APPENDIX E-9 Comprehensive H & H Study Reports

PREPARED BY

Mead & Hunt

Updated Study Report

Hydrologic and Hydraulic Modeling: Downstream Hydraulic Model

Pensacola Hydroelectric Project
Project No. 1494

September 30, 2022

CONTENTS

Table of Contents

Executive Summary iv

List of Abbreviations and Terms v

1. Introduction and Background 1

    1.1 Project Description 1

    1.2 Study Plan Proposals and Determination 1

    1.3 Vertical Datums 4

2. Model Development and Calibration 5

    2.1 Topographic and Bathymetric Data 5

    2.2 Model Geometry 7

    2.3 Manning's n-values 9

    2.4 Boundary Conditions for Calibration 9

    2.5 Model Calibration 10

3. Modeled Scenarios 16

    3.1 Scenarios Summary 16

    3.2 Modified Model Geometry 17

    3.3 Boundary Conditions 17

4. Study Results 22

5. Discussion of Results 25

    5.1 September 1993 (21 Year) Flow Event 25

    5.2 June 2004 (1 Year) Event 25

    5.3 July 2007 (4 Year) Event 26

    5.4 October 2009 (3 Year) Event 27

    5.5 December 2015 (15 Year) Event 28

    5.6 100-year Event 28

    5.7 Comparison of Historical Starting Stages 29

6. Anticipated Operations Analysis 30

7. Conclusions 33

8. References 34

List of Figures

Figure 1. Downstream Hydraulic Model Study Area..... 3
Figure 2. Datum Transformations and Conversions..... 4
Figure 3. Topographic and Bathymetric Data Extents..... 6
Figure 4. Model configuration just downstream of Pensacola Dam..... 8
Figure 5. July 2007 Event Stage Hydrographs at Kerr Dam..... 12
Figure 6. July 2007 Event Stage Hydrographs at Langley Gage..... 12
Figure 7. April 2008 Event Stage Hydrographs at Kerr Dam..... 13
Figure 8. April 2008 Event Stage Hydrographs at Langley Gage..... 13
Figure 9. April 2011 Event Stage Hydrographs at Kerr Dam..... 14
Figure 10. April 2011 Event Stage Hydrographs at Langley Gage..... 14
Figure 11. May 2015 Event Stage Hydrographs at Kerr Dam..... 15
Figure 12. May 2015 Event Stage Hydrographs at Langley Gage..... 15

List of Tables

Table 1. Manning's n-values Prior to Calibration..... 9
Table 2. USGS Stream Gage Stations..... 9
Table 3. Summary of Calibration Events..... 10
Table 4. Calibrated Manning's n-values..... 11
Table 5. Calibration Results at Langley Gage..... 11
Table 6. Summary of flow events analyzed..... 16
Table 7. List of additional Pensacola Dam initial pool elevations simulated..... 16
Table 8. Summary of operations model results used for HEC-RAS simulations..... 18
Table 9. Ratios used to subdivide lateral inflows..... 20
Table 10. Results of historical lateral inflow volume statistical analysis..... 21
Table 11. Summary of minimum and maximum downstream inundation areas for starting pool elevations at Pensacola Dam within GRDA's anticipated operational range..... 23
Table 12. Summary of minimum and maximum downstream inundation areas for all starting pool elevations at Pensacola Dam, including extreme, hypothetical values outside GRDA's anticipated operational range..... 23
Table 13. Summary of increases in downstream WSEL due to anticipated operations as compared to baseline operations..... 31

Appendices

Appendix A.....Simulated Hydrographs

Appendix B.....Historical Inflow Volume Statistical Analysis

Appendix C.....Maximum Water Surface Elevations

Appendix D.....Maximum Water Surface Elevation Profiles

Appendix E.....Inundation Maps

Appendix F.....Duration of Inundation

Appendix G.....Anticipated Operations Analysis

Executive Summary

Mead & Hunt is assisting Grand River Dam Authority (GRDA) with its intent to relicense the Pensacola Hydroelectric Project (Project), which is regulated by the Federal Energy Regulatory Commission (FERC). Flood control operations at the Project are regulated exclusively by the United States Army Corps of Engineers (USACE). This Updated Study Report (USR) documents the findings of the Hydrologic and Hydraulic (H&H) modeling downstream of the Project.

The Proposed Study Plan (PSP) and Revised Study Plan (RSP) recommended the development of a Comprehensive Hydraulic Model (CHM). The model downstream of the Project is referred to as the Downstream Hydraulic Model (DHM). Mead & Hunt developed a one-dimensional (1D) Hydrologic Engineering Center River Analysis System (HEC-RAS) model extending from just downstream of Pensacola Dam and through Lake Hudson to the Robert S. Kerr Dam (also referred to as the Markham Ferry Hydroelectric Project), where flood control operations are also regulated by USACE. The model geometry was developed from the best available topographic and bathymetric data. Bridge structures within the model were represented based on record drawings obtained from various agencies. The model was calibrated to four historical events based on measurements at the United States Geological Survey (USGS) stream gage near Langley, OK (USGS Gage No. 07190500) and observed water surface elevations (WSEL) at Kerr Dam.

The calibrated HEC-RAS model was used to analyze a range of operating conditions at Pensacola Dam utilizing results from the Operations Model (OM). Five historical flow events and one synthetic event were analyzed for a range of starting pool elevations at Pensacola Dam. An additional suite of simulations was computed to analyze an alternate operational scenario anticipated by GRDA for Pensacola Dam. Inflows to Lake Hudson for the synthetic 100-year event were derived from a statistical analysis of historical inflow volumes. Maximum WSEL values and inundation extents were extracted from HEC-RAS and analyzed.

The results of the DHM demonstrate that initial stages at the Project within GRDA's anticipated and extreme, hypothetical operational ranges have an impact on downstream WSELs and out-of-bank inundation. As the analysis shows, downstream WSELs, stages at Kerr Dam, and inundation extents are dependent on the magnitude and volume of releases from the Project, which in turn are dependent on initial stage at the Project. Out-of-bank inundation downstream of the Project is the result of spillway releases which are directed by the USACE. Under authority of Section 7 of the 1944 Flood Control Act, the Tulsa District of the USACE is responsible for prescribing and directing the flood control operations of the Project. The USACE is also responsible for directing spillway releases in accordance with the procedures for system balancing of flood storage outlined in the Arkansas River Basin Water Control Master Manual (USACE, 1980). This authority is reinforced by Section 7612 (c) of the National Defense Authorization Act (NDAA) of Fiscal Year 2020 which states that "The Secretary [of the Army] shall have exclusive jurisdiction and responsibility for management of the flood pool for flood control operations at Grand Lake O' the Cherokees" (116th Congress, 2019).

However, comparing anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes, the results of the DHM demonstrate that anticipated operations have an immaterial impact on downstream WSELs and inundation as compared to baseline operations.

List of Abbreviations and Terms

1D ..... One-Dimensional
CFS ..... Cubic Feet Per Second
CHM ..... Comprehensive Hydraulic Model
DEM ..... Digital Elevation Model
DHM ..... Downstream Hydraulic Model
FERC ..... Federal Energy Regulatory Commission
FRM ..... Flood Routing Model
GEV ..... Generalized Extreme Value
GRDA ..... Grand River Dam Authority
H&H ..... Hydrologic and Hydraulic
HEC-RAS ..... Hydrologic Engineering Center River Analysis System
ISR ..... Initial Study Report
MISR ..... Model Input Status Report
NAVD88 ..... North American Vertical Datum of 1988
NED ..... National Elevation Dataset
NDAA ..... National Defense Authorization Act
NGVD29 ..... National Geodetic Vertical Datum of 1929
OM ..... Operations Model
OWRB ..... Oklahoma Water Resources Board
PD ..... Pensacola Datum
PSP ..... Proposed Study Plan
RM ..... River Mile
RSP ..... Revised Study Plan
RWM ..... RiverWare Model
SPD ..... Study Plan Determination
UHM ..... Upstream Hydraulic Model
USACE ..... United States Army Corps of Engineers
USGS ..... United States Geological Survey
USR ..... Updated Study Report
WSEL ..... Water Surface Elevation

1. Introduction and Background

1.1 Project Description

The Pensacola Hydroelectric Project is owned and operated by GRDA and regulated by the FERC. The Pensacola Dam is in Mayes County, Oklahoma on the Grand-Neosho River. Pensacola Dam impounds Grand Lake. Construction of Pensacola Dam was completed in 1940. **Figure 1** displays the study area. Downstream of Pensacola Dam, GRDA also owns and operates the Robert S. Kerr Dam as the Markham Ferry Hydroelectric Project. Kerr Dam is also in Mayes County and impounds Lake Hudson, also known as Markham Ferry Reservoir. Flood control operations at both Pensacola Dam and Kerr Dam are regulated by USACE.

1.2 Study Plan Proposals and Determination

GRDA is currently relicensing the Project. The timeline of study plan proposals and determination is as follows:

1. On April 27, 2018, GRDA filed its PSP to address hydrologic and hydraulic modeling in support of its intent to relicense the Project.
2. On September 24, 2018, GRDA filed its RSP.
3. On November 8, 2018, the FERC issued its Study Plan Determination (SPD) for the Project.
4. On January 23, 2020, the FERC issued an Order on Request for Clarification and Rehearing, which clarified the timeline for certain milestones applicable to the relicensing study plan.
5. On September 30, 2021, GRDA filed its Initial Study Report (ISR).
6. On February 24, 2022, the FERC issued its Determination on Requests for Study Modifications and New Studies for the Project.
7. On September 30, 2022, GRDA filed this report, the Updated Study Report (USR).

The PSP and RSP recommended the development of a CHM as part of the H&H modeling study. This report discusses the DHM. As stated in the RSP, the objectives of the H&H modeling study are:

1. Determine the duration and extent of inundation under the current license operations of the Project during several measured inflow events.
2. Determine the duration and extent of inundation under any proposed change in these operations that occurs during several measured or synthetic inflow events.
3. Provide the model results in a format that can inform other analyses (to be completed separately) of Project effects, if any, in several resource areas.
4. Determine the feasibility of implementing alternative operations scenarios, if applicable, that may be proposed by GRDA as part of the relicensing effort.

The FERC's SPD and Order on Request for Clarification and Rehearing included direction to provide a model input status report by March 30, 2021 and hold a conference call on model inputs and calibration within 30 days of the input status report. The Downstream Hydraulic Model Input Status Report (Mead & Hunt, 2021) was filed with FERC and shared with stakeholders on March 30, 2021, and a Technical Conference was held on April 21, 2021, to allow relicensing participants to ask questions regarding the Model Input Status Report (MISR).

GRDA's ISR was a continuation of the MISR and incorporated comments provided on the MISR. The ISR documented the development of the DHM and findings from the analyses of historical and synthetic flow

events with different initial starting stages at Pensacola Dam. GRDA's ISR concluded that initial stages at Pensacola Dam have an impact on downstream WSELs and out-of-bank inundation.

FERC's February 2022 Determination recommended the following modifications to the DHM as part of the H&H modeling study:

1. Run scenarios with a starting elevation at Pensacola Dam of 734 feet PD and extending up to and including an elevation of 757 feet PD.
2. Report the frequency, timing, amplitude (i.e., elevation), and duration of inundation for each of the simulated inflow events with starting elevations between 734 and 757 feet PD.

As documented in this USR, GRDA has completed FERC's requested modifications as follows:

1. GRDA simulated scenarios with starting reservoir elevations at Pensacola Dam ranging from 734 feet PD up to and including 757 feet PD.
2. GRDA reported the frequency, timing, amplitude, and duration of flow events as follows:
    a. Frequency of the inflow events (*i.e.*, estimated return period) is reported in this document and its appendices.
    b. The term "timing" originates in the RSP and refers to seasonality of inflow to Pensacola Dam and inundation from the Upstream Hydraulic Model (UHM). Timing is discussed in Section 11 of the USR for the UHM. GRDA used the UHM to analyze the seasonality of normal (median) operational levels and inflows as it impacts the Aquatic Species Study, the Terrestrial Species Study, and the Wetlands and Riparian Habitat Study.
    c. Amplitude (*i.e.*, elevation) is reported as WSEL in this document and its appendices.
    d. Duration of inundation is reported in this document and its appendices.

The DHM and this report were updated during the second season according to FERC's February 2022 Determination. The study's purpose is to analyze the influence Project operations have on inundation downstream of the Project through Lake Hudson. This report documents the development of the DHM and findings from the analyses of several historical and synthetic flow events under different operational scenarios at Pensacola Dam.

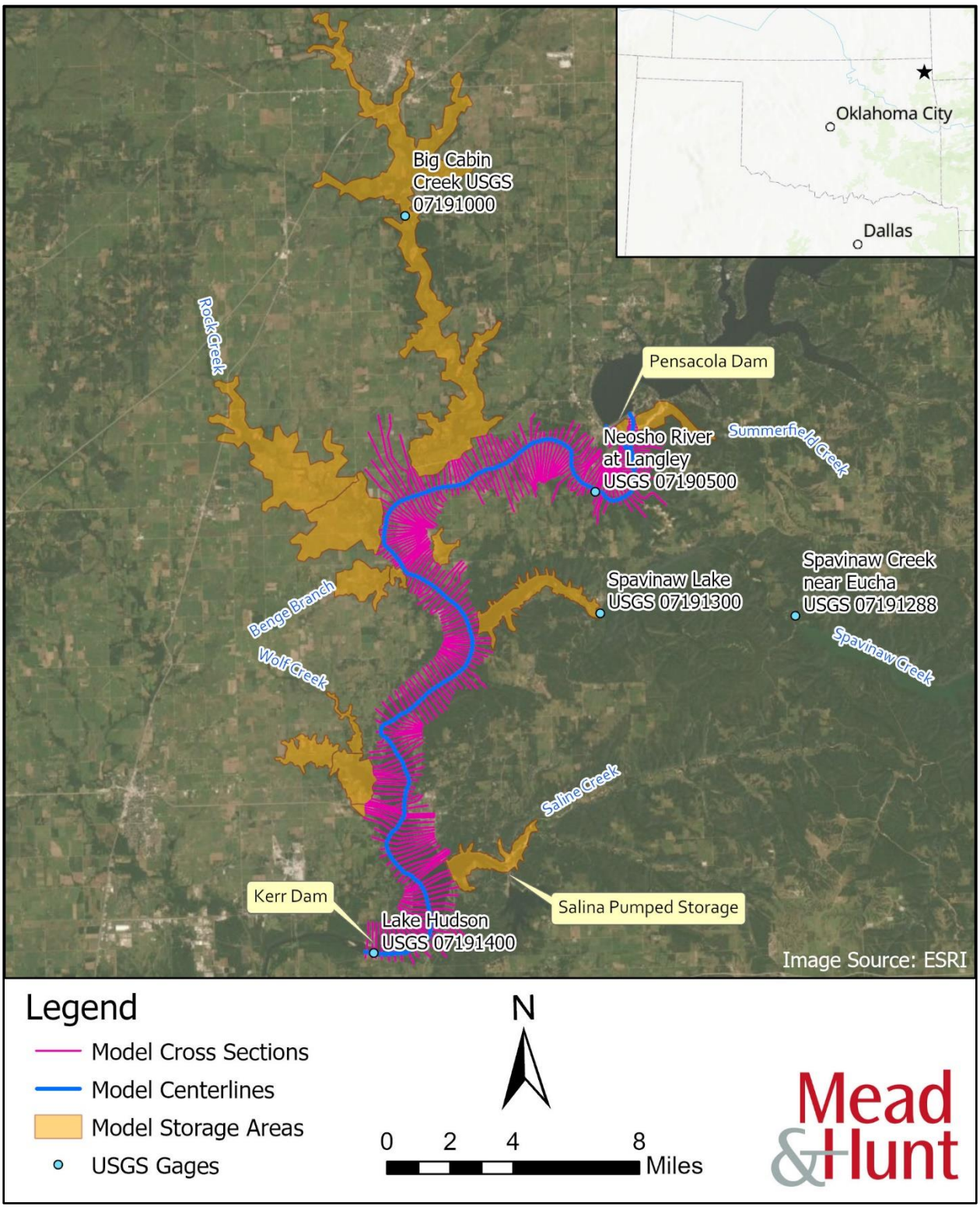
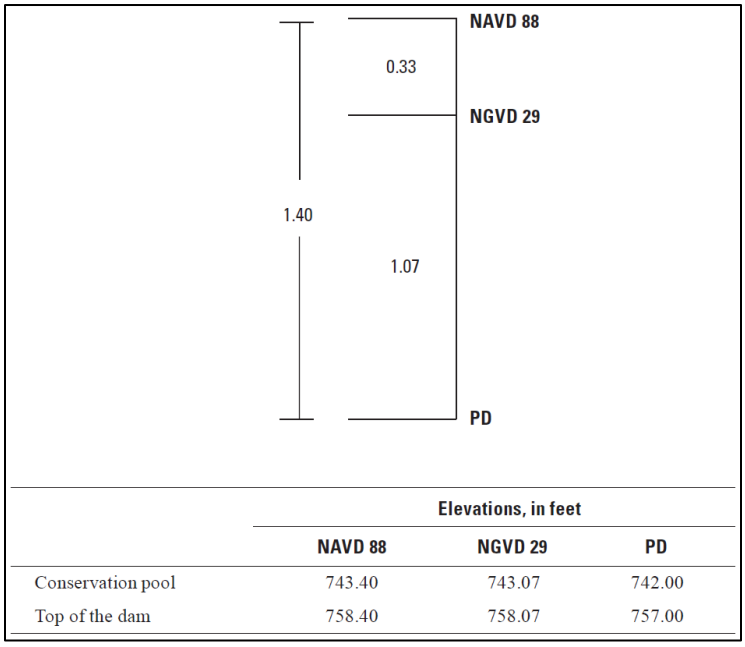


FIGURE 1. DOWNSTREAM HYDRAULIC MODEL STUDY AREA.

1.3 Vertical Datums

Data sources for this study use a variety of vertical datums. Unless otherwise noted, data are presented in the Pensacola Datum (PD). To convert from PD to the National Geodetic Vertical Datum of 1929 (NGVD29), add 1.07 feet. To convert from NGVD29 to the North American Vertical Datum of 1988 (NAVD88), add 0.33 feet. **Figure 2** displays datum transformations and conversions (Hunter, Trevisan, Villa, & Smith, 2020). The HEC-RAS model discussed in this report was developed in NGVD29.



	Elevations, in feet		
	NAVD 88	NGVD 29	PD
Conservation pool	743.40	743.07	742.00
Top of the dam	758.40	758.07	757.00

FIGURE 2. DATUM TRANSFORMATIONS AND CONVERSIONS. SOURCE: (HUNTER, TREVISAN, VILLA, & SMITH, 2020)

2. Model Development and Calibration

The DHM was developed using HEC-RAS Version 5.0.7 and is a 1D, unsteady-state model. The various model components along with model calibration are discussed in the following sections.

2.1 Topographic and Bathymetric Data

Topographic and bathymetric data used to develop the DHM consisted of a single Digital Elevation Model (DEM) to represent the bathymetry of the Neosho River, Lake Hudson, and overbank areas, as shown in **Figure 3**. The DEM was developed using the following data sources, listed in descending order of priority:

1. Oklahoma Water Resources Board (OWRB) bathymetry, representing the Neosho River and Lake Hudson from just downstream of Pensacola Dam to just upstream of Kerr Dam (Oklahoma Water Resources Board, 2008).
2. USGS National Elevation Dataset (NED) 1/3 arc-second elevation layer, representing the overbank areas (USGS, 2017a).

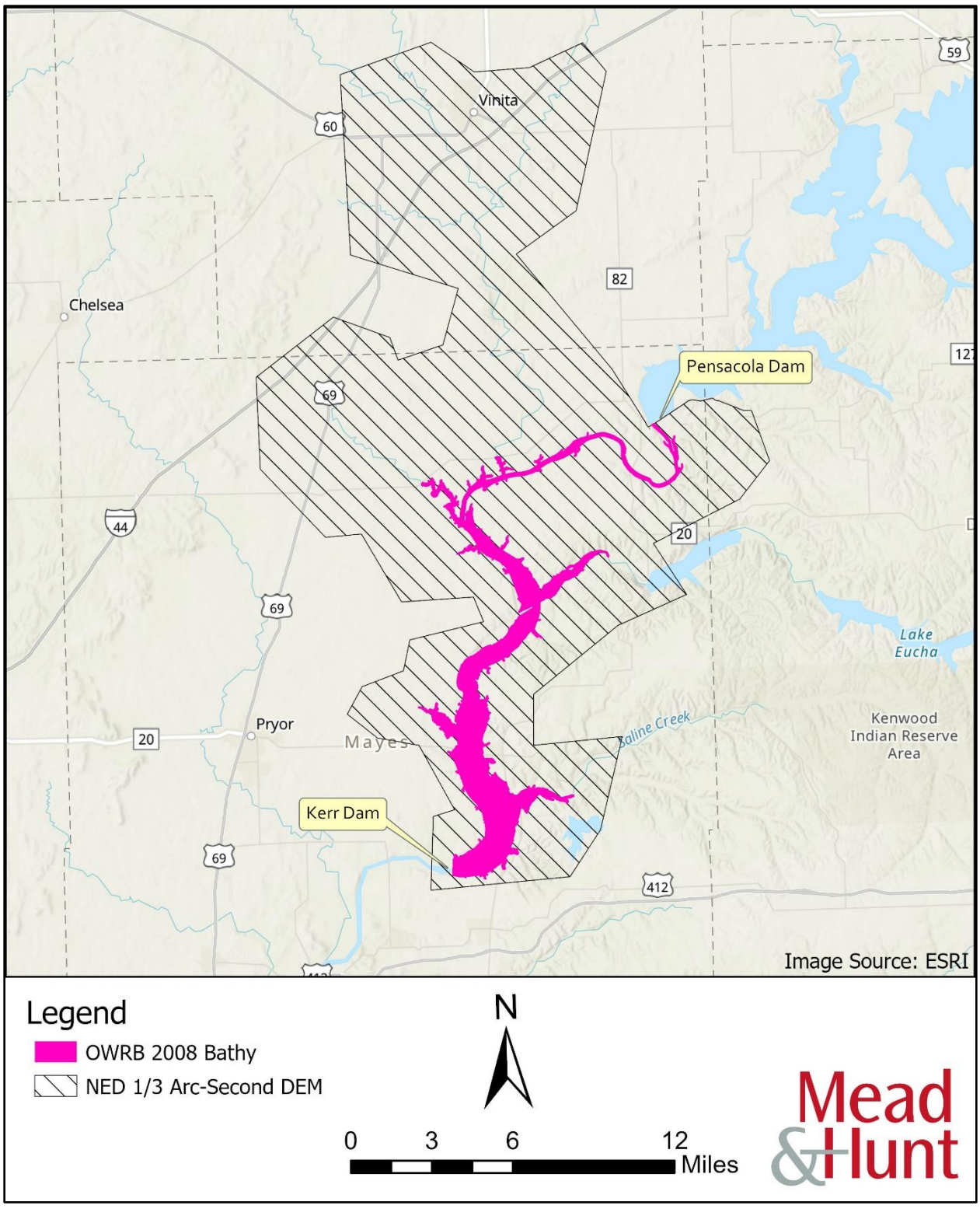


FIGURE 3. TOPOGRAPHIC AND BATHYMETRIC DATA EXTENTS.

2.2 Model Geometry

The model geometry was originally created using HEC-GeoRAS, a toolset used for processing geospatial data in ArcGIS for use in HEC-RAS. Cross-sections were defined for the Neosho River channel just downstream of Pensacola Dam to just downstream of Kerr Dam. As shown in **Figure 4**, separate parallel reaches were defined for the Neosho River channel just below Pensacola Dam and the main spillway channel below Pensacola Dam, with these reaches joining each other approximately 1.6 miles downstream of Pensacola Dam. A single reach then represents the remainder of the Neosho River and Lake Hudson to just downstream of Kerr Dam.

Storage areas were developed in the model at various tributaries to the Neosho River and Lake Hudson to represent the available storage volumes outside the main flow path of the reservoir. A storage area was also used to represent the east spillway channel downstream of the Project from just downstream of Pensacola Dam, to where it joins the main spillway channel. An additional storage area was used to represent the potential flow exchange between the river channel and the main spillway channel below the Project. Lateral structures were used to connect the storage areas to their respective cross-sections.

Four bridges that cross the Neosho River and Lake Hudson within the study area were included in the DHM. The bridges were defined within the model geometry based on record drawings obtained from the Oklahoma Department of Transportation and GRDA. For calibration purposes, Kerr Dam was represented by an inline structure near the downstream end of the model to assign a flow hydrograph boundary condition based on recorded discharges through the dam.

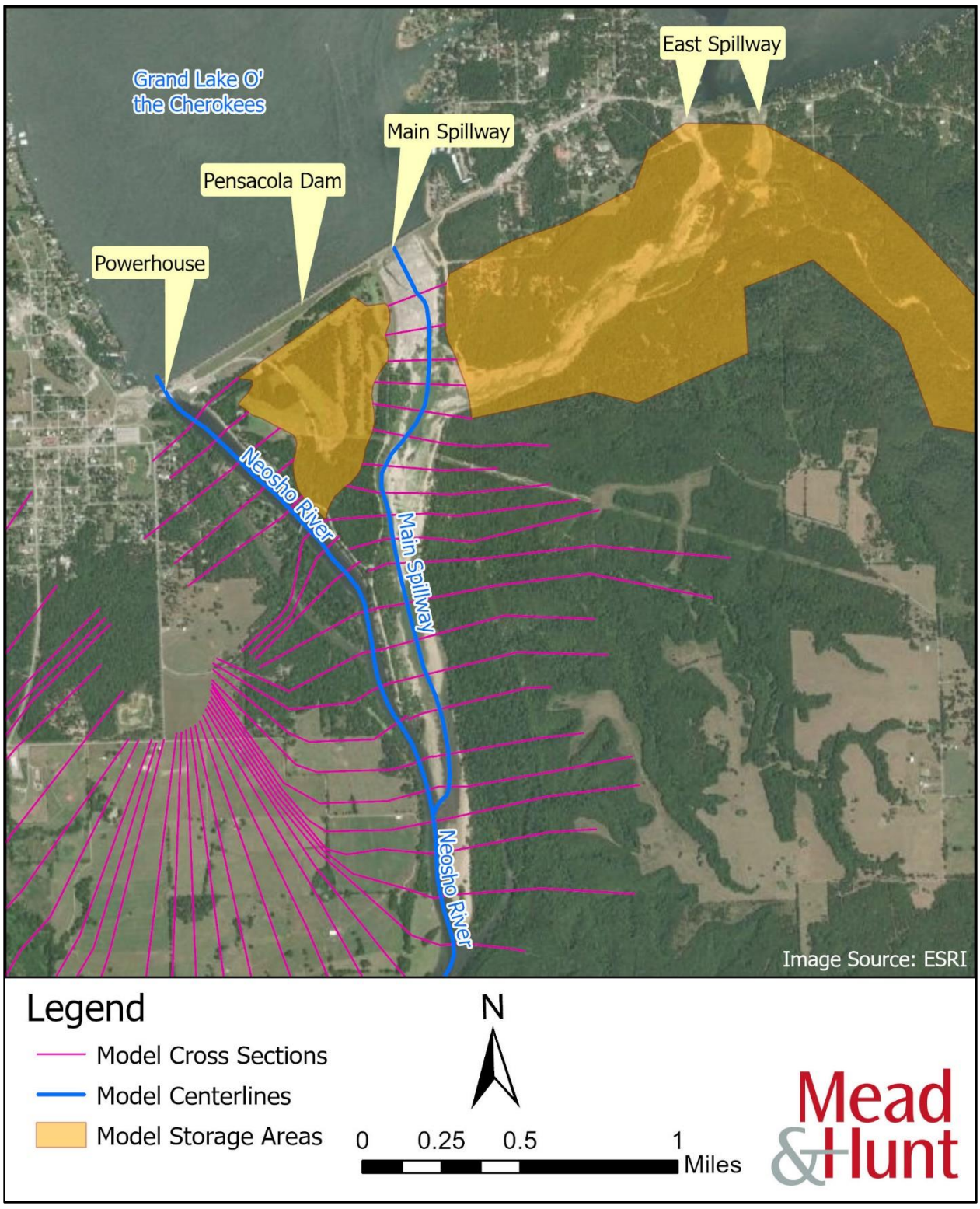


FIGURE 4. MODEL CONFIGURATION JUST DOWNSTREAM OF PENSACOLA DAM.

2.3 Manning's n-values

Manning's n-values for the DHM were delineated based on land cover type, vegetation density, and development visible in aerial imagery. The n-values were established based on guidance provided in the HEC-RAS Hydraulic Reference Manual (USACE, 2016). **Table 1** provides the land use categories and their respective n-values prior to calibration.

TABLE 1. MANNING'S N-VALUES PRIOR TO CALIBRATION.

Land Use Category	n-value
Channel	0.030
Pasture high grass or mature row crops	0.035
Mature field crops	0.040
Light brush and trees	0.060
Urban or residential	0.070
Dense urban or residential	0.090
Medium to dense brush	0.100

2.4 Boundary Conditions for Calibration

The boundary conditions used for model calibration were comprised of multiple boundary condition types including inflow hydrographs, lateral inflow hydrographs, outflow hydrographs, and a normal depth boundary condition at the downstream end of the model. A uniform lateral inflow hydrograph boundary condition was also included in the model to represent ungaged tributaries along the reservoir and is discussed further in **Section 2.5**. Where available, observed time series data were obtained from USGS stream gages within the study area (USGS, 2017b), (USGS, 2017c), (USGS, 2017d), (USGS, 2017e) and used to develop the inflow boundary conditions and aid in model calibration. The applicable USGS stream gages are listed in **Table 2** and their locations are displayed in **Figure 1**. USGS stream gage No. 07191400 reports storage (in acre-feet) for Lake Hudson and is included in **Figure 1** for context but was not used for model calibration and therefore not included in **Table 2**.

TABLE 2. USGS STREAM GAGE STATIONS.

USGS Gage No.	Station Name
07190500	Neosho River near Langley, OK
07191000	Big Cabin Creek near Big Cabin, OK
07191288	Spavinaw Creek near Eucha, OK
07191300	Spavinaw Lake at Spavinaw, OK

For calibration, outflows from Pensacola Dam were included as inflow hydrographs to the 1D reaches using time series data provided by GRDA. GRDA sends this data to USACE monthly. Flows were split between powerhouse discharges and main spillway discharges accordingly and assigned to the Neosho River channel and the main spillway channel, respectively.

Lateral inflow hydrographs were used to represent discharge from the east spillways at Pensacola Dam and flows from Big Cabin Creek, Lake Spavinaw, and Salina Pumped Storage Project. Discharges from the east spillways at Pensacola Dam were derived from USACE time series operations data. The gage locations for Big Cabin Creek and Lake Spavinaw are a considerable distance from the inflow locations represented in the model. Hydrologic routing parameters were obtained from the USACE Tulsa District's

HEC-HMS model of the Lower Grand Neosho River Watershed and used to route the gaged flows to the lateral inflow locations used in the HEC-RAS model. Flows from Lake Spavinaw were computed by using gaged outflows from upstream Lake Eucha (USGS Gage No. 07191288) and calculating the outflow from Lake Spavinaw using routing parameters obtained from the USACE HEC-HMS model. Flows from the Salina Pumped Storage Project were derived from power consumption and generation time series data obtained from GRDA. This data was converted from megawatts to cubic feet per second (cfs) using separate conversion factors for pumping mode and generating mode, with positive flow rates representing inflows from power generation and negative flow rates representing withdrawals from pumping.

For calibration, outflows through Kerr Dam were represented with an outflow hydrograph assigned to the inline structure in the model using observed time series data obtained from GRDA and USACE. A normal depth boundary condition is assigned to the furthest downstream cross-section of the model. The model results for the study area upstream of Kerr Dam for calibration are not sensitive to the assumed normal depth slope because the flow hydrograph assigned at Kerr Dam allows the model to compute WSELs upstream of the dam independent of the computed water levels downstream of the dam.

2.5 Model Calibration

The DHM was calibrated using four historical events which were chosen because they represent flow events for which suitable time series data were available with reasonable consistency. The four events used for calibration are summarized in **Table 3**.

TABLE 3. SUMMARY OF CALIBRATION EVENTS.

Event	Simulation Start/End Date	Pensacola Dam Peak Outflow (cfs)	Kerr Dam Peak Outflow (cfs)
July 2007	June 10, 2007 - July 23, 2007	106,941	99,034
April 2008	April 7, 2008 - April 17, 2008	82,340	91,287
April 2011	April 20, 2011 - May 15, 2011	80,559	91,852
May 2015	May 17, 2015 - June 9, 2015	107,246	121,400

The HEC-RAS model was calibrated based on measurements at the USGS stream gage along the Neosho River near Langley (USGS No. 07190500). The boundary conditions described in **Section 2.4** were used during calibration, with time series data specific to each event.

Initial model runs revealed discrepancies between the recorded data and actual data related to volume conservation errors, which caused modeled WSELs at Kerr Dam to vary significantly from the observed elevations through the course of the simulation. The most likely reason for the volume conservation errors is due to missing inflow from the ungaged tributaries and direct rainfall on Lake Hudson. The largest ungaged tributaries include Summerfield Creek, the lower portion of Big Cabin Creek, Rock Creek, Benge Branch, Wolf Creek, and Saline Creek. To correct for the volume conservation errors, a uniform lateral inflow hydrograph was used as an additional boundary condition in the model to distribute the missing inflow along the length of Lake Hudson. The lateral inflow hydrograph was computed for each event to minimize the difference between simulated and measured WSELs at Kerr Dam.

Manning's n-values were adjusted within the model in conjunction with the lateral inflow adjustments to provide a better match to the observed elevations at the Langley gage near the upstream end of the

model. The goal of the Manning's n-value adjustment was to match the peak WSELs closely for all the calibration events using a single model geometry. The final calibrated model included an 8% increase to each of the initially selected Manning's n-values (presented in **Table 1**). Calibrated Manning's n-values are provided in **Table 4**.

TABLE 4. CALIBRATED MANNING'S N-VALUES.

Land Use Category	Calibrated n-value
Channel	0.0324
Pasture high grass or mature row crops	0.0378
Mature field crops	0.0432
Light brush and trees	0.0648
Urban or residential	0.0756
Dense urban or residential	0.0972
Medium to dense brush	0.1080

A summary of peak WSELs from the calibrated model and observed elevations at the Langley gage are provided in **Table 5**. The eight figures that follow show the computed stage hydrographs versus the observed stages for each of the four calibration events at Kerr Dam (**Figure 5**, **Figure 7**, **Figure 9**, and **Figure 11**) and at the Langley Gage (**Figure 6**, **Figure 8**, **Figure 10**, and **Figure 12**). The stage hydrographs show a close match to the observed stages throughout each of the four events.

TABLE 5. CALIBRATION RESULTS AT LANGLEY GAGE.

Event	Observed Peak WSEL at Langley Gage (No. 07190500) (feet, PD)	Modeled Peak WSEL at Langley Gage (RS 73.315) (feet, PD)	Over/Under Prediction (feet)
July 2007	638.9	638.6	-0.3
April 2008	636.9	636.9	0.0
April 2011	635.8	635.9	0.1
May 2015	639.5	639.6	0.1

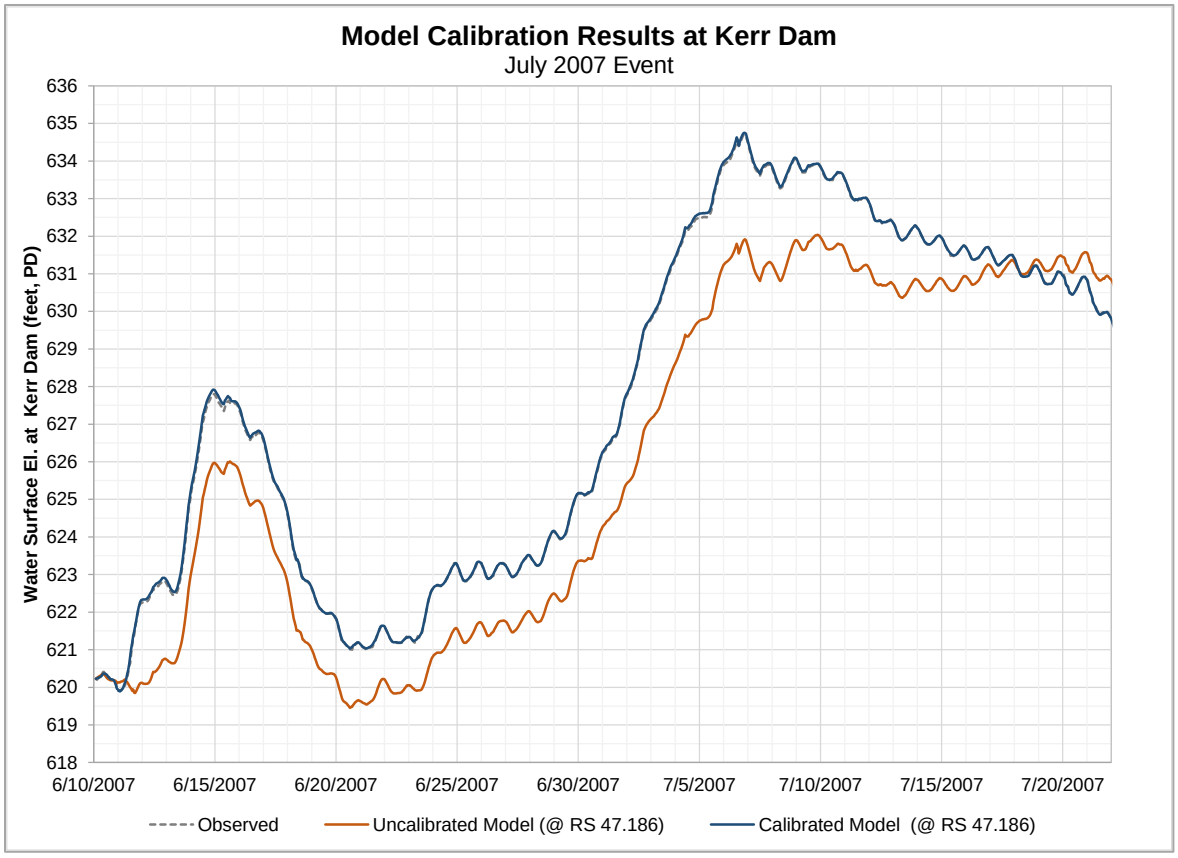


FIGURE 5. JULY 2007 EVENT STAGE HYDROGRAPHS AT KERR DAM.

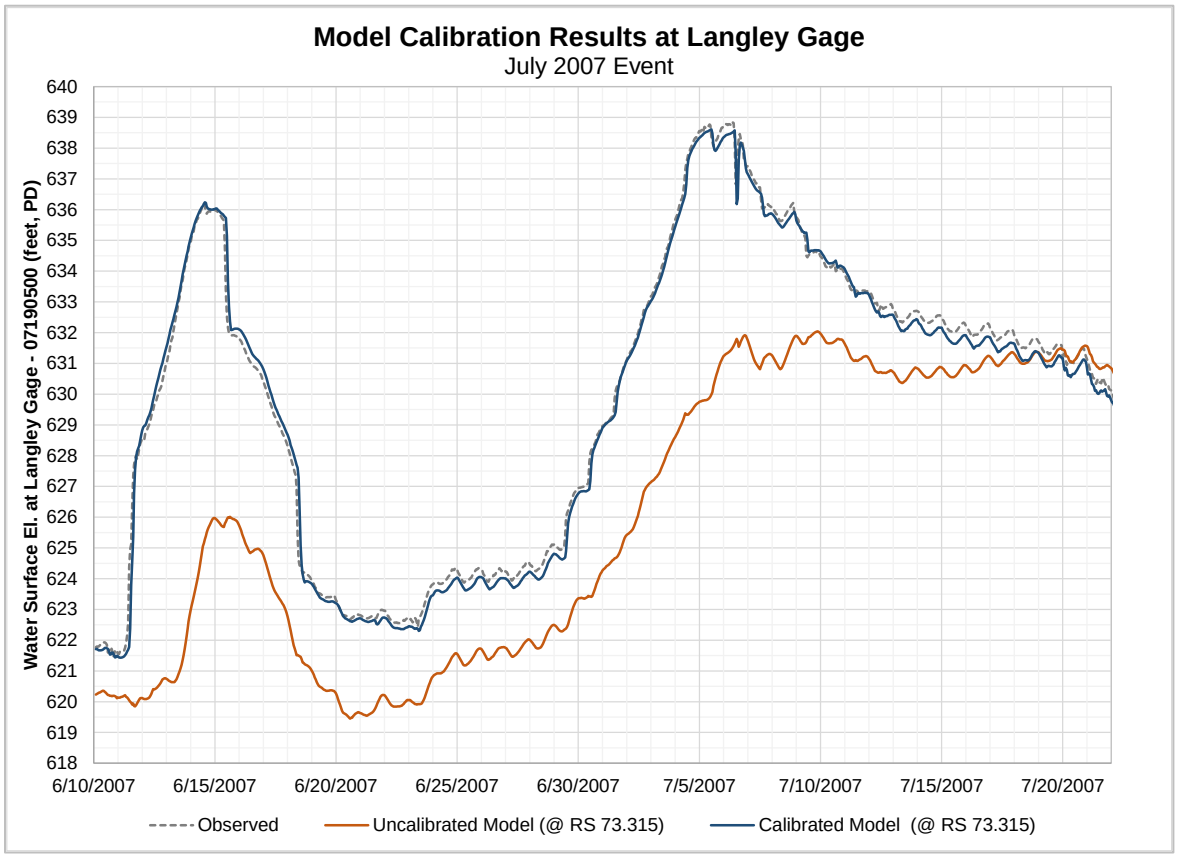


FIGURE 6. JULY 2007 EVENT STAGE HYDROGRAPHS AT LANGLEY GAGE.

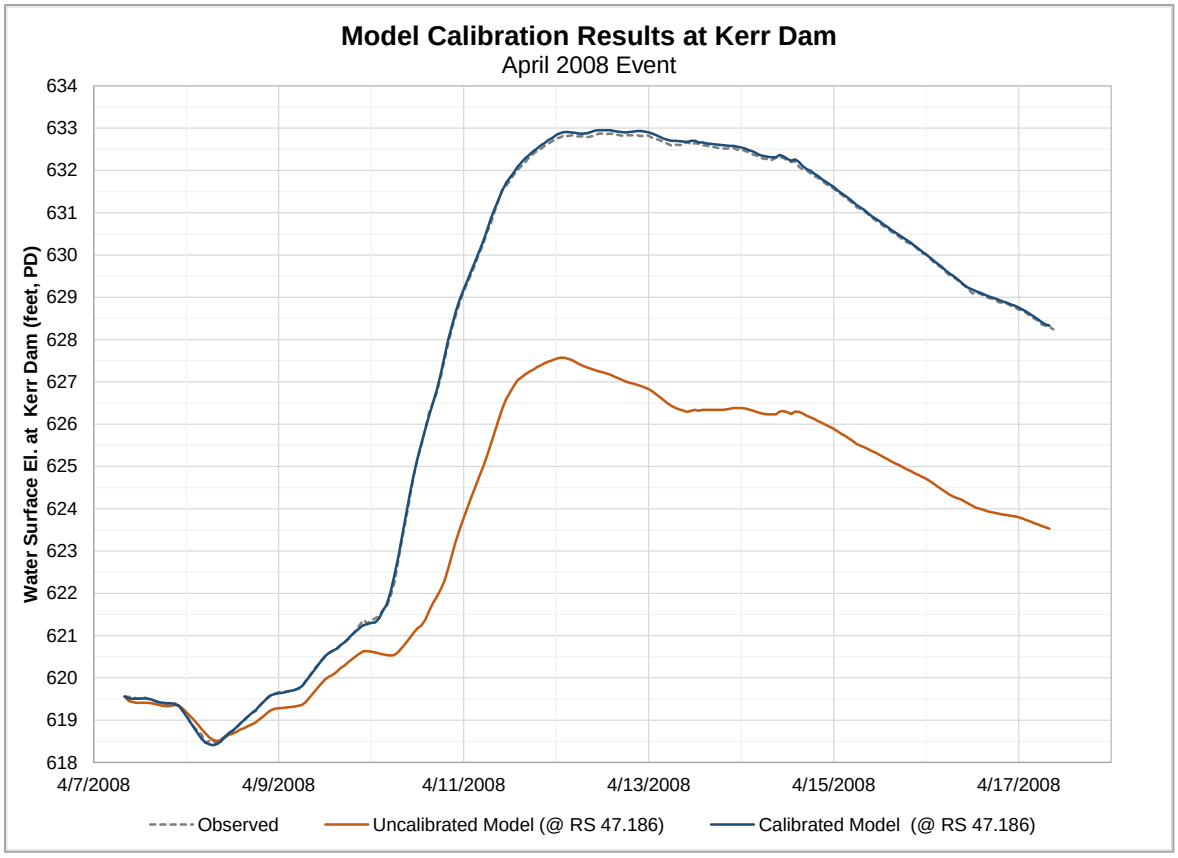


FIGURE 7. APRIL 2008 EVENT STAGE HYDROGRAPHS AT KERR DAM.

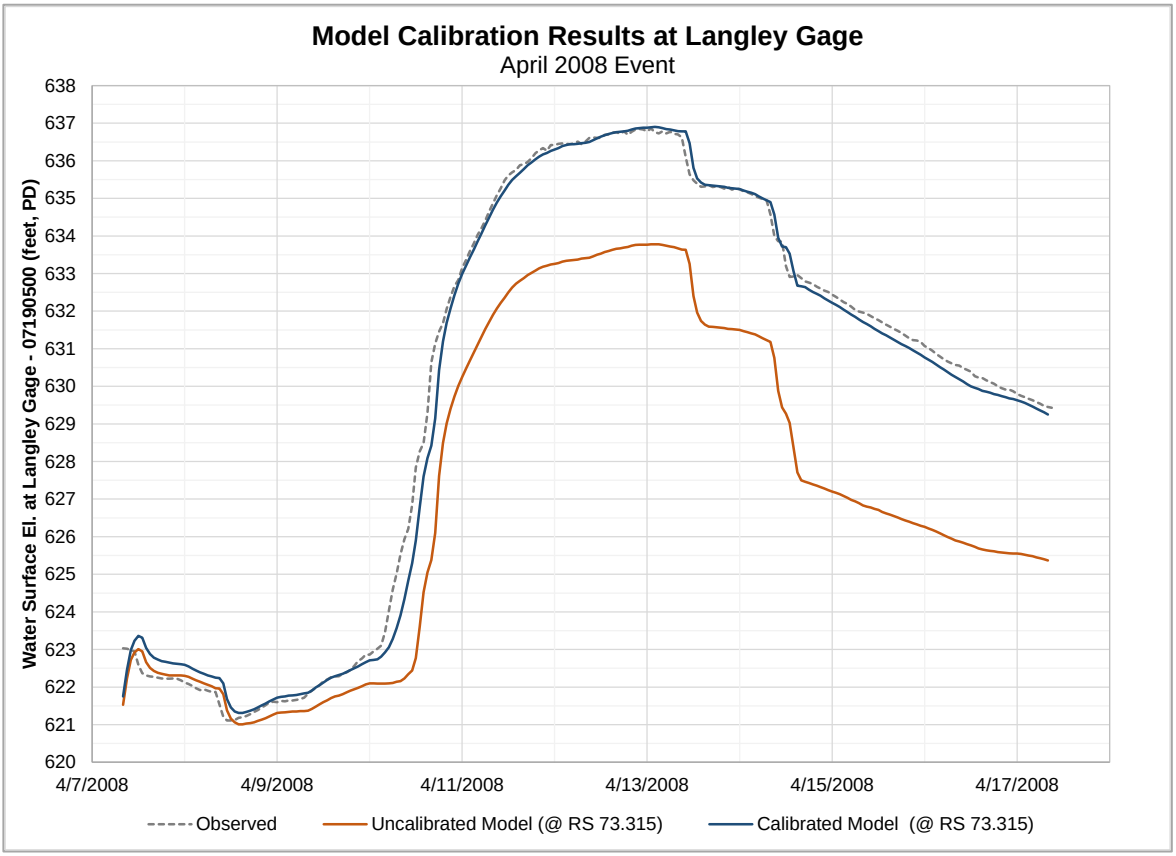


FIGURE 8. APRIL 2008 EVENT STAGE HYDROGRAPHS AT LANGLEY GAGE.

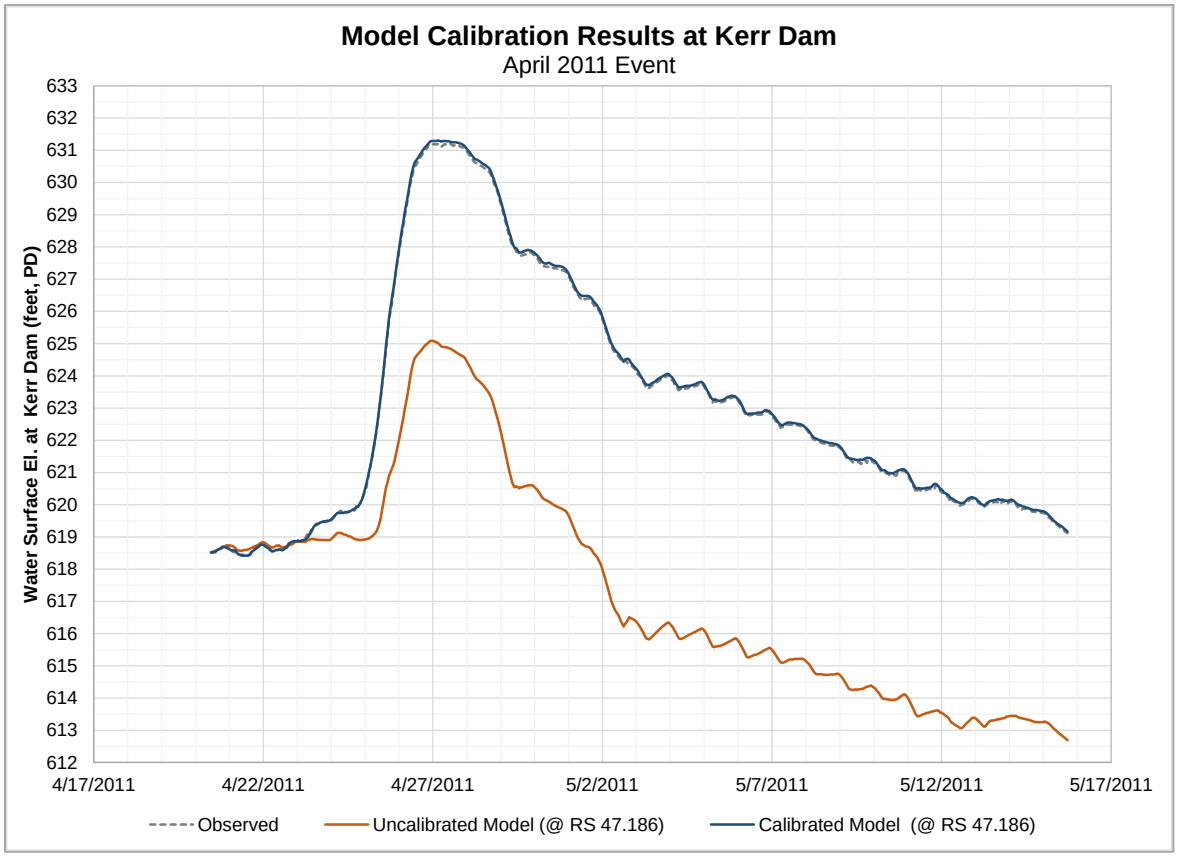


FIGURE 9. APRIL 2011 EVENT STAGE HYDROGRAPHS AT KERR DAM.

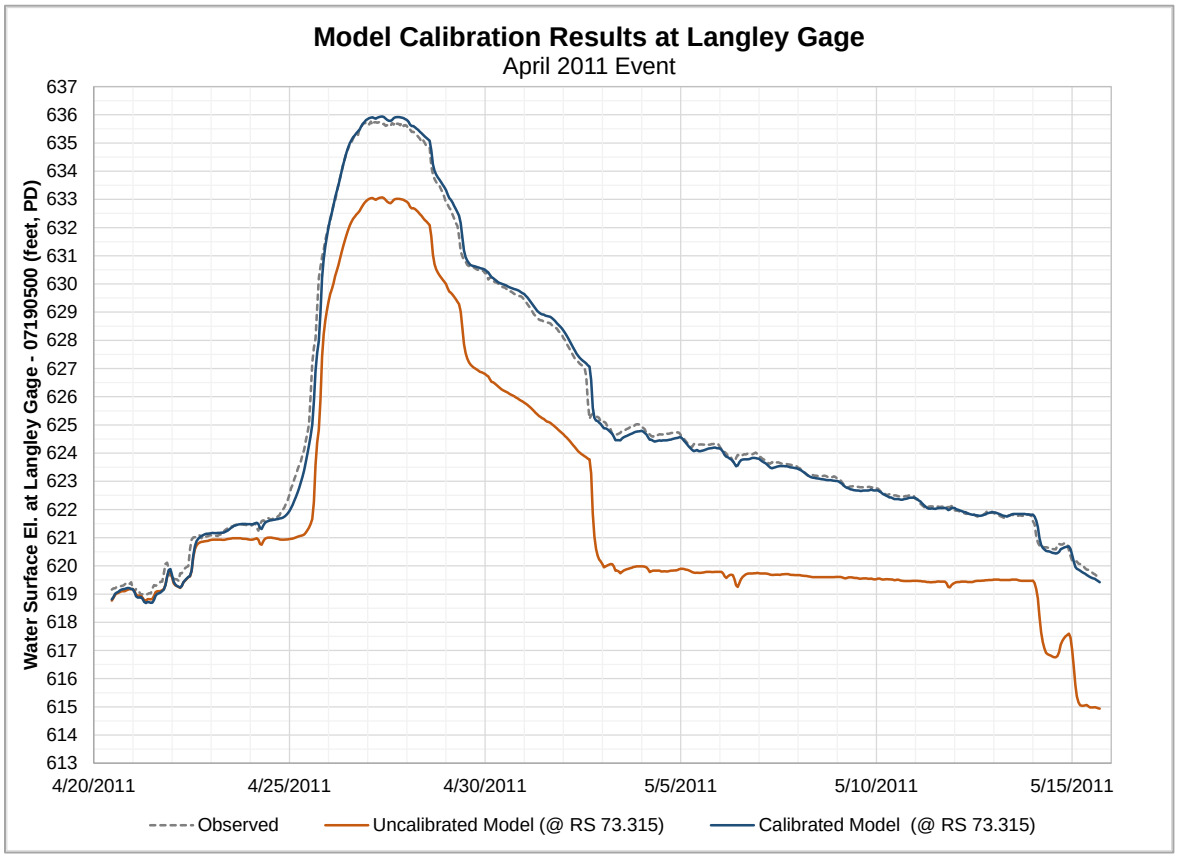


FIGURE 10. APRIL 2011 EVENT STAGE HYDROGRAPHS AT LANGLEY GAGE.

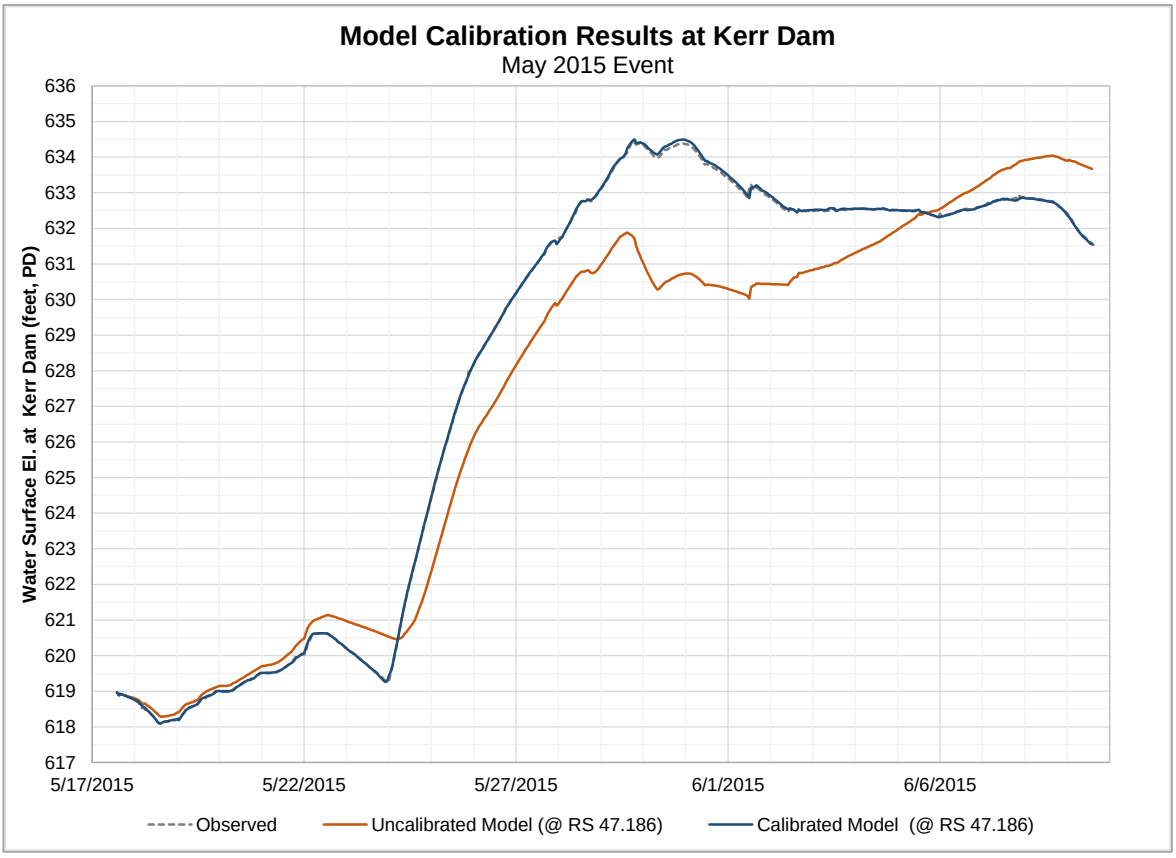


FIGURE 11. MAY 2015 EVENT STAGE HYDROGRAPHS AT KERR DAM.

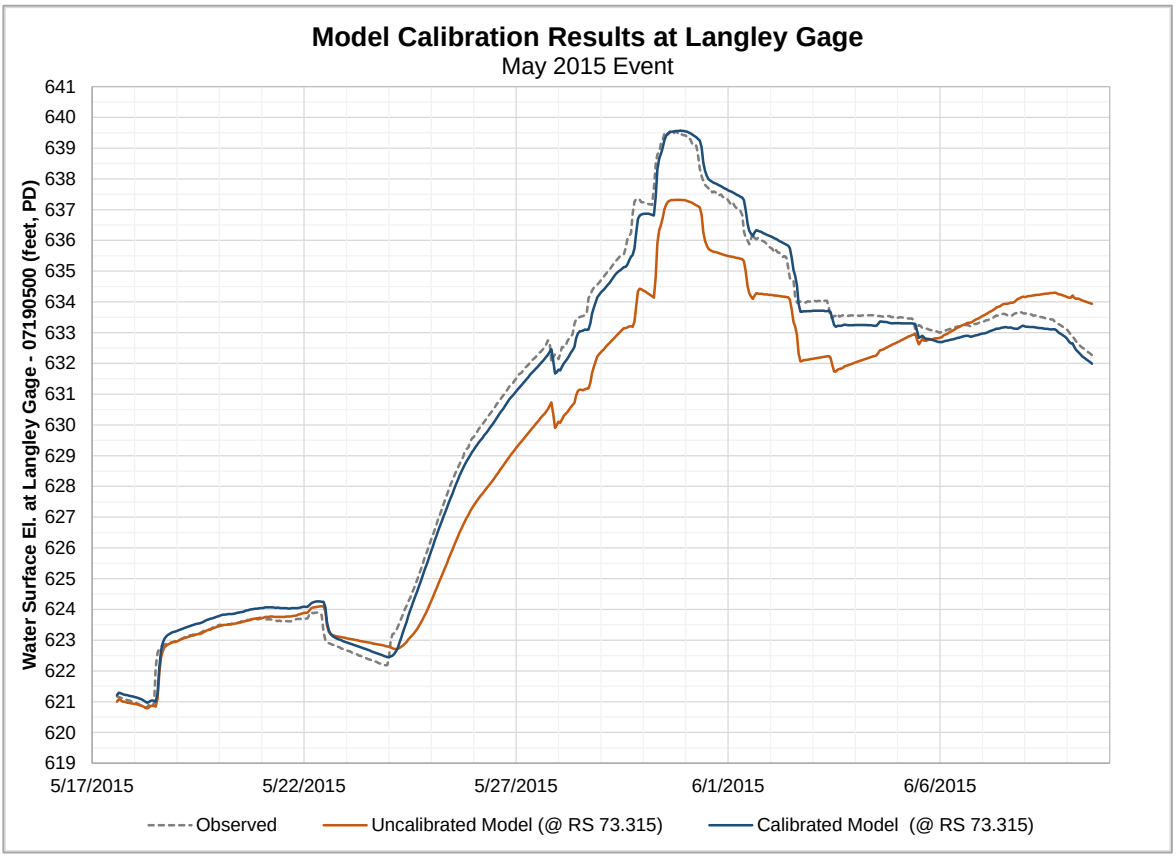


FIGURE 12. MAY 2015 EVENT STAGE HYDROGRAPHS AT LANGLEY GAGE.

3. Modeled Scenarios

The calibrated HEC-RAS model was used to analyze a variety of historical and synthetic flow events under a range of initial stages at Pensacola Dam. Inputs to the HEC-RAS model were developed using results generated from the Operations Model (OM), which was updated according to FERC's February 2022 Determination. The various model simulations are discussed below.

3.1 Scenarios Summary

For this study, five historical flow events and one synthetic flow event were analyzed for a range of initial stages at Pensacola Dam. The flow events are summarized in **Table 6**. Development of the 100-year event hydrograph is discussed in **Section 3.3**.

Each flow event was analyzed assuming starting pools at Pensacola Dam equal to the historical starting stage. In addition to the historical pool elevation, eleven other starting pool elevations were simulated. Starting pool elevations at Pensacola Dam were divided into two categories:

1. Starting reservoir elevations within GRDA's anticipated operational range of 742 to 745 feet PD.
2. Extreme, hypothetical values of starting reservoir elevations outside of GRDA's anticipated operational range. These extreme, hypothetical values below and above GRDA's anticipated operational range were included in the H&H Study based on FERC's February 2022 Determination.

TABLE 6. SUMMARY OF FLOW EVENTS ANALYZED.

Event	Type	Estimated Return Period[1]	Pensacola Dam Historical Pool Elev. At Simulation Start (ft, PD)	Simulation Time Window
September 1993	Historical	21 years	743.85	Sept. 24, 1993 – Oct. 17, 1993
June 2004	Historical	1 year	743.42	June 13, 2004 – June 26, 2004
July 2007	Historical	4 years	745.69	June 28, 2007 – July 25, 2007
October 2009	Historical	3 years	740.98	Oct. 8, 2009 – Oct. 22, 2009
December 2015	Historical	15 years	742.86	Dec. 26, 2015 – Jan. 17, 2016
100-year	Synthetic	100 years	N/A	N/A[2]

[1] *Return period for peak inflow at Pensacola Dam.*

[2] *Because the 100-year event is synthetic, there is no historical start or end date. The duration of the simulation is 14 days.*

Table 7 lists the non-historical Pensacola Dam starting pool elevations analyzed. The OM, which was updated according to FERC's February 2022 Determination, was used to compute the boundary conditions used in the DHM for the various starting pool elevations at Pensacola Dam. The model inputs for each event are discussed in more detail in **Section 3.3**.

TABLE 7. LIST OF ADDITIONAL PENSACOLA DAM INITIAL POOL ELEVATIONS SIMULATED.

Inflow Event	Pensacola Dam Pool Elevation at Simulation Start (ft, PD)	
	Anticipated Operational Range	Extreme, Hypothetical Range
Sept. 1993 (21 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
June 2004 (1 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
July 2007 (4 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
Oct. 2009 (3 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
Dec. 2015 (15 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
100-year	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0

3.2 Modified Model Geometry

Modifications were made to the calibrated HEC-RAS model geometry to be used for simulating the various Pensacola Dam initial stage and flow event scenarios based on the OM output. The downstream end of the calibrated model geometry was truncated to just upstream of Kerr Dam to allow the use of a downstream stage boundary condition. This involved removing the inline structure used to represent Kerr Dam and removing the two model cross sections downstream of Kerr Dam from the calibrated model geometry.

3.3 Boundary Conditions

Results from the OM were used as boundary conditions to the HEC-RAS model to simulate the various flow events and initial stages at Pensacola Dam. A summary of the OM results used in the HEC-RAS model simulations is provided in **Table 8**. Hydrograph plots showing results from the OM that were used as inputs to the HEC-RAS model are included in **Appendix A**.

TABLE 8. SUMMARY OF OPERATIONS MODEL RESULTS USED FOR HEC-RAS SIMULATIONS.

Event	Pensacola Starting Stage Category	Pensacola Starting Stage (ft, PD)	Pensacola Dam Peak Outflow[2] (cfs)	Kerr Dam Peak Stage (ft, PD)
September 1993 (21 Year)[1]	Historical	743.85	198,000	634.83
	Anticipated Operational Range	742	150,000	634.71
		742.5	150,000	634.71
		743	152,000	634.71
		743.5	162,000	634.71
		744	173,000	634.72
		744.5	184,000	634.72
		745	198,000	634.83
	Extreme Hypothetical Operational Range	734	124,000	630.83
		749	210,000	635.12
		753	215,000	635.17
		757	250,000	635.20
June 2004 (1 Year)[1]	Historical	743.42	45,000	619.48
	Anticipated Operational Range	742	15,000	619.09
		742.5	28,000	619.09
		743	22,000	619.09
		743.5	25,000	619.09
		744	21,000	619.09
		744.5	32,000	619.34
		745	45,000	620.36
	Extreme Hypothetical Operational Range	734	14,000	619.09
		749	50,000	624.42
		753	101,000	631.51
		757	124,000	632.20
July 2007 (4 Year)[1]	Historical	745.69	117,000	634.81
	Anticipated Operational Range	742	101,000	634.59
		742.5	117,000	634.62
		743	117,000	634.62
		743.5	117,000	634.62
		744	99,000	634.61
		744.5	117,000	634.62
		745	117,000	634.81
	Extreme Hypothetical Operational Range	734	100,000	634.55
		749	117,000	634.81
		753	125,000	634.81
		757	141,000	634.81
October 2009 (3 year)[1]	Historical	740.98	86,000	632.99
	Anticipated Operational Range	742	100,000	633.51
		742.5	81,000	630.93
		743	99,000	633.51
		743.5	76,000	629.70

Event	Pensacola Starting Stage Category	Pensacola Starting Stage (ft, PD)	Pensacola Dam Peak Outflow[2] (cfs)	Kerr Dam Peak Stage (ft, PD)
		744	79,000	630.62
		744.5	78,000	629.61
		745	98,000	632.99
	Extreme Hypothetical Operational Range	734	65,000	628.73
		749	91,000	634.39
		753	102,000	634.55
		757	113,000	634.56
December 2015 (15 year)[1]	Historical	742.86	195,000	634.82
	Anticipated Operational Range	742	195,000	634.82
		742.5	195,000	634.82
		743	195,000	634.82
		743.5	195,000	634.82
		744	195,000	634.82
		744.5	195,000	634.82
		745	195,000	634.82
	Extreme Hypothetical Operational Range	734	100,000	634.56
		749	195,000	634.86
		753	195,000	634.85
		757	232,000	634.89
100-year	Anticipated Operational Range	742	322,000	634.94
		742.5	322,000	634.92
		743	322,000	634.92
		743.5	322,000	634.92
		744	322,000	634.92
		744.5	322,000	634.92
		745	322,000	634.92
	Extreme Hypothetical Operational Range	734	322,000	634.93
		749	322,000	634.92
		753	322,000	634.92
		757	322,000	634.92

[1] *Return period for peak inflow at Pensacola Dam.*

[2] *Values rounded to the nearest 1,000 cfs.*

A stage hydrograph boundary condition was used at the downstream-most cross section of the model to represent stages at Kerr Dam. Outflows from the powerhouse at Pensacola Dam were input as inflow hydrograph boundary conditions. The OM reports spillway flows at Pensacola Dam for each time step as a single value; flows between the main spillway and east spillways are not divided. For input into the HEC-RAS model, the reported spillway flows from the OM for Pensacola Dam were divided between the main and east spillways using a ratio of the maximum discharge capacities of each spillway. Based on that ratio, 69 percent of the total spillway flow was modeled as an inflow boundary condition at the upstream end of the main spillway channel, and 31 percent of the total spillway flow was modeled as lateral inflow boundary condition at the east spillway storage area.

Lateral inflows to the Neosho River and Lake Hudson between Pensacola Dam and Kerr Dam are also reported as a single value for each time step in the OM. These lateral inflows are simply passed through the OM from the USACE RiverWare model (RWM) output; the OM does not modify the lateral inflow values. For input into the HEC-RAS model, the lateral inflows were divided between tributary inflows and local inflows based on drainage area ratios computed for each contributing source. The drainage area ratios used for subdividing the reported lateral inflows from the OM are provided in **Table 9**. Tributary inflows from Summerfield Creek, Big Cabin Creek, Spavinaw Creek, and Saline Creek were represented in the HEC-RAS model as lateral inflow hydrographs. A uniform lateral inflow hydrograph distributed along the length of Lake Hudson was used to represent local inflow to the reservoir via direct rainfall on the reservoir, local runoff from the adjacent hillsides, and inflows from smaller incoming streams.

TABLE 9. RATIOS USED TO SUBDIVIDE LATERAL INFLOWS.

Lateral Inflow Component	Ratio
Summerfield Creek	0.02
Big Cabin Creek	0.41
Saline Creek	0.10
Spavinaw Creek	0.33
Local inflow	0.14

For the synthetic 100-year event, a statistical analysis of historical inflow volume was computed to correlate lateral inflow volumes at Lake Hudson against the peak inflows to Pensacola Dam. The statistical model was developed based on a coefficient of determination (R^2) best-fit calculation assuming the Generalized Extreme Value (GEV) distribution (Bolívar et al., 2010; Takara, 2009). The GEV distribution is a family of distributions (Gumbel, Frechét, and Weibull) commonly used to model infrequent (extreme) random variables, including wind speed, precipitation, and stream flow. The USR for the UHM provides details on the statistical analysis of historical inflow volumes and peak flows at Pensacola Dam, and the development of the synthetic 100-year inflow hydrograph at Pensacola Dam.

Lake Hudson lateral inflow for 24-hour periods was extracted from the RWM output. Lateral inflow by 24-hour duration was converted to volume. Volumes were placed into bins with D+0 representing the day when the peak inflow at Pensacola Dam occurred, D-1 representing the day before the peak, D+1 representing the day after the peak, and so on. The outermost bins included the average over three days: D-8 to D-10, and D+7 to D+9. Thus, the full set of bins is as follows: D-8 to D-10, D-7, D-6, D-5, D-4, D-3, D-2, D-1, D+0, D+1, D+2, D+3, D+4, D+5, D+6, and D+7 to D+9.

As discussed in the USR for the UHM, sets of bins were calculated for the day within each USGS water year, centered around the date on which the annual maximum inflow at Pensacola Dam occurred (one set of bins per USGS water year). Bins were then ordered according to the maximum inflow at Pensacola Dam and used to calculate the Generalized Extreme Value (GEV) distribution parameters. The 100-year inflow at Pensacola Dam was predicted using the GEV distribution parameters and the annual peak inflow values from the RWM output. The reduced variate was calculated for each ordered peak inflow value, and the shape parameter was adjusted to maximize the R^2 correlation of the GEV-linearized discharges (annual peak inflows vs. reduced variate of peak inflows at Pensacola Dam). This resulted in a 100-year inflow at Pensacola Dam within 3 percent of the value calculated in Mead & Hunt's inflow frequency analysis. The shape parameter was then adjusted to match the 100-year inflow at Pensacola Dam based on the Grand Lake inflow frequency analysis, resulting in a shape parameter of -0.02 and a reduced variate of 4.41 for the Pensacola Dam 100-year peak inflow. Daily lateral inflows to Lake Hudson

corresponding to the day of the peak inflow at Pensacola Dam were also plotted against the reduced variates for the corresponding peak inflow at Pensacola Dam.

For each lateral inflow volume bin (D-8 to D-10, D-7… D+0… D+6, and D+7 to D+9), the binned daily volumes were plotted as a function of the reduced variates for the corresponding peak inflow values at Pensacola Dam, using the same adjusted shape parameter (k) used to predict the 100-year inflow at Pensacola Dam. A linear trend line for each volume bin (e.g., D+0) was calculated to obtain the scale parameter σ (linear slope, m) and a location parameter μ (linear intercept, b) for each volume bin. The R^2 values computed based on the linear trend lines fit through the data show a poor correlation between the peak inflows at Pensacola Dam and lateral inflows into Lake Hudson. This is due to the watersheds being mostly hydrologically independent from one another, and the relatively long average travel time for rainfall to reach Pensacola Dam as inflow. However, there is still a positive correlation between increasing peak inflow at Pensacola Dam and increasing lateral inflow into Lake Hudson, so the statistical model is useful for predicting lateral inflows into Lake Hudson expected to be coincident with a 100-year inflow event at Pensacola Dam.

The reduced variate for the 100-year peak inflow at Pensacola Dam (4.41), along with the scale and location parameters for each lateral inflow volume bin were then used to calculate the daily Lake Hudson lateral inflow volumes that are predicted to correspond to a 100-year peak inflow event at Pensacola Dam. **Table 10** displays the results of the statistical analysis, and plots from the analysis are shown in **Appendix B**. The resulting lateral inflow volume curve was used to develop a lateral inflow hydrograph for Lake Hudson. For use as boundary conditions in the HEC-RAS model for the 100-year event, the lateral inflow hydrograph was then divided into tributary and local inflow hydrographs using the ratios given in **Table 9**.

TABLE 10. RESULTS OF HISTORICAL LATERAL INFLOW VOLUME STATISTICAL ANALYSIS.

Volume Bin	Scale Parameter, σ (m)	Location Parameter, μ (b)	100-year Lake Hudson Lateral Inflow Volume (acre-feet)
D-8 to D-10 avg.	3,314	1,647	16,274
D-7	2,143	1,643	11,100
D-6	746	3,876	7,167
D-5	1,711	3,473	11,023
D-4	1,429	3,636	9,944
D-3	4,368	5,550	24,827
D-2	6,910	11,586	42,081
D-1	12,884	18,908	75,769
D+0	14,562	25,031	89,297
D+1	12,974	15,212	72,470
D+2	8,690	6,955	45,306
D+3	3,856	4,816	21,833
D+4	1,950	3,996	12,601
D+5	1,778	4,478	12,325
D+6	1,037	3,948	8,525
D+7 to D+9 avg.	1,568	3,626	10,547

4. Study Results

The HEC-RAS model results were used to extract the maximum WSELs throughout the DHM for each modeled flow event and scenario. The resulting maximum WSELs are documented in the tables provided in **Appendix C**. Tables are provided for each flow event comparing the maximum downstream WSELs for the various starting stages at Pensacola Dam (**Tables C.1** through **C.6**). These tables include two calculations of maximum difference in peak WSEL:

1. Maximum difference for simulations with starting stages at Pensacola Dam within GRDA's anticipated operational range (742 to 745 feet PD).
2. Maximum difference for simulations with starting stages at Pensacola Dam at extreme, hypothetical values (734 to 757 feet PD) which are outside GRDA's anticipated operational range.

A separate table was created for comparing the maximum downstream WSELs for each of the flow events using the historical starting stage at Pensacola Dam (**Table C.7**).

Graphical water surface profiles were also developed from the HEC-RAS model results showing the computed maximum downstream WSELs. The water surface profile plots are included in **Appendix D**. Similar to the tabular data, plots were developed for each flow event to compare the maximum downstream WSELs for the various starting stages at Pensacola Dam (**Figures D.1** through **D.6**). The plots include two profiles of calculated maximum difference in peak WSEL:

1. Maximum difference for simulations with starting stages at Pensacola Dam within GRDA's anticipated operational range (742 to 745 feet PD).
2. Maximum difference for simulations with starting stages at Pensacola Dam at extreme, hypothetical values (734 to 757 feet PD) which are outside GRDA's anticipated operational range.

A separate plot was developed to show the maximum downstream WSELs for each of the flow events using a historical starting stage at Pensacola Dam (**Figure D.7**).

In addition, the HEC-RAS model results were used to develop maps showing the downstream inundation extents resulting from the computed WSELs. The inundation maps are included in **Appendix E**. A series of 10 maps at a scale of 1:24,000 (1 inch = 2,000 feet) cover the downstream model area. Like the tabular and graphical results, separate map sets were developed to compare the maximum downstream inundation extents for each flow event using the various starting stages at Pensacola Dam (**Appendix E.1** through **E.6**), and a separate map set was developed to compare the maximum downstream inundation extents for all the flow events using a historical starting stage at Pensacola Dam (**Appendix E.7**). The inundation extents shown on the maps were developed using the RAS Mapper application and are based on the topographic data discussed in **Section 2.1**.

Table 11 presents a summary of smallest and largest downstream inundation areas, as well as the percentage difference between them, for simulated starting pool elevations at Pensacola Dam within GRDA's anticipated operational range. The first six rows in the table present smallest and largest maximum inundation areas for simulations with various starting pool elevations at Pensacola Dam within GRDA's anticipated operational range for a given flow event. The last row in the table presents the smallest and largest maximum inundation areas for the various flow events using the historical starting stage elevations. Stated another way, the first six rows in the table characterize the impact of GRDA's anticipated operations and the last row characterizes the impact of nature. The maximum downstream

inundation area differences for a given event due to a change in starting stage within GRDA's anticipated operational range are an order of magnitude smaller than the maximum differences when inflow events are compared against each other, and the historical starting stage is used.

TABLE 11. SUMMARY OF MINIMUM AND MAXIMUM DOWNSTREAM INUNDATION AREAS FOR STARTING POOL ELEVATIONS AT PENSACOLA DAM WITHIN GRDA'S ANTICIPATED OPERATIONAL RANGE.

Event	Area of Inundation (acres)		Difference (%)
	Smallest	Largest	
Sept. 1993 (21 year)	18,623	19,065	2.3%
June 2004 (1 year)	12,210	12,838	4.9%
July 2007 (4 year)	17,986	18,397	2.2%
Oct. 2009 (3 year)	15,759	17,504	10.0%
Dec. 2015 (15 year)	19,061	19,070	0.0%
100-year	20,721	20,736	0.1%
Historical Starting Stage (impact of nature)	12,593	19,069	34.0%

Table 12 presents a summary of smallest and largest downstream inundation areas for all simulated starting pool elevations at Pensacola Dam (734 to 757 feet PD), including extreme, hypothetical values outside GRDA's anticipated operational range. Except for the June 2004 event, the maximum inundation area differences for a given event due to change in starting stage are much smaller than the maximum differences when inflow events are compared against each other, and the historical starting stage is used.

TABLE 12. SUMMARY OF MINIMUM AND MAXIMUM DOWNSTREAM INUNDATION AREAS FOR ALL STARTING POOL ELEVATIONS AT PENSACOLA DAM, INCLUDING EXTREME, HYPOTHETICAL VALUES OUTSIDE GRDA'S ANTICIPATED OPERATIONAL RANGE.

Event	Area of Inundation (acres)		Difference (%)
	Smallest	Largest	
Sept. 1993 (21 year)	16,739	19,560	14.4%
June 2004 (1 year)	12,127	17,263	29.8%
July 2007 (4 year)	17,976	18,605	3.4%
Oct. 2009 (3 year)	15,215	17,994	15.4%
Dec. 2015 (15 year)	18,015	19,507	7.6%
100-year	20,720	20,757	0.2%
Historical Starting Stage (impact of nature)	12,593	19,069	34.0%

Tabulated results of downstream inundation duration are presented in **Appendix F**. Downstream inundation duration was defined as the time of inundation above the defined flowage easement for the Markham Ferry Hydroelectric Project. As defined in the Water Control Manual for Markham Ferry Reservoir (USACE, 1992), the flowage easement elevation varies from 637.5 feet NGVD29 to 658.0 feet NGVD29 and is based on a water surface profile computed by the USACE for a flow of 300,000 cfs through Markham Ferry Reservoir (Lake Hudson) with 230,000 cfs coming from Pensacola Dam.

In **Appendix F.1** through **Appendix F.6**, tables are organized by flow event. For example, the set of tables in **Appendix F.1** report downstream inundation duration for the September 1993 inflow event.

Each table in **Appendix F.1** through **Appendix F.6** includes two calculations of difference in inundation duration:

1. Inundation duration difference for simulations with starting pool elevations at Pensacola Dam within GRDA's anticipated operational range (742 to 745 feet PD).
2. Inundation duration difference for simulations with starting pool elevations at Pensacola Dam at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

Appendix F.7 presents a set of inundation duration tables for simulations that used historical starting pool elevations at Pensacola Dam where inundation durations are compared for the various inflow events. Of the flow events analyzed, the 100-year event is the only event to exceed the flowage easement for Lake Hudson. The maximum difference in duration of downstream inundation is 3 hours for 100-year scenarios with starting stages at Pensacola Dam within GRDA's anticipated operational range. The maximum difference in duration of downstream inundation is 22 hours for 100-year scenarios with starting stages at Pensacola Dam that include extreme, hypothetical values.

5. Discussion of Results

Maximum WSELs, maximum inundation extents, and inundation durations were analyzed to assess the downstream influence of various initial stages at Pensacola Dam. The following subsections provide a discussion of the results from the hydraulic modeling for each flow event analyzed.

5.1 September 1993 (21 Year) Flow Event

As shown in **Table 8**, when compared to all the flow events analyzed as part of this study, the September 1993 event represents the second largest in regard to releases from Pensacola Dam. According to the results of the OM, for this event, the maximum releases from Pensacola Dam are dependent on the starting stage of Pensacola Dam. For the scenarios analyzed, the peak stages at Kerr Dam follow a similar trend to the releases from Pensacola Dam. As shown in **Figure D.1**, the peak stages at Kerr Dam only differ slightly between the scenarios using starting stages at Pensacola Dam within GRDA's anticipated operational range between 742 and 745 feet PD (maximum difference in peak stage of 0.12 feet). The peak stages at Kerr Dam differ by a maximum of 4.4 feet between scenarios that include starting stages at Pensacola Dam that include extreme, hypothetical values (734 to 757 feet PD).

For the September 1993 event, the variability in releases from Pensacola Dam due to the different starting stages leads to differences in the maximum WSELs and inundation extents in the upstream portion of the DHM. These differences are most pronounced upstream of the Big Cabin Creek confluence (River Mile (RM) 66.78) where differences in maximum WSEL range from 1.1 to 3.4 feet for simulations with starting stages at Pensacola Dam within GRDA's anticipated operational range, and 6.6 to 10 feet for simulations with starting stages that include extreme, hypothetical values. This portion of the DHM is more riverine in nature and is upstream of the main body of Lake Hudson where peak stages at Kerr Dam have a greater influence on maximum WSELs. Therefore, for this event, variations in the releases from Pensacola Dam have an influence on the computed maximum WSELs and inundation extents through the upper portion of the DHM.

The differences in maximum WSEL and inundation extents due to the different starting stages are much smaller in the downstream portion of the DHM through Lake Hudson. As shown in **Table C.1**, downstream of the Strang Road Bridge (RM 63.32), the differences in maximum WSEL range from 0.10 to 0.24 feet for starting stages at Pensacola Dam within GRDA's anticipated operational range, and 4.3 to 4.9 feet for starting stages that include extreme, hypothetical values. As shown in **Appendix E.1**, the differences in maximum inundation extent through the downstream portion of the DHM are not appreciable.

The flowage easement for Lake Hudson is not exceeded for any of the September 1993 event simulations, including those with extreme value, hypothetical starting stages at Pensacola Dam. Therefore, as shown in **Table F.1**, the duration of downstream inundation at every location for all the September 1993 simulations is zero (0).

5.2 June 2004 (1 Year) Event

As shown in **Table 8**, when compared to all the flow events analyzed as part of this study, the June 2004 event represents the smallest releases from Pensacola Dam. For this event, the maximum releases from Pensacola Dam are dependent on the starting stage of Pensacola Dam.

According to results of the OM for the scenarios analyzed, the peak stages at Kerr Dam follow a similar trend to the releases from Pensacola Dam. As shown in **Table C.2** and **Figure D.2**, the peak stages at Kerr Dam for starting stages within GRDA's anticipated operational range (742 to 745 feet PD) differ by 1.3 feet. The peak stages at Kerr Dam differ by 13 feet when comparing simulations that include extreme, hypothetical values of starting stages at Pensacola Dam (734 to 757 feet PD).

For the June 2004 event, the variability in releases from Pensacola Dam due to the different starting stages leads to differences in the downstream maximum WSELs and maximum inundation extents (shown in **Appendix E.2**). These differences are most pronounced upstream of the Big Cabin Creek confluence (RM 66.78). For the simulations with starting stages at Pensacola Dam within GRDA's anticipated operational range (742 to 745 feet PD), the differences in maximum WSEL through this portion of the DHM range from 1.8 to 7.3 feet. For simulations with starting stages at Pensacola Dam that include extreme, hypothetical values the differences in maximum WSEL through this same portion of the DHM range from 14 feet to 20 feet. Because the portion of the DHM upstream of Big Cabin Creek is more riverine and is upstream of the main body of Lake Hudson where peak stages at Kerr Dam have the greatest influence on maximum WSELs, the variations in the releases from Pensacola Dam have an influence on the computed maximum WSELs and maximum inundation extents through the upper portion of the DHM.

The flowage easement for Lake Hudson is not exceeded for any of the June 2004 event simulations, including those with extreme, hypothetical value starting stages at Pensacola Dam. Therefore, as shown in **Table F.2**, the duration of downstream inundation at every location for all the June 2004 simulations is zero (0).

5.3 July 2007 (4 Year) Event

As shown in **Table 8**, when compared to all the flow events analyzed as part of this study, the July 2007 event represents the third smallest releases from Pensacola Dam. For this event, the maximum releases from Pensacola Dam are dependent on the starting stage of Pensacola Dam.

According to results of the OM and as shown in **Table C.3** and **Figure D.3**, the peak stages at Kerr Dam only differ slightly between the scenarios using starting stages at Pensacola Dam within GRDA's anticipated operational range of 742 to 745 feet PD (maximum difference in peak stage of 0.22 feet). The same can be said when comparing peak stages at Kerr Dam for scenarios with starting stages that include extreme, hypothetical values of 734 to 757 feet PD (maximum difference in peak stage of 0.26 feet).

For the July 2007 event, the variability in releases from Pensacola Dam due to the different starting stages leads to differences in the maximum downstream WSELs and inundation extents. As shown in **Table C.3**, these differences are most pronounced upstream of the Big Cabin Creek confluence where differences in maximum WSEL range from 0.69 to 1.9 feet for simulations with starting stages at Pensacola Dam within GRDA's anticipated operational range, and 0.96 to 3.8 feet for starting stages that include extreme, hypothetical values.

The differences in maximum WSEL and inundation extents due to the different starting stages are much smaller in the downstream portion of the DHM through Lake Hudson. As shown in **Table C.3**, downstream of the Strang Road Bridge (RM 63.32), the differences in maximum WSEL are consistent at approximately 0.20 feet for starting stages at Pensacola Dam within GRDA's anticipated operational

range, and range from 0.20 to 0.35 feet for starting stages that include extreme, hypothetical values. As shown in **Appendix E.3**, the differences in maximum inundation extent through the downstream portion of the DHM are not appreciable, while the differences in maximum inundation extent through the upstream portion of the DHM are more pronounced.

The flowage easement for Lake Hudson is not exceeded for any of the July 2007 event simulations, including those with extreme, hypothetical value starting stages at Pensacola Dam. Therefore, as shown in **Table F.3**, the duration of downstream inundation at every location for all the July 2007 simulations is zero (0).

5.4 October 2009 (3 Year) Event

As shown in **Table 8**, when compared to all the flow events analyzed as part of this study, the October 2009 event represents the second smallest releases from Pensacola Dam. For this event, the maximum releases from Pensacola Dam are dependent on the starting stage of Pensacola Dam.

According to results of the OM for the scenarios analyzed, the peak stages at Kerr Dam follow a similar trend to the releases from Pensacola Dam. As shown in **Table C.4** and **Figure D.4**, the peak stages at Kerr Dam differ by 3.9 feet between the scenarios using starting stages at Pensacola Dam within GRDA's anticipated operational range (742 to 745 feet PD). The peak stages at Kerr Dam differ by approximately 5.8 feet between the scenarios using starting stages at Pensacola Dam that include extreme, hypothetical values (734 to 757 feet PD).

For the October 2009 event, the variability in releases from Pensacola Dam due to the different starting stages in combination with the variability in the peak stages at Kerr Dam leads to nearly uniform differences in the maximum WSELs throughout the DHM. As shown in **Table C.4**, for the scenarios using starting stages at Pensacola Dam within GRDA's anticipated operational range the differences in downstream maximum WSEL range from approximately 3.5 feet just downstream of Pensacola Dam, to approximately 4.0 feet near Spavinaw Creek (RM 60.2). For the scenarios using starting stages at Pensacola Dam that include extreme, hypothetical values, the differences in maximum downstream WSEL range from approximately 5.8 feet at Kerr Dam, to approximately 6.6 feet just downstream of Pensacola Dam.

While the differences in maximum WSEL due to different starting elevations are nearly uniform through the DHM, the differences in maximum inundation extent are not. As shown in **Appendix E.4**, the differences in maximum inundation extent through the upper portion of the DHM (upstream of RM 62) are more pronounced due to the riverine-like conditions and flatter floodplain, whereas the differences in inundation extent through the lower portion of Lake Hudson (downstream of RM 62) are less pronounced due to the steeper valley walls.

The flowage easement for Lake Hudson is not exceeded for any of the October 2009 event simulations, including those with extreme, hypothetical value starting stages at Pensacola Dam. Therefore, as shown in **Table F.4**, the duration of downstream inundation at every location for all the October 2009 simulations is zero (0).

5.5 December 2015 (15 Year) Event

As shown in **Table 8**, when compared to all the flow events analyzed as part of this study, the December 2015 event represents the third largest releases from Pensacola Dam. For this event, the maximum releases from Pensacola Dam are not dependent on the starting stage of Pensacola Dam for scenarios with starting stages at Pensacola Dam within GRDA's anticipated operational range (742 to 745 feet PD). This is because, according to the results of the OM, the peak outflows from Pensacola Dam are nearly identical for all starting stages within GRDA's anticipated operational range. Therefore, as shown in **Table C.5**, the peak stages at Kerr Dam are also identical for all scenarios with starting stages within GRDA's anticipated operational range.

For scenarios with starting stages at Pensacola Dam that include extreme, hypothetical values (734 to 757 feet PD), maximum releases from Pensacola Dam are dependent on the starting stage at Pensacola Dam. However, as shown in **Table C.5**, the peak stages at Kerr Dam only differ by a maximum of approximately 0.3 feet between the scenarios with starting stages at Pensacola Dam that include extreme, hypothetical values.

Because the peak releases from Pensacola Dam are identical for all starting stage combinations within GRDA's anticipated operational range, as shown in **Table C.5** the differences in the maximum WSELs are small throughout the DHM (maximum difference of 0.05 feet). For scenarios with starting stages that include extreme, hypothetical values, the differences in maximum downstream WSEL are less pronounced through Lake Hudson and range from 0.33 feet at Kerr Dam to 1.2 feet at RM 62. In the upstream portions of the DHM, the maximum differences in WSEL range from 1.5 feet just upstream of Strang Road Bridge (RM 63.3) to 9.9 feet just downstream of Pensacola Dam.

As shown in **Appendix E.5**, the maximum downstream inundation extents are identical for all scenarios with starting stages at Pensacola Dam within GRDA's anticipated operational range. Downstream of Strang Road Bridge, the inundation extents are nearly identical, including the scenarios with starting stages at Pensacola Dam that include extreme, hypothetical values. Upstream of Strang Road Bridge, the differences in inundation extents for the scenarios with starting stages that include extreme, hypothetical values are more pronounced.

The flowage easement for Lake Hudson is not exceeded for any of the December 2015 event simulations, including those with extreme, hypothetical value starting stages at Pensacola Dam. Therefore, as shown in **Table F.5**, the duration of downstream inundation at every location for all the December 2015 simulations is zero (0).

5.6 100-year Event

As shown in **Table 8**, when compared to all the flow events analyzed as part of this study, the 100-year event represents the largest releases from Pensacola Dam. For this event, the maximum releases from Pensacola Dam are not dependent on the starting stage of Pensacola Dam because, according to the results of the OM, the peak outflows from Pensacola Dam are identical for all starting stages. As shown in **Table C.6**, the differences in peak stage at Kerr Dam are negligible when comparing all the simulations (0.02 feet), including the simulations with starting stages at Pensacola Dam with extreme, hypothetical values (734 to 757 feet PD).

As shown in **Table C.6** and on **Figure D.6**, the maximum WSELs for the 100-year event for all starting stages at Pensacola Dam, even those with extreme, hypothetical values, are nearly identical. The maximum difference in downstream WSEL for scenarios with starting stages at Pensacola Dam within GRDA's anticipated operational range (742 to 745 feet PD) is 0.03 feet, and the maximum difference in WSEL for scenarios with starting stages that include extreme, hypothetical values is 0.05 feet. As such, the maximum downstream inundation extents shown in **Appendix E.6** are also nearly identical.

Of the flow events analyzed, the 100-year event is the only event to exceed the flowage easement for Lake Hudson. As shown in **Table F.6**, the flowage easement is only exceeded between approximately RM 69.7 and RM 73.3. At these locations, the maximum difference in duration of downstream inundation is 3 hours for scenarios with starting stages at Pensacola Dam within GRDA's anticipated operational range. The maximum difference in duration of downstream inundation is 22 hours for scenarios with starting stages at Pensacola Dam that include extreme, hypothetical values. Refer to Section 6 for a comparison between baseline and anticipated operations.

5.7 Comparison of Historical Starting Stages

As shown in **Table 8**, the peak outflows from Pensacola Dam vary significantly between all five events analyzed with a starting stage at Pensacola Dam equal to the historical pool elevation. As shown in **Table C.7** and **Figure D.7**, the variability in peak outflows from Pensacola Dam for the historical starting stage simulations results in large differences between the maximum WSELs throughout the DHM. The peak stages at Kerr Dam differ by a maximum of approximately 15 feet.

Because the peak releases from Pensacola Dam differ greatly between each of the flow events using a historical starting stage at Pensacola Dam, the differences in maximum WSELs also differ greatly throughout the DHM. As shown in **Table C.7**, the differences in maximum WSEL become more pronounced upstream of Big Cabin Creek confluence (RM 66.78) where the differences in maximum WSEL range from approximately 17 feet at the confluence to approximately 19 feet just downstream of Pensacola Dam. Because this portion of the DHM is more riverine and is upstream of the main body of Lake Hudson where peak stages at Kerr Dam have the greatest influence on maximum WSELs, the variations in the releases from Pensacola Dam between each of the events have an influence on the computed maximum WSELs.

As shown in **Appendix E.7**, when comparing the flow events with historical starting stage at Pensacola Dam, the differences in maximum WSEL throughout the DHM translate into differences in the maximum inundation extents. The differences in maximum inundation extents are most pronounced upstream of the Big Cabin Creek confluence, with the inundation extents for the September 1993 and December 2015 events being nearly identical. Downstream of the Big Cabin Creek confluence, the maximum inundation extents for the September 1993, October 2009, July 2007, and December 2015 events are all similar, with the June 2004 event resulting in a much smaller inundation extent compared to the other four events.

The flowage easement for Lake Hudson is not exceeded for any of the events simulated with historical starting stages at Pensacola. Therefore, as shown in **Table F.7**, the duration of downstream inundation at every location for all the events simulated with historical starting stages at Pensacola Dam is zero (0).

6. Anticipated Operations Analysis

As proposed in Section 2.6.5 of the H&H Study RSP, "an additional suite of model runs following the same parameters" was run for the operational scenario anticipated by GRDA for Pensacola Dam. As discussed in Section 1.6.2 of GRDA's December 29, 2021 filing with FERC, GRDA anticipates the following operational parameters will apply for Pensacola Dam during the new license term:

1. GRDA will no longer utilize a rule curve with seasonal target elevations.
2. GRDA will maintain the reservoir between elevations 742 and 745 feet PD for purposes of normal hydropower operations. While hydropower operations may occur when the water surface elevations are outside this range (e.g. maintenance drawdowns and high-flow events), GRDA expects to generally maintain water surface elevations between 742 and 745 feet PD during normal Project operations.
3. Instead of managing the Project to target a specified seasonal elevation, GRDA's anticipated operations may fluctuate reservoir levels within the elevational range of 742 and 745 feet PD, for purposes of responding to grid demands, market conditions, and the public interest, such as environmental and recreational considerations.
4. GRDA will continue to adhere to the USACE's direction on flood control operations in accordance with the Water Control Manual.

This operational scenario is henceforth referred to as "anticipated operations". To characterize the impact of anticipated operations on the range of flow events and Pensacola Dam starting pool elevations studied, the following scenarios were simulated:

1. June 2004 (1 year) inflow event, starting pool elevation of 734.0 feet PD,
2. June 2004 (1 year) inflow event, starting pool elevation of 757.0 feet PD,
3. July 2007 (4 year) inflow event, using the OM period of record starting pool elevation,
4. 100-year inflow event, starting pool elevation of 734.0 feet PD, and
5. 100-year inflow event, starting pool elevation of 757.0 feet PD.

These 5 scenarios were simulated with (1) baseline operations and (2) anticipated operations for a total of 10 simulations. The suite of simulations represents:

1. The minimum and maximum starting pool elevations requested by FERC,
2. The smallest and largest inflow events requested by FERC, and
3. An event of historical importance to communities upstream of Pensacola Dam that is within the studied range of starting pool elevations and within the studied range of inflow magnitudes. The starting pool elevation at Pensacola Dam for this event was not arbitrary, but came out of the operational simulations, making it the most integrous comparison of the effects of anticipated operations versus baseline operations on maximum WSEL in this study.

Results from the analysis are presented in **Appendix G**. The input hydrographs to the DHM for this suite of simulations is included in **Appendix G.1**. Tabulated results of maximum downstream WSEL are included in **Appendix G.2**. Plots of maximum downstream WSEL profiles are included in **Appendix G.3**. Tabulated results of downstream inundation duration are presented in **Appendix G.4**.

Table 13 presents a summary of maximum increases in peak WSEL in the DHM for anticipated operations as compared to baseline operations. The following findings can be concluded from these results:

1. For the June 2004 (1 year) event, there are increases in peak downstream WSEL for a starting stage at Pensacola Dam of 734 feet PD. The increases occur through the upstream portion of the DHM (upstream of RM 69), with the largest increase being 0.53 feet. These increases are due to slight variations in the pattern of powerhouse releases at Pensacola Dam for the anticipated operations, but flows are contained within the riverbanks. No spillway releases from Pensacola Dam occur for this scenario.
2. For the June 2004 (1 year) flow event, there are no increases in peak downstream WSEL for a starting stage at Pensacola Dam of 757 feet PD.
3. For the July 2007 (4 year) flow event, there are no increases in peak downstream WSEL for the OM period of record starting stages at Pensacola Dam.
4. For the 100-year event, the maximum increase in peak downstream WSEL for a starting stage at Pensacola Dam of 734 feet PD is 0.01 feet.
5. For the 100-year inflow event, there are no increases in peak downstream WSEL for a starting stage at Pensacola Dam of 757 feet PD.

TABLE 13. SUMMARY OF INCREASES IN DOWNSTREAM WSEL DUE TO ANTICIPATED OPERATIONS AS COMPARED TO BASELINE OPERATIONS.

Simulation	Maximum Increase in Peak WSEL Due to Anticipated Operations (ft)
June 2004 (1 year) event, starting pool elevation of 734.0 feet PD	0.53*
June 2004 (1 year) event, starting pool elevation of 757.0 feet PD	0.00
July 2007 (4 year) event, period of record starting pool elevation	0.00
100-year event, starting pool elevation of 734.0 feet PD	0.01
100-year event, starting pool elevation of 757.0 feet PD	0.00

**Flows contained within riverbanks, no spillway releases from Pensacola Dam.*

The results show that anticipated operations have an immaterial impact on downstream WSELs as compared to baseline operations.

Plots of maximum downstream WSEL profiles from the analysis of anticipated operations are included in **Appendix G.3**. For the June 2004 (1 year) event and the 100-year event, the plots show peak water surface elevation profiles for the simulations with starting stages at Pensacola Dam of 734 and 757 feet PD (the minimum and maximum starting stages requested by FERC) for both baseline and anticipated operations. The dotted lines plot the increase in WSEL due to anticipated operations as compared to baseline operations and are plotted on the secondary y-axis. In some cases, the dotted line is not visible because the increase in peak WSEL due to anticipated operations is zero. Similarly, a plot is also included in **Appendix G.3** to show the maximum downstream WSEL profiles for baseline and anticipated operations for the July 2007 (4 year) event. The plots show how anticipated operations have an immaterial impact on downstream WSELs as compared to baseline operations for a suite of simulations that spans the FERC-requested range of starting pool elevations at Pensacola Dam and flow event magnitudes.

As shown in **Appendix G.4**, the maximum difference in duration of downstream inundation is 1 hour when comparing baseline operations to anticipated operations. This difference only occurs for the 100-year event as it is the only flow event to exceed the flowage easements.

Inundation maps are presented in **Appendix E**. Based on the maximum downstream WSELs, no additional inundation maps were created for this suite of analyses. While the results do show an increase in Max WSEL of up to 0.53 feet for the June 2004 (1 year) event with a starting stage of 734 feet PD, the increase is contained within the river channel and therefore the difference would not effectively be displayed on an inundation map. For the other scenarios, the maximum difference in WSEL is 0.01 feet and also cannot be effectively displayed on an inundation map. Therefore, for the purposes of this study, the extent of downstream inundation for anticipated operations is virtually identical to the extent of downstream inundation for baseline operations.

7. Conclusions

The results of the DHM demonstrate that initial stages at the Project within GRDA's anticipated and extreme, hypothetical operational ranges have an influence on downstream WSELs and out-of-bank inundation. As the analysis shows, downstream WSELs, stages at Kerr Dam, and inundation extents are dependent on the magnitude and volume of releases from the Project, which in turn are dependent on initial stage at the Project. Out-of-bank inundation downstream of the Project is the result of spillway releases which are directed by the USACE. Under authority of Section 7 of the 1944 Flood Control Act, the Tulsa District of the USACE is responsible for prescribing and directing the flood control operations of the Project. The USACE is also responsible for directing spillway releases in accordance with the procedures for system balancing of flood storage outlined in the Arkansas River Basin Water Control Master Manual (USACE, 1980). This authority is reinforced by Section 7612 (c) of the NDAA of Fiscal Year 2020 which states that "The Secretary [of the Army] shall have exclusive jurisdiction and responsibility for management of the flood pool for flood control operations at Grand Lake O' the Cherokees" (116th Congress, 2019).

However, comparing anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes, the results of the DHM demonstrate that anticipated operations have an immaterial impact as compared to baseline operations.

8. References

116th Congress. (2019). *S. 1790 National Defense Authorization Act for Fiscal Year 2020.* Public Law No. 116-92.

Bolivar, e. a. (2010). *Profile Likelihood Intervals for Quantiles in Extreme Value Distributions.* Guanajuato: Centro de Investifacion en Matematicas.

Hunter, S. L., Trevisan, A. R., Villa, J., & Smith, K. A. (2020). *Bathymetric Map, Surface Area, and Capacity of Grand Lake O' the Cherokees, Northeastern Oklahoma, 2019.* Denver: USGS.

Mead & Hunt. (2021). *H&H Modeling: Downstream Hydraulic Model Input Status Report.*

Oklahoma Water Resources Board. (2008). *Hydrographic Survey of Lake Hudson.*

Takara, K. (2009). *Frequency Analysis of Hydrological Extreme Events and How to Consider Climate Change.* Kyoto: Disaster Prevention Research Institute, Kyoto University.

USACE. (1980). *Arkansas River Basin Water Control Master Manual.* Tulsa and Little Rock Districts.

USACE. (1992). *Markham Ferry Reservoir Water Control Manual.* Tulsa District.

USACE. (2016). *HEC-RAS River Analysis System Hydraulic Reference Manual.* Davis: Hydrologic Engineering Center.

USGS. (2017a, January 20). *National Geospatial Program.* Retrieved from The National Map Viewer: https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map

USGS. (2017b, April 13). *USGS 07191000 Big Cabin Creek near Big Cabin, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/usa/nwis/uv?07191000

USGS. (2017c, April 14). *USGS 07190500 Neosho River near Langley, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/ok/nwis/uv?site_no=07190500

USGS. (2017d, april 17). *USGS 07191288 Spavinaw Creek near Eucha, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/usa/nwis/uv?07191288

USGS. (2017e, April 13). *USGS 07191300 Spavinaw Lake at Spavinaw, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/usa/nwis/uv?07191300

APPENDIX A:
SIMULATED HYDROGRAPHS

APPENDIX A.1:
SEPTEMBER 1993 (21 YEAR) EVENT SIMULATED HYDROGRAPHS

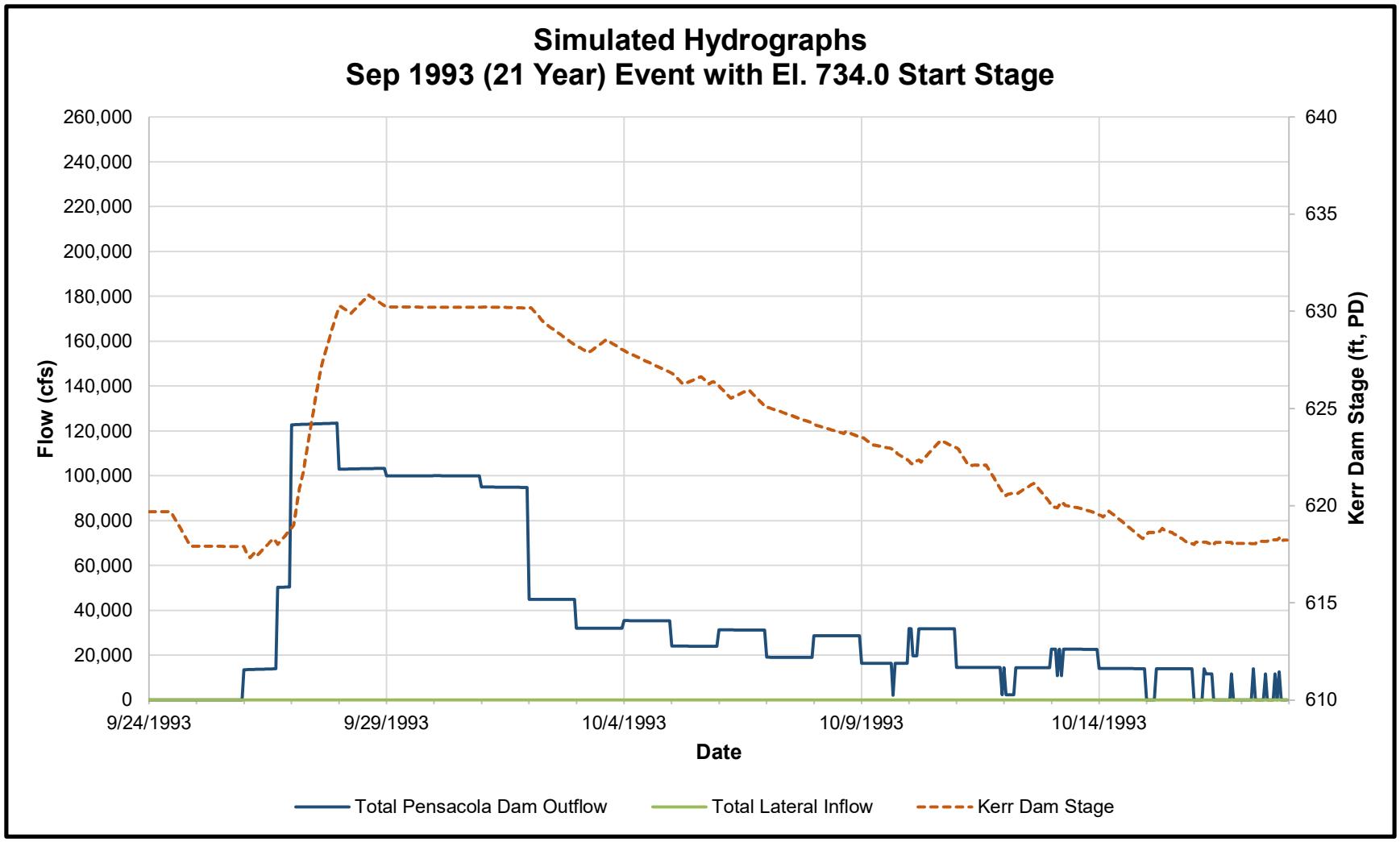


Figure A.1. Simulated hydrograph for the September 1993 (21 year) event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

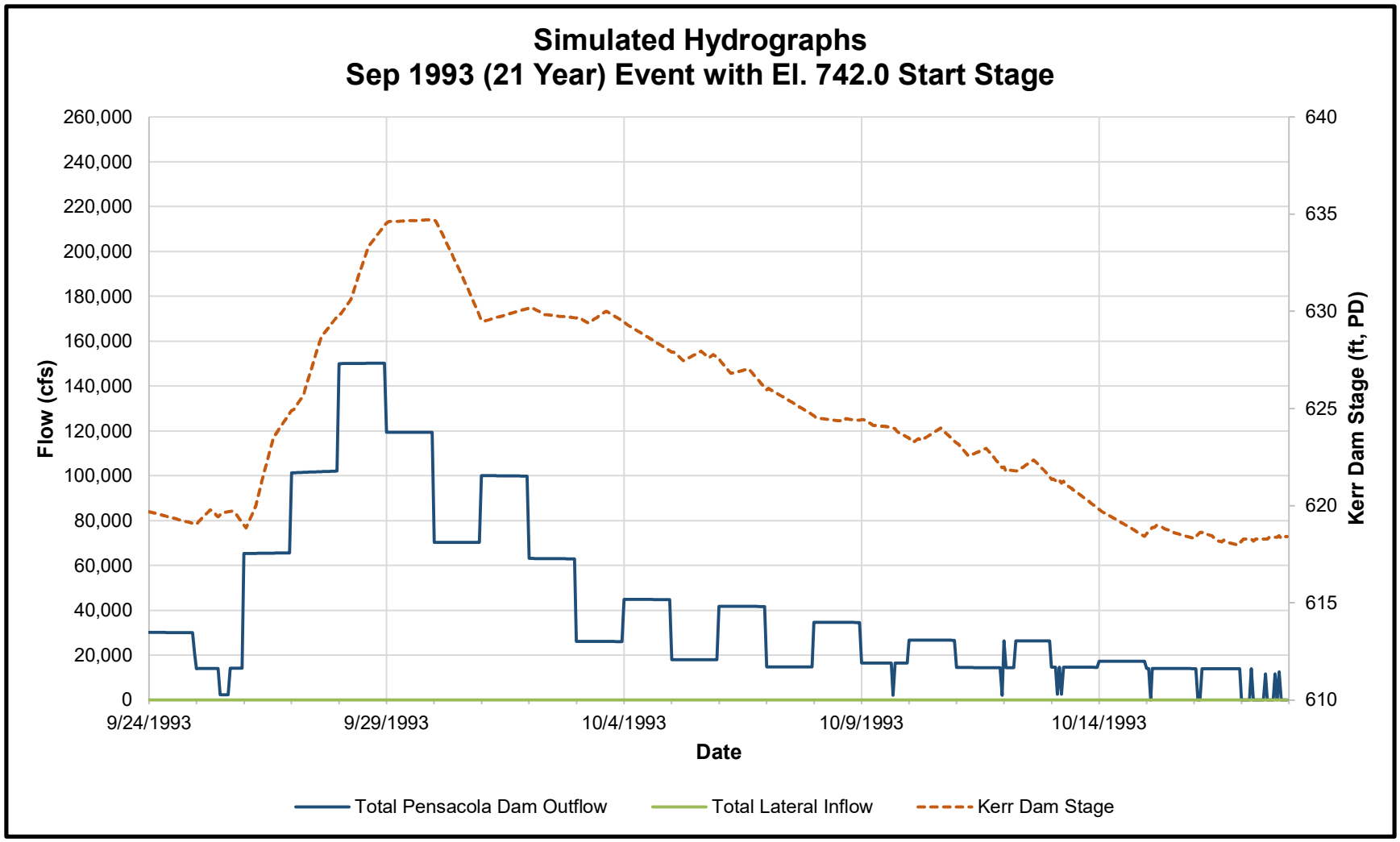


Figure A.2. Simulated hydrograph for the September 1993 (21 year) event with El. 742.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

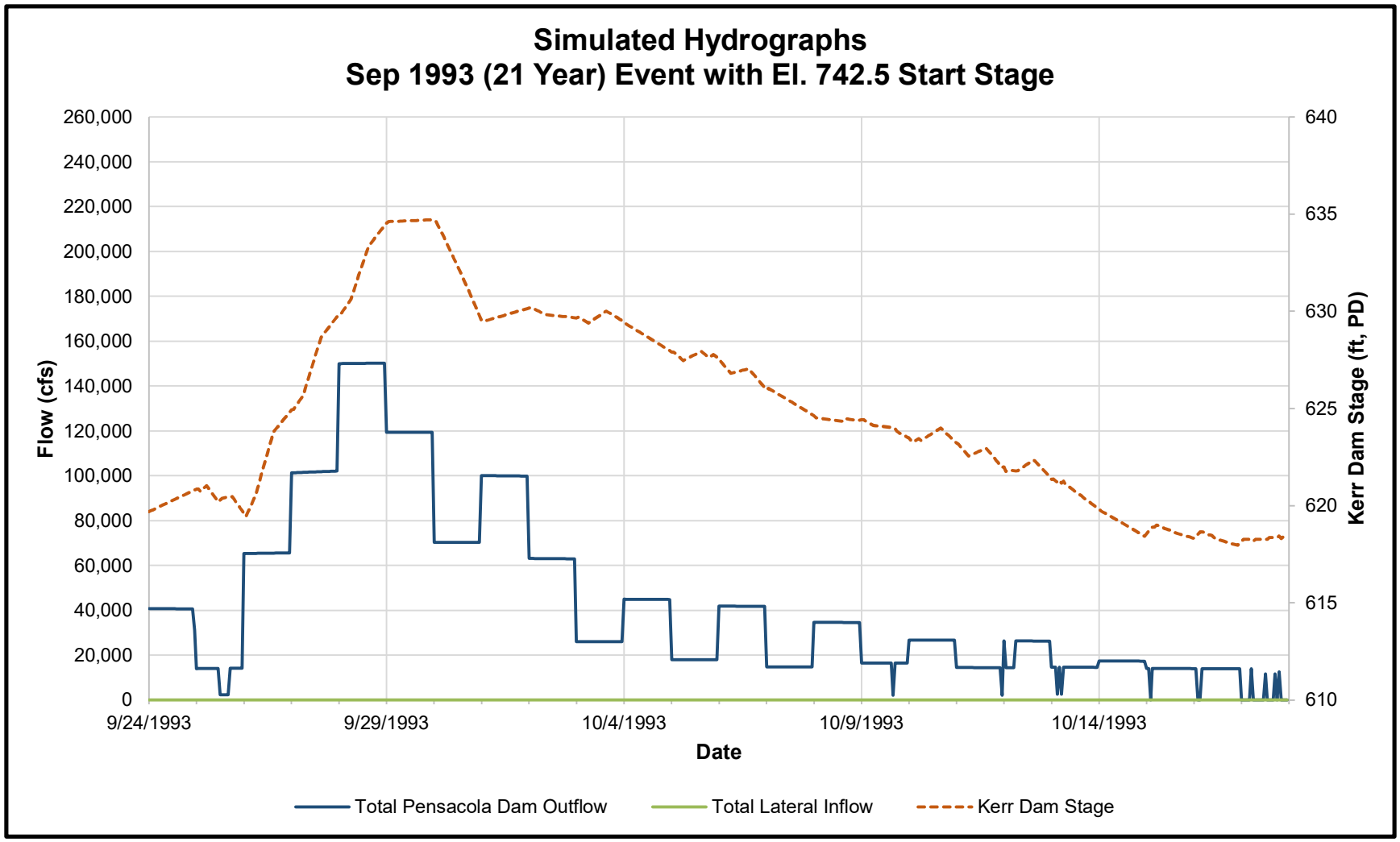


Figure A.3. Simulated hydrograph for the September 1993 (21 year) event with El. 742.5 starting stage at Pensacola Dam.

Notes:
1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

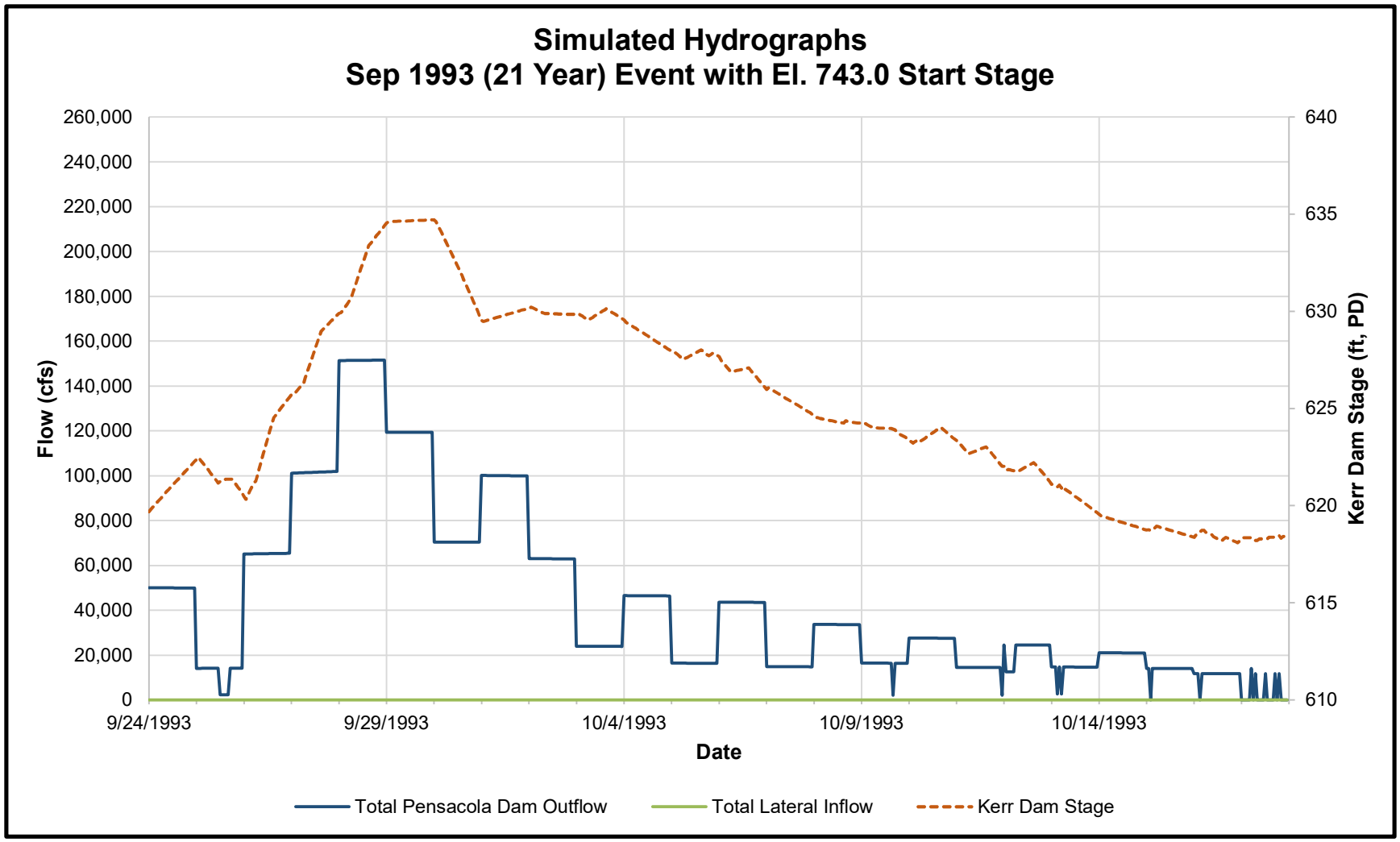


Figure A.4. Simulated hydrograph for the September 1993 (21 year) event with El. 743.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

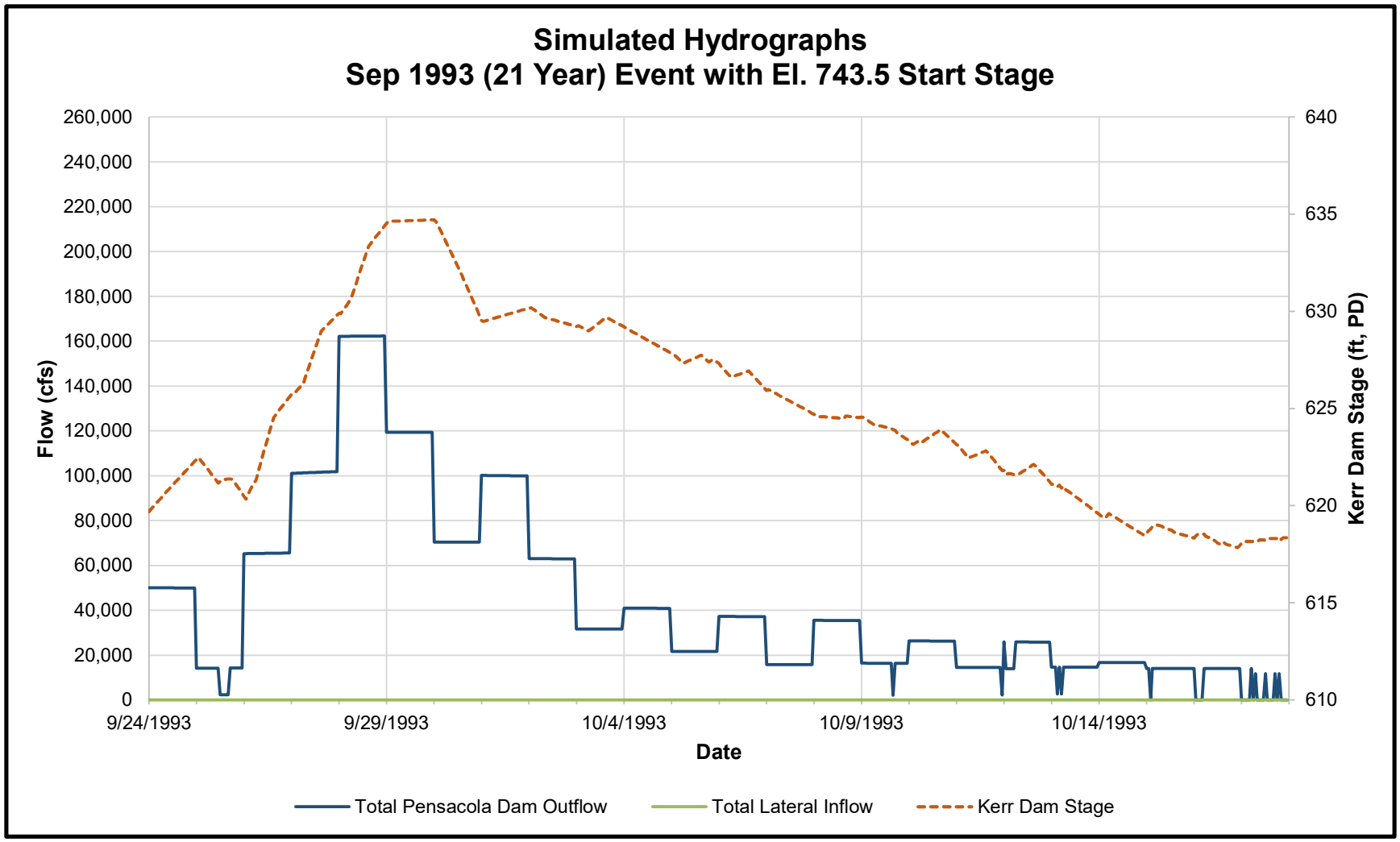


Figure A.5. Simulated hydrograph for the September 1993 (21 year) event with El. 743.5 starting stage at Pensacola Dam.

Notes:
1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

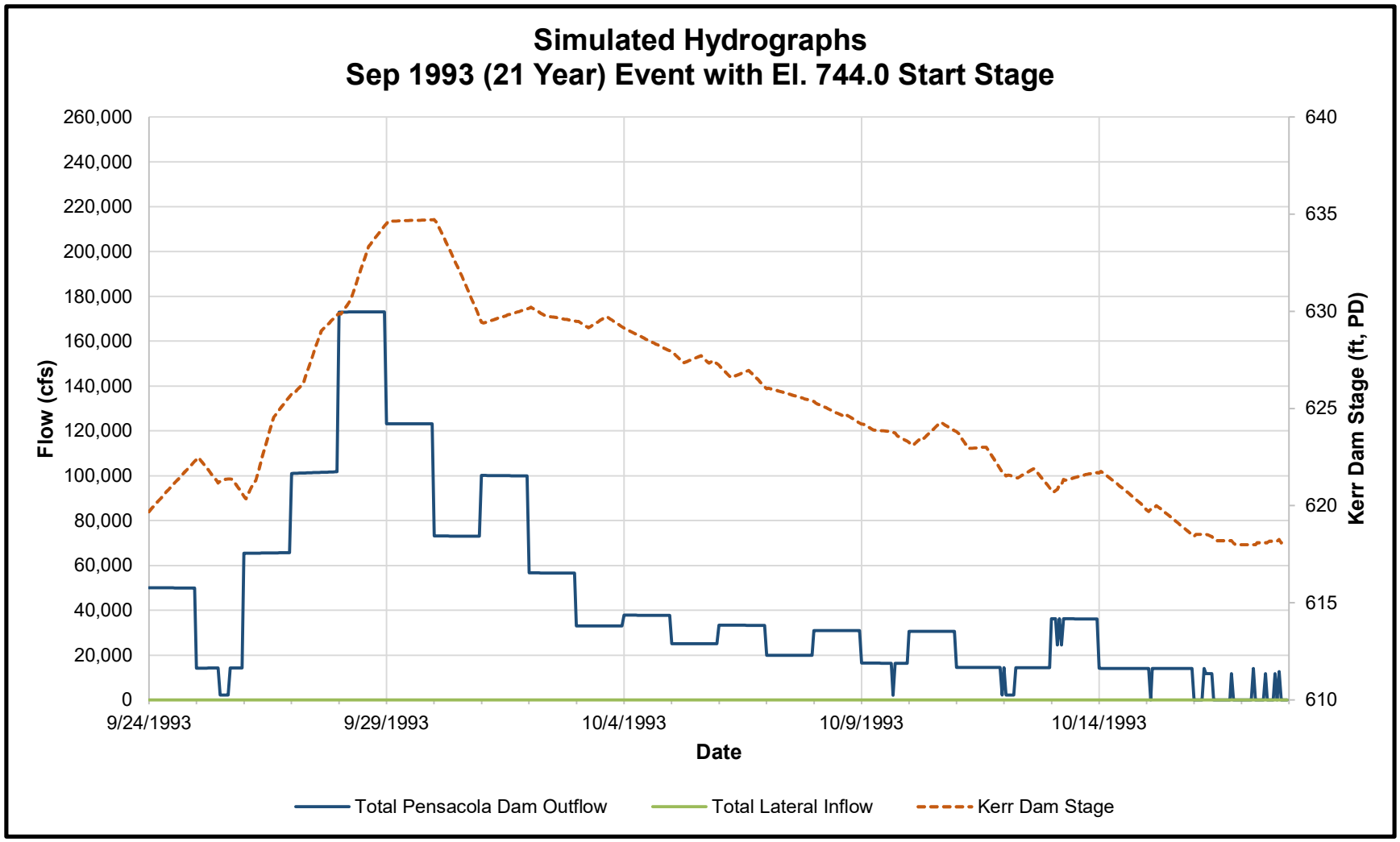


Figure A.6. Simulated hydrograph for the September 1993 (21 year) event with El. 744.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

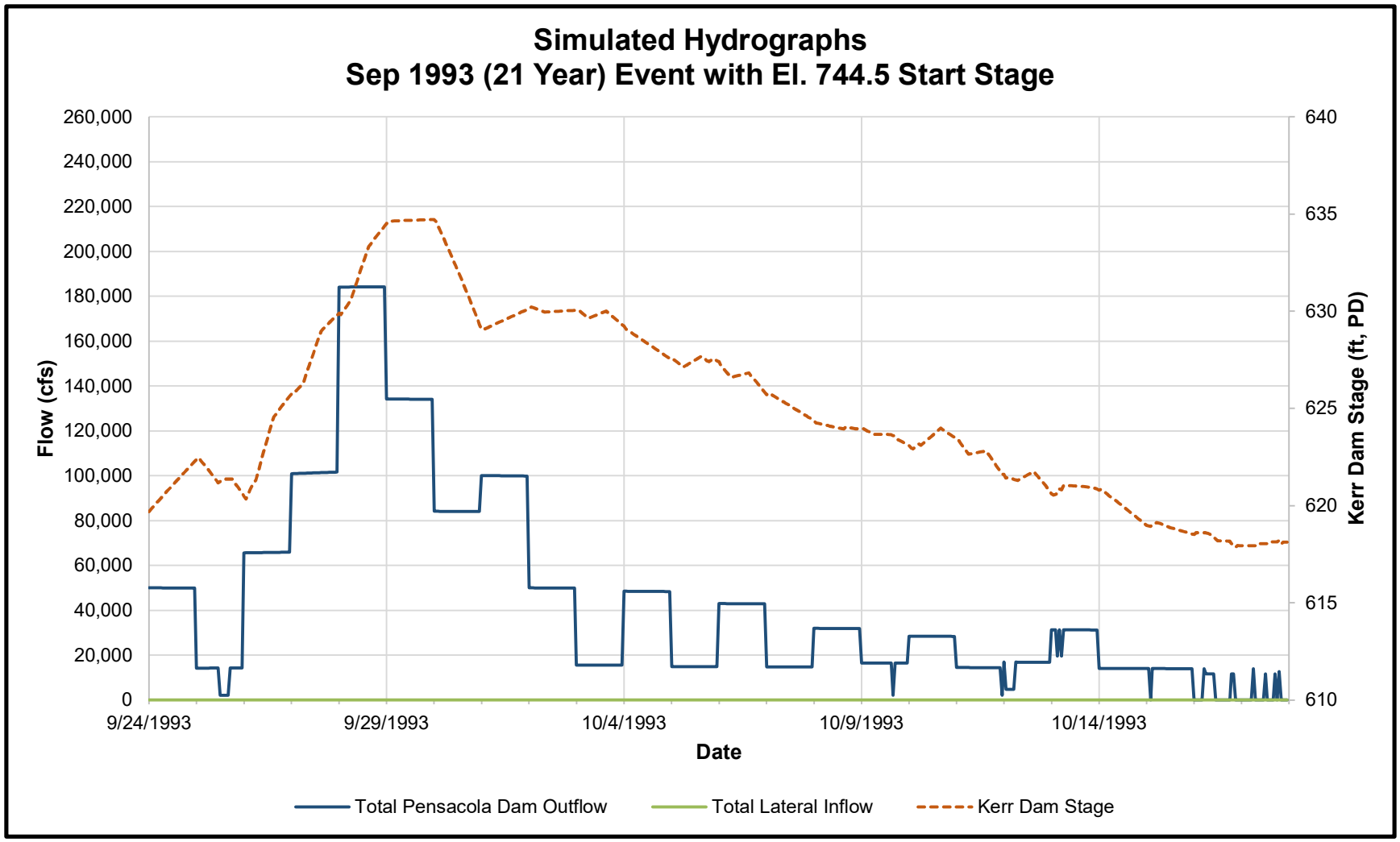


Figure A.7. Simulated hydrograph for the September 1993 (21 year) event with El. 744.5 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

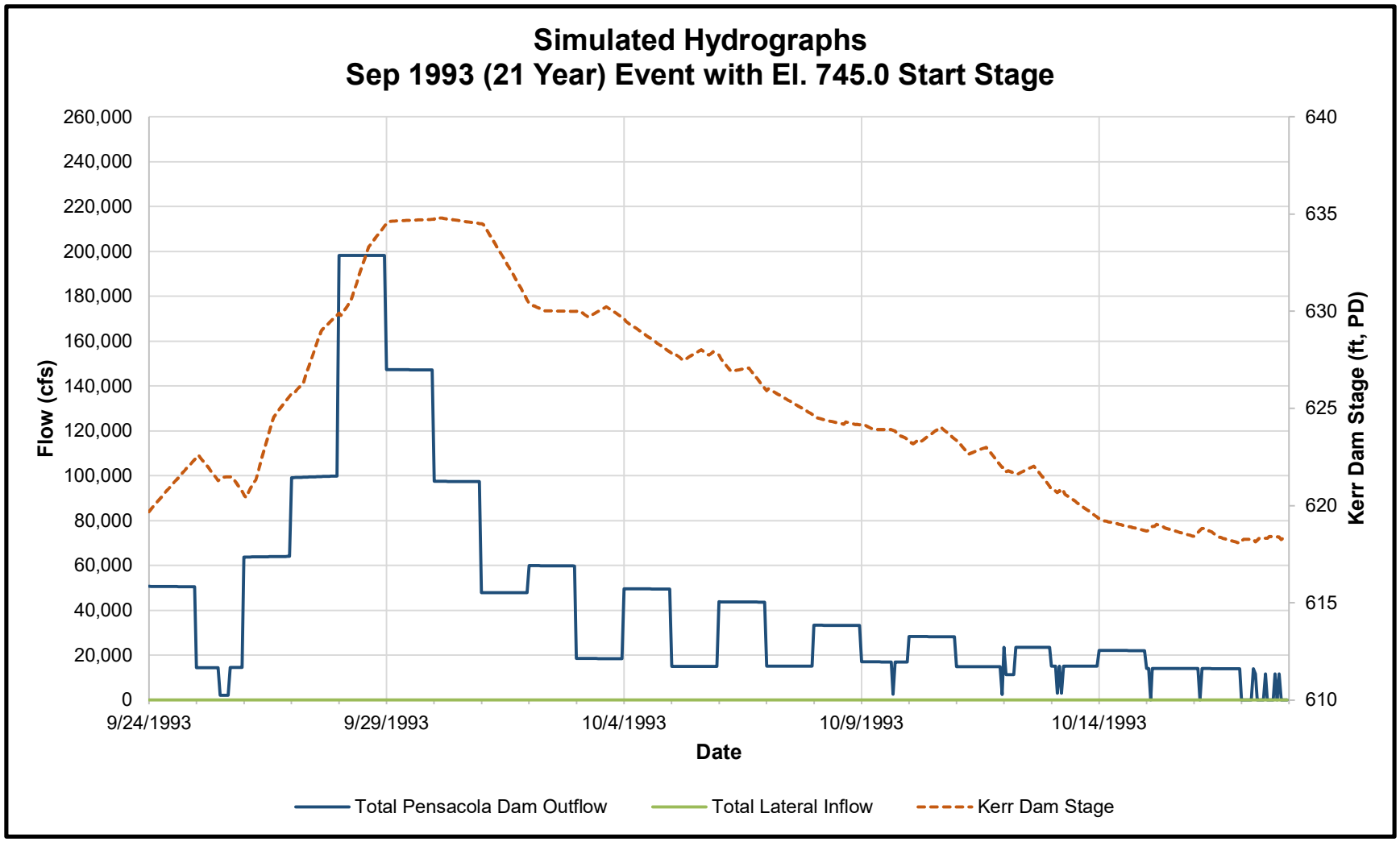


Figure A.8. Simulated hydrograph for the September 1993 (21 year) event with El. 745.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

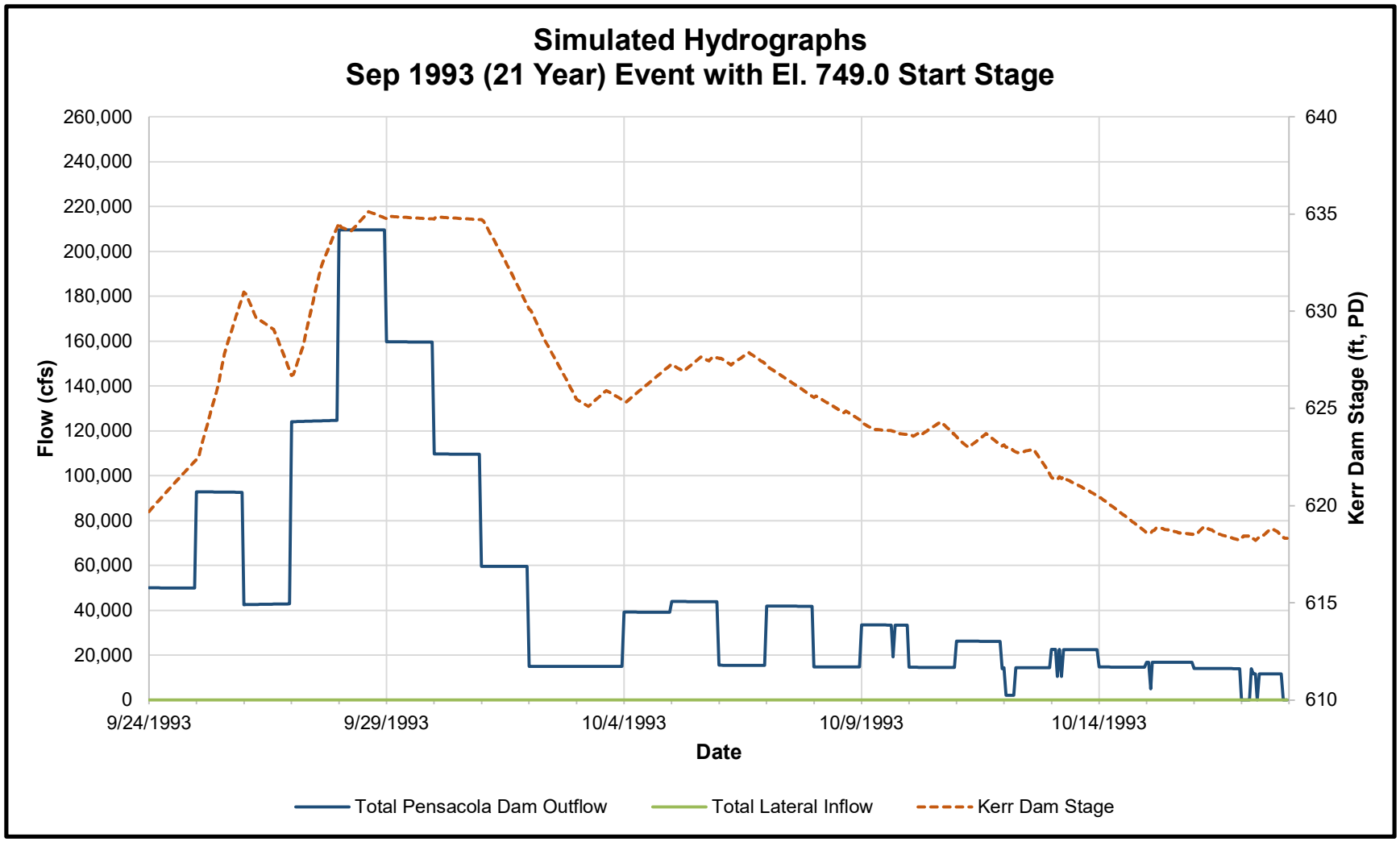


Figure A.9. Simulated hydrograph for the September 1993 (21 year) event with El. 749.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

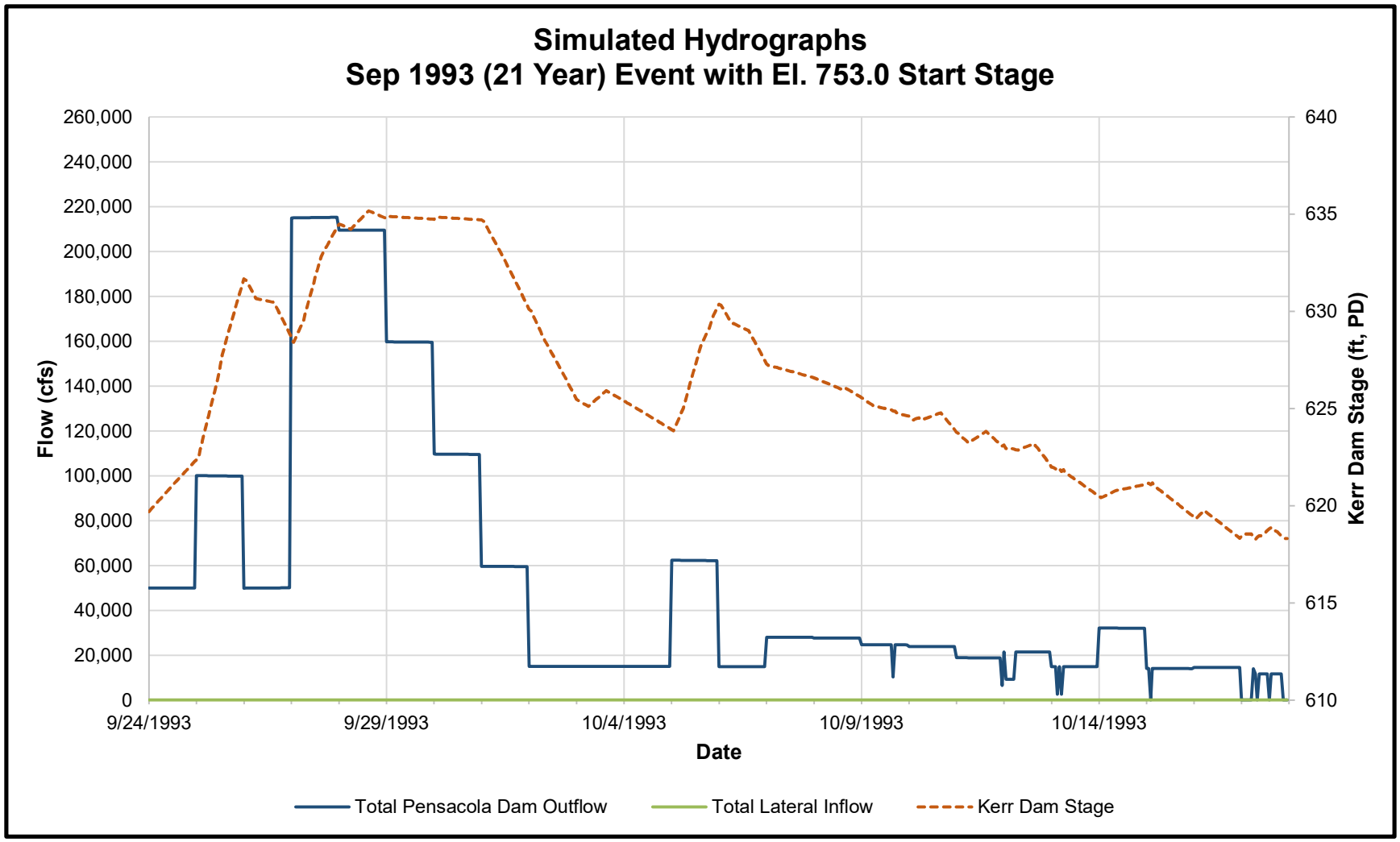


Figure A.10. Simulated hydrograph for the September 1993 (21 year) event with El. 753.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

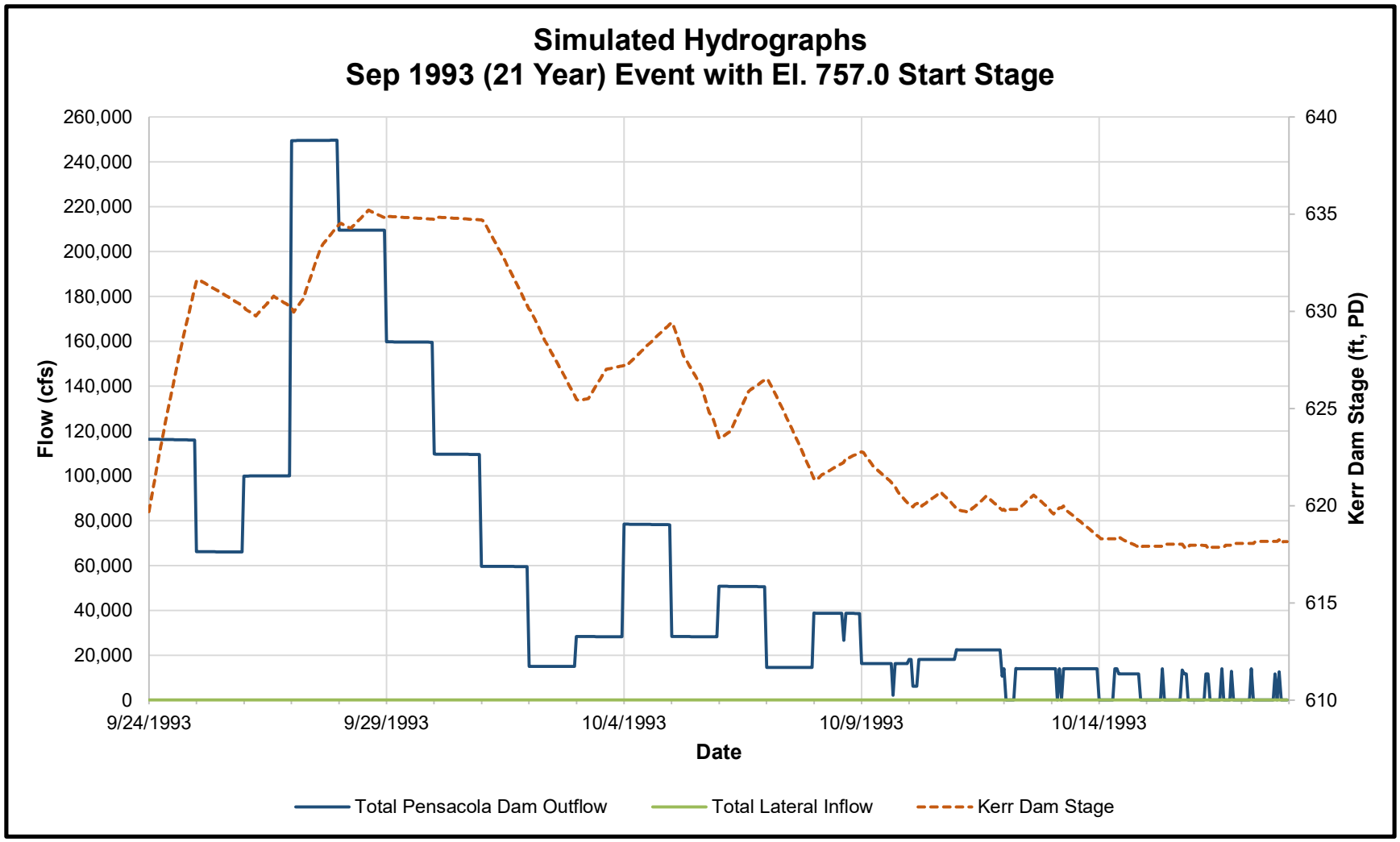


Figure A.11. Simulated hydrograph for the September 1993 (21 year) event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

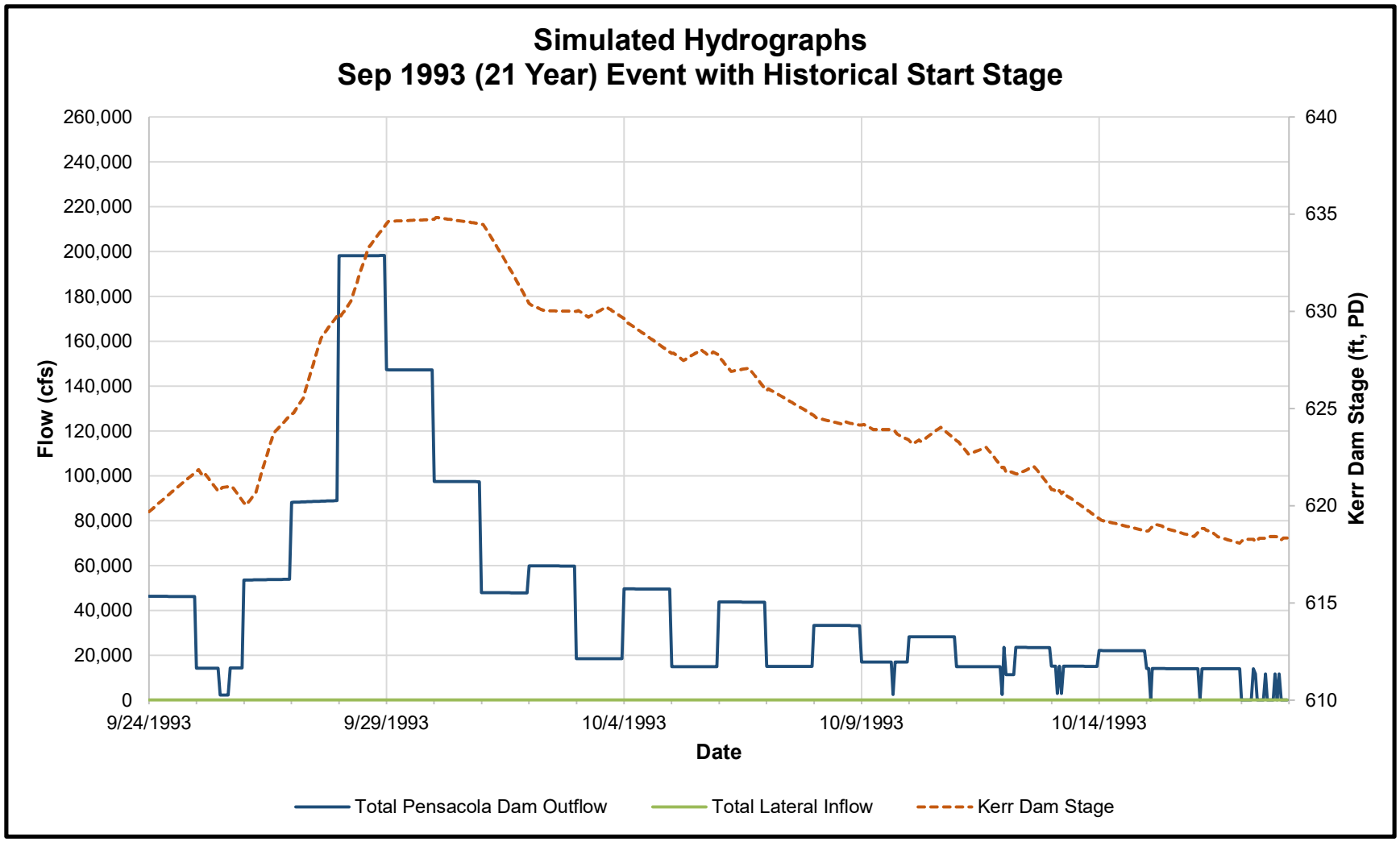


Figure A.12. Simulated hydrograph for the September 1993 (21 year) event with historical starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*
3. *Total Lateral Inflow is 0 cfs throughout the duration of the September 1993 (21 year) event.*

APPENDIX A.2:
JUNE 2004 (1 YEAR) EVENT SIMULATED HYDROGRAPHS

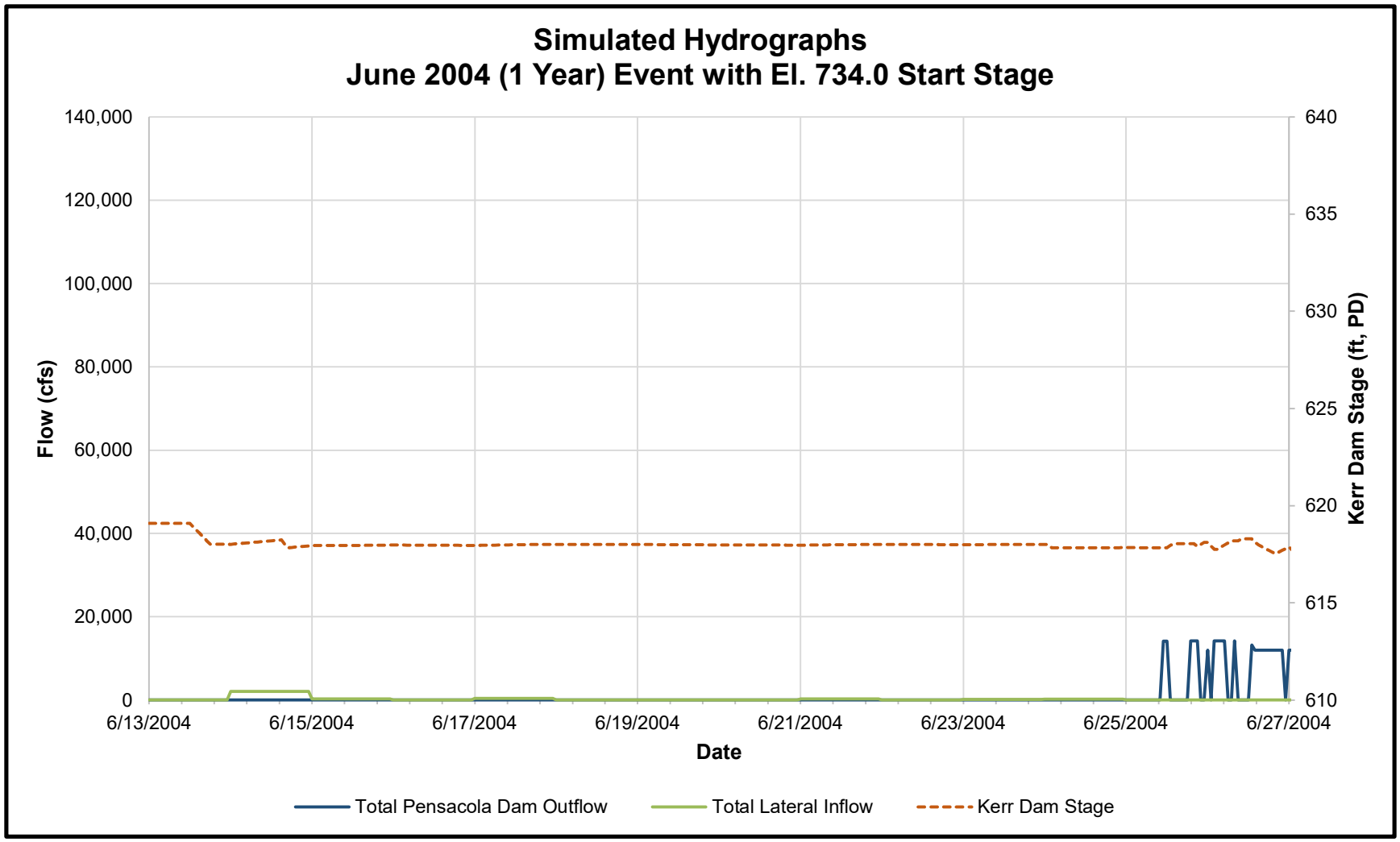


Figure A.13. Simulated hydrograph for the June 2004 (1 year) event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

