AND
LITTLE ROCK DISTRICT HYDROLOGY AND HYDRAULICS SECTION

30 JUNE 2005

APPENDIX A

ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA
HYDROLOGIC AND HYDRAULIC ANALYSIS

HYDROLOGY AND HYDRAULICS EXECUTIVE SUMMARY

The purpose of the Arkansas River Navigation Feasibility Study is to develop and evaluate various alternatives that could lead to solutions to problems associated with high flows on the McClellan-Kerr Arkansas River Navigation System. Sustained high flows result in decreased navigation traffic, increased flooding, losses to recreation use, and other adverse conditions.

Navigation interests maintain that river flows above 100,000 cubic feet per second (cfs) make the river unsafe and unprofitable to navigate. This group has requested that the Corps of Engineers investigate the possibility of decreasing the number of days the flows in the lower Arkansas River exceeds 100,000 cfs. It is believed that even though flows this high are a hindrance to navigation, any flow above 100,000 cfs will cause a total shutdown of the system. Optimal navigation river flows are below 60,000 cfs.

Farming interests in western Arkansas, downstream of Fort Smith, have identified about 7,000 acres of farmland that flood when flows are around 90,000 cfs. It has been determined that flows of around 75,000 cfs cause flooding of some fields along the Arkansas River. It is believed that a target of 60,000 cfs in place of the present 75,000 cfs bench would relieve much of this damage.

It has also been noted that the 75,000 cfs bench at Van Buren hampers channel recovery operations (dredging) in the lower reaches of the Arkansas River where intervening runoff increase the flows, in some cases, to over 85,000 cfs. Is has also been requested that an investigation to lower the bench from 75,000 cfs to 60,000 cfs be performed in order to assist in the maintenance dredging of the system.

Changes to the regulating flows on the river could impact farming, hydropower, recreation, flood control, and the environment. The impacts could be beneficial to some or all of the river stakeholders.

Input was received from local, State and Federal agencies, farming interests, navigation interests, and the public in order to formulate the study objectives. From this information, the study team determined the following objectives.

Objective 1: Minimize flow at Van Buren above 100,000 cfs.
Objective 2: Minimize flow at Van Buren above 60,000 cfs.
Objective 3: Improve the taper operation.

The study examined a variety of project alternatives, including operational changes to the existing system operating plan, the construction of additional reservoirs, and the construction of levees along the Arkansas River to allow for increased regulating flows. These alternatives have been developed with input from local, State and Federal agencies, and the public. A long list of alternatives has been evaluated and screened by the study team. After eliminating a number of alternatives that did not meet the study goals, the study team focused upon five alternatives in detail that met the stated objectives. The five alternatives are as follows:

List of Operational Alternatives

1. No Action (150,000 cfs)

2. 175,000 cfs Plan:
   - Van Buren and Sallisaw operated for 175,000 cfs
   - 60,000 cfs bench replacing the 75,000 cfs bench

3. 200,000 cfs Plan:
   - Van Buren and Sallisaw operated for 200,000 cfs
   - 60,000 cfs bench replacing the 75,000 cfs bench

4. Operations Only Plan:
   - Van Buren and Sallisaw operated for 150,000 cfs or 22-foot stage
   - 60,000 cfs bench replacing the 75,000 cfs bench
   - Van Buren and Sallisaw operated for 150,000 cfs to 250,000 cfs at 75% system storage. Regulating discharge depends upon highest flow achieved from local runoff at Van Buren greater than 150,000 cfs and less than or equal to 250,000 cfs.

5. Operations Only 60,000 cfs Bench Plan:
   - Existing operating plan with 60,000 cfs bench replacing the 75,000 cfs bench.

After evaluating these alternatives in detail, the recommended plan is the Operations Only 60,000 cfs Bench Plan. This plan is the National Economic Development (NED) Plan, as implementation of this alternative plan would provide the greatest annual net economic benefits.

The recommended alternative makes a minor change to the operating plan on the falling side of a system flood release. The maximum pool elevation for each lake will be the same with a 60,000 cfs bench as it is with a 75,000 cfs bench.

The maximum pool elevation for a flood event at Grand Lake will be the same with a 60,000 cfs bench as it is with a 75,000 cfs bench. Grand Lake is operated in a manner that keeps the pool level as low as possible during times of high inflows. This helps reduce backwater impacts in the Miami, Oklahoma area. After inflows have decreased, Grand Lake will be allowed to rise and balance with the flood control storage percent full at Hudson and Fort Gibson. This operation may also help prevent flooding to the Grey Bat caves at Grand Lake.

PART 1 – ARKANSAS RIVER BASIN PROJECTS AND SYSTEM OPERATION SUMMARY

The purpose of this section of the appendix is to present a description of the basin, runoff characteristics, and project descriptions. This section, also, presents an overview of the existing regulation plan of the Arkansas River System within the Tulsa and Little Rock Districts of the Corps of Engineers.

PART 2 – ARKANSAS RIVER SYSTEM OPERATION SCREENING STUDY SUMMARY

The purpose of this section of the report is to present; the procedures used in the development and screening of alternative operating plans for the Arkansas River Basin system, the logic used in the selection of each plan, the methodologies used to analyze the impacts of those plans, and the findings resulting from those efforts. The section identifies and compares the impacts of each alternative reservoir system operating plan on the system's purposes, including navigation, flood control, hydropower generation, and recreation.

The hydrologic portion of the study was performed using the "Southwestern Division Modeling System for the Simulation of the regulation of a Multipurpose Reservoir System" more affectionately know as SUPER. SUPER is a linked system of programs that have been designed to perform and analyze a "period of record" simulation for a specific system of multipurpose reservoirs using various plans of regulation.

The screening study resulted in the identification of four possible plans of operation, other than the existing operating plan. Two of the plans (A02X11 and A02X12) require increasing channel capacity in the lower Arkansas basin. This could require easements, flood proofing or some other method of mitigation.

The third possible plan of operation (A02X13) modifies the existing plan by replacing the 75,000 cfs bench with 60,000 cfs and by filling in behind the flood hydrograph when the system percent storage exceeds 75 percent.

The fourth possible plan of operation (A02X10) modifies the existing plan by replacing the 75,000 cfs bench with a 60,000 cfs bench starting 3% lower than the current plan of operations except June 15-October 1.

Each of these simulations were compared to the existing plan of operation (A01X16.) Short summaries of the plans are as follows:

A01X16 Existing Operating Plan

A simulation, using the existing operating plan, was performed with the updated period of record hydrology (January 1940 – December 2000) and updated power loads furnished by SWPA. The run established a base condition to which all other simulations were compared. The Van Buren Guide Curve for the Existing Operation is presented in Figure A-1.

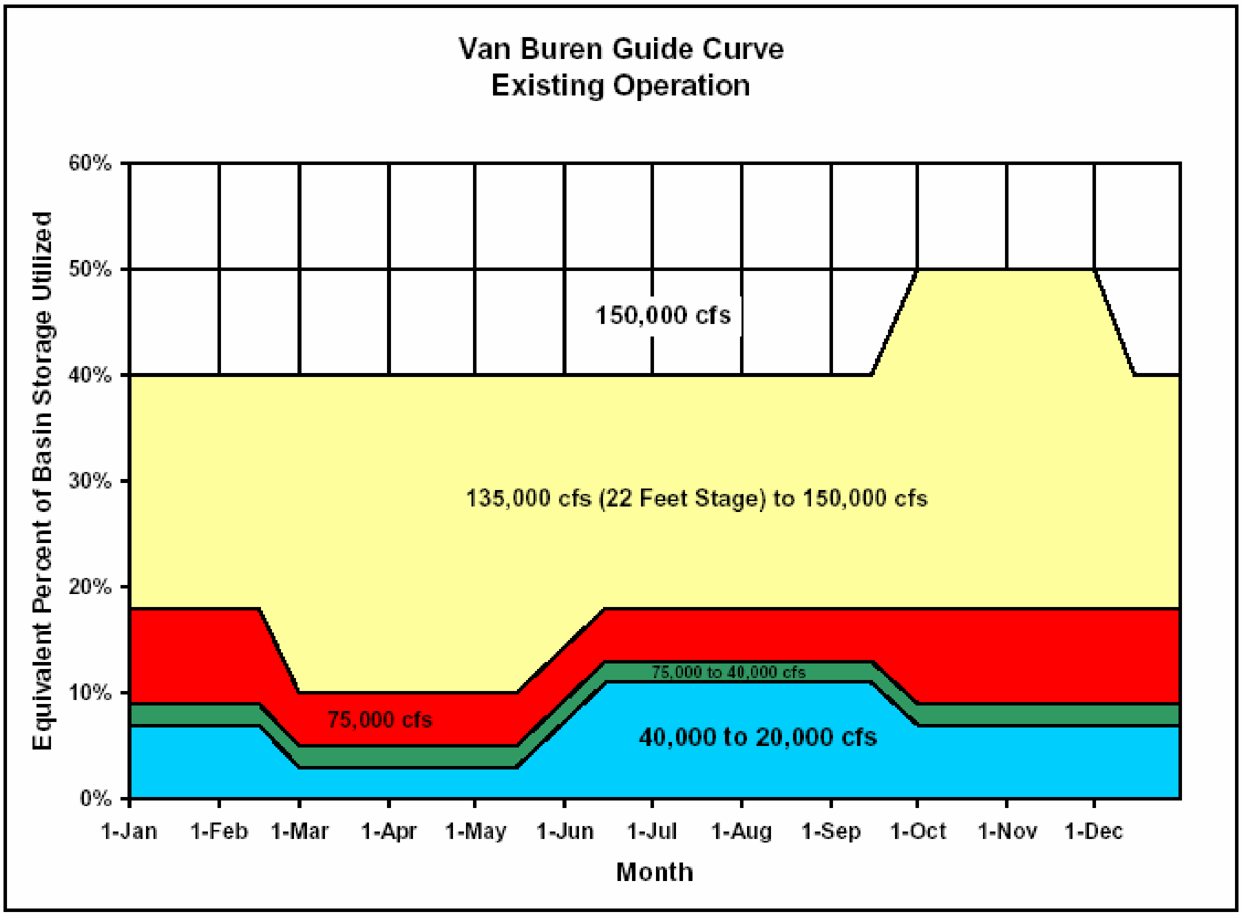

Figure A-1

A02X11 – Van Buren At 175,000 Cfs And Sallisaw At 175,000 Cfs With 60,000 Cfs Bench Replacing 75,000 Cfs Bench Lowered 3% Except June15-October 1

This run was made to evaluate a combination of 175,000 cfs increase in the target flow at Van Buren and Sallisaw (A01X23) and a modified 60,000 cfs bench replacing the 75,000 cfs bench (A02X10). Table A-1 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-2.

TABLE A-1

Summary of SUPER Model Screening Results A02X11 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-9 days
Difference in Days above 100,000 cfs at Van Buren	-16 days
Difference in Days above 137,000 cfs at Van Buren	-4 days
Agricultural/Structural Damages (%)	+3.1%
Navigation Damages (%)	-0.8%
Pool Damages (%)	+2.8%
Recreation Damages (%)	+7.8%
Hydropower (Reservoirs) Damages (%)	+0.6%
Hydropower (River) Damages (%)	-2.6%

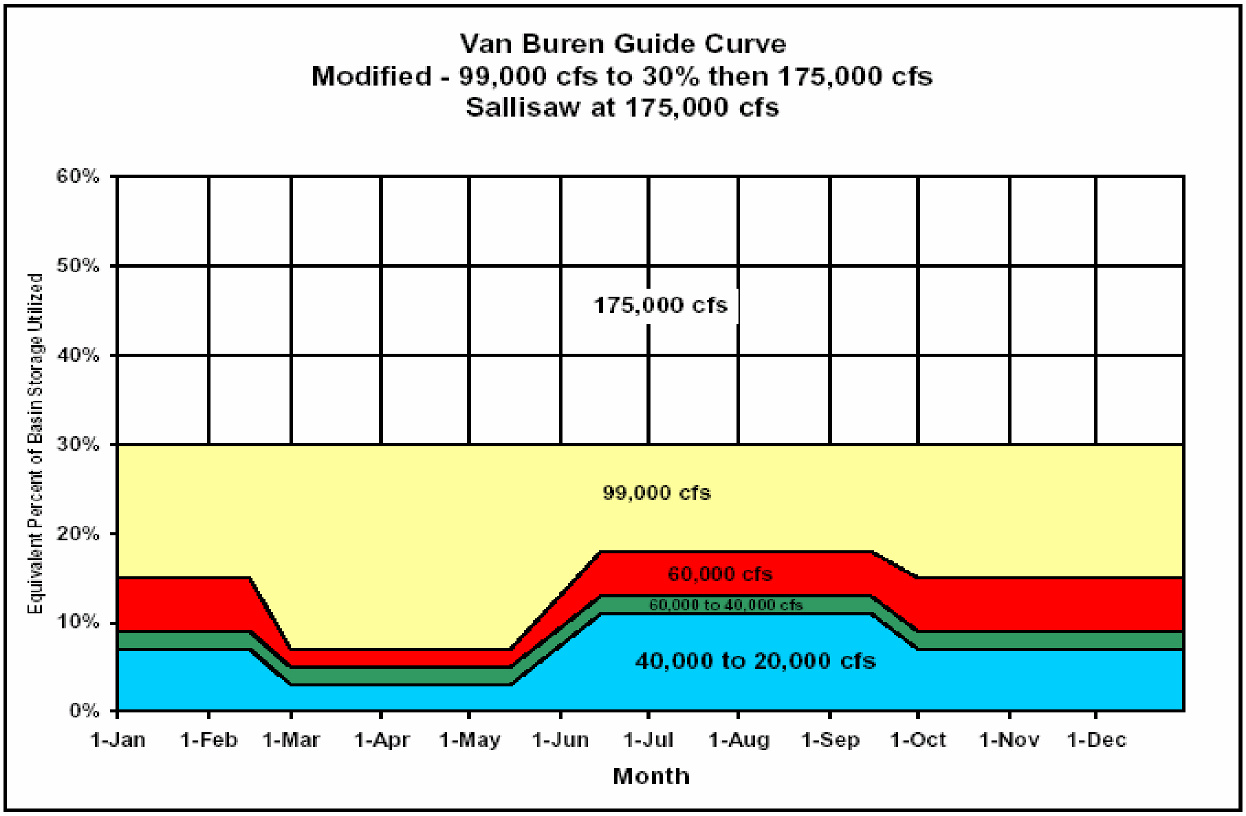

Figure A-2

A02X12 – Van Buren At 200,000 Cfs And Sallisaw At 200,000 Cfs With 60,000 Cfs Bench Replacing 75,000 Cfs Bench Lowered 3% Except June15-October 1

This run was made to evaluate a combination of 200,000 cfs increase in target at Van Buren and Sallisaw (A01X18) and a modified 60,000 cfs bench replacing the 75,000 cfs bench (A02X10). Table A-2 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-3.

TABLE A-2

Summary of SUPER Model Screening Results A02X12 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-9 days
Difference in Days above 100,000 cfs at Van Buren	-17 days
Difference in Days above 137,000 cfs at Van Buren	-5 days
Agricultural/Structural Damages (%)	+7.0%
Navigation Damages (%)	-0.6%
Pool Damages (%)	+1.1%
Recreation Damages (%)	+5.6%
Hydropower (Reservoirs) Damages (%)	+0.8%
Hydropower (River) Damages (%)	-2.8%

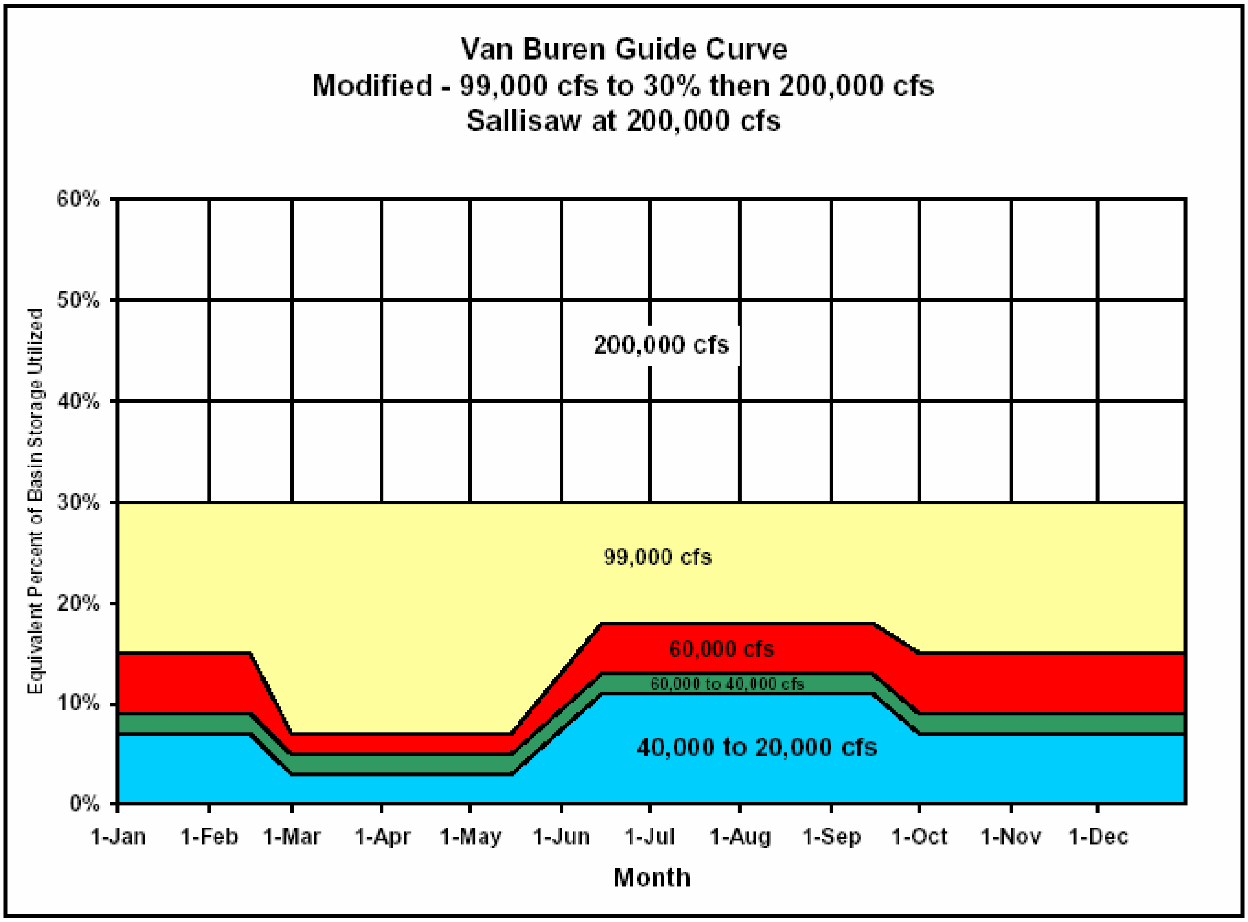

Figure A-3

A02X13 – Existing Plan With A Modified 60,000 Cfs Bench In Place Of The 75,000 Cfs Bench And Filling Behind The Flood When The Flow Reaches 150,000-250,000 Cfs And The System Storage Exceeds 75%

This run titled A02X13 was made to determine the impacts of a 60,000 cfs bench replacing the 75,000 cfs bench combined with filling in behind the flood hydrograph when the flow reach 150,000 – 250,000 cfs and the system percent storage exceeds 75 percent. Table A-3 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-4.

TABLE A-3

Summary of SUPER Model Screening Results A02X13 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-15 days
Difference in Days above 100,000 cfs at Van Buren	+1 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	+0.4%
Navigation Damages (%)	-0.3%
Pool Damages (%)	+0.2%
Recreation Damages (%)	+1.1%
Hydropower (Reservoirs) Damages (%)	+0.7%
Hydropower (River) Damages (%)	-0.7%

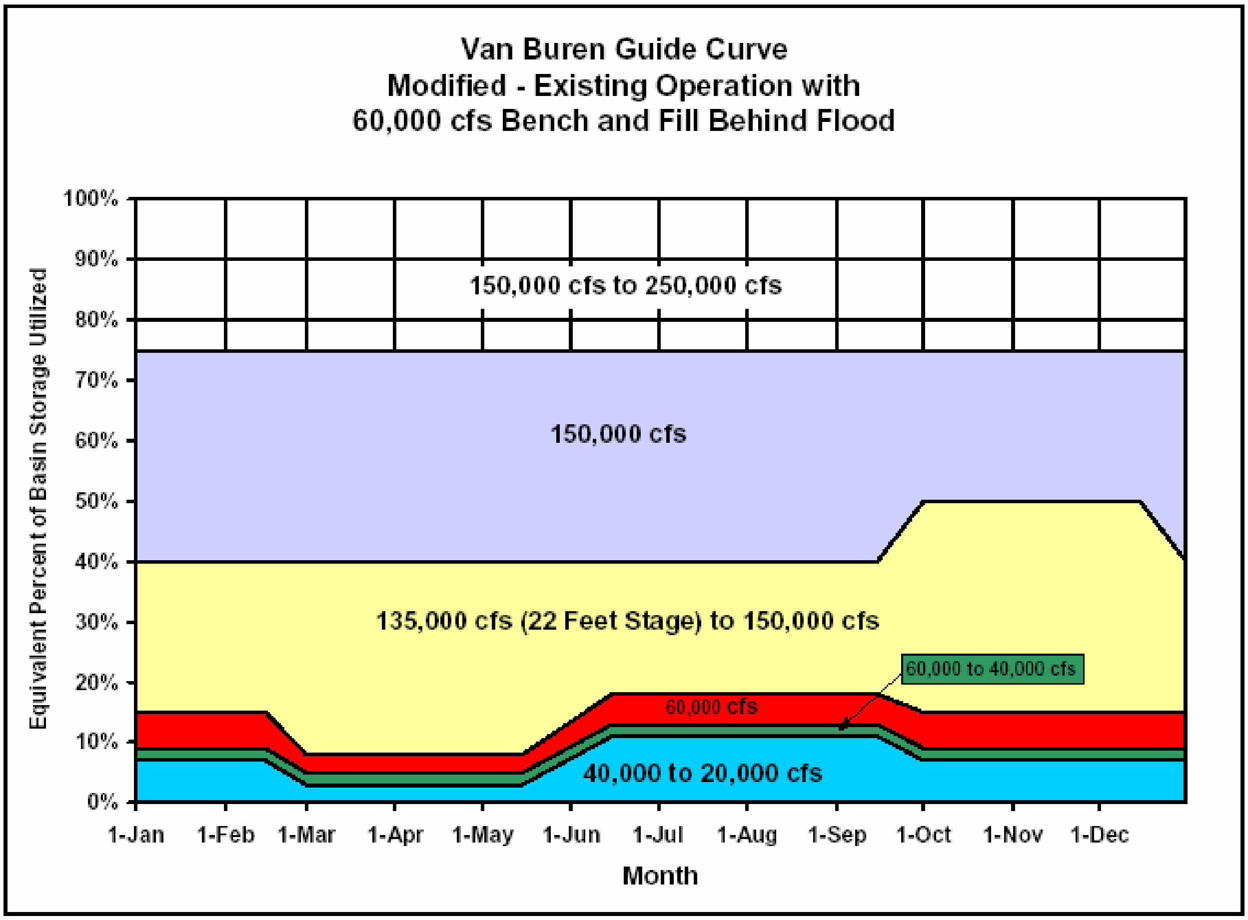

Figure A-4

A02X10 – Modification of A02x01 with the Upper Limit Of the 60,000 Cfs Bench Beginning At A 3% Lower System Storage Except During June 15-October 1

This run was made to determine if the negative impact of changing the 75,000 cfs bench at Van Buren to a 60,000 cfs bench could be mitigated by lowering the point at which the 60,000 cfs bench begins as demonstrated in A02X03, but keep the 18% storage from June 15 through October 1. Table A-4 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-5.

TABLE A-4

Summary of SUPER Model Screening Results A02X10 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-14 days
Difference in Days above 100,000 cfs at Van Buren	+2 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.5%
Navigation Damages (%)	-0.1%
Pool Damages (%)	+0.5%
Recreation Damages (%)	+1.8%
Hydropower (Reservoirs) Damages (%)	-0.1%
Hydropower (River) Damages (%)	-0.3%

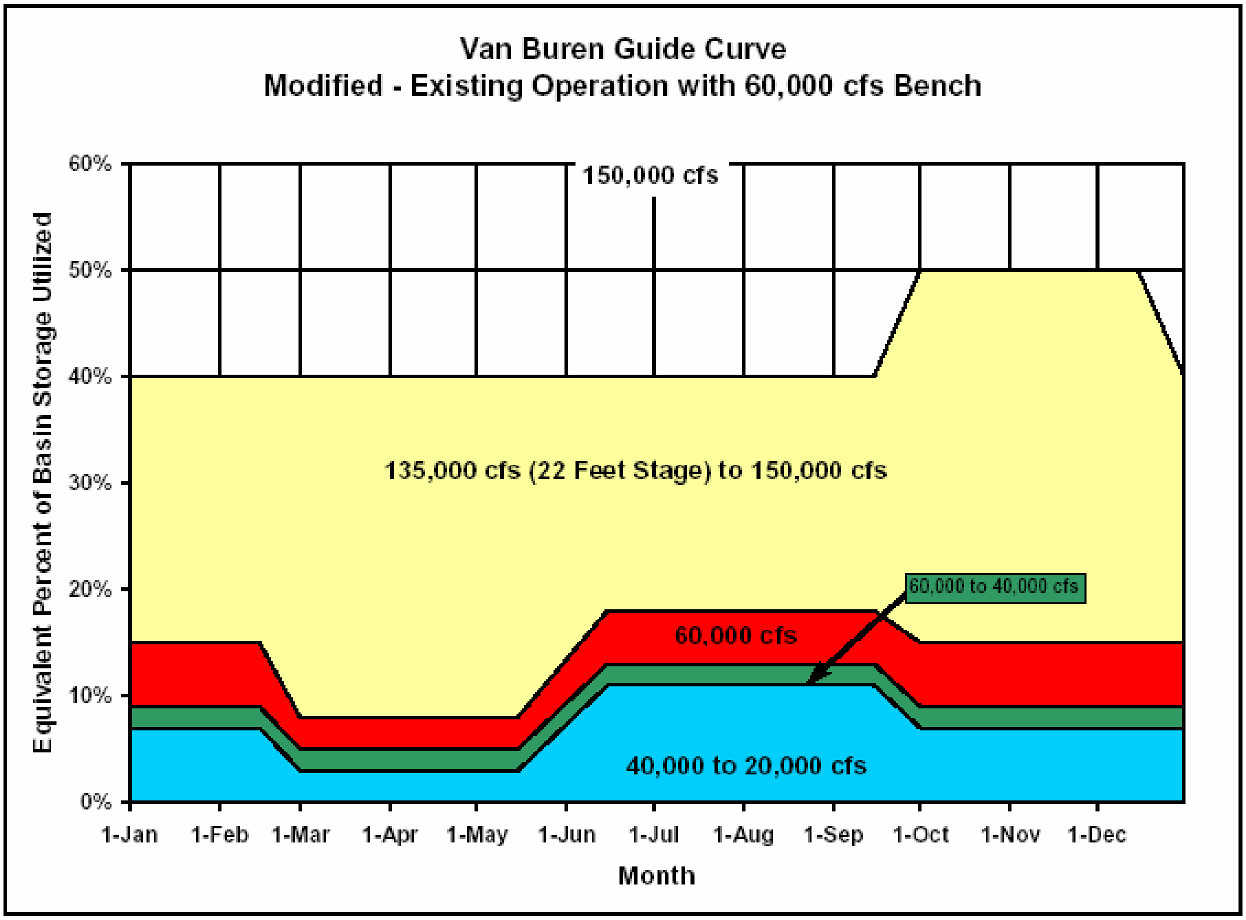

Figure A-5

PART 3 – TULSA DISTRICT HYDROLOGIC ANALYSIS SUMMARY

The purpose of Part 3 of this appendix is to present, in more detail, the hydrologic analysis performed on the No Action Plan and the four possible plans of operation as described in Part 2. This section presents the methods used in developing the frequency and duration relationships, the procedures used in determining the real estate requirements, and the techniques used in evaluating risk and uncertainty.

PART 4 – TULSA DISTRICT HYDRAULIC ANALYSIS SUMMARY

The purpose of Part 4 of this appendix is to present, in more detail, the Hydraulic studies conducted to determine the potential change in the extent of the floodplain for the No Action Plan and the four possible plans of operation. Backwater computations were performed for the Arkansas River from Keystone Lake to the Oklahoma-Arkansas state line. In addition, numerous tributaries were modeled including the Verdigris River upstream to the confluence with the Caney River, the Caney River through Bartlesville, OK, the Neosho River to Fort Gibson Lake, the Illinois River to Tenkiller Lake, and the Canadian River to Eufaula Lake.

PART 5 – LITTLE ROCK DISTRICT HYDROLOGIC AND HYDRAULIC ANALYSIS SUMMARY

The purpose of Part 5 of this appendix is to present, in more detail, the hydrologic and hydraulic analyses performed by the Little Rock District Hydrology and Hydraulics Section on the No Action Plan and the four possible plans of operation. Also presented in Part 5 is the basic hydrologic and hydraulic data for pre-project and post-project conditions that was assembled in order to make the necessary comparisons of pre-project to post-project conditions for each of the proposed alternative plans. This data was used to develop pre-project and post-project Elevation-Discharge, Flow-Frequency, and Flow-Duration relations at numerous locations throughout the length of each pool.

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APPENDIX A

ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA
HYDROLOGIC AND HYDRAULIC ANALYSIS

PART 1 – ARKANSAS RIVER BASIN PROJECTS AND SYSTEM OPERATION

1. BASIN DESCRIPTION

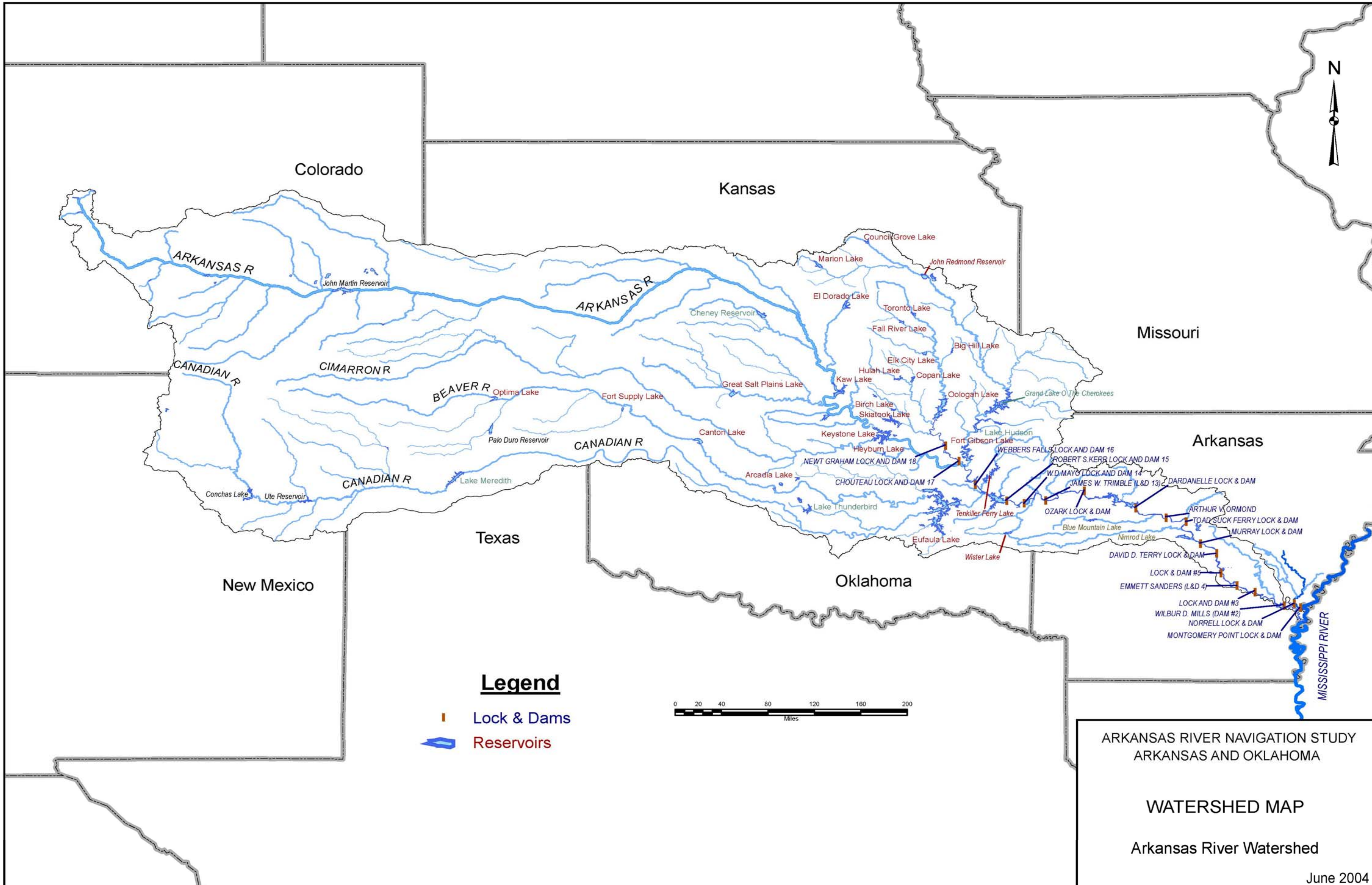
1.1. General characteristics

The Arkansas River begins in the Rocky Mountains about 90 miles upstream of Pueblo, Colorado at an elevation of approximately 11,500 feet, NGVD, and flows in an easterly direction through the rolling Kansas prairies, then through much of Oklahoma and Arkansas to its confluence with the Mississippi River. The total length of the Arkansas River is about 1460 miles. The elevation of the confluence is approximately 106 feet. The fall of the River ranges from 110 feet per mile at the source to approximately 0.4 feet per mile at the mouth. The river basin between Hutchinson, Kansas and the Kansas-Oklahoma state line varies in width from 600 to 2500 feet with banks about 5 feet high. Between the Kansas-Oklahoma State line and Grand River, the width is 600-3000 feet with banks from 10 to 20 feet high. Below the Grand River, the banks are 20 to 40 feet high. The area of the Arkansas River basin is 160,645 square miles.

The major Arkansas River tributaries that confluence in the State of Kansas are the Ninnescah River and the Walnut River. The major tributaries of the Arkansas River that confluence in the State of Oklahoma are the Salt Fork of the Arkansas River, Cimarron River, Verdigris River, Grand (Neosho) River, Illinois River, Canadian River, and Poteau River. Major Arkansas River tributaries that confluence in the State of Arkansas are Lee Creek, Petit Jean River, Fourche LaFave River, and Big Bayou Meto. A map of the Arkansas River Watershed can be found on Map A-1.

1.2. Ninnescah River

The Ninnescah River watershed contains 2,295 square miles and is entirely in Kansas. The North and South Forks form the main stem of the Ninnescah River, which flows southeasterly to its confluence with the Arkansas River. The watershed is about 108 miles long, 21 miles wide, and consists of hilly and rolling prairie land with flat undulating uplands and generally gentle slopes to the stream. From the confluence of the North and South Forks to the mouth, the river falls an average of 3.5 feet per mile.



N
Colorado
Kansas
Missouri
Arkansas
Oklahoma
Texas
New Mexico
ARKANSAS R
CANADIAN R
CIMARRON R
BEAVER R
MISSISSIPPI RIVER
John Martin Reservoir
Conchas Lake
Ute Reservoir
Lake Meredith
Palo Duro Reservoir
Optima Lake
Fort Supply Lake
Canton Lake
Great Salt Plains Lake
Cheney Reservoir
Council Grove Lake
Marion Lake
John Redmond Reservoir
El Dorado Lake
Toronto Lake
Fall River Lake
Big Hill Lake
Elk City Lake
Hulah Lake
Copan Lake
Kaw Lake
Oologah Lake
Grand Lake O The Cherokees
Birch Lake
Skiatook Lake
Keystone Lake
Lake Hudson
Fort Gibson Lake
Heyburn Lake
Arcadia Lake
Lake Thunderbird
Tenkiller Ferry Lake
Eufaula Lake
Wister Lake
Blue Mountain Lake
Nimrod Lake
NEWT GRAHAM LOCK AND DAM 18
CHOUTEAU LOCK AND DAM 17
WEBBERS FALLS LOCK AND DAM 16
ROBERT S.KERR LOCK AND DAM 15
W.D.MAYO LOCK AND DAM 14
JAMES W. TRIMBLE (L&D 13)
DARDANELLE LOCK & DAM
OZARK LOCK & DAM
ARTHUR V. ORMOND
TOAD SUCK FERRY LOCK & DAM
MURRAY LOCK & DAM
DAVID D. TERRY LOCK & DAM
LOCK & DAM #5
EMMETT SANDERS (L&D 4)
LOCK AND DAM #3
WILBUR D. MILLS (DAM #2)
NORRELL LOCK & DAM
MONTGOMERY POINT LOCK & DAM
Legend
Lock & Dams
Reservoirs
0 20 40 80 120 160 200
Miles
ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA
WATERSHED MAP
Arkansas River Watershed
June 2004

Map A-1

1.3. Walnut River

The watershed of the Walnut River contains an area of 1,955 square miles. The basin has a length of about 75 miles and has an average width of about 35 miles. The topography is generally rolling and is accentuated by the Flint Hills section in the eastern portion of the watershed. The river flows in a southerly direction to its confluence with the Arkansas River just upstream of the Kansas-Oklahoma State line. The fall of the river averages about 3.9 feet per mile near the source, and about 1.7 feet per mile at the mouth.

1.4. Salt Fork of the Arkansas River

The Salt Fork of the Arkansas River begins in the eastern part of Kiowa and Comanche Counties in south-central Kansas and flows in a southeasterly direction to its confluence with the Arkansas River about 50 miles downstream of the Kansas-Oklahoma State line. The watershed is about 150 miles long and has an average width of about 45 miles. The basin has a drainage area of 6,764 square miles. The river begins in the high rolling prairies that flatten eastward until there is very little apparent valley. The fall of the river varies from 10.1 feet per mile near the source to 1.3 feet per mile near the mouth.

1.5. Cimarron River

The Cimarron River begins in the mountains of northeastern New Mexico and flows about 698 miles in an easterly direction to its confluence with the Arkansas River in Keystone Lake, 17 miles above Tulsa, Oklahoma. The river flows from New Mexico through parts of Colorado and Kansas to the mouth in Oklahoma. The watershed contains 18,927 square miles of which 4,926 square miles is considered non-contributing to runoff. The basin is about 500 miles in length and about 50 miles in width. The fall of the river varies from 50.7 feet per mile near the source to about 1.5 feet per mile near the mouth. The upper reaches of the river in New Mexico lie in the mountains and hilly plateau region, which it leaves to emerge on the plains east of Kenton, Oklahoma, where the valley widens and the canyons disappear.

1.6. Verdigris River

The Verdigris River begins in the Flint Hills of Chase County, Kansas, and flows generally southeast from the vicinity of Madison to Neodesha, Kansas, and then in a southerly direction to its confluence with the Arkansas River, about 5 miles northeast of Muskogee, Oklahoma. The river basin is roughly elliptical in shape, with a total area of 8,303 square miles. The Verdigris River navigation system extends from the Arkansas River upstream about 50 miles to the Tulsa-Rogers County Port of Catoosa. Considerable channel widening and straightening along with construction of Newt Graham and Chouteau Locks and Dams have improved the water carrying capability of the channel considerably. The valley floor varies from approximate elevation 510.0 near its confluence with the Arkansas River and the mouth of the main stem to approximate elevation 1000.0 in the upper reaches of the basin. The slope of the river near its source averages about 3.7 feet per mile and the navigation channel has a total rise of 42 feet in 50 miles. The greater portion of the Verdigris River watershed is an undulating plain; however, the western boundary, formed by the Flint Hills in Kansas and the Osage Hills in Oklahoma, is rough and broken, with elevations rising to 1600 feet, NGVD. The valley side slopes are relatively steep, with most of the valley proper in cultivation or pasture land. Wooded areas are prevalent along the channel and in the river bottom in the lower reaches of the stream. The channel is well defined, but winds and contains many sharp bends in its course through the valley

1.7. Grand (Neosho) River

The Grand (Neosho) River begins in the Flint Hill region in Morris County, east central Kansas, near Parkerville, and flows in a southeasterly direction for approximately 347 miles, then in a southerly and southwesterly direction to its confluence with the Arkansas River near Fort Gibson, Oklahoma. The basin rises from an elevation of about 483 feet on the valley floor at Fort Gibson Dam to over 1,450 feet in the headwater area in Kansas. The average fall of the Grand (Neosho) River is about two feet per mile, varying from approximately 11 feet per mile in the upper reaches to about one foot per mile in the middle reaches. The valley is from one to four miles wide and the river channel varies in width from 50 feet in the upper reaches to about 400 feet in the lower reaches. The banks are generally stable and vary in height from 15 to 30 feet. The total drainage area above the confluence with the Arkansas River is 12,520 square miles. The watershed varies from rolling to rough hill country and its extreme eastern portion is located in the rugged area of the Boston Mountains of the Ozark uplift. The upper reaches of the basin are located in the Flint Hill region, which extends across Kansas from north to south. The valley slopes are gentle with woods and brush bordering the stream banks.

1.8. Illinois River

The watershed of the Illinois River contains 1,660 square miles of area in northwestern Arkansas and eastern Oklahoma. The drainage basin is about 80 miles long and averages about 20 miles in width. The northwestern part of the basin begins in the Ozark Mountain region of northwest Arkansas and is rough and extremely Hilly. The southeast portion of the watershed consists of rolling hills. The Illinois River flows in a southwesterly direction and confluences with the Arkansas River near Gore, Oklahoma. The total length of the river is about 150 miles, with and average fall of around 8 feet per mile.

1.9. Canadian River

The Canadian River begins in the Sangre de Christo Mountains in northeastern New Mexico at an elevation of approximately 8,000 feet, NGVD, and flows in an easterly direction through the Texas Panhandle and through western Oklahoma until it confluences with the Arkansas River near Webbers Falls, Oklahoma. The slope of the stream is about 43 feet per mile in the extreme headwaters area and varies from 9 to 5 feet per mile in New Mexico and Texas, 6 feet per mile in western Oklahoma, and about 2 feet per mile in eastern Oklahoma. The channel is wide and meandering with low banks above Norman, Oklahoma. Between Norman and the mouth, the banks gradually increase in height. Channel capacity at the Texas-Oklahoma state line is approximately 70,000 cfs, and at the mouth about 40,000 cfs. The river basin is approximately 560 miles long. It is wide in the western portion, narrows in the central portion, and widens again in the eastern portion with an average width of 85 miles. The basin area is 47,705 square miles, of which 9,700 square miles are normally classified as non-contributing.

1.10. Poteau River

The Poteau River drains an area of 1,888 square miles in southeastern Oklahoma and western Arkansas. The river begins in the rugged hilly area of western Arkansas. The Poteau River flows westerly for about 65 miles, then turns to a northeasterly direction in southeastern Oklahoma until it confluences with the Arkansas River just upstream of the Oklahoma-Arkansas State line. The total length of the river is about 128 miles and it has an average fall of about 5.2 feet per mile.

1.11. Lee Creek

The watershed of Lee Creek contains an area of 451 square miles. The basin is approximately 50 miles in length and about 35 miles in width. Lee Creek flows in a southerly direction where it confluences with the Arkansas River near Van Buren, Arkansas. The stream is located in the high relief area of western Arkansas. The slope of the creek varies from 40 feet per mile near the source to 0.1 foot per mile near the mouth.

1.12. Petit Jean River

The Petit Jean River watershed contains 1,080 square miles of area in western Arkansas. The river begins in the rugged area of Scott County, Arkansas and flows eastward through Logan and Yell Counties to its confluence with the Arkansas River about 13 miles upstream of Morrilton, Arkansas. The Petit Jean River is about 140 miles long. The drainage basin is about 80 miles long and about 13 miles wide. The upper portion of the watershed, 488 square miles, is controlled by Blue Mountain Dam. The river upstream of the dam has a slope of 20 feet per mile at the headwaters and 1.5 feet per mile at the dam. Downstream of the dam, the river is crooked and meanders throughout the valley a distance of 74 miles to its mouth. The average channel width is about 150 feet and the average bank height is about 20 feet. The channel slope averages about 1 foot per mile and varies from 1.5 feet per mile at the dam to 0.6 foot per mile near the Centerville gage.

1.13. Fourche LaFave River

The Fourche LaFave River begins in west-central Arkansas in Scott County. The river flows easterly through Yell and Perry Counties for about 160 miles to its confluence with the Arkansas River about 9 miles downstream of the Toad Suck Ferry Lock and Dam. The Fourche LaFave River watershed contains 1,110 square miles. The upper portion of the river basin, 680 square miles, is controlled by Nimrod Dam. Above Nimrod Dam, the basin averages about 10 miles in width and about 5 miles in width below the dam. The river falls about 2 feet per mile near the headwater to about 0.3 feet per mile at the mouth.

1.14. Big Bayou Meto

The Big Bayou Meto watershed is about 60 miles long and averages about 10 miles in width. The basin contains 995 square mile of drainage area. From headwaters near Jacksonville, Arkansas the bayou flows southeasterly about 100 miles through Pulaski, Lonoke, Jefferson, and Arkansas Counties to confluence with the Arkansas River about 9 miles upstream of the U.S. Highway 165 bridge. The slope of the bayou varies from 1.5 feet per mile near the source to near zero at the confluence.

2. RUNOFF CHARACTERISTICS

The Arkansas River and two of the main tributaries, the Cimarron and Canadian Rivers, all originate on the eastern side of the Rocky Mountains in Colorado and New Mexico. From the headwaters, the rivers flow east through the arid High Plains region of Colorado, Kansas, Texas, and Oklahoma. Rainfall in the High Plains region averages only about 15 inches per year. Therefore, runoff is very low in this area, but the water demand is high. As a result, most of the flow from each river is diverted before leaving the High Plains.

The Arkansas River watershed above Hutchinson, Kansas contributes very little to runoff downstream. Large flows in the Arkansas River in southeast Kansas, Oklahoma, and Arkansas are produced from rainfall events on watershed areas downstream of Hutchinson, Kansas.

The portion of the Cimarron River watershed upstream of Waynoka, Oklahoma is similar to the upper Arkansas River. This portion of the watershed produces very little runoff that contributes to floods downstream. Most of the flow on the Cimarron River comes from runoff downstream of Waynoka, Oklahoma and upstream of the confluence with the Arkansas River.

The watershed of the Canadian River includes two major basins, the Canadian and North Canadian Rivers. The upstream portion of both drainage basins, which lie in the High Plains region of Texas and Oklahoma, rarely produce flood flows that contribute to runoff. In general, stream flows of the Canadian Rivers along their entire lengths are characterized by irregularity, varying from flashy peak flows, which occur in all reaches, to long periods of low flow. Most major floods on the Canadian River that produce runoff at the confluence with the Arkansas River, originate downstream from Bridgeport, Oklahoma.

Floods on the Arkansas River are produced from rainfall events on the Arkansas River downstream of Hutchinson, Kansas and from tributaries in southeast Kansas and Oklahoma east of a line from Hutchinson, Kansas to Bridgeport Oklahoma.

3. EXISTING MAJOR PROJECTS IN THE ARKANSAS RIVER BASIN

The Arkansas River Basin currently contains 50 constructed reservoirs operated for flood control, hydropower, water supply, water quality, sediment control, navigation, recreation, and fish and wildlife. Eight reservoirs were completed in the 1940's; 4 in the 1950's; 23 in the 1960's; 9 in the 1970's; 5 in the 1980's; and 1 completed in 2004. Included in these, are five Section 7 projects in the Tulsa District Corps of Engineers. Section 7 projects are reservoirs that are owned by other government agencies, but are regulated during flood operations by the Corps of Engineers. A list of the projects is provided in Table A-1.

Eighteen of the 50 projects in the Arkansas River system are locks and dams constructed to provide navigation from the mouth of the Arkansas River to the Port of Catoosa near Tulsa, Oklahoma. Construction on the Arkansas River navigation project began in 1957. Navigation reached Little Rock, Arkansas, in December 1968 and the Port of Catoosa, Oklahoma in December 1970. The Montgomery Point Lock & Dam is the eighteenth project along the navigation system and was completed in 2004. This project is designed to aide in navigation during times of low flow on the Mississippi River.