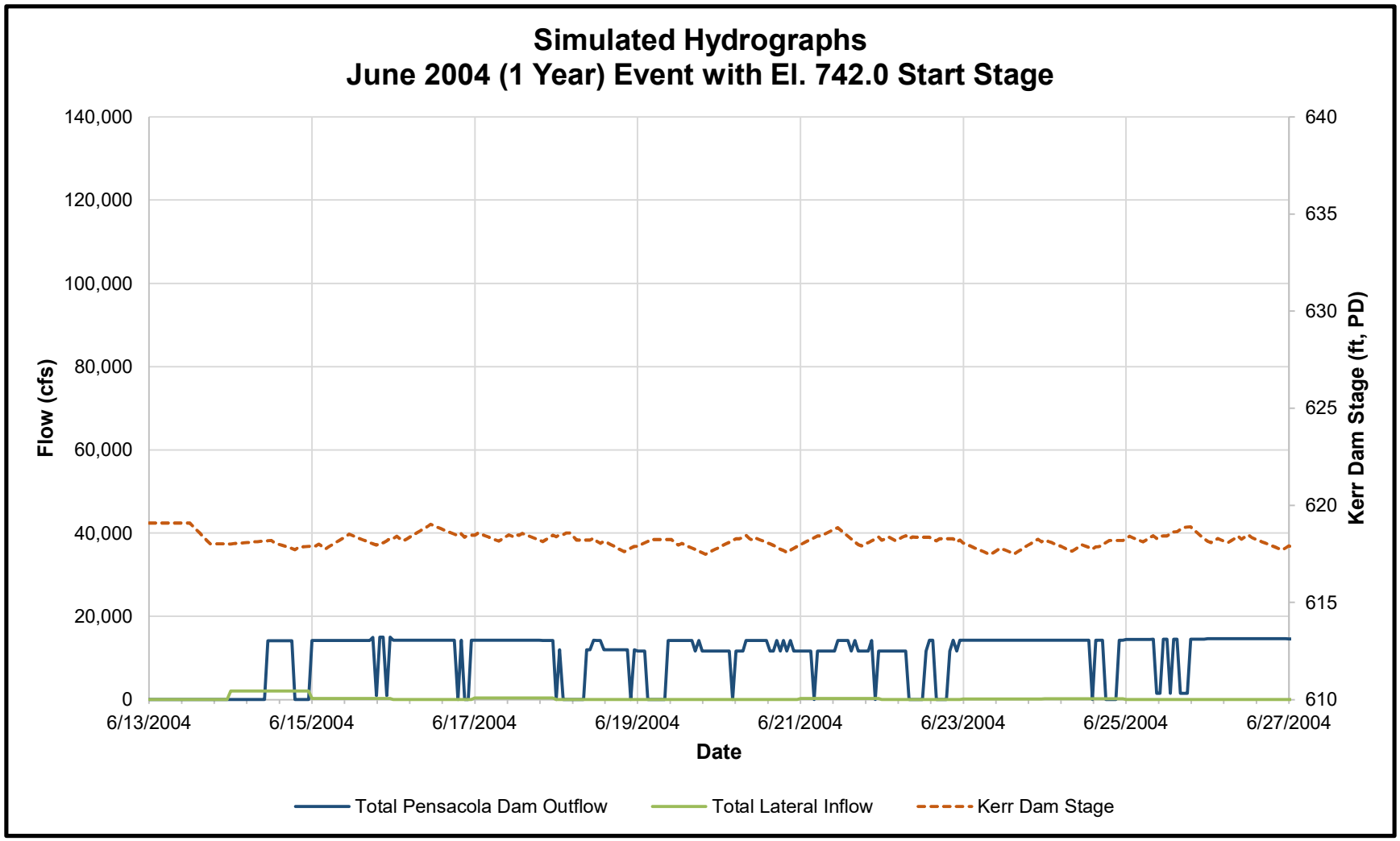


Figure A.14. Simulated hydrograph for the June 2004 (1 year) event with El. 742.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

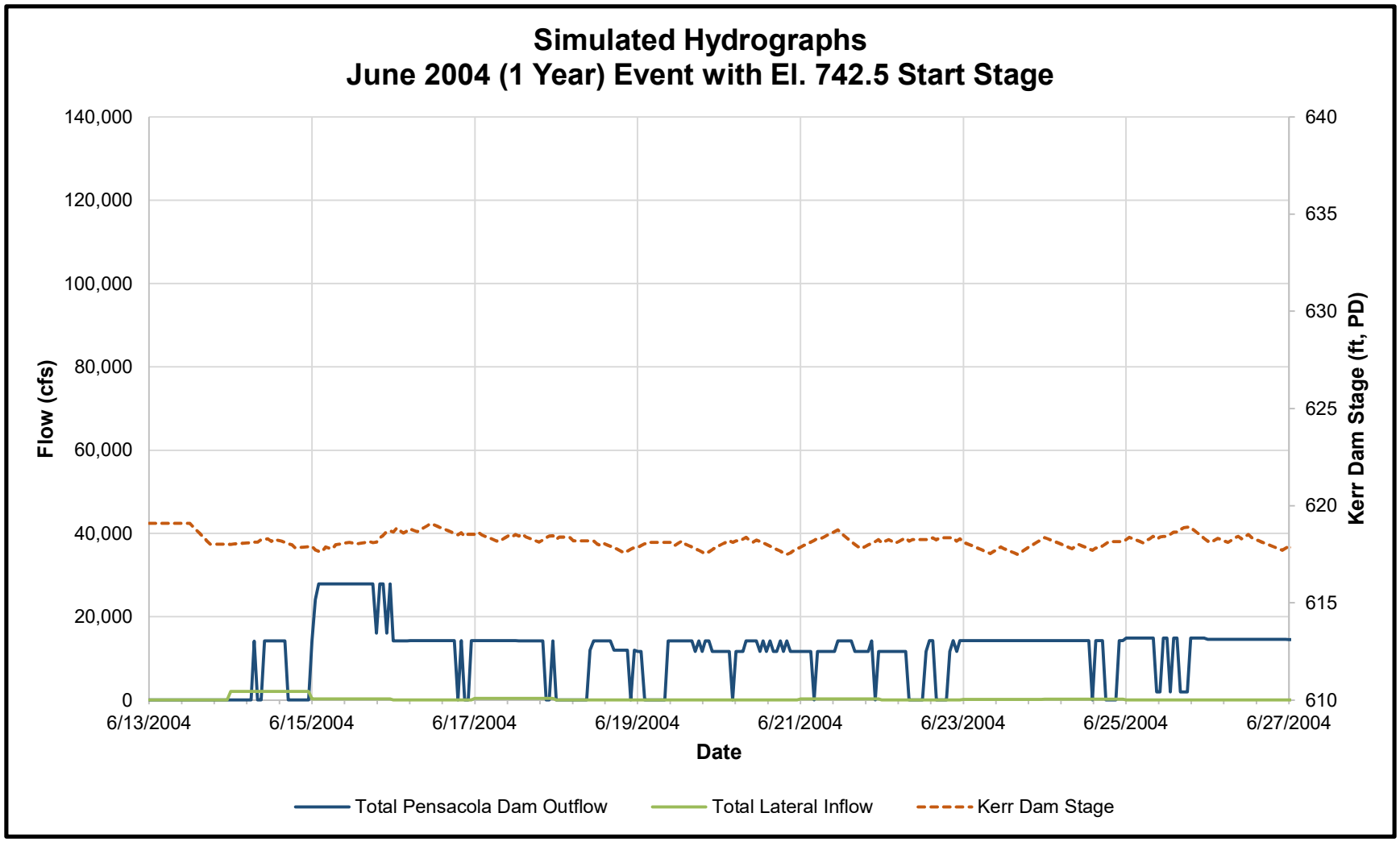


Figure A.15. Simulated hydrograph for the June 2004 (1 year) event with El. 742.5 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

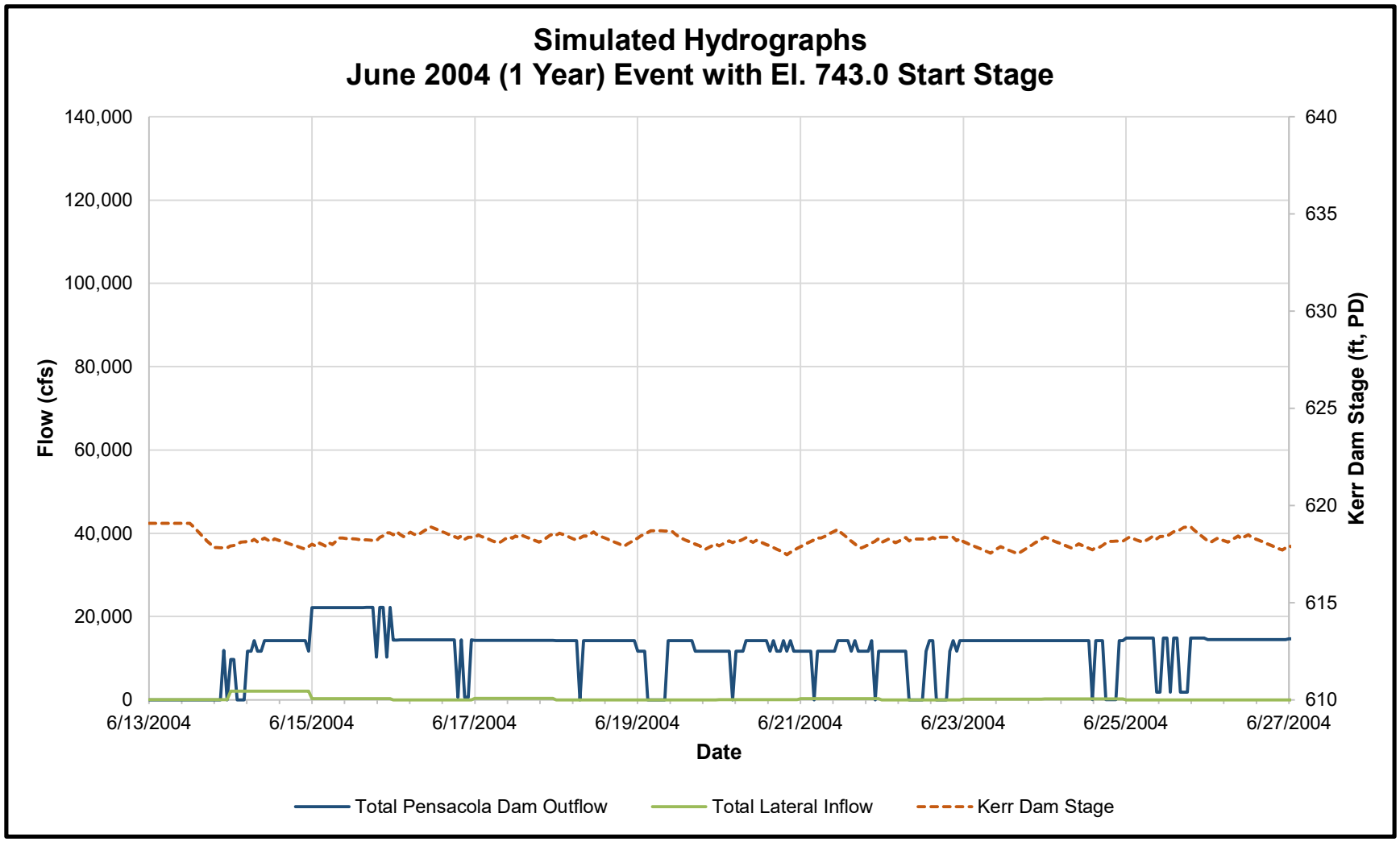


Figure A.16. Simulated hydrograph for the June 2004 (1 year) event with El. 743.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

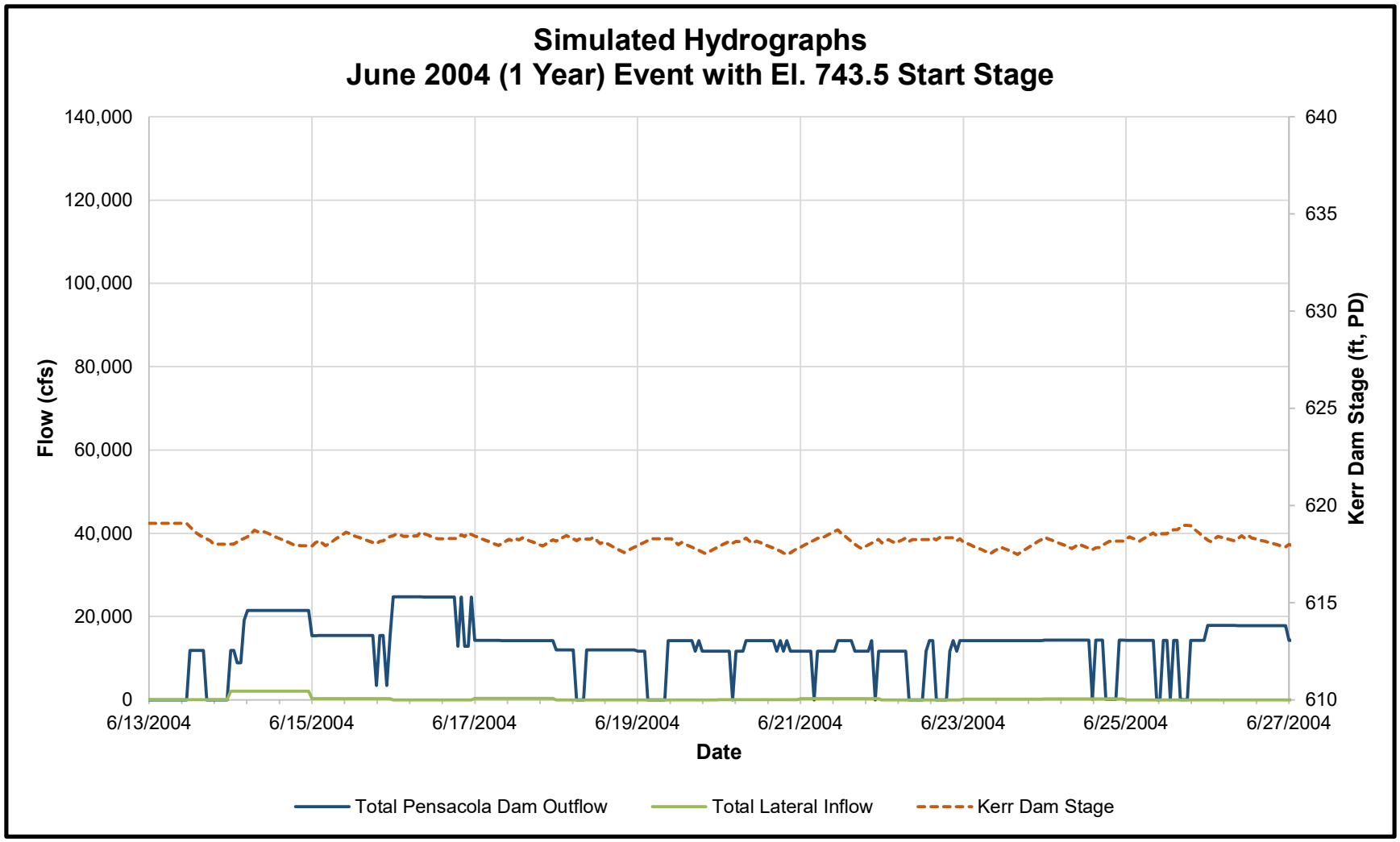


Figure A.17. Simulated hydrograph for the June 2004 (1 year) event with El. 743.5 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

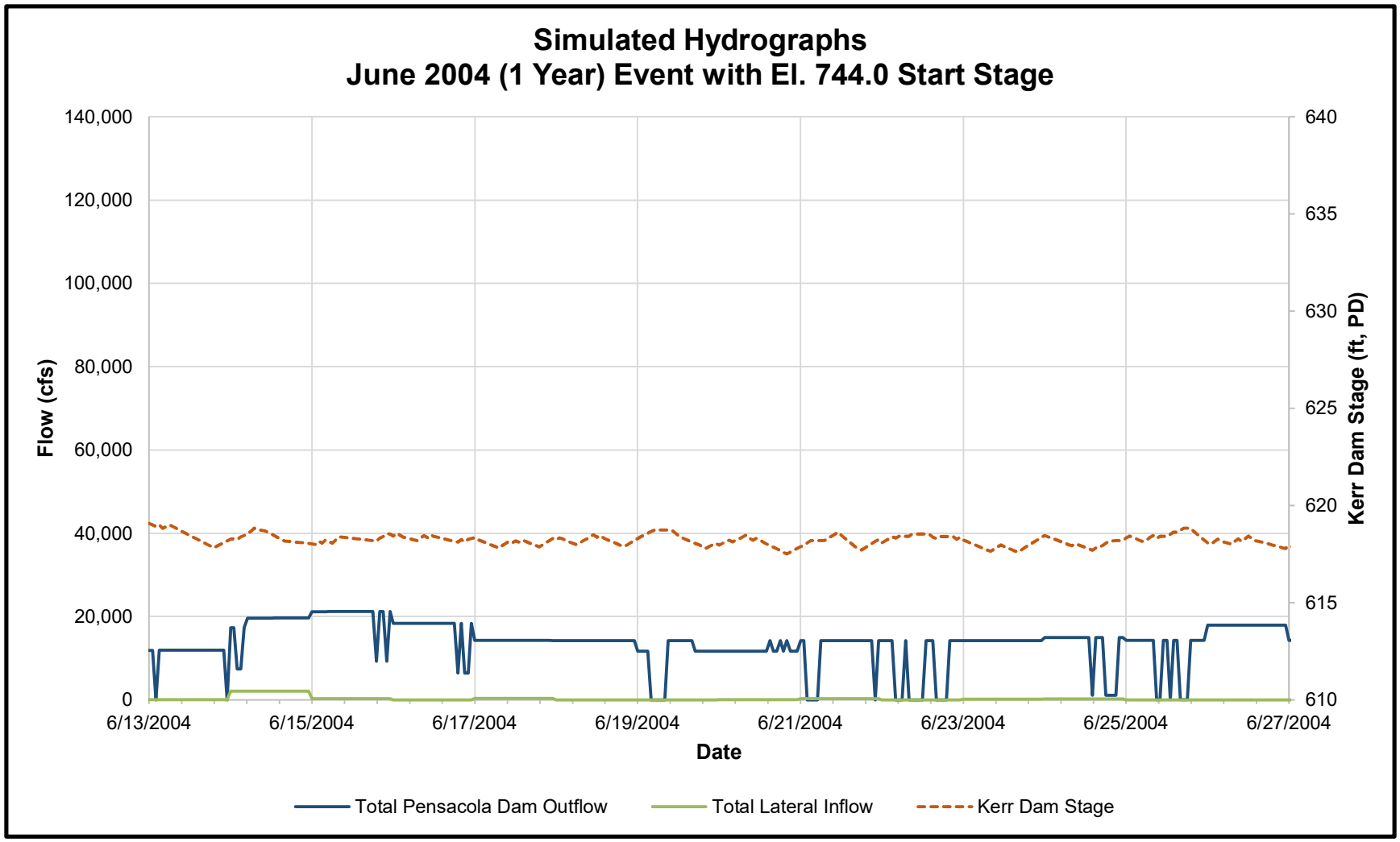


Figure A.18. Simulated hydrograph for the June 2004 (1 year) event with El. 744.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

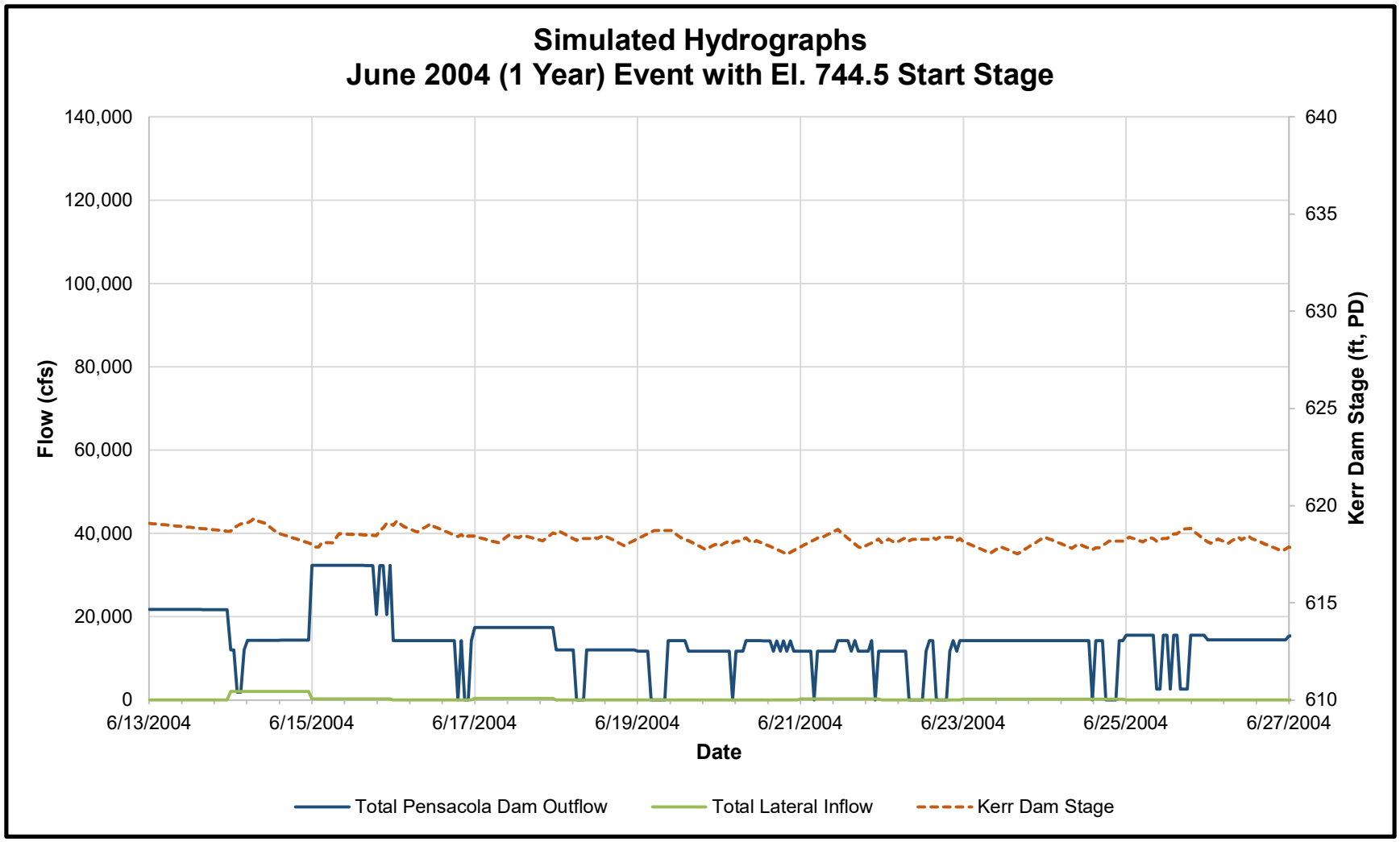


Figure A.19. Simulated hydrograph for the June 2004 (1 year) event with El. 744.5 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

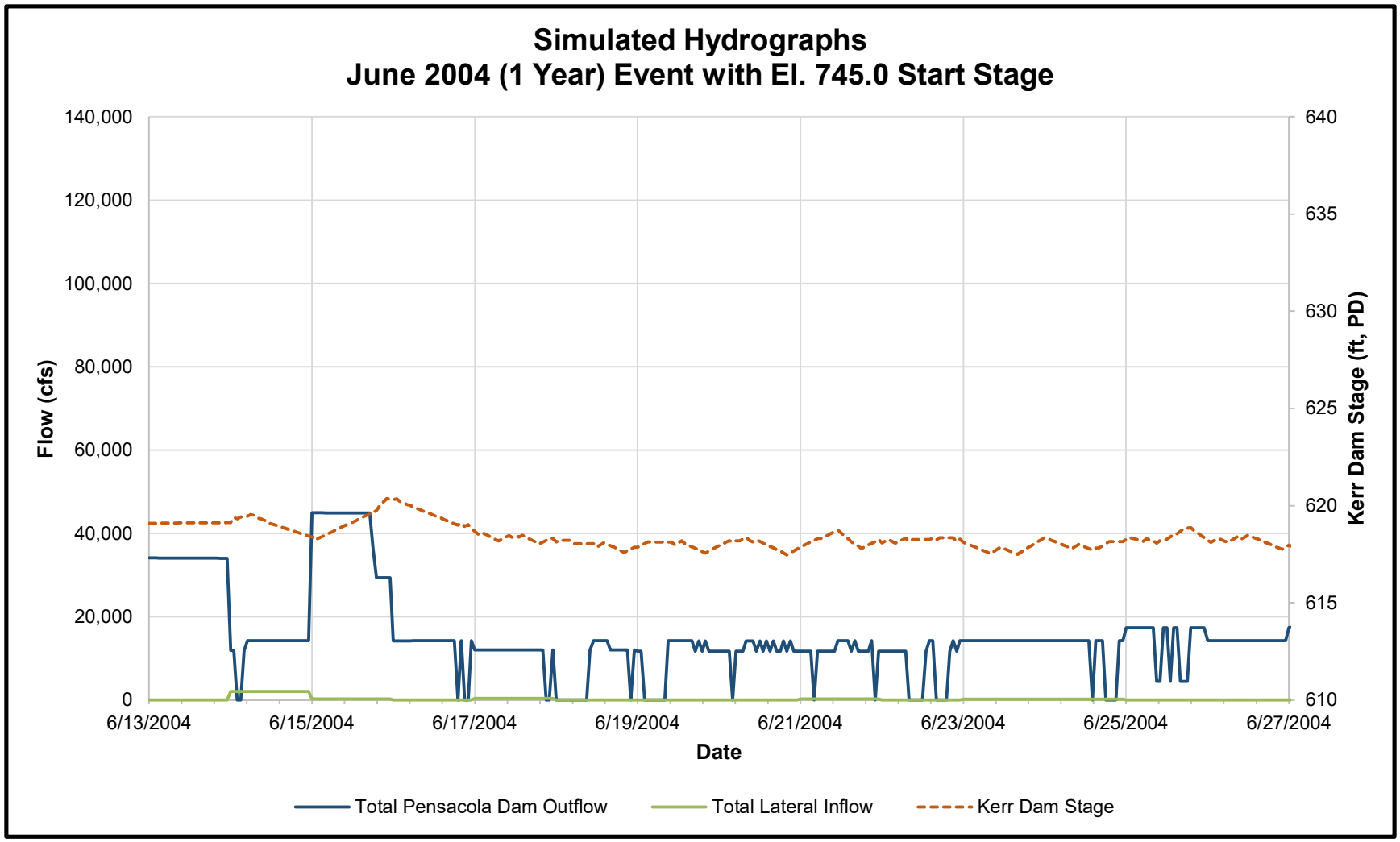


Figure A.20. Simulated hydrograph for the June 2004 (1 year) event with El. 745.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

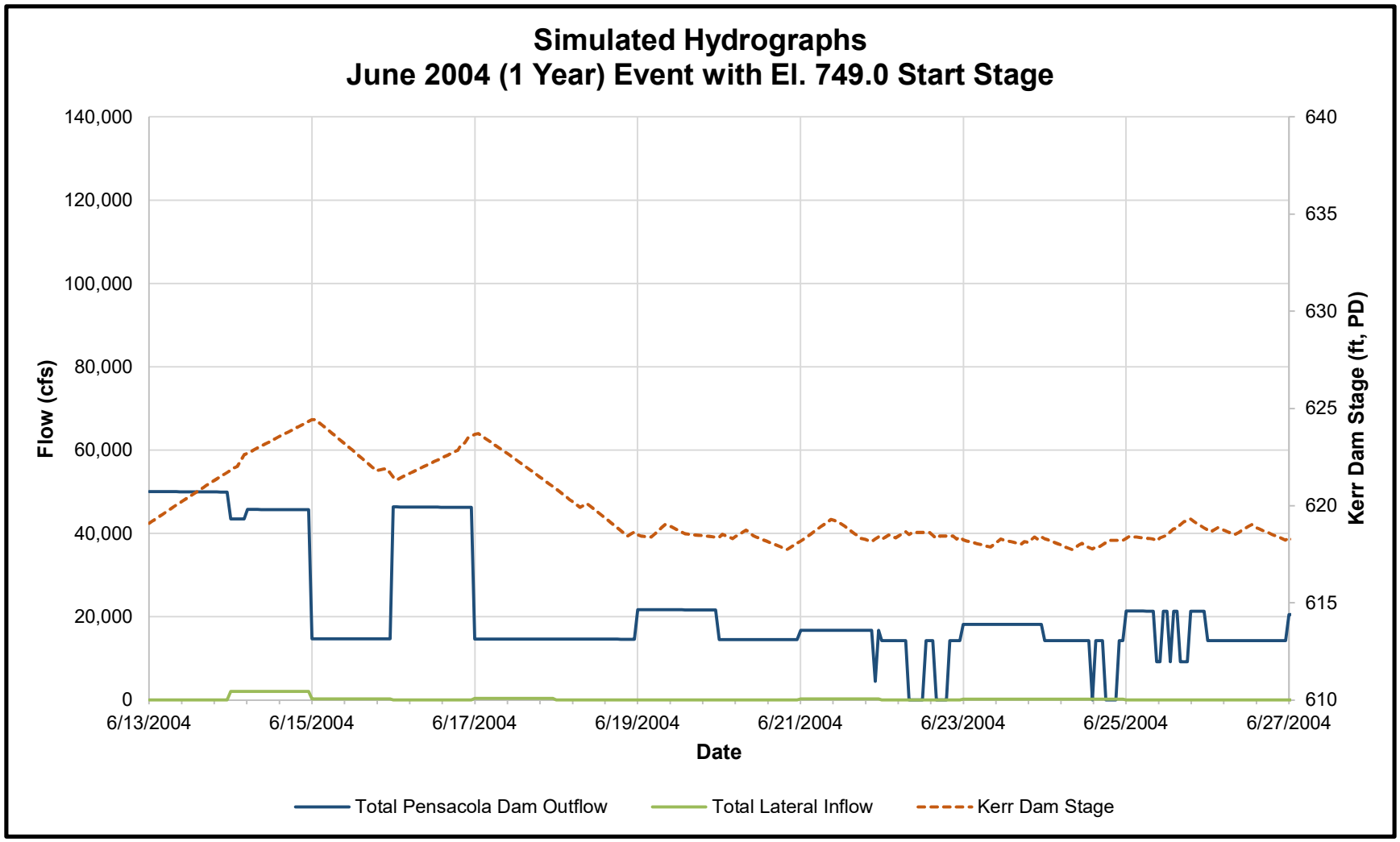


Figure A.21. Simulated hydrograph for the June 2004 (1 year) event with El. 749.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

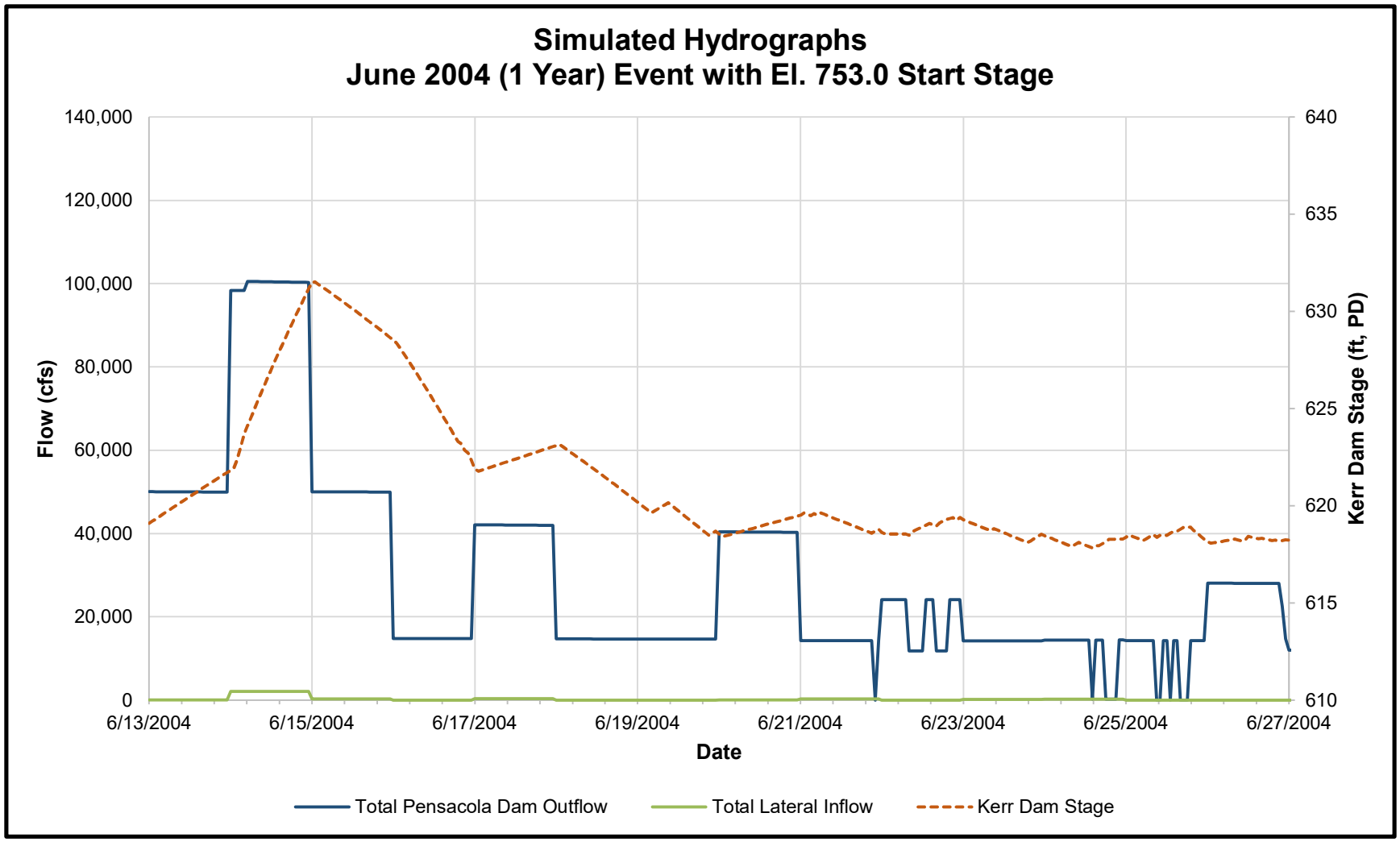


Figure A.22. Simulated hydrograph for the June 2004 (1 year) event with El. 753.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

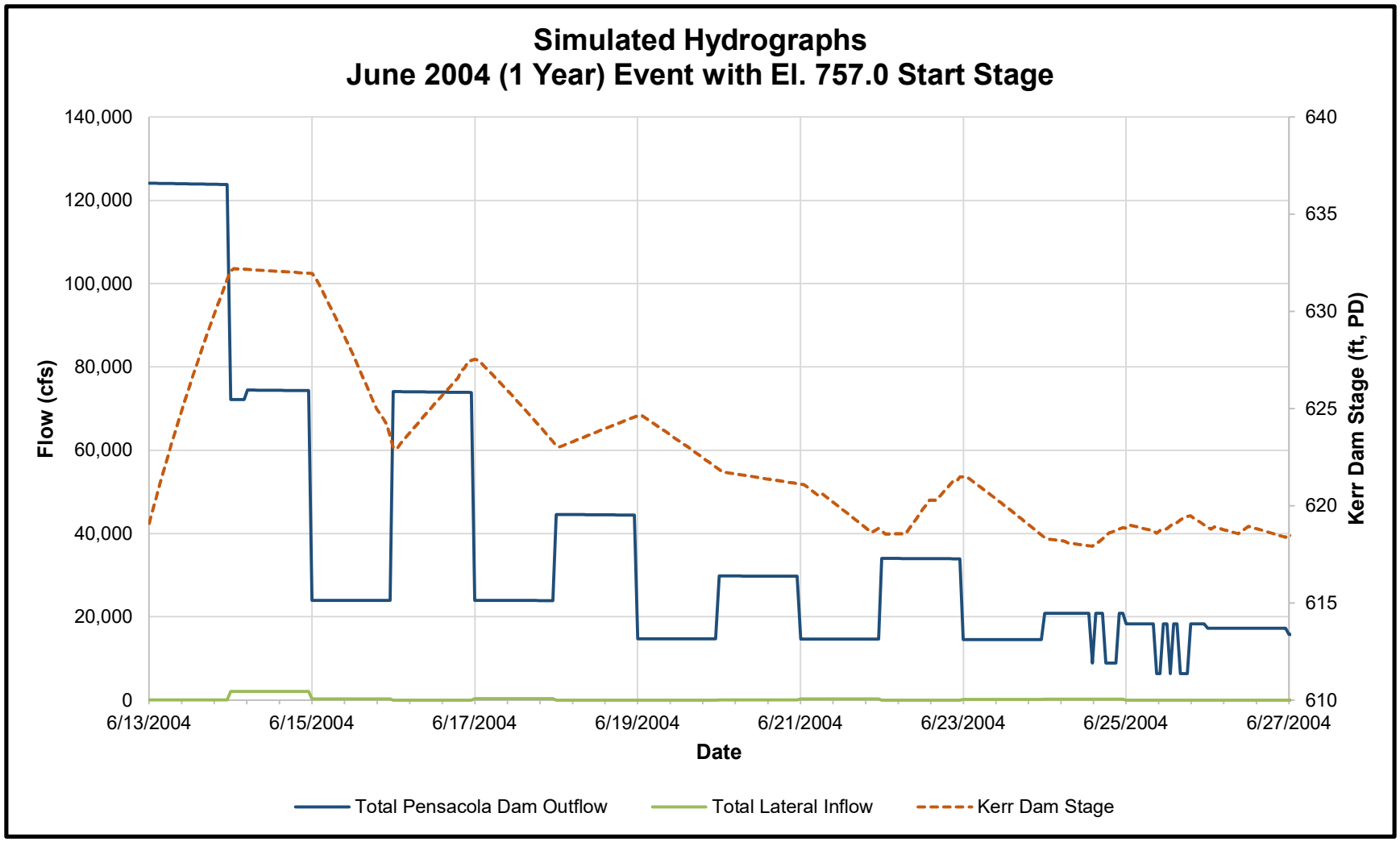


Figure A.23. Simulated hydrograph for the June 2004 (1 year) event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

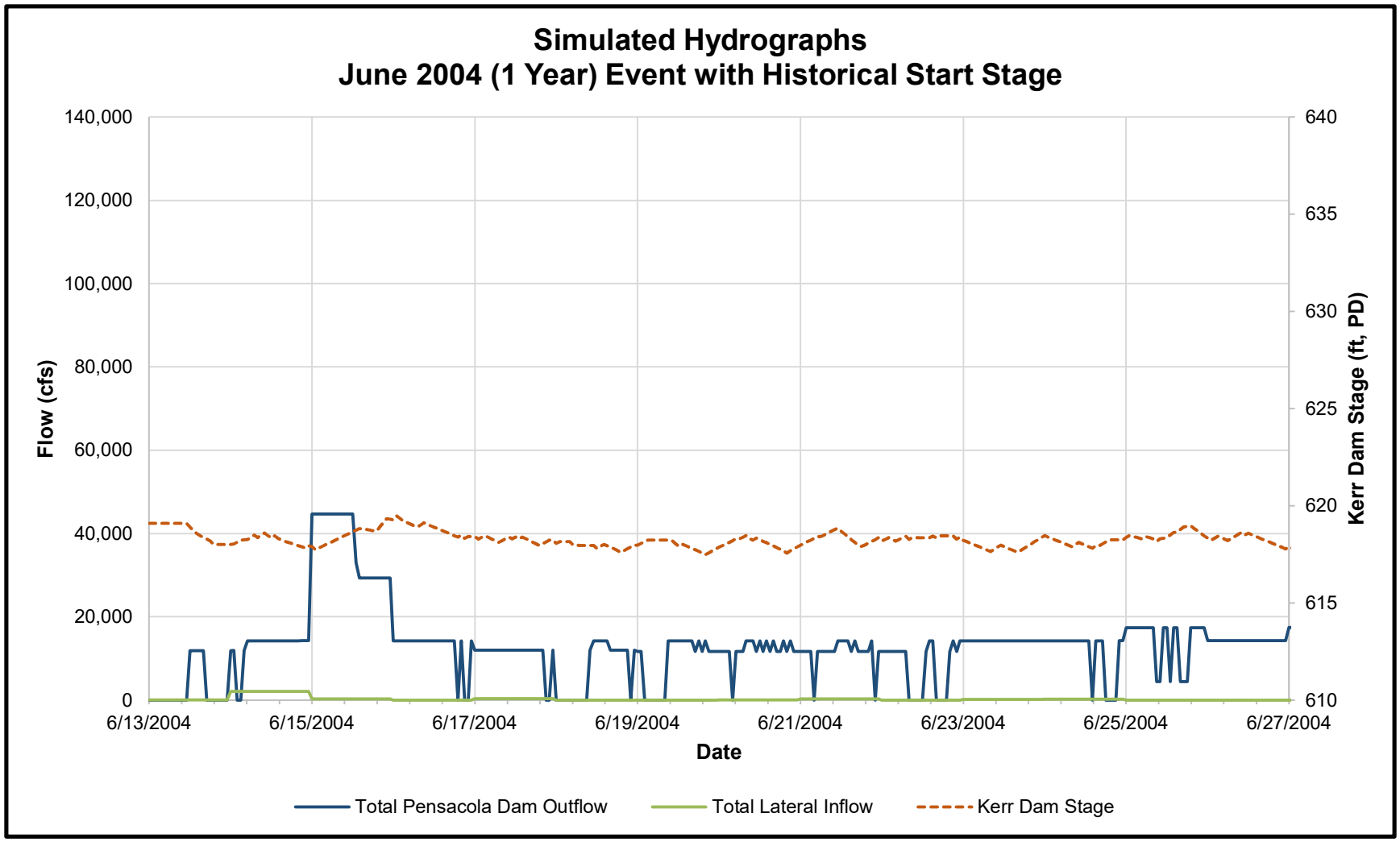


Figure A.24. Simulated hydrograph for the June 2004 (1 year) event with historical starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

APPENDIX A.3:
JULY 2007 (4 YEAR) EVENT SIMULATED HYDROGRAPHS

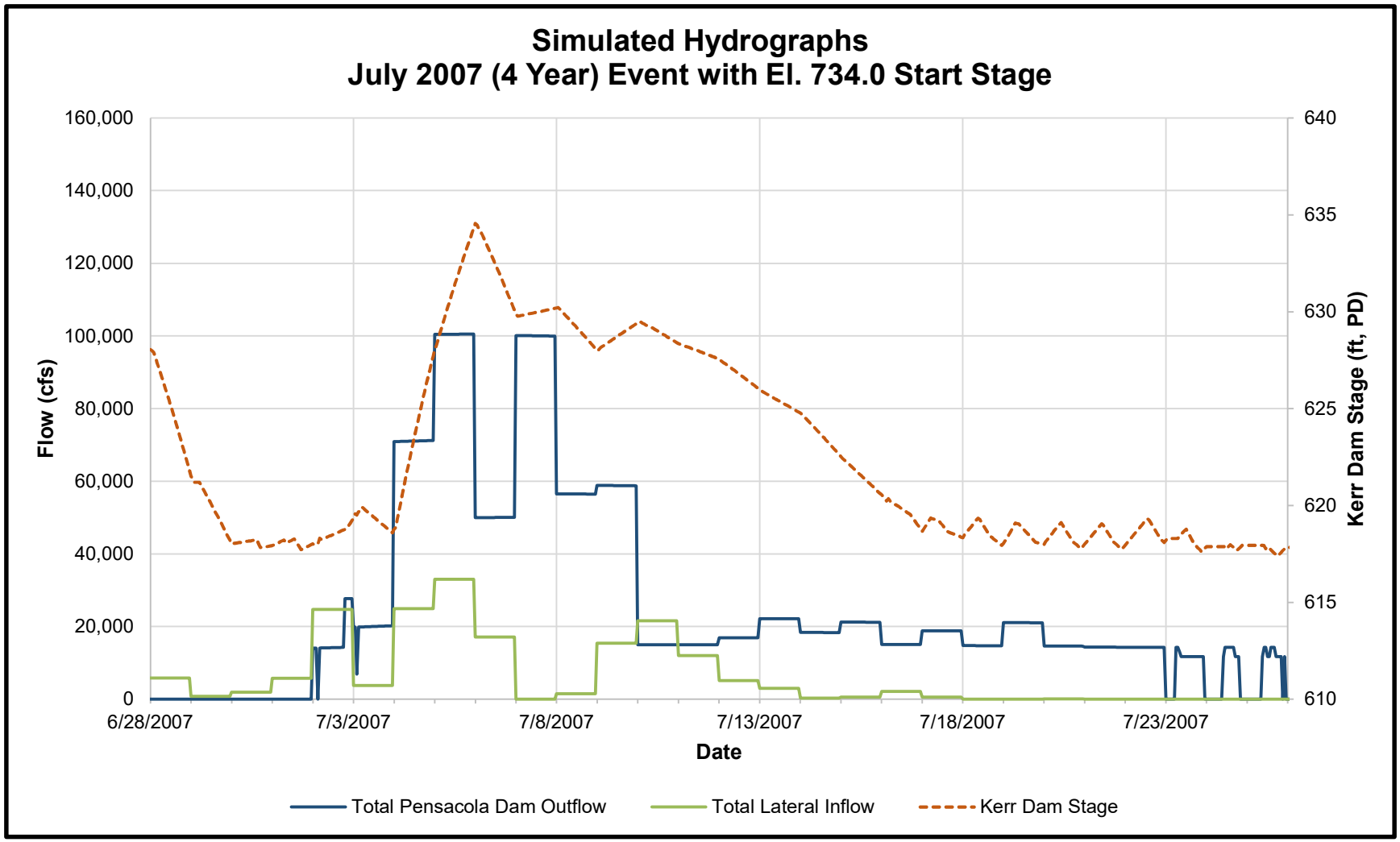


Figure A.25. Simulated hydrograph for the July 2007 (4 year) event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

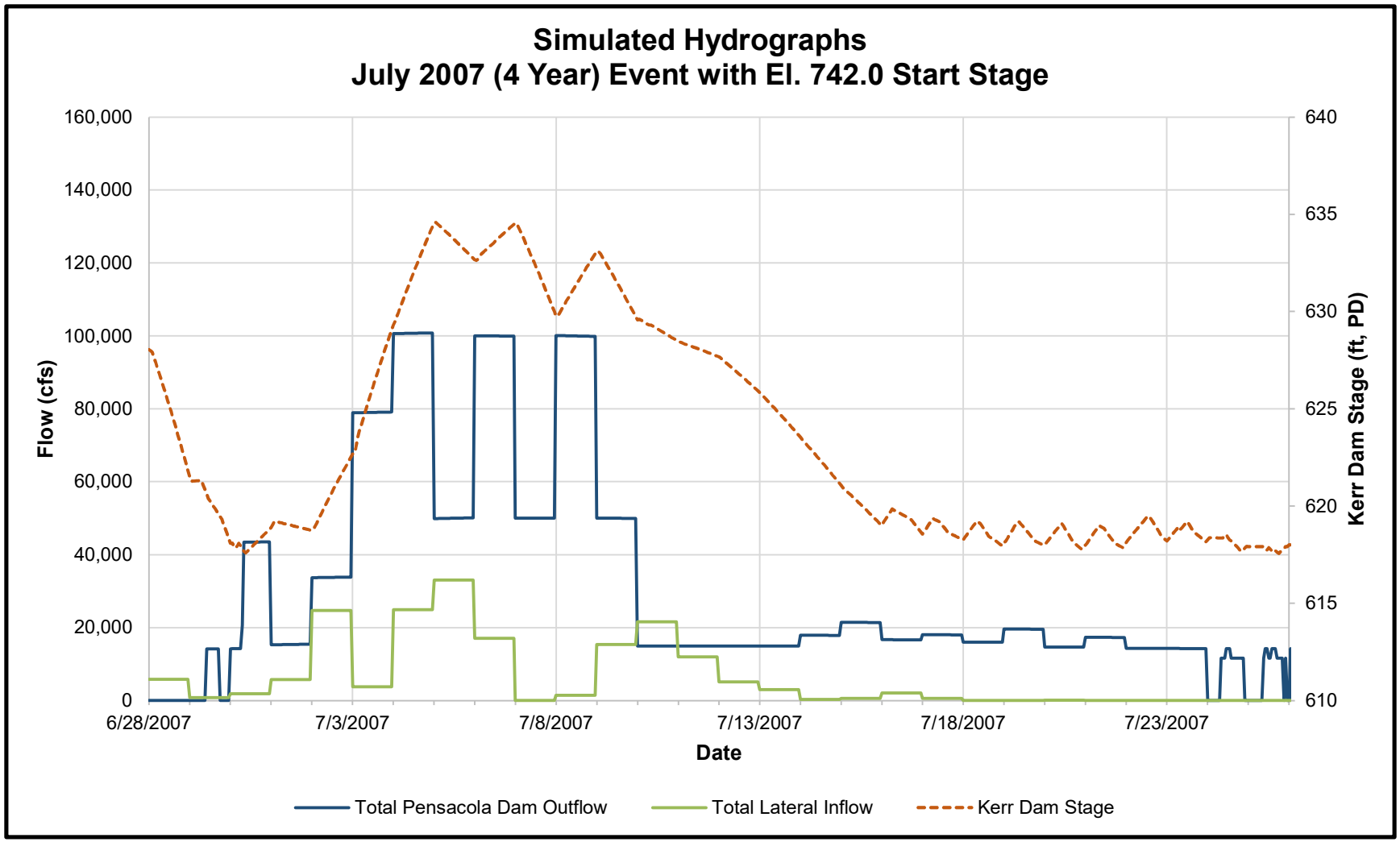


Figure A.26. Simulated hydrograph for the July 2007 (4 year) event with El. 742.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

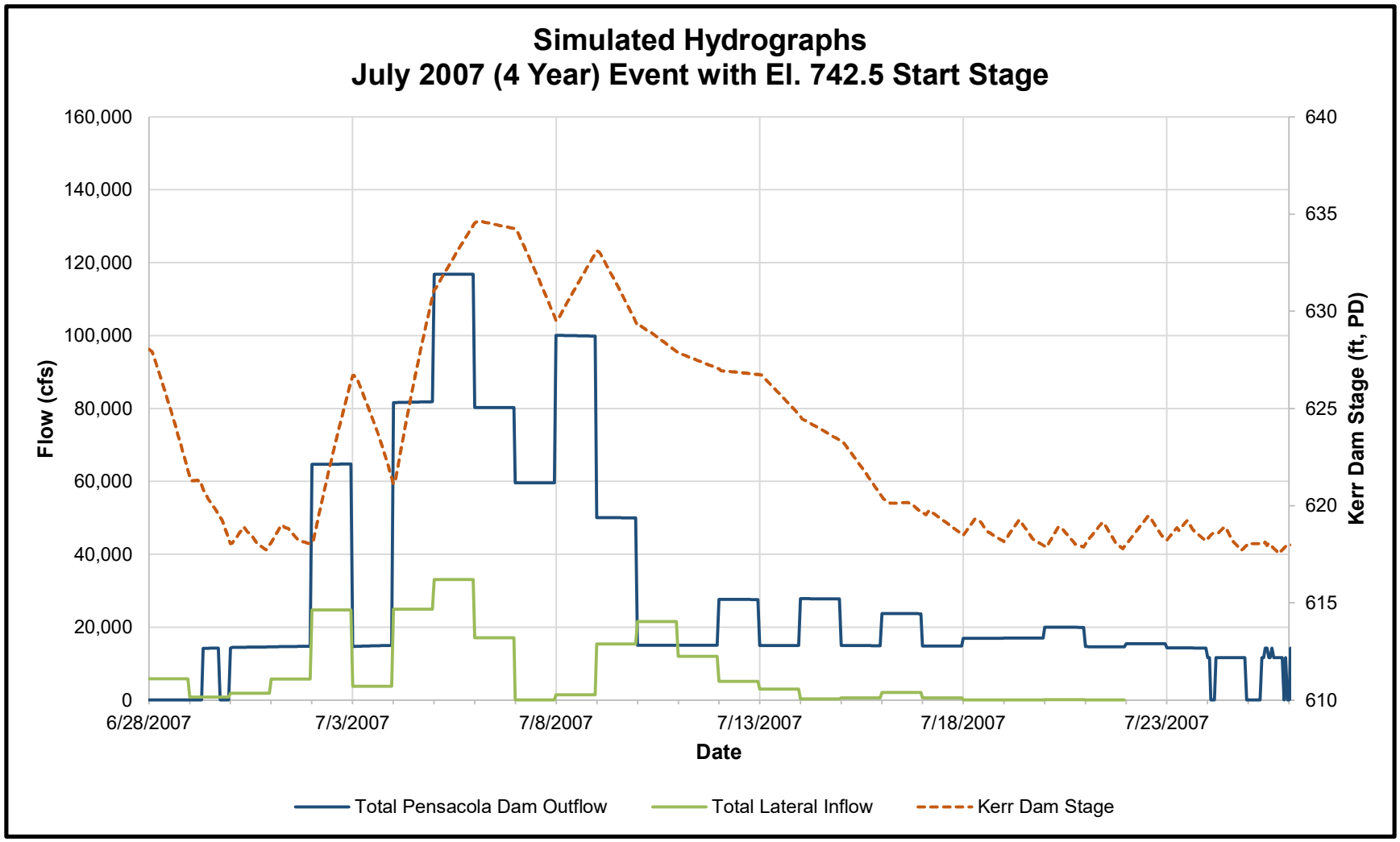


Figure A.27. Simulated hydrograph for the July 2007 (4 year) event with El. 742.5 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

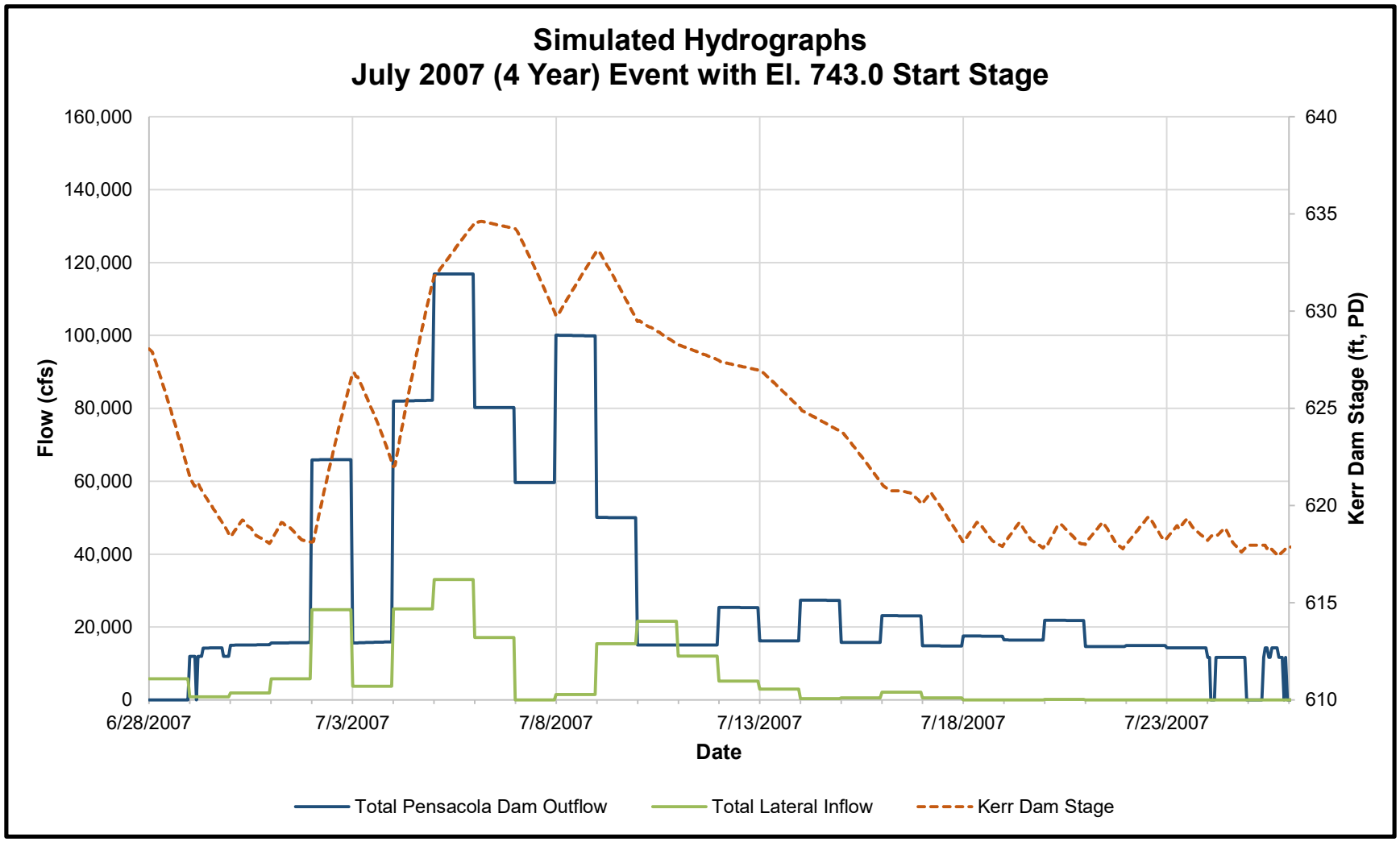


Figure A.28. Simulated hydrograph for the July 2007 (4 year) event with El. 743.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

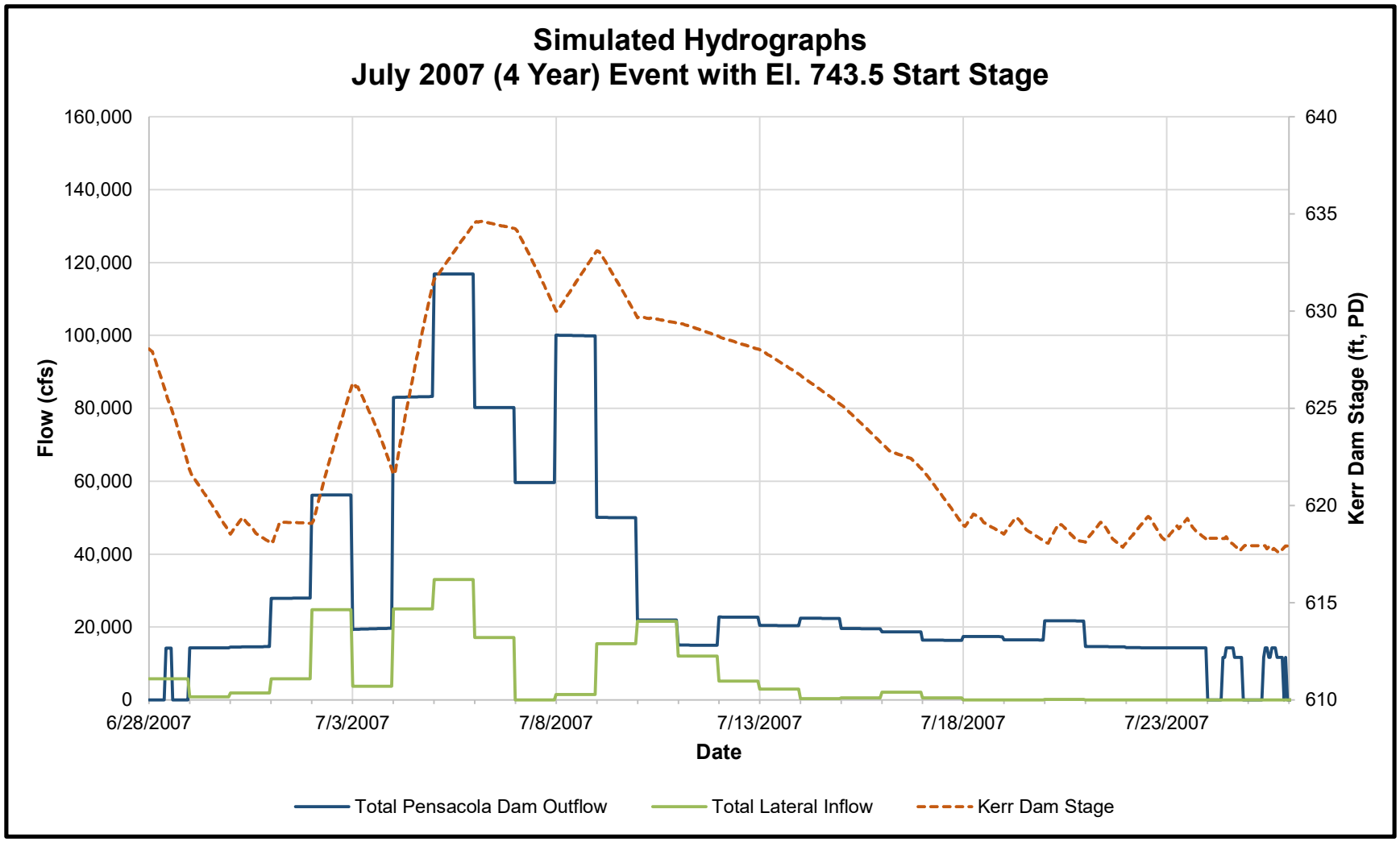


Figure A.29. Simulated hydrograph for the July 2007 (4 year) event with El. 743.5 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

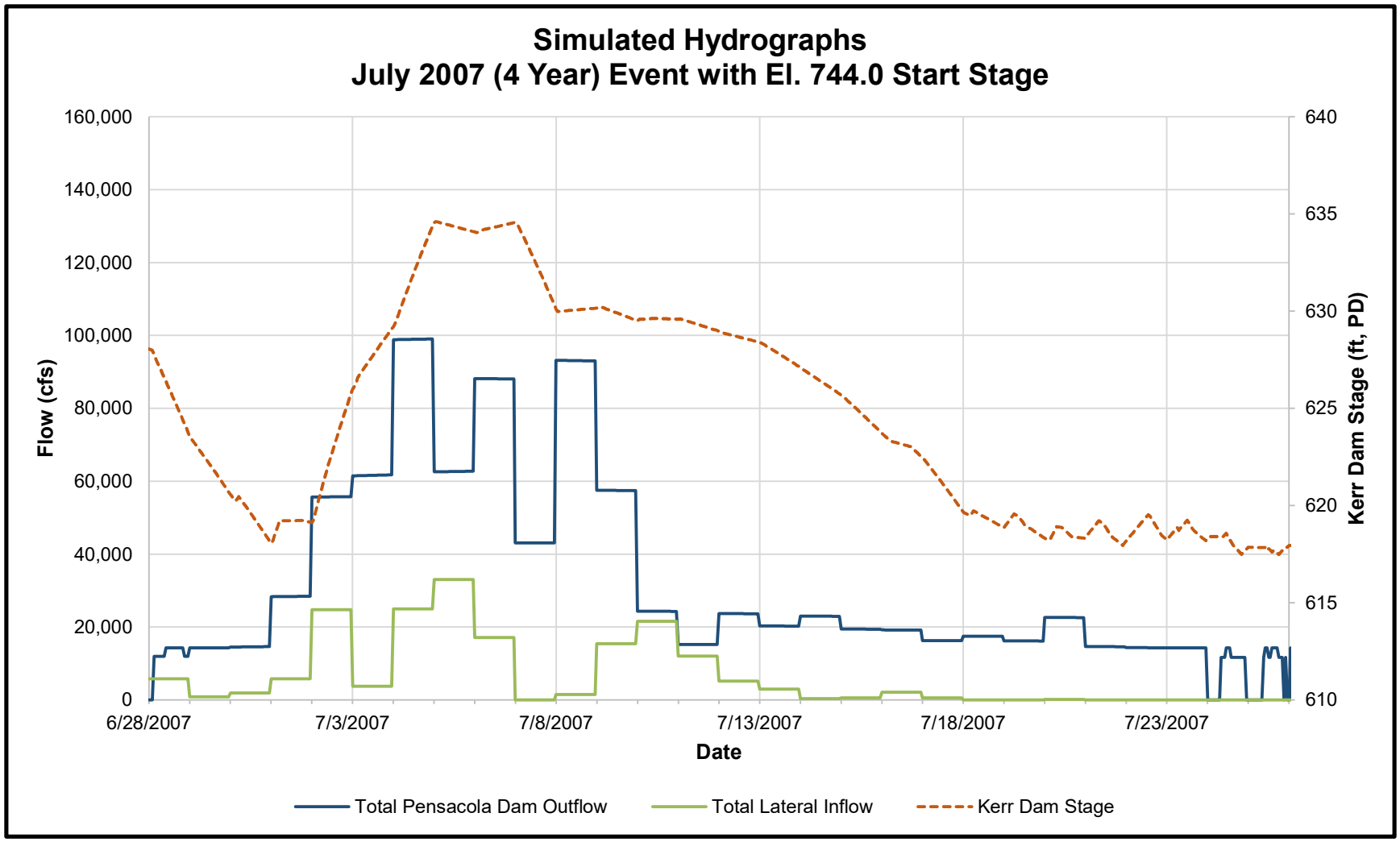


Figure A.30. Simulated hydrograph for the July 2007 (4 year) event with El. 744.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

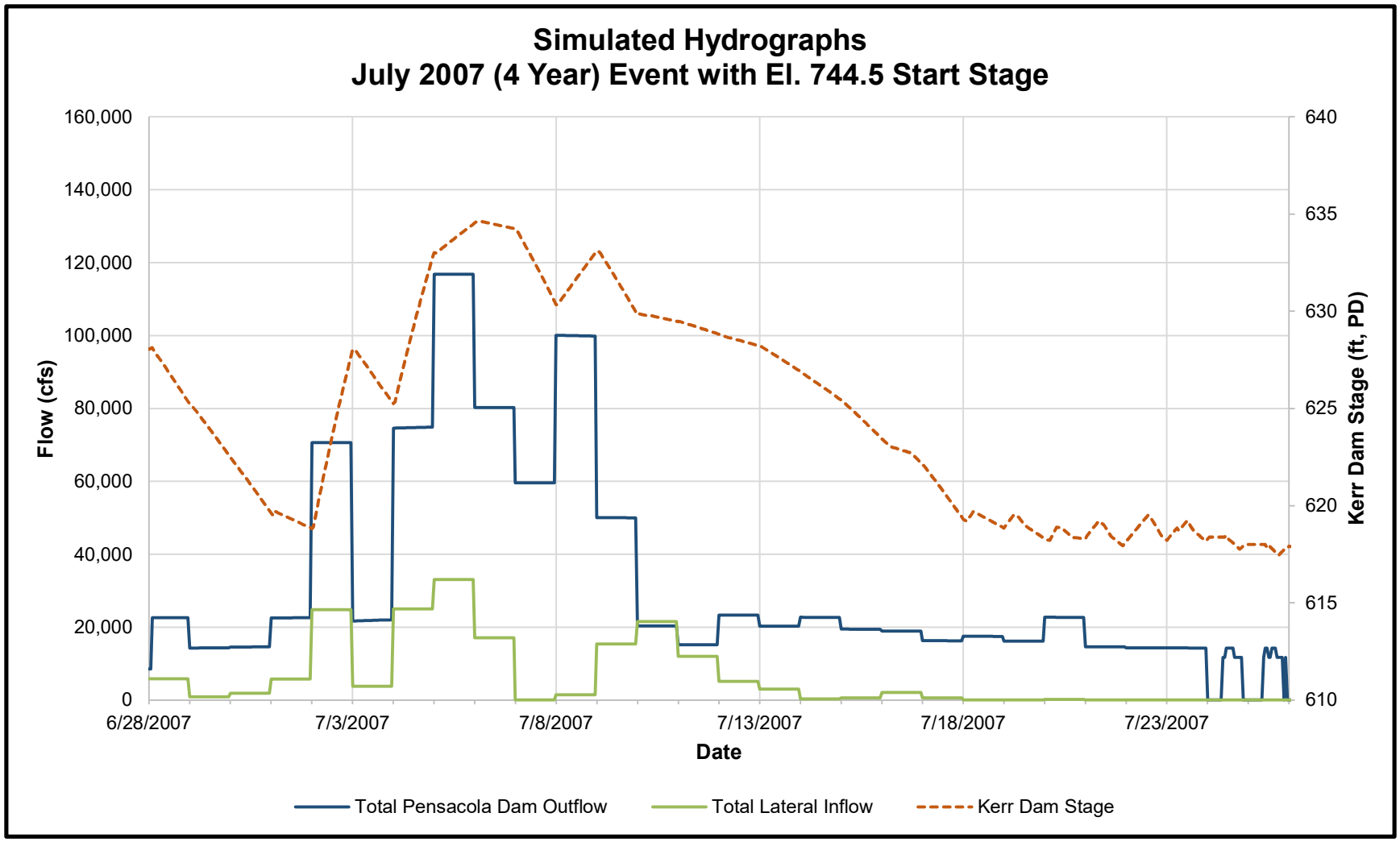


Figure A.31. Simulated hydrograph for the July 2007 (4 year) event with El. 744.5 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

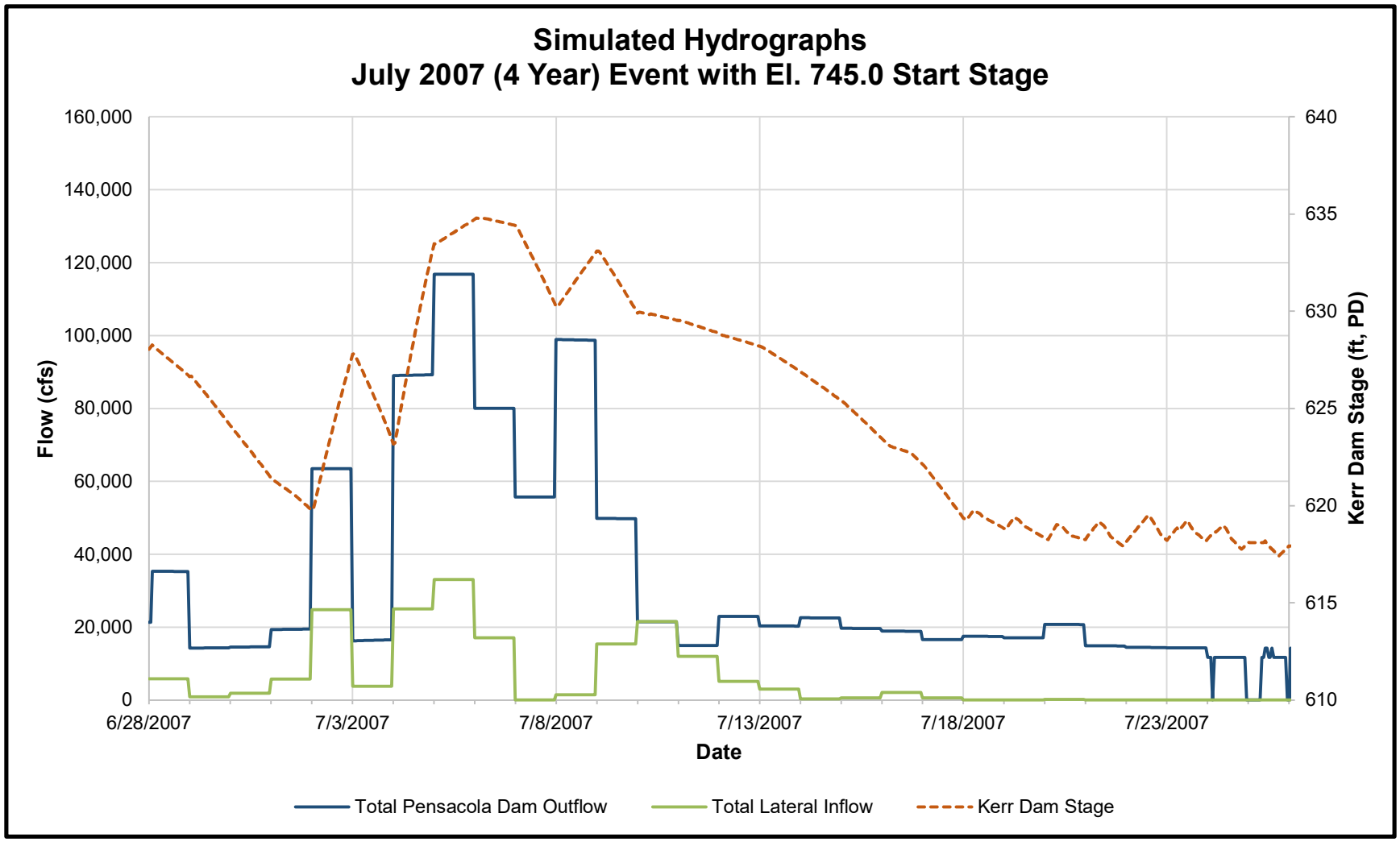


Figure A.32. Simulated hydrograph for the July 2007 (4 year) event with El. 745.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

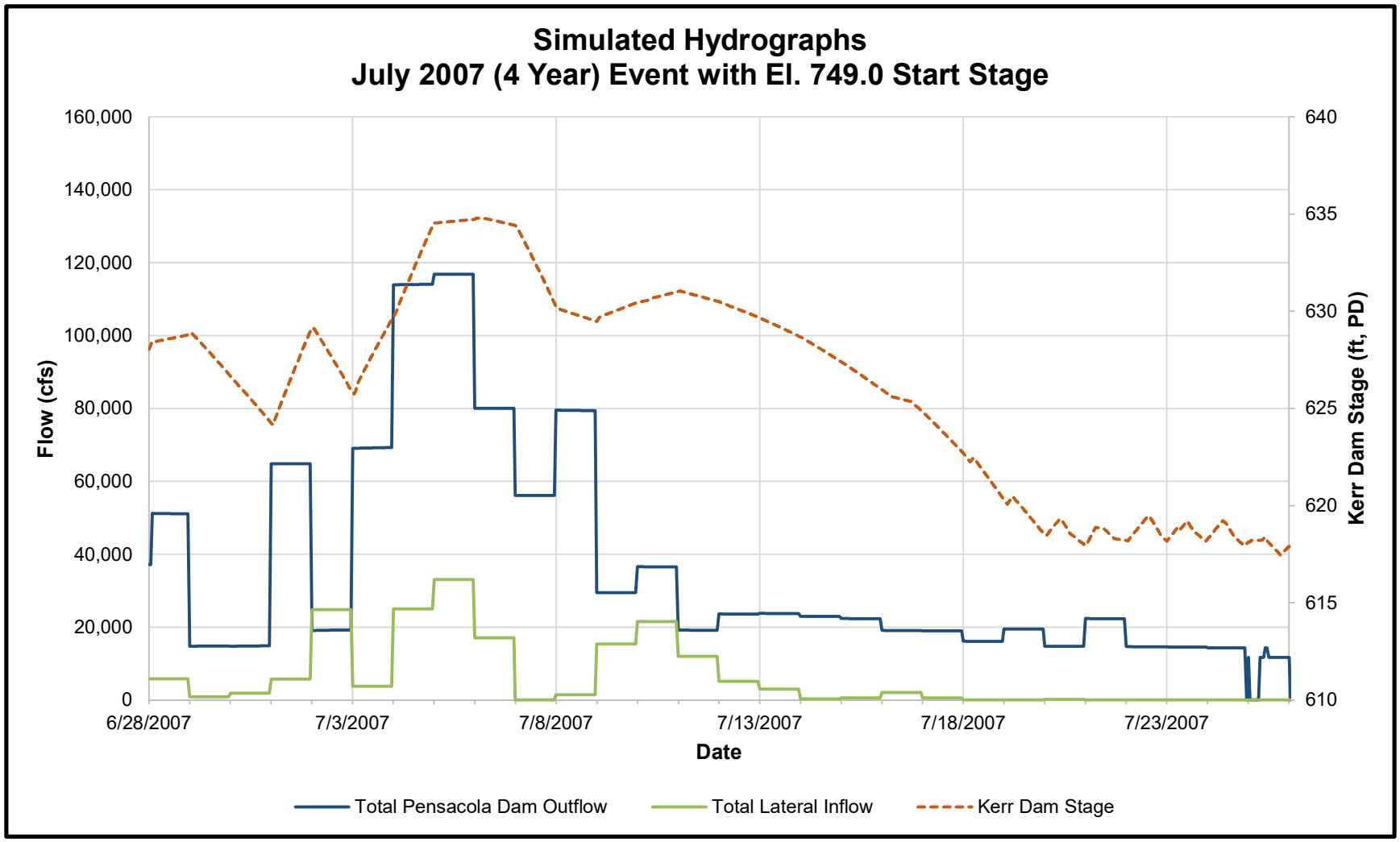


Figure A.33. Simulated hydrograph for the July 2007 (4 year) event with El. 749.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

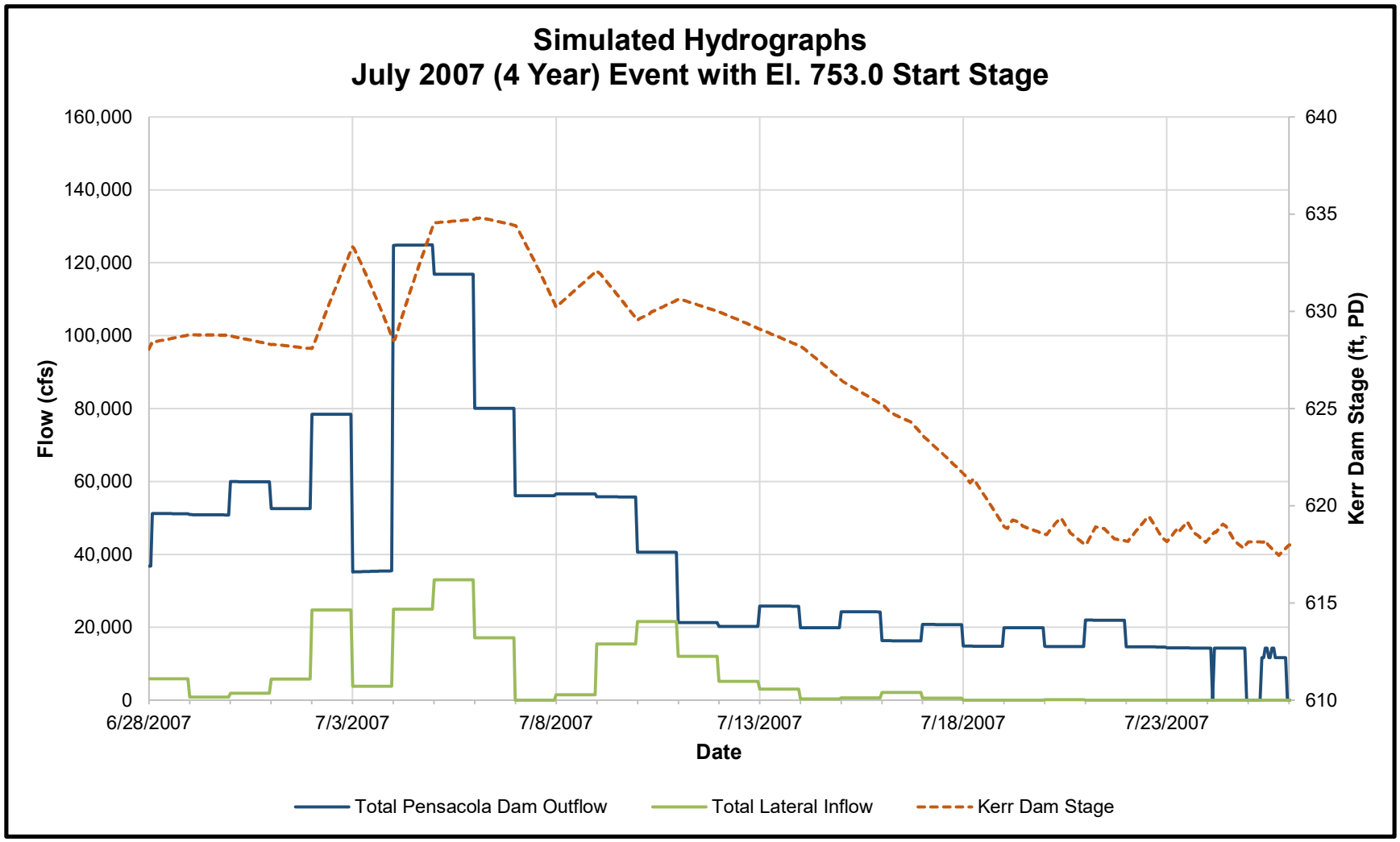


Figure A.34. Simulated hydrograph for the July 2007 (4 year) event with El. 753.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

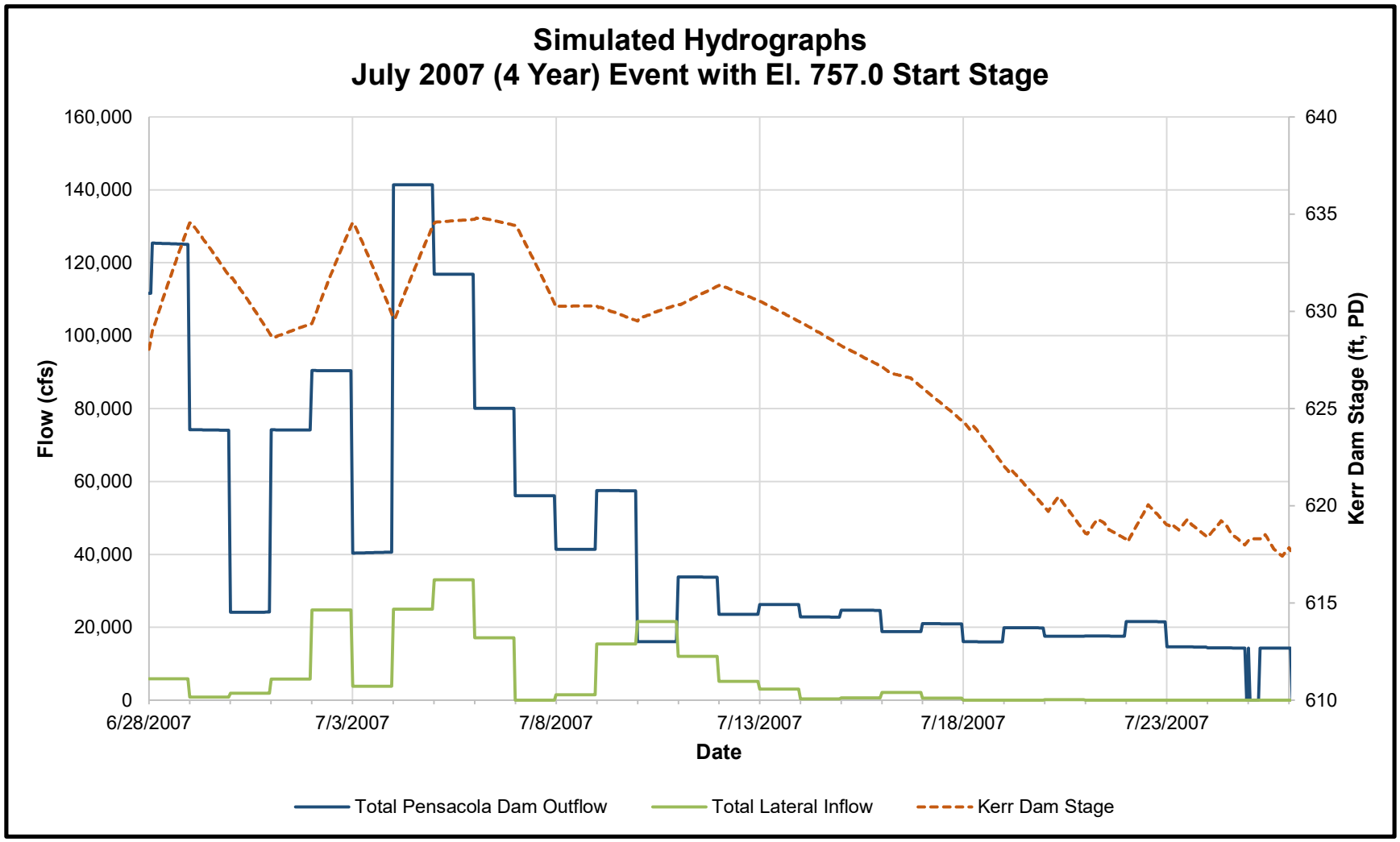


Figure A.35. Simulated hydrograph for the July 2007 (4 year) event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

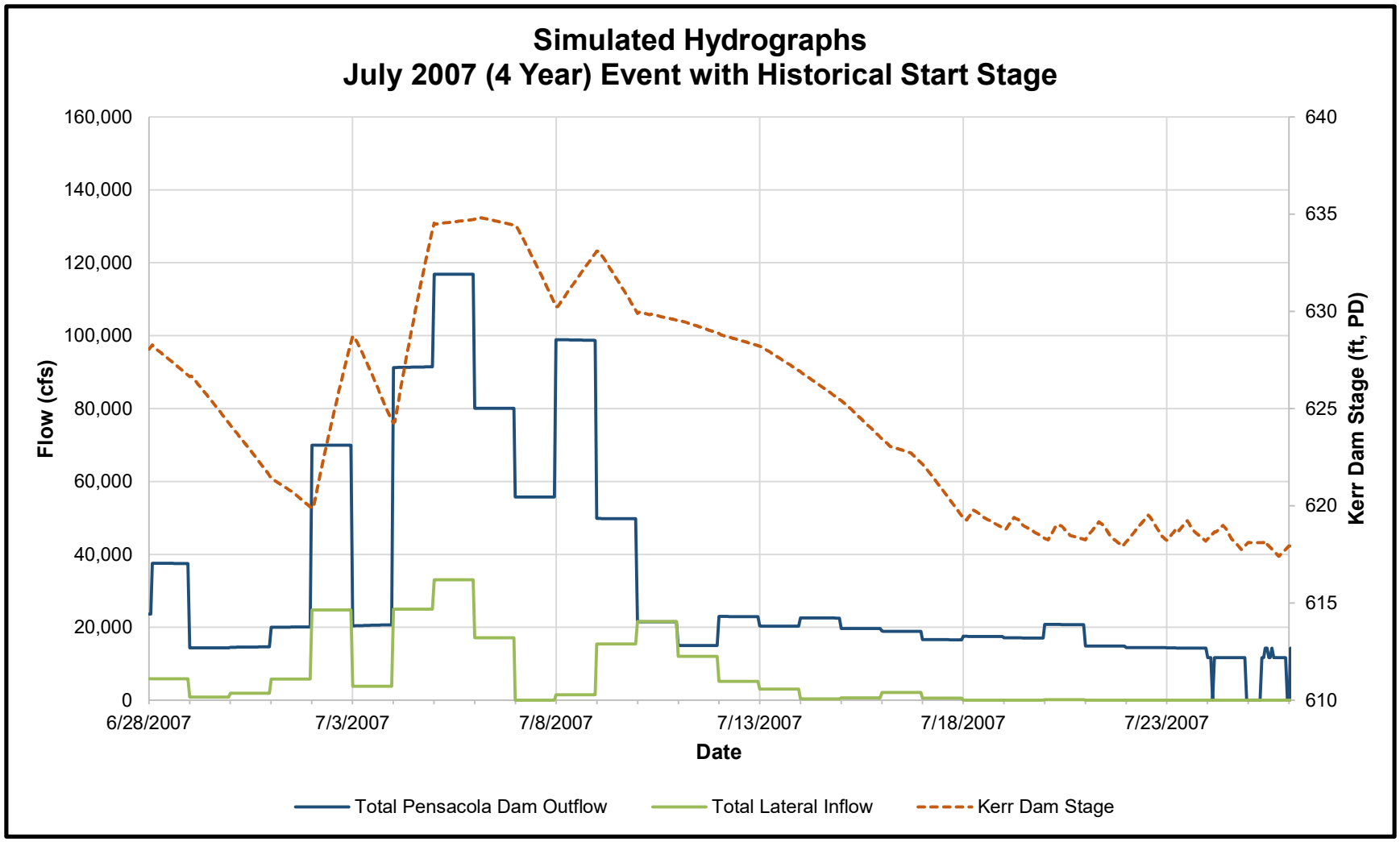


Figure A.36. Simulated hydrograph for the July 2007 (4 year) event with historical starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

APPENDIX A.4:
OCTOBER 2009 (3 YEAR) EVENT SIMULATED HYDROGRAPHS

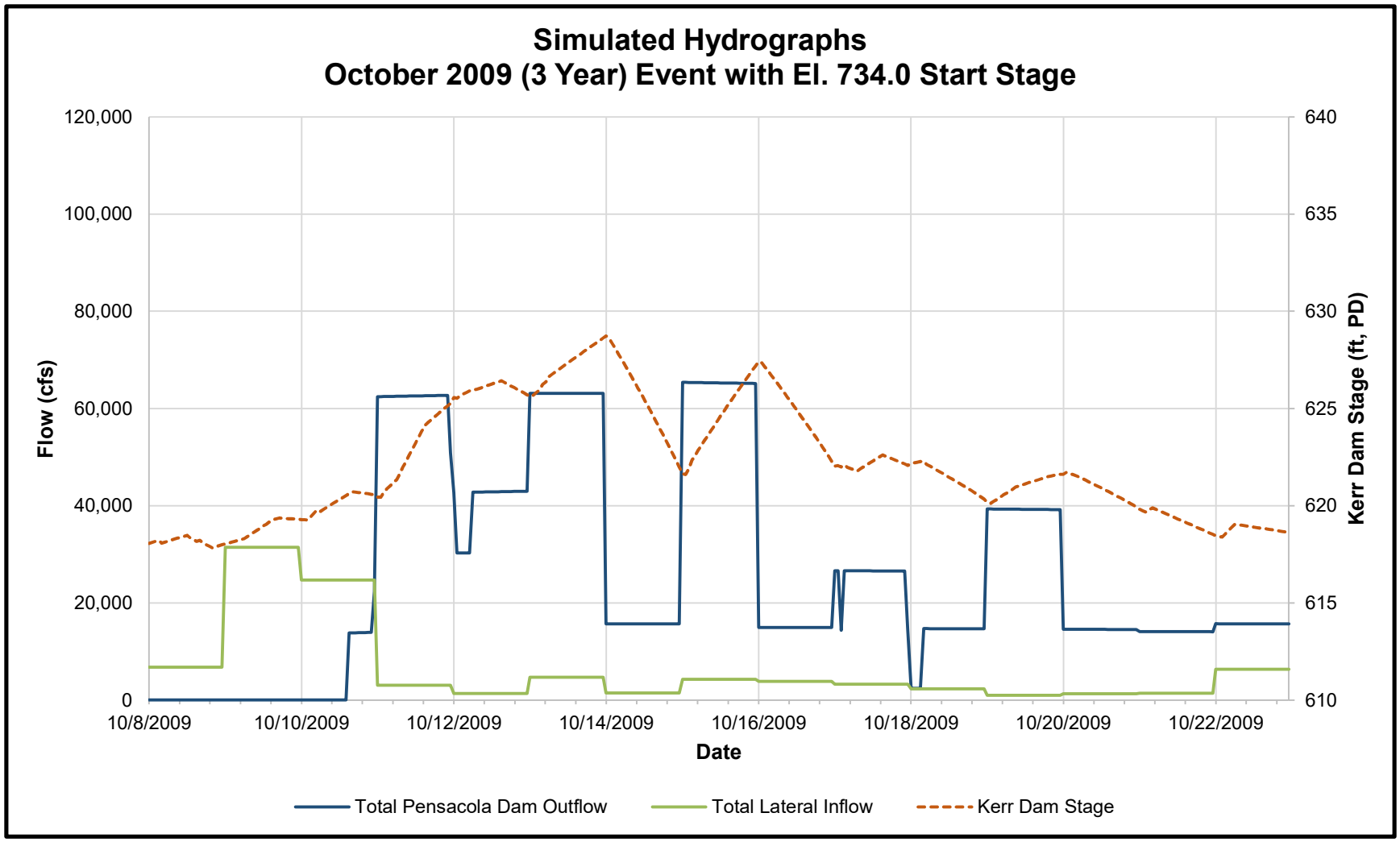


Figure A.37. Simulated hydrograph for the October 2009 (3 year) event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

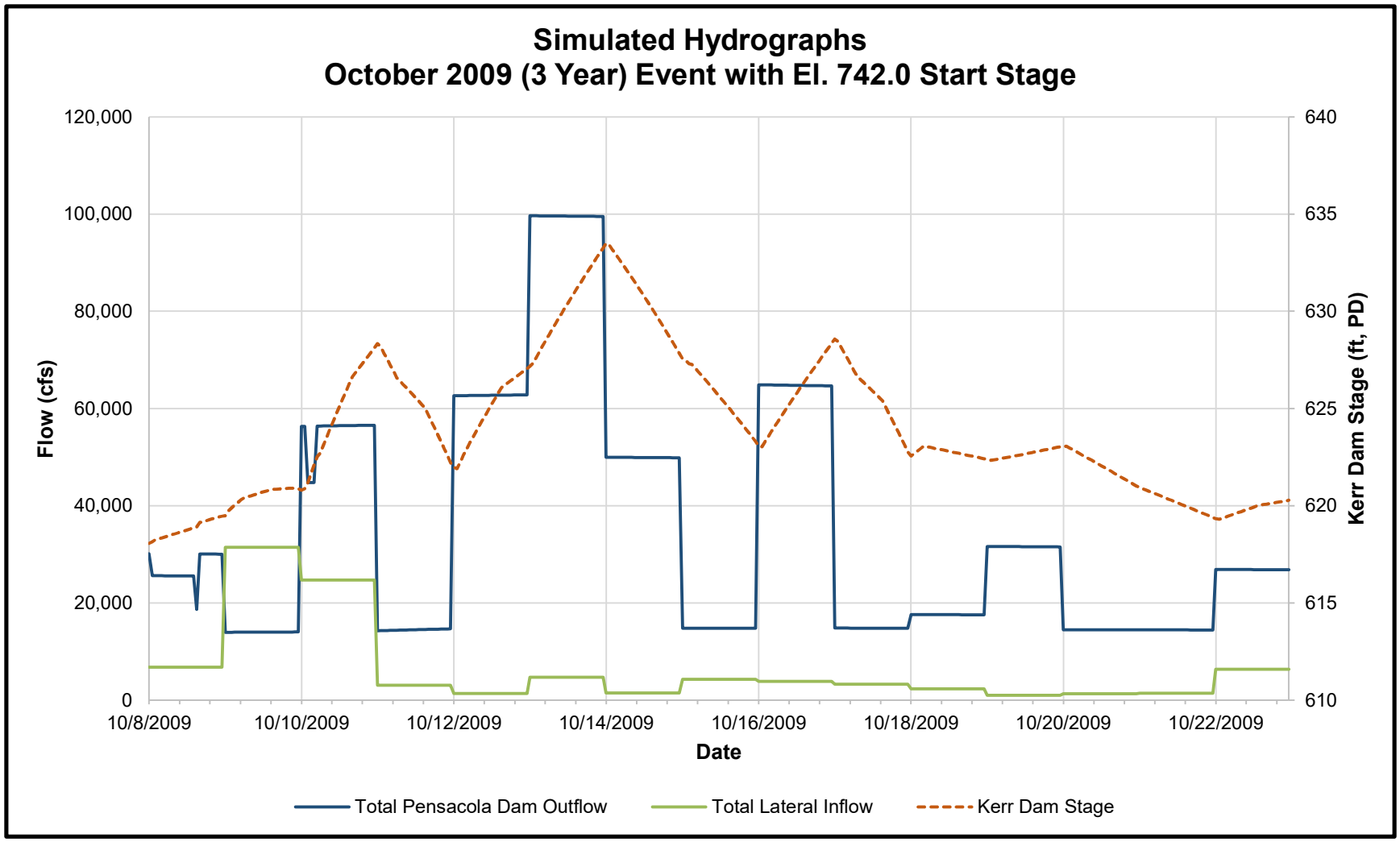


Figure A.38. Simulated hydrograph for the October 2009 (3 year) event with El. 742.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

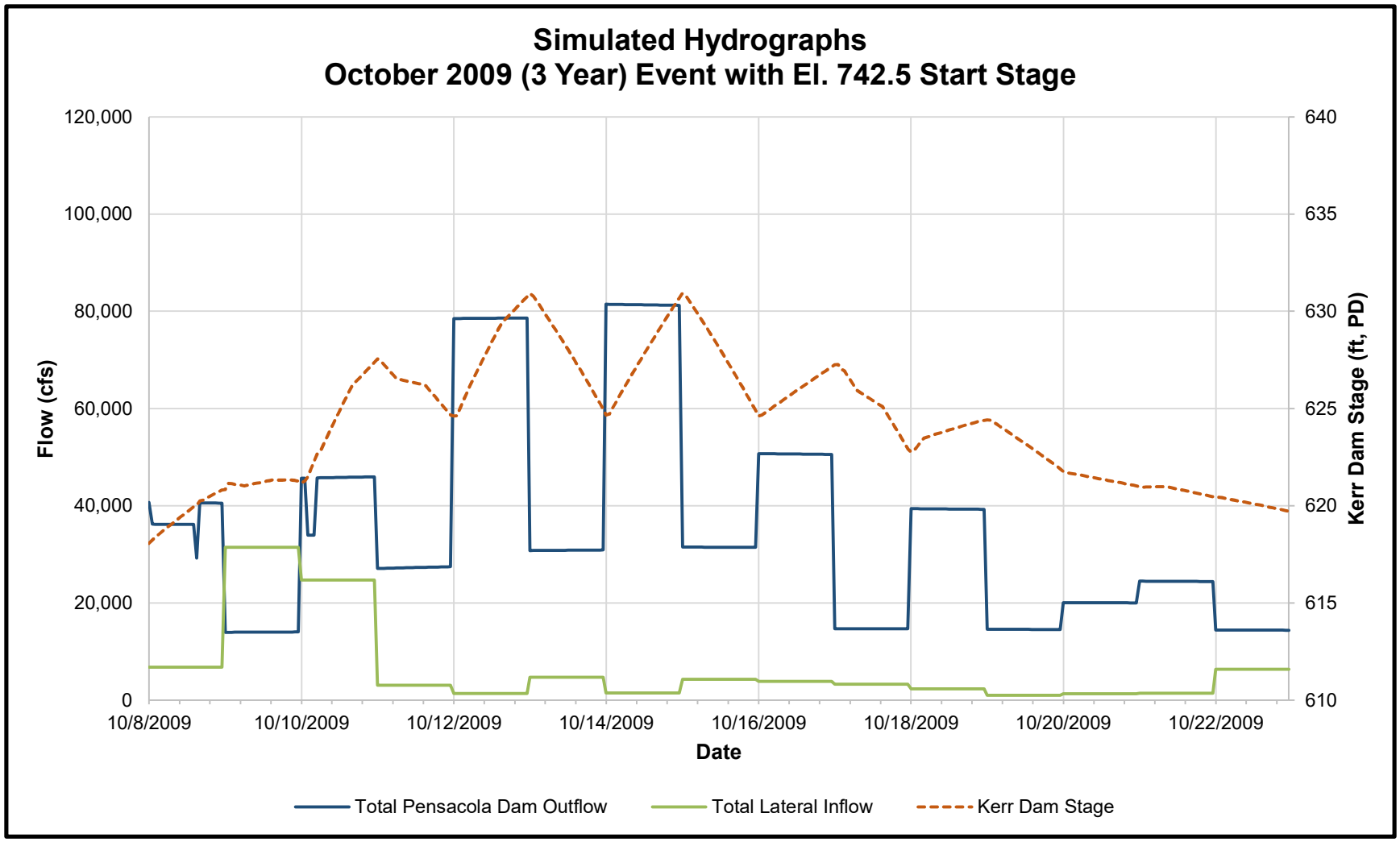


Figure A.39. Simulated hydrograph for the October 2009 (3 year) event with El. 742.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

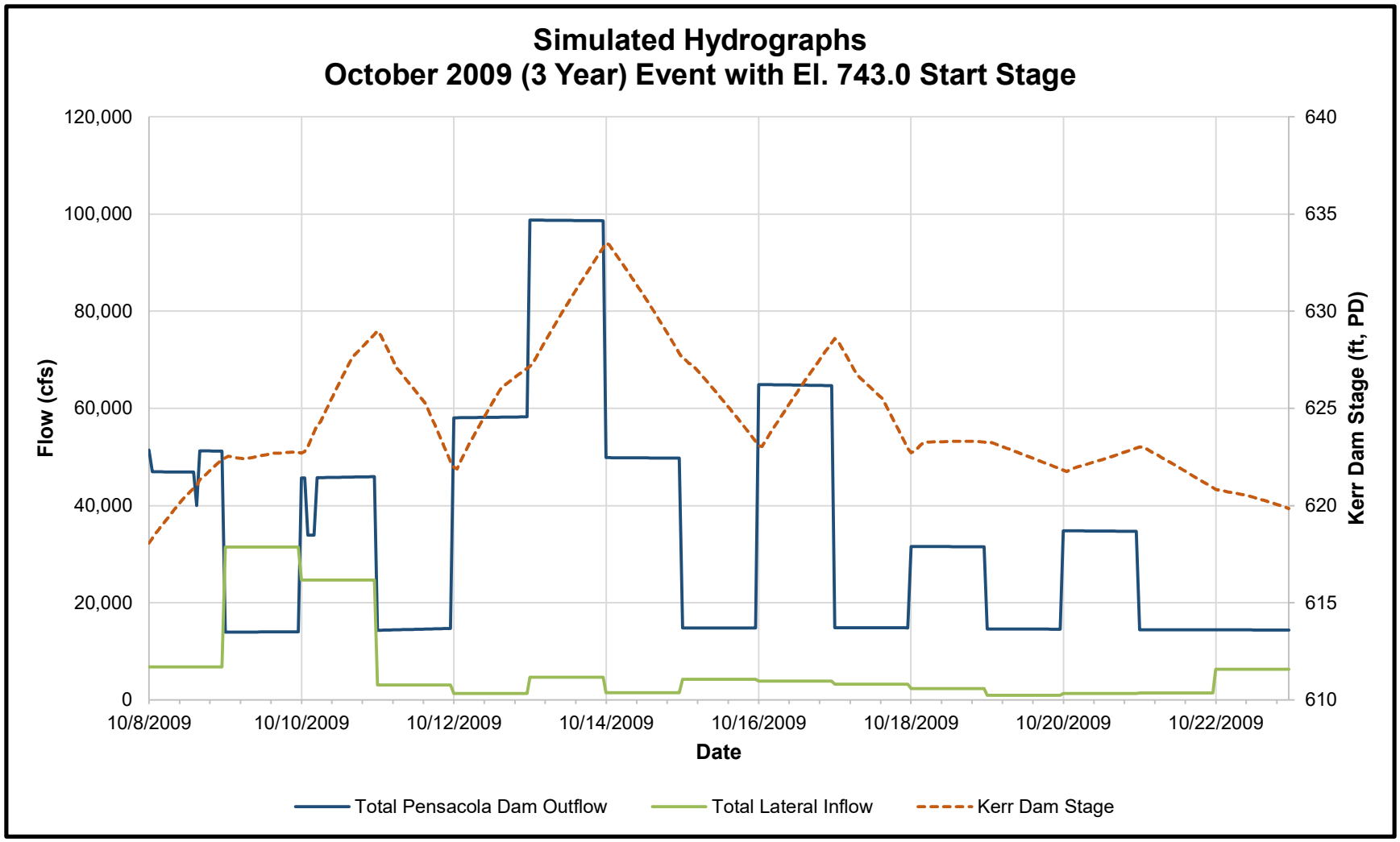


Figure A.40. Simulated hydrograph for the October 2009 (3 year) event with El. 743.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

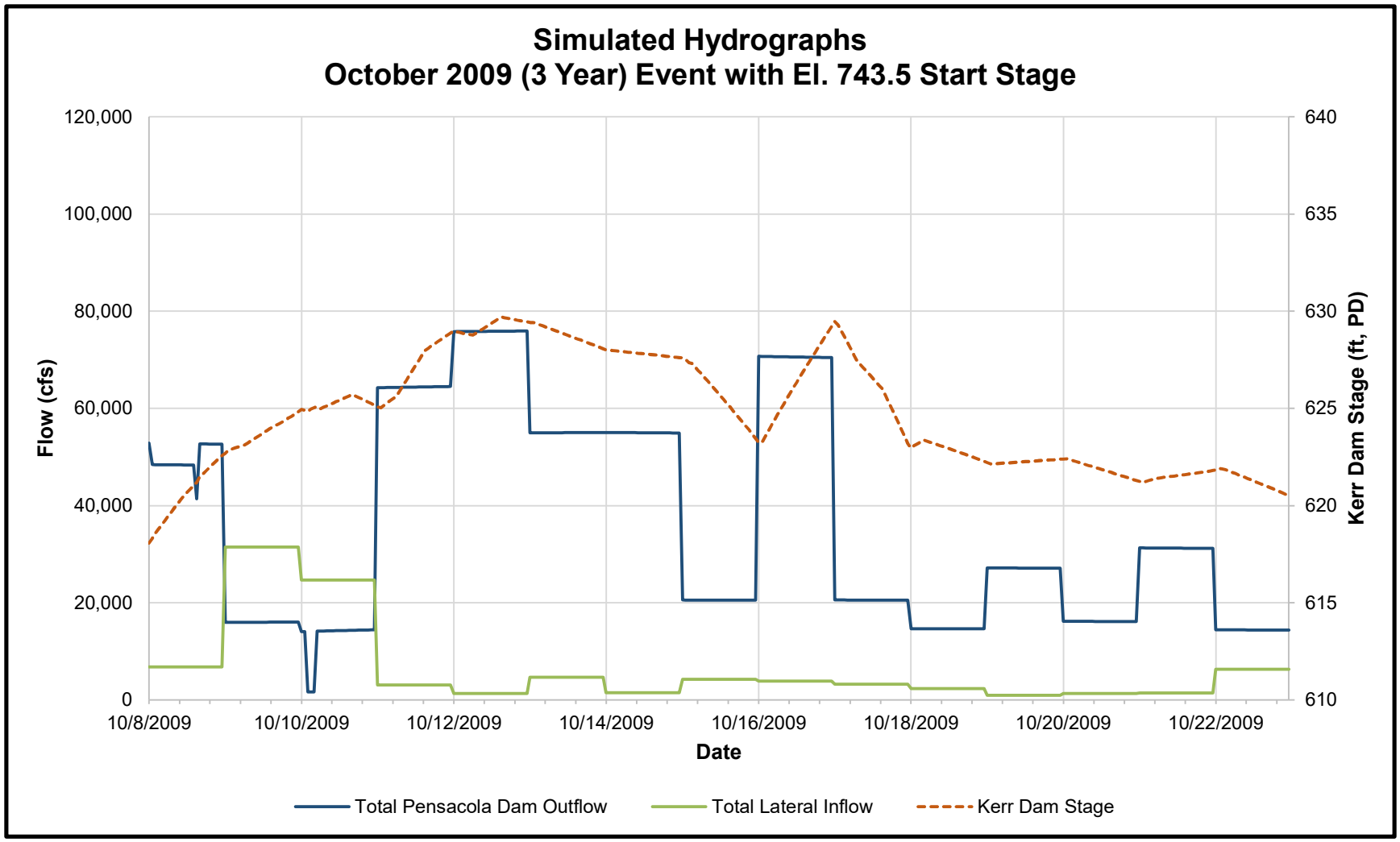


Figure A.41. Simulated hydrograph for the October 2009 (3 year) event with El. 743.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

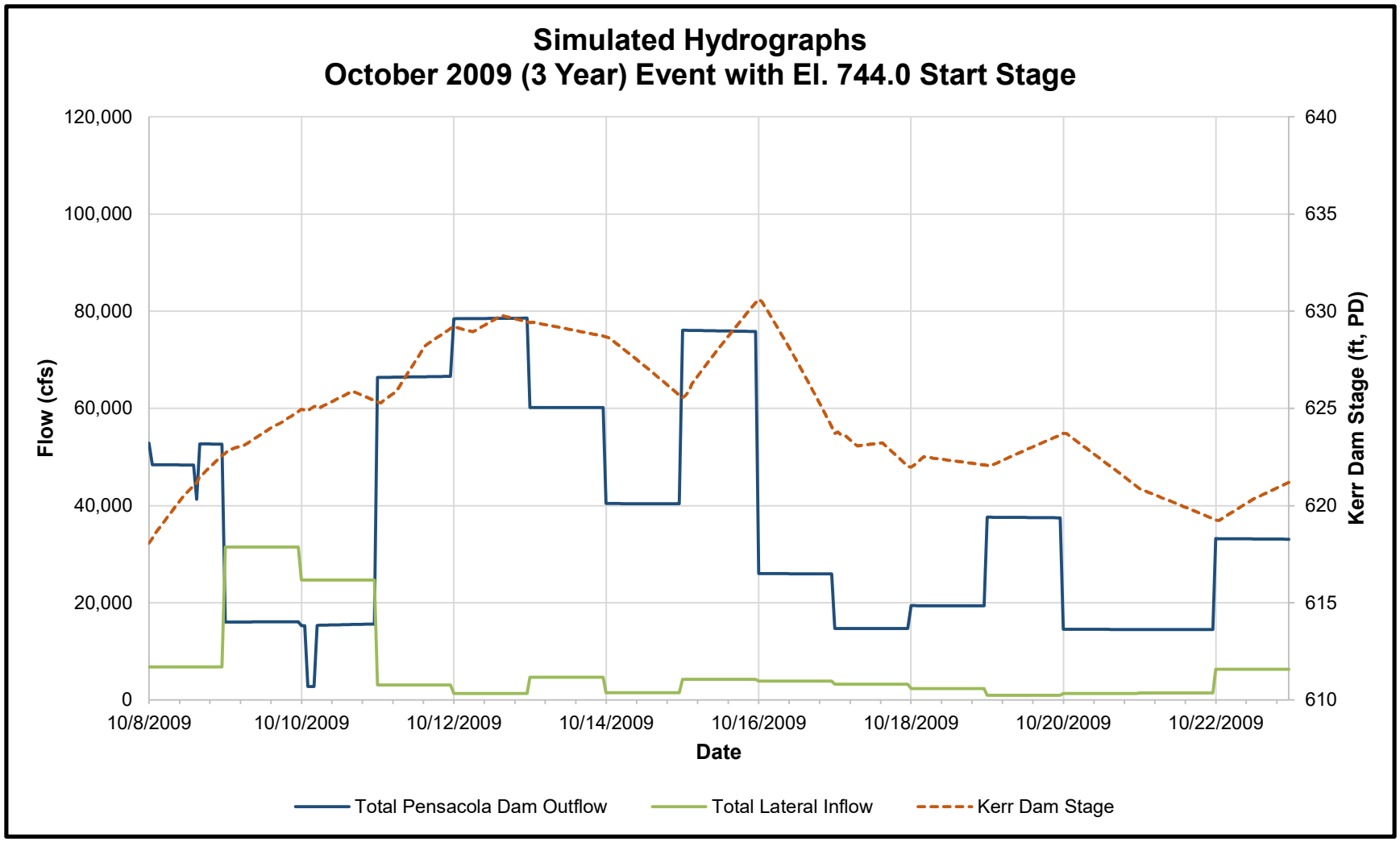


Figure A.42. Simulated hydrograph for the October 2009 (3 year) event with El. 744.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

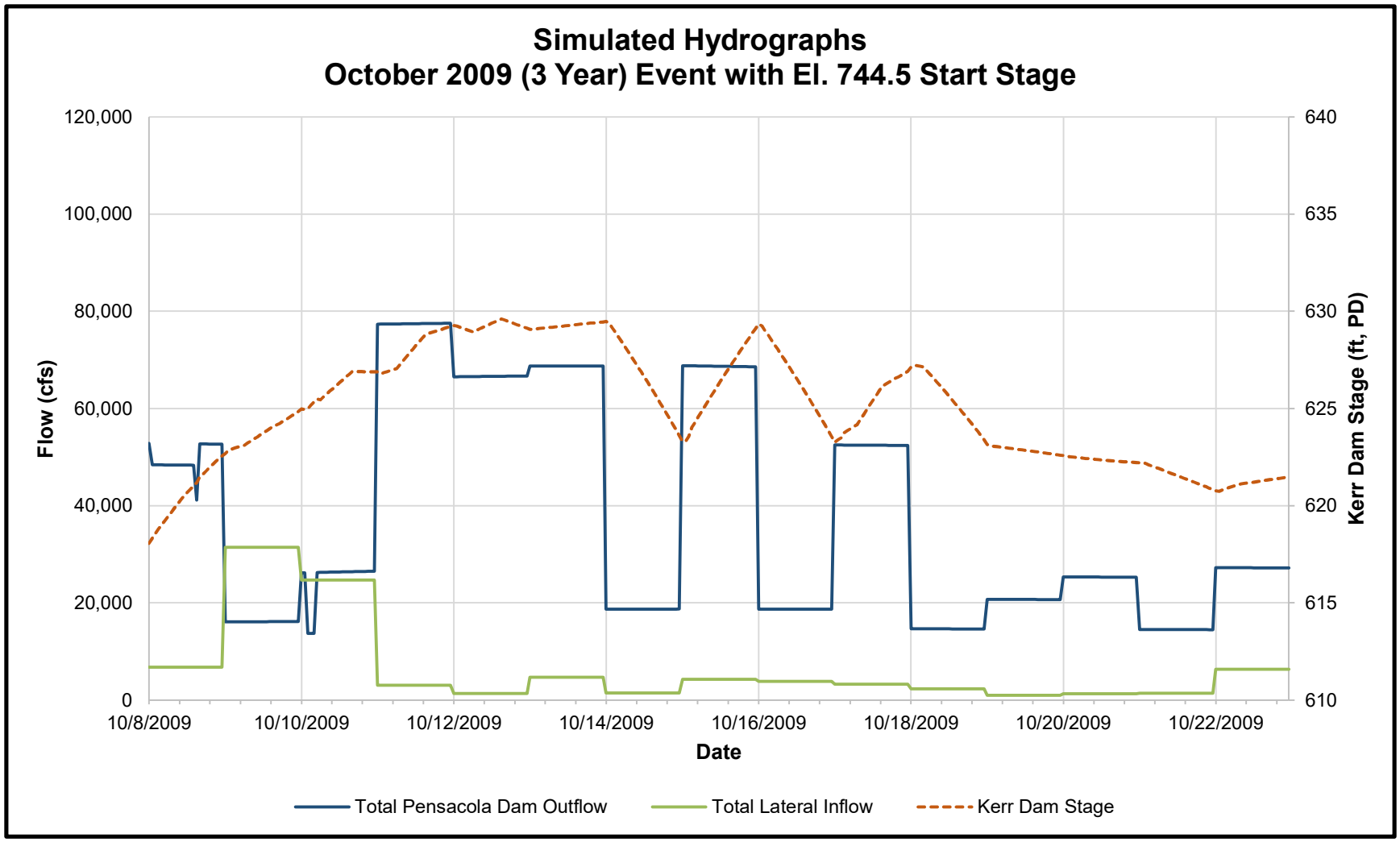


Figure A.43. Simulated hydrograph for the October 2009 (3 year) event with El. 744.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

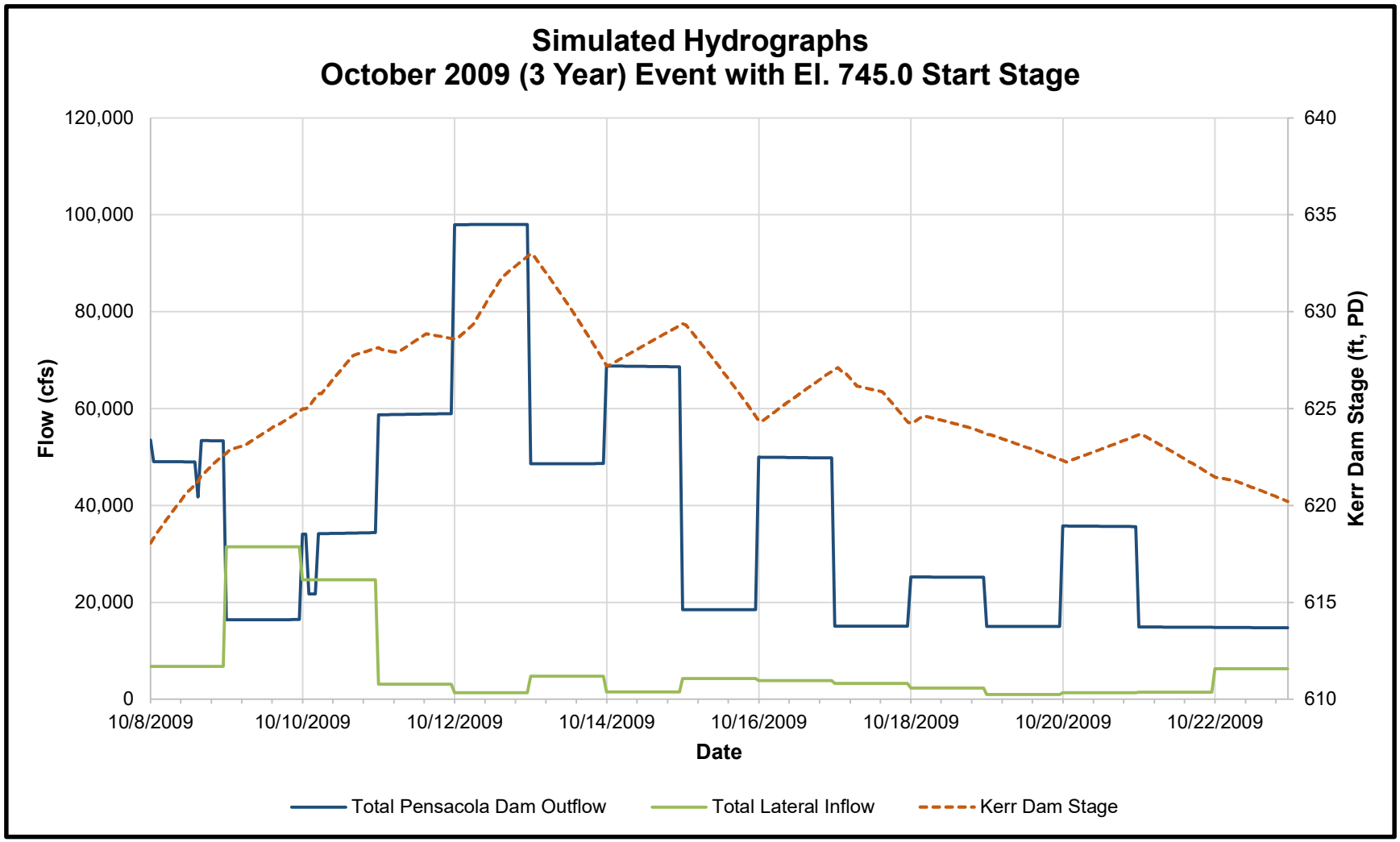


Figure A.44. Simulated hydrograph for the October 2009 (3 year) event with El. 745.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

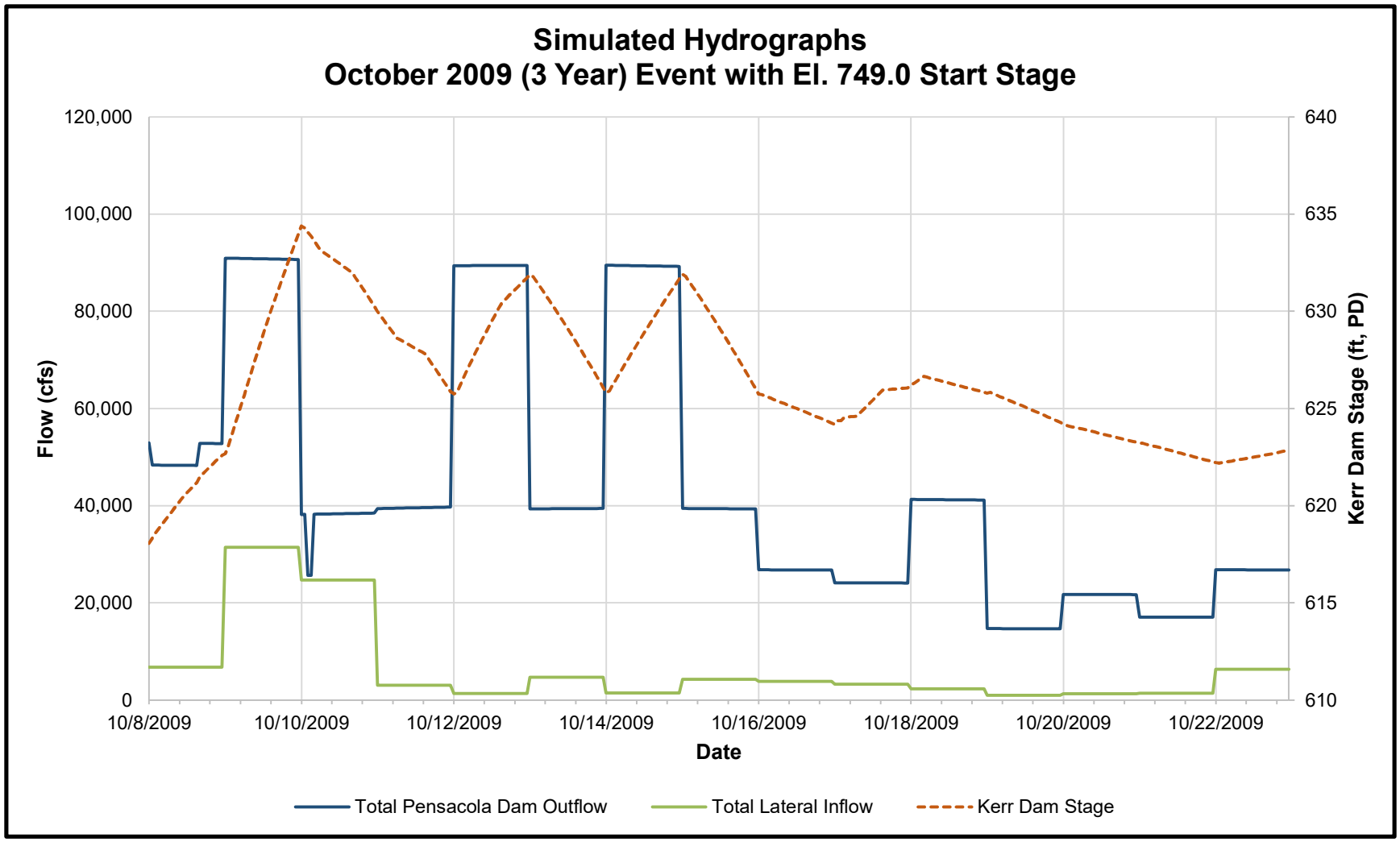


Figure A.45. Simulated hydrograph for the October 2009 (3 year) event with El. 749.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

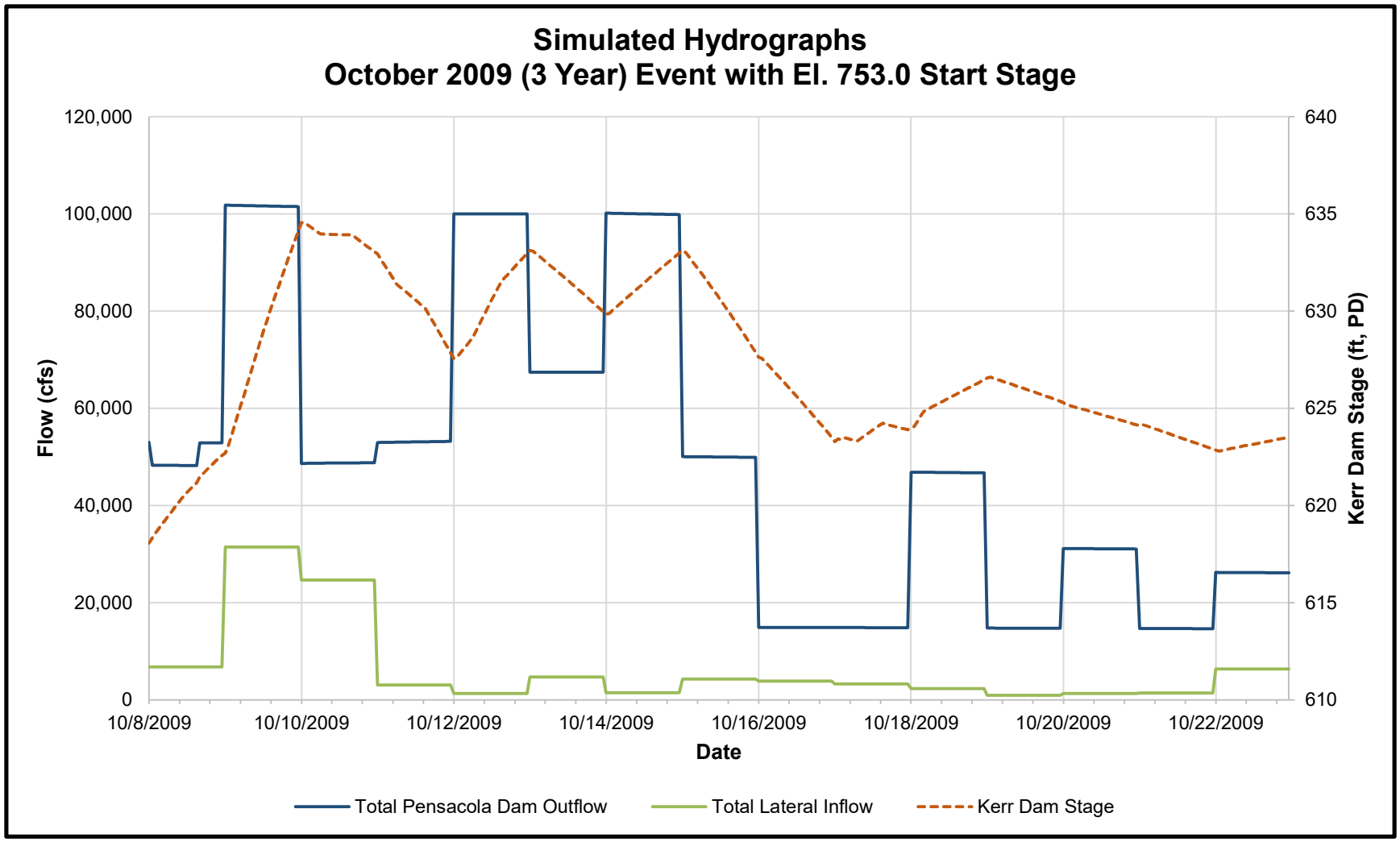


Figure A.46. Simulated hydrograph for the October 2009 (3 year) event with El. 753.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

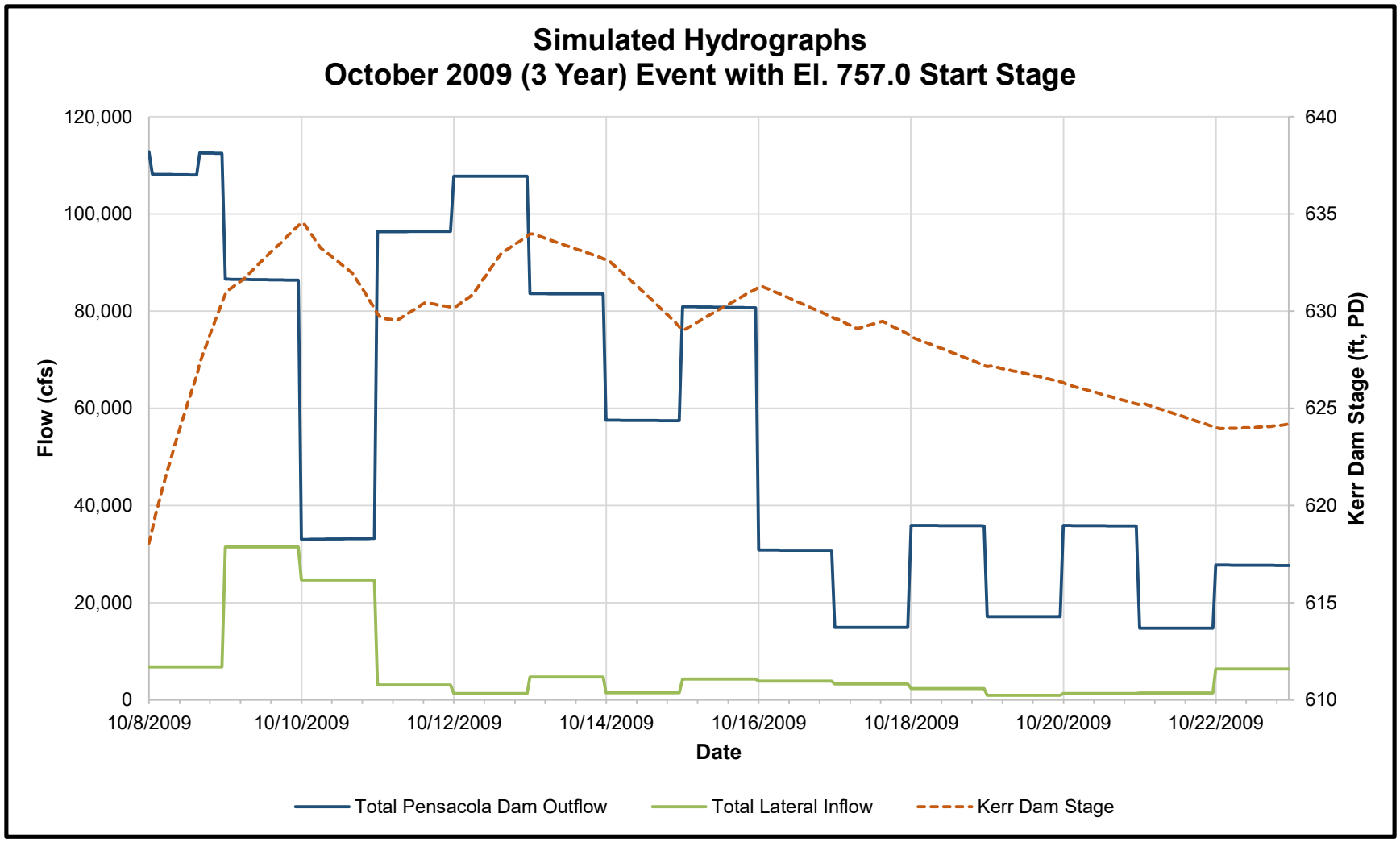


Figure A.47. Simulated hydrograph for the October 2009 (3 year) event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

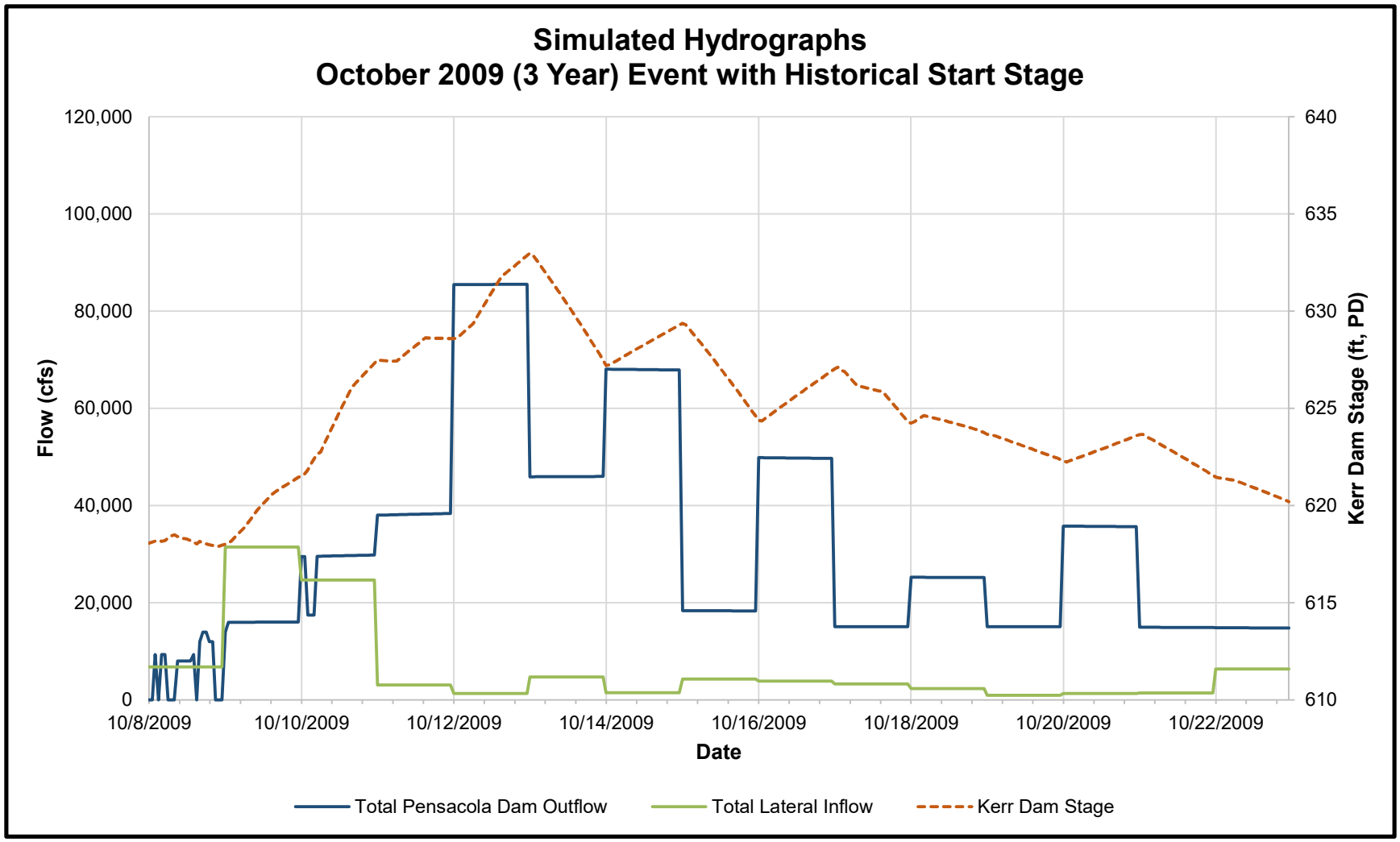


Figure A.48. Simulated hydrograph for the October 2009 (3 year) event with historical starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

APPENDIX A.5:
DECEMBER 2015 (15 YEAR) EVENT SIMULATED HYDROGRAPHS

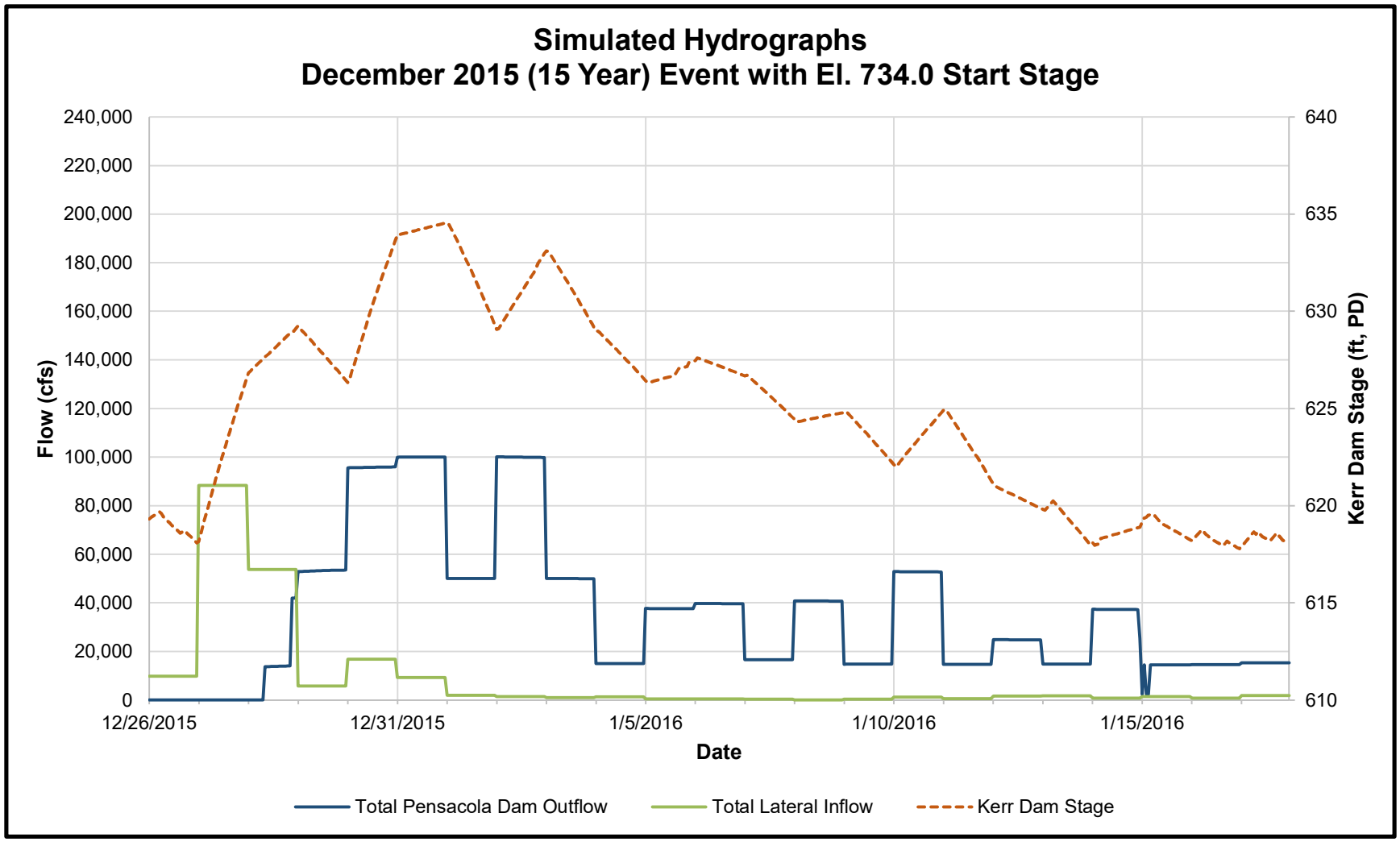


Figure A.49. Simulated hydrograph for the December 2015 (15 year) event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

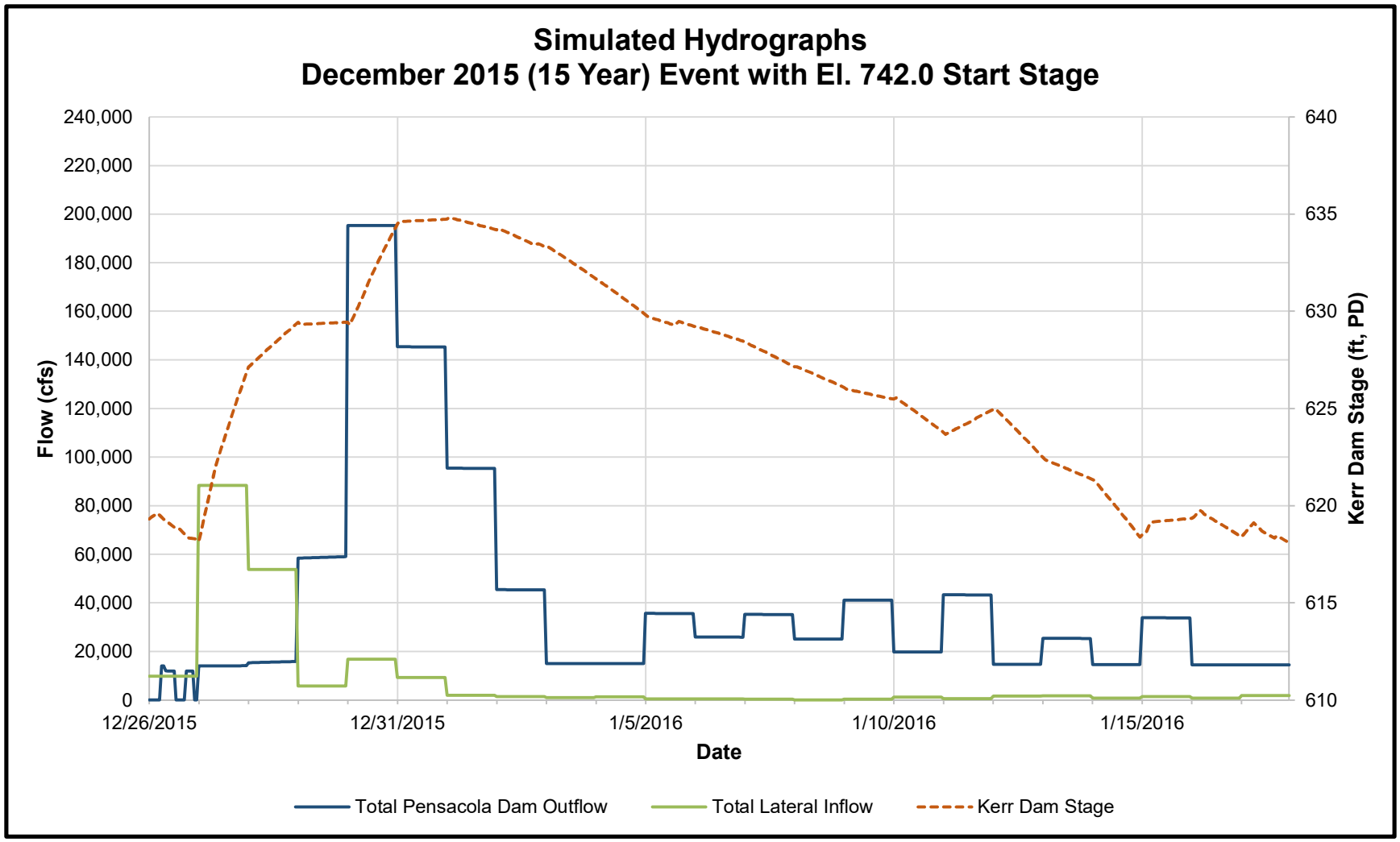


Figure A.50. Simulated hydrograph for the December 2015 (15 year) event with El. 742.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

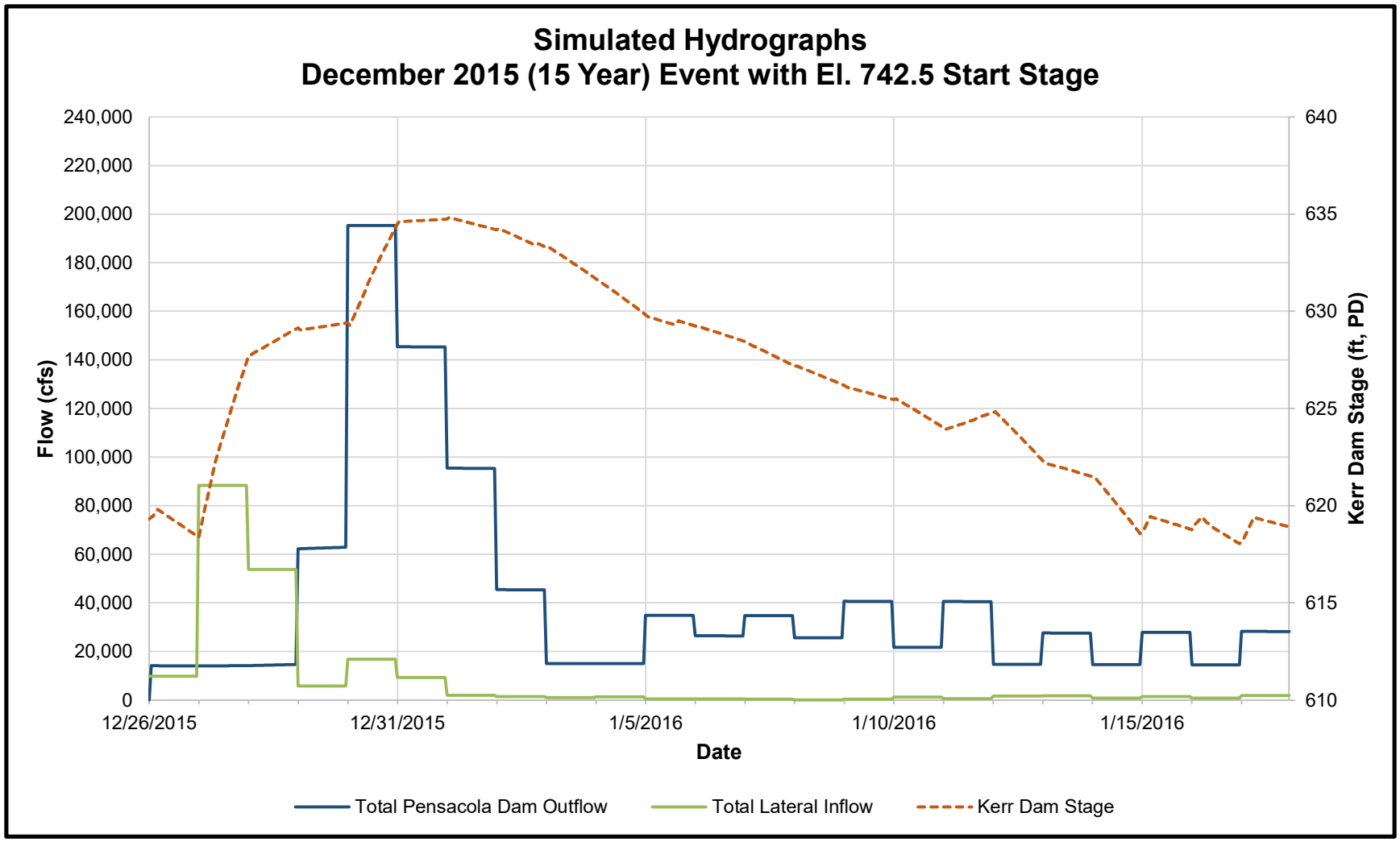


Figure A.51. Simulated hydrograph for the December 2015 (15 year) event with El. 742.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

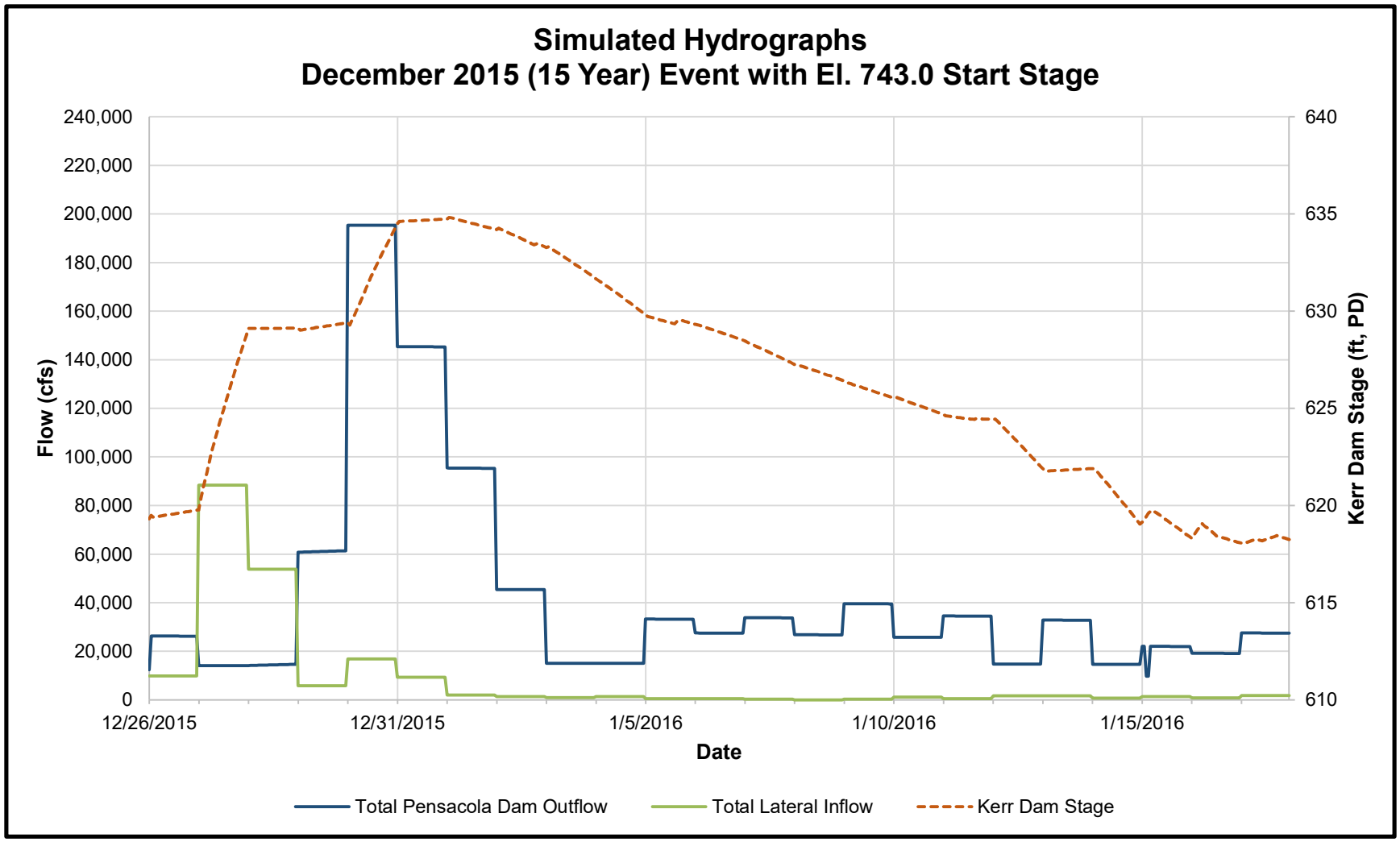


Figure A.52. Simulated hydrograph for the December 2015 (15 year) event with El. 743.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

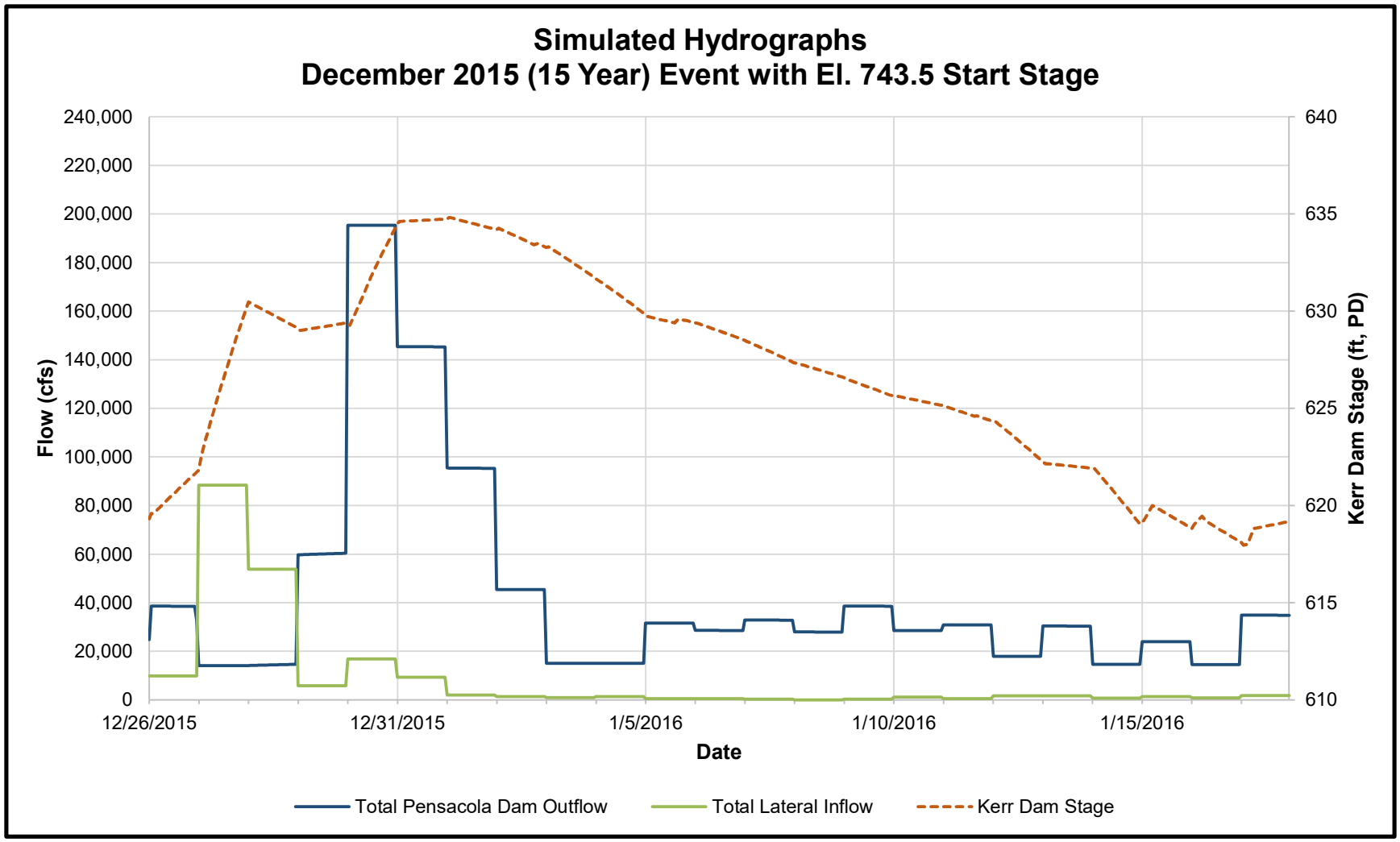


Figure A.53. Simulated hydrograph for the December 2015 (15 year) event with El. 743.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

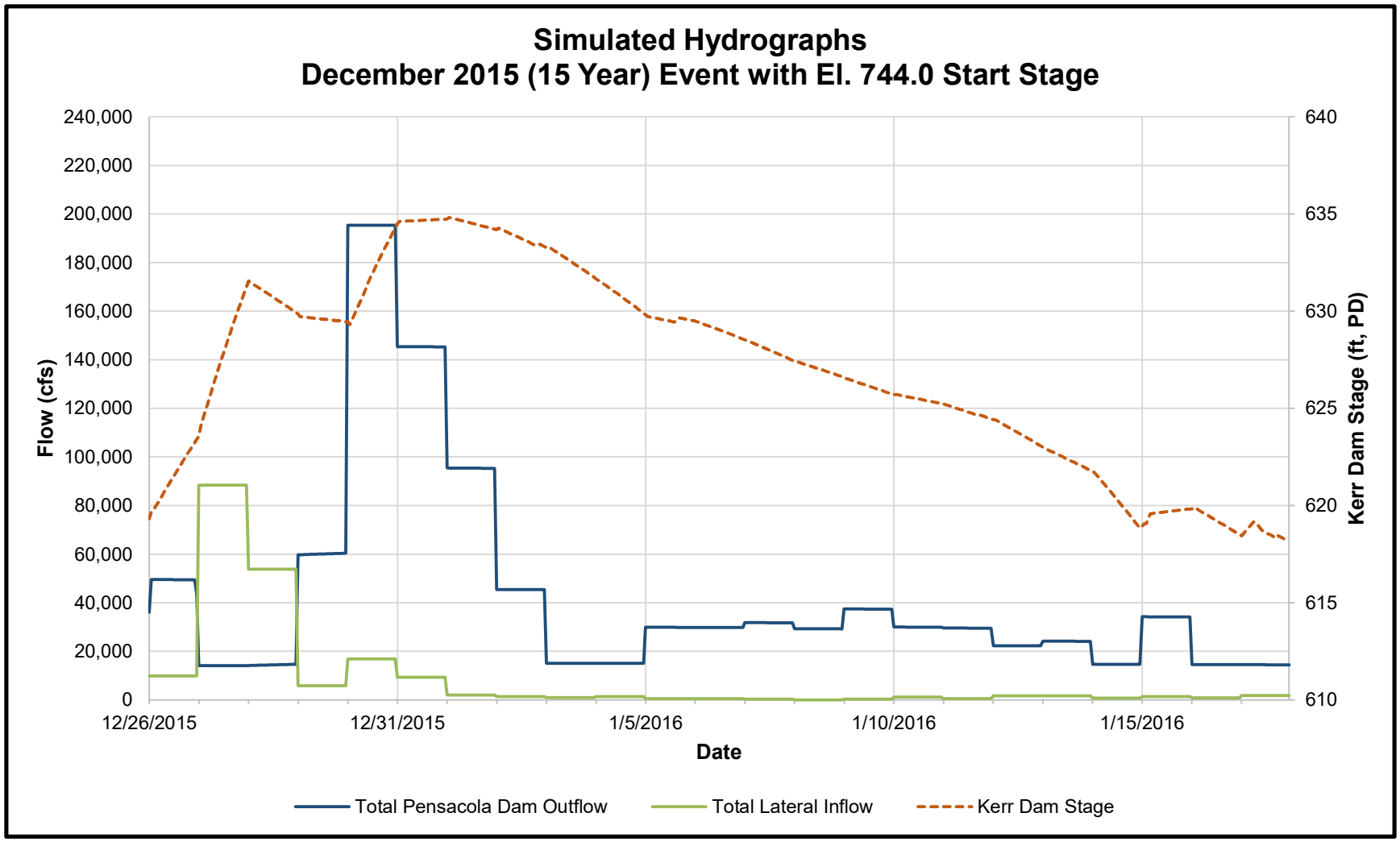


Figure A.54. Simulated hydrograph for the December 2015 (15 year) event with El. 744.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

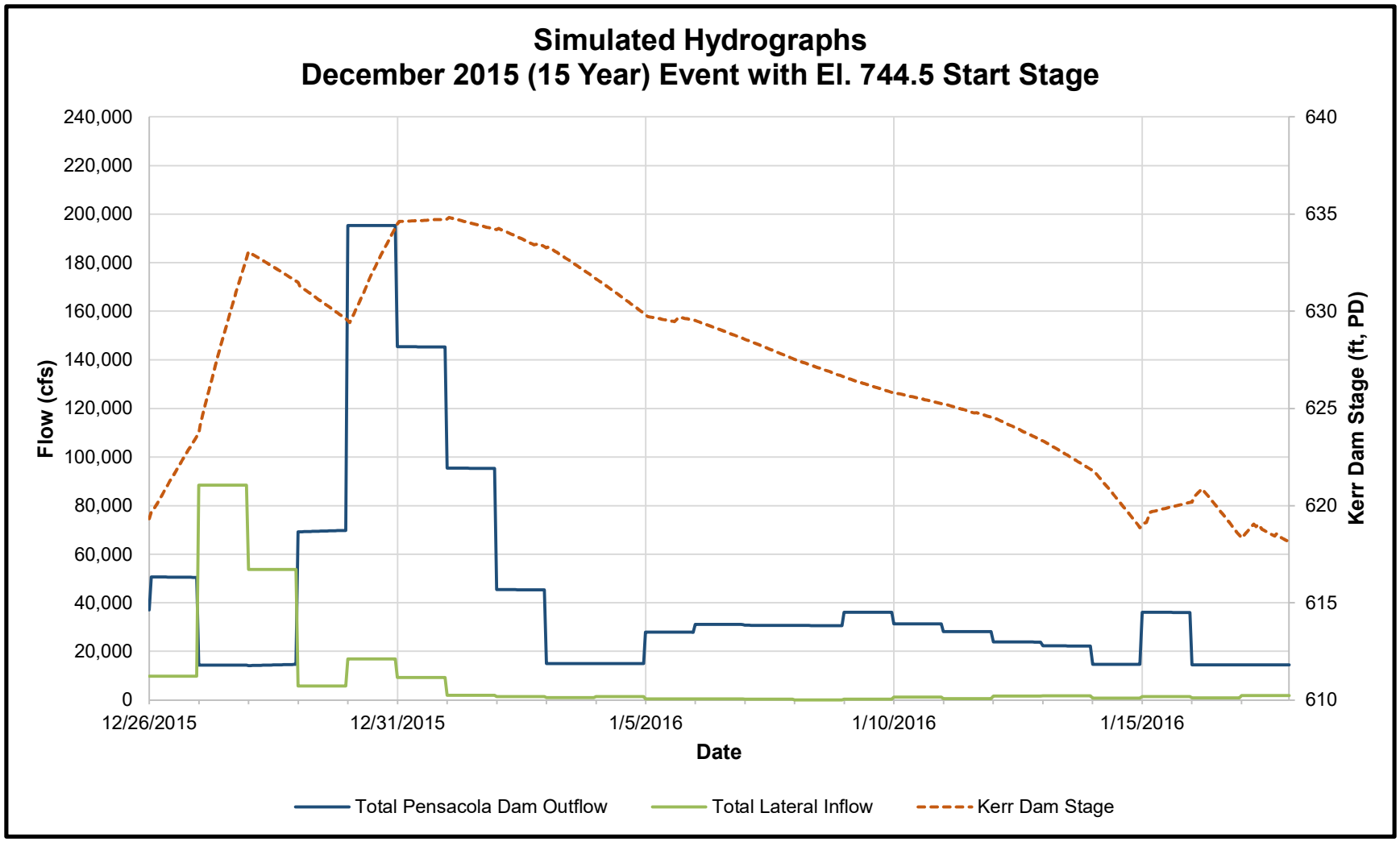


Figure A.55. Simulated hydrograph for the December 2015 (15 year) event with El. 744.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

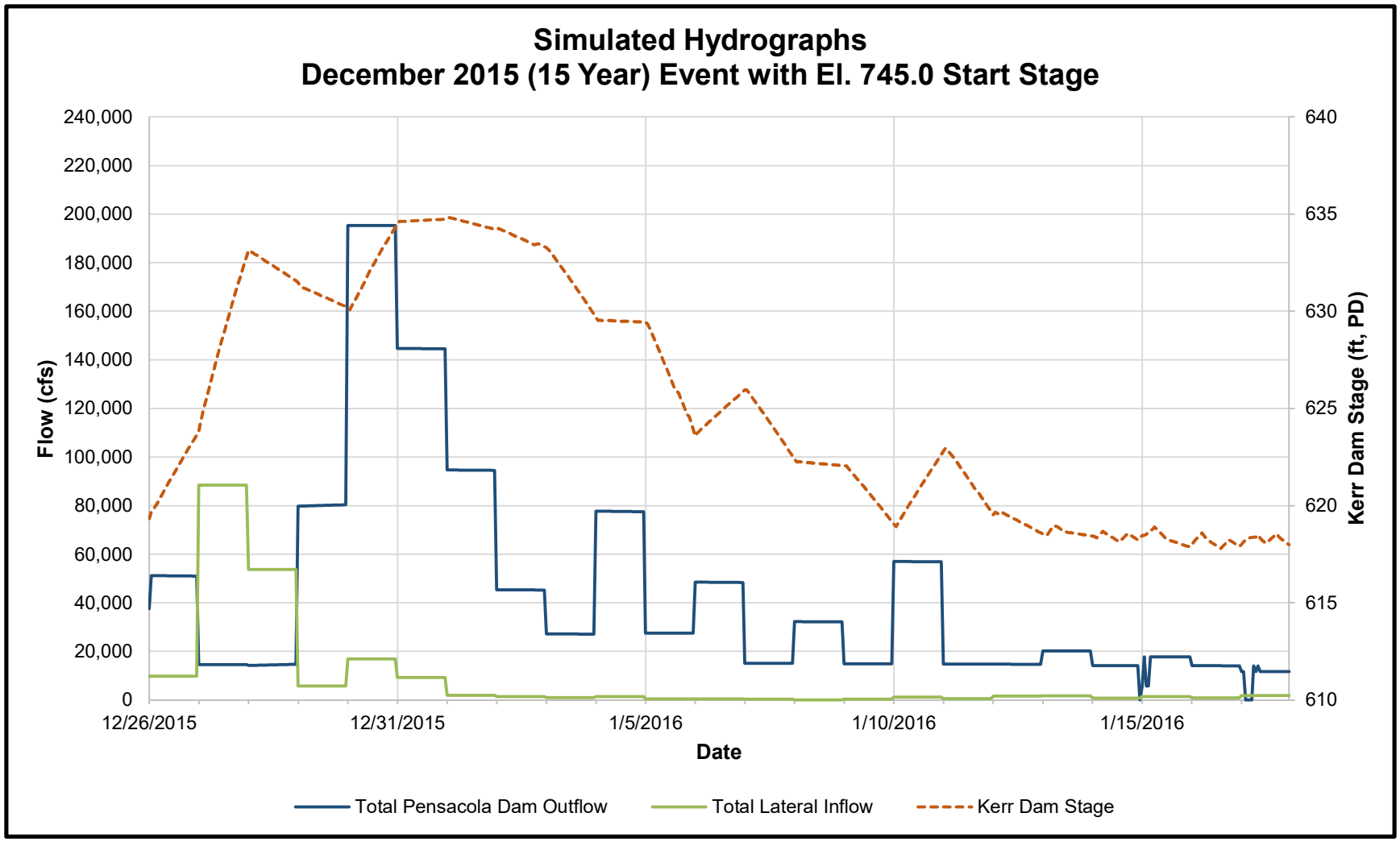


Figure A.56. Simulated hydrograph for the December 2015 (15 year) event with El. 745.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

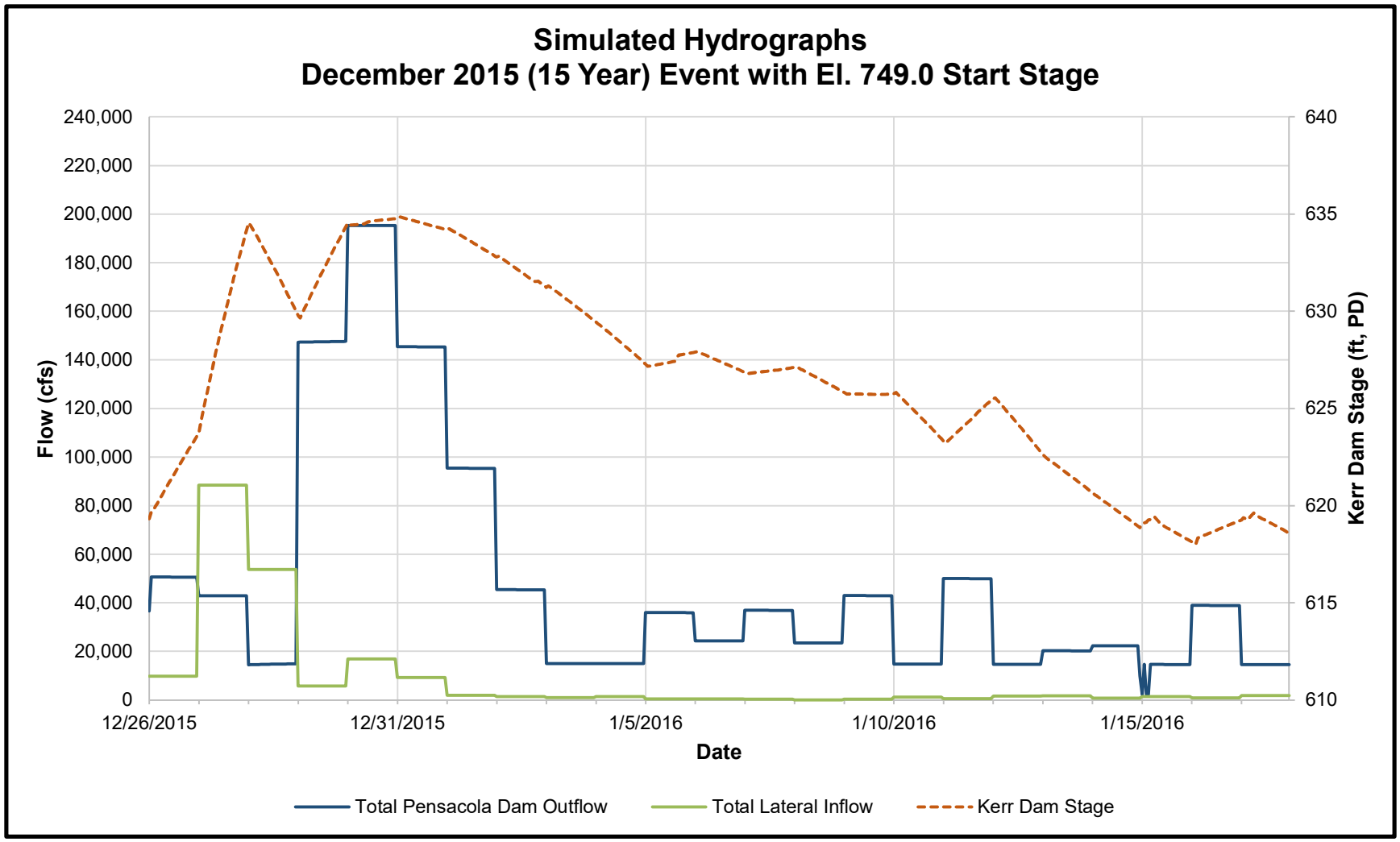


Figure A.57. Simulated hydrograph for the December 2015 (15 year) event with El. 749.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

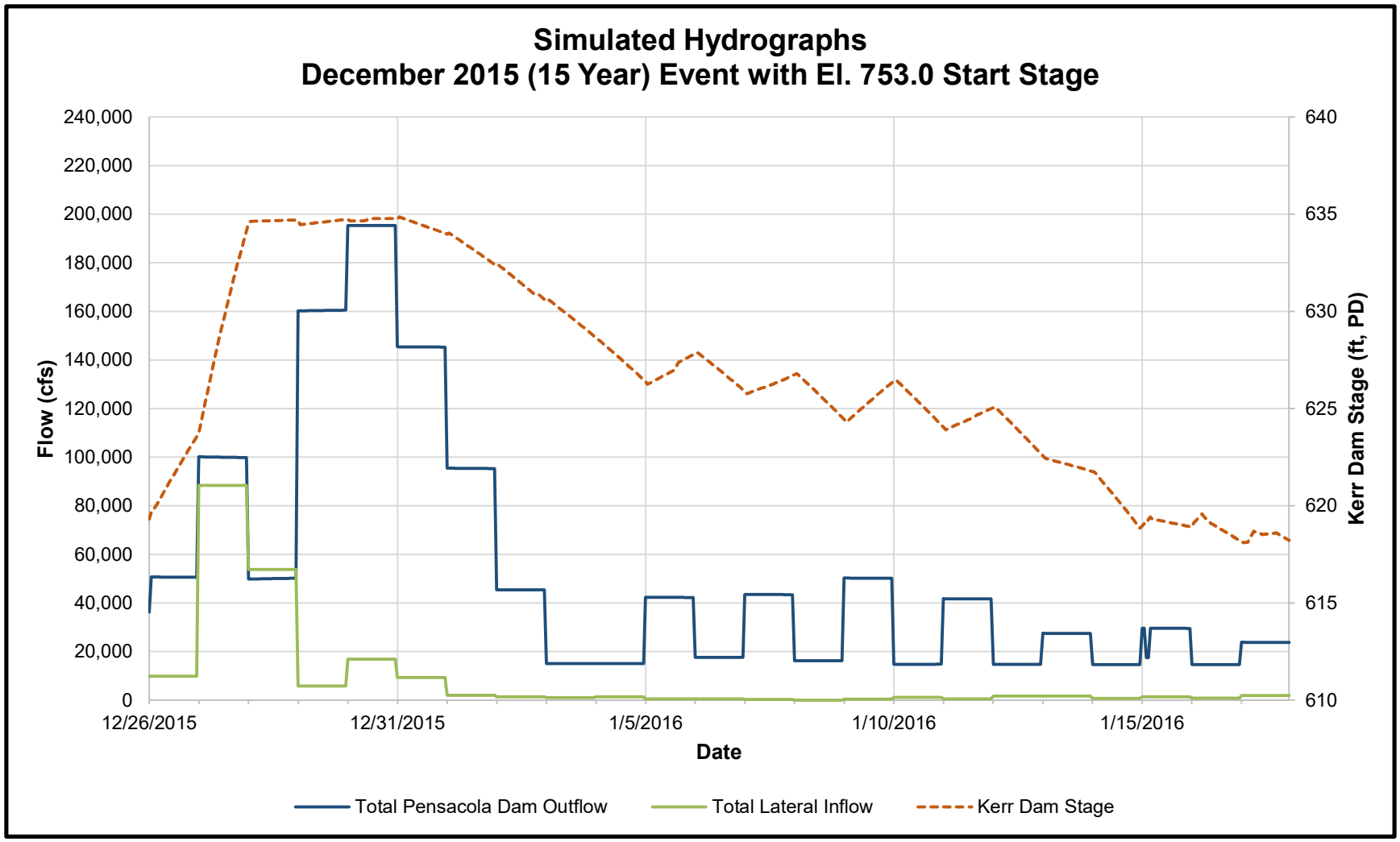


Figure A.58. Simulated hydrograph for the December 2015 (15 year) event with El. 753.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

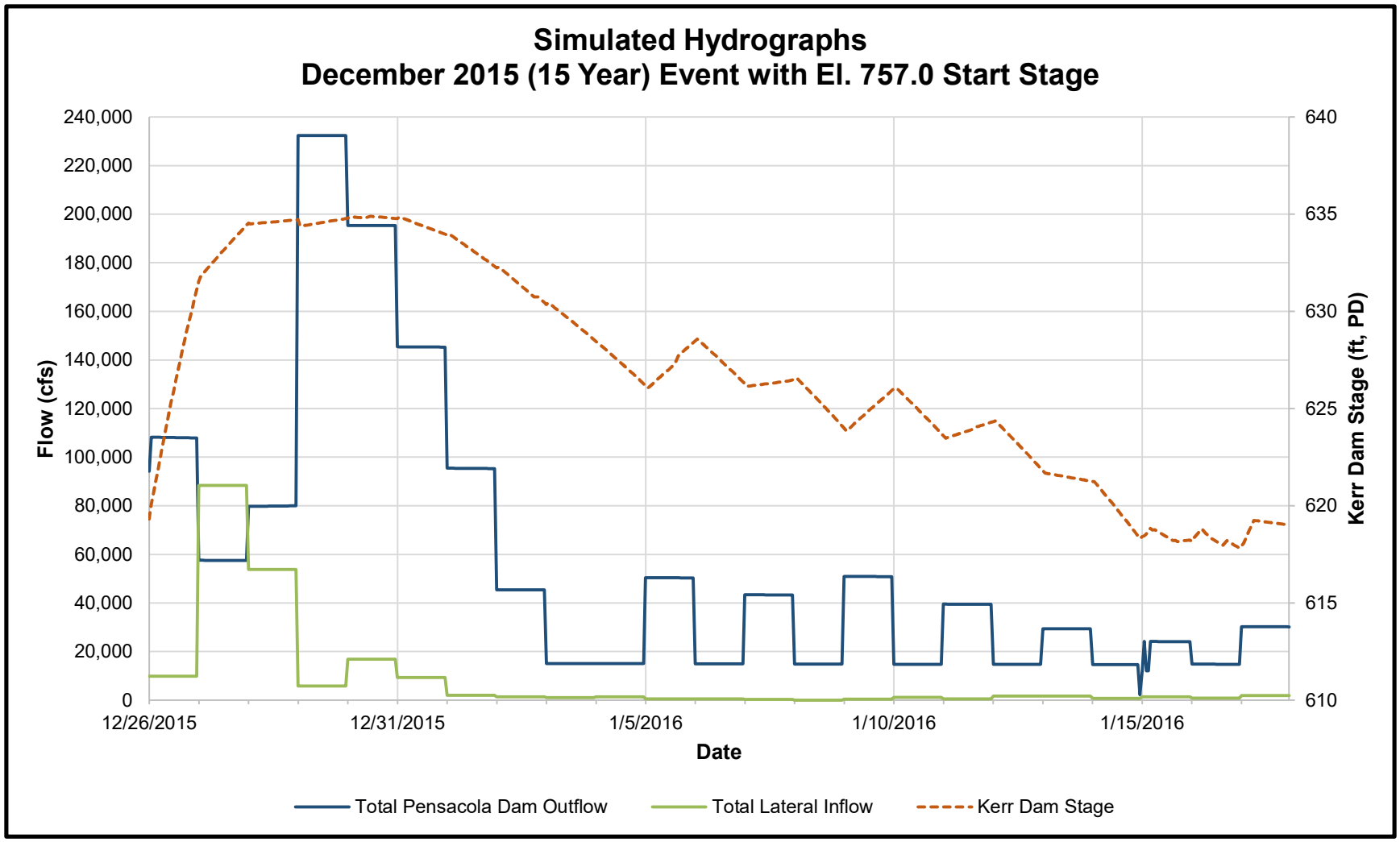


Figure A.59. Simulated hydrograph for the December 2015 (15 year) event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

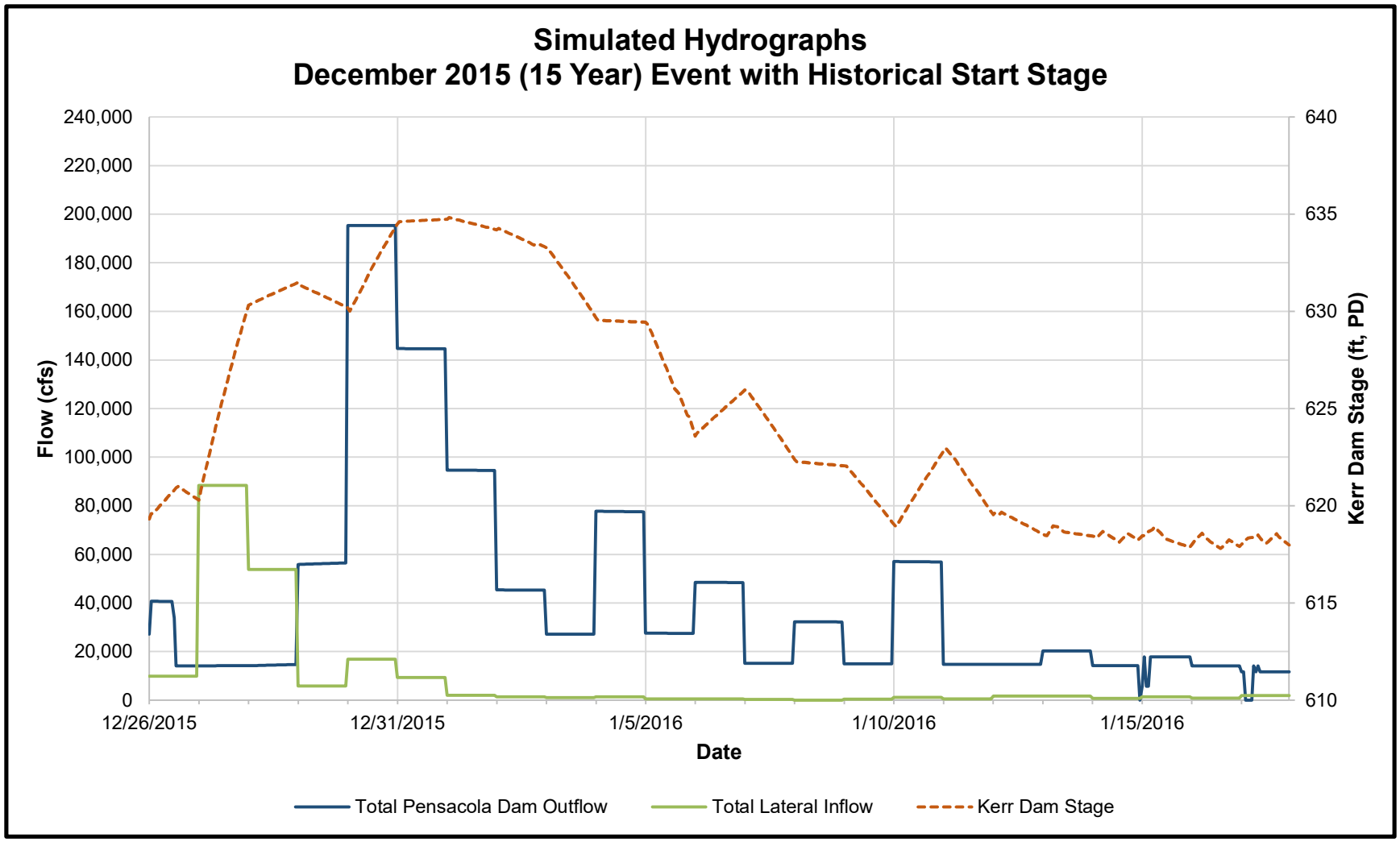


Figure A.60. Simulated hydrograph for the December 2015 (15 year) event with historical starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

APPENDIX A.6:
100-YEAR EVENT SIMULATED HYDROGRAPHS

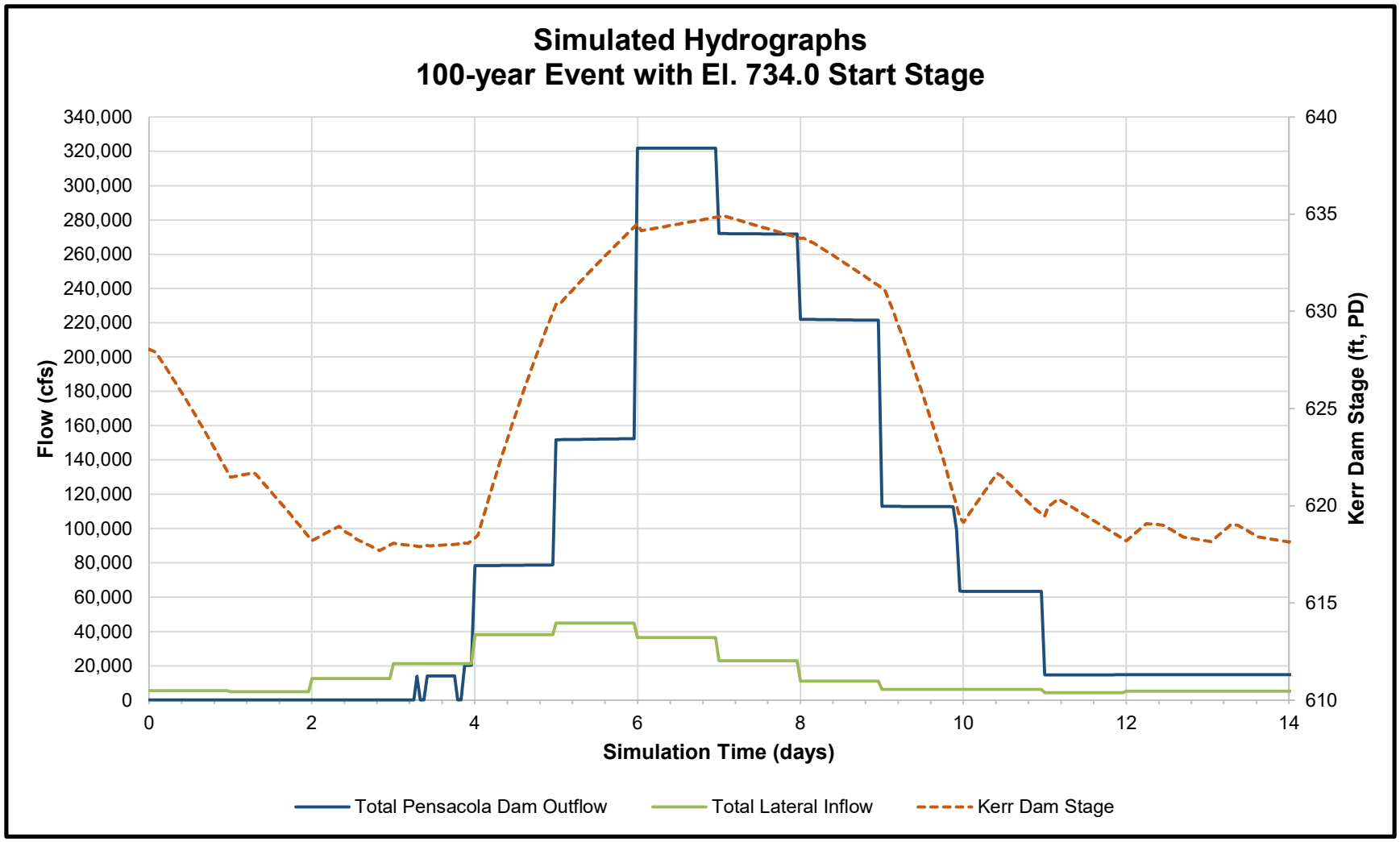


Figure A.61. Simulated hydrograph for the 100-year event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

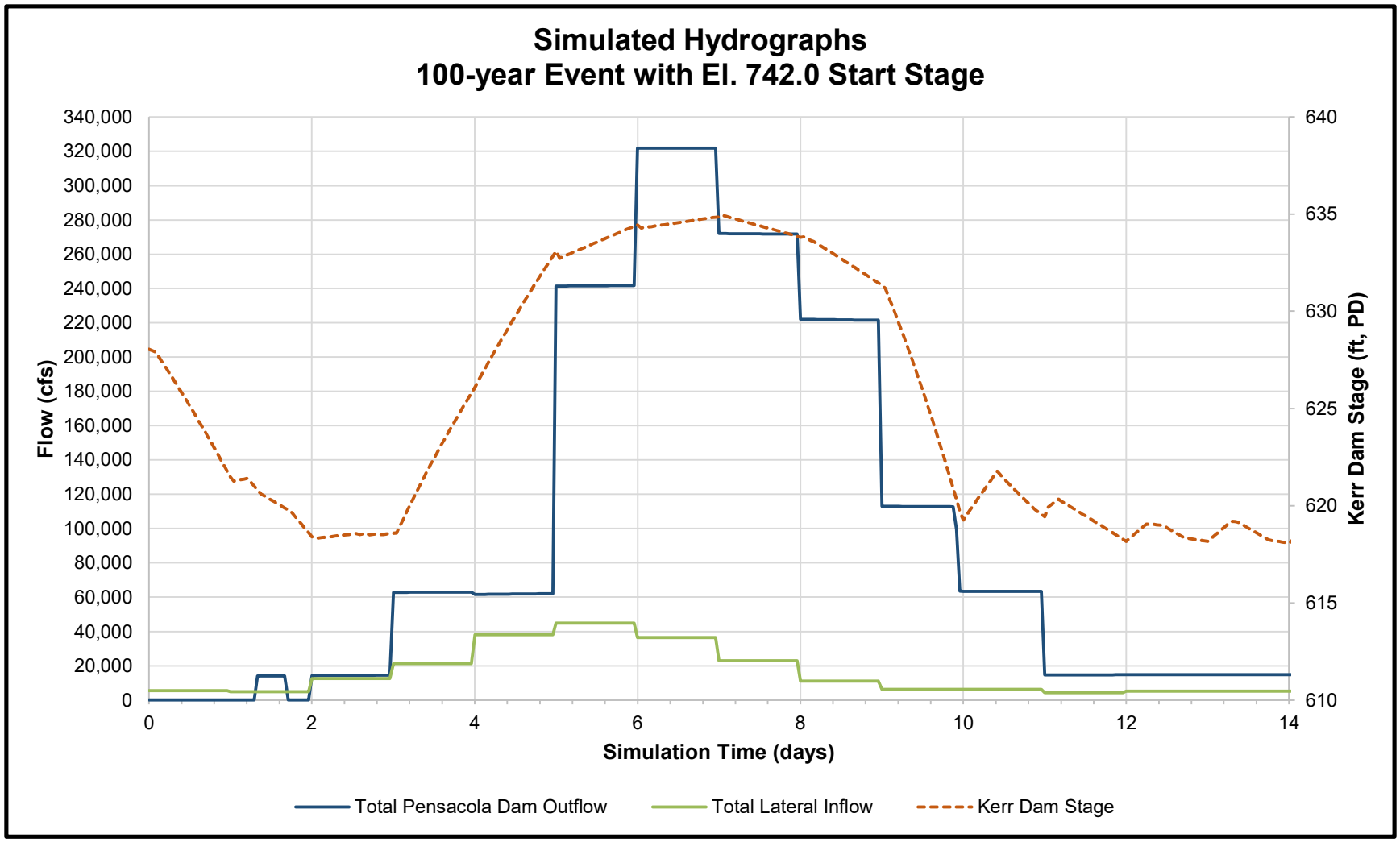


Figure A.62. Simulated hydrograph for the 100-year event with El. 742.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

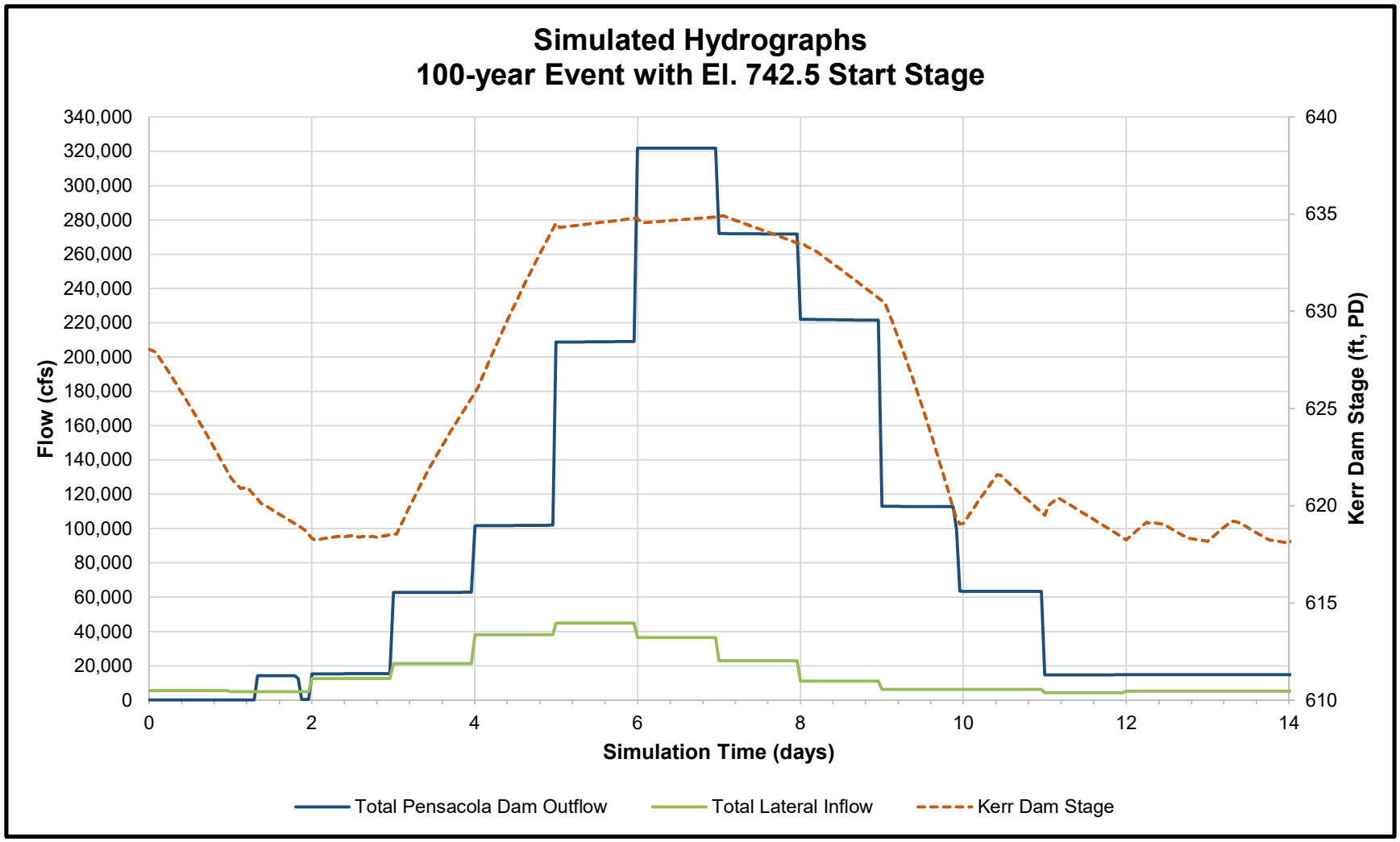


Figure A.63. Simulated hydrograph for the 100-year event with El. 742.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

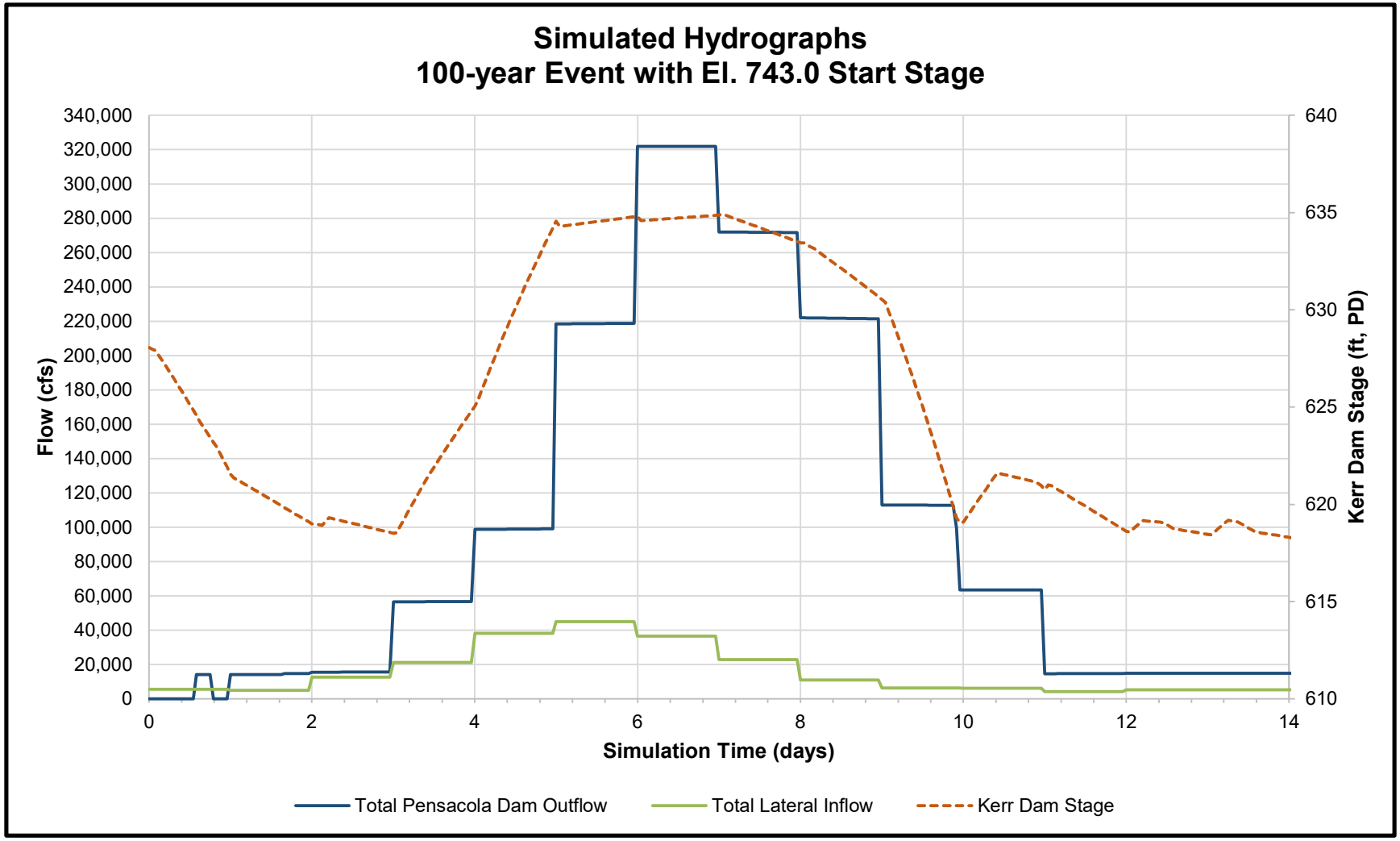


Figure A.64. Simulated hydrograph for the 100-year event with El. 743.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

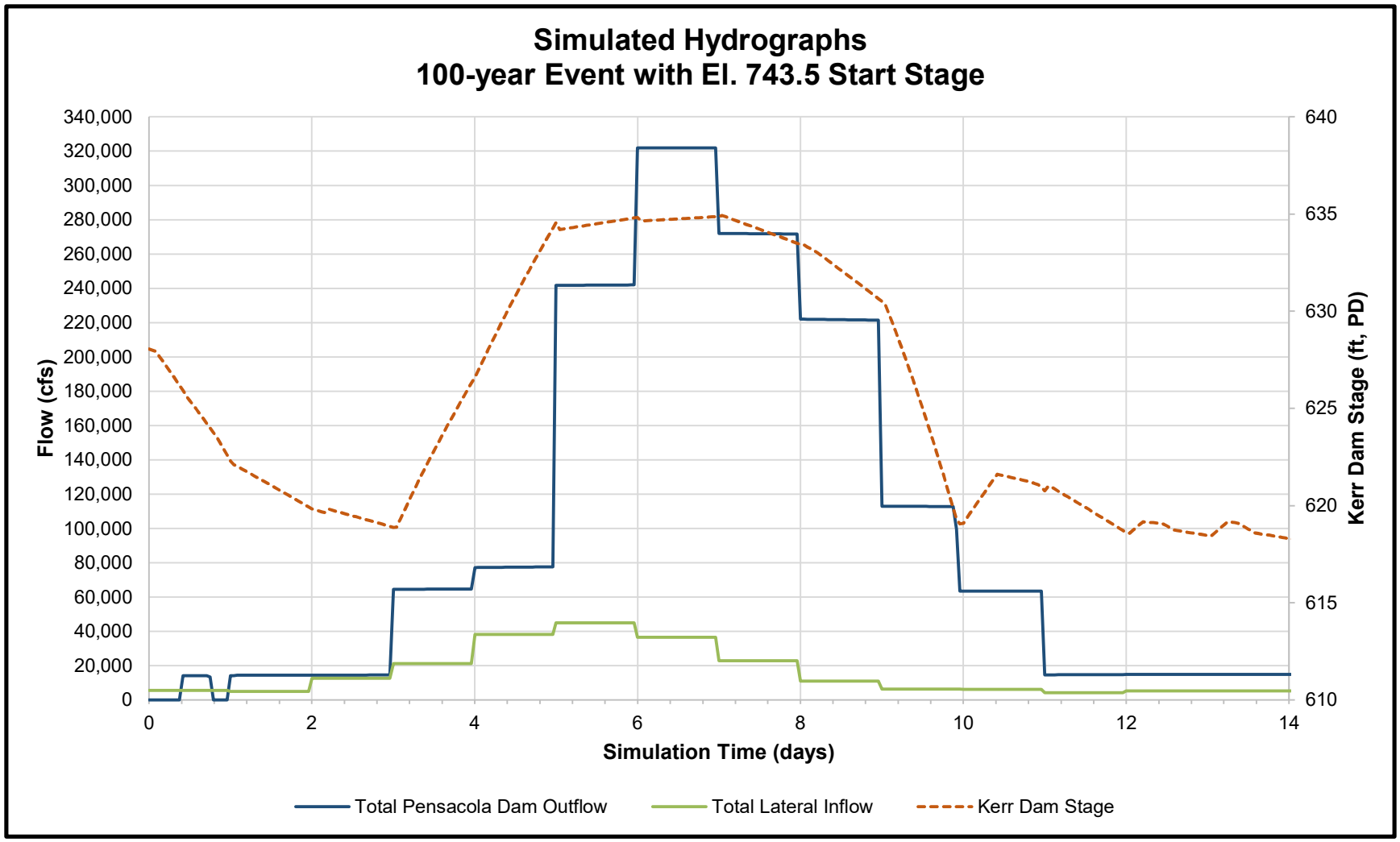


Figure A.65. Simulated hydrograph for the 100-year event with El. 743.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

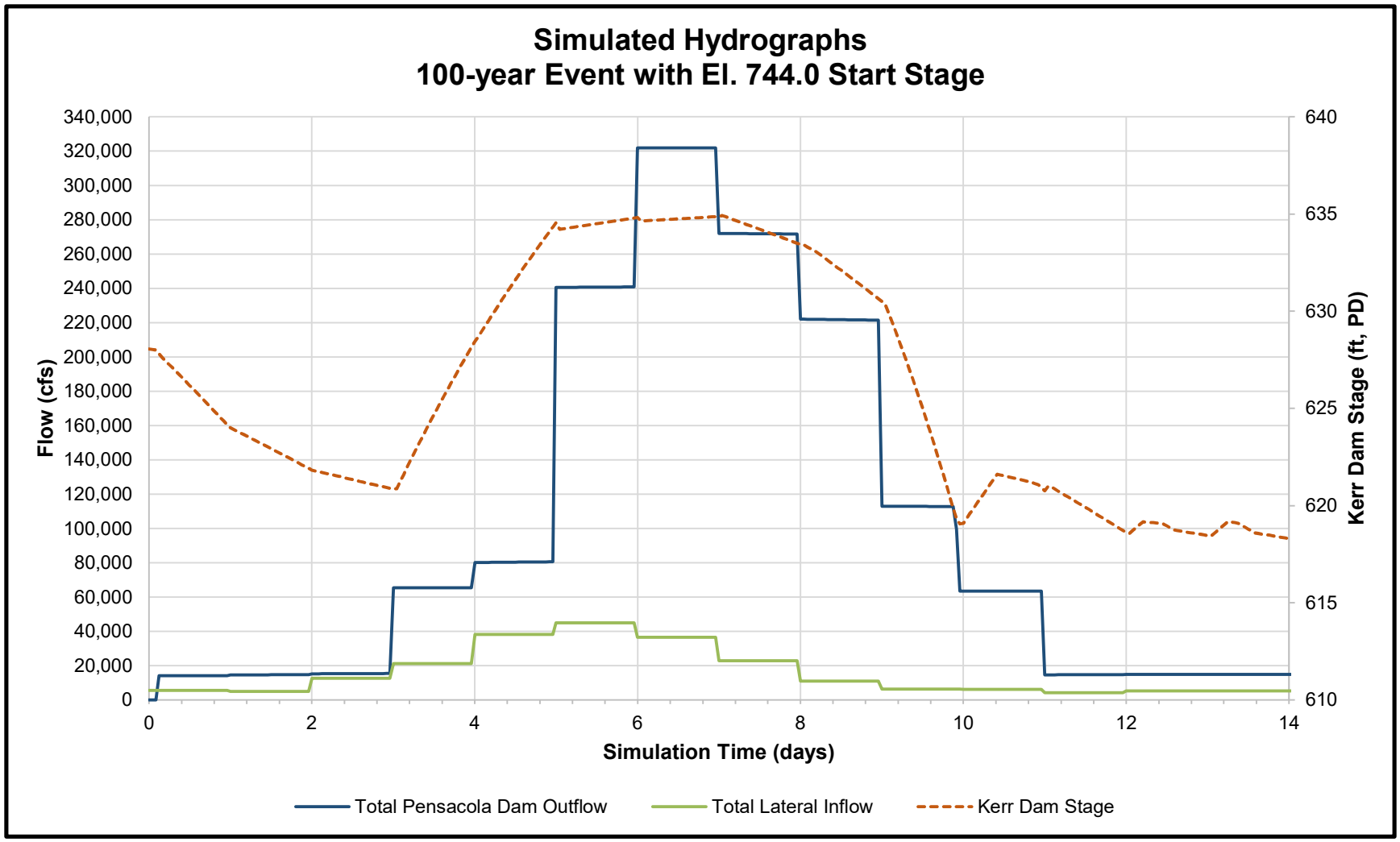


Figure A.66. Simulated hydrograph for the 100-year event with El. 744.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

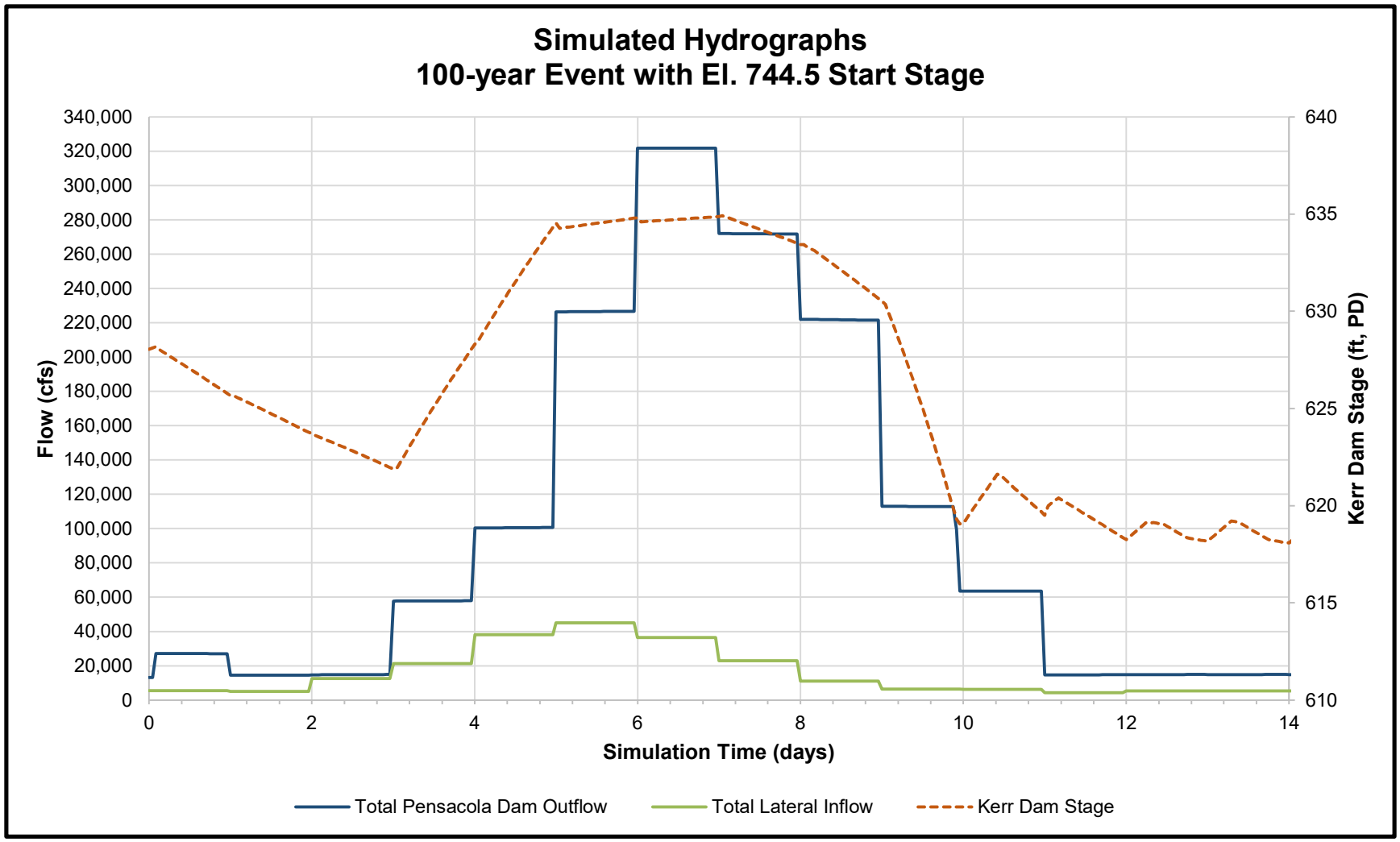


Figure A.67. Simulated hydrograph for the 100-year event with El. 744.5 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

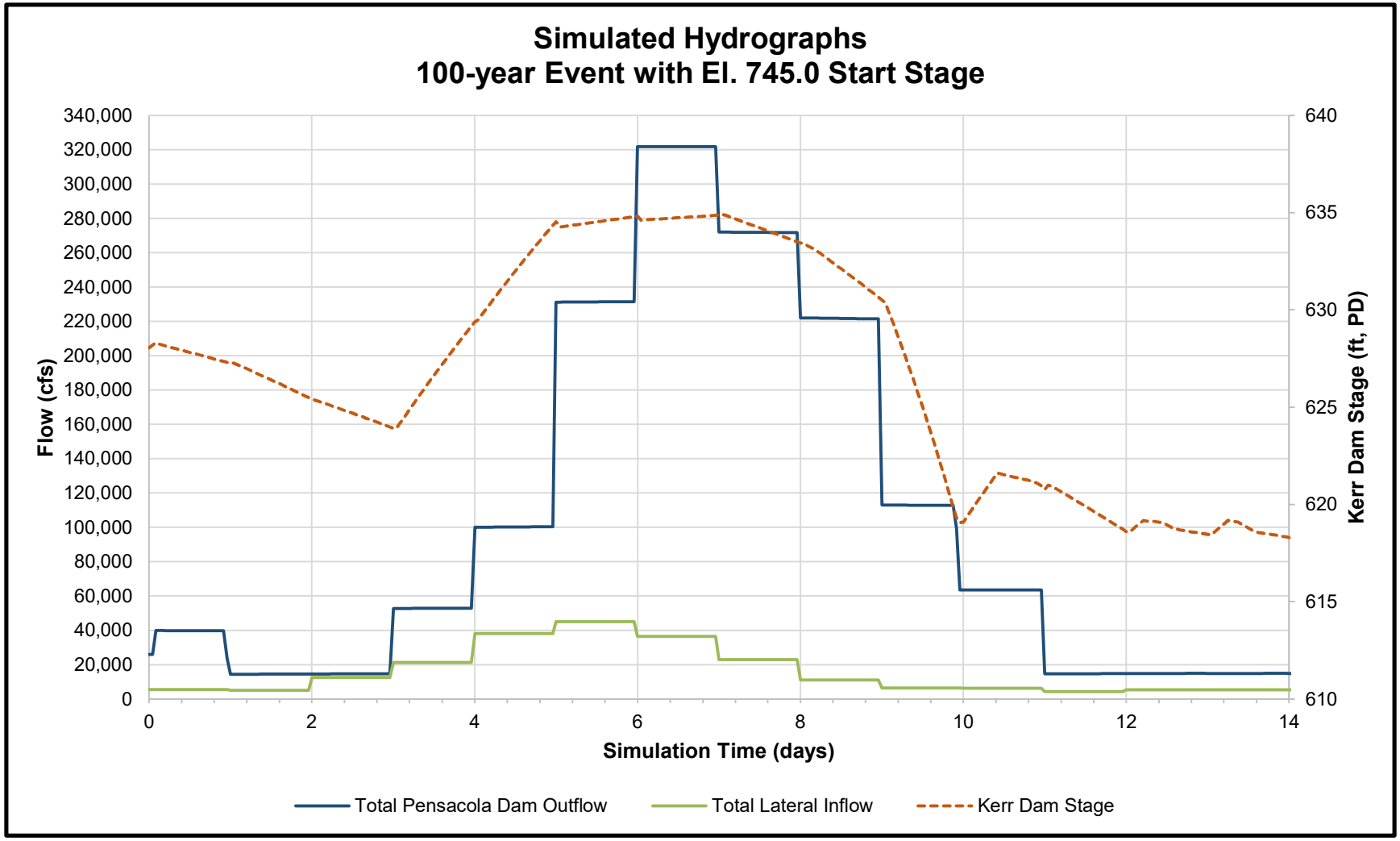


Figure A.68. Simulated hydrograph for the 100-year event with El. 745.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

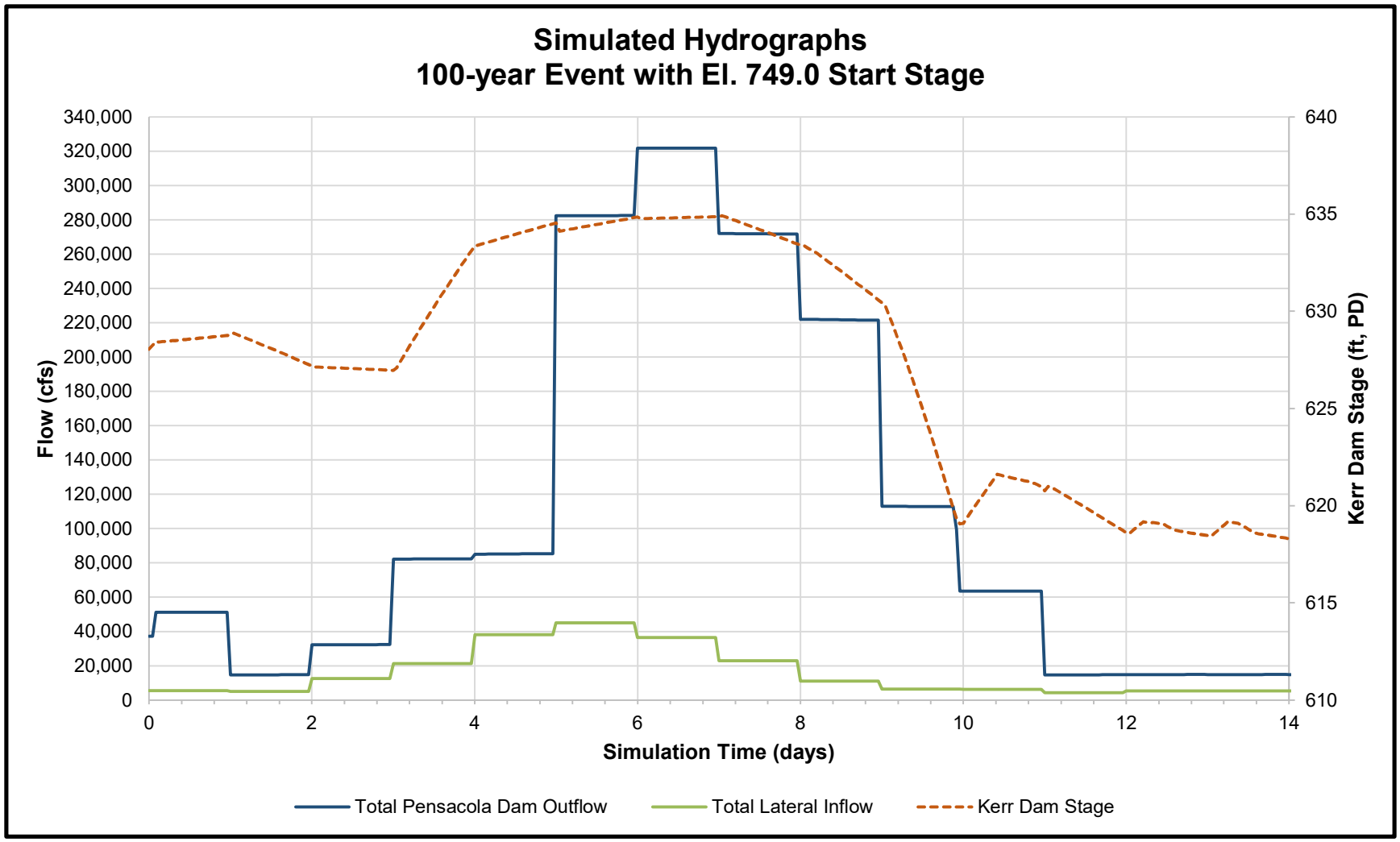


Figure A.69. Simulated hydrograph for the 100-year event with El. 749.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

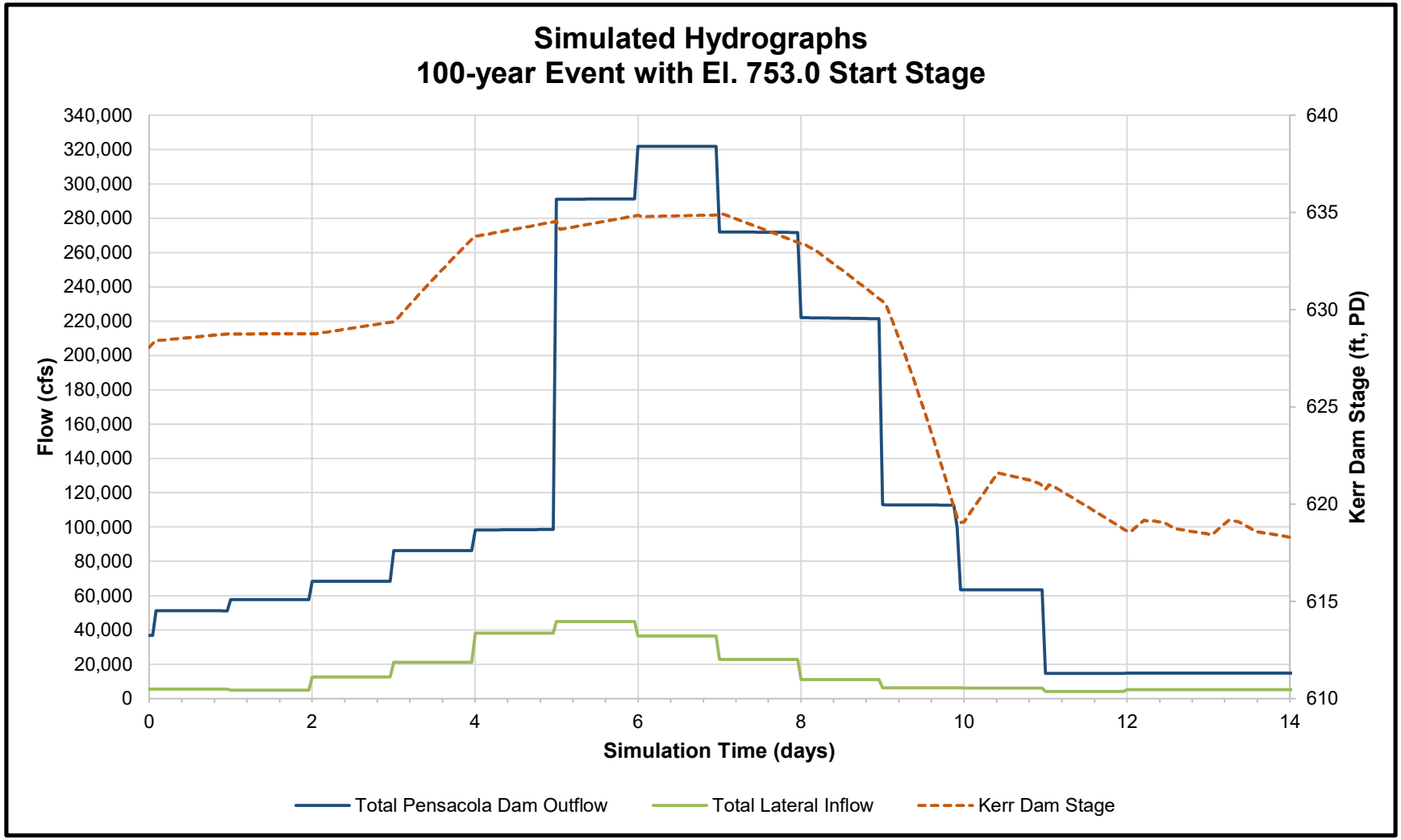


Figure A.70. Simulated hydrograph for the 100-year event with El. 753.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.

2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

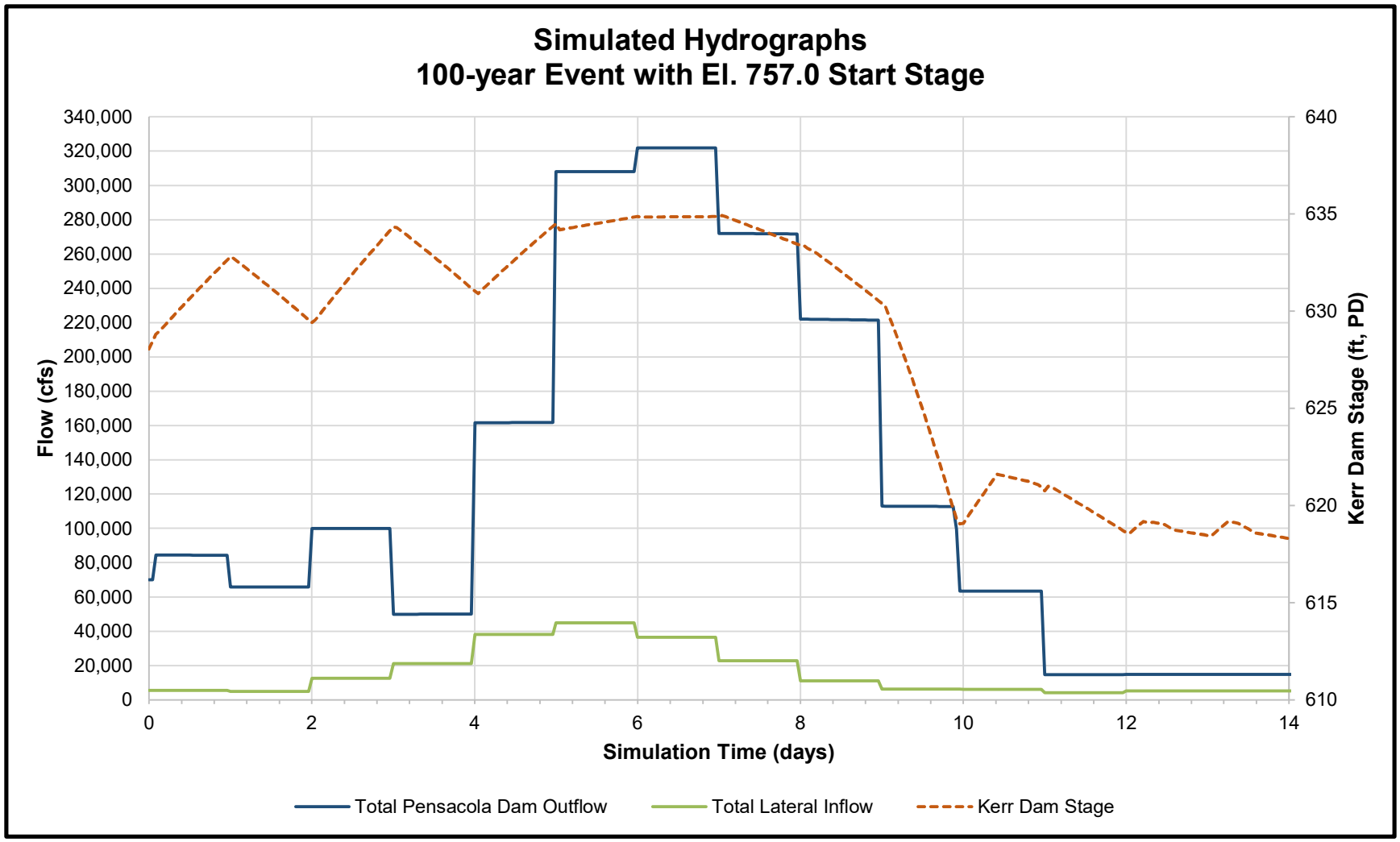
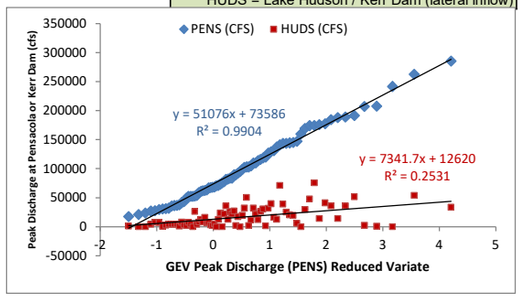


Figure A.71. Simulated hydrograph for the 100-year event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

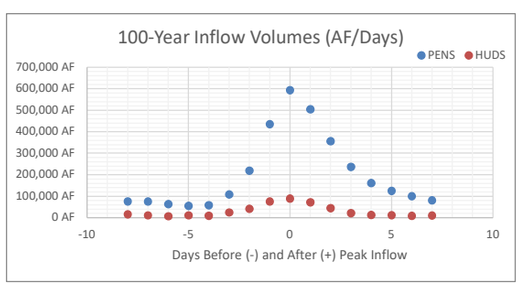
APPENDIX B:
HISTORICAL INFLOW VOLUME STATISTICAL ANALYSIS

PENS = Pensacola Dam / Grand Lake (total inflow)
HUDS = Lake Hudson / Kerr Dam (lateral inflow)

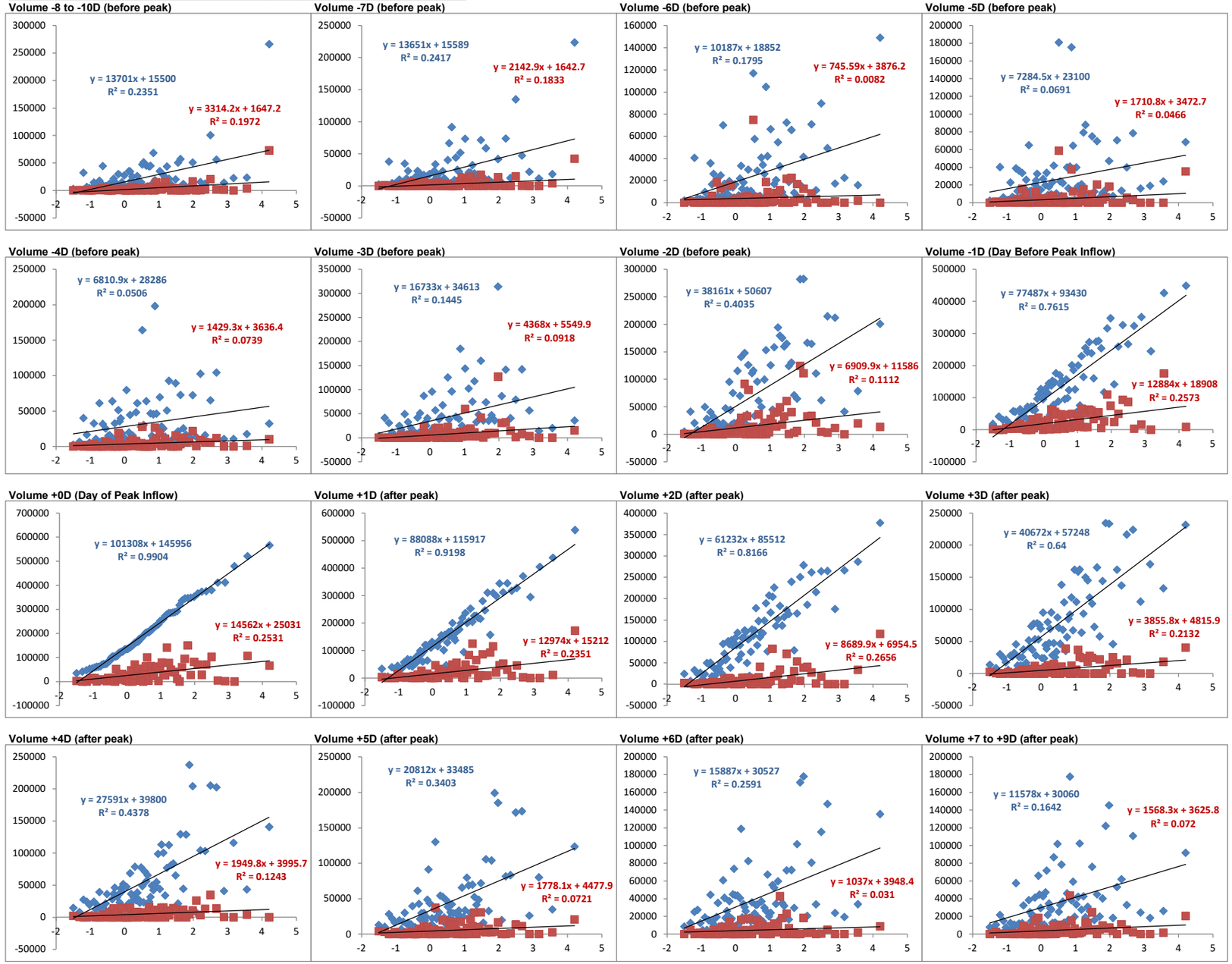


reduced variate for 100-year event, y = 4.41

	scale, σ (m)	location, μ (b)	100-year
PENS (CFS)	51076	73586	299,000 cfs
HUDS (CFS)	7342	12620	45,021 cfs
PENS D–8 to –10 (AF)	13701	15500	75,966 AF
PENS D–7 (AF)	13651	15589	75,835 AF
PENS D–6 (AF)	10187	18852	63,810 AF
PENS D–5 (AF)	7285	23100	55,249 AF
PENS D–4 (AF)	6811	28286	58,344 AF
PENS D–3 (AF)	16733	34613	108,461 AF
PENS D–2 (AF)	38161	50607	219,023 AF
PENS D–1 (AF)	77487	93430	435,403 AF
PENS D+0 (AF)	101308	145956	593,058 AF
PENS D+1 (AF)	88088	115917	504,675 AF
PENS D+2 (AF)	61232	85512	355,747 AF
PENS D+3 (AF)	40672	57248	236,745 AF
PENS D+4 (AF)	27591	39800	161,567 AF
PENS D+5 (AF)	20812	33485	125,334 AF
PENS D+6 (AF)	15887	30527	100,641 AF
PENS D+7 to +9 (AF)	11578	30060	81,157 AF
HUDS D–8 to –10 (AF)	3314	1647	16,274 AF
HUDS D–7 (AF)	2143	1643	11,100 AF
HUDS D–6 (AF)	746	3876	7,167 AF
HUDS D–5 (AF)	1711	3473	11,023 AF
HUDS D–4 (AF)	1429	3636	9,944 AF
HUDS D–3 (AF)	4368	5550	24,827 AF
HUDS D–2 (AF)	6910	11586	42,081 AF
HUDS D–1 (AF)	12884	18908	75,769 AF
HUDS D+0 (AF)	14562	25031	89,297 AF
HUDS D+1 (AF)	12974	15212	72,470 AF
HUDS D+2 (AF)	8690	6955	45,306 AF
HUDS D+3 (AF)	3856	4816	21,833 AF
HUDS D+4 (AF)	1950	3996	12,601 AF
HUDS D+5 (AF)	1778	4478	12,325 AF
HUDS D+6 (AF)	1037	3948	8,525 AF
HUDS D+7 to +9 (AF)	1568	3626	10,547 AF



Average Daily Volume (AF) vs GEV Peak Discharge (PENS) Reduced Variate Correlation Plots



APPENDIX C:
MAX WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE C.1**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - SEPTEMBER 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
77.000	Pensacola Dam													
76.880	608.88	642.40	645.76	645.76	645.88	646.72	647.53	648.30	649.20	650.09	650.27	652.40	3.44	10.00
76.463	607.35	642.36	645.72	645.72	645.83	646.67	647.47	648.24	649.14	650.04	650.21	652.33	3.42	9.97
76.414	N 4475 Rd. Bridge													
76.362	607.61	642.34	645.69	645.69	645.80	646.64	647.45	648.21	649.11	650.01	650.18	652.29	3.42	9.95
75.317	606.30	641.56	644.90	644.90	645.01	645.81	646.58	647.31	648.16	649.03	649.17	651.19	3.26	9.63
74.300	605.42	639.88	643.24	643.24	643.34	644.08	644.80	645.47	646.24	647.11	647.17	649.10	3.00	9.22
73.315	600.08	638.77	642.14	642.14	642.23	642.91	643.58	644.21	644.93	645.81	645.82	647.64	2.79	8.87
72.884	606.92	637.93	641.46	641.46	641.55	642.21	642.85	643.45	644.12	645.14	645.15	646.90	2.66	8.97
72.822	OK-82 Bridge													
72.772	604.91	637.67	641.15	641.15	641.23	641.84	642.44	643.01	643.81	644.68	644.70	646.17	2.66	8.50
71.645	603.05	636.74	640.41	640.41	640.49	641.09	641.68	642.24	642.92	643.80	643.81	645.30	2.51	8.56
70.910	601.50	635.36	639.08	639.08	639.14	639.65	640.17	640.69	641.36	642.34	642.36	643.77	2.28	8.41
69.686	599.92	634.18	638.24	638.24	638.30	638.75	639.22	639.71	640.34	641.37	641.39	642.69	2.10	8.51
68.685	597.81	633.10	637.27	637.27	637.32	637.68	638.06	638.45	638.97	639.99	640.02	640.99	1.70	7.89
67.715	594.14	632.57	636.59	636.60	636.63	636.91	637.21	637.53	637.96	638.97	639.00	639.70	1.37	7.13
66.855	592.57	632.16	636.15	636.15	636.18	636.40	636.65	636.91	637.27	638.25	638.29	638.76	1.12	6.60
66.780	Big Cabin Creek													
65.712	590.99	631.85	635.76	635.76	635.78	635.95	636.13	636.34	636.62	637.56	637.59	637.84	0.86	5.99
64.435	588.21	631.44	635.31	635.31	635.32	635.42	635.53	635.67	635.85	636.74	636.78	636.80	0.54	5.36
63.369	585.72	631.17	634.98	634.98	634.98	634.99	635.04	635.12	635.24	636.22	636.26	636.28	0.26	5.11
63.322	Strang Rd. Bridge													
63.299	587.89	631.15	634.93	634.93	634.93	634.93	634.95	635.00	635.07	635.80	635.86	635.89	0.14	4.74
62.325	582.59	631.17	634.99	634.99	634.99	635.02	635.06	635.12	635.23	635.99	636.04	636.07	0.24	4.90
61.308	584.75	631.12	634.95	634.95	634.95	634.95	634.99	635.04	635.12	635.80	635.85	635.88	0.17	4.76
60.263	582.15	631.08	634.92	634.92	634.92	634.92	634.95	635.00	635.07	635.73	635.78	635.80	0.15	4.72
60.200	Spavinaw Creek													
59.019	582.85	631.02	634.87	634.87	634.87	634.87	634.89	634.93	634.98	635.60	635.65	635.68	0.11	4.66
57.950	582.47	630.98	634.84	634.84	634.84	634.84	634.85	634.88	634.94	635.49	635.54	635.57	0.10	4.59
56.927	576.95	630.95	634.81	634.81	634.81	634.81	634.82	634.84	634.92	635.41	635.46	635.49	0.11	4.54
55.890	577.05	630.94	634.80	634.80	634.80	634.80	634.81	634.83	634.92	635.38	635.43	635.46	0.12	4.52
54.456	577.89	630.91	634.78	634.78	634.78	634.78	634.79	634.81	634.90	635.33	635.38	635.41	0.12	4.50
52.988	572.13	630.85	634.70	634.70	634.70	634.70	634.71	634.71	634.82	635.12	635.16	635.19	0.12	4.34
52.954	OK-20 Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.1**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - SEPTEMBER 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
52.922	569.25	630.84	634.69	634.69	634.69	634.69	634.70	634.69	634.80	635.08	635.13	635.16	0.11	4.32
50.500	Saline Creek													
50.396	569.69	630.85	634.73	634.73	634.73	634.73	634.74	634.74	634.85	635.17	635.22	635.25	0.12	4.40
49.110	562.60	630.84	634.72	634.72	634.72	634.72	634.73	634.73	634.84	635.15	635.21	635.23	0.12	4.39
48.118	558.27	630.84	634.72	634.72	634.72	634.72	634.73	634.73	634.84	635.14	635.19	635.22	0.12	4.38
47.186	553.07	630.83	634.71	634.71	634.71	634.71	634.72	634.72	634.83	635.12	635.17	635.20	0.12	4.37
47.120	Kerr Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.2**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - JUNE 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
77.000	Pensacola Dam													
76.880	608.88	623.14	623.62	626.61	625.32	625.96	625.11	627.66	630.33	631.47	640.28	642.63	6.71	19.49
76.463	607.35	622.84	623.35	626.48	625.14	625.80	624.93	627.55	630.27	631.43	640.26	642.59	6.92	19.75
76.414	N 4475 Rd. Bridge													
76.362	607.61	622.54	623.09	626.36	624.98	625.66	624.75	627.45	630.21	631.40	640.24	642.57	7.12	20.03
75.317	606.30	621.46	622.21	625.60	624.19	624.91	623.96	626.73	629.51	630.75	639.59	641.82	7.30	20.36
74.300	605.42	620.92	621.71	624.78	623.48	624.15	623.26	625.85	628.49	629.79	638.26	640.20	6.78	19.28
73.315	600.08	620.58	621.37	624.09	622.91	623.54	622.72	625.10	627.57	629.05	637.18	639.15	6.20	18.57
72.884	606.92	620.29	621.09	623.56	622.46	623.07	622.29	624.54	626.94	628.57	636.52	638.36	5.85	18.07
72.822	OK-82 Bridge													
72.772	604.91	620.20	621.01	623.40	622.33	622.92	622.16	624.37	626.74	628.42	636.32	638.12	5.73	17.92
71.645	603.05	619.18	620.13	621.75	620.88	621.46	620.77	622.78	625.20	627.46	635.54	637.30	5.07	18.12
70.910	601.50	619.09	619.86	620.99	620.31	620.84	620.30	621.96	624.20	626.81	634.55	636.03	4.34	16.94
69.686	599.92	619.09	619.55	620.01	619.59	620.03	619.76	620.87	622.84	626.08	633.73	635.06	3.29	15.97
68.685	597.81	619.09	619.38	619.56	619.25	619.54	619.46	620.18	621.69	625.52	633.01	634.14	2.44	15.05
67.715	594.14	619.09	619.31	619.37	619.18	619.34	619.34	619.95	621.21	625.24	632.58	633.58	2.03	14.49
66.855	592.57	619.09	619.26	619.31	619.13	619.22	619.24	619.75	620.97	625.01	632.30	633.23	1.84	14.14
66.780	Big Cabin Creek													
65.712	590.99	619.09	619.22	619.27	619.10	619.16	619.19	619.63	620.86	624.88	632.10	632.99	1.76	13.90
64.435	588.21	619.09	619.17	619.22	619.09	619.12	619.15	619.50	620.68	624.63	631.91	632.73	1.59	13.64
63.369	585.72	619.09	619.15	619.20	619.09	619.09	619.13	619.48	620.61	624.56	631.79	632.52	1.52	13.43
63.322	Strang Rd. Bridge													
63.299	587.89	619.09	619.15	619.19	619.09	619.09	619.13	619.47	620.60	624.56	631.78	632.51	1.51	13.42
62.325	582.59	619.09	619.14	619.18	619.09	619.09	619.12	619.46	620.58	624.55	631.81	632.54	1.49	13.45
61.308	584.75	619.09	619.12	619.17	619.09	619.09	619.12	619.45	620.55	624.53	631.79	632.50	1.46	13.41
60.263	582.15	619.09	619.11	619.16	619.09	619.09	619.11	619.44	620.52	624.52	631.77	632.48	1.43	13.39
60.200	Spavinaw Creek													
59.019	582.85	619.09	619.10	619.16	619.09	619.09	619.10	619.42	620.49	624.51	631.74	632.42	1.40	13.33
57.950	582.47	619.09	619.09	619.15	619.09	619.09	619.10	619.41	620.48	624.50	631.71	632.38	1.39	13.29
56.927	576.95	619.09	619.09	619.14	619.09	619.09	619.10	619.40	620.46	624.48	631.68	632.34	1.37	13.25
55.890	577.05	619.09	619.09	619.14	619.09	619.09	619.10	619.40	620.45	624.48	631.67	632.32	1.36	13.23
54.456	577.89	619.09	619.09	619.13	619.09	619.09	619.10	619.39	620.44	624.47	631.64	632.29	1.35	13.20
52.988	572.13	619.09	619.09	619.12	619.09	619.09	619.09	619.37	620.42	624.45	631.59	632.23	1.33	13.14
52.954	OK-20 Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.2**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - JUNE 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
52.922	569.25	619.09	619.09	619.12	619.09	619.09	619.09	619.37	620.41	624.44	631.59	632.22	1.32	13.13
50.500	Saline Creek													
50.396	569.69	619.09	619.09	619.10	619.09	619.09	619.09	619.36	620.39	624.44	631.56	632.23	1.30	13.14
49.110	562.60	619.09	619.09	619.09	619.09	619.09	619.09	619.35	620.38	624.43	631.54	632.22	1.29	13.13
48.118	558.27	619.09	619.09	619.09	619.09	619.09	619.09	619.34	620.37	624.43	631.52	632.21	1.28	13.12
47.186	553.07	619.09	619.09	619.09	619.09	619.09	619.09	619.34	620.36	624.42	631.51	632.20	1.27	13.11
47.120	Kerr Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.3**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - JULY 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0 Max WSE (ft, PD)	El. 742.0 Max WSE (ft, PD)	El. 742.5 Max WSE (ft, PD)	El. 743.0 Max WSE (ft, PD)	El. 743.5 Max WSE (ft, PD)	El. 744.0 Max WSE (ft, PD)	El. 744.5 Max WSE (ft, PD)	El. 745.0 Max WSE (ft, PD)	El. 749.0 Max WSE (ft, PD)	El. 753.0 Max WSE (ft, PD)	El. 757.0 Max WSE (ft, PD)		
77.000	Pensacola Dam													
76.880	608.88	641.40	641.50	643.06	643.10	643.09	641.27	643.16	643.24	643.30	643.62	645.09	1.97	3.82
76.463	607.35	641.37	641.47	643.03	643.06	643.05	641.24	643.12	643.20	643.27	643.58	645.04	1.96	3.80
76.414	N 4475 Rd. Bridge													
76.362	607.61	641.34	641.45	643.00	643.03	643.03	641.22	643.09	643.17	643.24	643.56	645.02	1.95	3.80
75.317	606.30	640.77	640.88	642.35	642.39	642.38	640.65	642.45	642.53	642.61	642.87	644.27	1.88	3.62
74.300	605.42	639.60	639.73	641.00	641.04	641.03	639.50	641.11	641.21	641.29	641.41	642.67	1.71	3.17
73.315	600.08	638.87	639.01	640.15	640.20	640.19	638.78	640.27	640.38	640.46	640.50	641.64	1.60	2.86
72.884	606.92	638.35	638.49	639.52	639.57	639.56	638.27	639.65	639.77	639.86	639.86	640.92	1.50	2.65
72.822	OK-82 Bridge													
72.772	604.91	638.19	638.34	639.34	639.39	639.37	638.11	639.46	639.59	639.69	639.69	640.69	1.48	2.58
71.645	603.05	637.68	637.83	638.78	638.83	638.82	637.61	638.91	639.04	639.14	639.14	640.01	1.43	2.40
70.910	601.50	636.91	637.06	637.82	637.87	637.86	636.85	637.95	638.10	638.20	638.20	638.78	1.25	1.93
69.686	599.92	636.39	636.52	637.19	637.24	637.23	636.35	637.33	637.50	637.60	637.60	638.02	1.15	1.67
68.685	597.81	635.88	635.99	636.53	636.57	636.56	635.87	636.66	636.84	636.95	636.95	637.18	0.97	1.31
67.715	594.14	635.55	635.64	636.08	636.12	636.11	635.59	636.21	636.40	636.51	636.51	636.63	0.81	1.08
66.855	592.57	635.33	635.43	635.77	635.81	635.80	635.41	635.90	636.10	636.21	636.21	636.29	0.69	0.96
66.780	Big Cabin Creek													
65.712	590.99	635.09	635.19	635.43	635.46	635.46	635.19	635.53	635.74	635.83	635.83	635.87	0.55	0.78
64.435	588.21	634.88	634.98	635.08	635.10	635.10	635.00	635.16	635.37	635.45	635.45	635.45	0.39	0.57
63.369	585.72	634.73	634.82	634.80	634.79	634.79	634.84	634.82	635.06	635.13	635.13	635.13	0.27	0.40
63.322	Strang Rd. Bridge													
63.299	587.89	634.72	634.80	634.78	634.77	634.77	634.83	634.79	634.99	635.05	635.05	635.05	0.22	0.33
62.325	582.59	634.77	634.85	634.84	634.84	634.84	634.87	634.86	635.06	635.12	635.12	635.12	0.22	0.35
61.308	584.75	634.76	634.83	634.81	634.80	634.80	634.84	634.81	635.01	635.07	635.07	635.07	0.21	0.31
60.263	582.15	634.75	634.81	634.79	634.78	634.78	634.82	634.78	634.97	635.03	635.03	635.03	0.19	0.28
60.200	Spavinaw Creek													
59.019	582.85	634.72	634.77	634.74	634.74	634.74	634.78	634.73	634.92	634.96	634.97	634.97	0.19	0.25
57.950	582.47	634.69	634.74	634.71	634.70	634.70	634.75	634.70	634.89	634.91	634.91	634.91	0.19	0.22
56.927	576.95	634.67	634.71	634.69	634.69	634.69	634.72	634.69	634.87	634.87	634.87	634.87	0.18	0.20
55.890	577.05	634.67	634.70	634.68	634.68	634.68	634.71	634.68	634.87	634.87	634.87	634.87	0.19	0.20
54.456	577.89	634.65	634.68	634.67	634.67	634.67	634.68	634.67	634.85	634.85	634.85	634.85	0.18	0.20
52.988	572.13	634.59	634.61	634.62	634.62	634.62	634.62	634.62	634.81	634.81	634.81	634.81	0.20	0.22
52.954	OK-20 Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.3**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - JULY 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
52.922	569.25	634.58	634.60	634.61	634.61	634.61	634.61	634.61	634.80	634.80	634.80	634.80	0.20	0.22
50.500	Saline Creek													
50.396	569.69	634.58	634.61	634.63	634.63	634.63	634.63	634.63	634.82	634.82	634.82	634.82	0.21	0.24
49.110	562.60	634.57	634.60	634.63	634.63	634.63	634.62	634.63	634.82	634.82	634.82	634.82	0.22	0.25
48.118	558.27	634.56	634.60	634.62	634.62	634.62	634.62	634.62	634.81	634.81	634.81	634.81	0.21	0.25
47.186	553.07	634.55	634.59	634.62	634.62	634.62	634.61	634.62	634.81	634.81	634.81	634.81	0.22	0.26
47.120	Kerr Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.4**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - OCTOBER 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
77.000	Pensacola Dam													
76.880	608.88	635.28	640.79	638.05	640.70	637.31	637.66	637.34	640.60	640.15	641.24	641.90	3.48	6.62
76.463	607.35	635.24	640.76	638.03	640.67	637.29	637.63	637.32	640.57	640.12	641.20	641.86	3.47	6.62
76.414	N 4475 Rd. Bridge													
76.362	607.61	635.22	640.74	638.01	640.65	637.27	637.61	637.29	640.55	640.10	641.18	641.84	3.47	6.62
75.317	606.30	634.68	640.14	637.44	640.06	636.70	637.04	636.71	639.95	639.57	640.60	641.21	3.44	6.53
74.300	605.42	633.76	638.92	636.34	638.85	635.64	635.95	635.60	638.73	638.51	639.39	639.92	3.32	6.16
73.315	600.08	632.98	638.12	635.44	638.05	634.76	635.04	634.68	637.91	637.82	638.65	639.10	3.44	6.12
72.884	606.92	632.52	637.55	634.91	637.49	634.23	634.49	634.12	637.33	637.35	638.10	638.50	3.43	5.98
72.822	OK-82 Bridge													
72.772	604.91	632.37	637.38	634.74	637.33	634.07	634.32	633.95	637.16	637.21	637.95	638.32	3.43	5.95
71.645	603.05	631.61	636.78	634.03	636.73	633.31	633.57	633.14	636.53	636.73	637.42	637.73	3.64	6.12
70.910	601.50	630.95	635.95	633.26	635.90	632.54	632.86	632.31	635.68	636.08	636.65	636.82	3.64	5.87
69.686	599.92	630.33	635.33	632.60	635.30	631.83	632.23	631.53	635.03	635.64	636.13	636.17	3.80	5.84
68.685	597.81	629.82	634.76	632.05	634.73	631.23	631.71	630.87	634.42	635.25	635.65	635.65	3.89	5.83
67.715	594.14	629.53	634.40	631.74	634.39	630.87	631.41	630.54	634.05	635.02	635.37	635.40	3.86	5.87
66.855	592.57	629.31	634.17	631.53	634.16	630.59	631.20	630.32	633.80	634.90	635.21	635.23	3.85	5.92
66.780	Big Cabin Creek													
65.712	590.99	629.16	634.00	631.37	633.99	630.39	631.04	630.15	633.59	634.77	635.05	635.03	3.85	5.89
64.435	588.21	628.97	633.82	631.21	633.81	630.12	630.86	629.94	633.36	634.71	634.96	634.85	3.88	5.99
63.369	585.72	628.86	633.70	631.13	633.70	629.95	630.77	629.81	633.18	634.65	634.86	634.70	3.89	6.00
63.322	Strang Rd. Bridge													
63.299	587.89	628.85	633.69	631.12	633.69	629.94	630.76	629.80	633.17	634.64	634.85	634.69	3.89	6.00
62.325	582.59	628.86	633.73	631.15	633.73	629.95	630.79	629.80	633.21	634.68	634.88	634.73	3.93	6.02
61.308	584.75	628.84	633.72	631.14	633.72	629.91	630.79	629.77	633.19	634.67	634.87	634.73	3.95	6.03
60.263	582.15	628.84	633.71	631.13	633.71	629.88	630.78	629.75	633.18	634.66	634.85	634.72	3.96	6.01
60.200	Spavinaw Creek													
59.019	582.85	628.82	633.68	631.11	633.68	629.84	630.76	629.72	633.15	634.63	634.81	634.70	3.96	5.99
57.950	582.47	628.81	633.66	631.09	633.66	629.82	630.75	629.70	633.12	634.60	634.78	634.68	3.96	5.97
56.927	576.95	628.80	633.64	631.07	633.64	629.79	630.73	629.68	633.10	634.58	634.76	634.66	3.96	5.96
55.890	577.05	628.79	633.63	631.06	633.63	629.78	630.72	629.67	633.09	634.57	634.74	634.65	3.96	5.95
54.456	577.89	628.78	633.61	631.04	633.61	629.77	630.71	629.66	633.07	634.54	634.72	634.64	3.95	5.94
52.988	572.13	628.75	633.56	631.00	633.56	629.73	630.67	629.63	633.02	634.49	634.66	634.59	3.93	5.91
52.954	OK-20 Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.4**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - OCTOBER 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
52.922	569.25	628.75	633.56	630.99	633.56	629.72	630.66	629.62	633.01	634.49	634.65	634.58	3.94	5.90
50.500	Saline Creek													
50.396	569.69	628.74	633.54	630.97	633.54	629.72	630.65	629.63	633.02	634.45	634.62	634.59	3.91	5.88
49.110	562.60	628.74	633.53	630.95	633.53	629.71	630.64	629.62	633.01	634.43	634.60	634.58	3.91	5.86
48.118	558.27	628.73	633.52	630.94	633.52	629.71	630.63	629.61	633.00	634.40	634.58	634.57	3.91	5.85
47.186	553.07	628.73	633.51	630.93	633.51	629.70	630.62	629.61	632.99	634.39	634.55	634.56	3.90	5.83
47.120	Kerr Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.5**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - DECEMBER 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
77.000	Pensacola Dam													
76.880	608.88	641.54	649.04	649.04	649.04	649.04	649.04	649.04	649.06	649.18	649.19	651.50	0.02	9.96
76.463	607.35	641.51	648.99	648.99	648.99	648.99	648.99	648.99	649.00	649.12	649.13	651.44	0.01	9.93
76.414	N 4475 Rd. Bridge													
76.362	607.61	641.49	648.96	648.96	648.96	648.96	648.96	648.96	648.97	649.09	649.10	651.40	0.01	9.91
75.317	606.30	640.92	648.02	648.01	648.01	648.01	648.02	648.02	648.03	648.16	648.17	650.36	0.02	9.44
74.300	605.42	639.77	646.11	646.11	646.11	646.11	646.11	646.11	646.13	646.30	646.31	648.35	0.02	8.58
73.315	600.08	639.05	644.81	644.81	644.81	644.81	644.81	644.82	644.84	645.04	645.05	646.98	0.03	7.93
72.884	606.92	638.53	644.02	644.02	644.02	644.02	644.02	644.02	644.04	644.26	644.27	646.27	0.02	7.74
72.822	OK-82 Bridge													
72.772	604.91	638.38	643.65	643.65	643.65	643.65	643.65	643.66	643.69	644.02	644.04	645.61	0.04	7.23
71.645	603.05	637.87	642.82	642.82	642.82	642.82	642.82	642.83	642.85	643.15	643.17	644.78	0.03	6.91
70.910	601.50	637.09	641.28	641.28	641.28	641.28	641.28	641.28	641.32	641.72	641.73	643.31	0.04	6.22
69.686	599.92	636.55	640.28	640.27	640.27	640.27	640.28	640.28	640.32	640.78	640.80	642.30	0.05	5.75
68.685	597.81	636.02	638.95	638.95	638.95	638.95	638.95	638.96	639.00	639.50	639.52	640.76	0.05	4.74
67.715	594.14	635.67	637.97	637.97	637.97	637.97	637.97	637.98	638.02	638.56	638.58	639.61	0.05	3.94
66.855	592.57	635.43	637.30	637.30	637.30	637.30	637.30	637.31	637.35	637.90	637.92	638.80	0.05	3.37
66.780	Big Cabin Creek													
65.712	590.99	635.21	636.61	636.61	636.61	636.61	636.61	636.62	636.66	637.18	637.21	637.92	0.05	2.71
64.435	588.21	634.96	635.85	635.85	635.85	635.85	635.85	635.86	635.88	636.37	636.39	636.92	0.03	1.96
63.369	585.72	634.74	635.28	635.28	635.28	635.28	635.28	635.28	635.28	635.79	635.81	636.26	0.00	1.52
63.322	Strang Rd. Bridge													
63.299	587.89	634.72	635.09	635.09	635.09	635.09	635.09	635.09	635.09	635.40	635.41	635.64	0.00	0.92
62.325	582.59	634.77	635.26	635.26	635.26	635.26	635.26	635.26	635.25	635.63	635.65	635.95	0.01	1.18
61.308	584.75	634.73	635.15	635.15	635.15	635.15	635.15	635.15	635.14	635.46	635.47	635.71	0.01	0.98
60.263	582.15	634.71	635.09	635.09	635.09	635.09	635.09	635.09	635.09	635.38	635.40	635.62	0.00	0.91
60.200	Spavinaw Creek													
59.019	582.85	634.68	635.00	635.00	635.00	635.00	635.00	635.00	635.00	635.25	635.26	635.46	0.00	0.78
57.950	582.47	634.65	634.94	634.94	634.94	634.94	634.94	634.94	634.93	635.14	635.15	635.33	0.01	0.68
56.927	576.95	634.63	634.91	634.91	634.91	634.91	634.91	634.91	634.90	635.08	635.07	635.22	0.01	0.59
55.890	577.05	634.62	634.90	634.90	634.90	634.90	634.90	634.90	634.90	635.06	635.05	635.19	0.00	0.57
54.456	577.89	634.61	634.89	634.89	634.89	634.89	634.89	634.89	634.89	635.02	635.01	635.13	0.00	0.52
52.988	572.13	634.55	634.80	634.80	634.80	634.80	634.80	634.80	634.80	634.83	634.82	634.87	0.00	0.32
52.954	OK-20 Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.5**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - DECEMBER 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
52.922	569.25	634.54	634.79	634.79	634.79	634.79	634.79	634.79	634.79	634.80	634.79	634.83	0.00	0.29
50.500	Saline Creek													
50.396	569.69	634.57	634.84	634.84	634.84	634.84	634.84	634.84	634.84	634.90	634.89	634.94	0.00	0.37
49.110	562.60	634.57	634.83	634.83	634.83	634.83	634.83	634.83	634.83	634.89	634.88	634.92	0.00	0.35
48.118	558.27	634.56	634.83	634.83	634.83	634.83	634.83	634.83	634.83	634.88	634.87	634.91	0.00	0.35
47.186	553.07	634.56	634.82	634.82	634.82	634.82	634.82	634.82	634.82	634.86	634.85	634.89	0.00	0.33
47.120	Kerr Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.6**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
77.000	Pensacola Dam													
76.880	608.88	656.34	656.35	656.35	656.35	656.35	656.35	656.35	656.35	656.35	656.35	656.35	0.00	0.01
76.463	607.35	656.28	656.28	656.28	656.28	656.28	656.28	656.28	656.28	656.29	656.29	656.29	0.00	0.01
76.414	N 4475 Rd. Bridge													
76.362	607.61	656.24	656.24	656.24	656.24	656.24	656.24	656.24	656.24	656.25	656.25	656.25	0.00	0.01
75.317	606.30	654.94	654.94	654.94	654.94	654.94	654.94	654.94	654.94	654.94	654.94	654.95	0.00	0.01
74.300	605.42	652.68	652.68	652.68	652.68	652.69	652.69	652.68	652.69	652.69	652.69	652.69	0.01	0.01
73.315	600.08	651.10	651.11	651.11	651.11	651.11	651.11	651.11	651.11	651.11	651.11	651.11	0.00	0.01
72.884	606.92	650.34	650.34	650.34	650.34	650.34	650.34	650.34	650.34	650.35	650.35	650.35	0.00	0.01
72.822	OK-82 Bridge													
72.772	604.91	649.64	649.65	649.66	649.66	649.66	649.66	649.66	649.66	649.66	649.66	649.66	0.01	0.02
71.645	603.05	648.74	648.75	648.75	648.75	648.76	648.76	648.75	648.76	648.76	648.76	648.76	0.01	0.02
70.910	601.50	647.48	647.48	647.49	647.49	647.49	647.49	647.49	647.49	647.50	647.50	647.50	0.01	0.02
69.686	599.92	646.43	646.43	646.44	646.44	646.45	646.45	646.44	646.44	646.45	646.45	646.45	0.02	0.02
68.685	597.81	644.60	644.61	644.62	644.62	644.62	644.62	644.62	644.62	644.63	644.63	644.63	0.01	0.03
67.715	594.14	643.11	643.12	643.13	643.14	643.14	643.14	643.14	643.14	643.14	643.14	643.15	0.02	0.04
66.855	592.57	642.00	642.01	642.03	642.03	642.03	642.03	642.03	642.03	642.03	642.04	642.04	0.02	0.04
66.780	Big Cabin Creek													
65.712	590.99	640.58	640.59	640.61	640.61	640.61	640.61	640.61	640.61	640.61	640.62	640.62	0.02	0.04
64.435	588.21	638.99	639.00	639.01	639.01	639.02	639.02	639.01	639.02	639.02	639.02	639.02	0.02	0.03
63.369	585.72	638.03	638.04	638.05	638.05	638.05	638.05	638.05	638.05	638.06	638.06	638.06	0.01	0.03
63.322	Strang Rd. Bridge													
63.299	587.89	637.08	637.09	637.11	637.11	637.12	637.12	637.11	637.11	637.12	637.12	637.13	0.03	0.05
62.325	582.59	637.19	637.20	637.22	637.22	637.23	637.23	637.23	637.23	637.24	637.24	637.24	0.03	0.05
61.308	584.75	636.69	636.70	636.72	636.72	636.73	636.73	636.73	636.73	636.73	636.74	636.74	0.03	0.05
60.263	582.15	636.52	636.52	636.54	636.54	636.55	636.55	636.55	636.55	636.56	636.56	636.57	0.03	0.05
60.200	Spavinaw Creek													
59.019	582.85	636.17	636.17	636.19	636.19	636.20	636.20	636.20	636.20	636.20	636.21	636.21	0.03	0.04
57.950	582.47	635.88	635.88	635.90	635.90	635.91	635.91	635.91	635.91	635.91	635.92	635.92	0.03	0.04
56.927	576.95	635.64	635.64	635.66	635.66	635.67	635.67	635.67	635.67	635.67	635.68	635.68	0.03	0.04
55.890	577.05	635.57	635.58	635.58	635.59	635.59	635.59	635.59	635.59	635.60	635.60	635.61	0.01	0.04
54.456	577.89	635.45	635.46	635.44	635.45	635.45	635.45	635.45	635.45	635.45	635.46	635.46	0.02	0.02
52.988	572.13	634.85	634.86	634.83	634.83	634.83	634.83	634.83	634.83	634.83	634.83	634.83	0.03	0.03
52.954	OK-20 Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.6**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range WSE Difference[1] (ft)	Extreme Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
52.922	569.25	634.74	634.75	634.73	634.73	634.73	634.73	634.73	634.73	634.73	634.73	634.73	0.02	0.02
50.500	Saline Creek													
50.396	569.69	635.06	635.07	635.05	635.05	635.05	635.05	635.05	635.05	635.05	635.05	635.05	0.02	0.02
49.110	562.60	635.02	635.03	635.01	635.01	635.01	635.01	635.01	635.01	635.01	635.01	635.01	0.02	0.02
48.118	558.27	634.98	634.99	634.97	634.97	634.97	634.97	634.97	634.97	634.97	634.97	634.97	0.02	0.02
47.186	553.07	634.93	634.94	634.92	634.92	634.92	634.92	634.92	634.92	634.92	634.92	634.92	0.02	0.02
47.120	Kerr Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE C.7**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - HISTORICAL EVENTS

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	
77.000	Pensacola Dam						
76.880	608.88	649.20	630.19	643.30	639.39	649.06	19.01
76.463	607.35	649.14	630.12	643.26	639.36	649.00	19.02
76.414	N 4475 Rd. Bridge						
76.362	607.61	649.11	630.06	643.24	639.35	648.97	19.05
75.317	606.30	648.16	629.35	642.60	638.82	648.03	18.81
74.300	605.42	646.24	628.31	641.28	637.79	646.13	17.93
73.315	600.08	644.93	627.37	640.46	636.97	644.83	17.56
72.884	606.92	644.12	626.71	639.86	636.48	644.04	17.41
72.822	OK-82 Bridge						
72.772	604.91	643.80	626.51	639.68	636.34	643.69	17.29
71.645	603.05	642.92	624.86	639.13	635.78	642.85	18.06
70.910	601.50	641.36	623.80	638.19	635.08	641.32	17.56
69.686	599.92	640.33	622.31	637.59	634.55	640.32	18.02
68.685	597.81	638.97	621.03	636.94	634.07	639.00	17.97
67.715	594.14	637.96	620.50	636.50	633.78	638.02	17.52
66.855	592.57	637.27	620.06	636.20	633.59	637.34	17.28
66.780	Big Cabin Creek						
65.712	590.99	636.61	619.91	635.82	633.43	636.65	16.74
64.435	588.21	635.85	619.71	635.44	633.26	635.88	16.17
63.369	585.72	635.24	619.64	635.12	633.14	635.28	15.64
63.322	Strang Rd. Bridge						
63.299	587.89	635.06	619.63	635.04	633.13	635.09	15.46
62.325	582.59	635.23	619.60	635.11	633.16	635.25	15.65
61.308	584.75	635.12	619.57	635.06	633.15	635.14	15.57
60.263	582.15	635.07	619.55	635.02	633.14	635.09	15.54
60.200	Spavinaw Creek						
59.019	582.85	634.98	619.53	634.96	633.12	635.00	15.47
57.950	582.47	634.94	619.52	634.90	633.10	634.93	15.42
56.927	576.95	634.92	619.52	634.87	633.08	634.90	15.40
55.890	577.05	634.91	619.52	634.87	633.08	634.90	15.39
54.456	577.89	634.90	619.52	634.85	633.06	634.89	15.38
52.988	572.13	634.82	619.51	634.81	633.02	634.80	15.31

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE C.7**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - HISTORICAL EVENTS

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993	June 2004	July 2007	Oct 2009	Dec 2015	
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	
52.954	OK-20 Bridge						
52.922	569.25	634.80	619.51	634.80	633.01	634.79	15.29
50.500	Saline Creek						
50.396	569.69	634.85	619.50	634.82	633.01	634.84	15.35
49.110	562.60	634.84	619.49	634.82	633.00	634.83	15.35
48.118	558.27	634.84	619.48	634.81	633.00	634.83	15.36
47.186	553.07	634.83	619.48	634.81	632.99	634.82	15.35
47.120	Kerr Dam						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

APPENDIX D:
WATER SURFACE ELEVATION PROFILES

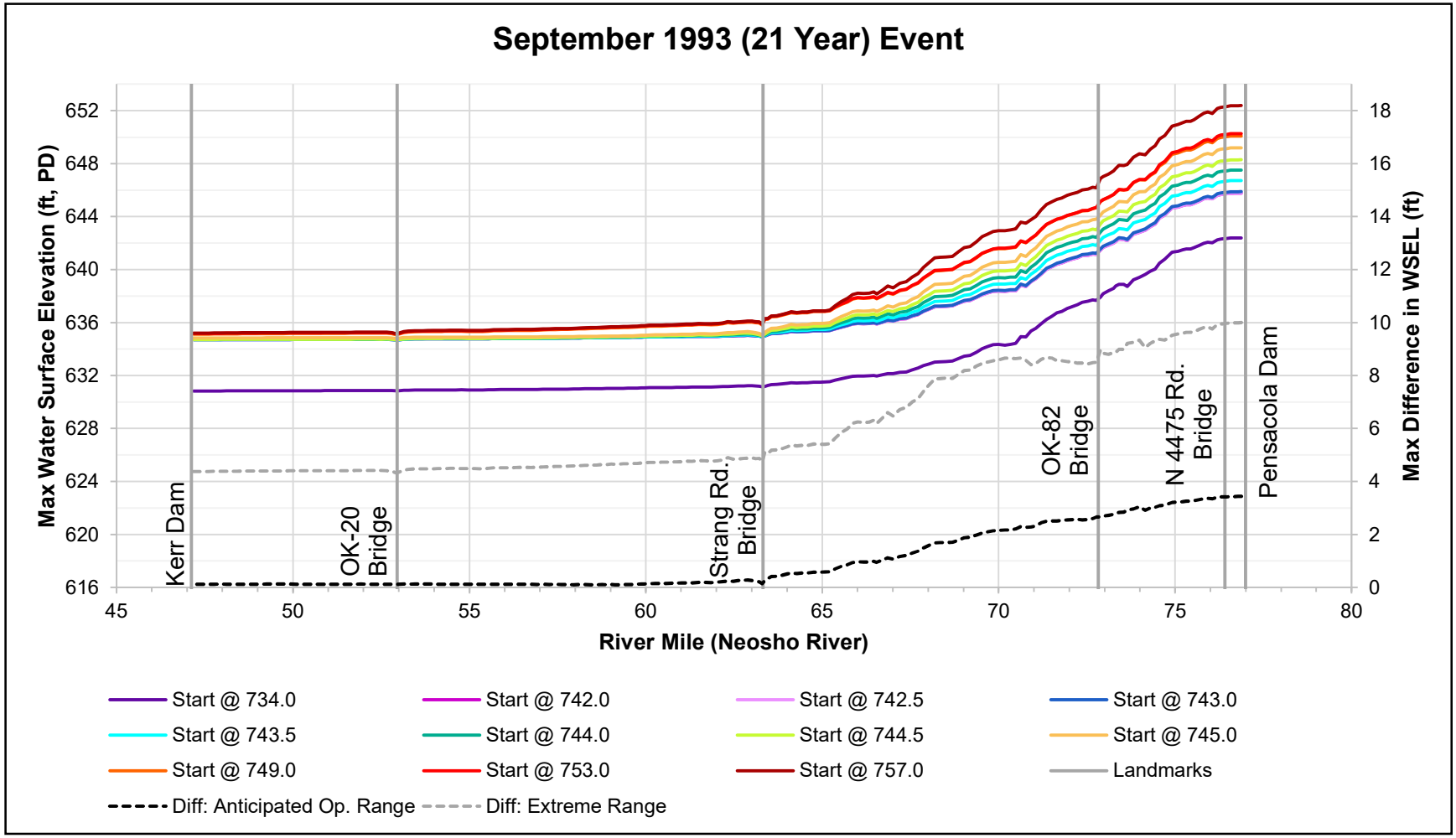


Figure D.1. Water surface elevations for the September 1993 (21 year) event downstream of Pensacola Dam along the Neosho River profile.

Notes: *1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742.0" means a starting pool elevation of 742.0 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

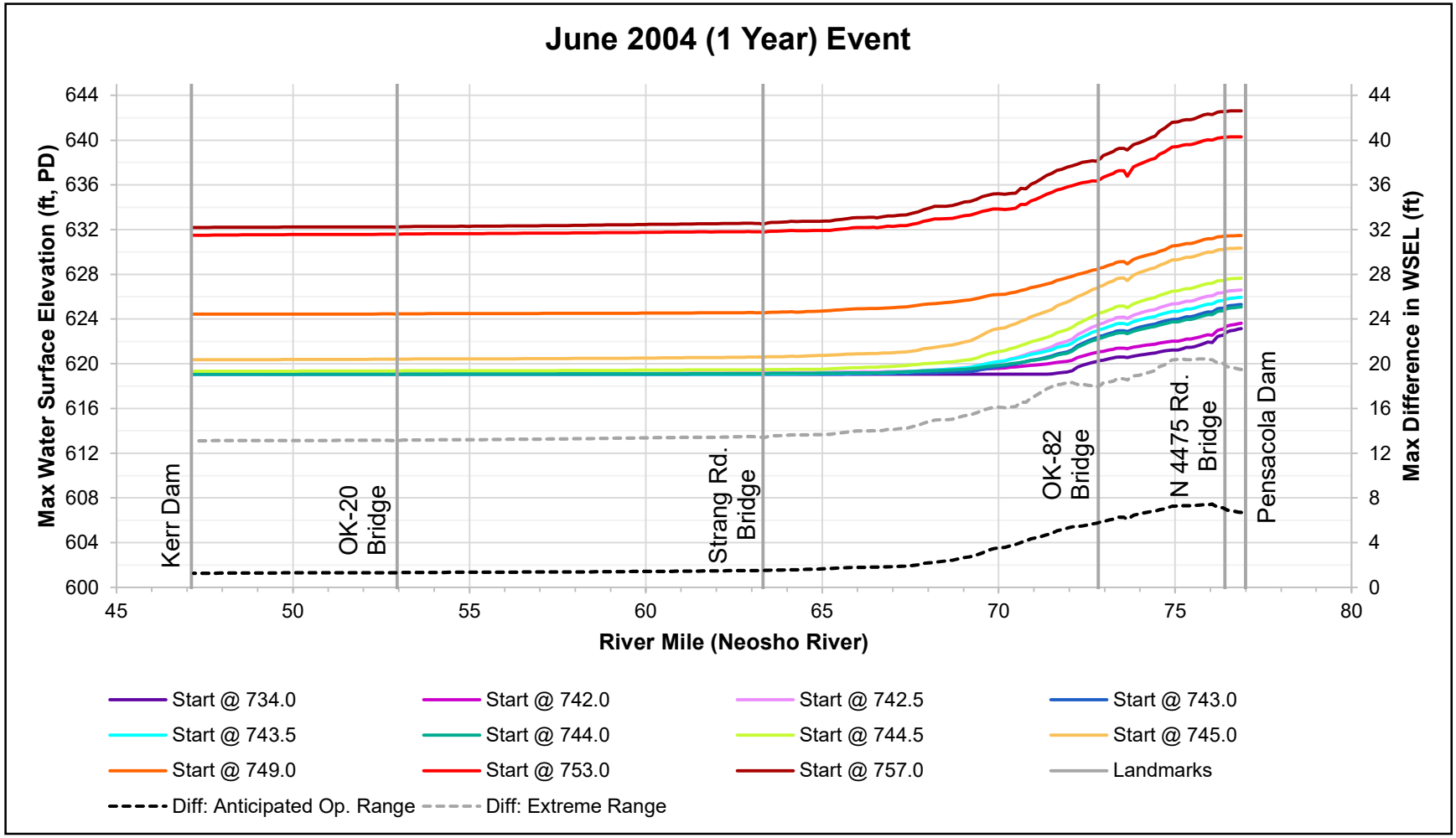


Figure D.2. Water surface elevations for the June 2004 (1 year) event downstream of Pensacola Dam along the Neosho River profile.

Notes: 1. *In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742.0" means a starting pool elevation of 742.0 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

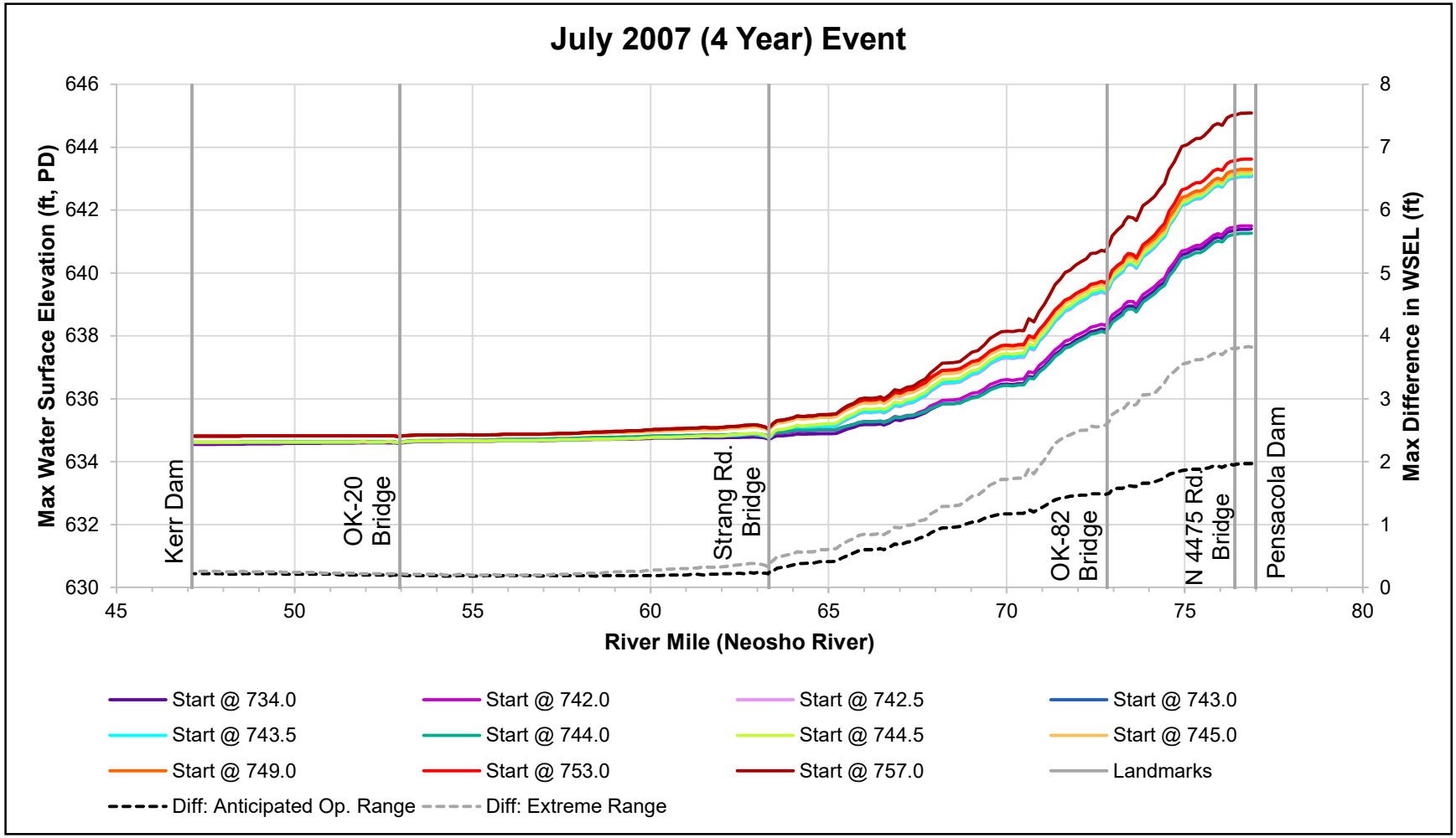


Figure D.3. Water surface elevations for the July 2007 (4 year) event downstream of Pensacola Dam along the Neosho River profile.

Notes: *1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742.0" means a starting pool elevation of 742.0 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

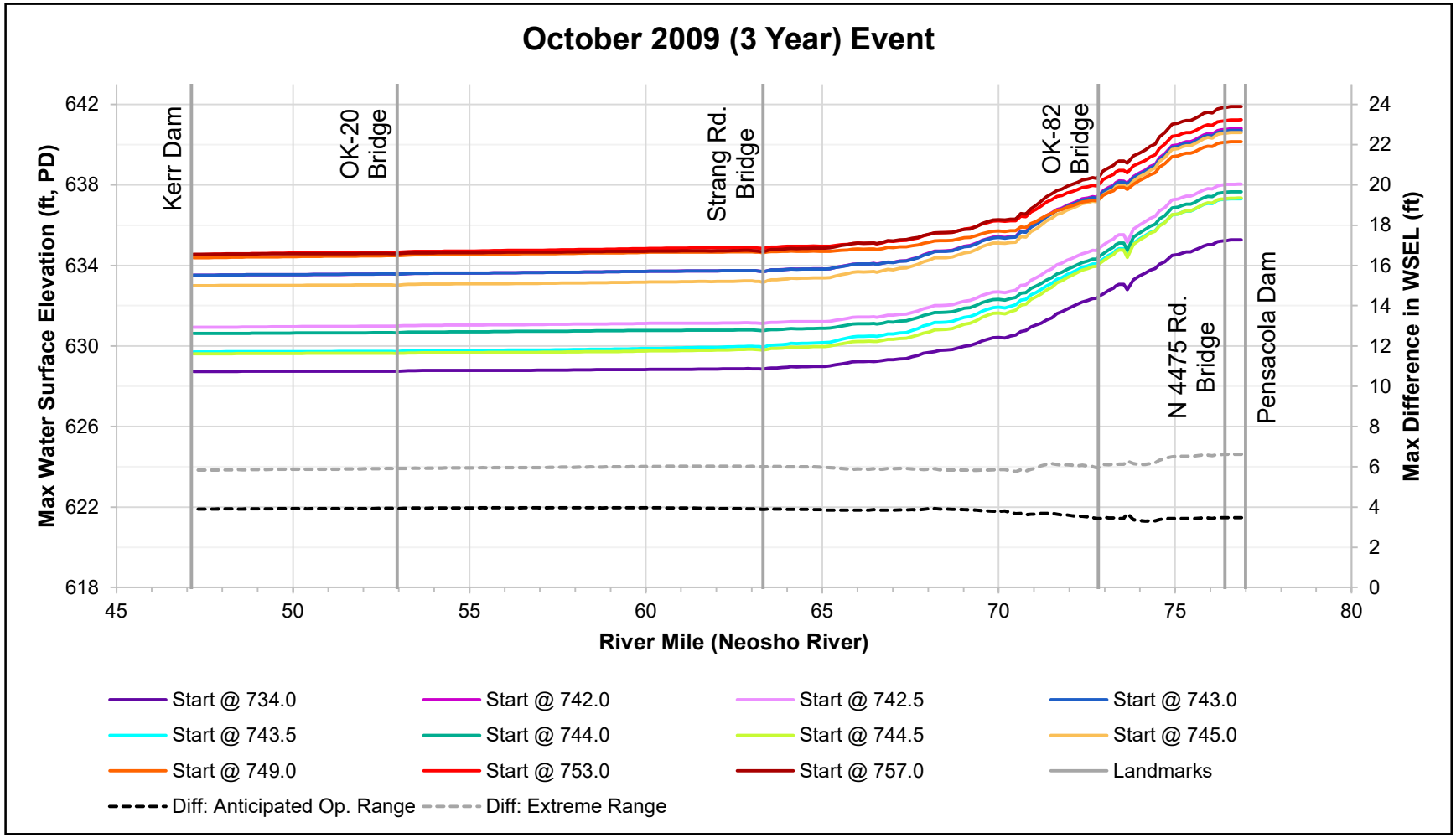


Figure D.4. Water surface elevations for the October 2009 (3 year) event downstream of Pensacola Dam along the Neosho River profile.

Notes: *1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742.0" means a starting pool elevation of 742.0 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

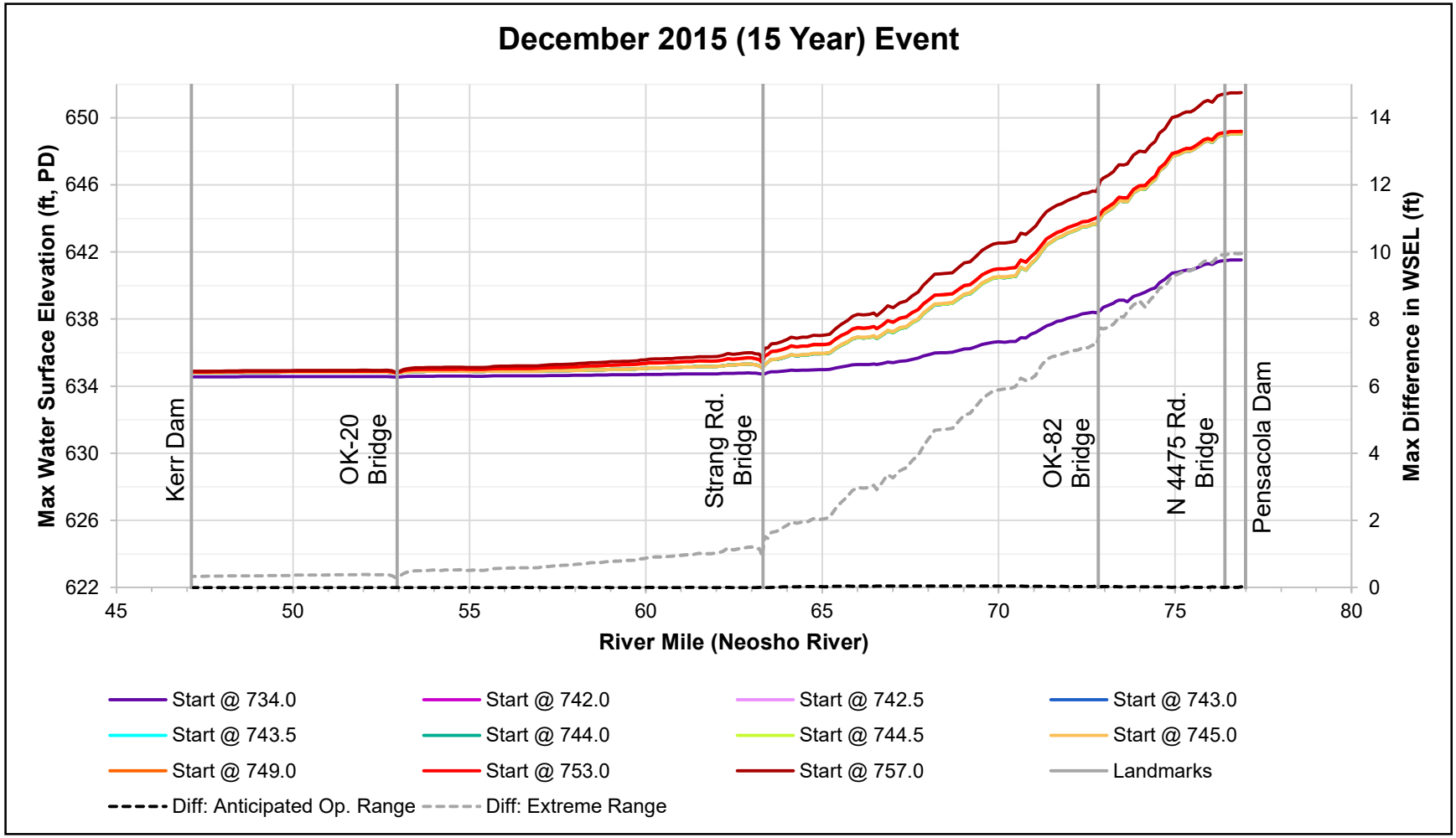


Figure D.5. Water surface elevations for the December 2015 (15 year) event downstream of Pensacola Dam along the Neosho River profile.

Notes: *1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742.0" means a starting pool elevation of 742.0 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

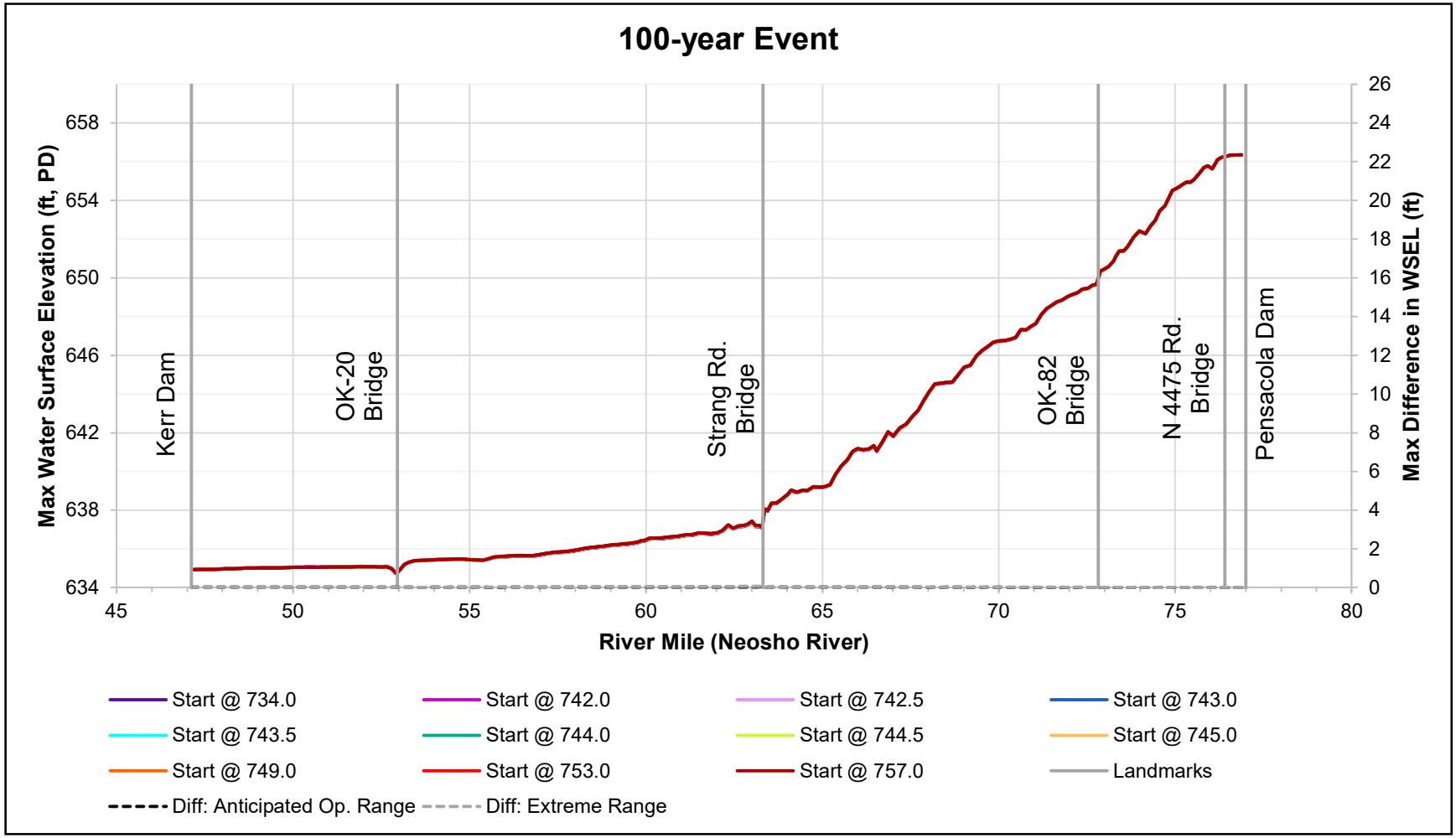


Figure D.6. Water surface elevations for the 100-year event downstream of Pensacola Dam along the Neosho River profile.

Notes: *1. In the legend, the first set of series names refers to pool elevation at Pensacola Dam at the start of the simulation. For example, "Start @ 742.0" means a starting pool elevation of 742.0 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

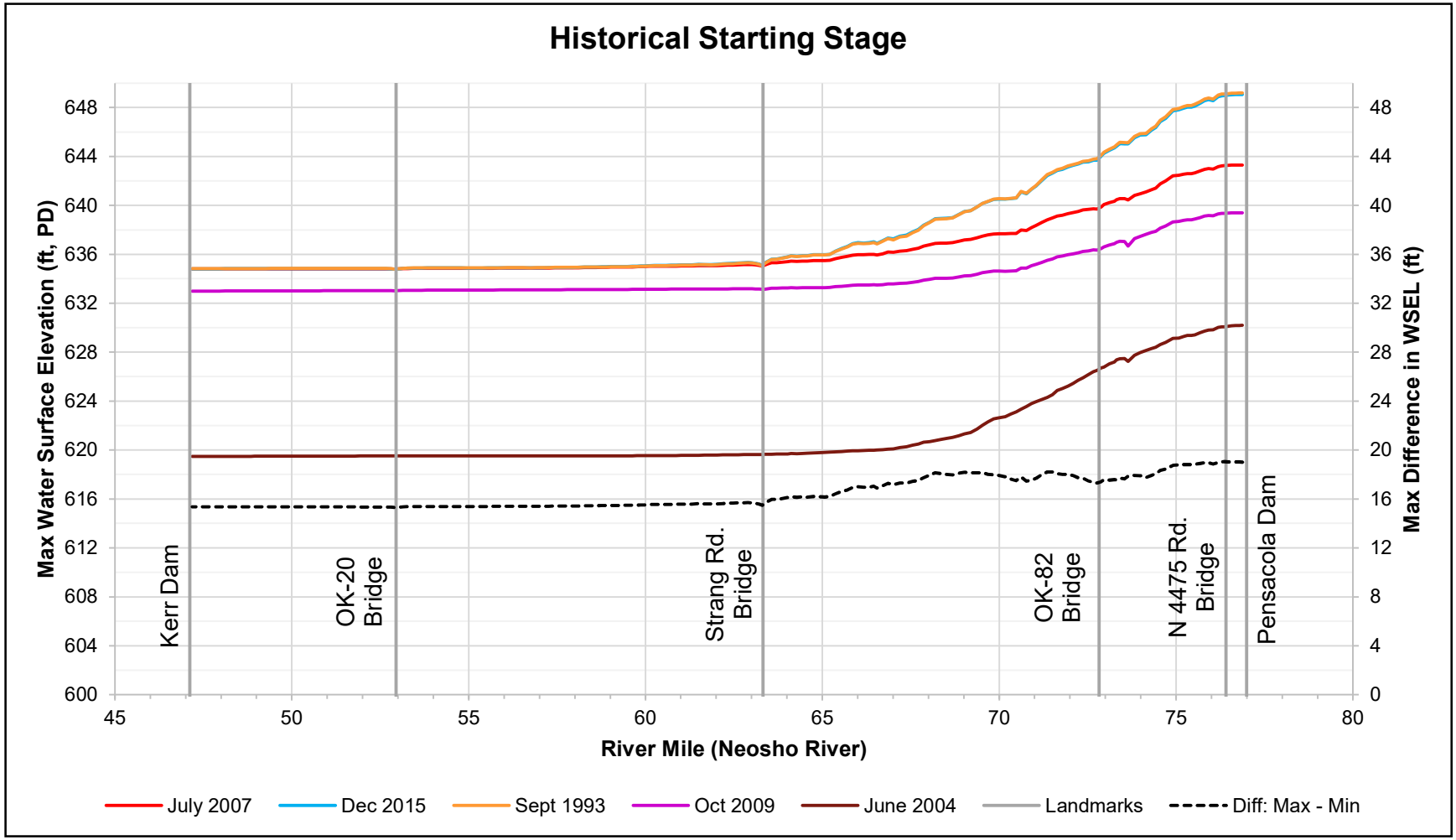


Figure D.7. Water surface elevations for events with historical starting stages downstream of Pensacola Dam along the Neosho River profile.

Note: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

APPENDIX E:
INUNDATION MAPS

Due to file size limits, the inundation maps, duration of inundation tables, and anticipated operations analysis are included as separate PDFs.

APPENDIX E.1:
SEPTEMBER 1993 (21 YEAR) EVENT INUNDATION MAPS

Downstream Model Results Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

Date: September 2022

Overview Map Legend

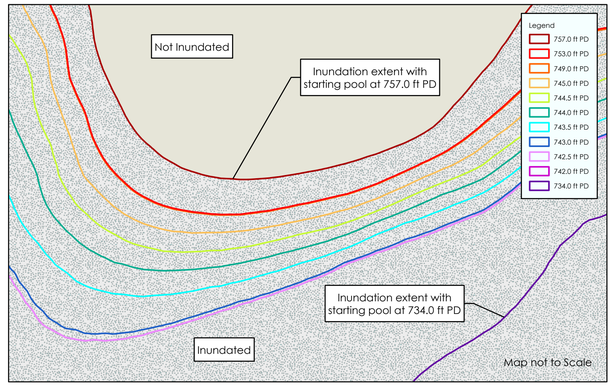
- 1:24,000-scale Map Sheet
- County Boundary
- Municipality
- Unincorporated

Road Class

- Interstate
- US Highway

Inundation Scenario Mapping

Mapping shows the extent of inundation for the selected hydraulic event under different starting pool elevations at Pensacola Dam: 734.0 ft PD, 742.0 ft PD, 742.5 ft PD, 743.0 ft PD, 743.5 ft PD, 744.0 ft PD, 744.5 ft PD, 745.0 ft PD, 749.0 ft PD, 753.0 ft PD, and 757.0 ft PD.



0 0.75 1.5 3 4.5 6 Miles

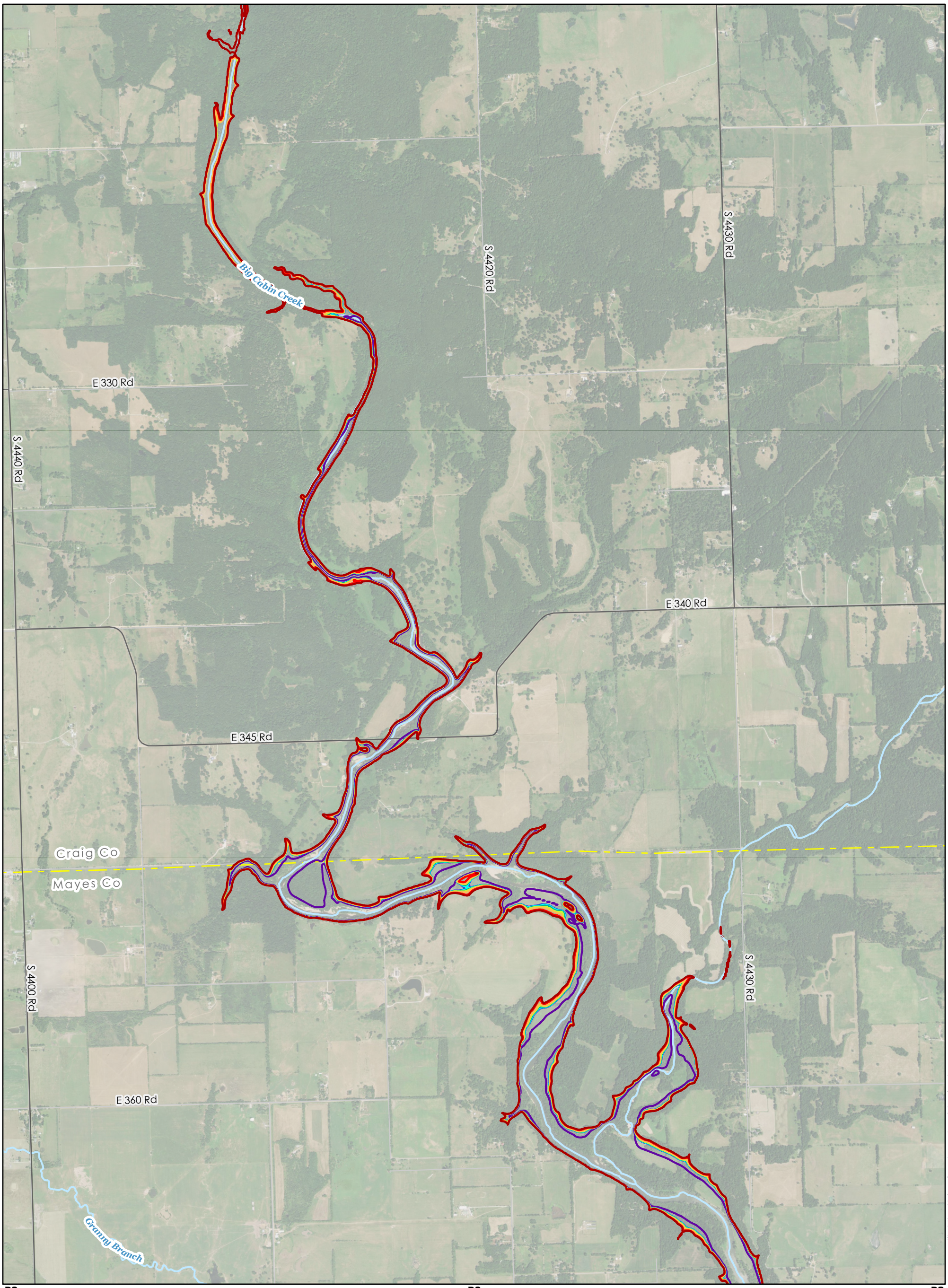
NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019.
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

Map Source: Esri, NASA, NGA, USGS, Missouri Dept. of Conservation, Missouri DNR, Texas Parks & Wildlife, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

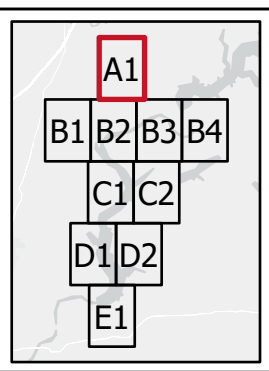


SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

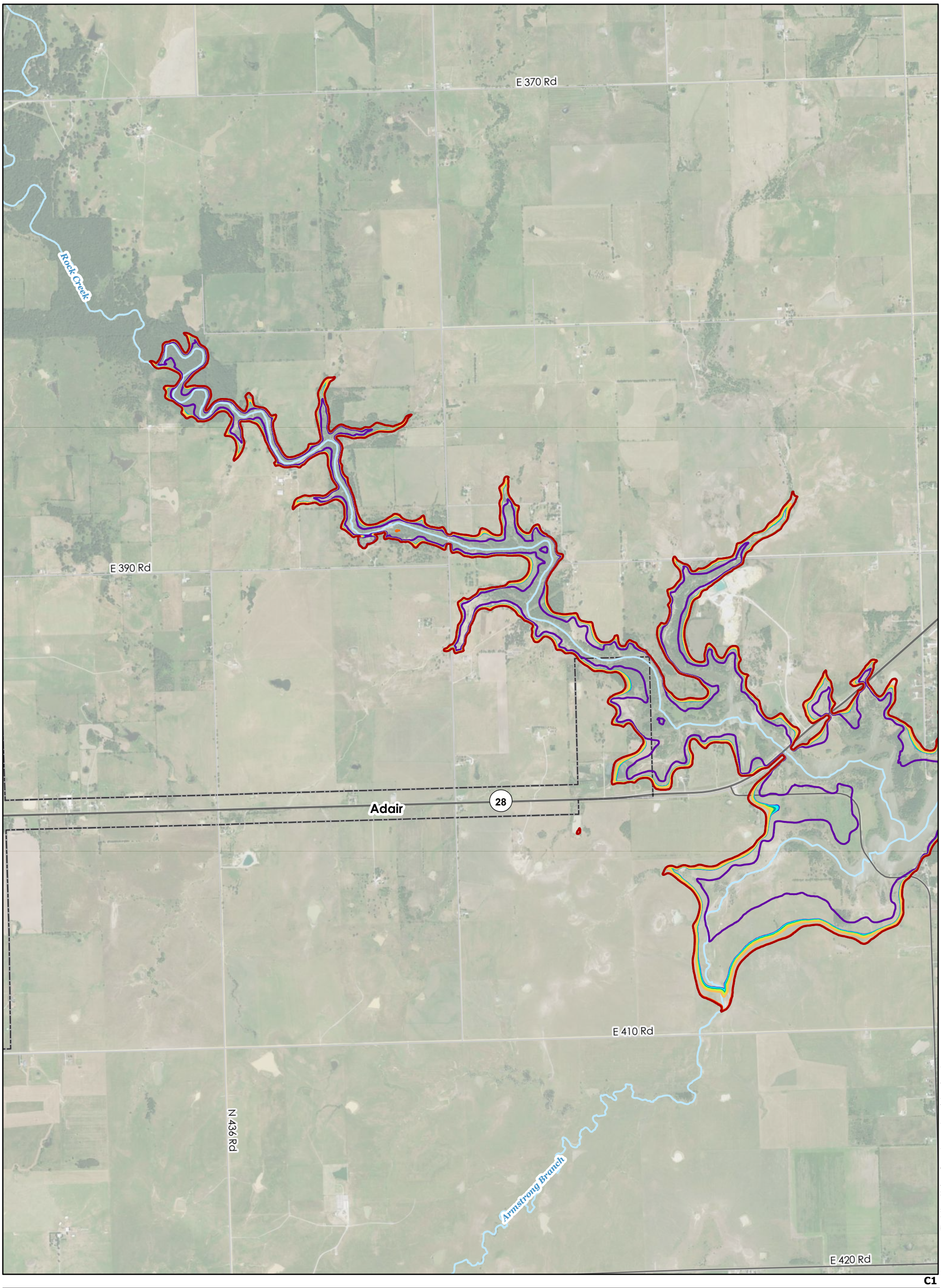
MAP: A1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

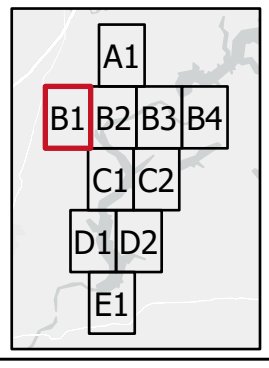


SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1 A1

B1 B3

C1 C1 C2

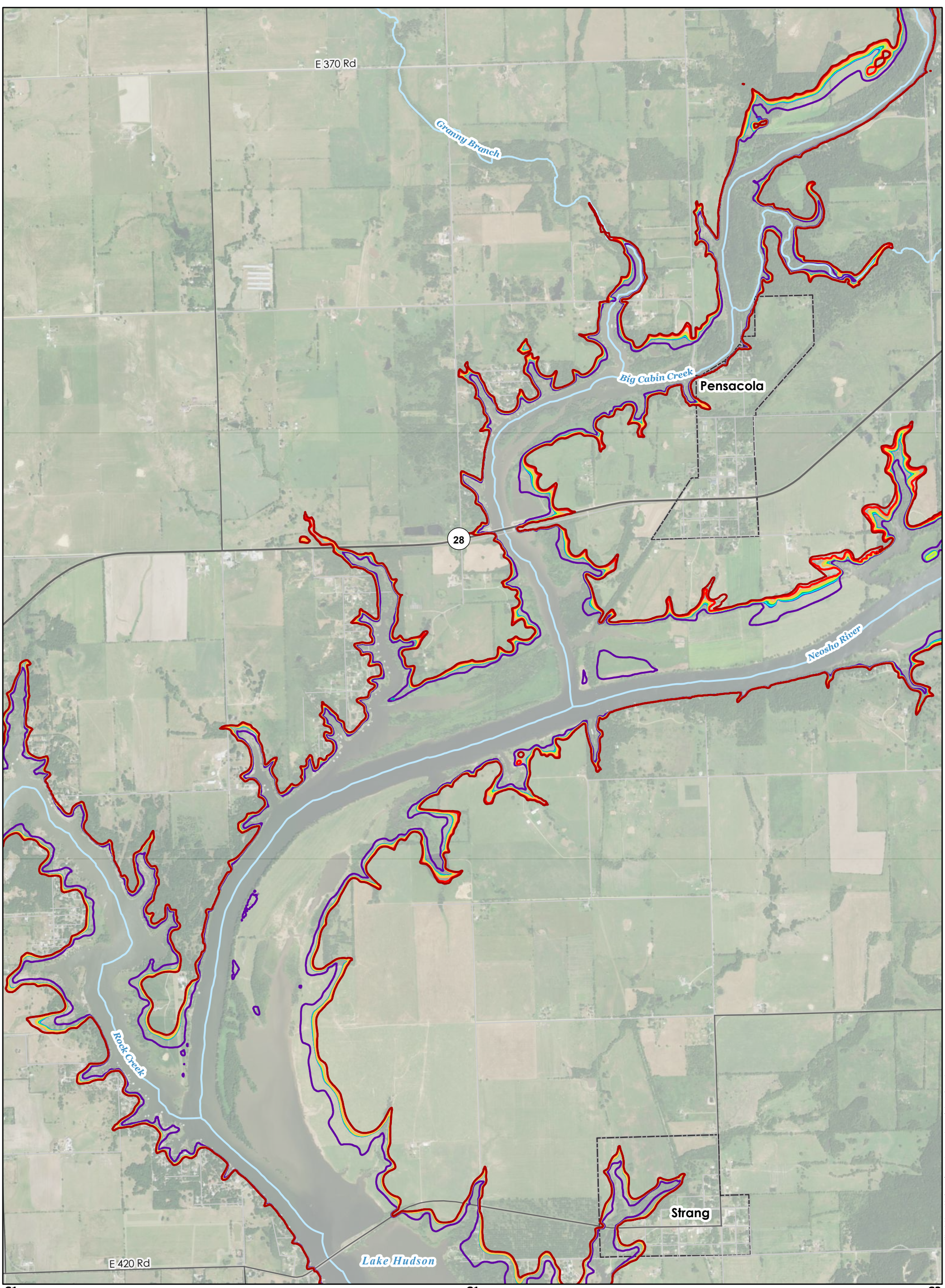


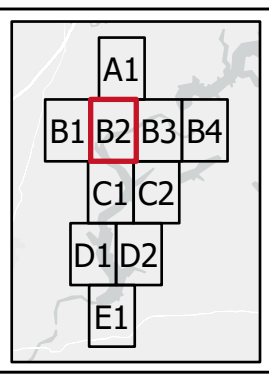
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

BOUNDARY TYPE

- Project
- County
- Municipal

- Stream

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1

B2

B4

C2

C2

Elm Creek

28

Grand lake O' the Cherokees

Langley

Langley

Neosho River

82

E 400 Rd

Spavinaw

20

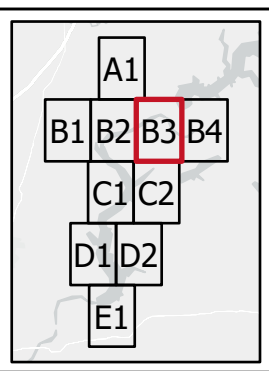
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

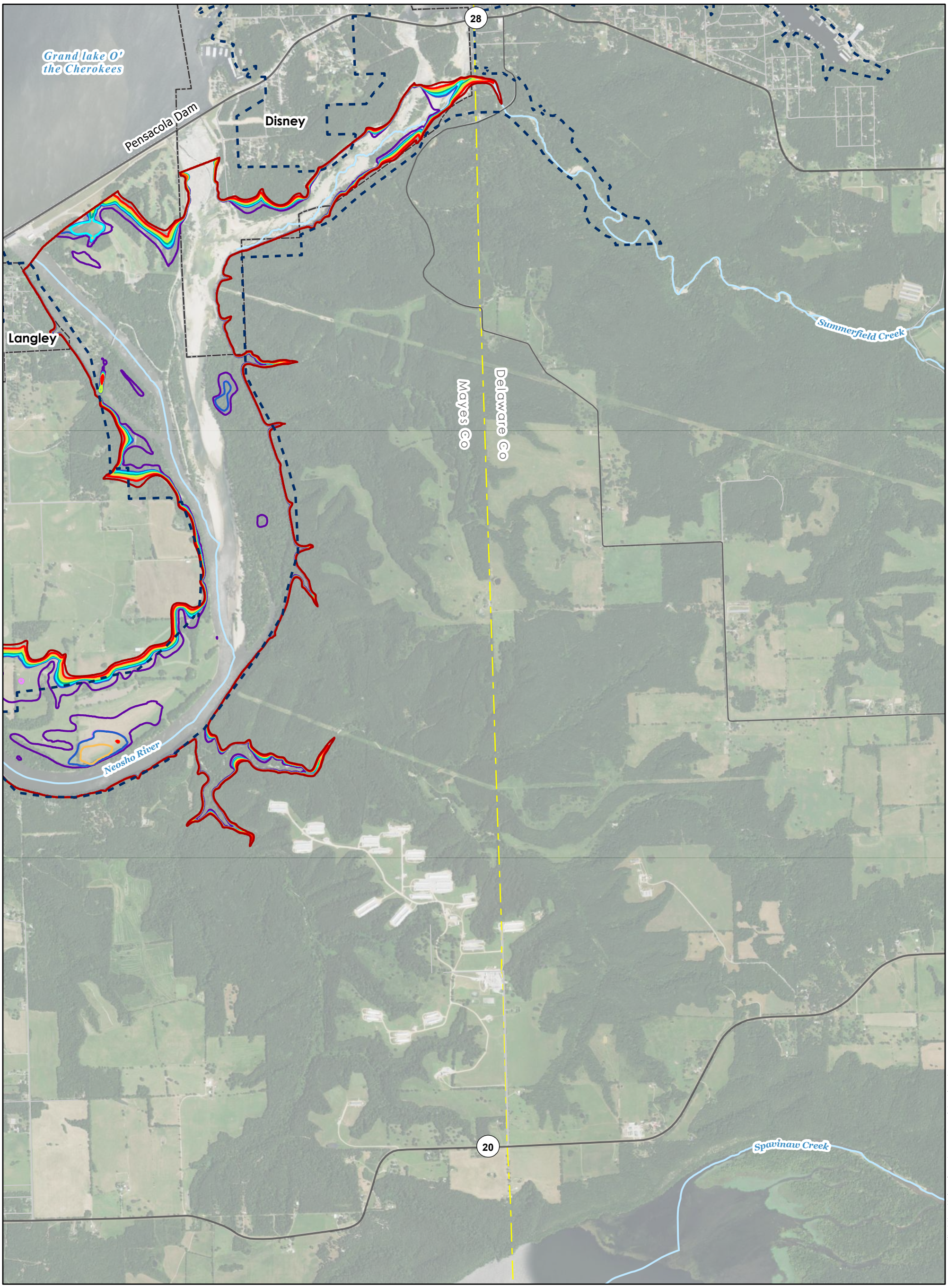


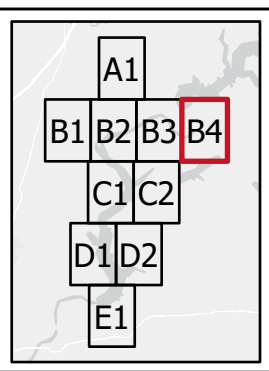
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B4

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B1 B2 B2

Benge Branch

E 430 Rd

E 440 Rd

N 440 Rd

Lake Hudson

E 467.5 Rd

Hoot Owl

Wolf Creek

C2

D1 D1 D2

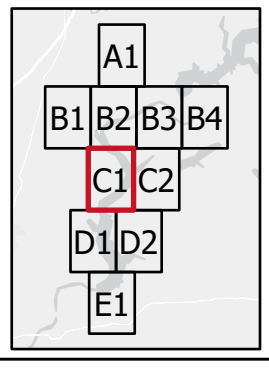
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B2 B3 B3

C1

Spavinaw Creek

Spavinaw

Hoot Owl

20

D2 D2

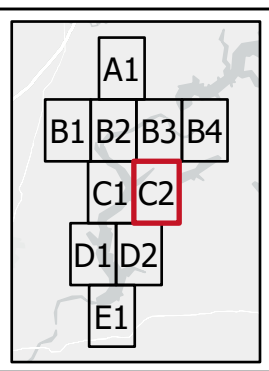
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C1

Wolf Creek
Lake Hudson
N 438 Rd
20
Sulphur Creek
Chapel Branch
S 438 Rd
Salina
Lake Hudson
E 520 Rd
D2

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

E1 E1

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1
B1 B2 B3 B4
C1 C2
D1 D2
E1

Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C2 C2

D1

E1

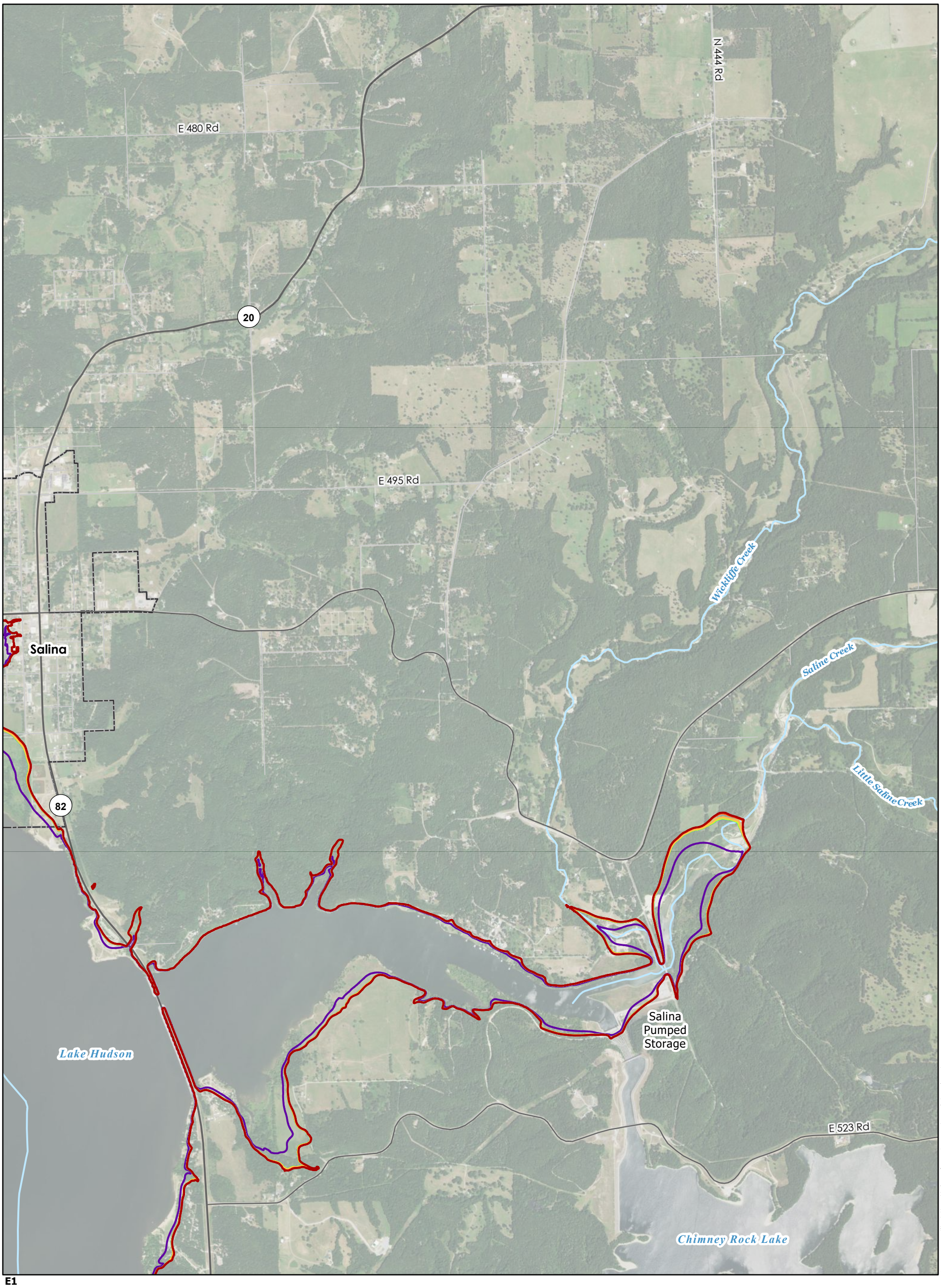


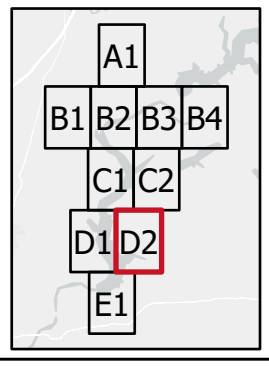
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

D1 D1 D2

Lake Hudson

Robert S. Kerr Dam
(Markham Ferry)

S 440 Rd

82

E 560 Rd

412A

Locust Grove

412

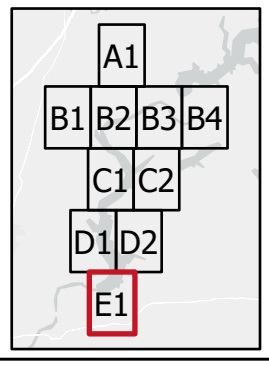
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

SEPTEMBER 1993 (21 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

SEP 1993 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: E1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX E.2:
JUNE 2004 (1 YEAR) EVENT INUNDATION MAPS

Downstream Model Results Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

Date: September 2022

Overview Map Legend

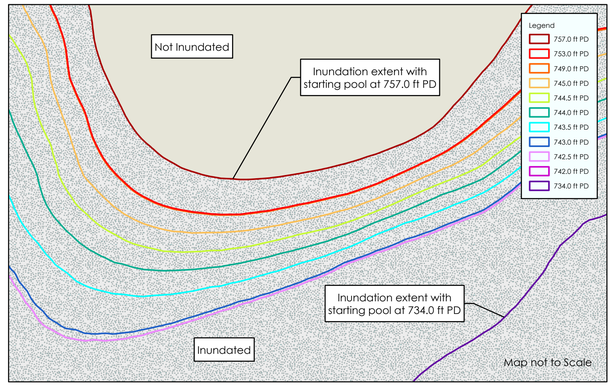
- 1:24,000-scale Map Sheet
- County Boundary
- Municipality
- Unincorporated

Road Class

- Interstate
- US Highway

Inundation Scenario Mapping

Mapping shows the extent of inundation for the selected hydraulic event under different starting pool elevations at Pensacola Dam: 734.0 ft PD, 742.0 ft PD, 742.5 ft PD, 743.0 ft PD, 743.5 ft PD, 744.0 ft PD, 744.5 ft PD, 745.0 ft PD, 749.0 ft PD, 753.0 ft PD, and 757.0 ft PD.