TABLE A-5

ARKANSAS RIVER BASIN PROJECTS

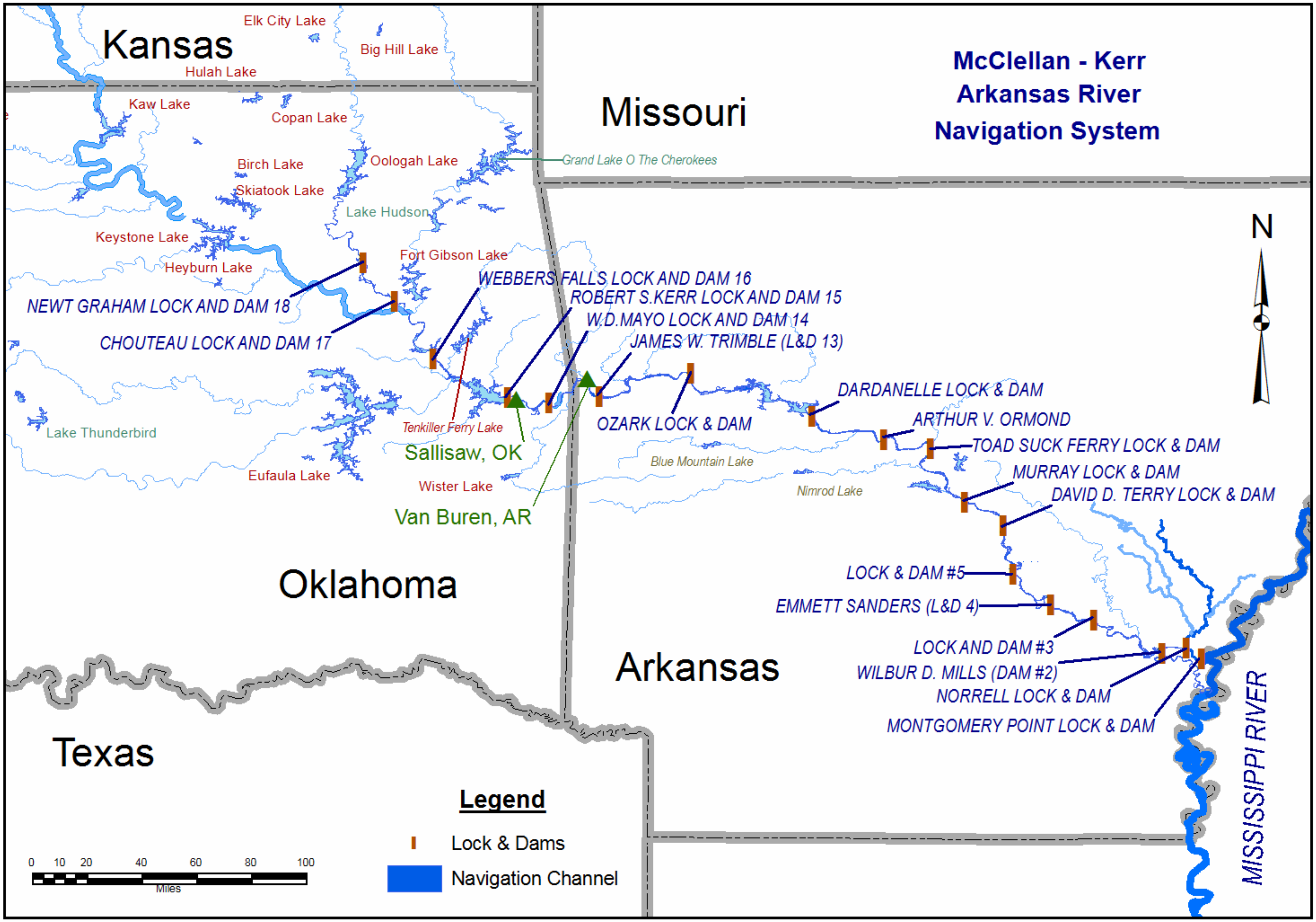
Project	Arkansas Tributary	Year Completed
Tulsa District Reservoirs		
El Dorado Lake	Walnut	1981
Kaw Lake	Arkansas	1976
Great Salt Plains Lake	Salt Fork	1941
Keystone Lake	Arkansas	1964
Heyburn Lake	Polecat	1950
Toronto Lake	Verdigris	1960
Fall River Lake	Verdigris	1949
Elk City Lake	Verdigris	1966
Big Hill Lake	Verdigris	1981
Oologah Lake	Verdigris	1974
Hulah Lake	Verdigris	1951
Copan Lake	Verdigris	1983
Birch Lake	Verdigris	1977
Skiatook Lake	Verdigris	1984
Council Grove lake	Grand (Neosho)	1964
Marion Lake	Grand (Neosho)	1968
John Redmond Lake	Grand (Neosho)	1964
Fort Gibson Lake	Grand (Neosho)	1952
Tenkiller Ferry Lake	Illinois	1952
Optima Lake	Canadian	1978
Fort Supply Lake	Canadian	1942
Canton Lake	Canadian	1948
Arcadia Lake	Canadian	1986
Eufaula Lake	Canadian	1964
Wister Lake	Poteau	1949
Tulsa District Section 7 Reservoirs		
Cheney Dam and Lake	Ninnescah	1964
Pensacola Dam (Grand Lake)	Grand (Neosho)	1940
Lake Hudson	Grand (Neosho)	1964
Sanford Dam and Lake Meredith	Canadian	1965
Norman Dam and Lake Thunderbird	Canadian	1965

Project	Arkansas Tributary	Year Completed
Little Rock District Reservoirs		
Blue Mountain Lake	Petit Jean	1947
Nimrod Lake	Fourche LaFave	1942
Tulsa District Locks and Dams		
Newt Graham Lock and Dam	Arkansas	1970
Chouteau Lock and Dam	Arkansas	1970
Webbers Fall Lock and Dam	Arkansas	1970
Robert S. Kerr Lock and Dam	Arkansas	1970
W. D. Mayo Lock and Dam	Arkansas	1970
Little Rock District Locks and Dams		
James W. Trimble Lock and Dam	Arkansas	1969
Ozark Jetta-Taylor Lock and Dam	Arkansas	1969
Dardanelle Lock and Dam	Arkansas	1964
Arthur V. Ormand Lock and Dam	Arkansas	1969
Toad Suck Ferry Lock and Dam	Arkansas	1969
Murray Lock and Dam	Arkansas	1969
David D. Terry Lock and Dam	Arkansas	1968
Lock and dam No. 5	Arkansas	1968
Emmitt Sanders Lock and Dam	Arkansas	1968
Joe Hardin Lock and Dam	Arkansas	1968
Wilbur D. Mills Lock and Dam	Arkansas	1968
Norrel Lock and Dam	Arkansas	1968
Montgomery Point Lock & Dam	Arkansas	2004

4. LOCK AND DAM OPERATION

4.1. General

Lock & Dam Reservoirs are operated for navigation and hydroelectric power production (when applicable) in conjunction with the other authorized system of locks and dams as well as multipurpose reservoirs in the Arkansas River Basin. A map of the main channel of the McClellan-Kerr Arkansas River Navigation System and some of the reservoirs is presented on Map A-2.


McClellan - Kerr
Arkansas River
Navigation System
Kansas
Missouri
Oklahoma
Arkansas
Texas
Elk City Lake
Big Hill Lake
Hulah Lake
Kaw Lake
Copan Lake
Birch Lake
Oologah Lake
Grand Lake O The Cherokees
Skiatook Lake
Lake Hudson
Keystone Lake
Heyburn Lake
Fort Gibson Lake
WEBBERS FALLS LOCK AND DAM 16
ROBERT S.KERR LOCK AND DAM 15
W.D.MAYO LOCK AND DAM 14
JAMES W. TRIMBLE (L&D 13)
NEWT GRAHAM LOCK AND DAM 18
CHOUTEAU LOCK AND DAM 17
DARDANELLE LOCK & DAM
ARTHUR V. ORMOND
TOAD SUCK FERRY LOCK & DAM
OZARK LOCK & DAM
Tenkiller Ferry Lake
Lake Thunderbird
Sallisaw, OK
Blue Mountain Lake
MURRAY LOCK & DAM
Eufaula Lake
Wister Lake
Nimrod Lake
DAVID D. TERRY LOCK & DAM
Van Buren, AR
LOCK & DAM #5
EMMETT SANDERS (L&D 4)
LOCK AND DAM #3
WILBUR D. MILLS (DAM #2)
NORRELL LOCK & DAM
MONTGOMERY POINT LOCK & DAM
MISSISSIPPI RIVER
N
Legend
Lock & Dams
Navigation Channel
0 10 20 40 60 80 100
Miles

Map A-2

4.2. Normal Regulations

The navigation pool is regulated to provide a navigable channel from one Lock and Dam through the next upstream Lock and Dam. Storage for hydroelectric power is included in several of these projects and is used to maintain head for the hydroelectric units.

4.3. Flood Control

There is no storage allocated for flood control in the Lock & Dam Reservoirs. During large flood events it is possible to slightly reshape the peak of the flood in some cases by manipulating releases but this can make minimal change at best.

5. MULTIPURPOSE STORAGE PROJECT OPERATION

5.1. General

Most of the lakes under the control of the Corps of Engineers in the Arkansas River Basin have multiple purposes. These purposes include hydropower, irrigation, recreation, fish and wildlife, water supply, navigation, flood control, and water quality. The following paragraphs describe the general guidelines set forth for the regulation of the lakes for the various project purposes. More detailed information on the current flood control and navigation system regulation plan will be presented later in this write-up.

5.2. Hydroelectric Power

The Southwestern Power Administration (SWPA) markets the hydroelectric power produced at the Corps of Engineers owned power projects. This marketing is done in accordance with contractual agreements that SWPA has developed with various power companies or CO-Ops. The Corps determines the availability of water for hydroelectric power production.

In addition to the federally owned power projects, there are seven non-federal power projects operated by other marketing agencies. These agencies own and operate the hydropower facilities at the following Corps of Engineers projects: The Oklahoma Municipal Power Authority (OMPA) is the marketing agency for Kaw Lake. The Arkansas Electric Cooperative Corporation (AECC) markets the power at James W. Trimble Lock and Dam, Arthur V. Ormond Dam, and Wilbur D. Mills Dam. The City of North Little Rock, Arkansas is the marketing agency for the hydropower production at Murray Lock and Dam. These marketing agencies do not own storage and can only generate by passing inflow.

The Grand River Dam Authority (GRDA) owns and operates the dam and power facilities at Pensacola Dam and Kerr Dam (Lake Hudson). The Corps of Engineers regulates these projects for flood control only.

5.3. Irrigation

Canton Lake in Tulsa District is the only operational Corps of Engineers project with irrigation as a project purpose; however, irrigation storage has not been utilized to date. Lake Meredith, designed and constructed by the Bureau of Reclamation, also has irrigation as a project purpose. The Corps of Engineers regulates this project for flood control only.

5.4. Water Supply

Water supply, when included in Corps of Engineers lakes, is contracted by the Corps with nonfederal entities or individuals. Normally, water is taken directly from storage in the lake; however, in some cases, the water user may pump from the stilling basin or river downstream, in which case releases are maintained for water supply purposes. Since the water supply demands have been limited to individual projects, a system water supply plan has not been developed.

5.5. Navigation

Hydroelectric power releases are considered sufficient for lockage along the Arkansas River Navigation system. Navigation storage of 168,000 acre-feet is provided in Oologah Lake. Releases of excess water from the upstream flood control projects are made at a rate, when possible, which does not jeopardize the navigation system facilities and their use by the public. Due to the natural characteristics of the Arkansas River, shoaling frequently occurs along the navigation channel. The shoaling causes insufficient depth and navigation hazards. The system regulation plan provides sufficient depth for continuing navigation while maintenance dredging is being accomplished (referred to as a taper operation). A more detailed discussion of the system regulation plan is presented later in this report.

5.6. Flood Control

The flood control regulation schedules for each lake are presented in the appropriate regulation manual. These regulations are based primarily on each lake acting as a unit in the system. The flood control regulations governing lakes built by the Corps of Engineers contain provisions for discharge of water when pool elevations are below the bottom of the flood control pool provided that the predicted inflow volume will be sufficient to restore the pool to the conservation regulating level. Regulating schedules for the Corps of Engineers projects provide that certain stages and/or discharges are not to be exceeded insofar as possible at specified locations downstream from the dams. Some of the regulating stations and discharges for the current system operation are shown in Table A-6.

TABLE A-6

CONTROL POINT VS MAXIMUM ALLOWABLE NON-DAMAGING FLOW
MAY 2003 CONDITIONS

Reservoir	Discharge (cfs)	Control Point	Discharge (cfs)
Cheney	1,500	Americus	16,800
El Dorado	4,200	Florence	7,300
Kaw	40,000	Plymouth	10,700
Great Salt Plains	10,000	Iola	18,600
Keystone	100,000	Parsons	17,200
Heyburn	4,000	Commerce	21,100
Toronto	6,500	Altoona	10,600
Fall River	4,500	Fredonia	6,600
Elk City	8,800	Independence	20,100
Big Hill	1,500	Lenapah	32,800
Oologah	30,000	Bartlesville	12,100
Hulah	6,500	Ramona	16,300
Copan	3,500	Claremore	52,500
Birch	2,000	Sperry	9,600
Skiatook	4,000	Inola	65,000
Council Grove	3,000	Augusta	10,500
Marion	4,000	Winfield	37,400
John Redmond	14,000	Ralston	78,900
Pensacola (Grand)	100,000	Haskell	132,700
Hudson	100,000	Muskogee	137,900
Fort Gibson	100,000	Sallisaw	150,000
Tenkiller	13,500	Poteau	7,800
Arcadia	1,000	Panama	10,900
Fort Supply	1,300	Van Buren	137,000*
Canton	1,000		
Thunderbird	2,000		
Eufaula	40,000		
Wister	7,200		
Blue Mountain	2,500		
Nimrod	6,000		

*Current rating is based on the 22-foot Regulating Stage at Van Buren.

5.7. Water Quality and Low-Flow

Water quality releases are made on a regular basis from projects containing storage reserved for that purpose. Details concerning water quality requirements at the various regulating stations can be obtained from the appropriate regulation manual. Releases are made as needed for dilution of pollutants, preventing or disposing of fish kills, and to relieve other critical conditions when they occur. Under provisions of Public Law 92-500, the Corps of Engineers cooperates with all state and Federal agencies to achieve the goals set forth by Congress in 1972 of improving the Nation's water quality.

5.8. Recreation

The development, operation, and maintenance of recreation areas and facilities around the lakes are usually done by the owning and operating agency. However, some recreational areas are developed and maintained by other Federal agencies or agencies of the various states in which the projects are located. Some cities also maintain small recreational areas on nearby lakes. No special system operations are made for recreation; however, impacts to recreation were evaluated in the development of the system regulation plan. Those impacts serve as a guide in the day-to-day decision making of the system operation. When possible, special operations are made to enhance the recreational benefits to be derived from the system. Special operations are considered on a case-by-case basis such as raft races and canoe float trips. Usually, these requests involve only a single lake rather than the whole system.

5.9. Fish and Wildlife

The Corps of Engineers cooperates with state and Federal fish and wildlife agencies, when requested, in developing plans for and providing regular seasonal pool fluctuations at Corps operated lakes. The seasonal pool variations help to improve the fish spawn during the spring months, the water recreation during the summer months, and the waterfowl food and hunting during the fall months. Regular surveillance of the stilling basins below the dams is made to detect poor water quality and prevent fish kills. Special releases to maintain fish life are made as necessary. Since most of the fish and wildlife benefits are derived for the individual projects, no special operations are designed in the system regulation plan for fish and wildlife.

6. DESCRIPTION OF SYSTEM OPERATION

6.1. General

Reservoirs are operated for their individual authorized purposes; which means that decisions concerning system operations require evaluation of the impacts on all of the authorized purposes. In the case of flood control, each reservoir has limitations immediately below their outlet works, which can limit the releases. Current limitations are found in Table A-6.

Since each reservoir is linked by their discharge to the same river system, Arkansas River main stem, they are not only operated for local conditions, but also must be operated as a part of a larger system in conjunction with other reservoirs. In many cases, a reservoir may be operated with one or more reservoirs as a system and as a part of a larger system. Example: Hulah and Copan are operated as a system for Bartlesville and Ramona and are operated in conjunction with nine other projects for control of the lower Arkansas basin. There are limitations along all reaches of the Arkansas River System; however, the most notable in the overall system is the Fort Smith and Van Buren area. About 128,000 square miles of the 138,000 square miles in the Arkansas River lay above Van Buren, Arkansas. It was recognized during the design stage that control of the main stem of the Arkansas depended on control of the flow past Van Buren, Arkansas. It was also recognized that 11 projects in the eastern part of Oklahoma were the key to any Van Buren flood operation. These reservoirs are: Pensacola (Grand Lake), Lake Hudson and Fort Gibson on the Grand (Neosho) River, Oologah on the Verdigris River, Hulah and Copan on the Caney River, Kaw and Keystone on the Arkansas River, Tenkiller on the Illinois River, Eufaula on the Canadian River, and Wister on the Poteau River. Their proximity to the main stem and the fact that each is the primary control for their respected river, make the operation of each reservoir critical to the flood control of the Arkansas River System.

7. EVOLUTION OF THE SYSTEM OPERATION PLAN

7.1. Taper Operation

Since the completion of the McClellan-Kerr Arkansas River Navigation System in 1970, the Corps of Engineers has modified the system operating plans several times to improve the flow regime and to enhance benefits to users of the system. Shortly after the completion of the Navigation System it was noted that following a flood event, shoaling would occur in the river channel and restrict navigation until maintenance dredging could be performed. To maintain navigation depths during dredging activities, a “taper” operation was implemented to gradually reduce flows following such floods events. This navigation taper operation required an increase in the time water was held in the lower few feet of the flood control pools in the Oklahoma lakes. Note: The taper operation does not increase the level in the flood control pools but it does delay the timing for complete evacuation of the flood pool. The first such navigation taper plan was utilized from 1979 to 1986.

7.2. Existing Plan (1986 Fine Tuning Plan)

In 1985, the volume of water flowing down the Arkansas River past Van Buren was the second largest of record (at that time) and was the fourth year in succession of above normal flows. Because of the high flows, navigation interests experienced increased costs and delays; and, farmers, who had been accustomed to farming land near the river, found it impossible to produce crops during this period.

To address these problems, the Corps of Engineers restudied the system-operating plan and in June 1986, following a public comment period, implemented a new operating plan. The objective of the new plan (Fine Tuning Plan) was to increase the number of days of flow below 80,000 cfs for the benefit of the navigation system and low-lying farmland, while causing minimal impacts on hydropower, recreation and flood control in Arkansas and Oklahoma.

The ‘Fine Tuning Plan’ has been used since June 1986 and is the current or existing operating plan. Key features of this plan are:

1. A taper operation of 40,000 cfs to 20,000 cfs. When the flood storage remaining in the 11 controlling reservoirs reaches from 3% in the spring to 11% in the summer, the target flow at Van Buren is gradually reduced from 40,000 cfs to 20,000 cfs. This allows navigation to continue until dredging operation can remove the sediment deposited in the channel during high flow.

2. A 75,000 cfs bench (a range where the flow is held at or below 75,000 cfs). This feature is also adjusted seasonally to maximize benefit to farming and minimize flood impacts during that portion of the year more susceptible to floods.

APPENDIX A

ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA
HYDROLOGIC AND HYDRAULIC ANALYSIS

PART 2 – ARKANSAS RIVER SYSTEM OPERATION SCREENING STUDY

8. SYSTEM STUDY METHODS AND ANALYSIS

The purpose of this section of the report is to present; the procedures used in the development and screening of alternative operating plans for the Arkansas River Basin system, the logic used in the selection of each plan, the methodologies used to analyze the impacts of those plans, and the findings resulting from those efforts. The report identifies and compares the impacts of each alternative reservoir system operating plan on the system's purposes, including navigation, flood control, hydropower generation, and recreation.

8.1. Study Tools

The hydrologic portion of the study was performed using the "Southwestern Division Modeling System for the Simulation of the regulation of a Multipurpose Reservoir System" more affectionately know as SUPER. SUPER was written by Ron Hula of the Corps of Engineers and evolved around the needs to model reservoir systems in the Southwestern Division. SUPER is a linked system of programs that have been designed to perform and analyze a "period of record" simulation for a specific system of multipurpose reservoirs using various plans of regulation. The hydrologic routing interval used for the simulation is a one-day period. The flow used to represent that period is the average flow for the particular 24-hour period. For a more complete description of SUPER see the write-up "Southwestern Division Modeling System for the Simulation of the Regulation of a Multipurpose Reservoir System", dated January 2000, written by Ronald L. Hula.

8.2. Arkansas River System Model

The Arkansas River System model is made up of 21 multipurpose storage reservoirs and 50 control points. The hydrologic period of simulation for this study is January 1940 through December 2000 or 61 years of daily records (22,282 days). This period is believed to be a good representation of what may be expected in the Arkansas River Basin since it contains floods with large volumes and high peak flow periods (1943, 1957, 1986, 1990, 1994, and 1995) as well as drought periods (1950's and 1970's).

Reservoirs are defined by their project features. There are several physical relationships used as input to describe each reservoir.

1. The elevation-area-capacity relationship.
2. The free flow discharge-rating curve (maximum release rate physically possibly).
3. The induced surcharge envelope curve (minimum release rate allowed).
4. Leakage from the reservoir (gate and other).
5. A description of the hydropower plant facilities including: power plant capacity, power plant efficiency, head loss in the approach to the turbine, and tail water rating curve.

The relationship between reservoirs is defined in terms of hydraulics, priorities, and purposes. The reservoirs are defined hydraulically by describing travel time between projects and their location within the system. Releases from upstream projects will add to the inflow of a downstream project. Releases from other projects in the system will add to the flows in the main stem and may further restrict releases. Damage reaches are also defined along the system by describing their flow/damage relationship.

A reservoir's priority in the system is described by establishing a relationship to other projects using elevation and storage. Since the projects are operated as a system, an elevation/storage balance level is defined for each reservoir that will be used to establish priority of operations within the reservoir system.

8.3. Analysis of Effects of Simulations

Each operating plan was analyzed to compare the effectiveness in controlling the water in the basin for the authorized purposes and quantifying the benefit or damage to each purpose. This was accomplished by simulating the same hydrologic period of record through the reservoir system using the different operating plans. The period of record for this study is January 1, 1940 through December 31, 2000.

Each operating plan was evaluated using the following methods:

8.3.1. <u>Flow Duration.</u> Since most of the challenges could be related to the control of flow in the Van Buren reach, a table for each simulation was developed to compare the number of days that selected flows were reached or exceeded on average per year. This was used to quantify the effectiveness of each plan in accomplishing the stated goals. For this study, fractions of days were rounded to the nearest whole day. The flows and their reason for selection follow:

60,000 cfs – Farming and navigation both benefit with flows below this level
75,000 cfs – Benched flow in the current operating plan
100,000 cfs – Above this flow navigation is restricted
137,000 cfs – Approximate channel capacity at Van Buren
150,000 cfs – Considered to be the design flow for the system

175,000 cfs – The flow that historically is reached or exceeded at least once per year

8.3.2. Damage Center Evaluation. Damages that occurred with each operating plan were tabulated and compared. (Note: These values were used for screening purposes only. The final evaluation was accomplished by a more traditional economic evaluation.) The following damages were tabulated and evaluated:

1. Total system damages
   a. Crop losses
   b. Pasture losses
2. Structural damages
   a. Urban
   b. Rural
3. Navigation Damages
   a. Daily fuel cost
   b. Daily time cost
4. Navigation pool damages
   a. Dredging cost
   b. Blocked navigation cost
5. Reservoir Pool Damage
6. Recreation Losses
7. Hydropower
   a. Power produced by the storage reservoirs
   b. Power produced on load
   c. Power produced at lock and dams
   d. Dump energy
   e. Thermal purchase

8.3.3. Effect on Taper Operation. Various floods were analyzed to see if the operation plan had a significant effect on the taper operation.

8.3.4. Reservoir Flood Control Impacts. Evaluation of impacts to the flood control pools at the storage reservoirs was accomplished by comparing each simulation with the existing operation plan. These evaluations involved the following:

1. Pool duration curves
2. Pool frequency curves
3. Pool duration tables

9. SYSTEM OPERATION SCREENING STUDY

The study was broken into phases corresponding to the stated objectives. It was determined early in the study that each change to the operating system should be evaluated separately. This separation of changes is necessary to evaluate the affects of each. It is not possible to tell which change had an impact on the authorized purposes if more than one change is made in a simulation. This screening study did not evaluate the impacts on environmental and cultural resources. Environmental and cultural impacts were determined using other methods and procedures.

The study objectives were developed based upon input from the stakeholders and are as follows:

Objective 1: Minimize flow at Van Buren above 100,000 cfs.
Objective 2: Minimize flow at Van Buren above 60,000 cfs.
Objective 3: Improve the taper operation.

The objective, a description of each simulation used to evaluate the operating system changes to accomplish that objective and conclusions are described in the following paragraphs.

9.1. Objective 1: Minimize Flow At Van Buren Above 100,000 Cfs

Navigation interests have stated that flows above 100,000 cfs at Van Buren cause the Arkansas system to be un-navigable. Therefore, the system would become more reliable for every additional day flows in the main stem of the Arkansas River could be held below 100,000 cfs. A summary of simulations used to accomplish this objective and analysis of each are described in the following paragraphs.

9.1.1. A01X16 – Existing Operating Plan. A simulation using the existing operating plan was run with the updated period of record hydrology and updated power loads furnished by SWPA. The run established a base condition by which all other simulations were compared.

Van Buren At 99,000 Cfs Above 75,000 Bench. An initial series of screenings were performed in which a 99,000 cfs target replaced the portion of the Van Buren guide curve above the taper and 75,000 cfs bench. (A target of 99,000 cfs was chosen to keep the flow below 100,000 cfs as much as possible.) The initial runs showed an unacceptable level of impact on the flood control pools. Subsequent simulations indicated that the target at Van Buren should be increased above the current channel capacity when the system storage exceeded 30%.

Action. Increase the Van Buren target flow when system storage exceeds 30%.

9.1.2. <u>A01X17 – 200,000 cfs At Van Buren Above 30%</u>. The purpose of run A01X17 was to evaluate the effects of the combination of a 99,000 cfs target above the 75,000 cfs bench to 30% system full capacity. The simulation showed a significant reduction in the average number of days per year the flow at Van Buren exceeded 100,000 cfs when compared to the existing conditions run A01X16. The simulation indicated a reduction of 13 days/year (from 34 days to 21 days). It is believed this reduction would make the navigation system more dependable. The change also reduced the flow above 137,000 cfs (channel capacity) by 2.5 days. Hydropower did not show a significant impact (less than 1%) at the storage projects but did increase generation at the lock and dams by 37.4-gigawatt-hours (gwh) (2%). (Note: this increase was probably due to the 99,000 cfs bench in place of the 137,000 cfs -150,000 cfs upper target and resulted in less spill). Using SUPER economics as a screening tool, it was determined that damages exceeded benefits by a significant amount (this was expected since the non-damaging flow at Van Buren is approximately 137,000 cfs.) The increase in damages was primarily along the main stem of the Arkansas River from Haskell, Oklahoma to the Little Rock, Arkansas area.

The increase in channel capacity at Van Buren from 150,000 cfs to 200,000 cfs above 30% system storage did reduce the amount of time (duration) floodwaters were stored in the upper flood pools. However, the duration of the storage below the 30% level was increased significantly resulting in a loss of recreation and increased pool damages (primarily recreation areas.) Fort Gibson, Oologah, Keystone, and Tenkiller increased duration of storage in the lower 10 feet of the pool while Eufaula showed an increase in the lower 6 feet. Hulah, Copan, and Wister showed little change in operation. Note: Hulah and Copan are regulated more by the channel capacity at Bartlesville and Ramona than by the restrictions on the main stem.

Evaluation of flow data passing the Van Buren gage indicated that 175,000 cfs was exceeded only 2 days per year as compared to 1 day in the existing conditions run. This led to the conclusion that some other control was restricting the releases. The target of 150,000 cfs at Sallisaw was identified as the probably restriction to the releases when the target at Van Buren was increase from 150,000 cfs to 200,000 cfs. Table A-7 presents results of this analysis.

TABLE A-7

Summary of SUPER Model Screening Results A01X17 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+5 days
Difference in Days above 100,000 cfs at Van Buren	-13 days
Difference in Days above 137,000 cfs at Van Buren	-3 days
Agricultural/Structural Damages (%)	+2.0%
Navigation Damages (%)	-0.3%
Pool Damages (%)	+3.2%
Recreation Damages (%)	+8.1%
Hydropower (Reservoirs) Damages (%)	+0.2%
Hydropower (River) Damages (%)	-2.1%

Action. Increase the Sallisaw target to 200,000 cfs to match the Van Buren target.

9.1.3. A01X18 – Van Buren At 200,000 cfs And Sallisaw At 200,000 cfs. This run titled A01X18 was made to allow the 200,000 cfs increase in target flow at Van Buren to realize it's full benefit by removing the restriction of 150,000 cfs at Sallisaw, OK.

Analysis indicated an additional 3 days reduction in flows above 100,000 cfs at Van Buren compared to A01X17. It also showed an increase above 175,000 cfs from a 2-day average/ year to 8 days average/year and 2.4 more days below the 137,000 cfs (channel capacity). There was a decreased duration in the upper limits of the flood pools between runs A01X17 and A01X18. There were fewer days duration of storage in the lower pools at Eufaula and Fort Gibson with only slight changes in Tenkiller, Keystone, and Oologah. Note: The increased duration in the lower portion of the flood pools is due to the change is target below 30% full from 137,000 cfs to 99,000 cfs.

The analysis also indicated 3 times the increase in overall damages to crops and structures and a 1% decrease in power production from A01X17. On the positive side pool damages, and recreation losses both decreased.

Since the number of days increased by only 2 days and the damages significantly increased, there may be a combination of Van Buren at 200,000 cfs and Sallisaw between 150,000 cfs and 200,000 cfs that would maximize days gained and minimize damages. Table A-8 presents results of this analysis.

TABLE A-8

Summary of SUPER Model Screening Results A01X18 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+3 days
Difference in Days above 100,000 cfs at Van Buren	-16 days
Difference in Days above 137,000 cfs at Van Buren	-5 days
Agricultural/Structural Damages (%)	+6.7%
Navigation Damages (%)	-0.5%
Pool Damages (%)	+0.6%
Recreation Damages (%)	+3.8%
Hydropower (Reservoirs) Damages (%)	+0.9%
Hydropower (River) Damages (%)	-2.2%

Action. Make run with Van Buren at 200,000 cfs and Sallisaw at 175,000.

9.1.4. A01X19 – Van Buren At 200,000 cfs And Sallisaw At 175,000 cfs. This run was made in an attempt to retain the extra days below 100,000 cfs at Van Buren gained in A01X18 without the dramatic increase in agricultural and structural damages.

This run did retain most of the 3 extra days below 100,000 cfs gained in A01X18 with approximately half the increase in agricultural and structural damages. It also retained 2 of the days below the 137,000 cfs (channel capacity.) Power production gained back a small amount of that lost in A01X18. Recreation losses and pool damages gave back half of the gain between the results of runs A01X17 and A01X18. The duration of the upper flood pools was similar to A01X18. Table A-9 presents results of this analysis.

Analysis of this run brought the question; “Would an upper target of 175,000 cfs at Van Buren rather than 200,000 cfs gain days below 100,000 cfs with less economic losses?”

TABLE A-9

Summary of SUPER Model Screening Results A01X19 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+4 days
Difference in Days above 100,000 cfs at Van Buren	-16 days
Difference in Days above 137,000 cfs at Van Buren	-4 days
Agricultural/Structural Damages (%)	+4.8%
Navigation Damages (%)	-0.6%
Pool Damages (%)	+1.0%
Recreation Damages (%)	+5.3%
Hydropower (Reservoirs) Damages (%)	+0.7%
Hydropower (River) Damages (%)	-2.1%

Action. Make two runs. One run made with the Van Buren upper target at 175,000 cfs and Sallisaw back to 150,000 cfs. The second run with Van Buren upper target at 175,000 cfs and Sallisaw at 175,000 cfs.
Note: Two runs are needed to evaluate the effects of the change. If only the second were made, it would be impossible to know whither the effects were from the Van Buren change or the Sallisaw change or both.

9.1.5. A01X20 – Van Buren At 175,000 cfs And Sallisaw At 150,000 cfs. This run was made to see if the days equaling or exceeding 100,000 cfs vs. damages could be improved by lowering the regulated flows at Van Buren to 175,000 cfs.

The run gave approximately the same 13 days below 100,000 cfs that were achieved in the 200,000 cfs run (A01X17). It also produced the same 2 days below the 137,000 cfs (channel capacity.) The agricultural and structural damages were slightly less than A01X17 as were the navigation damages. Pool damages, recreation and hydropower losses were slightly larger. The use of the upper flood pools was similar to A01X18.

It is believed that by opening Sallisaw to 175,000 cfs to match the Van Buren target the number of days below 100,000 cfs can be improved without a significant impact to other purposes. Table A-10 presents results of this analysis.

TABLE A-10

Summary of SUPER Model Screening Results A01X20 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+5 days
Difference in Days above 100,000 cfs at Van Buren	-13 days
Difference in Days above 137,000 cfs at Van Buren	-2 days
Agricultural/Structural Damages (%)	+1.3%
Navigation Damages (%)	-0.2%
Pool Damages (%)	+3.4%
Recreation Damages (%)	+8.3%
Hydropower (Reservoirs) Damages (%)	+0.1%
Hydropower (River) Damages (%)	-2.1%

Action. Increase Sallisaw target to 175,000 cfs to match Van Buren target.

9.1.6. A01X21 – Van Buren At 225,000 cfs And Sallisaw At 150,000 cfs. The study team wanted to evaluate the impacts of an increase of 25,000 cfs from A01X17. The days equaling or exceeding 100,000 cfs vs. damages were evaluated after increasing the regulated flows at Van Buren to 225,000 cfs.

The run gave very similar results to A01X17, which was restricted because of Sallisaw. The value of increasing the target at Van Buren cannot be realized without increasing Sallisaw. Table A-11 presents results of this analysis.

TABLE A-11

Summary of SUPER Model Screening Results A01X21 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+5 days
Difference in Days above 100,000 cfs at Van Buren	-14 days
Difference in Days above 137,000 cfs at Van Buren	-2 days
Agricultural/Structural Damages (%)	+2.3%
Navigation Damages (%)	-0.3%
Pool Damages (%)	+3.1%
Recreation Damages (%)	+8.3%
Hydropower (Reservoirs) Damages (%)	+0.2%
Hydropower (River) Damages (%)	-2.1%

Action. Increase Sallisaw target to 225,000 cfs to match Van Buren target.

9.1.7. A01X22 – Van Buren At 225,000 cfs And Sallisaw At 225,000 cfs. This run was made to allow the 225,000 cfs increase in target flow at Van Buren to realize it's full benefit by increasing the flow target at Sallisaw, Oklahoma from 150,000 cfs to 225,000 cfs.

This run did increase the number of days below 100,000 cfs by one more day over the 16 days gained in run A01X18. The total damages increase to agriculture and structures was even more dramatic, increasing by 9.68% in total damages compared to 6.68% increase in run A01X18. Navigation cost, recreation losses, and hydropower are approximately the same. Duration of floodwaters in the upper flood pools was similar to A01X18 with somewhat less impact on the lower pools. Pool damages were slightly less than existing conditions A01X16.

Note. The United States National Weather Service indicates that flows of 225,000 – 250,000 cfs can be expected to have the following results:

1. Extensive agricultural lowland flooding.
2. Marine terminals and similar businesses in the flood plain along the river will begin to flood.
3. Flooding of sand and gravel companies.
4. Residential subdivisions in the flood plain along the river will begin to flood.
5. Expect backwater flooding of roads and trailer parks next to Lee Creek.

It appears that 175,000 cfs or 200,000 cfs upper target at Van Buren are going to have the most benefit to navigation with the least impact on other purposes. Table A-12 presents results of this analysis

TABLE A-12

Summary of SUPER Model Screening Results A01X22 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+3 days
Difference in Days above 100,000 cfs at Van Buren	-17 days
Difference in Days above 137,000 cfs at Van Buren	-5 days
Agricultural/Structural Damages (%)	+9.7%
Navigation Damages (%)	-0.5%
Pool Damages (%)	-0.6%
Recreation Damages (%)	+3.4%
Hydropower (Reservoirs) Damages (%)	+0.9%
Hydropower (River) Damages (%)	-2.2%

Action. The team wants to see the upper limit target of 300,000 cfs to see if any other increases would have a positive effect.

9.1.8. A01X23 – Van Buren At 175,000 cfs And Sallisaw At 175,000 cfs. This run was made to allow the 175,000 cfs increase in target at Van Buren in A02X20 to realize it's full benefit by increasing the flow target at Sallisaw, OK from 150,000 cfs to 175,000 cfs.

The run retained most of the 16-day increase realized in A01X18. It increased by one day the flow above the 137,000 cfs (channel capacity). Agricultural and structural damages were found to increase 3.12% where as A01X18 increased by 6.68%. Pool damages and recreation damages were larger than A01X18. Hydropower production was slightly improved from A01X18.

It appears that the upper limit of channel capacity should be 175,000 cfs or 200,000 cfs depending on the cost of flood proofing and/or real estate requirements. Table A-13 presents results of this analysis.

TABLE A-13

Summary of SUPER Model Screening Results A01X23 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+4 days
Difference in Days above 100,000 cfs at Van Buren	-16 days
Difference in Days above 137,000 cfs at Van Buren	-4 days
Agricultural/Structural Damages (%)	+3.1%
Navigation Damages (%)	-0.6%
Pool Damages (%)	+1.8%
Recreation Damages (%)	+6.0%
Hydropower (Reservoirs) Damages (%)	+0.6%
Hydropower (River) Damages (%)	-2.1%

Action. Investigate the cost of a target to 175,000 cfs and 200,000 cfs flows at Sallisaw and Van Buren.

9.1.9. A01X24 – Van Buren At 300,000 cfs, Sallisaw At 300,000 cfs And Muskogee At 250,000 cfs. This run was made to see the effects of opening the lower Arkansas to match the maximum discharges allowed from all projects without exceeding channel capacity immediately below each reservoir. It was desired to see what maximum number of days could be attained without modifying the storage reservoirs or the channel below each reservoir.

This run did increase the number of days below 100,000 cfs by 19 days as compared to 16 days in run A01X18 (200,000 cfs target). There was a dramatic 300% increase in agricultural and structural damages over the A01X18 increase. There was also an increase of 7 days below the 137,000 cfs (channel capacity.) Power production was impacted more in this simulation than any other run with a loss of generation in all categories except the lock and dams with only minor gains there. Recreation losses and pool damages were improved over any of the previous run.

Note. The United States National Weather Service indicates that with flows of 300,000 cfs the expectations are:

1. Extensive agricultural lowland flooding.
2. Marine terminals and similar businesses in the flood plain along the river will begin to flood.
3. Flooding of sand and gravel companies.
4. Flooding of marine terminals and similar businesses along with residential subdivisions in the flood plain along the river.

5. Expect backwater flooding of roads and trailer parks next to Lee Creek.
6. Expect flooding in the town of Moffett, Oklahoma. Expect extensive flooding of businesses around Fort Smith and residential subdivisions in the flood plain of the Arkansas River, the Poteau River, and Lee Creek.
7. Very damaging flooding will occur along the Arkansas River flood plain from Moffett, Oklahoma downstream to Lock and Dam 12. The port of Fort Smith and nearby businesses along the Poteau River will be flooded. Backwater flooding will cover roads and trailer parks next to Lee Creek. Residential subdivisions in the flood plain of the Arkansas River will be flooded.
8. Above 335,000 cfs near catastrophic flooding will occur along the Arkansas River.

This run was the most favorable for recreation and in-pool damages and added another 3 days per year to flow below 100,000 cfs. However, with the added damages and negative impacts on hydropower, flow of this magnitude or larger will probably not be considered further. Table A-14 presents results of this analysis.

TABLE A-14

Summary of SUPER Model Screening Results A01X24 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+3 days
Difference in Days above 100,000 cfs at Van Buren	-19 days
Difference in Days above 137,000 cfs at Van Buren	-7 days
Agricultural/Structural Damages (%)	+23.9%
Navigation Damages (%)	-0.5%
Pool Damages (%)	-5.1%
Recreation Damages (%)	+0.2%
Hydropower (Reservoirs) Damages (%)	+1.4%
Hydropower (River) Damages (%)	-2.3%

<u>Action</u>. Investigate the cost of a target to 175,000 cfs and 200,000 cfs flows at Sallisaw and Van Buren.

9.2. Objective 2: Minimize Flow At Van Buren Above 60,000 cfs

Farming interests in western Arkansas requested the Corps investigate the possibility of reducing the flooding of agricultural land along the lower Arkansas River. It has been determined that flows above 60,000 cfs cause flooding of some fields along the main stem in western Arkansas.

It has also been noted that the existing 75,000 cfs (bench) flow hinders channel recovery operations (dredging) in the lower reaches of the Arkansas River where intervening runoff increase the flows to 85,000 or 90,000 cfs. It is difficult to perform dredging when flows exceed 70,000 cfs.

It is believed that lowering the bench from 75,000 cfs to 60,000 cfs would accomplish both objectives

9.2.1. <u>A01X25 – Van Buren At 60,000 cfs Target Above The Taper</u>. This run was used to determine the amount of additional storage that would be required in the 11 multipurpose projects to maintain a maximum target flow of 60,000 cfs at Van Buren. This was accomplished by simulating unlimited storage in the 11 controlling reservoirs and observing the maximum storage reached.

The goals were:

1. Establish the maximum number of days that flows could be controlled below 60,000 cfs. Note. Even with unlimited storage in the reservoirs, flows above 60,000 cfs will occur at Van Buren when rain falls on the 7500 square miles of drainage area below the controlling reservoir.

2. Answer the question "how much storage would have to be added to the storage projects to achieve maximum control on the lower Arkansas?"

<u>Analysis</u>. Unlimited storage in the controlling projects would reduce the flows above 61,000 cfs to an average of approximately 10 days per year (61,000 cfs was selected rather than 60,000 cfs to evaluate the flows "exceeding" rather than "<u>equaling</u> or exceeding" 60,000 cfs.) Flows above 75,000 cfs would be reduced to approximately 4 days per year. Flows above 100,000 cfs would be reduced to approximately 1.7 days per year. Flows above 137,000 cfs or bank full would be reduced to less than once per year on the average. Agricultural and structural damages would be much less in the lower Arkansas. Navigation costs would be significantly reduced. Recreation losses would be dramatically increased since the recreation areas would be flooded much of the year. Hydropower would be increased since any releases would be made through the hydropower units. Table A-15 presents results of this analysis.

<u>Note</u>. A 200% increase in storage would be required to accomplish maximum control below 60,000 cfs. The maximum storage needed for each project may be found in Table A-16.

TABLE A-15

Summary of SUPER Model Screening Results A01X25 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-57 days
Difference in Days above 100,000 cfs at Van Buren	-32 days
Difference in Days above 137,000 cfs at Van Buren	-18 days
Agricultural/Structural Damages (%)	+28.8%
Navigation Damages (%)	-6.1%
Pool Damages (%)	NA
Recreation Damages (%)	+196.3%
Hydropower (Reservoirs) Damages (%)	-12.8%
Hydropower (River) Damages (%)	-35.6%

TABLE A-16

FLOOD STORAGE REQUIRED
FOR 60,000 CFS AT VAN BUREN
(In acre-feet)

Reservoir	Current Total Storage	Required Maximum Storage
Fort Gibson	1,284,400	5,479,500
Oologah	1,519,000	4,896,200
Hulah	288,088	473,400
Copan	227,730	409,900
Keystone	1,737,631	6,959,600
Tenkiller	1,230,800	2,945,500
Eufaula	3,825,362	8,524,700
Wister	427,900	1,648,700
Total	10,281,631	31,337,500

9.2.2. A02X01 – Existing Operating Plan With A 60,000 cfs Bench Replacing The 75,000 cfs Bench. This run was made to determine the impact of changing the 75,000 cfs bench at Van Buren to a 60,000 cfs bench. Additional changes can be analyzed by comparing the impacts to the results of this simulation.

Analysis. The 60,000 cfs bench decreases the number of days above 60,000 cfs by 18 days over the existing run; it decreases the number of days above

75,000 cfs by 4 days; increases the number of days above 100,000 cfs by 1 day and has no effect on the number of days above channel capacity of 137,000 cfs.

Comparing the other impacts of this run to the existing regulation plan indicated a slight (.5%) decrease in overall damages to crops and structures. There was also a decrease in navigation damages. Pool damages and recreation losses were increased. Power production at the storage projects was negatively impacted while generation at locks and dams increased.

Changing the 75,000 cfs bench to a 60,000 cfs bench with all other parameters remaining equal increased the duration of flood water in the pools by as much as 9 days. The amount of pool affected ranged from 5 feet in Eufaula to 16 feet in Fort Gibson. The lower part of the pools was used more frequently resulting in a loss of recreation and more damages to in-pool facilities (primarily recreation facilities.)

The change from a 75,000 cfs bench to a 60,000 cfs bench with all other parameters equal appears to cause more damage than benefit. There may be ways to mitigate the increased duration in the pools by modifying the percent full parameters, a higher release target and/or the taper operation. Table A-17 presents results of this analysis.

TABLE A-17

Summary of SUPER Model Screening Results A02X01 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-18 days
Difference in Days above 100,000 cfs at Van Buren	+1 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.5%
Navigation Damages (%)	-0.3%
Pool Damages (%)	+2.8%
Recreation Damages (%)	+3.6%
Hydropower (Reservoirs) Damages (%)	+0.6%
Hydropower (River) Damages (%)	-1.1%

Action. Investigate the effect of moving the percent full at which the 60,000 cfs bench begins.

9.2.3. A02X02 – Modification Of A01x23 Operating Plan With A 60,000 cfs Bench Replacing The 75,000 cfs Bench. Previous screening analysis indicated that A01X23 or A01X18 were the best candidates for further investigation. This run was made to determine the impact of keeping the 175,000 cfs maximum target and changing the 75,000 cfs bench to a 60,000 cfs bench. This would indicate if the two objectives should be combined.

Analysis. The 60,000 cfs bench decreases the number of days above 60,000 cfs by 16 days over run A01X23; it decreases the number of days above 75,000 cfs by 4 days; it had no significant impact on the number of days above 100,000 cfs or the number of days above channel capacity of 137,000 cfs.

Comparing the other impacts of this run to A01X23 indicated no significant change in overall damages to crops and structures. There was a slight decrease in navigation damages. Pool damages and recreation losses were increased. Power production at the storage projects was negatively impacted while generation at locks and dams increased.

The change of the 75,000 cfs bench to a 60,000 cfs bench with all other parameters equal causes the lower 30% of the pools to be used more frequently thus resulting in a loss of recreation and more damages to in-pool facilities (primarily recreation facilities). Table A-18 presents results of this analysis.

Note. It should also be noted that opening the channel capacity to 175,000 cfs would require some type of mitigation for crops that are being damaged in this run.

TABLE A-18

Summary of SUPER Model Screening Results A02X02 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-13 days
Difference in Days above 100,000 cfs at Van Buren	-15 days
Difference in Days above 137,000 cfs at Van Buren	-3 days
Agricultural/Structural Damages (%)	+3.2%
Navigation Damages (%)	-1.0%
Pool Damages (%)	+4.1%
Recreation Damages (%)	+9.4%
Hydropower (Reservoirs) Damages (%)	+1.1%
Hydropower (River) Damages (%)	-3.2%

9.2.4. <u>A02X03 – Modification Of A02X01 With The Upper Limit Of The 60,000 cfs Bench Beginning At A 3% Lower System Storage</u>. This run was made to determine if lowering the point at which the 60,000 cfs bench begins could mitigate the negative impact of changing the 75,000 cfs bench at Van Buren to a 60,000 cfs bench.

<u>Analysis</u>. Lowering the 60,000 cfs bench by 3%, decreases the number of days above 60,000 cfs by 13 days over the existing plan, but increased 5 days from A02X01. The run increases the number of days above 75,000 cfs by 3 day and increases the number of days above 100,000 cfs by 1 day. This run has no effect on the number of days above channel capacity of 137,000 cfs.

Comparing the other impacts of this run to the existing regulation plan indicated a .25% decrease in overall damages to crops and structures. There was a slight increase in navigation damages. There was a slight decrease in pool damages, recreation losses, and power production.

Lowering the 60,000 cfs bench by 3%, with all other parameters remaining equal, eliminated most of the impact on the duration of floodwater being held in the pools experienced by lowering the bench from 75,000 cfs. There was only a few days increase in the lower 2-6 feet. Table A-19 presents results of this analysis.

<u>Note</u>. Lowering the 60,000 cfs bench by 3% does have some positive impact on the flows below 60,000 cfs with little impact on other purposes. It will have to be determined if 11 days out of 67 is significant for the crops in Arkansas.

TABLE A-19

Summary of SUPER Model Screening Results
A02X03 Compared to Existing Operating Plan – A01X16

Study Impact Item	Impact Difference
Difference in Days above 60,000 cfs at Van Buren	-13 days
Difference in Days above 100,000 cfs at Van Buren	+2 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.3%
Navigation Damages (%)	+0.4%
Pool Damages (%)	-0.2%
Recreation Damages (%)	-1.2%
Hydropower (Reservoirs) Damages (%)	+0.1%
Hydropower (River) Damages (%)	+0.2%

<u>Action</u>. Investigate the impacts of raising the 60,000 cfs bench by 3%.

9.2.5. <u>A02X04 – Modification Of A02X01 With The Upper Limit Of The 60,000 cfs Bench Beginning At A 3% Higher System Storage</u>. This run was made to determine the effect of raising the 60,000 cfs bench by 3%.

<u>Analysis</u>. Raising the 60,000 cfs bench by 3% decreases the number of days above 60,000 cfs by 22 days over the existing plan. The run decreases the number of days above 75,000 cfs by 8 days and decreases the number of days above 100,000 cfs by 1 day. There is no effect on the number of days above the channel capacity of 137,000 cfs.

The duration of floodwater in the lower 30% of the pools were increased by 5-15 days over the existing plan A01X16 and 2-9 days over A02X01. The amount of pool affected ranged from 5 feet in Eufaula to 16 feet in Fort Gibson. Similar to A02X01, the lower part of the pools was used more frequently, resulting in a loss of recreation and an increase in damages to in-pool facilities (primarily recreation facilities). The loss of hydropower at the storage projects is the result of restricting the releases to discharges below generation capacity.

Comparing the other impacts of this run to the existing regulation plan indicated a slight increase in overall damages to crops and structures in the Haskell area and Sallisaw area. Navigation damages decreased slightly while pool damages, recreation losses and power production at storage projects were negatively impacted. Table A-20 presents results of this analysis.

<u>Note</u>. Raising the 60,000 cfs bench by 3% has a positive impact on navigation and a negative impact on most other purposes. This change does not appear to be an option since it actually causes more damage to crops than the existing conditions run.

TABLE A-20

Summary of SUPER Model Screening Results A02X04 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-22 days
Difference in Days above 100,000 cfs at Van Buren	-1 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	+0.1%
Navigation Damages (%)	-0.9%
Pool Damages (%)	+5.0%
Recreation Damages (%)	+9.6%
Hydropower (Reservoirs) Damages (%)	+0.7%
Hydropower (River) Damages (%)	-2.5%

Action. Investigate the effect of not reducing the flood storage during the spring months.

9.2.6. A02X05 – Existing Plan With A 75,000 cfs Bench Upper Limit At 18%. This run was executed to determine the impact of changing the 75,000 cfs bench upper limit to 18%. This would evaluate the benefit of the reduction during the spring months.

Analysis. Eliminating the spring dip in the 75,000 cfs bench increases the number of days above 60,000 cfs by 4 days over the existing run. It decreases the number of days above 75,000 cfs by 1 day and decreases the number of days above 100,000 cfs by 3 days. The run has no effect on the number of days above the channel capacity of 137,000 cfs.

Comparing the other impacts of this run to the existing regulation plan indicated a slight (.5%) increase in overall damages to crops and structures, primarily in the Haskell and Sallisaw areas. There was a slight decrease in navigation damages. Pool damages and recreation losses were increased. Power production at the storage projects was negatively impacted while generation at locks and dams increased.

The amount of pool affected ranged from 4 feet in Eufaula to 12 feet in Fort Gibson. The lower part of the pools was used more frequently resulting in a loss of recreation and increasing damages to in-pool facilities (primarily recreation facilities). In addition, the loss of hydropower at the storage projects is the result of restricting the releases to discharges below generation capacity. The decrease in damages was relatively small.

The change appears to cause more damage than benefit. The lower 30% of the pools were used more frequently on the average and the upper pool was impacted only in the a few major floods (1975,1993,1995). There is probably not a reason to pursue this further until the taper operation is investigated. Table A-21 presents results of this analysis.