0 0.75 1.5 3 4.5 6 Miles

NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019.
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

Map Source: Esri, NASA, NGA, USGS, Missouri Dept. of Conservation, Missouri DNR, Texas Parks & Wildlife, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

Big Cabin Creek
Granny Branch
S 4400 Rd
S 4420 Rd
S 4430 Rd
S 4440 Rd
E 330 Rd
E 340 Rd
E 345 Rd
E 360 Rd
Craig Co
Mayes Co

B2 B2 B3

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1
B1 B2 B3 B4
C1 C2
D1 D2
E1

Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: A1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

E 370 Rd

Rock Creek

E 390 Rd

Adair

28

E 410 Rd

N 436 Rd

Armstrong Branch

E 420 Rd

B2

C1

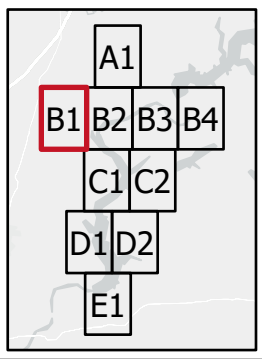
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1 A1

B1 B3

C1 C1 C2

E 370 Rd

Granny Branch

Big Cabin Creek

Pensacola

28

Neosho River

Rock Creek

Lake Hudson

E 420 Rd

Strang

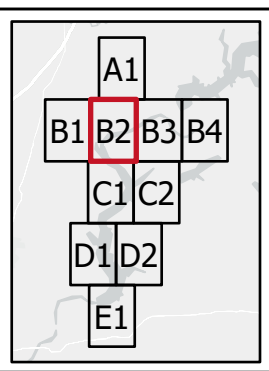
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1

B2

B4

C2

C2

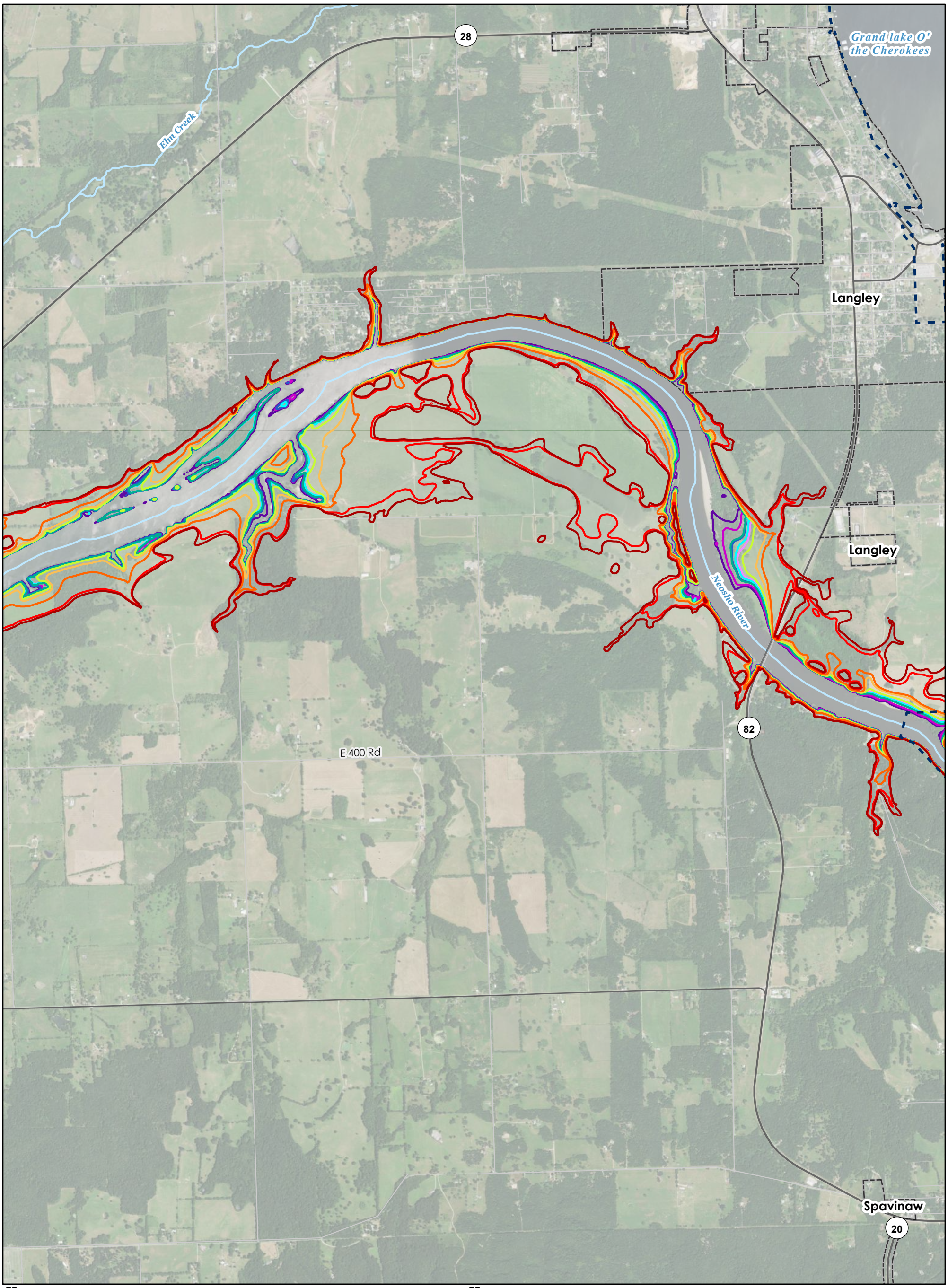


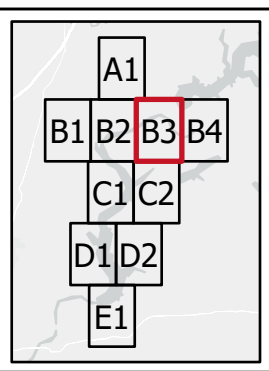
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM

DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B3

Grand lake O' the Cherokees

Pensacola Dam

Disney

Langley

28

Summerfield Creek

Mayes Co

Delaware Co

Neosho River

20

Spavinaw Creek

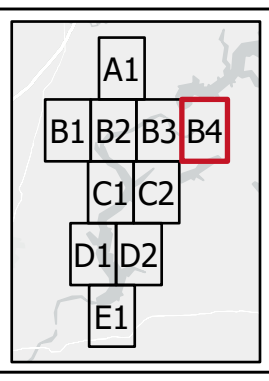
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

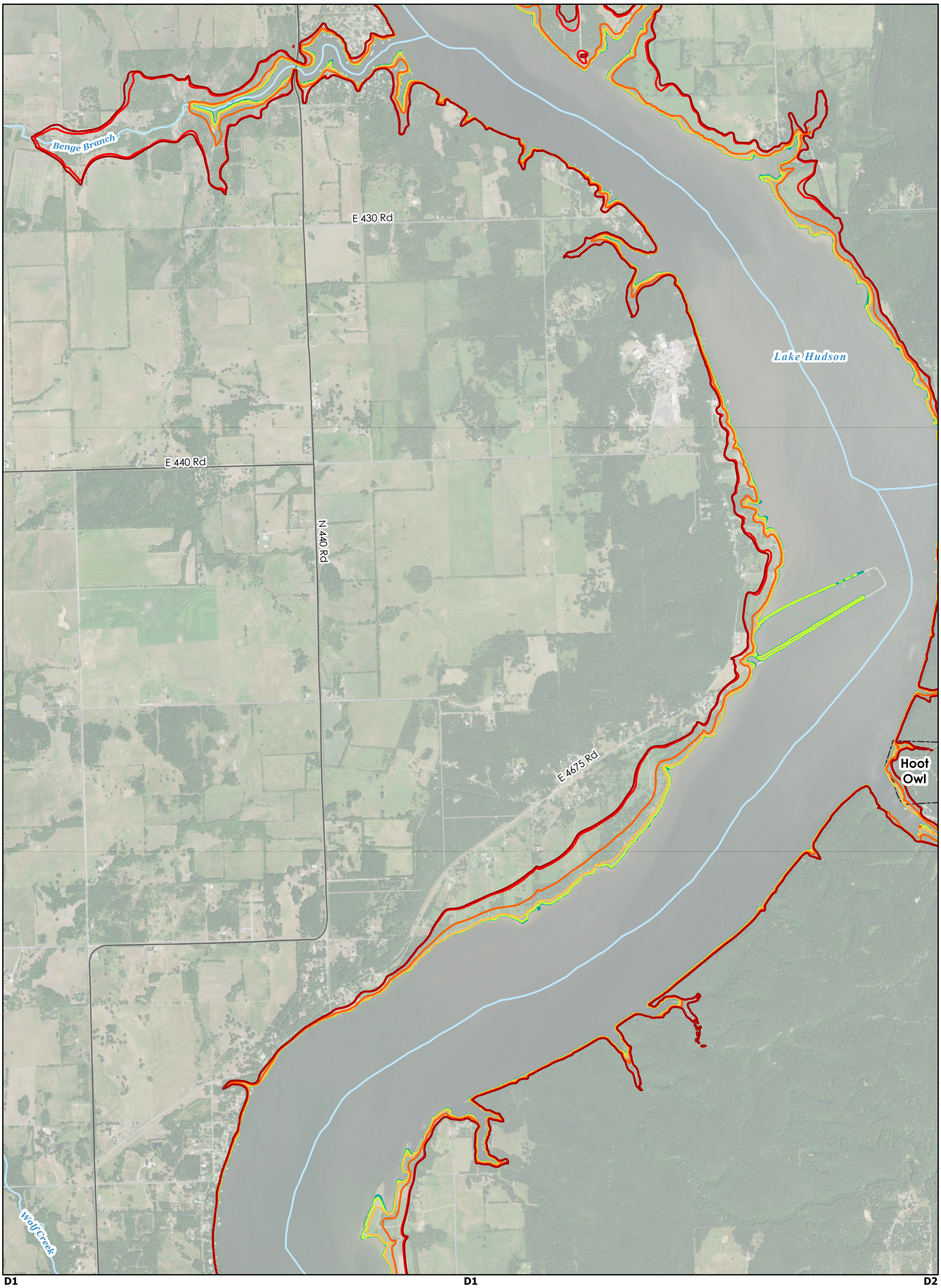
MAP: B4

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B1 B2 B2



C2

D1 D1 D2

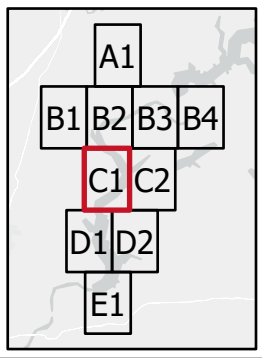
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B2 B3 B3

C1

Spavinaw Creek

Spavinaw

Hoot Owl

20

D2 D2

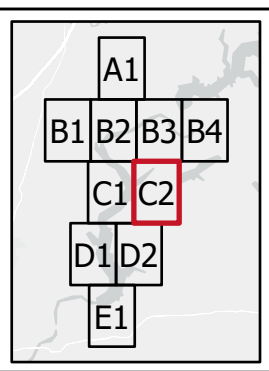
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C1

Wolf Creek
Lake Hudson
N 438 Rd
20
Sulphur Creek
Chapel Branch
S 438 Rd
Lake Hudson
Salina
D2
E 520 Rd

E1 E1

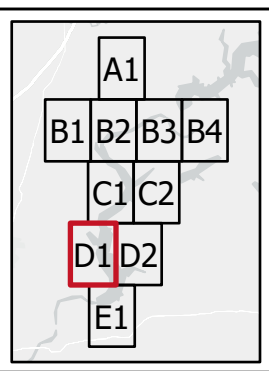
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C2 C2

D1

E1

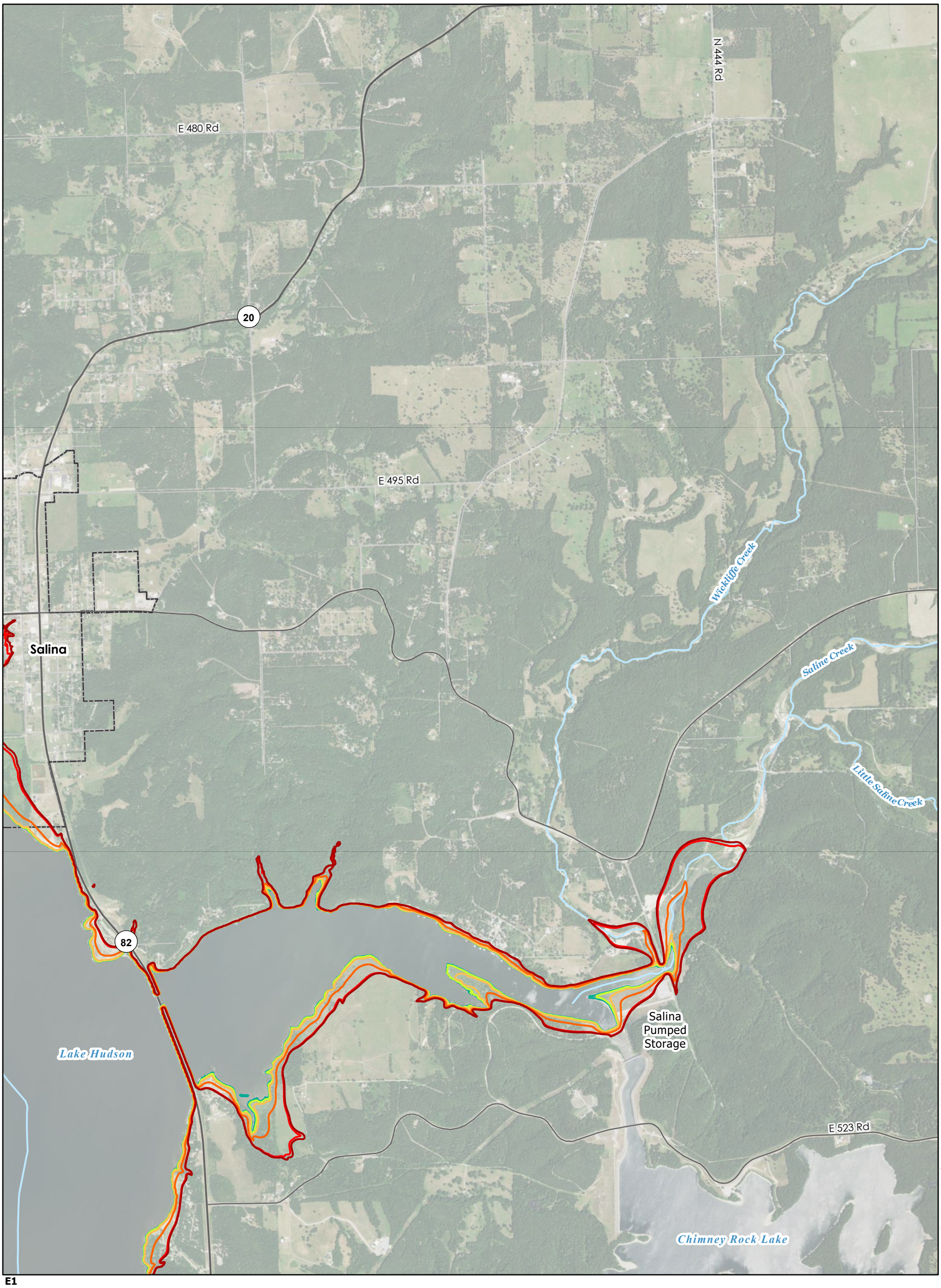


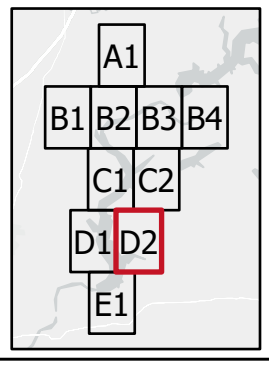
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

BOUNDARY TYPE

- Project
- County
- Municipal

- Stream

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

D1 D1 D2

Lake Hudson

Robert S. Kerr Dam
(Markham Ferry)

S 440 Rd

82

E 560 Rd

412A

Locust Grove

412

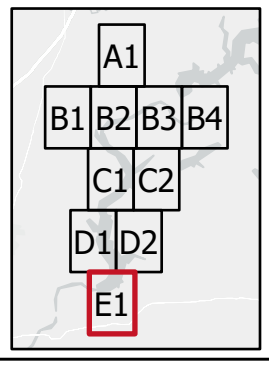
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JUNE 2004 (1 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUN 2004 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: E1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX E.3:
JULY 2007 (4 YEAR) EVENT INUNDATION MAPS

Downstream Model Results Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

Date: September 2022

Overview Map Legend

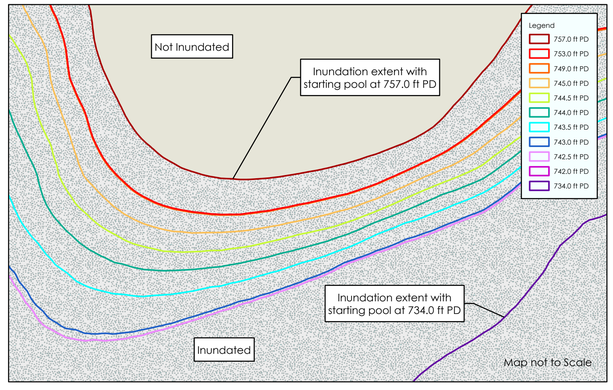
- 1:24,000-scale Map Sheet
- County Boundary
- Municipality
- Unincorporated

Road Class

- Interstate
- US Highway

Inundation Scenario Mapping

Mapping shows the extent of inundation for the selected hydraulic event under different starting pool elevations at Pensacola Dam: 734.0 ft PD, 742.0 ft PD, 742.5 ft PD, 743.0 ft PD, 743.5 ft PD, 744.0 ft PD, 744.5 ft PD, 745.0 ft PD, 749.0 ft PD, 753.0 ft PD, and 757.0 ft PD.



0 0.75 1.5 3 4.5 6 Miles

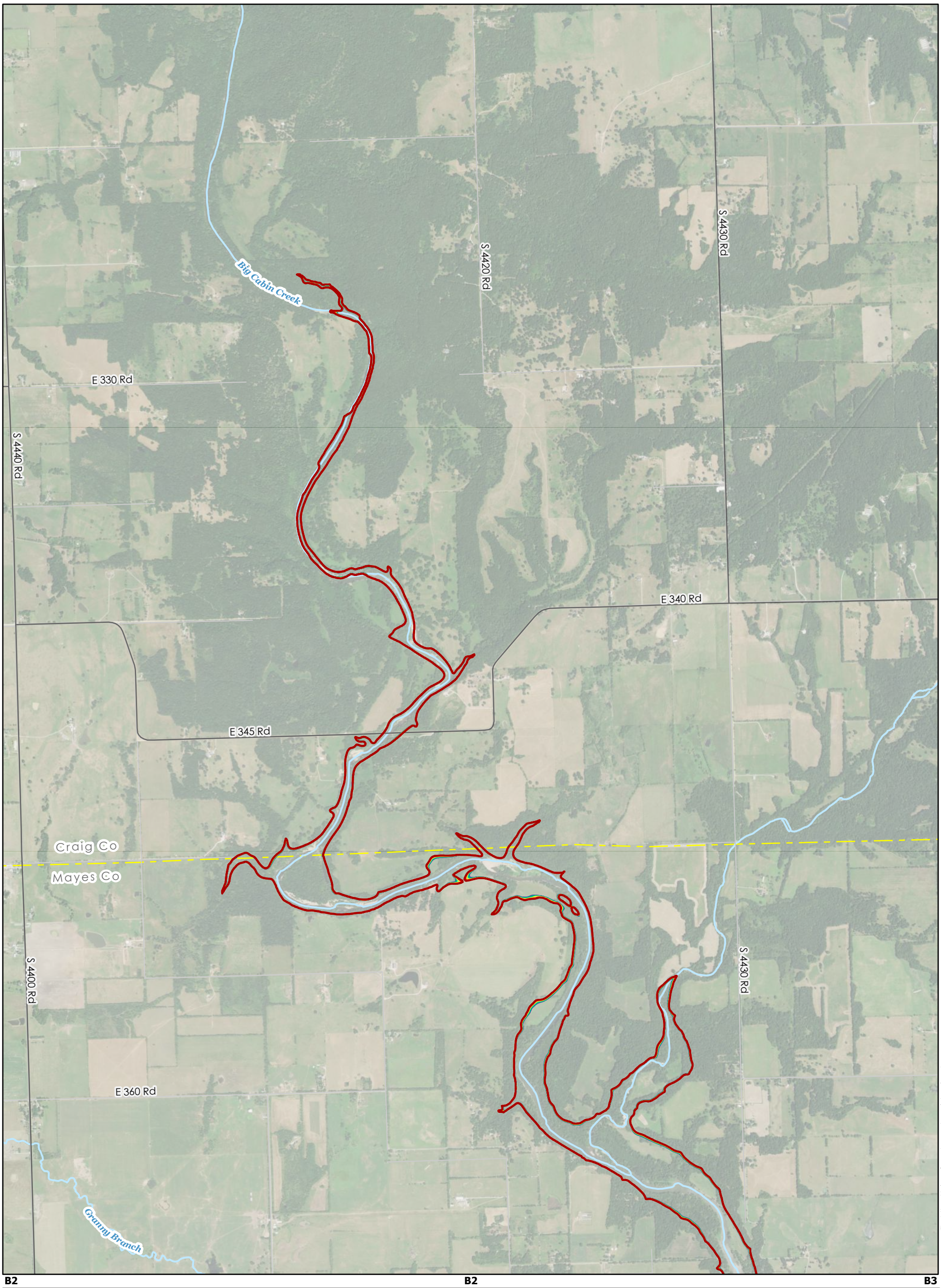
NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019.
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

Map Source: Esri, NASA, NGA, USGS, Missouri Dept. of Conservation, Missouri DNR, Texas Parks & Wildlife, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

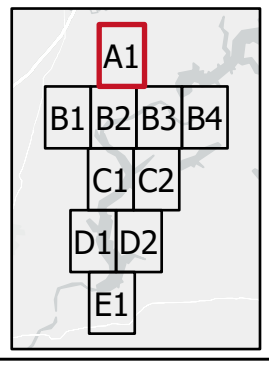


JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: A1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

E 370 Rd

Rock Creek

E 390 Rd

Adair

28

E 410 Rd

N 436 Rd

Armstrong Branch

E 420 Rd

B2

C1

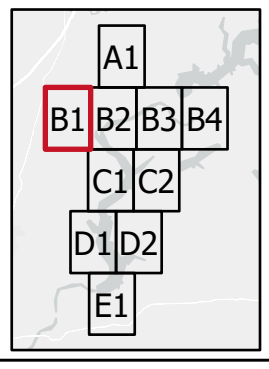
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1 A1

B1 B3

C1 C1 C2

E 370 Rd
Granny Branch
Big Cabin Creek
Pensacola
28
Neosho River
Rock Creek
Strang
Lake Hudson
E 420 Rd

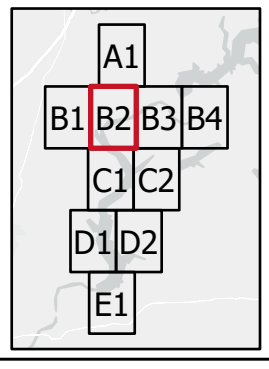
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1

B2

B4

C2

C2

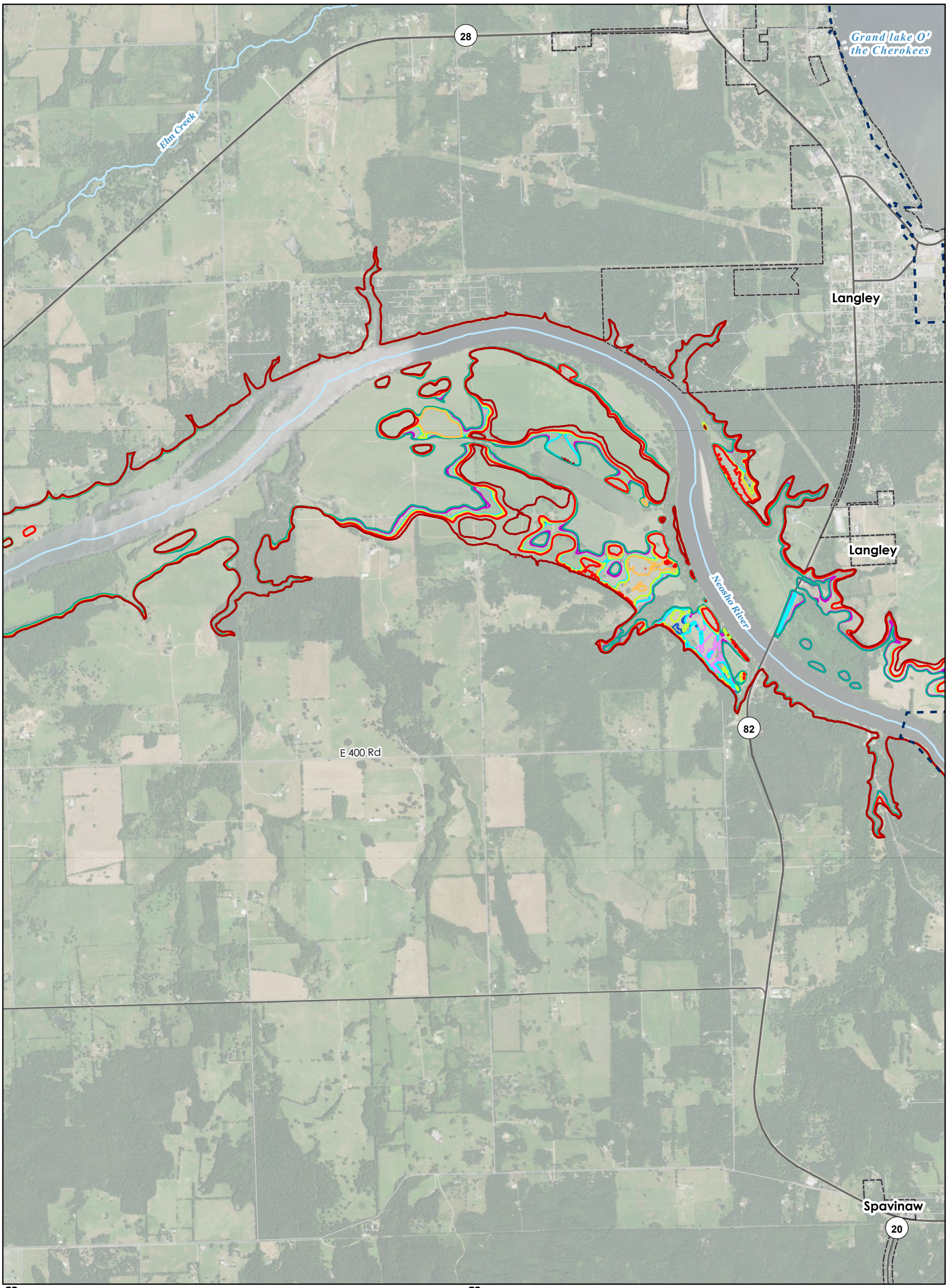


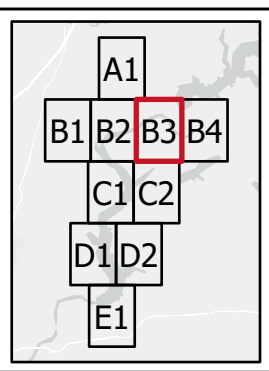
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

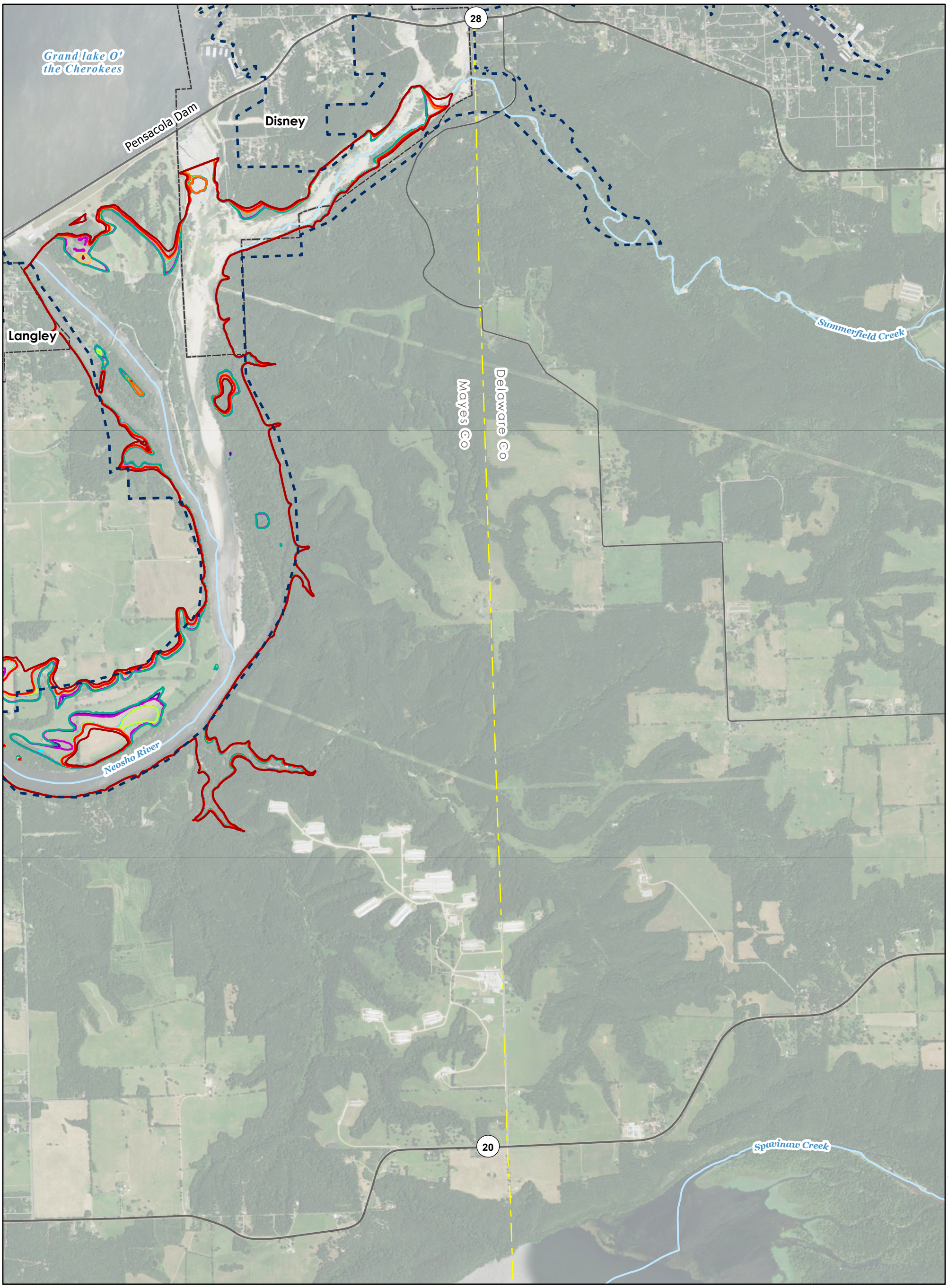


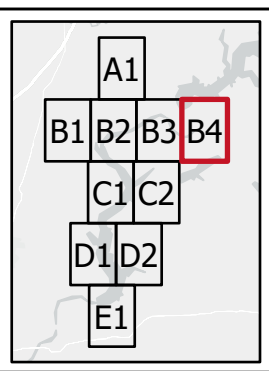
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

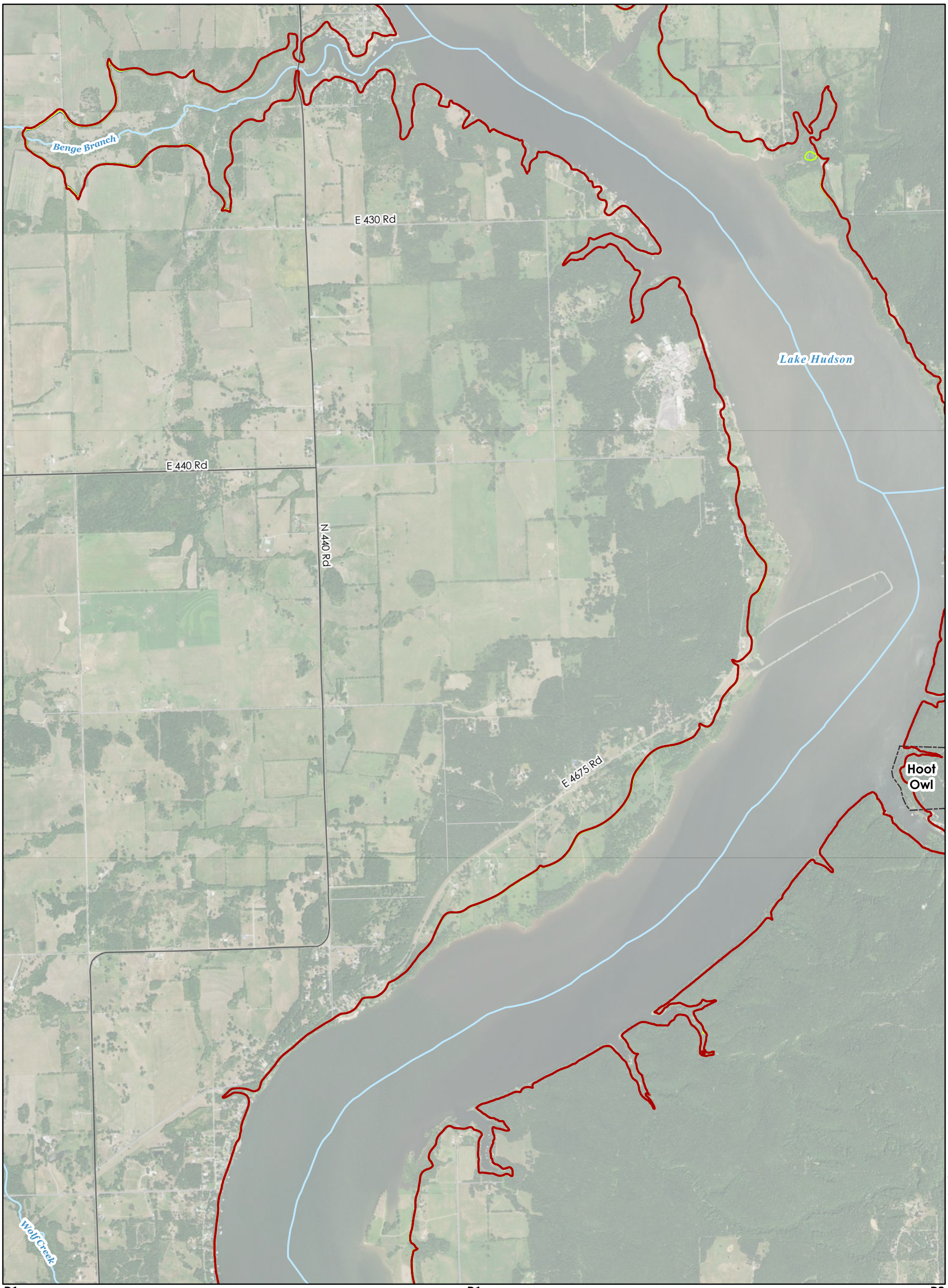
MAP: B4

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B1 B2 B2



C2

D1 D1 D2

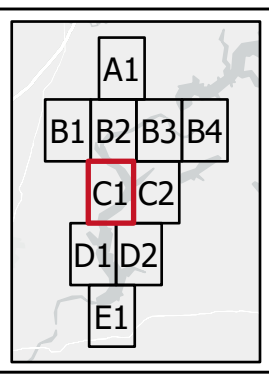
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B2 B3 B3

C1

Spavinaw Creek

Spavinaw

Hoot Owl

20

D2 D2

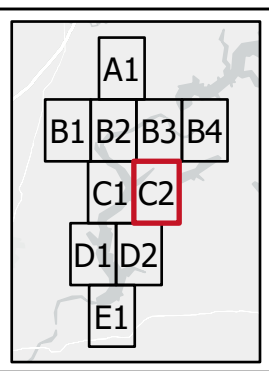
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C1

Wolf Creek
Lake Hudson
N 438 Rd
20
Sulphur Creek
Chapel Branch
S 438 Rd
Lake Hudson
Salina
D2
E 520 Rd

E1 E1

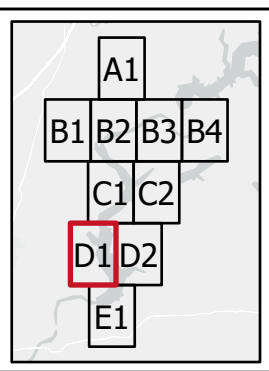
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C2 C2

D1

E1

E 480 Rd

N 444 Rd

20

E 495 Rd

Salina

Wickliffe Creek

Saline Creek

Little Saline Creek

82

Salina Pumped Storage

Lake Hudson

E 523 Rd

Chimney Rock Lake

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1 B1 B2 B3 B4 C1 C2 D1 D2 E1

Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

BOUNDARY TYPE

- Project
- County
- Municipal

- Stream

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

D1 D1 D2

Lake Hudson

Robert S. Kerr Dam
(Markham Ferry)

S 440 Rd

82

E 560 Rd

412A

Locust Grove

412

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

JULY 2007 (4 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1 B1 B2 B3 B4 C1 C2 D1 D2 E1

Legend

JUL 2007 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: E1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX E.4:
OCTOBER 2009 (3 YEAR) EVENT INUNDATION MAPS

Downstream Model Results Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

Date: September 2022

Overview Map Legend

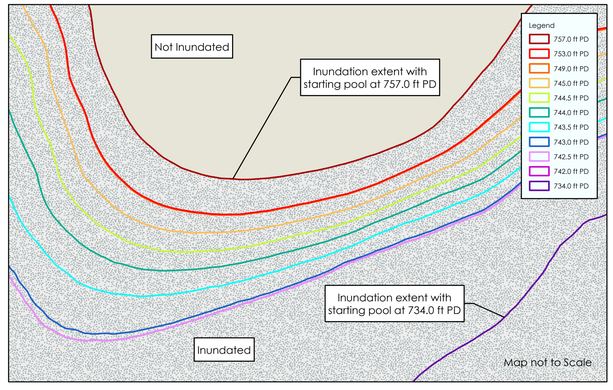
- 1:24,000-scale Map Sheet
- County Boundary
- Municipality
- Unincorporated

Road Class

- Interstate
- US Highway

Inundation Scenario Mapping

Mapping shows the extent of inundation for the selected hydraulic event under different starting pool elevations at Pensacola Dam: 734.0 ft PD, 742.0 ft PD, 742.5 ft PD, 743.0 ft PD, 743.5 ft PD, 744.0 ft PD, 744.5 ft PD, 745.0 ft PD, 749.0 ft PD, 753.0 ft PD, and 757.0 ft PD.



0 0.75 1.5 3 4.5 6 Miles

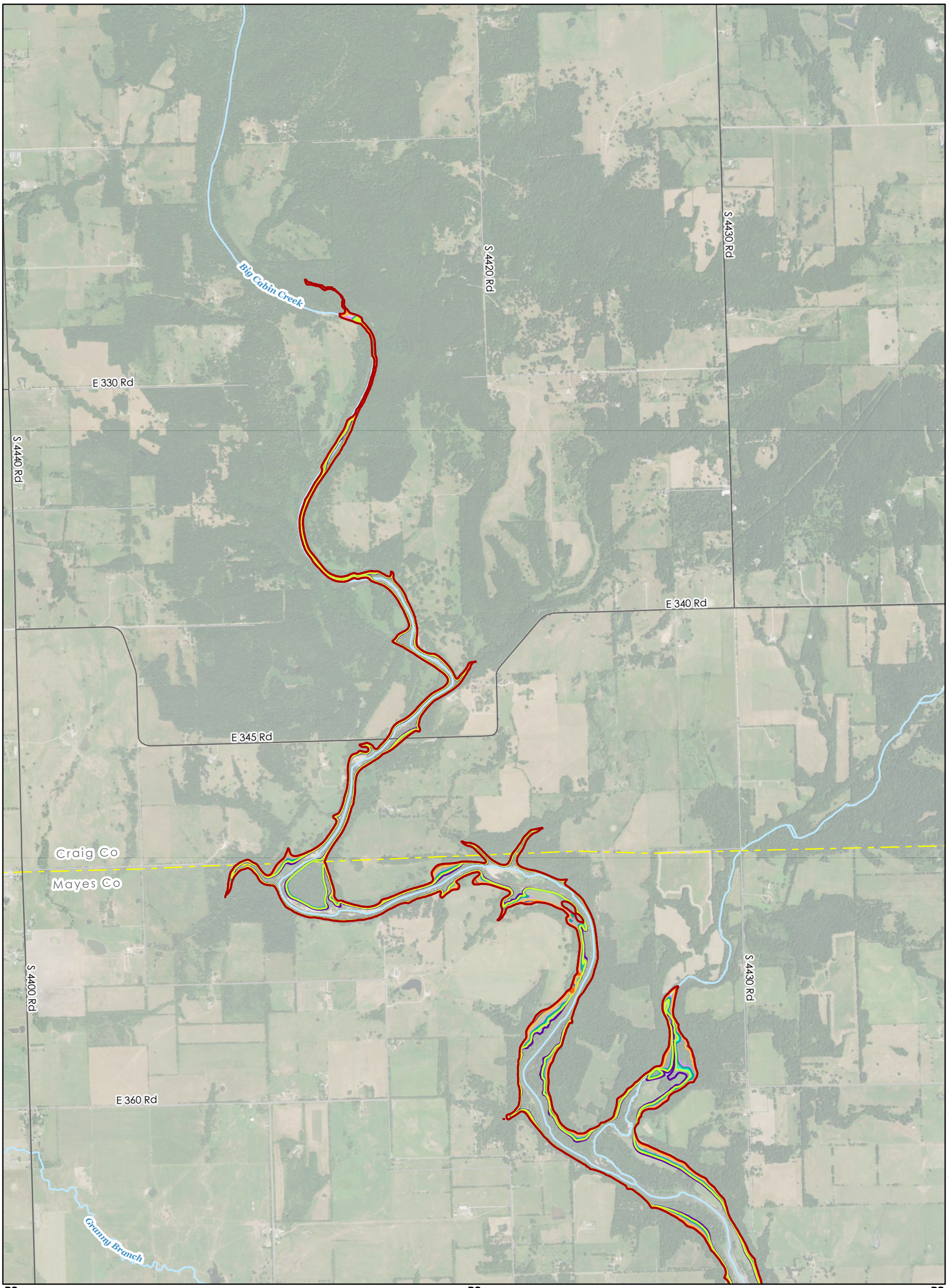
NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019.
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

Map Source: Esri, NASA, NGA, USGS, Missouri Dept. of Conservation, Missouri DNR, Texas Parks & Wildlife, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



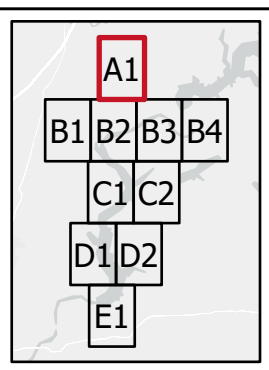
B2 B2 B3

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM

DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

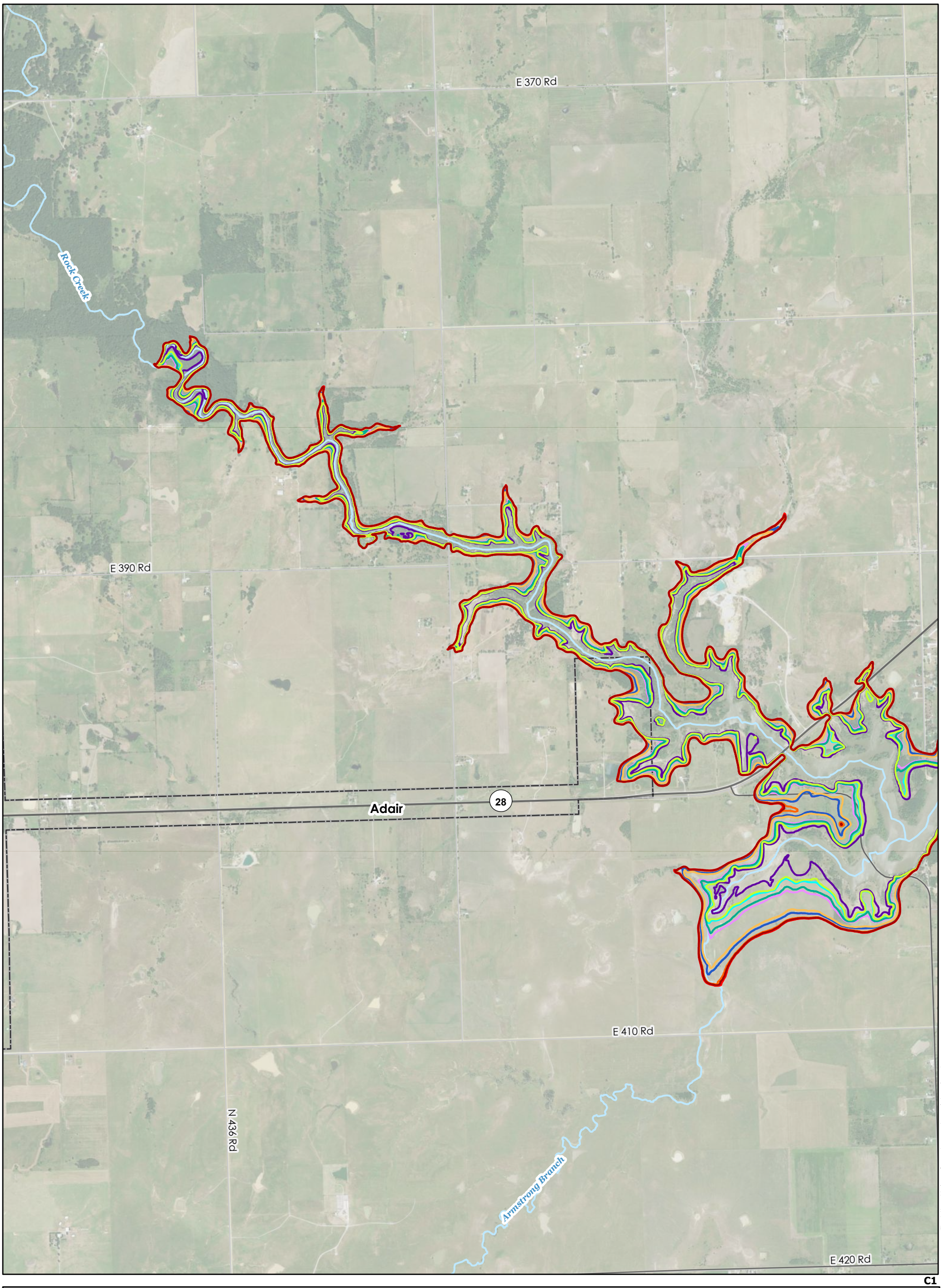
MAP: A1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

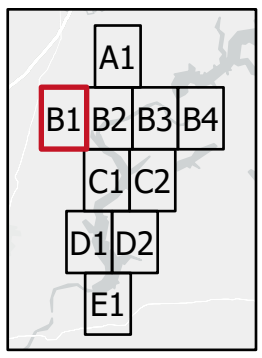


OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

A1 A1

E 370 Rd

Granny Branch

Big Cabin Creek

Pensacola

28

Neosho River

B1

B3

Rock Creek

Strang

Lake Hudson

E 420 Rd

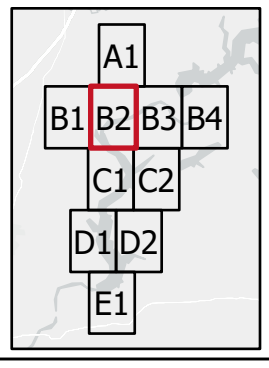
C1 C1 C2

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

A1

B2

B4

C2

C2

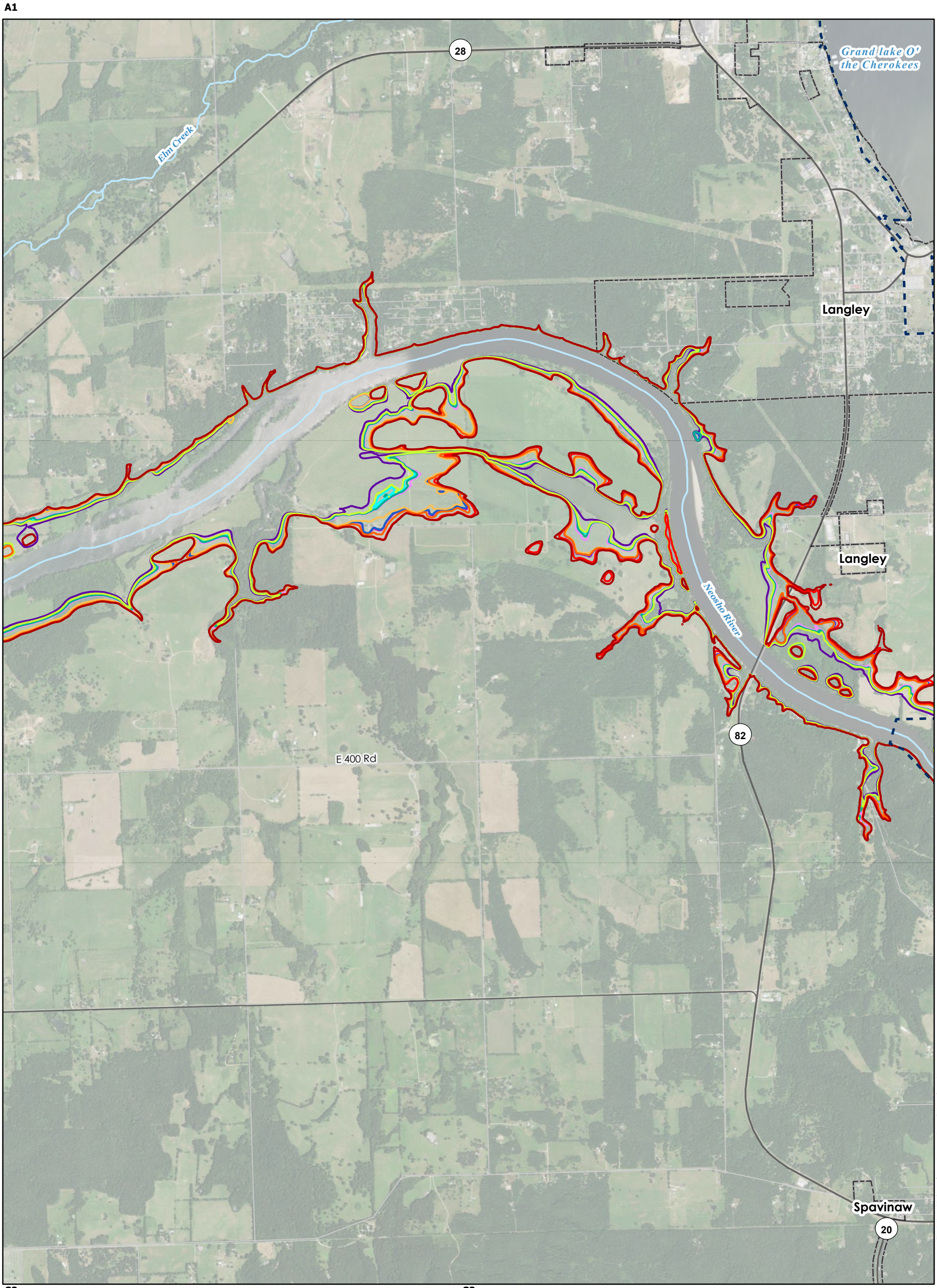


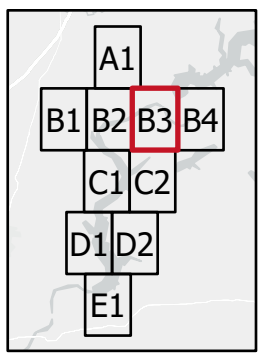
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

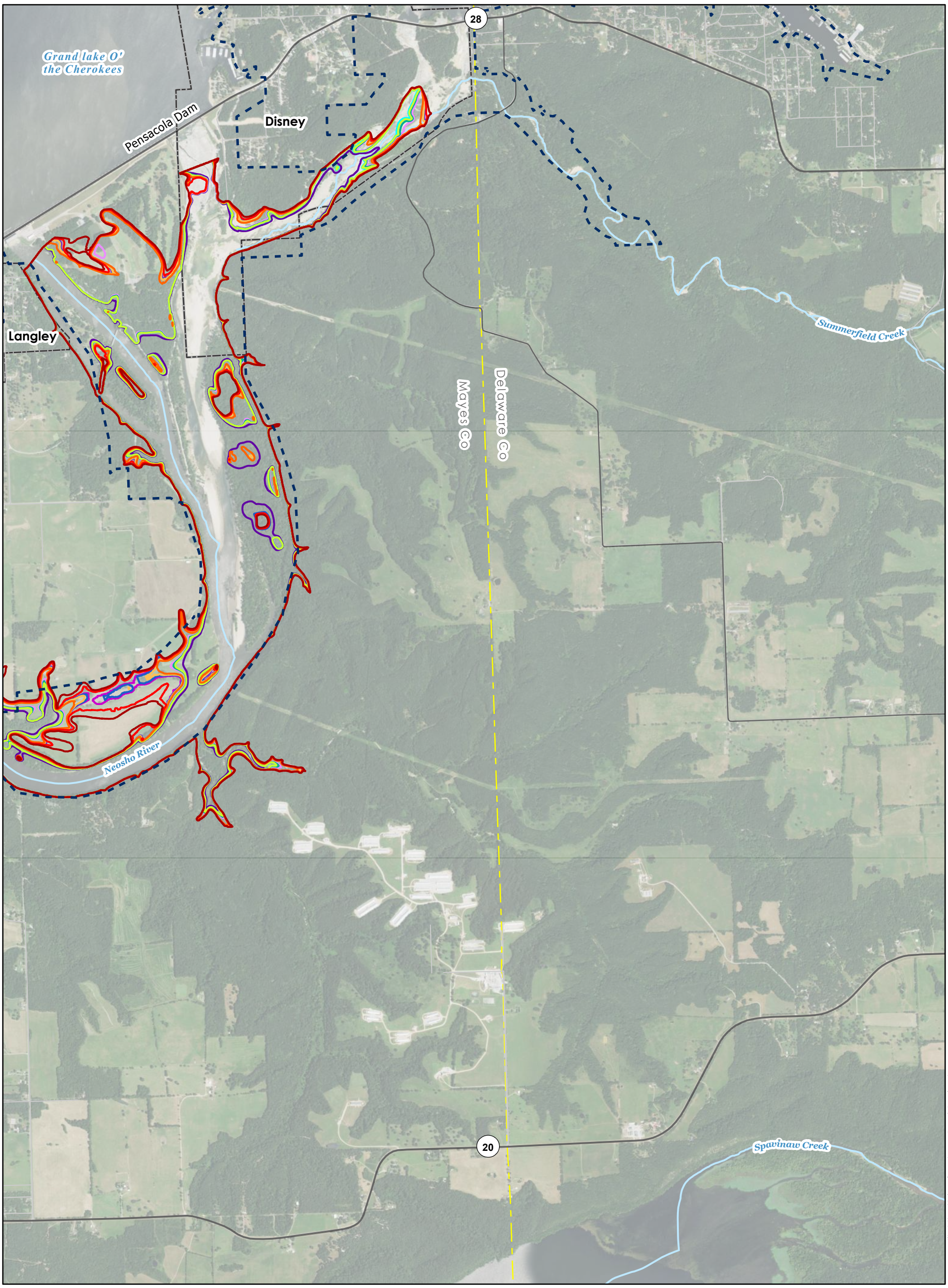


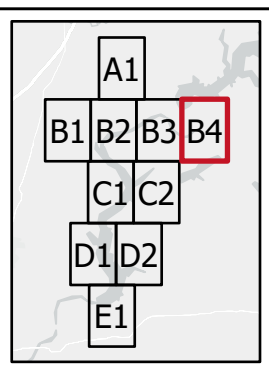
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B4

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B1 B2 B2

Benge Branch

E 430 Rd

Lake Hudson

E 440 Rd

N 440 Rd

E 4675 Rd

Hoot Owl

C2

Wolf Creek

D1 D1 D2

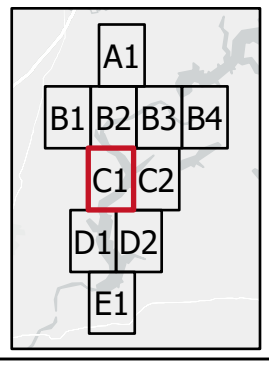
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM

DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B2 B3 B3

C1

Spavinaw Creek

Spavinaw

Hoot Owl

20

D2 D2

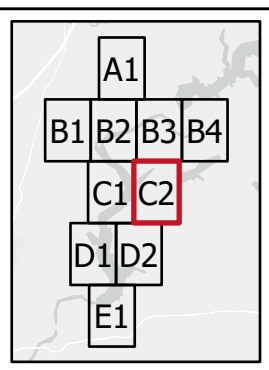
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C1

Wolf Creek
Lake Hudson
N 438 Rd
20
Sulphur Creek
Chapel Branch
S 438 Rd
Salina
Lake Hudson
E 520 Rd
D2

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

E1 E1

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1
B1 B2 B3 B4
C1 C2
D1 D2
E1

Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C2 C2

D1

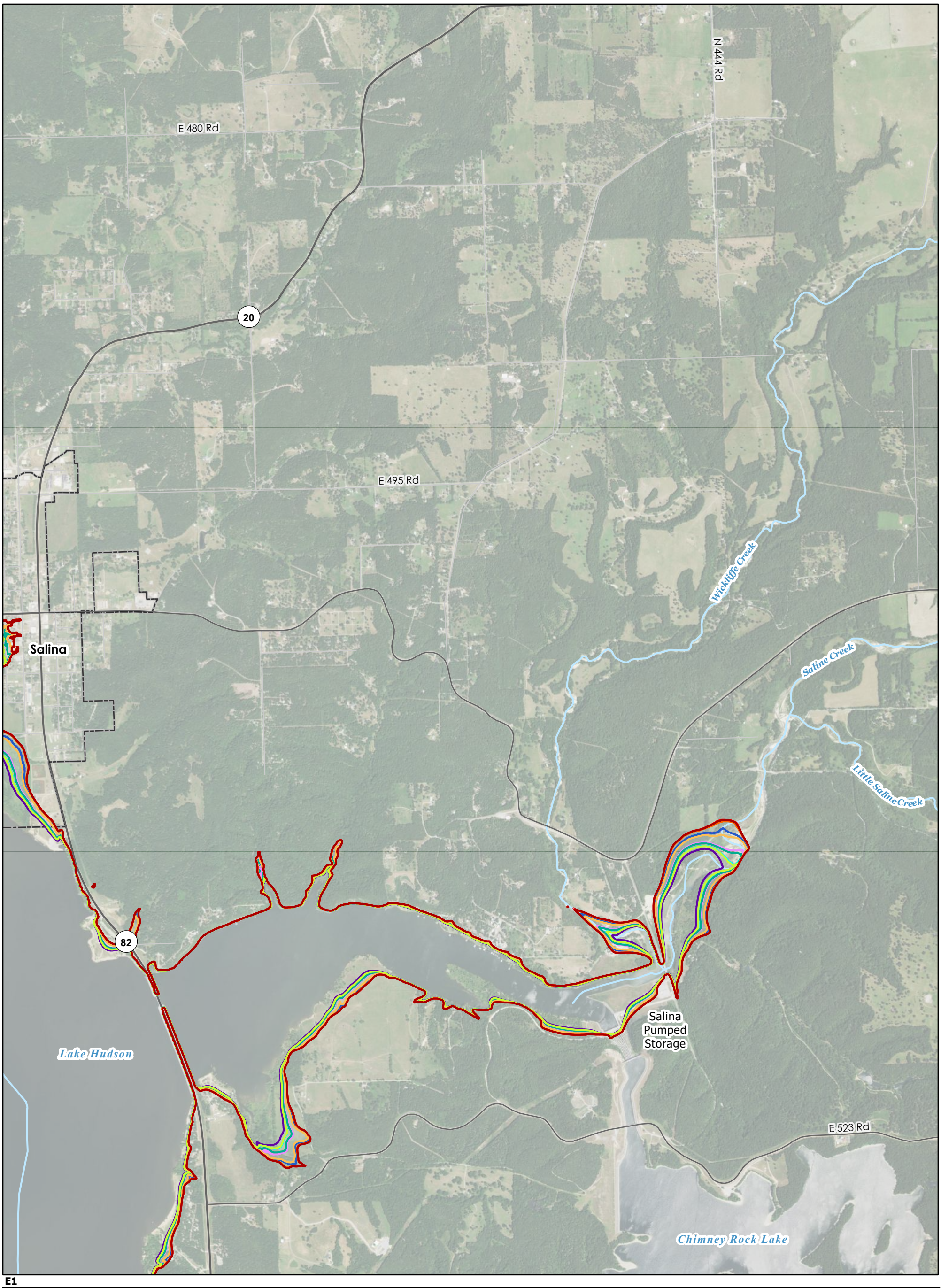


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

E1

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1 B1 B2 B3 B4 C1 C2 D1 D2 E1

Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

D1 D1 D2

Lake Hudson

Robert S. Kerr Dam
(Markham Ferry)

S 440 Rd

82

E 560 Rd

412A

Locust Grove

412

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

OCTOBER 2009 (3 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1 B1 B2 B3 B4 C1 C2 D1 D2 E1

Legend

OCT 2009 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: E1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX E.5:
DECEMBER 2015 (15 YEAR) EVENT INUNDATION MAPS

Downstream Model Results Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

Date: September 2022

Overview Map Legend

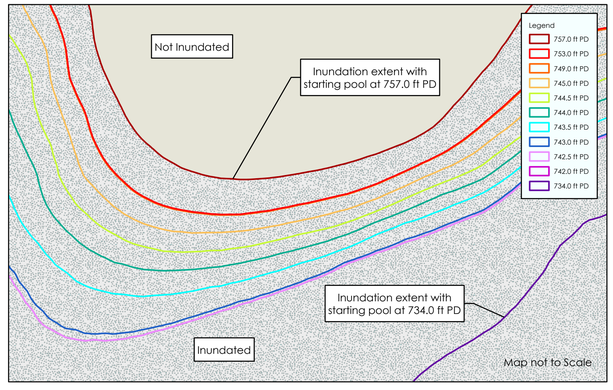
- 1:24,000-scale Map Sheet
- County Boundary
- Municipality
- Unincorporated

Road Class

- Interstate
- US Highway

Inundation Scenario Mapping

Mapping shows the extent of inundation for the selected hydraulic event under different starting pool elevations at Pensacola Dam: 734.0 ft PD, 742.0 ft PD, 742.5 ft PD, 743.0 ft PD, 743.5 ft PD, 744.0 ft PD, 744.5 ft PD, 745.0 ft PD, 749.0 ft PD, 753.0 ft PD, and 757.0 ft PD.



0 0.75 1.5 3 4.5 6 Miles

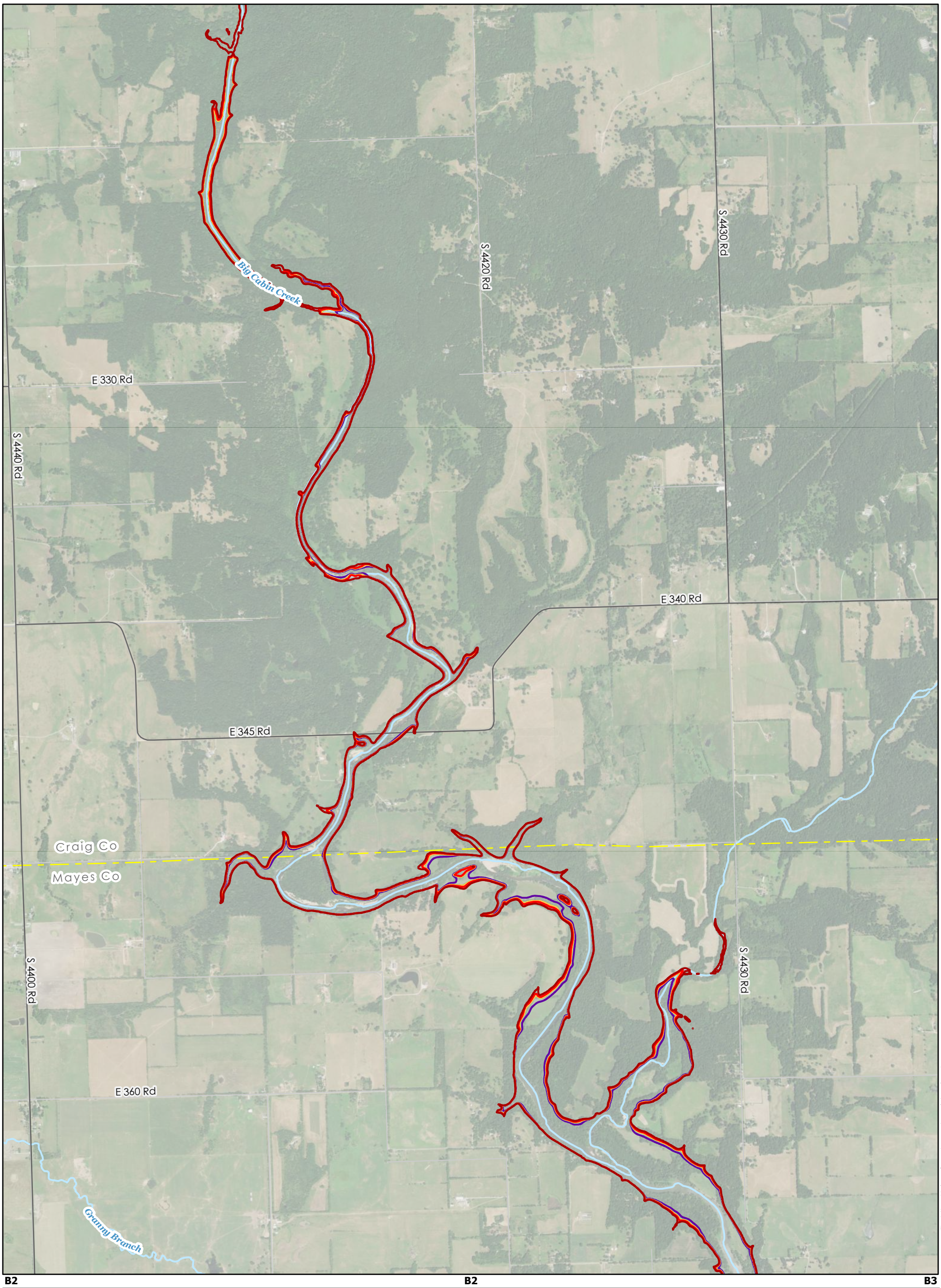
NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019.
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

Map Source: Esri, NASA, NGA, USGS, Missouri Dept. of Conservation, Missouri DNR, Texas Parks & Wildlife, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA



B2 B2 B3

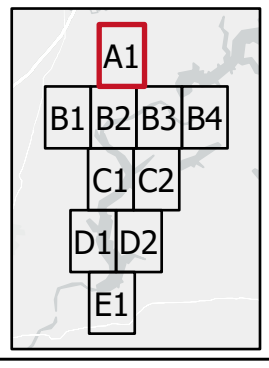
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: A1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

E 370 Rd

Rock Creek

E 390 Rd

Adair

28

E 410 Rd

N 436 Rd

Armstrong Branch

E 420 Rd

B2

C1

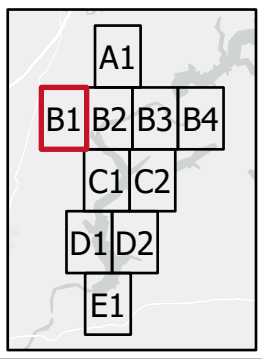
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

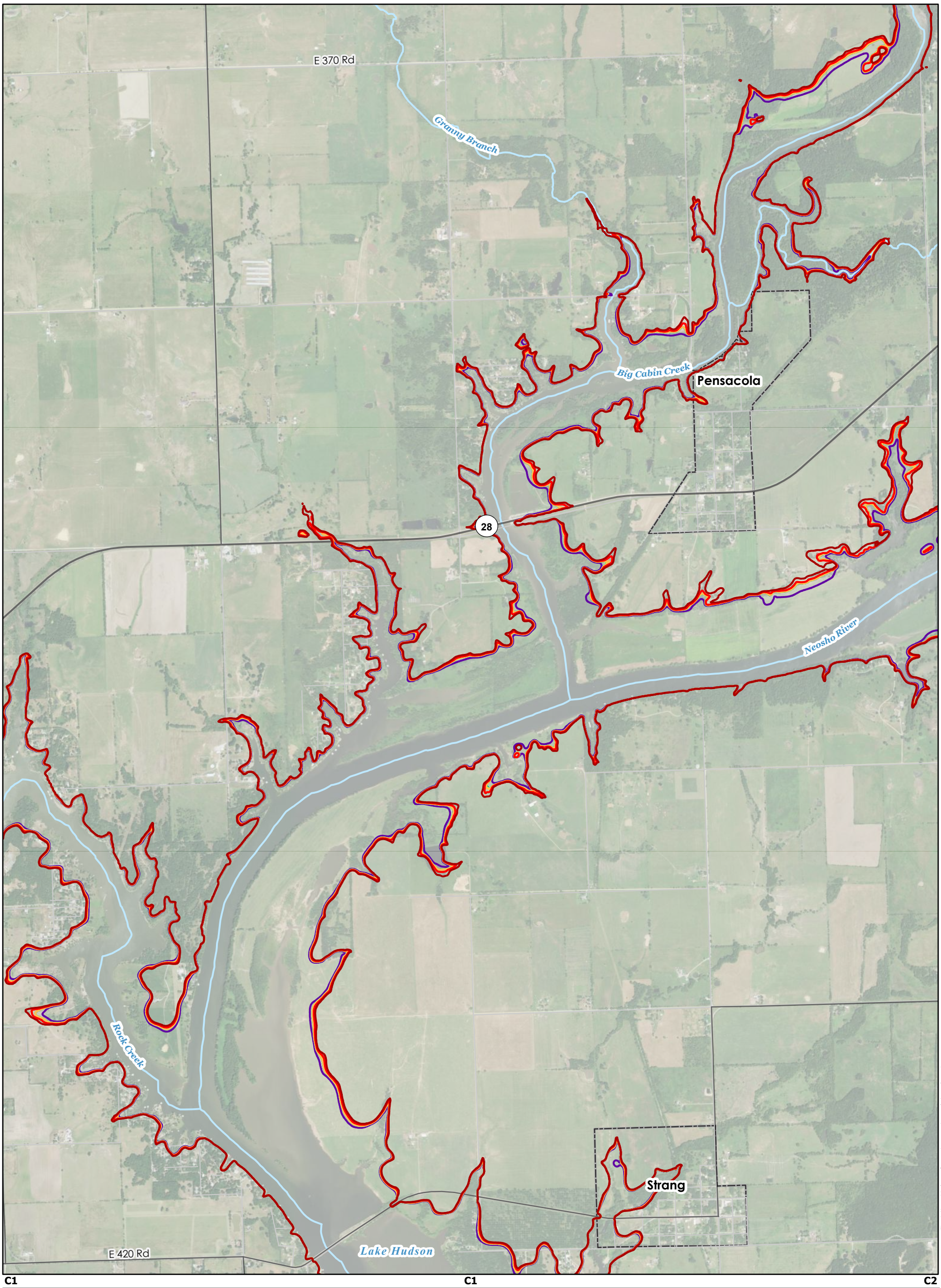
MAP: B1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1 A1



B1 B3

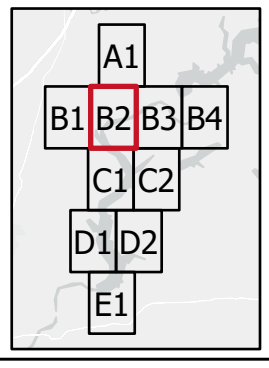
C1 C1 C2

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

BOUNDARY TYPE

- Project
- County
- Municipal

- Stream

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

A1

B2

B4

C2

C2

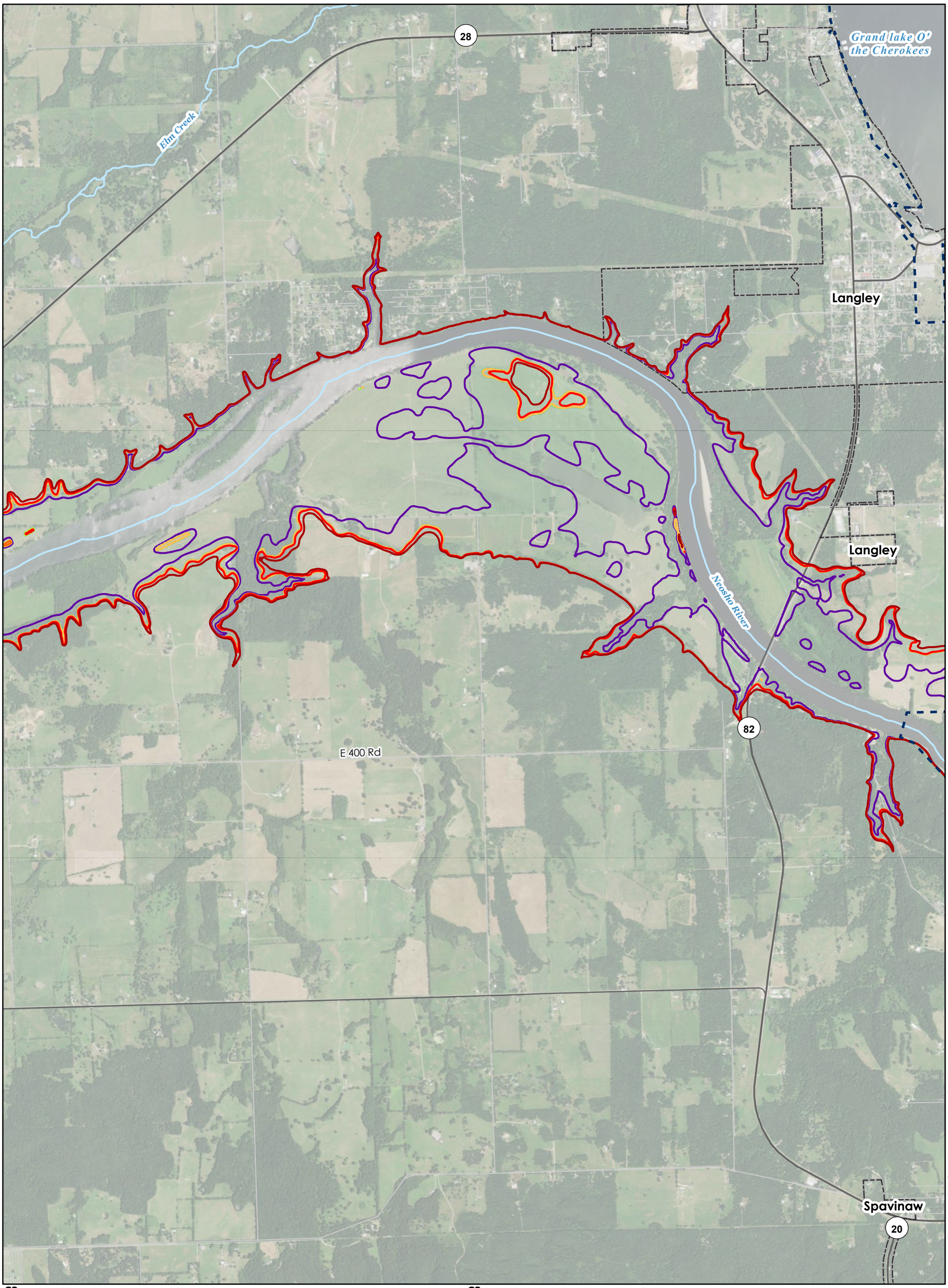


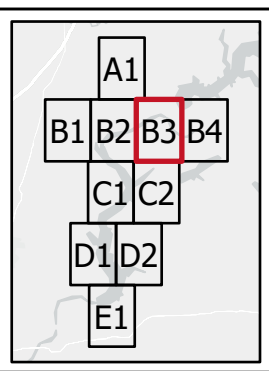
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM

DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

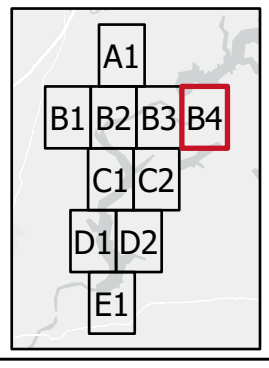
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

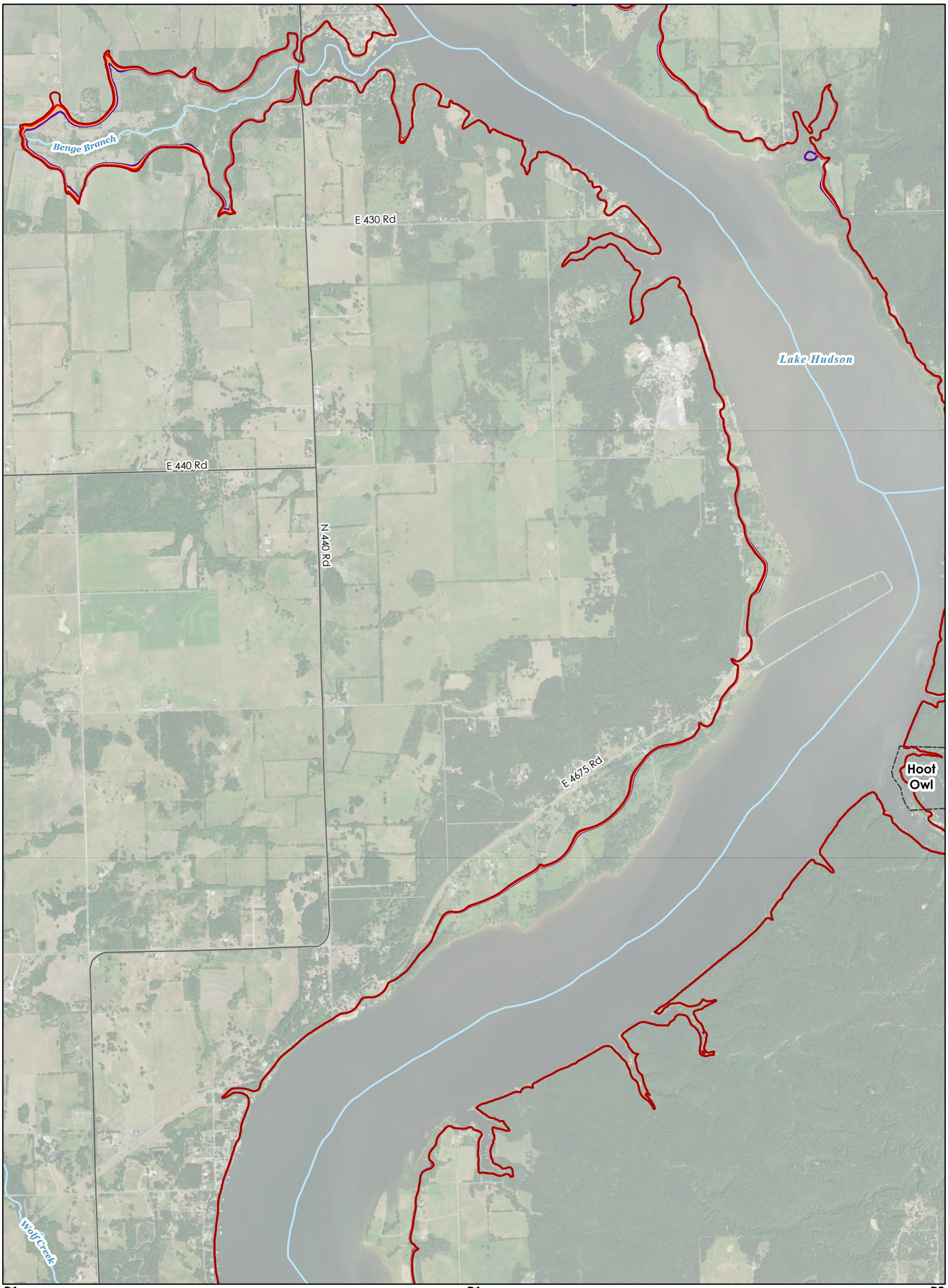
MAP: B4

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B1 B2 B2



C2

D1 D1 D2

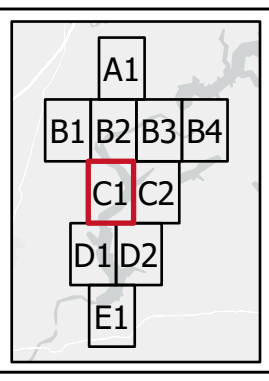
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B2 B3 B3

C1

Spavinaw Creek

Spavinaw

Hoot Owl

20

D2 D2

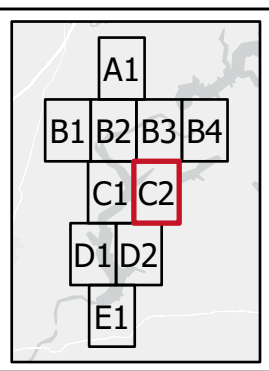
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C1

Wolf Creek
Lake Hudson
N 438 Rd
20
Sulphur Creek
Chapel Branch
S 438 Rd
Salina
D2
Lake Hudson
E 520 Rd

E1 E1

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C2 C2

D1

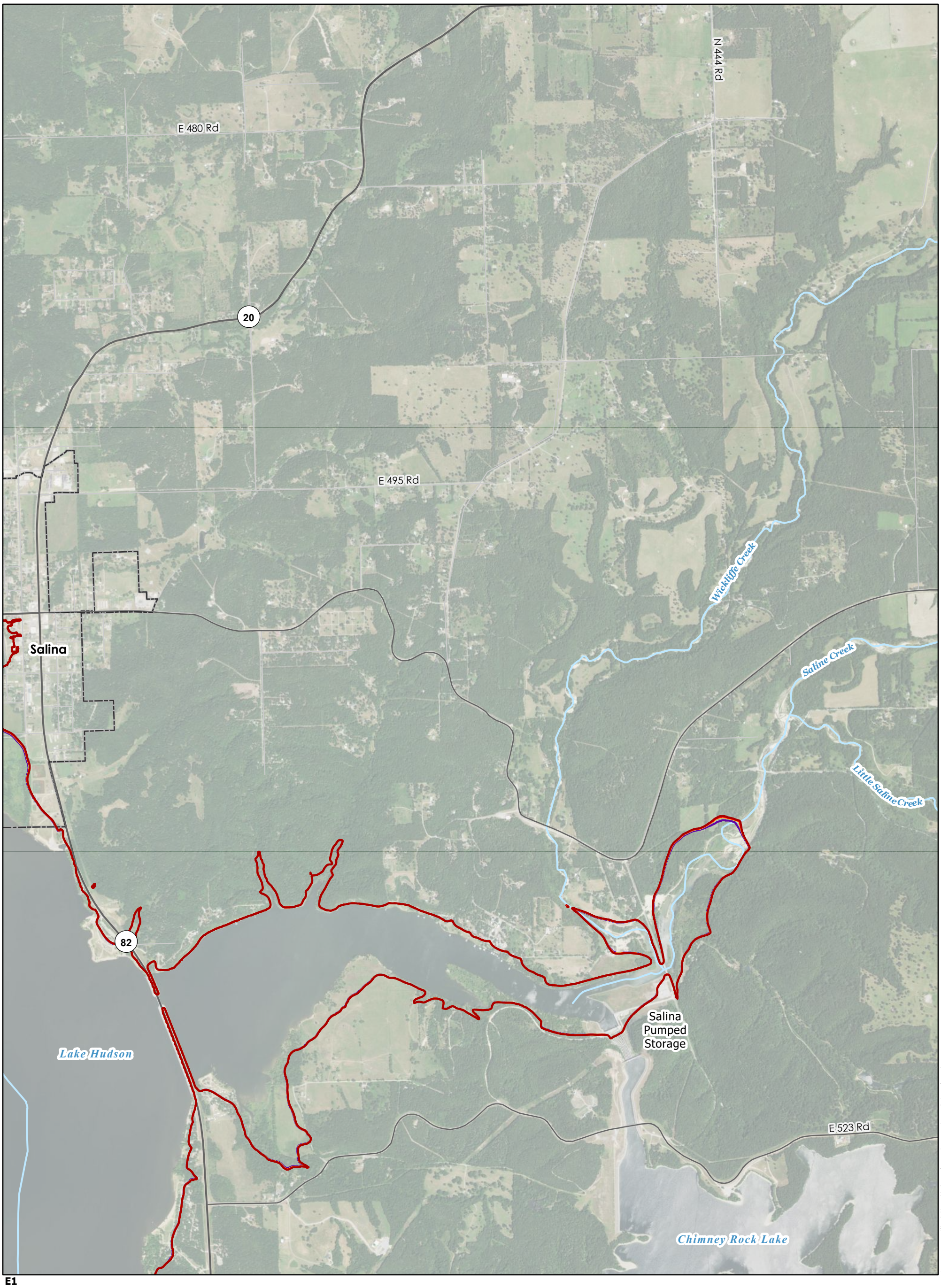


Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

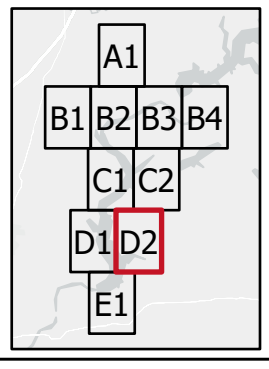
E1

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

BOUNDARY TYPE

- Project
- County
- Municipal

- Stream

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

D1 D1 D2

Lake Hudson

Robert S. Kerr Dam
(Markham Ferry)

S 440 Rd

82

E 560 Rd

412A

Locust Grove

412

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

DECEMBER 2015 (15 YEAR) INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet

A1 B1 B2 B3 B4 C1 C2 D1 D2 E1

Legend

DEC 2015 MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: E1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX E.6:
100-YEAR EVENT INUNDATION MAPS

Downstream Model Results Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

Date: September 2022

Overview Map Legend

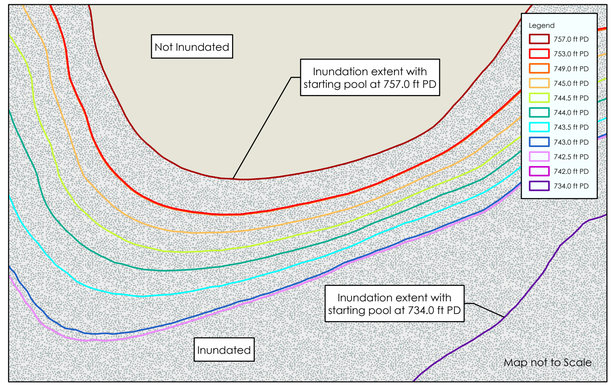
- 1:24,000-scale Map Sheet
- County Boundary
- Municipality
- Unincorporated

Road Class

- Interstate
- US Highway

Inundation Scenario Mapping

Mapping shows the extent of inundation for the selected hydraulic event under different starting pool elevations at Pensacola Dam: 734.0 ft PD, 742.0 ft PD, 742.5 ft PD, 743.0 ft PD, 743.5 ft PD, 744.0 ft PD, 744.5 ft PD, 745.0 ft PD, 749.0 ft PD, 753.0 ft PD, and 757.0 ft PD.



0 0.75 1.5 3 4.5 6 Miles

NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019.
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

Map Source: Esri, NASA, NGA, USGS, Missouri Dept. of Conservation, Missouri DNR, Texas Parks & Wildlife, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

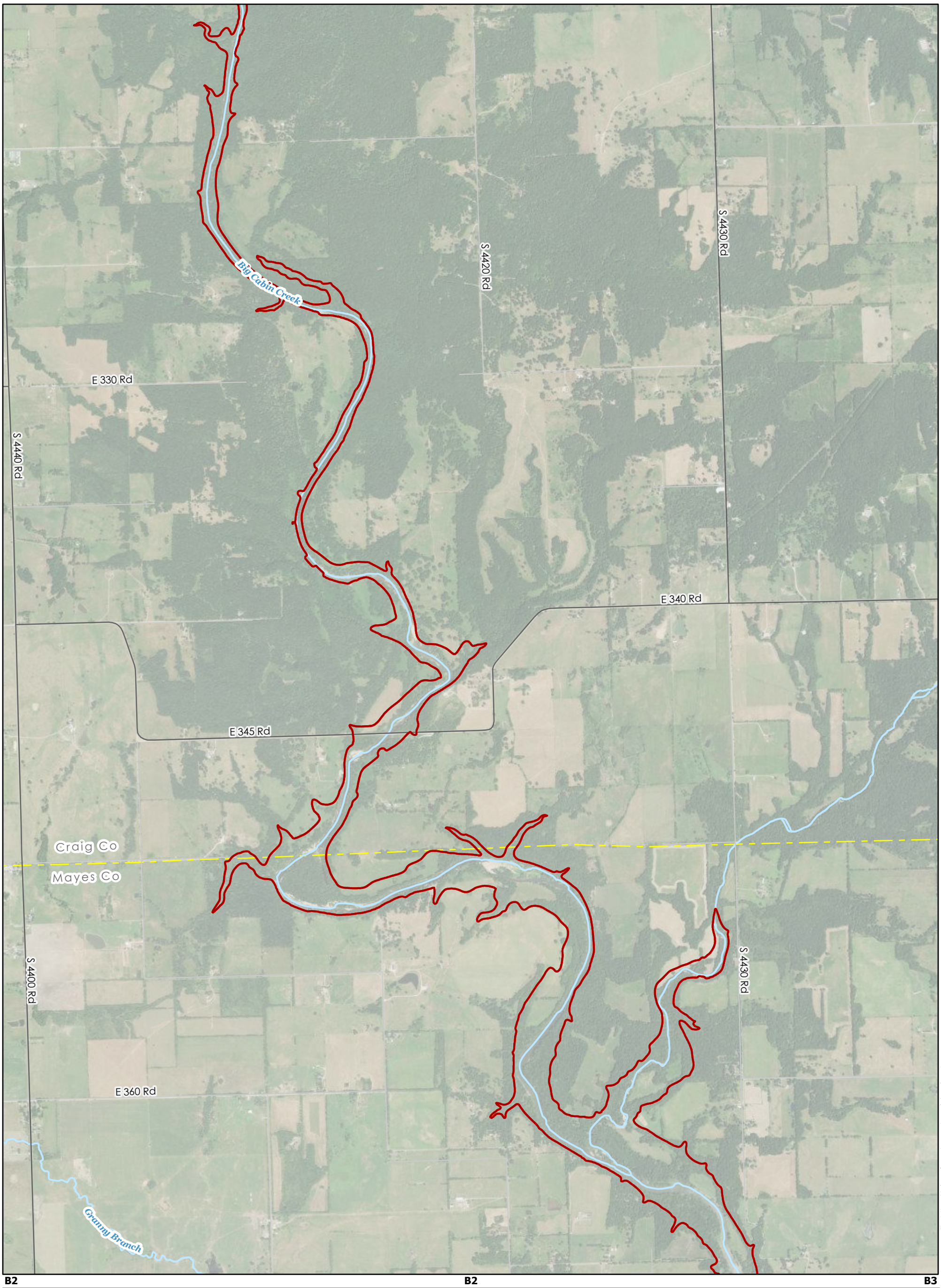


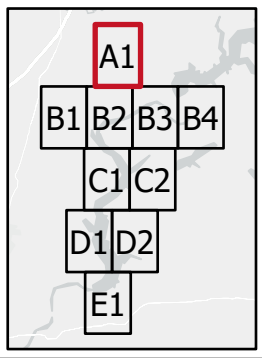
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM

DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: A1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

E 370 Rd

Rock Creek

E 390 Rd

28

Adair

E 410 Rd

N 436 Rd

Armstrong Branch

E 420 Rd

B2

C1

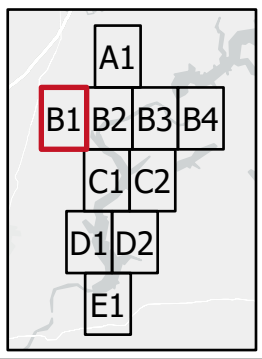
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1 A1

E 370 Rd

Granny Branch

Big Cabin Creek

Pensacola

28

Neosho River

B1 B3

Rock Creek

Strang

Lake Hudson

E 420 Rd

C1 C1 C2

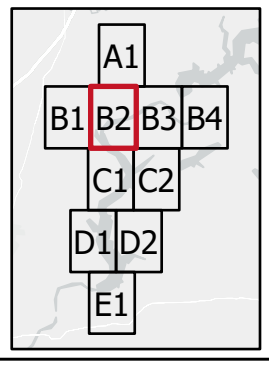
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1

B2

B4

C2

C2

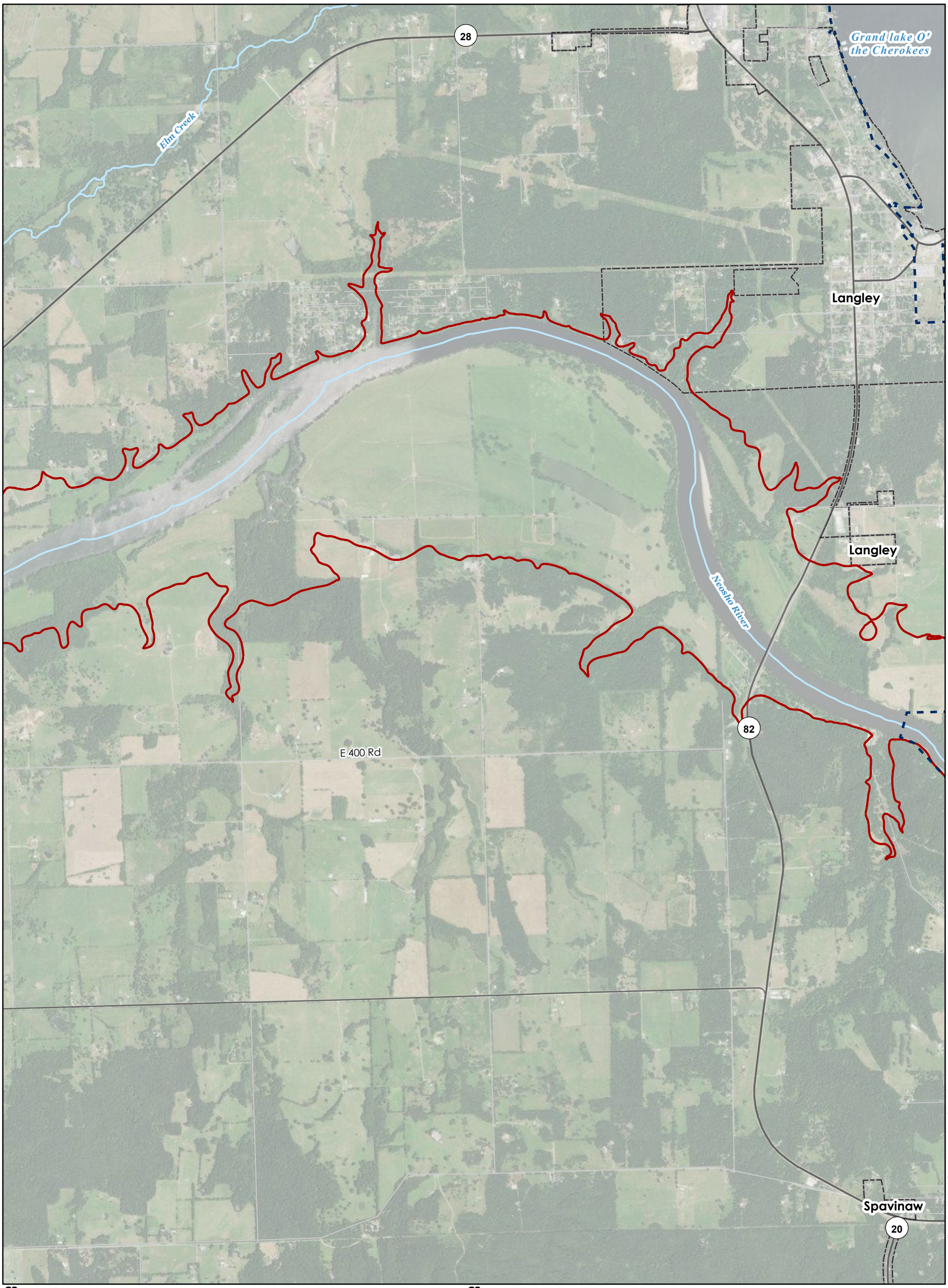


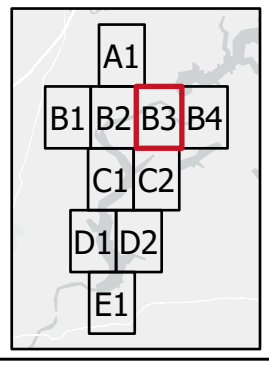
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

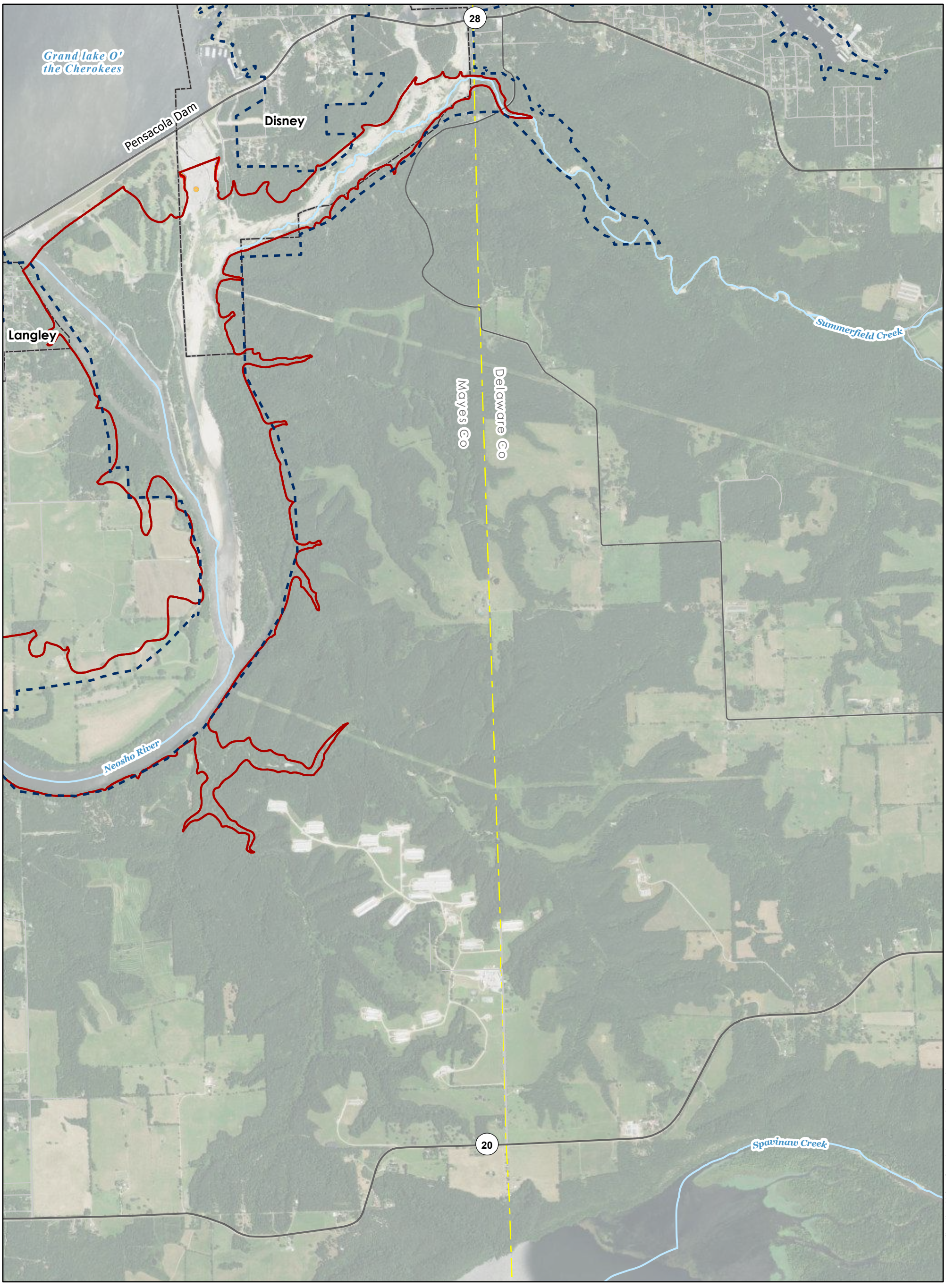
GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

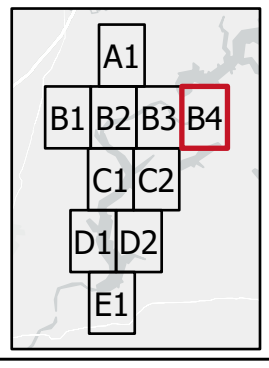


100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B4

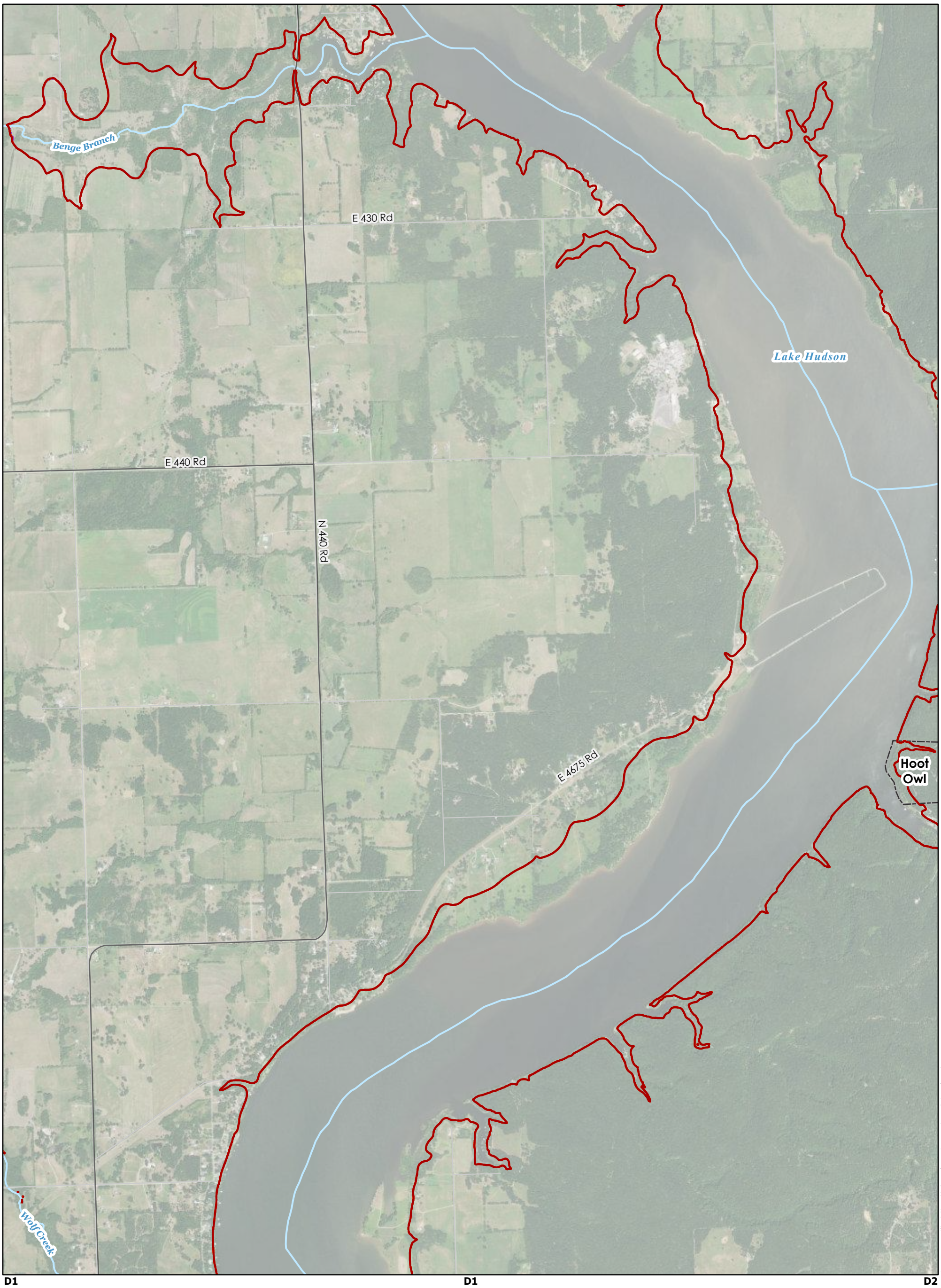
CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

B1 B2 B2



C2

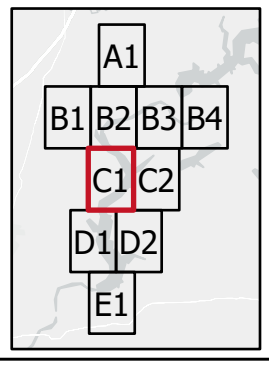
D1 D1 D2

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road
- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

B2 B3 B3

C1

Spavinaw Creek

Spavinaw

Hoot Owl

20

D2 D2

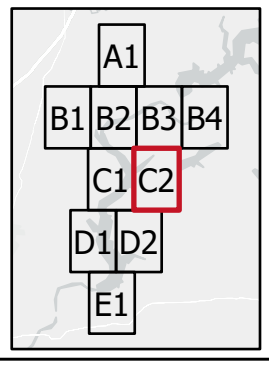
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C1

Wolf Creek

Lake Hudson

N 438 Rd

20

Sulphur Creek

Chapel Branch

S 438 Rd

Salina

D2

Lake Hudson

E 520 Rd

E1 E1

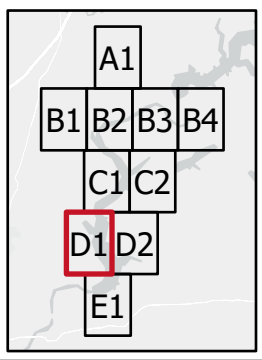
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C2 C2

D1

E1

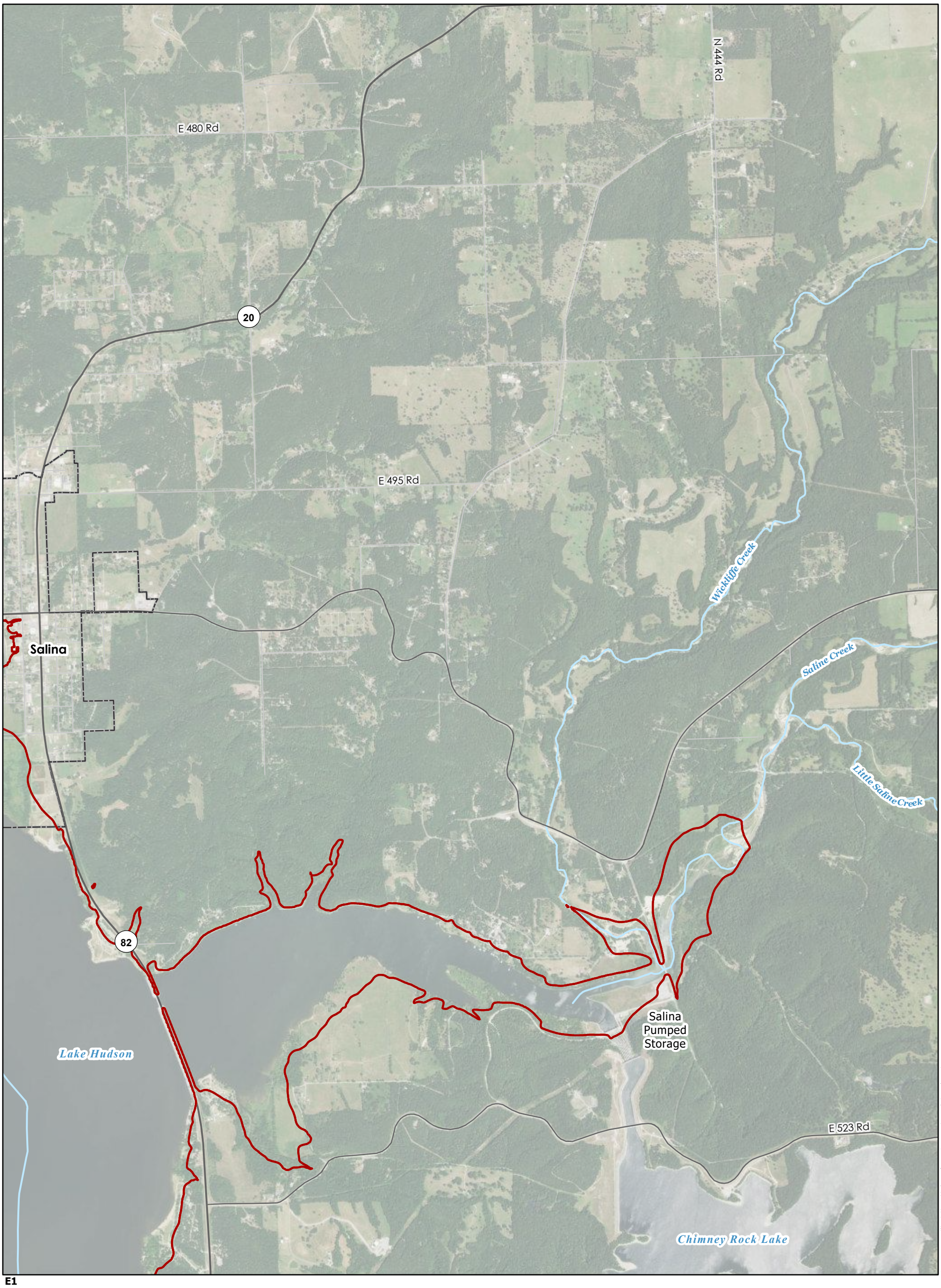


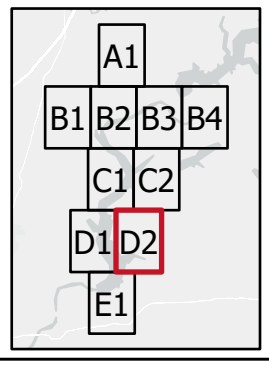
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

D1 D1 D2

Lake Hudson

Robert S. Kerr Dam
(Markham Ferry)

S 440 Rd

82

E 560 Rd

412A

Locust Grove

412

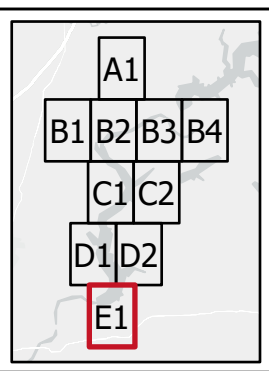
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

100-YEAR INUNDATION SCENARIO

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

100-YEAR MAX INUNDATION

- 757.0 ft PD
- 753.0 ft PD
- 749.0 ft PD
- 745.0 ft PD
- 744.5 ft PD
- 744.0 ft PD
- 743.5 ft PD
- 743.0 ft PD
- 742.5 ft PD
- 742.0 ft PD
- 734.0 ft PD

ROAD CLASS

- Interstate
- State Highway
- US Highway
- Major Collector
- Local Road

- Stream

BOUNDARY TYPE

- Project
- County
- Municipal

MAP AND LEGEND NOTES

1. For areas where only the highest starting elevation inundation boundary is visible, the inundation from other starting elevations is nearly identical.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: E1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX E.7:
HISTORICAL STARTING STAGE INUNDATION MAPS

Downstream Model Results
Historical Overview Map

Pensacola Dam

GRAND RIVER DAM AUTHORITY

Date: September 2022

Overview Map Legend

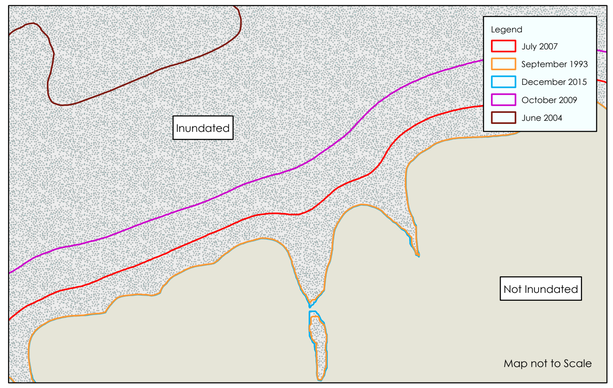
- 1:24,000-scale Map Sheet
- County Boundary
- Municipality
- Unincorporated

Road Class

- Interstate
- US Highway

Inundation Scenario Mapping

Mapping shows the extent of inundation for historical flow events, using the historical starting stage at Pensacola Dam. Pensacola Dam stage during the inflow event is calculated by the Operations Model.



0 0.75 1.5 3 4.5 6 Miles

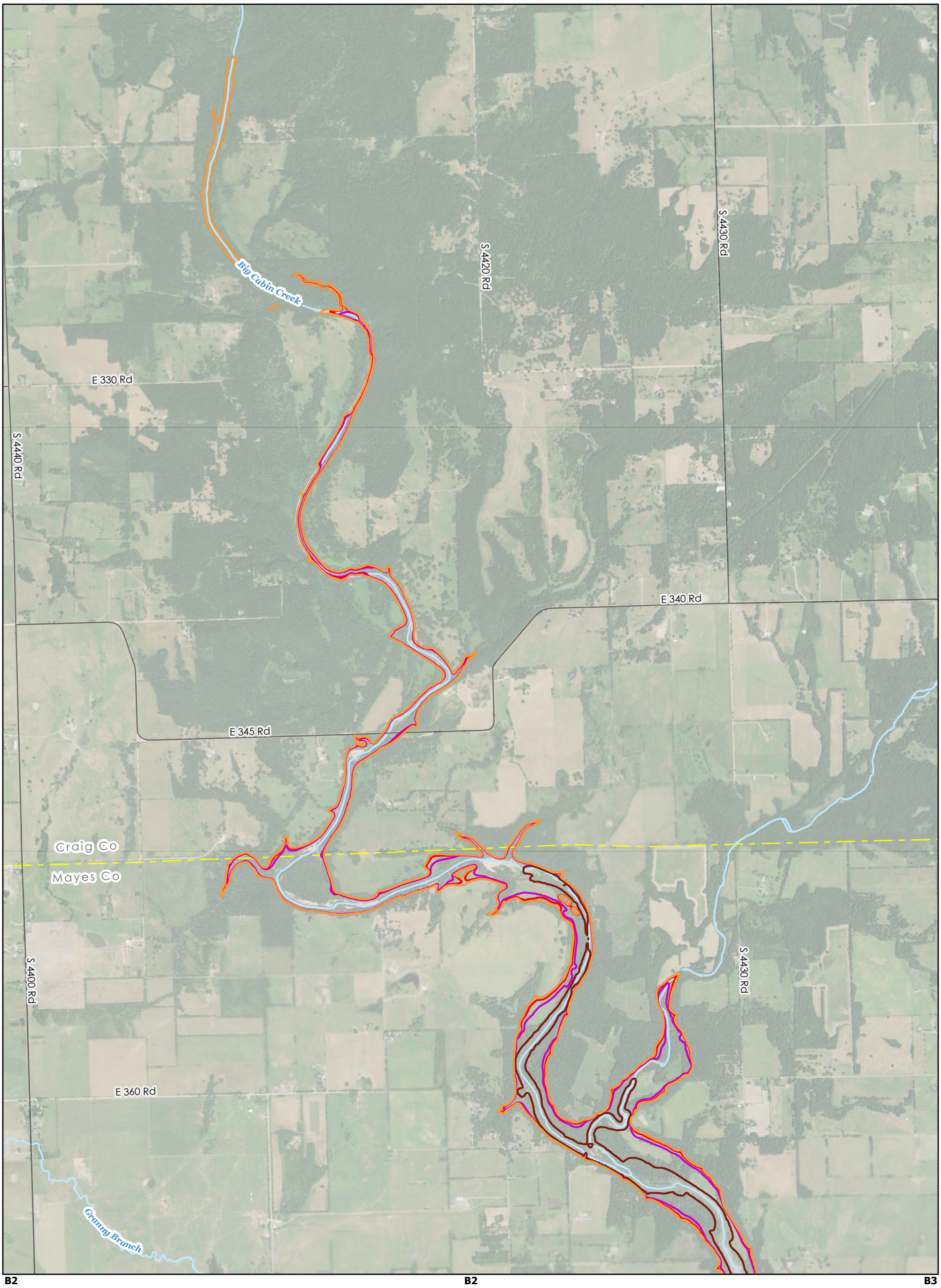
NORTH

Map Notes

Data Sources for Maps:

1. Base map images from https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019.
2. Transportation network (major roads, local roads, and railroads) and county boundaries obtained from the Oklahoma Office of Geographic Information (http://okmaps.org/ogi/search.aspx).

Map Source: Esri, NASA, NGA, USGS, FEMA, Missouri Dept. of Conservation, Missouri DNR, Texas Parks & Wildlife, Esri, HERE, Garmin, SafeGraph, GeoTechnologies, Inc, METI/NASA, USGS, EPA, NPS, USDA

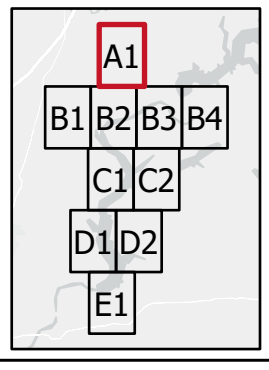


HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: A1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

E 370 Rd

Rock Creek

E 390 Rd

28

Adair

E 410 Rd

N 436 Rd

Armstrong Branch

E 420 Rd

B2

C1

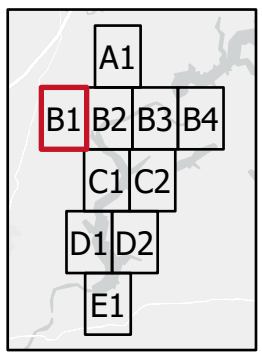
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1 A1

B1 B3

C1 C1 C2

E 370 Rd

Granny Branch

Big Cabin Creek

Pensacola

28

Neosho River

Rock Creek

Lake Hudson

E 420 Rd

Strang

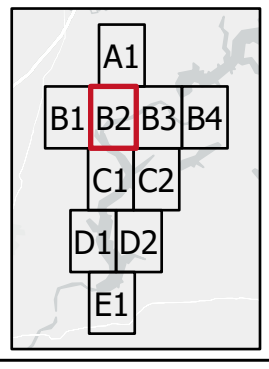
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

A1

B2

B4

C2

C2

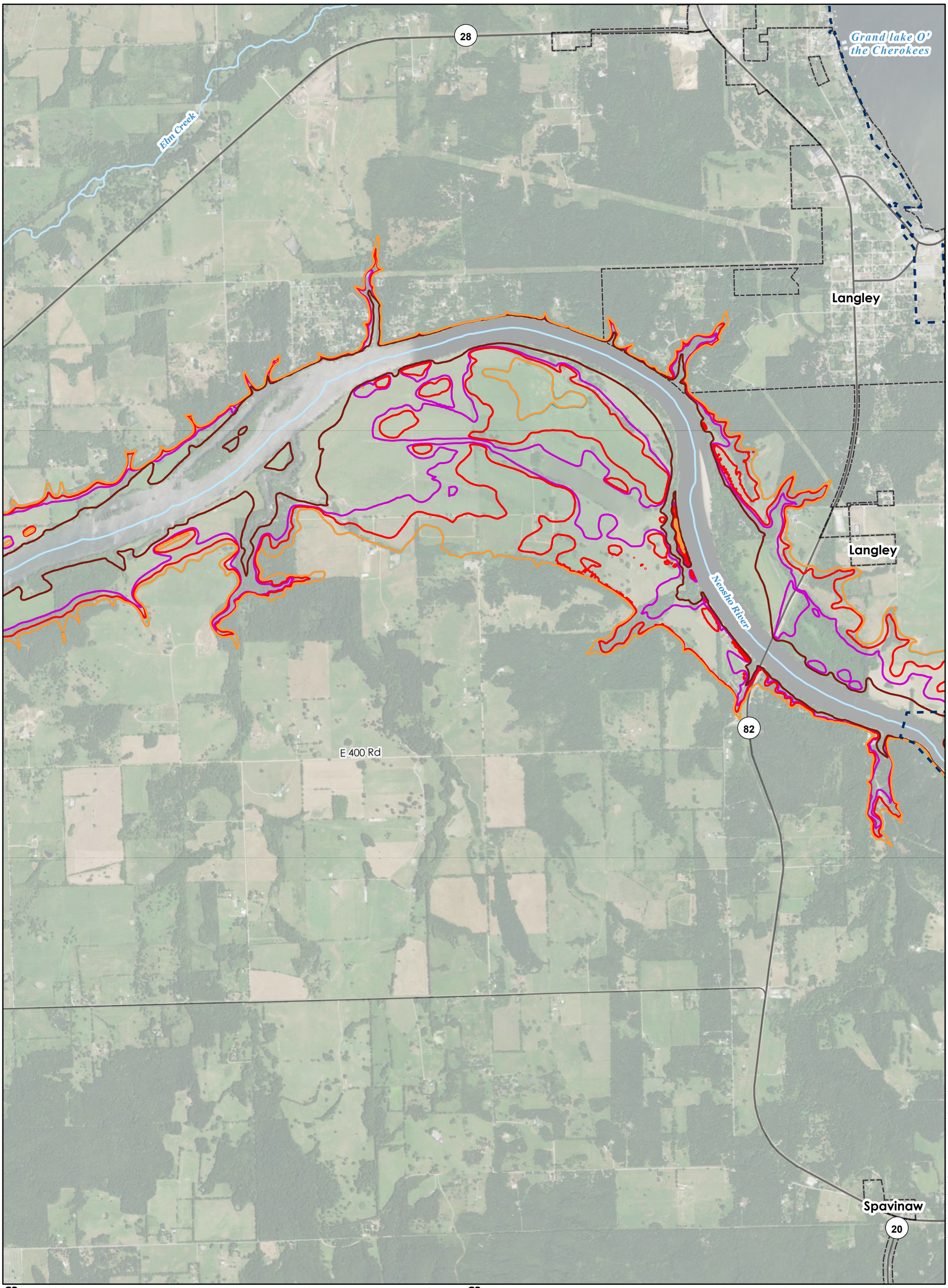


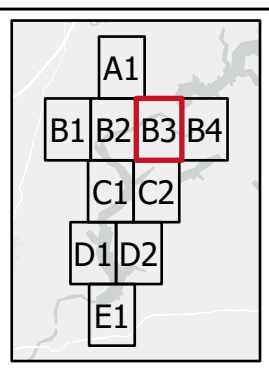
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: B3

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Grand lake O' the Cherokees
Pensacola Dam
Disney
Langley
28
Summerfield Creek
Mayes Co
Delaware Co
Neosho River
20
Spavinaw Creek
B3

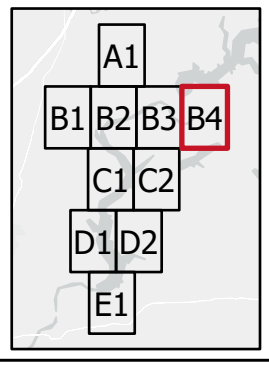
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

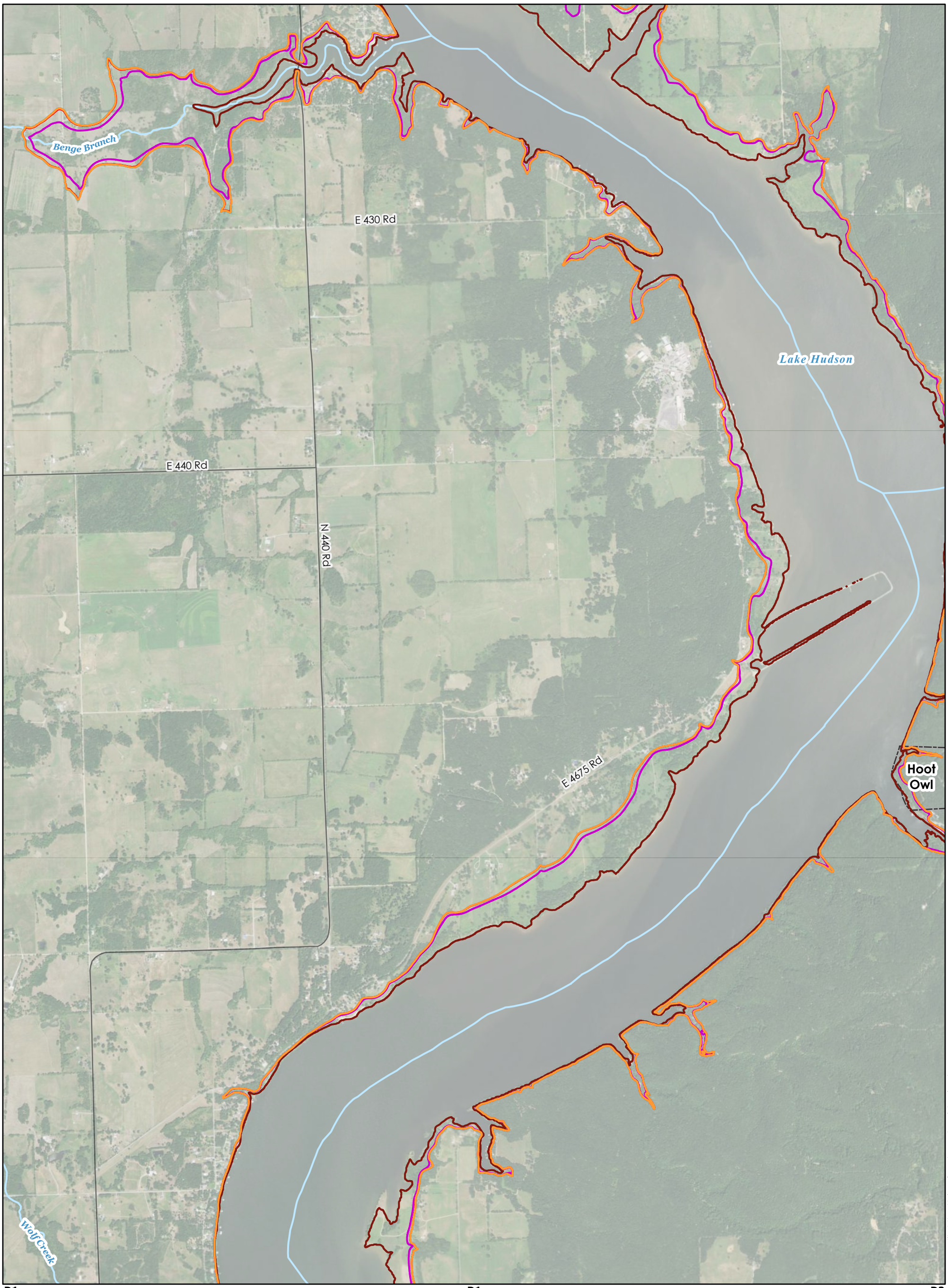
MAP: B4

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

B1 B2 B2



C2

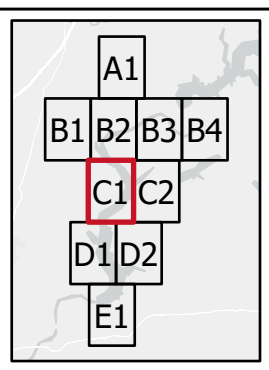
D1 D1 D2

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

B2 B3 B3

C1

Spavinaw Creek

Spavinaw

Hoot Owl

20

D2 D2

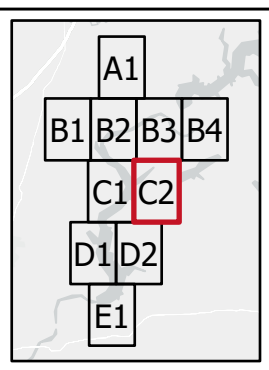
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: C2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C1

Wolf Creek

Lake Hudson

N 438 Rd

20

Sulphur Creek

Chapel Branch

S 438 Rd

Salina

D2

Lake Hudson

E 520 Rd

E1 E1

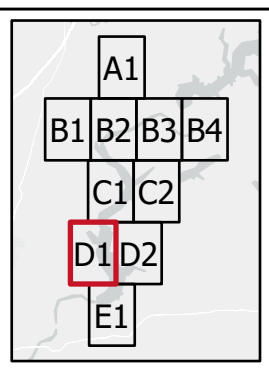
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

C1 C2 C2

D1

E1

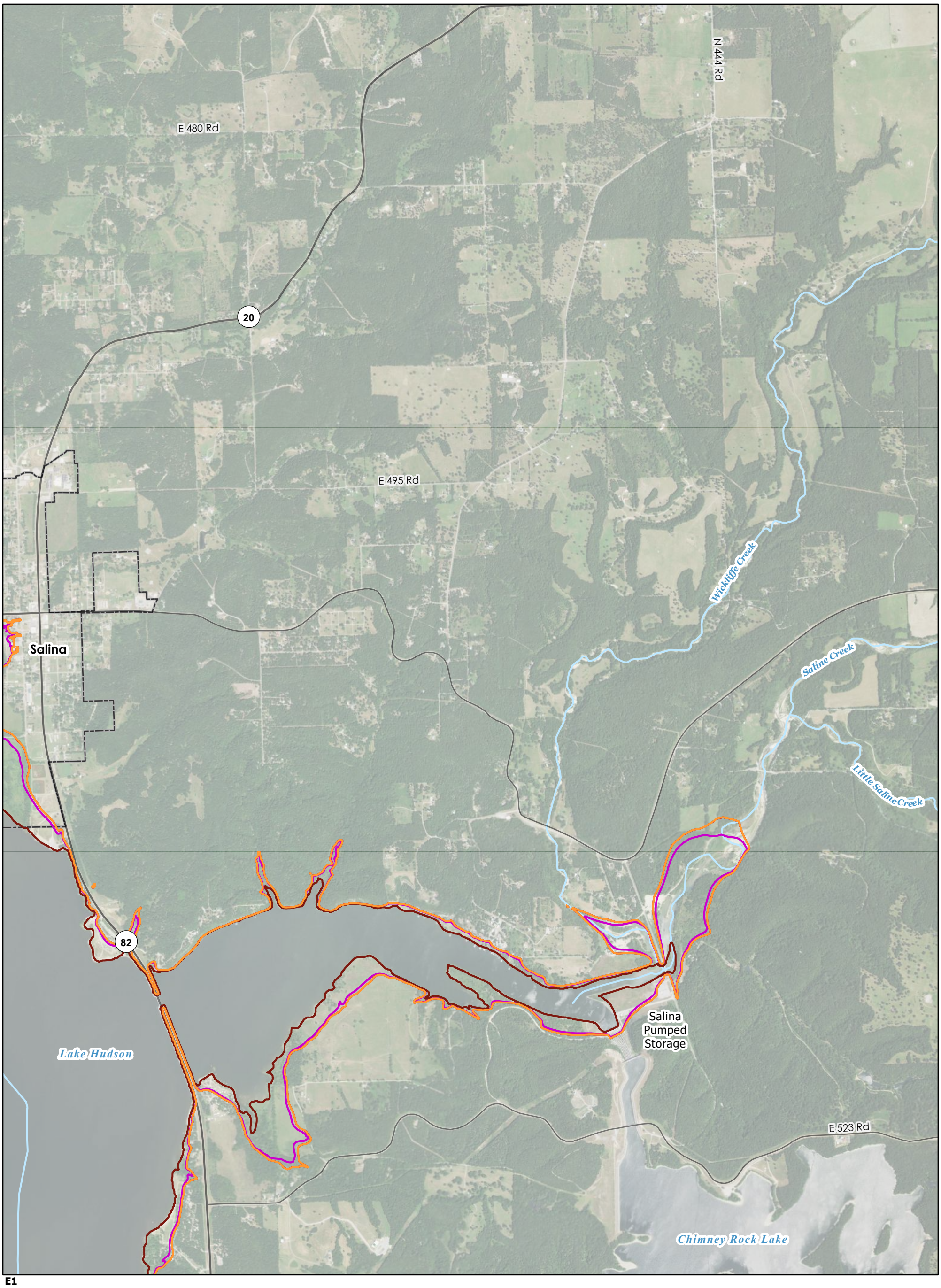


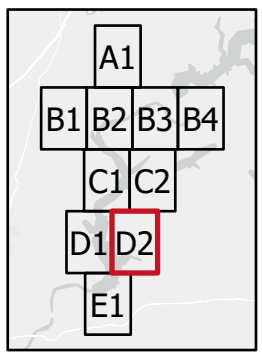
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: D2

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

D1 D1 D2

Lake Hudson

Robert S. Kerr Dam
(Markham Ferry)

S 440 Rd

82

E 560 Rd

412A

Locust Grove

412

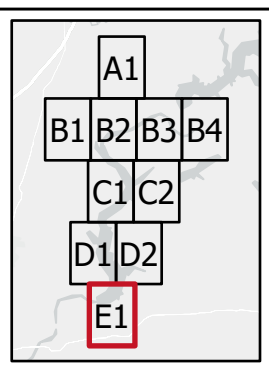
Image credits: https://gis.apfo.usda.gov/arcgis/services/NAIP/USDA_CONUS_PRIME/ImageServer, 2019

HISTORICAL INUNDATION SCENARIOS

NORTH

0 500 1,000 2,000 3,000 4,000 Feet

1 inch = 2,000 feet



Legend

MAX INUNDATION*
- July 2007
- September 1993
- December 2015
- October 2009
- June 2004

ROAD CLASS
- Interstate
- State Highway
- US Highway
- Major Collector
- Stream

BOUNDARY TYPE
- Project
- County
- Municipal

MAP NOTES

1. Simulations of historical inflow events use historical starting stage at Pensacola Dam. Stage at Pensacola Dam and Kerr Dam during the inflow event are calculated by the Operations Model.
2. See Overview Map for notes on data sources.

PENSACOLA DAM
DOWNSTREAM HYDRAULIC MODEL

GRAND RIVER DAM AUTHORITY

MAP: E1

CRAIG, DELAWARE, AND MAYES COUNTIES, OKLAHOMA

FERC No. 1494

September 2022

APPENDIX F:
DURATION OF INUNDATION

PENSACOLA DAM **Table F.1**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - SEPTEMBER 1993 (21 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range Duration Difference[1] (hours)	Extreme Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
77.000	Pensacola Dam												
76.880	0	0	0	0	0	0	0	0	0	0	0	0	0
76.463	0	0	0	0	0	0	0	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge												
76.362	0	0	0	0	0	0	0	0	0	0	0	0	0
75.317	0	0	0	0	0	0	0	0	0	0	0	0	0
74.300	0	0	0	0	0	0	0	0	0	0	0	0	0
73.315	0	0	0	0	0	0	0	0	0	0	0	0	0
72.884	0	0	0	0	0	0	0	0	0	0	0	0	0
72.822	OK-82 Bridge												
72.772	0	0	0	0	0	0	0	0	0	0	0	0	0
71.645	0	0	0	0	0	0	0	0	0	0	0	0	0
70.910	0	0	0	0	0	0	0	0	0	0	0	0	0
69.686	0	0	0	0	0	0	0	0	0	0	0	0	0
68.685	0	0	0	0	0	0	0	0	0	0	0	0	0
67.715	0	0	0	0	0	0	0	0	0	0	0	0	0
66.855	0	0	0	0	0	0	0	0	0	0	0	0	0
66.780	Big Cabin Creek												
65.712	0	0	0	0	0	0	0	0	0	0	0	0	0
64.435	0	0	0	0	0	0	0	0	0	0	0	0	0
63.369	0	0	0	0	0	0	0	0	0	0	0	0	0
63.322	Strang Rd. Bridge												
63.299	0	0	0	0	0	0	0	0	0	0	0	0	0
62.325	0	0	0	0	0	0	0	0	0	0	0	0	0
61.308	0	0	0	0	0	0	0	0	0	0	0	0	0
60.263	0	0	0	0	0	0	0	0	0	0	0	0	0
60.200	Spavinaw Creek												
59.019	0	0	0	0	0	0	0	0	0	0	0	0	0
57.950	0	0	0	0	0	0	0	0	0	0	0	0	0
56.927	0	0	0	0	0	0	0	0	0	0	0	0	0
55.890	0	0	0	0	0	0	0	0	0	0	0	0	0
54.456	0	0	0	0	0	0	0	0	0	0	0	0	0
52.988	0	0	0	0	0	0	0	0	0	0	0	0	0
52.954	OK-20 Bridge												
52.922	0	0	0	0	0	0	0	0	0	0	0	0	0
50.500	Saline Creek												
50.396	0	0	0	0	0	0	0	0	0	0	0	0	0
49.110	0	0	0	0	0	0	0	0	0	0	0	0	0
48.118	0	0	0	0	0	0	0	0	0	0	0	0	0
47.186	0	0	0	0	0	0	0	0	0	0	0	0	0
47.120	Kerr Dam												

1. Max difference in duration from simulations with Pensacola Dam starting stages of EL 742.0 to 745.0 ft.
2. Max difference in duration from simulations with Pensacola Dam starting stages of EL 734.0 to 757.0 ft.

PENSACOLA DAM **Table F.2**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - JUNE 2004 (1 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range Duration Difference[1] (hours)	Extreme Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
77.000	Pensacola Dam												
76.880	0	0	0	0	0	0	0	0	0	0	0	0	0
76.463	0	0	0	0	0	0	0	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge												
76.362	0	0	0	0	0	0	0	0	0	0	0	0	0
75.317	0	0	0	0	0	0	0	0	0	0	0	0	0
74.300	0	0	0	0	0	0	0	0	0	0	0	0	0
73.315	0	0	0	0	0	0	0	0	0	0	0	0	0
72.884	0	0	0	0	0	0	0	0	0	0	0	0	0
72.822	OK-82 Bridge												
72.772	0	0	0	0	0	0	0	0	0	0	0	0	0
71.645	0	0	0	0	0	0	0	0	0	0	0	0	0
70.910	0	0	0	0	0	0	0	0	0	0	0	0	0
69.686	0	0	0	0	0	0	0	0	0	0	0	0	0
68.685	0	0	0	0	0	0	0	0	0	0	0	0	0
67.715	0	0	0	0	0	0	0	0	0	0	0	0	0
66.855	0	0	0	0	0	0	0	0	0	0	0	0	0
66.780	Big Cabin Creek												
65.712	0	0	0	0	0	0	0	0	0	0	0	0	0
64.435	0	0	0	0	0	0	0	0	0	0	0	0	0
63.369	0	0	0	0	0	0	0	0	0	0	0	0	0
63.322	Strang Rd. Bridge												
63.299	0	0	0	0	0	0	0	0	0	0	0	0	0
62.325	0	0	0	0	0	0	0	0	0	0	0	0	0
61.308	0	0	0	0	0	0	0	0	0	0	0	0	0
60.263	0	0	0	0	0	0	0	0	0	0	0	0	0
60.200	Spavinaw Creek												
59.019	0	0	0	0	0	0	0	0	0	0	0	0	0
57.950	0	0	0	0	0	0	0	0	0	0	0	0	0
56.927	0	0	0	0	0	0	0	0	0	0	0	0	0
55.890	0	0	0	0	0	0	0	0	0	0	0	0	0
54.456	0	0	0	0	0	0	0	0	0	0	0	0	0
52.988	0	0	0	0	0	0	0	0	0	0	0	0	0
52.954	OK-20 Bridge												
52.922	0	0	0	0	0	0	0	0	0	0	0	0	0
50.500	Saline Creek												
50.396	0	0	0	0	0	0	0	0	0	0	0	0	0
49.110	0	0	0	0	0	0	0	0	0	0	0	0	0
48.118	0	0	0	0	0	0	0	0	0	0	0	0	0
47.186	0	0	0	0	0	0	0	0	0	0	0	0	0
47.120	Kerr Dam												

1. Max difference in duration from simulations with Pensacola Dam starting stages of EL 742.0 to 745.0 ft.
2. Max difference in duration from simulations with Pensacola Dam starting stages of EL 734.0 to 757.0 ft.

PENSACOLA DAM **Table F.3**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - JULY 2007 (4 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range Duration Difference[1] (hours)	Extreme Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
77.000	Pensacola Dam												
76.880	0	0	0	0	0	0	0	0	0	0	0	0	0
76.463	0	0	0	0	0	0	0	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge												
76.362	0	0	0	0	0	0	0	0	0	0	0	0	0
75.317	0	0	0	0	0	0	0	0	0	0	0	0	0
74.300	0	0	0	0	0	0	0	0	0	0	0	0	0
73.315	0	0	0	0	0	0	0	0	0	0	0	0	0
72.884	0	0	0	0	0	0	0	0	0	0	0	0	0
72.822	OK-82 Bridge												
72.772	0	0	0	0	0	0	0	0	0	0	0	0	0
71.645	0	0	0	0	0	0	0	0	0	0	0	0	0
70.910	0	0	0	0	0	0	0	0	0	0	0	0	0
69.686	0	0	0	0	0	0	0	0	0	0	0	0	0
68.685	0	0	0	0	0	0	0	0	0	0	0	0	0
67.715	0	0	0	0	0	0	0	0	0	0	0	0	0
66.855	0	0	0	0	0	0	0	0	0	0	0	0	0
66.780	Big Cabin Creek												
65.712	0	0	0	0	0	0	0	0	0	0	0	0	0
64.435	0	0	0	0	0	0	0	0	0	0	0	0	0
63.369	0	0	0	0	0	0	0	0	0	0	0	0	0
63.322	Strang Rd. Bridge												
63.299	0	0	0	0	0	0	0	0	0	0	0	0	0
62.325	0	0	0	0	0	0	0	0	0	0	0	0	0
61.308	0	0	0	0	0	0	0	0	0	0	0	0	0
60.263	0	0	0	0	0	0	0	0	0	0	0	0	0
60.200	Spavinaw Creek												
59.019	0	0	0	0	0	0	0	0	0	0	0	0	0
57.950	0	0	0	0	0	0	0	0	0	0	0	0	0
56.927	0	0	0	0	0	0	0	0	0	0	0	0	0
55.890	0	0	0	0	0	0	0	0	0	0	0	0	0
54.456	0	0	0	0	0	0	0	0	0	0	0	0	0
52.988	0	0	0	0	0	0	0	0	0	0	0	0	0
52.954	OK-20 Bridge												
52.922	0	0	0	0	0	0	0	0	0	0	0	0	0
50.500	Saline Creek												
50.396	0	0	0	0	0	0	0	0	0	0	0	0	0
49.110	0	0	0	0	0	0	0	0	0	0	0	0	0
48.118	0	0	0	0	0	0	0	0	0	0	0	0	0
47.186	0	0	0	0	0	0	0	0	0	0	0	0	0
47.120	Kerr Dam												

1. Max difference in duration from simulations with Pensacola Dam starting stages of EL 742.0 to 745.0 ft.
2. Max difference in duration from simulations with Pensacola Dam starting stages of EL 734.0 to 757.0 ft.

PENSACOLA DAM **Table F.4**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - OCTOBER 2009 (3 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range Duration Difference[1] (hours)	Extreme Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
77.000	Pensacola Dam												
76.880	0	0	0	0	0	0	0	0	0	0	0	0	0
76.463	0	0	0	0	0	0	0	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge												
76.362	0	0	0	0	0	0	0	0	0	0	0	0	0
75.317	0	0	0	0	0	0	0	0	0	0	0	0	0
74.300	0	0	0	0	0	0	0	0	0	0	0	0	0
73.315	0	0	0	0	0	0	0	0	0	0	0	0	0
72.884	0	0	0	0	0	0	0	0	0	0	0	0	0
72.822	OK-82 Bridge												
72.772	0	0	0	0	0	0	0	0	0	0	0	0	0
71.645	0	0	0	0	0	0	0	0	0	0	0	0	0
70.910	0	0	0	0	0	0	0	0	0	0	0	0	0
69.686	0	0	0	0	0	0	0	0	0	0	0	0	0
68.685	0	0	0	0	0	0	0	0	0	0	0	0	0
67.715	0	0	0	0	0	0	0	0	0	0	0	0	0
66.855	0	0	0	0	0	0	0	0	0	0	0	0	0
66.780	Big Cabin Creek												
65.712	0	0	0	0	0	0	0	0	0	0	0	0	0
64.435	0	0	0	0	0	0	0	0	0	0	0	0	0
63.369	0	0	0	0	0	0	0	0	0	0	0	0	0
63.322	Strang Rd. Bridge												
63.299	0	0	0	0	0	0	0	0	0	0	0	0	0
62.325	0	0	0	0	0	0	0	0	0	0	0	0	0
61.308	0	0	0	0	0	0	0	0	0	0	0	0	0
60.263	0	0	0	0	0	0	0	0	0	0	0	0	0
60.200	Spavinaw Creek												
59.019	0	0	0	0	0	0	0	0	0	0	0	0	0
57.950	0	0	0	0	0	0	0	0	0	0	0	0	0
56.927	0	0	0	0	0	0	0	0	0	0	0	0	0
55.890	0	0	0	0	0	0	0	0	0	0	0	0	0
54.456	0	0	0	0	0	0	0	0	0	0	0	0	0
52.988	0	0	0	0	0	0	0	0	0	0	0	0	0
52.954	OK-20 Bridge												
52.922	0	0	0	0	0	0	0	0	0	0	0	0	0
50.500	Saline Creek												
50.396	0	0	0	0	0	0	0	0	0	0	0	0	0
49.110	0	0	0	0	0	0	0	0	0	0	0	0	0
48.118	0	0	0	0	0	0	0	0	0	0	0	0	0
47.186	0	0	0	0	0	0	0	0	0	0	0	0	0
47.120	Kerr Dam												

1. Max difference in duration from simulations with Pensacola Dam starting stages of EL 742.0 to 745.0 ft.
2. Max difference in duration from simulations with Pensacola Dam starting stages of EL 734.0 to 757.0 ft.

PENSACOLA DAM **Table F.5**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - DECEMBER 2015 (15 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range Duration Difference[1] (hours)	Extreme Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
77.000	Pensacola Dam												
76.880	0	0	0	0	0	0	0	0	0	0	0	0	0
76.463	0	0	0	0	0	0	0	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge												
76.362	0	0	0	0	0	0	0	0	0	0	0	0	0
75.317	0	0	0	0	0	0	0	0	0	0	0	0	0
74.300	0	0	0	0	0	0	0	0	0	0	0	0	0
73.315	0	0	0	0	0	0	0	0	0	0	0	0	0
72.884	0	0	0	0	0	0	0	0	0	0	0	0	0
72.822	OK-82 Bridge												
72.772	0	0	0	0	0	0	0	0	0	0	0	0	0
71.645	0	0	0	0	0	0	0	0	0	0	0	0	0
70.910	0	0	0	0	0	0	0	0	0	0	0	0	0
69.686	0	0	0	0	0	0	0	0	0	0	0	0	0
68.685	0	0	0	0	0	0	0	0	0	0	0	0	0
67.715	0	0	0	0	0	0	0	0	0	0	0	0	0
66.855	0	0	0	0	0	0	0	0	0	0	0	0	0
66.780	Big Cabin Creek												
65.712	0	0	0	0	0	0	0	0	0	0	0	0	0
64.435	0	0	0	0	0	0	0	0	0	0	0	0	0
63.369	0	0	0	0	0	0	0	0	0	0	0	0	0
63.322	Strang Rd. Bridge												
63.299	0	0	0	0	0	0	0	0	0	0	0	0	0
62.325	0	0	0	0	0	0	0	0	0	0	0	0	0
61.308	0	0	0	0	0	0	0	0	0	0	0	0	0
60.263	0	0	0	0	0	0	0	0	0	0	0	0	0
60.200	Spavinaw Creek												
59.019	0	0	0	0	0	0	0	0	0	0	0	0	0
57.950	0	0	0	0	0	0	0	0	0	0	0	0	0
56.927	0	0	0	0	0	0	0	0	0	0	0	0	0
55.890	0	0	0	0	0	0	0	0	0	0	0	0	0
54.456	0	0	0	0	0	0	0	0	0	0	0	0	0
52.988	0	0	0	0	0	0	0	0	0	0	0	0	0
52.954	OK-20 Bridge												
52.922	0	0	0	0	0	0	0	0	0	0	0	0	0
50.500	Saline Creek												
50.396	0	0	0	0	0	0	0	0	0	0	0	0	0
49.110	0	0	0	0	0	0	0	0	0	0	0	0	0
48.118	0	0	0	0	0	0	0	0	0	0	0	0	0
47.186	0	0	0	0	0	0	0	0	0	0	0	0	0
47.120	Kerr Dam												

1. Max difference in duration from simulations with Pensacola Dam starting stages of EL 742.0 to 745.0 ft.
2. Max difference in duration from simulations with Pensacola Dam starting stages of EL 734.0 to 757.0 ft.

PENSACOLA DAM **Table F.6**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - 100-YEAR EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operational Range Duration Difference[1] (hours)	Extreme Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
77.000	Pensacola Dam												
76.880	0	0	0	0	0	0	0	0	0	0	0	0	0
76.463	0	0	0	0	0	0	0	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge												
76.362	0	0	0	0	0	0	0	0	0	0	0	0	0
75.317	0	0	0	0	0	0	0	0	0	0	0	0	0
74.300	0	0	0	0	0	0	0	0	0	0	0	0	0
73.315	9	11	13	13	14	14	14	14	16	17	19	3	10
72.884	16	17	17	17	18	18	17	17	19	20	22	1	6
72.822	OK-82 Bridge												
72.772	19	21	20	21	21	21	21	21	23	23	40	1	21
71.645	19	21	20	21	21	21	21	21	23	23	41	1	22
70.910	14	16	16	16	17	17	16	16	18	19	21	1	7
69.686	14	15	15	16	16	16	16	16	18	19	21	1	7
68.685	0	0	0	0	0	0	0	0	0	0	0	0	0
67.715	0	0	0	0	0	0	0	0	0	0	0	0	0
66.855	0	0	0	0	0	0	0	0	0	0	0	0	0
66.780	Big Cabin Creek												
65.712	0	0	0	0	0	0	0	0	0	0	0	0	0
64.435	0	0	0	0	0	0	0	0	0	0	0	0	0
63.369	0	0	0	0	0	0	0	0	0	0	0	0	0
63.322	Strang Rd. Bridge												
63.299	0	0	0	0	0	0	0	0	0	0	0	0	0
62.325	0	0	0	0	0	0	0	0	0	0	0	0	0
61.308	0	0	0	0	0	0	0	0	0	0	0	0	0
60.263	0	0	0	0	0	0	0	0	0	0	0	0	0
60.200	Spavinaw Creek												
59.019	0	0	0	0	0	0	0	0	0	0	0	0	0
57.950	0	0	0	0	0	0	0	0	0	0	0	0	0
56.927	0	0	0	0	0	0	0	0	0	0	0	0	0
55.890	0	0	0	0	0	0	0	0	0	0	0	0	0
54.456	0	0	0	0	0	0	0	0	0	0	0	0	0
52.988	0	0	0	0	0	0	0	0	0	0	0	0	0
52.954	OK-20 Bridge												
52.922	0	0	0	0	0	0	0	0	0	0	0	0	0
50.500	Saline Creek												
50.396	0	0	0	0	0	0	0	0	0	0	0	0	0
49.110	0	0	0	0	0	0	0	0	0	0	0	0	0
48.118	0	0	0	0	0	0	0	0	0	0	0	0	0
47.186	0	0	0	0	0	0	0	0	0	0	0	0	0
47.120	Kerr Dam												

1. Max difference in duration from simulations with Pensacola Dam starting stages of EL 742.0 to 745.0 ft.
2. Max difference in duration from simulations with Pensacola Dam starting stages of EL 734.0 to 757.0 ft.

PENSACOLA DAM **Table F.7**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - HISTORICAL STARTING STAGES

River Mile	Pensacola Dam Starting Stage (ft, PD)					Max Duration Difference* (hours)
	Sep 1993 (21 year)	Jun 2004 (1 year)	Jul 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	
77.000	Pensacola Dam					
76.880	0	0	0	0	0	0
76.463	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge					
76.362	0	0	0	0	0	0
75.317	0	0	0	0	0	0
74.300	0	0	0	0	0	0
73.315	0	0	0	0	0	0
72.884	0	0	0	0	0	0
72.822	OK-82 Bridge					
72.772	0	0	0	0	0	0
71.645	0	0	0	0	0	0
70.910	0	0	0	0	0	0
69.686	0	0	0	0	0	0
68.685	0	0	0	0	0	0
67.715	0	0	0	0	0	0
66.855	0	0	0	0	0	0
66.780	Big Cabin Creek					
65.712	0	0	0	0	0	0
64.435	0	0	0	0	0	0
63.369	0	0	0	0	0	0
63.322	Strang Rd. Bridge					
63.299	0	0	0	0	0	0
62.325	0	0	0	0	0	0
61.308	0	0	0	0	0	0
60.263	0	0	0	0	0	0
60.200	Spavinaw Creek					
59.019	0	0	0	0	0	0
57.950	0	0	0	0	0	0
56.927	0	0	0	0	0	0
55.890	0	0	0	0	0	0
54.456	0	0	0	0	0	0
52.988	0	0	0	0	0	0
52.954	OK-20 Bridge					
52.922	0	0	0	0	0	0
50.500	Saline Creek					
50.396	0	0	0	0	0	0
49.110	0	0	0	0	0	0
48.118	0	0	0	0	0	0
47.186	0	0	0	0	0	0
47.120	Kerr Dam					

* Max difference in duration from simulations with historical starting stages.

APPENDIX G:
ANTICIPATED OPERATIONS ANALYSIS

APPENDIX G.1:
ANTICIPATED OPERATIONS ANALYSIS
SIMULATED HYDROGRAPHS

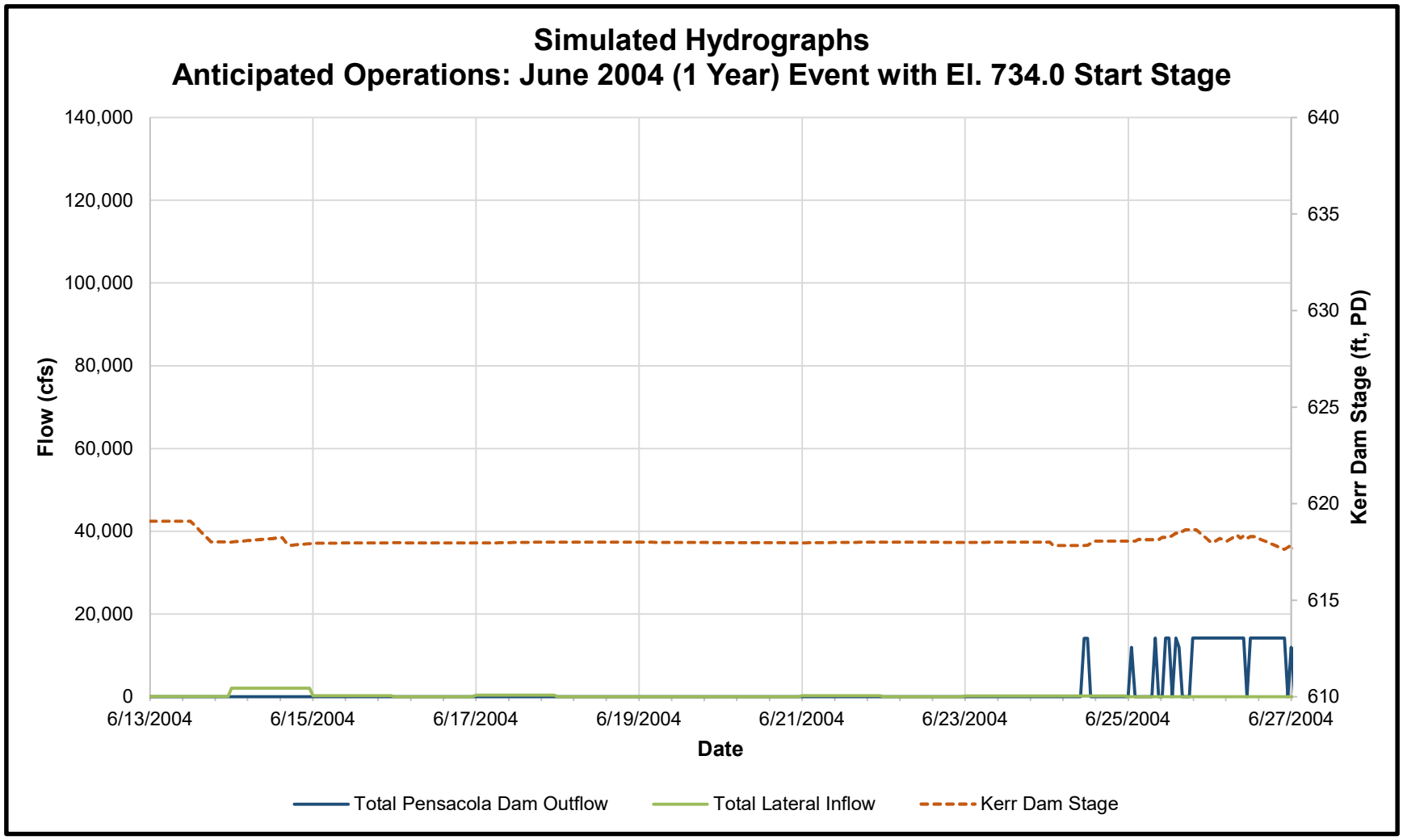


Figure G.1. Simulated hydrograph for Anticipated Operations for the June 2004 (1 year) event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

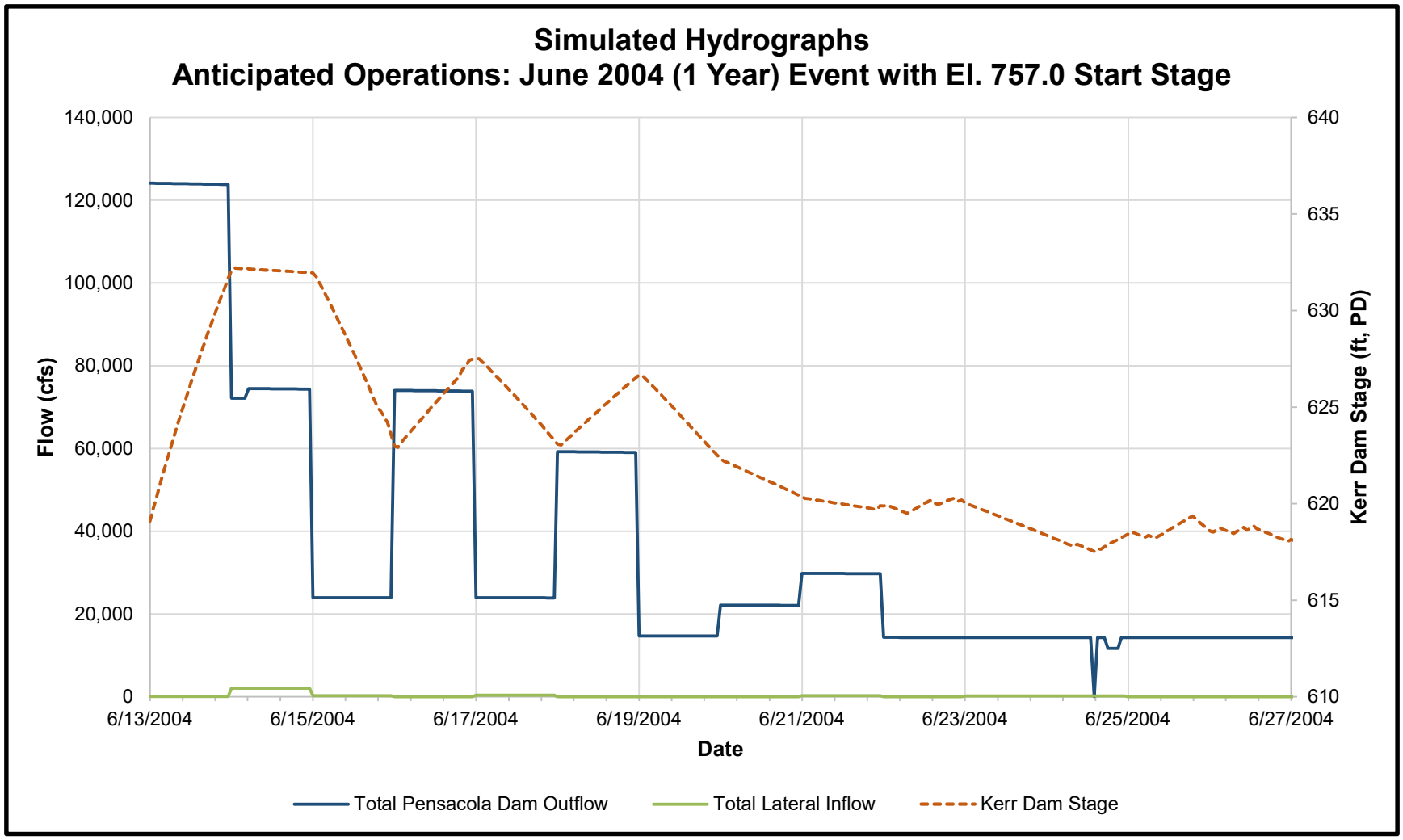


Figure G.2. Simulated hydrograph for Anticipated Operations for the June 2004 (1 year) event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

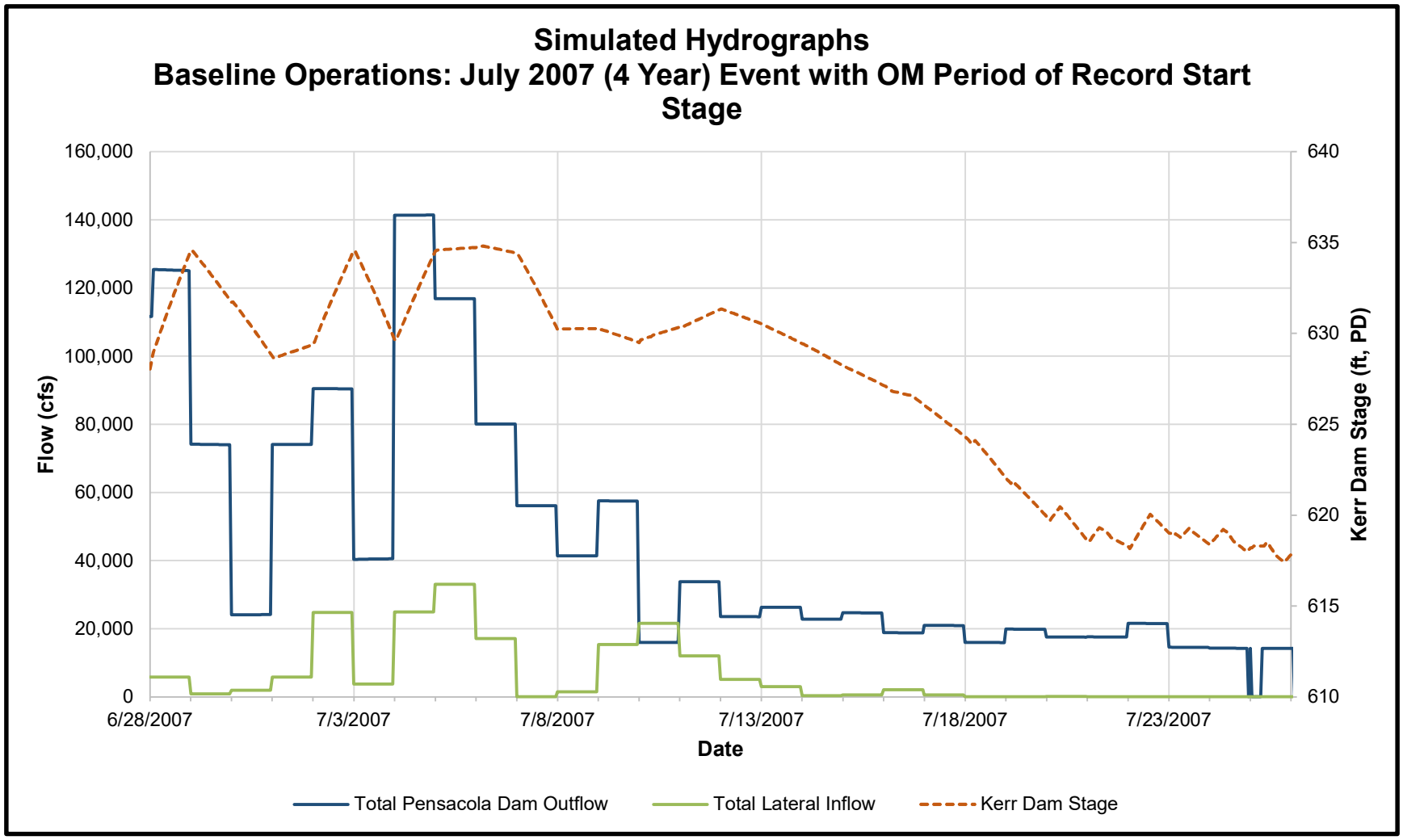


Figure G.3. Simulated hydrograph for Baseline Operations for the July 2007 (4 year) event with OM Period of Record starting stage at Pensacola Dam.

Notes: 1. *The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.*
2. *The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.*

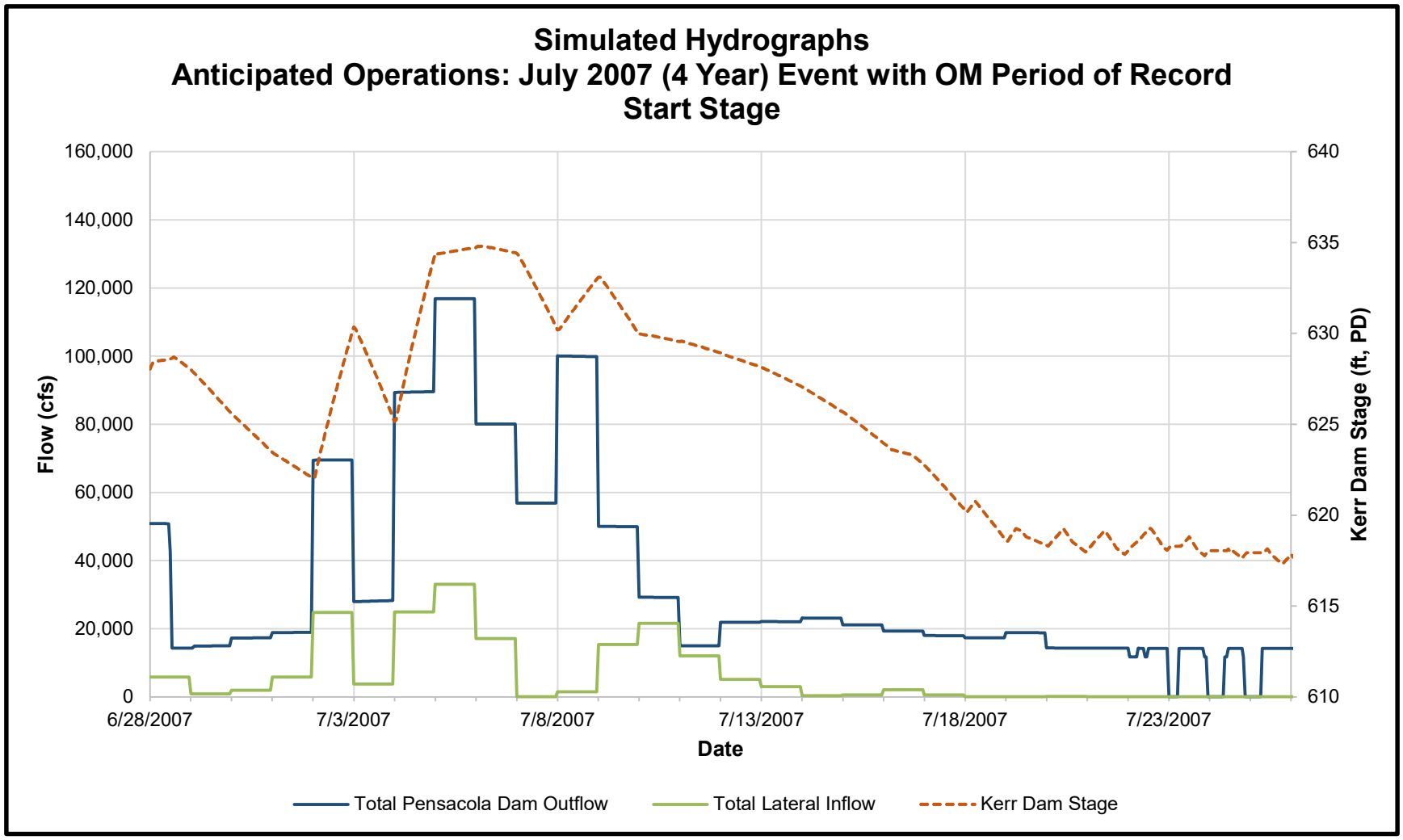


Figure G.4. Simulated hydrograph for Anticipated Operations for the July 2007 (4 year) event with OM Period of Record starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

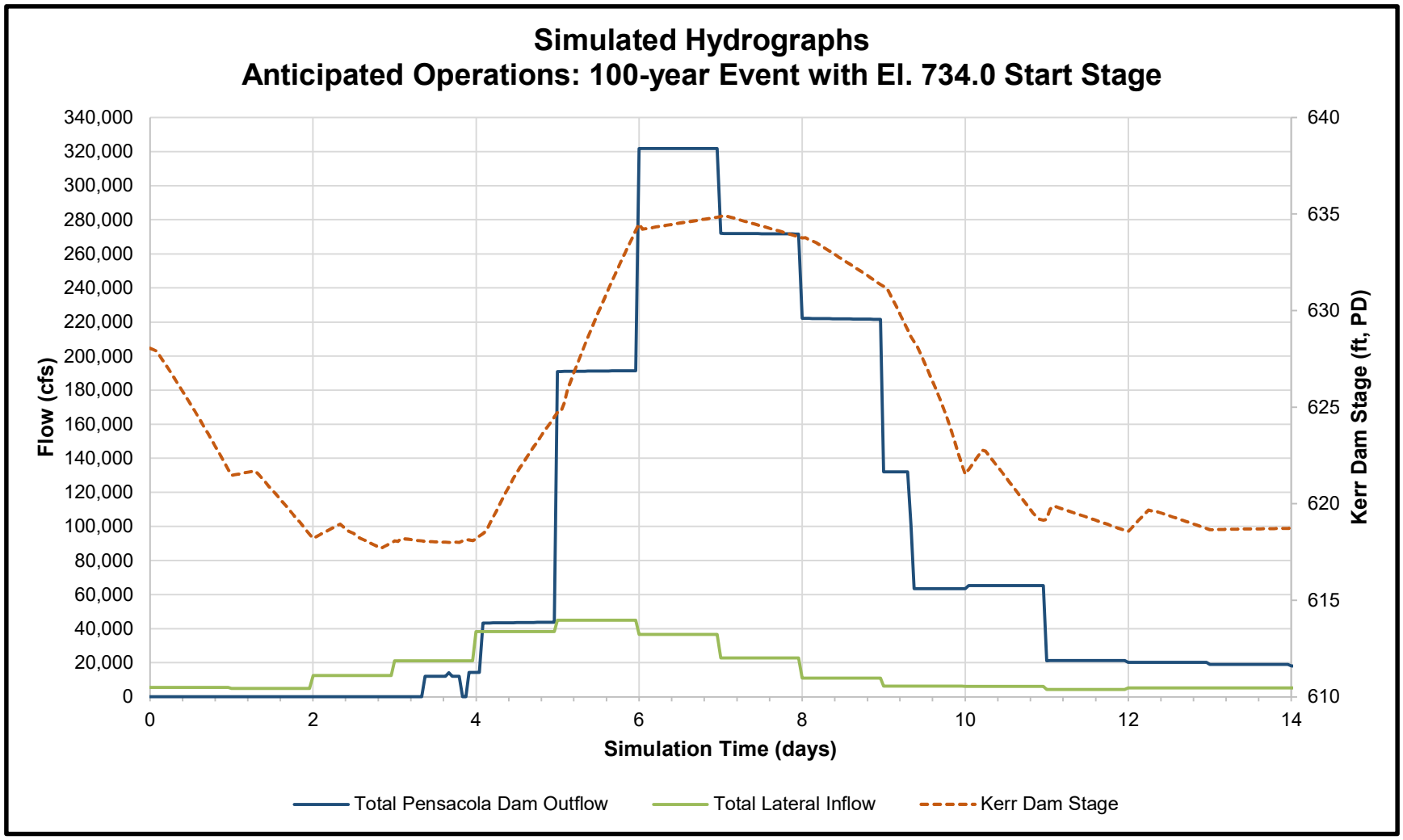


Figure G.5. Simulated hydrograph for Anticipated Operations for the 100-year event with El. 734.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

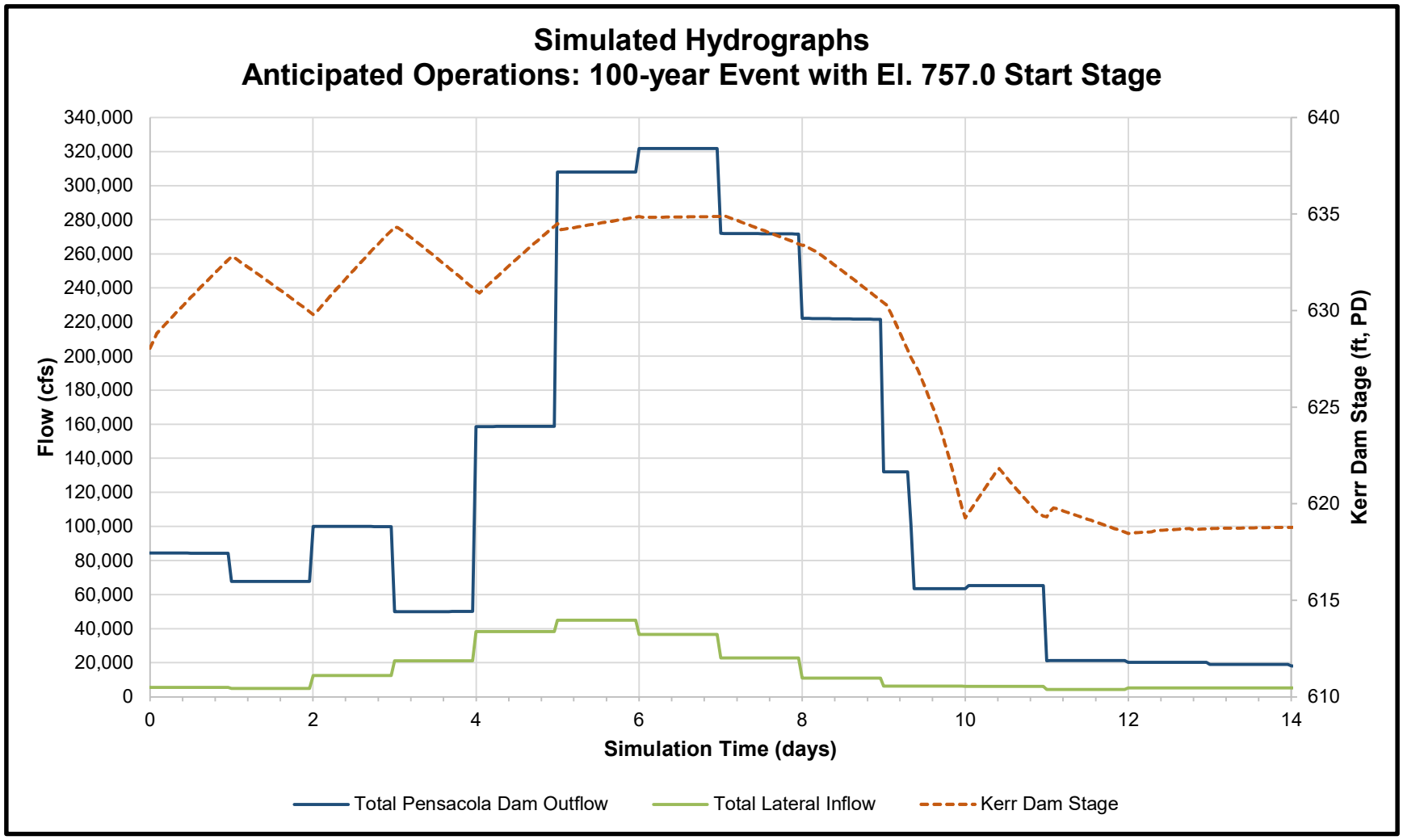


Figure G.6. Simulated hydrograph for Anticipated Operations for the 100-year event with El. 757.0 starting stage at Pensacola Dam.

Notes: 1. The solid blue and green lines are plotted against the left y-axis and represent the Total Pensacola Dam Outflow and Total Lateral Inflow respectively.
2. The dashed line is plotted against the right y-axis and represents the stage at Kerr Dam.

APPENDIX G.2:
ANTICIPATED OPERATIONS ANALYSIS
MAX WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE G.1**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004, Start @ 734 ft	Jun 2004, Start @ 757 ft	July 2007, Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004, Start @ 734 ft	Jun 2004, Start @ 757 ft	July 2007, Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
77.000	Pensacola Dam													
76.880	608.88	623.14	642.63	643.30	656.34	656.35	623.46	642.63	643.29	656.34	656.35	0.32	-0.01	0.00
76.463	607.35	622.84	642.59	643.26	656.28	656.29	623.18	642.59	643.26	656.28	656.29	0.34	0.00	0.00
76.414	N 4475 Rd. Bridge													
76.362	607.61	622.54	642.57	643.24	656.24	656.25	622.90	642.57	643.23	656.24	656.25	0.36	-0.01	0.00
75.317	606.30	621.46	641.82	642.60	654.94	654.95	621.97	641.82	642.59	654.94	654.95	0.51	-0.01	0.00
74.300	605.42	620.92	640.20	641.28	652.68	652.69	621.44	640.20	641.27	652.68	652.69	0.52	-0.01	0.00
73.315	600.08	620.58	639.15	640.46	651.10	651.11	621.08	639.15	640.45	651.10	651.11	0.50	-0.01	0.00
72.884	606.92	620.29	638.36	639.86	650.34	650.35	620.78	638.36	639.85	650.34	650.35	0.49	-0.01	0.00
72.822	OK-82 Bridge													
72.772	604.91	620.20	638.12	639.68	649.64	649.66	620.69	638.12	639.67	649.65	649.66	0.49	-0.01	0.01
71.645	603.05	619.18	637.30	639.13	648.74	648.76	619.71	637.30	639.12	648.74	648.76	0.53	-0.01	0.00
70.910	601.50	619.09	636.03	638.19	647.48	647.50	619.46	636.03	638.18	647.48	647.50	0.37	-0.01	0.00
69.686	599.92	619.09	635.06	637.59	646.43	646.45	619.18	635.06	637.58	646.43	646.45	0.09	-0.01	0.00
68.685	597.81	619.09	634.14	636.94	644.60	644.63	619.09	634.14	636.93	644.60	644.63	0.00	-0.01	0.00
67.715	594.14	619.09	633.58	636.50	643.11	643.15	619.09	633.58	636.49	643.12	643.15	0.00	-0.01	0.01
66.855	592.57	619.09	633.23	636.20	642.00	642.04	619.09	633.23	636.19	642.01	642.04	0.00	-0.01	0.01
66.780	Big Cabin Creek													
65.712	590.99	619.09	632.99	635.82	640.58	640.62	619.09	632.99	635.81	640.59	640.62	0.00	-0.01	0.01
64.435	588.21	619.09	632.73	635.44	638.99	639.02	619.09	632.73	635.43	638.99	639.02	0.00	-0.01	0.00
63.369	585.72	619.09	632.52	635.12	638.03	638.06	619.09	632.52	635.11	638.03	638.06	0.00	-0.01	0.00
63.322	Strang Rd. Bridge													
63.299	587.89	619.09	632.51	635.04	637.08	637.13	619.09	632.51	635.04	637.08	637.13	0.00	0.00	0.00
62.325	582.59	619.09	632.54	635.11	637.19	637.24	619.09	632.54	635.11	637.19	637.24	0.00	0.00	0.00
61.308	584.75	619.09	632.50	635.06	636.69	636.74	619.09	632.50	635.05	636.69	636.74	0.00	-0.01	0.00
60.263	582.15	619.09	632.48	635.02	636.52	636.57	619.09	632.48	635.02	636.52	636.57	0.00	0.00	0.00
60.200	Spavinaw Creek													
59.019	582.85	619.09	632.42	634.96	636.17	636.21	619.09	632.42	634.95	636.17	636.21	0.00	-0.01	0.00
57.950	582.47	619.09	632.38	634.90	635.88	635.92	619.09	632.38	634.90	635.88	635.92	0.00	0.00	0.00
56.927	576.95	619.09	632.34	634.87	635.64	635.68	619.09	632.34	634.87	635.64	635.68	0.00	0.00	0.00
55.890	577.05	619.09	632.32	634.87	635.57	635.61	619.09	632.32	634.87	635.57	635.61	0.00	0.00	0.00
54.456	577.89	619.09	632.29	634.85	635.45	635.46	619.09	632.29	634.85	635.45	635.46	0.00	0.00	0.00
52.988	572.13	619.09	632.23	634.81	634.85	634.83	619.09	632.23	634.81	634.85	634.83	0.00	0.00	0.00

1 Max difference in Max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE G.1**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004, Start @ 734 ft	Jun 2004, Start @ 757 ft	July 2007, Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004, Start @ 734 ft	Jun 2004, Start @ 757 ft	July 2007, Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
52.954	OK-20 Bridge													
52.922	569.25	619.09	632.22	634.80	634.74	634.73	619.09	632.22	634.80	634.74	634.73	0.00	0.00	0.00
50.500	Saline Creek													
50.396	569.69	619.09	632.23	634.82	635.06	635.05	619.09	632.23	634.82	635.06	635.05	0.00	0.00	0.00
49.110	562.60	619.09	632.22	634.82	635.02	635.01	619.09	632.22	634.82	635.02	635.01	0.00	0.00	0.00
48.118	558.27	619.09	632.21	634.81	634.98	634.97	619.09	632.21	634.81	634.98	634.97	0.00	0.00	0.00
47.186	553.07	619.09	632.20	634.81	634.93	634.92	619.09	632.20	634.81	634.93	634.92	0.00	0.00	0.00
47.120	Kerr Dam													

1 Max difference in Max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

APPENDIX G.3:
ANTICIPATED OPERATIONS ANALYSIS
WATER SURFACE ELEVATION PROFILES

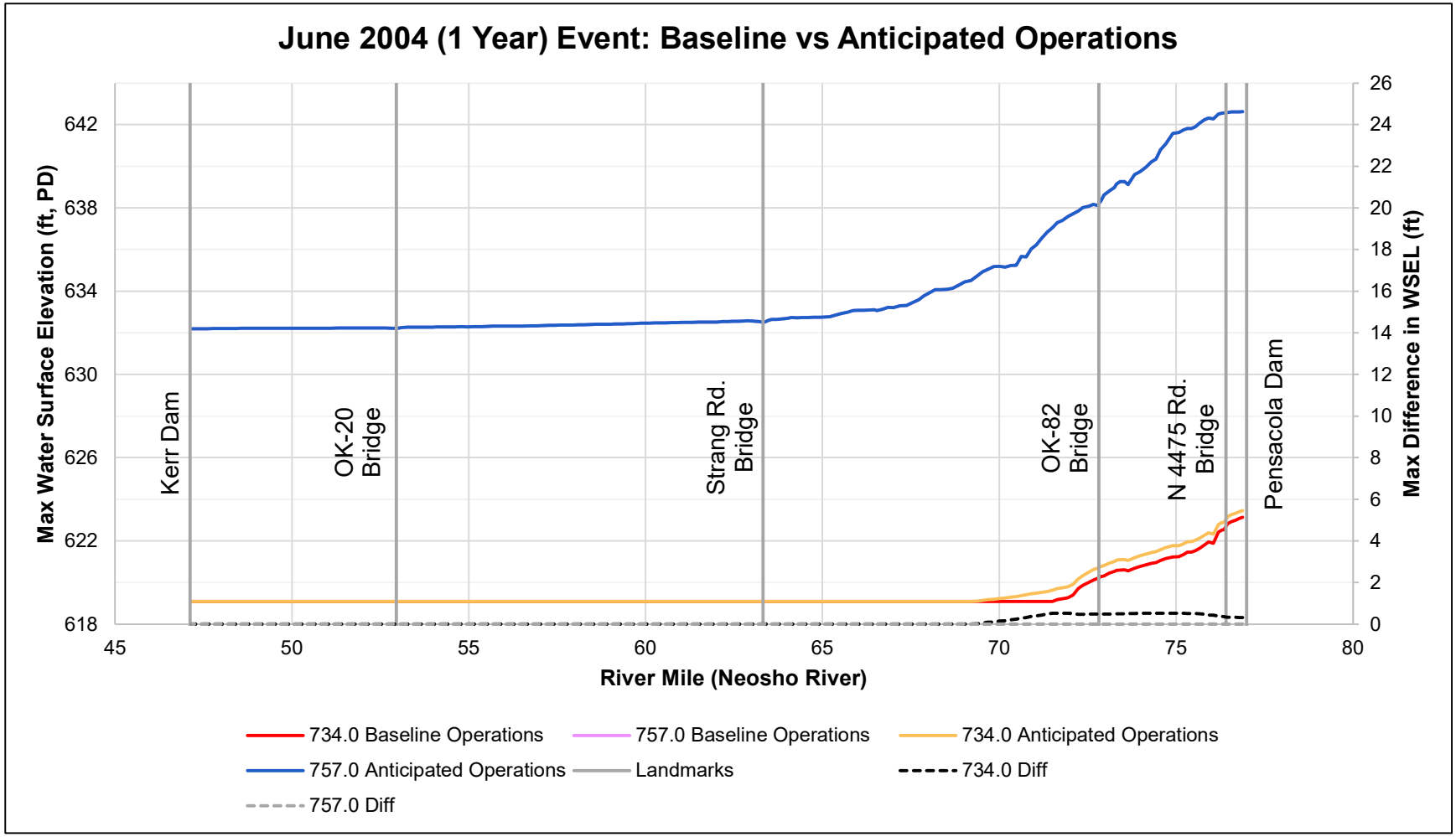


Figure G.7. Water surface elevations for Baseline vs Anticipated Operations for the June 2004 (1 year) event downstream of Pensacola Dam along the Neosho River profile.

Notes:
1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool of 734 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The gray dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for baseline operations is nearly identical.*

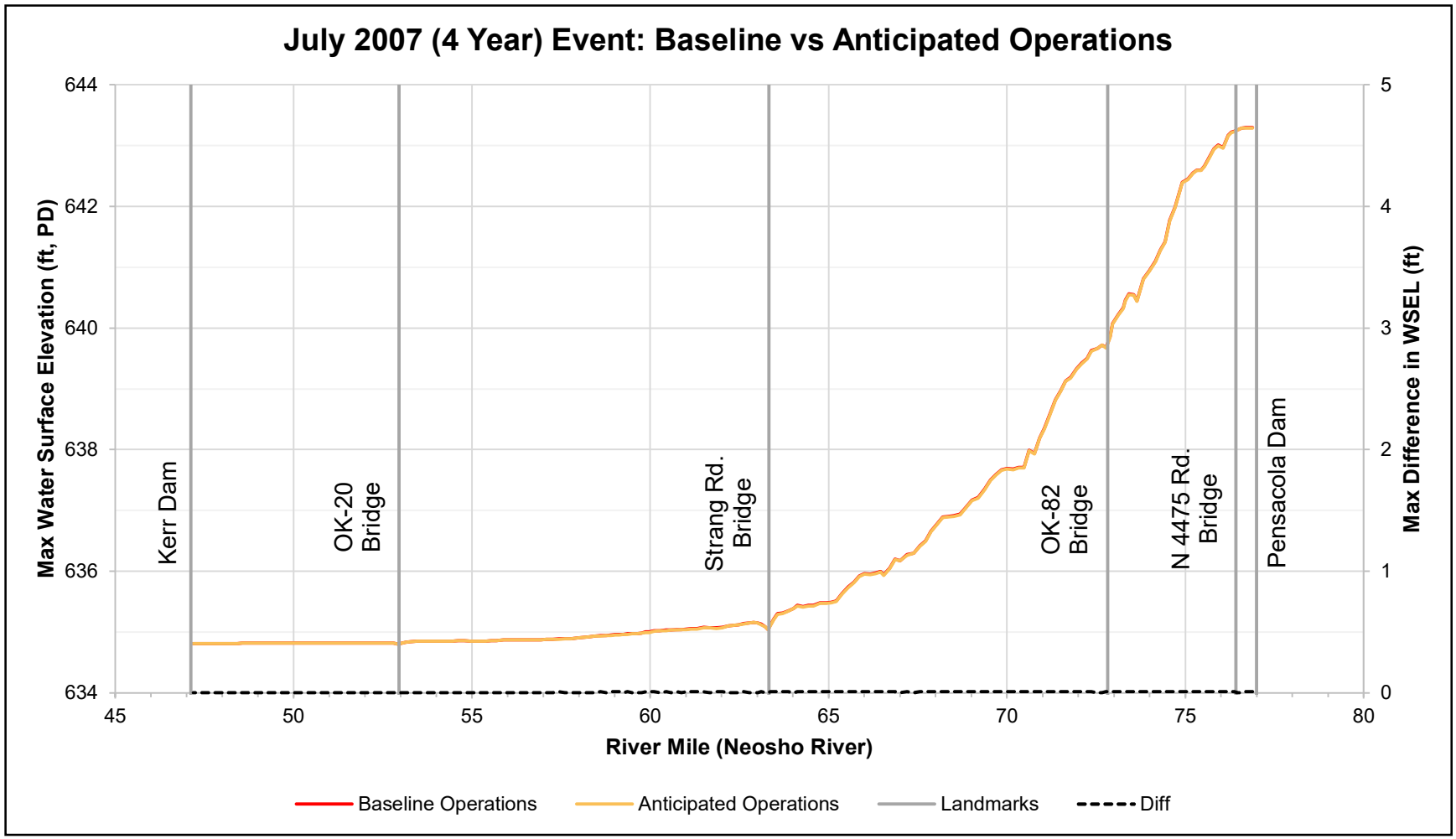


Figure G.8. Water surface elevations for Baseline vs Anticipated Operations for the July 2007 (4 year) event downstream of Pensacola Dam along the Neosho River profile.

Notes:
1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for baseline operations is nearly identical.*

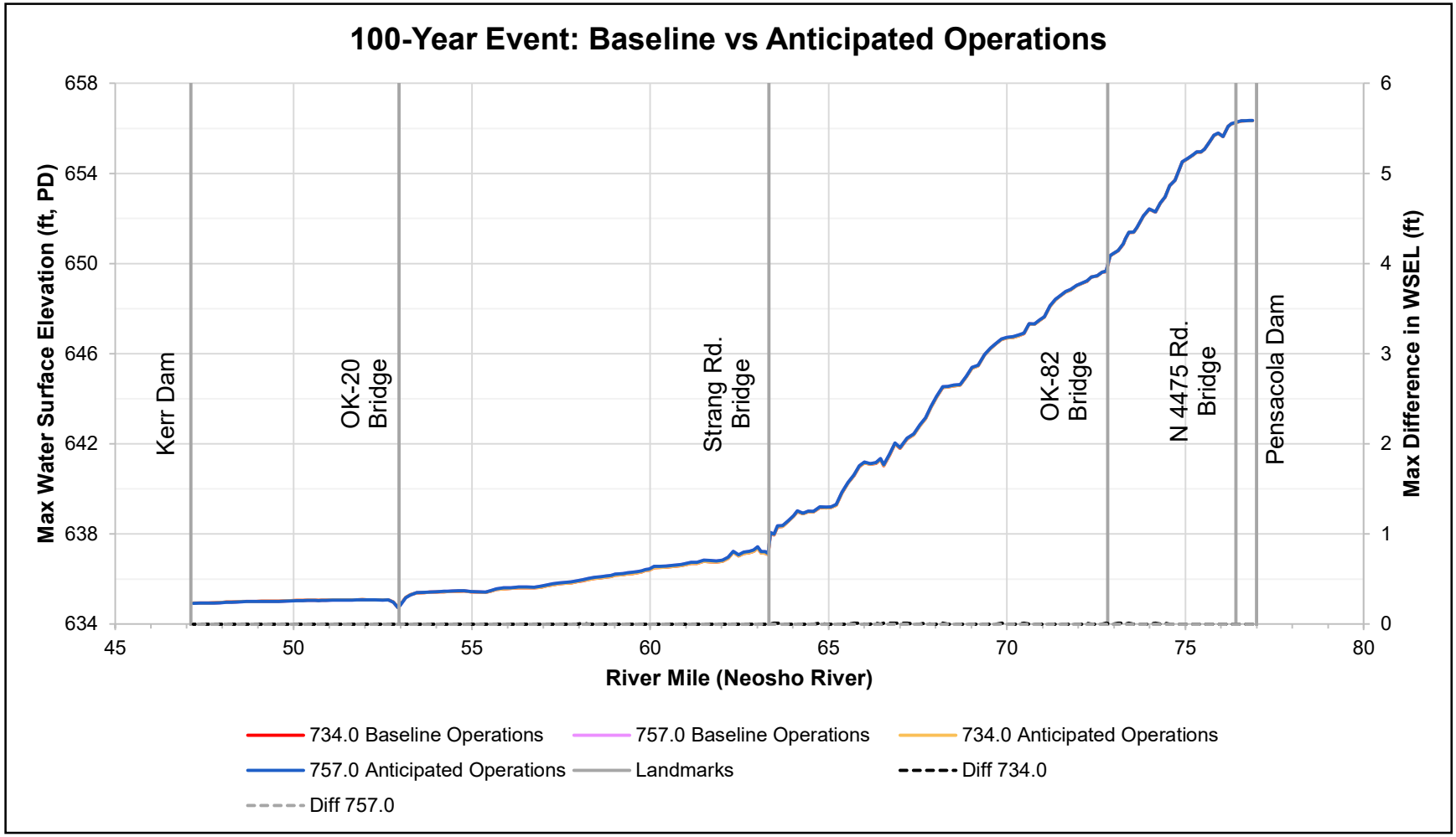


Figure G.9. Water surface elevations for Baseline vs Anticipated Operations for the 100-year event downstream of Pensacola Dam along the Neosho River profile.

Notes:
1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool of 734 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The gray dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for baseline operations is nearly identical.*

APPENDIX G.4:
ANTICIPATED OPERATIONS ANALYSIS
DURATION OF INUNDATION

PENSACOLA DAM **Table G.2**

GRAND RIVER DAM AUTHORITY DOWNSTREAM MODEL DURATIONS - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004, Start @ 734 ft	Jun 2004, Start @ 757 ft	July 2007, Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004, Start @ 734 ft	Jun 2004, Start @ 757 ft	July 2007, Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (hours)	July 2007 (4 year) Difference (hours)	100-Year Difference (hours)
		Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)			
77.000	Pensacola Dam													
76.880	608.88	0	0	0	0	0	0	0	0	0	0	0	0	0
76.463	607.35	0	0	0	0	0	0	0	0	0	0	0	0	0
76.414	N 4475 Rd. Bridge													
76.362	607.61	0	0	0	0	0	0	0	0	0	0	0	0	0
75.317	606.30	0	0	0	0	0	0	0	0	0	0	0	0	0
74.300	605.42	0	0	0	0	0	0	0	0	0	0	0	0	0
73.315	600.08	0	0	0	9	19	0	0	0	10	19	0	0	1
72.884	606.92	0	0	0	16	22	0	0	0	16	22	0	0	0
72.822	OK-82 Bridge													
72.772	604.91	0	0	0	19	40	0	0	0	20	40	0	0	1
71.645	603.05	0	0	0	19	41	0	0	0	20	41	0	0	1
70.910	601.50	0	0	0	14	21	0	0	0	14	21	0	0	0
69.686	599.92	0	0	0	14	21	0	0	0	14	21	0	0	0
68.685	597.81	0	0	0	0	0	0	0	0	0	0	0	0	0
67.715	594.14	0	0	0	0	0	0	0	0	0	0	0	0	0
66.855	592.57	0	0	0	0	0	0	0	0	0	0	0	0	0
66.780	Big Cabin Creek													
65.712	590.99	0	0	0	0	0	0	0	0	0	0	0	0	0
64.435	588.21	0	0	0	0	0	0	0	0	0	0	0	0	0
63.369	585.72	0	0	0	0	0	0	0	0	0	0	0	0	0
63.322	Strang Rd. Bridge													
63.299	587.89	0	0	0	0	0	0	0	0	0	0	0	0	0
62.325	582.59	0	0	0	0	0	0	0	0	0	0	0	0	0
61.308	584.75	0	0	0	0	0	0	0	0	0	0	0	0	0
60.263	582.15	0	0	0	0	0	0	0	0	0	0	0	0	0
60.200	Spavinaw Creek													
59.019	582.85	0	0	0	0	0	0	0	0	0	0	0	0	0
57.950	582.47	0	0	0	0	0	0	0	0	0	0	0	0	0
56.927	576.95	0	0	0	0	0	0	0	0	0	0	0	0	0
55.890	577.05	0	0	0	0	0	0	0	0	0	0	0	0	0
54.456	577.89	0	0	0	0	0	0	0	0	0	0	0	0	0
52.988	572.13	0	0	0	0	0	0	0	0	0	0	0	0	0
52.954	OK-20 Bridge													
52.922	569.25	0	0	0	0	0	0	0	0	0	0	0	0	0
50.500	Saline Creek													
50.396	569.69	0	0	0	0	0	0	0	0	0	0	0	0	0
49.110	562.60	0	0	0	0	0	0	0	0	0	0	0	0	0
48.118	558.27	0	0	0	0	0	0	0	0	0	0	0	0	0
47.186	553.07	0	0	0	0	0	0	0	0	0	0	0	0	0
47.120	Kerr Dam													

1. Max increase in duration for the simulated inflow event listed. Baseline operations duration is subtracted from anticipated operations duration to assess the impact of anticipated operations.

PREPARED BY

Mead & Hunt

Updated Study Report

Hydrologic and Hydraulic Modeling: Operations Model

Pensacola Hydroelectric Project
Project No. 1494

September 2022

CONTENTS

Table of Contents

Executive Summary iii

List of Abbreviations and Terms iv

1. Introduction and Background 1

    1.1 Project Description 1

    1.2 Study Plan Proposals and Determination 2

    1.3 Vertical Datums 3

2. USACE RiverWare Model 3

3. Flood Routing Model 6

    3.1 Input Data 6

    3.2 Methodology 6

4. Operations Model 7

    4.1 Input Data and Preparation 7

        4.1.1 Headloss vs. Turbine Discharge 7

        4.1.2 Stage-Area-Storage Tables 9

        4.1.3 Turbine Efficiency 9

        4.1.4 Turbine Maximum Discharge 10

        4.1.5 Tailwater Rating Curves 10

        4.1.6 Unit Outages 10

        4.1.7 Dissolved Oxygen Air Valves 10

        4.1.8 Electricity Prices 11

        4.1.9 Spillway Capacity 11

    4.2 Methodology 11

5. Validation 13

    5.1 Validation Results: Flood Routing Model 13

    5.2 Validation Results: Operations Model 18

    5.3 Validation Against USGS Gage Data 20

    5.4 Post-Validation Model Improvements 21

        5.4.1 Flood Routing Model Ramping Rate Restrictions 21

        5.4.2 Operations Model Turbine Shutoff Compensation 21

        5.4.3 Flood Routing Model Stage Matching 22

        5.4.4 Updated Stage-Area-Storage Table 23

6. Scenarios Computed for H&H and Sedimentation Studies 24

    6.1 Single Events for CHM, Baseline Operations 24

    6.2 Single Events for CHM, Anticipated Operations 25

    6.3 50-year Simulations for STM 27

CONTENTS

6.4 Single Events for 1D UHM, Anticipated Operations 28
7. Scenarios Computed for Other Studies 28
7.1 Aquatic Species Study 29
7.2 Terrestrial Species Study 29
7.3 Wetlands and Riparian Habitat Study 29
7.4 Recreation and Navigation 29
8. Summary 30
9. References 31

List of Figures

Figure 1. Operations Model Study Area 1
Figure 2. Datum Transformations and Conversions 3
Figure 3. RiverWare Model Domain 5
Figure 4. Flood Routing Model Validation Period of Record 14
Figure 5. Van Buren Guide Curve 15
Figure 6. Modeled July 2007 Pensacola Elevations 16
Figure 7. RiverWare vs. Flood Routing Model Oscillation Comparison 16
Figure 8. RiverWare Model vs. Flood Routing Model Correlation Plots at Pensacola 17
Figure 9. RiverWare Model vs. Flood Routing Model Correlation Plots at Kerr 17
Figure 10. Operations Model Validation Period of Record 18
Figure 11. RiverWare Model vs. Operations Model Correlation Plots at Pensacola 19
Figure 12. RiverWare Model vs. Operations Model Correlation Plots at Kerr 19
Figure 13. Validation Against USGS Gage Data, October 2009 20
Figure 14. Validation Against USGS Gage Data, December 2015 21
Figure 15. Minimum Threshold Price for Generation (Anticipated Operations) 26

Appendices

Appendix A – USACE RiverWare Data

Appendix B – Operations Model Input Data

Executive Summary

Mead & Hunt, Inc. (Mead & Hunt) is assisting Grand River Dam Authority (GRDA) with its intent to relicense the Pensacola Hydroelectric Project (Project), which is regulated by the Federal Energy Regulatory Commission (FERC). Flood control operations at the Project are regulated by the United States Army Corps of Engineers (USACE). GRDA proposed certain hydraulic and operations models for the relicensing study. The FERC's study plan determination requires GRDA to prepare an Updated Study Report (USR). Mead & Hunt has performed this task on behalf of GRDA. This report documents the updated results related to the Operations Model (OM) to be presented at the USR meeting.

USACE's RiverWare period-of-record model is a tool used by USACE Southwestern Division, Tulsa District (SWT) to simulate reservoir operations on the Arkansas River system upstream of United States Geological Survey (USGS) gage number 07250500 at Van Buren, Arkansas, including the Project. This model uses a daily time step and includes over 30 reservoirs.

Mead & Hunt developed a Flood Routing Model (FRM) for GRDA to replicate, as closely as possible, the Project flow routing decisions in the USACE RiverWare period-of-record model (RWM) as an input to the OM. The FRM is needed to investigate hypothetical events and operating scenarios that would be difficult and time-consuming to program into the RWM. The FRM includes three reservoirs (Pensacola, Kerr, and Fort Gibson), which operate as a subsystem for flow routing, and uses daily time steps like the RWM.

Mead & Hunt developed an OM for GRDA to simulate flow routing, hydropower scheduling, and other constraints on an hourly time step to support the Project relicensing effort. Because electricity prices vary widely within a day, hourly time steps provide improved accuracy for hydropower operations simulation. Output from the FRM – most importantly the average daily total discharge – is used as an input to the OM. The OM seeks to optimize the hydropower generation revenue at each facility while simultaneously satisfying various physical and operational constraints, including the flow routing decisions based on the RWM model as simulated in the FRM. The OM includes Pensacola Dam and Kerr Dam (Markham Ferry Hydroelectric Project), which is downstream of Pensacola Dam. Both Pensacola Dam and Kerr Dam are owned and operated by GRDA, and flow routing decisions at both projects are regulated by USACE under certain conditions.

The FRM and OM were validated against the RWM using the common metrics of the Coefficient of Determination (R^2) and the Nash-Sutcliffe Efficiency (NSE) to evaluate modeled total discharge and elevation. The OM was also validated by comparing the water surface elevation (WSEL) results to USGS gage data upstream of Pensacola Dam for two historical events recommended by the FERC. Sensitivity of OM results to stage-area-storage table updates were calculated.

The OM was used to simulate the reservoir levels resulting from different combinations of starting elevations, flow events, existing and future stage-storage relationships, and baseline or anticipated operation scenarios. The OM was also used to simulate the effects of changing elevation-storage relationships over time in support of the Sediment Transport Model (STM). Lastly, the OM was also used to simulate the effects of anticipated operations on reservoir water levels in support of the aquatic species study, terrestrial species study, wetlands and riparian habitat study, and assessment of recreation navigation impacts.

List of Abbreviations and Terms

1D	One-Dimensional
AFRC	Allowable Falling Release Change
CADSWES	Center for Advanced Decision Support for Water and Environmental Systems
CFR	Code of Federal Regulations
CFS	Cubic Feet Per Second
CHM	Comprehensive Hydraulic Model
DO	Dissolved Oxygen
EEC	English Electric Company Limited
GRDA	Grand River Dam Authority
FERC	Federal Energy Regulatory Commission
FRM	Flood Routing Model
H&H Study	Hydrologic and Hydraulic Modeling Study
ISR	Initial Study Report
kW	kilowatt
MWh	Megawatt-hour
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NSE	Nash-Sutcliffe Efficiency
OAC	Oklahoma Administrative Code
OM	Operations Model
PD	Pensacola Datum
POR	Period of Record
Project	Pensacola Hydroelectric Project
PSP	Proposed Study Plan
R^2	Coefficient of Determination
RSP	Revised Study Plan
RWM	RiverWare Model
SPD	Study Plan Determination
STM	Sediment Transport Model
SWT	Southwestern Division, Tulsa District
TW	Tailwater
UHM	Upstream Hydraulic Model
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USR	Updated Study Report
VBA	Visual Basic for Applications

1. Introduction and Background

1.1 Project Description

The Pensacola Hydroelectric Project is owned and operated by GRDA and regulated by the FERC. Pensacola Dam is located in Mayes County, Oklahoma on the Grand-Neosho River. Pensacola Dam impounds Grand Lake. Construction of Pensacola Dam was completed in 1940. Authorized purposes for the Project include flood control, recreation, and hydropower. **Figure 1** displays the study area. Downstream of Pensacola Dam, GRDA also owns and operates the Robert S. Kerr Dam as the Markham Ferry Hydroelectric Project. Kerr Dam is also in Mayes County and impounds Lake Hudson, also known as the Markham Ferry Reservoir. Flow routing decisions at both Pensacola Dam and Kerr Dam are regulated by USACE under certain conditions.

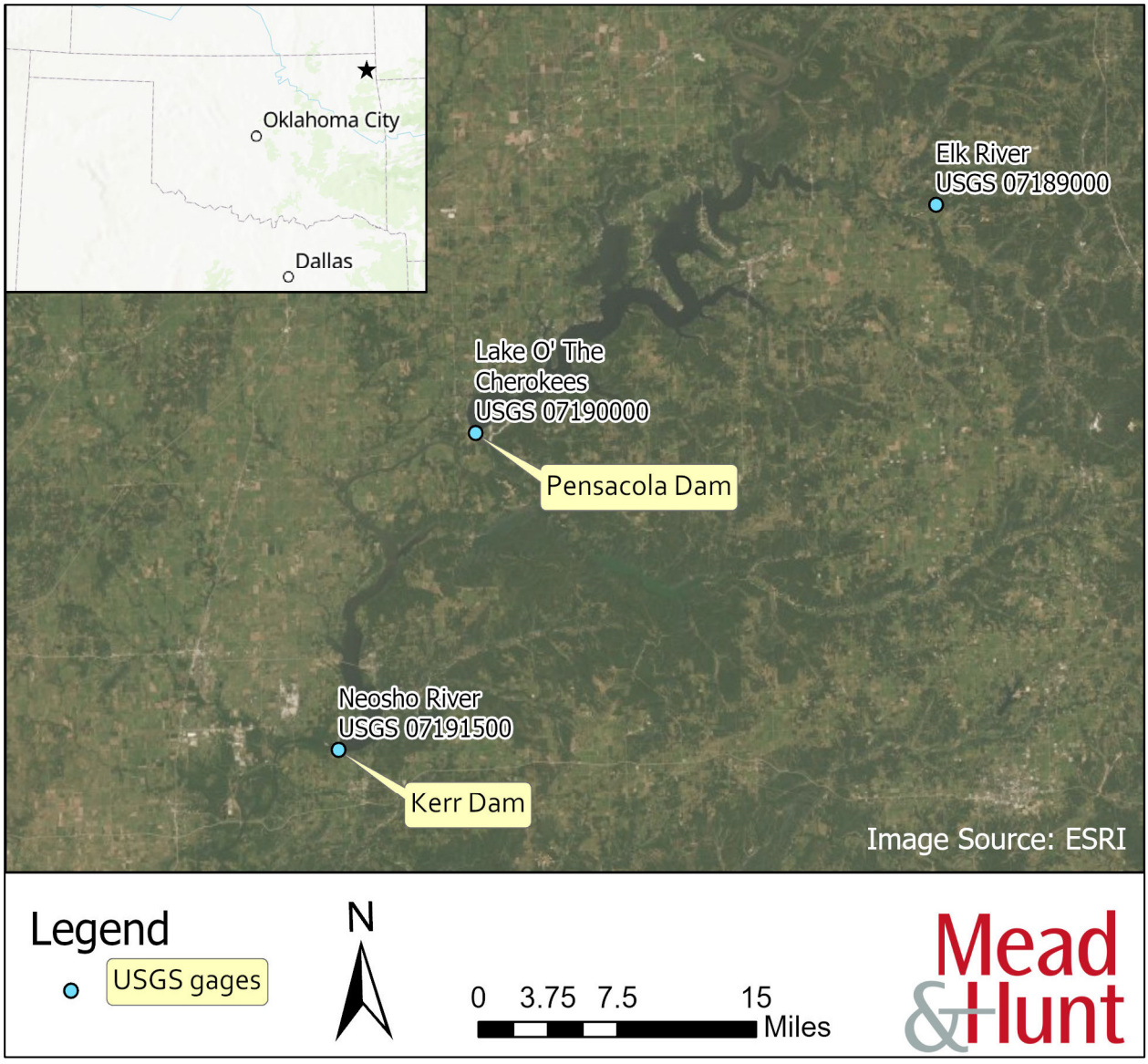


Figure 1. Operations Model Study Area

1.2 Study Plan Proposals and Determination

GRDA is currently in the relicensing of the Project. The timeline of study plan proposals and determination is as follows:

1. On April 27, 2018, GRDA filed its Proposed Study Plan (PSP) to address hydrologic and hydraulic modeling in support of its intent to relicense the Project.
2. On September 24, 2018, GRDA filed its Revised Study Plan (RSP).
3. On November 8, 2018, the FERC issued its Study Plan Determination (SPD) for the Project.
4. On January 23, 2020, the FERC issued an Order on the Request for Clarification and Rehearing, which clarified the timeline for certain milestones applicable to the relicensing study plan.
5. On September 30, 2021, GRDA filed its Initial Study Report (ISR).
6. On February 24, 2022, the FERC issued its Determination on Requests for Study Modifications and New Studies for the Project.
7. On May 27, 2022, the FERC issued its Determination on Requests for Study Modifications for the Pensacola Hydroelectric Project, related to the Sedimentation Study plan.
8. On September 30, 2022, GRDA filed this report, the USR.

The PSP and RSP recommended the development of an OM to synthesize and create events that inform or set boundaries for the Comprehensive Hydraulic Model (CHM). The FERC's SPD included the following determination specific to the OM:

> *We recommend that GRDA demonstrate in the ISR [Initial Study Report, filed September 2021] that it has validated its model results against the RiverWare output.*

The FERC's SPD and Order on Request for Clarification and Rehearing included direction to provide a model input status report by March 30, 2021 and hold a conference call on model inputs and calibration within 30 days of the input status report. The Operations Model Input Status Report was filed with FERC and shared with stakeholders on March 30, 2021 (Mead & Hunt, 2021). A Technical Conference was held on April 21, 2021, to allow relicensing participants to ask questions regarding the Model Input Status Report (MISR). GRDA's ISR was a continuation of the MISR and incorporated comments provided on the MISR. The ISR documented the development of the OM. On April 20, 2022 a Technical Conference was held to allow relicensing participants to ask questions regarding the Operations Model, discuss planned improvements to the model, and present the results of two historical validation cases recommended by the FERC.

FERC's February 2022 Determination recommended the following modifications relevant to the OM portion of the H&H modeling study:

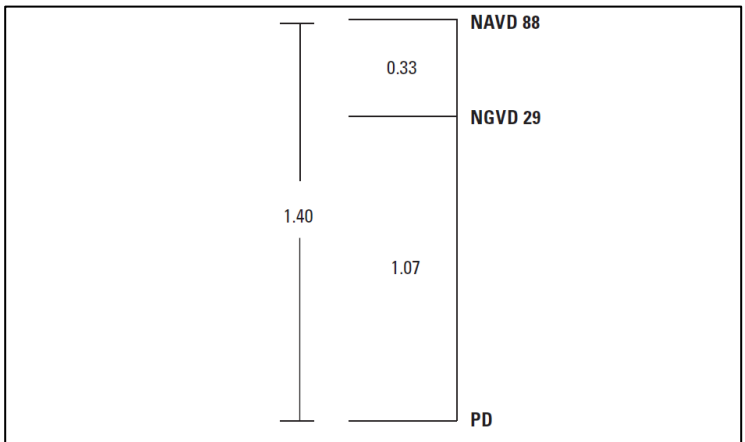
1. Run the OM to simulate all inflow events with starting reservoir surface elevations of 734 feet to 757 feet PD.
2. Compare water surface elevations observed at the USGS gage on the upstream side of the dam to simulated stage hydrographs for the December 2015 and October 2009 inflow events.
3. Run a sensitivity analysis on the effect of switching to the most recent (i.e., 2019) bathymetry data in the OM.

This report documents the development of the FRM and OM, the validation of results against the RWM

output, and the implementation of the OM to provide results in support of the CHM and other relicensing studies. As documented in this USR, GRDA has completed FERC's requested modifications.

1.3 Vertical Datums

Data sources for this study use a variety of vertical datums. Unless otherwise noted, data related to Pensacola Dam and Grand Lake is referenced to the Pensacola Datum (PD) and data related to Kerr Dam and Lake Hudson is referenced to the National Geodetic Vertical Datum of 1929 (NGVD29). To convert from PD to NGVD29, add 1.07 feet. To convert from NGVD29 to the North American Vertical Datum of 1988 (NAVD88), add 0.33 feet. **Figure 2** displays datum transformations and conversions (Hunter, Trevisan, Villa, & Smith, 2020).



	Elevations, in feet		
	NAVD 88	NGVD 29	PD
Conservation pool	743.40	743.07	742.00
Top of the dam	758.40	758.07	757.00

Figure 2. Datum Transformations and Conversions
Source: (Hunter, Trevisan, Villa, & Smith, 2020).

2. USACE RiverWare Model

The RWM is a tool used by USACE Southwestern Division, Tulsa District to simulate reservoir operations on the Arkansas River system upstream of USGS gage no. 07250500 at Van Buren, Arkansas (USACE, 2020). The model simulates hydrologic inflows, evaporation, seepage, water deliveries, reservoir management, flood control, and hydropower production on a daily time step from 1940 through 2019. The model area includes more than 30 reservoirs, and the main control point for flood routing decisions is at the Van Buren gage. When flows at Van Buren are projected to exceed the seasonal guide curve, upstream reservoirs store water to limit flow at Van Buren. Other reservoirs or reservoir subsystems also have their own flood release restrictions. Reservoir balance levels throughout the system are managed to limit flooding systemwide.

Under Section 7 of the Flood Control Act of 1944 (CFR, 1944), the USACE has the responsibility to prescribe releases from Pensacola Dam and Kerr Dam under active or anticipated flood conditions (CFR,

1945). The USACE may exercise direct control over the facilities or provide instructions to GRDA to manage releases for the purpose of basin-wide flood mitigation. The RWM illustrates how reservoir levels at Pensacola Dam and Kerr Dam may be increased during a large flood event impacting Van Buren, not because the spillway capacity or downstream channel capacity is exceeded at either facility, but because water is held back to limit flow at Van Buren.

USACE SWT provided Mead & Hunt, Inc. (Mead & Hunt) with time series, tabular, and other data from the RWM, and examples of these data are included in **Appendix A**. The model domain is shown in **Figure 3.**

Mead & Hunt downloaded the RiverWare Technical Documentation from the Center for Advanced Decision Support for Water and Environmental Systems (CADSWES) at University of Colorado Boulder, College of Engineering and Applied Science website and referenced it to understand how to replicate the modeling methods applicable to this study (CADSWES, 2020). CADSWES develops RiverWare, a river and reservoir/hydropower planning and management tool that is licensed by the University of Colorado Technology Transfer Office, and widely used by agencies and consultants. Documentation for the related TAPER model was also provided by USACE (Steffen, Stringer, Daylor, Neumann, & Zagona, 2015). USACE SWT and CADSWES staff also provided aid in understanding the RWM and how to apply its objects and methods to this study.

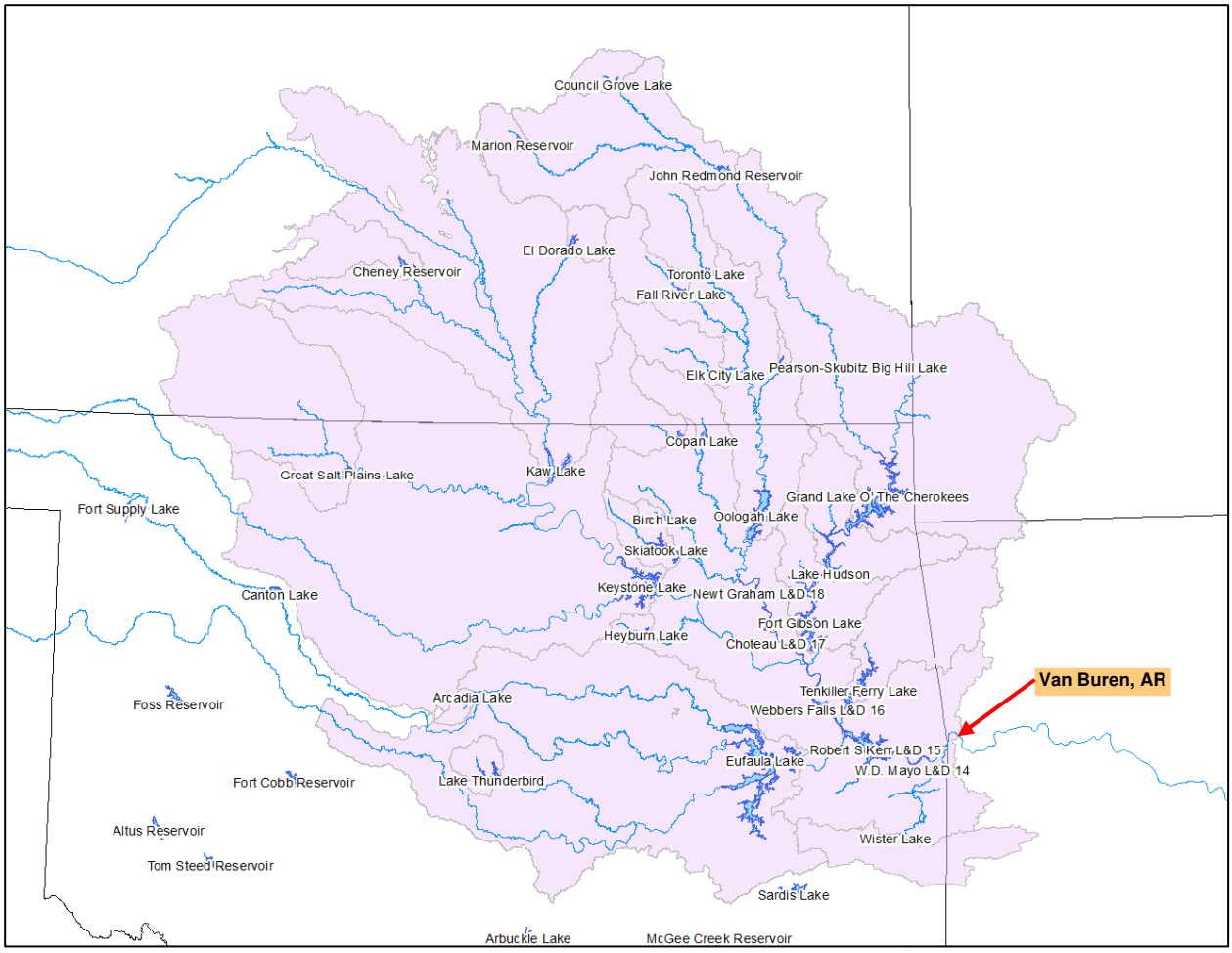


Figure 3. RiverWare Model Domain

3. Flood Routing Model

The FERC SPD recommended GRDA demonstrate it has validated its model results against the RWM output. Mead & Hunt developed the FRM to replicate, as closely as possible, the Project flow routing decisions in the RWM as an input to the OM. The FRM includes (from upstream to downstream) Pensacola Dam, Kerr Dam, and Fort Gibson Dam because these operate as a subsystem for reservoir level balancing. The FRM is needed to investigate hypothetical events and operating scenarios that would be difficult and time-consuming to program into the RWM.

3.1 Input Data

Input data for the FRM includes river discharge upstream of Pensacola Dam, local inflows to each reservoir, evaporation and seepage rates, reservoir stage-storage-area tables, reservoir operating level tables, maximum regulated spill tables, induced surcharge tables, seasonal Project target reservoir elevation table, and hydrologic routing coefficient tables from the RWM.

3.2 Methodology

The FRM was developed using Visual Basic for Applications (VBA) code within an Excel spreadsheet. The VBA code loops through the time series calculations to solve the model. The VBA code computes formulas to calculate the system state and flow routing decisions for each daily time step, then copies the formulas to the next daily time step and stores the results as plain text in the Excel spreadsheet. In this way, the file size is reduced, and the computation speed improved. The VBA code also dynamically updates a table that relates the operating balance level at Pensacola to the seasonal target elevation and corresponding flood pool elevations and volumes based on the current solution day.

Minimum surcharge and maximum regulated outflows are calculated individually for each dam from upstream to downstream. Operating levels are balanced upstream to downstream and highest to lowest, within calculated outflow limits. Individual dam and Lower Grand (Neosho) subsystem limits are checked. Conservation pool rules and hydropower rules are ignored for purposes of flow routing. Modeled objects include reservoirs, control points, and reaches.

Methods from the RWM replicated in the FRM include:

- Flow combined at nodes and routed downstream hydrologically.
- Evaporation calculated using historical evaporation rates considering modeled reservoir area.
- Constant seepage assumed: 10 cubic feet per second (cfs) at Kerr Dam and 20 cfs at Fort Gibson Dam.
- Minimum surcharge and maximum regulated outflow calculated using the USACE SWT flat top surcharge method.
- Allowable rising release change and allowable falling release change limit how quickly the controlled releases are increased or decreased, subject to other limitations such as minimum surcharge.
- Operating level balancing seeks to maintain similar balance levels in each reservoir.
- Regulating discharges of 100,000 cfs established in the water control manual are considered for Pensacola Dam, Kerr Dam, and Fort Gibson Dam (USACE, 1980).

4. Operations Model

Mead & Hunt developed an OM to simulate flow routing, hydropower scheduling, and other Project constraints on an hourly time step. Because electricity prices vary widely within a day, hourly time steps provide improved accuracy for hydropower operations simulation. The OM was developed using VBA code within an Excel spreadsheet, as described in more detail below.

4.1 Input Data and Preparation

Mead & Hunt obtained data for the OM from GRDA and USACE. Input data includes project drawings, rating curves, time series data, and information from the RWM. Most of the time series data was available in hourly or sub-hourly time steps from April 1, 2004 through December 31, 2019 (the end date in the RWM), so this period was selected for analysis. Descriptions and sources of each input data set are described below, along with descriptions of the methods used to prepare the data for input to the OM. **Appendix B** contains a collection of the information described in this section.

4.1.1 Headloss vs. Turbine Discharge

GRDA sent Mead & Hunt drawings of the Pensacola and Kerr hydroelectric facilities showing the dimensions of the water passages from the intake to the tailrace at each powerhouse (GRDA, 1961), (GRDA, 1987). The dimensions shown on these drawings were used to estimate the hydraulic friction and form losses as part of the turbine net head calculation.

Facility drawings for the Pensacola and Kerr facilities were used to identify specific friction loss (i.e., conduit roughness) and minor loss (e.g., bends, contractions, or entrance and exit losses) components between the reservoirs and the turbines. It is common practice for turbine manufacturers to include the hydraulic losses from the scroll case entrance through the tailrace in the turbine hill curve efficiencies, so these losses were specifically excluded from the headloss calculations.

Total headloss was calculated using a combination of the Darcy-Weisbach formula for friction losses and assumed minor loss coefficients. To simplify spreadsheet calculations, major and minor losses are expressed in terms of a flow-based headloss coefficient, Kq, according to the equations below:

$$H_L = Kq * Q^2$$

$$Kq = \frac{0.025 * f * L}{{D_h}^5}$$

$$Kq = \frac{Kv}{2gA^2}$$

where:
H_L = headloss (ft)
Kq = flow-based headloss coefficient
Kv = velocity-based headloss coefficient

Q = turbine discharge (ft^3/s)
L = pipe length (ft)
f = Darcy-Weisbach resistance coefficient
D_h = Hydraulic diameter (ft)
A = pipe wetted area (ft^2)
g = gravity constant (32.146 ft/s^2)

The resistance coefficient varies with pipe size, pipe roughness, fluid kinematic viscosity, and discharge. Resistance coefficients were determined based on the following equations, which approximate the curves of the Moody Diagram.

Von Karman-Prandtl equation for smooth pipe flow:

$$\frac{1}{\sqrt{f}} = 2\log_{10}\left(Re\sqrt{f}\right) - 0.8$$

$$Re = D_h V \nu$$

where:
Re = Reynold's Number
V = average velocity (ft/s)
ν = kinematic viscosity of fluid (ft^2/s)

Von Karman-Prandtl equation for rough pipe flow:

$$\frac{1}{\sqrt{f}} = 2\log_{10}\frac{D_h}{2k} + 1.74$$

where:
k = absolute roughness of pipe wall (ft)

Colebrook-White equation for transition flow:

$$\frac{1}{\sqrt{f}} = -2\log_{10}\left(\frac{k}{3.7D_h} + \frac{2.51}{Re\sqrt{f}}\right)$$

Friction losses for Pensacola were calculated assuming water at 50° F, roughness of 0.00015 feet (steel), and acceleration due to gravity of 32.146 ft/s^2. Minor loss coefficients were selected using the appropriate Hydraulic Design Criteria charts (USACE, 1987).

The total calculated flow-based headloss coefficient (Kq) for Pensacola was 4.50×10^{-7}, and for Kerr was 4.11×10^{-9}.

4.1.2 Stage-Area-Storage Tables

For model validation purposes, reservoir stage-area-storage-tables for Pensacola and Kerr from the RWM were used in the OM. As discussed in **Section 5.4.4**, other more recent bathymetric survey data were incorporated post-validation to improve later simulations (Dewberry, 2011), (Hunter, Trevisan, Villa, & Smith, 2020).

4.1.3 Turbine Efficiency

Pensacola

Efficiency curves for the Pensacola generators were transcribed from the Siemens efficiency calculations (Siemens, 1999) in terms of generator efficiency vs. percent rated generator load, assuming rated brake power of 18,112 kilowatt (kW) at 0.90 power factor.

Efficiency vs. turbine discharge vs. net head curves for the Pensacola turbines (air valves closed condition) were transcribed from the Voith hill curve (Voith, 1997). Efficiency curves for the condition when the dissolved oxygen (DO) air valves are fully open were transcribed from the Accusonic Unit 3 preliminary performance test report (Walsh, 1999).

Two efficiency curves were developed for Pensacola: one for normal operation with all the DO air valves closed, and one for derated operation with all the DO air valves fully open (90 degrees open).

The normal operation turbine efficiency vs. turbine discharge vs. net head curve was transcribed from the Voith hill curve into an Excel spreadsheet table. The generator efficiency vs. load curve was then multiplied by the turbine efficiencies to develop a total turbine-generator efficiency vs. discharge vs. net head table.

The derated operation (air valves open) turbine efficiencies at a net head of 117.5 feet were transcribed from the Accusonic report. The ratio of derated turbine efficiency to normal turbine efficiency for a given turbine discharge was assumed to be constant across the entire range of net head values used (95 feet to 140 feet). After extrapolating the derated turbine efficiencies, the generator efficiency vs. load curve was again applied to develop a total turbine-generator efficiency vs. turbine discharge vs. net head table for derated operation.

Kerr

Efficiency curves for the Kerr generators were transcribed from the table in Section 2.3.1 of the Alstom generator calculations (Bertrand, 2009) in terms of generator efficiency vs. percent rated generator load, assuming rated brake power of 33,036 kW at 0.93 power factor.

Power vs. turbine discharge vs. net head curves for the Kerr turbines (pre-refurbishment) were transcribed from the original 1962 prototype unit curves (EEC, 1962a). Relative turbine efficiencies for the Kerr turbines (post-refurbishment) were transcribed from the Alstom index test results (Alstom, 2010).

The efficiency curves for Kerr were developed based on the original 1962 prototype efficiency curve and the 2010 post-refurbishment index testing. The total turbine-generator efficiency vs.

turbine discharge vs. net head table for the original units was developed using a similar methodology as for Pensacola. Alstom reported index test results as a relative turbine efficiency (refurbished units relative to the original 1962 prototype units) vs. refurbished turbine power at a net head of 56 feet. Index efficiencies were applied across the entire domain of the original hill curve by multiplying the relative efficiency at an equivalent discharge by the maximum original turbine efficiency value at each net head.

4.1.4 Turbine Maximum Discharge

The maximum allowable turbine discharge (to avoid cavitation) vs. net head limit for Pensacola was determined from the entrance edge cavitation lines on the Voith hill curve (Voith, 1997). The maximum turbine discharge vs. net head limit for Kerr was determined from the limit of Kaplan operation line on the original 1962 prototype unit curves (EEC, 1962b).

4.1.5 Tailwater Rating Curves

The tailwater (TW) elevation vs. total discharge rating curve for Pensacola Dam was developed based on the historical observed TW elevation and discharge paired data provided by GRDA. The elevation-discharge data pairs were plotted, and a table of paired values was developed based on a best fit through the observed points.

The TW elevation vs. total discharge rating curve for Kerr Dam was developed using USGS gage data: Neosho River near Langley, OK (USGS Gage No. 07190500). The gage data pairs were plotted, and a table of paired values was developed based on a best fit through the gage data points.

4.1.6 Unit Outages

Individual turbine unit outages are recorded in terms of the start and end date/time of each outage. The outages can be either scheduled or unscheduled, and the type of outage can be forced, planned, maintenance, or de-rated generation output (e.g., DO air valve operation at Pensacola).

Records of the date and time for the beginning and ending of outages for individual turbine-generator units were used to construct time series of unit outages. Overlapping outages were reconciled when the beginning or ending timestamp of a listed outage fell within the timeframe of another outage for the same unit. An hourly time series was constructed to indicate the status of each individual unit (online or offline) for each time step. Lastly, the total number of units online for each time step at each facility was determined. This data was used by the OM to determine the total turbine discharge capacity available for a given time step.

4.1.7 Dissolved Oxygen Air Valves

Dissolved Oxygen data, including measured DO levels and the status of each of the six Pensacola DO air valves, was available between January 1, 2004 and April 13, 2006 (non-contiguous data). Oklahoma Water Resources Board Title 785.45-5-12 describes seasonal DO concentrations needed to support various subcategories of Fish and Wildlife beneficial use designations for streams (OAC, 2013). The prescribed seasonal DO concentrations were considered along with records of measured DO concentrations and individual air valve status

from Pensacola to estimate when the air valves may have typically been opened during the modeled period of analysis, as described below. The model accounts for the status of the air valves by switching between two different turbine efficiency curves to represent the decrease in turbine efficiency when the air valves are open.

For Pensacola, the prescribed seasonal DO concentrations were considered along with records of DO levels; individual air valve status; actual generation output; and head, efficiency, and flow data to estimate when the air valves may have typically been opened during the modeled period of analysis. There are no DO air valves at Kerr.

4.1.8 Electricity Prices

Hourly day-ahead and real-time locational marginal prices (in terms of dollars per megawatt-hour [MWh]) for electrical energy produced at Pensacola and Kerr were available from March 1, 2014 to December 31, 2020.

Daily natural gas settlement prices for the Henry Hub trading point were available from March 1, 2004 through December 31, 2020. Natural gas prices were used to index the electricity prices across the full range of analysis dates.

Hourly electricity prices for both day-ahead and real-time markets over the period between March 1, 2014 and December 31, 2020 were divided by the corresponding daily natural gas price to determine the hourly heat rate pattern for this period. This heat rate pattern was then applied to corresponding dates when no hourly electricity prices were available (prior to March 1, 2014). The assumed hourly heat rate was then multiplied by the actual daily historical natural gas settlement prices going back to April 1, 2004 to estimate the historical electricity prices for the period when actual hourly data was not available.

4.1.9 Spillway Capacity

USACE spillway discharge capacity ratings were reviewed for Pensacola and Kerr, but for the purposes of model validation the rating tables from the RWM will be used instead (USACE, 1990), (USACE, 1991).

4.2 Methodology

The objective function of the OM is to maximize the hydropower generation revenue at each facility while simultaneously satisfying various physical and operational constraints (e.g., reservoir level management, flow routing from the FRM, scheduling of power sales, and operation of the turbines within their allowable range). Many dependent functions comprise the overall objective function and are summarized here:

- Total discharge computed by the FRM is also used by the OM when the reservoir transitions into flood operations, which occurs when the pool is more than 0.5 feet from the target elevation. Otherwise, for normal operations, discharge is determined based on optimal hydropower generation scheduling.
- Modeled revenue is a function of scheduled power and electricity price (both day-ahead and real-time).
- Power is a function of turbine discharge, net head, and total turbine-generator efficiency.

- Net head is a function of headwater, tailwater, and headloss.
- Efficiency is a function of turbine discharge, net head, and DO air valve open/closed status (Pensacola only).
- Turbine discharge is a function of best efficiency point discharge, maximum allowable discharge (avoiding possible cavitation), current reservoir storage volume, forecast inflow volume, electricity price, production cost, the number of units online.
- Reservoir storage volume is a function of inflow, turbine discharge, spillway discharge, evaporation, and seepage (Kerr only, no seepage at Pensacola in RWM).
- Other parameter dependencies have been discussed in the description of the input data preparation in **Section 4.1**.

The OM is driven by VBA code to do two things: 1) solve an iterative loop for the net head values, and 2) step through the time series one day at a time. The Excel spreadsheets contain formulas to optimize the hydroelectric operations for a 24-hour period. The VBA code copies the formulas down from one day to the next as each 24-hour period is solved, preserving the solution values. In this way, the Excel spreadsheets are kept to a manageable size and overall calculation speed is improved.

At the beginning of the solution for a given 24-hour period, an estimated value for net head at each hourly time step is assumed (final values from one day are copied down to the next day to provide the first estimated value). The net head is used to calculate various parameters related to the turbine and spillway discharge, which in turn are used to calculate the TW elevation and headloss, which are then used to calculate the next estimated value for net head.

Each scenario model is solved first for Pensacola. The resulting total discharge (turbines plus spillway) from Pensacola is then hydrologically routed downstream to Kerr Dam in a manner consistent with the RWM hydrologic routing. The routed Pensacola Dam discharge for the given scenario, plus tributary inflows to Lake Hudson, are then combined and copied as inflow to the OM for Kerr.

Hourly time series data produced in the OM includes reservoir elevation, turbine discharge, spillway discharge, net head, power (scheduled day-ahead, real-time buy-back, real-time scheduled, and total), and revenue (day-ahead sales, buy-back cost, real-time sales, and total).

5. Validation

Model variables used to validate performance of the OM and FRM against the RWM output included total discharge from a reservoir and elevation of a reservoir. Reservoir storage and balance level were also available as validation parameters but were simple corollaries for elevation. Because elevation is a more intuitive parameter for understanding the system state, it was used rather than the other corresponding parameters.

The date range for OM validation was April 1, 2004 to December 31, 2019. This was the overlapping date range for which data were available from the RWM and when hourly data were available for the OM. The FRM was validated against the RWM using results as far back as 1940.

Performance metrics included the Coefficient of Determination (R^2) and the Nash-Sutcliffe Efficiency (NSE). R^2 is an index of the degree of linear relationship between source and simulated data. R^2 represents correlation between models and dispersion of data relative to that correlation. It does not evaluate accuracy, only correlation. NSE is an index of how well the source versus simulated data fits a perfect 1:1 correlation slope line. Plotting on a 1:1 line indicates consistent prediction at lower and higher values. However, NSE is more sensitive to extreme values. Formulas for R^2 and NSE are available in literature and given below for reference. The optimal value for both metrics is 1. For R^2, the optimal trendline intercept is 0,0 and the optimal trendline slope is 1. **Table 1** lists qualitative ranges for evaluating model validation using these metrics (Moriasi, Gitau, Pai, & Daggupati, 2015).

$$R^2 \qquad \left[\frac{\sum_{i=1}^{n}(O_i-\bar{O})(P_i-\bar{P})}{\sqrt{\sum_{i=1}^{n}(O_i-\bar{O})^2}\sqrt{\sum_{i=1}^{n}(P_i-\bar{P})^2}}\right]^2 \qquad \text{NSE} \qquad 1-\frac{\sum_{i=1}^{n}(O_i-P_i)^2}{\sum_{i=1}^{n}(O_i-\bar{O})^2}$$

Table 1. Summary of Performance Metrics

Metric	Range	Not Satisfactory	Satisfactory	Good	Very Good
R^2	0 to 1	≤ 0.60	0.60 to ≤ 0.75	0.75 to ≤ 0.85	> 0.85
NSE	-∞ to 1	≤ 0.50	0.50 to ≤ 0.70	0.70 to ≤ 0.80	> 0.80

Validation of the OM against the RWM output was performed using similar inputs as the RWM for historical discharge, evaporation, seepage, stage-storage-area tables, reservoir operating level tables, maximum regulated spill tables, induced surcharge tables, the seasonal Project target reservoir elevation table, and hydrologic routing coefficient tables. Following validation, some of these inputs were updated and expanded to meet the needs of the study, as discussed in **Section 5.4**.

5.1 Validation Results: Flood Routing Model

The first step in model validation was comparison of the FRM to the RWM results. The FRM was validated against the RWM results for the entire RWM period of record, which is Jan 1, 1940 through December 31, 2019 as shown in **Figure 4** below.

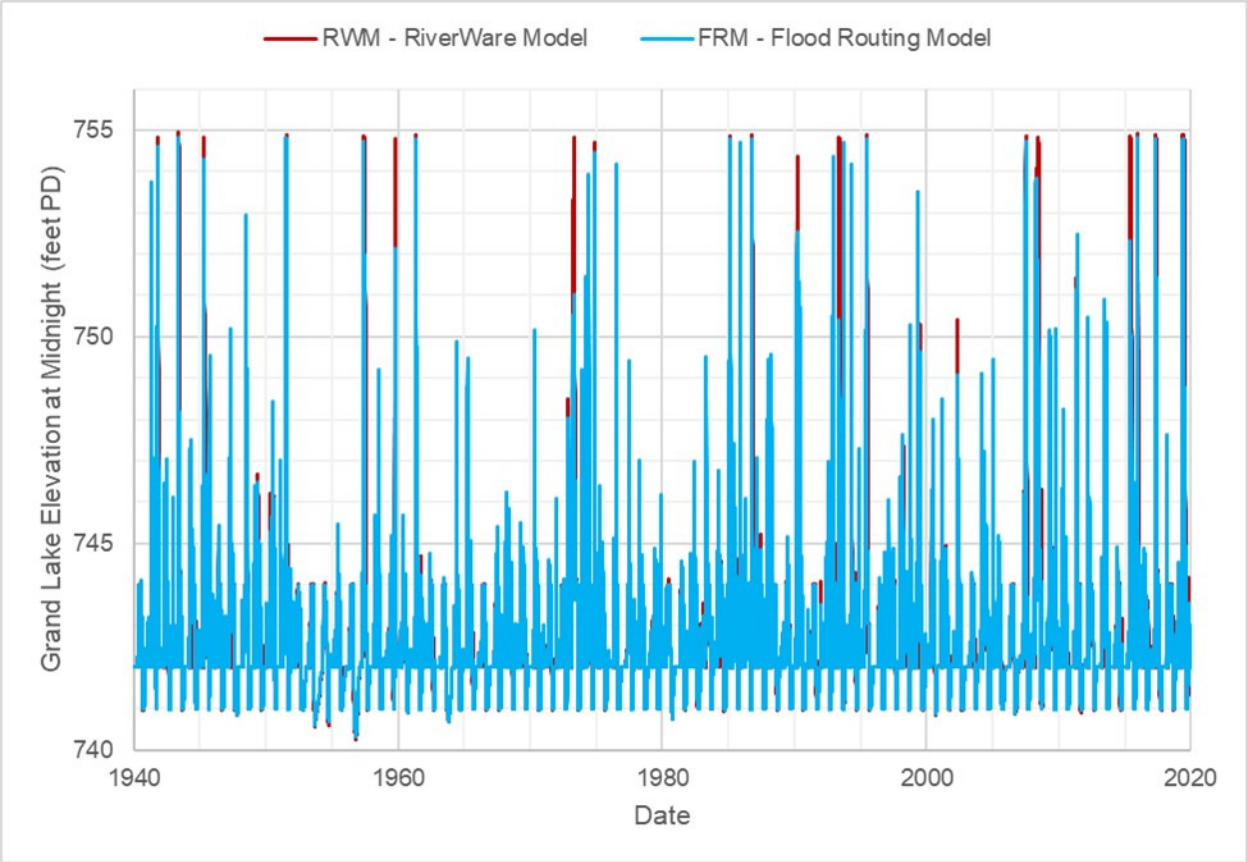


Figure 4. Flood Routing Model Validation Period of Record

The FRM simulates many of the rules and constraints in the RWM, with a notable exception: the FRM cannot account for operating level balancing due to the flow restriction at Van Buren, because it is outside the study area. The allowable maximum discharge at Van Buren is a function of the time of year and the amount of basin storage currently utilized at upstream reservoirs, as shown in **Figure 5**[1].

[1] Copy of Plate 7-58 from (USACE, 1980).

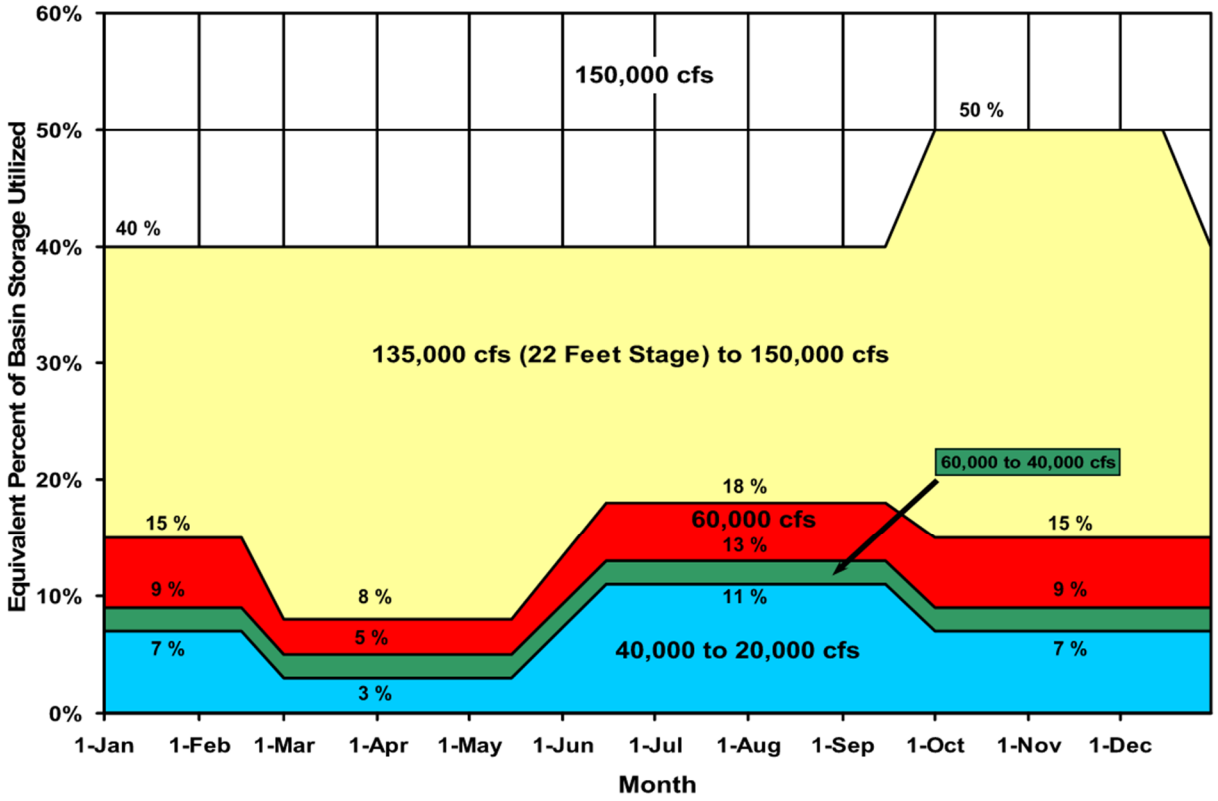


Figure 5. Van Buren Guide Curve

The RWM will sometimes hold the pool higher for extended periods at both Pensacola and Kerr to help manage the discharge at Van Buren. This can result in what appears to be underprediction of peak stages by the FRM on the correlation plots but is more often an underprediction of the duration of those peak stages, as illustrated in **Figure 6** below for the July 2007 event. The modeled peak stages were similar between the FRM and RWM for this event, but the FRM returned the pool to the normal elevation sooner than the RWM. The Van Buren Percent Full Regulation Parameter exceeded 90% for this event, resulting in significant outflow restrictions at upstream dams in the RWM, including at Pensacola and Kerr. Those restrictions were not present in the three-reservoir FRM, and therefore the pool was returned to the normal level soon after the peak inflows subsided. This resulted in a difference between the RWM and FRM stages up to about nine feet for several days, which had the effect of decreasing the correlation metrics.

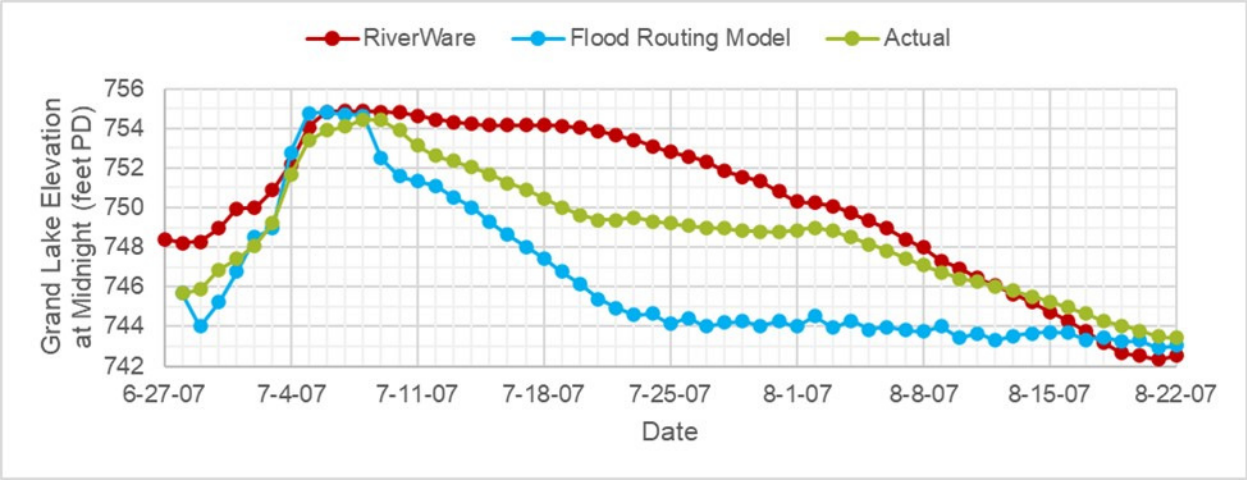


Figure 6. Modeled July 2007 Pensacola Elevations

Another feature of the RWM which decreases the correlation of the models is time step oscillation. As the model shifts between different operating rules at threshold pool levels (i.e., top of conservation pool), and as the total system state changes over time, the decision-making of the model can result in fluctuations from one daily time step to the next. For example, an increased discharge at one time step can increase the downstream reservoir level, resulting in an increased operating balance level and forcing a lower discharge at the next time step, and so on. **Figure 7** illustrates this effect as it occurs in both the RWM and FRM.

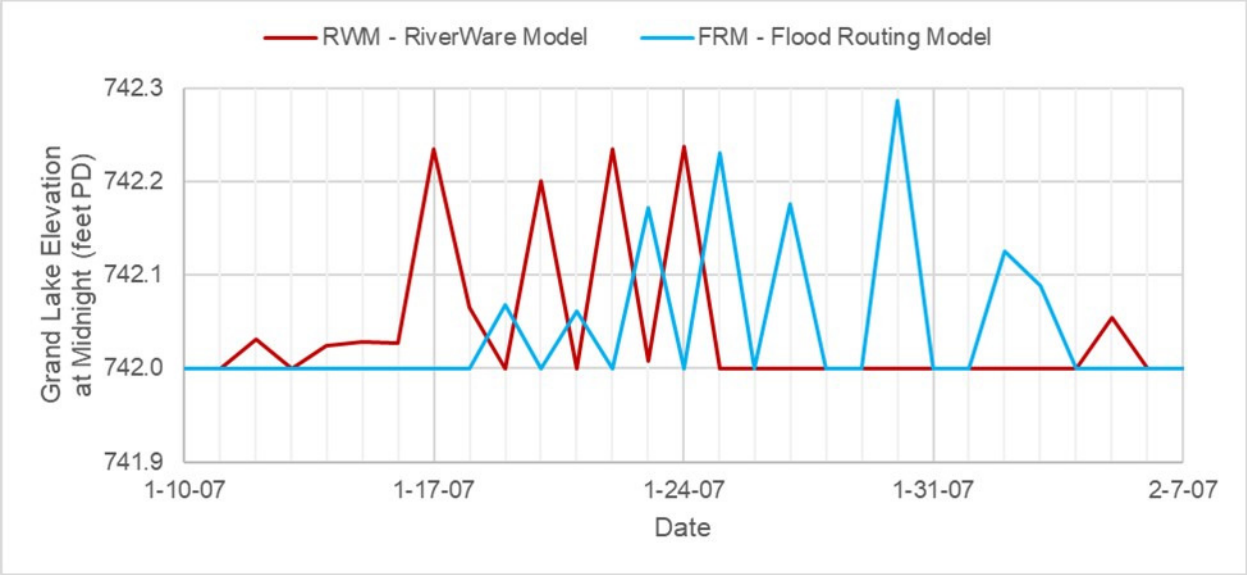


Figure 7. RiverWare vs. Flood Routing Model Oscillation Comparison

Time step oscillation can decrease the apparent correlation between the models, especially when the oscillation happens to begin at different time steps between the two models, so that one model is decreasing while the other is increasing. In order to obtain a clearer comparison between two models, the effect of time step oscillation must first be removed by time-averaging across two daily model time steps. This was done for both models before computing the correlation, and effectively mitigated the problem of oscillation on the model timestep-scale.

Figure 8 and **Figure 9** show the RWM vs. FRM validation plots for Pensacola and Kerr, respectively. The validation metrics are summarized in **Table 2** below.

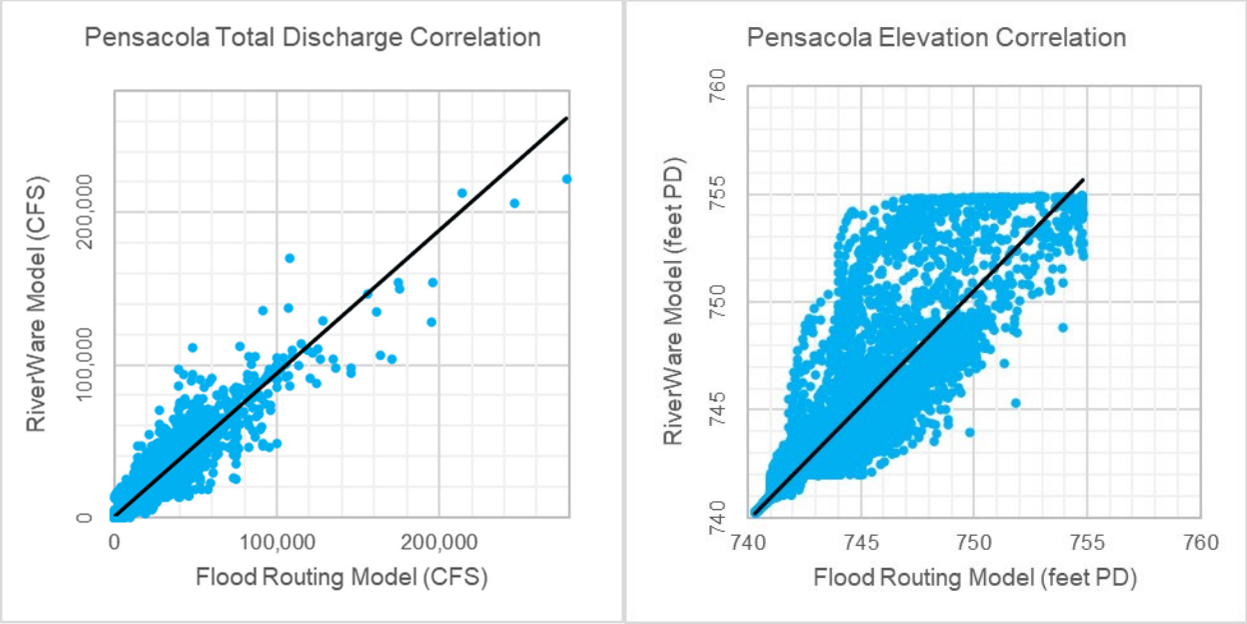


Figure 8. RiverWare Model vs. Flood Routing Model Correlation Plots at Pensacola

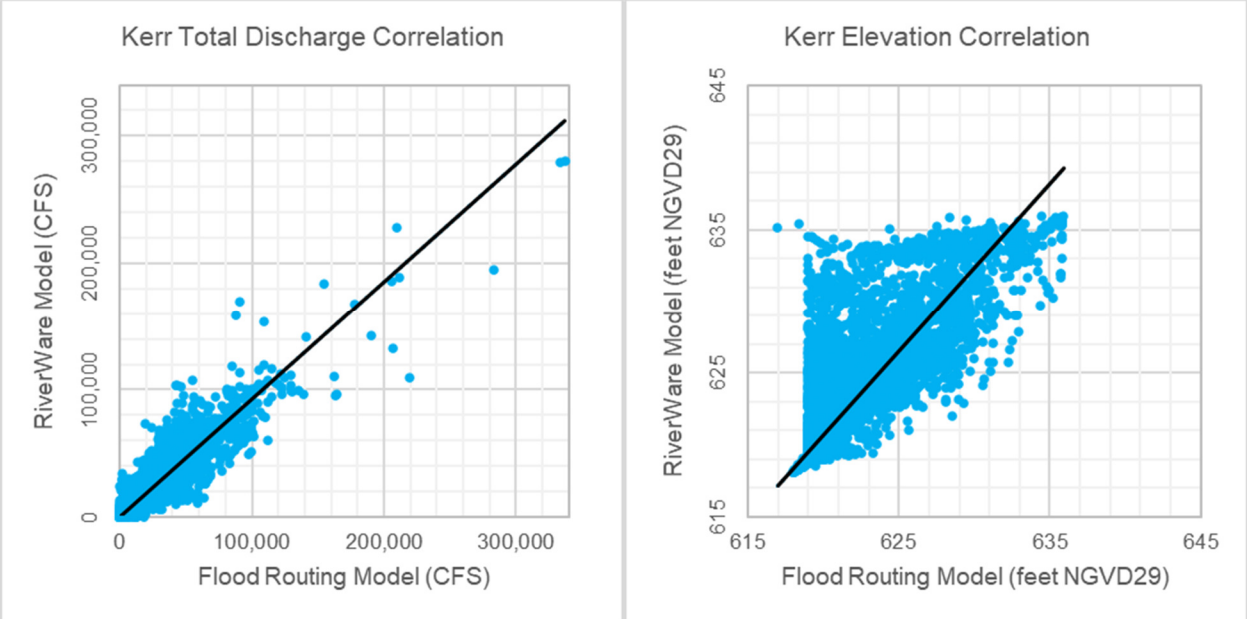


Figure 9. RiverWare Model vs. Flood Routing Model Correlation Plots at Kerr

Table 2. RiverWare Model vs. Flood Routing Model Validation Results

	Pensacola		Kerr	
	Discharge	Elevation	Discharge	Elevation
NSE	0.89 (Very Good)	0.81 (Very Good)	0.87 (Very Good)	0.68 (Satisfactory)
R^2	0.90 (Very Good)	0.81 (Good)	0.88 (Very Good)	0.752 (Good)

5.2 Validation Results: Operations Model

The OM was validated against the RWM results for the period for which hourly data was available for the OM, which is April 1, 2004 through December 31, 2019 as shown in **Figure 10** below.

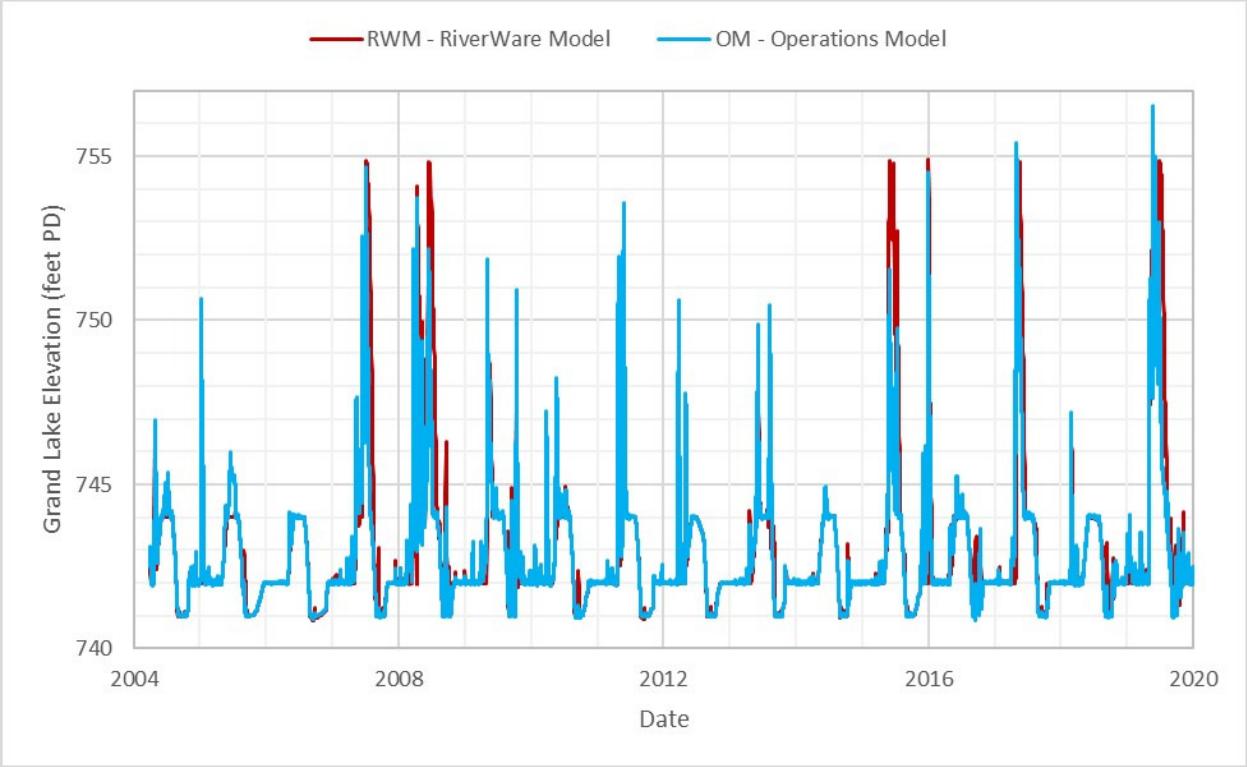


Figure 10. Operations Model Validation Period of Record

The OM builds on the flow routing decisions from the FRM by superimposing hydropower optimization logic onto the total discharge prescribed by the FRM. In order to link the OM to the FRM, a transition must take place between normal low-flow operations, when the hydropower optimization takes precedence, and higher-flow events, when the FRM-predicted releases take precedence. At the time of model validation, this transition was assumed to occur when the current elevation in the OM deviated more than 0.5 feet from the target elevation. When this occurred, the OM attempted to match the total discharge prescribed by the FRM until the pool again returned to within 0.5 feet of the target elevation. This was a simplified approach to linking the models for validation purposes and has since been improved, as discussed in **Section 5.4.3**. Because of this additional degree of separation, the validation results were slightly lower for the RWM vs. OM comparison, shown in **Figure 11** and **Figure 12** and summarized in **Table 3**.

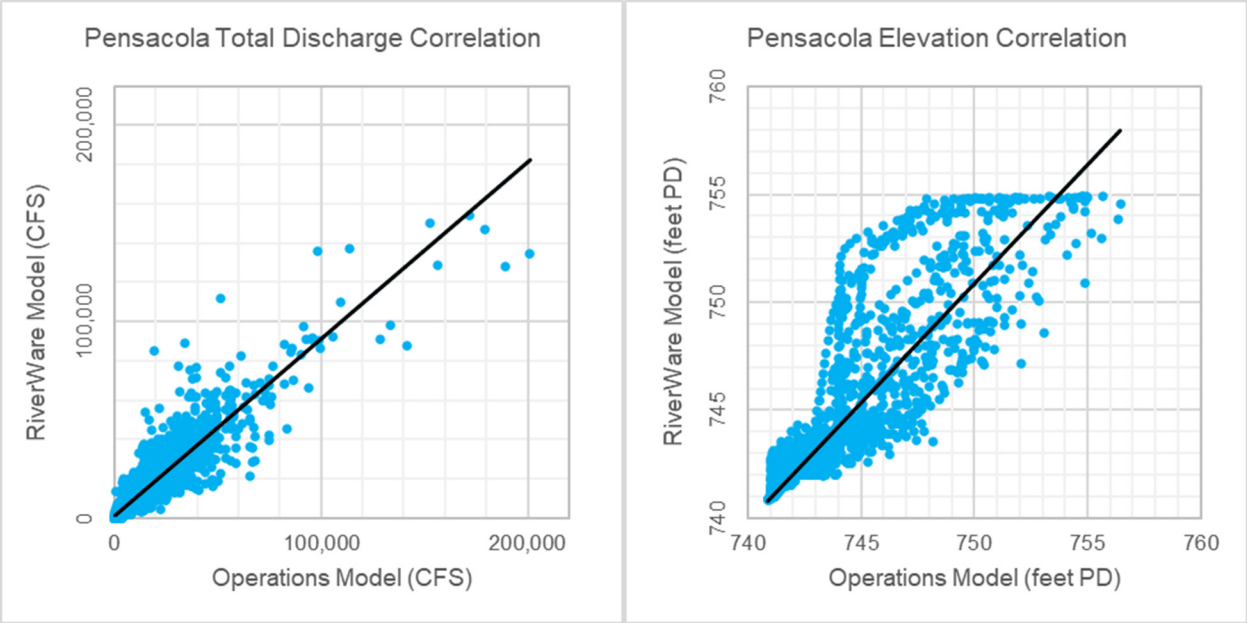


Figure 11. RiverWare Model vs. Operations Model Correlation Plots at Pensacola

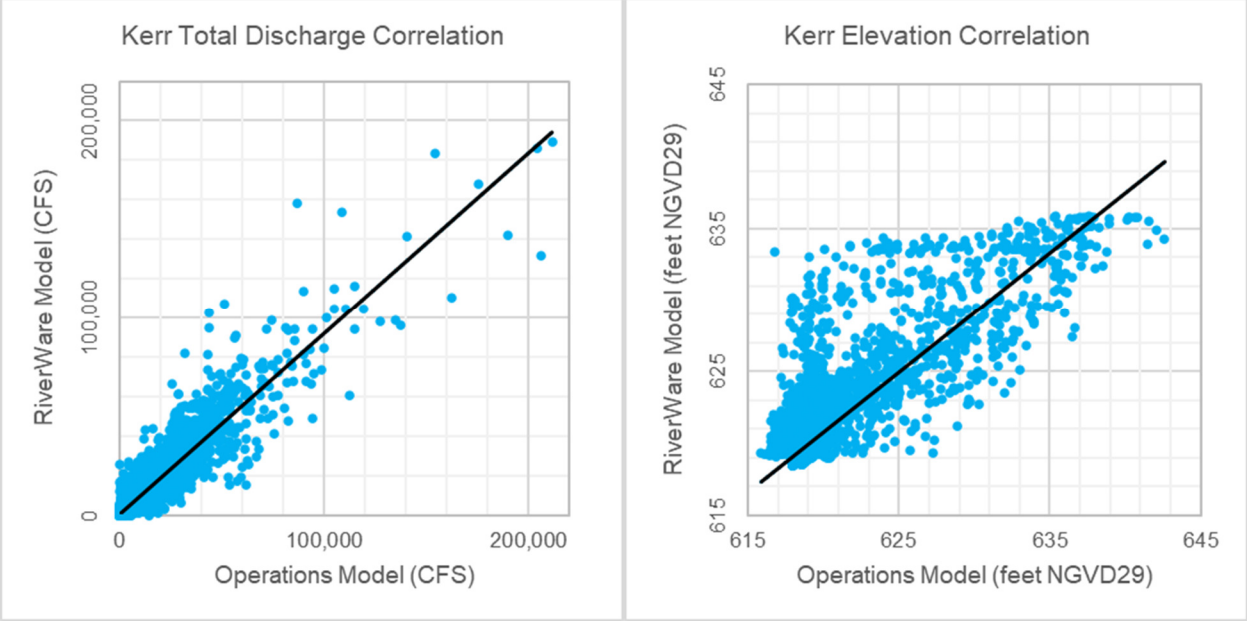


Figure 12. RiverWare Model vs. Operations Model Correlation Plots at Kerr

Table 3. RiverWare Model vs. Operations Model Validation Results

	Pensacola		Kerr	
	Discharge	Elevation	Discharge	Elevation
NSE	0.87 (Very Good)	0.80 (Very Good)	0.87 (Very Good)	0.61 (Satisfactory)
R^2	0.86 (Very Good)	0.81 (Good)	0.86 (Very Good)	0.69 (Satisfactory)

Despite the aforementioned limitations of the RWM, which has been replicated in the FRM with only three reservoirs while incorporating detailed hourly hydropower optimization calculations in the OM, the validation metrics are in the range of satisfactory to very good. Therefore, the models have been

validated against the RWM results and the study has since proceeded to improve the model inputs and logic beyond the limitations of the RWM, as discussed in **Section 5.4** below.

5.3 Validation Against USGS Gage Data

In its February 22, 2022 determination, FERC recommended that GRDA compare water surface elevations observed at the USGS gage on the upstream side of the dam to the simulated HEC-RAS stage hydrographs for the December 2015 and October 2009 inflow events and provide a graphical comparison of the simulated and observed water surface elevations over a daily time step for the duration of each flood event. GRDA included the FERC-requested comparison in this OM report because the HEC-RAS stage hydrographs at the dam are calculated by the OM.

Because the RWM and FRM do not reflect actual real-time decisions during past inflow events, but rather initial planning-level flow routing decisions, GRDA used the historical records of spillway gate openings to simulate operations for these two historical validation simulations. The reservoir inflow hydrographs for the December 2015 and October 2009 inflow events were back-calculated using GRDA's records of Project discharge and reservoir elevation and the stage-storage table from the 2019 USGS bathymetry survey. The USACE discharge rating for the spillway gates was used to calculate the spillway discharge for each time step based on the gate openings and the OM-simulated reservoir level. The OM made hydropower generation decisions as for the other simulations, but the spillway discharge was calculated using the historical spillway gate openings, which were set in response to USACE directives when the reservoir level was above, or expected to go above, Elevation 745 feet PD. The OM reservoir level simulated showed very good agreement with the observed USGS gage No. 07190000 data, as shown in **Figure 13** and **Figure 14**.

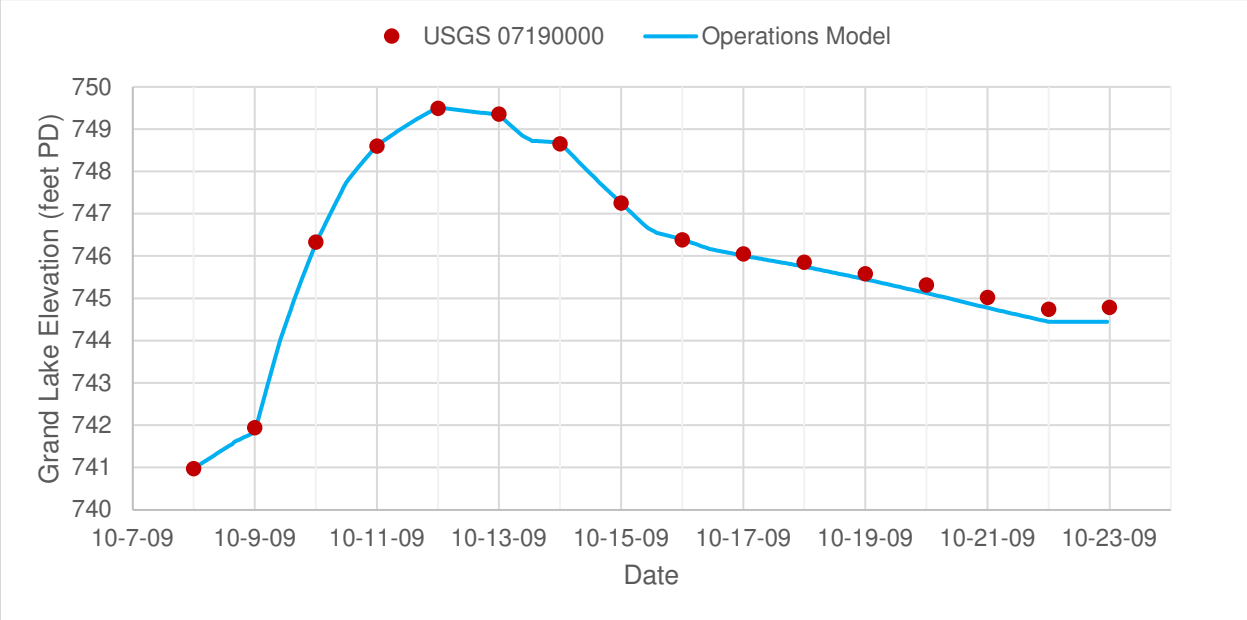


Figure 13. Validation Against USGS Gage Data, October 2009

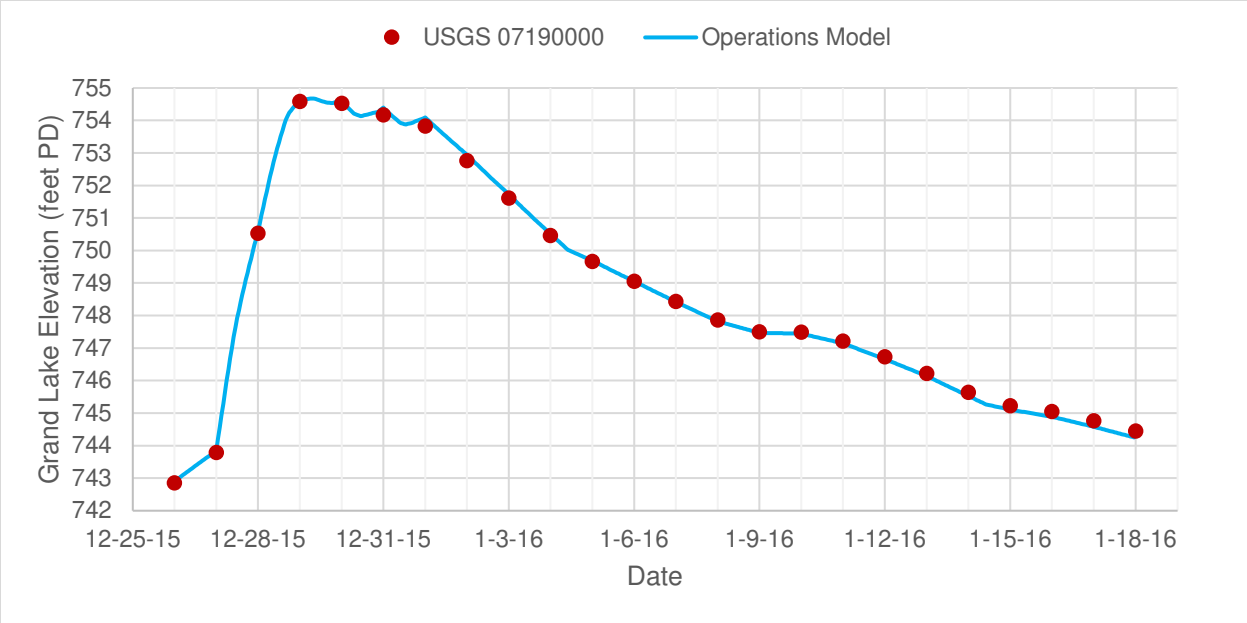


Figure 14. Validation Against USGS Gage Data, December 2015

5.4 Post-Validation Model Improvements

Following model validation, improvements were made to address known issues, as discussed below.

5.4.1 Flood Routing Model Ramping Rate Restrictions

In addition to the period-of-record model used to validate the FRM against the RWM results, various single-event simulations were previously computed to provide inputs to the CHM, as discussed below. One of those single-event simulations included a synthetic 100-year event, the development of which is documented in the USR report. It was noted that for the 100-year event simulation, the FRM caused the pool at Pensacola to drop below the target elevation on the falling limb of the hydrograph. This occurred because the RWM allowable falling release change (AFRC) of 99,174 AF/day disrupted the flow routing logic and resulted in too much discharge as the pool approached the target elevation. The AFRC does not typically interfere in this way for Pensacola, but the steeply falling discharge hydrograph of the hypothetical 100-year event simulation caused it to behave differently than for historical events. This issue was observed to affect the results for Kerr in some historical events, in addition to the 100-year event simulation.

This issue was corrected by adding logical checks to ensure that the target elevation would take precedence over the AFRC criterion.

5.4.2 Operations Model Turbine Shutoff Compensation

When power prices on the day-ahead market were positive, the OM scheduled the turbines to generate. If this occurred during a high-flow event, the OM subtracted the scheduled turbine discharge from the total discharge prescribed by the FRM when calculating the spillway discharge needed for that day. The spillway discharge was assumed to be constant for each day. If the power prices on the real-time market dropped below the production cost or went negative, the OM would buy back the scheduled generation, which resulted in total discharge less than the

average prescribed by the FRM for that day. This resulted in pool levels increasing above those predicted by the FRM in some cases.

This issue was corrected by allowing the spillway discharge to adjust on an hourly time step to compensate when the turbines shut down due to unprofitable market conditions.

5.4.3 Flood Routing Model Stage Matching

Total discharge computed by the FRM was also used by the OM when the reservoir transitioned into flood operations, which was assumed to occur when the current elevation in the OM drifted more than 0.5 feet from the target elevation. When this occurred, the OM attempted to match the total discharge prescribed by the FRM until the pool again returned to within 0.5 feet of the target elevation. Different initial conditions, such as alternative assumed starting elevations, in some cases resulted in inconsistencies in reservoir elevation for two simulations of the same event which continued throughout the peak of the event.

This issue was corrected by adding criteria for the OM to gradually bring the reservoir elevation back in line with the FRM results when the pool is in flood stage. Because most of the rules and constraints in the RWM relate to discharge, not stage (e.g., AFRC, spillway minimum surcharge, spillway maximum regulated discharge, downstream channel regulating discharges), the OM was originally set up to match discharge and not stage. The methodology used to constrain the OM to the FRM using both discharge and stage strikes a balance between attempting to match peak stages and keeping as closely aligned as possible to the discharge-related limitations in the RWM.

The criteria used to implement this solution included a two-step adjustment:

1. First, the model used the projected midnight reservoir level in the case of no spill to compute a ratio (FRM discharge vs. elevation ratio) to bring the OM back in line with the FRM discharge and/or elevation results based on a sliding scale:
    a. If the projected midnight reservoir level with no spill was below the midnight target elevation, then the FRM total discharge result was maintained (FRM discharge vs. elevation ratio = 1).
    b. If the projected midnight reservoir level with no spill was between the midnight target elevation and the top of flood pool (Elevation 755), then a ratio was assigned based on linearly interpolated storage values corresponding to those elevations (1 > FRM discharge vs. elevation ratio > 0).
    c. If the projected midnight reservoir level with no spill was at or above the top of flood pool (Elevation 755), then the FRM elevation result was maintained (FRM discharge vs. elevation ratio = 0).
2. Second, the magnitude of the adjustment used to match the FRM total discharge result was also computed as a ratio (FRM discharge multiplier) between 0 and 1 based on the difference in elevation between the projected midnight reservoir level in the case of no spill and the midnight target elevation:
    a. For differences less than 0.25 feet, no adjustment was made to spill discharge based on the FRM total discharge result (FRM discharge multiplier = 0).

b. For differences between 0.25 and 0.5 feet, the ratio was linearly interpolated by elevation between 0 and 0.75 (0 < FRM discharge multiplier < 0.75).
c. For differences between 0.5 and 0.75 feet, the ratio was linearly interpolated by elevation between 0.75 and 1 (0.75 < FRM discharge multiplier < 1).
d. For differences of 0.75 feet or more, the entire adjustment for matching FRM total discharge was used (FRM discharge multiplier = 1), but the OM spill discharge could still be adjusted down based on the FRM discharge vs. elevation ratio discussed above.

The final calculation to determine the spillway discharge at each time step was:

$$Q = a*Qq + (1-a)*(b*Qe)$$

where: Q = spillway discharge for OM time step (cfs)
Qq = OM spillway discharge needed to match total discharge of FRM (cfs)
Qe = OM spillway discharge needed to match midnight elevation of FRM (cfs)
a = FRM discharge vs. elevation ratio (0 < a < 1)
b = FRM discharge multiplier (0 < b < 1)

This approach allows the OM to optimize operations freely when the reservoir is within the conservation pool, and gradually shift to matching the FRM results as the reservoir begins to climb into the flood pool.

The cumulative result of the model improvements described above is more consistent in matching OM results to the FRM results during large events.

5.4.4 Updated Stage-Area-Storage Table

The Grand Lake stage-area-storage table used for the FRM and OM was updated following validation to use the data developed by USGS in 2019 and 2020 (Hunter, Trevisan, Villa, & Smith, 2020). The USGS data was interpolated at half-foot intervals and linearly extrapolated to Elevation 780. In response to stakeholder comments following the ISR, GRDA performed a sensitivity analysis of the OM to evaluate the impacts of the updated stage-area-storage table on computed reservoir level.

The OM results using the 2019 bathymetry data were very similar to the OM results using the RWM stage-area-storage table. **Table 4** compares reservoir level metrics for the hourly POR and for individual flow events that occurred within the POR. Differences are small and within the range of model oscillation typical for the RWM and FRM. The RWM and FRM make flow routing decisions based on key elevations, not fixed values of storage, so it is unsurprising that the results were similar after updating the stage-area-storage table. Therefore, the updated stage-area-storage table was used in the study.

Table 4. Sensitivity Analysis Results for Stage-Area-Storage Update

Sensitivity Parameter	RWM Stage-Storage Table	2019 Stage-Storage Table	Difference (feet)
POR Average (Mean) Grand Lake Elevation (feet PD)	742.87	742.86	0.01
POR Median Grand Lake Elevation (feet PD)	742.05	742.04	0.01
POR Minimum Grand Lake Elevation (feet PD)	740.87	740.88	0.01
POR Maximum Grand Lake Elevation (feet PD)	754.82	754.82	0.00
Peak Grand Lake Elevation (feet PD), June 2004 (1 year)	744.87	744.83	0.04
Peak Grand Lake Elevation (feet PD), July 2007 (4 year)	754.74	754.73	0.01
Peak Grand Lake Elevation (feet PD), Oct 2009 (3 year)	750.21	750.04	0.17
Peak Grand Lake Elevation (feet PD), Dec 2015 (15 year)	754.82	754.82	0.00

6. Scenarios Computed for H&H and Sedimentation Studies

The OM provides stage and discharge hydrograph inputs to other components of the hydrologic and hydraulic modeling study (H&H study), as well as other relicensing studies. For the upstream hydraulic model (UHM) and STM, only the stage hydrographs at Pensacola Dam are needed because the inflow hydrographs at the upstream boundary come from other sources. For the downstream hydraulic model, the stage hydrographs at Kerr Dam, lateral inflow hydrographs to Lake Hudson, and discharge hydrographs at Pensacola Dam are needed.

6.1 Single Events for CHM, Baseline Operations

The OM was used to provide CHM inputs for various single-event simulations, consisting of different combinations of historical or hypothetical flow events and initial reservoir elevations within GRDA's anticipated operating range or extreme, hypothetical range, summarized in **Table 5**. These simulations were computed using the baseline operating rules as represented in the RWM, which reflects the seasonal midnight rule curve that was in place prior to license amendment in 2015. For consistency throughout the model development and validation process, these baseline (pre-2015) operating rules were used to reflect what was in the RWM information provided by USACE SWT, which was the baseline for model validation as recommended in the FERC SPD. This is referred to as baseline operations.

Table 5. Single Events for CHM, Baseline Operations

	Pensacola Initial Elevation (feet PD)	Sep 1993 (21 year)	Jun 2004 (1 year)	Jul 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	100-year
Extreme, Hypothetical Range	757.0	✔	✔	✔	✔	✔	✔
	753.0	✔	✔	✔	✔	✔	✔
	749.0	✔	✔	✔	✔	✔	✔
Anticipated Range	745.0	✔	✔	✔	✔	✔	✔
	744.5	✔	✔	✔	✔	✔	✔
	744.0	✔	✔	✔	✔	✔	✔
	743.5	✔	✔	✔	✔	✔	✔
	743.0	✔	✔	✔	✔	✔	✔
	742.5	✔	✔	✔	✔	✔	✔
	742.0	✔	✔	✔	✔	✔	✔
Extreme, Hypothetical Range	734.0	✔	✔	✔	✔	✔	✔
	Historical (Varies)	✔	✔	✔	✔	✔	N/A
POR Simulation, 746.46				✔*			

*Corresponds to **Table 6**, see description below.

6.2 Single Events for CHM, Anticipated Operations

As proposed in Section 2.6.5 of the H&H Study RSP, "an additional suite of model runs following the same parameters" was run for the operational scenario anticipated by GRDA. As discussed in Section 1.6.2 of GRDA's December 29, 2021 filing with FERC, GRDA anticipates the following operational parameters will apply during the new license term:

1. GRDA will no longer utilize a rule curve with seasonal target elevations.
2. GRDA will maintain the conservation pool between elevations 742 and 745 feet PD for purposes of normal hydropower operations. While hydropower operations may occur when water surface elevations are outside this range (e.g., maintenance drawdowns and high-flow events), GRDA expects to generally maintain water surface elevations between 742 and 745 feet PD during normal project operations.
3. Instead of managing the project to target a specified seasonal elevation, GRDA's anticipated operations may fluctuate reservoir levels within the elevational range of 742 and 745 feet PD, for purposes of responding to grid demands, market conditions, and the public interest, such as environmental and recreational considerations.
4. GRDA will continue to adhere to USACE's direction on flood control operations in accordance with the Water Control Manual.

This operational scenario is referred to as "anticipated operations." The modeling approach used to demonstrate the potential value of the anticipated operations for hydropower production relies on a statistical comparison of the electricity prices for the current day/hour versus the previous 24-hour or 2-day price patterns. For power scheduled on the day-ahead market, each hourly price for the current calculation day is compared to all the hourly prices within the current and previous calculation days (2-day pattern). The average (mean) and standard deviation is calculated from the 48 hourly values. The number

of standard deviations above or below the 2-day mean is calculated for each hour in the current calculation day. These values are then compared to an incentive table which relates the reservoir level (based on forecast reservoir volume at midnight) to a threshold value (in terms of standard deviations of price) above which generation may be scheduled, subject to other constraints as described in **Section 4 Operations Model**. The incentive table is shaped somewhat like an S-curve so that power scheduling can transition gradually to be more conservative as the pool drops closer to Elevation 742 PD or less conservative (more generation scheduled) as the pool rises closer to Elevation 745 PD. Above and below Elevations 745 and 742 PD, respectively, there is a sharp decrease or increase, respectively, in the standard deviation threshold values so that power generation is always scheduled (subject to other constraints) or never scheduled, respectively, outside of this range.

For power sold on the real-time market, the approach is similar except a moving 24-hour price pattern window is used, comparing the current hourly price to the previous 24 hours. The relationship between elevation and minimum generation price (in standard deviations) is shown in **Figure 15**.

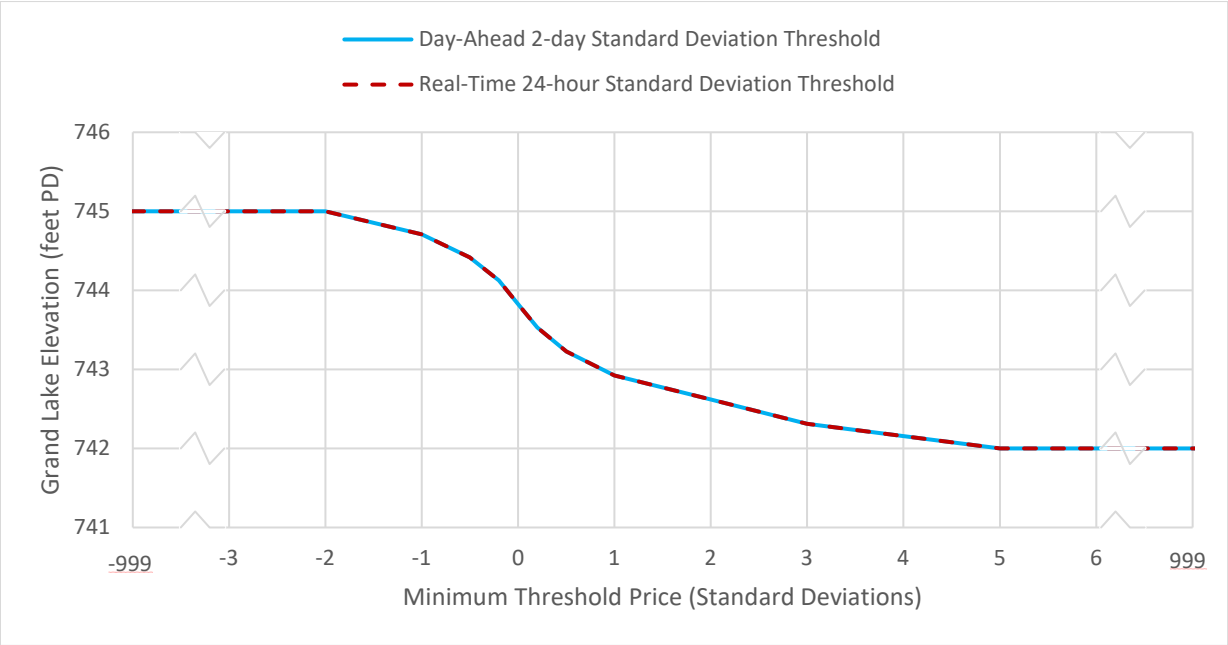


Figure 15. Minimum Threshold Price for Generation (Anticipated Operations)

Because the reservoir level fluctuates in response to water availability and electricity market conditions, the average (mean) reservoir level below 745 feet PD was used as the guide curve elevation in the FRM. For the hourly period of record from April 1, 2004 through December 31, 2019, this average elevation was 743.1 feet PD.

The OM was used to provide CHM inputs for single-event simulations consisting of the minimum and maximum bounding cases for flow events and initial reservoir elevations in the extreme, hypothetical range. Another event of historical importance to upstream communities (July 2007 [4 year]) was also simulated using the expected initial reservoir elevation based on the OM period-of-record simulation with anticipated operations. These simulations were computed using the anticipated operating rules and are summarized in **Table 6**.

Table 6. Single Events for CHM, Anticipated Operations

Pensacola Initial Elevation (feet PD)		Jun 2004 (1 year)	Jul 2007 (4 year)	100-year
Extreme, Hypothetical Range	757.0	✔		✔
POR Simulation	745.9		✔	
Extreme, Hypothetical Range	734.0	✔		✔

Differences in WSEL computed for these anticipated operation scenarios have been compared to the corresponding baseline operation scenarios, and that information is presented in the UHM report. One additional baseline operation scenario was added for this purpose: the July 2007 (4 year) event with the expected initial reservoir elevation (746.46 feet PD) based on the OM period-of-record simulation with baseline operations.

6.3 50-year Simulations for STM

The STM was used to predict changes in river and lake bathymetry based on sediment transport processes occurring over the expected license term of 50 years, as discussed in the STM report. The OM was used to provide STM inputs in terms of stage hydrographs at Pensacola Dam for various scenarios related to baseline and anticipated operations, including a sensitivity analysis for higher and lower sedimentation rates.

Another version of the OM was developed to calculate the STM inputs for the 50-year period from January 1, 2020 through December 31, 2069. The hydrologic inputs over this timeframe were randomized from the historical RWM data between January 1, 1970 and December 31, 2019. For the OM-specific inputs, data from the 12-year period from January 1, 2008 through December 31, 2019 was repeated to cover the rest of the 50-year simulation. This applied to electricity price factors, turbine air valve status, and the number of units online.

The OM was modified so that the reservoir stage-area-storage table could be interpolated through time as the average storage volume changed. For the first iteration, the OM was computed for the 50-year simulation using existing stage-area-storage data only, for both baseline and anticipated operations, and the resulting stage hydrographs at Pensacola Dam were passed to the STM. Then the STM was computed for both baseline and anticipated operation scenarios, and the resulting stage-storage tables at the end of the 50-year period were passed back to the OM. Because the simplified 1D geometry of the STM does not predict the reservoir surface area as well as the USGS survey data, the 2019 table for Grand Lake was modified to calculate future area based on the proportional changes in storage at a given elevation as computed by the STM. For the second iteration, the OM interpolated between the existing and future stage-area-storage tables using linear interpolation for each day in the 50-year simulation. The OM stage results were again passed to the STM, and the STM re-computed. The stage-area-storage tables resulting from this second iteration were compared to the first to confirm that no further iteration was needed. The future stage-area-storage tables thus computed could then be used to examine the effect of sedimentation over the license term on upstream water levels using the 1D UHM, as discussed in the following section.

In addition to the STM scenarios computed using the expected parameters for sedimentation, two sensitivity cases were computed using lower and higher rates of sedimentation. The 50-year OM scenarios computed in support of the STM are summarized in **Table 7**.

Table 7. 50-year Simulations for STM

Operations	Lower Sediment Rate	Expected Sediment Rate	Higher Sediment Rate
Baseline		✔	
Anticipated	✔	✔	✔

6.4 Single Events for 1D UHM, Anticipated Operations

The OM was used to provide 1D UHM inputs for single-event simulations consisting of three initial reservoir elevations, two inflow events, and five different sedimentation conditions. The 1D UHM is a version of the STM reconfigured to run short-duration events to predict the resulting upstream water surface profiles, as described in the STM report. The simulations included the July 2007 (4 year) and 100-year events and initial reservoir elevations of 740-, 745-, and 750-feet PD as recommended in the May 27, 2022 FERC Determination. Scenarios were computed to compare:

- future vs. existing (2019) bathymetry conditions for anticipated operations,
- expected sedimentation rate vs. lower and higher sensitivity cases, and
- anticipated vs. baseline operations using future bathymetry.

Scenarios computed in support of the 1D UHM are summarized in **Table 8**.

Table 8. Single Events for 1D UHM

Stage-Storage Condition	July 2007 (4 year)			100-year		
	740	745	750	740	745	750
Existing, Anticipated Operations	✔	✔	✔	✔	✔	✔
Future, Anticipated Operations, Lower Sediment Rate	✔	✔	✔	✔	✔	✔
Future, Anticipated Operations, Expected Sediment Rate	✔	✔	✔	✔	✔	✔
Future, Anticipated Operations, Higher Sediment Rate	✔	✔	✔	✔	✔	✔
Future, Baseline Operations, Expected Sediment Rate	✔	✔	✔	✔	✔	✔

7. Scenarios Computed for Other Studies

The OM was used to calculate statistical changes in water levels and to provide UHM inputs in support of other relicensing studies, including the Aquatic Species Study, Terrestrial Species Study, and Wetlands and Riparian Habitat Study. For each study and certain specific resources within a study, specific seasons were identified as key for determining impacts. The hourly period-of-record OM was truncated slightly to November 1, 2004 through November 1, 2019 so that a whole number of years was used to calculate statistics. The OM was computed for both baseline and anticipated operations using stage-area-storage tables based on the USGS 2019 bathymetry. The specific results computed for each study and resource are discussed below.

7.1 Aquatic Species Study

For the Aquatic Species Study, a comparison between anticipated operations and baseline operations during normal operations and inflows was completed. The Aquatic Species Study team identified the annual seasonal period of May 15 to July 8 as a critical time period surrogate for all lake spawning fish, based upon the nursery period for largemouth bass. For this season, the median reservoir elevation was 744.14 and 744.73 feet PD for baseline and anticipated operations, respectively. The seasonal median inflows on the Neosho River and other Grand Lake tributaries were also calculated from the RWM data for this timeframe. These median reservoir elevations and inflows were then used by the UHM to calculate the upstream water levels and extent of inundation for baseline and anticipated operations.

7.2 Terrestrial Species Study

For the Terrestrial Species Study, the entire calendar year, January 1 through December 31 was recommended by the Terrestrial Species Study Team as the seasonal analysis period because several critical terrestrial species could be most impacted during both their active and inactive or hibernation periods each year. For this season, the median reservoir elevation was 742.04 and 743.10 feet PD for baseline and anticipated operations, respectively. The seasonal median reservoir elevations and inflows were then used by the UHM to calculate the upstream water levels and extent of inundation for baseline and anticipated operations.

Additionally, a seasonal period from April 1 to July 31 was calculated to quantify potential impacts to gray bats. For this season, the percentage of time the reservoir elevation exceeded threshold values of 746, 751, and 752 feet PD were calculated for baseline and anticipated operations.

7.3 Wetlands and Riparian Habitat Study

For the Wetland and Riparian Habitat Study, the annual seasonal period of March 30 to November 2 was recommended by the Wetland and Riparian Habitat Study Team as critical for identifying areas that could change from seasonally flooded to permanently flooded. The critical period corresponds with the growing season as determined from Tulsa, OK climatological records. For this season, the median reservoir elevation was 742.92 and 743.46 feet PD for baseline and anticipated operations, respectively. The seasonal median reservoir elevations and inflows were then used by the UHM to calculate the upstream water levels and extent of inundation for baseline and anticipated operations.

7.4 Recreation and Navigation

Although not part of an official study, an additional case was calculated for the season from June 1 through October 31, which is the peak season for recreation / boating navigation on Grand Lake. For this season, the median reservoir elevation was 743.14 and 743.07 feet PD for baseline and anticipated operations, respectively.

8. Summary

On behalf of GRDA, Mead & Hunt developed a three-reservoir version of the RiverWare model, referred to as the FRM, to investigate operating alternatives and hypothetical (non-historical) events. The FRM includes Pensacola, Kerr, and Fort Gibson Dams. Mead & Hunt also developed an OM to simulate hourly hydropower operations at Pensacola and Kerr. GRDA validated its model results against the RWM output, as recommended in the FERC SPD. The OM was also validated by comparing the WSEL results to USGS gage data upstream of Pensacola Dam for two historical events recommended by the FERC. Sensitivity of OM results to stage-area-storage table updates were calculated. The OM was then improved to fix known issues and expanded to include anticipated operations. All FERC-requested modifications have been completed. The OM was used to provide inputs for the CHM, STM, 1D UHM, and other relicensing studies and resource evaluations. This report documents the development of the OM updated results that will be presented at the USR meeting.

9. References

Bertrand, A. (2009). *Electrical and Mechanical Calculations Characteristics of Generators 1, 2, 3, and 4.* Alstom Power & Transport Canada Inc. (Rev. July 7, 2014).

CADSWES. (2020). *RiverWare Technical Documentation Version 8.1.* University of Colorado Boulder.

CFR. (1944). *Regulations for use of storage waters.* 33 U.S. Code § 709.

CFR. (1945). *Pensacola Dam and Reservoir, Grand (Neosho) River, Okla.* 33 CFR § 208.25.

Dewberry. (2011). *USGS Grand Lake, OK LiDAR Project.* Prepared for the U.S. Geological Survey.

EEC. (1962a). *Full-Size Turbine Power and Discharge Predicted from Model Tests, Markham Ferry.* The English Electric Company Limited, Hydraulics Research Laboratory, Water Turbine Department, Rugby. Figure 12. March 1962.

EEC. (1962b). *Variation of Predicted Turbine Output with Tail Water Elevation, Markham Ferry.* The English Electric Company Limited, Hydraulics Research Laboratory, Water Turbine Department, Rugby. Figure 23. October 1962.

GRDA. (1961). As-Built Drawings. *Dam and Power House, Power House and Intake, Transverse Sections, Markham Ferry Project*.

GRDA. (1987). Drawings. *Dam and Powerhouse Section and Elevation of Dam and Powerhouse, Pensacola Dam Hydropower Project. Application for FERC License, FERC No. 1494-169*, Exhibit F, Sheet 2.

Hunter, S. L., Trevisan, A. R., Villa, J., & Smith, K. A. (2020). *Bathymetric Map, Surface Area, and Capacity of Grand Lake O' the Cherokees, Northeastern Oklahoma, 2019.* Denver: USGS.

Mead & Hunt. (2021). *H&H Modeling: Operations Model Input Status Report.*

Moriasi, D. N., Gitau, M. W., Pai, N., & Daggupati, P. (2015). Hydrologic and Water Quality Models: Performance Measures and Evaluation Criteria. *Transactions of the American Society of Agricultural and Biological Engineers*, Vol. 58(6): 1763-1785.

OAC. (2013). *Title 785. Oklahoma Water Resources Board. Chapter 45. Oklahoma's Water Quality Standards.* Oklahoma Administrative Code. OAC 785.45-5-12. July 1, 2013.

Siemens. (1999). *Efficiency Calculations, Pensacola Power Plant, Unit No. 3.* Siemens Westinghouse Generator Engineering. Page V of V. January 13, 1999.

Steffen, J., Stringer, J., Daylor, J., Neumann, D., & Zagona, E. (2015). TAPER - A Real-Time Decision Support Tool for Balanced Flood Operation of the Arkansas River in Tulsa District. *3rd Joint Federal Interagency Conference on Sedimentation and Hydrologic Modeling.* Reno, Nevada.

USACE. (1980). *Arkansas River Basin Water Control Master Manual.* Tulsa and Little Rock Districts.

USACE. (1987). *Hydraulic Design Criteria.*

USACE. (1990). *Discharge Rating Curves, Main Spillway. Discharge Rating Curves, East Spillway. Pensacola Reservoir.* Dept. of the Army, Tulsa District Corps of Engineers.

USACE. (1991). *Spillway Rating Curves, Partial and Full Gate Openings. Markham Ferry Reservoir.* Department of the Army, Tulsa District.

USACE. (2020). RiverWare Model for the Arkansas Basin Reservoir System.

Voith. (1997). *Expected Prototype Turbine Performance, Pensacola, Speed = 150 rpm, Centerline Elevation = 630 ft.* Voith Hydro Inc. York, PA. Drawing No. 2677-0146. Figure No. 5.1.3. October, 1997.

Walsh, J. (1999). *Pensacola Power Plant Performance Test on Unit 3 (Preliminary).* Accusonic Technologies. Falmouth, MA. Report FP-27108B. Figure 2. December 15, 1999.