TABLE A-21

Summary of SUPER Model Screening Results A02X05 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	+4 days
Difference in Days above 100,000 cfs at Van Buren	-3 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	+0.5%
Navigation Damages (%)	-0.4%
Pool Damages (%)	+2.9%
Recreation Damages (%)	+4.2%
Hydropower (Reservoirs) Damages (%)	+0.6%
Hydropower (River) Damages (%)	-0.9%

Action. Investigate the affect of removing Hulah and Copan from the 11 controlling projects. Most of the runs to date indicate that Hulah and Copan are not affected by changes at Van Buren.

9.2.7. A02X06 – Existing Operating Plan With Hulah And Copan Removed From 11 Controlling Projects. This run was made to determine if Hulah and Copan were making a significant contribution to the control of flooding in the lower Arkansas. It was suspected that the restrictions at Bartlesville and Ramona were the primary control on these reservoirs.

Analysis. The removal of Hulah and Copan had little if any effect on the Van Buren flows. Comparing the other impacts of this run to the existing regulation plan indicated little or no change in overall damages to crops and structures. There was a slight increase in navigation damages. Pool damages and recreation losses were changed only slightly. Power production was not impacted.

There was little impact on the duration of the storage projects including Hulah and Copan. Removal of Hulah and Copan from the 11 controlling projects does not appear to have a significant impact on the system. Table A-22 presents results of this analysis.

TABLE A-22

Summary of SUPER Model Screening Results A02X06 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	0 days
Difference in Days above 100,000 cfs at Van Buren	0 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.1%
Navigation Damages (%)	+0.3%
Pool Damages (%)	-0.3%
Recreation Damages (%)	-0.7%
Hydropower (Reservoirs) Damages (%)	0%
Hydropower (River) Damages (%)	+0.1%

Action. Consider removal of Hulah and Copan from the system full calculation for Van Buren.

9.2.8. A02X10 – Modification Of A02X01 With The Upper Limit Of The 60,000 cfs Bench Beginning At A 3% Lower System Storage Except During June 15-October 1. This run was made to determine if the negative impact of changing the 75,000 cfs bench at Van Buren to a 60,000 cfs bench could be mitigated by lowering the point at which the 60,000 cfs bench begins as demonstrated in A02X03, but keep the 18% storage from June 15 through October 1.

Analysis. Not lowering the 60,000 cfs bench by 3% from June-October has a similar affect on the Van Buren flows as A02X03 (lowering the bench by 3% year round). The run decreases the number of days above 60,000 cfs by 14 days over the existing plan, but increased 5 days from A02X01. It increases the number of days above 75,000 cfs by 3 days and increases the number of days above 100,000 cfs by 1 day. The run has no effect on the number of days above channel capacity of 137,000 cfs.

Comparing the other impacts of this run to the existing regulation plan indicated the same less than .5% decrease in overall damages to crops and structures. There was little change in navigation damages, pool damages, recreation losses, or power production when compared to the existing plan (A01X16).

Lowering the 60,000 cfs bench by 3%, except June-October, with all other parameters remaining equal, eliminated most of the impact on the duration of floodwater being held in the pools experienced by lowering the bench from 75,000 cfs. There was only a few days increase in the lower 2-6 feet. Making an exception of June 15-October

1 in lowering the 60,000 cfs bench retains the mitigation to pool damages with little impact on other purposes. Table A-23 presents results of this analysis.

TABLE A-23

Summary of SUPER Model Screening Results A02X10 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-14 days
Difference in Days above 100,000 cfs at Van Buren	+2 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.5%
Navigation Damages (%)	-0.1%
Pool Damages (%)	+0.5%
Recreation Damages (%)	+1.8%
Hydropower (Reservoirs) Damages (%)	-0.1%
Hydropower (River) Damages (%)	-0.3%

Action. Include the reduction of the 60,000 cfs bench by 3% except for June 15-October 1 for the final runs.

9.3. Objective 3: Improve The Taper Operation

The navigation taper from 40,000 cfs to 20,000 cfs was developed during the early days of the system operation. The operation has undergone very little change during the past 30 years.

The purpose of this objective is to evaluate the present taper operation and determine if it can be improved to facilitate channel recovery operations.

9.3.1. A02X07 – Existing Operating Plan With 60,000 cfs – 20,000 cfs Taper. This simulation was made to determine if a 60,000 cfs – 20,000 cfs taper could be used in the place of the 40,000 cfs – 20,000 cfs taper, the 75,000 cfs bench, and/or the 60,000 cfs bench requested by farming interest in Arkansas.

Analysis. Eliminating the 75,000 cfs bench and tapering the target at Van Buren from 60,000 cfs – to 20,000 cfs increases the number of days above 20,000 cfs by 4 days over the existing run. It increases the number of days above 40,000 cfs by 12 days and decreases the number of days above 60,000 cfs by 18 days. The run decreases the number of days above 75,000 cfs by 4 days; increases the number of days above 100,000 cfs by 2 days; and there was little change in the number of days above 137,000 cfs.

Comparing the other impacts of this run to the existing regulation plan indicated a slight decrease in overall damages to crops and structures, but a 4% increase in the Haskell area. There was a slight decrease in navigation damages. A 4% increase in pool damages and a 6% increase in recreation losses (primarily in Fort Gibson, Oologah, Keystone, Eufaula, and Tenkiller Ferry). Power production at the storage projects was negatively impacted (1%) while generation at locks and dams increased 2%.

The amount of pool affected ranged from 5 feet in Eufaula to 12 feet in Fort Gibson. The duration ranged from 1-2 days up to 20 days. The lower part of the pools was used more frequently resulting in a loss of recreation and more damages to in-pool facilities (primarily recreation facilities).

Taper evaluation. This simulation produced more time available in the 60,000 cfs to 20,000 cfs range and indicates more days available for the removal of silt from the channels. This is shown by the increase in the number of days above 20,000 cfs by 4 days over the existing run, the increase in the number of days above 40,000 cfs by 12 day and the decrease in the number of days above 60,000 cfs by 18 day. This simulation also indicates a positive control for the farming industry since it decreases the number of days per year above 60,000 cfs. Table A-24 presents results of this analysis.

TABLE A-24

Summary of SUPER Model Screening Results
A02X07 Compared to Existing Operating Plan – A01X16

Study Impact Item	Impact Difference
Difference in Days above 60,000 cfs at Van Buren	-18 days
Difference in Days above 100,000 cfs at Van Buren	+2 days
Difference in Days above 137,000 cfs at Van Buren	+1 days
Agricultural/Structural Damages (%)	-0.2%
Navigation Damages (%)	-1.0%
Pool Damages (%)	+3.9%
Recreation Damages (%)	+6.4%
Hydropower (Reservoirs) Damages (%)	+0.9%
Hydropower (River) Damages (%)	-2.1%

Action. Investigate the affect of moving the percent full at which the taper begins.

9.3.2. <u>A02X08 – Existing Operating Plan + 60K – 20K cfs Taper Lowered 3%</u>. This simulation was made to determine if lowering the 60,000 cfs – 20,000 cfs taper could lower the impacts to the storage projects experienced in A02X07.

<u>Analysis</u>. Lowering the 60,000 cfs – to 20,000 cfs taper by 3%, increases the number of days over 20,000 cfs by 2 days over the existing run. It increases the number of days above 40,000 cfs by 7 days and decreases the number of days above 60,000 cfs by 11 days. The run decreases the number of days above 75,000 cfs by 1 day and increases the number of days above 100,000 cfs by 2 days. There was little change in the number of days above 137,000 cfs.

Comparing the other impacts of this run to the existing regulation plan indicated a slight decrease in overall damages to crops and structures with a 1% increase in the Haskell area. There was a slight decrease in navigation damages. This run resulted in a 1% increase in pool damages and a 2% increase in recreation losses (primarily in Fort Gibson, Oologah, Keystone, Eufaula, and Tenkiller Ferry). Power production at the storage projects registered a slight negative impact while generation at locks and dams increased 2%.

The amount of pool affected ranged from 3 feet in Eufaula to 8 feet in Fort Gibson. The duration ranged from 1-2 days up to 10 days. The lower part of the pools was used less than in A02X07 resulting in less damage to in-pool facilities.

<u>Taper evaluation</u>. This simulation also produced more time available in the 60,000 cfs to 20,000 cfs range, though less than run A02X07, but did indicate improved days available for the removal of silt form the channels. This is shown by the increase in the number of days above 20,000 cfs by 2 days over the existing run, the increase in the number of days above 40,000 cfs by 7 days and the decrease in the number of days above 60,000 cfs by 11 days. This simulation also indicates a positive control for the farming industry since it decreases the number of days per year above 60,000 cfs. Table A-25 presents results of this analysis.

TABLE A-25

Summary of SUPER Model Screening Results A02X08 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-11 days
Difference in Days above 100,000 cfs at Van Buren	+2 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.4%
Navigation Damages (%)	-0.4%
Pool Damages (%)	+1.1%
Recreation Damages (%)	+1.6%
Hydropower (Reservoirs) Damages (%)	+0.2%
Hydropower (River) Damages (%)	-1.0%

Action. Investigate the affect of making a 75,000 cfs to 60,000 cfs taper in the range of the 3% storage lowered in this run.

9.3.3. A02X09 – Existing Operating Plan + 75K-60K And 60K – 20K cfs Taper. This simulation was made to determine if replacing the 3% of 75,000 cfs lost in A02X08 with a 75,000 cfs to 60,000 cfs taper would give benefit without additional damages.

Analysis. Replacing the 137,000 cfs for 3% above the taper with a 75,000 cfs - 60,000 cfs taper, increases the number of days over 20,000 cfs by 2 days over the existing run. It increases the number of days above 40,000 cfs by 9 days and decreases the number of days above 60,000 cfs by 10 days. This run decreases the number of days above 75,000 cfs by 4 days, increases the number of days above 100,000 cfs by 1 day, and changes only slightly the number of days above 137,000 cfs.

Comparing the other impacts of this run to the existing regulation plan indicated a slight decrease in overall damages to crops and structures, but a 3% increase in damages in the Haskell areas. There was a slight decrease in navigation damages. A 3% increase in pool damages and a 3% increase in recreation losses (primarily in Oologah, Keystone, Eufaula and Tenkiller Ferry). Power production at the storage projects reflected a slight negative impact, while generation at locks and dams increased 2%.

The amount of pools affected, ranged from 5 feet in Eufaula to 10 feet in Fort Gibson. The duration ranged from 1-2 days up to 13 days. The lower part of the pools was used more frequently than in A02X08, but less frequently than in A02X07 as was expected.

Taper evaluation. This simulation produced similar results as A02X08 in terms of the taper operation. Table A-26 presents results of this analysis.

TABLE A-26

Summary of SUPER Model Screening Results A02X09 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-10 days
Difference in Days above 100,000 cfs at Van Buren	+1 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.4%
Navigation Damages (%)	-0.9%
Pool Damages (%)	+2.6%
Recreation Damages (%)	+3.4%
Hydropower (Reservoirs) Damages (%)	+0.4%
Hydropower (River) Damages (%)	-1.6%

Action. Unless the operations teams from Tulsa or Little Rock have additional tapers they want investigated this appears to be the best taper to insert in the final runs.

Note March 2002. After meeting with Little Rock Operations representatives it was determined that the 60,000 cfs bench was more important than the added days of taper operation. This bench would produce self-scouring in the channel and reduce the need for dredging. Therefore, it is recommended that the 60,000 cfs to 20,000 cfs taper be abandoned in the final runs.

9.4. Consolidated Simulations

Each of the objectives identified by the study team were evaluated separately to assess the impacts of individual changes on the system operation. The following simulations are a combination of the changes indicated in the screening study as possible solutions to existing problems. These runs are submitted as candidates for final analysis.

9.4.1. A02X11 – Van Buren At 175,000 cfs And Sallisaw At 175,000 cfs With 60,000 cfs Bench Replacing 75,000 cfs Bench Lowered 3% Except June15-October 1. This run was made to evaluate a combination of 175,000 cfs increase in the target flow at Van Buren and Sallisaw (A01X23) and a modified 60,000 cfs bench replacing the 75,000 cfs bench (A02X10).

Analysis. The run decreased the number of days above 60,000 cfs by 9 days per year (a 13 % improvement). It decreased the number of days above 100,000 cfs by 16 days (a 46% improvement). It decreased by 4 days the flow above 137,000 cfs (a 20% improvement). Agricultural and structural damages were found to increase approximately 3% (a similar result to A01X23.) Navigation damages decreased less than 1%. Pool damages and recreation damages increased by 3% and 8% respectively. Hydropower production was slightly lower at the storage projects (less than 1%) and increased by 3% at the hydropower lock and dams. Tables A-27 and A-28 present results of this analysis.

TABLE A-27

NUMBER OF DAYS OF DURATION ABOVE EXISTING PLAN
Columns Represent Feet Above Conservation Pool

STORAGE	0 feet	2 feet	4 feet	6 feet	8 feet	10 feet	12 feet
Gibson	1	2	6	6	2	-1	-2
Oologah	5	11	14	9	0	-1	-2
Hulah	0	0	0	0	0	0	0
Copan	1	1	1	0	0	0	0
Keystone	3	10	12	13	11	2	-1
Tenkiller	4	9	13	11	7	-1e	-2e
Eufaula	4	9	0	0	-1	0	0
Wister	3	3	2	1	0	0	-1

Note: e for Tenkiller indicates estimated values.

TABLE A-28

Summary of SUPER Model Screening Results A02X11 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-9 days
Difference in Days above 100,000 cfs at Van Buren	-16 days
Difference in Days above 137,000 cfs at Van Buren	-4 days
Agricultural/Structural Damages (%)	+3.1%
Navigation Damages (%)	-0.8%
Pool Damages (%)	+2.8%
Recreation Damages (%)	+7.8%
Hydropower (Reservoirs) Damages (%)	+0.6%
Hydropower (River) Damages (%)	-2.6%

Action. Produce data for external economic evaluation.

9.4.2. A02X12 – Van Buren At 200,000 cfs And Sallisaw At 200,000 cfs With 60,000 cfs Bench Replacing 75,000 CFS Bench Lowered 3% Except June15-October 1. This run was made to evaluate a combination of 200,000 cfs increase in target at Van Buren and Sallisaw (A01X18) and a modified 60,000 cfs bench replacing the 75,000 cfs bench (A02X10).

Analysis. The run decreased the number of days above 60,000 cfs by 9 days per year (a 13 % improvement). It decreased the number of days above 100,000 cfs by 17 days (a 48% improvement). It decreased by 5 days the flow above 137,000 cfs (a 26% improvement). Agricultural and structural damages were found to increase approximately 7% (a similar result to A01X18.) Navigation damages decreased slightly. Pool damages and recreation damages increased by 1% and 6% respectively. Hydropower production was 1% lower at the storage projects and increased by 3% at the hydropower lock and dams. Tables A-29 and A-30 present results of this analysis.

TABLE A-29

NUMBER OF DAYS OF DURATION ABOVE EXISTING PLAN
Columns Represent Feet Above Conservation Pool

STORAGE	0 feet	2 feet	4 feet	6 feet	8 feet	10 feet	12 feet
Gibson	1	2	5	4	1	-2	-3
Oologah	5	11	12	7	-1	-2	-2
Hulah	1	1	1	1	1	1	1
Copan	1	1	0	0	0	0	0
Keystone	3	10	11	11	8	0	-2
Tenkiller	4	8	8	3	-1	-5e	-4e
Eufaula	4	6	-1	-1	-1	-1	0
Wister	2	3	1	-1	-1	-1	-1

Note: e for Tenkiller indicates estimated values.

TABLE A-30

Summary of SUPER Model Screening Results A02X12 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-9 days
Difference in Days above 100,000 cfs at Van Buren	-17 days
Difference in Days above 137,000 cfs at Van Buren	-5 days
Agricultural/Structural Damages (%)	+7.0%
Navigation Damages (%)	-0.6%
Pool Damages (%)	+1.1%
Recreation Damages (%)	+5.6%
Hydropower (Reservoirs) Damages (%)	+0.8%
Hydropower (River) Damages (%)	-2.8%

Action. Produce data for external economic evaluation.

9.4.3. A02X13 – Existing Plan With A Modified 60,000 cfs Bench In Place Of The 75,000 cfs Bench And Filling Behind The Flood When The Flow Reaches 150,000-250,000 cfs And The System Storage Exceeds 75%. This run titled A02X13 was made to determine the impacts of a 60,000 cfs bench replacing the 75,000 cfs bench combined with filling in behind the flood hydrograph when the flow reach 150,000 – 250,000 cfs and the system percent storage exceeds 75 percent.

NOTE: This is similar to a plan identified in the 1989 report but never implemented.

Analysis. The analysis indicated approximately 15 days reduction in flows above 60,000 cfs. It also produced less than 1 day increase in flows above 100,000 cfs at Van Buren compared to A01X16 (existing operation plan). It also showed an increase above 175,000 cfs of less than 1 day and essentially no change at 137,000 cfs (channel capacity). There was decreased duration in the upper limits of the flood pools from run A01X16. There was an increase in duration of storage in the lower 2-6 feet of the pools at the storage projects.

The analysis indicated less than 1% increase in overall damages to crops and structures and less than 1% decrease in power production from A01X16. Navigation and in pool damages had negligible changes. Table A-31 presents results of this analysis.

TABLE A-31

Summary of SUPER Model Screening Results
A02X13 Compared to Existing Operating Plan – A01X16

Study Impact Item	Impact Difference
Difference in Days above 60,000 cfs at Van Buren	-15 days
Difference in Days above 100,000 cfs at Van Buren	+1 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	+0.4%
Navigation Damages (%)	-0.3%
Pool Damages (%)	+0.2%
Recreation Damages (%)	+1.1%
Hydropower (Reservoirs) Damages (%)	+0.7%
Hydropower (River) Damages (%)	-0.7%

Note. This run had minor negative affects on the project purposes. The run had three positive changes:

1. The reduction of 15 days above 60,000 cfs (a key level for farming interest in Arkansas).
2. An increase in days between 40,000 cfs and 60,000 cfs (key to scouring flows in the navigation system).
3. In addition, this run accelerated the evacuation of the storage projects when the system percent full exceeds 75%.

10. STUDY RESULTS

The screening study resulted in the identification of four possible plans of operation, other than the existing operating plan. Two of the plans (A02X11 and A02X12) require increasing channel capacity in the lower Arkansas basin. This could require easements, flood proofing or some other method of mitigation.

The third possible plan of operation (A02X13) modifies the existing plan by replacing the 75,000 cfs bench with 60,000 cfs and by filling in behind the flood hydrograph when the system percent storage exceeds 75 percent.

The fourth possible plan of operation (A02X10) modifies the existing plan by replacing the 75,000 cfs bench with a 60,000 cfs bench starting 3% lower than the current plan of operations except June 15-October 1.

Each of these plans is to be analyzed economically using various analysis tools. Part 3 of this appendix, describes how data was prepared from these four plans and the No Action Plan to be used for plan formulation and evaluation.

Each of these simulations were compared to the existing plan of operation (A01X16.) Short summaries of the plans are as follows:

10.1. A01X16 Existing Operating Plan

A simulation, using the existing operating plan, was performed with the updated period of record hydrology (January 1940 – December 2000) and updated power loads furnished by SWPA. The run established a base condition to which all other simulations were compared. The Van Buren Guide Curve for the Existing Operation is presented in Figure A-6.

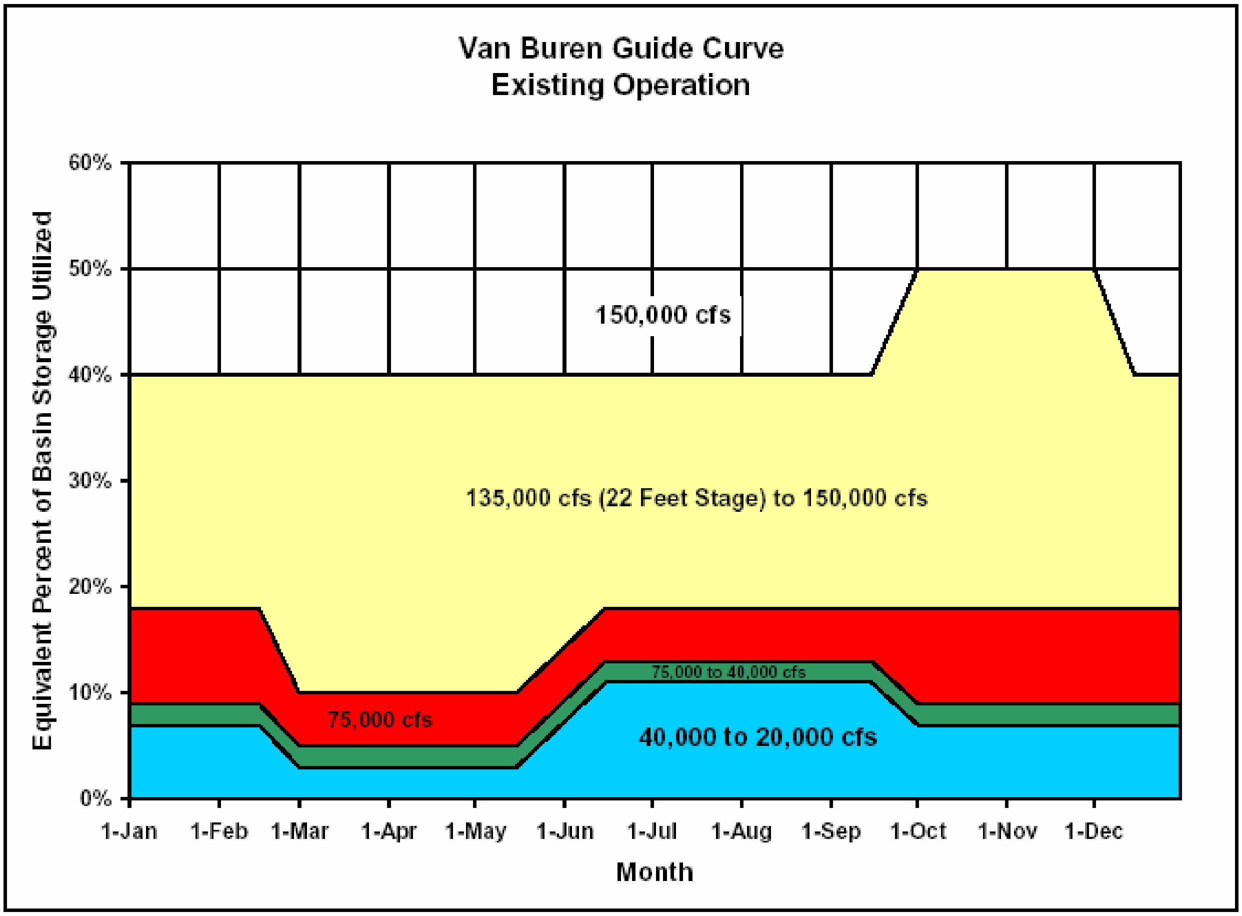


Figure A-6

10.2. A02X11 – Van Buren At 175,000 Cfs And Sallisaw At 175,000 Cfs With 60,000 Cfs Bench Replacing 75,000 Cfs Bench Lowered 3% Except June15-October 1

This run was made to evaluate a combination of 175,000 cfs increase in the target flow at Van Buren and Sallisaw (A01X23) and a modified 60,000 cfs bench replacing the 75,000 cfs bench (A02X10). Table A-32 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-7.

TABLE A-32

Summary of SUPER Model Screening Results A02X11 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-9 days
Difference in Days above 100,000 cfs at Van Buren	-16 days
Difference in Days above 137,000 cfs at Van Buren	-4 days
Agricultural/Structural Damages (%)	+3.1%
Navigation Damages (%)	-0.8%
Pool Damages (%)	+2.8%
Recreation Damages (%)	+7.8%
Hydropower (Reservoirs) Damages (%)	+0.6%
Hydropower (River) Damages (%)	-2.6%

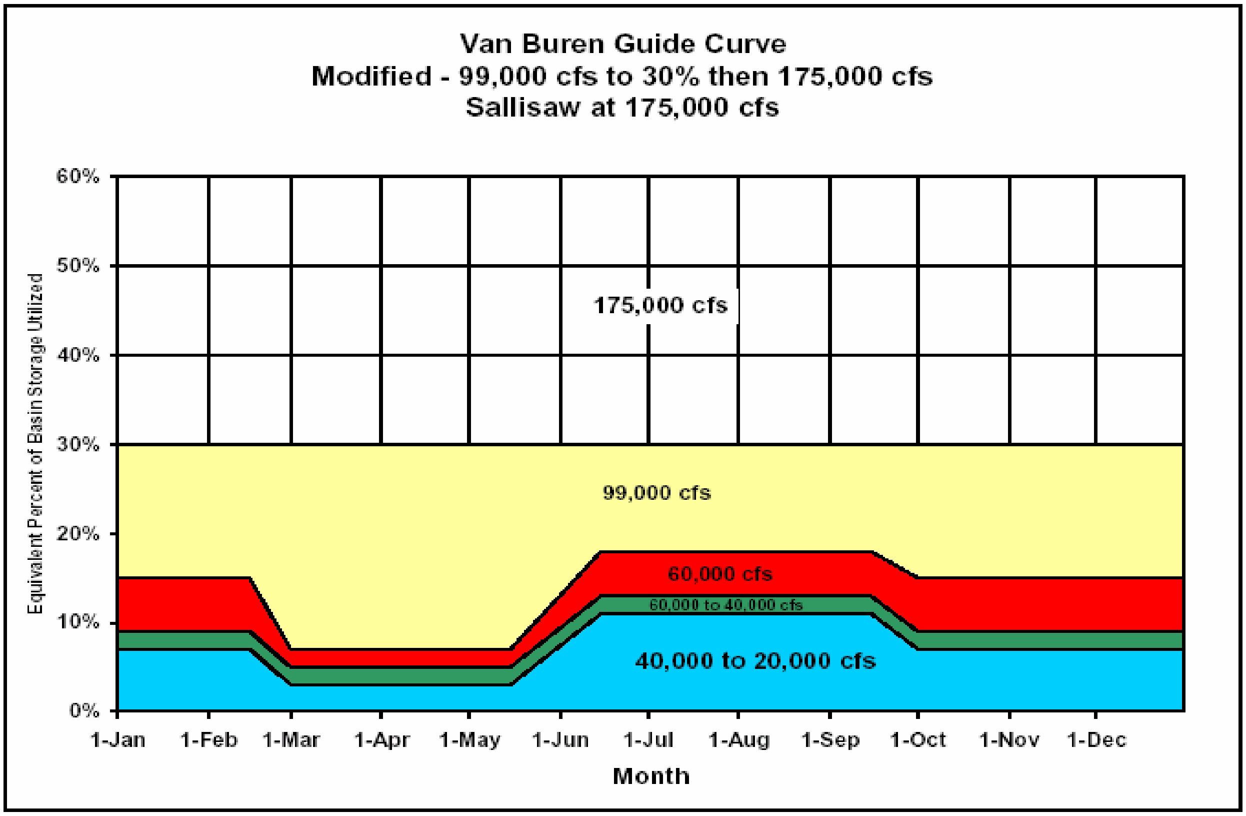


Figure A-7

10.3. A02X12 – Van Buren At 200,000 Cfs And Sallisaw At 200,000 Cfs With 60,000 Cfs Bench Replacing 75,000 Cfs Bench Lowered 3% Except June15-October 1

This run was made to evaluate a combination of 200,000 cfs increase in target at Van Buren and Sallisaw (A01X18) and a modified 60,000 cfs bench replacing the 75,000 cfs bench (A02X10). Table A-33 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-8.

TABLE A-33

Summary of SUPER Model Screening Results A02X12 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-9 days
Difference in Days above 100,000 cfs at Van Buren	-17 days
Difference in Days above 137,000 cfs at Van Buren	-5 days
Agricultural/Structural Damages (%)	+7.0%
Navigation Damages (%)	-0.6%
Pool Damages (%)	+1.1%
Recreation Damages (%)	+5.6%
Hydropower (Reservoirs) Damages (%)	+0.8%
Hydropower (River) Damages (%)	-2.8%

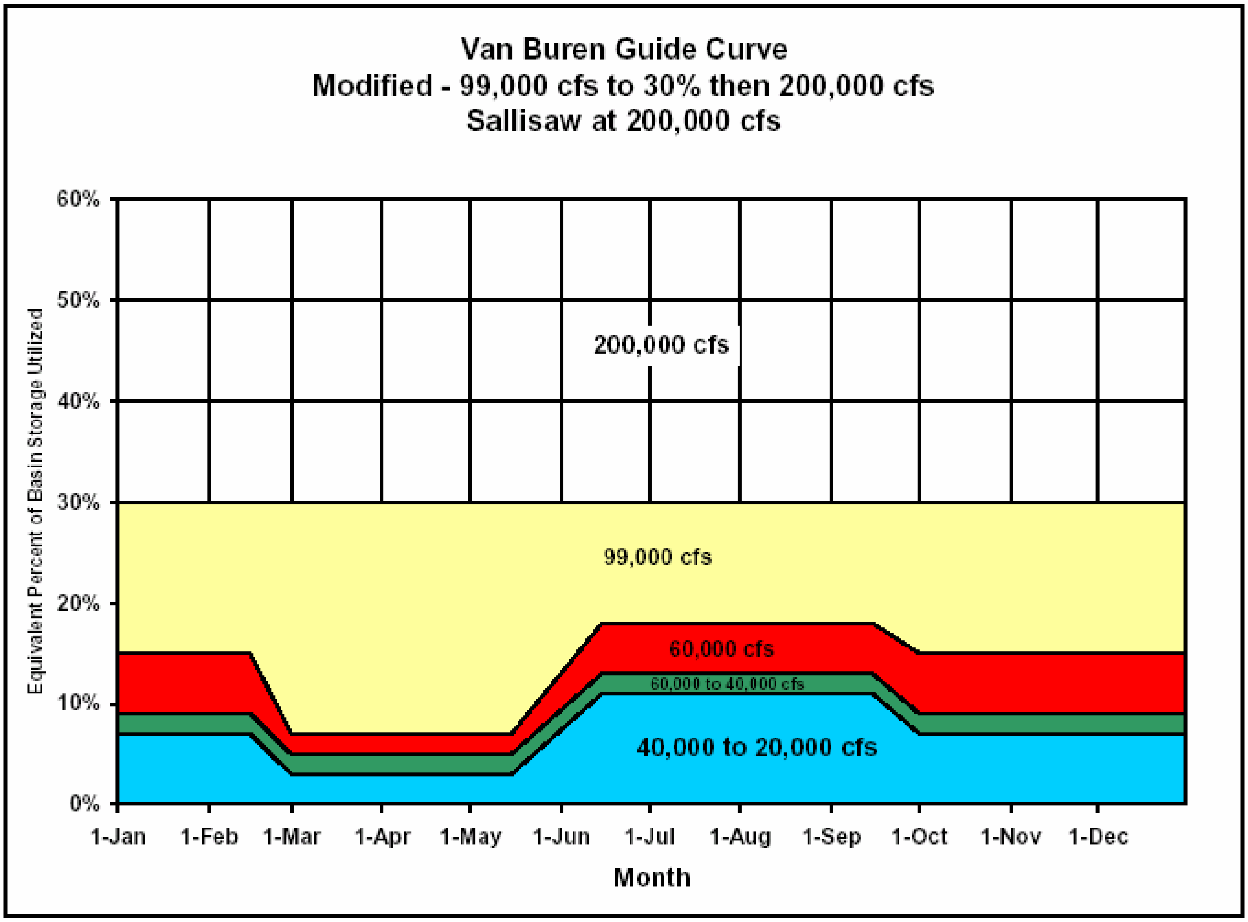


Figure A-8

10.4. A02X13 – Existing Plan With A Modified 60,000 Cfs Bench In Place Of The 75,000 Cfs Bench And Filling Behind The Flood When The Flow Reaches 150,000-250,000 Cfs And The System Storage Exceeds 75%

This run titled A02X13 was made to determine the impacts of a 60,000 cfs bench replacing the 75,000 cfs bench combined with filling in behind the flood hydrograph when the flow reach 150,000 – 250,000 cfs and the system percent storage exceeds 75 percent. Table A-34 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-9.

TABLE A-34

Summary of SUPER Model Screening Results A02X13 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-15 days
Difference in Days above 100,000 cfs at Van Buren	+1 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	+0.4%
Navigation Damages (%)	-0.3%
Pool Damages (%)	+0.2%
Recreation Damages (%)	+1.1%
Hydropower (Reservoirs) Damages (%)	+0.7%
Hydropower (River) Damages (%)	-0.7%

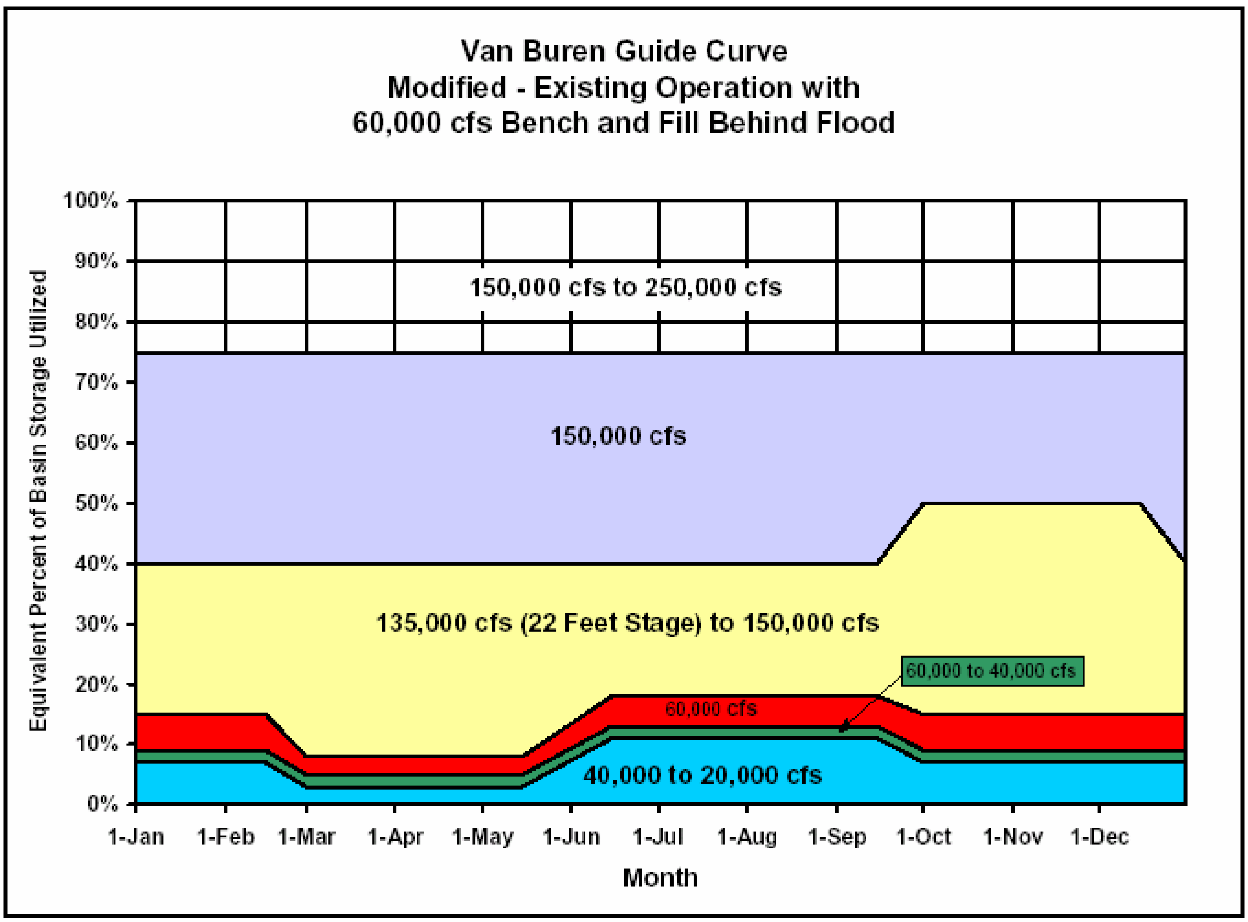


Figure A-9

10.5. A02X10 – Modification of A02x01 with the Upper Limit Of the 60,000 Cfs Bench Beginning At A 3% Lower System Storage Except During June 15-October 1

This run was made to determine if the negative impact of changing the 75,000 cfs bench at Van Buren to a 60,000 cfs bench could be mitigated by lowering the point at which the 60,000 cfs bench begins as demonstrated in A02X03, but keep the 18% storage from June 15 through October 1. Table A-35 presents results of this analysis. The Van Buren Guide Curve for this plan is presented in Figure A-10.

TABLE A-35

Summary of SUPER Model Screening Results A02X10 Compared to Existing Operating Plan – A01X16	
Study Impact Item	**Impact Difference**
Difference in Days above 60,000 cfs at Van Buren	-14 days
Difference in Days above 100,000 cfs at Van Buren	+2 days
Difference in Days above 137,000 cfs at Van Buren	0 days
Agricultural/Structural Damages (%)	-0.5%
Navigation Damages (%)	-0.1%
Pool Damages (%)	+0.5%
Recreation Damages (%)	+1.8%
Hydropower (Reservoirs) Damages (%)	-0.1%
Hydropower (River) Damages (%)	-0.3%

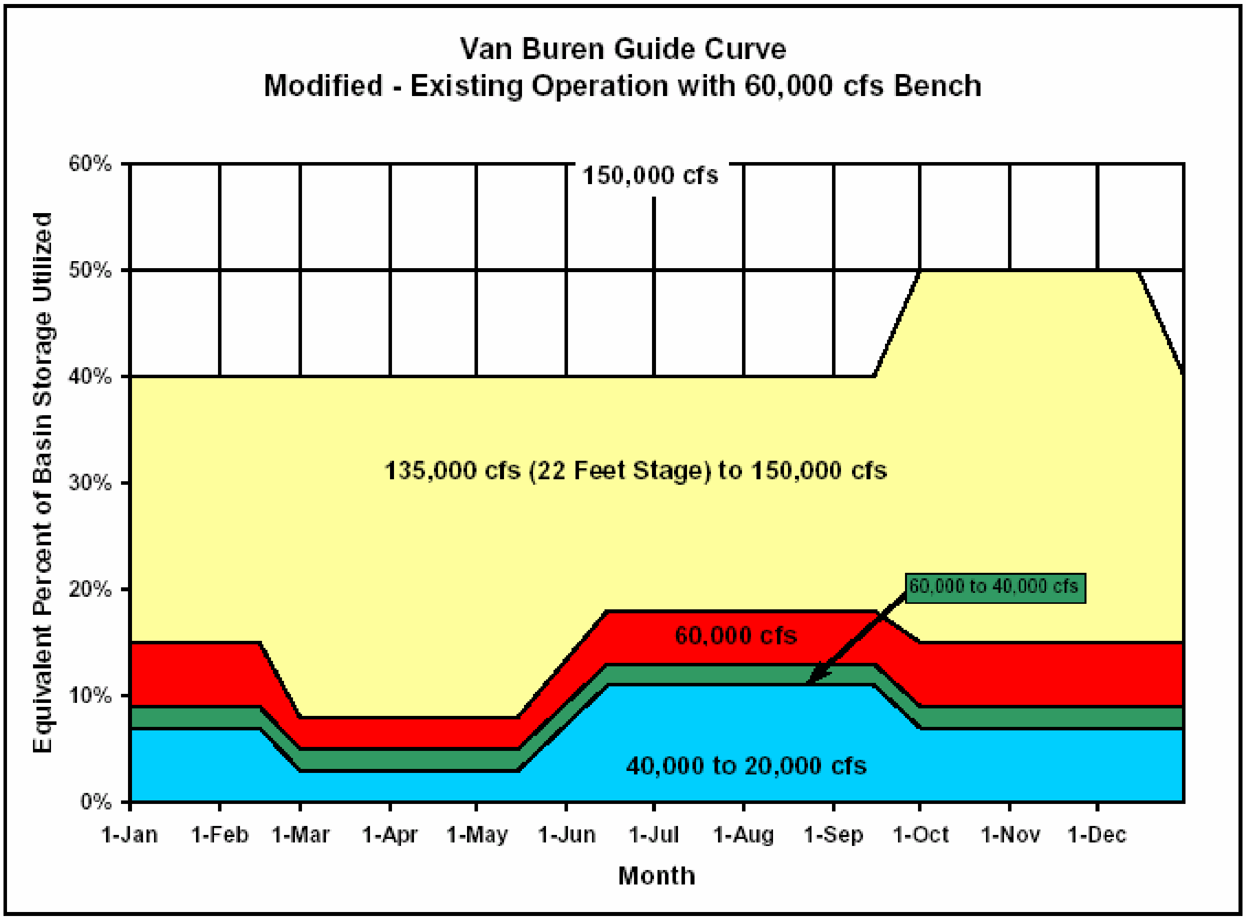

Van Buren Guide Curve
Modified - Existing Operation with 60,000 cfs Bench
150,000 cfs
135,000 cfs (22 Feet Stage) to 150,000 cfs
60,000 to 40,000 cfs
60,000 cfs
40,000 to 20,000 cfs
Equivalent Percent of Basin Storage Utilized
60%
50%
40%
30%
20%
10%
0%
1-Jan
1-Feb
1-Mar
1-Apr
1-May
1-Jun
1-Jul
1-Aug
1-Sep
1-Oct
1-Nov
1-Dec
Month

Figure A-10

APPENDIX A

ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA
HYDROLOGIC AND HYDRAULIC ANALYSIS

PART 3 – TULSA DISTRICT HYDROLOGIC ANALYSIS

11. GENERAL

The purpose of this section of the appendix is to present the results of the detailed hydrologic analysis performed on the No Action Plan and the four possible plans of operation as described in Part 2. This section presents the methods used in developing the frequency and duration relationships, the procedures used in determining the real estate requirements, and the techniques used in evaluating risk and uncertainty.

12. DISCHARGE FREQUENCY RELATIONSHIPS

12.1. General

Discharge frequency relationships at control point locations were developed using techniques defined in EM 1110-2-1415 entitled “Hydrologic Frequency Analysis”, dated March 5, 1993. The control point locations were determined based upon available data from the Arkansas River System model developed for SUPER. SUPER, as described in Part 2, is a system of linked computer programs that have been designed to perform and analyze a “period of record” simulation for a specific system of multipurpose reservoirs using various plans of regulation.

The Arkansas River System model is made up of 21 multipurpose storage reservoirs and 50 control points. The hydrologic period of simulation for this study is January 1940 through December 2000 or 61 years of daily records (22,282 days).

The Arkansas River Basin is a basin that has changed dramatically over the last 65 years. The first reservoir was completed in 1940 and the latest project (Montgomery Point Lock and Dam) was completed in 2004. The guidelines presented in EM 1110-2-1415 states that frequency and duration studies must be performed using uniform data. Since the Arkansas River Basin has changed so much since 1940, the data recorded at gage locations during this period would not be uniform. In order to perform frequency and duration studies, the gage data must be modified to represent a uniform condition in the basin. This in the purpose of the Arkansas River System model developed for SUPER. The model changes the long-term gage records by simulating the operations of the many reservoirs in the basin and producing a modified period of record for each control point. Using this modified period of record at the control points, frequency and durations studies can be performed which conforms to the EM 1110-2-1415 guidelines.

One of the tables that were produced using SUPER is the Annual Series and Partial Duration Series Peak Flow Data Table. An example of this table is presented in Table A-36. This table contains the annual peak flow and the date the peak occurred as well as the partial duration peak flows and the date the partial duration peak occurred. This instantaneous peak value is computed by applying an adjustment factor, built into SUPER, to the maximum 24-hour flow. The adjustment factor was developed by correlating peak discharges with daily flows at gaged sites using linear correlation techniques. This adjustment factor was also applied to the partial duration series values. Since the period of record contained 61 years, each series contains 61 peak values. The peak values are the largest values from each year of record. The partial series values are the top 61 peak values above a set base occurring anytime during the 61-year period. Each of the peak values, for each series, are ordered from largest to smallest. The median plotting position formula was used to compute the percent chance exceedance for each peak. The median plotting position formula is as follows:

$$\mathbf{P_m = 100 \times \frac{(m - 0.3)}{(N + 0.4)}}$$

m = the order number of the event
N = the number of events

TABLE A-36

CONTROL POINT NO. 48			VAN BUREN					EXISTING	
ANNUAL SERIES AND PARTIAL DURATION SERIES PEAK FLOW DATA									
<-------------------------------ANNUAL SERIES DATA ---------------------->					<--------------------------PARTIAL DURATION SERIES DATA--------->				
←CHRONOLOGICAL DATA→		<----------ORDERED DATA------------->			←CHRONOLOGICAL DATA→		<---------ORDERED DATA------------>		
DATE	DISCHARGE (CFS)	DATE	DISCHARGE (CFS)	PLOTTING POSITION	DATE	DISCHARGE (CFS)	DATE	DISCHARGE (CFS)	PLOTTING POSITION
18-Aug-40	60851	23-May-43	488995	0.011	19-Apr-41	156061	23-May-43	488995	0.011
2-Nov-41	169622	4-May-90	396032	0.028	2-Nov-41	169622	4-May-90	396032	0.028
27-Apr-42	150224	7-Oct-86	307892	0.044	27-Apr-42	150224	7-Oct-86	307892	0.044
23-May-43	488995	15-Apr-45	271241	0.060	24-Jun-42	135236	15-Apr-45	271241	0.060
6-May-44	140718	15-Jun-95	262628	0.076	23-May-43	488995	15-Jun-95	262628	0.076
15-Apr-45	271241	11-May-93	252764	0.093	6-May-44	140718	11-May-93	252764	0.093
14-Dec-46	122603	11-May-50	251568	0.109	15-Apr-45	271241	11-May-50	251568	0.109
17-May-47	143224	4-Jun-57	249968	0.125	29-Apr-47	135228	4-Jun-57	249968	0.125
7-Jul-48	150335	25-Nov-73	249453	0.142	17-May-47	143224	25-Nov-73	249453	0.142
14-Jun-49	150185	16-Dec-92	214910	0.158	7-Jul-48	150335	16-Dec-92	214910	0.158
11-May-50	251568	24-Feb-85	210958	0.174	14-Feb-49	137450	24-Feb-85	210958	0.174
12-Jul-51	150090	5-Jan-98	188893	0.190	14-Jun-49	150185	19-Nov-85	192810	0.190
24-Apr-52	105982	5-Nov-74	187827	0.207	11-May-50	251568	5-Jan-98	188893	0.207
13-May-53	80500	27-Apr-99	183899	0.223	2-Aug-50	135231	5-Nov-74	187827	0.223
3-May-54	88871	1-May-70	177961	0.239	17-Sep-50	144680	27-Apr-99	183899	0.239
22-Mar-55	59100	2-Nov-41	169622	0.256	21-Feb-97	136361	1-May-70	177961	0.256
18-May-56	17929	6-May-61	169253	0.272	12-Jul-51	150090	2-Nov-41	169622	0.272
4-Jun-57	249968	21-Apr-76	166051	0.288	28-Apr-57	135181	6-May-61	169253	0.288
15-Jul-58	135057	20-May-60	160772	0.305	4-Jun-57	249968	25-Mar-73	168880	0.305
5-Nov-59	152777	25-Dec-97	159350	0.321	25-Nov-96	145700	21-Apr-76	166051	0.321
20-May-60	160772	22-Jun-00	156330	0.337	5-Nov-59	152777	15-Apr-93	161139	0.337
6-May-61	169253	10-Dec-71	153692	0.353	20-May-60	160772	20-May-60	160772	0.353
27-Mar-62	72189	28-Mar-75	153312	0.370	22-Jun-00	156330	22-Jun-00	156330	0.370
14-Mar-63	22715	21-Mar-68	153072	0.386	6-May-61	169253	19-Apr-41	156061	0.386
6-Apr-64	79880	5-Nov-59	152777	0.402	21-Mar-68	153072	19-Oct-85	154478	0.402
8-Apr-65	122999	7-Jul-48	150335	0.419	15-Jun-95	262628	10-Dec-71	153692	0.419
25-Apr-66	75106	7-Mar-87	150225	0.435	1-May-70	177961	28-Mar-75	153312	0.435
8-Jul-67	61714	6-Apr-88	150224	0.451	10-Dec-71	153692	21-Mar-68	153072	0.451
21-Mar-68	153072	27-Apr-42	150224	0.467	25-Mar-73	168880	5-Nov-59	152777	0.467
25-Mar-69	135144	14-Jun-49	150185	0.484	25-Nov-73	249453	17-Mar-98	152118	0.484
1-May-70	177961	12-Jul-51	150090	0.500	5-May-94	146403	1-May-85	151549	0.500
10-Dec-71	153692	5-May-94	146403	0.516	12-Mar-74	150232	7-Jul-48	150335	0.516
14-Nov-72	135135	25-Nov-96	145700	0.533	2-May-74	135180	12-Mar-74	150232	0.533
25-Nov-73	249453	17-May-47	143224	0.549	8-Jun-74	150223	7-Mar-87	150225	0.549
5-Nov-74	187827	6-May-44	140718	0.565	5-Nov-74	187827	6-Apr-88	150224	0.566
28-Mar-75	153312	8-Jun-82	140696	0.581	23-Feb-75	135941	27-Apr-42	150224	0.582
21-Apr-76	166051	13-Jun-89	135447	0.598	28-Mar-75	153312	5-Jul-99	150223	0.598
28-Mar-77	102157	15-Apr-84	135153	0.614	18-Jun-75	135271	8-Jun-74	150223	0.615
28-Mar-78	110695	25-Mar-69	135144	0.630	21-Apr-76	166051	14-Jun-49	150185	0.631
12-Jun-79	95456	14-Nov-72	135135	0.647	5-Jan-98	188893	26-Dec-87	150144	0.648
28-Apr-80	75137	22-Dec-91	135131	0.663	27-Apr-99	183899	12-Jul-51	150090	0.664
10-Nov-81	56072	7-Apr-83	135073	0.679	8-Jun-82	140696	5-May-94	146403	0.680
8-Jun-82	140696	15-Jul-58	135057	0.695	5-Jul-99	150223	2-Jan-85	146146	0.697
7-Apr-83	135073	8-Apr-65	122999	0.712	2-Jan-85	146146	25-Nov-96	145700	0.713
15-Apr-84	135153	14-Dec-46	122603	0.728	24-Feb-85	210958	17-Sep-50	144680	0.730
24-Feb-85	210958	28-Mar-78	110695	0.744	1-May-85	151549	17-May-47	143224	0.746
7-Oct-86	307892	24-Apr-52	105982	0.761	12-Jun-85	135212	6-May-44	140718	0.762
7-Mar-87	150225	28-Mar-77	102157	0.777	19-Oct-85	154478	8-Jun-82	140696	0.779
6-Apr-88	150224	12-Jun-79	95456	0.793	19-Nov-85	192810	14-Feb-49	137450	0.795
13-Jun-89	135447	3-May-54	88871	0.810	7-Oct-86	307892	21-Feb-97	136361	0.811
4-May-90	396032	13-May-53	80500	0.826	7-Mar-87	150225	23-Feb-75	135941	0.828
22-Dec-91	135131	6-Apr-64	79880	0.842	30-May-87	135444	21-Jan-93	135860	0.844
16-Dec-92	214910	28-Apr-80	75137	0.858	26-Dec-87	150144	13-Jun-89	135447	0.861
11-May-93	252764	25-Apr-66	75106	0.875	6-Apr-88	150224	30-May-87	135444	0.877
5-May-94	146403	27-Mar-62	72189	0.891	13-Jun-89	135447	18-Jun-75	135271	0.893
15-Jun-95	262628	8-Jul-67	61714	0.907	17-Mar-98	152118	24-Jun-42	135236	0.910
25-Nov-96	145700	18-Aug-40	60851	0.924	4-May-90	396032	2-Aug-50	135231	0.926
25-Dec-97	159350	22-Mar-55	59100	0.940	16-Dec-92	214910	29-Apr-47	135228	0.943
5-Jan-98	188893	10-Nov-81	56072	0.956	21-Jan-93	135860	12-Jun-85	135212	0.959
27-Apr-99	183899	14-Mar-63	22715	0.972	15-Apr-93	161139	28-Apr-57	135181	0.975
22-Jun-00	156330	18-May-56	17929	0.989	11-May-93	252764	2-May-74	135180	0.992

12.2. Graphical Frequency Analysis

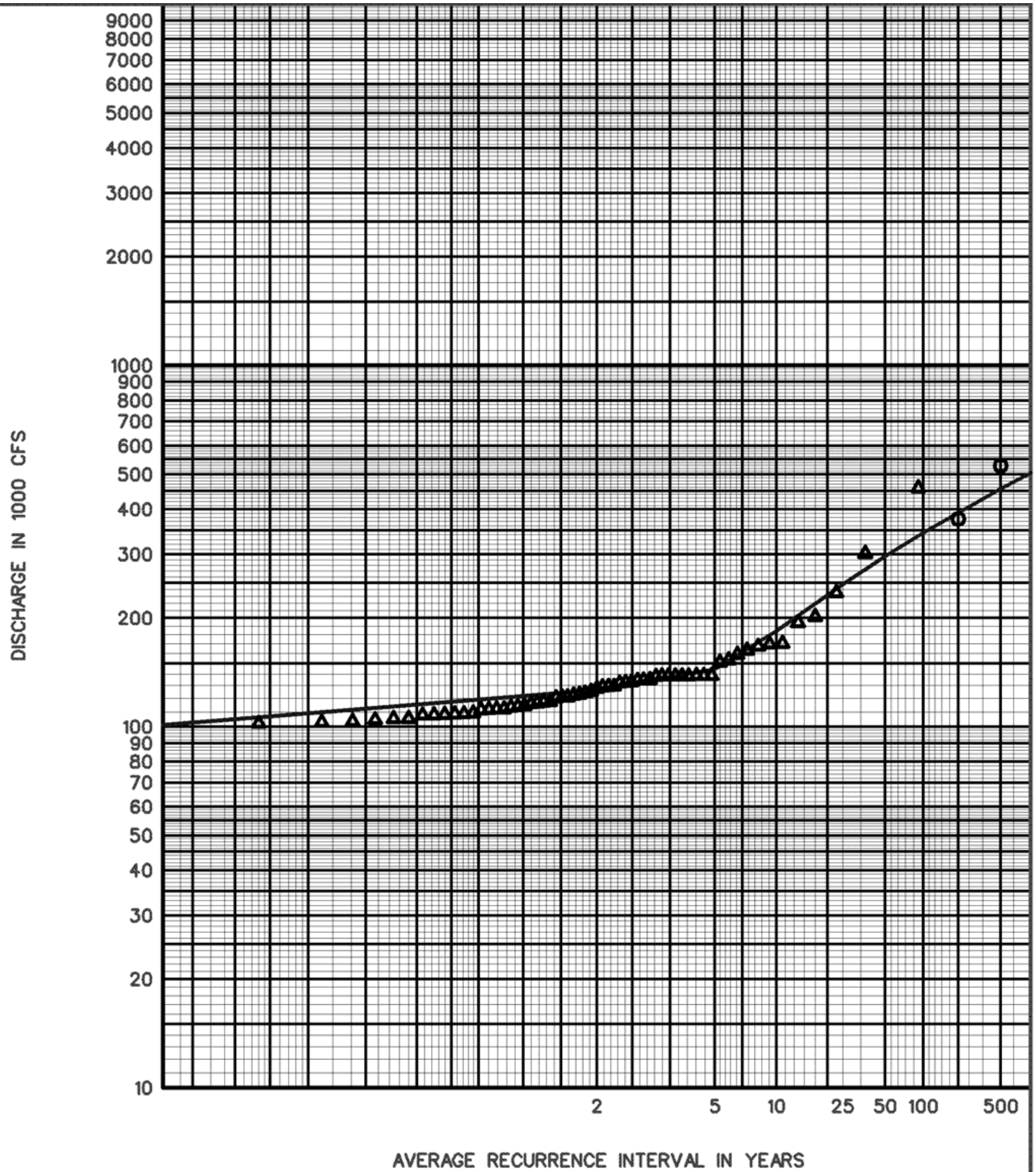
In order to use analytical methods to obtain discharge frequency relationships, the flows must be unregulated by manmade storage or diversion structure. Since the Arkansas River basin is highly regulated by many reservoirs, analytical methods could not be used to derive discharge frequency relationships. Therefore, the graphical method was used to obtain discharge frequency curves. Using this method, the partial series peak discharges were graphed against the plotting positions using probability scaled graph paper. A best-fit smooth curve was drawn through the points and extrapolated to obtain smaller exceedance probabilities. From this curve, discharges for selected return intervals were obtained. The return intervals used in this study were, 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 500-year, and 1000-year.