Appendix A. USACE RiverWare Data

		USACE SWT RiverWare Period-of-Record Model, Daily Time Series Data															
Element		PARS	PARS-COMM	PARS-COMM	COMM	COMM-PENS	COMM-PENS	PENS	PENS	PENS	PENS	PENS	PENS	PENS-HUDS	PENS-HUDS	HUDS	HUDS
Parameter		FLOW-LOC CUM	INFLOW	OUTFLOW	FLOW-LOC CUM	INFLOW	OUTFLOW	ELEV	STORAGE	FLOOD-STORAGE	FLOW-RES IN	OPLEVEL	FLOW-RES OUT	INFLOW	OUTFLOW	ELEV	FLOOD-STORAGE
Units		cfs	cfs	cfs	cfs	cfs	cfs	ft	acre-ft	acre-ft	cfs	-	cfs	cfs	cfs	ft	acre-ft
1	01Jan1940	50	50	50	51	51	51	742.00	1392694	16	262	8.00001	238	238	238	619.02	263
2	02Jan1940	50	50	50	53	53	52	742.00	1392686	8	81	7.07267	69	69	69	619.01	54
3	03Jan1940	50	50	50	52	52	53	742.00	1392682	4	134	6.08950	120	120	120	619.00	0
4	04Jan1940	50	50	50	54	54	53	742.00	1392681	3	347	5.84333	331	331	331	619.00	0
5	05Jan1940	50	50	50	56	56	55	742.00	1392682	4	280	6.17988	264	264	264	619.04	462
6	06Jan1940	50	50	50	54	54	55	742.00	1392682	4	252	6.19854	235	235	235	619.01	141
7	07Jan1940	50	50	50	55	55	55	742.00	1392682	4	261	6.03920	245	245	245	619.01	135
8	08Jan1940	50	50	50	50	50	52	742.00	1392681	3	297	5.64767	282	282	282	619.00	34
9	09Jan1940	51	51	51	51	51	50	742.00	1392680	2	393	5.57045	377	377	377	619.02	229
10	10Jan1940	51	51	51	51	51	51	742.00	1392681	3	367	5.63389	351	351	351	619.02	189
11	11Jan1940	50	50	50	50	50	51	742.00	1392682	4	372	6.08029	356	356	356	619.02	225
12	12Jan1940	50	50	50	51	51	51	742.00	1392682	4	372	6.03123	356	356	356	619.01	128
13	13Jan1940	50	50	50	51	51	51	742.00	1392682	4	433	6.08367	417	417	417	619.02	249
14	14Jan1940	50	50	50	57	57	55	742.00	1392683	5	434	6.32674	418	418	418	619.03	307
15	15Jan1940	50	50	50	53	53	55	742.00	1392683	5	325	6.31415	308	308	308	619.01	128
16	16Jan1940	50	50	50	50	50	51	742.00	1392682	4	396	6.01742	381	381	381	619.02	166
17	17Jan1940	50	50	50	51	51	51	742.00	1392681	3	420	5.97649	405	405	405	619.03	313
18	18Jan1940	50	50	50	52	52	51	742.00	1392682	4	318	6.33774	302	302	302	619.02	213
19	19Jan1940	50	50	50	50	50	51	742.00	1392683	5	302	6.57443	286	286	286	619.02	168
20	20Jan1940	50	50	50	50	50	50	742.00	1392682	4	325	6.26857	309	309	309	619.02	229
21	21Jan1940	50	50	50	50	50	50	742.00	1392682	4	296	6.24674	280	280	280	619.02	192
22	22Jan1940	50	50	50	50	50	50	742.00	1392682	4	292	6.34733	275	275	275	619.02	189
23	23Jan1940	50	50	50	50	50	50	742.00	1392683	5	288	6.51573	271	271	271	619.02	186
24	24Jan1940	50	50	50	50	50	50	742.00	1392683	5	274	6.49099	257	257	257	619.01	146
25	25Jan1940	50	50	50	50	50	50	742.00	1392683	5	284	6.57288	268	268	268	619.01	125
26	26Jan1940	50	50	50	50	50	50	742.00	1392683	5	300	6.62145	284	284	284	619.01	150
27	27Jan1940	50	50	50	50	50	50	742.00	1392683	5	291	6.47114	275	275	275	619.01	120
28	28Jan1940	50	50	50	50	50	50	742.00	1392682	4	320	6.17769	305	305	305	619.02	172
29	29Jan1940	50	50	50	50	50	50	742.00	1392682	4	299	6.01550	283	283	283	619.01	104
30	30Jan1940	50	50	50	50	50	50	742.00	1392681	3	362	5.91130	347	347	347	619.02	221
31	31Jan1940	50	50	50	50	50	50	742.00	1392682	4	346	6.09173	330	330	330	619.02	221
32	01Feb1940	50	50	50	50	50	50	742.00	1392682	4	424	6.18151	458	458	458	619.04	470
33	02Feb1940	50	50	50	51	51	50	742.00	1392683	5	393	6.47594	426	426	426	619.04	457
34	03Feb1940	50	50	50	52	52	52	742.00	1392683	5	399	6.58737	433	433	433	619.05	510
35	04Feb1940	50	50	50	54	54	53	742.00	1392683	5	363	6.46727	397	397	397	619.04	398
36	05Feb1940	60	60	53	53	53	54	742.00	1392681	3	416	5.68030	452	452	452	619.04	411
37	06Feb1940	63	63	59	59	59	57	742.00	1392680	2	400	5.54077	435	435	435	619.04	401
38	07Feb1940	55	55	59	59	59	59	742.00	1392680	2	306	5.49845	341	341	341	619.02	200
39	08Feb1940	68	68	61	64	64	62	742.00	1392680	2	329	5.53507	363	363	363	619.02	226
40	09Feb1940	72	72	67	69	69	67	742.00	1392680	2	380	5.48346	415	415	415	619.04	441
41	10Feb1940	63	63	68	73	73	72	742.00	1392680	2	331	5.52878	366	366	366	619.02	236
42	11Feb1940	59	59	63	73	73	73	742.00	1392680	2	393	5.54404	428	428	428	619.03	357
43	12Feb1940	52	52	57	67	67	70	742.00	1392680	2	362	5.44471	397	397	397	619.03	368
44	13Feb1940	50	50	53	62	62	64	742.00	1392680	2	297	5.56904	331	331	331	619.03	306
45	14Feb1940	50	50	51	56	56	59	742.00	1392680	2	286	5.72258	320	320	320	619.02	194
46	15Feb1940	50	50	50	57	57	57	742.00	1392681	3	321	6.03727	355	355	355	619.02	203
47	16Feb1940	50	50	50	80	80	71	742.00	1392682	4	355	6.19091	389	389	389	619.03	325
48	17Feb1940	50	50	50	194	194	149	742.00	1392681	3	357	5.82935	392	392	392	619.03	313
49	18Feb1940	57	57	53	190	190	192	742.00	1392679	1	437	5.19429	473	473	473	619.06	597
50	19Feb1940	60	60	57	125	125	151	742.00	1392679	1	377	5.31640	412	412	412	619.04	380
51	20Feb1940	57	57	58	109	109	115	742.00	1392679	1	488	5.19398	523	523	523	619.04	451
52	21Feb1940	50	50	55	99	99	103	742.00	1392680	2	508	5.55060	542	542	542	619.05	512
53	22Feb1940	50	50	51	91	91	94	742.00	1392680	2	491	5.47451	526	526	526	619.04	484
54	23Feb1940	51	51	51	80	80	84	742.00	1392679	1	418	5.19442	454	454	454	619.04	399
55	24Feb1940	52	52	51	86	86	83	742.00	1392679	1	412	5.34691	446	446	446	619.03	348
56	25Feb1940	59	59	54	74	74	79	742.00	1392680	2	423	5.55188	457	457	457	619.02	234
57	26Feb1940	68	68	61	64	64	68	742.00	1392679	1	488	5.19397	524	524	524	619.04	431
58	27Feb1940	50	50	60	80	80	73	742.00	1392681	3	454	5.83498	488	488	488	619.04	466
59	28Feb1940	50	50	53	86	86	83	742.00	1392681	3	412	5.70285	447	447	447	619.04	393
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28435	06Nov2017	155	155	165	179	179	188	742.00	1392679	1	566	5.20849	537	537	537	619.00	0
28436	07Nov2017	148	148	155	175	175	177	742.00	1392679	1	565	5.20675	453	453	453	619.03	367
28437	08Nov2017	126	126	142	164	164	169	742.01	1393189	511	564	8.00827	195	195	195	619.00	0
28438	09Nov2017	112	112	126	153	153	158	742.00	1392679	1	464	5.21000	610	610	610	619.08	869
28439	10Nov2017	117	117	118	132	132	141	742.00	1392679	1	464	5.20465	352	352	352	619.02	173
28440	11Nov2017	117	117	117	127	127	129	742.00	1392679	1	464	5.20465	352	352	352	619.02	170
28441	12Nov2017	126	126	120	129	129	128	742.00	1392679	1	464	5.20465	352	352	352	619.02	220
28442	13Nov2017	122	122	123	133	133	131	742.00	1392679	1	414	5.20361	302	302	302	619.00	0
28443	14Nov2017	128	128	124	132	132	132	742.00	1392679	1	764	5.21088	652	652	652	619.02	171
28444	15Nov2017	136	136	130	134	134	133	742.00	1392679	1	1064	5.21711	952	952	952	619.00	0
28445	16Nov2017	133	133	133	149	149	143	742.00	1392679	1	664	5.20881	552	552	552	619.08	936
28446	17Nov2017	122	122	129	132	132	139	742.00	1392679	1	564	5.20673	452	452	452	619.00	0
28447	18Nov2017	137	137	129	129	129	130	742.00	1392679	1	467	5.20472	355	355	355	619.06	648
28448	19Nov2017	126	126	131	131	131	130	742.00	1392679	1	466	5.20470	354	354	354	619.03	266
28449	20Nov2017	114	114	123	123	123	126	742.00	1392679	1	465	5.20467	353	353	353	619.04	399
28450	21Nov2017	121	121	119	119	119	121	742.00	1392679	1	467	5.20473	356	356	356	619.00	0
28451	22Nov2017	117	117	119	119	119	119	742.00	1392679	1	469	5.23644	357	357	357	619.03	321
28452	23Nov2017	103	103	113	113	113	115	742.00	1392679	1	468	5.20474	357	357	357	619.02	236
28453	24Nov2017	107	107	107	107	107	110	742.00	1392679	1	468	5.20474	356	356	356	619.00	0
28454	25Nov2017	106	106	107	107	107	107	742.00	1392679	1	466	5.20470	355	355	355	619.02	192
28455	26Nov2017	106	106	107	107	107	107	742.00	1392679	1	466	5.20469	354	354	354	619.02	245
28456	27Nov2017	97	97	103	103	103	105	742.00	1392679	1	469	5.20476	358	358	358	619.00	0
28457	28Nov2017	91	91	97	97	97	99	742.00	1392679	1	1173	5.21938	1061	1061	1061	619.00	0
28458	29Nov2017	99	99	95	98	98	97	742.00	1392679	1	2318	5.24315	2206	2206	2206	619.00	0
28459	30Nov2017	93	93	96	108	108	104	742.00	1392679	1	1084	5.21753	972	972	972	619.01	148
28460	01Dec2017	85	85	91	98	98	102	742.00	1392679	1	714	5.20693	632	632	632	619.05	487
28461	02Dec2017	116	116	98	98	98	98	742.00	1392678	0	571	5.00761	490	490	490	619.03	369
28462	03Dec2017	119	119	112	112	112	106	742.00	1392678	0	483	5.00646	401	401	401	619.04	485
28463	04Dec2017	141	141	124	124	124	119	742.00	1392678	0	593	5.00813	511	511	511	619.05	531
28464	05Dec2017	137	137	134	134	134	130	742.00	1392678	0	493	5.00663	412	412	412	619.03	342
28465	06Dec2017	112	112	127	127	127	130	742.00	1392678	0	490	5.00660	409	409	409	619.03	268
28466	07Dec2017	125	125	121	121	121	123	742.00	1392678	0	493	5.00664	412	412	412	619.02	241
28467	08Dec2017	120	120	122	122	122	122	742.00	1392678	0	507	5.00682	425	425	425	619.04	433
28468	09Dec2017	114	114	118	118	118	120	742.00	1392678	0	460	5.00606	378	378	378	619.04	430
28469	10Dec2017	101	101	111	111	111	114	742.00	1392678	0	404	5.00519	323	323	323	619.02	231
28470	11Dec2017	87	87	99	99	99	104	742.00	1392678	0	400	5.00510	318	318	318	619.02	202
28471	12Dec2017	87	87	91	91	91	94	742.00	1392678	0	397	5.00505	315	315	315	619.02	210
28472	13Dec2017	98	98	92	92	92	91	742.00	1392678	0	403	5.00514	321	321	321	619.00	0
28473	14Dec2017	101	101	97	97	97	95	742.00	1392678	0	404	5.00515	322	322	322	619.03	327
28474	15Dec2017	105	105	101	101	101	100	742.00	1392678	0	402	5.00512	320	320	320	619.03	310
28475	16Dec2017	111	111	106	106	106	104	742.00	1392678	0	307	5.00369	226	226	226	619.00	0
28476	17Dec2017	138	138	119	119	119	114	742.00	1392678	0	814	5.01304	733	733	733	619.00	0
28477	18Dec2017	182	182	148	148	148	136	742.00	1392678	0	632	5.00913	550	550	550	619.09	1040
28478	19Dec2017	189	189	175	175	175	164	742.00	1392678	0	1855	5.02728	1773	1773	1773	619.18	1977
28479	20Dec2017	157	157	174	174	174	174	742.00	1392678	0	709	5.00982	627	627	627	619.05	564
28480	21Dec2017	135	135	154	154	154	162	742.00	1392678	0	1352	5.01957	1270	1270	1270	619.08	956
28481	22Dec2017	127	127	138	138	138	145	742.00	1392678	0	1342	5.01943	1261	1261	1261	619.03	291
28482	23Dec2017	110	110	124	124	124	130	742.00	1392678	0	974	5.01384	893	893	893	619.05	549
28483	24Dec2017	116	116	116	116	116	119	742.00	1392678	0	1210	5.01741	1128	1128	1128	619.07	833
28484	25Dec2017	136	136	123	123	123	120	742.00	1392678	0	917	5.01296	835	835	835	619.00	0
28485	26Dec2017	117	117	126	126	126	125	742.00	1392678	0	723	5.01002	642	642	642	619.06	635
28486	27Dec2017	94	94	112	112	112	117	742.00	1392678	0	614	5.00836	533	533	533	619.05	543
28487	28Dec2017	78	78	94	94	94	101	742.00	1392678	0	251	5.00283	169	169	169	619.00	0
28488	29Dec2017	79	79	83	83	83	87	742.00	1392678	0	1495	5.02167	1414	1414	1414	619.09	1015
28489	30Dec2017	89	89	84	84	84	83	742.00	1392678	0	1552	5.02251	1470	1470	1470	619.14	1537
28490	31Dec2017	83	83	86	114	114	102	742.00	1392678	0	939	5.01321	857	857	857	619.08	888
28491	01Jan2018		73	80		80	94		1393467	789		8.01287		0	0		868
28492	02Jan2018		45	65		65	71		1394061	1383		8.02271		0	0		848
28493	03Jan2018		24	43		43	52		1394504	1826		8.03004		0	0		828
28494	04Jan2018		12	26		26	33		1394823	2145		8.03534		0	0		808
28495	05Jan2018		6	14		14	19		1395051	2373		8.03911		0	0		788
28496	06Jan2018		3	7		7	10		1395214	2536		8.04180		0	0		769
28497	07Jan2018		1	4		4	5		1395331	2653		8.04374		0	0		749
28498	08Jan2018		1	2		2	2		1395416	2738		8.04516		0	0		729
28499	09Jan2018		0	1		1	1		1395479	2801		8.04620		0	0		709

		USACE SWT RiverWare Period-of-Record Model, Daily Time Series Data															
Element		HUDS	HUDS	HUDS	HUDS-FGIB	HUDS-FGIB	FGIB	FGIB	FGIB	FGIB	FGIB	FT GIBSON-MUSKOGEE	FT GIBSON-MUSKOGEE	PENS	HUDS	FGIB	Van Buren
Parameter		FLOW-RES IN	OPLEVEL	OUTFLOW	INFLOW	OUTFLOW	ELEV	FLOOD-STORAGE	FLOW-RES IN	FLOW-RES OUT	OP-LEVEL	INFLOW	OUTFLOW	EVAP	EVAP	EVAP	Percent Full Regulation Parameter
Units		cfs	-	cfs	cfs	cfs	ft	acre-ft	cfs	cfs	-	cfs	cfs	in/day	in/day	in/day	-
1	01Jan1940	238	8.01077	91	91	91	554.00	67	91	0	8.00075	0	0	0.0094	0.0087	0.0232	0.000
2	02Jan1940	69	8.00222	160	160	160	553.98	0	160	368	4.90163	368	276	0.0094	0.0087	0.0232	0.000
3	03Jan1940	145	5.41351	158	158	158	553.98	0	158	91	4.90570	91	161	0.0094	0.0087	0.0232	0.000
4	04Jan1940	365	5.21055	351	351	351	554.01	140	351	0	8.00157	0	23	0.0094	0.0087	0.0232	0.000
5	05Jan1940	264	8.01894	17	17	17	554.00	60	17	0	8.00067	0	0	0.0094	0.0087	0.0232	0.000
6	06Jan1940	244	8.00576	392	392	392	554.03	497	392	114	8.00558	114	86	0.0094	0.0087	0.0232	0.000
7	07Jan1940	245	8.00553	234	234	234	553.99	0	234	486	4.97502	486	393	0.0094	0.0087	0.0232	0.000
8	08Jan1940	312	8.00138	349	349	349	554.01	123	349	171	8.00138	171	250	0.0094	0.0087	0.0232	0.000
9	09Jan1940	434	8.00939	321	321	321	554.02	397	321	126	8.00445	126	137	0.0094	0.0087	0.0232	0.000
10	10Jan1940	407	8.00776	413	413	413	553.99	0	413	670	4.95146	670	534	0.0094	0.0087	0.0232	0.000
11	11Jan1940	432	8.00924	400	400	400	554.01	260	400	97	8.00292	97	240	0.0094	0.0087	0.0232	0.000
12	12Jan1940	370	8.00526	405	405	405	553.99	0	405	548	4.97057	548	435	0.0094	0.0087	0.0232	0.000
13	13Jan1940	494	8.01020	419	419	419	554.02	335	419	123	8.00376	123	229	0.0094	0.0087	0.0232	0.000
14	14Jan1940	443	8.01260	399	399	399	553.98	0	399	680	4.92797	680	541	0.0094	0.0087	0.0232	0.000
15	15Jan1940	308	8.00524	385	385	385	554.00	0	385	167	4.99589	167	296	0.0094	0.0087	0.0232	0.000
16	16Jan1940	424	8.00679	390	390	390	553.87	0	390	1541	4.48341	1541	1197	0.0094	0.0087	0.0232	0.000
17	17Jan1940	455	8.01282	367	367	367	553.90	0	367	0	4.61478	0	385	0.0094	0.0087	0.0232	0.000
18	18Jan1940	302	8.00873	338	338	338	553.93	0	338	0	4.73378	0	0	0.0094	0.0087	0.0232	0.000
19	19Jan1940	286	8.00691	294	294	294	553.96	0	294	0	4.83413	0	0	0.0094	0.0087	0.0232	0.000
20	20Jan1940	309	8.00939	265	265	265	553.97	0	265	67	4.89346	67	50	0.0094	0.0087	0.0232	0.000
21	21Jan1940	280	8.00785	285	285	285	553.99	0	285	96	4.94909	96	89	0.0094	0.0087	0.0232	0.000
22	22Jan1940	275	8.00777	262	262	262	554.00	0	262	118	4.98610	118	112	0.0094	0.0087	0.0232	0.000
23	23Jan1940	277	8.00764	265	265	265	554.01	86	265	131	8.00097	131	128	0.0094	0.0087	0.0232	0.000
24	24Jan1940	269	8.00598	275	275	275	554.02	306	275	107	8.00343	107	113	0.0094	0.0087	0.0232	0.000
25	25Jan1940	291	8.00511	287	287	287	553.99	0	287	460	4.96792	460	372	0.0094	0.0087	0.0232	0.000
26	26Jan1940	310	8.00616	283	283	283	554.00	33	283	133	8.00037	133	215	0.0094	0.0087	0.0232	0.000
27	27Jan1940	294	8.00493	295	295	295	554.01	205	295	151	8.00230	151	146	0.0094	0.0087	0.0232	0.000
28	28Jan1940	329	8.00707	289	289	289	554.02	414	289	126	8.00464	126	132	0.0094	0.0087	0.0232	0.000
29	29Jan1940	293	8.00425	314	314	314	553.99	0	314	518	4.97749	518	420	0.0094	0.0087	0.0232	0.000
30	30Jan1940	404	8.00905	331	331	331	554.01	254	331	92	8.00285	92	199	0.0094	0.0087	0.0232	0.000
31	31Jan1940	454	8.00906	440	440	440	553.73	0	440	3031	3.93044	3031	2296	0.0094	0.0087	0.0232	0.000
32	01Feb1940	609	8.01927	497	497	497	553.79	0	507	0	4.14142	0	758	-0.0207	-0.0507	-0.0376	0.000
33	02Feb1940	604	8.01875	624	624	624	553.85	0	646	0	4.41167	0	0	-0.0207	-0.0507	-0.0376	0.000
34	03Feb1940	615	8.02089	602	602	602	553.92	0	648	0	4.68285	0	0	-0.0207	-0.0507	-0.0376	0.000
35	04Feb1940	577	8.01631	647	647	647	553.99	0	647	0	4.95357	0	0	-0.0207	-0.0507	-0.0376	0.000
36	05Feb1940	576	8.01686	582	582	582	554.04	745	582	89	8.00835	89	66	-0.0207	-0.0507	-0.0376	0.000
37	06Feb1940	499	8.01644	517	517	517	553.98	0	517	1105	4.90614	1105	851	-0.0207	-0.0507	-0.0376	0.000
38	07Feb1940	374	8.00821	489	489	489	554.02	309	489	102	8.00347	102	353	-0.0207	-0.0507	-0.0376	0.000
39	08Feb1940	430	8.00927	430	430	430	553.99	0	430	710	4.94358	710	558	-0.0207	-0.0507	-0.0376	0.000
40	09Feb1940	549	8.01810	454	454	454	554.03	540	454	40	8.00606	40	207	-0.0207	-0.0507	-0.0376	0.000
41	10Feb1940	444	8.00969	561	561	561	553.99	0	561	963	4.94139	963	732	-0.0207	-0.0507	-0.0376	0.000
42	11Feb1940	507	8.01465	460	460	460	554.02	447	460	88	8.00501	88	306	-0.0207	-0.0507	-0.0376	0.000
43	12Feb1940	469	8.01507	477	477	477	553.68	0	477	3673	3.73568	3673	2777	-0.0207	-0.0507	-0.0376	0.000
44	13Feb1940	418	8.01257	462	462	462	553.73	0	466	0	3.92962	0	918	-0.0207	-0.0507	-0.0376	0.000
45	14Feb1940	362	8.00794	432	432	432	553.78	0	432	0	4.10903	0	0	-0.0207	-0.0507	-0.0376	0.000
46	15Feb1940	394	8.00833	403	403	403	553.82	0	403	0	4.27613	0	0	-0.0207	-0.0507	-0.0376	0.000
47	16Feb1940	499	8.01333	451	451	451	553.86	0	451	0	4.46341	0	0	-0.0207	-0.0507	-0.0376	0.000
48	17Feb1940	538	8.01285	557	557	557	553.93	0	610	0	4.71835	0	0	-0.0207	-0.0507	-0.0376	0.000
49	18Feb1940	738	8.02447	609	609	609	554.01	163	755	0	8.00182	0	0	-0.0207	-0.0507	-0.0376	0.000
50	19Feb1940	621	8.01559	744	744	744	553.98	0	818	1102	4.91057	1102	826	-0.0207	-0.0507	-0.0376	0.000
51	20Feb1940	683	8.01851	660	660	660	554.04	758	694	92	8.00850	92	345	-0.0207	-0.0507	-0.0376	0.000
52	21Feb1940	715	8.02101	697	697	697	553.97	0	697	1348	4.88231	1348	1034	-0.0207	-0.0507	-0.0376	0.000
53	22Feb1940	642	8.01983	670	670	670	553.64	0	694	3790	3.56475	3790	3180	-0.0207	-0.0507	-0.0376	0.000
54	23Feb1940	579	8.01635	635	635	635	553.71	0	684	0	3.85093	0	948	-0.0207	-0.0507	-0.0376	0.000
55	24Feb1940	546	8.01426	586	586	586	553.77	0	591	0	4.09763	0	0	-0.0207	-0.0507	-0.0376	0.000
56	25Feb1940	510	8.00958	581	581	581	553.84	0	581	0	4.34035	0	0	-0.0207	-0.0507	-0.0376	0.000
57	26Feb1940	629	8.01765	544	544	544	553.89	0	546	0	4.56819	0	0	-0.0207	-0.0507	-0.0376	0.000
58	27Feb1940	623	8.01911	618	618	618	553.96	0	629	20	4.82258	20	15	-0.0207	-0.0507	-0.0376	0.000
59	28Feb1940	562	8.01611	612	612	612	554.02	324	678	88	8.00363	88	71	-0.0207	-0.0507	-0.0376	0.000
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28435	06Nov2017	1968	8.00000	1939	1939	1939	554.05	1027	2184	2907	8.01152	2907	2203	0.0665	0.0399	0.0782	0.000
28436	07Nov2017	615	8.01503	402	402	402	554.01	163	402	736	8.00183	736	1279	0.0665	0.0399	0.0782	0.000
28437	08Nov2017	822	8.00000	978	978	978	554.11	2133	1183	89	8.02392	89	250	0.0665	0.0399	0.0782	0.000
28438	09Nov2017	610	8.03564	143	143	143	554.00	0	143	1136	4.99200	1136	874	0.0665	0.0399	0.0782	0.000
28439	10Nov2017	402	8.00709	725	725	725	554.05	861	725	170	8.00965	170	412	0.0665	0.0399	0.0782	0.000
28440	11Nov2017	402	8.00695	375	375	375	554.01	202	375	606	8.00227	606	497	0.0665	0.0399	0.0782	0.000
28441	12Nov2017	402	8.00903	348	348	348	554.02	430	348	132	8.00482	132	250	0.0665	0.0399	0.0782	0.000
28442	13Nov2017	352	8.00000	435	435	435	554.03	638	435	228	8.00715	228	204	0.0665	0.0399	0.0782	0.000
28443	14Nov2017	852	8.00700	738	738	738	554.00	40	988	1188	8.00045	1188	948	0.0665	0.0399	0.0782	0.000
28444	15Nov2017	2094	8.00000	2152	2152	2152	554.17	3288	2152	413	8.03686	413	607	0.0665	0.0399	0.0782	0.000
28445	16Nov2017	552	8.03837	52	52	52	553.99	0	602	2235	4.96717	2235	1780	0.0665	0.0399	0.0782	0.000
28446	17Nov2017	1275	8.00000	1718	1718	1718	554.13	2493	1868	432	8.02796	432	883	0.0665	0.0399	0.0782	0.000
28447	18Nov2017	355	8.02659	0	0	0	554.00	0	180	1381	4.98061	1381	1144	0.0665	0.0399	0.0782	0.000
28448	19Nov2017	354	8.01092	518	518	518	554.02	445	518	147	8.00499	147	456	0.0665	0.0399	0.0782	0.000
28449	20Nov2017	676	8.01635	581	581	581	553.98	0	650	993	4.90668	993	781	0.0665	0.0399	0.0782	0.000
28450	21Nov2017	1083	8.00000	1255	1255	1255	554.00	0	1705	1403	4.99195	1403	1300	0.0665	0.0399	0.0782	0.000
28451	22Nov2017	531	8.01314	341	341	341	554.02	394	341	22	8.00442	22	367	0.0665	0.0399	0.0782	0.000
28452	23Nov2017	371	8.00968	385	385	385	554.03	637	385	161	8.00714	161	126	0.0665	0.0399	0.0782	0.000
28453	24Nov2017	1043	8.00000	1134	1134	1134	553.96	0	1184	1752	4.85221	1752	1354	0.0665	0.0399	0.0782	0.000
28454	25Nov2017	437	8.00787	311	311	311	553.98	0	361	89	4.92480	89	505	0.0665	0.0399	0.0782	0.000
28455	26Nov2017	477	8.01004	422	422	422	554.00	56	422	115	8.00063	115	108	0.0665	0.0399	0.0782	0.000
28456	27Nov2017	474	8.00000	569	569	569	554.04	724	593	154	8.00812	154	144	0.0665	0.0399	0.0782	0.000
28457	28Nov2017	1311	8.00000	1283	1283	1283	553.96	0	1433	2067	4.84289	2067	1589	0.0665	0.0399	0.0782	0.000
28458	29Nov2017	4522	8.00000	4494	4494	4494	554.09	1683	5090	3770	8.01887	3770	3344	0.0665	0.0399	0.0782	0.000
28459	30Nov2017	1836	8.00606	1733	1733	1733	554.02	342	1733	2308	8.00383	2308	2673	0.0665	0.0399	0.0782	0.000
28460	01Dec2017	632	8.01997	438	438	438	553.96	0	1715	2153	4.85453	2153	2192	0.0485	0.0300	0.0472	0.000
28461	02Dec2017	490	8.01513	525	525	525	553.99	0	525	210	4.95579	210	696	0.0485	0.0300	0.0472	0.000
28462	03Dec2017	823	8.01988	741	741	741	554.06	1109	741	1	8.01243	1	53	0.0485	0.0300	0.0472	0.000
28463	04Dec2017	717	8.02179	670	670	670	553.97	0	1459	2228	4.87834	2228	1671	0.0485	0.0300	0.0472	0.000
28464	05Dec2017	575	8.01404	646	646	646	554.04	679	796	91	8.00761	91	625	0.0485	0.0300	0.0472	0.000
28465	06Dec2017	491	8.01098	505	505	505	553.82	0	505	2504	4.26447	2504	1900	0.0485	0.0300	0.0472	0.000
28466	07Dec2017	412	8.00987	402	402	402	553.85	0	402	0	4.40240	0	626	0.0485	0.0300	0.0472	0.000
28467	08Dec2017	620	8.01775	499	499	499	553.92	0	704	1	4.66834	1	1	0.0485	0.0300	0.0472	0.000
28468	09Dec2017	578	8.01762	556	556	556	553.97	0	556	1	4.87124	1	1	0.0485	0.0300	0.0472	0.000
28469	10Dec2017	423	8.00947	499	499	499	554.01	90	499	74	8.00101	74	55	0.0485	0.0300	0.0472	0.000
28470	11Dec2017	341	8.00830	332	332	332	554.02	340	332	129	8.00381	129	115	0.0485	0.0300	0.0472	0.000
28471	12Dec2017	315	8.00861	287	287	287	554.02	461	287	149	8.00517	149	144	0.0485	0.0300	0.0472	0.000
28472	13Dec2017	771	8.00000	853	853	853	554.00	0	853	1027	4.99243	1027	807	0.0485	0.0300	0.0472	0.000
28473	14Dec2017	622	8.01340	433	433	433	554.04	671	433	1	8.00752	1	257	0.0485	0.0300	0.0472	0.000
28474	15Dec2017	420	8.01270	405	405	405	553.67	0	405	3720	3.70426	3720	2790	0.0485	0.0300	0.0472	0.000
28475	16Dec2017	376	8.00000	508	508	508	553.72	0	508	0	3.88742	0	930	0.0485	0.0300	0.0472	0.000
28476	17Dec2017	1867	8.00000	1843	1843	1843	553.91	0	1843	3	4.63563	3	2	0.0485	0.0300	0.0472	0.000
28477	18Dec2017	550	8.04262	2	2	2	553.90	0	2	2	4.60315	2	2	0.0485	0.0300	0.0472	0.000
28478	19Dec2017	1873	8.08107	1376	1376	1376	554.00	9	1376	360	8.00010	360	271	0.0485	0.0300	0.0472	0.000
28479	20Dec2017	1670	8.02314	2359	2359	2359	553.86	0	2359	3590	4.44696	3590	2782	0.0485	0.0300	0.0472	0.000
28480	21Dec2017	1620	8.03921	1398	1398	1398	554.06	1142	2298	342	8.01281	342	1154	0.0485	0.0300	0.0472	0.000
28481	22Dec2017	2386	8.01192	2697	2697	2697	553.99	0	2697	3284	4.96278	3284	2549	0.0485	0.0300	0.0472	0.000
28482	23Dec2017	1950	8.02250	1796	1796	1796	553.97	0	2131	2262	4.87461	2262	2517	0.0485	0.0300	0.0472	0.000
28483	24Dec2017	1197	8.03416	1030	1030	1030	554.03	610	1030	350	8.00684	350	828	0.0485	0.0300	0.0472	0.000
28484	25Dec2017	2060	8.00000	2456	2456	2456	553.69	0	2656	5772	3.77607	5772	4417	0.0485	0.0300	0.0472	0.000
28485	26Dec2017	872	8.02605	528	528	528	553.76	0	715	0	4.04690	0	1443	0.0485	0.0300	0.0472	0.000
28486	27Dec2017	533	8.02227	555	555	555	553.61	0	555	1905	3.44187	1905	1429	0.0485	0.0300	0.0472	0.000
28487	28Dec2017	669	8.00000	919	919	919	553.78	0	1669	1	4.11732	1	477	0.0485	0.0300	0.0472	0.000
28488	29Dec2017	1814	8.04160	1278	1278	1278	553.93	0	1828	342	4.71544	342	257	0.0485	0.0300	0.0472	0.000
28489	30Dec2017	1769	8.06303	1482	1482	1482	554.08	1543	1832	306	8.01730	306	315	0.0485	0.0300	0.0472	0.000
28490	31Dec2017	857	8.03640	1161	1161	1161	553.95	0	1261	2428	4.80211	2428	1898	0.0485	0.0300	0.0472	0.000
28491	01Jan2018		8.03558								4.81059						0.000
28492	02Jan2018		8.03477								4.80890						0.000
28493	03Jan2018		8.03396								4.80313						0.000
28494	04Jan2018		8.03314								4.79573						0.000
28495	05Jan2018		8.03233								4.78768						0.000
28496	06Jan2018		8.03152								4.77936						0.000
28497	07Jan2018		8.03070								4.77095						0.000
28498	08Jan2018		8.02989								4.76249						0.000
28499	09Jan2018		8.02908								4.75402						0.000

		USACE SWT RiverWare Period-of-Record Model, Daily Time Series Data																	
Element		El Dorado	Kaw	Keystone	Birch	Skiatook	Hulah	Copan	Toronto	Fall River	Elk City	Big Hill	Oologah	Marion	Council Grove	John Redmond	Tenkiller	Eufaula	Wister
Parameter		Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level	Operating Level
Units		-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-	-
1	01Jan1940	5	5	5	5	4.99901	5	5	5	5	5	5	4.99	5	5	5	5	5	5
2	02Jan1940	5	5	5	5	4.99803	4.99	5	4.99	5	4.99	5	4.98	5	5	4.99	4.98	4.98	5
3	03Jan1940	5	5	4.98	5	4.99706	4.99	4.99	4.99	4.99	4.99	5	4.98	5	5	4.99	4.98	4.98	4.99
4	04Jan1940	5	5	4.96	4.99	4.99609	4.99	4.99	4.99	4.99	4.98	5	4.97	5	5	4.99	4.96	4.95	4.99
5	05Jan1940	5	5	4.96	4.99	4.99512	4.99	4.99	4.98	4.99	4.98	5	4.97	5	5	4.99	4.96	4.95	4.99
6	06Jan1940	5	5	4.96	4.99	4.99414	4.98	4.99	4.98	4.99	4.98	5	4.97	5	5	4.99	4.96	4.95	4.99
7	07Jan1940	5	5	4.96	4.99	4.99317	4.98	4.99	4.98	4.98	4.97	5	4.97	5	5	4.98	4.96	4.95	4.98
8	08Jan1940	5	5	4.96	4.99	4.99221	4.98	4.99	4.98	4.98	4.97	5	4.96	5	5	4.98	4.97	4.95	4.98
9	09Jan1940	5	5	4.94	4.99	4.99123	4.97	4.98	4.97	4.98	4.96	5	4.96	4.99	5	4.98	4.94	4.93	4.98
10	10Jan1940	4.99	5	4.94	4.98	4.99026	4.97	4.98	4.97	4.98	4.96	5	4.96	4.99	4.99	4.98	4.95	4.93	4.98
11	11Jan1940	4.99	5	4.94	4.98	4.9893	4.97	4.98	4.97	4.97	4.95	5	4.95	4.99	4.99	4.98	4.92	4.91	4.98
12	12Jan1940	4.99	5	4.94	4.98	4.98833	4.97	4.98	4.96	4.97	4.95	5	4.95	4.99	4.99	4.98	4.9	4.91	4.97
13	13Jan1940	4.99	5	4.94	4.98	4.98736	4.96	4.98	4.96	4.97	4.95	5	4.95	4.99	4.99	4.98	4.9	4.91	4.97
14	14Jan1940	4.99	5	4.94	4.98	4.98639	4.96	4.98	4.96	4.97	4.94	4.99	4.95	4.99	4.99	4.98	4.91	4.91	4.97
15	15Jan1940	4.99	5	4.94	4.98	4.98542	4.96	4.97	4.95	4.96	4.94	4.99	4.94	4.99	4.99	4.97	4.91	4.91	4.97
16	16Jan1940	4.99	5	4.94	4.97	4.98445	4.96	4.97	4.95	4.96	4.93	4.99	4.94	4.99	4.99	4.97	4.91	4.89	4.97
17	17Jan1940	4.99	5	4.94	4.97	4.98348	4.95	4.97	4.95	4.96	4.93	4.99	4.94	4.99	4.99	4.97	4.91	4.89	4.97
18	18Jan1940	4.99	5	4.93	4.97	4.98251	4.95	4.97	4.94	4.96	4.93	4.99	4.93	4.99	4.99	4.97	4.89	4.86	4.96
19	19Jan1940	4.99	5	4.88	4.97	4.98154	4.95	4.97	4.94	4.95	4.92	4.99	4.93	4.99	4.99	4.97	4.87	4.86	4.96
20	20Jan1940	4.99	5	4.88	4.97	4.98057	4.94	4.97	4.94	4.95	4.92	4.99	4.92	4.99	4.99	4.97	4.87	4.86	4.96
21	21Jan1940	4.99	5	4.88	4.97	4.9796	4.94	4.96	4.94	4.95	4.91	4.99	4.92	4.99	4.99	4.96	4.87	4.86	4.96
22	22Jan1940	4.99	5	4.87	4.97	4.97863	4.94	4.96	4.93	4.95	4.91	4.99	4.92	4.99	4.99	4.96	4.87	4.86	4.95
23	23Jan1940	4.99	5	4.87	4.96	4.97766	4.94	4.96	4.93	4.94	4.91	4.99	4.92	4.99	4.99	4.96	4.88	4.86	4.95
24	24Jan1940	4.99	5	4.86	4.96	4.97669	4.93	4.96	4.93	4.94	4.9	4.99	4.91	4.99	4.99	4.96	4.85	4.84	4.95
25	25Jan1940	4.99	5	4.86	4.96	4.97572	4.93	4.96	4.92	4.94	4.9	4.99	4.91	4.98	4.99	4.96	4.83	4.82	4.95
26	26Jan1940	4.99	5	4.86	4.96	4.97475	4.93	4.96	4.92	4.94	4.89	4.99	4.91	4.98	4.99	4.96	4.83	4.82	4.95
27	27Jan1940	4.99	5	4.86	4.96	4.97377	4.92	4.96	4.92	4.93	4.89	4.99	4.9	4.98	4.99	4.95	4.83	4.82	4.94
28	28Jan1940	4.99	5	4.84	4.96	4.9728	4.92	4.95	4.91	4.93	4.88	4.99	4.9	4.98	4.99	4.95	4.84	4.82	4.94
29	29Jan1940	4.98	5	4.84	4.95	4.97183	4.92	4.95	4.91	4.93	4.88	4.99	4.9	4.98	4.99	4.95	4.81	4.8	4.94
30	30Jan1940	4.98	5	4.84	4.95	4.97086	4.92	4.95	4.91	4.93	4.88	4.99	4.9	4.98	4.98	4.95	4.82	4.8	4.94
31	31Jan1940	4.98	5	4.84	4.95	4.96989	4.91	4.95	4.91	4.92	4.87	4.99	4.9	4.98	4.98	4.95	4.82	4.8	4.93
32	01Feb1940	4.98	5	4.84	4.95	4.96933	4.91	4.95	4.9	4.92	4.87	4.99	4.9	4.98	4.98	4.95	4.8	4.79	4.93
33	02Feb1940	4.98	5	4.84	4.95	4.96878	4.91	4.95	4.9	4.92	4.86	4.99	4.89	4.98	4.98	4.94	4.8	4.79	4.93
34	03Feb1940	4.98	5	4.85	4.95	4.96822	4.91	4.95	4.9	4.92	4.86	4.99	4.89	4.98	4.98	4.94	4.8	4.79	4.93
35	04Feb1940	4.98	5	4.85	4.95	4.96766	4.91	4.95	4.89	4.91	4.86	4.99	4.89	4.98	4.98	4.94	4.8	4.79	4.93
36	05Feb1940	4.98	5	4.86	4.95	4.9671	4.91	4.94	4.89	4.91	4.85	4.99	4.88	4.98	4.98	4.94	4.8	4.79	4.93
37	06Feb1940	4.98	5	4.81	4.95	4.96654	4.9	4.94	4.89	4.91	4.85	4.99	4.88	4.98	4.98	4.94	4.8	4.77	4.93
38	07Feb1940	4.98	5	4.82	4.95	4.96598	4.9	4.94	4.88	4.91	4.85	4.99	4.88	4.98	4.98	4.93	4.78	4.77	4.94
39	08Feb1940	4.98	5	4.82	4.95	4.96542	4.9	4.94	4.88	4.9	4.84	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.95
40	09Feb1940	4.98	5	4.83	4.95	4.96487	4.9	4.94	4.88	4.9	4.84	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.95
41	10Feb1940	4.98	5	4.83	4.95	4.96431	4.9	4.94	4.87	4.9	4.83	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.96
42	11Feb1940	4.98	5	4.83	4.95	4.96374	4.89	4.94	4.87	4.89	4.83	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.97
43	12Feb1940	4.98	5	4.84	4.95	4.96319	4.89	4.94	4.87	4.89	4.83	4.99	4.88	4.98	4.98	4.93	4.78	4.75	4.98
44	13Feb1940	4.98	5	4.84	4.94	4.96263	4.89	4.94	4.86	4.89	4.82	4.99	4.88	4.98	4.98	4.93	4.76	4.75	4.98
45	14Feb1940	4.97	5	4.85	4.94	4.96206	4.89	4.94	4.86	4.89	4.82	4.99	4.87	4.97	4.98	4.93	4.76	4.75	4.99
46	15Feb1940	4.97	5	4.85	4.94	4.96151	4.89	4.94	4.86	4.88	4.82	4.99	4.87	4.97	4.98	4.93	4.76	4.75	5
47	16Feb1940	4.97	5	4.86	4.94	4.96095	4.89	4.94	4.86	4.88	4.81	4.99	4.86	4.97	4.98	4.93	4.74	4.73	5
48	17Feb1940	4.97	5	4.87	4.94	4.96043	4.88	4.94	4.85	4.88	4.81	4.99	4.86	4.97	4.98	4.93	4.74	4.73	5
49	18Feb1940	4.97	5	4.89	4.94	4.95993	4.88	4.94	4.85	4.88	4.81	4.99	4.86	4.97	4.98	4.93	4.75	4.73	5
50	19Feb1940	4.97	5	4.8	4.94	4.95944	4.88	4.94	4.85	4.87	4.8	4.99	4.86	4.97	4.98	4.93	4.75	4.73	8
51	20Feb1940	4.97	5	4.82	4.94	4.959	4.88	4.93	4.85	4.87	4.8	4.99	4.86	4.97	4.98	4.93	4.75	4.72	8.01
52	21Feb1940	4.97	5	4.84	4.94	4.95858	4.88	4.93	4.84	4.87	4.79	4.99	4.86	4.97	4.98	4.93	4.73	4.72	8.01
53	22Feb1940	4.97	5	4.86	4.94	4.95814	4.88	4.93	4.84	4.87	4.79	4.99	4.86	4.97	4.98	4.93	4.73	4.72	8.01
54	23Feb1940	4.97	5	4.77	4.94	4.95767	4.87	4.93	4.84	4.86	4.79	4.99	4.86	4.97	4.98	4.93	4.74	4.72	8.01
55	24Feb1940	4.97	5	4.79	4.94	4.95716	4.87	4.93	4.84	4.86	4.78	4.99	4.86	4.97	4.98	4.93	4.74	4.72	8
56	25Feb1940	4.97	5	4.8	4.94	4.95665	4.87	4.93	4.83	4.86	4.78	4.98	4.86	4.97	4.98	4.93	4.74	4.73	5
57	26Feb1940	4.97	5	4.81	4.94	4.95613	4.87	4.93	4.83	4.86	4.78	4.98	4.85	4.97	4.98	4.93	4.75	4.73	5
58	27Feb1940	4.97	5	4.83	4.94	4.9556	4.87	4.93	4.83	4.85	4.77	4.98	4.85	4.97	4.97	4.93	4.73	4.73	5
59	28Feb1940	4.97	5	4.84	4.94	4.95507	4.87	4.93	4.82	4.85	4.77	4.98	4.85	4.97	4.97	4.93	4.73	4.73	5
...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...	...
28435	06Nov2017	4.82	7.05	7.05	4.95	4.99311	4.99	4.99	4.99	4.99	4.97	4.99	7.05	4.68	4.87	4.99	7.08	7.1	4.85
28436	07Nov2017	4.82	5	7	4.95	4.99232	4.99	4.99	4.98	4.99	4.97	4.99	5	4.68	4.87	4.99	5	7	4.85
28437	08Nov2017	4.82	5	7.03	4.94	4.99154	4.99	4.98	4.98	4.99	4.96	4.99	5	4.68	4.87	4.99	7	7	4.84
28438	09Nov2017	4.82	5	6.11	4.94	4.99072	4.99	4.98	4.98	4.98	4.96	4.99	5	4.68	4.87	4.99	5	7	4.84
28439	10Nov2017	4.82	5	5.09	4.94	4.98987	4.98	4.98	4.98	4.98	4.95	4.98	5	4.68	4.87	4.99	5	5	4.84
28440	11Nov2017	4.82	5	5.1	4.94	4.98902	4.98	4.98	4.98	4.98	4.95	4.98	5	4.68	4.87	4.99	5	5	4.83
28441	12Nov2017	4.82	5	5.09	4.94	4.98816	4.98	4.97	4.97	4.98	4.95	4.98	4.99	4.68	4.86	4.99	5	5	4.83
28442	13Nov2017	4.82	5	7	4.93	4.9873	4.98	4.97	4.97	4.98	4.95	4.98	4.99	4.68	4.86	4.99	5	5	4.82
28443	14Nov2017	4.82	5	7	4.93	4.98645	4.98	4.97	4.97	4.98	4.95	4.98	4.99	4.68	4.87	4.99	4.98	4.98	4.82
28444	15Nov2017	4.82	5	5.09	4.93	4.9856	4.98	4.97	4.98	4.99	4.94	4.98	4.99	4.68	4.87	4.99	4.99	4.98	4.82
28445	16Nov2017	4.81	5	4.99	4.93	4.98477	4.98	4.97	4.99	5.05	4.94	4.98	4.99	4.68	4.87	4.99	4.96	4.98	4.81
28446	17Nov2017	4.81	5	7	4.93	4.98393	4.98	4.96	4.99	8	4.94	4.98	4.99	4.68	4.87	4.99	4.97	4.96	4.81
28447	18Nov2017	4.81	5	5.08	4.92	4.98311	4.98	4.97	4.98	8	4.94	4.98	4.99	4.68	4.86	4.99	4.97	4.96	4.8
28448	19Nov2017	4.81	5	7	4.92	4.98229	4.97	4.96	4.98	5	4.94	4.98	4.99	4.68	4.86	4.99	4.97	4.96	4.8
28449	20Nov2017	4.81	5	4.97	4.92	4.98147	4.97	4.96	4.98	5	4.94	4.98	4.99	4.68	4.86	4.99	4.95	4.96	4.8
28450	21Nov2017	4.81	5	4.99	4.92	4.98065	4.97	4.96	4.97	4.99	4.93	4.98	4.99	4.68	4.86	4.99	4.95	4.94	4.79
28451	22Nov2017	4.81	5	4.95	4.92	4.97993	4.96	4.96	4.97	4.99	4.93	4.97	4.99	4.68	4.86	4.99	4.92	4.93	4.79
28452	23Nov2017	4.81	5	4.96	4.91	4.97918	4.96	4.95	4.97	4.99	4.93	4.97	4.99	4.68	4.86	4.99	4.93	4.91	4.79
28453	24Nov2017	4.81	5	4.98	4.91	4.97846	4.96	4.95	4.97	4.99	4.93	4.97	4.98	4.68	4.86	4.99	4.9	4.91	4.78
28454	25Nov2017	4.81	5	5	4.91	4.97773	4.95	4.95	4.96	4.99	4.93	4.97	4.98	4.68	4.86	4.99	4.91	4.91	4.78
28455	26Nov2017	4.8	5	7	4.91	4.9773	4.95	4.95	4.96	4.98	4.92	4.97	4.98	4.67	4.86	4.99	4.91	4.91	4.77
28456	27Nov2017	4.8	5	4.93	4.9	4.97688	4.96	4.94	4.96	4.98	4.92	4.97	4.98	4.67	4.86	4.99	4.91	4.89	4.77
28457	28Nov2017	4.81	5	4.94	4.9	4.97631	4.96	4.94	4.96	4.98	4.92	4.97	4.98	4.67	4.86	5	4.89	4.89	4.77
28458	29Nov2017	4.81	5	4.94	4.9	4.97584	4.96	4.94	4.96	4.97	4.92	4.97	4.98	4.67	4.85	5	4.89	4.89	4.76
28459	30Nov2017	4.8	5	4.96	4.9	4.97532	4.96	4.94	4.96	4.97	4.92	4.97	4.98	4.67	4.85	5	4.89	4.89	4.76
28460	01Dec2017	4.8	5	4.99	4.9	4.97473	4.96	4.94	4.96	4.97	4.91	4.97	4.98	4.67	4.85	5	4.87	4.87	4.76
28461	02Dec2017	4.8	5	5.07	4.9	4.97417	4.96	4.93	4.96	4.97	4.91	4.97	4.97	4.67	4.85	5	4.88	4.87	4.75
28462	03Dec2017	4.8	5	5.08	4.9	4.97362	4.96	4.93	4.96	4.97	4.91	4.97	4.97	4.67	4.85	5	4.88	4.87	4.75
28463	04Dec2017	4.8	5	4.94	4.89	4.97357	4.96	4.93	4.96	4.99	4.91	4.97	4.97	4.67	4.85	5	4.89	4.87	4.75
28464	05Dec2017	4.8	5	4.89	4.89	4.97314	4.96	4.93	4.97	5.08	4.91	4.97	4.97	4.66	4.85	5	4.86	4.85	4.75
28465	06Dec2017	4.8	5	4.92	4.89	4.97268	4.96	4.93	4.97	6.24	4.91	4.97	4.97	4.66	4.85	5	4.87	4.85	4.74
28466	07Dec2017	4.8	5	4.93	4.89	4.972	4.96	4.92	4.97	5	4.9	4.96	4.97	4.66	4.85	5	4.87	4.83	4.74
28467	08Dec2017	4.8	5	4.89	4.89	4.97122	4.96	4.92	4.97	5	4.9	4.96	4.97	4.66	4.85	5	4.85	4.83	4.73
28468	09Dec2017	4.8	5	4.91	4.88	4.97042	4.95	4.92	4.96	5.02	4.9	4.96	4.97	4.66	4.85	5	4.85	4.83	4.73
28469	10Dec2017	4.8	5	4.92	4.88	4.96961	4.95	4.92	4.96	5	4.89	4.96	4.96	4.66	4.85	5	4.85	4.82	4.73
28470	11Dec2017	4.79	5	4.86	4.88	4.96886	4.94	4.91	4.96	5	4.89	4.96	4.96	4.66	4.84	5	4.83	4.8	4.72
28471	12Dec2017	4.79	5	4.87	4.88	4.96808	4.94	4.91	4.96	5	4.89	4.96	4.96	4.66	4.84	5	4.83	4.8	4.72
28472	13Dec2017	4.79	5	4.89	4.88	4.96731	4.94	4.91	4.96	8	4.88	4.96	4.96	4.66	4.84	5	4.81	4.78	4.72
28473	14Dec2017	4.79	5	4.85	4.88	4.96649	4.93	4.91	4.96	8	4.88	4.96	4.96	4.65	4.84	5	4.81	4.78	4.71
28474	15Dec2017	4.79	5	4.89	4.87	4.96567	4.93	4.91	4.96	8	4.88	4.96	4.96	4.65	4.84	5	4.79	4.76	4.71
28475	16Dec2017	4.79	5	4.91	4.87	4.96486	4.93	4.9	4.95	8	4.88	4.96	4.96	4.65	4.84	5	4.79	4.76	4.71
28476	17Dec2017	4.79	5	4.93	4.87	4.96405	4.94	4.9	4.96	5	4.88	4.96	4.96	4.65	4.84	5	4.79	4.76	4.71
28477	18Dec2017	4.79	5	4.85	4.87	4.96325	4.94	4.9	4.96	5.02	4.88	4.96	4.95	4.65	4.84	5	4.77	4.74	4.71
28478	19Dec2017	4.79	5	4.87	4.87	4.96245	4.94	4.9	4.97	7.89	4.88	4.96	4.95	4.65	4.85	5	4.77	4.74	4.72
28479	20Dec2017	4.79	5	4.89	4.86	4.96164	4.94	4.89	4.97	8	4.88	4.96	4.95	4.65	4.85	5	4.78	4.74	4.72
28480	21Dec2017	4.79	5	4.82	4.86	4.96084	4.94	4.89	4.96	5	4.87	4.96	4.96	4.65	4.85	5	4.76	4.72	4.72
28481	22Dec2017	4.78	5	4.84	4.86	4.96004	4.94	4.89	4.96	5	4.87	4.95	4.96	4.65	4.84	5	4.76	4.72	4.75
28482	23Dec2017	4.78	5	4.86	4.86	4.95927	4.93	4.89	4.96	8	4.87	4.95	4.96	4.65	4.84	5	4.77	4.72	4.78
28483	24Dec2017	4.78	5	4.87	4.86	4.95849	4.93	4.89	4.95	8	4.86	4.95	4.96	4.65	4.84	5	4.77	4.72	4.81
28484	25Dec2017	4.78	5	4.79	4.85	4.95769	4.92	4.88	4.95	5.03	4.86	4.95	4.96	4.65	4.84	5	4.75	4.72	4.83
28485	26Dec2017	4.78	5	4.8	4.85	4.95689	4.92	4.88	4.95	5.04	4.86	4.95	4.96	4.65	4.84	5	4.74	4.7	4.84
28486	27Dec2017	4.78	5	4.81	4.85	4.95608	4.91	4.88	4.95	5.03	4.85	4.95	4.96	4.65	4.84	5	4.74	4.7	4.85
28487	28Dec2017	4.78	5	4.74	4.85	4.95529	4.91	4.88	4.94	5.03	4.85	4.95	4.95	4.65	4.84	5	4.72	4.68	4.85
28488	29Dec2017	4.78	5	4.75	4.85	4.9545	4.91	4.88	4.94	5	4.85	4.95	4.95	4.65	4.84	5	4.7	4.68	4.86
28489	30Dec2017	4.78	5	4.76	4.85	4.95371	4.9	4.87	4.94	5.04	4.84	4.95	4.95	4.64	4.84	5	4.71	4.68	4.86
28490	31Dec2017	4.78	5	4.78	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	5	4.71	4.68	4.86
28491	01Jan2018	4.78	7	4.8	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8	4.71	4.68	4.87
28492	02Jan2018	4.78	7.01	4.83	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8	4.71	4.68	4.87
28493	03Jan2018	4.78	7.01	4.84	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28494	04Jan2018	4.78	7.01	4.85	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28495	05Jan2018	4.78	7.01	4.85	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28496	06Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28497	07Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28498	08Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87
28499	09Jan2018	4.78	7.01	4.86	4.84	4.95291	4.9	4.87	4.94	5	4.84	4.95	4.95	4.64	4.84	8.01	4.71	4.68	4.87

Pensacola

Elevation ft PD	Area acre	Storage acre-ft	Elevation ft PD	OPLEVEL 1 - 16.1	Elevation ft PD	Max Regulated Spill cfs	Induced Surcharge cfs
612	0	0	612	1	612	0	0
613	1	0.3	705.5	2	633	0	0
614	6	3.5	705.5001	3	730	1	0
615	30	15	727.8	4	735	47200	0
616	36	48	742	5	740	84500	0
617	42	86	742.0001	6	742	117000	0
618	51	132	742.0002	7	745.01	190000	0
619	66	190	742.0003	8	745.5	204000	0
620	128	269	743.49	9	745.95	217000	0
621	144	406	746.52	10	748	278000	0
622	158	556	749.21	11	752.4	422000	0
623	174	722	751.66	12	754	484000	0
624	196	906	753.92	13	754.8	515000	13500
625	269	1126	755	14	754.85	518000	50000
626	298	1411	755.6	15	754.9	520800	100000
627	329	1724	757	16	754.95	523700	200000
628	365	2070	758	16.1	754.98	525400	300000
629	402	2453			754.99	526000	500000
630	471	2879			755	527000	525000
631	502	3366			756	557000	550000
632	529	3882			756.7	567200	567200
633	556	4425			757	614900	614900
634	587	4996			758	700000	700000
635	653	5601					
636	687	6270					
637	728	6977					
638	781	7731					
639	837	8539					
640	924	9408					
641	967	10354					
642	1007	11341					
643	1054	12371					
644	1105	13450					
645	1231	14594					
646	1328	15876					
647	1420	17250					
648	1531	18723					
649	1658	20317					
650	1863	22045					
651	1995	23978					
652	2118	26035					
653	2226	28209					
654	2335	30489					
655	2500	32884					
656	2608	35441					
657	2721	38105					
658	2834	40883					
659	2956	43776					
660	3137	46798					
661	3277	50008					
662	3407	53350					
663	3544	56826					
664	3699	60446					
665	3954	64239					
666	4160	68300					
667	4350	72556					
668	4537	77000					
669	4741	81636					
670	5029	86486					
671	5249	91629					
672	5459	96984					
673	5674	102550					
674	5896	108336					
675	6189	114350					
676	6454	120680					
677	6678	127249					
678	6904	134040					
679	7136	141059					
680	7442	148319					
681	7687	155888					
682	7934	163699					
683	8201	171765					
684	8484	180108					
685	8854	188752					
686	9195	197780					
687	9535	207146					
688	9860	216848					
689	10160	226859					
690	10533	237178					
691	10828	247869					
692	11112	258838					
693	11420	270099					
694	11747	281679					
695	12154	293602					

Hudson

Elevation ft M.S.L.	Area acre	Storage acre-ft	Elevation ft M.S.L.	OPLEVEL 1 - 16.1	Elevation ft M.S.L.	Max Regulated Spill cfs	Induced Surcharge cfs
558	0	0	558	1	558	0	0
559	1	1	618.5	2	599	29000	0
560	1.5	2	618.5	3	610	82800	0
561	2	3	618.5	4	619	220000	0
562	9	8	619	5	624	315000	0
563	22	23	619.001	6	630	449000	0
564	59	57	619.002	7	633	527500	0
565	74	127	619.003	8	635	583100	70000
566	80	204	621.16	9	635.43	594000	85000
567	93	290	625.12	10	635.77	606000	100000
568	119	395	628.65	11	635.94	611000	360000
569	184	535	631.81	12	635.99	612000	500000
570	221	745	634.66	13	636	613000	613000
571	240	975	636	14	645	884000	884000
572	262	1226	636.001	15	648	974333	974333
573	289	1501	645	16			
574	337	1807	648	16.1			
575	367	2164					
576	391	2543					
577	421	2948					
578	459	3388					
579	563	3876					
580	641	4492					
581	686	5156					
582	733	5865					
583	788	6624					
584	916	7450					
585	1040	8446					
586	1137	9530					
587	1251	10721					
588	1429	12066					
589	1807	13601					
590	2143	15618					
591	2399	17892					
592	2615	20396					
593	2860	23141					
594	3210	26121					
595	3515	29513					
596	3751	33157					
597	3987	37015					
598	4269	41153					
599	4693	45579					
600	5019	50470					
601	5238	55603					
602	5464	60952					
603	5690	66529					
604	6160	72390					
605	6525	78771					
606	6782	85426					
607	7033	92334					
608	7300	99500					
609	7717	106953					
610	8101	114904					
611	8366	123135					
612	8633	131636					
613	8905	140403					
614	9309	149470					
615	9687	159000					
616	9976	168833					
617	10277	178951					
618	10608	189382					
618.5	10819	194784					
619	11029	200185					
620	11210	211304					
621	11570	222694					
622	11930	234443					
623	12300	246558					
624	12670	259042					
625	13065	271909					
626	13460	285171					
627	13880	298841					
628	14300	312930					
629	14800	327480					
630	15300	342529					
631	15855	358106					
632	16410	374237					
633	16975	390929					
634	17540	408186					
635	18145	426027					
636	18750	444474					
637	19440	463568					
638	20130	483352					
639	20880	503856					
640	21630	525110					

Pensacola

Elevation ft PD	Area acre	Storage acre-ft	Elevation ft PD	OPLEVEL 1 - 16.1	Elevation ft PD	Max Regulated Spill cfs	Induced Surcharge cfs
696	12490	305932					
697	12813	318584					
698	13142	331561					
699	13487	344873					
700	13934	358558					
701	14259	372661					
702	14550	387069					
703	14846	401769					
704	15157	416769					
705	15584	432106					
706	15921	447863					
707	16263	463955					
708	16629	480402					
709	17016	497224					
710	17556	514468					
711	18036	532267					
712	18520	550554					
713	18986	569302					
714	19509	588551					
715	20190	608359					
716	20726	628825					
717	21262	649820					
718	21830	671364					
719	22478	693521					
720	23244	716333					
721	23859	739896					
722	24443	764054					
723	25007	788782					
724	25592	814081					
725	26354	840006					
726	26991	866684					
727	27655	894007					
728	28359	922021					
729	29035	950728					
730	29745	980096					
731	30386	1010168					
732	31052	1040888					
733	31788	1072304					
734	32607	1104503					
735	33530	1137530					
736	34275	1171445					
737	34989	1206086					
738	35760	1241453					
739	36638	1277662					
740	37788	1314761					
741	38918	1353101					
742	40021	1392678					
743	40636	1433025					
744	41221	1473920					
745	41779	1515412					
746	43551	1558073					
747	45323	1602507					
748	47095	1648714					
749	48867	1696692					
750	50639	1746443					
751	52411	1797965					
752	54184	1851261					
753	55956	1906328					
754	57728	1963167					
755	59300	2021679					
756	61100	2081877					
757	62950	2143900					
758	64800	2207773					

Hudson

Elevation ft M.S.L.	Area acre	Storage acre-ft	Elevation ft M.S.L.	OPLEVEL 1 - 16.1	Elevation ft M.S.L.	Max Regulated Spill cfs	Induced Surcharge cfs
641	22375	547111					
642	23120	569858					
643	23870	593352					
644	24620	617596					
645	25400	642605					
648	27910	722482					

Parsons-Commerce

Routing Coefficients	
Lag	Coeff
1	0.353
2	0.4568
3	0.1344
4	0.0395
5	0.0116
6	0.0034
7	0.001
8	0.0003

Commerce-Pensacola

Routing Coefficients	
Lag	Coeff
1	0.6
2	0.4

Pensacola-Hudson

Routing Coefficients	
Lag	Coeff
1	1

Hudson-Ft Gibson

Routing Coefficients	
Lag	Coeff
1	1

Appendix B. Operations Model Input Data

HEAD LOSS CALCULATIONS - 1 OF 6

Component	Pipe Size (ft)	Description	Reference for Headloss Estimation	Minor Losses Kv	A (ft^2)	L (ft)	Total Headloss Kq	Q (cfs)	hL (ft)
Trashrack	---	Trashrack losses neglected: very large area, low velocity	---	---	---	---	---	---	---
Inlet	15x15	Standard sharp-edged inlet loss	---	0.50	225.00	---	1.54E-07	2505	0.96
Contraction: 15' sq. to 15' diam.	15	Area 1 = 225.0 ft^2; Area 2 = 176.7 ft^2; A2/A1 = 0.78	[USACE HDC 228 - 4]	0.07	176.71	---	3.49E-08	2505	0.22
42° bend	15	r = 75'; Assume r/D=5	[USACE HDC 228-1]	0.075	176.71	---	3.74E-08	2505	0.23
Butterfly Valve	15	15' Diameter Butterfly Valve	[USACE HDC 331-1]	0.34	176.71	---	1.68E-07	2505	1.06
Penstock Friction	15	194' +/- Total Length	Darcy-Weisbach	---	---	194	5.58E-08	2505	0.35
						Totals:	4.50E-07	2505	2.82

Governing Equations:

$H = Q^2/(C^2*A^2*2g)$

$Q = C*A*(2gH)^{1/2}$

$A = B*Go$

$H = Kv*V^2/(2g)$

$Q = A*(2gH/Kv)^{1/2}$

$Kv = 1/C^2$

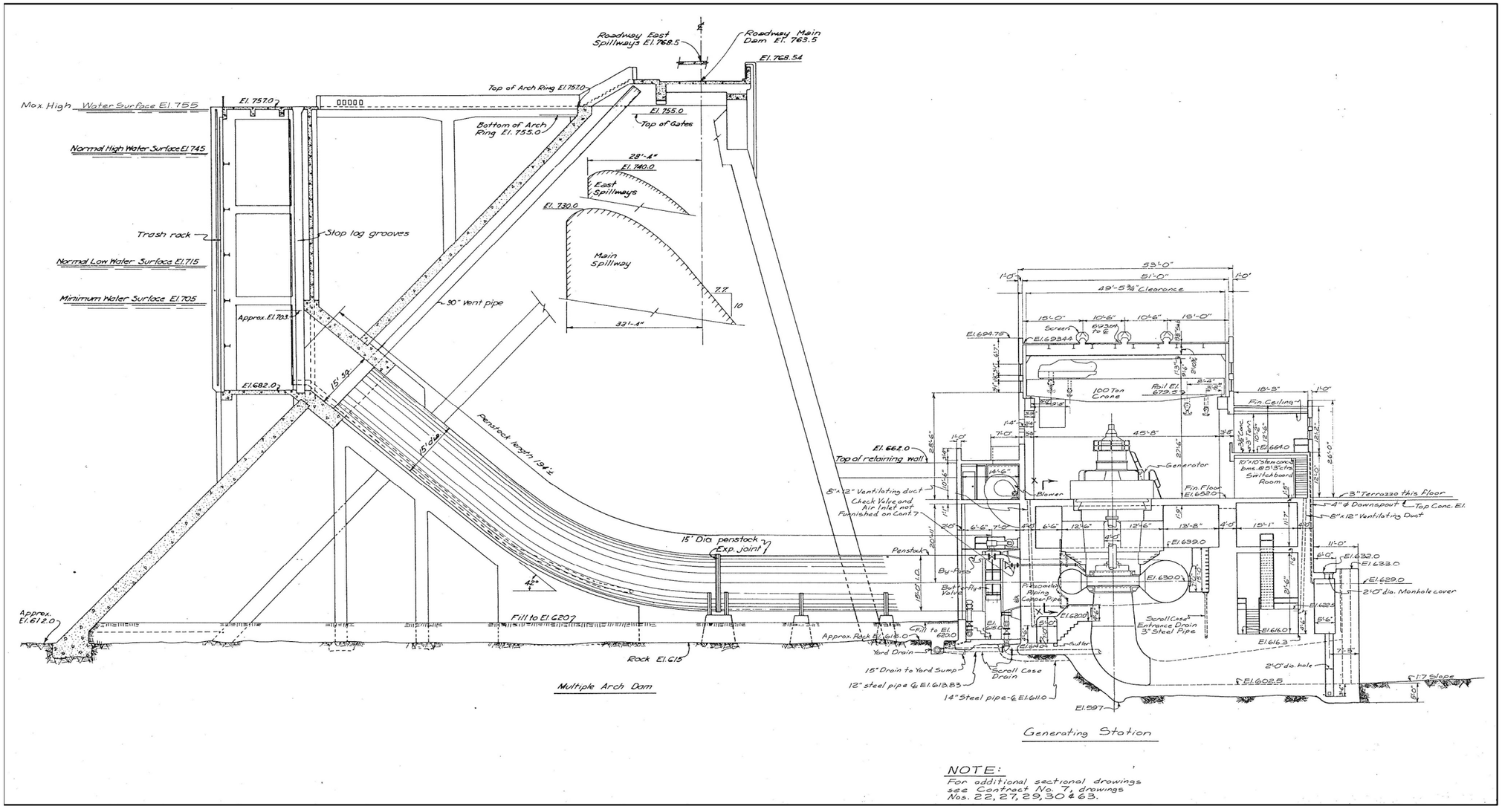
$H = Q^2 * Kq$

$Q = (H/Kq)^{1/2}$

$Kq = 1/(C^2*A^2*2g)$

where:

H = energy head immediately upstream of gate, measured to centerlin
Q = gate discharge (cfs)
A = open area of gate (ft^2)
B = gate width (feet)
Go = gate vertical opening (feet)
V = velocity through open area of gate (ft/s)
C = discharge coefficient
Kv = gate valve loss coefficient (velocity-based)
Kq = gate valve loss coefficient (discharge-based)
g (gravity constant) = 32.146 ft/s^2 [HDC 000-1]
Site Latitude = 36.5 deg
Site Elevation = 750 feet



NOTE:
For additional sectional drawings see Contract No. 7, drawings Nos. 22, 27, 29, 30 & 83.

Darcy-Weisbach Resistance Coefficients for Various Pipe Sizes and Discharges

Discharge (cfs)	Conduit Diameter (feet)	Gravity Constant (ft/s^2)	Wetted Area (ft^2)	Wetted Perimeter (feet)	Hydraulic Diameter (feet)	Velocity (ft/sec)	Fluid Type 3	Kinematic Viscosity ft^2/s	Density $slugs/ft^3$	Specific Weight lbf/ft^3	Reynolds Number (Re)	Conduit Material 2	Roughness (feet)	Relative Roughness	Laminar Zone (f)	Critical Zone (f)
1	15	32.14577	176.71	47.12	15	0.0	Water, 50° F	1.41E-05	1.94	62.36	6.03E+03	Steel or wrought Iron	0.00015	1.00E-05	0.010609	indeterminate
2	15	32.14577	176.71	47.12	15	0.0		1.41E-05	1.94	62.36	1.21E+04		0.00015	1.00E-05	0.005304	indeterminate
3	15	32.14577	176.71	47.12	15	0.0		1.41E-05	1.94	62.36	1.81E+04		0.00015	1.00E-05	0.003536	indeterminate
10	15	32.14577	176.71	47.12	15	0.1		1.41E-05	1.94	62.36	6.03E+04		0.00015	1.00E-05	0.001061	indeterminate
20	15	32.14577	176.71	47.12	15	0.1		1.41E-05	1.94	62.36	1.21E+05		0.00015	1.00E-05	0.000530	indeterminate
30	15	32.14577	176.71	47.12	15	0.2		1.41E-05	1.94	62.36	1.81E+05		0.00015	1.00E-05	0.000354	indeterminate
40	15	32.14577	176.71	47.12	15	0.2		1.41E-05	1.94	62.36	2.41E+05		0.00015	1.00E-05	0.000265	indeterminate
50	15	32.14577	176.71	47.12	15	0.3		1.41E-05	1.94	62.36	3.02E+05		0.00015	1.00E-05	0.000212	indeterminate
75	15	32.14577	176.71	47.12	15	0.4		1.41E-05	1.94	62.36	4.52E+05		0.00015	1.00E-05	0.000141	indeterminate
100	15	32.14577	176.71	47.12	15	0.6		1.41E-05	1.94	62.36	6.03E+05		0.00015	1.00E-05	0.000106	indeterminate
150	15	32.14577	176.71	47.12	15	0.8		1.41E-05	1.94	62.36	9.05E+05		0.00015	1.00E-05	0.000071	indeterminate
200	15	32.14577	176.71	47.12	15	1.1		1.41E-05	1.94	62.36	1.21E+06		0.00015	1.00E-05	0.000053	indeterminate
400	15	32.14577	176.71	47.12	15	2.3		1.41E-05	1.94	62.36	2.41E+06		0.00015	1.00E-05	0.000027	indeterminate
600	15	32.14577	176.71	47.12	15	3.4		1.41E-05	1.94	62.36	3.62E+06		0.00015	1.00E-05	0.000018	indeterminate
800	15	32.14577	176.71	47.12	15	4.5		1.41E-05	1.94	62.36	4.83E+06		0.00015	1.00E-05	0.000013	indeterminate
1000	15	32.14577	176.71	47.12	15	5.7		1.41E-05	1.94	62.36	6.03E+06		0.00015	1.00E-05	0.000011	indeterminate
1200	15	32.14577	176.71	47.12	15	6.8		1.41E-05	1.94	62.36	7.24E+06		0.00015	1.00E-05	0.000009	indeterminate
1400	15	32.14577	176.71	47.12	15	7.9		1.41E-05	1.94	62.36	8.45E+06		0.00015	1.00E-05	0.000008	indeterminate
1600	15	32.14577	176.71	47.12	15	9.1		1.41E-05	1.94	62.36	9.65E+06		0.00015	1.00E-05	0.000007	indeterminate
1800	15	32.14577	176.71	47.12	15	10.2		1.41E-05	1.94	62.36	1.09E+07		0.00015	1.00E-05	0.000006	indeterminate
2000	15	32.14577	176.71	47.12	15	11.3		1.41E-05	1.94	62.36	1.21E+07		0.00015	1.00E-05	0.000005	indeterminate
2200	15	32.14577	176.71	47.12	15	12.4		1.41E-05	1.94	62.36	1.33E+07		0.00015	1.00E-05	0.000005	indeterminate
2400	15	32.14577	176.71	47.12	15	13.6		1.41E-05	1.94	62.36	1.45E+07		0.00015	1.00E-05	0.000004	indeterminate
2600	15	32.14577	176.71	47.12	15	14.7		1.41E-05	1.94	62.36	1.57E+07		0.00015	1.00E-05	0.000004	indeterminate
2800	15	32.14577	176.71	47.12	15	15.8		1.41E-05	1.94	62.36	1.69E+07		0.00015	1.00E-05	0.000004	indeterminate
3000	15	32.14577	176.71	47.12	15	17.0		1.41E-05	1.94	62.36	1.81E+07		0.00015	1.00E-05	0.000004	indeterminate

Smooth Pipes				Transition Zone							
Guess Value (f)	Left Half Equation	Right Half Equation	Difference (<0.001)	Guess Value (f)	Left Half Equation	Right Half Equation	Difference (<0.001)	Rough Pipes (f)	Rough Pipe Limit (Re)	Flow Regime	Selected Coeff. (f)
0.035456	5.31074	5.31074	0.0000	0.035461	5.31039	5.31039	0.0000	0.008061	2.23E+08	Transition	0.035461
0.029406	5.83154	5.83154	0.0000	0.029417	5.83044	5.83044	0.0000	0.008061	2.23E+08	Transition	0.029417
0.026533	6.13908	6.13908	0.0000	0.026549	6.13726	6.13726	0.0000	0.008061	2.23E+08	Transition	0.026549
0.020045	7.06306	7.06306	0.0000	0.020082	7.05659	7.05659	0.0000	0.008061	2.23E+08	Transition	0.020082
0.017307	7.60133	7.60133	0.0000	0.017364	7.58876	7.58875	0.0000	0.008061	2.23E+08	Transition	0.017364
0.015950	7.91805	7.91806	0.0000	0.016024	7.89967	7.89967	0.0000	0.008061	2.23E+08	Transition	0.016024
0.015079	8.14354	8.14354	0.0000	0.015168	8.11954	8.11954	0.0000	0.008061	2.23E+08	Transition	0.015168
0.014450	8.31886	8.31886	0.0000	0.014553	8.28939	8.28939	0.0000	0.008061	2.23E+08	Transition	0.014553
0.013401	8.63831	8.63831	0.0000	0.013535	8.59563	8.59563	0.0000	0.008061	2.23E+08	Transition	0.013535
0.012723	8.86563	8.86563	0.0000	0.012883	8.81025	8.81025	0.0000	0.008061	2.23E+08	Transition	0.012883
0.011848	9.18689	9.18689	0.0000	0.012057	9.10727	9.10727	0.0000	0.008061	2.23E+08	Transition	0.012057
0.011280	9.41543	9.41543	0.0000	0.011530	9.31274	9.31274	0.0000	0.008061	2.23E+08	Transition	0.011530
0.010064	9.96796	9.96796	0.0000	0.010452	9.78138	9.78138	0.0000	0.008061	2.23E+08	Transition	0.010452
0.009440	10.29232	10.29233	0.0000	0.009937	10.03147	10.03147	0.0000	0.008061	2.23E+08	Transition	0.009937
0.009031	10.52295	10.52295	0.0000	0.009621	10.19489	10.19489	0.0000	0.008061	2.23E+08	Transition	0.009621
0.008731	10.70211	10.70211	0.0000	0.009403	10.31245	10.31245	0.0000	0.008061	2.23E+08	Transition	0.009403
0.008497	10.84866	10.84866	0.0000	0.009242	10.40205	10.40205	0.0000	0.008061	2.23E+08	Transition	0.009242
0.008306	10.97268	10.97268	0.0000	0.009117	10.47306	10.47306	0.0000	0.008061	2.23E+08	Transition	0.009117
0.008145	11.08020	11.08019	0.0000	0.009017	10.53095	10.53095	0.0000	0.008061	2.23E+08	Transition	0.009017
0.008008	11.17509	11.17509	0.0000	0.008935	10.57918	10.57918	0.0000	0.008061	2.23E+08	Transition	0.008935
0.007887	11.26003	11.26003	0.0000	0.008866	10.62006	10.62006	0.0000	0.008061	2.23E+08	Transition	0.008866
0.007781	11.33691	11.33691	0.0000	0.008808	10.65521	10.65521	0.0000	0.008061	2.23E+08	Transition	0.008808
0.007685	11.40712	11.40712	0.0000	0.008758	10.68577	10.68577	0.0000	0.008061	2.23E+08	Transition	0.008758
0.007599	11.47174	11.47174	0.0000	0.008714	10.71262	10.71262	0.0000	0.008061	2.23E+08	Transition	0.008714
0.007520	11.53159	11.53159	0.0000	0.008675	10.73640	10.73640	0.0000	0.008061	2.23E+08	Transition	0.008675
0.007448	11.58733	11.58733	0.0000	0.008641	10.75763	10.75763	0.0000	0.008061	2.23E+08	Transition	0.008641

y-Weisbach Resistance	
Discharge (cfs)	15' Dia. Steel
0	*0.03546*
1	0.03546
2	0.02942
3	0.02655
10	0.02008
20	0.01736
30	0.01602
40	0.01517
50	0.01455
75	0.01353
100	0.01288
150	0.01206
200	0.01153
400	0.01045
600	0.00994
800	0.00962
1000	0.00940
1200	0.00924
1400	0.00912
1600	0.00902
1800	0.00894
2000	0.00887
2200	0.00881
2400	0.00876
2600	0.00871
2800	0.00868
3000	0.00864
99999	*0.00864*
D_h =	15

d Friction Slope Factors	
Discharge (cfs)	15' Dia. Steel
0	0.00E+00
1	1.17E-09
2	3.87E-09
3	7.87E-09
10	6.61E-08
20	2.29E-07
30	4.75E-07
40	7.99E-07
50	1.20E-06
75	2.51E-06
100	4.24E-06
150	8.93E-06
200	1.52E-05
400	5.51E-05
600	1.18E-04
800	2.03E-04
1000	3.10E-04
1200	4.38E-04
1400	5.88E-04
1600	7.60E-04
1800	9.53E-04
2000	1.17E-03
2200	1.40E-03
2400	1.66E-03
2600	1.94E-03
2800	2.24E-03
3000	2.56E-03
99999	*2.56E-03*
D_h =	15

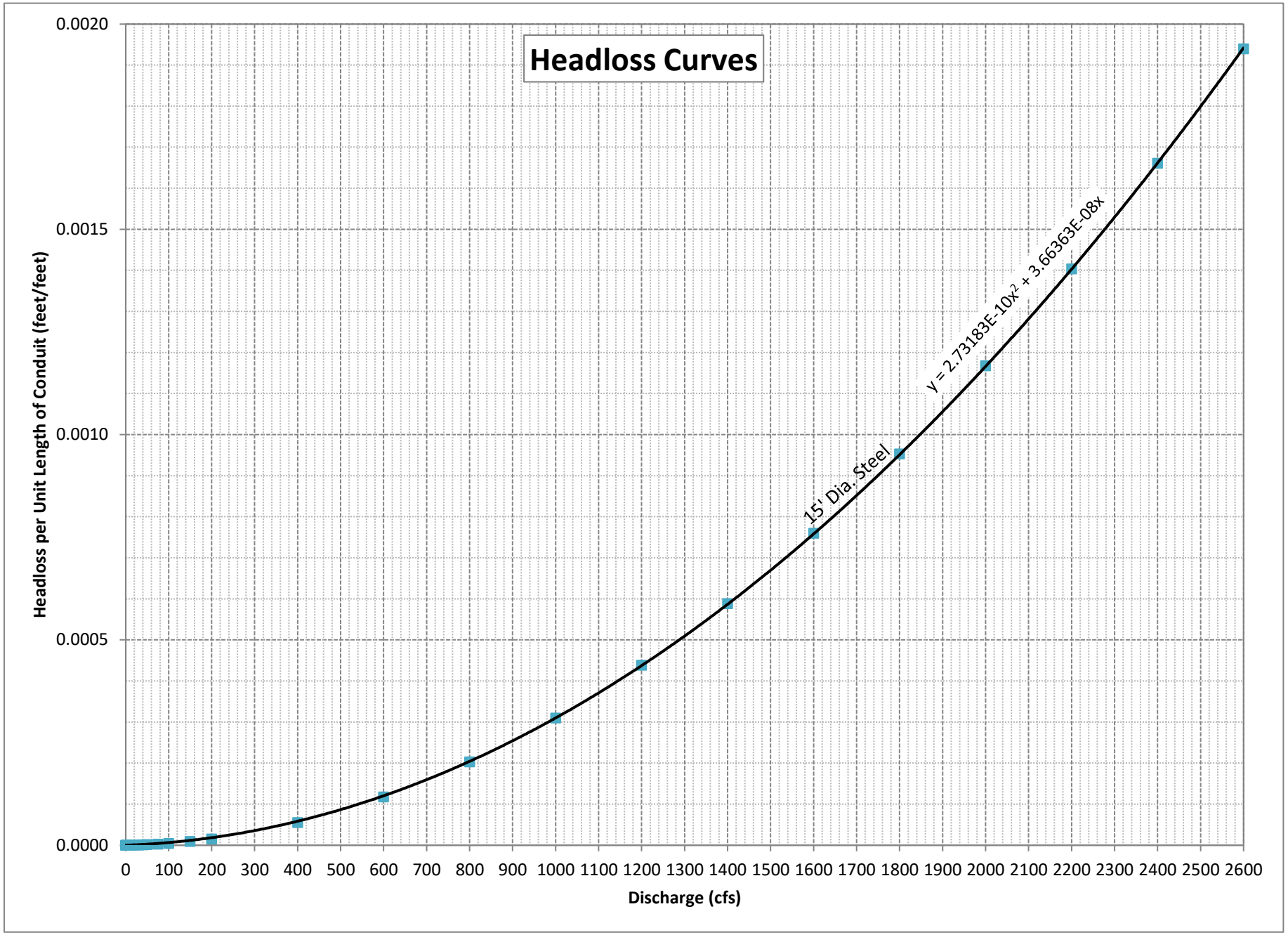
eadloss Coefficients (K	
Discharge (cfs)	15' Dia. Steel
0	1.17E-09
1	1.17E-09
2	9.68E-10
3	8.74E-10
10	6.61E-10
20	5.72E-10
30	5.28E-10
40	4.99E-10
50	4.79E-10
75	4.46E-10
100	4.24E-10
150	3.97E-10
200	3.80E-10
400	3.44E-10
600	3.27E-10
800	3.17E-10
1000	3.10E-10
1200	3.04E-10
1400	3.00E-10
1600	2.97E-10
1800	2.94E-10
2000	2.92E-10
2200	2.90E-10
2400	2.88E-10
2600	2.87E-10
2800	2.86E-10
3000	2.84E-10
99999	*2.84E-10*
D_h =	15

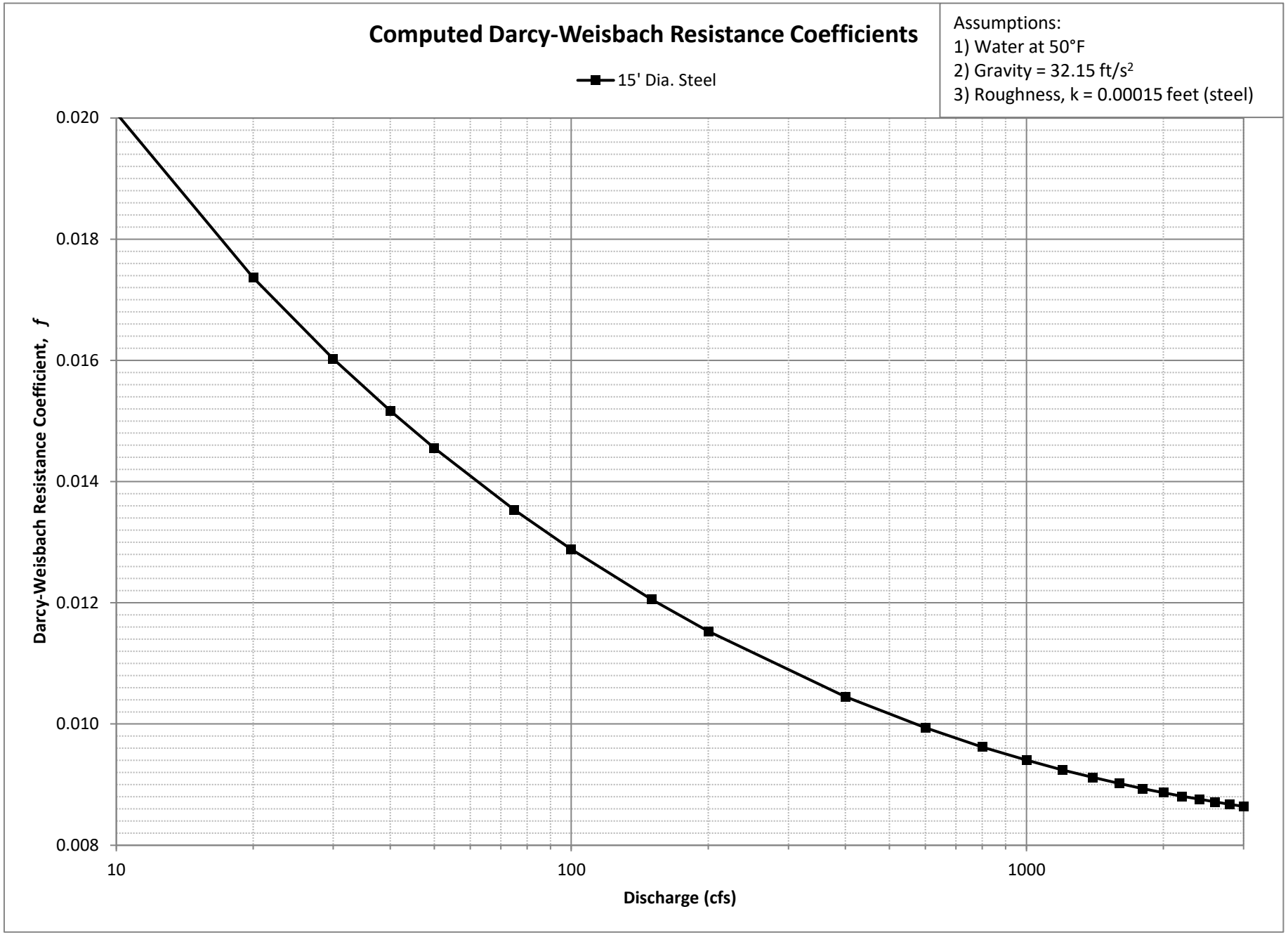
loss per Unit Length of Co	
Discharge (cfs)	15' Dia. Steel
0	0.00E+00
1	1.17E-09
2	3.87E-09
3	7.87E-09
10	6.61E-08
20	2.29E-07
30	4.75E-07
40	7.99E-07
50	1.20E-06
75	2.51E-06
100	4.24E-06
150	8.93E-06
200	1.52E-05
400	5.51E-05
600	1.18E-04
800	2.03E-04
1000	3.10E-04
1200	4.38E-04
1400	5.88E-04
1600	7.60E-04
1800	9.53E-04
2000	1.17E-03
2200	1.40E-03
2400	1.66E-03
2600	1.94E-03
2800	2.24E-03
3000	2.56E-03
99999	2.84E+00
D_h =	15

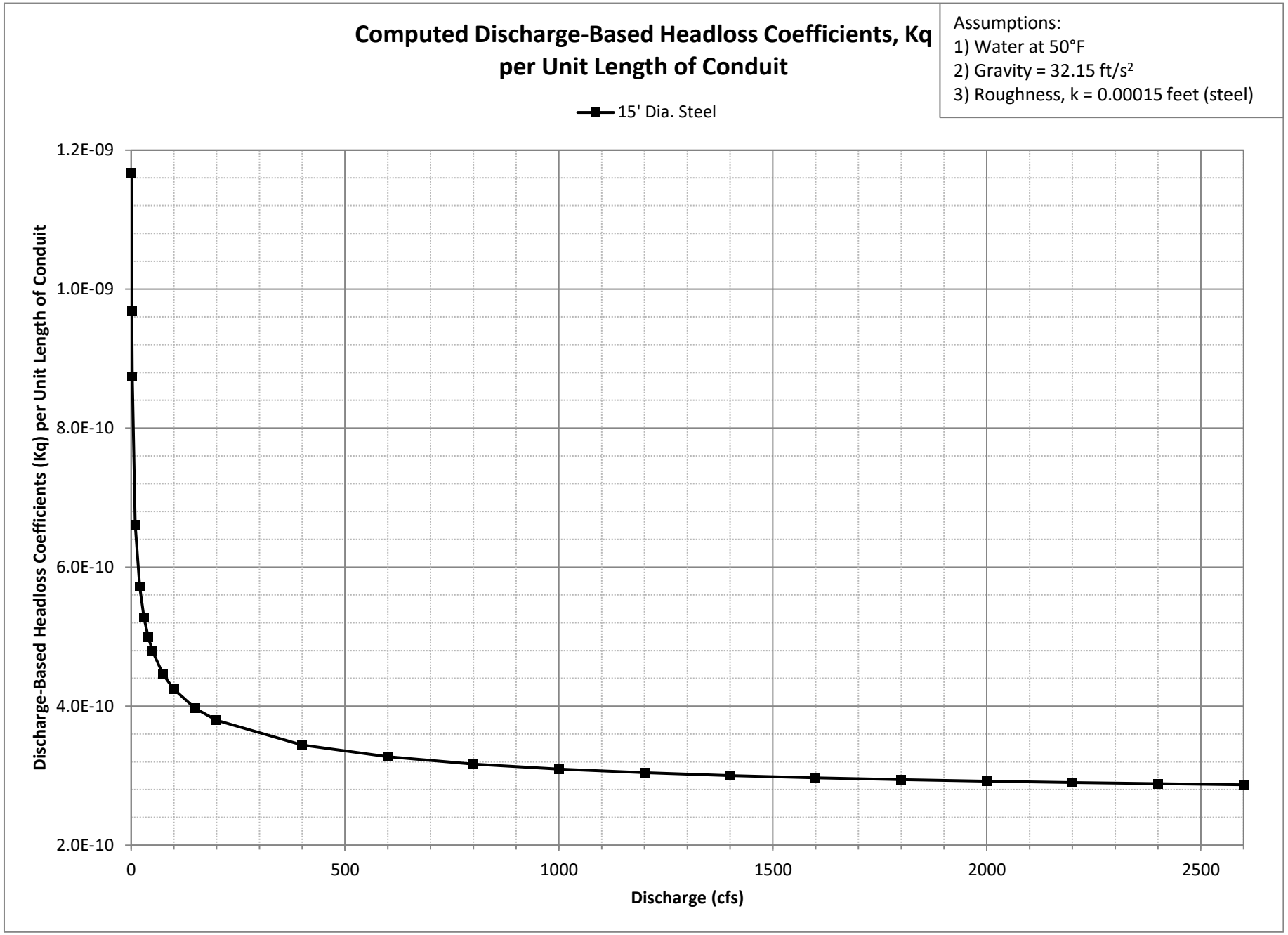
$y=ax^2+bx$; where y=headloss per foot, x=discharge, and a/b are constants determined from trendline equation

a = 2.73183E-10

b = 3.66363E-08


Headloss Curves
Headloss per Unit Length of Conduit (feet/feet)
0.0020
0.0015
0.0010
0.0005
0.0000
0 100 200 300 400 500 600 700 800 900 1000 1100 1200 1300 1400 1500 1600 1700 1800 1900 2000 2100 2200 2300 2400 2500 2600
Discharge (cfs)
15' Dia. Steel
y = 2.73183E-10x² + 3.66363E-08x


Computed Darcy-Weisbach Resistance Coefficients
15' Dia. Steel
Assumptions:
1) Water at 50°F
2) Gravity = 32.15 ft/s²
3) Roughness, k = 0.00015 feet (steel)
Darcy-Weisbach Resistance Coefficient, f
0.020
0.018
0.016
0.014
0.012
0.010
0.008
10
100
1000
Discharge (cfs)


Computed Discharge-Based Headloss Coefficients, Kq per Unit Length of Conduit
Assumptions:
1) Water at 50°F
2) Gravity = 32.15 ft/s²
3) Roughness, k = 0.00015 feet (steel)
15' Dia. Steel
Discharge-Based Headloss Coefficients (Kq) per Unit Length of Conduit
1.2E-09
1.0E-09
8.0E-10
6.0E-10
4.0E-10
2.0E-10
0
500
1000
1500
2000
2500
Discharge (cfs)

Pensacola Turbine-Generator Efficiency Hill Curve with Air Valves Closed

Discharge	Total Turbine-Generator Efficiency (%) vs. Net Head (ft)												
(cfs)	0	95	100	105	110	115	117.5	120	125	130	135	140	999
0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
700	0.0%	60.6%	54.1%	47.3%	40.4%	32.9%	28.3%	23.9%	16.2%	12.9%	12.2%	11.6%	0.0%
750	0.0%	68.2%	63.5%	56.2%	50.6%	45.1%	42.4%	39.7%	34.6%	31.9%	31.3%	30.6%	0.0%
800	0.0%	72.6%	72.0%	66.4%	60.9%	55.4%	52.7%	50.2%	47.2%	46.0%	45.6%	45.2%	0.0%
850	0.0%	74.8%	75.1%	74.5%	71.8%	65.9%	63.2%	61.5%	58.5%	57.7%	57.4%	57.0%	0.0%
900	0.0%	76.5%	77.0%	77.0%	75.7%	73.9%	73.4%	72.5%	69.9%	69.6%	69.2%	68.9%	0.0%
950	0.0%	77.7%	78.4%	78.6%	77.9%	76.4%	76.0%	75.5%	74.8%	74.4%	74.3%	74.3%	0.0%
1000	0.0%	78.7%	79.6%	79.9%	79.4%	78.3%	77.8%	77.5%	76.6%	76.0%	75.7%	75.5%	0.0%
1050	0.0%	79.3%	80.4%	81.0%	80.6%	79.7%	79.4%	79.0%	78.1%	77.4%	77.0%	76.7%	0.0%
1100	0.0%	79.7%	80.8%	81.6%	81.5%	80.9%	80.6%	80.2%	79.5%	78.7%	78.3%	77.9%	0.0%
1150	0.0%	80.0%	81.2%	81.9%	82.2%	81.8%	81.6%	81.3%	80.6%	80.0%	79.5%	79.1%	0.0%
1200	0.0%	80.4%	81.4%	82.2%	82.9%	82.6%	82.3%	82.1%	81.7%	81.1%	80.6%	80.2%	0.0%
1250	0.0%	80.8%	81.6%	82.5%	83.3%	83.3%	83.1%	82.9%	82.5%	82.1%	81.7%	81.2%	0.0%
1300	0.0%	81.2%	81.9%	82.8%	83.6%	84.0%	83.8%	83.7%	83.4%	83.0%	82.6%	82.2%	0.0%
1350	0.0%	81.7%	82.4%	83.2%	83.9%	84.5%	84.4%	84.3%	84.1%	83.8%	83.5%	83.1%	0.0%
1400	0.0%	82.2%	82.9%	83.6%	84.2%	84.8%	85.0%	84.9%	84.8%	84.5%	84.3%	84.0%	0.0%
1450	0.0%	82.7%	83.5%	84.1%	84.6%	85.1%	85.3%	85.5%	85.5%	85.3%	85.0%	84.7%	0.0%
1500	0.0%	83.2%	84.0%	84.7%	85.2%	85.7%	85.9%	86.1%	86.2%	86.0%	85.7%	85.4%	0.0%
1550	0.0%	83.8%	84.6%	85.3%	85.8%	86.2%	86.5%	86.6%	86.8%	86.7%	86.4%	86.1%	0.0%
1600	0.0%	84.7%	85.4%	86.0%	86.5%	86.9%	87.0%	87.2%	87.4%	87.4%	87.1%	86.8%	0.0%
1650	0.0%	85.6%	86.2%	86.8%	87.2%	87.5%	87.6%	87.7%	88.0%	88.1%	87.8%	87.5%	0.0%
1700	0.0%	86.5%	87.0%	87.6%	88.0%	88.2%	88.3%	88.4%	88.7%	88.8%	88.6%	88.2%	0.0%
1750	0.0%	87.4%	88.0%	88.5%	88.9%	88.9%	89.0%	89.1%	89.4%	89.6%	89.4%	89.0%	0.0%
1800	0.0%	88.5%	88.9%	89.3%	89.6%	89.9%	89.9%	90.0%	90.1%	90.2%	90.2%	89.7%	0.0%
1850	0.0%	89.5%	89.7%	90.1%	90.4%	90.6%	90.7%	90.8%	90.8%	90.8%	90.8%	90.5%	0.0%
1900	0.0%	90.0%	90.5%	90.8%	91.1%	91.2%	91.3%	91.4%	91.4%	91.4%	91.3%	91.0%	0.0%
1950	0.0%	89.9%	90.7%	91.3%	91.5%	91.6%	91.7%	91.8%	91.9%	91.8%	91.8%	91.5%	0.0%
2000	0.0%	89.5%	90.0%	91.0%	91.3%	91.5%	91.6%	91.7%	91.9%	92.0%	91.8%	91.4%	0.0%
2050	0.0%	89.1%	89.5%	90.3%	90.9%	91.2%	91.3%	91.4%	91.5%	91.6%	91.7%	91.3%	0.0%
2100	0.0%	88.5%	89.1%	89.6%	90.4%	90.6%	90.8%	91.0%	91.1%	91.2%	91.3%	91.1%	0.0%
2150	0.0%	87.7%	88.7%	89.2%	89.8%	90.2%	90.3%	90.4%	90.7%	90.8%	90.8%	90.7%	0.0%
2200	0.0%	87.0%	88.0%	88.7%	89.3%	89.8%	89.9%	90.0%	90.1%	90.3%	90.4%	90.5%	0.0%
2250	0.0%	86.2%	87.2%	88.1%	88.8%	89.4%	89.6%	89.7%	89.8%	89.9%	90.0%	90.2%	0.0%
2300	0.0%	85.5%	86.5%	87.4%	88.2%	88.9%	89.1%	89.3%	89.4%	89.5%	89.7%	89.8%	0.0%
2350	0.0%	84.6%	85.7%	86.6%	87.5%	88.2%	88.5%	88.7%	89.0%	89.2%	89.2%	89.3%	0.0%
2400	0.0%	83.6%	84.8%	85.8%	86.7%	87.5%	87.8%	88.0%	88.4%	88.7%	88.8%	88.7%	0.0%
2450	0.0%	82.3%	83.7%	84.9%	85.9%	86.7%	87.0%	87.3%	87.7%	88.1%	88.3%	88.1%	0.0%
2500	0.0%	80.7%	82.5%	83.9%	84.9%	85.7%	86.0%	86.4%	86.9%	87.4%	87.6%	87.5%	0.0%
2550	0.0%	78.0%	80.9%	82.5%	83.7%	84.6%	85.0%	85.4%	86.0%	86.6%	86.8%	86.9%	0.0%
2600	0.0%	74.7%	78.1%	80.7%	82.3%	83.4%	83.9%	84.3%	85.0%	85.6%	85.9%	86.0%	0.0%

Pensacola Turbine-Generator Efficiency Hill Curve with Air Valves Fully Open (90 degrees open)

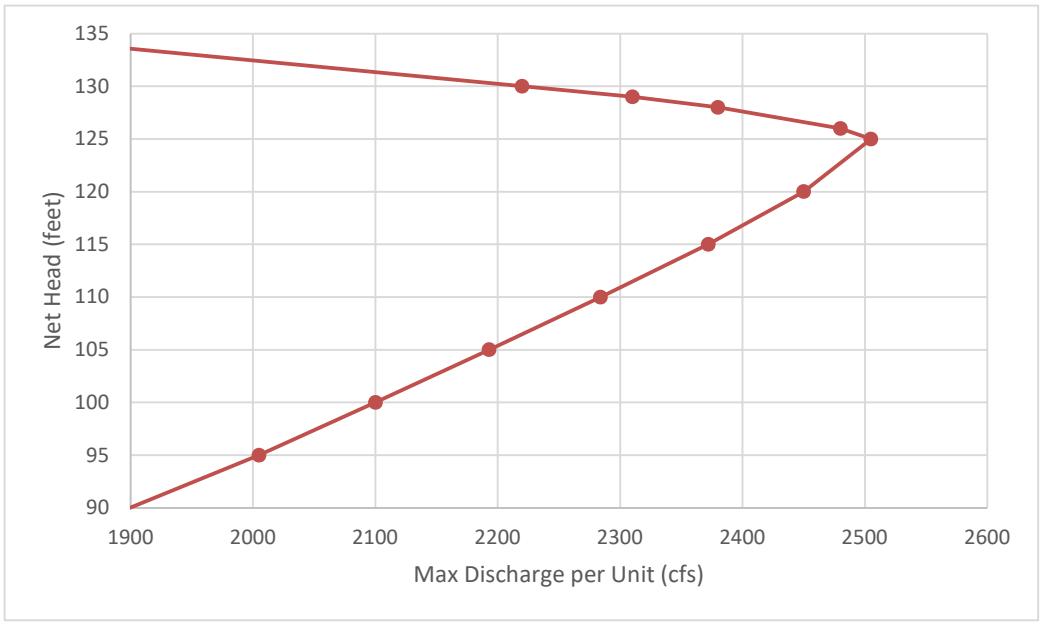
Discharge	Total Turbine-Generator Efficiency (%) vs. Net Head (ft)												
(cfs)	0	95	100	105	110	115	117.5	120	125	130	135	140	999
0	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%	0.0%
700	0.0%	40.3%	36.0%	31.5%	26.9%	21.9%	18.9%	15.9%	10.8%	8.6%	8.1%	7.7%	0.0%
750	0.0%	38.0%	35.4%	31.3%	28.2%	25.1%	23.7%	22.2%	19.3%	17.8%	17.5%	17.1%	0.0%
800	0.0%	39.1%	38.8%	35.8%	32.8%	29.9%	28.4%	27.1%	25.5%	24.8%	24.6%	24.4%	0.0%
850	0.0%	39.4%	39.6%	39.2%	37.8%	34.7%	33.3%	32.4%	30.8%	30.4%	30.2%	30.0%	0.0%
900	0.0%	39.7%	40.0%	40.0%	39.3%	38.3%	38.1%	37.6%	36.3%	36.1%	35.9%	35.7%	0.0%
950	0.0%	44.0%	44.4%	44.4%	44.0%	43.2%	43.0%	42.7%	42.3%	42.1%	42.0%	42.0%	0.0%
1000	0.0%	48.4%	48.9%	49.1%	48.8%	48.1%	47.9%	47.6%	47.1%	46.7%	46.6%	46.4%	0.0%
1050	0.0%	50.7%	51.4%	51.8%	51.6%	51.0%	50.8%	50.6%	50.0%	49.6%	49.3%	49.1%	0.0%
1100	0.0%	53.1%	53.9%	54.4%	54.4%	54.0%	53.8%	53.5%	53.0%	52.6%	52.3%	52.0%	0.0%
1150	0.0%	55.6%	56.4%	56.9%	57.1%	56.9%	56.7%	56.6%	56.1%	55.6%	55.3%	55.0%	0.0%
1200	0.0%	58.2%	58.9%	59.5%	60.1%	59.9%	59.7%	59.5%	59.2%	58.8%	58.4%	58.1%	0.0%
1250	0.0%	60.9%	61.5%	62.2%	62.8%	62.8%	62.6%	62.5%	62.1%	61.8%	61.5%	61.2%	0.0%
1300	0.0%	63.5%	64.1%	64.8%	65.4%	65.7%	65.6%	65.5%	65.2%	64.9%	64.6%	64.3%	0.0%
1350	0.0%	66.4%	66.9%	67.5%	68.1%	68.6%	68.5%	68.4%	68.2%	68.0%	67.7%	67.4%	0.0%
1400	0.0%	69.2%	69.8%	70.3%	70.8%	71.3%	71.5%	71.4%	71.2%	71.1%	70.9%	70.6%	0.0%
1450	0.0%	72.2%	72.9%	73.4%	73.9%	74.3%	74.5%	74.6%	74.6%	74.4%	74.2%	74.0%	0.0%
1500	0.0%	75.1%	75.8%	76.4%	76.8%	77.3%	77.5%	77.7%	77.7%	77.6%	77.5%	77.2%	0.0%
1550	0.0%	77.7%	78.4%	79.1%	79.5%	79.9%	80.1%	80.3%	80.5%	80.4%	80.2%	79.9%	0.0%
1600	0.0%	79.7%	80.3%	80.9%	81.4%	81.7%	81.9%	82.1%	82.3%	82.2%	82.0%	81.8%	0.0%
1650	0.0%	81.3%	81.9%	82.4%	82.8%	83.1%	83.2%	83.3%	83.6%	83.7%	83.4%	83.2%	0.0%
1700	0.0%	82.2%	82.7%	83.3%	83.7%	83.8%	83.9%	84.1%	84.4%	84.5%	84.3%	83.9%	0.0%
1750	0.0%	82.7%	83.3%	83.8%	84.3%	84.3%	84.3%	84.5%	84.8%	84.9%	84.7%	84.4%	0.0%
1800	0.0%	83.3%	83.8%	84.2%	84.5%	84.7%	84.8%	84.9%	85.0%	85.1%	85.1%	84.7%	0.0%
1850	0.0%	84.0%	84.3%	84.7%	85.0%	85.1%	85.3%	85.4%	85.3%	85.4%	85.4%	85.0%	0.0%
1900	0.0%	84.3%	84.8%	85.1%	85.4%	85.5%	85.6%	85.7%	85.7%	85.7%	85.6%	85.3%	0.0%
1950	0.0%	83.9%	84.6%	85.2%	85.3%	85.5%	85.6%	85.7%	85.7%	85.7%	85.7%	85.5%	0.0%
2000	0.0%	83.2%	83.7%	84.6%	85.0%	85.1%	85.2%	85.3%	85.5%	85.6%	85.5%	85.2%	0.0%
2050	0.0%	82.3%	82.7%	83.4%	84.0%	84.3%	84.4%	84.5%	84.6%	84.8%	84.9%	84.6%	0.0%
2100	0.0%	81.3%	81.9%	82.4%	83.1%	83.4%	83.5%	83.6%	83.8%	83.9%	84.1%	83.9%	0.0%
2150	0.0%	80.1%	81.0%	81.5%	82.1%	82.4%	82.5%	82.6%	82.9%	83.1%	83.2%	83.1%	0.0%
2200	0.0%	78.6%	79.5%	80.2%	80.8%	81.2%	81.3%	81.4%	81.6%	81.8%	82.0%	82.1%	0.0%
2250	0.0%	77.1%	78.0%	78.8%	79.5%	80.0%	80.1%	80.3%	80.5%	80.7%	80.9%	81.0%	0.0%
2300	0.0%	75.7%	76.6%	77.4%	78.1%	78.8%	79.0%	79.2%	79.4%	79.6%	79.8%	79.9%	0.0%
2350	0.0%	74.5%	75.5%	76.3%	77.1%	77.7%	78.0%	78.3%	78.6%	78.8%	78.9%	79.1%	0.0%
2400	0.0%	73.3%	74.3%	75.2%	76.0%	76.8%	77.1%	77.3%	77.8%	78.1%	78.2%	78.3%	0.0%
2450	0.0%	72.0%	73.2%	74.2%	75.1%	75.8%	76.2%	76.5%	77.0%	77.3%	77.6%	77.6%	0.0%
2500	0.0%	70.7%	72.3%	73.5%	74.4%	75.1%	75.5%	75.8%	76.5%	76.9%	77.2%	77.3%	0.0%
2550	0.0%	68.5%	71.1%	72.5%	73.6%	74.4%	74.8%	75.2%	75.9%	76.4%	76.8%	77.0%	0.0%
2600	0.0%	66.0%	69.0%	71.2%	72.6%	73.7%	74.2%	74.6%	75.3%	75.9%	76.3%	76.7%	0.0%

Kerr Turbine Efficiency Hill Curve (Refurbished Units 2010)

Discharge	Total Turbine-Generator Efficiency (%) vs. Head (ft)								
(cfs)	0	35	51	54	56	58	61	80	999
0	0%	61.2%	76.5%	76.5%	76.7%	76.9%	76.9%	61.5%	0%
2000	0%	65.6%	83.8%	84.1%	84.4%	84.7%	84.7%	67.9%	0%
2500	0%	66.8%	85.3%	85.5%	85.8%	86.1%	86.2%	69.0%	0%
3000	0%	68.0%	86.7%	86.9%	87.2%	87.6%	87.7%	70.3%	0%
3500	0%	69.2%	88.1%	88.3%	88.7%	89.1%	89.1%	71.3%	0%
4000	0%	70.2%	89.4%	89.6%	89.9%	90.2%	90.1%	72.2%	0%
4500	0%	70.7%	90.0%	90.1%	90.4%	90.7%	90.7%	72.6%	0%
4750	0%	71.2%	90.5%	90.6%	90.9%	91.2%	91.2%	73.0%	0%
5000	0%	71.6%	90.9%	91.1%	91.3%	91.6%	91.6%	73.3%	0%
5250	0%	71.9%	91.3%	91.4%	91.7%	92.0%	91.9%	73.5%	0%
5500	0%	72.1%	91.4%	91.6%	91.9%	92.1%	92.0%	73.6%	0%
6000	0%	72.2%	91.4%	91.5%	91.7%	92.0%	91.9%	73.5%	0%
6500	0%	72.1%	91.0%	91.1%	91.3%	91.6%	91.5%	73.2%	0%
7000	0%	71.6%	90.2%	90.3%	90.6%	90.8%	90.7%	72.6%	0%
7500	0%	71.5%	89.8%	89.9%	90.2%	90.4%	90.3%	72.2%	0%
8500	0%	70.1%	87.9%	88.0%	88.2%	88.4%	88.2%	70.5%	0%
9000	0%	69.3%	87.0%	87.0%	87.2%	87.3%	87.2%	69.6%	0%

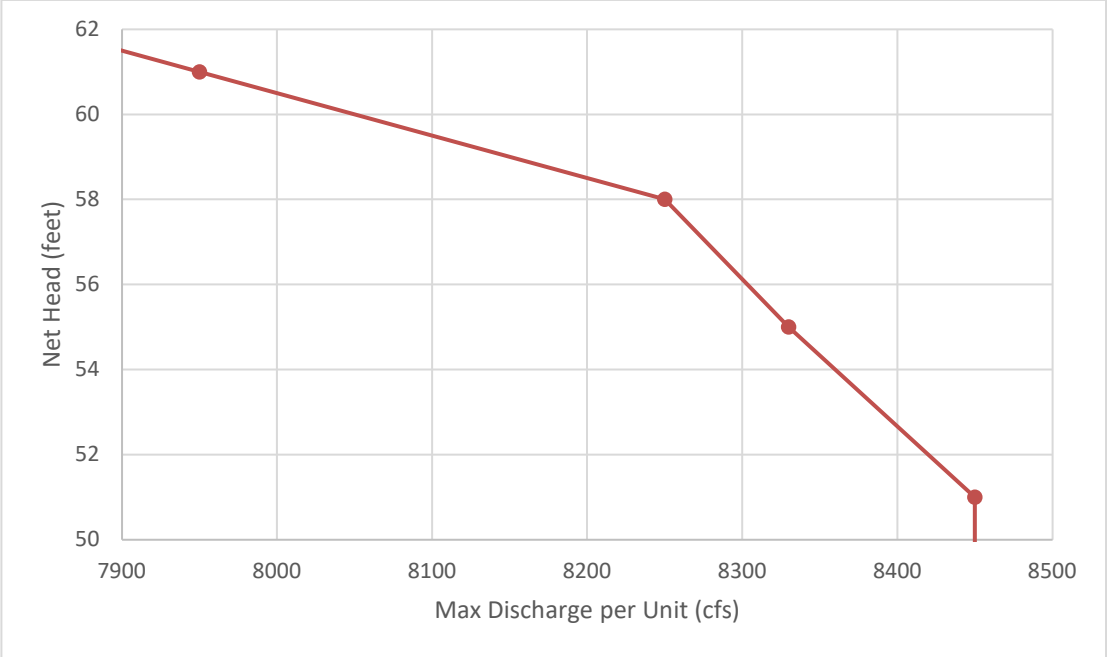
Pensacola Dam Maximum Discharge (cfs) per Unit vs. Net HeadDischarge Limited by Cavitation - 6 Units Total

Net Head (ft)	Max Discharge per Unit (cfs)	Max Discharge Total (cfs)
0	0	0
95	2005	12030
100	2100	12600
105	2193	13158
110	2284	13704
115	2372	14232
120	2450	14700
125	2505	15030
126	2480	14880
128	2380	14280
129	2310	13860
130	2220	13320
154.67	0	0
999.00	0	0



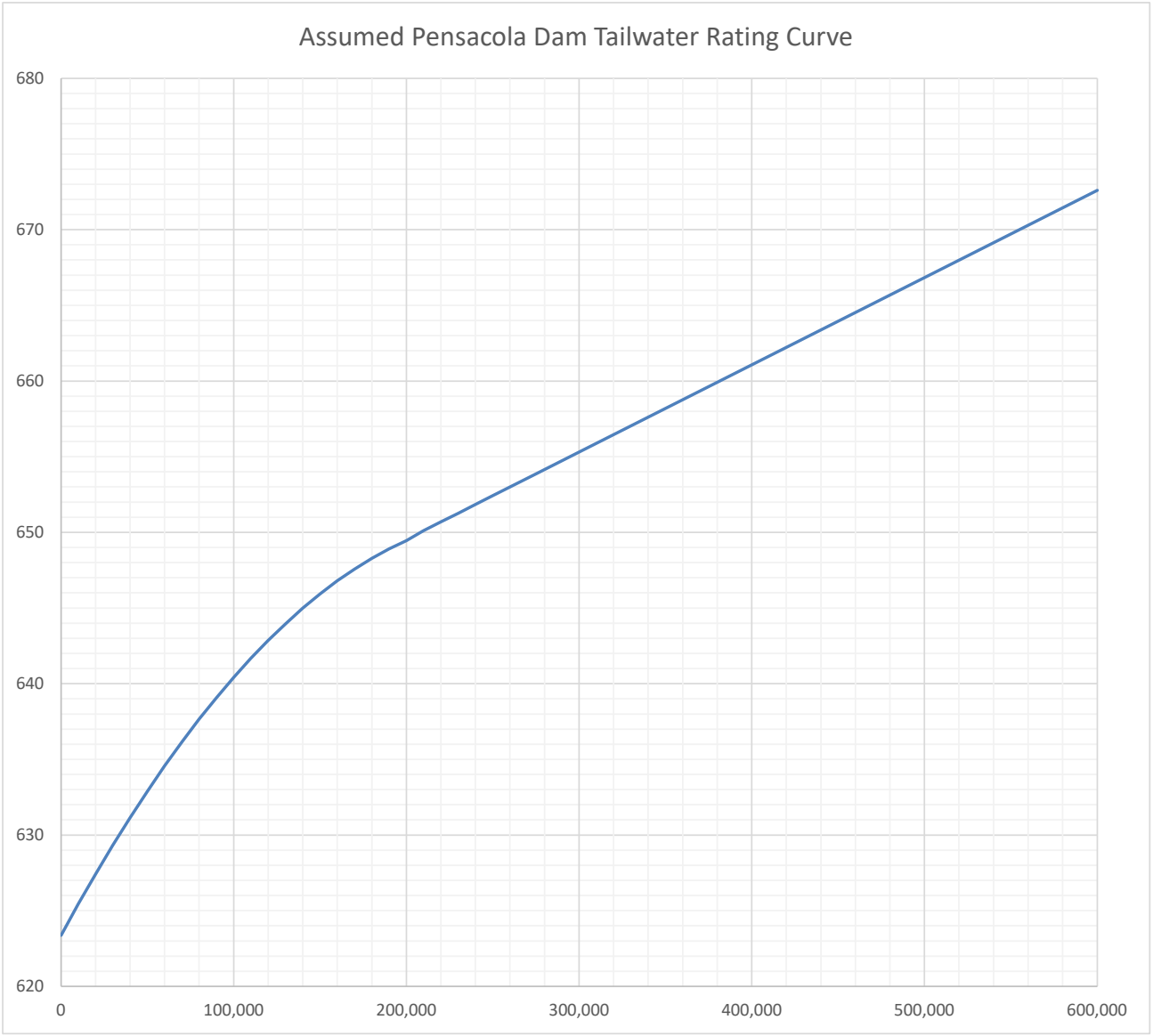
Kerr Dam Maximum Discharge (cfs) per Unit vs. Net HeadDischarge Limited by Cavitation - 4 Units Total

Net Head (ft)	Max Discharge per Unit (cfs)	Max Discharge Total (cfs)
0	8450	33800
51	8450	33800
55	8330	33320
58	8250	33000
61	7950	31800
140.50	0	0
999	0	0



Pensacola Dam Tailwater Rating Curve

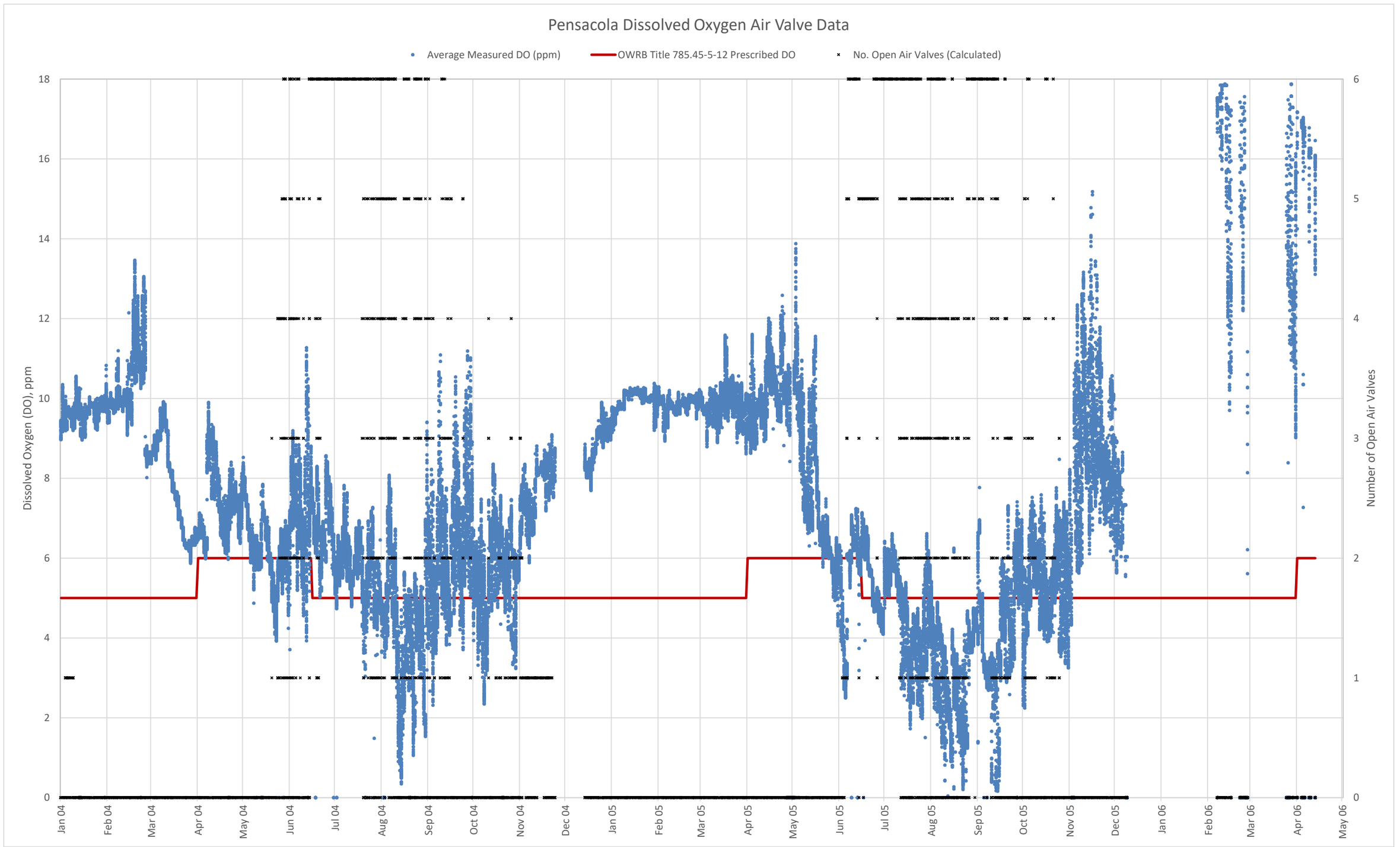
Discharge (cfs)	TW Elev (ft PD)
0	623.37
10000	625.43
20000	627.42
30000	629.32
40000	631.15
50000	632.89
60000	634.56
70000	636.14
80000	637.65
90000	639.07
100000	640.41
110000	641.68
120000	642.86
130000	643.97
140000	644.99
150000	645.93
160000	646.80
170000	647.58
180000	648.28
190000	648.90
200000	649.45
210000	650.11
220000	650.69
230000	651.27
240000	651.84
250000	652.42
275000	653.86
300000	655.30
600000	672.61



SAMPLE TURBINE-GENERATOR OUTAGE DATA

Plant	Unit No.	Outage Begin	Outage End
Pensacola	1	5/15/2003 13:00	5/15/2003 16:00
Pensacola	1	9/19/2004 5:00	10/3/2004 5:00
Pensacola	1	9/29/2004 7:00	10/3/2004 5:00
Pensacola	1	10/3/2004 5:00	10/6/2004 5:00
Pensacola	1	10/6/2004 5:00	10/15/2004 5:00
Pensacola	1	10/15/2004 5:00	2/1/2005 6:00
Pensacola	1	1/18/2005 6:00	2/15/2005 6:00
Pensacola	1	10/24/2005 5:00	10/25/2005 5:00
Pensacola	1	12/13/2005 23:00	12/16/2005 23:00
Pensacola	1	12/19/2005 6:00	12/20/2005 6:00
Pensacola	1	8/10/2006 5:00	8/15/2006 5:00
Pensacola	1	9/19/2006 12:00	9/22/2006 20:00
Pensacola	1	9/25/2006 20:00	9/27/2006 5:00
Pensacola	1	9/27/2006 12:00	10/2/2006 5:00
Pensacola	1	9/27/2006 14:00	10/2/2006 5:00
Pensacola	1	10/3/2006 13:00	10/5/2006 5:00
Pensacola	1	10/5/2006 5:00	10/6/2006 5:00
Pensacola	1	10/6/2006 5:00	10/8/2006 5:00
Pensacola	1	11/28/2006 18:00	12/31/2006 6:00
Pensacola	1	3/14/2007 13:00	3/15/2007 4:00
Pensacola	1	3/14/2007 19:00	3/15/2007 4:00
Pensacola	1	3/15/2007 14:00	3/17/2007 19:00
Pensacola	1	8/23/2007 5:00	8/25/2007 5:00
Pensacola	1	9/26/2007 13:00	9/29/2007 5:00
Pensacola	1	11/13/2007 18:00	11/15/2007 6:00
Pensacola	1	3/26/2008 20:08	3/29/2008 4:00
Pensacola	1	3/27/2008 12:00	3/29/2008 4:00
Pensacola	1	10/27/2009 13:00	1/30/2010 6:00
Pensacola	1	4/20/2010 5:00	4/30/2010 5:00
Pensacola	1	6/25/2010 11:00	6/25/2010 12:00
Pensacola	1	6/28/2010 11:00	6/28/2010 12:00
Pensacola	1	9/9/2010 20:25	9/10/2010 17:00
Pensacola	1	7/26/2011 17:05	7/31/2011 5:00
Pensacola	1	10/25/2011 15:02	12/31/2012 23:59
Pensacola	1	10/25/2011 15:02	12/31/2013 22:02
Pensacola	1	11/22/2011 8:10	11/23/2011 0:00
Pensacola	1	12/13/2011 8:00	12/13/2011 11:00
Pensacola	1	12/19/2011 8:00	12/19/2011 10:00
Pensacola	1	12/20/2011 9:31	12/21/2011 16:00
Pensacola	1	12/23/2011 9:19	12/23/2011 16:00
Pensacola	1	2/28/2012 8:11	3/6/2012 8:00
Pensacola	1	3/21/2012 13:05	3/22/2012 16:00
Pensacola	1	4/5/2012 9:05	4/5/2012 10:00
Pensacola	1	4/20/2012 13:30	4/20/2012 16:00
Pensacola	1	4/27/2012 9:41	4/27/2012 12:00
Pensacola	1	7/13/2012 9:39	8/1/2012 17:39
Pensacola	1	7/26/2012 8:03	7/26/2012 16:00
Pensacola	1	8/1/2012 9:36	8/2/2012 16:00
Pensacola	1	8/8/2012 14:59	8/8/2012 16:00
Pensacola	1	8/21/2012 12:40	8/21/2012 16:01
Pensacola	1	9/14/2012 9:35	9/14/2012 16:00
Pensacola	1	9/17/2012 8:03	9/17/2012 10:00
Pensacola	1	9/28/2012 12:31	9/29/2012 16:00
Pensacola	1	9/28/2012 12:53	9/29/2012 16:00
Pensacola	1	9/28/2012 13:00	9/29/2012 16:00
Pensacola	1	4/8/2013 7:33	4/8/2013 12:41
Pensacola	1	7/24/2013 18:32	7/24/2013 18:56
Pensacola	1	8/13/2013 15:10	8/13/2013 16:33
Pensacola	1	9/19/2013 6:05	9/19/2013 10:59
Pensacola	1	3/19/2014 0:54	3/19/2014 3:32
Pensacola	1	3/26/2014 12:57	3/26/2014 13:18
Pensacola	1	9/2/2014 14:16	9/2/2014 14:49
Pensacola	1	11/18/2014 6:41	11/18/2014 10:20
Pensacola	1	6/20/2015 18:40	6/20/2015 19:14
Pensacola	1	9/21/2015 10:54	9/21/2015 12:30
Pensacola	1	9/24/2015 15:35	9/24/2015 16:27
Pensacola	1	9/28/2015 9:15	12/9/2015 15:50
Pensacola	2	5/15/2003 13:00	5/15/2003 16:00
Pensacola	2	8/14/2003 5:00	8/15/2003 5:00
Pensacola	2	9/5/2004 5:00	9/19/2004 5:00
Pensacola	2	9/25/2004 11:00	10/2/2004 5:00
Pensacola	2	4/4/2005 14:00	4/4/2005 20:00
Pensacola	2	10/31/2005 19:00	12/31/2005 6:00
Pensacola	2	1/1/2006 18:00	2/28/2006 6:00
Pensacola	2	3/1/2006 6:00	3/31/2006 6:00
Pensacola	2	8/10/2006 5:00	8/15/2006 5:00
Pensacola	2	9/19/2006 12:00	9/22/2006 20:00
Pensacola	2	9/25/2006 20:00	9/27/2006 5:00
Pensacola	2	9/27/2006 12:00	10/2/2006 5:00
Pensacola	2	9/27/2006 14:00	10/2/2006 5:00
Pensacola	2	10/3/2006 13:00	10/5/2006 5:00
Pensacola	2	10/5/2006 5:00	10/6/2006 5:00
Pensacola	2	10/6/2006 5:00	10/8/2006 5:00
Pensacola	2	11/28/2006 18:00	12/31/2006 6:00
Pensacola	2	3/14/2007 13:00	3/15/2007 4:00
Pensacola	2	3/14/2007 19:00	3/15/2007 4:00
Pensacola	2	3/15/2007 14:00	3/17/2007 19:00
Pensacola	2	10/3/2007 17:00	10/4/2007 21:00
Pensacola	2	11/14/2007 3:50	11/15/2007 6:00
Pensacola	2	11/15/2007 6:00	11/22/2007 6:00
Pensacola	2	11/24/2007 6:00	11/30/2007 6:00
Pensacola	2	11/30/2007 6:00	12/31/2007 6:00
Pensacola	2	3/25/2008 12:00	3/27/2008 4:00
Pensacola	2	1/30/2009 22:04	2/3/2009 6:00
Pensacola	2	2/3/2009 6:00	2/7/2009 6:00
Pensacola	2	5/10/2010 20:14	5/20/2010 5:00
Pensacola	2	6/25/2010 11:00	6/25/2010 12:00
Pensacola	2	10/4/2010 5:00	1/21/2011 22:00
Pensacola	2	8/20/2011 18:30	8/23/2011 5:00
Pensacola	2	8/25/2011 0:00	8/26/2011 5:00
Pensacola	2	8/31/2011 20:02	9/1/2011 20:30
Pensacola	2	10/3/2011 5:00	12/31/2011 6:00
Pensacola	2	10/25/2011 15:02	12/31/2012 23:59
Pensacola	2	10/25/2011 15:02	12/31/2013 22:02
Pensacola	2	12/13/2011 8:00	12/13/2011 11:00
Pensacola	2	12/20/2011 10:22	12/21/2011 16:00
Pensacola	2	4/27/2012 9:41	4/27/2012 12:00
Pensacola	2	5/7/2012 21:31	5/7/2012 23:00
Pensacola	2	7/17/2012 10:42	7/18/2012 16:00
Pensacola	2	8/8/2012 14:26	8/8/2012 16:00
Pensacola	2	8/21/2012 12:40	8/21/2012 16:03
Pensacola	2	8/27/2012 10:23	8/27/2012 16:00
Pensacola	2	9/12/2012 8:13	9/12/2012 16:12
Pensacola	2	9/17/2012 8:03	9/17/2012 10:00
Pensacola	2	8/13/2013 15:10	8/13/2013 15:42
Pensacola	2	9/19/2013 6:05	9/19/2013 10:59
Pensacola	2	12/22/2013 19:52	12/22/2013 20:13
Pensacola	2	7/6/2014 20:15	7/6/2014 21:30
Pensacola	2	10/29/2014 16:05	10/29/2014 16:06
Pensacola	2	1/6/2015 7:40	1/6/2015 9:44
Pensacola	2	1/12/2015 9:43	1/26/2015 14:47
Pensacola	2	3/8/2015 7:23	3/8/2015 9:38
Pensacola	2	3/21/2015 14:03	3/21/2015 16:10
Pensacola	2	6/20/2015 18:40	6/20/2015 19:14
Pensacola	2	9/24/2015 15:35	9/24/2015 16:28
Pensacola	2	10/2/2015 17:11	10/2/2015 20:55
Pensacola	2	10/29/2015 9:08	10/30/2015 10:36
Pensacola	3	2/10/2003 6:00	3/1/2003 6:00
Pensacola	3	5/15/2003 13:00	5/17/2003 5:00
Pensacola	3	8/14/2003 5:00	8/15/2003 5:00
Pensacola	3	8/23/2003 5:00	8/28/2003 5:00
Pensacola	3	12/1/2003 6:00	3/1/2004 6:00
Pensacola	3	6/10/2004 5:00	6/14/2004 5:00
Pensacola	3	9/2/2004 5:00	9/5/2004 5:00
Pensacola	3	9/9/2004 13:00	9/10/2004 21:00
Pensacola	3	5/31/2005 17:00	6/1/2005 21:00
Pensacola	3	6/1/2005 21:00	6/2/2005 17:00
Pensacola	3	12/13/2005 23:00	12/16/2005 23:00
Pensacola	3	12/17/2005 6:00	12/20/2005 6:00
Pensacola	3	2/27/2006 6:00	3/4/2006 6:00
Pensacola	3	8/10/2006 5:00	8/15/2006 5:00
Pensacola	3	9/19/2006 12:00	9/22/2006 20:00
Pensacola	3	9/25/2006 20:00	9/27/2006 5:00
Pensacola	3	9/27/2006 12:00	10/2/2006 5:00
Pensacola	3	9/27/2006 14:00	10/2/2006 5:00
Pensacola	3	10/3/2006 13:00	10/5/2006 5:00
Pensacola	3	10/3/2006 13:02	10/5/2006 5:00
Pensacola	3	10/5/2006 5:00	10/6/2006 5:00
Pensacola	3	10/6/2006 5:00	10/8/2006 5:00
Pensacola	3	11/28/2006 18:00	12/31/2006 6:00
Pensacola	3	3/8/2007 5:00	3/8/2007 18:00
Pensacola	3	3/14/2007 13:00	3/15/2007 4:00
Pensacola	3	3/14/2007 19:00	3/15/2007 4:00
Pensacola	3	3/15/2007 14:00	3/17/2007 19:00
Pensacola	3	3/12/2008 15:00	3/14/2008 14:00
Pensacola	3	1/7/2009 13:32	3/1/2009 20:00
Pensacola	3	1/7/2009 14:00	3/1/2009 20:00
Pensacola	3	6/25/2010 11:00	6/25/2010 12:00
Pensacola	3	8/10/2010 12:00	8/17/2010 21:00
Pensacola	3	8/1/2011 12:38	8/5/2011 21:00
Pensacola	3	8/1/2011 13:00	8/5/2011 21:00
Pensacola	3	10/25/2011 15:02	12/31/2012 23:59
Pensacola	3	10/25/2011 15:02	12/31/2013 22:02
Pensacola	3	12/13/2011 8:00	12/13/2011 11:00
Pensacola	3	12/20/2011 12:23	12/20/2011 20:00
Pensacola	3	12/20/2011 19:05	12/21/2011 16:00
Pensacola	3	1/12/2012 8:32	1/12/2012 10:00
Pensacola	3	2/18/2012 20:20	2/19/2012 0:01
Pensacola	3	2/26/2012 5:30	2/27/2012 10:00
Pensacola	3	4/27/2012 9:41	4/27/2012 12:00
Pensacola	3	7/16/2012 12:04	7/16/2012 16:00
Pensacola	3	7/17/2012 8:19	7/18/2012 16:00
Pensacola	3	8/8/2012 13:45	8/8/2012 16:03
Pensacola	3	8/28/2012 12:20	8/28/2012 16:00
Pensacola	3	8/30/2012 8:36	8/30/2012 16:00
Pensacola	3	9/10/2012 7:57	9/10/2012 13:59
Pensacola	3	9/17/2012 8:03	9/17/2012 10:00
Pensacola	3	7/8/2013 12:48	7/8/2013 14:51
Pensacola	3	8/13/2013 15:10	8/13/2013 15:42
Pensacola	3	9/19/2013 6:05	9/19/2013 10:59
Pensacola	3	12/22/2013 20:22	12/22/2013 20:34
Pensacola	3	10/1/2014 0:01	12/22/2014 7:25
Pensacola	3	6/20/2015 18:40	6/20/2015 19:14
Pensacola	3	7/24/2015 20:37	7/25/2015 9:45
Pensacola	3	8/11/2015 21:39	8/12/2015 2:16
Pensacola	3	8/12/2015 9:29	8/12/2015 11:19
Pensacola	3	9/24/2015 15:35	9/24/2015 16:27
Pensacola	3	10/2/2015 15:30	10/2/2015 20:55
Pensacola	3	11/13/2015 19:42	11/14/2015 10:13
Pensacola	3	12/16/2015 8:01	12/16/2015 8:54
Pensacola	4	1/29/2003 14:30	1/29/2003 17:00
Pensacola	4	2/7/2003 6:00	2/8/2003 6:00
Pensacola	4	2/10/2003 6:00	2/11/2003 6:00
Pensacola	4	2/11/2003 6:00	2/13/2003 6:00
Pensacola	4	9/8/2003 14:00	10/9/2003 5:00
Pensacola	4	10/31/2003 6:00	11/4/2003 6:00
Pensacola	4	4/5/2005 14:00	4/5/2005 20:00
Pensacola	4	12/13/2005 23:00	12/16/2005 23:00
Pensacola	4	12/17/2005 6:00	12/20/2005 6:00
Pensacola	4	8/10/2006 5:00	8/15/2006 5:00
Pensacola	4	9/19/2006 12:00	9/22/2006 20:00
Pensacola	4	9/25/2006 20:00	9/27/2006 5:00
Pensacola	4	9/27/2006 14:00	10/2/2006 5:00
Pensacola	4	10/3/2006 13:00	10/5/2006 5:00
Pensacola	4	10/5/2006 5:00	10/6/2006 5:00
Pensacola	4	10/6/2006 5:00	10/8/2006 5:00
Pensacola	4	11/28/2006 18:00	12/31/2006 6:00
Pensacola	4	3/14/2007 19:00	3/15/2007 4:00
Pensacola	4	3/29/2008 12:00	3/31/2008 4:00
Pensacola	4	12/19/2008 6:00	12/29/2009 14:33
Pensacola	4	5/13/2010 12:30	5/15/2010 17:00
Pensacola	4	6/25/2010 11:00	6/25/2010 18:00
Pensacola	4	12/13/2010 12:00	3/11/2011 22:00
Pensacola	4	10/3/2011 6:00	12/31/2011 6:00
Pensacola	4	10/3/2011 8:13	12/31/2011 0:00
Pensacola	4	10/3/2011 13:13	12/31/2011 6:00
Pensacola	4	10/25/2011 15:02	12/31/2012 23:59
Pensacola	4	10/25/2011 15:02	12/31/2013 22:02
Pensacola	4	12/20/2011 12:52	12/20/2011 14:00
Pensacola	4	3/13/2012 7:13	3/13/2012 12:00
Pensacola	4	3/14/2012 8:29	3/14/2012 16:00
Pensacola	4	3/14/2012 13:42	3/14/2012 16:00
Pensacola	4	7/19/2012 12:20	7/20/2012 16:00
Pensacola	4	7/23/2012 8:10	7/23/2012 16:00
Pensacola	4	8/9/2012 13:04	8/9/2012 16:00
Pensacola	4	8/21/2012 13:16	8/21/2012 16:00
Pensacola	4	8/27/2012 12:52	8/28/2012 16:00
Pensacola	4	9/7/2012 8:06	9/8/2012 16:06
Pensacola	4	9/15/2012 0:05	9/15/2012 3:00
Pensacola	4	9/17/2012 8:03	9/17/2012 10:00
Pensacola	4	9/20/2012 5:19	9/20/2012 9:58
Pensacola	4	9/21/2012 7:00	9/21/2012 18:00
Pensacola	4	10/3/2012 9:17	10/3/2012 15:58
Pensacola	4	12/10/2012 8:33	12/10/2012 16:00
Pensacola	4	12/11/2012 8:00	12/11/2012 16:00
Pensacola	4	12/27/2012 8:00	12/27/2012 12:00
Pensacola	4	1/30/2013 13:22	1/30/2013 14:19
Pensacola	4	2/7/2013 9:43	2/7/2013 12:50
Pensacola	4	8/13/2013 15:10	8/13/2013 16:29
Pensacola	4	9/19/2013 6:05	9/19/2013 10:59
Pensacola	4	12/6/2013 18:00	12/7/2013 9:35
Pensacola	4	12/7/2013 9:35	12/7/2013 10:37
Pensacola	4	12/24/2013 9:46	12/24/2013 13:43
Pensacola	4	1/5/2015 5:30	1/5/2015 7:45
Pensacola	4	4/18/2015 15:21	4/18/2015 20:26
Pensacola	4	6/20/2015 18:40	6/20/2015 19:14
Pensacola	4	6/24/2015 10:44	6/24/2015 11:03
Pensacola	4	9/24/2015 15:35	9/24/2015 16:27
Pensacola	4	10/2/2015 15:30	10/2/2015 20:55
Pensacola	5	1/24/2003 15:00	2/3/2003 22:00
Pensacola	5	11/6/2004 13:24	11/8/2004 22:00
Pensacola	5	12/13/2005 23:00	12/16/2005 23:00
Pensacola	5	12/17/2005 6:00	12/20/2005 6:00
Pensacola	5	8/10/2006 5:00	8/15/2006 5:00
Pensacola	5	9/19/2006 12:00	9/22/2006 20:00
Pensacola	5	9/25/2006 20:00	9/27/2006 5:00
Pensacola	5	9/27/2006 12:00	10/2/2006 5:00
Pensacola	5	9/27/2006 14:00	10/2/2006 5:00
Pensacola	5	10/3/2006 13:00	10/5/2006 5:00
Pensacola	5	10/5/2006 5:00	10/6/2006 5:00
Pensacola	5	10/6/2006 5:00	10/8/2006 5:00
Pensacola	5	11/28/2006 18:00	12/31/2006 6:00
Pensacola	5	1/4/2007 16:00	3/4/2007 6:00
Pensacola	5	3/14/2007 19:00	3/15/2007 4:00
Pensacola	5	4/12/2007 13:11	4/17/2007 5:00
Pensacola	5	2/4/2008 15:10	2/5/2008 20:30
Pensacola	5	3/29/2008 18:15	4/2/2008 4:00
Pensacola	5	3/31/2008 12:00	4/2/2008 4:00
Pensacola	5	12/19/2008 6:00	1/31/2009 6:00
Pensacola	5	6/25/2010 11:00	6/25/2010 18:00
Pensacola	5	12/13/2010 12:00	3/11/2011 22:00
Pensacola	5	9/12/2011 18:25	10/1/2011 5:00
Pensacola	5	10/25/2011 15:02	12/31/2012 23:59
Pensacola	5	12/8/2011 14:00	12/8/2011 17:00
Pensacola	5	1/17/2012 10:30	1/18/2012 16:00
Pensacola	5	1/20/2012 11:39	1/20/2012 16:00
Pensacola	5	1/23/2012 14:47	1/24/2012 12:00
Pensacola	5	7/24/2012 12:28	7/25/2012 16:00
Pensacola	5	8/21/2012 13:16	8/21/2012 16:00
Pensacola	5	8/21/2012 13:26	8/21/2012 16:00
Pensacola	5	8/28/2012 8:20	8/28/2012 16:00
Pensacola	5	9/2/2012 20:56	9/3/2012 16:00
Pensacola	5	9/6/2012 8:00	9/6/2012 14:00
Pensacola	5	9/17/2012 8:03	9/17/2012 10:00
Pensacola	5	9/21/2012 7:00	9/21/2012 18:00
Pensacola	5	10/1/2012 0:00	12/31/2012 0:00
Pensacola	5	10/1/2012 8:00	3/11/2013 16:00
Pensacola	5	12/10/2012 8:33	12/10/2012 16:00
Pensacola	5	12/11/2012 8:00	12/11/2012 16:00
Pensacola	5	12/27/2012 8:00	12/27/2012 12:00
Pensacola	5	3/4/2013 9:42	3/4/2013 9:43
Pensacola	5	8/8/2013 2:23	8/8/2013 3:15
Pensacola	5	8/8/2013 14:38	8/8/2013 15:33
Pensacola	5	8/13/2013 15:10	8/13/2013 15:59
Pensacola	5	9/19/2013 6:05	9/19/2013 10:59
Pensacola	5	4/14/2014 18:45	4/14/2014 19:24
Pensacola	5	2/6/2015 13:17	2/6/2015 14:42
Pensacola	5	3/20/2015 9:37	3/20/2015 10:06
Pensacola	5	6/20/2015 18:40	6/20/2015 19:14
Pensacola	5	8/31/2015 14:31	8/31/2015 14:57
Pensacola	5	9/24/2015 15:35	9/24/2015 16:30
Pensacola	5	9/28/2015 9:03	9/28/2015 14:01
Pensacola	5	10/2/2015 15:30	10/2/2015 20:55
Pensacola	5	11/5/2015 8:53	11/6/2015 13:25
Pensacola	6	5/31/2003 5:00	6/15/2003 5:00
Pensacola	6	10/26/2005 5:00	10/27/2005 5:00
Pensacola	6	12/13/2005 23:00	12/16/2005 23:00
Pensacola	6	12/17/2005 6:00	12/20/2005 6:00
Pensacola	6	8/10/2006 5:00	8/15/2006 5:00
Pensacola	6	9/19/2006 12:00	9/22/2006 20:00
Pensacola	6	9/25/2006 20:00	9/27/2006 5:00
Pensacola	6	9/27/2006 12:00	10/2/2006 5:00
Pensacola	6	9/27/2006 14:00	10/5/2006 5:00
Pensacola	6	10/5/2006 5:00	10/6/2006 5:00
Pensacola	6	10/6/2006 5:00	10/8/2006 5:00
Pensacola	6	11/28/2006 18:00	12/31/2006 6:00
Pensacola	6	3/14/2007 19:00	3/15/2007 4:00
Pensacola	6	11/5/2007 14:28	12/5/2007 6:00
Pensacola	6	1/7/2008 6:00	2/7/2008 4:00
Pensacola	6	3/31/2008 18:08	4/4/2008 4:00
Pensacola	6	4/2/2008 12:00	4/4/2008 4:00
Pensacola	6	12/19/2008 6:00	1/31/2009 6:00
Pensacola	6	1/22/2009 16:59	1/24/2009 6:00
Pensacola	6	6/25/2010 11:00	6/25/2010 18:00
Pensacola	6	12/13/2010 12:00	3/11/2011 22:00
Pensacola	6	5/16/2011 19:37	5/18/2011 5:00
Pensacola	6	10/25/2011 15:02	12/31/2012 23:59
Pensacola	6	10/25/2011 15:02	12/31/2013 22:02
Pensacola	6	1/19/2012 9:42	1/20/2012 16:00
Pensacola	6	3/16/2012 5:45	3/16/2012 16:03
Pensacola	6	7/25/2012 7:34	7/25/2012 15:58
Pensacola	6	8/21/2012 13:34	8/21/2012 16:00
Pensacola	6	8/28/2012 9:59	8/28/2012 16:00
Pensacola	6	9/5/2012 7:55	9/6/2012 16:00
Pensacola	6	9/5/2012 23:08	9/6/2012 16:00
Pensacola	6	9/17/2012 8:03	9/17/2012 10:00
Pensacola	6	9/21/2012 7:00	9/21/2012 18:00
Pensacola	6	12/10/2012 8:33	12/10/2012 16:00
Pensacola	6	12/11/2012 8:00	12/11/2012 16:00
Pensacola	6	12/27/2012 8:00	12/27/2012 12:00
Pensacola	6	5/8/2013 16:21	5/8/2013 17:34
Pensacola	6	8/13/2013 15:10	8/13/2013 15:59
Pensacola	6	9/19/2013 6:05	9/19/2013 10:59
Pensacola	6	10/1/2013 8:00	12/10/2013 12:57
Pensacola	6	3/27/2014 14:10	3/27/2014 14:15
Pensacola	6	6/20/2015 18:40	6/20/2015 19:14
Pensacola	6	10/2/2015 15:30	10/2/2015 20:55
Pensacola	6	11/9/2015 18:31	11/10/2015 9:50
Pensacola	6	11/12/2015 8:33	11/12/2015 14:00

Pensacola Dissolved Oxygen Air Valve Data



PREPARED BY

Mead & Hunt

Updated Study Report

Hydrologic and Hydraulic Modeling: Upstream Hydraulic Model

Pensacola Hydroelectric Project
Project No. 1494

September 30, 2022

CONTENTS

Table of Contents

Executive Summary vii

List of Abbreviations and Terms ix

1. Introduction and Background 1

1.1 Project Description 1

1.2 Vertical Datums 1

1.3 Study Plan Proposals and Determination 1

2. Model Development 5

2.1 HEC-RAS Version 5

2.2 Grand Lake 2DFA 5

2.3 Upstream 2DFAs 6

2.4 2DFA Cell Refinement 6

2.5 Cross-Section Adjustments 7

2.6 1D/2D Boundaries 7

2.7 Bridge Geometries 9

2.8 Bank Stations and Ineffective Flow Areas 9

2.9 Spring River 11

2.10 Elk River 12

2.11 Updated Bathymetry 13

2.12 Computational Parameters 15

3. Model Calibration 17

3.1 Stream Gage Data 17

3.1.1 Neosho River near Commerce, OK 17

3.1.2 Neosho River at Miami, OK 17

3.1.3 Tar Creek at 22nd Street Bridge at Miami, OK 18

3.1.4 Spring River near Quapaw, OK 18

3.1.5 Elk River near Tiff City, MO 18

3.1.6 Lake O' the Cherokees at Langley, OK 18

3.2 Historical Events 19

3.2.1 July 2007 19

3.2.2 October 2009 19

3.2.3 December 2015 19

3.2.4 January 2017 20

3.2.5 April 2017 20

3.2.6 May 2019 20

3.3 Methodology 20

3.4 Results 22

CONTENTS

3.5 July 2007 Additional Data 25
3.5.1 Neosho River near Commerce, OK 26
3.5.2 Neosho River at Miami, OK 26
3.5.3 Elk River near Tiff City, OK 27
3.5.4 Spring River near Quapaw, OK 27
3.5.5 Summary of Findings and Conclusions Regarding Additional Data 28
4. Flood Frequency Analysis 29
5. Inflow Event Analysis 31
6. Definition of “Material Difference” 35
7. Simulated Scenarios 36
8. Study Results 39
9. Discussion of Results 41
10. Anticipated Operations Analysis 62
11. Supporting Analysis for Other Studies 66
11.1 Aquatic Species Study 66
11.2 Terrestrial Species Study 66
11.3 Wetlands and Riparian Habitat Study 67
11.4 Sedimentation Study 67
12. Conclusions 68
13. References 69

List of Figures

Figure 1. Datum transformations and conversions. 1
Figure 2. UHM study area. 4
Figure 3. Comparison of model geometries. 6
Figure 4. Comparison of 2DFA cells. 7
Figure 5. Comparison of cross-sections and most upstream 1D/2D boundary. 8
Figure 6. Example comparison of bridge geometry. 9
Figure 7. Example comparison of modified ineffective flow areas. 10
Figure 8. Riverbed profile of the Spring River. 11
Figure 9. Riverbed profile of the Elk River. 12
Figure 10. Bathymetric and topographic data sources. 14
Figure 11. Grand Lake capacity curves. 15
Figure 12. Simulation results from preliminary comparison of Diffusion Wave to Full Momentum

CONTENTS

equation sets. 16
Figure 13. Over/underprediction of simulated WSEL at USGS gages. 22
Figure 14. Comparison of UHM results to July 2007 high water marks. 23
Figure 15. Comparison of UHM results to October 2009 high water marks. 23
Figure 16. Comparison of UHM results to December 2015 high water marks. 23
Figure 17. Locations of WSEL loggers installed by project team. 24
Figure 18. Over/underprediction of simulated WSEL at loggers installed by project team. 25
Figure 19. 1986 and 1987 water years in HEC-SSP. 29
Figure 20. Flood frequency analysis graphical results. 30
Figure 21. Graphical comparison of HEC-RAS results to statistical analysis for the 100-year flood event. 33
Figure 22. Maximum WSELs near Miami, OK for the September 1993 (21 year) event. 50
Figure 23. Maximum inundation extents near Miami, OK for the September 1993 (21 year) event. 50
Figure 24. Maximum WSELs near Miami, OK for the June 2004 (1 year) event. 51
Figure 25. Maximum inundation extents near Miami, OK for the June 2004 (1 year) event. 51
Figure 26. Maximum WSELs near Miami, OK for the July 2007 (4 year) event. 52
Figure 27. Maximum inundation extents near Miami, OK for the July 2007 (4 year) event. 52
Figure 28. Maximum WSELs near Miami, OK for the October 2009 (3 year) event. 53
Figure 29. Maximum inundation extents near Miami, OK for the October 2009 (3 year) event. 53
Figure 30. Maximum WSELs near Miami, OK for the December 2015 (15 year) event. 54
Figure 31. Maximum inundation extents near Miami, OK for the December 2015 (15 year) event. 54
Figure 32. Maximum WSELs near Miami, OK for the 100-year event. 55
Figure 33. Maximum inundation extents near Miami, OK for the 100-year event. 55
Figure 34. Maximum WSELs near Miami, OK for simulations with historical starting stages. 56
Figure 35. Maximum inundation extents near Miami, OK for simulations with historical starting stages. 56
Figure 36. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 734 feet. 57
Figure 37. Maximum inundation extents near Miami, OK for various natural inflow events, using a starting pool elevation of 734 feet. 57
Figure 38. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 742 feet. 58

CONTENTS

Figure 39. Maximum inundation extents near Miami, OK for various natural inflow events, using a starting pool elevation of 742 feet. 58

Figure 40. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 745 feet. 59

Figure 41. Maximum inundation extents near Miami, OK for various natural inflow events, using a starting pool elevation of 745 feet. 59

Figure 42. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 757 feet. 60

Figure 43. Maximum inundation extents near Miami, OK for natural various inflow events, using a starting pool elevation of 757 feet. 60

Figure 44. Comparison of maximum WSEL differences near Miami, OK. 61

Figure 45. Maximum WSELs near Miami, OK for baseline and anticipated operations during the June 2004 inflow event. 64

Figure 46. Maximum WSELs near Miami, OK for baseline and anticipated operations during the July 2007 inflow event. 64

Figure 47. Maximum WSELs near Miami, OK for baseline and anticipated operations during the 100-year inflow event. 65

List of Tables

Table 1. Summary of historical event boundary conditions used in UHM calibration. 19

Table 2. Overbank Manning's n-values. 21

Table 3. Channel Manning's n-values. 21

Table 4. Flow roughness factors. 21

Table 5. Comparison of additional data for the Neosho River near Commerce, OK 26

Table 6. Comparison of additional data for the Neosho River at Miami, OK 27

Table 7. Comparison of additional data for the Elk River near Tiff City, OK 27

Table 8. Comparison of additional data for the Spring River near Quapaw, OK 28

Table 9. Flood frequency analysis tabular results. 30

Table 10. Peak inflows at Pensacola Dam for four recent events. 31

Table 11. GEV distribution parameters and results. 32

Table 12. Results of historical inflow volume statistical analysis. 33

Table 13. Tabular comparison of HEC-RAS results to statistical analysis for the 100-year flood event. 34

Table 14. List of inflow events simulated and historical pool elevations at simulation start. 36

CONTENTS

Table 15. List of additional initial pool elevations simulated. 36

Table 16. Summary of peak inflows. 37

Table 17. Summary of peak pool elevations at Pensacola Dam (USGS Gage No. 07190000) for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range. 37

Table 18. Summary of peak pool elevations at Pensacola Dam (USGS Gage No. 07190000) for starting elevations within GRDA's anticipated operational range. 38

Table 19. Summary of maximum WSEL differences for starting elevations within GRDA's anticipated operational range. 41

Table 20. Summary of maximum WSEL differences for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range. 42

Table 21. Summary of maximum WSEL differences through Miami, OK for starting elevations within GRDA's anticipated operational range. 43

Table 22. Summary of maximum WSEL differences through Miami, OK for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range. 43

Table 23. Summary of smallest and largest inundation areas for starting elevations within GRDA's anticipated operational range. 44

Table 24. Summary of smallest and largest maximum inundation areas for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range. 44

Table 25. Summary of maximum inundation area differences through Miami, OK for starting elevations within GRDA's anticipated operational range. 45

Table 26. Summary of maximum inundation area differences through Miami, OK for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range. 45

Table 27. Summary of inundation duration differences for starting elevations within GRDA's anticipated operational range. 46

Table 28. Summary of inundation duration differences for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range. 47

Table 29. Summary of maximum duration differences through Miami, OK for starting elevations within GRDA's anticipated operational range. 48

Table 30. Summary of maximum duration differences through Miami, OK for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range. 48

Table 31. Summary of increases in WSEL due to anticipated operations, as compared to baseline operations. 63

Table 32. Summary of increases in duration due to anticipated operations, as compared to baseline operations. 65

CONTENTS

List of Appendices

Appendix A ..... Response to City of Miami Comments
Appendix B ..... Historical Inflow Volume Statistical Analysis
Appendix C ..... Hydrographs
Appendix D ..... Maximum Water Surface Elevations
Appendix E ..... Water Surface Elevation Profiles
Appendix F ..... Inundation Maps
Appendix G ..... Duration of Inundation
Appendix H ..... Anticipated Operations Analysis
Appendix I ..... Supporting Maps for Other Studies

Executive Summary

Mead & Hunt is assisting Grand River Dam Authority (GRDA) with its intent to relicense the Pensacola Hydroelectric Project (Project), which is regulated by the Federal Energy Regulatory Commission (FERC). Pursuant to federal law, including the Flood Control Act of 1944 and section 7612 of the National Defense Authorization Act for 2020, flood control operations at the Project are regulated exclusively by the United States Army Corps of Engineers (USACE). This Updated Study Report (USR) documents the findings of Hydrologic and Hydraulic (H&H) modeling upstream of the Project.

The Proposed Study Plan (PSP) and Revised Study Plan (RSP) recommended the development of a Comprehensive Hydraulic Model (CHM). The model upstream of the Project is referred to as the Upstream Hydraulic Model (UHM). Mead & Hunt used a Hydrologic Engineering Center River Analysis System (HEC-RAS) model, previously developed by Tetra Tech, as the base for UHM development. Mead & Hunt conducted a detailed review of Tetra Tech's model and identified ways in which the model should be improved (Mead & Hunt, 2016). As part of this study, Mead & Hunt transformed the Tetra Tech model by updating the version of HEC-RAS from a beta version to a full release version, modifying the geometry to contain larger flood events and to improve model stability and accuracy, updating bridge geometry, adding the Spring River and the Elk River, replacing the reservoir bathymetry to reflect newly surveyed conditions, and by using computational parameters recommended by the HEC-RAS development team. This resulted in an improved hydraulic model of Grand Lake and the river system upstream of Pensacola Dam.

Mead & Hunt calibrated the UHM using measured data, including United States Geological Survey (USGS) gage elevations, high water marks, and recorded data from loggers installed by the project team. Six historical events were used to calibrate the model. Manning's n-values were adjusted until simulated water surface elevations reasonably matched measured data. Flow roughness factors were used to fine-tune the model.

A flood frequency analysis was performed for the study area using data from USACE. Data from 1940 (dam construction date) to 2019 (latest available data at time of data delivery from USACE) were used and a graphical frequency analysis of peak inflows was performed. The analysis estimated a 100-year event flow at Pensacola Dam of approximately 300,000 cubic feet per second (cfs). The largest events of recent record did not meet or exceed the 100-year event threshold at Pensacola Dam. The July 2007 event was scaled so the peak flow at Pensacola Dam approximately matched the estimated 100-year event, with a daily inflow volume to Pensacola Dam that approximately matched the results of a statistical analysis of historical inflow volumes.

The calibrated UHM was used to analyze five historical inflow events and one synthetic event with a range of starting pool elevations at Pensacola Dam. Maximum water surface elevation (WSEL) values and inundation extents were extracted from HEC-RAS and analyzed.

The results of the UHM demonstrate that starting pool elevations at Pensacola Dam within GRDA's anticipated operational range have an immaterial impact on upstream WSELs, inundation, and duration for a range of inflow events. Compared to starting elevations within GRDA's anticipated operational range, only a different natural inflow event caused an appreciable difference in maximum WSEL, maximum inundation extent, or duration. The differences in WSEL, inundation extent, and duration due to

the size of the natural inflow event were orders of magnitude greater than the differences in WSEL, inundation extent, and duration due to the initial stage at Pensacola Dam. The maximum impact of nature typically ranged from over 10 times to over 100 or even over 1,000 times the maximum simulated impact of GRDA's anticipated operational range.

Even if extreme, hypothetical starting pool elevations outside GRDA's anticipated operational range are used, the maximum impact of nature is much greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet. The impact of nature typically ranged from 2 times to 10 or even 100 times the impact of the extreme, hypothetical starting stage range.

Comparing anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes, the results of the UHM demonstrate that anticipated operations have an immaterial impact on upstream WSELs, inundation, and duration as compared to baseline operations.

All conclusions on potential lentic or lotic conversion areas are discussed in each of the individual biological assessment reports.

List of Abbreviations and Terms

1D	One-Dimensional
2D	Two-Dimensional
2DFA	Two-Dimensional Flow Area
CFS	Cubic Feet Per Second
CHM	Comprehensive Hydraulic Model
DEM	Digital Elevation Model
FEMA	Federal Emergency Management Agency
FERC	Federal Energy Regulatory Commission
GEV	Generalized Extreme Value
GRDA	Grand River Dam Authority
H&H	Hydrologic and Hydraulic
ISR	Initial Study Report
HEC	Hydrologic Engineering Center
LiDAR	Light Detection and Ranging
MISR	Model Input Status Report
NAVD88	North American Vertical Datum of 1988
NGVD29	National Geodetic Vertical Datum of 1929
NED	National Elevation Dataset
NWIS	National Water Information System
OM	Operations Model
PD	Pensacola Datum
Project	Pensacola Hydroelectric Project
PSP	Proposed Study Plan
RAS	River Analysis System
RM	River Mile
RSP	Revised Study Plan
SPD	Study Plan Determination
SSP	Statistical Software Package
UHM	Upstream Hydraulic Model
USACE	United States Army Corps of Engineers
USGS	United States Geological Survey
USR	Updated Study Report
WSEL	Water Surface Elevation

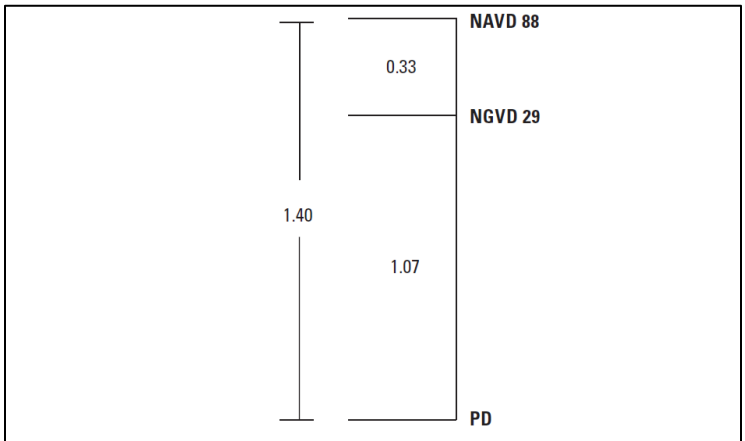
1. Introduction and Background

1.1 Project Description

The Pensacola Hydroelectric Project is owned and operated by GRDA and regulated by the FERC. The Pensacola Dam is in Mayes County, Oklahoma on the Grand-Neosho River. Pensacola Dam impounds Grand Lake. Construction of Pensacola Dam was completed in 1940. **Figure 2** displays the study area. Downstream of Pensacola Dam, GRDA also owns and operates the Robert S. Kerr Dam as the Markham Ferry Hydroelectric Project. Kerr Dam is also in Mayes County and impounds Lake Hudson, also known as Markham Ferry Reservoir. Flood control operations at both Pensacola Dam and Kerr Dam are regulated exclusively by USACE.

1.2 Vertical Datums

Data sources for this study use a variety of vertical datums. Unless otherwise noted, data are presented in the Pensacola Datum (PD). To convert from PD to the National Geodetic Vertical Datum of 1929 (NGVD29), add 1.07 feet. To convert from NGVD29 to the North American Vertical Datum of 1988 (NAVD88), add 0.33 feet. **Figure 1** displays datum transformations and conversions (Hunter, Trevisan, Villa, & Smith, 2020). The HEC-RAS model discussed in this report was developed in NGVD29.



	Elevations, in feet		
	NAVD 88	NGVD 29	PD
Conservation pool	743.40	743.07	742.00
Top of the dam	758.40	758.07	757.00

Figure 1. Datum transformations and conversions.
Source: (Hunter, Trevisan, Villa, & Smith, 2020).

1.3 Study Plan Proposals and Determination

GRDA is currently relicensing the Project. The timeline of study plan proposals and determination is as follows:

1. On April 27, 2018, GRDA filed its PSP to address hydrologic and hydraulic modeling in support of its intent to relicense the Project.
2. On September 24, 2018, GRDA filed its RSP.
3. On November 8, 2018, the FERC issued its Study Plan Determination (SPD) for the Project.

4. On January 23, 2020, the FERC issued an Order on the Request for Clarification and Rehearing, which clarified the timeline for certain milestones applicable to the relicensing study plan.
5. On September 30, 2021, GRDA filed its Initial Study Report (ISR).
6. On February 24, 2022, the FERC issued its Determination on Requests for Study Modifications and New Studies for the Project.
7. On September 30, 2022, GRDA filed this report, the Updated Study Report (USR).

The PSP and RSP recommended the development of a CHM. This report discusses the UHM. As stated in the RSP, the objectives of the H&H modeling study are to:

1. Determine the duration and extent of inundation under the current license operations of the Project during several measured inflow events.
2. Determine the duration and extent of inundation under any proposed change in these operations that occurs during several measured or synthetic inflow events.
3. Provide the model results in a format that can inform other analyses (to be completed separately) of Project effects, if any, in several resource areas.
4. Determine the feasibility of implementing alternative operations scenarios, if applicable, that may be proposed by GRDA as part of the relicensing effort.