12.2.1. <u>Baseline Year 2000 Operating Conditions – No Action Plan</u>. The No Action Plan, the SUPER (A01X16) run, is the existing operating plan for the Arkansas River system as previously described. Graphical frequency curves were developed for this plan using the plotting positions and discharges from the Annual Series and Partial Duration Series Peak Flow Data tables generated by SUPER. Table A-37 lists the discharge location and the adopted frequency discharge relationships for this plan. Figures A-11 to A-13 present graphs of the points representing plotting position versus discharge and the adopted frequency curve at the Muskogee, Sallisaw, and Van Buren locations. The different plans focus on changing the regulation discharge at Van Buren. Therefore, all differences in frequency discharges are for values that have frequencies around the chosen regulating discharge, which is less than the 10% exceedance for all plans.

TABLE A-37

ARKANSAS RIVER – BASELINE YEAR 2000 OPERATING CONDITIONS – NO ACTION PLAN

	Discharge (cfs)								
	Exceedance Frequency / Return Interval								
	0.999	0.5	0.2	0.1	0.04	0.02	0.01	0.002	0.001
Control Point	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	1000-yr
Fort Gibson Outflow	67500	80600	89600	92900	94900	95500	115900	159100	177700
Oologah Outflow	29500	29900	30100	30100	30200	30300	32100	36300	38100
Hulah Outflow	4000	5500	6500	6500	6500	22700	52900	122900	153100
Copan Outflow	3000	3000	3000	3000	6100	10700	18700	68200	119000
Tenkiller Outflow	13500	13500	13500	13500	13500	13500	16500	84300	103300
Eufaula Outflow	40000	40000	40000	40000	63800	116200	156800	199200	205300
Wister Outflow	6600	6600	6600	6600	16300	23600	31000	48100	55400
Caney River at Bartlesville, OK	6000	8000	9500	12400	21800	33400	51300	138500	212500
Caney River at Ramona, OK	10400	13300	20200	27800	42600	58700	80800	170300	234700
Bird Creek near Sperry, OK	9300	12600	18800	24300	34400	44600	58000	106400	138200
Verdigris River near Claremore, OK	28900	32100	34100	34800	54900	108800	162700	287900	341900
Verdigris River near Inola, OK	32300	37300	45300	52300	107200	162200	217200	345000	400000
Poteau River at Poteau, OK	8800	11300	15700	20200	28100	36100	46300	82700	106100
Poteau River at Panama, OK	20200	26000	36200	46600	64900	83500	107400	192700	247800
Arkansas River at Tulsa, OK	71000	83200	90500	92900	116700	148500	180300	254000	285800
Arkansas River at Haskell, OK	49500	60700	79500	97500	127600	154900	178700	233800	257500
Arkansas River at Muskogee, OK	101200	126500	144600	184300	248100	296400	344700	456700	505000
Arkansas River at Sallisaw, OK	137000	148700	165800	240700	324100	387300	450400	597000	660100
Arkansas River at Van Buren, AR	132700	153400	195100	256700	338200	399800	461400	604500	666200



EXCEEDENCE PROBABILITY

△ SUPER SIMULATED HISTORICAL EVENTS

O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

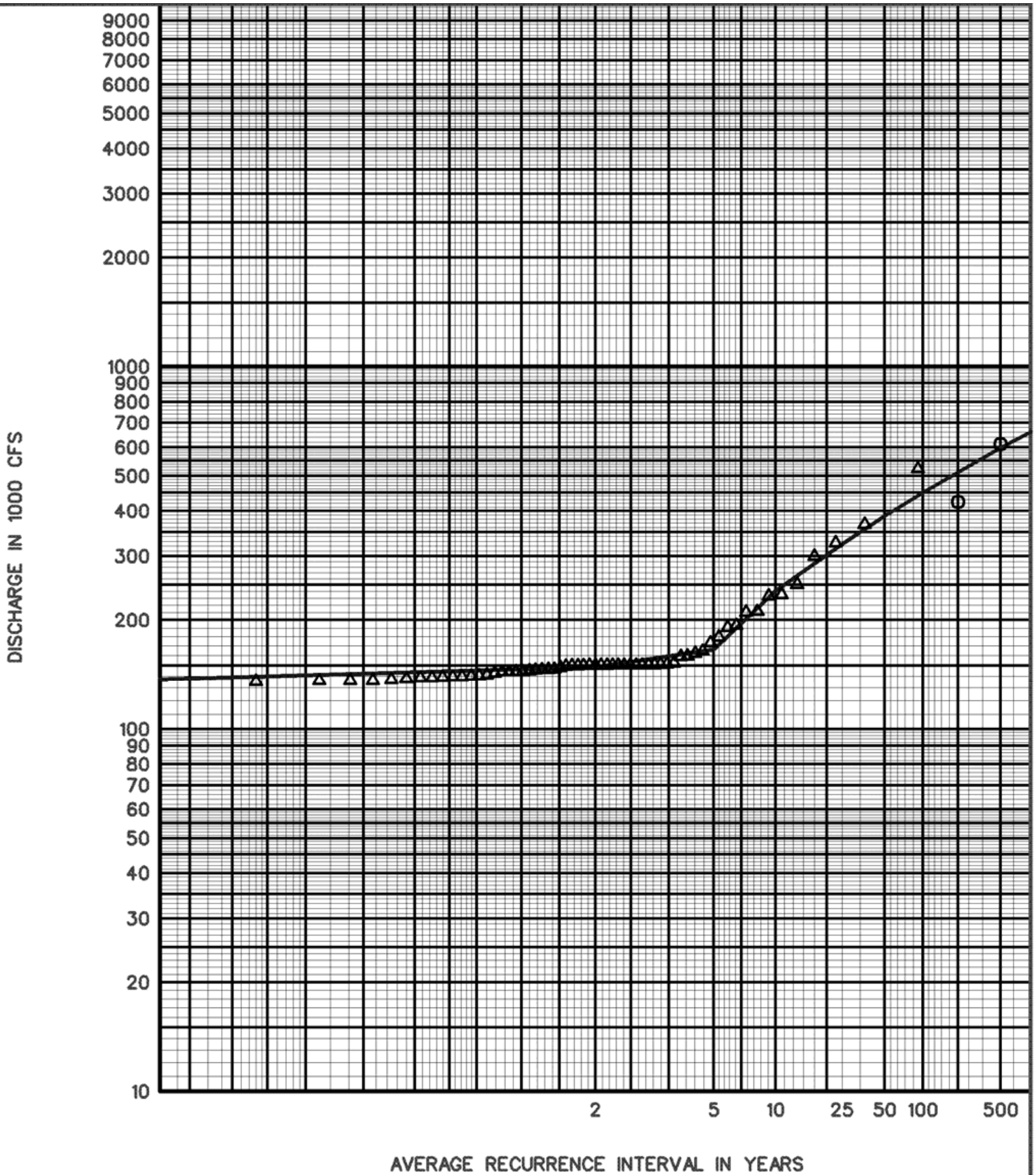
ARKANSAS RIVER AT MUSKOGEE, OK

EXCEEDENCE PROBABILITY CURVES

BASELINE YEAR 2000 OPERATING CONDITIONS - NO ACTION PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-11



EXCEEDENCE PROBABILITY
△ SUPER SIMULATED HISTORICAL EVENTS
O SUPER HYPOTHETICAL EVENTS

NOTE:
1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

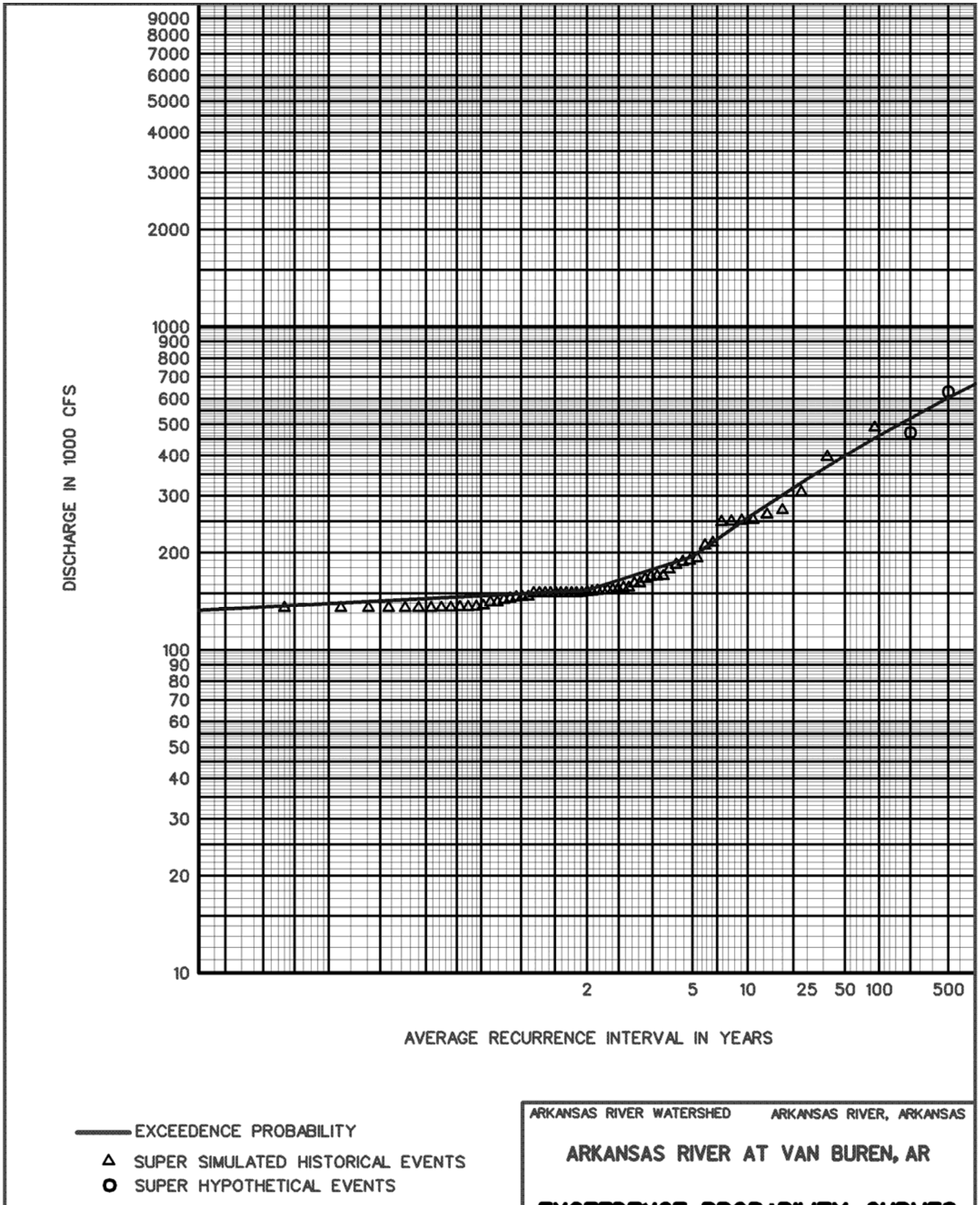
ARKANSAS RIVER AT SALLISAW, OK

EXCEEDENCE PROBABILITY CURVES

BASELINE YEAR 2000 OPERATING CONDITIONS - NO ACTION PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-12



NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, ARKANSAS

ARKANSAS RIVER AT VAN BUREN, AR

EXCEEDENCE PROBABILITY CURVES

BASELINE YEAR 2000 OPERATING CONDITIONS - NO ACTION PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

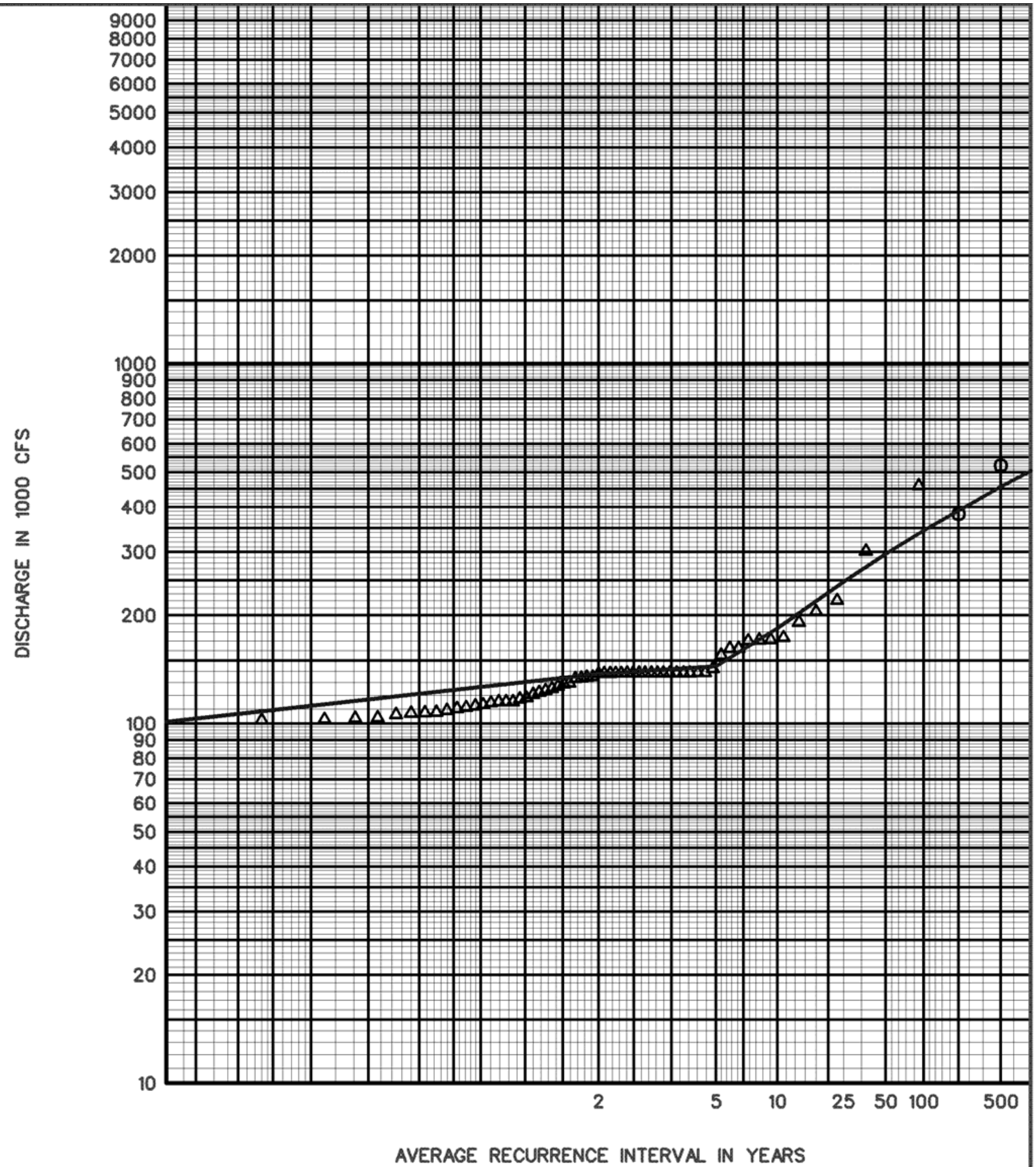
Figure A-13

12.2.2. <u>175,000 cfs Plan</u>. The 175,000 cfs Plan, the SUPER run (A02X11), increases the regulation discharge at Van Buren, Arkansas to 175,000 cfs and includes the 60,000 cfs bench. Graphical frequency curves were developed for this plan using the plotting positions and discharges from the Annual Series and Partial Duration Series Peak Flow Data tables generated by SUPER. Table A-38 lists the discharge location and the adopted frequency discharge relationships for this plan. Figures B14 to B16 present graphs of the points representing plotting position versus discharge and the adopted frequency curve at the Muskogee, Sallisaw, and Van Buren locations. The only differences in discharges between this plan and the No Action Plan are at the Muskogee, Sallisaw, and Van Buren locations and at frequencies less than the 10% exceedance or 10-year event.

TABLE A-38

ARKANSAS RIVER – 175,000 CFS PLAN

	Discharge (cfs)								
	Exceedance Frequency / Return Interval								
	0.999	0.5	0.2	0.1	0.04	0.02	0.01	0.002	0.001
Control Point	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	1000-yr
Fort Gibson Outflow	67500	80600	89600	92900	94900	95500	115900	159100	177700
Oologah Outflow	29500	29900	30100	30100	30200	30300	32100	36300	38100
Hulah Outflow	4000	5500	6500	6500	6500	22700	52900	122900	153100
Copan Outflow	3000	3000	3000	3000	6100	10700	18700	68200	119000
Tenkiller Outflow	13500	13500	13500	13500	13500	13500	16500	84300	103300
Eufaula Outflow	40000	40000	40000	40000	63800	116200	156800	199200	205300
Wister Outflow	6600	6600	6600	6600	16300	23600	31000	48100	55400
Caney River at Bartlesville, OK	6000	8000	9500	12400	21800	33400	51300	138500	212500
Caney River at Ramona, OK	10400	13300	20200	27800	42600	58700	80800	170300	234700
Bird Creek near Sperry, OK	9300	12600	18800	24300	34400	44600	58000	106400	138200
Verdigris River near Claremore, OK	28900	32100	34100	34800	54900	108800	162700	287900	341900
Verdigris River near Inola, OK	32300	37300	45300	52300	107200	162200	217200	345000	400000
Poteau River at Poteau, OK	8800	11300	15700	20200	28100	36100	46300	82700	106100
Poteau River at Panama, OK	20200	26000	36200	46600	64900	83500	107400	192700	247800
Arkansas River at Tulsa, OK	71000	83200	90500	92900	116700	148500	180300	254000	285800
Arkansas River at Haskell, OK	49500	60700	79500	97500	127600	154900	178700	233800	257500
Arkansas River at Muskogee, OK	101200	137800	144600	184300	248100	296400	344700	456700	505000
Arkansas River at Sallisaw, OK	110000	175000	176000	240700	324100	387300	450400	597000	660100
Arkansas River at Van Buren, AR	120000	175000	195100	256700	338200	399800	461400	604500	666200



EXCEEDENCE PROBABILITY

△ SUPER SIMULATED HISTORICAL EVENTS

O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

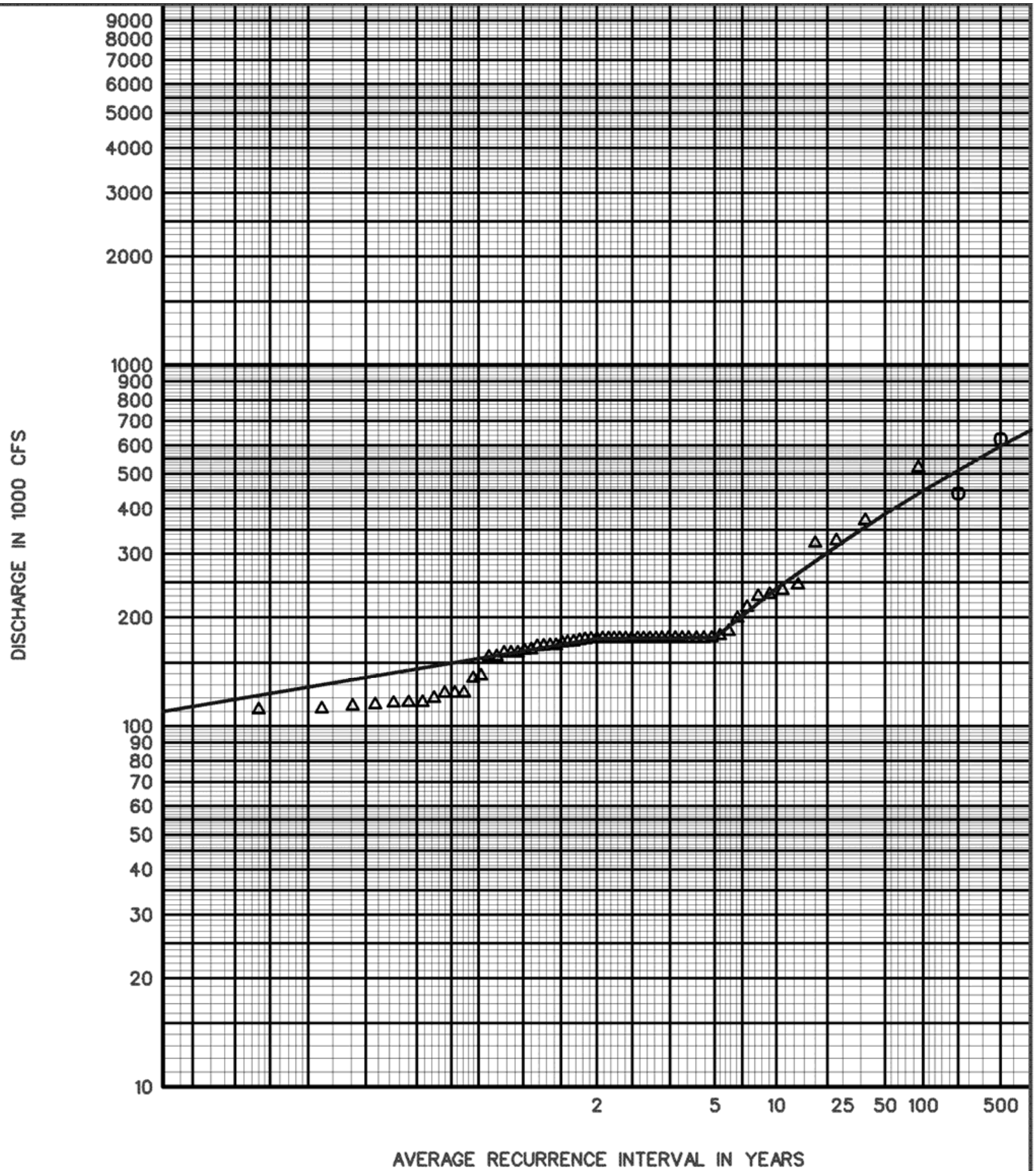
ARKANSAS RIVER AT MUSKOGEE, OK

EXCEEDENCE PROBABILITY CURVES

175,000 CFS PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-14



—— EXCEEDENCE PROBABILITY
△ SUPER SIMULATED HISTORICAL EVENTS
O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

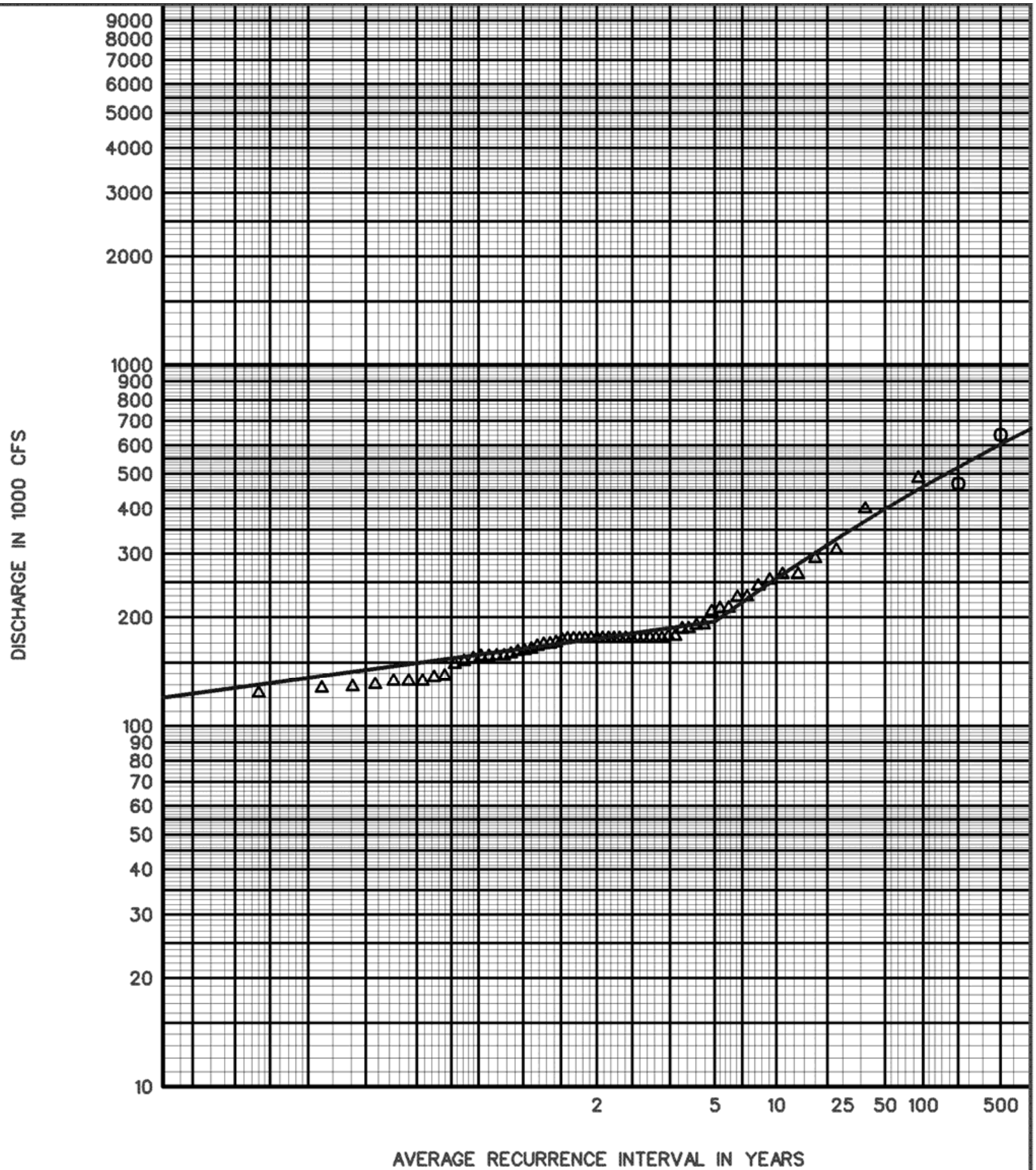
ARKANSAS RIVER AT SALLISAW, OK

EXCEEDENCE PROBABILITY CURVES

175,000 CFS PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-15



EXCEEDENCE PROBABILITY
△ SUPER SIMULATED HISTORICAL EVENTS
O SUPER HYPOTHETICAL EVENTS

NOTE:
1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, ARKANSAS

ARKANSAS RIVER AT VAN BUREN, AR

EXCEEDENCE PROBABILITY CURVES

175,000 CFS PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

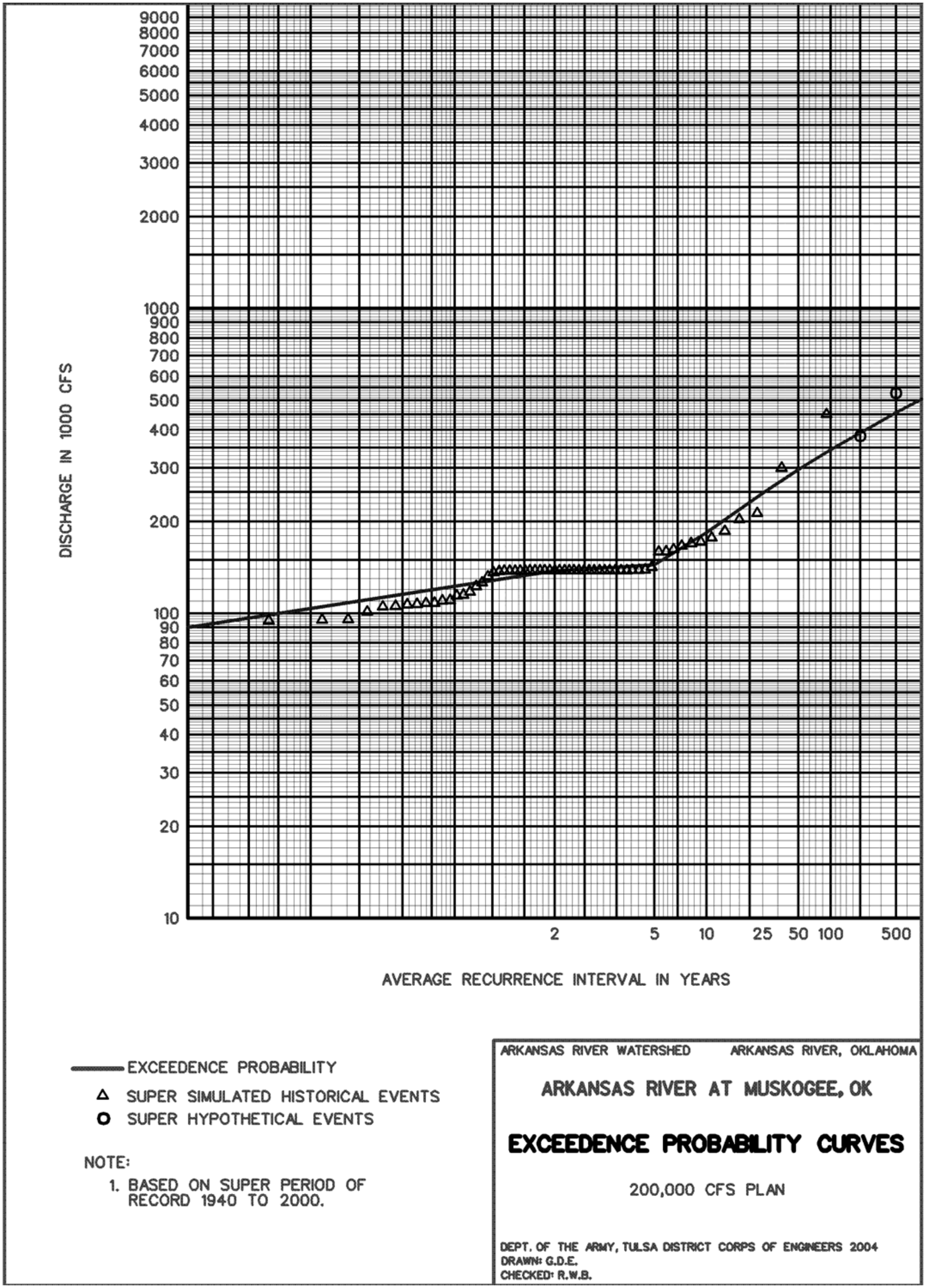
Figure A-16

12.2.3. <u>200,000 cfs Plan</u>. The 200,000 cfs Plan, the SUPER run (A02X12), increases the regulation discharge at Van Buren, Arkansas to 200,000 cfs and includes the 60,000 cfs bench. Graphical frequency curves were developed for this plan using the plotting positions and discharges from the Annual Series and Partial Duration Series Peak Flow Data tables generated by SUPER. Table A-39 lists the discharge location and the adopted frequency discharge relationships for this plan. Figures A-17 to A-19 present graphs of the points representing plotting position versus discharge and the adopted frequency curve at the Muskogee, Sallisaw, and Van Buren locations. The only differences in discharges between this plan and the No Action Plan are at the Muskogee, Sallisaw, and Van Buren locations and at frequencies less than the 10% exceedance or 10-year event.

TABLE A-39

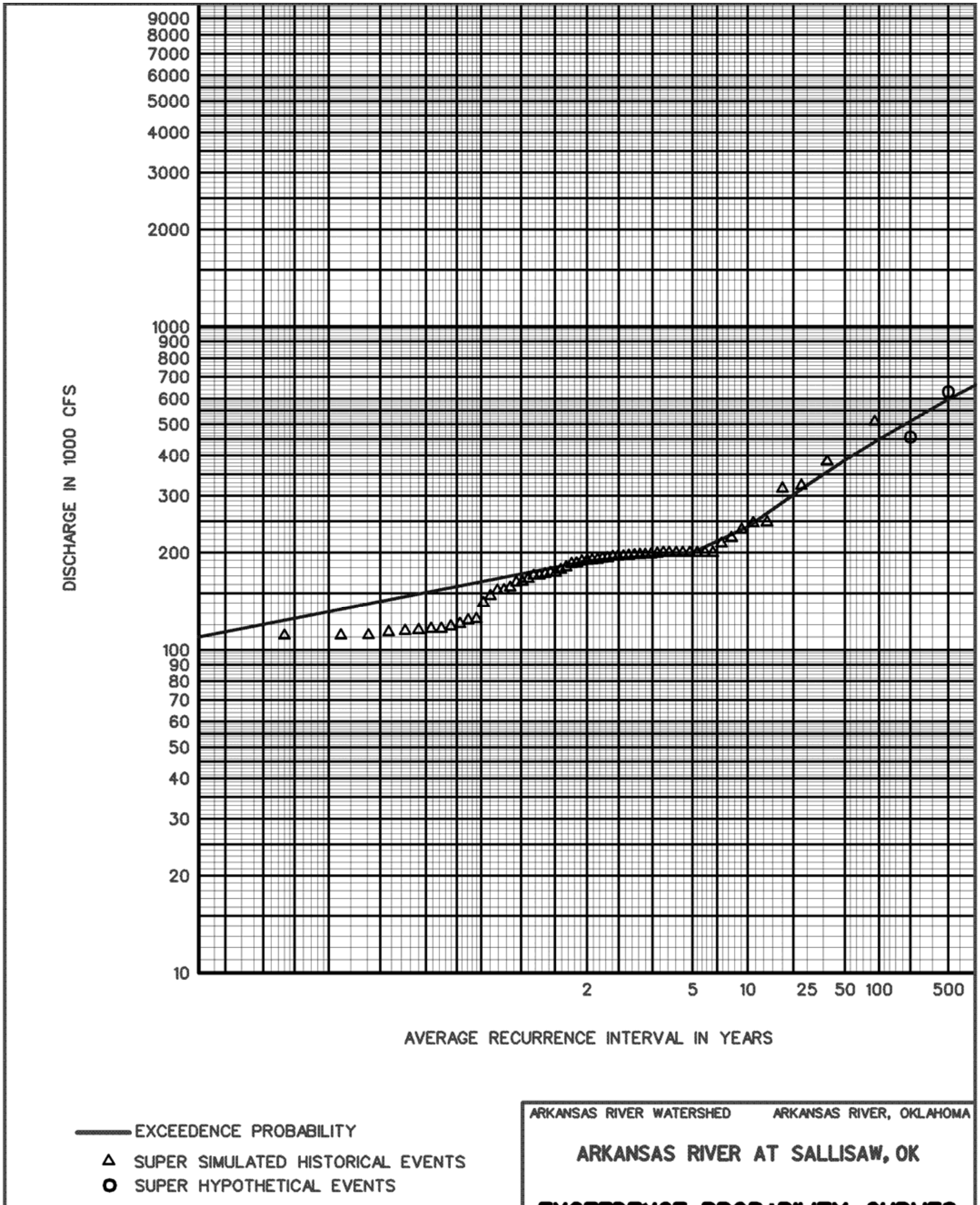
ARKANSAS RIVER – 200,000 CFS PLAN

	Discharge (cfs)								
	Exceedance Frequency / Return Interval								
	0.999	0.5	0.2	0.1	0.04	0.02	0.01	0.002	0.001
Control Point	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	1000-yr
Fort Gibson Outflow	67500	80600	89600	92900	94900	95500	115900	159100	177700
Oologah Outflow	29500	29900	30100	30100	30200	30300	32100	36300	38100
Hulah Outflow	4000	5500	6500	6500	6500	22700	52900	122900	153100
Copan Outflow	3000	3000	3000	3000	6100	10700	18700	68200	119000
Tenkiller Outflow	13500	13500	13500	13500	13500	13500	16500	84300	103300
Eufaula Outflow	40000	40000	40000	40000	63800	116200	156800	199200	205300
Wister Outflow	6600	6600	6600	6600	16300	23600	31000	48100	55400
Caney River at Bartlesville, OK	6000	8000	9500	12400	21800	33400	51300	138500	212500
Caney River at Ramona, OK	10400	13300	20200	27800	42600	58700	80800	170300	234700
Bird Creek near Sperry, OK	9300	12600	18800	24300	34400	44600	58000	106400	138200
Verdigris River near Claremore, OK	28900	32100	34100	34800	54900	108800	162700	287900	341900
Verdigris River near Inola, OK	32300	37300	45300	52300	107200	162200	217200	345000	400000
Poteau River at Poteau, OK	8800	11300	15700	20200	28100	36100	46300	82700	106100
Poteau River at Panama, OK	20200	26000	36200	46600	64900	83500	107400	192700	247800
Arkansas River at Tulsa, OK	71000	83200	90500	92900	116700	148500	180300	254000	285800
Arkansas River at Haskell, OK	49500	60700	79500	97500	127600	154900	178700	233800	257500
Arkansas River at Muskogee, OK	90000	138000	144600	184300	248100	296400	344700	456700	505000
Arkansas River at Sallisaw, OK	110000	189000	200300	240700	324100	387300	450400	597000	660100
Arkansas River at Van Buren, AR	67500	80600	89600	92900	94900	95500	115900	159100	177700



DISCHARGE IN 1000 CFS
9000
8000
7000
6000
5000
4000
3000
2000
1000
900
800
700
600
500
400
300
200
100
90
80
70
60
50
40
30
20
10
2
5
10
25
50
100
500
AVERAGE RECURRENCE INTERVAL IN YEARS
EXCEEDENCE PROBABILITY
SUPER SIMULATED HISTORICAL EVENTS
SUPER HYPOTHETICAL EVENTS
NOTE:
1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.
ARKANSAS RIVER WATERSHED
ARKANSAS RIVER, OKLAHOMA
ARKANSAS RIVER AT MUSKOGEE, OK
EXCEEDENCE PROBABILITY CURVES
200,000 CFS PLAN
DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-17



NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

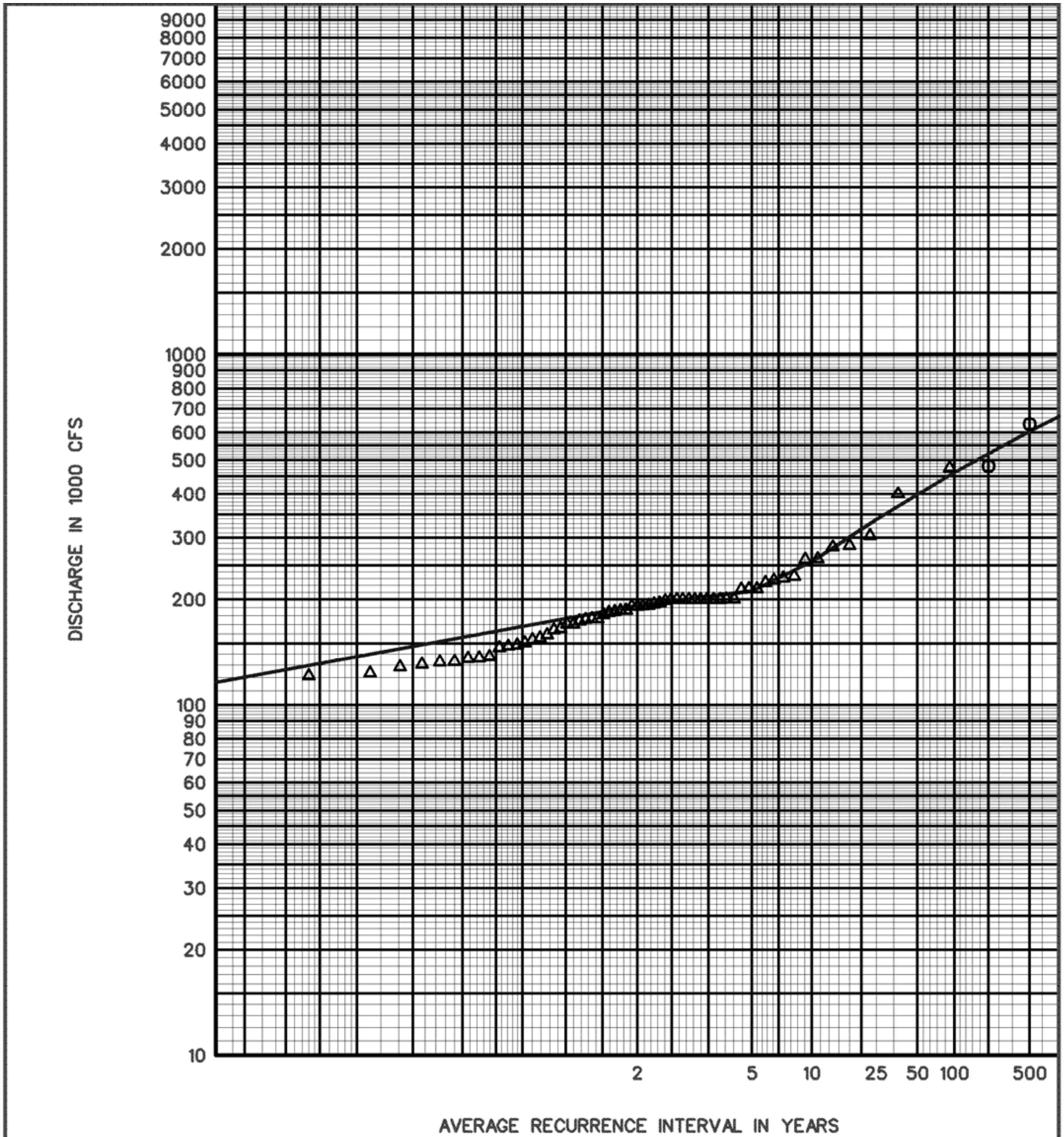
ARKANSAS RIVER AT SALLISAW, OK

EXCEEDENCE PROBABILITY CURVES

200,000 CFS PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-18



EXCEEDENCE PROBABILITY
△ SUPER SIMULATED HISTORICAL EVENTS
O SUPER HYPOTHETICAL EVENTS

NOTE:
1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, ARKANSAS

ARKANSAS RIVER AT VAN BUREN, AR

EXCEEDENCE PROBABILITY CURVES

200,000 CFS PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-19

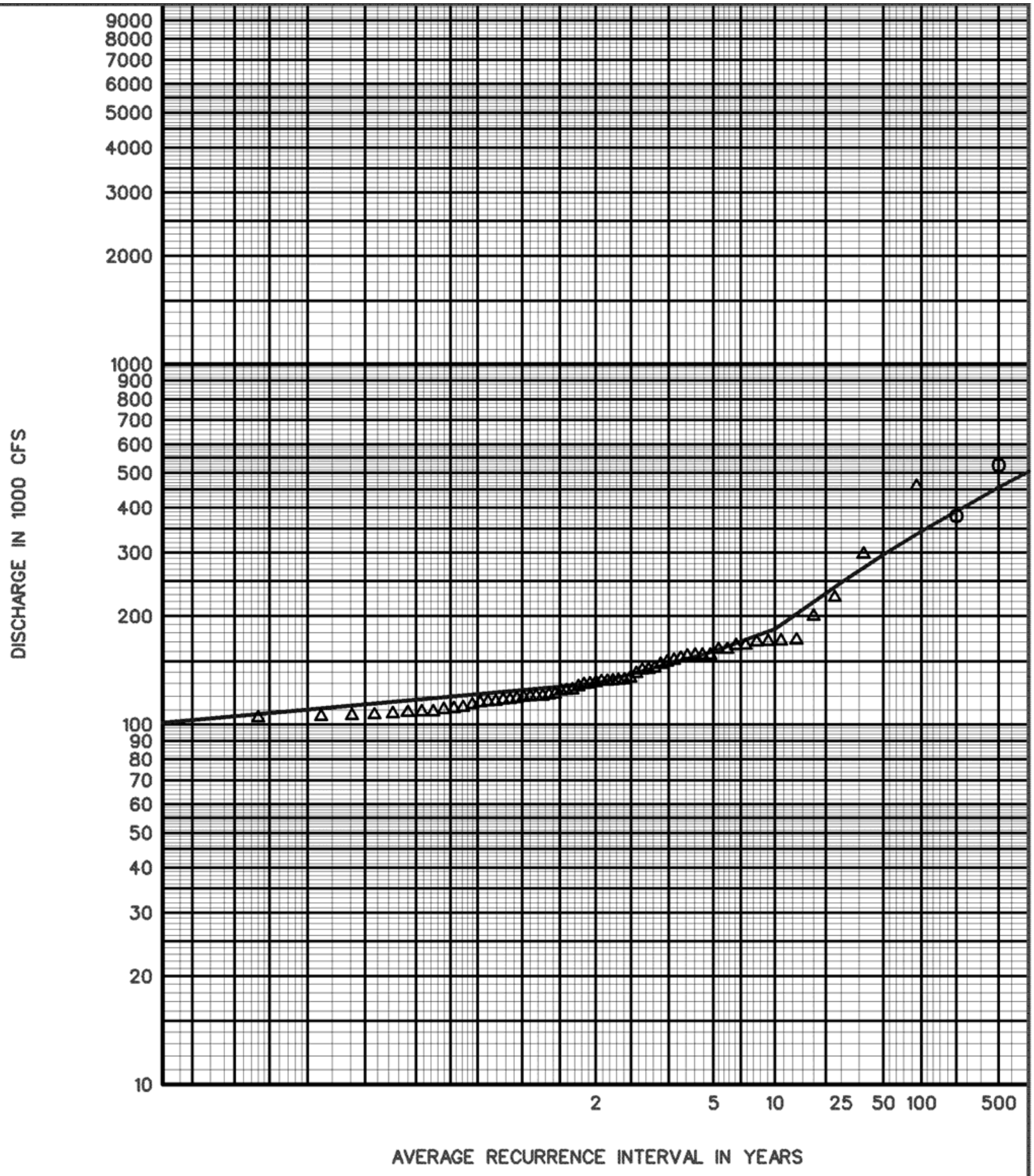
12.2.4. Operations Only Plan – 60,000 cfs Bench with Fill Behind Flood.