The FERC's SPD and Order on Request for Clarification and Rehearing included direction to provide a model input status report by March 30, 2021, and hold a conference call on model inputs and calibration within 30 days of the input status report. The Upstream Hydraulic Model Input Status Report was filed with FERC and shared with stakeholders on March 30, 2021 (Mead & Hunt, 2021). A Technical Conference was held on April 21, 2021, to allow relicensing participants to ask questions regarding the Model Input Status Report (MISR).

GRDA's ISR was a continuation of the MISR and incorporated comments provided on the MISR as addressed in **Appendix A**. The ISR documented the development of the UHM and findings from the analyses of historical and synthetic flow events with different initial stages at Pensacola Dam. GRDA's ISR concluded only natural inflows—and not Project operation—have an appreciable impact on maximum water surface elevation (WSEL) and maximum inundation extent.

FERC's February 2022 Determination found GRDA's conclusion in the ISR premature and recommended the following modifications to the UHM portion of the H&H modeling study:

1. Run inflow event scenarios at starting reservoir elevations from 734 feet PD up to and including 757 feet PD.
2. Report the frequency, timing, amplitude (*i.e.,* elevation), and duration for each of the simulated inflow events with starting elevations between 734 feet PD and 757 feet PD.
3. Provide the means necessary to complete any additional return frequency analysis that may be deemed necessary following review of the USR.

As documented in this USR, GRDA has completed FERC's requested modifications as follows:

1. GRDA simulated inflow event scenarios with starting reservoir elevations ranging from 734 feet PD up to and including 757 feet PD.
2. GRDA reported the frequency, timing, amplitude, and duration of inflow events as follows:
    a. Frequency of the inflow events (*i.e.*, estimated return period) is reported in this document

and its appendices.

b. The term “timing” originates in the RSP and refers to seasonality of inflow and inundation. Timing (or seasonality) is discussed in Section 11. GRDA analyzed the seasonality of normal (median) operational levels and inflows as it impacts the Aquatic Species Study, the Terrestrial Species Study, and the Wetlands and Riparian Habitat Study.
c. Amplitude (*i.e.*, elevation) is reported as WSEL in this document and its appendices.
d. Duration of inundation is reported in this document and its appendices.

3. GRDA has included the return frequency analysis (*i.e.*, flood frequency analysis) as an electronic attachment to the USR.
4. As required by the approved study plan, GRDA has developed maps showing areas of potential lentic or lotic conversion (see Section 11.2).

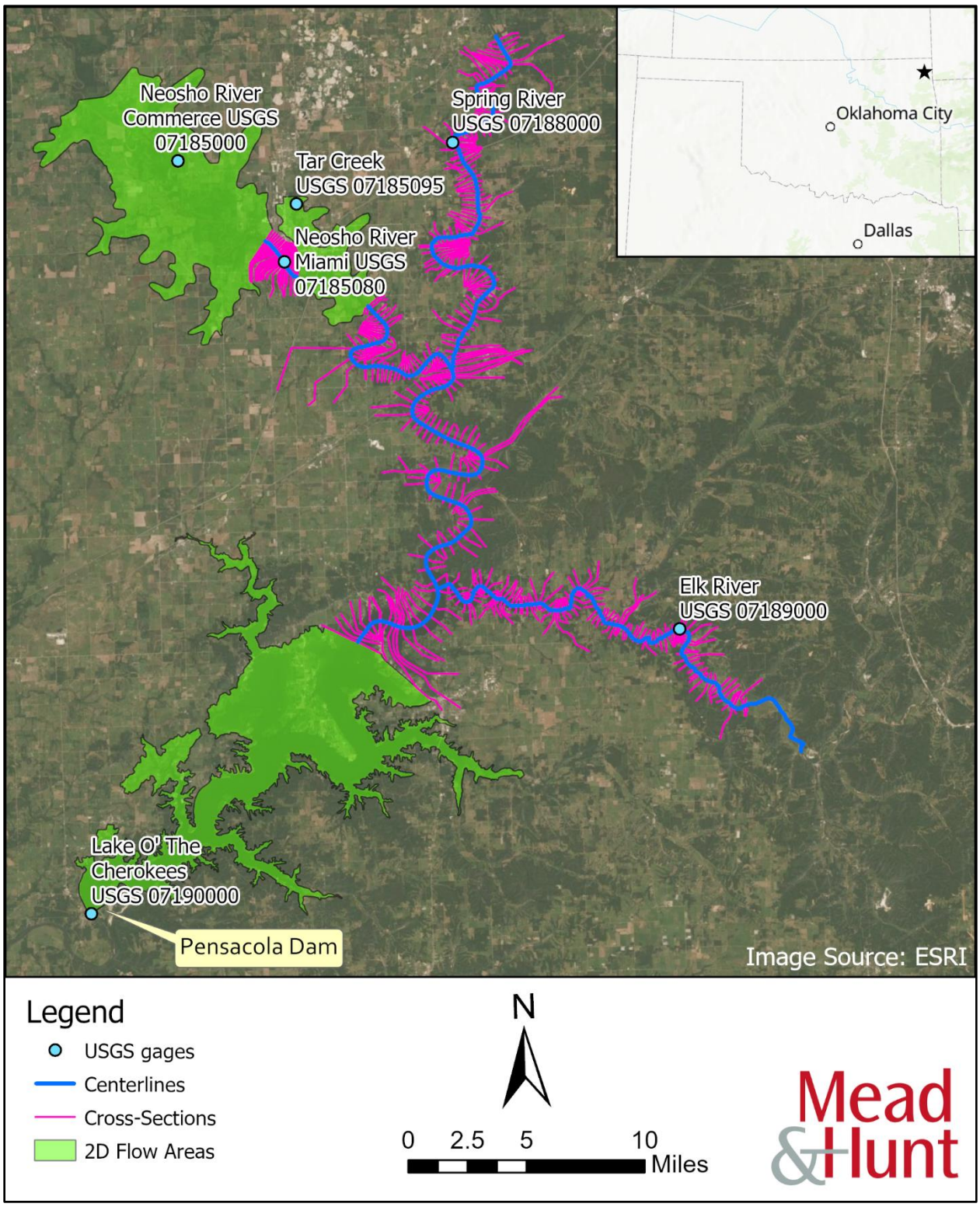


Figure 2. UHM study area.

2. Model Development

Tetra Tech previously developed a HEC-RAS model of the study area (Tetra Tech, 2015, 2016). Mead & Hunt used Tetra Tech's model as the base for UHM development. After a detailed review, the Tetra Tech model was transformed in the following ways, resulting in an improved comprehensive hydraulic model of Grand Lake and the river system upstream of Pensacola Dam.

1. Model was converted from a beta version of HEC-RAS to version 5.0.7.
2. Two-dimensional (2D) flow area (2DFA) was added for Grand Lake, replacing cross-sections.
3. 2DFAs in the vicinity of Miami, Oklahoma were expanded to fully contain inundation from larger flow events.
4. Mesh cell centers within 2DFAs were reviewed and adjusted in accordance with USACE guidance (USACE, 2016a).
5. Cross-sections were extended to fully contain the inundation from larger flow events.
6. 1D/2D flow boundaries were reviewed and adjusted in accordance with USACE guidance (USACE 2016a, USACE 2016b).
7. Bridge geometries were updated to reflect current conditions.
8. Bank stations and ineffective flow areas were reviewed and adjusted in accordance with USACE guidance (USACE, 2016b).
9. Elk River was added to the model.
10. Spring River was added to the model.
11. Recently published USGS Grand Lake bathymetry data were incorporated into model geometry (Hunter, Trevisan, Villa, & Smith, 2020).
12. Computational parameters were reviewed and adjusted in accordance with USACE guidance (USACE, 2016a).

UHM improvements are discussed in detail below.

2.1 HEC-RAS Version

Tetra Tech performed hydraulic modeling with the August 2016 5.0 beta version of HEC-RAS (Tetra Tech, 2015; Tetra Tech, 2016). At the time of Mead & Hunt's RSP and the FERC's SPD, the current version of HEC-RAS was 5.0.7. Therefore, Mead & Hunt used HEC-RAS 5.0.7 for analysis.

2.2 Grand Lake 2DFA

Tetra Tech used cross-sections to represent Grand Lake. Mead & Hunt replaced the cross-sections downstream of River Mile (RM) 100 with a 2DFA. The 2DFA better accounts for the volume in Grand Lake. **Figure 3** displays a comparison of Tetra Tech's model geometry to Mead & Hunt's geometry.

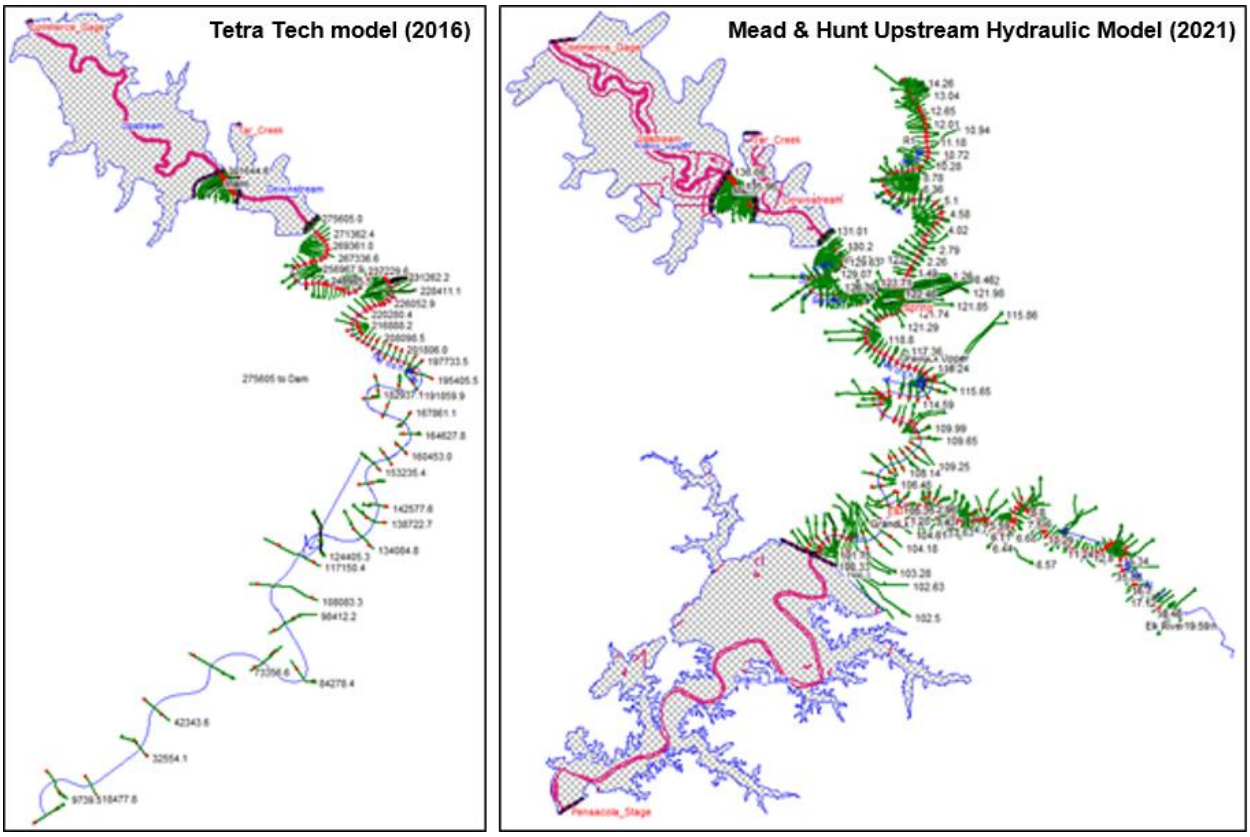


Figure 3. Comparison of model geometries.

2.3 Upstream 2DFAs

Tetra Tech included two 2DFAs in their HEC-RAS model: one just downstream of the City of Miami and one upstream of the City of Miami. Preliminary simulations showed that large flow events (e.g., the 100-year event) were not contained within the 2DFAs. Mead & Hunt expanded the 2DFAs so large flow events could be contained within the model boundaries. The expanded 2DFAs are displayed in **Figure 3**. In Mead & Hunt's model, the most upstream 2DFA is named "Miami_Upper" and the next 2DFA downstream is named "Miami_Lower".

The upstream boundary of the model along the Neosho River was not modified. Tetra Tech determined that it takes 4 hours for a flood wave to travel from the upstream end of the model (RM 152.2) to the Commerce gage (Tetra Tech, 2015). Mead & Hunt's preliminary simulations confirmed the 4-hour travel time. Therefore, Mead & Hunt applied a negative 4.0 hour offset to the USGS flow hydrographs, which were used as inflows at the upstream end of the Neosho River 2DFA. Flow data are further discussed in **Section 3.1**.

2.4 2DFA Cell Refinement

Tetra Tech included some refinement of 2DFA cells. However, cell faces were not aligned to the top of the river channel. Mead & Hunt refined cell alignments to follow the banks of the Neosho River in accordance with USACE guidance (USACE, 2016a). **Figure 4** displays an example comparison of Tetra Tech's 2DFA cell alignment to Mead & Hunt's cell alignment.

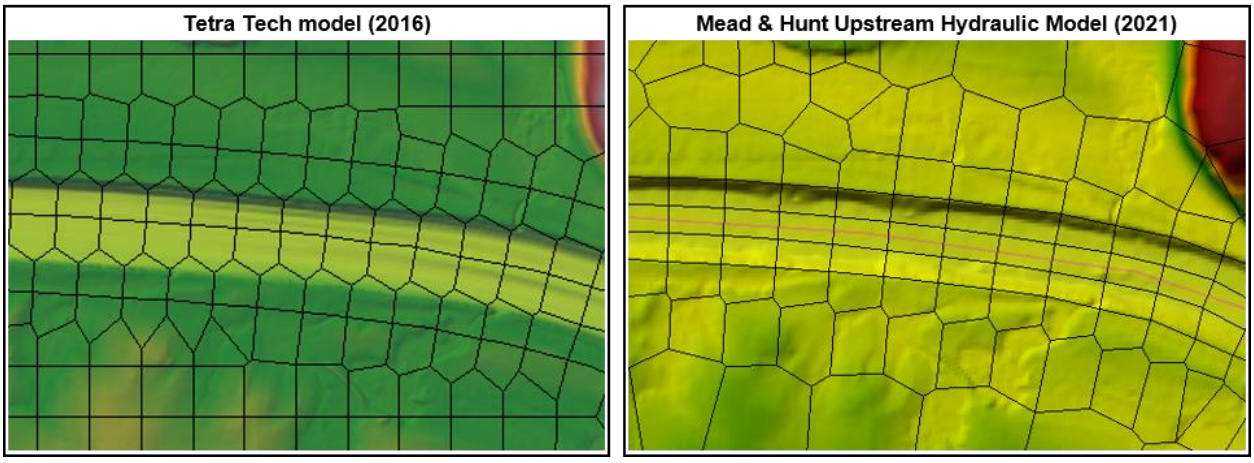


Figure 4. Comparison of 2DFA cells.

2.5 Cross-Section Adjustments

Like the 2DFAs, preliminary simulations showed large flow events (e.g., 100-year event) were not contained within the cross-sections. Mead & Hunt extended the cross-sections laterally so large flow events were contained within the cross-sections. An example of extended cross-sections is displayed in **Figure 5**.

2.6 1D/2D Boundaries

Mead & Hunt reviewed the 1D/2D boundaries in the Tetra Tech model and moved the boundaries to determine if model stability could be improved. Moving the most upstream 1D/2D boundary further upstream resulted in a more stable, accurate model. The adjusted boundary was placed in accordance with USACE guidance (USACE, 2016a; USACE, 2016b). The revised location of the 1D/2D model boundary is displayed in **Figure 5**.

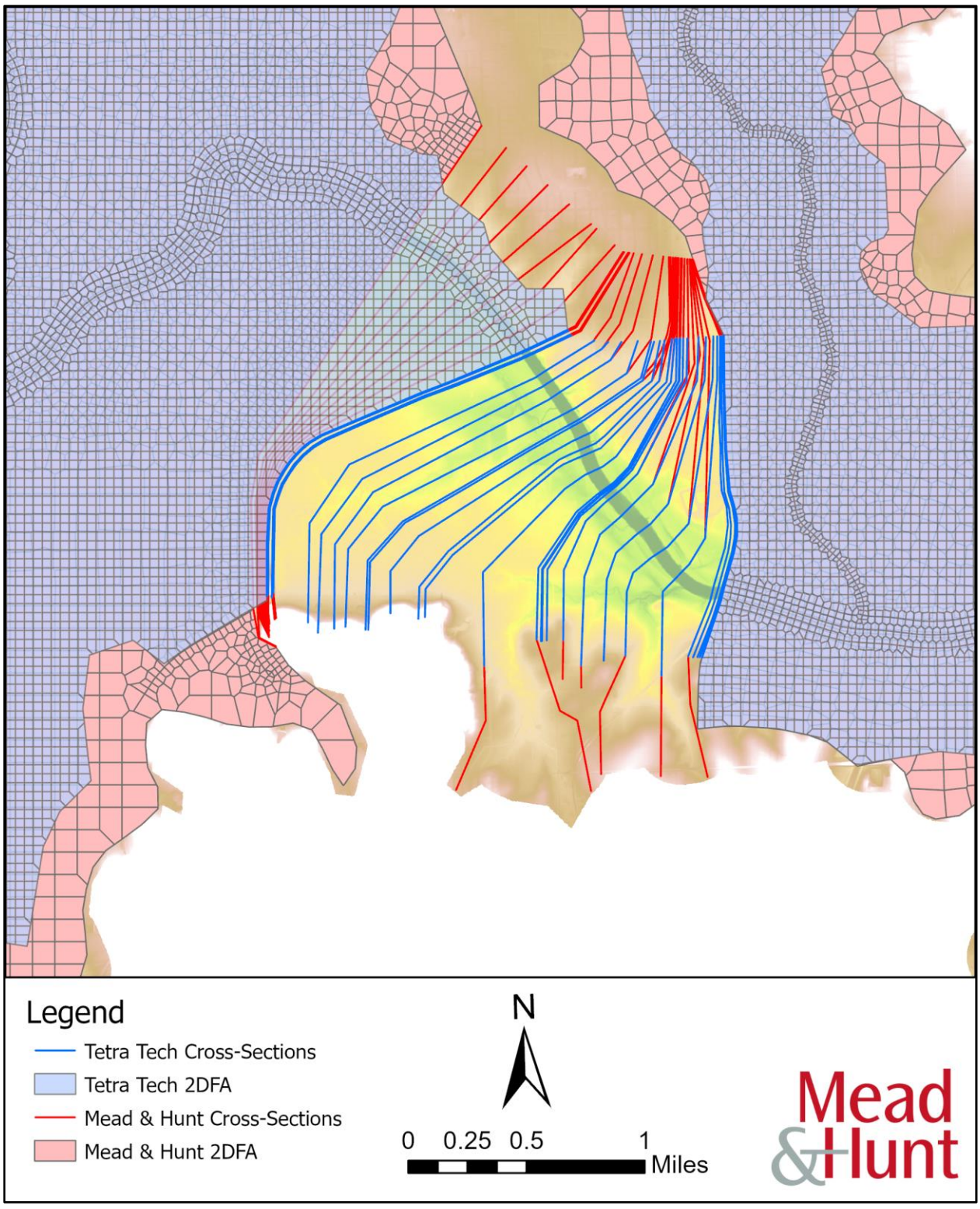


Figure 5. Comparison of cross-sections and most upstream 1D/2D boundary.

2.7 Bridge Geometries

Tetra Tech (2016) stated bridge geometry in their HEC-RAS model was primarily obtained from a Simons & Associates HEC-2 model (Simons & Associates, Inc., 1996). Mead & Hunt updated roadway bridge geometry using as-built drawings obtained from the Oklahoma Department of Transportation, Missouri Department of Transportation, and local/county road commissions. Railroad bridge geometries were updated using measurements provided by GRDA. An example of the updated bridge geometry at the Old Highway 69 Bridge in Miami, OK (RM 135.941) is displayed in **Figure 6**.

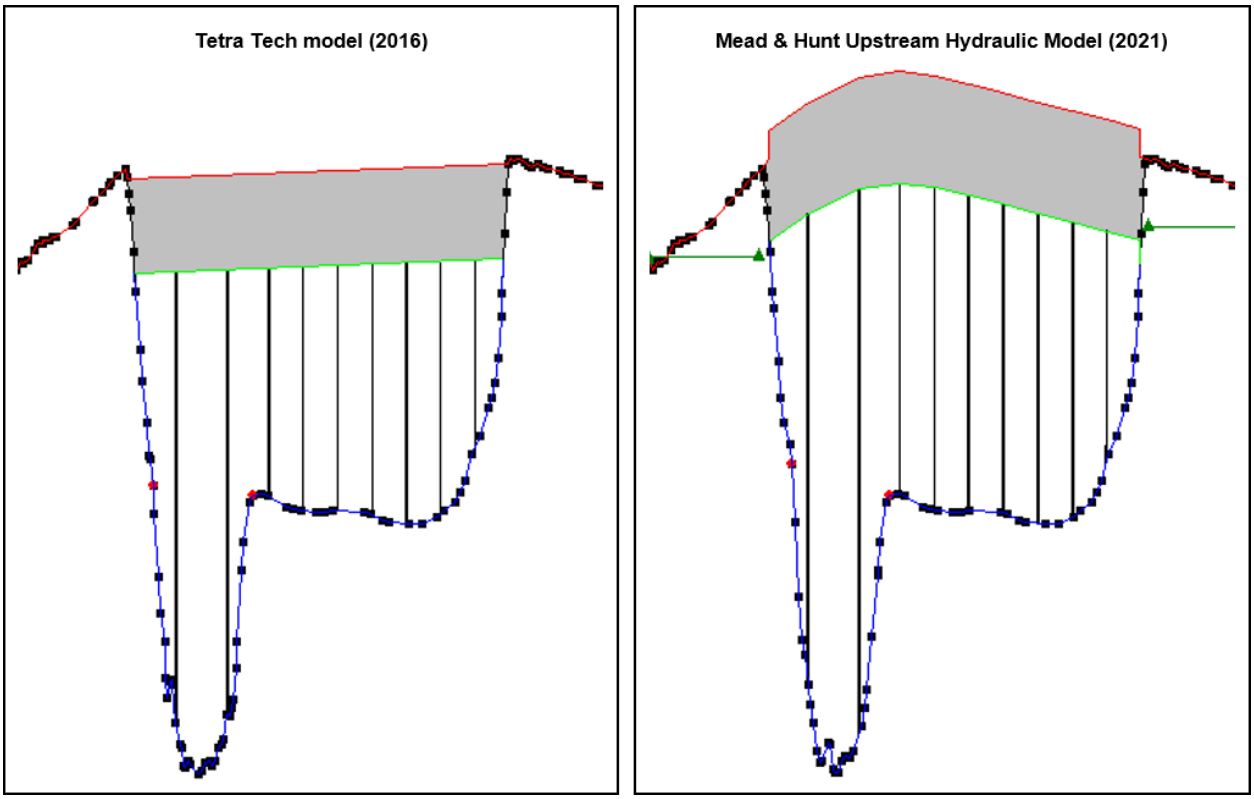


Figure 6. Example comparison of bridge geometry.

2.8 Bank Stations and Ineffective Flow Areas

Mead & Hunt reviewed and adjusted the bank stations and ineffective flow areas in the UHM according to best practices and the HEC-RAS Reference Manual (USACE, 2016b). Most adjustments to ineffective flow areas were upstream and downstream of bridges and were due to the updated bridge geometry. An example comparison of ineffective flow areas is displayed in **Figure 7**.

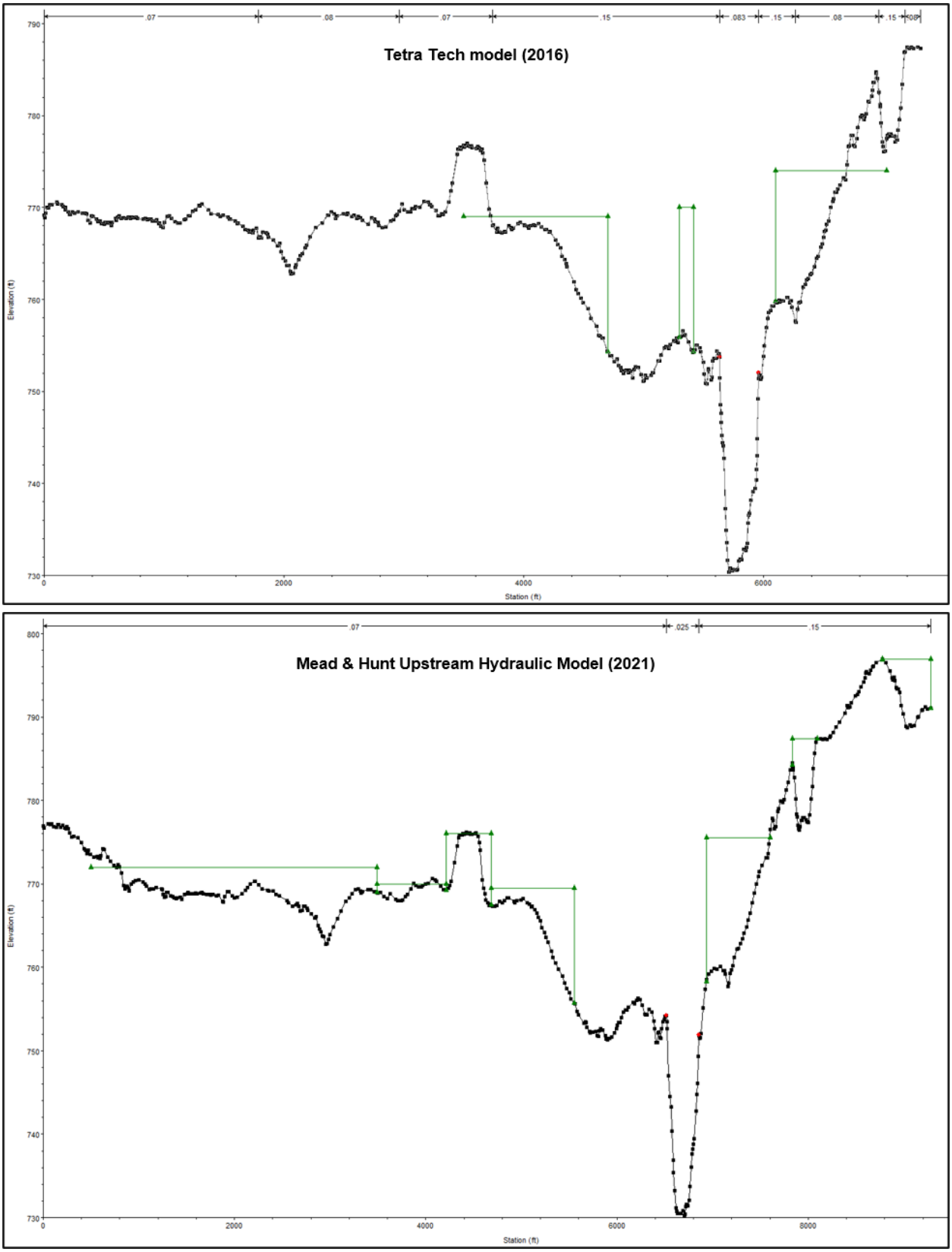


Figure 7. Example comparison of modified ineffective flow areas.

2.9 Spring River

Mead & Hunt added the Spring River to the UHM. The portion of the Spring River modeled by Mead & Hunt extended from the confluence with the Neosho River at the downstream end to RM 21.0 at the upstream end. The river centerline was digitized, and cross-sections were drawn perpendicular to the flow. Cross-sections were extended laterally far enough to contain large flow events (e.g., 100-year event). Bank stations were digitized and then adjusted in HEC-RAS. Ineffective flow areas were defined using guidance from the HEC-RAS Reference Manual (USACE, 2016b). **Figure 8** displays the riverbed profile of the Spring River. There are four bridges within the modeled reach:

1. E 57 Road (RM 14.16),
2. Interstate 44 Will Rogers Turnpike (RM 13.50),
3. OK 100 / E 10 Road (RM 8.01), and
4. US Highway 60 (RM 0.57).

There is one stream gage within the reach: Spring River near Quapaw, OK (USGS Gage No. 07188000). The gage is at E 57 Road (RM 14.16). Preliminary simulations indicated it takes 2.5 hours for a flood wave to travel from RM 21.0 (upstream end of the Spring River reach) to the USGS gage. Therefore, a negative 2.5-hour offset was applied to the USGS flow hydrographs, which were used as inflows at the upstream end of the Spring River.

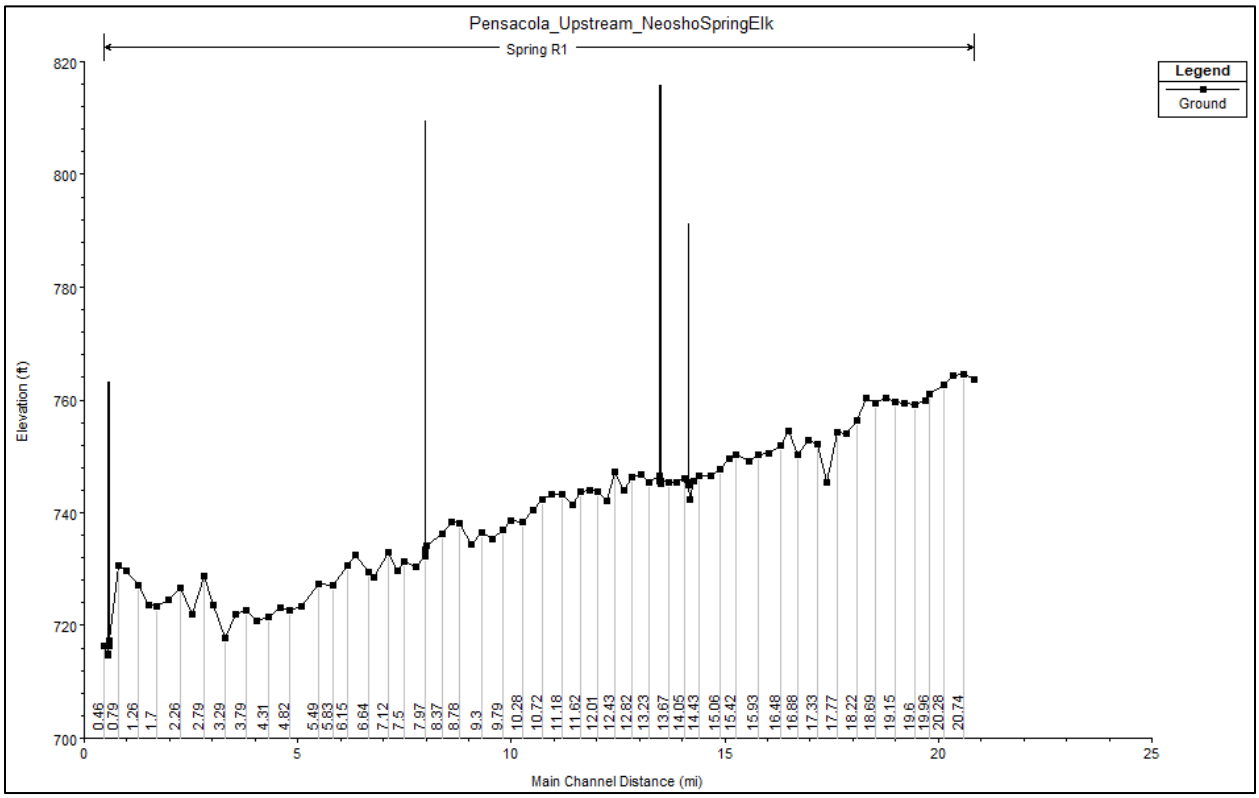


Figure 8. Riverbed profile of the Spring River.

2.10 Elk River

Mead & Hunt added the Elk River to the UHM. The portion of the Elk River modeled by Mead & Hunt extended from the confluence with Grand Lake at the downstream end to RM 19.59 at the upstream end. The river centerline, cross-sections, bank stations, and ineffective flow areas were defined with the same methodology used for the Spring River. **Figure 9** displays the riverbed profile of the Elk River. There are two bridges within the modeled reach:

1. Highway 10 (RM 4.67) and
2. Highway 43 (RM 14.22).

There is one stream gage within the reach: Elk River near Tiff City, MO (USGS Gage No. 07189000). The gage is at Highway 43 (RM 14.22). Preliminary simulations indicated that it takes 2 hours for a flood wave to travel from RM 19.59 (upstream end of the Elk River reach) to the USGS gage. Therefore, a negative 2.0-hour offset was applied to the USGS flow hydrographs, which were used as inflows at the upstream end of the Elk River.

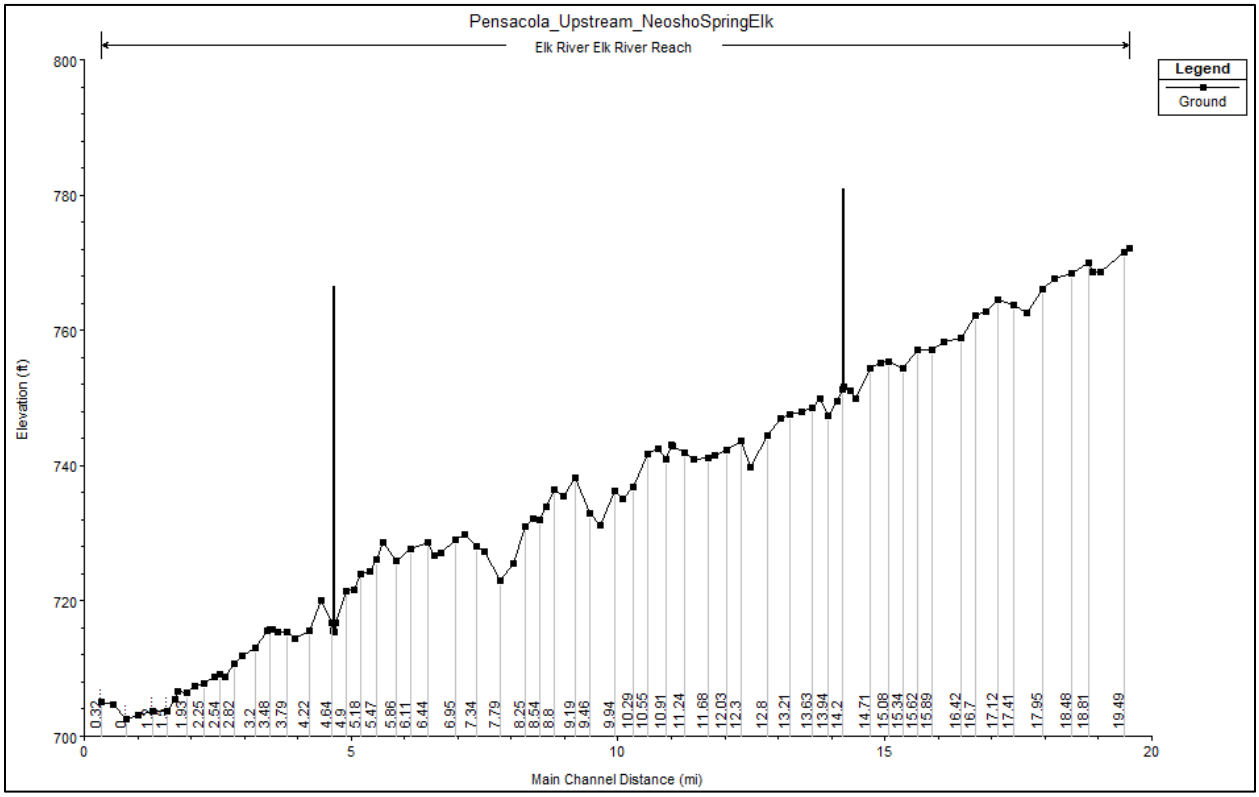


Figure 9. Riverbed profile of the Elk River.

2.11 Updated Bathymetry

In response to the FERC's SPD, GRDA enlisted USGS to perform a bathymetric survey of Grand Lake (Hunter, Trevisan, Villa, & Smith, 2020). Mead & Hunt integrated the Grand Lake bathymetry with a combined Digital Elevation Model (DEM) of the study area. The DEM was created with the following data, in descending order of priority:

1. USGS 2020 bathymetry, representing Grand Lake (Hunter, Trevisan, Villa, & Smith, 2020).
2. USGS 2017 bathymetry, representing the Neosho River, Spring River, and Elk River (Smith, Hunter, & Ashworth, 2017).
3. Federal Emergency Management Agency (FEMA) 2016 bathymetry from cross-section data, representing Tar Creek (FEMA, 2019).
4. Dewberry 2011 Light Detection and Ranging (LiDAR) overbank area (Dewberry, 2011).
5. USGS National Elevation Dataset (NED) 1/3 arc-second elevation layer, representing the overbank area in areas where no LiDAR data were available (USGS, 2017).

Figure 10 displays bathymetric and topographic data sources. USGS's 2020 report compared the capacity of Grand Lake, based on 2020 bathymetry, to previous capacity curves. **Figure 11** displays the capacity curves presented in USGS's report (Hunter, Trevisan, Villa, & Smith, 2020).

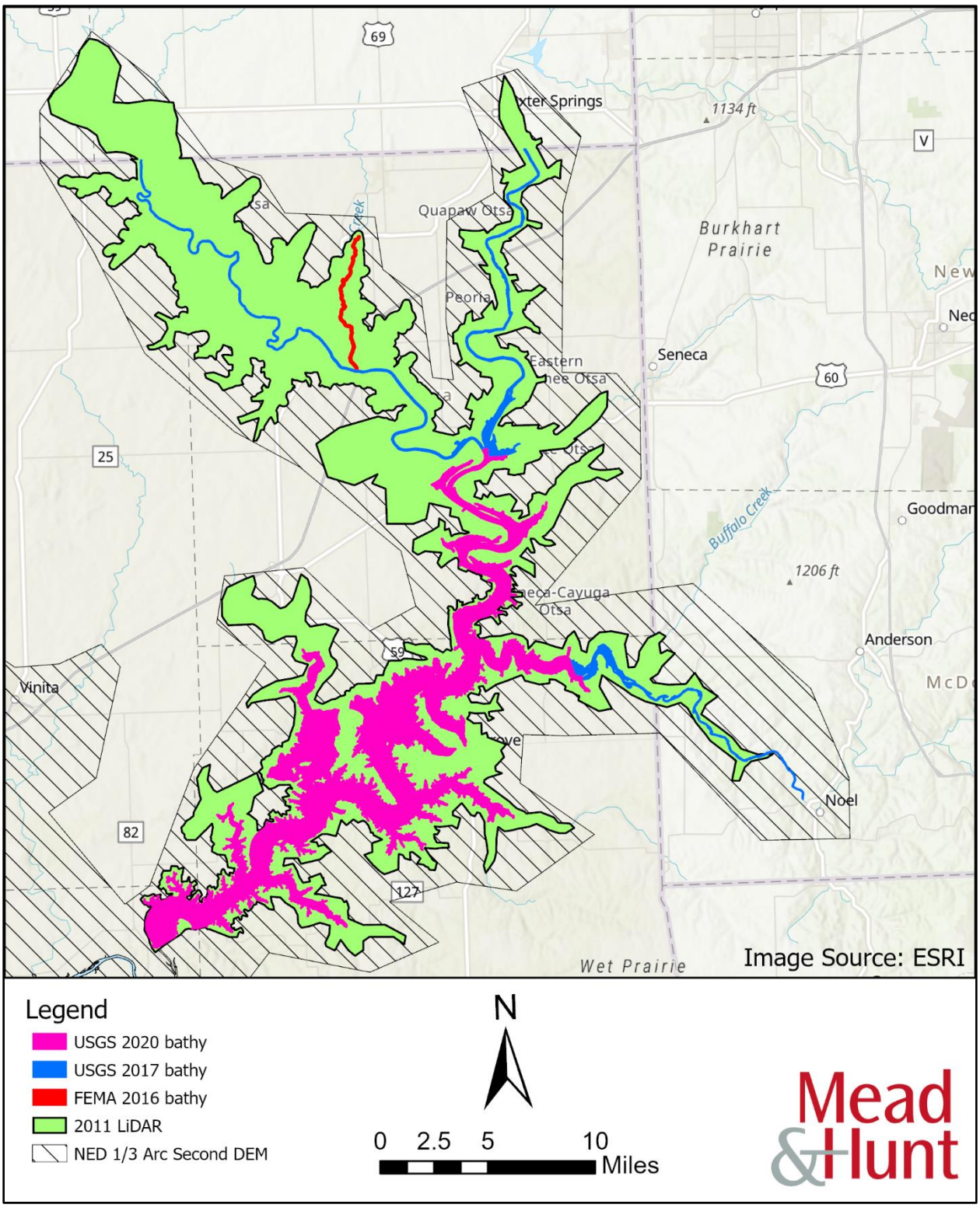


Figure 10. Bathymetric and topographic data sources.

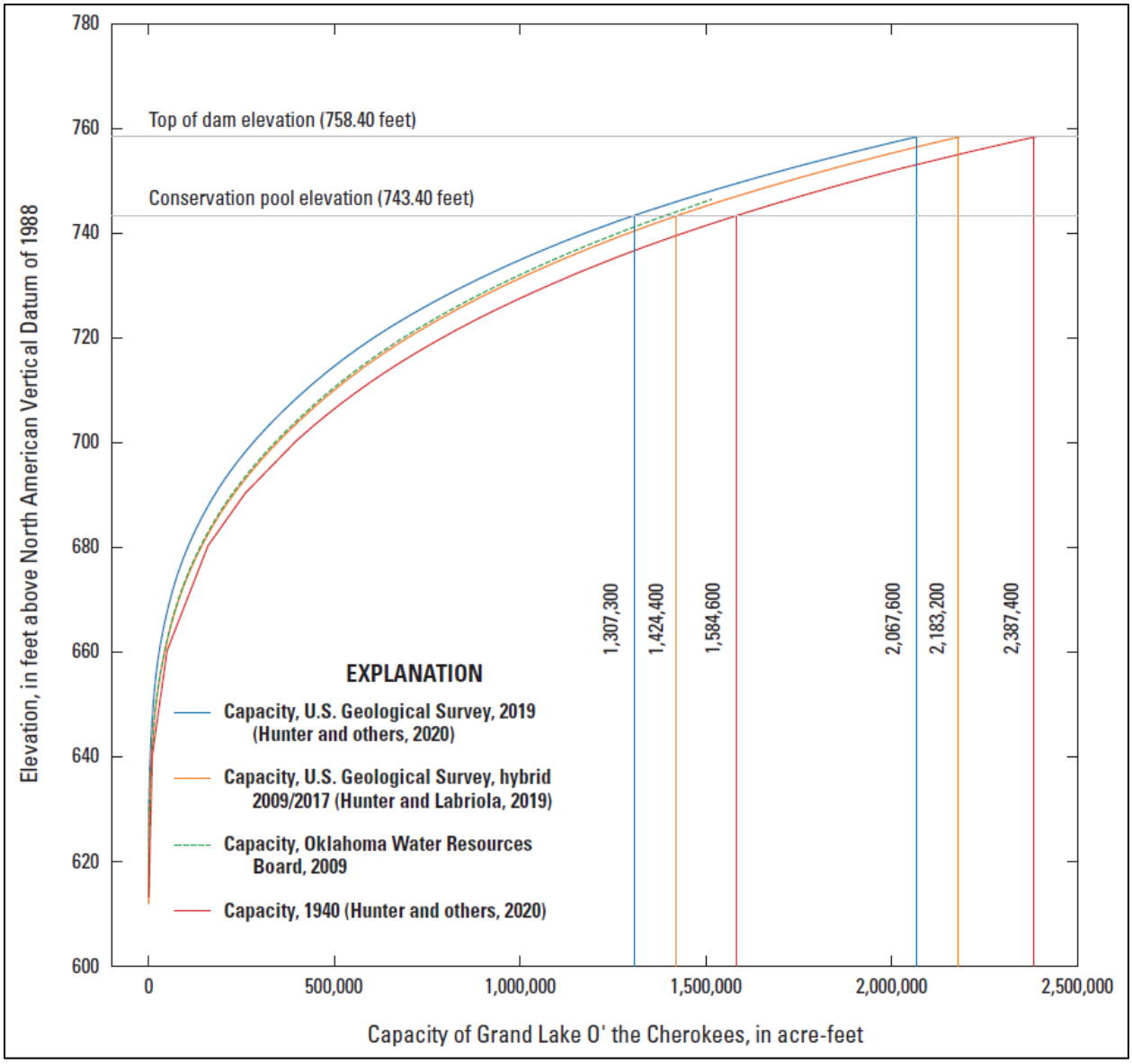


Figure 11. Grand Lake capacity curves.
Source: (Hunter, Trevisan, Villa, & Smith, 2020).

2.12 Computational Parameters

Tetra Tech's simulations all used the Diffusion Wave equation set. The HEC-RAS 2D Modeling User's Manual states the Diffusion Wave equations can be used while developing the model, but the Full Momentum equations should always be tested:

> *Once the model is in good working order, then make a second HEC-RAS Plan and switch the computational method to the Full Momentum equation option… Run the second plan and compare the two answers throughout the system. If there are significant differences between the two runs, the user should assume the Full Momentum (Saint Venant equations) answer is more accurate, and proceed with that equation set for model calibration and other event simulations* (USACE, 2016a).

Mead & Hunt ran preliminary simulations of the UHM with both Diffusion Wave and Full Momentum equation sets. Results from one simulation are displayed in **Figure 12**. The displayed reach (RM 131 to RM 151) approximately covers the two upstream 2DFAs and the 1D reach between the two upstream 2DFAs. Based on the WSEL differences in the test results, Mead & Hunt used Full Momentum for the two most upstream 2DFAs: Miami Upper and Miami Lower (see again **Figure 12**).

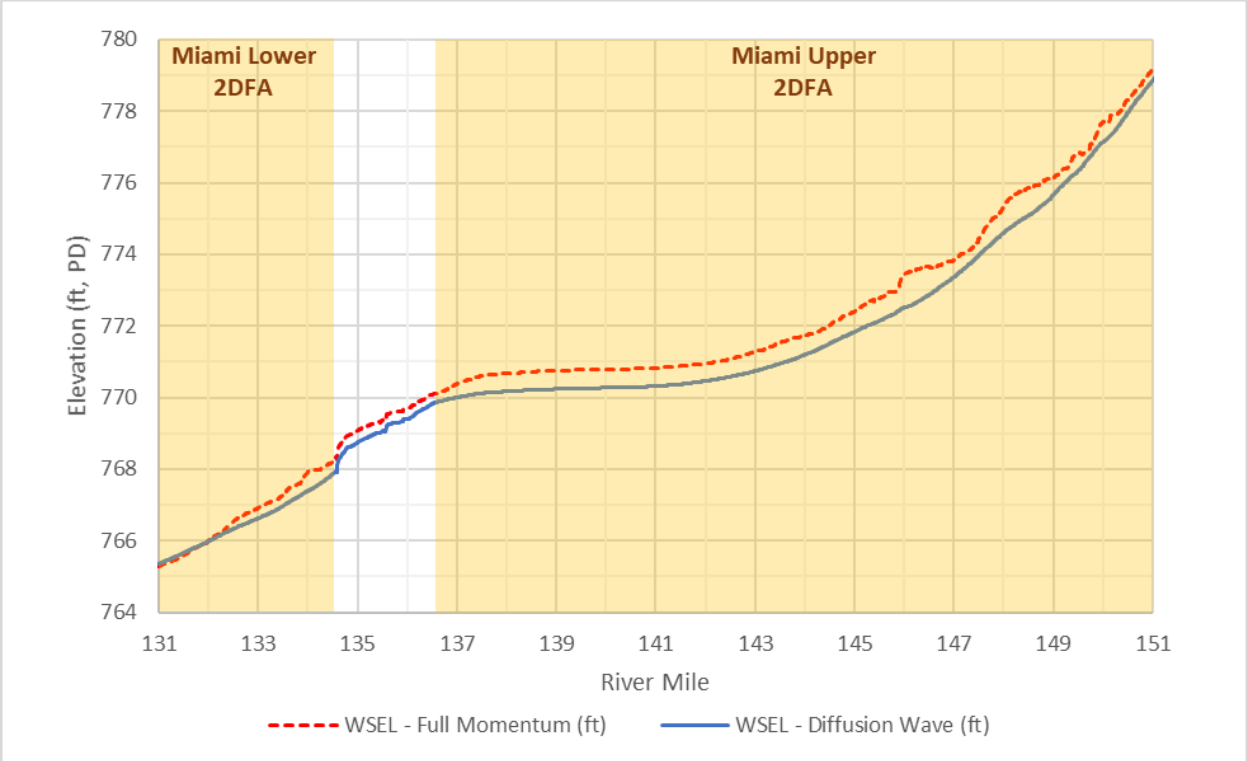


Figure 12. Simulation results from preliminary comparison of Diffusion Wave to Full Momentum equation sets.

Test results showed very little difference in WSEL in the Grand Lake 2DFA. Therefore, Mead & Hunt used the Diffusion Wave equation set for the Grand Lake 2DFA.

3. Model Calibration

The UHM was calibrated using several historical inflow events that represented a range of flows. Stream gage data were used for model boundary conditions and to compare measured WSEL to simulated values. High water marks and loggers installed by the project team were also used to compare measured and simulated WSEL.

3.1 Stream Gage Data

Data from the following stream gages were used for calibration:

1. Neosho River near Commerce, OK (USGS Gage No. 07185000)
2. Neosho River at Miami, OK (USGS Gage No. 07185080)
3. Tar Creek at 22nd Street Bridge at Miami, OK (USGS Gage No. 07185095)
4. Spring River near Quapaw, OK (USGS Gage No. 07188000)
5. Elk River near Tiff City, MO (USGS Gage No. 07189000)
6. Lake O' the Cherokees at Langley, OK (USGS Gage No. 07190000)

Details regarding the individual stream gages are discussed below. Stream gage data were obtained from the USGS National Water Information System (NWIS).

3.1.1 Neosho River near Commerce, OK

The Neosho River near Commerce, OK (USGS Gage No. 07185000) stream gage is at the Stepps Ford Bridge, approximately 6.7 miles downstream of the upper boundary of the model. Discharge data were available in hourly increments from April 1990 onward and stage data were available in hourly increments from October 2007 onward. The gage datum is 748.97 feet above NGVD29 (USGS, 2021a). Stage data at the gage were used in calibration.

Flow data were used as an upstream boundary condition for the Neosho River. Tetra Tech determined that it takes 4 hours for a flood wave to travel from the upstream end of the model (RM 152.2) to the Commerce gage (Tetra Tech, 2015). Mead & Hunt's preliminary simulations confirmed the 4-hour travel time. Therefore, Mead & Hunt applied a negative 4.0 hour offset to the USGS flow hydrographs, which were used as inflows at the upstream end of the Neosho River 2DFA.

3.1.2 Neosho River at Miami, OK

The Neosho River at Miami, OK (USGS Gage No. 07185080) stream gage is at the Highway 125 Bridge (RM 135.46) in the City of Miami. Stage data were available in hourly increments from October 2007 onward. Daily minimum, maximum, and mean stage data were available from October 1994 onward (USGS, 2021b). Stage data at the gage were used in calibration. Regarding the gage datum, Tetra Tech concluded that:

> *Although the NWIS website indicates that the datum for the Miami gage is referenced to NGVD29, field surveys to support this and previous Tetra Tech studies indicate that the datum is actually reported in the GRDA Pensacola Datum (PD). The reported values were, therefore, converted to NGVD29 for use in this analysis by adding 1.07 feet so that they are consistent with the Commerce data and the mapping and other data used for the modeling.*

Mead & Hunt analyzed the gage data and came to the same conclusion. Mead & Hunt contacted Scott Strong from the USGS Tulsa Field Office; Scott confirmed that the datum of the Miami gage is indeed in the Pensacola Datum.

3.1.3 Tar Creek at 22nd Street Bridge at Miami, OK

The Tar Creek at 22nd Street Bridge at Miami, OK (USGS Gage No. 07185095) stream gage had stage data available in hourly increments from October 2007 onward and had discharge data available in hourly increments from October 1989 onward. The gage datum is 762.23 feet above NGVD29 (USGS, 2021c).

Flow data were used as an upstream boundary condition for Tar Creek. No time offset was necessary because the gage is located at the upstream end of the model.

3.1.4 Spring River near Quapaw, OK

The Spring River near Quapaw, OK (USGS Gage No. 07188000) stream gage is at E 57 Road (RM 14.16). Stage data were available in hourly increments from October 2007 onward and discharge data were available in hourly increments from October 1989 onward. The gage datum is 746.25 feet above NGVD29 (USGS, 2021d).

Stage data at the gage were used in calibration. Flow data were used as an upstream boundary condition for the Spring River. As discussed in **Section 2.9**, a negative 2.5-hour offset was applied to flow hydrographs to account for flood wave travel time.

3.1.5 Elk River near Tiff City, MO

The Elk River near Tiff City, MO (USGS Gage No. 07189000) stream gage is at Highway 43 (RM 14.22). Stage data were available in hourly increments from October 2007 onward and discharge data were available in hourly increments from May 1990 onward. The gage datum is 750.61 feet above NGVD29 (USGS, 2021e).

Stage data at the gage were used in calibration. Flow data were used as an upstream boundary condition for the Elk River. As discussed in **Section 2.10**, a negative 2.0-hour offset was applied to flow hydrographs to account for flood wave travel time.

3.1.6 Lake O' the Cherokees at Langley, OK

The Lake O' the Cherokees at Langley, OK (USGS Gage No. 07190000) gage measures Grand Lake stage levels. Hourly stage data were available from October 2010 onward (USGS, 2021f). Stage data prior to October 2010 were provided by GRDA. Stage data were used as the downstream boundary condition for the model.

3.2 Historical Events

The following historical inflow events were used for calibration of the UHM.

1. July 2007
2. October 2009
3. December 2015
4. January 2017
5. April 2017
6. May 2019

Details regarding the individual inflow events are discussed below. For all historical events used in calibration of the UHM, USGS gage data were used for the upstream inflow boundaries and WSELs at Pensacola Dam were used for the downstream stage boundary. **Table 1** lists a summary of the historical event boundary conditions.

Table 1. Summary of historical event boundary conditions used in UHM calibration.

Historical Event	Peak Inflow (cfs)				Pensacola Peak Stage (feet, PD)
	Neosho River	Tar Creek	Spring River	Elk River	
July 2007	141,000	726	33,300	1,190	754.53
October 2009	46,100	4,630	66,200	39,300	749.59
December 2015	45,400	4,710	151,000	107,000	754.93
January 2017	10,200	678	15,900	1,140	742.82
April 2017	58,100	3,550	114,000	107,000	754.59
May 2019	91,400	6,410	109,000	66,500	755.08

3.2.1 July 2007

For the July 2007 event, hourly flow data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Daily minimum, mean, and maximum WSELs were available for the Neosho River at Miami gage. Grand Lake stage data were provided by GRDA. High water marks, compiled by Tetra Tech (2016), were available for this inflow event. Of the selected calibration events, the July 2007 event had the highest recorded flow on the Neosho River at the Commerce gage.

3.2.2 October 2009

For the October 2009 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. High water marks, compiled by Tetra Tech (2016), were available for this inflow event.

3.2.3 December 2015

For the December 2015 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. High water marks, compiled by Tetra Tech (2016), were available for this inflow event. Of the selected calibration events, the December 2015 event had the highest recorded flow on the Spring River at Quapaw gage. The peak flow at the Elk River near Tiff City gage was 107,000 cfs, which is equal to the peak flow that occurred at this gage

during the April 2017 event. This flow is the highest recorded flow on the Elk River for the selected calibration events.

3.2.4 January 2017

For the January 2017 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. Hourly WSEL logger data throughout the study area were collected by the project team for this event. Of the selected calibration events, the January 2017 event had the lowest recorded flow on all gages.

3.2.5 April 2017

For the April 2017 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. Hourly WSEL logger data throughout the study area were collected by the project team for this event. The peak flow at the Elk River near Tiff City gage was 107,000 cfs, which is equal to the peak flow that occurred at this gage during the December 2015 event. This flow is the highest recorded flow on the Elk River for the selected calibration events.

3.2.6 May 2019

For the May 2019 event, hourly flow and stage data were available for the Neosho River at Commerce gage, Tar Creek at Miami gage, Spring River at Quapaw gage, and Elk River near Tiff City gage. Hourly stage data were available for the Neosho River at Miami gage and Lake O' the Cherokees at Langley gage. Hourly WSEL logger data throughout the study area were collected by the project team for this event. Of the selected calibration events, the May 2019 event had the highest recorded flow at the Tar Creek at Miami gage.

3.3 Methodology

The goal of model calibration was to create a single geometry file that could be used for a variety of synthetic/hypothetical simulations. Simulated WSEL values were compared to stream gage elevations within the study area, high water marks, and WSEL logger data collected by the project team.

Tetra Tech previously digitized land cover along the Neosho River from the confluence with the Spring River to the upstream end of the model (Tetra Tech, 2015). Mead & Hunt expanded the coverage, digitizing land cover in the following areas:

1. Neosho River, downstream of the confluence with the Spring River
2. Grand Lake
3. Elk River
4. Spring River

Tetra Tech assigned Manning's n-values to land cover categories (Tetra Tech, 2015). Tetra Tech's work relied on commonly used guidance (Arcement & Schneider, 1989) and area-specific investigation (Mussetter, 1998). Mead & Hunt continued to use the same Manning's n-values in overbank areas. Mead & Hunt digitized two new categories of land cover: field crops and dense urban areas. Manning's n-values were assigned to these categories based on other n-values and engineering judgment. Horizontal variation in n-values was applied to the cross-sections and spatially varied n-values were applied to the 2DFAs. **Table 2** lists the overbank Manning's n-values.

Table 2. Overbank Manning's n-values.

Land Cover	n-Value
Field crops	0.040
Pasture	0.080
Urban	0.070
Urban, dense	0.090
Water	0.040
Woody vegetation	0.100
Woody vegetation, dense	0.150

Manning's n-values in the main channel were iteratively adjusted until simulated WSELs reasonably agreed with measured data. **Table 3** lists the in-channel Manning's n-values that resulted from model calibration.

Table 3. Channel Manning's n-values.

Reach	n-Value
Grand Lake (reservoir, up to RM 121.29)	0.020
Neosho River (RM 121.51 up to RM 128.81)	0.035
Neosho River (RM 129.07 up to RM 135.44)	0.037
Neosho River (RM 135.47 up to RM 152.2)	0.025
Elk River (full reach)	0.042
Spring River (full reach)	0.038

After the base n-values were determined, flow roughness factors were iteratively applied to further decrease the differences between simulated and measured WSELs. **Table 4** lists the flow roughness factors that resulted from model calibration.

Table 4. Flow roughness factors.

Neosho River		Spring River		Elk River	
Flow (cfs)	Roughness Factor	Flow (cfs)	Roughness Factor	Flow (cfs)	Roughness Factor
0	0.60	0	0.79	0	1.15
20,000	0.60	20,000	0.79	40,000	1.15
40,000	0.70	40,000	0.94	60,000	0.80
45,000	0.70	60,000	0.94	80,000	0.80
50,000	1.00	80,000	0.94	100,000	1.00
55,000	1.25	100,000	1.00	120,000	1.00
60,000	1.25	120,000	1.00	140,000	1.00
80,000	1.25	140,000	1.10	160,000	1.00
90,000	1.30	160,000	1.10	350,000	1.00
110,000	1.30	180,000	1.00		
140,000	1.30	350,000	1.00		
150,000	1.30				
160,000	1.00				
350,000	1.00				

3.4 Results

The results from the model calibration are discussed in the following paragraphs. **Figure 13** displays the over/underprediction of peak simulated WSEL at USGS gages. The average difference between simulated WSELs and measured USGS gage WSELs is -0.1 feet; the model is slightly underpredicting the WSEL at USGS gages.

UHM results were also compared to the high water marks compiled by Tetra Tech (2016). **Figure 14** compares model results to the July 2007 high water marks, **Figure 15** compares results to the October 2009 marks, and **Figure 16** compares results to the December 2015 marks. The average underprediction of simulated WSEL is 0.5 feet for the July 2007 event, the average overprediction is 0.4 feet for the October 2009 event, and the average underprediction is 0.1 feet for the December 2015 event.

The project team installed WSEL loggers throughout the study area. Loggers were in place during three calibration events: January 2017, April 2017, and May 2019. **Figure 17** displays the logger locations. Not all logger locations have data for a given event; some loggers were missing when the project team visited to perform maintenance and download data. Loggers 3, 4, 11, and 12 were missing for the May 2019 event. Logger 9 was missing for all three events. Data from loggers 7, 8, 13, 14, and 15 were not included in calibration because the logger WSEL was influenced by incoming, un-gaged streams not modeled in the UHM. The loggers were placed in support of the Sedimentation Study, early in the pre-study period before model parameters were fully defined. **Figure 18** displays the over/underprediction of peak simulated WSEL at the loggers used for model calibration for the three events. The average difference between simulated WSELs and measured WSELs is -0.6 feet; the model is underpredicting the WSEL at the loggers.

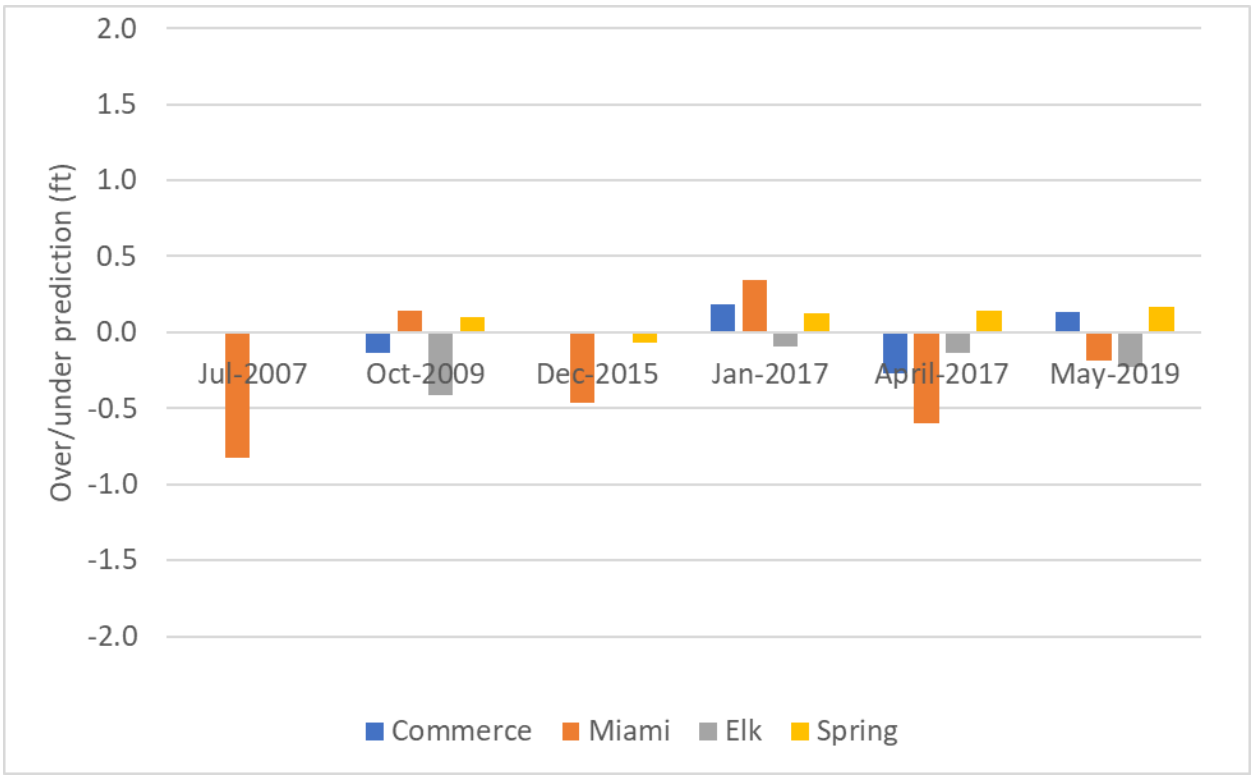


Figure 13. Over/underprediction of simulated WSEL at USGS gages.

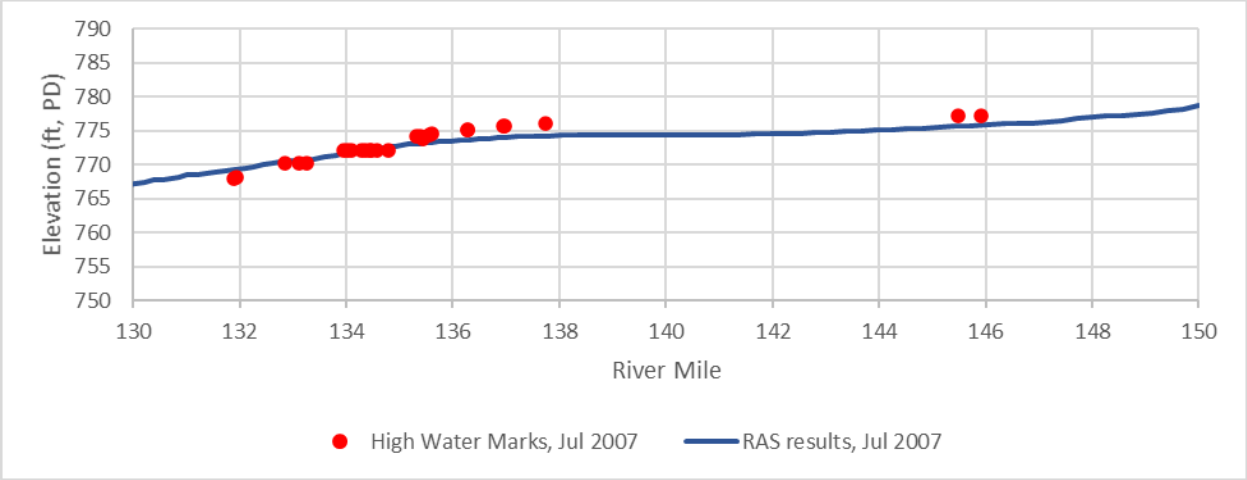


Figure 14. Comparison of UHM results to July 2007 high water marks.

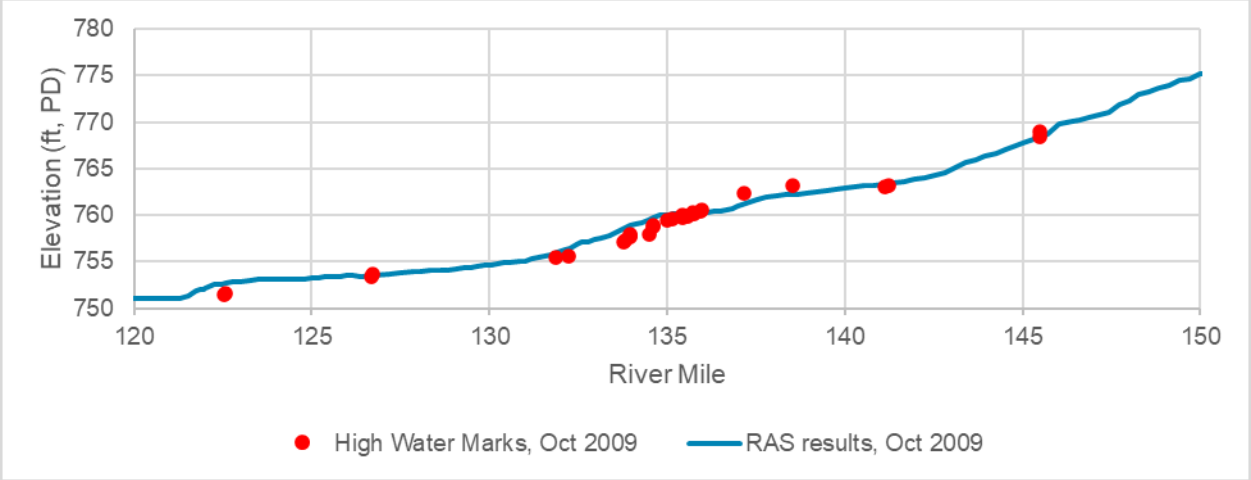


Figure 15. Comparison of UHM results to October 2009 high water marks.

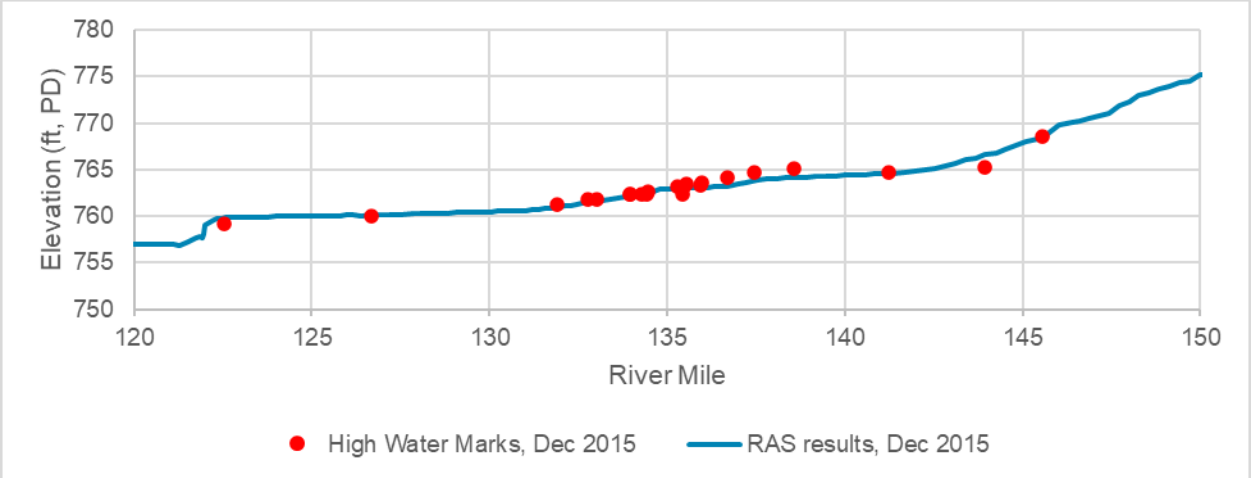


Figure 16. Comparison of UHM results to December 2015 high water marks.

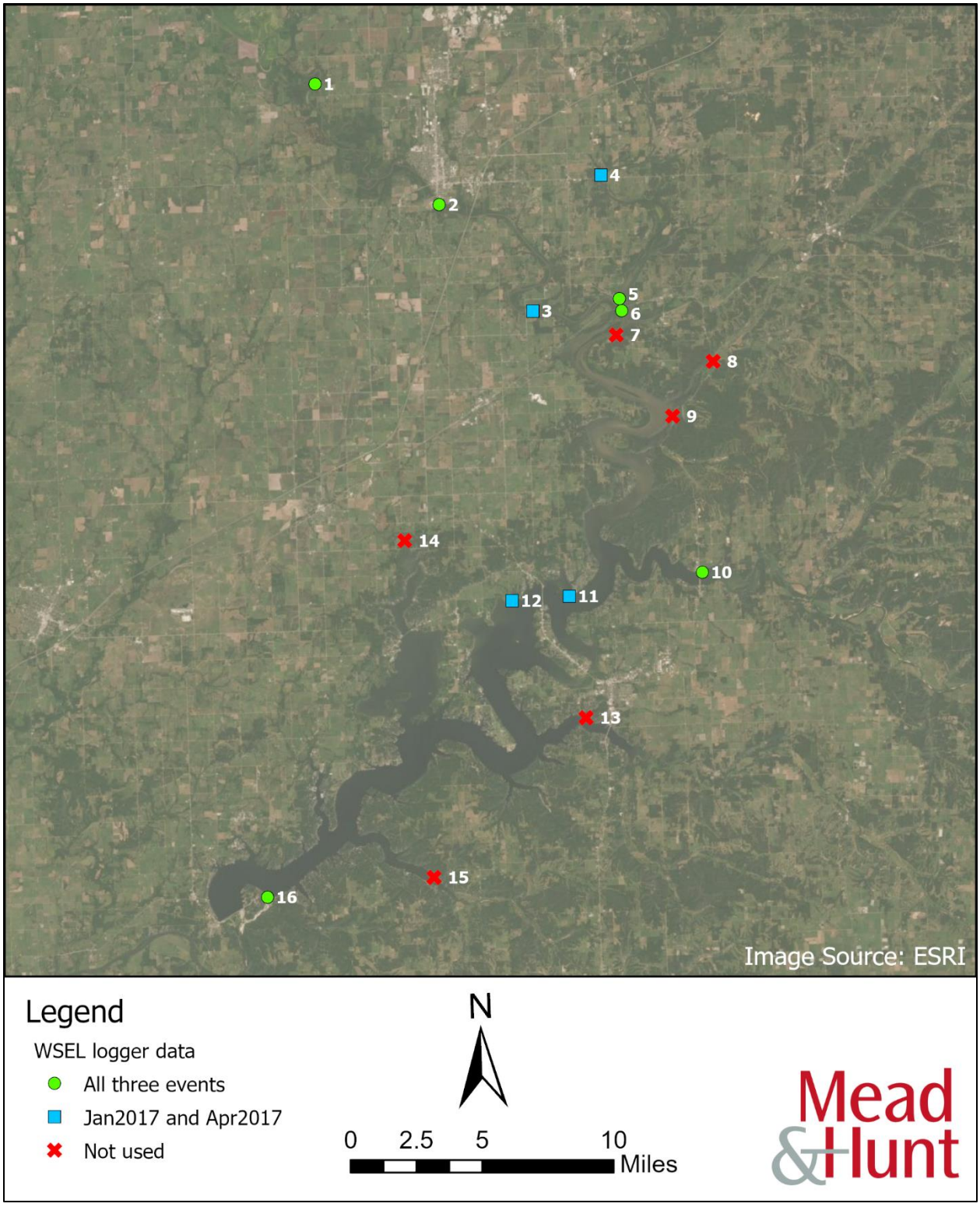


Figure 17. Locations of WSEL loggers installed by project team.

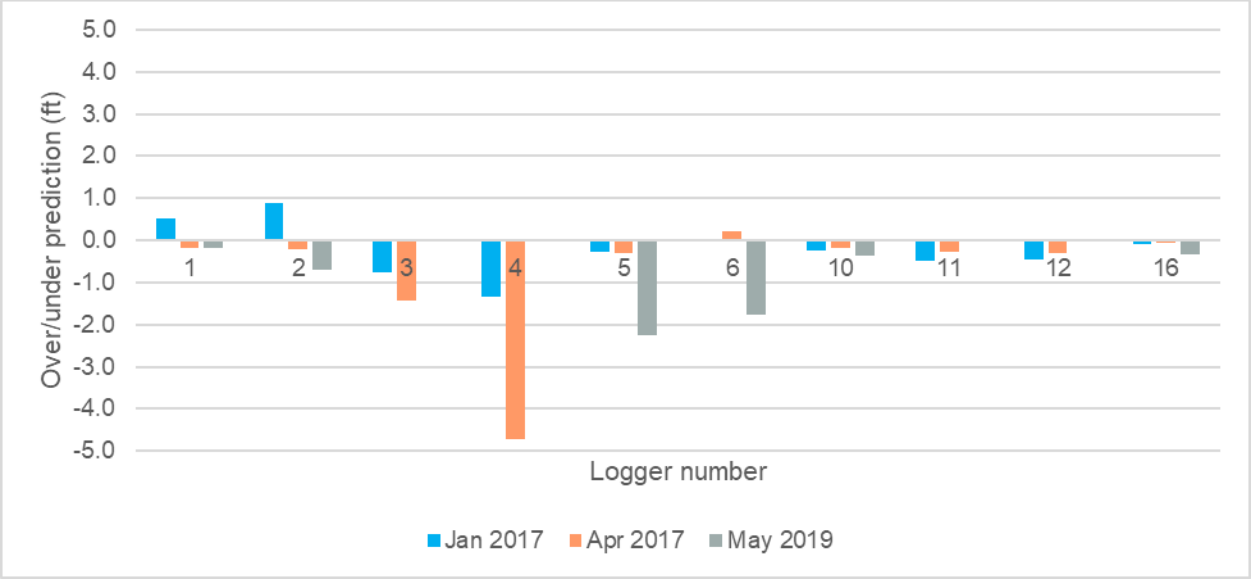


Figure 18. Over/underprediction of simulated WSEL at loggers installed by project team.

3.5 July 2007 Additional Data

As noted in **Section 3.1**, for gages where inflow hydrographs were defined, stage data were available in hourly increments from October 2007 onward. After the Technical Conference on April 21, 2021, the City of Miami, Oklahoma, provided comments regarding the Upstream MISR (City of Miami, 2021). The City of Miami noted that stage data for the Commerce gage from circa 1990 to October 2007 were not published online but were available upon request from USGS. The City of Miami recommended obtaining the data from USGS and using it in the calibration process.

Mead & Hunt contacted USGS and requested the pre-October 2007 hourly stage data for the Commerce gage on the Neosho River, the Miami gage on the Neosho River, the Tiff City gage on the Elk River, and the Quapaw gage on the Spring River. Scott Strong, from the USGS Tulsa Field Office, provided the pre-October 2007 hourly stage data for the gages to Mead & Hunt with the following disclaimer (USGS disclaimer):

> *Please note that prior to October 2007, instantaneous stage values were not considered a reportable data product. A small possibility exists that some of the data provided in this email was not processed in accordance with current USGS standards and could contain errors.*

Because of this disclaimer, Mead & Hunt compared the pre-October 2007 USGS data to other publicly available USGS data:

1. Peak streamflow is the maximum flow that occurred during the USGS water year. Stage associated with the peak streamflow is reported by USGS and was converted to WSEL (feet, PD datum) by Mead & Hunt for analysis. For the Miami gage, USGS reports maximum stage that occurred during the USGS water year because streamflow is not reported at the gage.
2. Streamflow measurements are USGS field measurements and are independent of gage-recorded values. USGS reports flow and gage height for streamflow measurements. Stage was converted to WSEL (feet, PD datum) by Mead & Hunt for analysis.

USGS data for the July 2007 event are discussed below.

3.5.1 Neosho River near Commerce, OK

For the Commerce gage, Mead & Hunt also reviewed USGS data available from the gage Peak Streamflow webpage (USGS, 2021g) and the gage Streamflow Measurements webpage (USGS, 2021h). These data, along with the pre-October 2007 USGS data and results from the HEC-RAS model, are presented in **Table 5**.

Mead & Hunt analyzed the difference between the USGS measurements and the HEC-RAS model results. The WSEL for the peak streamflow value is 0.15 feet lower than the maximum WSEL caculated by the HEC-RAS model. The WSELs from the streamflow measurements range from 0.58 feet to 1.29 feet higher than the HEC-RAS maximum WSEL. The maximum WSEL of the pre-October 2007 hourly time series data provided by USGS is 1.45 feet higher than the HEC-RAS maximum WSEL.

USGS measurements were also compared against each other. The highest USGS streamflow measurement is 0.16 feet lower than the maximum WSEL of the pre-October 2007 hourly time series data provided by USGS. The peak streamflow WSEL is 1.60 feet lower than the maximum WSEL of USGS hourly time series. The peak streamflow WSEL is reported on July 3, 2007. Compared to the two streamflow measurements collected on July 3, 2007, the peak streamflow WSEL ranges from 0.73 feet to 1.13 feet lower than the streamflow measurements.

While there are differences between the HEC-RAS results and the USGS measurements, there are also differences between the various USGS measurements. The magnitude of the differences between HEC-RAS results and USGS measurements is similar to the magnitude of differences between the various USGS measurements.

Table 5. Comparison of additional data for the Neosho River near Commerce, OK

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	7/3/2007 (no time listed)	775.55
USGS Streamflow Measurements	7/3/2007 1615 hours	776.28
	7/3/2007 1930 hours	776.68
	7/4/2007 1222 hours	776.99
Pre-October 2007 USGS Data Maximum WSEL	7/3/2007 2300 hours	777.15
HEC-RAS Maximum WSEL	7/4/2007 1200 hours	775.70

3.5.2 Neosho River at Miami, OK

For the Miami gage, Mead & Hunt also reviewed the USGS data available from the gage Peak Streamflow webpage (USGS, 2021i). No data were available for the July 2007 event on the gage Streamflow Measurements webpage (USGS, 2021j). The gage peak streamflow value, along with the pre-October 2007 USGS data, USGS daily maximum (see **Section 3.1.2**) and results from the HEC-RAS model, are presented in **Table 6**.

The WSELs for the peak streamflow, the pre-October 2007 USGS data, and the USGS daily maximum are all 774.05 ft. Because the values are exact matches, the peak streamflow value and daily maximum were potentially based on the pre-October 2007 data that USGS delivered to Mead & Hunt. The USGS WSELs are 0.83 feet higher than the maximum WSEL in the HEC-RAS model.

Table 6. Comparison of additional data for the Neosho River at Miami, OK

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	7/4/2007 (no time listed)	774.05
USGS Streamflow Measurements	*No data*	
Pre-October 2007 USGS Data Maximum WSEL	7/4/2007 0300 hours	774.05
USGS Daily Maximum WSEL	7/4/2007 (no time listed)	774.05
HEC-RAS Maximum WSEL	7/4/2007 1800 hours	773.22

3.5.3 Elk River near Tiff City, OK

For the Tiff City gage on the Elk River, Mead & Hunt also reviewed USGS data available from the gage Peak Streamflow webpage (USGS, 2021k) and the gage Streamflow Measurements webpage (USGS, 2021l). These data, along with the pre-October 2007 USGS data and results from the HEC-RAS model, are presented in **Table 7**.

The WSEL for the peak streamflow matches the WSEL for the pre-October 2007 USGS data. Because the values are exact matches, the peak streamflow value was potentially based on the pre-October 2007 data that USGS delivered to Mead & Hunt. The streamflow measurement occurred six days after the peak had passed and thus is not a good point for comparison. The WSEL for the peak streamflow is 0.58 feet lower than the maximum WSEL in the HEC-RAS model.

Table 7. Comparison of additional data for the Elk River near Tiff City, OK

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	6/13/2007 (no time listed)	758.32
USGS Streamflow Measurements	6/19/2007 1107 hours	754.20
Pre-October 2007 USGS Data Maximum WSEL	6/13/2007 0100 hours	758.32
HEC-RAS Maximum WSEL	6/13/2007 0300 hours	758.90

3.5.4 Spring River near Quapaw, OK

For the gage near Quapaw on the Spring River, Mead & Hunt also reviewed USGS data available from the gage Peak Streamflow webpage (USGS, 2021m) and the gage Streamflow Measurements webpage (USGS, 2021n). These data, along with the pre-October 2007 USGS data and results from the HEC-RAS model, are presented in **Table 8**.

The WSEL for the peak streamflow matches the WSEL for the pre-October 2007 USGS data. Because the values are exact matches, the peak streamflow value was potentially based on the pre-October 2007 data that USGS delivered to Mead & Hunt. Comparing USGS measurements to HEC-RAS, the WSEL for the peak streamflow is 0.63 feet higher than the maximum WSEL in the HEC-RAS model. The streamflow measurement is 0.97 feet lower than the maximum WSEL in the HEC-RAS model.

Comparing USGS measurements against each other, the peak streamflow WSEL is 1.60 feet higher than the streamflow measurement. The difference between the USGS measurements exceeds the difference between the HEC-RAS results and either of the USGS measurements.

Table 8. Comparison of additional data for the Spring River near Quapaw, OK

Source	Date and Time	Water Surface Elevation (ft, PD)
USGS Peak Streamflow	6/13/2007 (no time listed)	779.21
USGS Streamflow Measurements	6/13/2007 1218 hours	777.61
Pre-October 2007 USGS Data Maximum WSEL	6/13/2007 0400 hours	779.21
HEC-RAS Maximum WSEL	6/13/2007 0700 hours	778.58

3.5.5 Summary of Findings and Conclusions Regarding Additional Data

Mead & Hunt considered the following factors when determining if the model should be recalibrated to match the pre-October 2007 USGS data for the July 2007 event:

1. USGS included a disclaimer for the pre-October 2007 data, noting that the data may not have been processed in accordance with current USGS standards and could contain errors.
2. Differences between various USGS measurements are similar to or greater than differences between HEC-RAS results and USGS measurements.
    a. For the Neosho River near Commerce gage, the magnitude of the differences between HEC-RAS results and USGS measurements is similar to the magnitude of differences between the various USGS measurements.
    b. For the Spring River near Quapaw gage, the difference between the USGS measurements exceeds the difference between the HEC-RAS results and either of the USGS measurements.
3. In the HEC-RAS User's Manual, USACE states that a ± 5% flow measurement, which may be "optimistic," translates into a stage error of ±1.0 feet (USACE, 2016c). Considering the differences between the various USGS measurements at the gage locations, there may be errors for the July 2007 event flow measurement that result in stage errors of 1.0 feet or more.
4. In their comments on the Upstream MISR, the City of Miami recommended reducing the Commerce gage peak flow for the July 2007 event hydrograph. The City of Miami's lack of comfort using publicly available USGS flow data for the July 2007 event further reinforces the recommendation against recalibrating the model to match the pre-October 2007 USGS data (which was delivered by USGS with a data accuracy disclaimer).

The goal of UHM development and calibration is to create a single geometry file that could be used for a variety of synthetic/hypothetical simulations. Adjusting model calibration to match a dataset suspected to have accuracy issues contradicts that goal. Considering the factors listed above, it is inadvisable to recalibrate the model to match the pre-October 2007 USGS data for the July 2007 event.

4. Flood Frequency Analysis

Mead & Hunt performed a flood frequency analysis for the study area. USACE has developed a period of record RiverWare model that includes Pensacola Dam. Mead & Hunt extracted the total inflow at Pensacola Dam from 1940 (dam construction date) to 2019 (latest available data at time of data delivery from USACE) from the RiverWare model.

Annual peak inflows at Pensacola Dam were extracted using HEC's Statistical Software Package (SSP) version 2.2. The full inflow time series was imported into HEC-SSP and the annual peaks were automatically filtered. Water years were set to start at October 1st to align with USGS water years (USGS, 2016). One manual adjustment was necessary for an event that occurred in September and October 1986. HEC-SSP automatically selected September 30, 1986 for the peak of water year 1986 and October 2, 1986 for the peak of water year 1987, as displayed in **Figure 19**. The September 30th peak is not hydrologically independent of the October 2nd peak. Mead & Hunt manually selected the next highest peak for water year 1986: November 19, 1985. Manually correct flood peaks were re-imported and a Graphical Frequency Analysis of Peak Inflows was performed in HEC-SSP. Weibull plotting positions were used and a best-fit was digitized through the peak flows. Annual recurrence interval flows were rounded to the nearest thousand cubic feet per second (cfs).

Tabular results of flood frequency analysis are presented in **Table 9** and graphical results are presented in **Figure 20**. **Figure 20** also displays the exceedance curve from the Real Estate Adequacy Study (USACE, 1998), which was developed using similar methodology as Mead & Hunt's analysis. At lower recurrence intervals (2-year through 10-year), the new analysis resulted in higher flows. At higher recurrence intervals (20-year through 500-year), the new analysis resulted in lower flows. Differences between the Mead & Hunt analysis and the Real Estate Adequacy Study Analysis are primarily due to the additional two decades of data used in the new analysis.

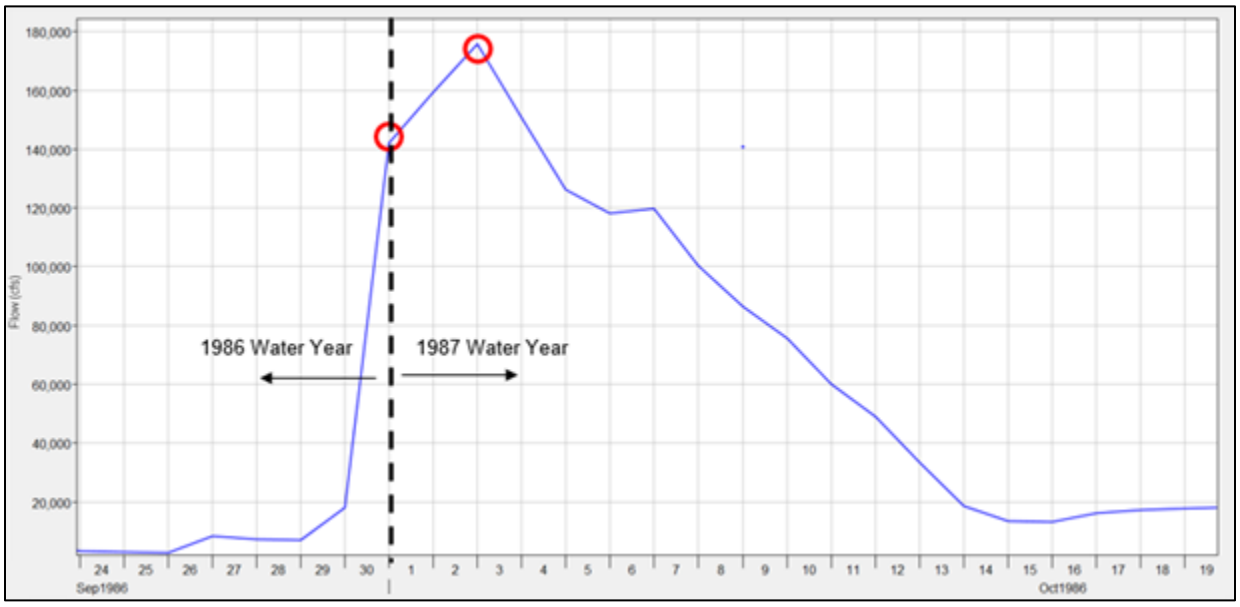


Figure 19. 1986 and 1987 water years in HEC-SSP.

Table 9. Flood frequency analysis tabular results.

Annual Recurrence Interval	Flow (cfs)
2	90,000
5	152,000
10	192,000
20	225,000
50	266,000
100	299,000
200	330,000
500	375,000

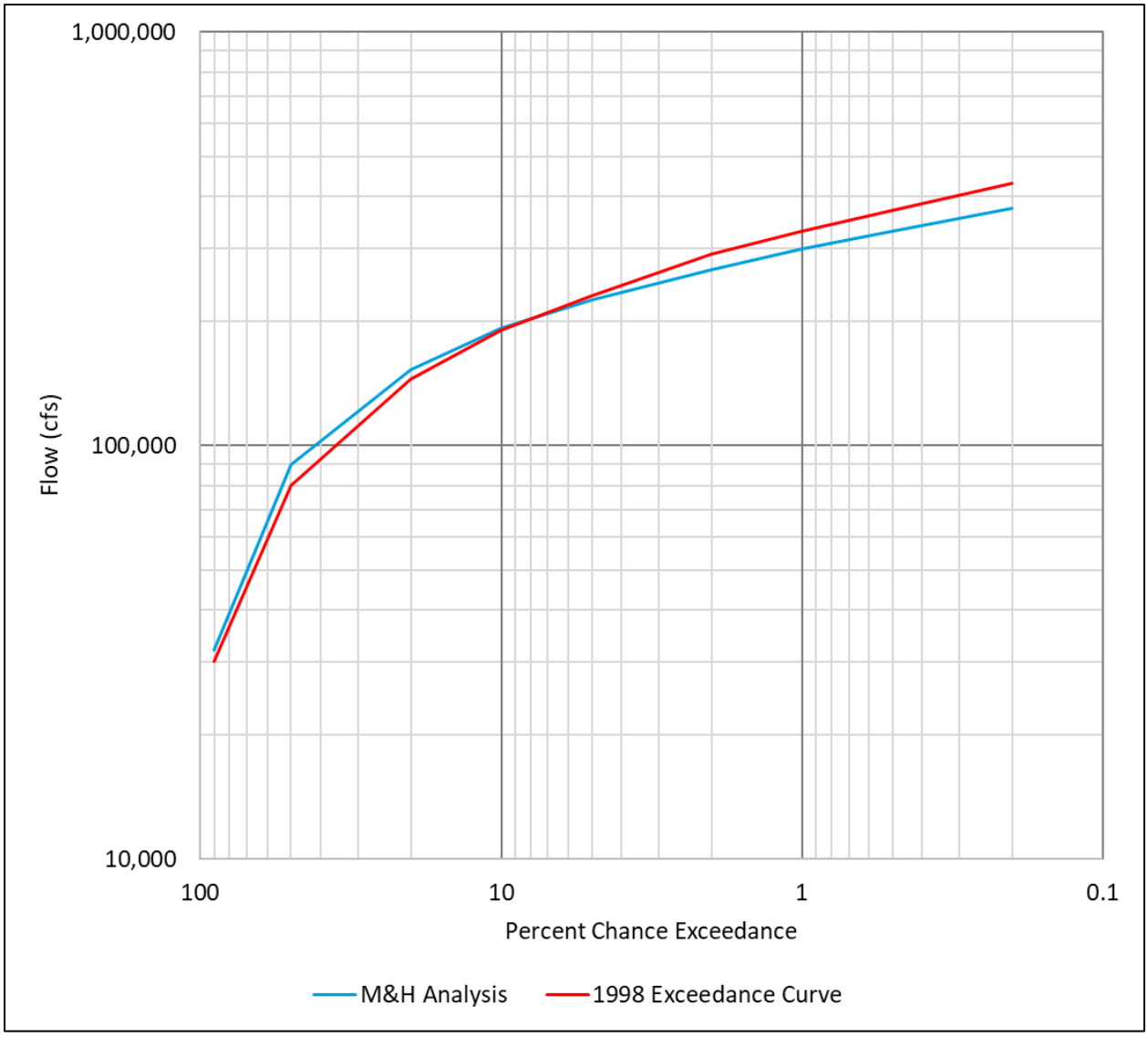


Figure 20. Flood frequency analysis graphical results.

5. Inflow Event Analysis

The flood frequency analysis estimated that the 100-year event flow at Pensacola Dam is approximately 300,000 cfs. The July 2007 event is the largest event of recent record on the Neosho River, with a peak flow of 141,000 cfs at the Commerce gage. Simulation results estimated a total peak inflow of approximately 130,000 at Pensacola Dam, which includes inflow from Tar Creek, the Elk River, and the Spring River. It also includes attenuation of the flood peaks as they travel to Pensacola Dam. When flood frequency at Pensacola Dam is considered, the July 2007 event is a 4-year return period event.

Three other recent events resulted in a large inflow at Pensacola Dam: September 1993, December 2015, and May 2019. Simulation results estimated a total peak inflow at Pensacola Dam of 226,000 cfs for the September 1993 event; 210,000 cfs for the December 2015 event; and 190,000 cfs for the May 2019 event. The peak inflow for the September 1993, July 2007, December 2015, and May 2019 events are listed in **Table 10**, along with the estimated return period.

The FERC's SPD stated that "If the flood frequency analysis shows that the selected historical inflow events do not exceed a 100-year recurrence interval, inflow events up to and including the 100-year recurrence interval would be evaluated." Therefore, Mead & Hunt iteratively scaled the events listed in **Table 10** until the total peak inflow at Pensacola Dam was approximately 300,000 cfs. The scaling factors are listed in **Table 10**. The scaled events were simulated in the UHM.

Table 10. Peak inflows at Pensacola Dam for four recent events.

Event	Peak Inflow[1] at Pensacola Dam (cfs)	Estimated Return Period	Scaling Factor to Estimate 100-year Return Period
September 1993	226,000	21 years	1.17
July 2007	130,000	4 years	2.26
December 2015	210,000	15 years	1.50
May 2019	190,000	9 years	1.70

[1] *Peak inflow rounded to the nearest 10,000 cfs*

Mead & Hunt selected the scaled July 2007 event to represent the 100-year inflow to Pensacola Dam. Mead & Hunt used a statistical analysis of historical inflow volumes and peak flows to adjust the inflow hydrograph volume for the scaled July 2007 event. For each 24-hour period of the hydrograph, the total volume to Pensacola Dam was estimated using a modeled volume vs. peak flow relationship. The statistical model was developed based on a coefficient of determination (R^2) best-fit calculation assuming the Generalized Extreme Value (GEV) distribution (Bolívar, Díaz-Francés, Ortega, & Vilchis, 2010.; Takara, 2009). The GEV distribution is a family of distributions (Gumbel, Frechét, and Weibull) commonly used to model infrequent (extreme) random variables, including wind speed, precipitation, and stream flow.

Pensacola Dam inflow for 24-hour periods was extracted from the USACE RiverWare model. Inflow by 24-hour duration was converted to volume. Volumes were placed into bins with D+0 representing the day when the peak inflow occurred, D-1 representing the day before the peak, D+1 representing the day after the peak, and so on. The outermost bins included the average over three days: D-8 to D-10, and D+7 to D+9. Thus, the full set of bins is as follows: D-8 to D-10, D-7, D-6, D-5, D-4, D-3, D-2, D-1, D+0, D+1, D+2, D+3, D+4, D+5, D+6, and D+7 to D+9.

Sets of bins were calculated for the day within each USGS water year for which the annual maximum inflow to Pensacola Dam occurred (one set of bins per USGS water year). Bins were then ordered according to maximum inflow to Pensacola Dam and used to calculate the GEV distribution parameters.

First, the 100-year inflow to Pensacola Dam was predicted using the GEV distribution parameters and the annual peak inflow values from RiverWare. The reduced variate was calculated for each ordered peak inflow value, and the shape parameter was adjusted to maximize the R^2 correlation of the GEV-linearized discharges (peak inflow vs. reduced variate of peak inflow). This resulted in a 100-year inflow to Pensacola Dam of 306,317 cfs, which is within 3 percent of the value calculated in Mead & Hunt's flood frequency analysis using the Graphical Frequency Analysis of Peak Inflows method, which validates the flood frequency analysis results. The shape parameter was then adjusted so the 100-year inflow would match the value of 299,000 cfs from the flood frequency analysis, for consistency. **Table 11** presents the GEV distribution parameters and flow results for both cases. Note that the R^2 value was very high for both the original and adjusted cases.

Table 11. GEV distribution parameters and results.

Parameter	Prediction of 100-year Inflow	Adjusted to Match Flood Frequency Analysis 100-year Inflow
shape parameter, k (approximate)	0.01	-0.02
scale parameter, σ (linear slope, m)	49703	51076
location parameter, μ (linear intercept, b)	73193	73586
coefficient of determination, R^2	0.991	0.990
reduced variate for 100-year event, y	4.69	4.41
100-year inflow (cfs)	306,317	299,000

For each volume bin (D-8 to D-10, D-7… D+0… D+6, and D+7 to D+9), the binned daily volumes were plotted as a function of the reduced variates for the corresponding peak inflow values, using the same adjusted shape parameter (k) used to predict the 100-year inflow. A linear trend line for each volume bin (e.g., D+0) was calculated to obtain the scale parameter σ (linear slope, m) and a location parameter μ (linear intercept, b) for each volume bin. The reduced variate for the 100-year peak inflow (4.41), along with the scale and location parameters were then used to calculate the daily inflow volumes for each bin that are predicted to correspond to a 100-year peak inflow event. **Table 12** displays the results of the statistical analysis. Additional information including correlation plots can be found in **Appendix B**.

Table 12. Results of historical inflow volume statistical analysis.

Volume Bin	Scale Parameter, σ (m)	Location Parameter, μ (b)	100-Year Inflow Volume (acre-feet)
D-8 to D-10 avg.	13701	15500	75,966
D-7	13651	15589	75,835
D-6	10187	18852	63,810
D-5	7285	23100	55,249
D-4	6811	28286	58,344
D-3	16733	34613	108,461
D-2	38161	50607	219,023
D-1	77487	93430	435,403
D+0	101308	145956	593,058
D+1	88088	115917	504,675
D+2	61232	85512	355,747
D+3	40672	57248	236,745
D+4	27591	39800	161,567
D+5	20812	33485	125,334
D+6	15887	30527	100,641
D+7 to D+9 avg.	11578	30060	81,157

The resulting volume curve at Pensacola Dam was used as a goal for the volume at Pensacola Dam in HEC-RAS. In HEC-RAS, variable factors were applied at different times along the inflow hydrographs iteratively until the resulting daily inflow volume at Pensacola Dam closely matched the results of the statistical analysis. The peak flow at Pensacola Dam is still scaled to approximately match the predicted 100-year peak flow at the dam, calculated in the flood frequency analysis. **Figure 21** presents the results graphically and **Table 13** presents the results in tabular format.

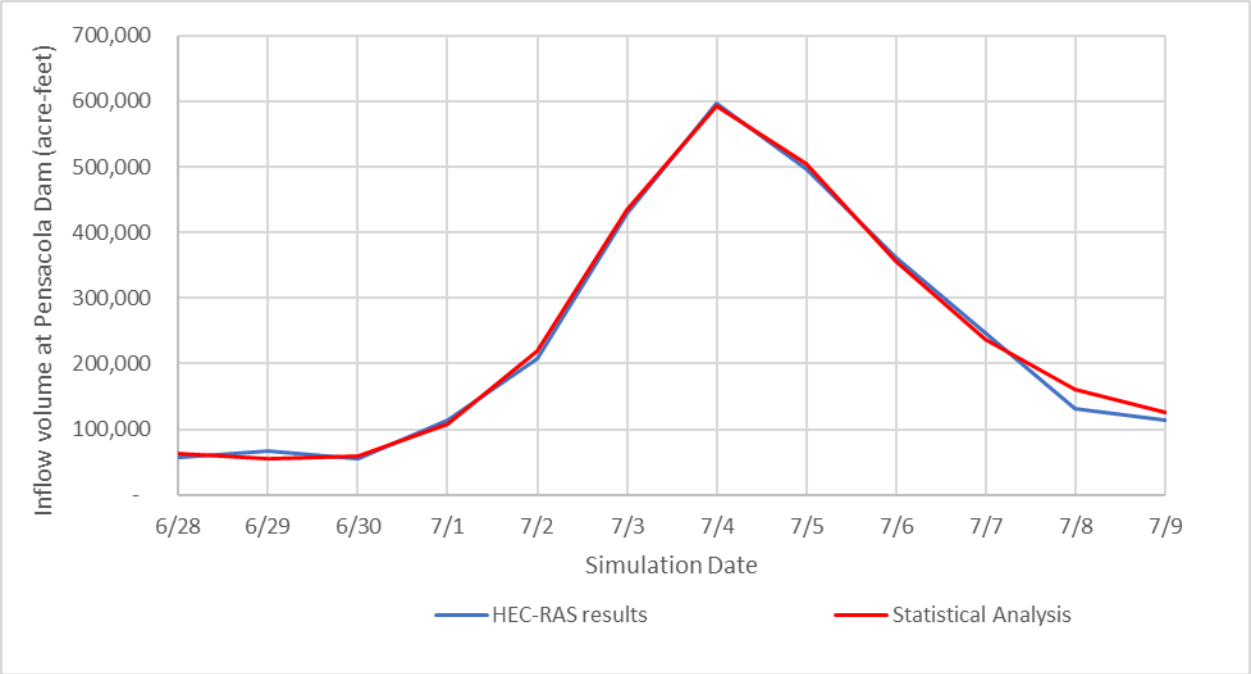


Figure 21. Graphical comparison of HEC-RAS results to statistical analysis for the 100-year flood event.

Table 13. Tabular comparison of HEC-RAS results to statistical analysis for the 100-year flood event.

Simulation Date	Volume (acre-feet)	
	Statistical Analysis	HEC-RAS Results
6/28/2007	63,810	57,073
6/29/2007	55,246	67,085
6/30/2007	58,345	55,453
7/1/2007	108,461	114,053
7/2/2007	219,027	207,606
7/3/2007	435,403	429,269
7/4/2007	593,058	596,025
7/5/2007	504,674	496,290
7/6/2007	355,747	361,363
7/7/2007	236,745	246,033
7/8/2007	161,566	130,901
7/9/2007	125,335	113,355

6. Definition of “Material Difference”

The RSP states that:

> *The H&H study area will encompass the channel and overbank areas of the Grand/Neosho River watershed that have a material difference in water surface elevation due to Project operation during the measured inflow events of the H&H Study. A material difference in water surface elevation due to Project operations will be based on professional judgment.*

In the SPD, the FERC recommended GRDA propose a definition of “material difference.” On GRDA’s behalf, Mead & Hunt reviewed how various government entities quantify difference in WSEL, and the findings are as follows:

1. FEMA requires base flood elevations, which is commonly the 100-year event WSEL, to “match within one-half foot” at the transition between a revised study and the study it is replacing (Office of the Federal Register, 2021).
2. USACE published an engineering manual for the Hydrologic Engineering Requirements for Reservoirs (USACE, 2018). The manual dictates the point of intersection between pre-project and post-project WSEL profiles is established where the profiles are within one foot of each other.
3. USGS defines field measurements of discharge as “excellent” if the flow measurement is within 2% of the actual value and as “good” if the measurement is within 5% of the actual value. Mead & Hunt ran all the calibration simulations with the gage inflows increased and decreased by 2%. WSELs between the two sets of simulations were compared at the USGS gages within the study area. There was a difference in WSEL of approximately one-half foot between the simulation results.

In an effort to follow generally accepted scientific practice, Mead & Hunt completed a review of how government agencies approach differences in WSEL. Material difference represents expected precision when comparing model results for the sole purpose of determining areas to be included in the model. Mead & Hunt is defining material difference as 0.5 feet of WSEL for out of bank events or 0.5 feet of WSEL within the banks where inundation impacts infrastructure or other sensitive resources. The study results (**Section 8**) confirmed that WSEL differences at the upstream ends of the model did not exceed 0.5 feet for either in bank or out of bank events.

7. Simulated Scenarios

The calibrated HEC-RAS model was used to analyze a range of operating conditions at Pensacola Dam. Five historical inflow events and one synthetic inflow event were analyzed. The inflow events and historical pool elevations at the start of the inflow events are listed in **Table 14**. In addition to the historical pool elevation, eleven other starting pool elevations were simulated. Starting pool elevations were divided into two categories:

1. Starting pool elevations within GRDA's anticipated operational range of 742 feet PD to 745 feet PD.
2. Extreme, hypothetical values of starting pool elevations outside GRDA's anticipated operational range. Values below and above GRDA's anticipated operational range were included in the study based on FERC's February 2022 Determination.

Table 15 lists the non-historical starting pool elevations analyzed. The Operations Model (OM), which was updated according to FERC's February 2022 Determination, was used to calculate stage hydrographs at Pensacola Dam for the various starting pool elevations. The starting pool elevations ranged from 734 feet PD up to 757 feet PD, which is the elevation of the crest of the dam.

Table 14. List of inflow events simulated and historical pool elevations at simulation start.

Inflow Event	Type	Estimated Return Period[1]	Pensacola Dam Historical Pool Elevation at Simulation Start (ft, PD)	Simulation Start/End Date
Sept. 1993	Historical	21 years	743.85	9/24/1993 – 10/16/1993
June 2004	Historical	1 year	743.42	6/13/2004 – 6/30/2004
July 2007	Historical	4 years	745.69	6/28/2007 – 7/25/2007
Oct. 2009	Historical	3 years	740.98	10/8/2009 – 10/21/2009
Dec. 2015	Historical	15 years	742.86	12/26/2015 – 1/16/2016
100-year	Synthetic	100 years	N/A[2]	

[1] Return period for peak inflow at Pensacola Dam.

[2] Because the 100-year event is synthetic, there is no historical pool elevation, or event start/end dates. The duration of simulation is 12.5 days.

Table 15. List of additional initial pool elevations simulated.

Inflow Event	Pensacola Dam Pool Elevation at Simulation Start (ft, PD)	
	Anticipated Operational Range	Extreme, Hypothetical Range
Sept. 1993 (21 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
June 2004 (1 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
July 2007 (4 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
Oct. 2009 (3 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
Dec. 2015 (15 year)	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0
100-year	742.0, 742.5, 743.0, 743.5, 744.0, 744.5, 745.0	734.0, 749.0, 753.0, 757.0

USGS flow data were used to define inflow hydrographs at the upstream ends of the model for the historical inflow events. The development of the inflow hydrographs for the synthetic 100-year event is discussed in **Section 5**. Peak inflows for the various inflow locations and inflow events are listed in **Table 16**. The flow hydrographs for the inflow events are included in **Appendix C**. Of the inflow events:

1. The September 1993 event had the highest recorded flow on the Spring River gage near Quapaw.

2. The June 2004 event had the lowest recorded flow on the Neosho River at the Commerce gage, the Spring River at the Quapaw gage, and the Elk River at the Tiff City gage.
3. The July 2007 event had the highest recorded flow on the Neosho River at the Commerce gage.
4. The October 2009 event had the second highest recorded flow on Tar Creek at the 22nd Street gage.
5. The December 2015 event had the highest recorded flow on the Elk River at the Tiff City gage.

Table 16. Summary of peak inflows.

Inflow Event	Peak Inflow (cfs)			
	Neosho River	Tar Creek	Spring River	Elk River
Sept. 1993 (21 year)	75,600	8,200	230,000	18,100
June 2004 (1 year)	24,800	749	10,500	577
July 2007 (4 year)	141,000	726	33,300	1,190
Oct. 2009 (3 year)	46,100	4,630	66,200	39,300
Dec. 2015 (15 year)	45,400	4,710	151,000	107,000
100-year	308,264	1,641	74,975	2,689

The inflow hydrographs and the Pensacola Dam starting pool elevations were input into the OM, which calculated the stage hydrographs at Pensacola Dam for the various scenarios. The OM USR, filed simultaneously with this report, discusses the development and results of the OM. **Table 17** summarizes, by inflow event, the lowest and highest peak elevation of the Pensacola Dam pool for the simulations with various Pensacola Dam starting pool elevations. The stage hydrographs at Pensacola Dam for the various starting pool elevations are included in **Appendix C**.

The highest peak elevation of the Pensacola Dam pool (757 feet PD for all inflow events) listed in **Table 17** is unrelated to the magnitude of the inflow event or GRDA operations during the inflow event. Rather, it is simply the maximum starting pool elevation simulated in accordance with FERC's February 2022 Determination. Because an elevation of 757 feet PD is equal to the crest of the dam, the OM immediately begins reducing the pool elevation after the start of the simulation. The highest peak pool elevation is thus only a function of the initial Pensacola Dam pool condition. When the highest peak is set at the top of the dam, there is no correlation to the magnitude of the inflow event or GRDA operations during the inflow event. The difference between the highest peak pool elevation when set at the top of the dam, and the lowest peak pool elevation likewise has little to do with the inflow event magnitude or GRDA operations.

Table 17. Summary of peak pool elevations at Pensacola Dam (USGS Gage No. 07190000) for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range.

Event	Pensacola Dam Pool Elevation (ft, PD)		Difference (ft)
	Lowest Peak	Highest Peak	
Sept. 1993 (21 year)	754.1	757.0	2.9
June 2004 (1 year)	744.2	757.0	12.8
July 2007 (4 year)	754.0	757.0	3.0
Oct. 2009 (3 year)	747.5	757.0	9.5
Dec. 2015 (15 year)	754.5	757.0	2.5
100-year	754.9	757.0	2.1

The limited usability of **Table 17** shows the need for presentation of results within GRDA's anticipated operational range, rather than the extreme, hypothetical range of starting WSELs. **Table 18** summarizes

the lowest and highest peak elevation at Pensacola Dam for starting elevations within GRDA's anticipated operational range (742 to 745 ft PD). The maximum difference is 0.8 feet and occurs for the October 2009 (3-year) inflow event. Note that for the larger inflow events (15-year, 21-year, 100-year), there was no difference in peak pool elevation for the different starting elevations within GRDA's anticipated operational range.

Table 18. Summary of peak pool elevations at Pensacola Dam (USGS Gage No. 07190000) for starting elevations within GRDA's anticipated operational range.

Event	Pensacola Dam Pool Elevation (ft, PD)		Difference (ft)
	Lowest Peak	Highest Peak	
Sept. 1993 (21 year)	754.8	754.8	0.0
June 2004 (1 year)	744.6	745.0	0.4
July 2007 (4 year)	754.3	754.8	0.5
Oct. 2009 (3 year)	750.1	750.9	0.8
Dec. 2015 (15 year)	754.8	754.8	0.0
100-year	754.9	754.9	0.0

8. Study Results

Maximum WSELs and maximum inundation extents were extracted from HEC-RAS for each simulation. Maximum WSELs are presented in **Appendix D** (tabular format) and **Appendix E** (graphical format). Maximum inundation extents are presented in **Appendix F**. Durations of inundation are presented in **Appendix G**.

Tabulated results of maximum WSEL and maximum WSEL differences are presented in **Appendix D**. Within a set of tables, there is one table per modeled inflow source: the Neosho River, the Spring River, the Elk River, and Tar Creek. In **Appendix D.1** through **Appendix D.6**, tables are organized by inflow event. For example, the set of tables in **Appendix D.1** report maximum WSEL for the September 1993 inflow event. Each table in **Appendix D.1** through **Appendix D.6** includes two calculations of maximum difference in peak WSEL:

1. Maximum difference for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD).
2. Maximum difference for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

Appendix D.7 presents a set of tables for simulations that used historical starting pool elevations. Maximum WSELs are compared for the various inflow events. Each table in **Appendix D.7** includes the maximum difference in peak WSEL between the various inflow scenarios.

Plots of maximum WSEL profiles are presented in **Appendix E**. Like the tabulated results, **Appendix E.1** through **Appendix E.6** present profiles organized by inflow event, with simulation results from various starting pool elevations compared against each other. Each plot in **Appendix E.1** through **Appendix E.6** includes two profiles of calculated maximum difference in peak WSEL:

1. Maximum difference for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD).
2. Maximum difference for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

Appendix E.7 presents maximum WSEL profiles for simulations that used historical starting pool elevations. Maximum WSEL profiles are compared for the various inflow events. Each plot in **Appendix E.7** includes a profile of the maximum difference in peak WSEL between the various inflow events.

Appendix E.8 presents comparisons of maximum WSEL differences. Each plot in **Appendix E.8** includes the following plotted profiles:

1. Maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD).
2. Maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.
3. Maximum difference in WSEL for the historical inflow events (not including the synthetic 100-year inflow event).
4. Maximum difference in WSEL for all inflow events (including the synthetic 100-year inflow event).

The first profile listed above is the only profile that characterizes the impact of GRDA's anticipated

operational range on differences in WSEL upstream of the dam. The second profile listed characterizes the potential impact of extreme, hypothetical starting elevations. The third profile listed characterizes the impact of nature, but only for the historical inflow events simulated. The fourth profile listed characterizes the impact of nature for all inflow events studied, including the synthetic 100-year inflow event[1].

Maps of maximum inundation extent are presented in **Appendix F**. **Appendix F.1** through **Appendix F.6** present mapped inundation extent organized by inflow event, with mapped results from various starting pool elevations compared against each other. **Appendix F.7** presents mapped inundation extent for simulations that used historical starting pool elevations, with mapped results from various inflow events compared against each other.

Tabulated results of inundation duration are presented in **Appendix G**. For areas within the boundary of the flowage easement for the Project, inundation duration was defined as the time of inundation above the flowage easement elevation. For areas outside the boundary of the flowage easement, inundation duration was defined as the time of inundation above the channel bank elevation. In **Appendix G.1** through **Appendix G.6**, tables are organized by inflow event. For example, the set of tables in **Appendix G.1** report inundation duration for the September 1993 inflow event. Each table in **Appendix G.1** through **Appendix G.6** includes two calculations of inundation duration:

1. Inundation duration for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD).
2. Inundation duration for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

Appendix G.7 presents a set of inundation duration tables for simulations that used historical starting pool elevations. Inundation durations are compared for the various inflow events. Each table in **Appendix G.7** includes the maximum difference in inundation duration between the various inflow scenarios.

[1] Because the 100-year inflow event is synthetic, there is no historical starting pool elevation. To be conservative, a starting pool elevation of 734 feet PD was used for the 100-year inflow event when calculating the maximum difference in WSEL due to all inflow events.

9. Discussion of Results

Maximum WSELs, maximum inundation extents, and inundation durations were analyzed to determine the upstream impacts, if any, of various initial stages at Pensacola Dam. **Table 19** presents a summary of maximum WSEL differences along the modeled inflow reaches for simulated starting elevations within GRDA's anticipated operational range. The first six rows in the table present maximum WSEL differences for the various starting pool elevations for a given inflow event. The last two rows in the table present maximum WSEL differences for the various natural inflow events, first for the historical inflow events simulated, then for all inflow events simulated (including the 100-year event). Stated another way, the first six rows in the table characterize the impact of starting pool elevations within GRDA's anticipated operational range and the last two rows characterize the impact of nature. The maximum simulated WSEL differences due to a change in starting pool elevation within GRDA's anticipated operational range are orders of magnitude smaller than the maximum WSEL differences that can be caused by nature. More specifically:

1. Along the Neosho River, the maximum impact of nature ranges from 16 to 797 times greater than the maximum simulated impact of GRDA's anticipated operational range.
2. Along the Spring River, the maximum impact of nature ranges from 34 to 525 times greater than the maximum simulated impact of GRDA's anticipated operational range.
3. Along the Elk River, the maximum impact of nature ranges from 31 to 669 times greater than the maximum simulated impact of GRDA's anticipated operational range.
4. Along Tar Creek, the maximum impact of nature ranges from 59 to 2,922 times greater than the maximum simulated impact of GRDA's anticipated operational range.

Table 19. Summary of maximum WSEL differences for starting elevations within GRDA's anticipated operational range.

Event(s)	Maximum WSEL Differences (ft) for Starting Elevations Within GRDA's Anticipated Operational Range			
	Neosho River[1]	Spring River	Elk River	Tar Creek
Sept. 1993 (21 year)	0.40	0.12	0.06	0.16
June 2004 (1 year)	0.80	0.95	0.44	0.35
July 2007 (4 year)	1.29	1.07	0.53	0.12
Oct. 2009 (3 year)	0.99	0.50	0.87	0.10
Dec. 2015 (15 year)	0.06	0.14	0.06	0.04
100-year	0.04	0.07	0.04	0.01
Impact of inflow events (historical events only)	21.03	36.78	26.75	20.58
Impact of all inflow events (inc. 100-year event)	31.88	36.78	26.75	32.15

[1] Along the Neosho River, the maximum WSEL differences for the anticipated operations simulations occur at various locations between RM 112.6 and RM 128.8, which is downstream of Miami, OK. For the impact of inflow (impact of nature) simulations, the maximum WSEL difference occurs at RM 135.9, which is located in Miami, OK.

In accordance with FERC's February 2022 Determination, **Table 20** presents a summary of maximum WSEL differences along the modeled inflow reaches for simulated starting pool elevations outside GRDA's anticipated operational range. Even using these extreme, hypothetical starting stages, which range from 734 to 757 feet PD, the impact of nature is much greater than that of a 23-foot change in starting pool elevation. More specifically:

1. Along the Neosho River, the maximum impact of nature ranges from 1.6 to 16 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.

2. Along the Spring River, the maximum impact of nature ranges from 2.9 to 111 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.
3. Along the Elk River, the maximum impact of nature ranges from 2.1 to 14 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.
4. Along Tar Creek, the maximum impact of nature ranges from 3.0 to 564 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.

Along the Neosho River, the maximum WSEL differences for the extreme, hypothetical simulations occur at various locations between RM 77 (Pensacola Dam) and RM 122.0, which is downstream of Miami, OK.

Table 20. Summary of maximum WSEL differences for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range.

Event(s)	Maximum WSEL Differences (ft) for All Starting Elevations, Including Extreme, Hypothetical Values Outside GRDA's Anticipated Operational Range			
	Neosho River[1]	Spring River	Elk River	Tar Creek
Sept. 1993 (21 year)	2.92	0.98	2.97	0.71
June 2004 (1 year)	12.82	12.56	12.81	6.77
July 2007 (4 year)	3.02	2.13	3.00	0.29
Oct. 2009 (3 year)	9.69	6.32	9.65	2.03
Dec. 2015 (15 year)	3.15	3.10	2.59	1.84
100-year	2.05	0.33	1.88	0.06
Impact of inflow events (historical events only)	21.03	36.78	26.75	20.58
Impact of all inflow events (inc. 100-year event)	31.88	36.78	26.75	32.15

[1] Along the Neosho River, the maximum WSEL differences for the extreme, hypothetical simulations occur at various locations between RM 77 (Pensacola Dam) and RM 122.0, which is downstream of Miami, OK. For the impact of inflow (impact of nature) simulations, the maximum WSEL difference occurs at RM 135.9, which is located in Miami, OK .

Table 21 presents results of maximum WSEL differences through the City of Miami, OK in more detail for simulated starting pool elevations within GRDA's anticipated operational range. **Table 22** presents the same information for extreme, hypothetical starting elevations outside GRDA's anticipated operational range. In both tables, the columns on the right present maximum simulated differences in WSEL for four individual river mile segments that cover the City of Miami. The results show that any simulated impact of starting stage – whether within GRDA's anticipated operational range or for extreme, hypothetical stages – has little impact on WSELs when compared to nature's impact. More specifically:

1. The maximum impact of nature ranges from 46 to 3,188 times greater than the maximum simulated impact of GRDA's anticipated operational range.
2. The maximum impact of nature ranges from 2.3 to 531 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.

Table 21. Summary of maximum WSEL differences through Miami, OK for starting elevations within GRDA's anticipated operational range.

Event(s)	Maximum WSEL Differences Through Miami, OK (ft) for Starting Elevations Within GRDA's Anticipated Operational Range			
	RM 133-134	RM 134-135	RM 135-136	RM 136-137
Sept. 1993 (21 year)	0.20	0.16	0.14	0.12
June 2004 (1 year)	0.45	0.35	0.31	0.26
July 2007 (4 year)	0.16	0.12	0.08	0.07
Oct. 2009 (3 year)	0.13	0.10	0.09	0.08
Dec. 2015 (15 year)	0.04	0.04	0.05	0.05
100-year	0.01	0.01	0.01	0.02
Impact of inflow events (historical events only)	20.81	20.51	20.89	20.89
Impact of all inflow events (inc. 100-year event)	31.65	31.67	31.88	31.82

Table 22. Summary of maximum WSEL differences through Miami, OK for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range.

Event(s)	Maximum WSEL Differences Through Miami, OK (ft) for All Starting Elevations, Including Extreme, Hypothetical Values Outside GRDA's Anticipated Operational Range			
	RM 133-134	RM 134-135	RM 135-136	RM 136-137
Sept. 1993 (21 year)	0.83	0.70	0.61	0.58
June 2004 (1 year)	8.88	6.68	5.65	4.97
July 2007 (4 year)	0.33	0.28	0.23	0.21
Oct. 2009 (3 year)	2.61	2.00	1.71	1.60
Dec. 2015 (15 year)	2.12	1.82	1.65	1.60
100-year	0.06	0.06	0.06	0.06
Impact of inflow events (historical events only)	20.81	20.51	20.89	20.89
Impact of all inflow events (inc. 100-year event)	31.65	31.67	31.88	31.82

Table 23 presents a summary of smallest and largest inundation areas for simulated starting elevations within GRDA's anticipated operational range. The first six rows in the table present smallest and largest inundation areas for simulations with various starting pool elevations for a given inflow event. The last two rows in the table present smallest and largest inundation areas for the natural various inflow events, first for the historical inflow events simulated, then for all inflow events simulated (including the 100-year event). Stated another way, the first six rows in the table characterize the impact of GRDA's anticipated operations and the last two rows characterize the impact of nature. The simulated inundation area differences due to a change in starting pool elevation within GRDA's anticipated operational range are orders of magnitude smaller than the inundation differences that can be caused by nature. More specifically, regarding the difference in inundation area:

1. If only historical inflow events are considered, the maximum impact of nature ranges from 35 to 4,444 times greater than the maximum simulated impact of GRDA's anticipated operational range.
2. If all inflow events are considered, the maximum impact of nature ranges from 43 to 5,479 times greater than the maximum simulated impact of GRDA's anticipated operational range.

Table 23. Summary of smallest and largest inundation areas for starting elevations within GRDA's anticipated operational range.

Event(s)	Area of Inundation (acres) for Starting Elevations Within GRDA's Anticipated Operational Range		Difference (%)
	Smallest	Largest	
Sept. 1993 (21 year)	81,954	82,039	0.1%
June 2004 (1 year)	49,778	50,466	1.4%
July 2007 (4 year)	80,328	81,018	0.9%
Oct. 2009 (3 year)	70,506	71,085	0.8%
Dec. 2015 (15 year)	78,499	78,508	0.0%
100-year	92,637	92,649	0.0%
Impact of inflow events (historical events only)	50,102	82,033	48.3%
Impact of all inflow events (inc. 100-year event)	50,102	92,631	59.6%

In accordance with FERC's February 2022 Determination, **Table 24** presents a summary of smallest and largest inundation areas for simulated starting pool elevations outside GRDA's anticipated operational range. Even using these extreme, hypothetical stages, which range from 734 to 757 feet PD, the impact of nature is much greater than that of a 23-foot change in starting pool elevation. More specifically:

1. If only historical inflow events are considered, the maximum impact of nature ranges from 1.7 to 29 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.
2. If all inflow events are considered, the maximum impact of nature ranges from 2.1 to 36 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.

Table 24. Summary of smallest and largest maximum inundation areas for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range.

Event(s)	Area of Inundation (acres) for All Starting Elevations, Including Extreme, Hypothetical Values Outside GRDA's Anticipated Operational Range		Difference (%)
	Smallest	Largest	
Sept. 1993 (21 year)	81,277	84,085	3.4%
June 2004 (1 year)	48,943	65,075	28.3%
July 2007 (4 year)	79,989	82,910	3.6%
Oct. 2009 (3 year)	68,613	76,971	11.5%
Dec. 2015 (15 year)	77,482	80,606	4.0%
100-year	92,631	94,192	1.7%
Impact of inflow events (historical events only)	50,102	82,033	48.3%
Impact of all inflow events (inc. 100-year event)	50,102	92,631	59.6%

Table 25 presents results of maximum inundation area differences through the City of Miami, OK in more detail for simulated starting pool elevations within GRDA's anticipated operational range. **Table 26** presents the same information for extreme, hypothetical starting elevations outside GRDA's anticipated

operational range. The results show that any simulated impact of starting stage – whether within GRDA's anticipated operational range or for extreme, hypothetical stages – has little impact on inundation area within the City of Miami when compared to nature's impact. More specifically:

1. The maximum impact of nature ranges from 13 to 8,917 times greater than the maximum simulated impact of GRDA's anticipated operational range.
2. The maximum impact of nature ranges from 1.2 to 1,633 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.

Table 25. Summary of maximum inundation area differences through Miami, OK for starting elevations within GRDA's anticipated operational range.

Event(s)	Maximum Inundation Area Differences Through Miami, OK for Starting Elevations Within GRDA's Anticipated Operational Range			
	RM 133-134	RM 134-135	RM 135-136	RM 136-137
Sept. 1993 (21 year)	1.1%	0.8%	1.1%	0.9%
June 2004 (1 year)	11.3%	5.3%	6.2%	9.6%
July 2007 (4 year)	0.7%	0.8%	0.4%	0.2%
Oct. 2009 (3 year)	0.7%	0.4%	0.7%	0.7%
Dec. 2015 (15 year)	4.3%	0.2%	0.4%	0.5%
100-year	0.0%	0.1%	0.0%	0.0%
Impact of inflow events (historical events only)	143%	142%	134%	142%
Impact of all inflow events (inc. 100-year event)	162%	164%	147%	151%

Table 26. Summary of maximum inundation area differences through Miami, OK for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range.

Event(s)	Maximum Inundation Area Differences Through Miami, OK for All Starting Elevations, Including Extreme, Hypothetical Values Outside GRDA's Anticipated Operational Range			
	RM 133-134	RM 134-135	RM 135-136	RM 136-137
Sept. 1993 (21 year)	4%	3%	4%	5%
June 2004 (1 year)	116%	83%	70%	88%
July 2007 (4 year)	1%	2%	1%	0%
Oct. 2009 (3 year)	16%	8%	16%	15%
Dec. 2015 (15 year)	14%	9%	14%	19%
100-year	0%	0%	0%	0%
Impact of inflow events (historical events only)	143%	142%	134%	142%
Impact of all inflow events (inc. 100-year event)	162%	164%	147%	151%

Table 27 presents a summary of inundation duration differences for simulated starting elevations within GRDA's anticipated operational range. The first six rows in the table present the maximum differences in duration for simulations with various starting pool elevations for a given inflow event. The last two rows in the table present the maximum difference in duration for the various natural inflow events, first for the historical inflow events simulated, then for all inflow events simulated (including the 100-year event). Stated another way, the first six rows in the table characterize the impact of starting pool elevations within GRDA's anticipated operational range and the last two rows characterize the impact of nature. The

simulated duration differences due to a change in starting pool elevation within GRDA's anticipated operational range are orders of magnitude smaller than the duration differences that can be caused by nature. More specifically:

1. Along the Neosho River, the maximum impact of nature ranges from 6 to 261 times greater than the maximum simulated impact of GRDA's anticipated operational range.
2. Along the Spring River, the maximum impact of nature ranges from 14 to 115 times greater than the maximum simulated impact of GRDA's anticipated operational range.
3. Along the Elk River, the maximum impact of nature is 118 times greater than the maximum simulated impact of GRDA's anticipated operational range.
4. Along Tar Creek, the maximum impact of nature ranges from 79 to 210 times greater than the maximum simulated impact of GRDA's anticipated operational range.

As **Table 27** presents, some of the maximum duration differences for a given inflow event on a given reach were zero. In such instances, a value of one hour was used instead of zero to calculate the ratios listed above, which would otherwise be undefined.

Table 27. Summary of inundation duration differences for starting elevations within GRDA's anticipated operational range.

Event(s)	Maximum Duration Difference (hours) for Starting Elevations Within GRDA's Anticipated Operational Range			
	Neosho River	Spring River	Elk River	Tar Creek
Sept. 1993 (21 year)	20	6	0	2
June 2004 (1 year)	1	0	0	0
July 2007 (4 year)	43	8	0	2
Oct. 2009 (3 year)	4	1	0	1
Dec. 2015 (15 year)	3	2	0	1
100-year	2	2	0	1
Impact of inflow events (historical events only)	239	112	118	158
Impact of all inflow events (inc. 100-year event)	261	115	118	210

The largest differences in duration for simulated starting elevations within GRDA's anticipated operational range occur in rural, sparsely populated areas. For the September 1993 (21 year) inflow event, the 20-hour maximum simulated difference in duration listed in **Table 27** is isolated to RM 124 to 125 on the Neosho River. This location is between the Highway 60 Bridge at Twin Bridges State Park (RM 122.57) and the S 590 Road Bridge (RM 126.70). The simulated difference in duration is isolated to this location and does not extend either upstream or downstream. For the September 1993 (21 year) inflow event, there are no other locations along the Neosho River with differences in duration greater than 8 hours. For the July 2007 (4 year) inflow event, the 43-hour simulated difference listed in **Table 27** is also isolated to RM 124 to 125 on the Neosho River. The simulated difference in duration does not extend either upstream or downstream. For the July 2007 (4 year) inflow event, there are no other locations along the Neosho River with differences in duration greater than 8 hours.

In accordance with FERC's February 2022 Determination, **Table 28** presents a summary of duration differences for simulated starting pool elevations outside GRDA's anticipated operational range. Even using these extreme, hypothetical stages, which range from 734 to 757 feet PD, the impact of nature is much greater than that of a 23-foot change in starting pool elevation. More specifically:

1. Along the Neosho River, the maximum impact of nature ranges from 4 to 10 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.
2. Along the Spring River, the maximum impact of nature ranges from 3 to 115 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.
3. Along the Elk River, the maximum impact of nature ranges from 39 to 118 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.
4. Along Tar Creek, the maximum impact of nature ranges from 2 to 210 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.

As **Table 28** presents, some of the maximum duration differences for a given inflow event on a given reach were zero. In such instances, a value of one hour was used instead of zero to calculate the ratios listed above, which would otherwise be undefined.

Table 28. Summary of inundation duration differences for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range.

Event(s)	Maximum Duration Difference (hours) for All Starting Elevations, Including Extreme, Hypothetical Values Outside GRDA's Anticipated Operational Range			
	Neosho River	Spring River	Elk River	Tar Creek
Sept. 1993 (21 year)	42	25	1	15
June 2004 (1 year)	41	0	0	0
July 2007 (4 year)	51	41	0	13
Oct. 2009 (3 year)	59	23	1	91
Dec. 2015 (15 year)	52	41	3	59
100-year	25	15	0	7
Impact of inflow events (historical events only)	239	112	118	158
Impact of all inflow events (inc. 100-year event)	261	115	118	210

Table 29 presents results of maximum duration differences through the City of Miami, OK in more detail for simulated starting pool elevations within GRDA's anticipated operational range. **Table 30** presents the same information for extreme, hypothetical starting elevations outside GRDA's anticipated operational range. The results show that any simulated impact of starting stage – whether within GRDA's anticipated operational range or for extreme, hypothetical stages – has little impact on duration when compared to nature's impact. More specifically:

1. The maximum impact of nature ranges from 42 to 223 times greater than the maximum simulated impact of GRDA's anticipated operational range.
2. The maximum impact of nature ranges from 3 to 223 times greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet.

Table 29. Summary of maximum duration differences through Miami, OK for starting elevations within GRDA's anticipated operational range.

Event(s)	Maximum Duration Differences Through Miami, OK (hours) for Starting Elevations Within GRDA's Anticipated Operational Range			
	RM 133-134	RM 134-135	RM 135-136	RM 136-137
Sept. 1993 (21 year)	1	1	2	1
June 2004 (1 year)	0	0	0	0
July 2007 (4 year)	2	3	3	2
Oct. 2009 (3 year)	0	4	3	2
Dec. 2015 (15 year)	1	1	1	0
100-year	1	1	1	0
Impact of inflow events (historical events only)	154	166	168	175
Impact of all inflow events (inc. 100-year event)	210	219	220	223

Table 30. Summary of maximum duration differences through Miami, OK for all starting elevations, including extreme, hypothetical values outside GRDA's anticipated operational range.

Event(s)	Maximum Duration Differences Through Miami, OK (hours) for All Starting Elevations, Including Extreme, Hypothetical Values Outside GRDA's Anticipated Operational Range			
	RM 133-134	RM 134-135	RM 135-136	RM 136-137
Sept. 1993 (21 year)	9	10	10	10
June 2004 (1 year)	0	0	0	0
July 2007 (4 year)	13	14	15	16
Oct. 2009 (3 year)	59	59	35	31
Dec. 2015 (15 year)	32	22	18	16
100-year	7	7	7	7
Impact of inflow events (historical events only)	154	166	168	175
Impact of all inflow events (inc. 100-year event)	210	219	220	223

Figure 22 through **Figure 33** display examples of maximum WSEL profiles and maximum inundation extent organized by inflow event, as presented in **Appendix E.1** through **Appendix E.6** (WSEL profiles) and **Appendix F.1** through **Appendix F.6** (maximum inundation extent). **Figure 34** and **Figure 35** display examples of maximum WSEL profiles and maximum inundation extents, respectively, for simulations that used historical starting pool elevations for various inflow events, as presented in **Appendix E.7** and **Appendix F.7**.

Figure 22 through **Figure 35** are representative of the data presented in **Table 19** through **Table 26**. The magnitude of the incoming flow event is the primary determining factor of maximum WSEL and maximum inundation extent upstream of Pensacola Dam. For the various inflow events, modifying the starting pool elevation within GRDA's anticipated operational range (742 to 745 feet PD, a range of 3 feet) resulted in little difference in maximum WSEL and little difference in maximum inundation extent. The maximum WSEL differences due to a change in starting pool elevation within GRDA's anticipated operational range (**Figure 22** through **Figure 33**) are orders of magnitude smaller than the maximum WSEL differences that can be caused by nature (**Figure 34** and **Figure 35**). Even if the operational range were expanded to the

extreme, hypothetical stages analyzed in accordance with FERC's February 2022 Determination, nature is the controlling factor. For an extreme 23-foot starting pool range (734 to 757 feet PD, with a maximum starting pool elevation equal to the top of the dam), the differences are still far less than the differences caused by nature. The differences in maximum WSEL and maximum inundation extent caused by nature are twice or more than simulated differences for a 23-foot change in starting pool elevation.

To show this more explicitly, **Figure 36** through **Figure 43** display examples of maximum WSEL profiles and maximum inundation extents for simulations that used various natural inflow events and a single starting pool elevation. The figures display results for the following starting pool elevations:

1. 734 feet PD, the lowest extreme, hypothetical starting stage FERC recommended simulating,
2. 742 feet PD, the lowest elevation of GRDA's anticipated operational range,
3. 745 feet PD, the highest elevation of GRDA's anticipated operational range, and
4. 757 feet PD, the highest extreme, hypothetical starting stage FERC recommended simulating and the elevation of the top of the dam.

These figures show that for the same starting pool elevation, there are large differences in maximum WSEL and maximum inundation extent due to the magnitude of the incoming natural inflow event. The magnitude of the natural inflow event is the primary determining factor of maximum WSEL and maximum inundation extent.

A final comparison is presented to show how the magnitude of the natural inflow event is the primary determining factor of maximum WSEL, as opposed to the starting pool elevation. **Figure 44** displays an example comparison of maximum WSEL differences, as presented in **Appendix E.8**. The figure includes four plots of maximum difference in peak WSEL:

1. Maximum difference due to changes in starting pool elevation within GRDA's anticipated operational range (742 to 745 feet PD).
2. Maximum difference due to changes in starting pool elevation at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.
3. Maximum difference in WSEL due to the magnitude of the historical inflow events (does not include synthetic, 100-year event).
4. Maximum difference in WSEL due to the magnitude of the inflow event (1-year to 100-year).

Figure 44 shows the following:

1. The magnitude of the natural inflow event is the primary determining factor of maximum WSEL.
2. Starting pool elevations within GRDA's anticipated operational range have an immaterial impact on upstream WSELs.
3. Even if extreme, hypothetical values of starting pool elevations outside GRDA's anticipated operational range are used, the impact of nature is much greater than that of a 23-foot change in starting pool elevation.

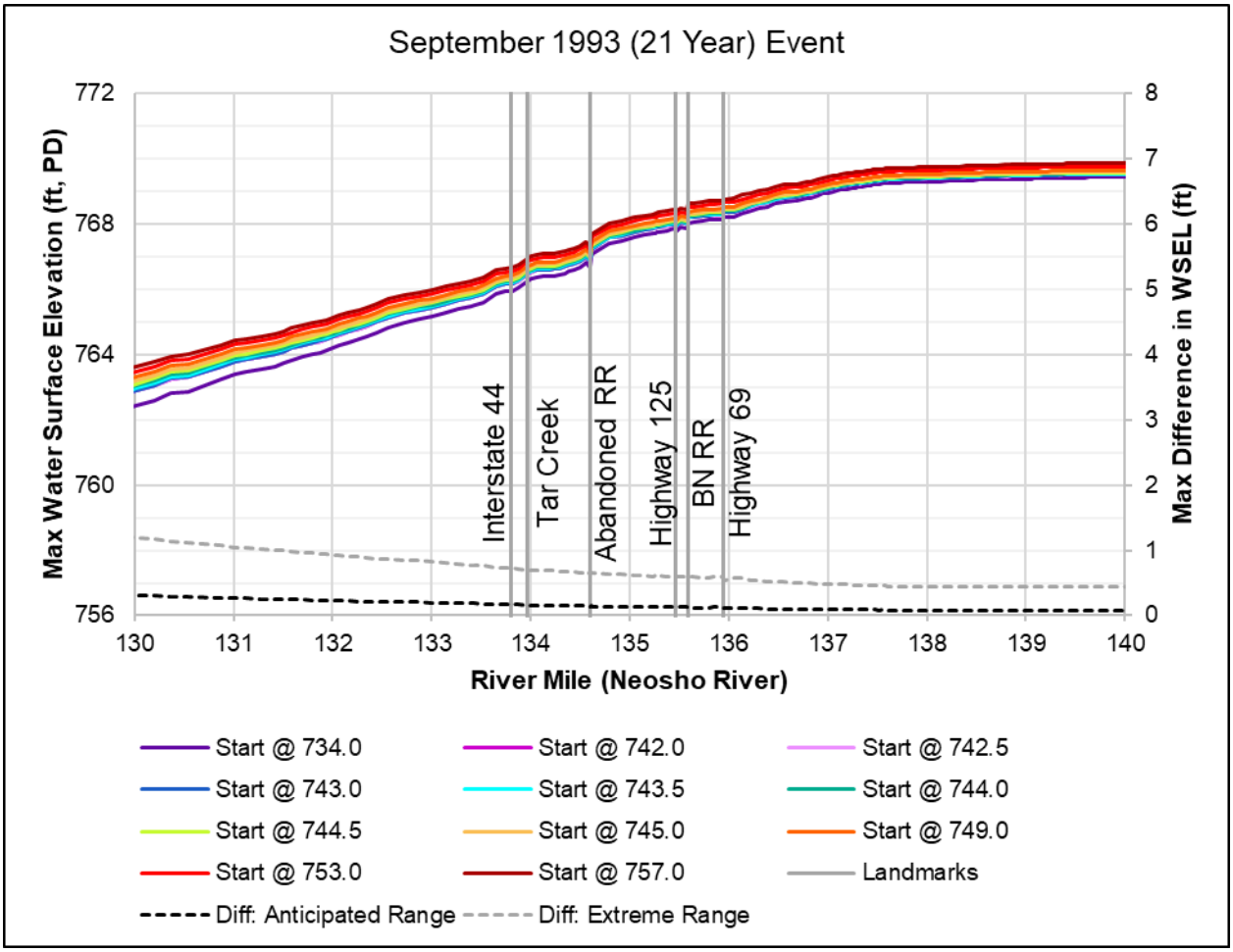


Figure 22. Maximum WSELs near Miami, OK for the September 1993 (21 year) event.

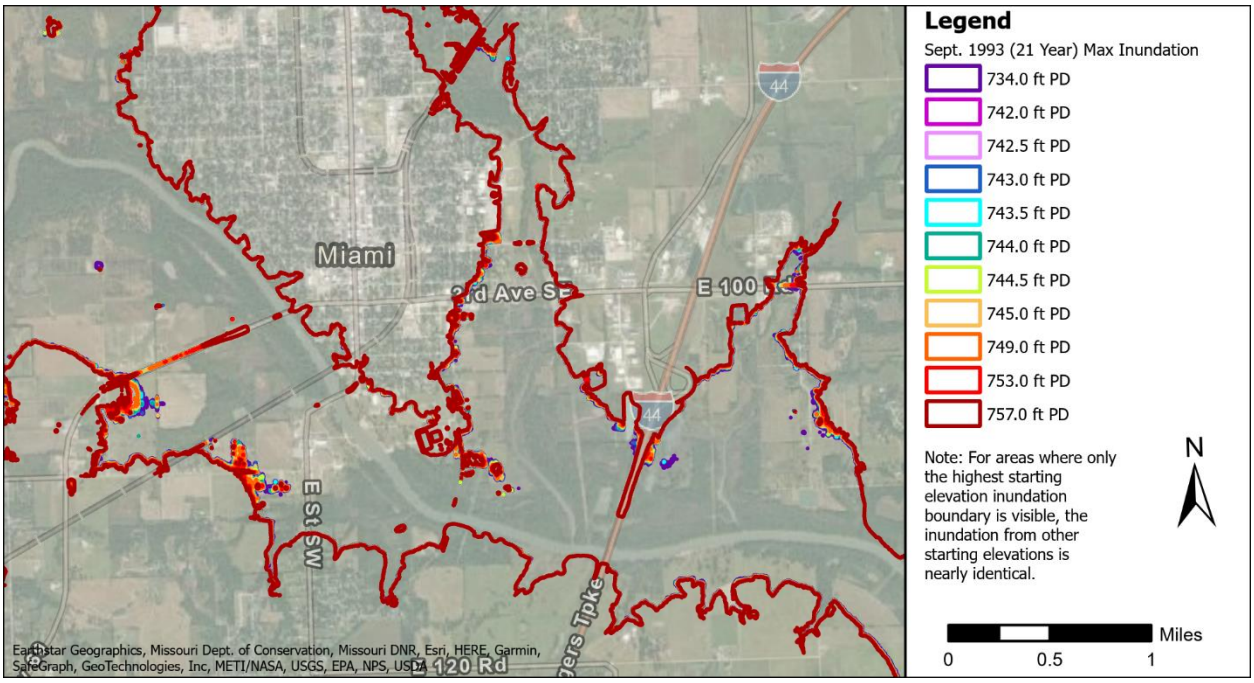


Figure 23. Maximum inundation extents near Miami, OK for the September 1993 (21 year) event.

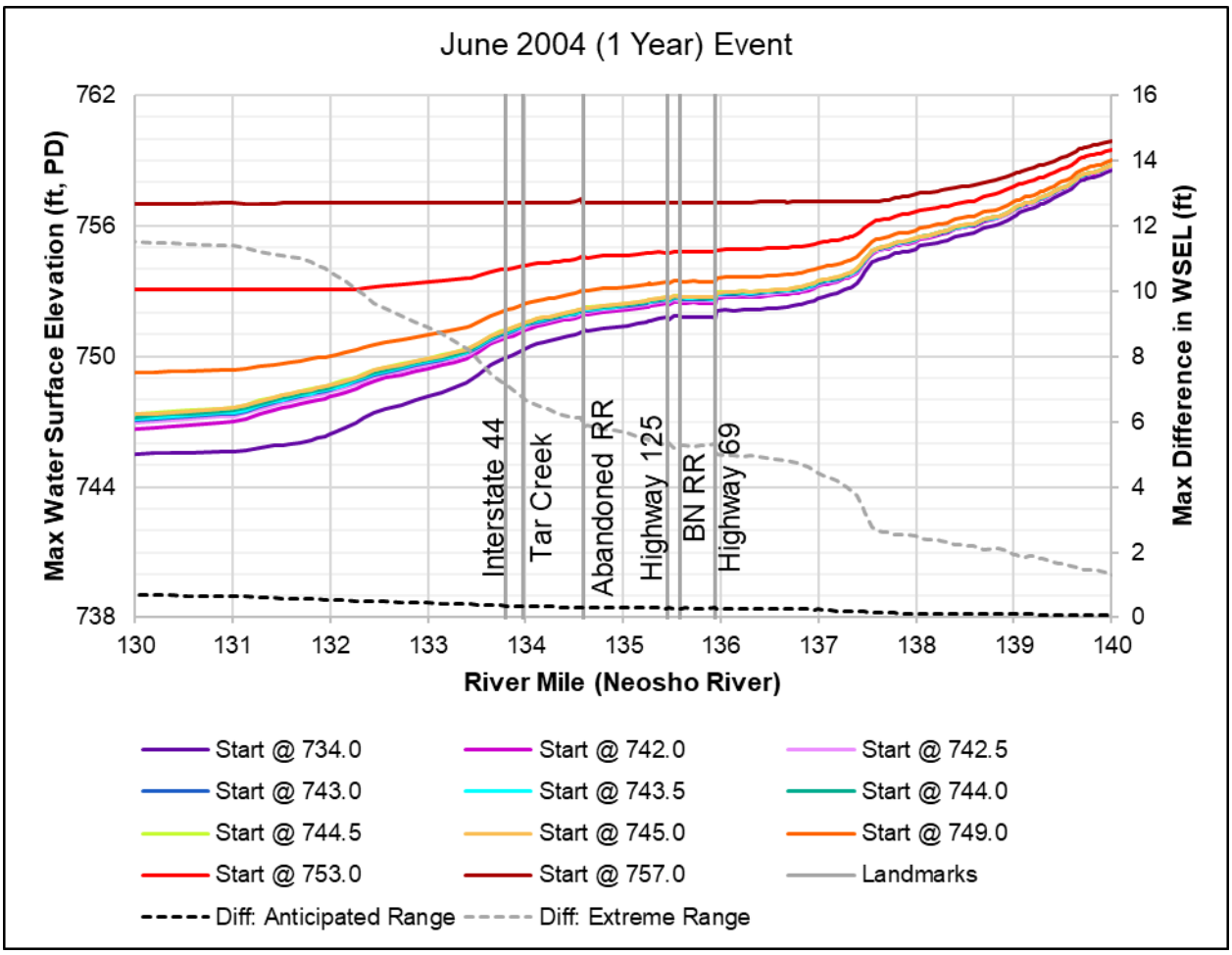


Figure 24. Maximum WSELs near Miami, OK for the June 2004 (1 year) event.

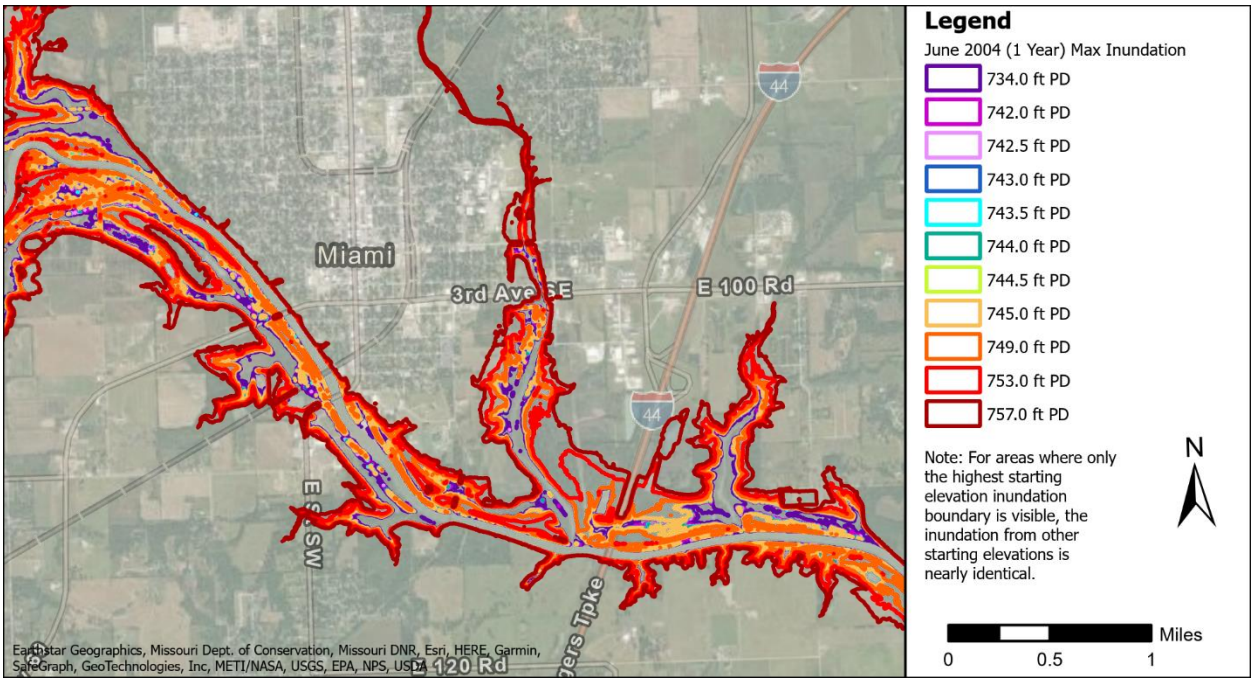


Figure 25. Maximum inundation extents near Miami, OK for the June 2004 (1 year) event.

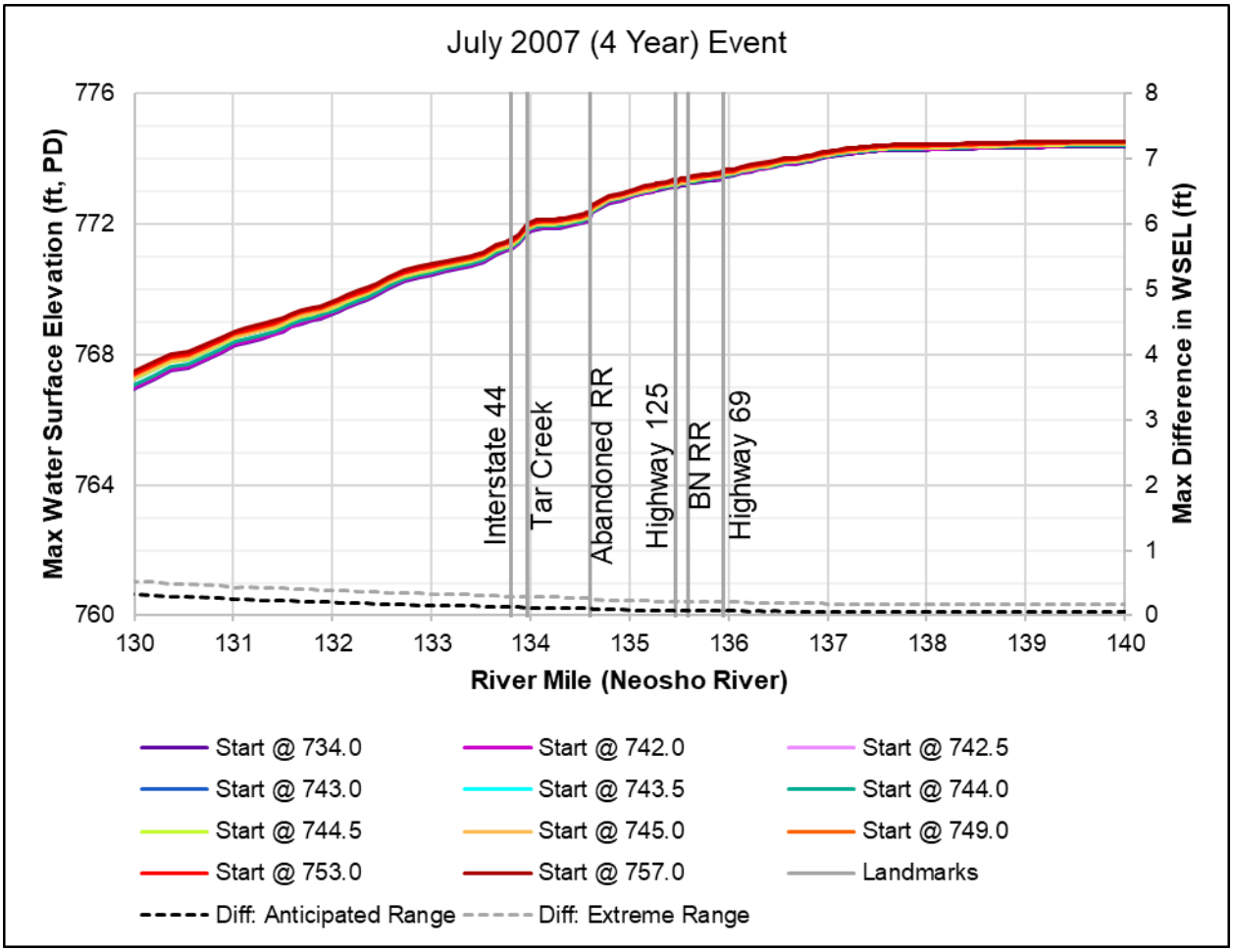


Figure 26. Maximum WSELs near Miami, OK for the July 2007 (4 year) event.

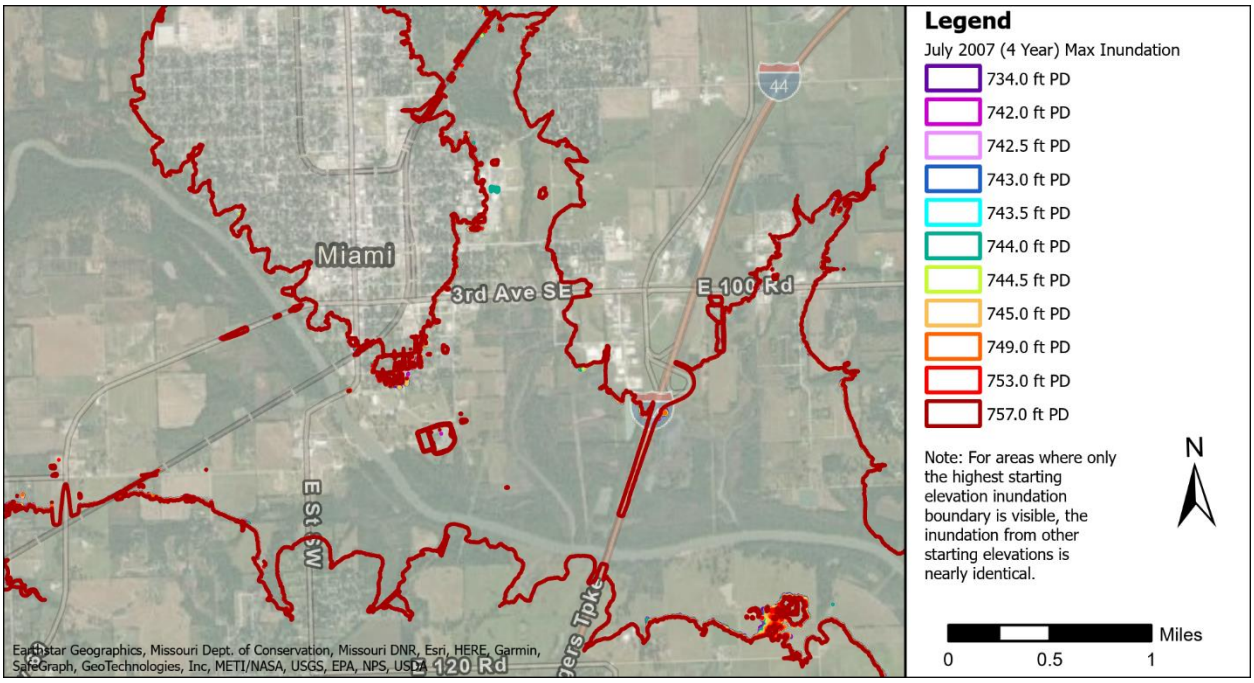


Figure 27. Maximum inundation extents near Miami, OK for the July 2007 (4 year) event.