This Operations Only Plan, SUPER run (A02X13), maintains the regulation discharge at Van Buren, Arkansas at 150,000 cfs, for system storage less than 75 percent. This plan also, includes the 60,000 cfs bench and a fill behind flood, from 150,000 cfs to 250,000 cfs, when the system storage is equal to or greater than 75 percent. Graphical frequency curves were developed for this plan using the plotting positions and discharges from the Annual Series and Partial Duration Series Peak Flow Data tables generated by SUPER. Table A-40 lists the discharge location and the adopted frequency discharge relationships for this plan. Figures A-20 to A-22 present graphs of the points representing plotting position versus discharge and the adopted frequency curve at the Muskogee, Sallisaw, and Van Buren locations. The only differences in discharges between this plan and the No Action Plan are at the Muskogee, Sallisaw, and Van Buren locations and at frequencies less than the 10% exceedance or 10-year event.

TABLE A-40

ARKANSAS RIVER – OPERATIONS ONLY PLAN – 60,000 CFS BENCH WITH FILL BEHIND FLOOD

	Discharge (cfs)								
	Exceedance Frequency / Return Interval								
	0.999	0.5	0.2	0.1	0.04	0.02	0.01	0.002	0.001
Control Point	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	1000-yr
Fort Gibson Outflow	67500	80600	89600	92900	94900	95500	115900	159100	177700
Oologah Outflow	29500	29900	30100	30100	30200	30300	32100	36300	38100
Hulah Outflow	4000	5500	6500	6500	6500	22700	52900	122900	153100
Copan Outflow	3000	3000	3000	3000	6100	10700	18700	68200	119000
Tenkiller Outflow	13500	13500	13500	13500	13500	13500	16500	84300	103300
Eufaula Outflow	40000	40000	40000	40000	63800	116200	156800	199200	205300
Wister Outflow	6600	6600	6600	6600	16300	23600	31000	48100	55400
Caney River at Bartlesville, OK	6000	8000	9500	12400	21800	33400	51300	138500	212500
Caney River at Ramona, OK	10400	13300	20200	27800	42600	58700	80800	170300	234700
Bird Creek near Sperry, OK	9300	12600	18800	24300	34400	44600	58000	106400	138200
Verdigris River near Claremore, OK	28900	32100	34100	34800	54900	108800	162700	287900	341900
Verdigris River near Inola, OK	32300	37300	45300	52300	107200	162200	217200	345000	400000
Poteau River at Poteau, OK	8800	11300	15700	20200	28100	36100	46300	82700	106100
Poteau River at Panama, OK	20200	26000	36200	46600	64900	83500	107400	192700	247800
Arkansas River at Tulsa, OK	71000	83200	90500	92900	116700	148500	180300	254000	285800
Arkansas River at Haskell, OK	49500	60700	79500	97500	127600	154900	178700	233800	257500
Arkansas River at Muskogee, OK	101200	130000	160000	184300	248100	296400	344700	456700	505000
Arkansas River at Sallisaw, OK	137000	153000	187000	240700	324100	387300	450400	597000	660100
Arkansas River at Van Buren, AR	132700	153400	205000	256700	338200	399800	461400	604500	666200



NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

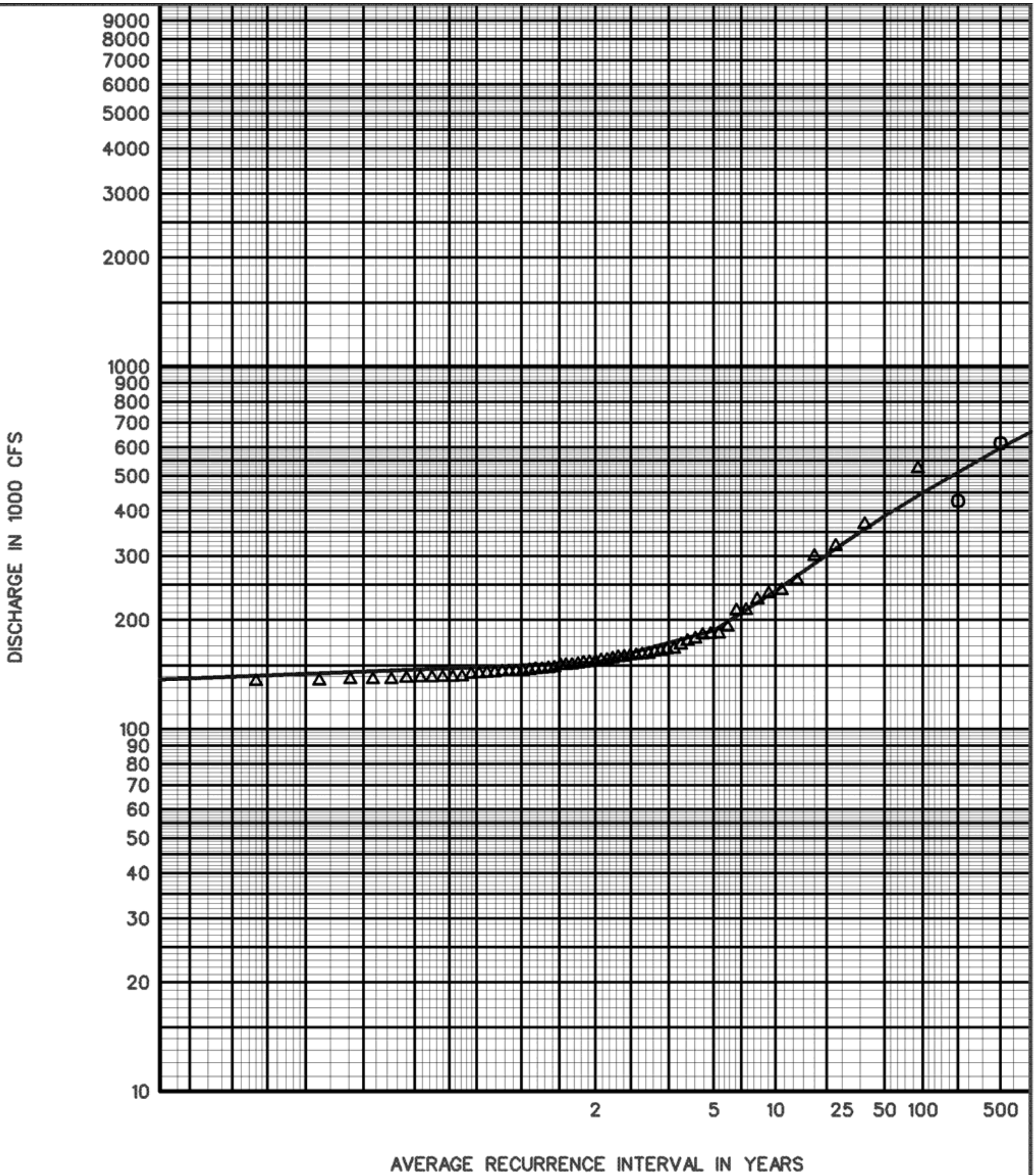
ARKANSAS RIVER AT MUSKOGEE, OK

EXCEEDENCE PROBABILITY CURVES

OPERATIONS ONLY 60,000 CFS BENCH
WITH FILL BEHIND FLOOD PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-20



EXCEEDENCE PROBABILITY

△ SUPER SIMULATED HISTORICAL EVENTS

O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

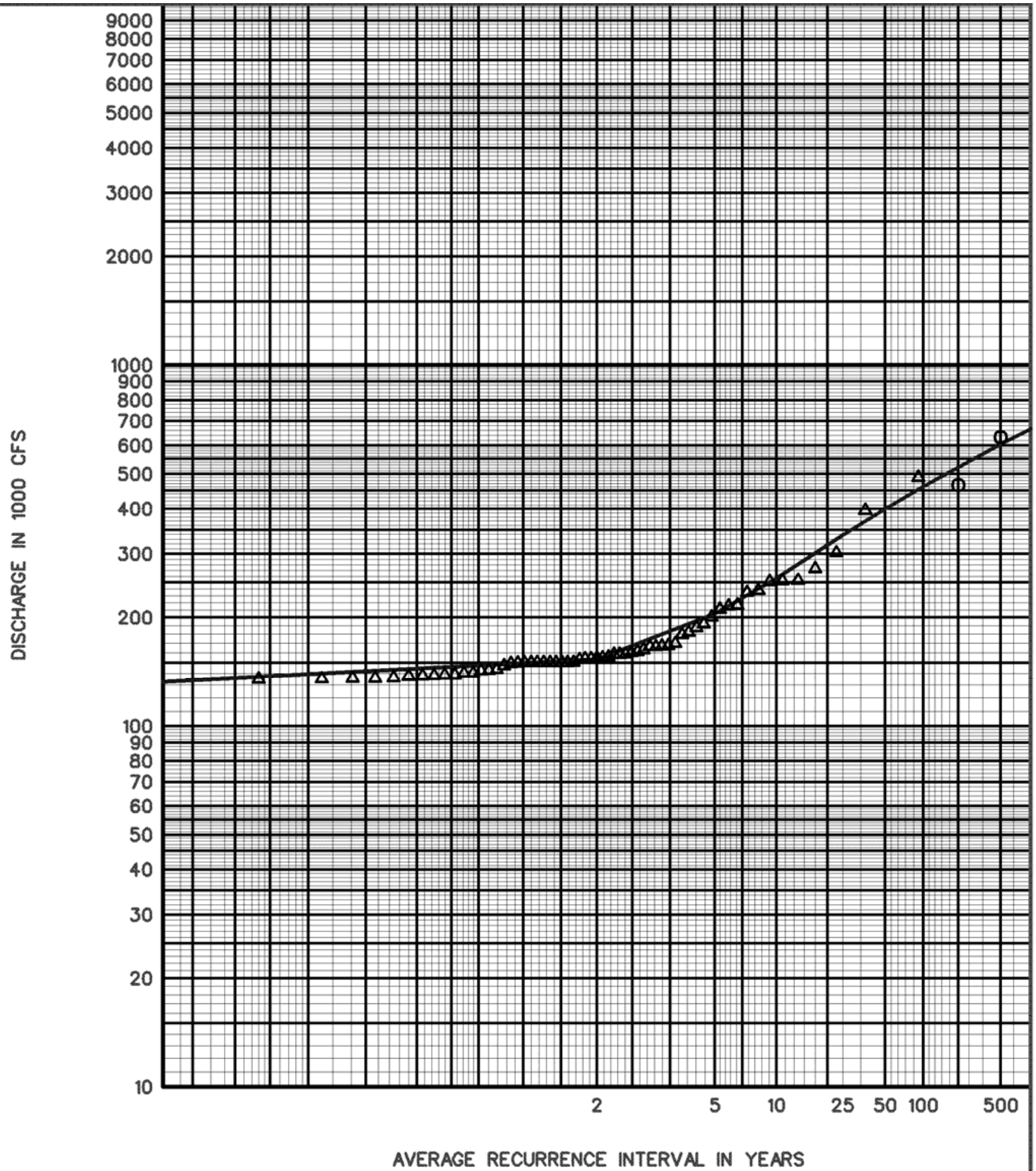
ARKANSAS RIVER AT SALLISAW, OK

EXCEEDENCE PROBABILITY CURVES

OPERATIONS ONLY 60,000 CFS BENCH WITH FILL BEHIND FLOOD PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-21



EXCEEDENCE PROBABILITY
△ SUPER SIMULATED HISTORICAL EVENTS
O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, ARKANSAS

ARKANSAS RIVER AT VAN BUREN, AR

EXCEEDENCE PROBABILITY CURVES

OPERATIONS ONLY 60,000 CFS BENCH
WITH FILL BEHIND FLOOD PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

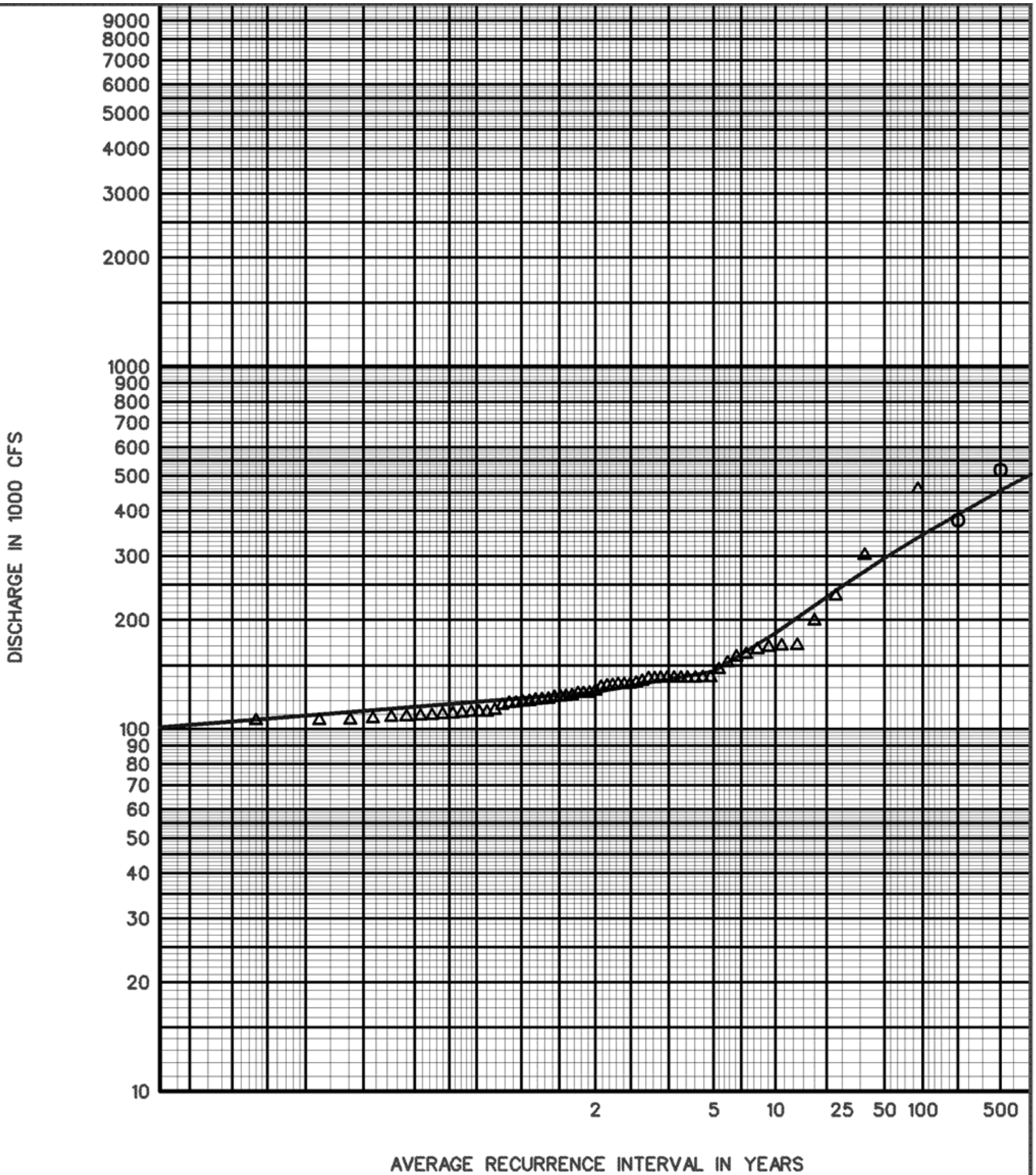
Figure A-22

12.2.5. <u>Operations Only 60,000 cfs Bench Plan</u>. This Operations Only Plan, SUPER run (A02X10), is the same as the No Action Plan, except for replacing the 75,000 cfs bench with a 60,000 cfs bench and reducing the system storage for the bench from 18 to 15 percent. This modification to the No Action Plan had no effect upon the plotting positions and discharges from the Annual Series and Partial Duration Series Peak Flow Data tables generated by SUPER. Therefore, the discharge frequency curves were the same as for the No Action Plan and can be found in Table A-41. Figures A-23 to A-25 present graphs of the points representing plotting position versus discharge and the adopted frequency curve at the Muskogee, Sallisaw, and Van Buren locations.

TABLE A-41

ARKANSAS RIVER – OPERATIONS ONLY 60,000 CFS BENCH PLAN

	Discharge (cfs)								
	Exceedance Frequency / Return Interval								
	0.999	0.5	0.2	0.1	0.04	0.02	0.01	0.002	0.001
Control Point	1-yr	2-yr	5-yr	10-yr	25-yr	50-yr	100-yr	500-yr	1000-yr
Fort Gibson Outflow	67500	80600	89600	92900	94900	95500	115900	159100	177700
Oologah Outflow	29500	29900	30100	30100	30200	30300	32100	36300	38100
Hulah Outflow	4000	5500	6500	6500	6500	22700	52900	122900	153100
Copan Outflow	3000	3000	3000	3000	6100	10700	18700	68200	119000
Tenkiller Outflow	13500	13500	13500	13500	13500	13500	16500	84300	103300
Eufaula Outflow	40000	40000	40000	40000	63800	116200	156800	199200	205300
Wister Outflow	6600	6600	6600	6600	16300	23600	31000	48100	55400
Caney River at Bartlesville, OK	6000	8000	9500	12400	21800	33400	51300	138500	212500
Caney River at Ramona, OK	10400	13300	20200	27800	42600	58700	80800	170300	234700
Bird Creek near Sperry, OK	9300	12600	18800	24300	34400	44600	58000	106400	138200
Verdigris River near Claremore, OK	28900	32100	34100	34800	54900	108800	162700	287900	341900
Verdigris River near Inola, OK	32300	37300	45300	52300	107200	162200	217200	345000	400000
Poteau River at Poteau, OK	8800	11300	15700	20200	28100	36100	46300	82700	106100
Poteau River at Panama, OK	20200	26000	36200	46600	64900	83500	107400	192700	247800
Arkansas River at Tulsa, OK	71000	83200	90500	92900	116700	148500	180300	254000	285800
Arkansas River at Haskell, OK	49500	60700	79500	97500	127600	154900	178700	233800	257500
Arkansas River at Muskogee, OK	101200	126500	144600	184300	248100	296400	344700	456700	505000
Arkansas River at Sallisaw, OK	137000	148700	165800	240700	324100	387300	450400	597000	660100
Arkansas River at Van Buren, AR	132700	153400	195100	256700	338200	399800	461400	604500	666200



EXCEEDENCE PROBABILITY

△ SUPER SIMULATED HISTORICAL EVENTS

O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED ARKANSAS RIVER, OKLAHOMA

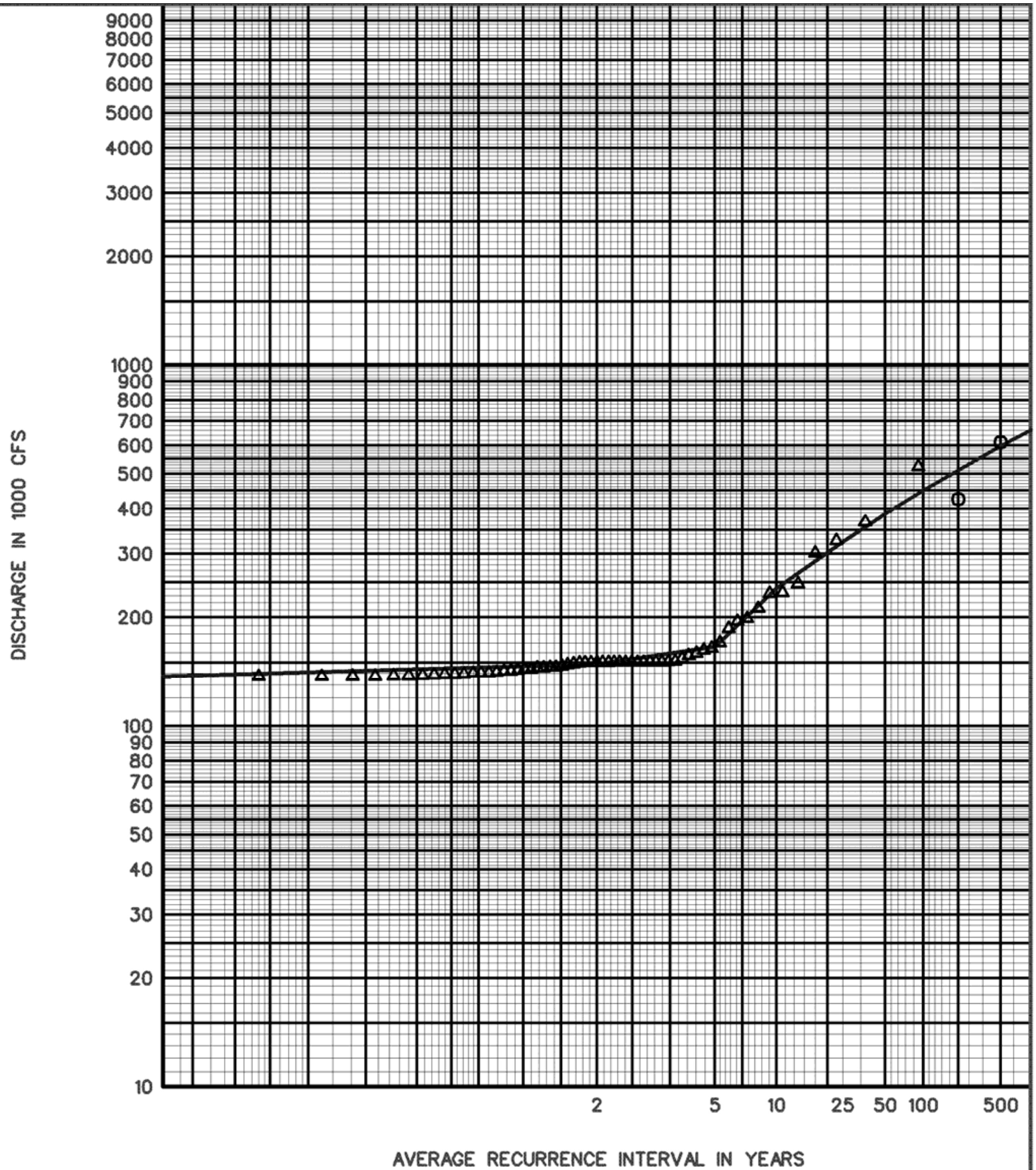
ARKANSAS RIVER AT MUSKOGEE, OK

EXCEEDENCE PROBABILITY CURVES

OPERATIONS ONLY 60,000 CFS BENCH PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-23



EXCEEDENCE PROBABILITY

△ SUPER SIMULATED HISTORICAL EVENTS

O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, OKLAHOMA

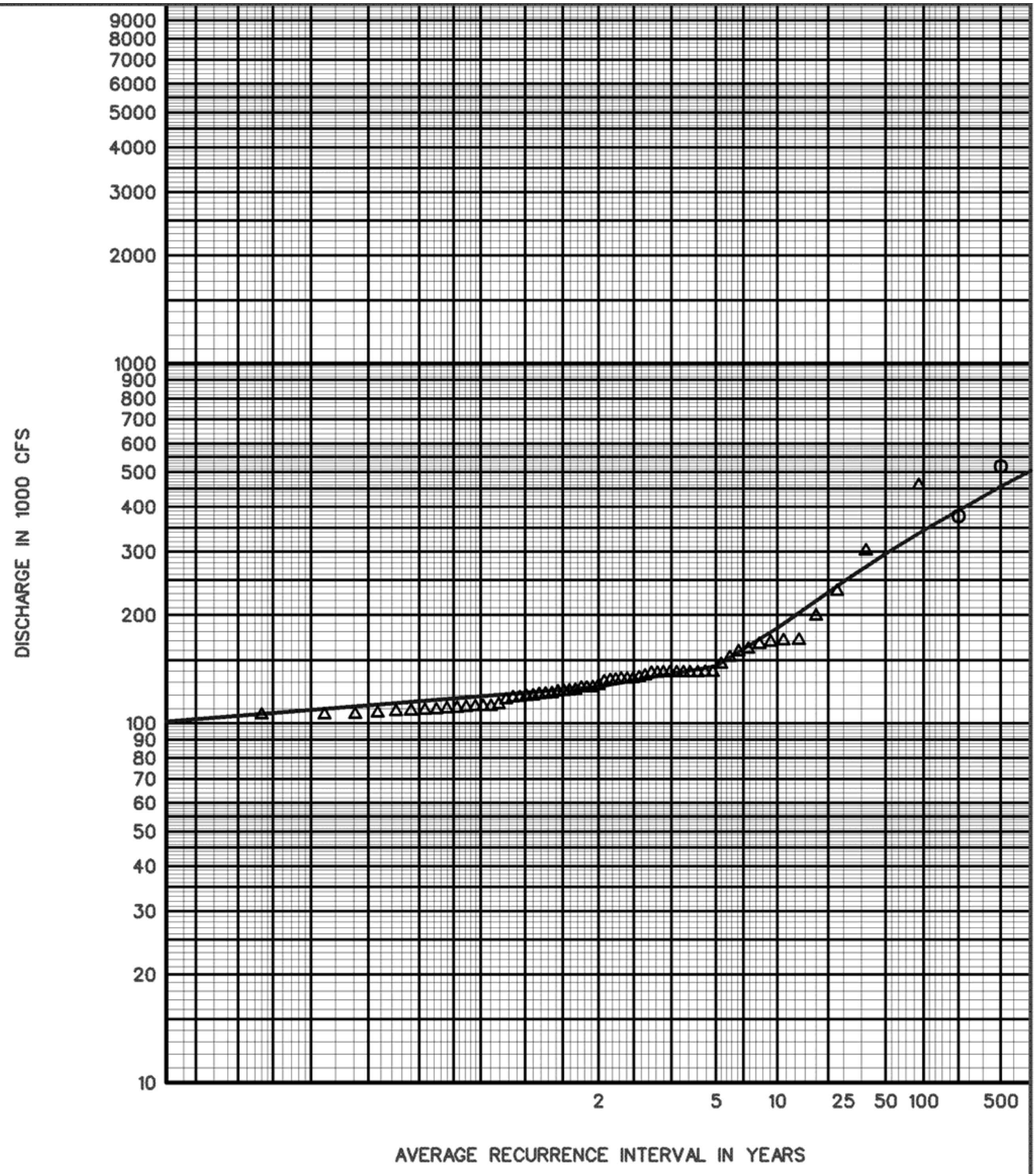
ARKANSAS RIVER AT SALLISAW, OK

EXCEEDENCE PROBABILITY CURVES

OPERATIONS ONLY 60,000 CFS BENCH PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-24



EXCEEDENCE PROBABILITY

△ SUPER SIMULATED HISTORICAL EVENTS

O SUPER HYPOTHETICAL EVENTS

NOTE:

1. BASED ON SUPER PERIOD OF RECORD 1940 TO 2000.

ARKANSAS RIVER WATERSHED — ARKANSAS RIVER, ARKANSAS

ARKANSAS RIVER AT VAN BUREN, AR

EXCEEDENCE PROBABILITY CURVES

OPERATIONS ONLY 60,000 CFS BENCH PLAN

DEPT. OF THE ARMY, TULSA DISTRICT CORPS OF ENGINEERS 2004
DRAWN: G.D.E.
CHECKED: R.W.B.

Figure A-25

13. FLOOD VOLUME-DURATION FREQUENCY ANALYSIS

13.1. General

One of the required items needed for the economic analysis of this study was the agricultural crop damages and benefits. In order to determine the annualized crop damages and benefits, flood frequency hydrographs were needed. The SUPER program does not generate a flood frequency hydrograph, but only modifies the daily flows at selected control points. However, using techniques defined in EM 1110-2-1415 entitled “Hydrologic Frequency Analysis”, dated March 5, 1993, flood frequency hydrographs can be produced. Using this method, discharge frequency curves, flood volume-duration frequency comprehensive series curves, and a representative hydrograph to be used as a pattern, are needed.

13.2. Flood Volume-Durations

The average annual flows for the maximum 1-day, 2-day, 3-day, 7-day, 10-day, 15-day, 30-day, 60-day, 90-day, and 120-day durations were determined for each year in the period of record based upon the modified daily flows from SUPER. This data was ordered from highest to lowest and the median plotting position formula was used to compute the percent chance exceedance for each annual peak volume-duration value. The data for the annual peak values and the annual peak volume-duration values were plotted on probability graph paper. A best-fit smooth curve was drawn through each set of points and extrapolated to obtain smaller exceedance probabilities. From these curves, discharges for selected return intervals and flood volume-duration frequencies were obtained. Flood volume-duration frequency analyses were performed for the Arkansas River at Muskogee, Arkansas River at Sallisaw, and Arkansas River at Van Buren control point locations.

13.2.1. Baseline Year 2000 Operating Conditions – No Action Plan. The No Action Plan, the SUPER (A01X16) run, is the existing operating plan for the Arkansas River system as previously described. Graphical frequency curves were developed for this plan using the plotting positions and discharges for the annual peak values and the annual peak volume-duration values. Tables A-42 to A-44 list the adopted flood volume-duration frequencies for this plan and for the Arkansas River at Muskogee, Arkansas River at Sallisaw, and Arkansas River at Van Buren control point locations.

TABLE A-42

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River - Baseline Year 2000 Operating Conditions

Arkansas River at Muskogee, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	505000	490000	470000	440000	420000	340000	270000	192000	157000	137000
0.20%	456700	440000	420000	400000	380000	315000	255000	185000	153000	133000
1.00%	344700	330000	320000	310000	293000	250000	212000	168000	138000	122000
2.00%	296400	285000	275000	270000	255000	223000	192000	158000	133000	115000
4.00%	248100	238000	233000	225000	210000	188000	170000	148000	123000	108000
10.00%	184300	178000	173000	165000	155000	143000	137000	125000	113000	93000
20.00%	144600	142000	137000	133000	129000	126000	122000	111000	96000	73000
50.00%	126500	112000	108000	105000	95000	91000	83000	69000	54500	47500
99.90%	101200	8300	7800	7500	5600	4000	3000	2600	2300	2100

TABLE A-43

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River - Baseline Year 2000 Operating Conditions

Arkansas River at Sallisaw, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	660100	650000	620000	600000	530000	450000	340000	255000	184000	160000
0.20%	597000	590000	560000	540000	480000	410000	315000	240000	180000	157000
1.00%	450400	440000	420000	400000	365000	317000	257000	210000	168000	150000
2.00%	387300	380000	360000	345000	315000	275000	232000	193000	163000	145000
4.00%	324100	320000	300000	287000	265000	235000	205000	177000	155000	140000
10.00%	240700	235000	220000	210000	192000	177000	170000	166000	143000	132000
20.00%	165800	160000	150000	148000	146000	144000	142000	140000	117000	100000
50.00%	148700	143000	135000	130000	125000	118000	114000	110000	73000	64000
99.90%	137000	25000	17500	17000	13200	10200	8100	7000	6100	5500

TABLE A-44

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River - Baseline Year 2000 Operating Conditions

Arkansas River at Van Buren, Arkansas

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	666200	640000	620000	590000	530000	460000	390000	275000	205000	180000
0.20%	604500	580000	560000	530000	480000	420000	355000	260000	200000	177000
1.00%	461400	445000	420000	400000	365000	325000	283000	225000	183000	163000
2.00%	399800	385000	367000	347000	315000	280000	253000	207000	175000	157000
4.00%	338200	325000	310000	293000	265000	240000	217000	187000	165000	148000
10.00%	256700	247000	235000	220000	200000	185000	173000	160000	150000	137000
20.00%	195100	185000	177000	167000	160000	153000	150000	147000	123000	98000
50.00%	153400	147000	143000	140000	133000	130000	127000	110000	87000	72000
99.90%	132700	18300	16500	15000	10000	9400	8300	7700	6400	5800

13.2.2. <u>175,000 cfs Plan</u>. The 175,000 cfs Plan, the SUPER run (A02X11), increases the regulation discharge at Van Buren, Arkansas to 175,000 cfs and includes the 60,000 cfs bench. Graphical frequency curves were developed for this plan using the plotting positions and discharges for the annual peak values and the annual peak volume-duration values. Tables A-45 to A-47 list the adopted flood volume-duration frequencies for this plan and for the Arkansas River at Muskogee, Arkansas River at Sallisaw, and Arkansas River at Van Buren control point locations.

TABLE A-45

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River - 175,000 cfs Regulating Discharge at Van Buren

Arkansas River at Muskogee, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	505000	480000	460000	443000	428000	385000	340000	247000	177000	137000
0.20%	456700	430000	413000	398000	383000	350000	305000	230000	170000	135000
1.00%	344700	320000	307000	295000	283000	263000	230000	190000	152000	125000
2.00%	296400	275000	263000	253000	243000	227000	200000	173000	142000	118000
4.00%	248100	232000	222000	213000	203000	190000	168000	153000	130000	112000
10.00%	184300	175000	167000	160000	152000	143000	137000	130000	113000	95000
20.00%	144600	143000	140000	137000	133000	130000	125000	114000	95000	78000
50.00%	137800	120000	115000	110000	96000	92000	82000	72000	55000	45500
99.90%	101200	16600	15700	15400	10200	8000	6000	5200	4600	4200

TABLE A-46

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River - 175,000 cfs Regulating Discharge at Van Buren

Arkansas River at Sallisaw, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	660100	630000	610000	585000	470000	405000	333000	243000	204000	168000
0.20%	597000	580000	555000	535000	430000	375000	310000	237000	200000	165000
1.00%	450400	440000	420000	410000	335000	295000	257000	215000	185000	155000
2.00%	387300	375000	360000	350000	293000	258000	230000	204000	175000	152000
4.00%	324100	313000	300000	290000	247000	220000	202000	193000	165000	145000
10.00%	240700	230000	220000	210000	190000	178000	174000	168000	147000	127000
20.00%	176000	174000	172000	170000	168000	165000	162000	144000	118000	103000
50.00%	175000	165000	153000	147000	113000	105000	97000	89000	80000	64000
99.90%	110000	17500	17000	16700	11500	9400	8100	7000	6100	5500

TABLE A-47

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River - 175,000 cfs Regulating Discharge at Van Buren

Arkansas River at Van Buren, Arkansas

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	666200	640000	610000	580000	515000	445000	390000	273000	205000	180000
0.20%	604500	575000	550000	525000	470000	403000	355000	260000	200000	177000
1.00%	461400	440000	420000	400000	355000	310000	280000	230000	187000	165000
2.00%	399800	380000	365000	345000	310000	270000	250000	215000	183000	160000
4.00%	338200	325000	310000	295000	265000	230000	220000	200000	175000	153000
10.00%	256700	247000	240000	230000	205000	192000	185000	180000	157000	137000
20.00%	195100	190000	185000	178000	175000	170000	165000	155000	127000	110000
50.00%	175000	167000	160000	150000	133000	125000	115000	100000	85000	71000
99.90%	120000	18000	16100	15400	11800	9500	8400	7800	6500	5800

13.2.3. 200,000 cfs Plan. The 200,000 cfs Plan, the SUPER run (A02X12), increases the regulation discharge at Van Buren, Arkansas to 200,000 cfs and includes the 60,000 cfs bench. Graphical frequency curves were developed for this plan using the plotting positions and discharges for the annual peak values and the annual peak volume-duration values. Tables A-48 to A-50 list the adopted flood volume-duration frequencies for this plan and for the Arkansas River at Muskogee, Arkansas River at Sallisaw, and Arkansas River at Van Buren control point locations.

TABLE A-48

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – 200,000 cfs Regulating Discharge at Van Buren

Arkansas River at Muskogee, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	505000	475000	455000	430000	385000	365000	300000	215000	145000	122000
0.20%	456700	427000	407000	387000	350000	330000	275000	207000	143000	120000
1.00%	344700	317000	303000	290000	262000	247000	217000	180000	137000	117000
2.00%	296400	273000	260000	250000	225000	212000	193000	167000	133000	115000
4.00%	248100	228000	220000	210000	188000	177000	167000	153000	128000	112000
10.00%	184300	170000	165000	159000	144000	140000	137000	134000	113000	93000
20.00%	144600	143000	140000	137000	134000	132000	129000	115000	89000	72000
50.00%	138000	130000	123000	112000	96000	88000	82000	65000	53000	45500
99.90%	90000	16600	15700	15400	10200	8000	6000	5200	4600	4260

TABLE A-49

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – 200,000 cfs Regulating Discharge at Van Buren

Arkansas River at Sallisaw, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	660100	625000	605000	580000	495000	395000	323000	263000	213000	168000
0.20%	597000	565000	545000	525000	450000	365000	305000	250000	208000	165000
1.00%	450400	425000	405000	395000	340000	297000	258000	223000	193000	157000
2.00%	387000	365000	350000	340000	293000	265000	236000	210000	184000	152000
4.00%	324100	305000	292000	284000	245000	230000	212000	195000	173000	145000
10.00%	240700	222000	218000	212000	200000	195000	190000	179000	148000	130000
20.00%	200300	198000	195000	192000	185000	178000	172000	155000	123000	108000
50.00%	189000	165000	150000	140000	115000	107000	103000	89000	73000	63000
99.90%	110000	17500	17000	16700	11500	9400	8100	7000	6100	5500

TABLE A-50

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – 200,000 cfs Regulating Discharge at Van Buren

Arkansas River at Van Buren, Arkansas

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	666200	640000	610000	590000	495000	405000	357000	297000	220000	185000
0.20%	604500	575000	555000	530000	455000	375000	337000	283000	217000	182000
1.00%	461400	440000	420000	400000	350000	305000	278000	242000	202000	173000
2.00%	399300	380000	365000	350000	305000	273000	248000	223000	193000	165000
4.00%	338200	323000	310000	295000	257000	240000	222000	203000	180000	155000
10.00%	256700	247000	240000	233000	217000	207000	197000	183000	157000	137000
20.00%	212000	210000	205000	197000	194000	188000	182000	160000	132000	113000
50.00%	193000	172000	163000	156000	134000	123000	115000	99000	85000	71000
99.90%	116000	17900	16100	15400	11800	9500	8400	7800	6500	5800

13.2.4. Operations Only Plan – 60,000 cfs Bench with Fill Behind Flood.

This Operations Only Plan, SUPER run (A02X13), maintains the regulation discharge at Van Buren, Arkansas at 150,000 cfs, for system storage less than 75 percent. This plan also, includes the 60,000 cfs bench and a fill behind flood, from 150,000 cfs to 250,000 cfs, when the system storage is equal to or greater than 75 percent. Graphical frequency curves were developed for this plan using the plotting positions and discharges for the annual peak values and the annual peak volume-duration values. Tables A-51 to A-53 list the adopted flood volume-duration frequencies for this plan and for the Arkansas River at Muskogee, Arkansas River at Sallisaw, and Arkansas River at Van Buren control point locations.

TABLE A-51

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – Operations Only Plan – 60,000 cfs Bench with Fill Behind Flood

Arkansas River at Muskogee, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	505000	495000	480000	465000	430000	400000	350000	275000	178000	140000
0.20%	456700	445000	430000	415000	385000	360000	320000	250000	170000	136000
1.00%	344700	333000	318000	305000	285000	268000	238000	194000	147000	124000
2.00%	296400	285000	270000	260000	243000	228000	205000	173000	136000	117000
4.00%	248100	237000	225000	218000	203000	190000	173000	153000	124000	111000
10.00%	184300	177000	170000	157000	143000	138000	134000	123000	108000	94000
20.00%	160000	155000	147000	138000	132000	127000	122000	111000	93000	78000
50.00%	130000	118000	112000	104000	97000	92000	87000	75000	60000	56500
99.90%	101200	16600	15700	15400	10200	8000	6000	5200	4600	4200

TABLE A-52

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – Operations Only Plan – 60,000 cfs Bench with Fill Behind Flood

Arkansas River at Sallisaw, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	660100	630000	605000	575000	505000	465000	415000	325000	220000	178000
0.20%	597000	570000	545000	515000	457000	420000	375000	303000	212000	173000
1.00%	450400	425000	405000	385000	345000	317000	285000	245000	190000	160000
2.00%	387300	365000	350000	330000	300000	275000	250000	218000	177000	152000
4.00%	324100	307000	295000	280000	255000	233000	213000	192000	165000	142000
10.00%	240700	235000	225000	212000	192000	180000	167000	160000	143000	123000
20.00%	187000	182000	175000	163000	155000	150000	147000	142000	124000	105000
50.00%	153000	146000	140000	135000	128000	123000	116000	112000	80000	63000
99.90%	137000	17500	17000	16700	11500	9400	8100	7000	6100	5500

TABLE A-53

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – Operations Only Plan – 60,000 cfs Bench with Fill Behind Flood

Arkansas River at Van Buren, Arkansas

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	666200	650000	610000	570000	515000	465000	420000	370000	235000	180000
0.20%	604500	585000	550000	505000	460000	413000	380000	337000	225000	177000
1.00%	461400	445000	420000	380000	350000	313000	290000	260000	200000	164000
2.00%	399800	382000	363000	330000	300000	270000	253000	227000	187000	157000
4.00%	338200	325000	307000	283000	255000	230000	215000	195000	173000	147000
10.00%	256700	250000	235000	220000	197000	175000	167000	157000	150000	130000
20.00%	205000	187000	180000	167000	155000	150000	146000	142000	128000	111000
50.00%	153400	151000	148000	143000	137000	133000	128000	113000	87000	69000
99.90%	132700	17900	16100	15400	11800	9500	9400	7800	6500	5800

13.2.5. Operations Only 60,000 cfs Bench Plan. This Operations Only Plan, SUPER run (A02X10), is the same as the No Action Plan, except for replacing the 75,000 cfs bench with a 60,000 cfs bench and reducing the system storage for the bench from 18 to 15 percent. This modification to the No Action Plan had no effect upon the plotting positions and discharges for the annual peak values and the annual peak volume-duration values. Therefore, the discharge frequency curves and the flood volume-duration frequency comprehensive series curves were the same as for the No Action Plan and can be found in Tables A-54 to A-56.

TABLE A-54

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – Operations Only 60,000 cfs Bench Plan

Arkansas River at Muskogee, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	505000	490000	470000	440000	420000	340000	270000	192000	157000	137000
0.20%	456700	440000	420000	400000	380000	315000	255000	185000	153000	133000
1.00%	344700	330000	320000	310000	293000	250000	212000	168000	138000	122000
2.00%	296400	285000	275000	270000	255000	223000	192000	158000	133000	115000
4.00%	248100	238000	233000	225000	210000	188000	170000	148000	123000	108000
10.00%	184300	178000	173000	165000	155000	143000	137000	125000	113000	93000
20.00%	144600	142000	137000	133000	129000	126000	122000	111000	96000	73000
50.00%	126500	112000	108000	105000	95000	91000	83000	69000	54500	47500
99.90%	101200	8300	7800	7500	5600	4000	3000	2600	2300	2100

TABLE A-55

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – Operations Only 60,000 cfs Bench Plan

Arkansas River at Sallisaw, Oklahoma

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	660100	650000	620000	600000	530000	450000	340000	255000	184000	160000
0.20%	597000	590000	560000	540000	480000	410000	315000	240000	180000	157000
1.00%	450400	440000	420000	400000	365000	317000	257000	210000	168000	150000
2.00%	387300	380000	360000	345000	315000	275000	232000	193000	163000	145000
4.00%	324100	320000	300000	287000	265000	235000	205000	177000	155000	140000
10.00%	240700	235000	220000	210000	192000	177000	170000	166000	143000	132000
20.00%	165800	160000	150000	148000	146000	144000	142000	140000	117000	100000
50.00%	148700	143000	135000	130000	125000	118000	114000	110000	73000	64000
99.90%	137000	25000	17500	17000	13200	10200	8100	7000	6100	5500

TABLE A-56

FLOOD VOLUME FREQUENCY ANALYSIS

Arkansas River – Operations Only 60,000 cfs Bench Plan

Arkansas River at Van Buren, Arkansas

Exceedence Frequency percent	Peak Flow cfs	1-Day Flow cfs	2-Day Flow cfs	3-Day Flow cfs	7-Day Flow cfs	10-Day Flow cfs	15-Day Flow cfs	30-Day Flow cfs	60-Day Flow cfs	90-Day Flow cfs
0.10%	666200	640000	620000	590000	530000	460000	390000	275000	205000	180000
0.20%	604500	580000	560000	530000	480000	420000	355000	260000	200000	177000
1.00%	461400	445000	420000	400000	365000	325000	283000	225000	183000	163000
2.00%	399800	385000	367000	347000	315000	280000	253000	207000	175000	157000
4.00%	338200	325000	310000	293000	265000	240000	217000	187000	165000	148000
10.00%	256700	247000	235000	220000	200000	185000	173000	160000	150000	137000
20.00%	195100	185000	177000	167000	160000	153000	150000	147000	123000	98000
50.00%	153400	147000	143000	140000	133000	130000	127000	110000	87000	72000
99.90%	132700	18300	16500	15000	10000	9400	8300	7700	6400	5800

13.3. Representative Hydrographs

In order to develop frequency related representative hydrographs, flood hydrographs to be used as pattern hydrographs, were needed. Two flood hydrographs for the 1995 flood were used as pattern hydrographs. The May 1, 1995 to July 31, 1995 flood inflow hydrograph for Webber Falls Lock and Dam was used to develop frequency related representative hydrographs for the Arkansas River at Muskogee control point. The flood inflow hydrograph for the same event, but for Robert S. Kerr Lock and Dam was used to produce the frequency related representative hydrographs for the Arkansas River at Sallisaw, Oklahoma and the Arkansas River at Van Buren, Arkansas control points. The two pattern hydrographs are presented in figures A-26 and A-27.

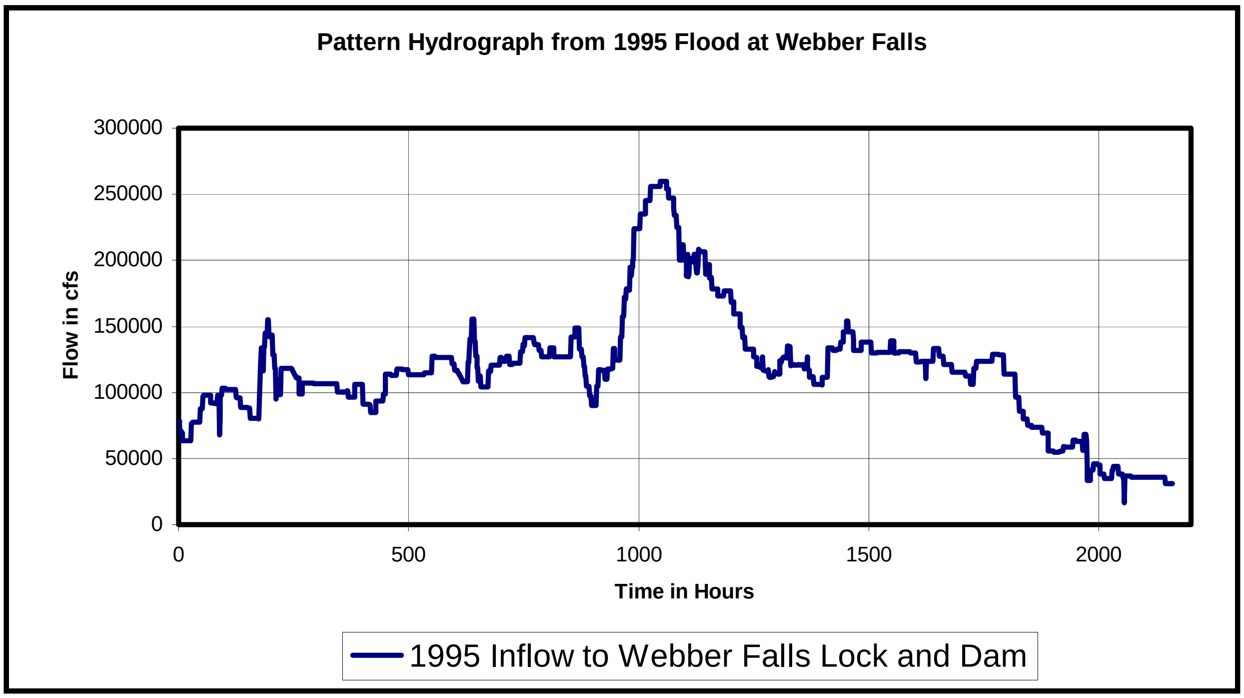


Figure A-26

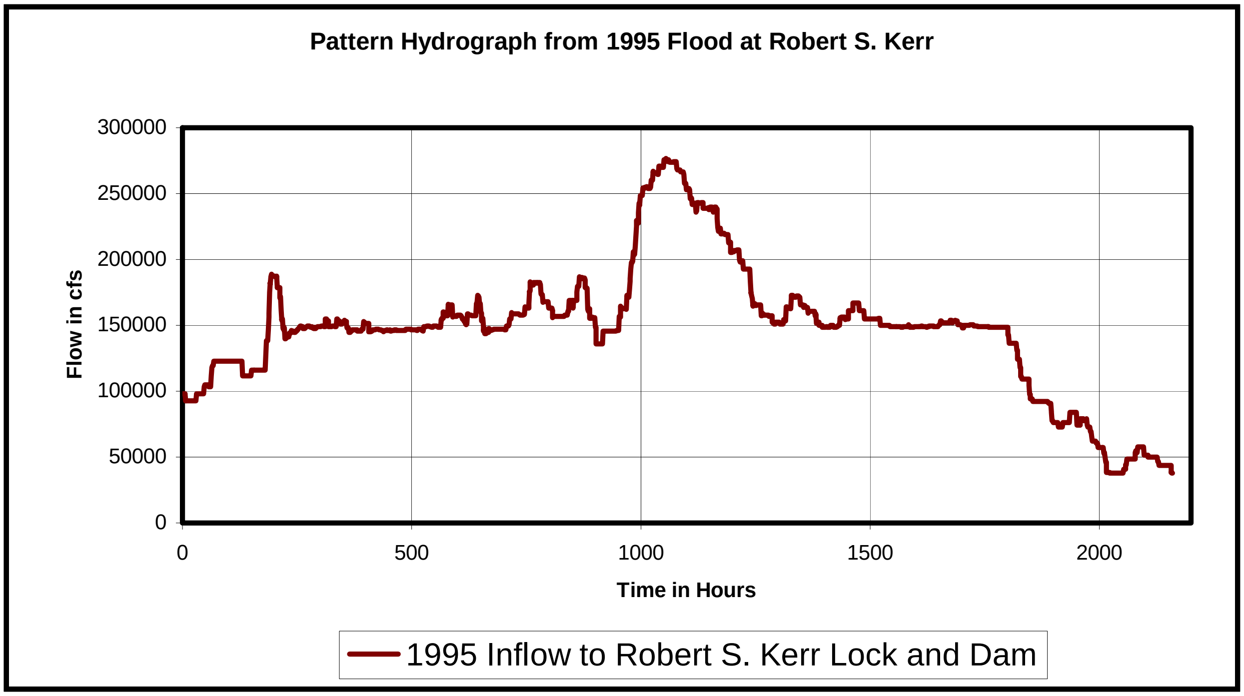


Figure A-27

Adjusting the ordinates of the pattern hydrographs to be equal to the peak discharge frequency values and the flood volume-duration frequency values for each desired frequency, a representative hydrograph was produce. Representative hydrographs were produced for control points, Arkansas River at Muskogee, Oklahoma, Arkansas River at Sallisaw, Oklahoma, and Arkansas River at Van Buren, Arkansas. A representative hydrograph was produced for each control point and for the 1-year, 2-year, 5-year, 10-year, 25-year, 50-year, 100-year, 500-year, and 1000-year frequencies. In addition, representative hydrographs were produced for the No Action, 175,000 cfs, 200,000 cfs, Operations Only, and Operations Only 60,000 cfs Bench Plans. For an example, Figure A-28 shows representative frequency hydrographs for the Arkansas River at Van Buren, Arkansas control point and for the No Action Plan.

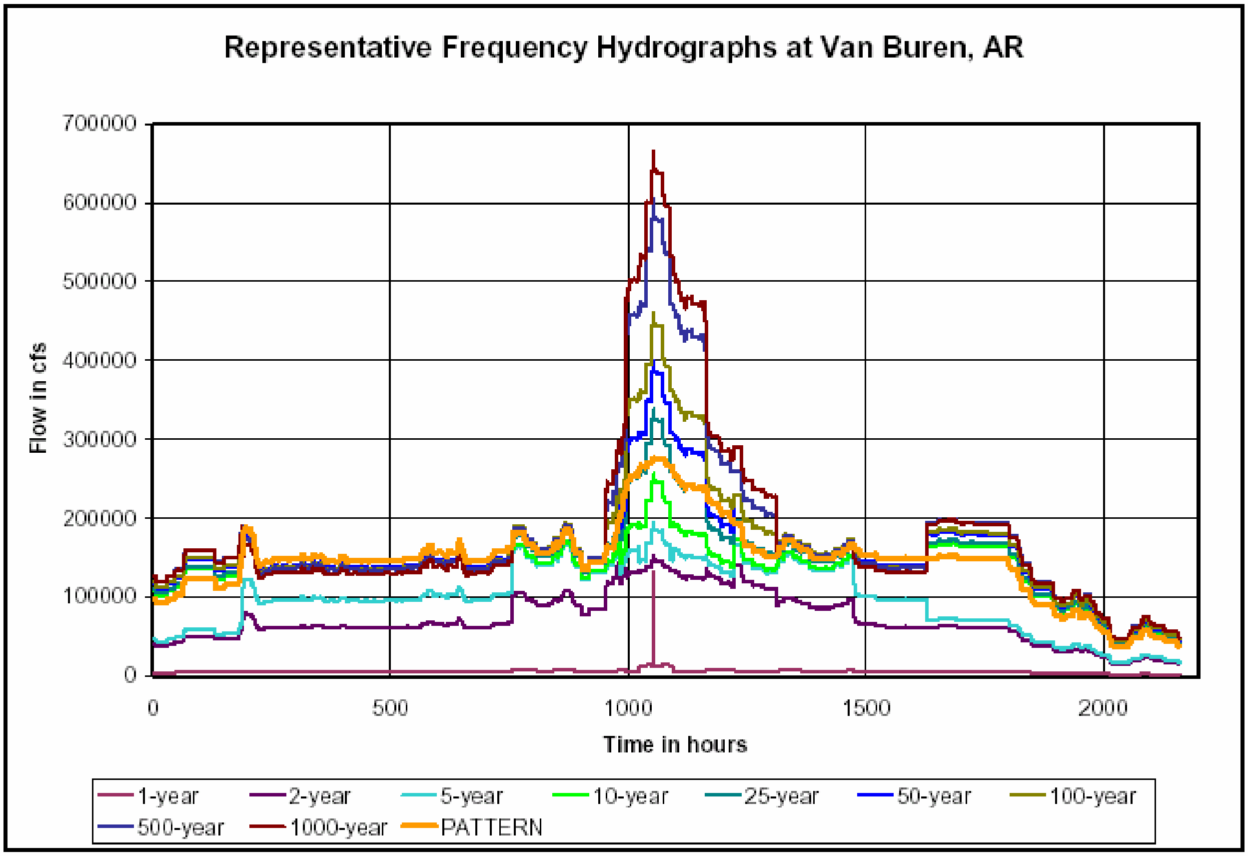


Figure A-28

Each representative flood frequency hydrograph covered a period of 90 days. The 90-day period was duplicated four times, with each 90-day period representing a season. The flood frequency hydrographs were placed in a database that could be retrieved by the economic programs. For each season and frequency, a percentage was determined for the likelihood of the frequency flood occurring during that season of the year. Table A-57 presents the percentages applied to each season at the control point Arkansas River at Robert S. Kerr Lock and Dam. Table A-58 presents the percentages applied to each season at the control point Arkansas River at Webber Falls Lock and Dam. This data was used in the economic programs to determine agricultural damages.

TABLE A-57

ARKANSAS RIVER AT ROBERT S. KERR LOCK AND DAM SEASONAL PERCENTAGE FACTORS

Return Period (years)	Jan-Mar (percent)	Apr-Jun (percent)	Jul-Sep (percent)	Oct-Dec (percent)
2	0.20	0.38	0.20	0.22
5	0.22	0.42	0.19	0.17
10	0.23	0.40	0.17	0.20
20	0.24	0.40	0.15	0.21
50	0.25	0.42	0.14	0.19

TABLE A-58

ARKANSAS RIVER AT WEBBER FALLS LOCK AND DAM SEASONAL PERCENTAGE FACTORS

Return Period (years)	Jan-Mar (percent)	Apr-Jun (percent)	Jul-Sep (percent)	Oct-Dec (percent)
2	0.21	0.35	0.20	0.24
5	0.21	0.39	0.20	0.20
10	0.23	0.38	0.19	0.20
20	0.23	0.37	0.18	0.22
50	0.23	0.39	0.16	0.22

14. RESERVOIR POOL ELEVATION FREQUENCY

Reservoir pool elevation frequency data was developed in order to show the effects of the proposed operating plans on the reservoirs. This data was used to determine the damages in the pools to roads and recreational structures. Graphical pool elevation frequency curves at each lake were developed for each plan using the plotting positions and the annual maximum pool elevations generated by SUPER. The frequency elevation relationships for each alternative and lake, modeled with SUPER, are presented in Tables A-59 to A-79.

TABLE A-59

EL DORADO LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	1352.0	1352.0	1352.0	1352.0	1352.0
500	0.002	1350.9	1350.9	1350.9	1350.9	1350.9
100	0.01	1348.7	1348.7	1348.7	1348.7	1348.7
50	0.02	1347.3	1347.3	1347.4	1347.4	1347.3
25	0.04	1346.3	1346.3	1346.3	1346.4	1346.3
10	0.1	1344.2	1344.2	1344.1	1344.2	1344.2
5	0.2	1342.3	1342.3	1342.2	1342.2	1342.3
2	0.5	1340.3	1340.3	1340.4	1340.3	1340.3
1	0.99	1316.8	1316.8	1316.8	1316.8	1316.8

Top of Conservation pool = 1339.0

Top of Flood Control pool = 1347.5

TABLE A-60

KAW LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	1047.5	1047.5	1047.5	1047.5	1047.5
500	0.002	1047.5	1047.5	1047.5	1047.5	1047.5
100	0.01	1046.8	1046.8	1046.8	1046.9	1046.8
50	0.02	1045.8	1045.8	1045.8	1045.7	1045.8
25	0.04	1043.7	1043.7	1043.7	1043.6	1043.7
10	0.1	1038.3	1037.8	1037.2	1037.5	1038.3
5	0.2	1030.1	1029.8	1029.4	1029.6	1030.1
2	0.5	1018.6	1019.1	1019.0	1018.9	1018.6
1	0.99	1011.0	1011.0	1011.0	1011.0	1011.0

Top of Conservation Pool = 1010.0
Top of Flood Control Pool = 1044.5
Top of Surcharge Pool = 1047.5

TABLE A-61

KEYSTONE LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	757.0	757.0	757.0	757.0	757.0
500	0.002	757.0	757.0	757.0	757.0	757.0
100	0.01	757.0	757.0	757.0	757.0	757.0
50	0.02	756.9	756.8	756.7	756.9	756.9
25	0.04	755.9	755.5	755.2	755.8	755.9
10	0.1	752.5	751.5	750.6	752.0	752.5
5	0.2	746.0	745.1	743.9	745.4	746.0
2	0.5	732.7	734.0	733.8	732.7	732.7
1	0.99	717.8	718.0	718.3	717.9	717.8

Top of Conservation Pool = 723.0
Top of Flood Control Pool = 754.0
Top of Surcharge Pool = 757.0

TABLE A-62

TORONTO LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	936.0	936.0	936.0	936.0	936.0
500	0.002	934.7	934.9	934.8	934.6	934.7
100	0.01	934.0	934.3	934.2	934.0	934.0
50	0.02	933.3	933.5	933.4	933.2	933.3
25	0.04	931.9	932.1	932.1	931.9	931.9
10	0.1	928.8	928.7	928.8	928.7	928.8
5	0.2	925.4	925.2	925.2	925.2	925.4
2	0.5	916.9	917.4	917.3	916.9	916.9
1	0.99	901.2	901.2	901.2	901.2	901.2

Top of Conservation Pool = 901.5
Top of Flood Control Pool = 931.0
Top of Surcharge pool = 936.0

TABLE A-63

FALL RIVER LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	990.0	990.0	990.0	990.0	990.0
500	0.002	986.1	986.2	986.2	986.1	986.1
100	0.01	985.5	985.5	985.5	985.5	985.5
50	0.02	984.8	984.8	984.7	984.7	984.8
25	0.04	983.3	983.3	983.3	983.2	983.3
10	0.1	979.7	979.6	979.6	979.4	979.7
5	0.2	975.1	975.2	975.2	974.8	975.1
2	0.5	964.7	965.3	965.2	964.7	964.7
1	0.99	947.1	947.1	947.2	947.1	947.1

Top of Conservation Pool = 948.5
Top of Flood Control Pool = 987.5
Top of Surcharge Pool = 990.0

TABLE A-64

ELK CITY LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	829.5	829.5	829.5	829.5	829.5
500	0.002	829.0	829.0	829.0	829.0	829.0
100	0.01	828.3	828.2	828.3	828.3	828.3
50	0.02	827.7	827.6	827.7	827.7	827.7
25	0.04	826.4	826.4	826.4	826.4	826.4
10	0.1	823.0	822.9	822.9	822.9	823.0
5	0.2	818.0	818.0	817.9	817.9	818.0
2	0.5	807.4	807.7	807.5	807.5	807.4
1	0.99	793.7	793.4	793.4	793.4	793.7

Top of Conservation Pool = 796.0
Top of Flood Control Pool = 825.0
Top of Surcharge Pool= 829.5

TABLE A-65

BIG HILL LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	872.2	872.2	872.2	872.2	872.2
500	0.002	872.1	872.1	872.1	872.1	872.1
100	0.01	871.6	871.6	871.6	871.6	871.6
50	0.02	871.0	871.0	871.0	871.0	871.0
25	0.04	869.9	869.9	869.9	869.9	869.9
10	0.1	867.4	867.4	867.4	867.4	867.4
5	0.2	865.0	865.0	865.0	865.0	865.0
2	0.5	861.4	861.4	861.4	861.4	861.4
1	0.99	856.5	856.5	856.5	856.5	856.5

Top of Conservation pool = 858.0
Top of Flood Control pool = 867.5

TABLE A-66

OOLOGAH LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	666.0	666.0	666.0	666.0	666.0
500	0.002	666.0	666.0	666.0	666.0	666.0
100	0.01	663.7	663.7	663.3	663.2	663.7
50	0.02	663.0	662.8	662.5	662.5	663.0
25	0.04	661.6	661.3	661.0	661.0	661.6
10	0.1	657.7	657.1	657.0	657.2	657.7
5	0.2	652.5	652.0	652.0	652.0	652.5
2	0.5	644.8	645.7	645.6	645.0	644.8
1	0.99	632.2	632.3	632.3	632.0	632.2

Top of Conservation Pool = 638.0
Top of Flood Control Pool = 661.0
Top of Surcharge Pool = 666.0

TABLE A-67

HULAH LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	767.0	767.0	767.0	767.0	767.0
500	0.002	765.8	765.8	765.8	765.8	765.8
100	0.01	765.1	765.1	765.1	765.1	765.1
50	0.02	764.2	763.4	763.7	763.7	764.2
25	0.04	762.5	761.9	762.1	762.1	762.5
10	0.1	758.5	758.2	758.3	758.3	758.5
5	0.2	754.4	754.4	754.4	754.3	754.4
2	0.5	748.6	748.6	748.7	748.5	748.6
1	0.99	732.8	732.8	732.9	732.8	732.8

Top of Conservation Pool = 733.0
Top of Flood Control Pool = 765.0
Top of Surcharge Pool = 767.0

TABLE A-68

COPAN LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	738.0	738.0	738.0	738.0	738.0
500	0.002	734.4	734.3	734.5	734.3	734.4
100	0.01	733.8	733.8	733.9	733.8	733.8
50	0.02	733.2	733.2	733.3	733.2	733.2
25	0.04	732.0	732.0	732.1	732.0	732.0
10	0.1	729.0	729.0	729.0	728.9	729.0
5	0.2	725.4	725.4	725.4	725.3	725.4
2	0.5	719.5	719.5	719.5	719.5	719.5
1	0.99	708.3	708.2	708.3	708.3	708.3

Top of Conservation Pool = 710.0
Top of Flood Control Pool = 732.0
Top of Surcharge Pool = 738.0

TABLE A-69

BIRCH LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	774.1	774.1	774.1	774.1	774.1
500	0.002	772.3	770.7	770.7	770.5	772.3
100	0.01	771.6	770.1	770.1	769.9	771.6
50	0.02	770.8	769.4	769.5	769.2	770.8
25	0.04	769.2	768.0	768.2	767.9	769.2
10	0.1	765.0	764.4	764.6	764.3	765.0
5	0.2	759.9	759.7	760.0	759.7	759.9
2	0.5	754.1	754.2	754.2	754.1	754.1
1	0.99	742.5	742.5	742.4	742.4	742.5

Top of Conservation Pool = 750.5
Top of Flood Control Pool = 774.0

TABLE A-70

SKIATOOK LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	731.7	731.7	731.7	731.7	731.7
500	0.002	731.0	731.0	731.0	731.0	731.0
100	0.01	729.0	729.0	728.9	729.0	729.0
50	0.02	728.1	728.0	728.0	728.0	728.1
25	0.04	726.4	726.3	726.3	726.3	726.4
10	0.1	722.7	722.6	722.7	722.6	722.7
5	0.2	719.3	719.3	719.5	719.3	719.3
2	0.5	715.3	715.4	715.4	715.4	715.3
1	0.99	690.7	690.6	690.6	690.7	690.7

Top of Conservation Pool = 714.0
Top of Flood Control Pool = 729.0

TABLE A-71

COUNCIL GROVE LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	1299.0	1299.0	1299.0	1299.0	1299.0
500	0.002	1297.8	1297.8	1297.8	1297.8	1297.8
100	0.01	1294.9	1294.9	1294.9	1294.9	1294.9
50	0.02	1293.5	1293.3	1293.3	1293.3	1293.5
25	0.04	1292.3	1292.1	1292.1	1292.1	1292.3
10	0.1	1289.1	1288.9	1288.9	1288.9	1289.1
5	0.2	1284.8	1284.7	1284.7	1284.7	1284.8
2	0.5	1278.4	1278.5	1278.4	1278.4	1278.4
1	0.99	1271.2	1271.3	1271.3	1271.3	1271.2

Top of Conservation Pool = 1274.0
Top of Flood Control Pool = 1289.0
Top of Surcharge pool = 1294.0

TABLE A-72

MARION LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	1360.0	1360.0	1360.0	1360.0	1360.0
500	0.002	1359.7	1359.7	1359.7	1359.7	1359.7
100	0.01	1358.8	1358.8	1358.8	1358.8	1358.8
50	0.02	1358.3	1358.3	1358.3	1358.3	1358.3
25	0.04	1357.5	1357.5	1357.5	1357.5	1357.5
10	0.1	1355.8	1355.8	1355.8	1355.8	1355.8
5	0.2	1354.6	1354.6	1354.6	1354.5	1354.6
2	0.5	1352.0	1352.0	1352.0	1352.0	1352.0
1	0.99	1338.3	1338.3	1338.0	1338.4	1338.3

Top of Conservation Pool = 1350.5

Top of Flood Control Pool = 1358.5

Top of Surcharge Pool = 1360.0

TABLE A-73

JOHN REDMOND LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	1073.0	1073.0	1073.0	1073.0	1073.0
500	0.002	1071.0	1071.0	1071.1	1071.2	1071.0
100	0.01	1070.6	1070.6	1070.7	1070.8	1070.6
50	0.02	1070.2	1070.1	1070.2	1070.3	1070.2
25	0.04	1069.2	1069.2	1069.2	1069.2	1069.2
10	0.1	1066.5	1066.5	1066.4	1066.4	1066.5
5	0.2	1062.4	1062.4	1062.3	1062.2	1062.4
2	0.5	1052.1	1052.3	1052.3	1052.2	1052.1
1	0.99	1038.2	1038.2	1038.1	1038.3	1038.2

Top of Conservation Pool = 1039.0
Top of Flood Control Pool = 1068.0
Top of Surcharge Pool = 1073.0

TABLE A-74

PENSACOLA LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	755.0	755.0	755.0	755.0	755.0
500	0.002	755.0	755.0	755.0	755.0	755.0
100	0.01	755.0	755.0	755.0	755.0	755.0
50	0.02	754.9	754.9	754.9	754.9	754.9
25	0.04	754.7	754.6	754.6	754.6	754.7
10	0.1	754.1	753.9	753.8	754.1	754.1
5	0.2	752.8	752.4	752.3	752.7	752.8
2	0.5	748.6	748.6	748.7	748.6	748.6
1	0.99	744.9	744.9	744.9	744.9	744.9

Top of Conservation Pool = 745.0
Top of Flood Control Pool = 755.0

TABLE A-75

LAKE HUDSON
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	636.0	636.0	636.0	636.0	636.0
500	0.002	636.0	636.0	636.0	636.0	636.0
100	0.01	636.0	636.0	636.0	636.0	636.0
50	0.02	636.0	636.0	636.0	635.8	636.0
25	0.04	635.8	635.5	635.4	635.4	635.8
10	0.1	634.7	634.2	634.0	634.3	634.7
5	0.2	632.6	632.0	631.8	632.2	632.6
2	0.5	626.0	626.0	626.0	625.9	626.0
1	0.99	620.3	620.3	620.3	620.3	620.3

Top of Conservation Pool = 619.0
Top of Flood Control Pool = 636.0

TABLE A-76

FORT GIBSON LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	582.0	582.0	582.0	581.2	582.0
500	0.002	582.0	582.0	582.0	581.2	582.0
100	0.01	582.0	582.0	582.0	581.2	582.0
50	0.02	581.8	581.8	581.7	581.1	581.8
25	0.04	581.4	581.1	581.0	580.8	581.4
10	0.1	580.0	579.0	578.6	579.3	580.0
5	0.2	576.2	574.9	574.4	575.6	576.2
2	0.5	564.4	565.1	564.9	564.4	564.4
1	0.99	554.8	554.8	554.8	554.8	554.8

Top of Conservation Pool = 554.0
Top of Flood Control Pool = 582.0

TABLE A-77

TENKILLER LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	671.0	671.0	671.0	671.0	671.0
500	0.002	671.0	671.0	671.0	667.2	671.0
100	0.01	668.1	668.1	668.1	666.6	668.1
50	0.02	667.1	667.1	667.1	665.9	667.1
25	0.04	665.2	665.2	665.2	664.4	665.2
10	0.1	661.0	660.2	658.4	660.1	661.0
5	0.2	654.6	653.5	651.6	653.6	654.6
2	0.5	642.7	644.0	643.6	642.8	642.7
1	0.99	631.9	631.9	631.9	632.1	631.9

Top of Conservation Pool = 632.0
Top of Flood Control Pool = 667.0
Top of Surcharge Pool = 671.0

TABLE A-78

EUFAULA LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	600.0	600.0	600.0	600.0	600.0
500	0.002	599.8	599.8	600.0	599.7	599.8
100	0.01	599.5	599.5	599.8	599.4	599.5
50	0.02	599.2	599.2	599.3	599.1	599.2
25	0.04	598.6	598.6	598.5	598.5	598.6
10	0.1	596.9	596.6	596.4	596.8	596.9
5	0.2	594.5	594.4	594.0	594.4	594.5
2	0.5	589.4	589.7	589.6	589.3	589.4
1	0.99	584.6	584.5	584.5	584.6	584.6

Top of Conservation Pool = 585.0
Top of Flood Control Pool = 597.0
Top of Surcharge Pool = 600.0

TABLE A-79

WISTER LAKE
POOL ELEVATION FREQUENCY RELATIONSHIPS

Frequency (years)	Frequency (exceedance)	Baseline No Action Plan (feet)	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops Only Plan (feet)	Ops 60K Bench Plan (feet)
1000	0.001	508.4	508.1	507.9	508.5	508.4
500	0.002	508.3	508.1	507.9	508.4	508.3
100	0.01	507.9	507.7	507.5	508.0	507.9
50	0.02	507.4	507.2	507.0	507.5	507.4
25	0.04	506.4	506.2	506.1	506.4	506.4
10	0.1	503.6	503.5	503.5	503.7	503.6
5	0.2	500.0	500.0	500.1	500.0	500.0
2	0.5	493.4	493.5	493.5	493.5	493.4
1	0.99	479.7	479.7	479.7	479.6	479.7

Top of Conservation Pool = 478.0
Top of Flood Control Pool = 502.5

15. RESERVOIR POOL ELEVATION DURATION

Monthly elevation duration curves were developed in order to show seasonal effects on reservoirs for evaluating recreational damages or benefits associated from each of the alternative plans. This information was obtained from one of the output tables from SUPER. The elevation duration curves for the months April to September are presented in Tables A-80 through A-100 for each reservoir and alternative plan.

TABLE A-80

Council Grove Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1289.05	1290.01	1289.37	1294.53	1286.79	1285.50
1.0	1286.04	1288.86	1286.79	1288.59	1283.78	1280.44
5.0	1280.05	1285.04	1281.71	1280.61	1276.34	1275.24
10.0	1277.16	1278.34	1278.60	1277.62	1274.51	1274.46
20.0	1275.00	1275.34	1276.63	1275.01	1274.31	1274.22
50.0	1274.21	1274.26	1274.36	1274.11	1273.75	1273.62

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1289.05	1289.69	1289.69	1294.14	1286.50	1285.55
1.0	1286.03	1288.70	1286.82	1288.28	1283.53	1280.38
5.0	1280.08	1283.53	1281.51	1280.37	1276.23	1275.30
10.0	1277.20	1277.91	1278.38	1277.35	1274.40	1274.37
20.0	1275.26	1275.43	1276.28	1275.01	1274.26	1274.21
50.0	1274.14	1274.18	1274.27	1274.10	1273.83	1273.68

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1288.91	1289.76	1289.12	1294.22	1286.56	1285.61
1.0	1285.77	1288.69	1286.56	1288.35	1283.58	1280.46
5.0	1280.06	1282.94	1280.82	1280.27	1276.35	1275.34
10.0	1277.16	1277.85	1278.31	1277.16	1274.42	1274.40
20.0	1275.07	1275.33	1276.14	1275.03	1274.27	1274.22
50.0	1274.15	1274.20	1274.29	1274.11	1273.82	1273.67

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1289.06	1290.03	1289.38	1294.55	1286.80	1285.51
1.0	1286.02	1288.88	1286.80	1288.35	1283.25	1280.21
5.0	1279.96	1284.80	1281.25	1279.70	1276.36	1275.36
10.0	1277.18	1278.35	1278.39	1276.84	1274.51	1274.47
20.0	1274.97	1275.27	1276.39	1274.92	1274.32	1274.22
50.0	1274.21	1274.27	1274.35	1274.11	1273.75	1273.62

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1289.06	1290.02	1289.38	1294.54	1286.80	1285.51
1.0	1286.06	1288.81	1286.80	1288.60	1283.78	1280.21
5.0	1279.99	1284.99	1281.73	1280.60	1276.47	1275.31
10.0	1277.17	1278.32	1278.56	1277.68	1274.51	1274.47
20.0	1275.01	1275.34	1276.65	1275.06	1274.32	1274.22
50.0	1274.21	1274.27	1274.35	1274.13	1273.76	1273.62

Top of Conservation pool = 1274.0
Top of Flood Control pool = 1289.0
Top of Surcharge pool = 1294.0

TABLE A-81

Marion Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	1356.68	1356.82	1356.82	1358.57	1356.12	1355.37
1.0	1355.97	1356.12	1356.02	1356.16	1355.08	1353.21
5.0	1352.95	1354.83	1353.50	1353.04	1351.36	1351.20
10.0	1351.79	1352.35	1352.25	1351.36	1350.63	1350.81
20.0	1350.90	1350.99	1351.19	1350.81	1350.28	1350.36
50.0	1350.21	1350.39	1350.44	1350.12	1349.62	1349.43

175,000 cfs Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	1356.70	1356.82	1356.82	1358.56	1356.12	1355.37
1.0	1355.66	1356.09	1355.97	1356.16	1354.90	1353.21
5.0	1353.09	1354.08	1353.18	1352.62	1351.30	1351.25
10.0	1351.77	1352.23	1352.10	1351.37	1350.64	1350.82
20.0	1350.93	1350.99	1351.16	1350.82	1350.28	1350.37
50.0	1350.22	1350.41	1350.45	1350.11	1349.62	1349.42

200,000 cfs Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	1356.70	1356.82	1356.82	1358.56	1356.12	1355.37
1.0	1355.66	1356.07	1355.95	1356.15	1354.84	1353.21
5.0	1353.13	1353.87	1353.18	1352.62	1351.32	1351.21
10.0	1351.86	1352.29	1352.10	1351.38	1350.67	1350.81
20.0	1350.92	1350.98	1351.15	1350.82	1350.29	1350.37
50.0	1350.22	1350.41	1350.45	1350.11	1349.62	1349.42

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	1356.70	1356.82	1356.82	1358.56	1356.12	1355.37
1.0	1356.03	1356.13	1355.95	1356.15	1354.84	1353.21
5.0	1352.93	1354.61	1353.24	1352.68	1351.33	1351.25
10.0	1351.83	1352.42	1352.21	1351.32	1350.63	1350.82
20.0	1350.89	1350.98	1351.15	1350.80	1350.27	1350.36
50.0	1350.21	1350.39	1350.44	1350.11	1349.62	1349.42

Operations Only 60,000 cfs Bench Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	1356.68	1356.82	1356.82	1358.57	1356.12	1355.37
1.0	1355.97	1356.12	1356.02	1356.17	1355.08	1353.21
5.0	1352.93	1354.86	1353.41	1353.04	1351.41	1351.24
10.0	1351.82	1352.35	1352.27	1351.36	1350.66	1350.82
20.0	1350.89	1350.98	1351.21	1350.81	1350.28	1350.37
50.0	1350.21	1350.39	1350.45	1350.12	1349.63	1349.43

Top of Conservation pool = 1350.5
Top of Flood Control pool = 1358.5
Top of Surcharge pool = 1360.0

TABLE A-82

John Redmond Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1067.53	1068.32	1068.72	1070.69	1064.38	1058.85
1.0	1063.99	1067.00	1065.16	1066.35	1059.64	1052.54
5.0	1053.33	1060.43	1059.46	1056.23	1045.84	1043.28
10.0	1049.79	1054.12	1054.56	1049.26	1038.80	1038.38
20.0	1042.52	1043.02	1046.67	1040.78	1037.47	1037.48
50.0	1039.03	1039.05	1039.29	1037.35	1037.15	1037.14

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1067.52	1068.70	1068.70	1070.67	1064.36	1058.84
1.0	1063.97	1066.99	1065.15	1066.14	1059.63	1052.53
5.0	1053.67	1058.05	1059.18	1055.43	1045.44	1043.47
10.0	1049.68	1052.04	1054.58	1048.45	1038.80	1038.45
20.0	1043.32	1043.63	1046.03	1041.49	1037.47	1037.48
50.0	1039.04	1039.07	1039.30	1037.36	1037.15	1037.13

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1067.52	1068.70	1068.70	1070.67	1064.36	1059.63
1.0	1063.97	1066.99	1065.15	1066.14	1059.63	1052.53
5.0	1053.45	1058.05	1058.05	1054.51	1045.64	1043.60
10.0	1048.99	1051.59	1054.01	1048.27	1038.77	1038.46
20.0	1043.04	1043.39	1045.62	1041.30	1037.47	1037.48
50.0	1039.04	1039.07	1039.26	1037.35	1037.15	1037.13

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1067.53	1068.32	1068.72	1070.69	1064.38	1058.85
1.0	1063.59	1067.00	1064.38	1066.15	1059.64	1052.54
5.0	1053.28	1059.96	1058.15	1052.54	1045.84	1043.86
10.0	1049.71	1053.65	1054.12	1047.42	1038.97	1038.45
20.0	1042.50	1043.24	1046.31	1040.71	1037.47	1037.48
50.0	1039.03	1039.05	1039.29	1037.35	1037.15	1037.14

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1067.54	1068.33	1068.73	1070.70	1064.38	1058.86
1.0	1063.86	1067.01	1065.17	1066.36	1059.65	1052.55
5.0	1053.29	1060.55	1059.47	1056.17	1046.24	1043.67
10.0	1049.95	1054.13	1054.48	1048.94	1039.00	1038.45
20.0	1042.59	1043.24	1046.76	1041.24	1037.48	1037.49
50.0	1039.03	1039.05	1039.27	1037.37	1037.16	1037.14

Top of Conservation pool = 1039.0
Top of Flood Control pool = 1068.0
Top of Surcharge pool = 1073.0

TABLE A-83

Pensacola Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.62	754.86	754.55	752.38	748.35	753.00
1.0	752.48	753.31	753.00	750.83	746.70	746.10
5.0	748.40	750.77	750.52	747.76	745.65	745.07
10.0	746.43	748.32	747.34	746.08	743.96	743.53
20.0	745.43	745.70	745.89	745.38	742.46	741.22
50.0	742.82	744.51	745.18	744.09	741.18	741.08

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.31	754.86	754.55	752.07	748.66	753.00
1.0	751.45	753.31	753.00	750.83	746.80	746.41
5.0	748.25	749.33	749.65	747.54	745.66	745.08
10.0	746.82	747.71	747.22	746.12	743.61	743.52
20.0	745.57	745.79	746.01	745.39	742.44	741.22
50.0	742.92	744.54	745.19	744.11	741.18	741.08

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.00	754.86	754.24	752.07	748.66	753.00
1.0	751.04	753.31	753.00	750.52	746.80	746.41
5.0	748.20	748.97	749.28	747.46	745.65	745.11
10.0	746.73	747.56	747.22	746.09	743.79	743.53
20.0	745.48	745.76	745.97	745.40	742.44	741.22
50.0	742.91	744.54	745.18	744.12	741.18	741.08

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.31	754.86	754.55	751.76	748.04	753.00
1.0	751.76	753.16	752.57	750.00	746.76	746.34
5.0	748.47	750.68	749.28	747.15	745.61	745.10
10.0	746.49	748.18	747.16	745.95	743.51	743.53
20.0	745.42	745.72	745.90	745.30	742.43	741.22
50.0	742.85	744.52	745.18	744.03	741.18	741.08

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.62	754.86	754.55	752.38	748.51	753.00
1.0	752.48	753.31	753.00	751.20	746.80	746.41
5.0	748.35	750.79	750.52	747.81	745.71	745.12
10.0	746.44	748.32	747.35	746.18	743.96	743.55
20.0	745.40	745.68	745.95	745.42	742.46	741.22
50.0	742.86	744.51	745.18	744.10	741.18	741.08

Top of Conservation pool = 745.0

Top of Flood Control pool = 755.0

TABLE A-84

Hudson Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	634.10	635.90	635.72	633.30	624.72	629.05
1.0	631.57	634.32	634.46	630.42	621.59	622.01
5.0	625.08	629.77	629.05	624.18	620.26	620.23
10.0	621.83	625.31	623.18	620.92	619.81	619.75
20.0	619.95	620.13	620.35	619.55	619.37	619.28
50.0	619.19	619.16	619.17	619.16	619.12	619.05

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	632.65	635.90	635.54	632.65	624.35	628.68
1.0	630.13	634.27	634.45	630.13	621.83	621.47
5.0	625.26	627.89	628.03	623.54	620.28	620.20
10.0	621.97	624.08	622.60	620.80	619.85	619.70
20.0	619.99	620.03	620.08	619.61	619.43	619.28
50.0	619.19	619.17	619.17	619.17	619.13	619.05

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	632.29	635.90	635.53	631.57	625.07	628.68
1.0	629.85	634.18	634.45	629.58	621.95	621.83
5.0	624.95	627.60	627.42	623.27	620.34	620.25
10.0	621.74	623.84	622.51	620.82	619.88	619.72
20.0	619.91	620.01	620.26	619.57	619.43	619.28
50.0	619.19	619.16	619.17	619.16	619.13	619.05

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	633.37	635.90	635.54	630.85	625.08	629.05
1.0	630.49	633.74	632.65	627.96	621.95	621.47
5.0	625.26	629.14	627.33	623.13	620.31	620.22
10.0	621.83	625.14	622.63	620.80	619.85	619.71
20.0	619.97	620.00	620.28	619.57	619.41	619.28
50.0	619.20	619.16	619.17	619.16	619.12	619.05

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	634.46	635.90	635.54	633.30	625.08	629.05
1.0	632.29	634.32	634.46	630.97	622.19	621.83
5.0	625.08	629.41	629.17	624.18	620.38	620.29
10.0	621.87	625.38	623.27	621.04	619.88	619.77
20.0	619.94	620.13	620.26	619.63	619.42	619.28
50.0	619.19	619.16	619.17	619.17	619.12	619.05

Top of Conservation pool = 619.0
Top of Flood Control pool = 636.0

TABLE A-85

Fort Gibson Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	579.04	582.09	581.48	578.84	563.78	563.78
1.0	577.82	579.85	580.11	574.77	560.97	559.51
5.0	563.02	573.14	571.41	562.56	557.88	557.34
10.0	559.35	565.98	562.83	559.34	556.52	556.43
20.0	557.78	558.25	558.98	557.51	554.61	554.89
50.0	555.39	554.89	555.87	554.64	553.94	553.81

175,000 cfs Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	577.81	582.08	580.86	578.12	566.22	566.83
1.0	573.74	579.64	580.10	573.54	561.19	560.12
5.0	564.15	569.27	569.27	562.83	557.92	557.67
10.0	561.29	563.73	562.90	560.26	556.37	556.49
20.0	558.17	559.09	559.48	557.84	554.63	554.88
50.0	555.63	555.00	556.01	554.71	553.95	553.82

200,000 cfs Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	577.20	582.08	580.86	575.37	565.61	566.83
1.0	572.63	579.34	579.79	572.32	560.53	560.27
5.0	564.04	567.59	568.25	562.90	557.98	557.52
10.0	560.84	563.27	562.74	560.09	556.48	556.38
20.0	558.06	558.95	559.45	557.79	554.61	554.84
50.0	555.57	554.99	555.96	554.69	553.95	553.82

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	578.23	582.09	581.18	574.47	563.17	564.39
1.0	574.77	578.43	578.02	569.47	561.54	560.43
5.0	563.58	572.56	568.36	562.26	557.81	557.62
10.0	559.61	564.85	562.31	559.63	556.39	556.43
20.0	557.78	558.27	559.04	557.65	554.60	554.86
50.0	555.45	554.96	555.90	554.63	553.94	553.82

Operations Only 60,000 cfs Bench Plan

Percent of	Pool Elevations					
Time Exceeded	April	May	June	July	August	September
0.1	579.35	582.09	581.18	578.84	564.39	565.00
1.0	577.52	579.85	580.11	574.97	562.05	560.73
5.0	563.29	573.09	571.41	563.48	557.99	557.51
10.0	559.32	565.98	563.03	560.08	556.70	556.41
20.0	557.62	558.21	559.21	557.86	554.62	554.89
50.0	555.39	554.90	555.92	554.68	553.94	553.82

Top of Conservation pool = 554.0

Top of Flood Control pool = 582.0

TABLE A-86

Toronto Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	926.57	928.10	929.62	932.68	918.17	926.19
1.0	925.04	926.29	927.59	928.48	912.06	913.84
5.0	917.22	922.52	923.01	917.92	906.79	906.63
10.0	911.51	915.66	915.33	910.86	902.36	902.48
20.0	905.27	905.02	909.71	905.77	902.00	901.99
50.0	901.84	901.88	902.01	901.83	901.54	901.53

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	926.59	928.12	929.65	932.70	918.95	926.21
1.0	923.41	926.21	927.49	928.50	913.99	913.86
5.0	917.12	920.77	923.03	916.66	907.36	906.78
10.0	913.13	915.02	914.84	911.39	903.20	902.76
20.0	907.12	906.72	909.53	906.88	902.02	902.00
50.0	901.87	901.92	902.06	901.87	901.55	901.53

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	927.36	928.12	929.39	932.70	920.48	926.21
1.0	924.45	926.17	927.36	928.50	915.13	913.99
5.0	917.12	919.71	922.52	916.66	907.49	906.86
10.0	912.62	914.54	914.66	911.54	903.44	902.90
20.0	906.91	906.01	909.38	906.86	902.02	902.00
50.0	901.87	901.91	902.03	901.86	901.55	901.54

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	926.57	928.10	929.37	932.68	917.41	926.19
1.0	924.86	926.14	927.34	928.48	911.11	913.59
5.0	917.41	922.35	922.14	916.50	906.78	907.00
10.0	911.51	915.45	914.88	910.54	902.56	902.82
20.0	904.99	904.86	909.69	906.37	902.00	902.00
50.0	901.84	901.88	902.01	901.84	901.54	901.53

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	926.58	928.11	929.63	932.69	918.18	926.20
1.0	925.24	926.29	927.56	928.49	912.45	913.85
5.0	917.41	922.62	922.95	917.92	907.48	906.95
10.0	911.48	915.63	915.41	911.09	902.90	902.82
20.0	904.95	904.79	910.10	906.51	902.01	902.00
50.0	901.84	901.87	902.01	901.84	901.54	901.53

Top of Conservation pool = 901.5
Top of Flood Control pool = 931.0
Top of Surcharge pool = 936.0

TABLE A-87

Fall River Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	979.70	981.24	984.00	986.15	969.58	972.80
1.0	977.25	979.70	981.09	981.55	960.55	959.45
5.0	966.23	973.84	972.34	968.66	953.47	950.94
10.0	959.37	962.87	964.97	959.55	949.29	949.27
20.0	950.20	951.72	957.77	952.75	949.11	949.06
50.0	948.90	948.97	949.07	948.92	948.56	948.43

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	979.40	980.55	984.02	986.33	972.47	972.93
1.0	974.97	978.67	980.97	982.02	963.22	959.52
5.0	967.02	970.93	972.24	968.21	955.02	951.21
10.0	963.15	962.67	964.66	960.45	949.36	949.32
20.0	953.79	954.65	957.11	954.69	949.15	949.09
50.0	948.97	949.04	949.16	948.99	948.53	948.40

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	979.86	980.32	984.02	986.33	973.39	972.01
1.0	975.24	978.42	980.97	982.63	965.07	961.84
5.0	967.12	969.38	971.77	967.74	955.18	951.21
10.0	962.43	962.05	963.88	960.45	949.35	949.33
20.0	953.81	952.95	957.12	954.67	949.14	949.09
50.0	948.96	949.02	949.13	948.96	948.52	948.39

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	979.68	981.29	983.82	986.12	965.88	972.78
1.0	977.61	978.58	980.83	981.52	959.62	960.36
5.0	966.34	973.36	971.58	967.49	953.35	951.69
10.0	960.51	962.59	964.27	959.21	949.29	949.28
20.0	950.13	951.23	957.89	953.63	949.11	949.07
50.0	948.90	948.97	949.07	948.95	948.56	948.42

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	979.51	981.28	983.89	986.20	969.61	971.91
1.0	977.29	979.43	981.06	981.59	960.70	960.39
5.0	966.29	973.90	972.37	968.87	955.09	951.33
10.0	959.93	962.40	965.35	959.98	949.32	949.29
20.0	950.11	951.12	958.27	953.90	949.13	949.08
50.0	948.90	948.97	949.09	948.95	948.56	948.43

Top of Conservation pool = 948.5
Top of Flood Control pool = 987.5
Top of Surcharge pool = 990.0

TABLE A-88

Elk City Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	819.22	825.21	825.69	824.74	808.19	815.75
1.0	815.75	820.48	824.27	822.37	803.08	805.35
5.0	807.83	813.04	813.39	810.32	798.97	797.45
10.0	803.31	806.49	807.40	803.02	796.77	796.71
20.0	797.64	798.95	802.30	798.53	796.45	796.37
50.0	796.34	796.44	796.52	796.19	795.60	795.51

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	817.18	825.21	825.21	824.98	810.55	815.75
1.0	813.58	821.43	823.08	822.37	804.40	804.40
5.0	808.06	810.50	812.92	809.13	800.15	797.60
10.0	805.09	806.23	806.61	803.41	796.82	796.73
20.0	799.67	800.30	802.41	799.88	796.50	796.40
50.0	796.37	796.49	796.58	796.25	795.62	795.53

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	816.70	825.21	825.21	824.98	811.97	815.75
1.0	813.86	821.43	822.24	822.37	805.35	805.35
5.0	808.12	809.80	812.68	809.13	800.25	797.62
10.0	804.88	805.50	806.50	803.46	796.83	796.74
20.0	799.44	799.50	802.17	799.70	796.50	796.41
50.0	796.37	796.48	796.54	796.23	795.62	795.53

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	819.54	825.21	825.69	824.74	807.24	815.75
1.0	815.75	820.48	822.37	821.43	802.67	805.35
5.0	807.95	812.56	812.54	808.90	798.97	797.86
10.0	803.55	806.10	806.93	802.83	796.78	796.74
20.0	797.51	798.85	802.17	799.19	796.46	796.40
50.0	796.34	796.44	796.51	796.23	795.61	795.52

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	819.54	825.21	825.69	824.74	809.13	815.75
1.0	815.52	820.48	824.27	822.18	803.22	805.35
5.0	807.95	812.83	813.39	810.32	799.96	797.69
10.0	803.39	806.30	807.42	803.35	796.82	796.73
20.0	797.48	798.82	802.60	799.37	796.49	796.39
50.0	796.34	796.44	796.52	796.23	795.61	795.51

Top of Conservation pool = 796.0
Top of Flood Control pool = 825.0
Top of Surcharge pool= 829.5

TABLE A-89

Big Hill Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	866.77	868.22	868.01	868.84	861.79	864.28
1.0	864.69	865.52	867.43	865.11	859.90	860.96
5.0	861.18	863.11	863.76	861.79	858.60	858.45
10.0	859.62	861.34	861.11	859.78	858.16	858.20
20.0	858.43	858.65	859.39	858.67	857.95	857.95
50.0	857.94	857.99	858.11	857.88	857.57	857.45

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	866.77	868.22	868.01	868.84	862.41	864.28
1.0	863.55	865.69	867.37	864.57	860.34	861.06
5.0	861.40	862.65	863.66	861.51	858.88	858.45
10.0	860.39	861.17	860.96	859.96	858.27	858.23
20.0	858.77	858.88	859.41	858.99	857.97	857.96
50.0	857.96	858.01	858.13	857.91	857.61	857.46

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	866.77	868.22	868.01	868.84	862.62	864.28
1.0	863.66	865.63	867.29	864.10	860.54	860.96
5.0	861.43	862.50	863.59	861.59	858.88	858.46
10.0	860.24	861.03	860.91	860.01	858.27	858.23
20.0	858.70	858.77	859.29	858.92	857.97	857.96
50.0	857.96	858.01	858.12	857.90	857.59	857.45

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	866.77	868.22	868.01	868.84	861.37	864.28
1.0	864.90	865.52	867.04	864.11	859.65	860.96
5.0	861.28	863.03	863.55	861.44	858.59	858.45
10.0	859.69	861.13	860.87	859.71	858.18	858.21
20.0	858.42	858.65	859.32	858.77	857.96	857.96
50.0	857.93	857.99	858.11	857.91	857.61	857.47

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	866.77	868.22	868.01	868.84	862.20	864.28
1.0	864.90	865.63	867.42	865.11	859.97	860.86
5.0	861.28	863.18	863.81	861.85	858.78	858.45
10.0	859.61	861.18	861.10	859.91	858.27	858.22
20.0	858.42	858.64	859.44	858.81	857.97	857.96
50.0	857.93	857.98	858.11	857.91	857.61	857.48

Top of Conservation pool = 867.5
Top of Flood Control pool = 858.0

TABLE A-90

Oologah Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	657.78	663.66	662.40	660.83	645.77	643.83
1.0	653.30	656.84	661.04	654.24	644.36	643.26
5.0	644.70	650.57	649.54	645.56	643.13	641.78
10.0	642.48	645.86	645.21	643.88	642.09	640.68
20.0	639.82	640.81	643.67	643.24	639.45	638.70
50.0	637.96	638.06	639.81	639.72	637.64	637.34

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	654.70	663.64	661.62	657.68	649.05	644.82
1.0	651.14	657.52	660.11	652.66	644.74	643.67
5.0	645.59	648.64	649.21	645.76	643.57	642.22
10.0	644.40	645.29	645.26	644.53	642.53	641.16
20.0	640.96	642.86	644.18	643.68	639.82	638.86
50.0	638.05	638.14	640.17	639.90	637.64	637.34

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	654.63	663.55	661.21	656.04	649.47	645.24
1.0	650.65	657.22	659.80	651.97	644.93	643.79
5.0	645.54	647.59	648.53	645.81	643.67	642.29
10.0	644.27	644.73	644.99	644.54	642.68	641.12
20.0	640.94	642.42	644.04	643.67	639.77	638.83
50.0	638.06	638.12	640.15	639.87	637.64	637.33

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	657.70	663.66	661.30	657.07	645.77	644.83
1.0	653.30	655.97	659.11	651.73	644.48	643.69
5.0	644.77	650.08	648.49	645.14	643.35	642.09
10.0	642.45	645.42	645.11	644.29	642.33	641.07
20.0	639.95	640.89	643.90	643.44	639.69	638.85
50.0	638.02	638.14	640.18	639.76	637.64	637.34

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	657.78	663.66	662.40	660.83	646.71	644.83
1.0	653.61	656.84	660.95	654.24	644.61	643.52
5.0	644.69	650.68	649.85	645.63	643.50	642.04
10.0	642.23	645.77	645.43	644.35	642.58	640.96
20.0	639.69	640.49	643.99	643.45	639.77	638.89
50.0	637.97	638.06	639.64	639.74	637.63	637.34

Top of Conservation pool = 638.0
Top of Flood Control pool = 661.0
Top of Surcharge pool = 666.0

TABLE A-91

Hulah Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.98	758.87	764.51	760.00	753.80	752.11
1.0	751.66	757.59	759.81	756.20	748.35	747.37
5.0	748.19	749.85	751.88	748.05	739.48	737.31
10.0	745.67	746.35	746.55	743.09	734.00	733.98
20.0	741.18	742.25	741.34	735.66	733.05	733.16
50.0	733.84	734.05	733.84	732.85	732.10	732.05

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	754.36	758.75	763.95	762.26	753.23	752.11
1.0	751.73	757.56	758.76	755.94	748.35	747.37
5.0	748.23	749.99	751.49	747.72	739.70	737.31
10.0	745.80	746.56	746.55	743.09	734.00	733.99
20.0	741.18	742.32	741.35	735.96	733.06	733.18
50.0	733.84	734.04	733.84	732.85	732.10	732.05

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.98	758.75	764.13	763.38	753.80	752.11
1.0	751.79	757.59	758.87	756.17	748.50	747.37
5.0	748.30	750.35	751.92	748.95	740.38	737.45
10.0	745.73	747.04	747.07	743.09	734.03	734.00
20.0	741.20	742.36	741.50	735.92	733.07	733.18
50.0	733.84	734.04	733.85	732.85	732.10	732.05

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	754.36	759.72	764.23	762.26	753.80	752.11
1.0	751.79	757.30	759.44	755.94	748.35	747.37
5.0	748.58	750.01	751.45	747.91	739.14	737.31
10.0	745.73	746.42	746.71	742.98	733.98	733.98
20.0	741.14	742.35	741.34	735.80	733.03	733.17
50.0	733.84	734.04	733.85	732.85	732.10	732.05

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	753.98	758.87	764.51	758.87	753.80	752.11
1.0	751.63	757.59	759.81	756.12	748.35	747.37
5.0	748.04	749.85	751.70	748.05	739.95	737.45
10.0	745.70	746.13	746.62	743.20	734.02	733.99
20.0	741.18	742.24	741.36	735.77	733.06	733.18
50.0	733.84	734.04	733.84	732.85	732.10	732.05

Top of Conservation pool = 733.0
Top of Flood Control pool = 765.0
Top of Surcharge pool = 767.0

TABLE A-92

Copan Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	726.00	732.24	732.51	729.91	722.48	720.62
1.0	724.33	729.45	731.19	727.49	719.38	715.97
5.0	720.26	721.55	724.18	721.15	713.19	710.88
10.0	717.04	718.70	719.09	716.90	710.29	710.23
20.0	713.62	714.68	714.69	711.07	709.94	709.67
50.0	710.11	710.22	710.22	709.75	708.78	708.44

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	725.26	732.24	732.39	729.91	722.95	720.62
1.0	723.99	729.35	731.12	727.12	719.69	715.97
5.0	720.28	721.55	724.70	720.99	713.00	710.93
10.0	717.11	719.09	719.38	716.90	710.29	710.25
20.0	713.65	714.77	714.80	711.24	709.93	709.68
50.0	710.12	710.23	710.23	709.75	708.79	708.41

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	724.33	732.24	732.47	729.91	722.48	720.62
1.0	723.24	729.60	731.15	726.89	719.38	715.97
5.0	720.09	721.90	725.13	720.99	713.19	710.95
10.0	716.98	719.38	719.50	716.76	710.29	710.26
20.0	713.68	714.67	714.79	711.22	709.93	709.68
50.0	710.11	710.23	710.23	709.75	708.77	708.41

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	726.19	732.24	732.47	729.91	722.48	720.62
1.0	724.33	729.60	731.15	726.50	719.07	715.97
5.0	720.29	721.83	724.33	720.29	712.13	710.91
10.0	717.19	719.01	719.07	716.56	710.27	710.24
20.0	713.66	714.96	714.71	711.18	709.92	709.67
50.0	710.11	710.23	710.23	709.75	708.78	708.41

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	724.34	732.24	732.57	729.91	722.48	720.62
1.0	723.64	729.45	731.37	727.31	719.39	715.98
5.0	720.21	721.50	724.34	721.15	713.20	710.90
10.0	717.12	718.77	719.06	716.81	710.30	710.24
20.0	713.65	714.70	714.67	711.13	709.94	709.68
50.0	710.12	710.23	710.23	709.76	708.78	708.43

Top of Conservation pool = 710.0
Top of Flood Control pool = 732.0
Top of Surcharge pool = 738.0

TABLE A-93

Birch Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	761.93	774.21	771.19	764.76	754.37	759.09
1.0	756.26	764.29	768.54	753.90	750.83	752.01
5.0	751.31	753.27	756.74	750.57	750.41	750.46
10.0	750.59	751.15	751.14	750.48	750.18	750.20
20.0	750.42	750.50	750.47	750.29	749.72	749.67
50.0	749.89	750.02	749.99	749.71	748.69	748.10

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	761.86	774.12	771.06	759.03	754.32	759.03
1.0	756.20	764.22	764.69	755.26	751.02	752.05
5.0	751.40	753.38	755.57	750.69	750.39	750.45
10.0	750.89	751.26	751.23	750.46	750.17	750.20
20.0	750.43	750.51	750.46	750.27	749.72	749.68
50.0	749.87	750.00	749.96	749.69	748.72	748.12

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	761.93	774.21	772.32	763.82	754.37	759.09
1.0	758.42	764.36	763.82	755.69	750.83	752.29
5.0	751.78	755.43	755.31	750.58	750.41	750.47
10.0	750.80	751.32	751.29	750.48	750.18	750.21
20.0	750.44	750.52	750.49	750.29	749.72	749.70
50.0	749.90	750.02	750.00	749.72	748.71	748.13

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	761.93	774.21	772.32	758.15	754.37	759.09
1.0	756.03	763.82	764.76	753.43	750.83	752.01
5.0	751.32	752.60	755.32	750.57	750.41	750.47
10.0	750.59	751.09	751.07	750.48	750.18	750.21
20.0	750.41	750.50	750.47	750.29	749.72	749.70
50.0	749.89	750.01	749.99	749.71	748.70	748.11

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	761.93	774.21	771.19	763.82	754.37	759.09
1.0	756.26	764.29	768.54	753.74	750.86	752.01
5.0	751.31	753.16	756.74	750.58	750.41	750.46
10.0	750.59	751.15	751.14	750.48	750.18	750.20
20.0	750.42	750.50	750.47	750.29	749.72	749.67
50.0	749.89	750.02	749.99	749.71	748.70	748.10

Top of Conservation pool = 750.5
Top of Flood Control pool = 774.0

TABLE A-94

Skiatook Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	721.00	729.97	729.27	718.16	715.79	717.92
1.0	717.92	723.83	723.89	716.22	714.35	715.44
5.0	714.98	716.64	715.67	714.31	714.13	714.10
10.0	714.27	714.54	714.35	714.19	713.85	713.66
20.0	713.99	714.11	714.11	713.95	713.29	712.86
50.0	713.16	713.29	713.38	713.22	712.14	711.44

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	721.04	729.89	729.18	720.92	716.43	717.85
1.0	718.29	723.37	723.87	717.74	714.30	715.07
5.0	715.26	717.14	715.62	714.27	714.09	714.02
10.0	714.25	714.64	714.40	714.15	713.82	713.61
20.0	713.96	714.06	714.06	713.91	713.29	712.83
50.0	713.09	713.24	713.33	713.19	712.12	711.45

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	720.92	729.88	728.47	722.80	716.43	717.85
1.0	718.87	723.37	724.00	718.08	714.30	715.07
5.0	715.51	717.70	716.33	714.30	714.09	714.02
10.0	714.27	714.85	714.62	714.18	713.82	713.61
20.0	713.98	714.08	714.08	713.93	713.30	712.83
50.0	713.10	713.25	713.33	713.19	712.12	711.45

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	721.00	729.98	728.21	721.00	715.79	717.92
1.0	718.16	722.88	723.83	717.03	714.35	715.26
5.0	714.98	715.88	715.65	714.32	714.13	714.07
10.0	714.27	714.37	714.36	714.20	713.85	713.64
20.0	714.00	714.10	714.11	713.96	713.28	712.86
50.0	713.16	713.29	713.38	713.23	712.14	711.43

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	721.00	729.98	729.27	718.43	715.79	717.92
1.0	717.92	723.83	723.89	716.60	714.36	715.08
5.0	714.90	716.53	715.68	714.31	714.13	714.07
10.0	714.27	714.36	714.37	714.19	713.85	713.64
20.0	713.99	714.10	714.12	713.95	713.28	712.86
50.0	713.15	713.29	713.38	713.22	712.14	711.44

Top of Conservation pool = 714.0
Top of Flood Control pool = 729.0

TABLE A-95

El Dorado Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1344.62	1345.65	1347.90	1346.49	1343.48	1341.54
1.0	1343.76	1344.54	1344.37	1344.85	1342.07	1340.35
5.0	1340.14	1341.54	1341.58	1339.82	1339.38	1339.43
10.0	1339.32	1339.41	1339.78	1339.33	1339.22	1339.18
20.0	1339.00	1339.14	1339.22	1339.08	1338.88	1338.67
50.0	1337.78	1338.28	1338.50	1338.29	1337.83	1337.35

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1344.49	1345.64	1347.75	1346.44	1343.35	1341.42
1.0	1343.63	1344.50	1344.41	1344.85	1341.95	1340.30
5.0	1340.36	1341.74	1341.36	1340.02	1339.26	1339.50
10.0	1339.25	1339.69	1339.99	1339.23	1339.11	1339.12
20.0	1338.93	1339.06	1339.13	1339.00	1338.82	1338.67
50.0	1337.79	1338.26	1338.42	1338.31	1337.86	1337.28

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1344.74	1345.79	1348.04	1346.63	1343.44	1341.67
1.0	1343.79	1344.61	1344.85	1344.85	1341.99	1340.43
5.0	1340.39	1341.63	1341.46	1340.21	1339.47	1339.49
10.0	1339.43	1339.86	1339.92	1339.46	1339.28	1339.21
20.0	1339.00	1339.27	1339.33	1339.18	1338.90	1338.67
50.0	1337.75	1338.22	1338.57	1338.28	1337.81	1337.41

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1344.65	1345.71	1347.94	1346.53	1343.44	1341.58
1.0	1343.70	1344.76	1344.76	1344.76	1341.93	1340.36
5.0	1340.21	1341.48	1341.26	1340.04	1339.39	1339.42
10.0	1339.34	1339.44	1339.75	1339.36	1339.22	1339.17
20.0	1339.00	1339.16	1339.24	1339.10	1338.88	1338.66
50.0	1337.76	1338.26	1338.51	1338.29	1337.81	1337.35

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1344.78	1345.81	1348.08	1346.67	1343.48	1341.70
1.0	1343.83	1344.57	1344.47	1344.89	1341.94	1340.43
5.0	1340.11	1341.38	1341.36	1339.87	1339.50	1339.51
10.0	1339.40	1339.55	1339.64	1339.46	1339.30	1339.22
20.0	1338.94	1339.26	1339.34	1339.19	1338.89	1338.64
50.0	1337.75	1338.21	1338.59	1338.28	1337.80	1337.42

Top of Conservation pool = 1339.0
Top of Flood Control pool = 1347.5

TABLE A-96

Kaw Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1032.23	1044.66	1044.26	1043.86	1029.43	1019.01
1.0	1029.91	1033.44	1039.05	1035.84	1024.22	1015.80
5.0	1017.80	1024.42	1023.82	1021.41	1013.19	1012.06
10.0	1012.95	1015.57	1017.56	1015.00	1010.15	1010.22
20.0	1011.10	1012.02	1012.47	1011.79	1009.22	1009.27
50.0	1009.92	1010.32	1010.20	1010.02	1008.49	1008.68

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1031.83	1044.66	1044.26	1041.86	1027.83	1019.01
1.0	1030.03	1031.83	1034.24	1035.84	1023.82	1016.60
5.0	1019.65	1024.39	1022.92	1021.41	1013.51	1012.19
10.0	1013.46	1016.92	1018.27	1015.53	1010.06	1010.25
20.0	1010.96	1011.97	1012.67	1011.87	1009.20	1009.28
50.0	1009.89	1010.27	1010.20	1010.02	1008.48	1008.68

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1031.83	1044.65	1044.25	1038.24	1027.82	1019.00
1.0	1029.69	1033.03	1035.03	1035.03	1024.21	1015.80
5.0	1019.61	1024.27	1023.01	1021.41	1013.62	1012.04
10.0	1013.64	1018.68	1018.15	1015.75	1010.19	1010.31
20.0	1011.01	1011.99	1012.72	1012.08	1009.22	1009.28
50.0	1009.90	1010.29	1010.24	1010.03	1008.49	1008.68

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1031.61	1044.73	1043.93	1041.12	1027.87	1019.03
1.0	1029.74	1033.49	1034.29	1035.09	1023.85	1016.35
5.0	1018.03	1023.45	1023.58	1021.17	1013.17	1012.21
10.0	1012.77	1015.82	1017.42	1015.33	1010.08	1010.26
20.0	1011.15	1011.86	1012.29	1011.91	1009.20	1009.27
50.0	1009.91	1010.25	1010.19	1010.03	1008.49	1008.68

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	1032.01	1044.53	1044.93	1044.12	1027.98	1019.10
1.0	1029.59	1033.09	1039.28	1036.05	1023.94	1015.87
5.0	1017.48	1024.14	1023.94	1021.52	1013.27	1012.13
10.0	1012.84	1015.67	1017.14	1015.36	1010.12	1010.20
20.0	1011.13	1011.99	1012.40	1011.77	1009.21	1009.28
50.0	1009.91	1010.25	1010.19	1010.03	1008.49	1008.65

Top of Conservation pool = 1010.0
Top of Flood Control pool = 1044.5
Top of Surcharge pool = 1047.5

TABLE A-97

Keystone Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	750.85	755.49	754.46	753.94	735.90	732.81
1.0	748.27	753.82	753.91	745.44	732.55	730.85
5.0	732.07	741.93	740.54	732.94	729.98	728.43
10.0	727.65	734.23	732.94	731.05	728.65	727.08
20.0	725.07	727.24	730.52	729.42	726.20	724.90
50.0	723.25	724.06	725.90	725.84	722.30	721.26

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	749.30	755.49	754.46	750.33	736.93	732.81
1.0	742.08	753.54	753.52	743.46	732.98	731.37
5.0	734.08	737.96	737.96	733.35	730.67	728.63
10.0	732.04	733.75	733.30	732.08	729.38	727.38
20.0	726.23	729.91	731.46	730.48	726.29	724.97
50.0	723.34	724.46	726.44	726.07	722.40	721.30

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	748.27	755.48	754.45	748.79	737.96	732.80
1.0	741.39	752.91	753.16	742.42	732.74	731.45
5.0	733.62	736.29	736.59	733.22	730.68	728.92
10.0	731.54	733.17	732.99	731.94	729.28	727.37
20.0	726.42	728.92	731.18	730.45	726.20	725.06
50.0	723.35	724.34	726.31	725.98	722.37	721.27

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	749.82	755.48	754.45	750.33	736.93	732.80
1.0	745.38	751.77	749.92	741.39	732.67	731.15
5.0	732.63	740.88	736.93	732.74	730.32	728.62
10.0	728.17	733.83	732.70	731.50	728.91	727.28
20.0	725.21	727.25	730.67	730.05	726.07	724.89
50.0	723.31	724.37	726.06	725.96	722.36	721.32

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	750.33	755.49	754.98	753.94	737.96	732.81
1.0	748.44	753.82	753.94	745.44	733.15	731.21
5.0	732.35	741.77	740.54	733.25	730.64	728.73
10.0	728.02	734.59	732.94	731.79	729.07	727.36
20.0	725.02	726.92	730.91	730.12	726.30	725.00
50.0	723.25	724.06	725.71	725.99	722.34	721.30

Top of Conservation pool = 723.0
Top of Flood Control pool = 754.0
Top of Surcharge Pool = 757.0

TABLE A-98

Tenkiller Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	664.10	665.41	666.62	661.37	643.89	638.33
1.0	661.07	662.92	663.59	655.11	639.63	637.32
5.0	642.66	654.16	650.96	640.89	637.12	635.21
10.0	637.32	646.79	641.53	638.31	635.64	633.53
20.0	635.82	636.40	638.45	636.80	633.40	632.03
50.0	633.00	633.37	633.95	633.14	630.71	629.68

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	666.89	665.37	666.39	661.31	646.57	639.12
1.0	651.65	663.03	663.85	651.65	640.99	637.56
5.0	643.25	650.64	649.11	640.94	637.88	635.97
10.0	640.59	643.81	642.24	639.33	636.10	633.91
20.0	636.35	638.29	639.98	637.38	633.86	632.17
50.0	633.55	634.01	634.01	633.35	630.79	629.80

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	666.01	664.51	665.51	656.03	646.55	639.06
1.0	651.04	662.27	662.02	643.05	640.69	637.57
5.0	641.61	647.79	643.65	639.56	637.49	635.90
10.0	638.74	640.91	641.13	638.30	635.60	633.87
20.0	636.61	637.33	639.20	636.90	633.69	632.03
50.0	633.55	633.99	633.98	633.20	630.78	629.86

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	663.89	665.36	663.89	652.55	643.35	639.40
1.0	659.45	662.25	658.46	646.88	640.28	637.39
5.0	643.31	651.89	645.40	640.61	637.85	635.53
10.0	637.96	644.94	641.11	639.09	636.27	633.86
20.0	636.18	636.74	638.45	637.41	633.85	632.28
50.0	633.12	633.67	634.19	633.34	630.77	629.87

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	664.07	665.39	666.60	661.34	644.02	639.05
1.0	660.87	663.22	663.56	655.48	640.15	637.53
5.0	642.77	654.22	650.93	641.15	637.79	635.43
10.0	637.22	646.38	641.78	639.15	635.91	633.81
20.0	635.80	636.27	638.75	637.28	633.69	632.08
50.0	633.05	633.37	633.82	633.20	630.75	629.83

Top of Conservation pool = 632.0
Top of Flood Control pool = 667.0
Top of Surcharge pool = 671.0

TABLE A-99

Eufaula Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	598.17	599.73	598.69	597.04	590.97	591.19
1.0	595.92	597.94	598.10	593.55	588.27	587.82
5.0	588.94	593.82	591.94	588.38	587.08	586.56
10.0	587.00	591.42	589.60	587.55	586.59	586.00
20.0	586.30	587.44	587.98	587.11	585.80	585.22
50.0	585.20	585.73	586.28	585.80	584.81	584.02

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	598.29	599.75	598.70	595.25	592.78	591.88
1.0	595.70	597.95	598.01	592.70	588.50	587.98
5.0	589.15	593.79	592.76	588.56	587.45	586.65
10.0	588.00	591.05	590.38	588.12	586.93	586.15
20.0	586.54	587.87	588.37	587.45	586.03	585.26
50.0	585.24	585.90	586.32	585.92	584.83	584.03

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	598.29	599.75	598.70	595.25	592.78	591.43
1.0	595.70	597.84	597.86	592.55	588.50	587.99
5.0	588.60	593.81	592.42	588.44	587.38	586.70
10.0	587.60	590.72	590.01	587.96	586.78	586.14
20.0	586.49	587.58	588.04	587.32	585.93	585.25
50.0	585.25	585.88	586.32	585.88	584.82	584.04

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	598.17	599.74	598.62	595.69	590.97	591.04
1.0	595.99	597.75	597.79	592.09	588.72	587.98
5.0	589.32	593.76	591.32	588.45	587.29	586.60
10.0	587.04	591.19	589.73	587.89	586.78	586.10
20.0	586.36	587.47	588.07	587.35	585.94	585.26
50.0	585.22	585.85	586.33	585.93	584.82	584.03

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	598.17	599.74	598.69	597.04	590.97	590.97
1.0	595.69	597.94	598.10	593.55	588.73	587.87
5.0	589.06	593.89	591.87	588.73	587.21	586.58
10.0	586.98	591.35	589.95	587.94	586.73	586.08
20.0	586.30	587.42	588.14	587.31	585.86	585.25
50.0	585.20	585.79	586.24	585.84	584.81	584.02

Top of Conservation pool = 585.0
Top of Flood Control pool = 597.0
Top of Surcharge pool = 600.0

TABLE A-100

Wister Lake - Monthly Pool Elevation Duration

Baseline Year 2000 Operating Conditions - No Action Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	506.76	507.48	505.31	502.06	491.59	486.54
1.0	503.44	504.23	504.05	498.09	482.93	483.65
5.0	493.86	500.02	498.27	484.37	478.57	478.64
10.0	489.00	495.06	492.23	480.19	478.44	478.48
20.0	483.62	488.14	484.99	478.55	478.20	478.26
50.0	478.58	479.87	478.47	477.98	477.60	477.59

175,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	506.81	507.53	505.36	500.30	491.98	486.56
1.0	502.47	504.28	503.91	497.04	483.18	483.42
5.0	492.52	499.84	497.64	483.30	478.77	478.60
10.0	488.90	494.87	491.88	480.93	478.48	478.49
20.0	484.24	488.33	485.02	478.82	478.24	478.27
50.0	478.73	480.01	478.54	478.03	477.62	477.60

200,000 cfs Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	506.53	507.25	505.10	500.08	491.83	486.81
1.0	502.47	504.09	503.80	494.34	483.34	483.34
5.0	492.61	499.90	497.33	482.66	478.87	478.63
10.0	488.80	494.16	491.47	480.71	478.45	478.46
20.0	483.95	488.20	484.43	478.75	478.22	478.26
50.0	478.75	479.99	478.48	478.03	477.61	477.62

Operations Only Plan - 60,000 cfs Bench with Fill Behind Flood

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	506.74	507.47	505.30	500.25	491.58	486.53
1.0	503.50	504.22	503.74	493.03	482.68	484.01
5.0	494.11	500.07	496.78	483.64	478.58	478.59
10.0	489.11	494.16	491.36	480.63	478.46	478.48
20.0	484.07	488.54	485.00	478.78	478.23	478.26
50.0	478.61	480.00	478.50	478.03	477.63	477.60

Operations Only 60,000 cfs Bench Plan

Percent of Time Exceeded	Pool Elevations					
	April	May	June	July	August	September
0.1	506.72	507.44	505.28	502.03	491.57	486.52
1.0	503.54	504.26	504.10	498.42	482.55	483.46
5.0	494.10	499.99	498.06	484.27	478.64	478.59
10.0	489.36	495.54	492.19	480.82	478.47	478.48
20.0	483.81	488.00	485.08	478.59	478.22	478.26
50.0	478.57	479.87	478.48	478.01	477.60	477.59

Top of Conservation pool = 478.0
Top of Flood Control pool = 502.5

16. REAL ESTATE REQUIREMENTS

16.1. Ordinary High Water Mark

The data for the ordinary high water mark (OHWM) for natural conditions on the Arkansas River from the current site of the Robert S. Kerr Lock and Dam to the Arkansas and Oklahoma state line could not be found. The natural conditions OHWM is defined as the OHWM that existed prior to the construction of the 49 federally constructed reservoirs, of which 17 are locks and dams on the Arkansas River navigation system. The remaining 32 reservoirs are flood control reservoirs that are operated to reduce flooding downstream, compared to natural conditions. Since the OHWM is normally established primarily through field investigations, the natural conditions OHWM could not be reproduced. This presented a problem because the OHWM is needed in order to determine the impacts caused by induced flooding. At the Arkansas River Navigation Study Issue Resolution Conference held in the Southwestern Division office on 22 January 2003, it was determined that the existing conditions, 1-year frequency flood profile should be used as the OHWM profile.

16.2. Induced Flooding

Induced flooding is that flooding that occurs when the different planning alternatives cause an increase in water elevations, due to increases in peak frequency or duration discharges, over some base condition. The base condition used was the existing Arkansas River Basin system regulation plan, which for this study was considered the “No Action Plan”. The alternatives investigated consisted of changes in the system regulation plan and are referred to as the No Action Plan, 175,000 cfs Plan, 200,000 cfs Plan, Operations Only Plan, and Operations Only 60,000 cfs Bench Plan. The Operations Only 60,000 cfs Bench Plan consisted of changing the 75,000 cfs bench to a 60,000 cfs bench. The frequency and duration discharges remained the same for the Operations Only 60,000 cfs Bench Plan compared to the No Action Plan or base condition. The induced flooding which will occur with the 175,000 cfs Plan, the 200,000 cfs Plan, and the Operations Only Plan result from changes in the frequency discharges rather than the duration discharges. This seems reasonable since the No Action Plan is the existing operating plan, which includes all of the 48 reservoirs. The peak frequency discharges were the same for all plans from the 10-year frequency through the 1000-year frequency.

The No Action Plan frequency curve was graphed with each of the frequency curves from the alternative plans. The discharge point where the two curves merged was considered the upper limit of the induced flooding for that plan. The induced flooding upper limit discharge for each plan and control point is presented in Table A-101.

TABLE A-101

REAL ESTATE EASEMENTS DISCHARGES
INDUCED FLOODING UPPER LIMIT DISCHARGES

Control point	175,000 cfs - Plan (cfs)	200,000 cfs - Plan (cfs)	Operations Only Plan (cfs)
Arkansas River at Muskogee, OK	142,000	142,000	170,000
Arkansas River at Sallisaw, Ok	205,000	230,000	235,000
Arkansas River at Van Buren, AR	200,000	240,000	222,000

Operations Only 60,000 cfs Bench Plan is the same as No Action Plan

In order to determine the extent of induced flooding, a profile for the induced flooding upper limit discharges was computed from the backwater model. This profile was compared to the profile for the OHWM and the elevation and area differences were determined. These area differences for each plan represent the real estate that would be affected by induced flooding from each of the proposed plans. Since the discharge frequency curves are the same for the No Action Plan and the Operations Only 60,000 cfs Bench Plan, there is no induced flooding for the Operations Only 60,000 cfs Bench Plan. Therefore, there is no real estate requirement for the Operations Only 60,000 cfs Bench Plan.

17. RISK AND UNCERTAINTY

The risk-based analysis was performed on the graphical discharge frequency curves using the method defined in the ETL 1110-2-537, “Uncertainty Estimates for Nonanalytic Frequency Curves, dated October 31, 1997. The economic program HEC-FDA used this method to compute uncertainty for each of the graphical discharge frequency curves based upon the probability ordinates and equivalent record length of 61 years.

APPENDIX A

ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA
HYDROLOGIC AND HYDRAULIC ANALYSIS

PART 4 – TULSA DISTRICT HYDRAULIC ANALYSIS

18. SCOPE OF STUDY

Hydraulic studies were conducted to determine the potential change in the extent of the floodplain for operational modifications. Backwater computations were conducted for the Arkansas River from Keystone Lake to the Oklahoma-Arkansas state line. In addition, numerous tributaries were modeled including the Verdigris River upstream to the confluence with the Caney River, the Caney River through Bartlesville, OK, the Neosho River to Fort Gibson Lake, the Illinois River to Tenkiller Lake, and the Canadian River to Eufaula Lake. Plate 1 shows the river reaches included in this study.

19. ASSESSMENT OF AVAILABLE DATA

19.1. Stream Gages

Twelve stream gages were used in this study to aid in development of the backwater models. The location of the gages as well as the elevation datum of the gages was obtained from USGS publications. The actual rating curves used were the same as those currently used and on file in the Tulsa District Corps of Engineers Water Control Computer. Table A-102 lists the stream gages and pertinent data used in this study. The locations of the gages are shown on Plate 2.

TABLE A-102

PERTINENT DATA FOR STREAM GAGING STATIONS

River	Station	Gage Number	River Mile	Zero Of Gage (NGVD29)
Arkansas	Van Buren, AR	07250500	300.4	372.36
Arkansas	Sallisaw, OK	07246500	335.8	413.42
Arkansas	Muskogee, OK	07194500	392.5	471.38
Arkansas	Haskell, OK	07165570	483.7	530.00
Arkansas	Tulsa, OK	07164500	523.7	615.23
Verdigris	Claremore, OK	07176000	76.0	538.62
Verdigris	Inola, OK	07178600	48.9	506.87
Caney	Collinsville, OK	07175550	15.8	565.72
Caney	Ramona, OK	07175500	32.0	586.43
Caney	Bartlesville, OK	07174500	69.2	653.33
Illinois	Gore, OK	07198000	8.5	468.00
Canadian	Whitefield, OK	07245000	18.8	473.16

19.2. Mapping

Topographic maps were obtained from the United States Geological Survey (USGS) as Digital Elevation Models (DEM). These maps were available for the entire study area and had a 10-foot contour interval. Aerial photography was also obtained from the USGS. The entire aerial and survey information was collected in digital format and cross sectional measurements for the channel and overbanks were obtained from this information. Cross sections were located in areas that would best describe the flow through the basin as well as at bridges, low water dams, and any natural obstructions. All cross sections were oriented with zero station on the left overbank looking downstream.

19.3. Existing Hydraulic Modeling

Previous backwater models exist only for short reaches of the study area. Existing HEC-2 models were in the form of Flood Insurance Studies (FIS) and other local study projects. Many of the existing models information was developed from a local topographic survey and degradation range survey data. This data was used to refine the cross section data from the DEM.

20. HYDRAULIC ANALYSIS

The study included development of hydraulic computer models using the BOSS International Computer Program RiverCAD 2000, Version 2000 Windows; May 8 2002. RiverCAD incorporates the use of Geographical Information Systems (GIS) and the US Army Corps of Engineers computer program HEC-RAS[1] version 2.2, September 1998. The following paragraphs discuss the pertinent information used to develop the RiverCAD models for each river reach and tributary in the study.

20.1. Field Investigation

Field reconnaissance was conducted to collect information for development, verification, and calibration of the HEC-RAS models. The information collected includes verification of topographic maps and determination of Manning's "n" values. Information obtained from previous studies was used when applicable.

20.2. Channel Sections

Channel sections were taken along each reach and were oriented to properly represent the capability of the stream to convey flow and store volume. Cross section data was measured from the digital mapping and taken at a rate of about 1 section every 2 miles. Additional sections were taken in areas with extreme changes in channel width and stream conveyance such as bridges, levees areas, and bends. The channel area below the water line was estimated using available degradation range survey data. Channel cross sections for all of the study reaches are shown in Appendix I.

20.3. Roughness Values

Cross sections were developed so as to include the full floodplain storage potential. Areas not considered contributing to the effective flow were designated using the Ineffective Area option or by using a higher Manning's "n" value to retard flow. Table A-103 lists the Manning's "n" values by study area.

1 "HEC-RAS, River Analysis System, Version 2.2, September 1998", Computer program developed by the U.S. Army Corps of Engineers, Hydrologic Engineering Center, 609 Second Street, Davis, CA 95616.

TABLE A-103

MANNING'S "n" VALUES

River Reach	Channel		Left Over Bank		Right Over Bank	
	Min	Max	Min	Max	Min	Max
Arkansas Van Buren-R.S. Kerr	0.025	0.035	0.06	0.08	0.06	0.08
Arkansas R.S. Kerr-Webbers Falls	0.022	0.028	0.07	0.07	0.08	0.08
Arkansas Webbers Falls-Three Forks	0.009	0.009	0.03	0.03	0.03	0.03
Arkansas Three Forks-Leonard	0.022	0.026	0.08	0.11	0.08	0.11
Arkansas Leonard-Tulsa	0.02	0.044	0.065	0.10	0.065	0.10
Lower Verdigris	0.02	0.02	0.04	0.06	0.04	0.06
Upper Verdigris	0.04	0.04	0.06	0.06	0.07	0.07
Lower Caney	0.04	0.04	0.06	0.06	0.07	0.07
Upper Caney	0.045	0.055	0.065	0.12	0.065	0.12
Neosho	0.03	0.03	0.10	0.10	0.10	0.10
Illinois	0.027	0.027	0.10	0.10	0.10	0.10
Canadian	0.025	0.025	0.05	0.05	0.05	0.05

20.4. Bridge Modeling

Bridges were not modeled as part of this phase of the study. Navigable waterway bridges are generally well above the water surface and are not likely to constrict flow.

20.5. Starting Conditions

Starting conditions for the lower Arkansas River was the rating curve available at James W. Trimble Lock and Dam No. 13. The starting conditions for the upstream models along the Arkansas River were the backwater elevations taken from the next downstream model cross section. Tributary starting conditions used the Slope-Area Method from HEC-RAS. The energy slope was calculated for each tributary reach and an initial water surface was estimated. Flood outlines at the tributary confluences were shown as the highest resulting flood elevation. Starting conditions for each reach are shown in Table A-104.

TABLE A-104

STARTING WATER SURFACE ELEVATIONS

Downstream Starting Water Surface Elevation				
	River Reach			
Location	Existing Conditions	Plan 1	Plan 2	Plan 3
Arkansas Van Buren to R.S. Kerr	Rating Curve	Rating Curve	Rating Curve	Rating Curve
Arkansas R.S. Kerr to Webbers Falls	Known Water Surface	Known Water Surface	Known Water Surface	Known Water Surface
Arkansas Webbers Falls to Three Forks	Known Water Surface	Known Water Surface	Known Water Surface	Known Water Surface
Arkansas Three Forks to Leonard	Normal Depth S=0.005	Normal Depth S=0.005	Normal Depth S=0.005	Normal Depth S=0.005
Arkansas Leonard to Tulsa	Known Water Surface	Known Water Surface	Known Water Surface	Known Water Surface
Lower Verdigris	Normal Depth S=0.003	Normal Depth S=0.003	Normal Depth S=0.003	Normal Depth S=0.003
Upper Verdigris	Known Water Surface	Known Water Surface	Known Water Surface	Known Water Surface
Lower Caney	Normal Depth S=0.00019	Normal Depth S=0.00019	Normal Depth S=0.00019	Normal Depth S=0.00019
Upper Caney	Known Water Surface	Known Water Surface	Known Water Surface	Known Water Surface
Neosho	Normal Depth S=0.003	Normal Depth S=0.003	Normal Depth S=0.003	Normal Depth S=0.003
Illinois	Normal Depth S=0.01835	Normal Depth S=0.01835	Normal Depth S=0.01835	Normal Depth S=0.01835
Canadian	Normal Depth S=0.003	Normal Depth S=0.003	Normal Depth S=0.003	Normal Depth S=0.003

20.6. Backwater Verification

The hydraulic backwater model was verified by reproducing peak stage readings at the referenced gages for flows experienced during storms in October 1986 and May 1990. The Manning's "n" values were adjusted along the Arkansas River in order to match the gages. Values for the tributaries were estimated based on verifications from the Arkansas River and local FIS studies. Discharges for each event were taken from the stream flow gage data and verified with the SUPER program.

21. PLAN BACKWATER ANALYSIS

Backwater computations were performed along all of the study reaches for Existing Conditions and each of the previously described plans. The expected peak discharge for each condition was used in the backwater model and is presented in Table A-105. Water surface elevations along the tributary reaches experienced only minor changes from existing conditions. The peak flow on the tributaries was assumed to be the regulatory flow currently established and is not expected to change with adoption of a new plan. The increase in peak flows for Plans 1, 2, and 3 would be the result of a change in duration of flows from the tributaries and timing of the peak discharges.

TABLE A-105

PLAN PEAK DISCHARGES

Peak Discharge in cfs				
	River Reach			
Location	Existing Conditions	Plan 1	Plan 2	Plan 3
Arkansas Van Buren to R.S. Kerr	150,000	175,000	200,000	150,000
Arkansas R.S. Kerr to Webbers Falls	150,000	175,000	200,000	150,000
Arkansas Webbers Falls to Three Forks	100,000	150,000	150,000	100,000
Arkansas Three Forks to Leonard	124,000	124,000	124,000	124,000
Arkansas Leonard to Tulsa	124,000	124,000	124,000	124,000
Lower Verdigris	35,000	35,000	35,000	35,000
Upper Verdigris	35,000	35,000	35,000	35,000
Lower Caney	35,000	35,000	35,000	35,000
Upper Caney	35,000	35,000	35,000	35,000
Neosho	100,000	100,000	100,000	100,000
Illinois	10,800	10,800	10,800	10,800
Canadian	40,000	40,000	40,000	40,000

22. FREQUENCY BACKWATER ANALYSIS

Backwater computations were performed along all of the study reaches for a range of frequency discharges. Water surface elevations for each reach and frequency are shown in Tables A-106 through A-108.

23. SUMMARY

The backwater models for existing navigation operation and Plans 1 through 3 have been presented in this document. The modeling represents the maximum anticipated flooded area due only to the expected peak discharges along the navigation system for each condition. The differences in elevation and flood extent between the existing conditions and each plan are clearly shown while the duration of flooding is not. Incorporating changes in the operation plan would increase flood area while possibly lowering the duration of flooding. In addition, affects from operational changes could be reduced by flood proofing and future floodplain zoning.

TABLE A-106

PLAN WATER SURFACE ELEVATIONS
ROBERT S. KERR L&D 14 TO JAMES W. TRIMBLE L&D 13

Description	River Station	Minimum Channel Elevation	Existing Conditions 150,000 cfs	Plan 1 175,000 cfs	Plan 2 200,000 cfs	Plan 3 150,000 cfs
	292.84	369.50	392.01	392.02	392.02	392.01
	293.84	369.50	394.48	395.22	396.03	394.48
	295.13	348.80	394.87	395.70	396.59	394.87
	296.26	359.70	394.78	395.59	396.44	394.78
	297.67	343.60	395.28	396.22	397.21	395.28
	298.45	355.50	395.25	396.18	397.16	395.25
	299.17	360.90	395.14	396.05	397.01	395.14
	300.47	359.60	395.76	396.75	397.76	395.76
	301.15	351.20	396.33	397.46	398.62	396.33
	301.37	358.50	396.34	397.48	398.64	396.34
	301.81	365.80	396.18	397.28	398.41	396.18
	302.11	363.30	397.14	398.42	399.71	397.14
	302.18	363.40	397.08	398.35	399.64	397.08
	302.92	365.90	397.22	398.51	399.80	397.22
	303.45	364.80	397.42	398.72	400.01	397.42
	303.92	365.30	397.83	399.19	400.55	397.83
	304.66	365.90	398.22	399.58	400.92	398.22
	305.45	371.00	398.90	400.26	401.60	398.90
	306.36	373.00	400.01	401.40	402.73	400.01
	306.93	374.20	400.84	402.28	403.63	400.84
	308.38	367.20	401.52	403.00	404.37	401.52
	309.86	370.40	402.56	404.18	405.66	402.56
	311.07	371.10	403.48	405.13	406.59	403.48
	312.34	377.30	404.33	406.04	407.56	404.33
	313.67	376.60	405.56	407.19	408.65	405.56
	315.65	377.10	407.43	409.10	410.54	407.43
	317.15	378.10	408.33	410.02	411.50	408.33
	318.95	376.30	409.32	411.10	412.67	409.32
	319.56	365.60	415.10	416.85	418.60	415.10
	319.64	366.00	416.20	417.95	419.70	416.20
	321.52	385.80	416.70	418.45	420.20	416.70
	322.58	384.60	418.55	420.56	422.52	418.55
	323.51	387.50	418.83	420.82	422.76	418.83
	324.37	390.30	418.87	420.80	422.63	418.87
	324.99	383.50	420.19	422.33	424.36	420.19
	326.14	392.70	420.29	422.39	424.42	420.29
	326.82	394.30	421.02	423.26	425.32	421.02
	327.77	393.70	421.85	423.81	425.72	421.85
	328.76	394.30	422.40	424.37	426.26	422.40
	329.86	396.50	423.28	425.14	426.92	423.28
	331.56	396.10	424.31	426.20	428.00	424.31
	332.68	395.60	424.97	426.82	428.57	424.97
	334.01	398.30	425.52	427.38	429.13	425.52
	335.12	404.10	425.96	427.79	429.52	425.96
	336.14	405.20	428.62	430.47	432.23	428.62

TABLE A-107

PLAN WATER SURFACE ELEVATIONS
WEBBERS FALLS L&D 16 TO ROBERT S. KERR L&D 14

Description	River Station	Minimum Channel Elevation	Existing Conditions 150,000 cfs	Plan 1 175,000 cfs	Plan 2 200,000 cfs	Plan 3 150,000 cfs
	336.08	411.00	430.64	432.61	434.41	430.64
	336.14	411.00	430.42	432.36	434.13	430.42
	336.20	411.00	430.54	432.49	434.27	430.54
	336.22	392.00	460.00	460.00	460.00	460.00
	336.25	392.00	460.00	460.00	460.00	460.00
	336.83	414.30	460.17	460.24	460.31	460.17
	338.09	413.10	460.24	460.33	460.43	460.24
	339.45	414.00	460.31	460.42	460.54	460.31
	343.00	422.10	460.36	460.49	460.63	460.36
	344.40	416.70	460.41	460.55	460.70	460.41
	346.90	427.80	460.48	460.65	460.83	460.48
	348.90	446.20	460.97	461.27	461.59	460.97
	351.90	460.00	461.86	462.34	462.83	461.86
	353.40	426.90	462.02	462.54	463.07	462.02
	355.10	435.80	462.15	462.71	463.27	462.15
	357.05	438.30	463.39	464.08	464.85	463.39
	358.25	443.10	464.70	465.51	466.43	464.70
	359.55	430.50	465.38	466.25	467.18	465.38
	360.29	442.00	465.65	466.57	467.53	465.65
	360.83	435.50	466.02	467.01	468.04	466.02
	362.11	444.10	467.14	468.20	469.25	467.14
	363.09	439.10	468.52	469.79	471.01	468.52
	364.28	443.70	469.23	470.59	471.86	469.23
	365.24	447.70	470.07	471.50	472.85	470.07
	365.90	442.80	471.01	472.50	473.89	471.01
	366.50	442.80	472.00	473.53	474.96	472.00

TABLE A-108

PLAN WATER SURFACE ELEVATIONS
THREE FORKS TO WEBBERS FALLS L&D 16

Description	River Station	Minimum Channel Elevation	Existing Conditions 100,000 cfs	Plan 1 150,000 cfs	Plan 2 150,000 cfs	Plan 3 100,000 cfs
	366.44	460.00	472.00	473.53	474.96	472.00
	366.46	460.00	471.83	469.98	471.93	471.83
	366.57	460.00	490.02	490.04	490.04	490.02
	367.05	450.80	490.00	490.00	490.00	490.00
	367.51	448.80	490.01	490.02	490.02	490.01
	367.94	447.20	490.01	490.02	490.02	490.01
	368.57	444.20	489.96	489.91	489.91	489.96
	369.25	426.20	490.07	490.15	490.15	490.07
	369.77	444.90	490.06	490.14	490.14	490.06
	370.22	460.39	490.01	490.02	490.02	490.01
	370.72	453.40	490.18	490.42	490.42	490.18
	371.45	446.30	490.19	490.43	490.43	490.19
	371.92	445.50	490.20	490.46	490.46	490.20
	373.16	452.10	490.21	490.47	490.47	490.21
	374.12	453.10	490.21	490.48	490.48	490.21
	375.01	459.90	490.22	490.49	490.49	490.22
	375.90	454.60	490.21	490.47	490.47	490.21
	376.19	455.70	490.20	490.46	490.46	490.20
	377.91	456.80	490.24	490.55	490.55	490.24
	378.53	454.80	490.27	490.60	490.60	490.27
	379.52	464.10	490.34	490.76	490.76	490.34
	380.60	453.90	490.36	490.79	490.79	490.36
	381.62	459.90	490.32	490.71	490.71	490.32
	382.64	456.00	490.42	490.93	490.93	490.42
	383.32	455.00	490.44	490.98	490.98	490.44
	383.38	468.50	490.35	490.77	490.77	490.35
	384.10	469.20	490.37	490.81	490.81	490.37
	385.35	464.10	490.38	490.83	490.83	490.38
	386.02	464.10	490.51	491.14	491.14	490.51
	387.04	465.90	490.64	491.38	491.38	490.64
	387.80	465.90	490.71	491.55	491.55	490.71
	388.70	464.30	490.83	491.84	491.84	490.83
	390.61	474.80	490.97	492.07	492.07	490.97
	392.50	469.00	491.55	493.15	493.15	491.55
	393.55	474.50	491.26	492.63	492.63	491.26
	394.00	469.90	492.00	493.94	493.94	492.00

APPENDIX A

ARKANSAS RIVER NAVIGATION STUDY
ARKANSAS AND OKLAHOMA
HYDROLOGIC AND HYDRAULIC ANALYSIS

PART 5 – LITTLE ROCK DISTRICT HYDROLOGIC AND HYDRAULIC ANALYSIS

24. GENERAL

In the late 1980's, Land Impact Study (LIS) the Little Rock District evaluated the effects of the McClellan-Kerr Arkansas River Navigation System (MKARNS) on flood heights along the Arkansas River to determine the flood related land impacts of the MKARNS. The study compared pre-project to post-project flood heights and identified river reaches where additional real estate acquisitions should be made due to increased flooding caused by the MKARNS. The analysis of post-project flood heights was based on the reservoir regulation plan of operation implemented in 1986. The "1986 Forward", or "1986 Fine Tune" reservoir regulation plan of operation continues in use today.

The analyses described herein were performed as a part of the Arkansas River Navigation Study. Alternative 1 is the no action alternative representing the current reservoir regulation plan of operation and is henceforth referred to in this report as the Baseline. Alternatives 2, 3, and 4, respectively, are henceforth referred to in this report as the 175K, the 200K, and the Ops alternatives. Each of the alternative plans; 175K, 200K, and Ops were compared to the Baseline to determine the respective differences in flood heights that can be expected as a result of plan implementation.

24.1. Scope of Work

Hydrologic and hydraulic studies were performed to determine, for each of the respective alternative reservoir regulation plans of operation, the elevation profiles above which the MKARNS did not increase the frequency or duration of flooding as compared to pre-project conditions. These elevation profiles are referred to as Lines of Zero Percent Increase in Flooding. The studies were limited to the main stem of the Arkansas River and did not include the effects of the system on the tributaries.

24.2. Methods and Procedures

Basic hydrologic and hydraulic data for pre-project and post-project conditions were assembled in order to make the necessary comparisons of pre-project to post-project conditions for each of the proposed alternative plans. This data was used to develop pre-project and post-project Elevation-Discharge, Flow-Frequency, and Flow-Duration relations at numerous locations throughout the length of each pool. Elevation-Frequency and Elevation-Duration curves based on these relations were then plotted at each location for pre-project and post-project conditions. A comparison of these curves revealed the elevation at each location below which post-project conditions are higher than pre-project conditions. In the lower reach of each pool, where flat pool conditions are prevalent, three feet of freeboard was added to the maximum operating pool elevation to account for wave action and saturation. An envelope curve was then plotted by connecting the highest elevation at each location due either to frequency, duration, or freeboard. At the upstream end of most pools the increase in flood heights due to the navigation project tended to decrease or there was no project related increase in flooding. Where this occurred the envelope curve was tied into the 1963 (pre-project) Ordinary High Water (OHW) profile. The combination of the envelope curve and the 1963 OHW profile was designated as the Line of Zero Percent Increase in Flooding and represents the upper elevation limit of project related flooding.

25. HYDROLOGIC DATA

The basic hydrologic data were developed using the Arkansas River Basin hydrologic routing model “SUPER”, which was developed by Southwestern Division. The model was calibrated to documented historical events at specific control points. The calibrated model was then used to simulate the 1940-2000 period of record flows for pre-project (natural) conditions and for each post-project alternative reservoir regulation plan of operation. These simulations resulted in continuous 61-year period of record mean daily flows for pre-project conditions and for each post-project alternative at specific control points. The resulting mean daily flow data at the control points located at Van Buren, Dardanelle, and Little Rock, Arkansas, were used in this study. Table A-109 lists the SUPER Model runs for each alternative.

TABLE A-109

SUPER MODEL RUNS
PERIOD OF RECORD 1940-2000 (61 YEARS)

Alternative Plans	Super Run Id	Description
Natural	A01X00	Natural Conditions (Pre-Project)
Alternative 1 - Baseline	A01X16	Existing Operating Plan – 1986 Fine Tune
Alternative 2 – 175K	A02X11	175,000 cfs at Van Buren with Bench of 60,000 cfs
Alternative 3 – 200K	A02X12	200,000 cfs at Van Buren with Bench of 60,000 cfs
Alternative 4 - Ops	A02X10	Existing (150,000 cfs) at Van Buren with Bench of 60,000 cfs

25.1. Frequency Data

The mean daily flows resulting from the SUPER model simulations were used to determine annual peak discharges at each control point for pre-project conditions and for each post-project alternative reservoir regulation plan of operation. These peak discharges were then used in developing the annual series peak discharge-frequency curves. Then peak discharges for the 0.95 through the 0.01 exceedance probability events were selected for comparisons. The discharge-frequency data developed for the Van Buren control point was used directly for John Paul Hammerschmidt Lake (Pool 13). The drainage area ratio method was used to develop discharge frequency data for Ozark Lake (Pool 12) based on the discharge-frequency data developed for the Van Buren and Dardanelle control points. The discharge-frequency data developed for the Dardanelle control point was used directly for Lake Dardanelle (Pool 10). The drainage area ratio method was used to develop discharge frequency data for Winthrop Rockefeller Lake (Pool 9) and for Pool 8 based on the discharge-frequency data developed for the Dardanelle and Little Rock control points. The discharge-frequency data developed for the Little Rock control point was used directly for Pool 7 and all remaining downstream pools. Minor adjustments were applied to the resulting discharge-frequency data to reflect a realistic transition from control point to control point consistent with observed events and to achieve consistency in data use. Table A-110 lists the discharge-frequency at the Van Buren, Dardanelle, and Little Rock control points.

TABLE A-110

DISCHARGE-FREQUENCY AT CONTROL POINTS (IN 1000 CFS)

Frequency	Natural A01X00	Baseline Alt. 1 A01X16	175K Plan Alt. 2 A02X11	200K Plan Alt. 3 A02X12	Ops Plan Alt. 4 A02X10
	VAN BUREN				
0.01	935	500	500	500	500
0.02	880	440	440	440	440
0.04	780	330	330	330	330
0.10	685	250	260	260	250
0.20	595	190	200	210	190
0.50	335	150	165	170	150
0.80	195	95	100	100	95
0.95	95	55	55	55	55
	DARDANELLE				
0.01	930	550	550	550	550
0.02	875	485	485	485	485
0.04	775	355	355	355	355
0.10	705	305	305	305	305
0.20	600	260	260	270	260
0.50	335	190	195	200	190
0.80	215	135	130	130	135
0.95	100	60	60	60	60
	LITTLE ROCK				
0.01	880	505	505	505	505
0.02	845	450	450	450	450
0.04	760	355	360	360	355
0.10	670	295	300	300	295
0.20	585	250	265	270	250
0.50	345	195	205	210	195
0.80	220	155	152	152	155
0.95	110	75	75	75	75

25.2. Duration Data

The mean daily flows from the SUPER model simulations were used to develop flow-duration data at each respective control point for pre-project conditions and for each respective post-project alternative reservoir regulation plan of operation. The flow-duration data developed for the Van Buren control point was used directly for John Paul Hammerschmidt Lake. The drainage area ratio method was used to develop flow-duration data for Ozark Lake based on the flow-duration data developed for the Van

Buren and Dardanelle control points. The flow-duration data developed for the Dardanelle control point was used directly for Lake Dardanelle. The drainage area ratio method was used to develop flow-duration data for Winthrop Rockefeller Lake and for Pool 8 based on the flow-duration data developed for the Dardanelle and Little Rock control points. The flow-duration data developed for the Little Rock control point was used directly for Pool 7 and all remaining downstream pools. Table A-111 lists the discharge-duration at the Van Buren, Dardanelle, and Little Rock control points.

TABLE A-111

DISCHARGE-DURATION AT CONTROL POINTS (IN 1000 CFS)

Duration (% of Time Equaled or Exceeded) %	Natural A01X00 (1000 cfs)	No Action Plan A01X16 (1000 cfs)	175K cfs Plan A02X11 (1000 cfs)	200K cfs Plan A02X12 (1000 cfs)	Ops 60k cfs Bench Plan A02X10 (1000 cfs)
	VAN BUREN				
0.1	690	268	267	282	269
1	307	158	182	195	158
6	129	134	105	103	135
10	91	91	96	95	97
20	51	56	56	56	54
	DARDANELLE				
0.1	687	309	313	318	310
1	320	174	189	204	175
6	139	138	113	113	140
10	99	103	97	97	107
20	56	62	60	60	58
	LITTLE ROCK				
0.1	654	320	322	325	320
1	343	198	211	220	199
6	156	151	135	133	152
10	115	121	110	110	124
20	66	72	72	71	69

26. HYDRAULIC DATA

Hydraulic data used in this study include results of studies performed in support of the late 1980's LIS and results of analyses performed for this study. Previously developed data included:

1. Pre-project water surface profiles
2. HEADWATER AND TAILWATER RATING CURVES FOR EACH LOCK AND DAM
3. Pre-project elevation-discharge rating curves at numerous locations throughout each pool

New data developed included:

1. Post-project water surface profiles for each alternative plan
2. Elevation-frequency curves for pre-project conditions and for each post-project alternative plan
3. Elevation-duration curves for pre-project conditions and for each post-project alternative plan

26.1. Water Surface Profiles

26.1.1. <u>Pre-Project Conditions</u>. The pre-project water surface profiles developed for the LIS were based on several documented pre-project events. The events occurred during a period spanning from 1927 through 1957. The flows associated with the events ranged from 1,300 cfs to 639,000 cfs. The pre-project elevation-discharge rating curves developed at numerous locations throughout each pool for the LIS were based on the above described pre-project water surface profiles and were used directly in this study.

26.1.2. <u>Post-Project Conditions</u>. Post-project water surface profiles were developed using computer program HEC-RAS version 3.0.1 released in March 2001. The model for Pool 13 was obtained from Tulsa District and the model basis with regard to date of cross-section geometry and calibration methodology is unknown at this time. The models for pools 2 through 12 were based on year 2000 hydrographic surveys of the channel and 1986 overbank surveys. The models were calibrated to the most current lock and dam tailwater ratings and spot checked against high water marks from the flood of 1990.

The calibrated models were used to compute post-project water surface profiles for the “Maximum Operating Pool” condition. The maximum operating pool is based on the physical limitations of the existing structure, whether it is the top of the clay core in the overflow embankments or the top of the gates. The starting conditions for the backwater models were based on headwater rating curves for each lock and dam.

26.2. Rating Curves

26.2.1. <u>Structure Ratings</u>. The structure headwater ratings developed in the late 1980’s for the LIS were used directly with two exceptions. The headwater rating curves for Pool 8 and Pool 13 were updated based on an analysis of experienced flows from 1970 to 2001. The tailwater ratings used for Ozark Lock and Dam was last updated in 1988. The tailwater ratings for the remaining lock and dam structures were last updated at different times between 1991 and 1995.

26.2.2. <u>Pre-Project Section Ratings</u>. The pre-project elevation-discharge rating curves developed for the LIS were used directly for this study. The curves were developed at numerous locations throughout each pool with locations based established sediment ranges. The rating curves were developed using the pre-project water surface profiles described in paragraph 26.1.1.

26.2.3. Post-Project Section Ratings. Post-project elevation-discharge rating curves were developed at the same locations as the pre-project elevation-discharge curves. The rating curves were developed using the post-project water surface profiles described in paragraph 26.1.2.

26.3. Elevation Frequency Curves

26.3.1. Pre-Project Conditions. Pre-project elevation-frequency curves were developed for each location using the pre-project peak discharge-frequency data described in paragraph 25.1 in conjunction with the pre-project elevation-discharge rating curves described in paragraph 26.2.2.

26.3.2. Post-Project Conditions. Post-project elevation-frequency curves were developed for each location using the post-project peak discharge-frequency data described in paragraph 25.1 in conjunction with the post-project elevation-discharge rating curves described in paragraph 26.2.3.

26.4. Elevation Duration Curves

26.4.1. Pre-Project Conditions. Pre-project elevation-duration curves were developed for each location using the pre-project discharge-duration data described in paragraph 25.2 in conjunction with the pre-project elevation-discharge rating curves described in paragraph 26.2.2.

26.4.2. Post-Project Conditions. Post-project elevation-duration curves were developed for each location using the post-project discharge-duration data described in paragraph 25.2 in conjunction with the post-project elevation-discharge rating curves described in paragraph 26.2.3.

27. RESULTS AND CONCLUSIONS

The computed lines of zero percent increase in frequency and/or duration for each of the four alternatives are shown on Figures A-29 thru A-39, Pages A-151 thru A-161. The zero percent line computed for the LIS in the late 1980's (1986 Fwd) is shown for comparison. Differences between the Baseline zero percent lines and the 1986 Fwd zero percent lines may be most significantly attributed to the period of record (1940-2000) flow data upon which the current analyses were based verses that (1940-1974) upon which the LIS related work performed in the late 1980's was based. The differences in elevation are summarized in Table A-112.

TABLE A-112

BASELINE VS. 1986 FWD (LIS) ZERO PERCENT LINES
COMPARISON OF ELEVATION DIFFERENCES

Pool ID No.	Maximum Positive Delta feet	Maximum Negative Delta feet	Average Delta feet
13	0.4	-3.8	-1.3
12	2.5	-0.0	+1.2
10	0.0	-2.6	-1.0
9	0.0	-5.9	-2.4
8	5.9	-1.3	+1.7
7	0.7	-9.5	-2.0
6	0.0	-2.0	-0.6
5	0.2	-0.0	-0.0
4	0.3	-0.3	+0.1
3	0.0	-2.0	-0.9
2	1.6	-0.0	+0.6

Delta = (Baseline ELEV) minus (1986 Fwd ELEV)

A comparison of the zero percent lines for proposed Alternatives 2 (175K Plan), 3 (200K Plan), and 4 (Ops Plan) to no-action Alternative 1 (Baseline) indicates implementation of any of Alternatives 2 thru 4 can be expected to result in little or no additional inundation depth as compared to the Baseline, or current condition. The maximum additional inundation depth computed for each respective pool, for each of Alternatives 2 thru 4, as compared to no-action Alternative 1 (Baseline) is shown in Table A-113.

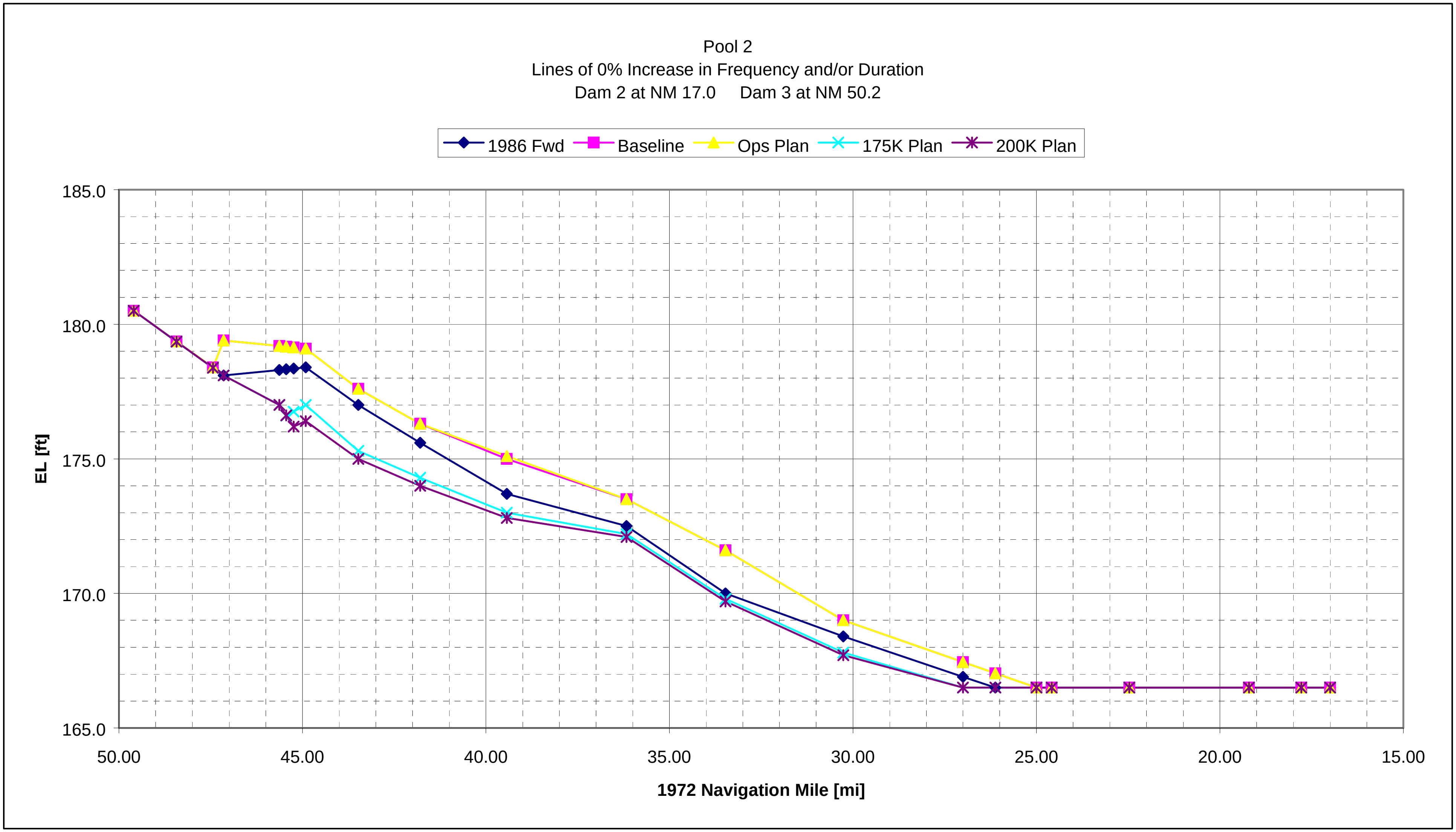
TABLE A-113

SUMMARY OF ALTERNATIVE PLANS MAXIMUM ADDITIONAL INUNDATION DEPTH AS COMPARED TO NO-ACTION ALTERNATIVE 1 (BASELINE)

Pool ID No.	175K cfs Plan (feet)	200K cfs Plan (feet)	Ops 60k cfs Bench Plan (feet)
13	0.0	0.0	0.0
12	1.3	1.9	0.8
10	1.6	2.4	0.2
9	0.9	1.4	0.1
8	0.0	0.0	0.0
7	0.8	1.3	0.1
6	0.0	0.0	0.0
5	0.0	0.0	0.0
4	0.0	0.0	0.0
3	0.0	0.0	0.0
2	0.0	0.0	0.1

28. REFERENCES

McClellan-Kerr Arkansas River Navigation System Land Impact Study, Appendix A, Hydrologic and Hydraulic Report, CESWL (July 1989).



Pool 2
Lines of 0% Increase in Frequency and/or Duration
Dam 2 at NM 17.0 Dam 3 at NM 50.2
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
EL [ft]
185.0
180.0
175.0
170.0
165.0
50.00
45.00
40.00
35.00
30.00
25.00
20.00
15.00
1972 Navigation Mile [mi]

Figure A-29

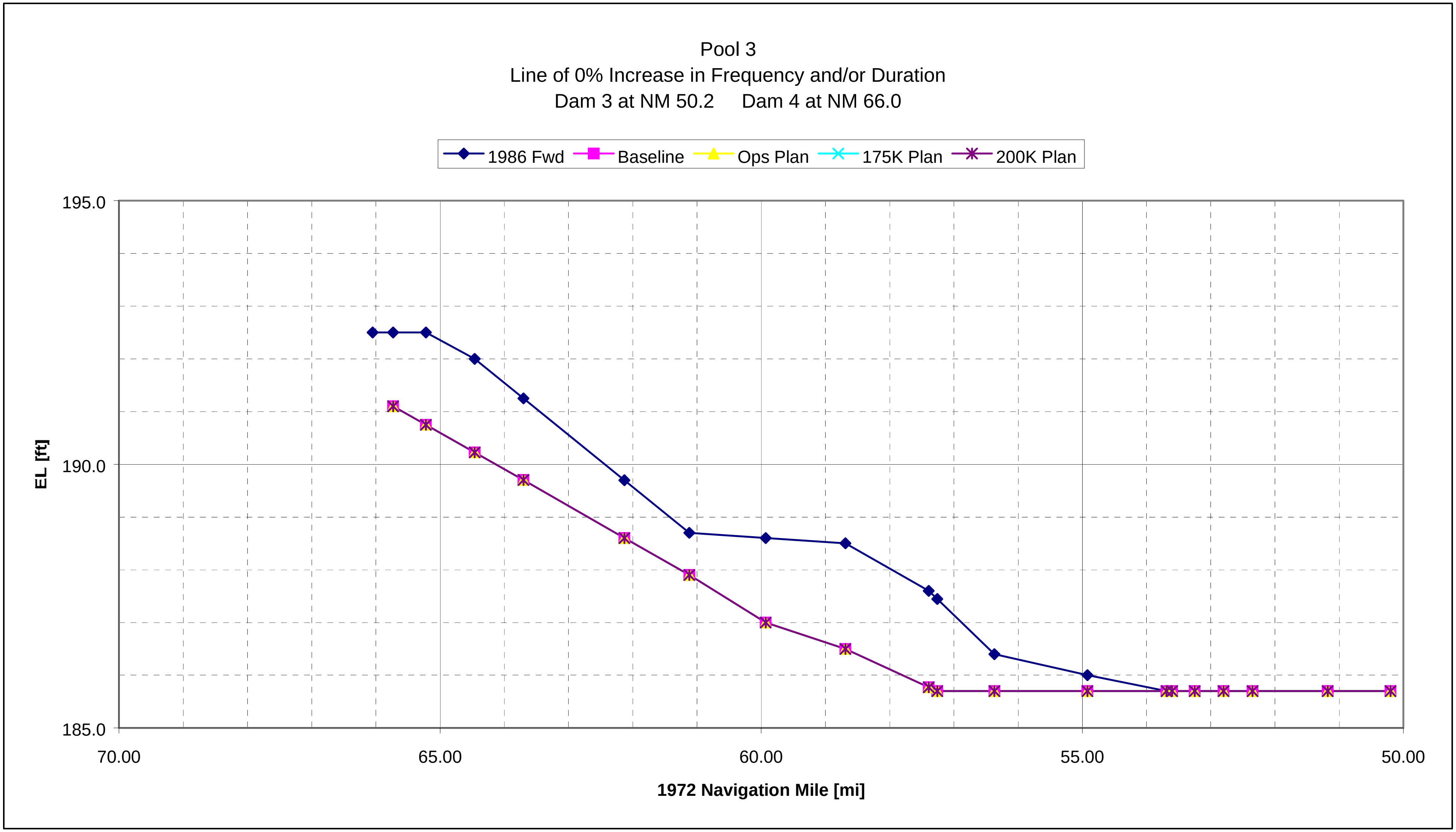

Pool 3
Line of 0% Increase in Frequency and/or Duration
Dam 3 at NM 50.2 Dam 4 at NM 66.0
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
195.0
190.0
185.0
EL [ft]
70.00
65.00
60.00
55.00
50.00
1972 Navigation Mile [mi]

Figure A-30

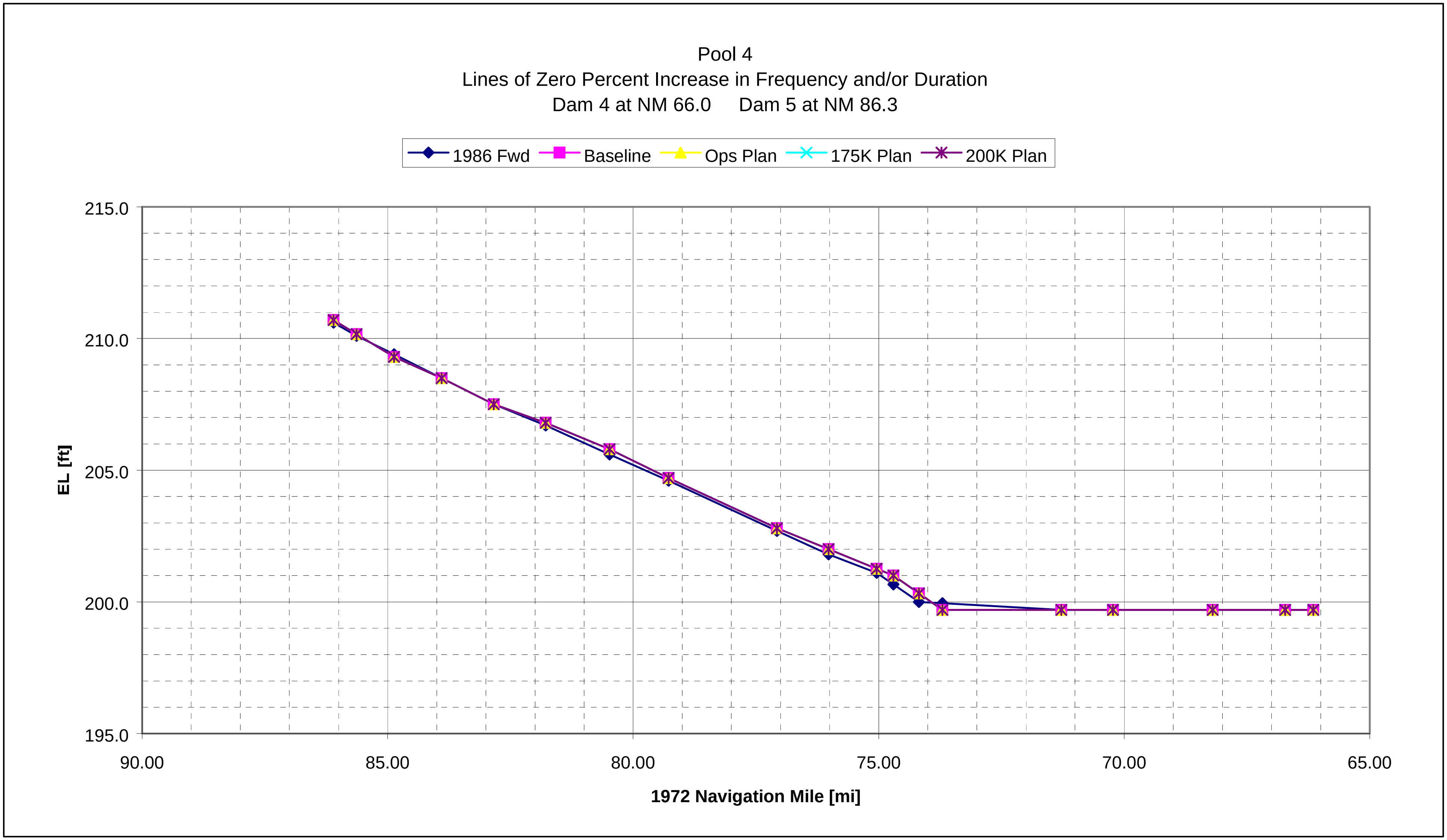
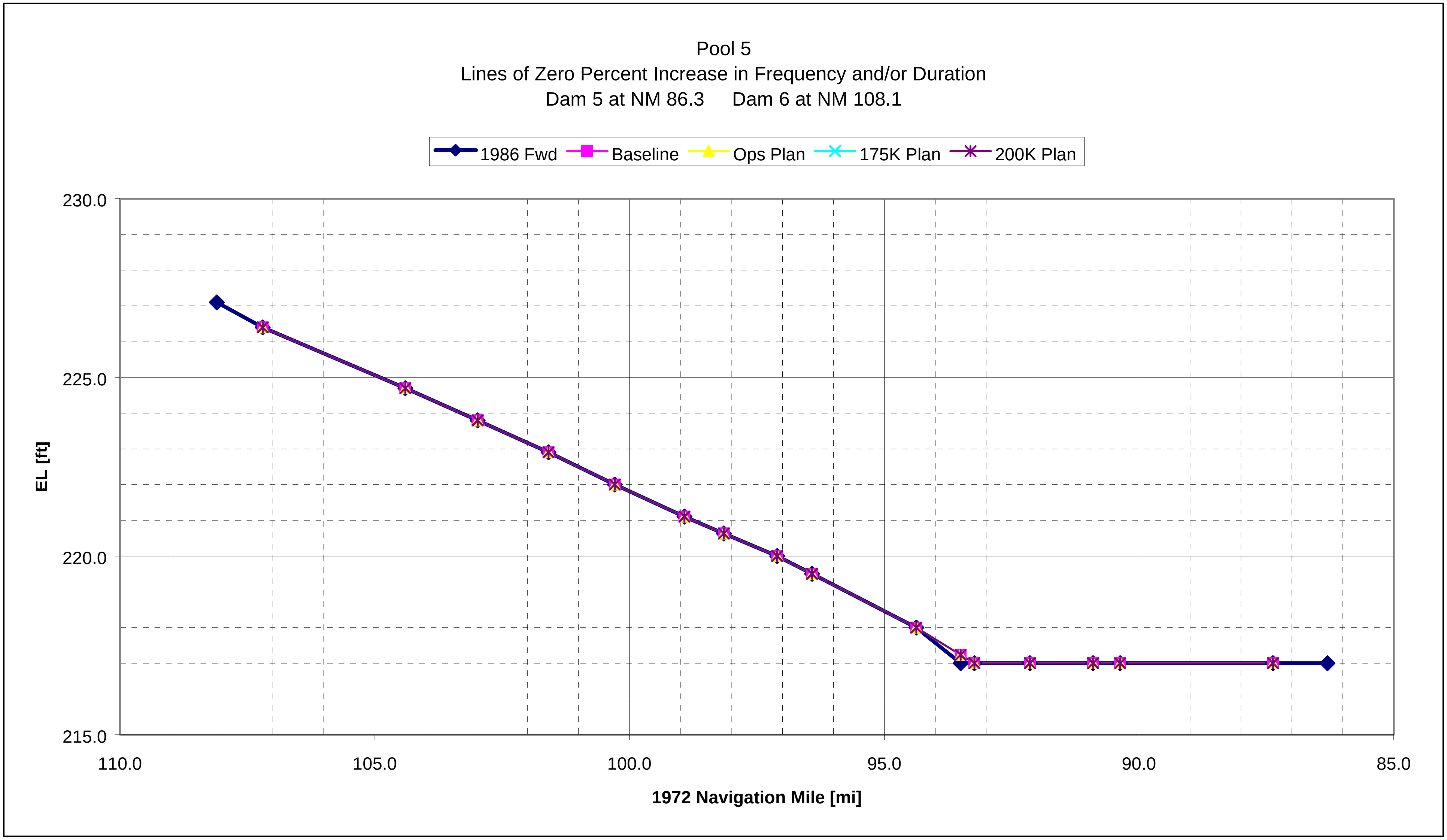

Pool 4
Lines of Zero Percent Increase in Frequency and/or Duration
Dam 4 at NM 66.0 Dam 5 at NM 86.3
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
215.0
210.0
205.0
200.0
195.0
EL [ft]
90.00
85.00
80.00
75.00
70.00
65.00
1972 Navigation Mile [mi]

Figure A-31



Pool 5
Lines of Zero Percent Increase in Frequency and/or Duration
Dam 5 at NM 86.3 Dam 6 at NM 108.1
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
230.0
225.0
220.0
215.0
EL [ft]
110.0
105.0
100.0
95.0
90.0
85.0
1972 Navigation Mile [mi]

Figure A-32

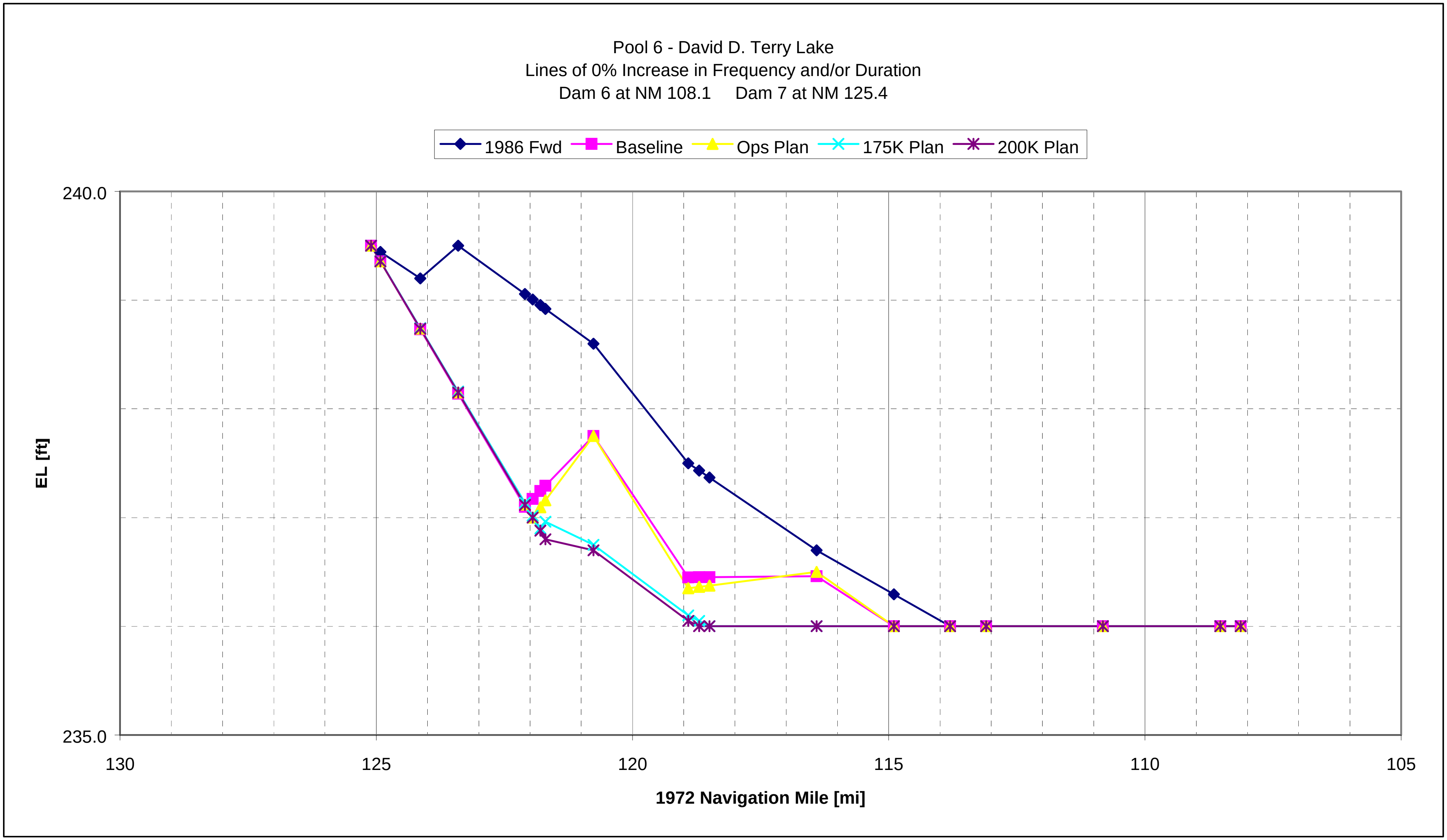

Pool 6 - David D. Terry Lake
Lines of 0% Increase in Frequency and/or Duration
Dam 6 at NM 108.1 Dam 7 at NM 125.4
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
EL [ft]
240.0
235.0
130
125
120
115
110
105
1972 Navigation Mile [mi]

Figure A-33

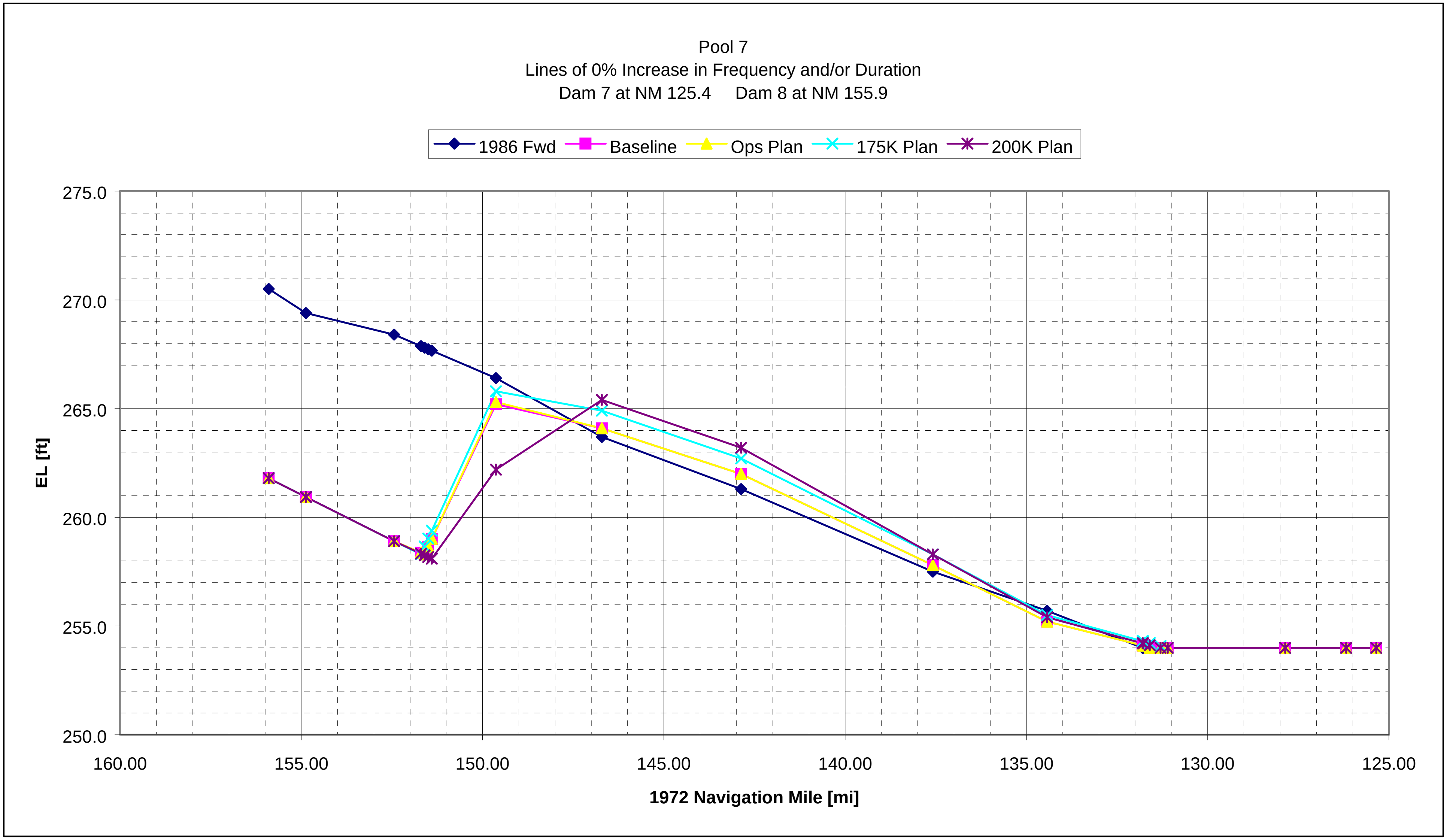

Pool 7
Lines of 0% Increase in Frequency and/or Duration
Dam 7 at NM 125.4   Dam 8 at NM 155.9
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
EL [ft]
275.0
270.0
265.0
260.0
255.0
250.0
160.00
155.00
150.00
145.00
140.00
135.00
130.00
125.00
1972 Navigation Mile [mi]

Figure A-34

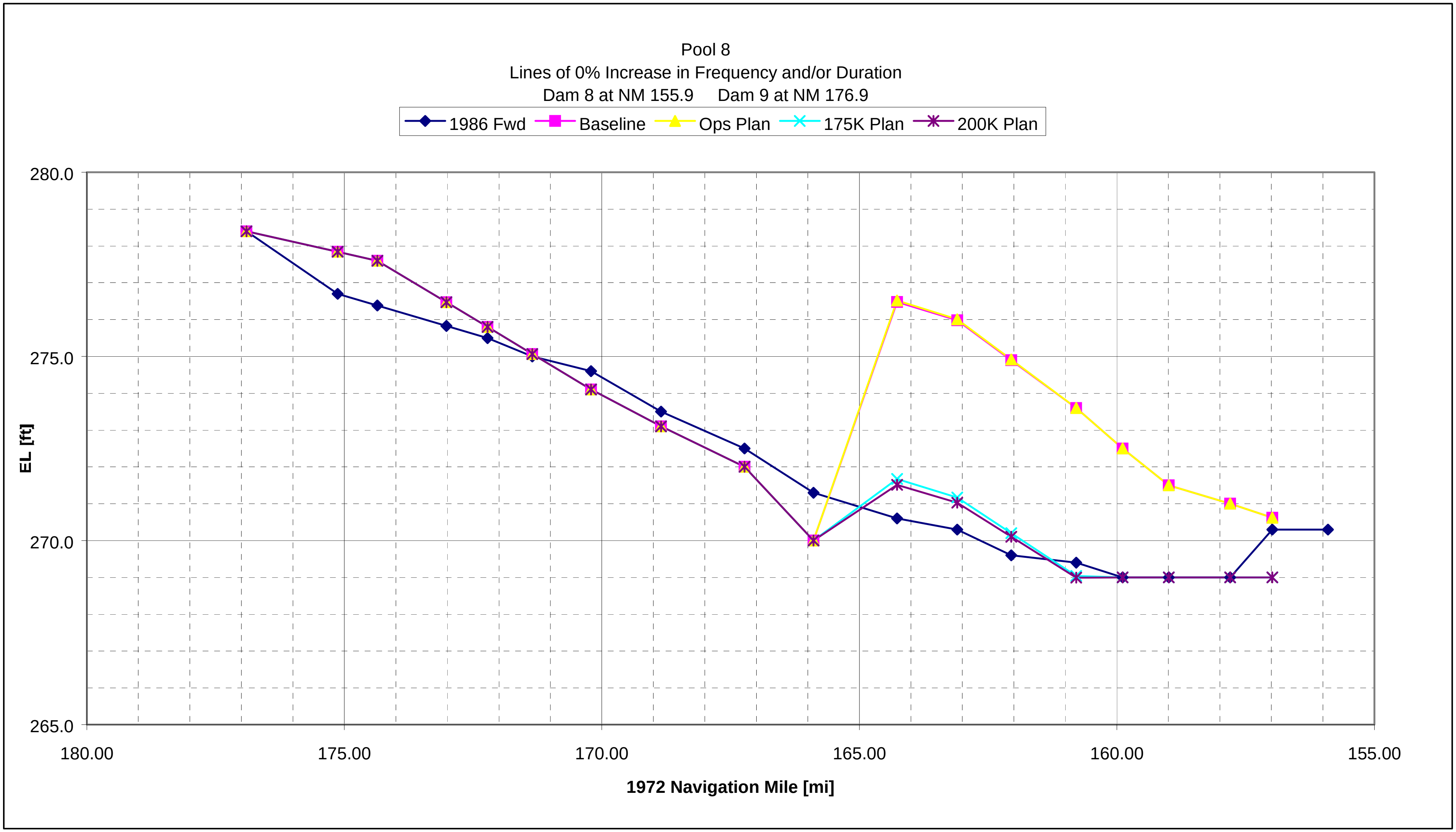

Pool 8
Lines of 0% Increase in Frequency and/or Duration
Dam 8 at NM 155.9   Dam 9 at NM 176.9
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
EL [ft]
280.0
275.0
270.0
265.0
180.00
175.00
170.00
165.00
160.00
155.00
1972 Navigation Mile [mi]

Figure A-35

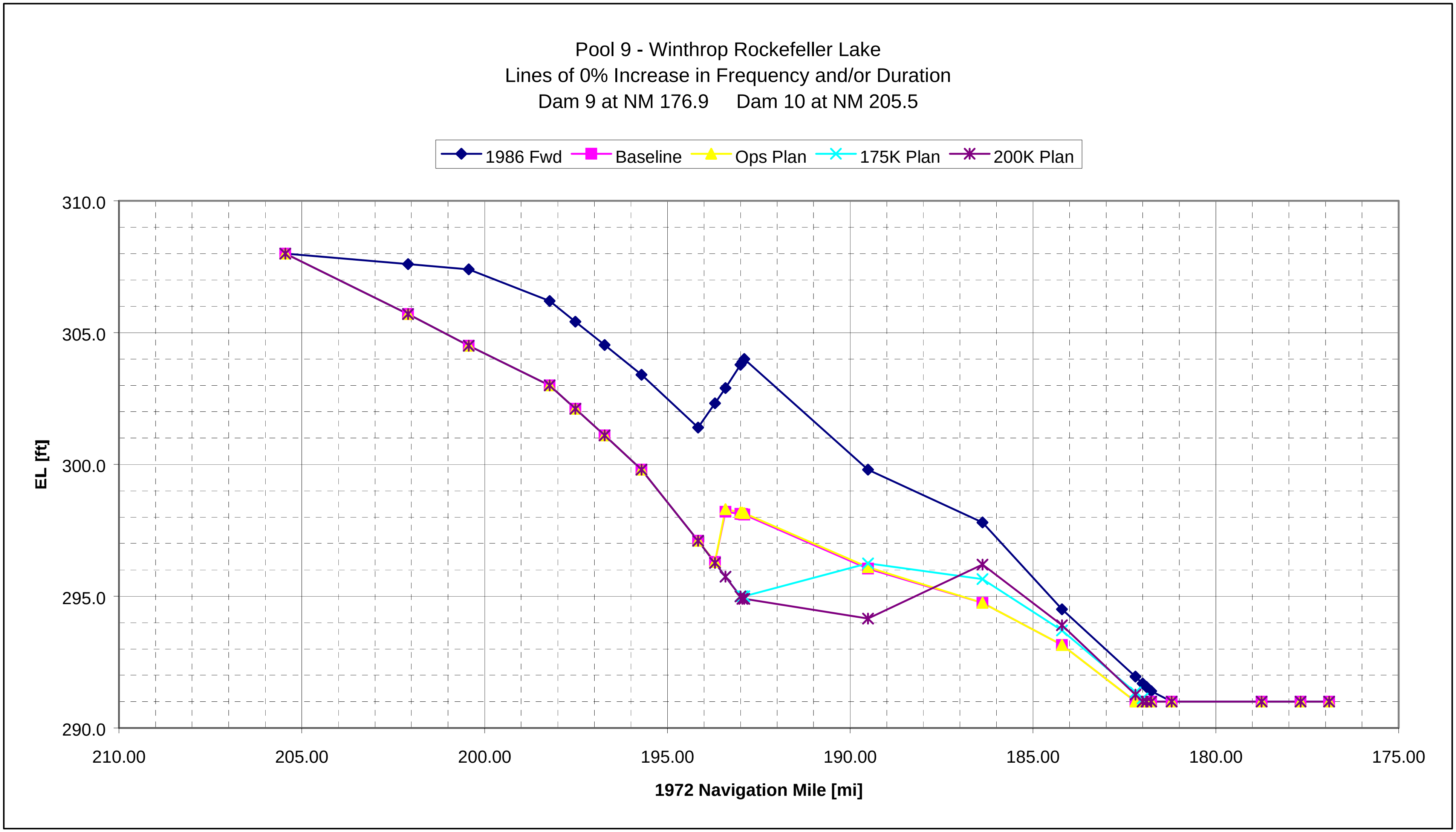
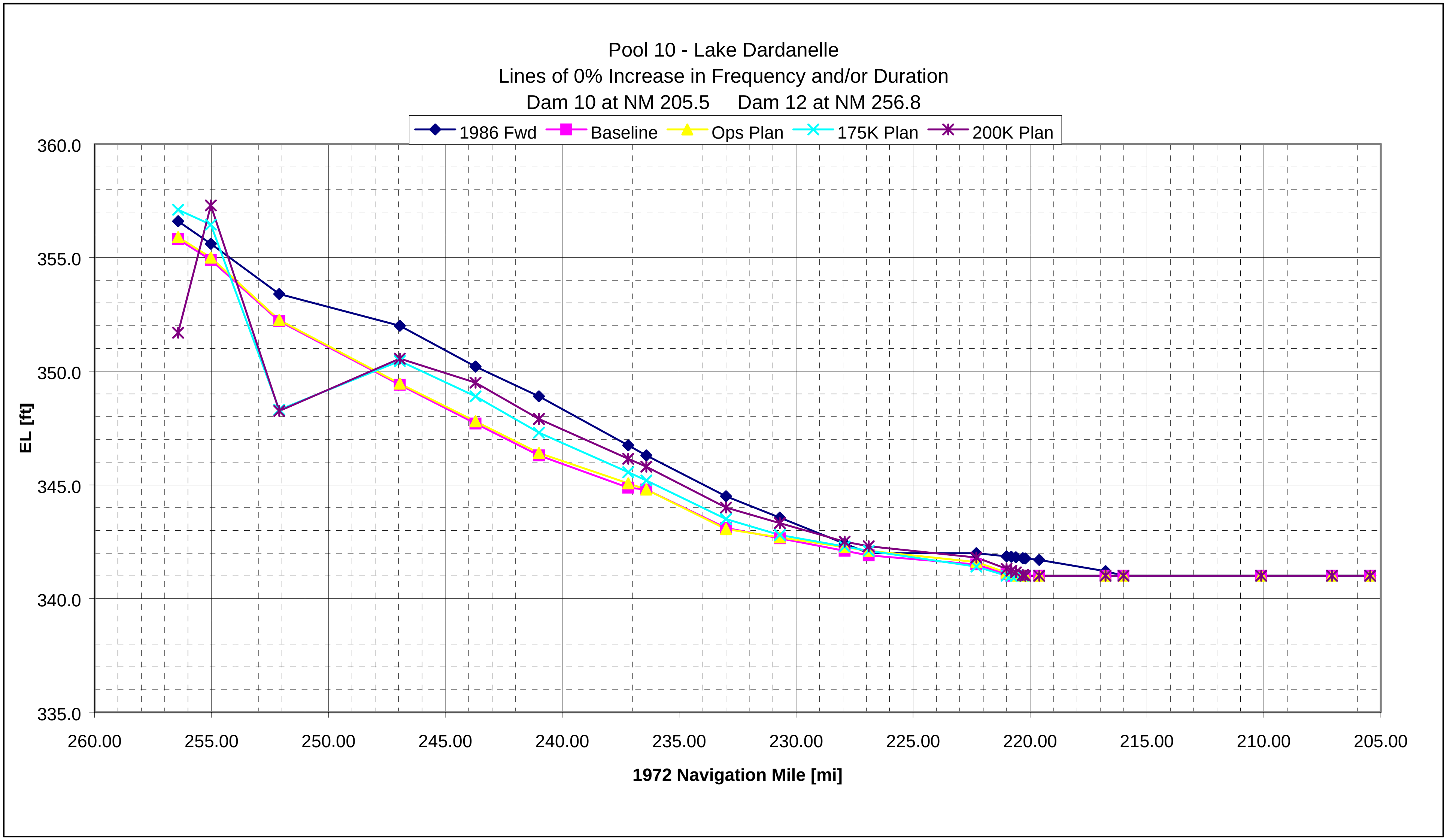

Pool 9 - Winthrop Rockefeller Lake
Lines of 0% Increase in Frequency and/or Duration
Dam 9 at NM 176.9 Dam 10 at NM 205.5
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
310.0
305.0
300.0
295.0
290.0
EL [ft]
210.00
205.00
200.00
195.00
190.00
185.00
180.00
175.00
1972 Navigation Mile [mi]

Figure A-36



Pool 10 - Lake Dardanelle
Lines of 0% Increase in Frequency and/or Duration
Dam 10 at NM 205.5 Dam 12 at NM 256.8
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
EL [ft]
360.0
355.0
350.0
345.0
340.0
335.0
260.00
255.00
250.00
245.00
240.00
235.00
230.00
225.00
220.00
215.00
210.00
205.00
1972 Navigation Mile [mi]

Figure A-37

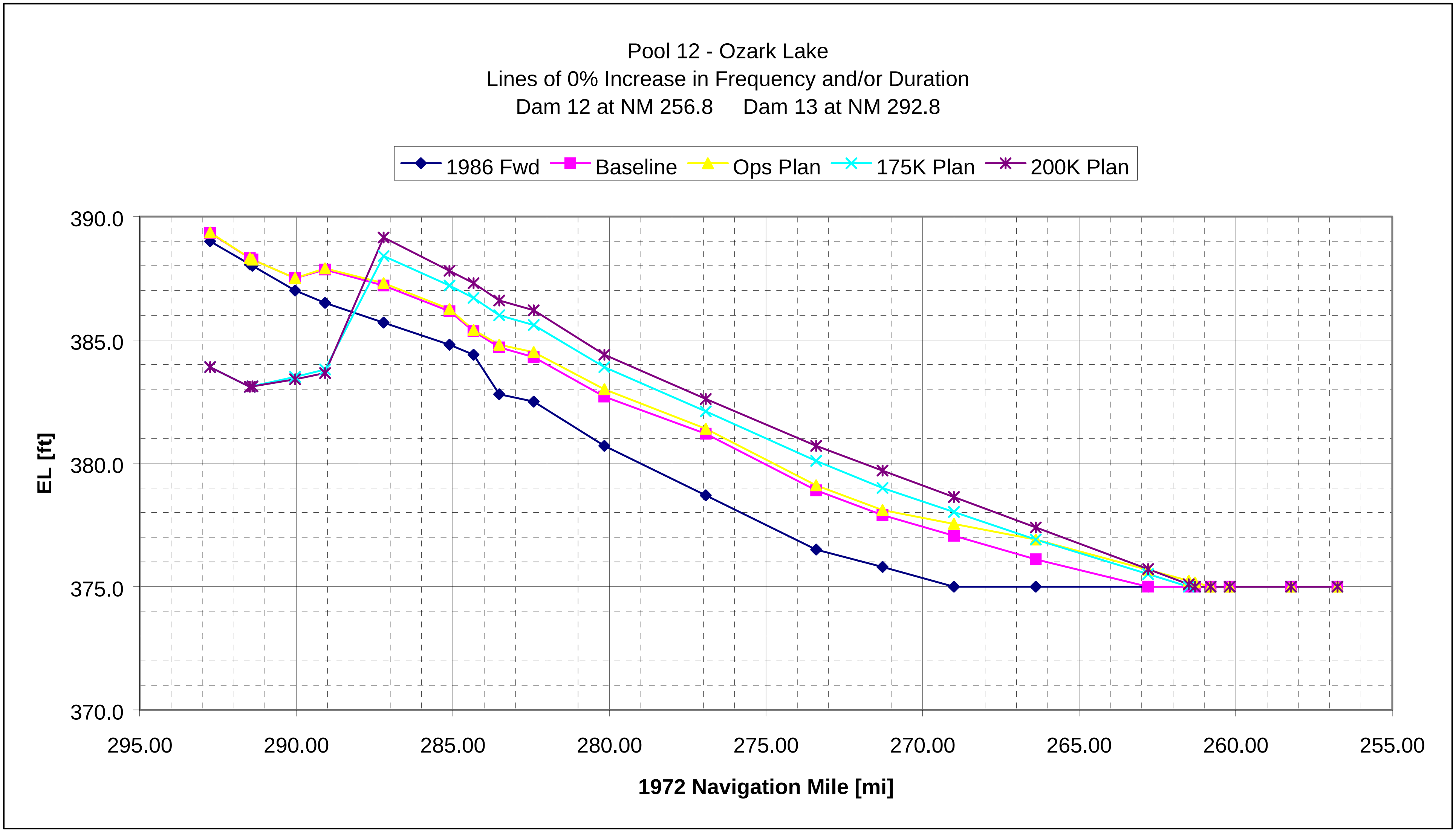
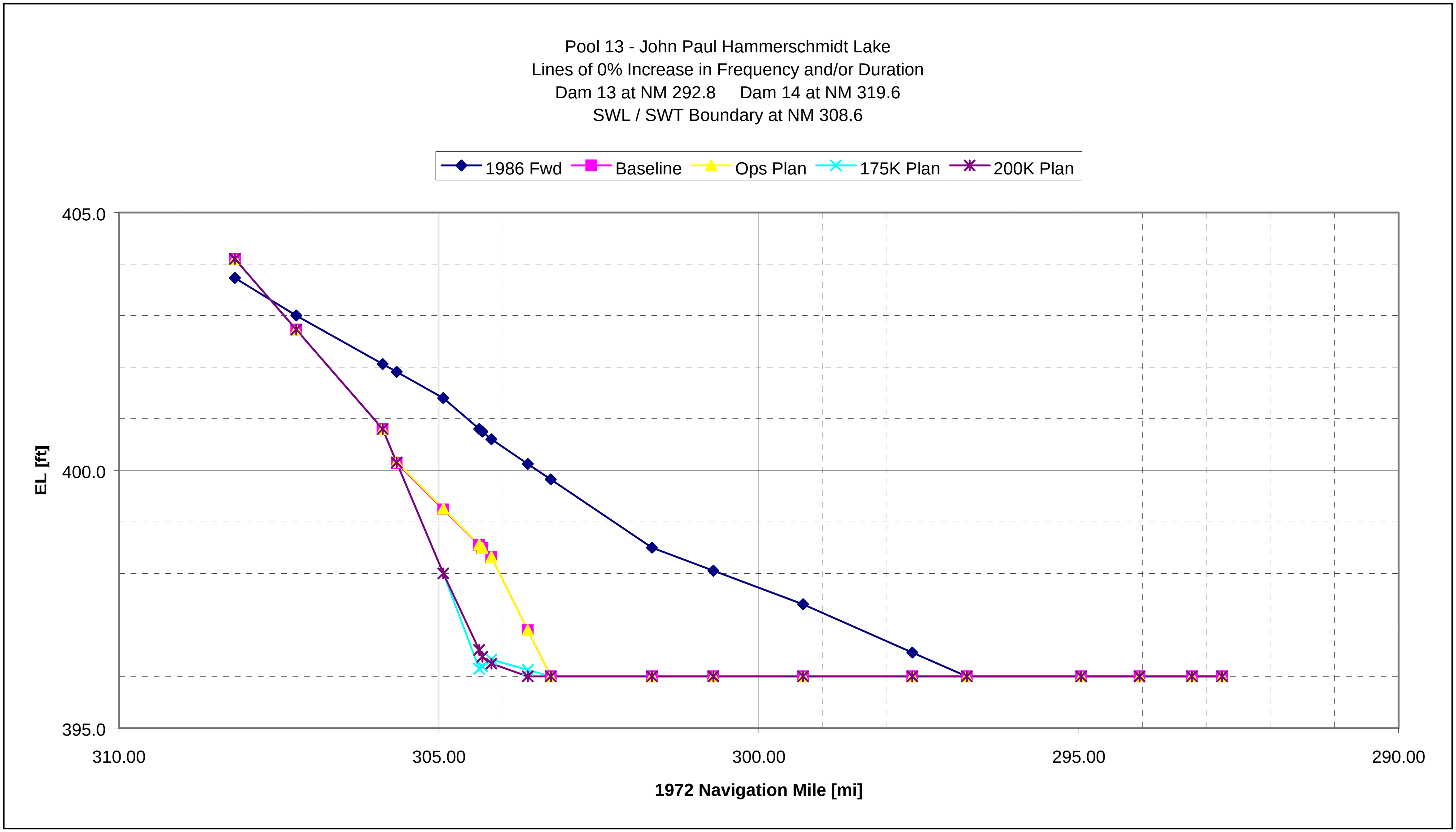

Pool 12 - Ozark Lake
Lines of 0% Increase in Frequency and/or Duration
Dam 12 at NM 256.8   Dam 13 at NM 292.8
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
EL [ft]
390.0
385.0
380.0
375.0
370.0
295.00
290.00
285.00
280.00
275.00
270.00
265.00
260.00
255.00
1972 Navigation Mile [mi]

Figure A-38



Pool 13 - John Paul Hammerschmidt Lake
Lines of 0% Increase in Frequency and/or Duration
Dam 13 at NM 292.8   Dam 14 at NM 319.6
SWL / SWT Boundary at NM 308.6
1986 Fwd
Baseline
Ops Plan
175K Plan
200K Plan
EL [ft]
405.0
400.0
395.0
310.00
305.00
300.00
295.00
290.00
1972 Navigation Mile [mi]

Figure A-39