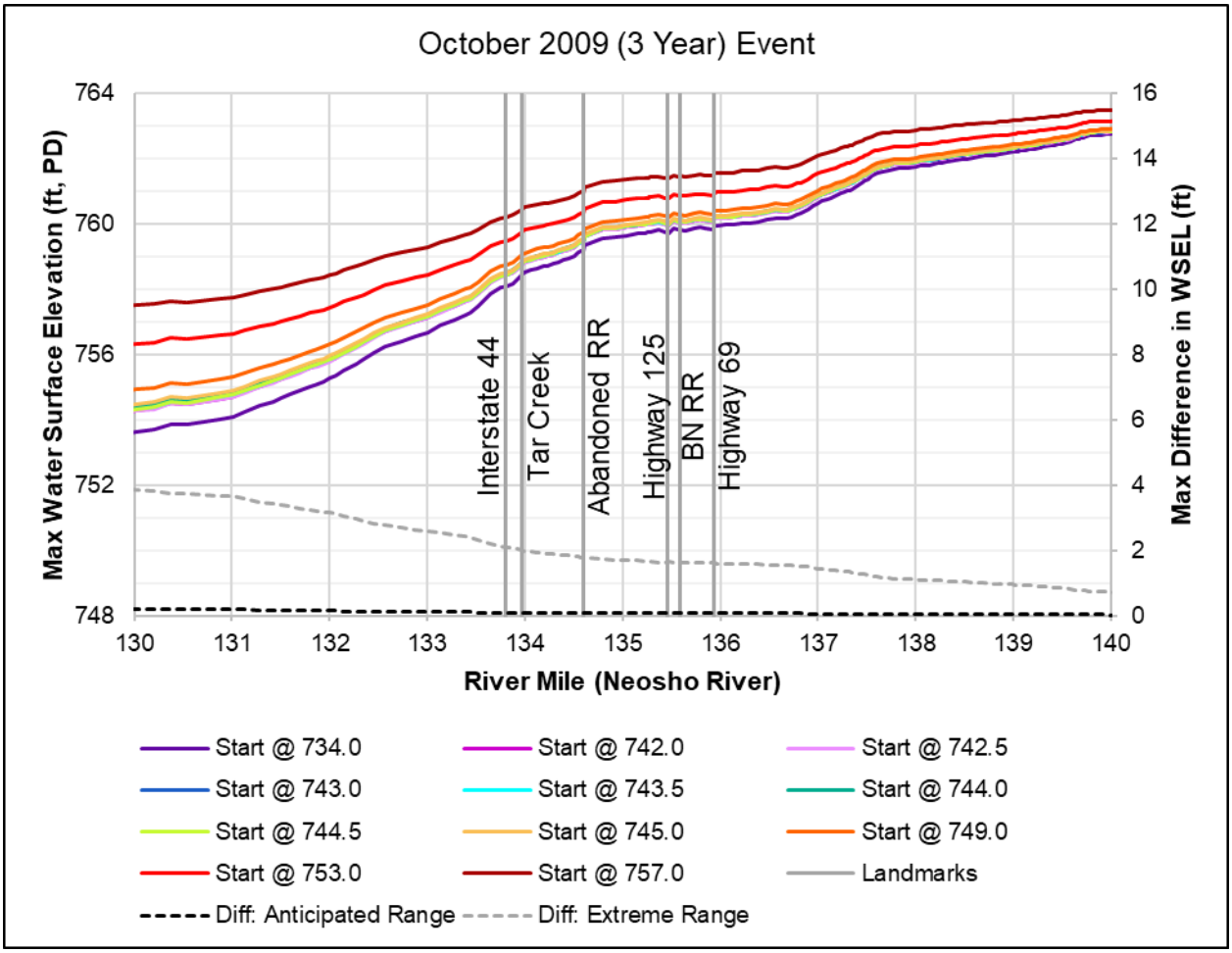


Figure 28. Maximum WSELs near Miami, OK for the October 2009 (3 year) event.

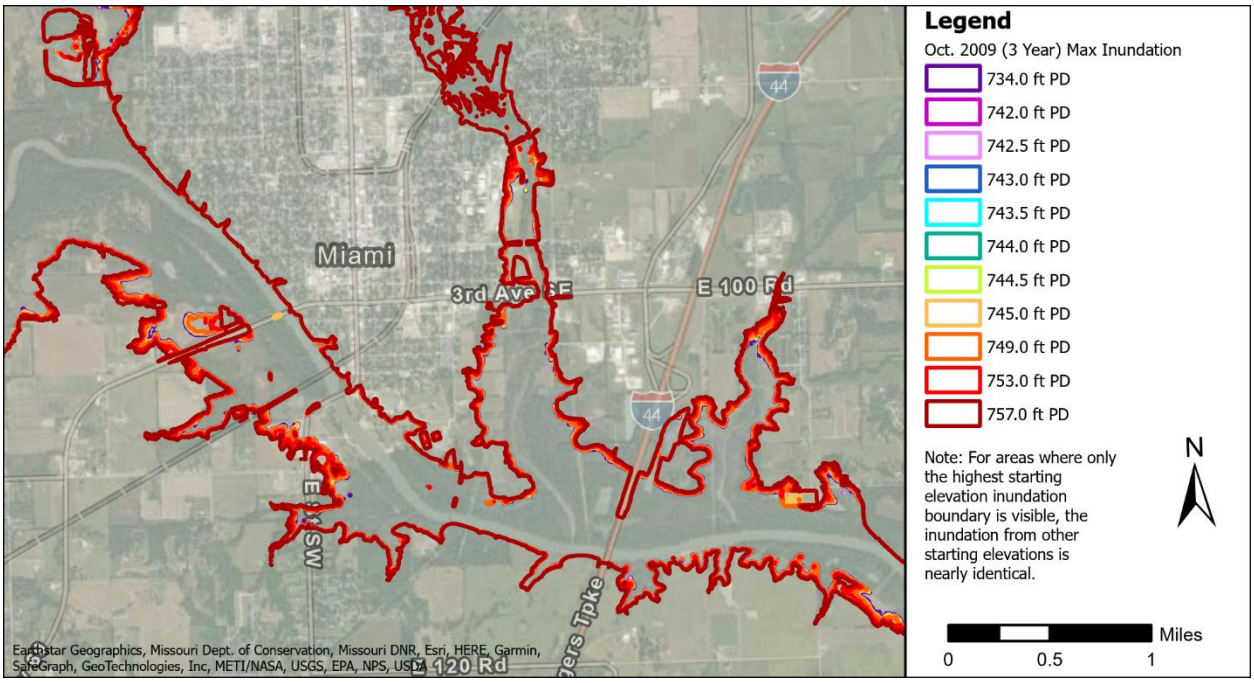


Figure 29. Maximum inundation extents near Miami, OK for the October 2009 (3 year) event.

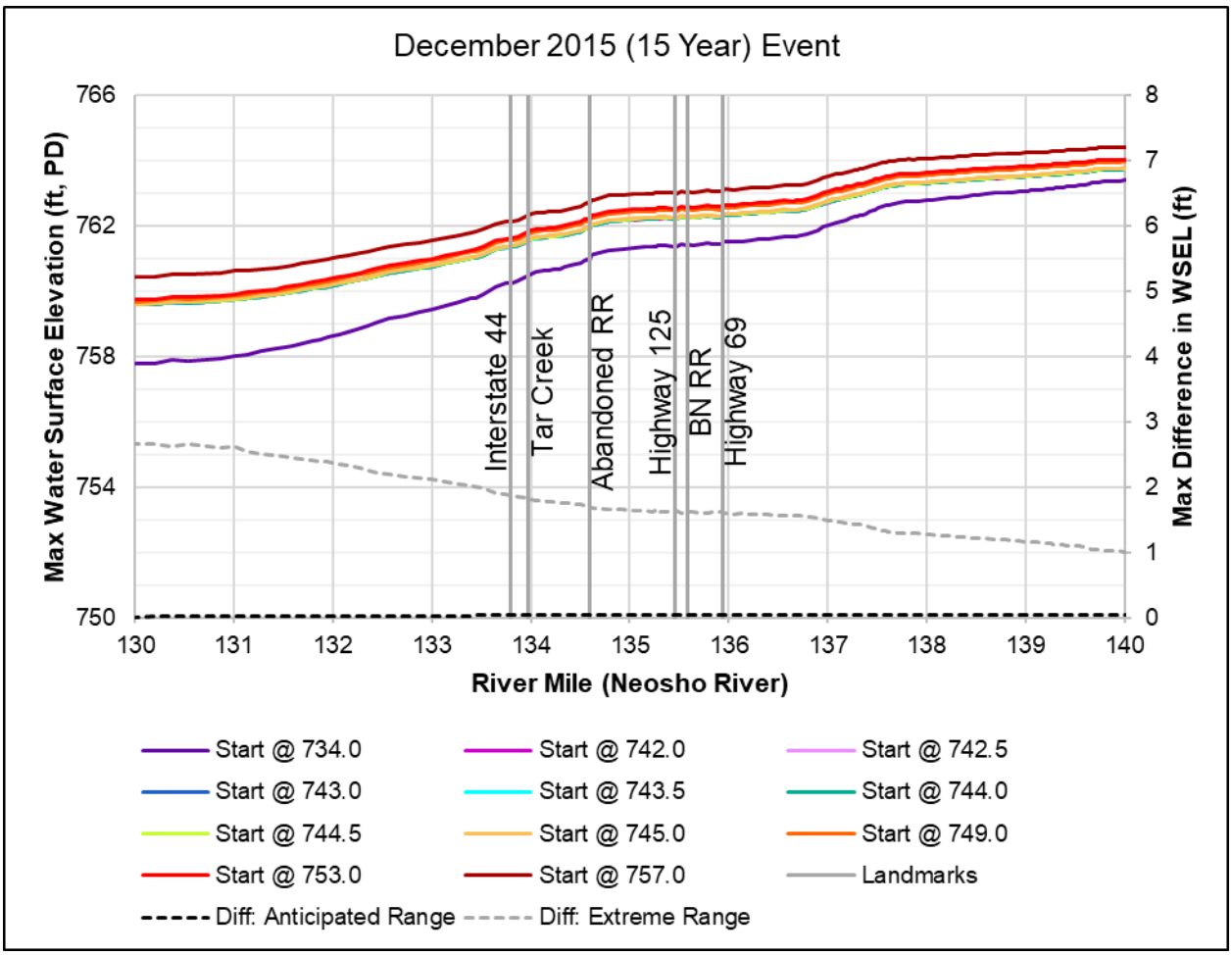


Figure 30. Maximum WSELs near Miami, OK for the December 2015 (15 year) event.

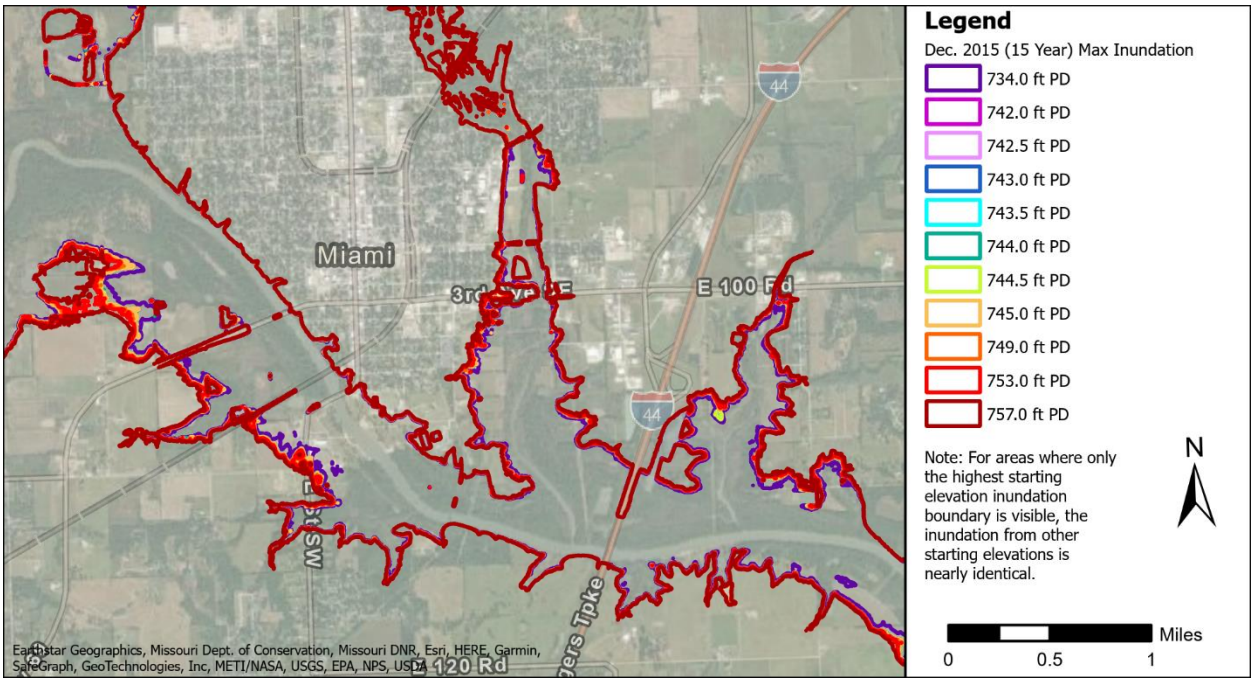


Figure 31. Maximum inundation extents near Miami, OK for the December 2015 (15 year) event.

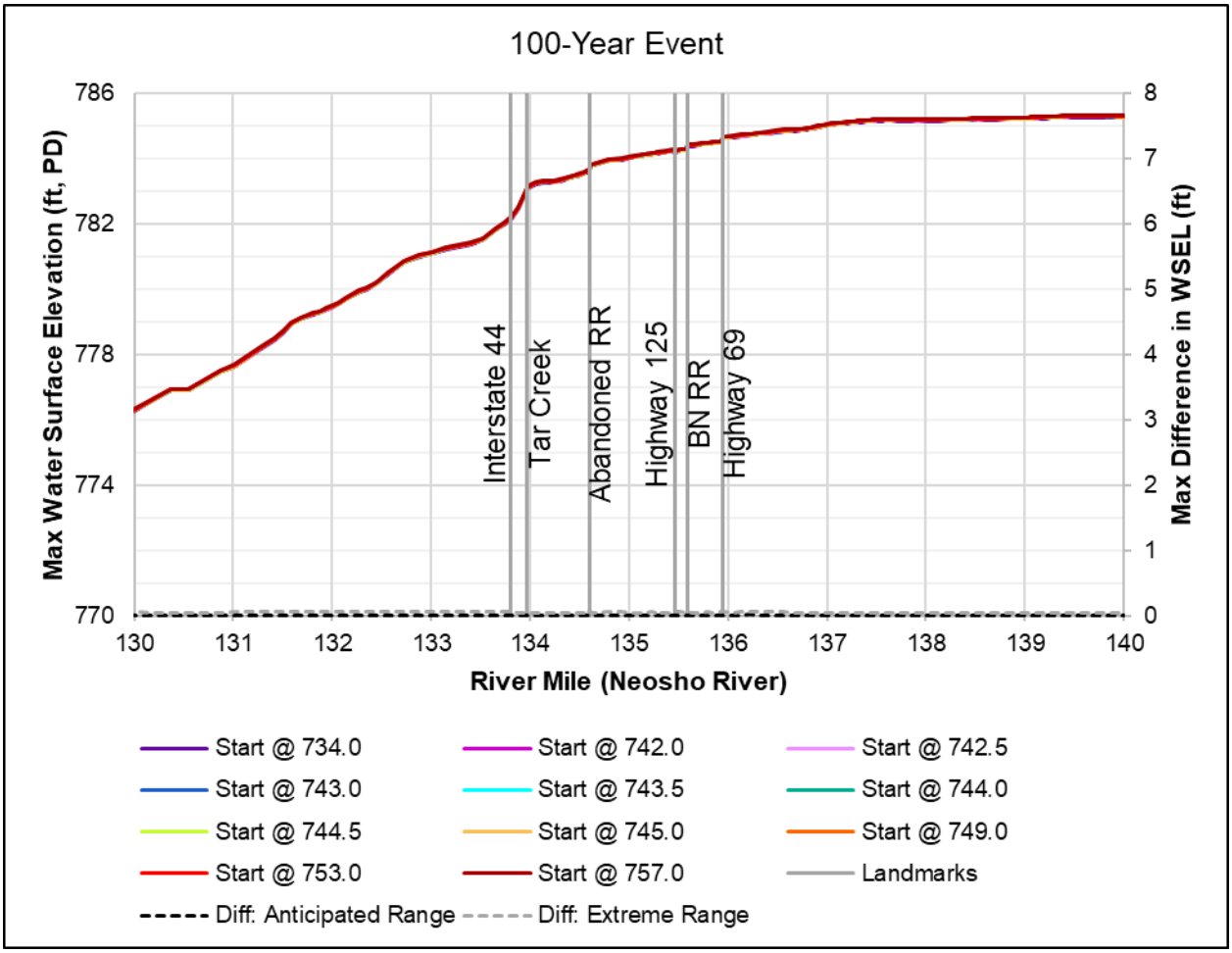


Figure 32. Maximum WSELs near Miami, OK for the 100-year event.

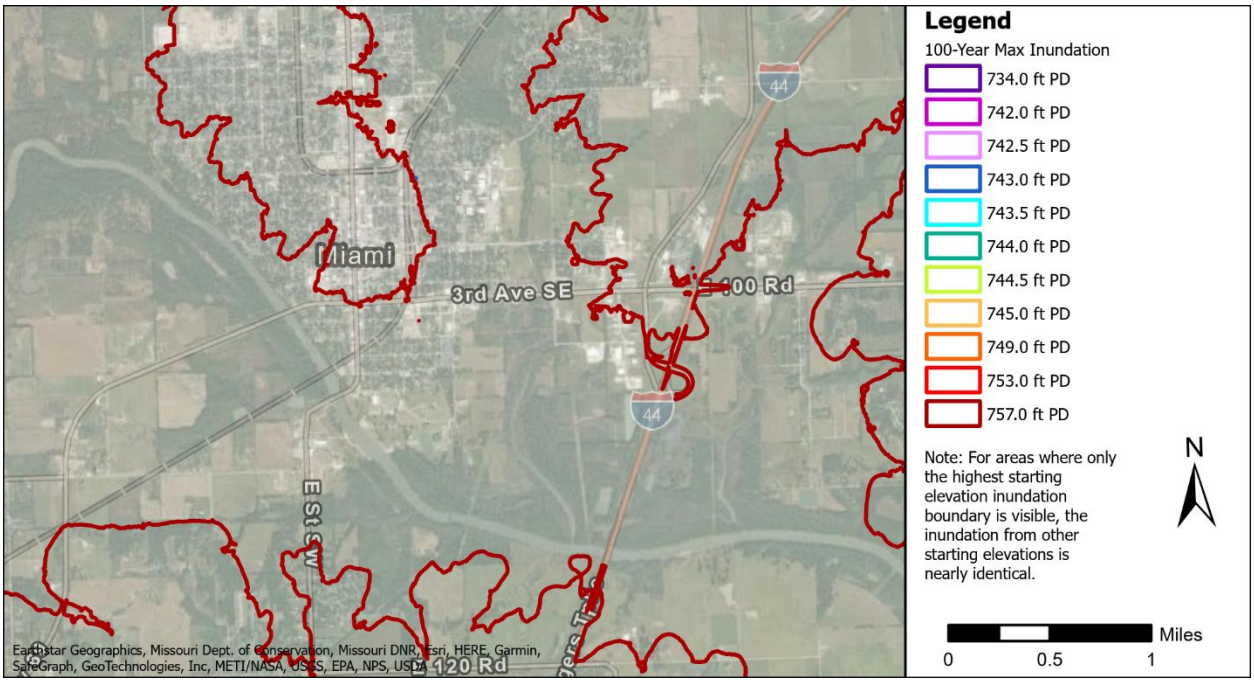


Figure 33. Maximum inundation extents near Miami, OK for the 100-year event.

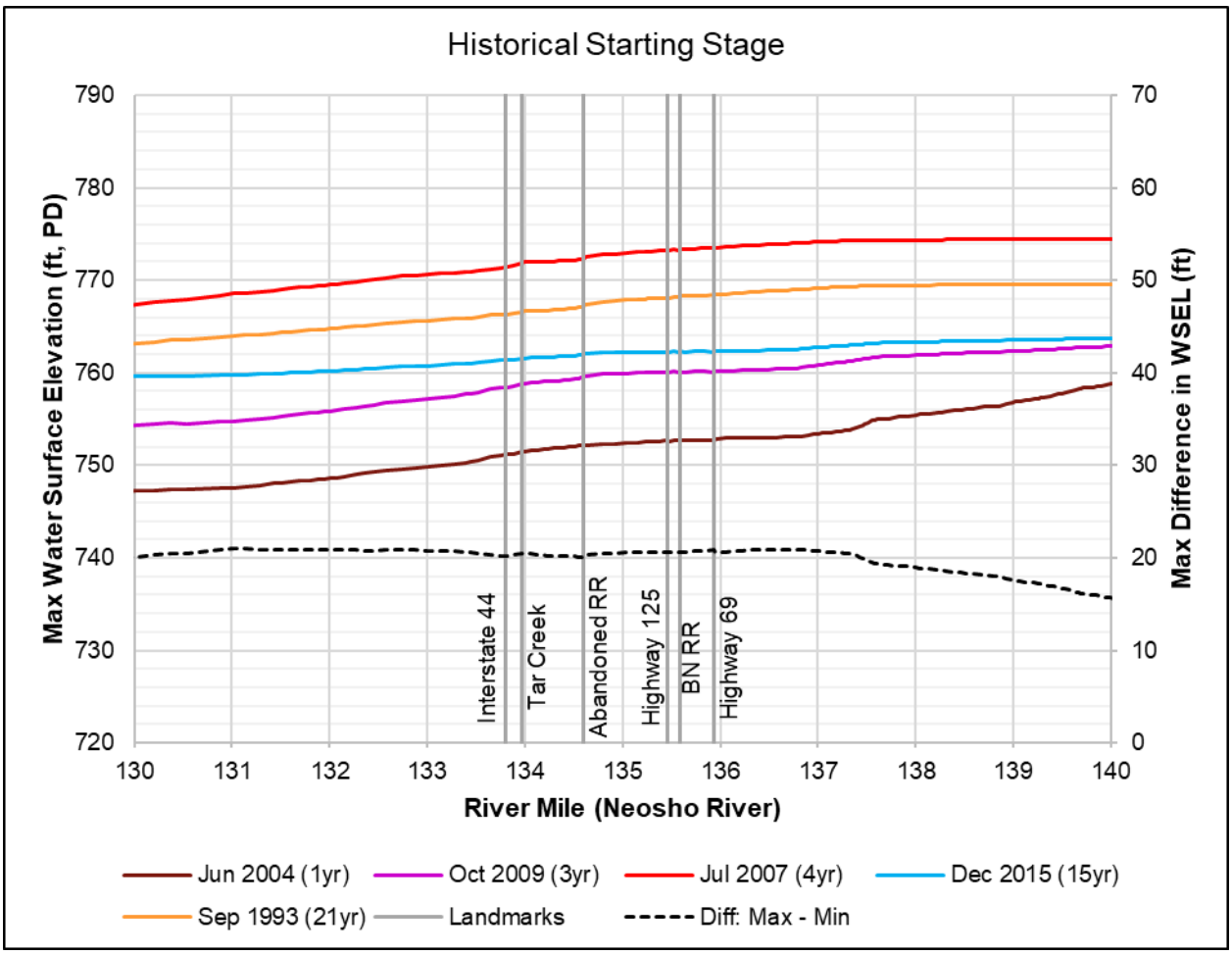


Figure 34. Maximum WSELs near Miami, OK for simulations with historical starting stages.

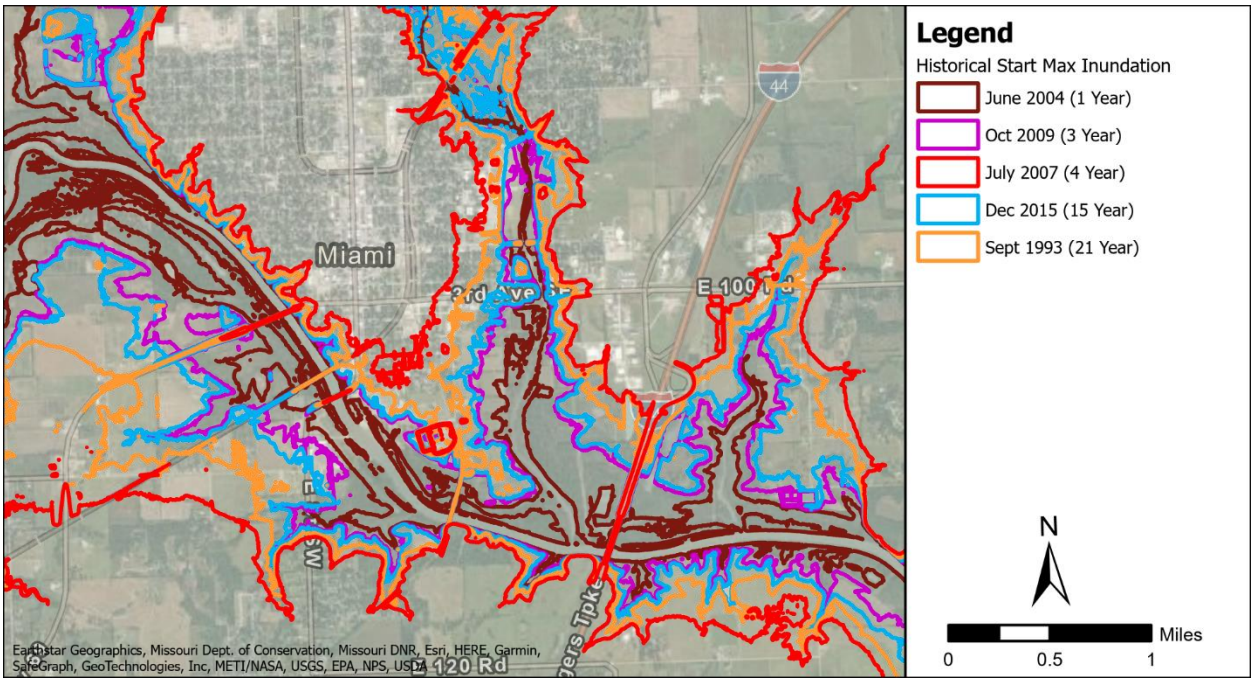


Figure 35. Maximum inundation extents near Miami, OK for simulations with historical starting stages.

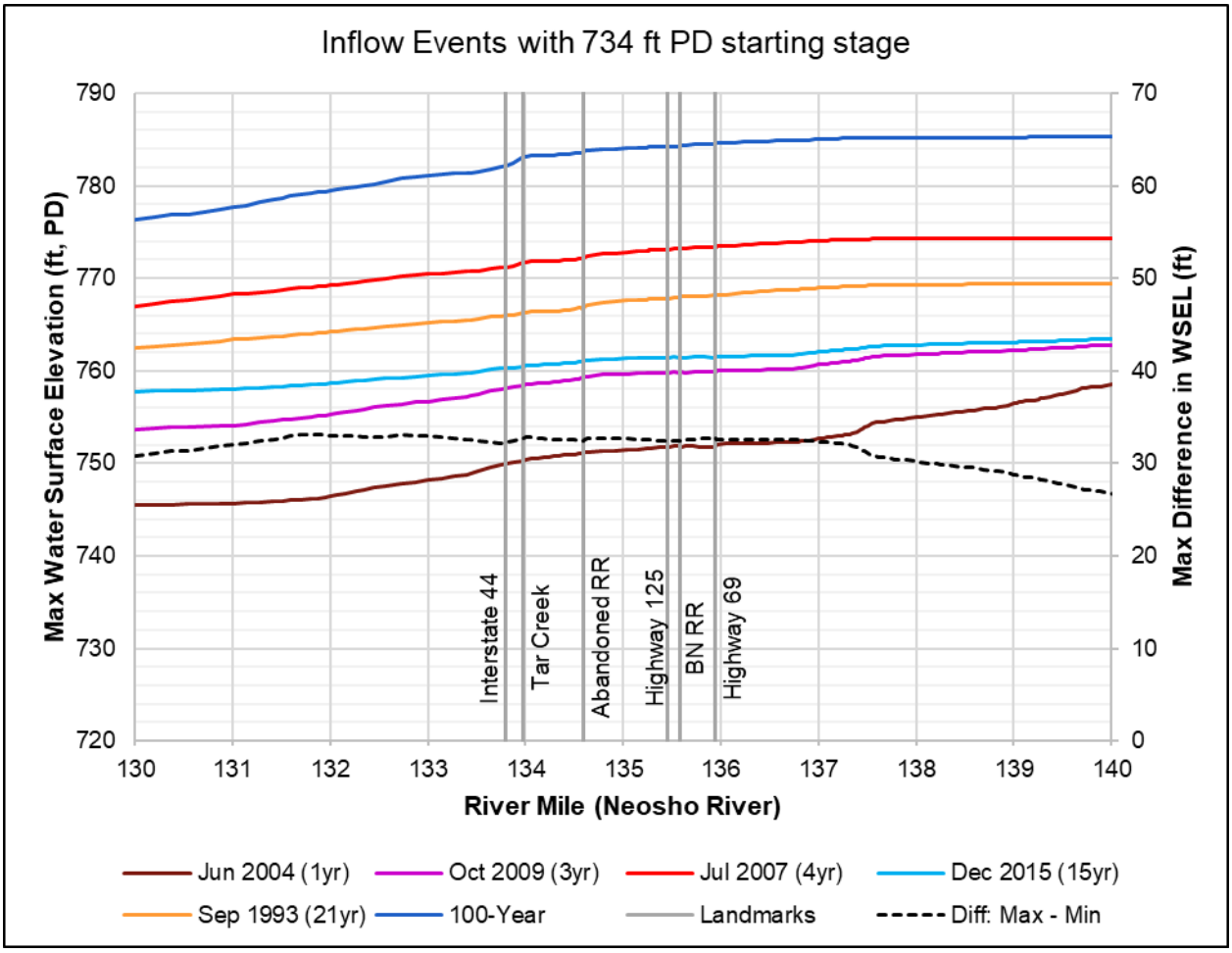


Figure 36. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 734 feet.

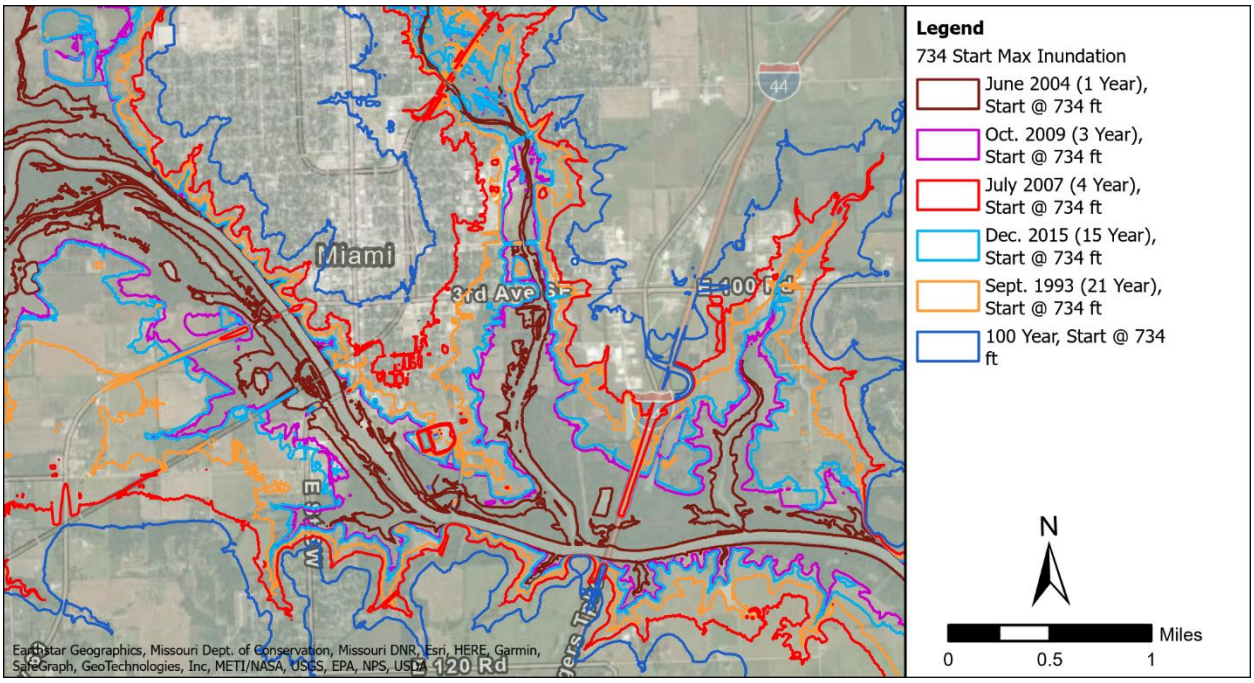


Figure 37. Maximum inundation extents near Miami, OK for various natural inflow events, using a starting pool elevation of 734 feet.

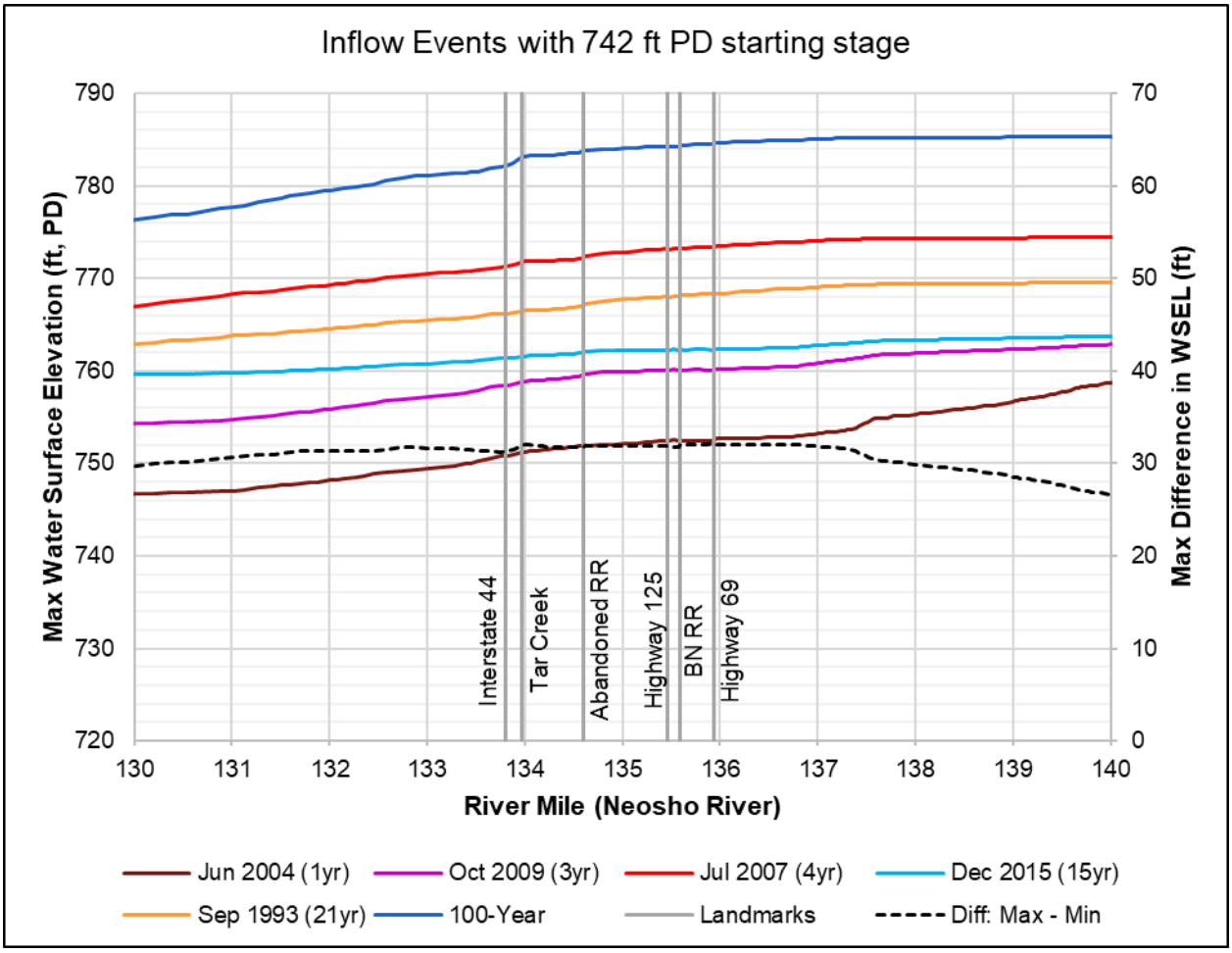


Figure 38. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 742 feet.

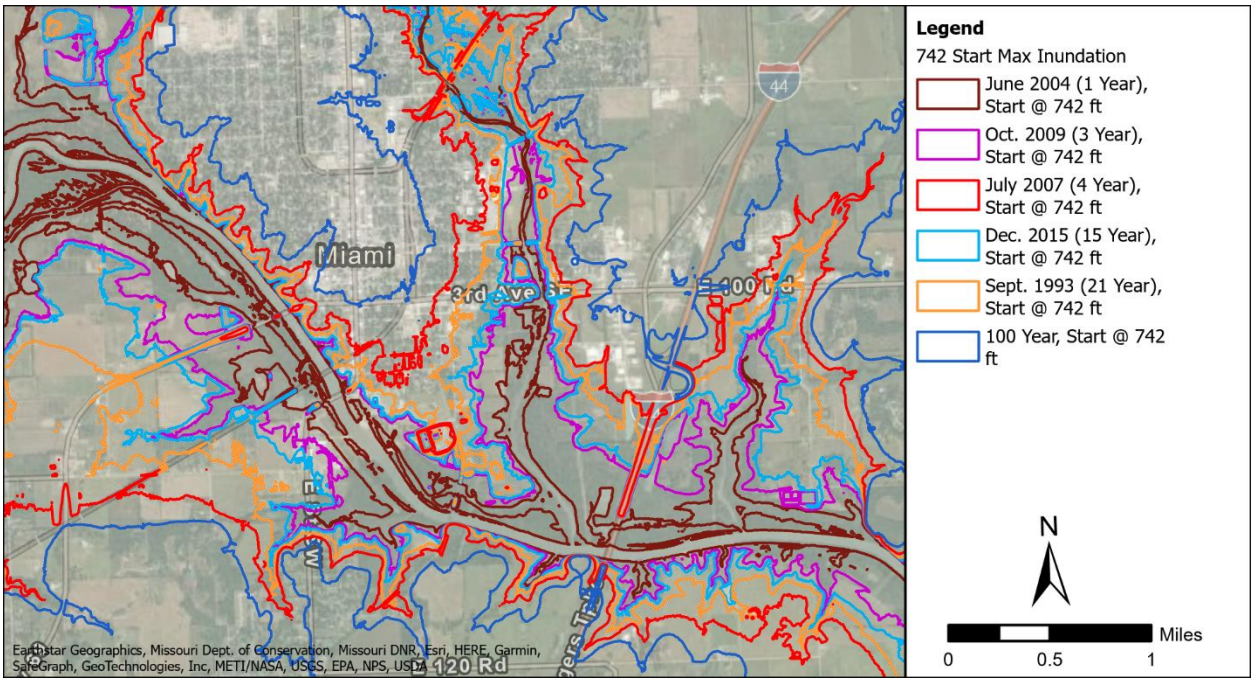


Figure 39. Maximum inundation extents near Miami, OK for various natural inflow events, using a starting pool elevation of 742 feet.

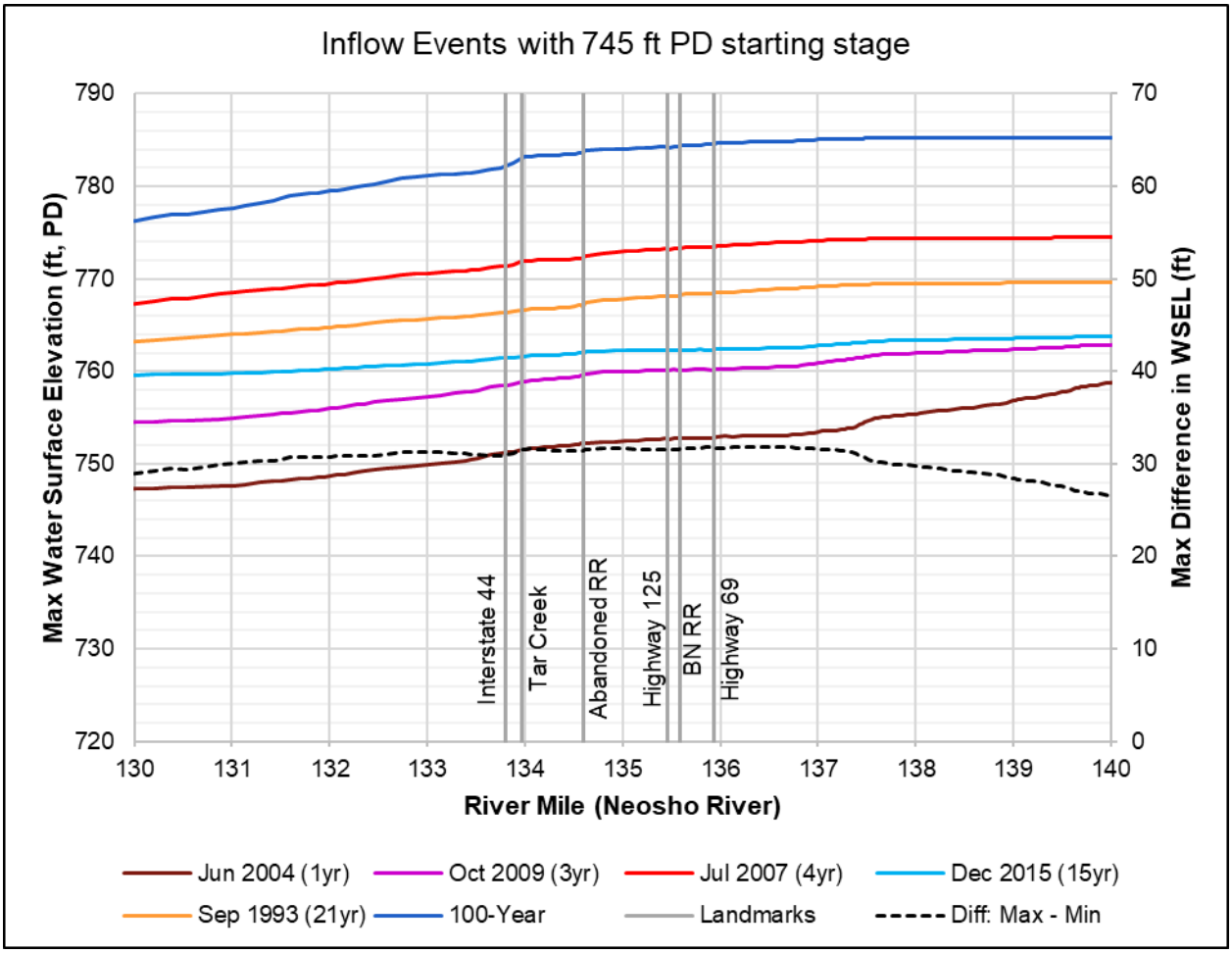


Figure 40. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 745 feet.

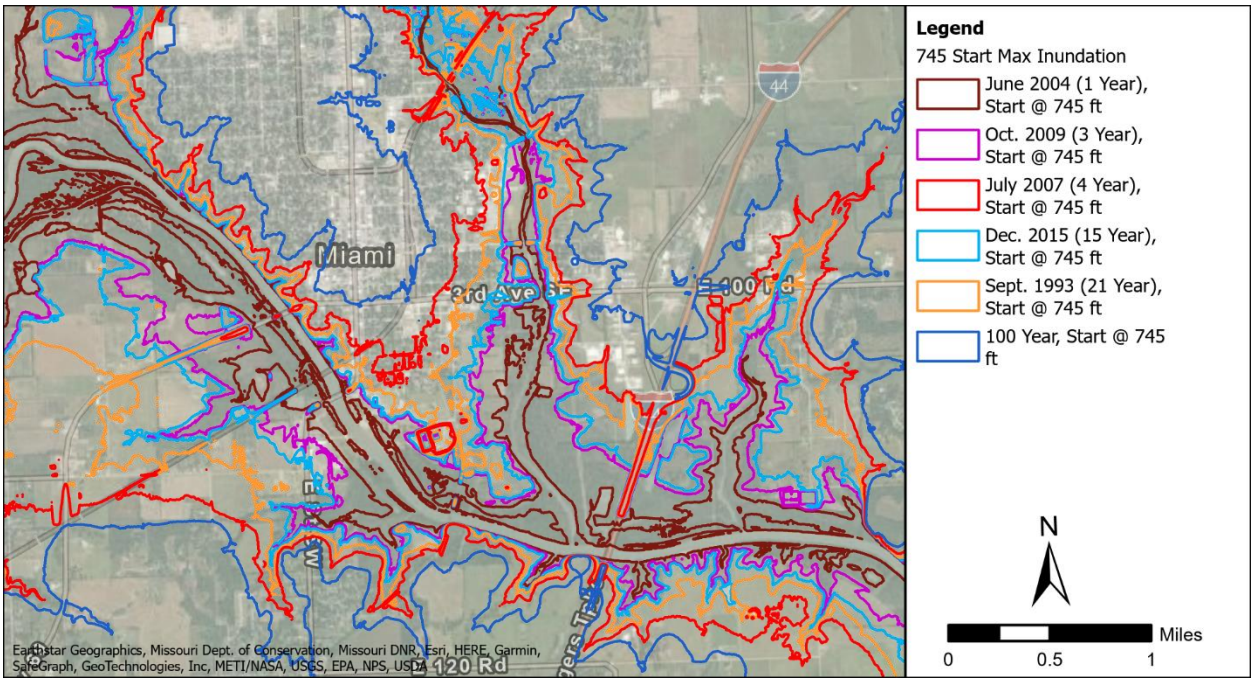


Figure 41. Maximum inundation extents near Miami, OK for various natural inflow events, using a starting pool elevation of 745 feet.

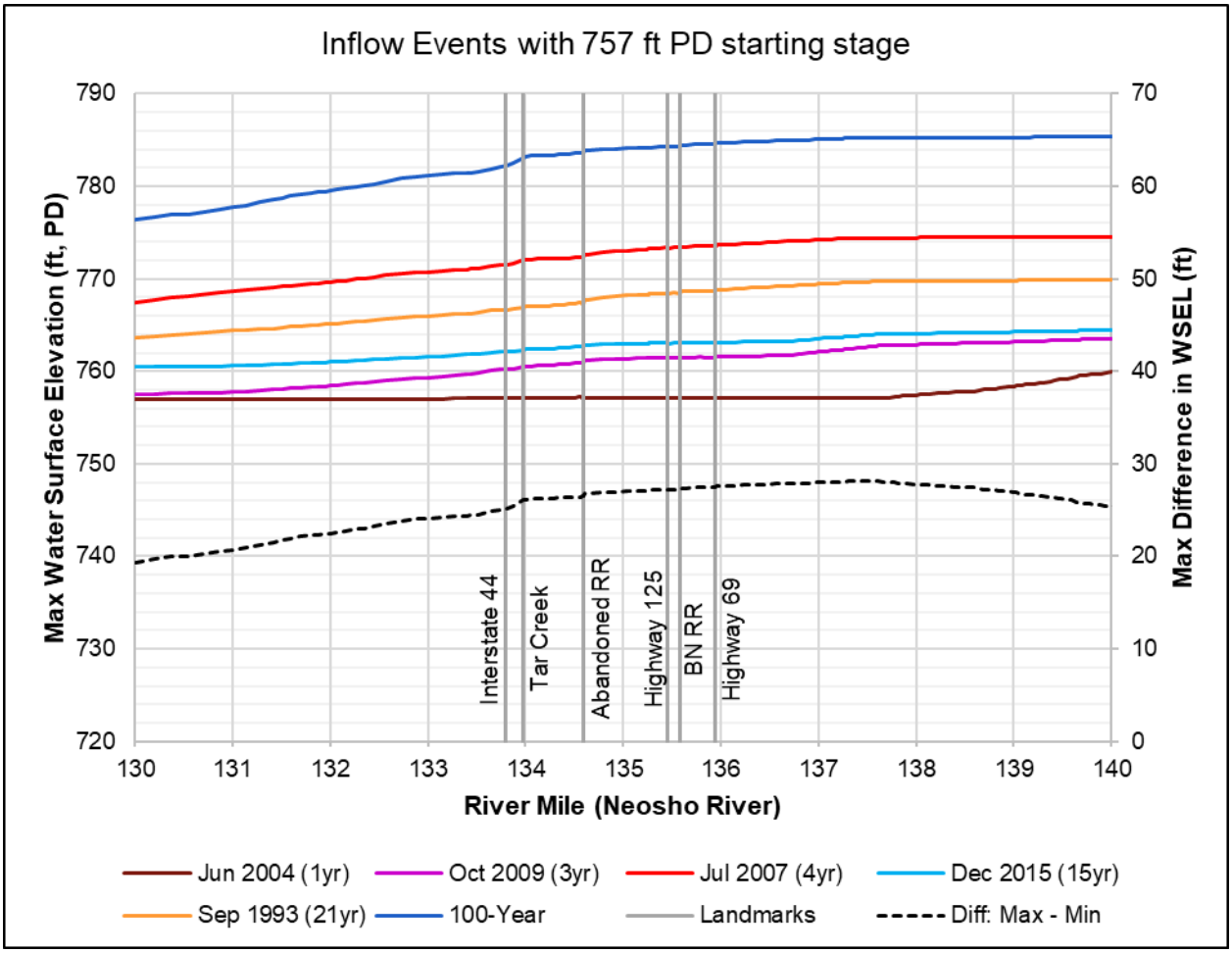


Figure 42. Maximum WSELs near Miami, OK for various natural inflow events, using a starting pool elevation of 757 feet.

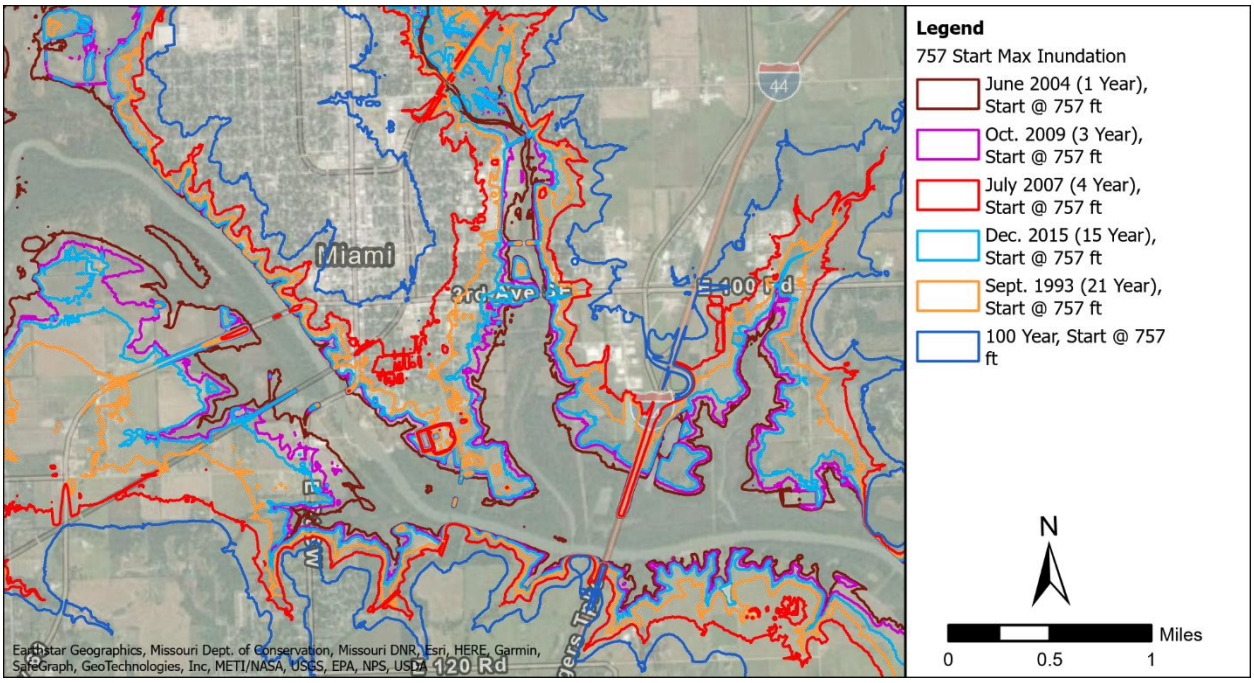


Figure 43. Maximum inundation extents near Miami, OK for natural various inflow events, using a starting pool elevation of 757 feet.

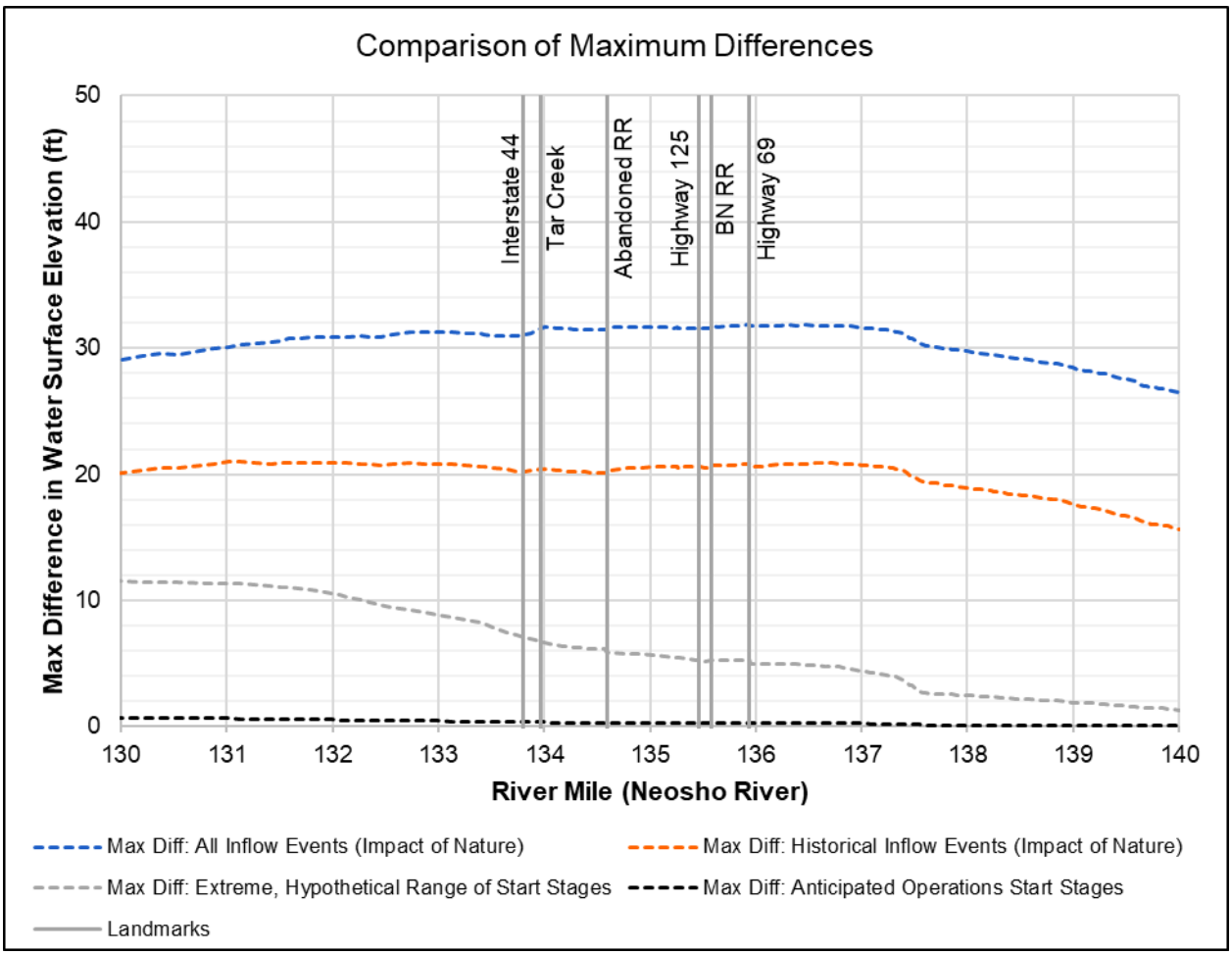


Figure 44. Comparison of maximum WSEL differences near Miami, OK.

10. Anticipated Operations Analysis

As proposed in Section 2.6.5 of the H&H Study RSP, “an additional suite of model runs following the same parameters” was run for the operational scenario anticipated by GRDA. As discussed in Section 1.6.2 of GRDA’s December 29, 2021 filing with FERC, GRDA anticipates the following operational parameters will apply during the new license term:

1. GRDA will no longer utilize a rule curve with seasonal target elevations.
2. GRDA will maintain the reservoir between elevations 742 and 745 feet PD for purposes of normal hydropower operations. While hydropower operations may occur when water surface elevations are outside this range (e.g., maintenance drawdowns and high-flow events), GRDA expects to generally maintain water surface elevations between 742 and 745 feet PD during normal Project operations.
3. Instead of managing the Project to target a specified seasonal elevation, GRDA’s anticipated operations may fluctuate reservoir levels within the elevational range of 742 and 745 feet PD, for purposes of responding to grid demands, market conditions, and the public interest, such as environmental and recreational considerations.
4. GRDA will continue to adhere to USACE’s direction on flood control operations in accordance with the Water Control Manual.

This operational scenario is henceforth referred to as “anticipated operations”. To characterize the impact of anticipated operations on the range of inflow events and starting pool elevations studied, the following scenarios were simulated:

1. June 2004 (1 year) inflow event, starting pool elevation of 734.0 feet PD,
2. June 2004 (1 year) inflow event, starting pool elevation of 757.0 feet PD,
3. July 2007 (4 year) inflow event, using the OM period of record starting pool elevation,
4. 100-year inflow event, starting pool elevation of 734.0 feet PD, and
5. 100-year inflow event, starting pool elevation of 757.0 feet PD.

These 5 scenarios were simulated with (1) baseline operations and (2) anticipated operations for a total of 10 simulations. The suite of simulations represents:

1. The minimum and maximum starting pool elevations requested by FERC,
2. The smallest and largest inflow events requested by FERC, and
3. An event of historical importance to upstream communities that is within the studied range of starting pool elevations and within the studied range of inflow magnitudes. The starting pool elevation for this event was not arbitrary, but came out of the operational simulations, making it the most integrous comparison of the effects of anticipated operations versus baseline operations on maximum WSEL in this study.

Results from the analysis are presented in **Appendix H**. The baseline operations stage hydrographs and anticipated operations stage hydrographs[2] are included in **Appendix H.1**. Tabulated results of maximum WSEL are included in **Appendix H.2**. Plots of maximum WSEL profiles are included in **Appendix H.3**. Tabulated results of inundation duration are presented in **Appendix H.4**.

[2] Inflow hydrographs are included in **Appendix C.2**.

Table 31 presents a summary of maximum increases in peak WSEL for anticipated operations as compared to baseline operations. For each simulation, the maximum increase in peak WSEL along all reaches (Neosho River, Spring River, Elk River, Tar Creek) is presented.

1. For the June 2004 (1 year) inflow event, there are no increases in peak WSEL along any modeled reach for a starting elevation of 734 feet PD.
2. For the June 2004 (1 year) inflow event, there are no increases in peak WSEL along any modeled reach for a starting elevation of 757 feet PD.
3. For the July 2007 (4 year) inflow event, the maximum increase in peak WSEL is 0.02 feet, which occurs along the Elk River. Maximum increases of 0.01 feet also occur along the Neosho River and Tar Creek. There are no increases along the Spring River.
4. For the 100-year inflow event with a starting pool elevation of 734 feet, the maximum increase is 0.05 feet, which occurs along the Spring River. A maximum increase of 0.03 feet also occurs along the Neosho River and an increase of 0.01 occurs along Tar Creek. There are no increases along the Elk River.
5. For the 100-year inflow event, there are no increases in peak WSEL for a starting elevation of 757 feet PD.

The results show that anticipated operations have an immaterial impact on upstream WSELs as compared to baseline operations.

Table 31. Summary of increases in WSEL due to anticipated operations, as compared to baseline operations.

Simulation	Maximum Increase in WSEL Due to Anticipated Operations (ft)
June 2004 (1 year) event, starting pool elevation of 734.0 feet PD	0.00
June 2004 (1 year) event, starting pool elevation of 757.0 feet PD	0.00
July 2007 (4 year) event, period of record starting pool elevation	0.02
100-year event, starting pool elevation of 734.0 feet PD	0.05
100-year event, starting pool elevation of 757.0 feet PD	0.00

Figure 45 displays maximum WSEL profiles for the June 2004 (1 year) inflow event, the smallest inflow event studied, near Miami, OK. Baseline and anticipated operational results are displayed for starting elevations of 734 and 757 feet, the minimum and maximum starting pool elevations requested by FERC. The dotted lines plot the increase in WSEL due to anticipated operations as compared to baseline operations and are plotted on the secondary y-axis. The dotted lines are not visible because the increase in WSEL is zero. Similarly, **Figure 46** displays maximum WSEL profiles for the July 2007 (4 year) inflow event, and **Figure 47** displays profiles for the 100-year inflow event. The dotted lines, which plot the increase in WSEL due to anticipated operations as compared to baseline operations, are difficult to see because the increase in WSEL is nearly zero.

The plots show how anticipated operations have an immaterial impact on upstream WSELs as compared to baseline operations for a suite of simulations that spans the FERC-requested range of starting pool elevations and inflow event magnitudes.

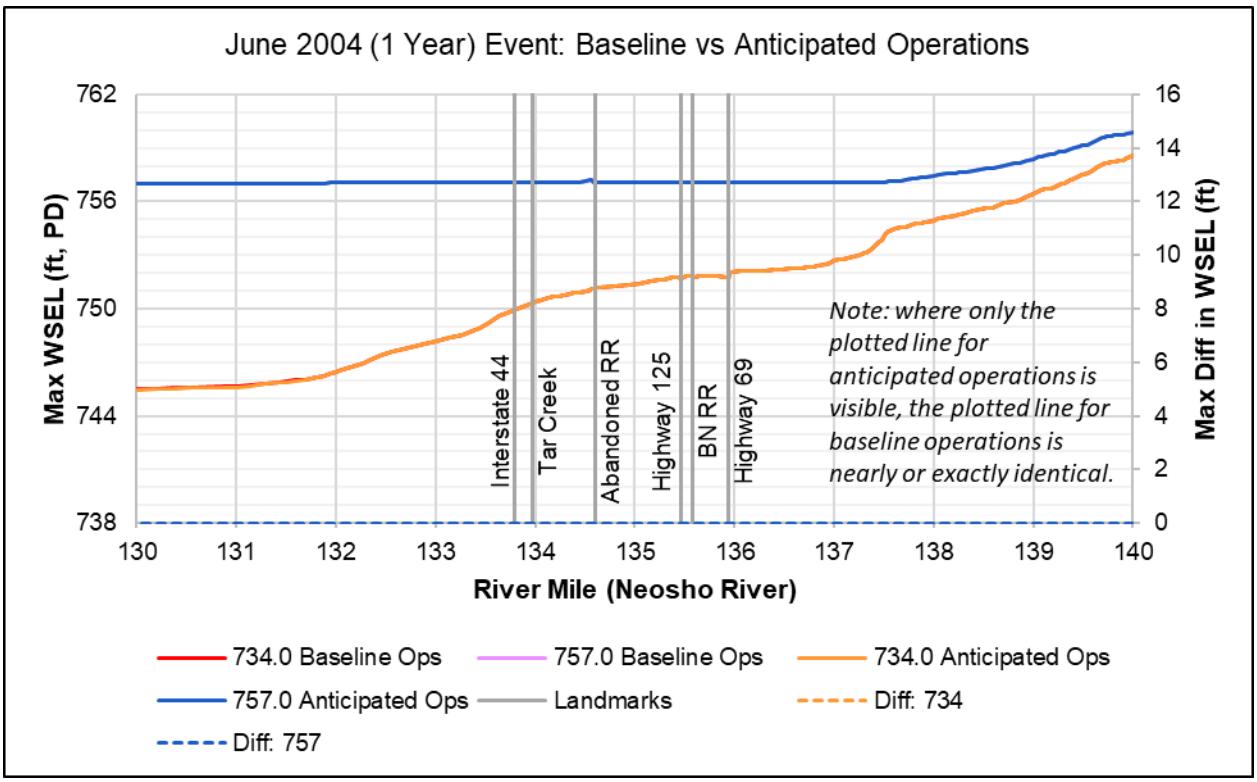


Figure 45. Maximum WSELs near Miami, OK for baseline and anticipated operations during the June 2004 inflow event.

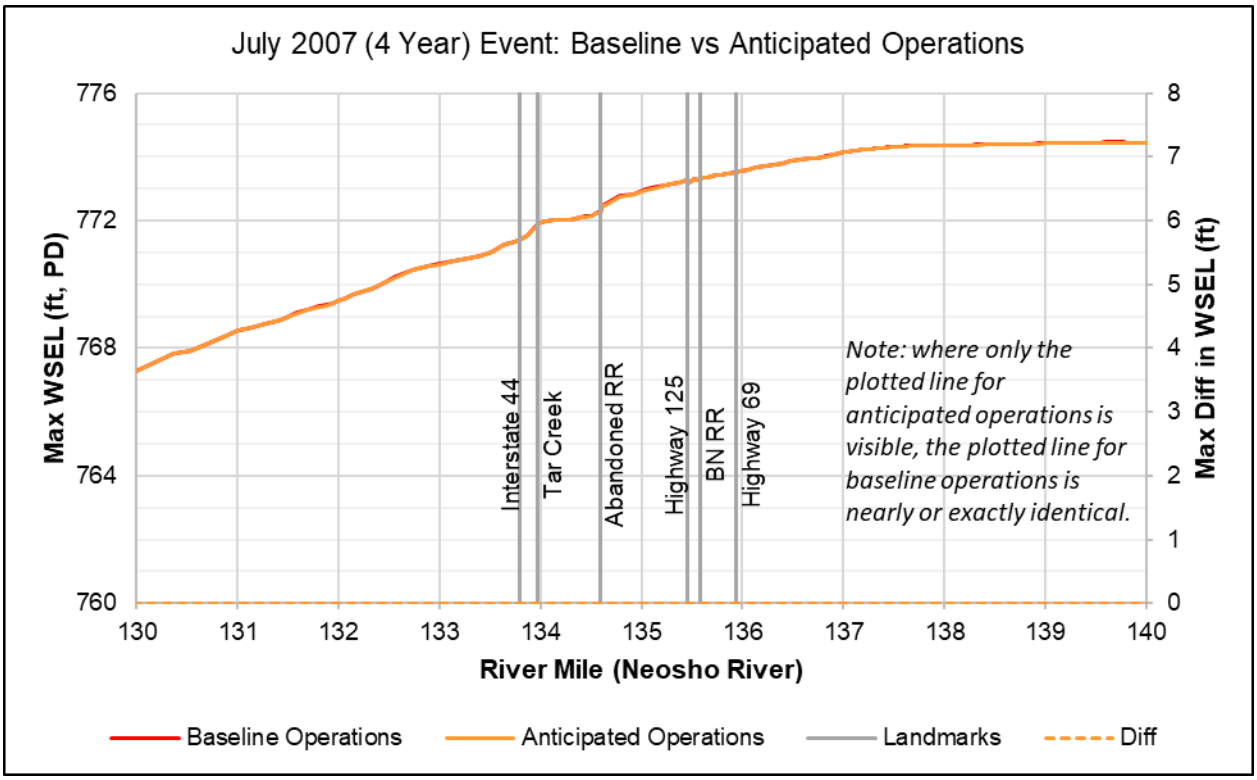


Figure 46. Maximum WSELs near Miami, OK for baseline and anticipated operations during the July 2007 inflow event.

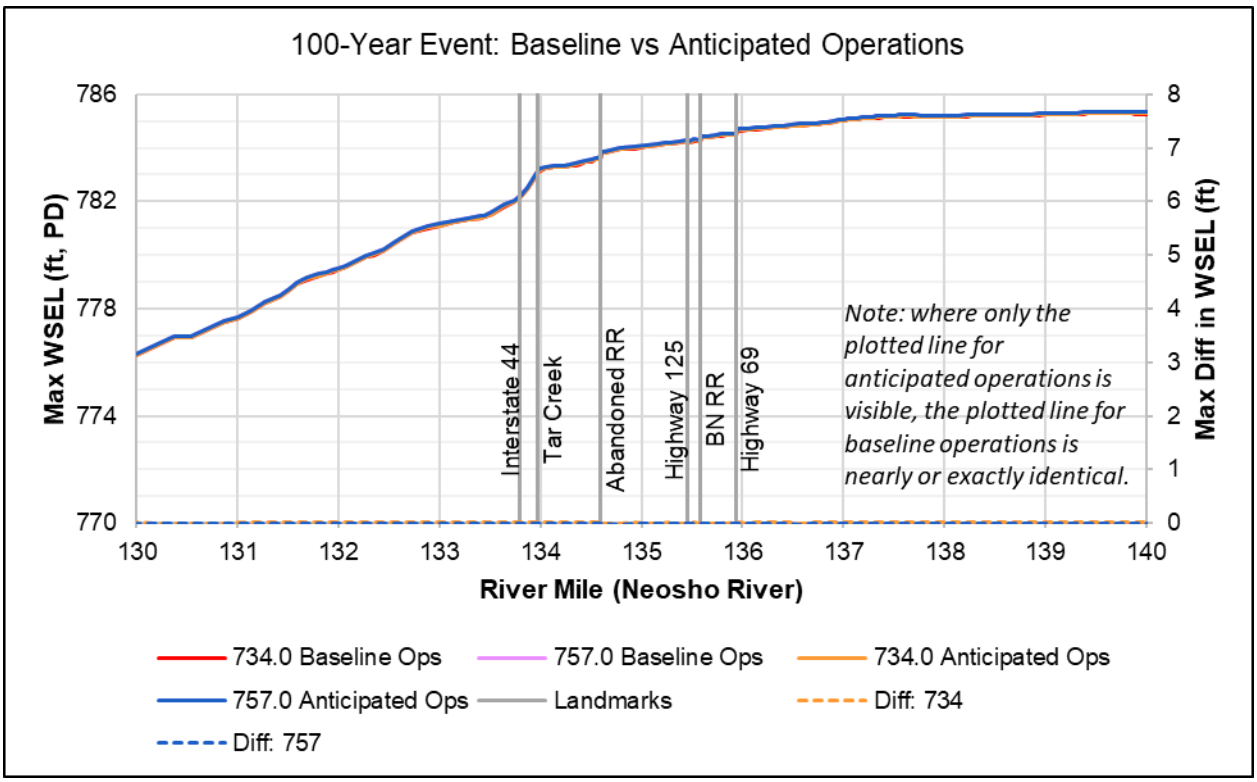


Figure 47. Maximum WSELs near Miami, OK for baseline and anticipated operations during the 100-year inflow event.

Inundation maps are presented in **Appendix F**. Based on the maximum WSEL results, no additional inundation maps were created. A difference in inundation extent for differences in WSEL of 0.05 feet or less at a few discrete locations cannot be effectively displayed on an inundation map. The extent of inundation for anticipated operations is virtually identical to the extent of inundation for baseline operations.

Table 32 presents a summary of maximum increases in duration for anticipated operations as compared to baseline operations. Only the 100-year event simulations resulted in an increase in duration along any modeled reach. For both simulations of the 100-year event, the increases in duration occurred at RM 129.0, just upstream of the S 590 Road or Connor Bridge (RM 126.7). This area is rural, sparsely populated, and the 2-hour increase in duration is isolated to this location.

Table 32. Summary of increases in duration due to anticipated operations, as compared to baseline operations.

Simulation	Maximum Increase in Inundation Duration Due to Anticipated Operations (hours)
June 2004 (1 year) event, starting pool elevation of 734.0 feet PD	0
June 2004 (1 year) event, starting pool elevation of 757.0 feet PD	0
July 2007 (4 year) event, period of record starting pool elevation	0
100-year event, starting pool elevation of 734.0 feet PD	2
100-year event, starting pool elevation of 757.0 feet PD	2

11. Supporting Analysis for Other Studies

Mead & Hunt performed analysis in support of four studies: the Aquatic Species Study, the Terrestrial Species Study, the Wetlands and Riparian Habitat Study, and the Sedimentation Study. Mead & Hunt's supporting analysis is discussed below.

11.1 Aquatic Species Study

In support of the Aquatic Species Study, Mead & Hunt performed additional simulations that were used to assess operational impact to specific aquatic species. One product of the simulations was the development of maps showing changes to potential lake spawning species. The Aquatic Species Study team requested a comparison between anticipated operations and baseline operations during normal operations and inflows. The focus on normal operations and inflows and not flood events is necessary in biological assessments. This is because flood events do not occur at a frequency that causes long term changes to the physical and biological environment such that the biological entities need to adapt to survive. Whereas normal events and operations represent conditions that occur at a frequency and persist for long periods of time such that biological habits may need to change to survive.

To represent normal operations and inflows, Mead & Hunt simulated inflows and operations for the 2004 to 2019 period of record in the OM under both anticipated operations and baseline operations. Based on the period of record, normal (median) operational level and inflows were extracted for the annual seasonal period of May 15 to July 8, a time period identified by the Aquatic Species Study team as a critical time period sensitive to water level fluctuations. The critical time period is surrogate for all lake spawning fish and was based upon the nursery period for largemouth bass (Zale, 1991). For both anticipated operations and baseline operations, the seasonal median operational level and inflows were simulated in the UHM. Results were provided to the Aquatic Species Study team. In accordance with Section 2.6 of the Aquatic Species RSP, maximum inundation was also identified on all maps showing changes to potential lake spawning species. To develop a boundary of maximum inundation during the period of record, the maximum inundations for all major inflow events during the period of record (July 2007, December 2015, April 2017, and May 2019) were merged into a single inundation boundary. This procedure was performed for both anticipated and baseline operations. The maximum inundation was virtually identical for anticipated and baseline operations. Therefore, a single boundary of maximum inundation was mapped. Maps showing changes to potential lake spawning species habitat are presented in **Appendix I.1**.

11.2 Terrestrial Species Study

In support of the Terrestrial Species Study, Mead & Hunt performed additional simulations that were used to assess operational impact to specific terrestrial species. One product of the simulations was the development of maps showing areas of potential lentic or lotic conversion which could impact the habits of specific terrestrial species. Mead & Hunt followed the same process as the Aquatic Species Study. The seasonal period identified by the Terrestrial Species Study team was the entire calendar year, January 1 to December 31 because several critical terrestrial species could be most impacted during both their active and inactive or hibernation periods each year. For both anticipated operations and baseline operations, the seasonal median operational level and inflows were simulated in the UHM. Results were mapped and provided to the Terrestrial Species Study team. Maximum inundation, discussed in **Section 11.1**, was included on the maps. Maps showing areas of potential lentic or lotic conversion are presented in **Appendix I.2**.

11.3 Wetlands and Riparian Habitat Study

In support of the Wetlands and Riparian Habitat Study, Mead & Hunt performed additional simulations and developed maps of potential wetland and riparian inundation changes that could cause the areas to change from seasonally flooded to permanently flooded. Mead & Hunt followed the same process used to develop maps for the Terrestrial Species Study. The annual seasonal period identified by the Wetland and Riparian Habitat Study team was March 30 to November 2, which is the growing season based on Tulsa, OK climatological records. For both anticipated operations and baseline operations, the seasonal median operational level and inflows were simulated in the UHM. Results were mapped and provided to the Wetlands and Riparian Habitat Study team. Maximum inundation, discussed in **Section 11.1**, was included on the maps. Maps of potential wetland and riparian inundation changes are presented in **Appendix I.3**.

11.4 Sedimentation Study

In accordance with FERC's May 27, 2022 Determination regarding the Sedimentation Study, Mead & Hunt used a 1D version of the UHM to simulate the July 2007 (4 year) historical inflow event and the 100-year inflow event with starting reservoir elevations of 740-, 745-, and 750-feet PD. These scenarios were simulated to understand the effects of project operation and predicted channel geometry on upstream WSELs. The OM was used to calculate downstream stage hydrographs at Pensacola Dam and geometry files were provided by the Sedimentation Study team. Sedimentation scenario results are discussed in the Sedimentation USR.

12. Conclusions

The results of the UHM demonstrate that starting pool elevations at Pensacola Dam within GRDA's anticipated operational range have an immaterial impact on upstream WSELs, inundation, and duration for a range of inflow events. Compared to starting elevations within GRDA's anticipated operational range, only natural inflows—and not Project operation—caused an appreciable difference in maximum WSEL, maximum inundation extent, or duration. The differences in WSEL, inundation extent, and duration due to the size of the natural inflow event were orders of magnitude greater than the differences in WSEL, inundation extent, and duration due to the initial stage at Pensacola Dam. The maximum impact of nature typically ranged from over 10 times to over 100 or even over 1,000 times the maximum simulated impact of GRDA's anticipated operations.

Even if extreme, hypothetical starting pool elevations outside GRDA's anticipated operational range are used, the maximum impact of nature is much greater than the maximum simulated impact of an extreme, hypothetical starting stage range of 23 feet. The impact of nature typically ranged from 2 times to 10 or even 100 times the impact of the extreme, hypothetical starting stage range.

Comparing anticipated operations to baseline operations for a suite of simulations that spanned the FERC-requested range of starting pool elevations and inflow event magnitudes, the results of the UHM demonstrate that anticipated operations have an immaterial impact on upstream WSELs, inundation, and duration as compared to baseline operations.

All conclusions on potential lentic or lotic conversion areas are discussed in each of the individual biological assessment reports.

13. References

Arcement, G., & Schneider, V. (1989). *Guide for Selecting Manning's Roughness Coefficients for Natural Channels and Floodplains. U.S. Geological Survey Water Supply Paper 2339.*

Bolivar, A., Diaz-Frances, E., Ortega, J., & Vilchis, E. (2010). *Likelihood-Confidence Intervals for Quantiles in Extreme Value Distributions.* Guanajuato: Centro de Investigacion en Matematicas.

City of Miami. (2021). *Comments of Tetra Tech on Behalf of the City of Miami, Oklahoma (Corrected) on Mead & Hunt's H&H Modeling Upstream Hydraulic Model Input Status Report on Behalf of GRDA.* Davis Wright Tremaine LLP.

Dewberry. (2011). *USGS Grand Lake, OK LiDAR Project, Prepared for the U.S. Geological Survey.*

FEMA. (2019). *Flood Insurance Study - Ottawa County, Oklahoma and Incorporated Areas (40115CV000B).* Washington.

Hunter, S. L., Trevisan, A. R., Villa, J., & Smith, K. A. (2020). *Bathymetric Map, Surface Area, and Capacity of Grand Lake O' the Cherokees, Northeastern Oklahoma, 2019.* Denver: USGS.

Mead & Hunt. (2016). *Review of Tetra Tech's Hydraulic Modeling for the Pensacola Project.*

Mead & Hunt. (2021). *H&H Modeling: Upstream Hydraulic Model Input Status Report.*

Mussetter, R. (1998). *Evaluation of the Roughness Characteristics of the Neosho River in the Vicinity of Miami, Oklahoma.*

Office of the Federal Register. (2021, February 11). 44 C.F.R. § 65.6(a)(2). *Title 44: Emergency Management and Assistance*. Retrieved from https://www.ecfr.gov/

Simons & Associates, Inc. (1996). *Backwater Analysis of Pensacola Reservoir on the Neosho River, Miami, Oklahoma.*

Smith, S., Hunter, S., & Ashworth, C. (2017). *Bathymetric surveyes of the Neosho River, Spring River, and Elk River, northeastern Oklahoma and southwestern Missouri, 2016-2017.* Denver: USGS.

Takara, K. (2009). *Frequency Analysis of Hydrological Extreme Events and How to Consider Climate Change.* Kyoto: Disaster Prevention Research Institute, Kyoto University.

Tetra Tech. (2015). *Hydraulic Analysis of the Effects of Pensacola Dam on the Neosho River in the Vicinity of Miami, Oklahoma.* Fort Collins.

Tetra Tech. (2016). *Hydraulic Analysis of the Effects of Proposed Rule Curve Change at Pensacola Dam on Neosho River Flooding in the Vicinity of Miami, Oklahoma.* Fort Collins.

USACE. (1998). *Grand Lake, Oklahoma Real Estate Adequacy Study.*

USACE. (2016a). *HEC-RAS River Analysis System 2D Modeling User's Manual.* Davis: Hydrologic Engineering Center.

USACE. (2016b). *HEC-RAS River Analysis System Hydraulic Reference Manual.* Davis: Hydrologic Engineering Center.

USACE. (2016c). *HEC-RAS River Analysis System User's Manual.* Davis: Hydrologic Engineering Center.

USACE. (2018). *Engineering Manual No. 1110-2-1420: Hydrologic Engineering Requirements for Reservoirs.* Washington.

USGS. (2016, February 10). *Explainations for the National Water Conditions*. Retrieved from Water Resources of the United States: https://water.usgs.gov/nwc/explain_data.html

USGS. (2017, March 21). *National Geospatial Program.* Retrieved from The National Map Viewer: https://www.usgs.gov/core-science-systems/national-geospatial-program/national-map

USGS. (2021a, February 5). *USGS 07185000 Neosho River near Commerce, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/uv?site_no=07185000

USGS. (2021b, February 5). *USGS 07185080 Neosho River at Miami, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/ok/nwis/uv?site_no=07185080

USGS. (2021c, February 5). *USGS 07185095 Tar Creek at 22nd Street Bridge at Miami, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/uv?site_no=07185095

USGS. (2021d, February 5). *USGS 07188000 Spring River near Quapaw, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/uv?site_no=07188000

USGS. (2021e, February 5). *USGS 07189000 Elk River near Tiff City, Mo*. Retrieved from National Water Information System: https://waterdata.usgs.gov/mo/nwis/uv?site_no=07189000

USGS. (2021f, February 5). *USGS 07190000 Lake O' the Cherokees at Langley, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/ok/nwis/uv?site_no=07190000

USGS. (2021g, August 17). *Peak Streamflow for Oklahoma: USGS 07185000 Neosho River near Commerce, OK*. Retrieved from National Water Information System: https://nwis.waterdata.usgs.gov/ok/nwis/peak?site_no=07185000&agency_cd=USGS&format=html

USGS. (2021h, August 17). *Streamflow Measurements for the Nation: USGS 07185000 Neosho River near Commerce, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/measurements/?site_no=07185000

USGS. (2021i, August 17). *Peak Streamflow for Oklahoma: USGS 07185080 Neosho River at Miami, OK*. Retrieved from National Water Information System: https://nwis.waterdata.usgs.gov/ok/nwis/peak?site_no=07185080&agency_cd=USGS&format=html

USGS. (2021j, August 17). *Streamflow Measurements for the Nation: USGS 07185080 Neosho River at Miami, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/measurements/?site_no=07185080

USGS. (2021k, August 17). *Peak Streamflow for Oklahoma: USGS 07189000 Elk River near Tiff City, MO*. Retrieved from National Water Information System: https://nwis.waterdata.usgs.gov/ok/nwis/peak?site_no=07189000&agency_cd=USGS&format=html

USGS. (2021l, August 17). *Streamflow Measurements for the Nation: USGS 07189000 Elk River near Tiff City, MO*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/measurements/?site_no=07189000

USGS. (2021m, August 17). *Peak Streamflow for Oklahoma: USGS 0718800 Spring River near Quapaw, OK*. Retrieved from National Water Information System: https://nwis.waterdata.usgs.gov/ok/nwis/peak?site_no=07188000&agency_cd=USGS&format=html

USGS. (2021n, August 17). *Streamflow Measurements for the Nation: USGS 07188000 Spring River near Quapaw, OK*. Retrieved from National Water Information System: https://waterdata.usgs.gov/nwis/measurements/?site_no=07188000

Zale, W. L. (1991). Effect of Water Level Fluctuations on Abundance of Youn-of-year Largemouth Bass in a Hydropower Reservoir. *Annual Conference of Southeast Association of Fish and Wildlife Agencies*, (pp. 422-431).

APPENDIX A:
RESPONSE TO CITY OF MIAMI COMMENTS

This document compiles comments received on *H&H Modeling: Upstream Hydraulic Model – Model Input Status Report*, filed with FERC on March 30, 2021. The City of Miami was the only entity to file comments; their comments were filed with FERC on June 23, 2021. After each comment, Mead & Hunt has provided a response. Page numbers listed below reference the *Model Input Status Report*.

Comment No. 1, Section 2.1, page 4

City of Miami Comment

The USACE's Hydrologic Engineering Center (HEC) has recently released HEC-RAS Version 6.0. This model has several improvements over Version 5.0.7, including the ability to represent bridges within a 2-D area. Tetra Tech recommends developing and calibrating a fully 2-D hydraulic model using HEC-RAS Version 6.0.

Mead & Hunt Response to Comment No. 1

The FERC-approved Revised Study Plan states that HEC-RAS version 5.0.3 or later will be used. Consistent with this requirement, the model was developed in HEC-RAS version 5.0.7. Version 6.0 includes an expanded set of features. The ability to represent bridges within a 2D Flow Area is new to version 6.0. The engineering community has not yet extensively tested this, or other new features. It is inadvisable to move the model to this new version at this time.

Comment No. 2, Section 2.2, page 4

City of Miami Comment

Because the 2DFA better accounts for the volume in Grand Lake, it should be applied to the entire area of the lake.

Mead & Hunt Response to Comment No. 2

The cross-sections upstream of River Mile 100 extend across the reservoir and thus properly account for the volume.

Comment No. 3, Section 2.2, page 4

City of Miami Comment

The River Miles along Grand Lake and the Neosho River are different by approximately 8 miles compared to previous studies (Holly, 2001; Tetra Tech, 2015). For comparative purposes with previous studies, Tetra Tech recommends using the original river mile stationing.

Mead & Hunt Response to Comment No. 3

Mead & Hunt used USGS river miles because it is a publicly available dataset.

Comment No. 4, Section 2.4, page 6

City of Miami Comment

The Mead & Hunt hydraulic model has many areas where the cell alignments do not follow the top of banks, as shown in Figure A. Mead & Hunt should therefore review the cell alignments in its model and refine them to ensure that they meet Mead & Hunt's stated goal of matching cell alignments to waterway banks.

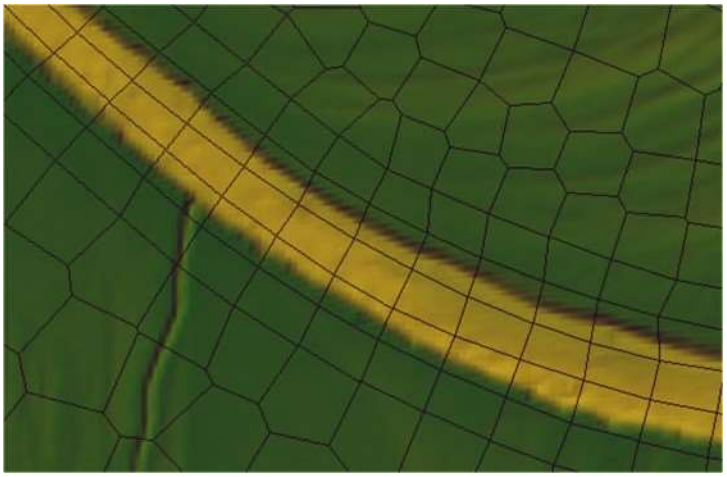


Figure A. Example of 2DFA mesh of the Mead & Hunt model where the cell alignments do not follow the top of banks. This section of mesh is located on the Neosho River upstream from the City of Miami.

Mead & Hunt Response to Comment No. 4

Mead & Hunt followed USACE guidance in the 2D Modeling User's Manual when aligning cell faces near the Neosho River banks (USACE, February 2016). USACE provides the following guidance in the 2D Modeling User's Manual:

> "*Break lines can… be placed along the main channel banks in order to keep flow in the channel until it gets high enough to overtop any high ground berm along the main channel*" (page 3-3).

Mead & Hunt followed this guidance and aligned the cell faces so that faces did not go into the channel.

Secondly, Mead & Hunt followed the guidance in the 2D Modeling User's Manual by not placing the break lines too close to each other. The 2D Modeling User's Manual states:

> *"[Cells with collinear faces are] generally caused by placing two or more break lines parallel to each other, and* ***close together****, such that the creation of cells along one break line can create problems with cells along the other break line*" (page 3-18, emphasis added).

The 2D Modeling User's Manual warns:

> "*If cells end up [with collinear faces],* ***the software will run, but the computation across cell faces that are like this will not be correct***" (page 3-17, emphasis added).

Tetra Tech's recommendation would not improve model performance and may result in a degraded computational mesh, which could result in incorrect computations. It is more important for the cell face to represent a consistent overbank elevation than be as close to the bank as possible. Mead & Hunt's cell face alignment follows USACE guidance.

Comment No. 5, Section 2.11, page 12

City of Miami Comment

In reviewing the Mead & Hunt model input status report, Tetra Tech developed bed elevation profiles along the centerline of the historic Grand and Neosho Rivers using the 2008 OWRB, 2015 Tetra Tech, 2017 USGS, and 2019 USGS hydrographic data; the following observations were made about the profiles (**Figure B**):

- Bed elevations from the 2015 Tetra Tech and 2017 USGS surveys along the centerline of the channel between Twin Bridges and Miami are in good agreement.
- Upstream of Twin Bridges, there is significant variability in the 2017 USGS profile. The model input status report indicates that Mead & Hunt used the 2017 USGS survey of the Neosho River to represent the channel from Twin Bridges to approximately the Kansas border. From Twin Bridges to about 3 miles upstream of the City of Miami, the USGS surveyed cross-sections approximately perpendicular to the flow. From 3 miles upstream of the City to the Kansas border, the USGS surveyed the channel in a zig-zag pattern (**Figure C**). The resulting interpolation of the survey points provides a poor representation of the channel topography, as indicated by the variability in the bed profile and bed elevations shown in Figure C. The interpolation method applied by the USGS is not known. Tetra Tech recommends re-evaluating the USGS survey data to develop representative channel conditions. Tetra Tech recommends using the Tetra Tech survey data, where available, to supplement the USGS data.
- The 2008 OWRB and 2019 USGS surveys show similar amounts of aggradation between about the Elk River and Twin Bridges; however, elevations from the 2019 USGS surveys are typically higher. From Pensacola Dam to about 30 miles upstream, the 2019 USGS survey is 5 to 8 feet higher than 2008 OWRB survey. The nearby upstream tributaries are relatively small and likely do not contribute enough sediment to cause this amount of aggradation. Tetra Tech would expect minor aggradation in this area between construction of the dam and the present, therefore, the differences are likely due to differences in surveying equipment and method, an error in one (or both) of the surveys, or a combination of both.

For this review, Tetra Tech also developed a comparison of the 2008 OWRB and 2019 USGS digital elevation models (surfaces) of Grand Lake, shows that:

- The differences are larger at the downstream end (near Pensacola Dam) compared to upstream (Figure D); this is consistent with the centerline profiles in Figure B but is an unexpected result. Typically, it would be expected that there would be relatively little difference between the surveys near Pensacola Dam and larger differences near Twin Bridges due to sedimentation at the head of Grand Lake.
- The USGS (2019) report presents an elevation-volume rating curve (Figure 11) that indicates a reduction in volume at the dam crest elevation (755 feet) of about 10 percent between 2008 and 2019 and about 17 percent between 1940 and 2019 (USGS Figure 5). The USGS (2019) attributes the difference to survey methods and equipment but does not provide either profile or planform comparisons of the two surveys to allow independent evaluation of this conclusion.

Tetra Tech recommends that Mead and Hunt perform an analysis of the differences between the OWRB and USGS surveys and substantiate why the USGS survey is being used for the study. Tetra Tech would support Mead & Hunt collecting spot elevations of the lake bed in the vicinity of the dam to confirm that the USGS survey is correct.

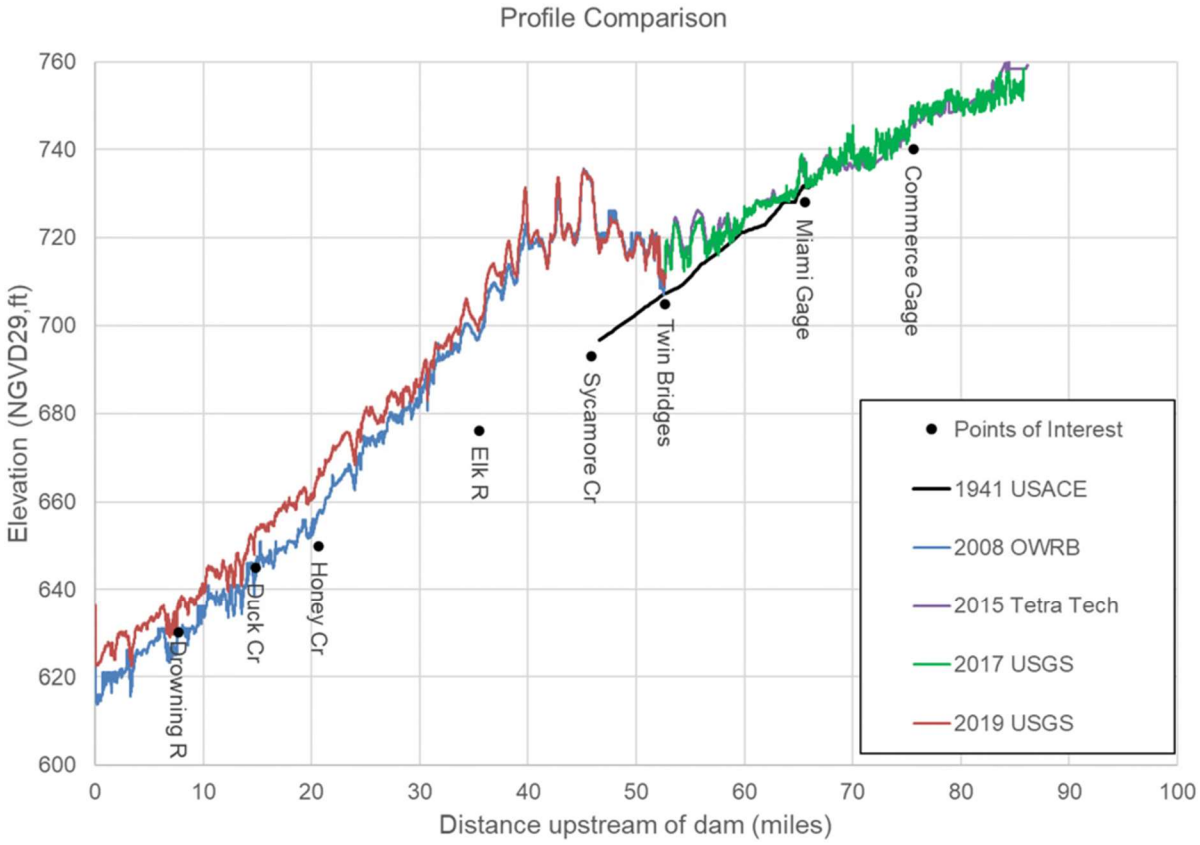


Figure B. Comparison of the 1941 USACE, 2008 OWRB, 2015 Tetra Tech, 2017 USGS and 2019 USGS profiles along the centerline of the historic Grand River and Neosho River.

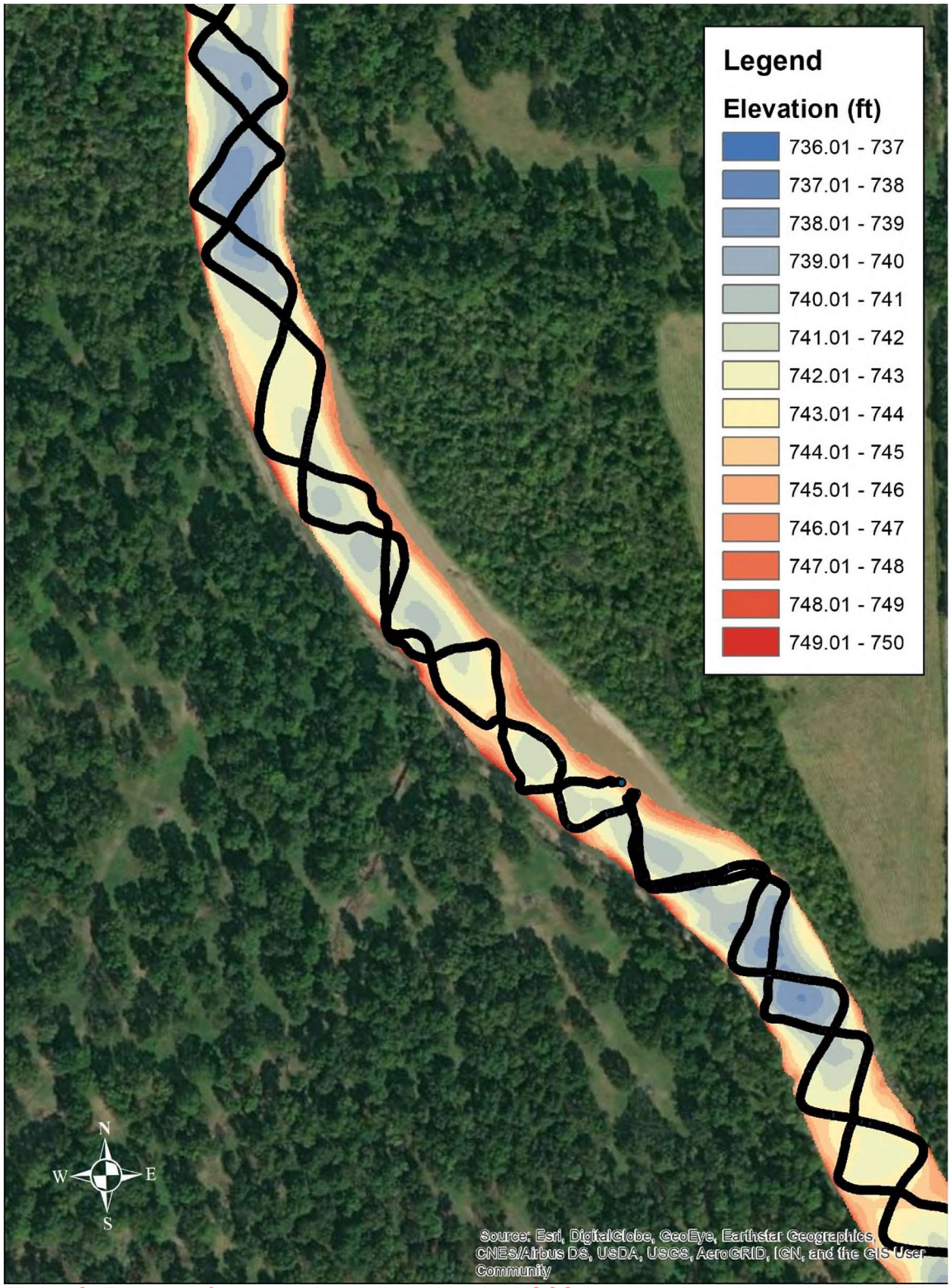


Figure C. Example of survey points collected by the USGS (2017) and overlaying the Digital Elevation Model developed by the USGS. The irregular bed elevations are due to the surface development method and are not representative of actual conditions.

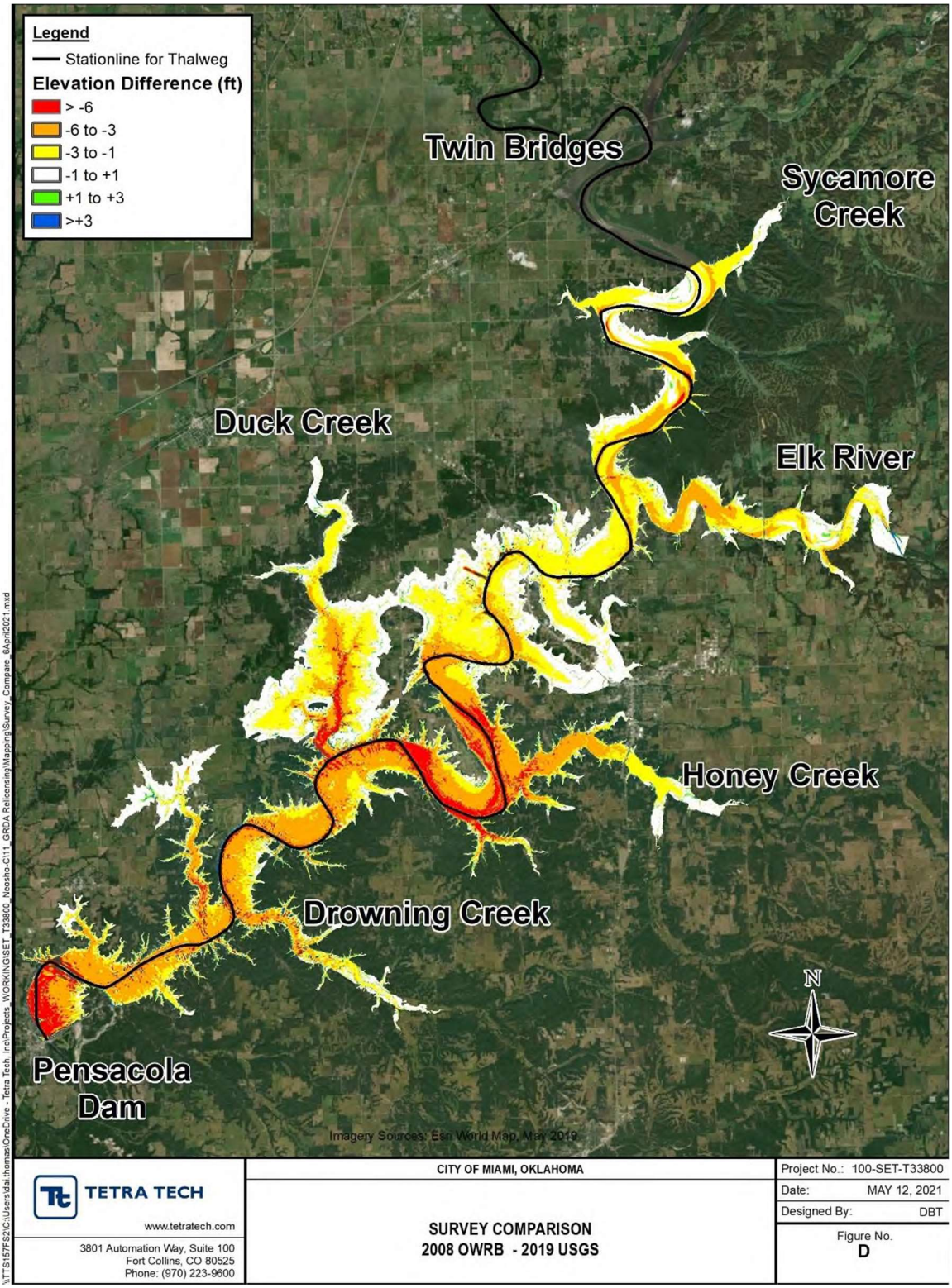


Figure D. Difference in elevation between the 2008 OWRB and 2019 USGS surveys.

Mead & Hunt Response to Comment No. 5

There is no basis to question the accuracy of the 2017 or 2019 bathymetry data collected by USGS for the following reasons:

1. The 2019 bathymetry was completed at the City of Miami's request and at FERC's direction in the Study Plan Determination. USGS is a nationally recognized agency for their expertise in data collection. USGS was selected as a non-biased, objective entity for bathymetric data collection. USGS performed the data collection in accordance with the Study Plan Determination.
2. USGS's 2019 report documents the use of industry standard practices for multi-beam bathymetric data collection quality assurance, namely beam-angle checks and patch tests. USGS also documented the use of industry standards when estimating uncertainty in the collected data.
3. USGS's 2017 report documents the use of industry standard practices for single-beam bathymetric data collection quality assurance, namely independent speed of sound measurements and bar checks at depths that spanned the range of measured depth. USGS also documented the use of industry standards when estimating uncertainty in the collected data.
4. USGS's 2017 bathymetry data was officially released in September 2017. The Proposed Study Plan (April 2018) and the Revised Study Plan (September 2018) both discussed the proposed use of USGS's 2017 bathymetry data. Tetra Tech had ample time to review USGS's data prior to and during the study planning process and did not object to the use of the USGS 2017 bathymetry during the study planning process. Raising issues with the 2017 data at this point in the relicensing process is not appropriate.

GRDA and Mead & Hunt have followed City of Miami and Tetra Tech recommendations regarding bathymetric data collection. Further inquiries regarding USGS data should be directed to USGS.

Comment No. 6, Section 2.12, page 15

City of Miami Comment

Figure 12 indicates up to 5 feet of difference in water-surface elevation between the full momentum and diffusion wave methods. Tetra Tech ran Mead & Hunt's model applying the diffusion wave method. Comparison of the water-surface elevations between the two methods showed differences of up to 0.8 feet (Figure E), significantly less than the 5-feet reported by Mead and Hunt.

Tetra Tech also ran its own 2015 model for the 2007 flood and found differences in the water-surface elevation of less than 0.5 feet. Therefore, it appears to Tetra Tech that the Mead & Hunt model results presented in this section and Figure 12 are wrong. Tetra Tech has encountered this issue before and recommends deleting the output files (including the dss file) and re-running the model. Tetra Tech would be pleased to discuss these results with Mead & Hunt to identify and eliminate the discrepancy.

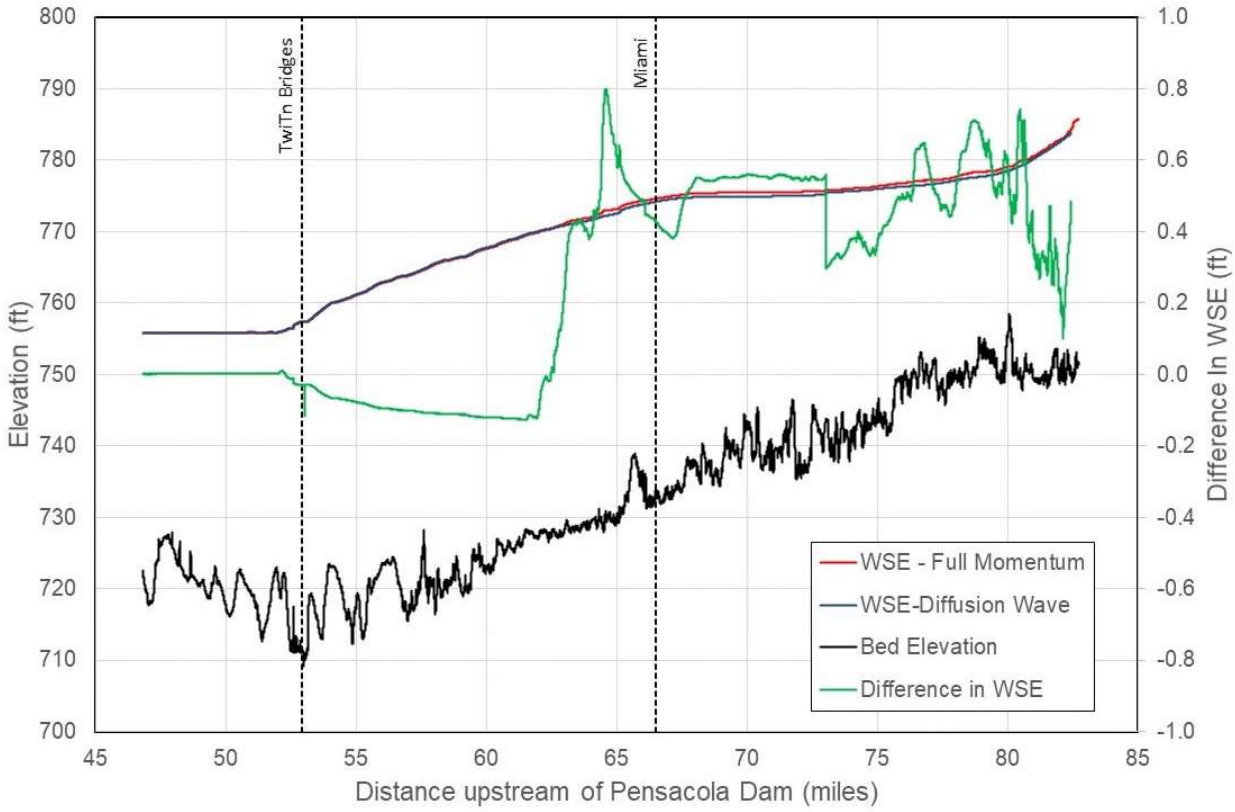


Figure E. Comparison of the predicted water-surface elevation profiles by the Mead & Hunt model applying the full momentum and diffusion wave equations for the June 2007 flood.

Mead & Hunt Response to Comment No. 6

The results displayed in Figure 12 are from a preliminary simulation, as stated in the report. Part of the process that FERC recommended in the Study Plan Determination is the presentation of preliminary results in the Model Input Status Report.

The Manning's n-values used in the calibrated model were not yet applied when this simulation was performed, so differences between the figure and Tetra Tech's re-run of the model are to be expected. Updated results are presented in the Initial Study Report.

Comment No. 7, Section 3.1.1, page 16

City of Miami Comment

Stage data for the period from c1990 to October 2007 are not published online but are available upon request from the USGS. Tetra Tech received the data from:
Scott Strong sstrong@usgs.gov
Jason Lewis jmlewis@usgs.gov
U.S. Geological Survey
Oklahoma City, OK 73116
(405) 810-4404
Tetra Tech recommends obtaining that data from USGS and using it in the calibration process.

Mead & Hunt Response to Comment No. 7

Discussion of data availability for the July 2007 event has been updated in Mead & Hunt's report.

Comment No. 8, Section 3.1.2, page 16

City of Miami Comment

The Neosho River at Miami, OK (USGS Gage No. 07185080) started operating in 1994. Hourly gage data are available from the USGS upon request. Tetra Tech recommends obtaining these data and using them in calibration.

Mead & Hunt Response to Comment No. 8

In general, Mead & Hunt looked at hourly time series data when calibrating. For the 2007 event, Mead & Hunt used the daily maximum values at the Miami gage because hourly data was not publicly available. Because the flood event occurred over multiple days, the publicly available daily maximum values were sufficient.

Comment No. 9, Section 3.2.1, page 18

City of Miami Comment

The spike in flow near the peak of the 2007 flood is likely an anomaly, as it does not occur in the stage data (Figure F). The USGS measured the flow near the peak of the 2007 flood and applied a shift to the rating-curve for the data collected after the measurement. As a result, the USGS applied two rating curves to the 2007 flood, which has led to the downward shift in the flow hydrograph. Tetra Tech recommends that Mead and Hunt re-calculate the flows prior to the peak using the stage-versus-discharge rating-curve reported near the peak.

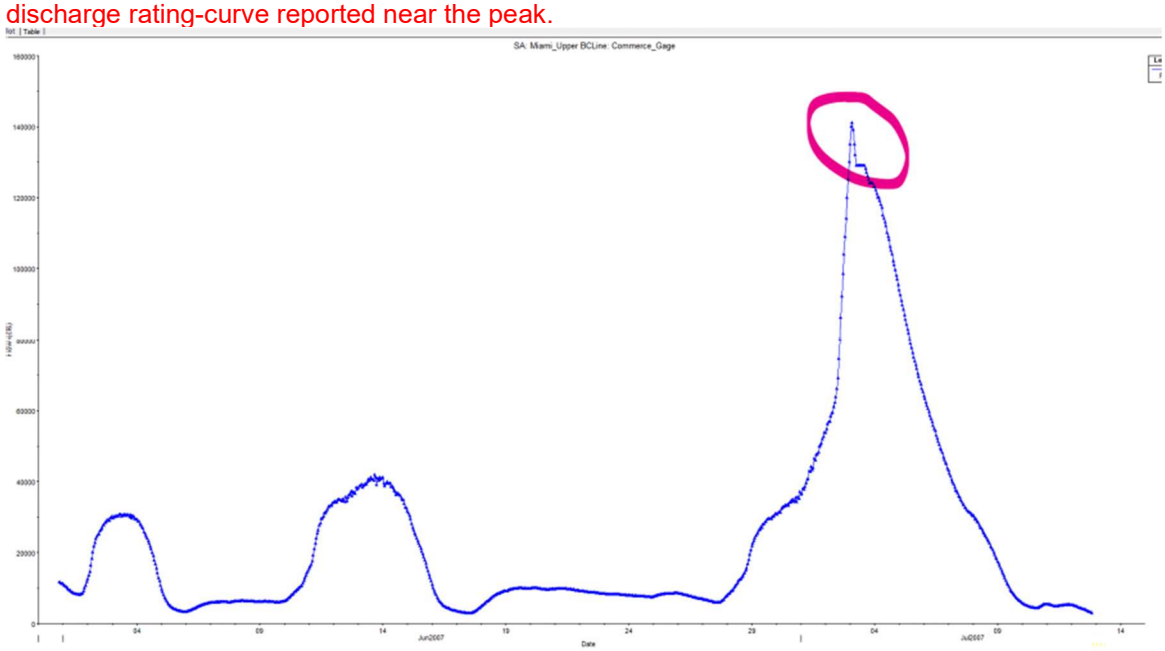
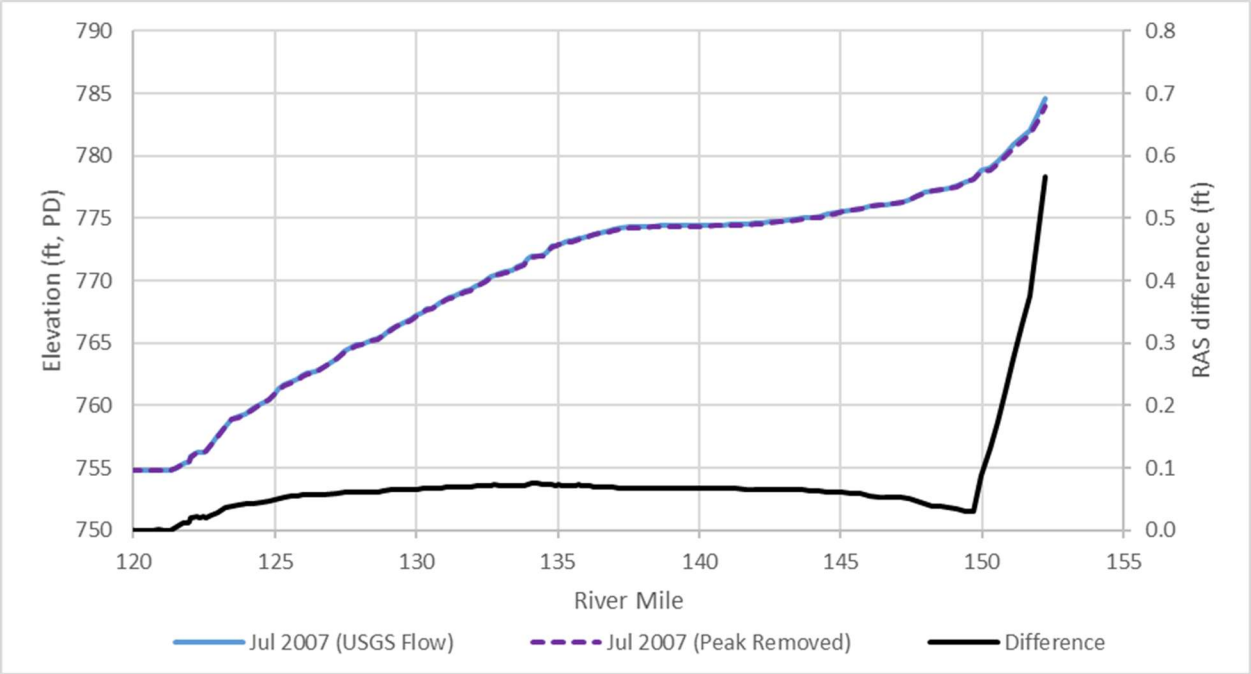


Figure F. The highlighted section represents a spike in the hydrograph that is not representative of the actual flows.

Mead & Hunt Response to Comment No. 9

Mead & Hunt simulated the July 2007 event with the spike at the peak of the hydrograph removed. The results from the simulation with the peak removed were compared to results from the simulation using the publicly available USGS flow hydrograph. See the figure below. The difference in water surface elevation is less than 0.6 feet at the very upstream end of the model, and quickly drops to less than 0.1 feet. Given the choice between (1) using USGS flow data directly and (2) manipulating the flow data using the second rating curve, it is best to use the USGS data directly.


790
785
780
775
770
765
760
755
750
Elevation (ft, PD)
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
RAS difference (ft)
120
125
130
135
140
145
150
155
River Mile
Jul 2007 (USGS Flow)
Jul 2007 (Peak Removed)
Difference

Comment No. 10, Section 3.3, page 21

City of Miami Comment

HEC-RAS has the ability to simulate vertically varied Manning's n-values for 1-D areas but not for 2-D areas. In general, the Manning's n-values increase at higher flows due to the increased roughness of the tree canopy. The application of the roughness factors only to 1-D areas does not make physical sense. There could be a difference in Manning's n value by a factor of 0.6 or 1.3 on either side of the 1D/2D boundary. For example, the Manning's n roughness value in the 2-D area is 0.037, while the n-value in the 1-D area varies from 0.022 to 0.047. Also, it does not make physical sense to increase the Manning's n values in the lake. Since the lake is deep, the model is likely to be relatively insensitive to the Manning's n (within a reasonable range of n-values). Tetra Tech recommends performing a sensitivity analysis of the effects of changing Manning n-values in the lake as well as along the Neosho, Spring and Elk Rivers.

For the Neosho River, the roughness factor in the Mead & Hunt model decreases from 1.3 at 150,000 cfs to 1.0 at flows greater than 160,000 cfs. This does not make physical sense as there is no obvious reason why the roughness would decrease at greater discharges. If Mead & Hunt continue using this method, Tetra Tech recommends keeping the roughness factor the same at the larger flow events.

Mead & Hunt Response to Comment No. 10

USACE recommends the use of flow roughness factors in model calibration (HEC-RAS User's Manual, page 8-65). By using flow roughness factors, Mead & Hunt is following USACE guidance.

Tetra Tech raises a concern with the discontinuity in n-values at the 1D/2D boundary. Tetra Tech notes that the Mead & Hunt model has a difference in n-value at the 1D/2D boundary of 0.037 (2D) and a range from 0.022 to 0.047 (1D). In the same area, Tetra Tech's 2016 analysis used n-values of 0.037, then 0.083, then 0.035, then 0.043, with abrupt transitions between these values (Tetra Tech, 2016). Mead & Hunt's approach results in less abrupt changes in n-values.

Regarding increasing n-values in the lake, there were no flow roughness factors applied to Grand Lake. Flow roughness factors were not applied below River Mile 121.51.

Regarding the suggestion of a sensitivity analysis, Mead & Hunt tested the sensitivity to Manning's n-values early in our modeling and found that the Neosho River, the Spring River, and the Elk River were relatively sensitive to changes in n-values. Grand Lake was relatively insensitive to n-values.

Regarding the flow roughness factor of 1.0 for flows higher than those used in calibration, there is no available, comprehensive set of observed data collected at higher flows to justify the application of flow roughness factors at higher flows.

Comment No. 11, Section 3.4, page 21

City of Miami Comment

Based on the Mead & Hunt model output for the October 2009 flood, the average of the absolute differences between the predicted maximum water-surface elevations and measured high-water marks is 0.57 feet.

For the 2007 flood, the average of the absolute differences between the predicted maximum water-surface elevations and measured high-water marks is 1.19 feet. As shown in Figure 13, the greatest calibration differences occur at the Miami Gage, which is a key area of interest to the City of Miami.

In general, the Mead & Hunt model is underpredicting the measured water-surface elevations for the larger flood events. Because much of the flood plain upstream of Grand Lake is relatively flat, small underpredictions of water surface elevation translate into much greater underpredictions in the lateral extent of flooding in many areas. Therefore, Tetra Tech supports calibrating the individual high-water marks to an absolute difference of less than 0.5 feet, and not the average of all the differences to less than 0.5 feet, which can under-represent the differences.

Mead & Hunt Response to Comment No. 11

Mead & Hunt followed USACE guidance in the HEC-RAS User's Manual when calibrating (USACE, February 2016).

1. USACE states that a ± 5% flow measurement, which may be "*optimistic*", "*translates into a stage error of ±1.0 feet*" (page 8-54). It is inadvisable to further modify the model to force the water surface elevation profiles to match each high-water mark within 0.5 feet.
2. USACE states that "*high water marks in the overbank area are often higher than in the channel*" (page 8-55). Because many of the high-water marks were collected in the overbank area, a slight model underprediction is expected when compared to measured water surface elevations.
3. USACE recommends the user to "*not force a calibration to fit with unrealistic Manning's n-values*" (page 8-65). Rather than force the water surface elevation to match each high-water mark within 0.5 feet by aggressively modifying n-values, Mead & Hunt followed USACE guidance and accomplished the goal of a water surface elevation profile that passes through or near the high-water marks.

Mead & Hunt's report has been updated with a comparison of measured water surface elevations for the July 2007 event.

Comment No. 12, Section 3.4, page 21

City of Miami Comment

Tetra Tech's review of the predicted flow hydrograph neat the mouth of the Elk River indicated probable model instability for the 2007 flood (Figure G). Tetra Tech recommends reviewing the model output and adjusting the model to prevent model instability.

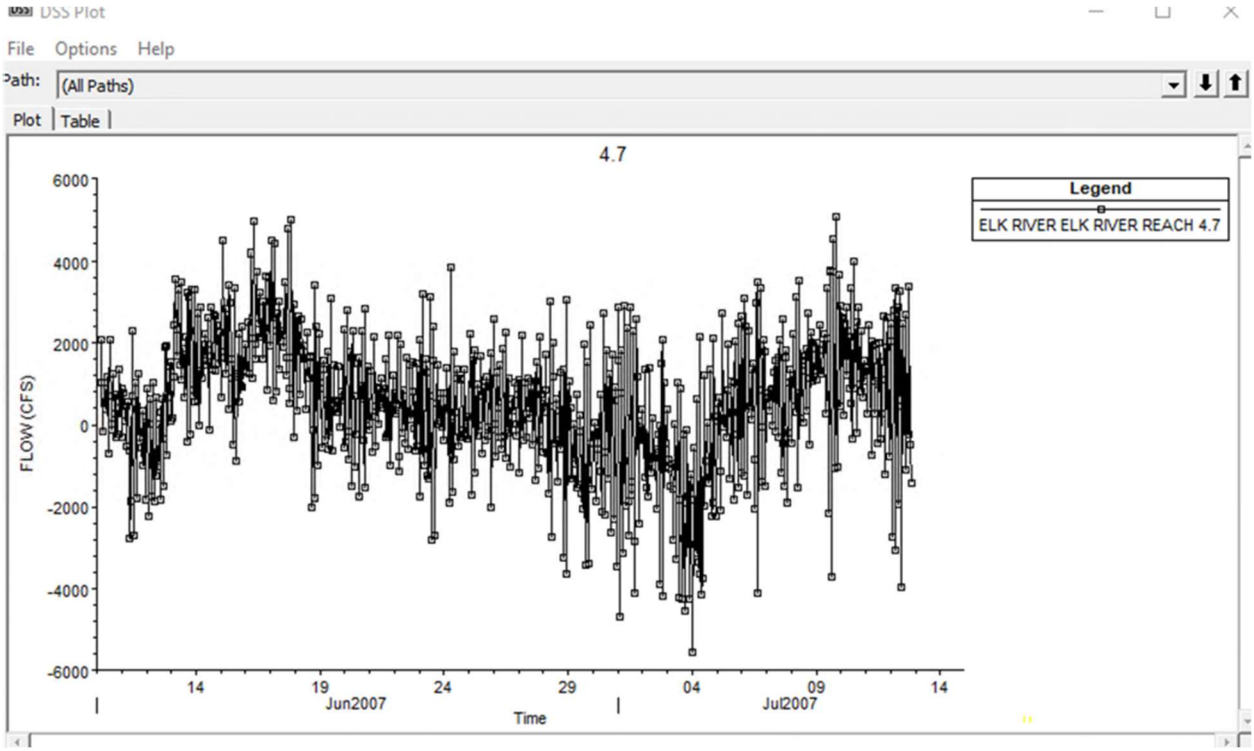


Figure G. Screen capture from HEC-RAS showing the predicted flow for the 2007 flood at cross- section 4.7 on the Elk River. The variability in the predicted flow indicates numerical instability in the model.

Mead & Hunt Response to Comment No. 12

The fluctuating flow, which is different than model instability, is due to the use of recorded historical stage hydrograph as the downstream boundary. The recorded stage hydrograph includes fluctuations which create fluctuating flow toward the downstream end of the model. Synthetic or smoothed stage boundary conditions, which are used for the operational scenario simulations, result in less flow fluctuation.

Comment No. 13, Section 3.4, page 22

City of Miami Comment

Figure 13 does not show the calibration of the 2007 flood at Commerce gage. Tetra Tech recommends obtaining the hourly stage data from the USGS and calibrating the Mead & Hunt Model to the Commerce gage.

Mead & Hunt Response to Comment No. 13

Peak stage at the Commerce gage for the July 2007 event is discussed in Mead & Hunt's Initial Study Report.

Comment No. 14, Section 3.4, page 23

City of Miami Comment

Figure 16 shows a significant drop in water-surface elevation near RM 123. Mead & Hunt should explain the reason for the drop, and why it does not call into question Mead & Hunt's modeling results.

Mead & Hunt Response to Comment No. 14

The decrease in water surface elevation occurs at the downstream face of the Burlington Northern Railroad Bridge and is a function of bridge hydraulics.

Comment No. 15, Section 4, page 26

City of Miami Comment

Tetra Tech recommends a comparison between the peak flows reported by the RiverWare and gage records to ensure the data sets match by a reasonable amount. Tetra Tech recommends a flood-frequency and/or partial duration flood-frequency analysis for all the gages contributing to Grand Lake, including the Neosho, Spring, and Elk Rivers and Tar Creek.

Mead & Hunt Response to Comment No. 15

By using RiverWare for the flood frequency analysis, Mead & Hunt is following the City's recommendation.

Comment No. 16, Section 4, page 26

City of Miami Comment

Tetra Tech understands that the Real Estate Adequacy Study (U.S. Army Corps of Engineers, 1998) may have significant problems in terms of both the methods and results. The report was admitted into evidence in the 1998 state civil trial, Dalrymple et al v. Grand River Dam Authority, CJ 94-444, regarding the question of "'to what extent' Pensacola Dam causes backwater effects in the subject reach." Dr. Forrest Holly, the Referee agreed to by all parties, placed little weight in the study, making no reference to it in coming to his conclusions (Referee Report, February 15, 1999). Further, Holly (2001) concluded that there was substantially more backwater effect in the Miami reach than the Corps concluded in its September 1998 Real Estate Adequacy Study. Tetra Tech recommends independently verifying any methods or results presented in the study.

Mead & Hunt Response to Comment No. 16

Mead & Hunt's objective is not to verify previous studies, including the 1998 REAS. The flood frequency curve from the 1998 REAS is only presented in the report for comparative purposes. Mead & Hunt's methodology for the flood frequency analysis follows best practices (USGS Bulletin 17C, USACE EM 1110-2-1415).

Comment No. 17, Section 5, page 28

City of Miami Comment

In addition to the peak flow, the hydrograph volume has an important impact on the lake elevation and outflow operations during flood events. The Mead & Hunt (2021) report does not provide any analysis of the inflow flood volume.

During flood events, the USACE attempts to limit the outflow to 100,000 cfs to prevent downstream flooding. During large floods, such as the 2019 flood, the lake reached its highest level in history at 755.1 feet Pensacola Datum and the outflow peaked at approximately 180,000 cfs.

A large inflow volume can result in a significant increase in Grand Lake's water-surface elevation and an associated increase in flooding along the Neosho, Spring, and Elk Rivers.

The application of the scaling number to determine the 100-year inflow to Grand Lake is not appropriate, as it may result in unrealistic peak flows and flow volumes. For example, FEMA developed the 100-year peak flow hydrograph for the Neosho River by performing a flood-frequency analysis (using the HEC-SSP software) to estimate the peak flow, then performing hydrologic (rainfall/runoff) modeling (using the HEC-HMS software) to estimate the flood volume. The resulting hydrograph had a peak flow of about 165,000 cfs and volume of about 1,424,000 ac-ft (Figure H). In comparison, multiplying the 2007 flood hydrograph by scaling factor of 2.15 produces a peak flow of about 319,000 cfs and volume of 2,884,300 cfs; both the peak flow and volume are far in excess of FEMA's 100-year peak flow and volume, and physically unrealistic for the 100-year event (Figure H).

The flood-frequency curve for the Neosho River at Commerce Gage is shown in Figure I. The 100-year peak flow is approximately 165,000 cfs. The 100-year peak flow applied by Mead & Hunt plots well outside the 95th percentile confidence limit.

Tetra Tech recommends that Mead & Hunt perform a basin-wide hydrologic analysis to develop flood hydrographs at each of the inflow locations that have physically based rationale for predicting the peak flow and volume.

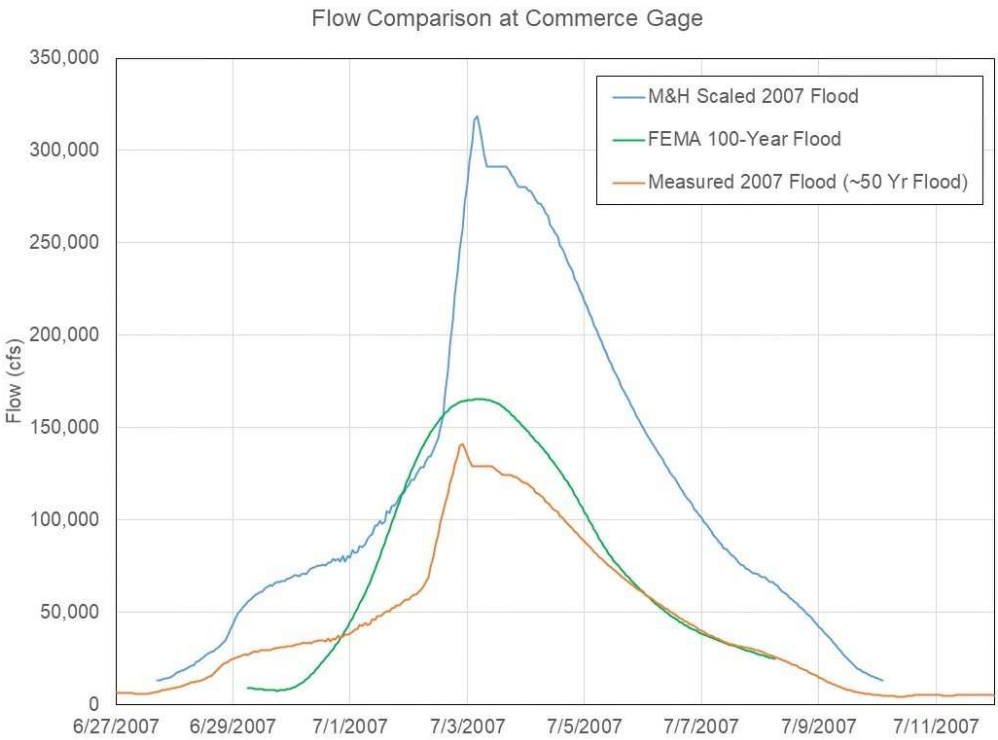


Figure H. Comparison of the measured 2007 flood at Commerce Gage, FEMA 100-year flood hydrograph, and scaled 2007 flood in the Mead & Hunt model used to represent the 100-year inflow to Grand Lake.

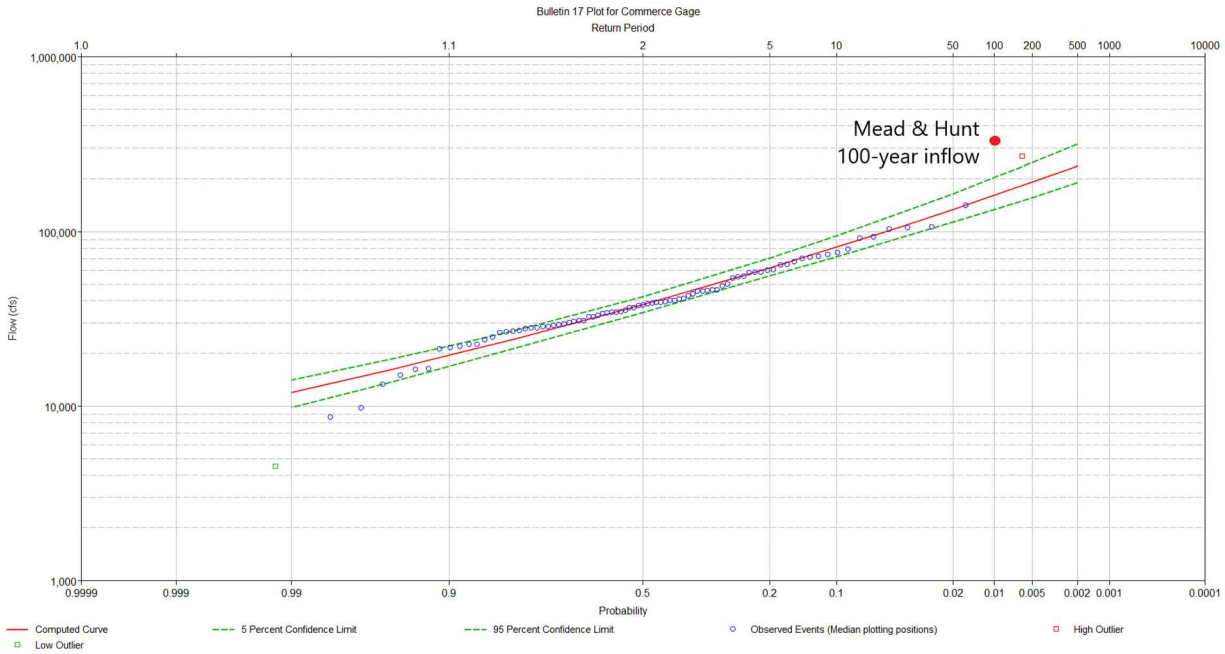


Figure I. Flood-frequency curve for the Neosho River at Commerce gage. Note that the scaled 100-year peak flow predicted by the Mead & Hunt model falls well outside the confidence limits of the flood-frequency curve.

Mead & Hunt Response to Comment No. 17

A basin-wide hydrologic analysis was not recommended in the Revised Study Plan, nor required in FERC's Study Plan Determination.

The FEMA flood-frequency analysis referenced by Tetra Tech was performed using a HEC-HMS model. A single sub-basin was used to represent the 5,927 square miles that drain to the Commerce gage and the model did not include John Redmond Reservoir. Model calibration was performed using the 2007 event and model validation was performed using a flood frequency curve computed using statistical methods in USGS's PeakFQ software. FEMA's approach includes the following deficiencies:

1. Not including John Redmond Reservoir (thus treating a regulated system like an unregulated system) and then calibrating to historic data from the regulated system will result in inaccurate model parameters, which will decrease the predictive capability of the model.
2. Statistical methods should not be used to estimate flood frequency for regulated basins. Using statistical methods within PeakFQ to validate the HEC-HMS model does not follow best practices (USGS Bulletin 17C).

Regarding the inflow volume, Mead & Hunt used a statistical analysis of historic inflow volume to better estimate the hydrograph volume.

Comment No. 18, Section 6, page 29

City of Miami Comment

This method is for determining the Guide Take Line for real estate takings. It should not be used to define the "material difference" for calibration purposes.

Adjusting the flows by ±2% and comparing the difference in water-surface elevations is essentially a sensitivity analysis. The results are valid only for the selected site and for the modeled flood event. This method should not be evaluated for determining the "material difference".

Mead & Hunt Response to Comment No. 18

Mead & Hunt reviewed how various government entities quantify difference in water surface elevation. We understand that the scenarios for which these quantifications are applied are not exactly like the scenario at hand. However, they are still instructive for the purpose of defining material difference.

Comment No. 19, Section 6, page 29

City of Miami Comment

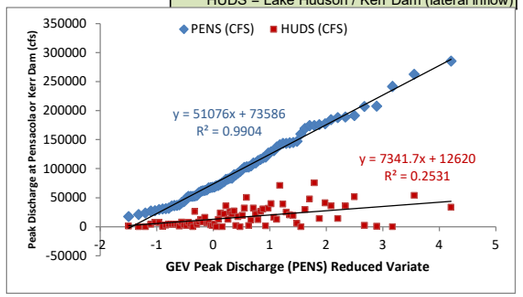
In addition to the "out of bank events", the "material difference" criterion of 0.5 feet should be applied to the calibration for the within bank flows.

Mead & Hunt Response to Comment No. 19

Mead & Hunt is considering 0.5 feet of difference in water surface elevation within banks where it is required to meet the objectives of the study. Specifically, we are considering 0.5 feet of water surface elevation difference within the banks where the inundation impacts infrastructure or other sensitive resources.

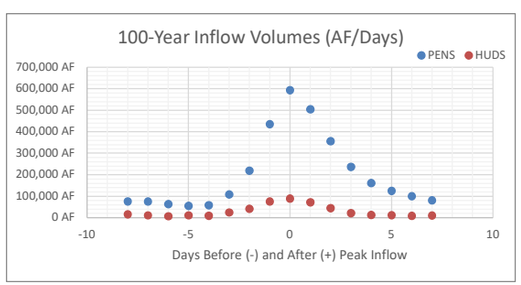
APPENDIX B:
HISTORICAL INFLOW VOLUME STATISTICAL ANALYSIS

PENS = Pensacola Dam / Grand Lake (total inflow)
HUDS = Lake Hudson / Kerr Dam (lateral inflow)

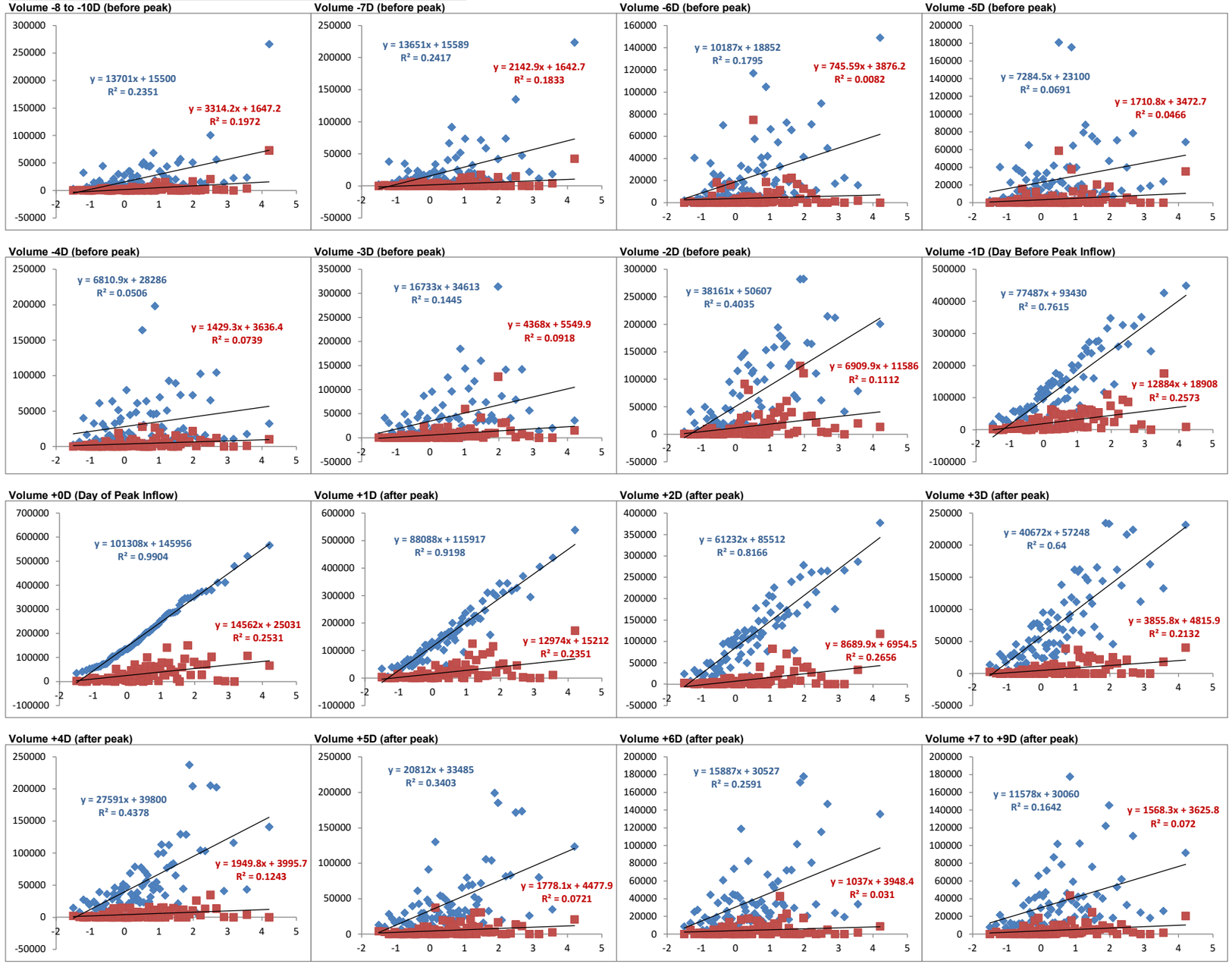


reduced variate for 100-year event, y = 4.41

	scale, σ (m)	location, μ (b)	100-year
PENS (CFS)	51076	73586	299,000 cfs
HUDS (CFS)	7342	12620	45,021 cfs
PENS D–8 to –10 (AF)	13701	15500	75,966 AF
PENS D–7 (AF)	13651	15589	75,835 AF
PENS D–6 (AF)	10187	18852	63,810 AF
PENS D–5 (AF)	7285	23100	55,249 AF
PENS D–4 (AF)	6811	28286	58,344 AF
PENS D–3 (AF)	16733	34613	108,461 AF
PENS D–2 (AF)	38161	50607	219,023 AF
PENS D–1 (AF)	77487	93430	435,403 AF
PENS D+0 (AF)	101308	145956	593,058 AF
PENS D+1 (AF)	88088	115917	504,675 AF
PENS D+2 (AF)	61232	85512	355,747 AF
PENS D+3 (AF)	40672	57248	236,745 AF
PENS D+4 (AF)	27591	39800	161,567 AF
PENS D+5 (AF)	20812	33485	125,334 AF
PENS D+6 (AF)	15887	30527	100,641 AF
PENS D+7 to +9 (AF)	11578	30060	81,157 AF
HUDS D–8 to –10 (AF)	3314	1647	16,274 AF
HUDS D–7 (AF)	2143	1643	11,100 AF
HUDS D–6 (AF)	746	3876	7,167 AF
HUDS D–5 (AF)	1711	3473	11,023 AF
HUDS D–4 (AF)	1429	3636	9,944 AF
HUDS D–3 (AF)	4368	5550	24,827 AF
HUDS D–2 (AF)	6910	11586	42,081 AF
HUDS D–1 (AF)	12884	18908	75,769 AF
HUDS D+0 (AF)	14562	25031	89,297 AF
HUDS D+1 (AF)	12974	15212	72,470 AF
HUDS D+2 (AF)	8690	6955	45,306 AF
HUDS D+3 (AF)	3856	4816	21,833 AF
HUDS D+4 (AF)	1950	3996	12,601 AF
HUDS D+5 (AF)	1778	4478	12,325 AF
HUDS D+6 (AF)	1037	3948	8,525 AF
HUDS D+7 to +9 (AF)	1568	3626	10,547 AF



Average Daily Volume (AF) vs GEV Peak Discharge (PENS) Reduced Variate Correlation Plots



APPENDIX C:
HYDROGRAPHS

APPENDIX C.1:
INFLOW HYDROGRAPHS

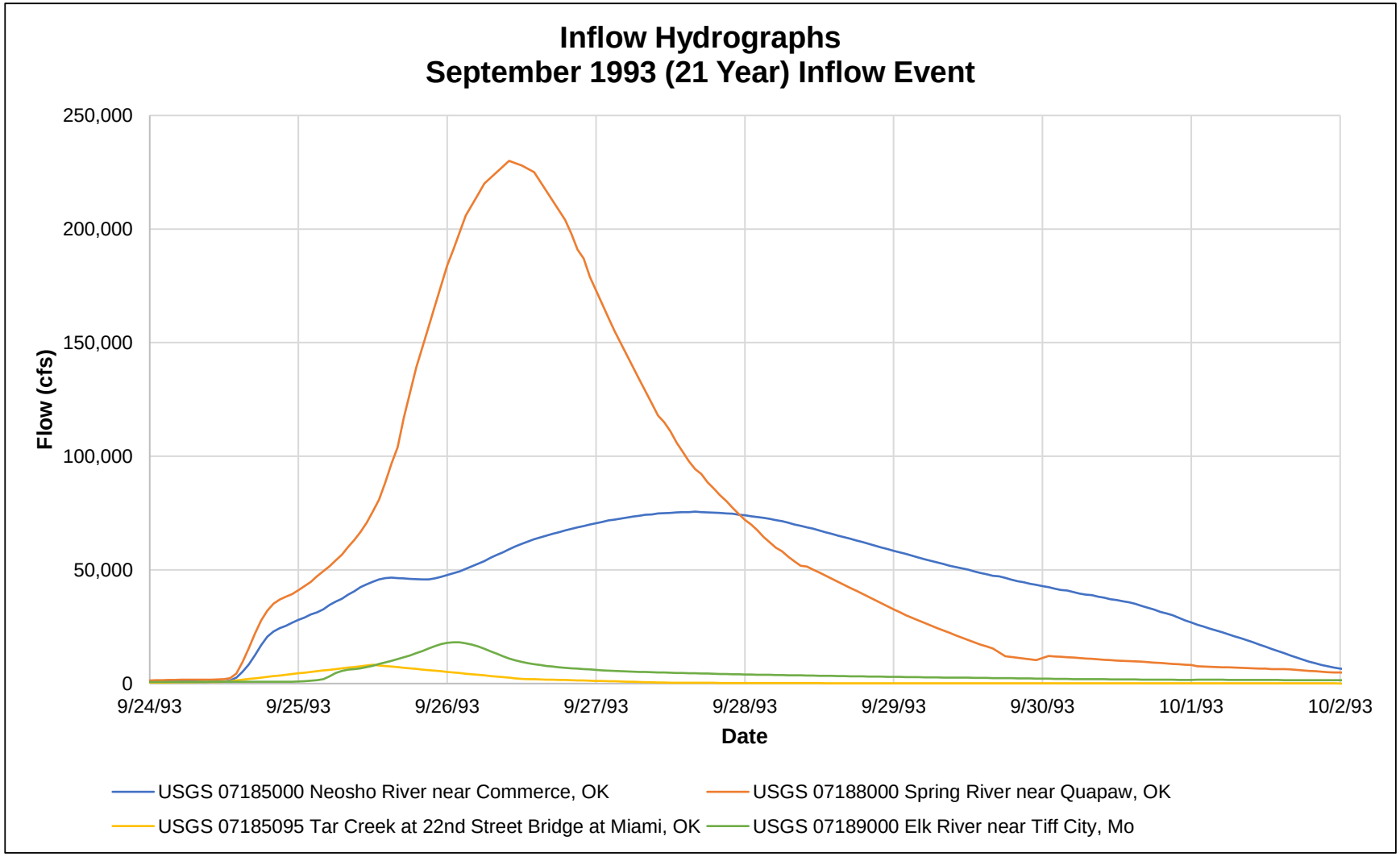


Figure C.1. Inflow hydrographs for the September 1993 (21 year) inflow event upstream of Pensacola Dam.

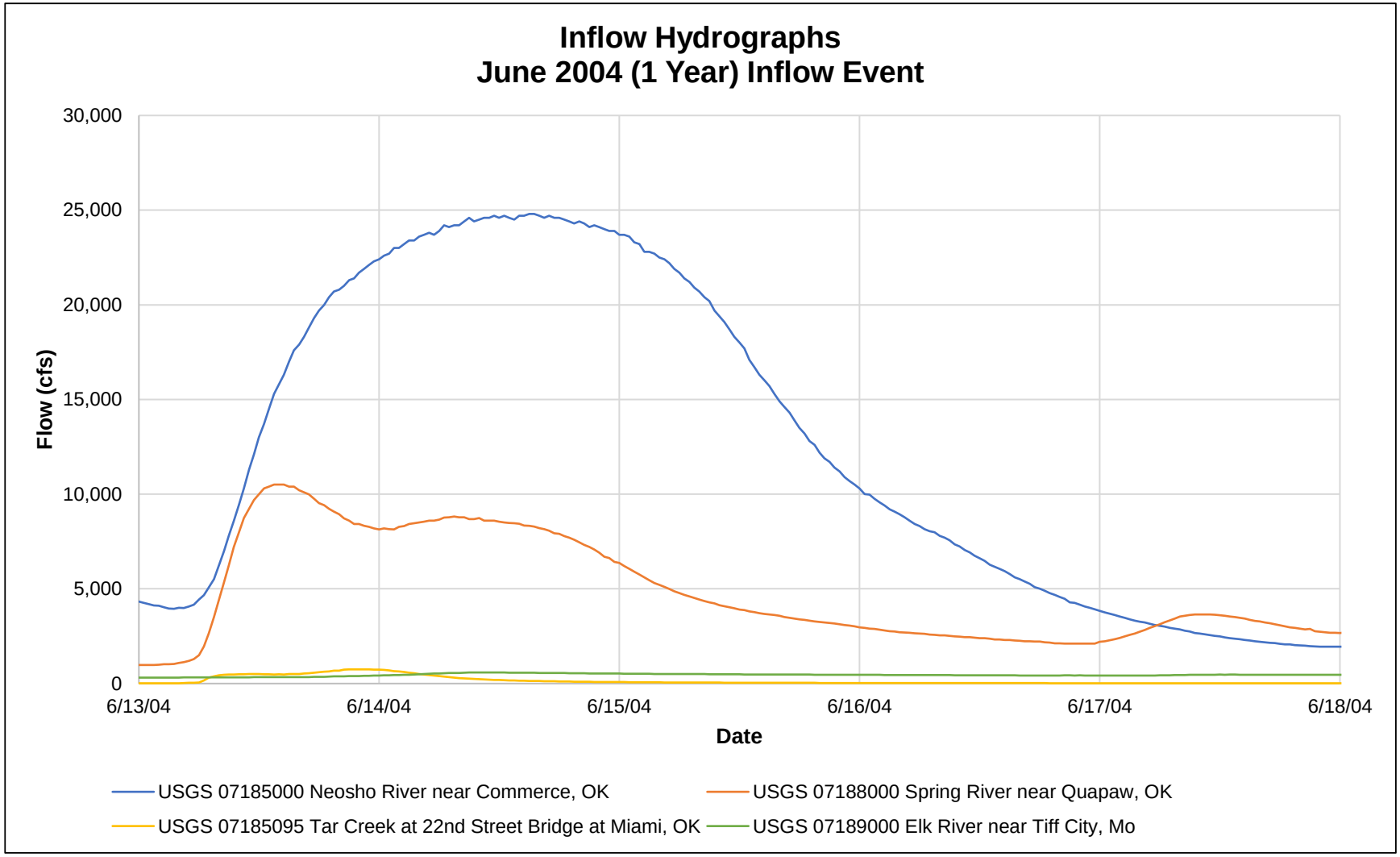


Figure C.2. Inflow hydrographs for the June 2004 (1 year) inflow event upstream of Pensacola Dam.

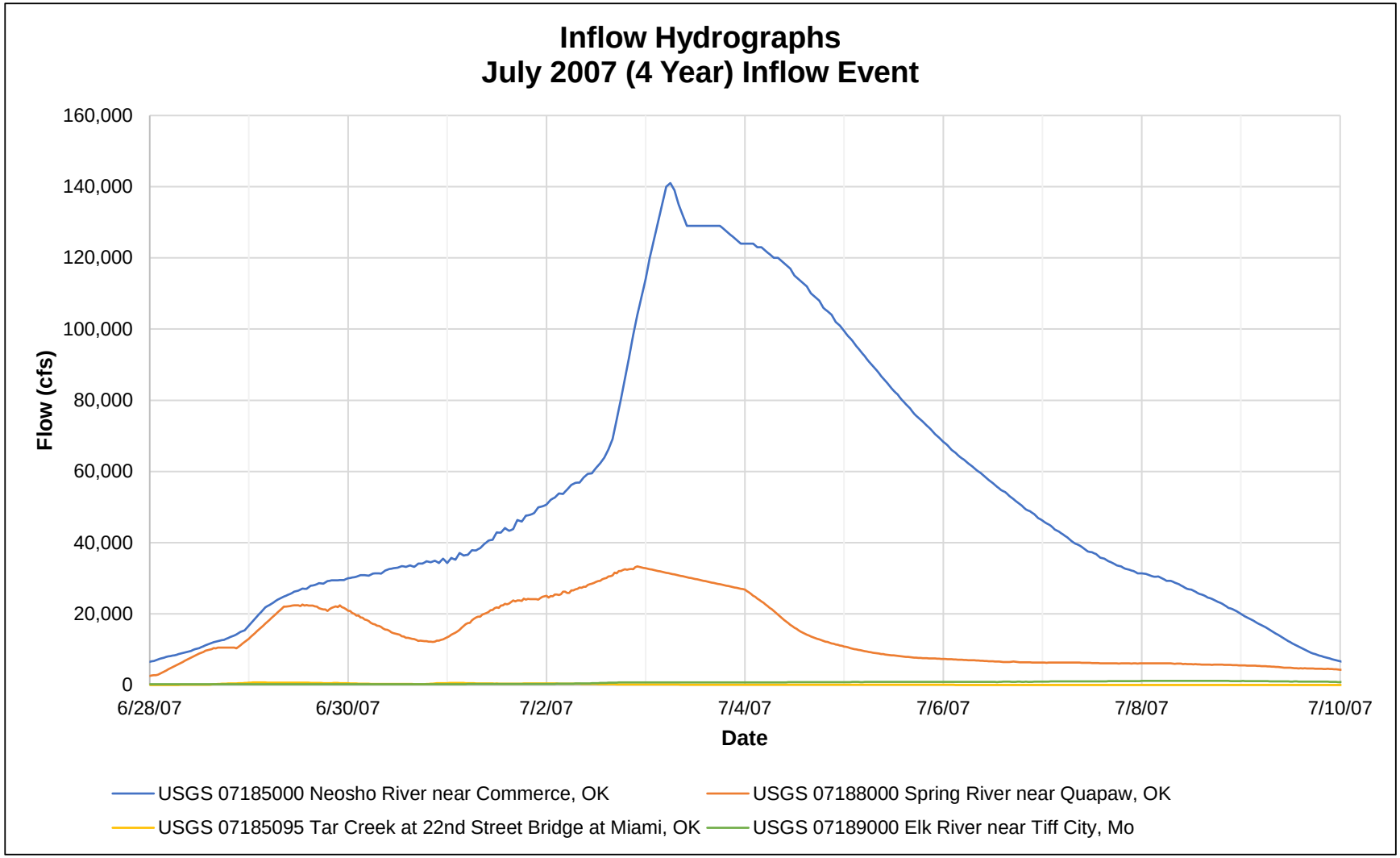


Figure C.3. Inflow hydrographs for the July 2007 (4 year) inflow event upstream of Pensacola Dam.

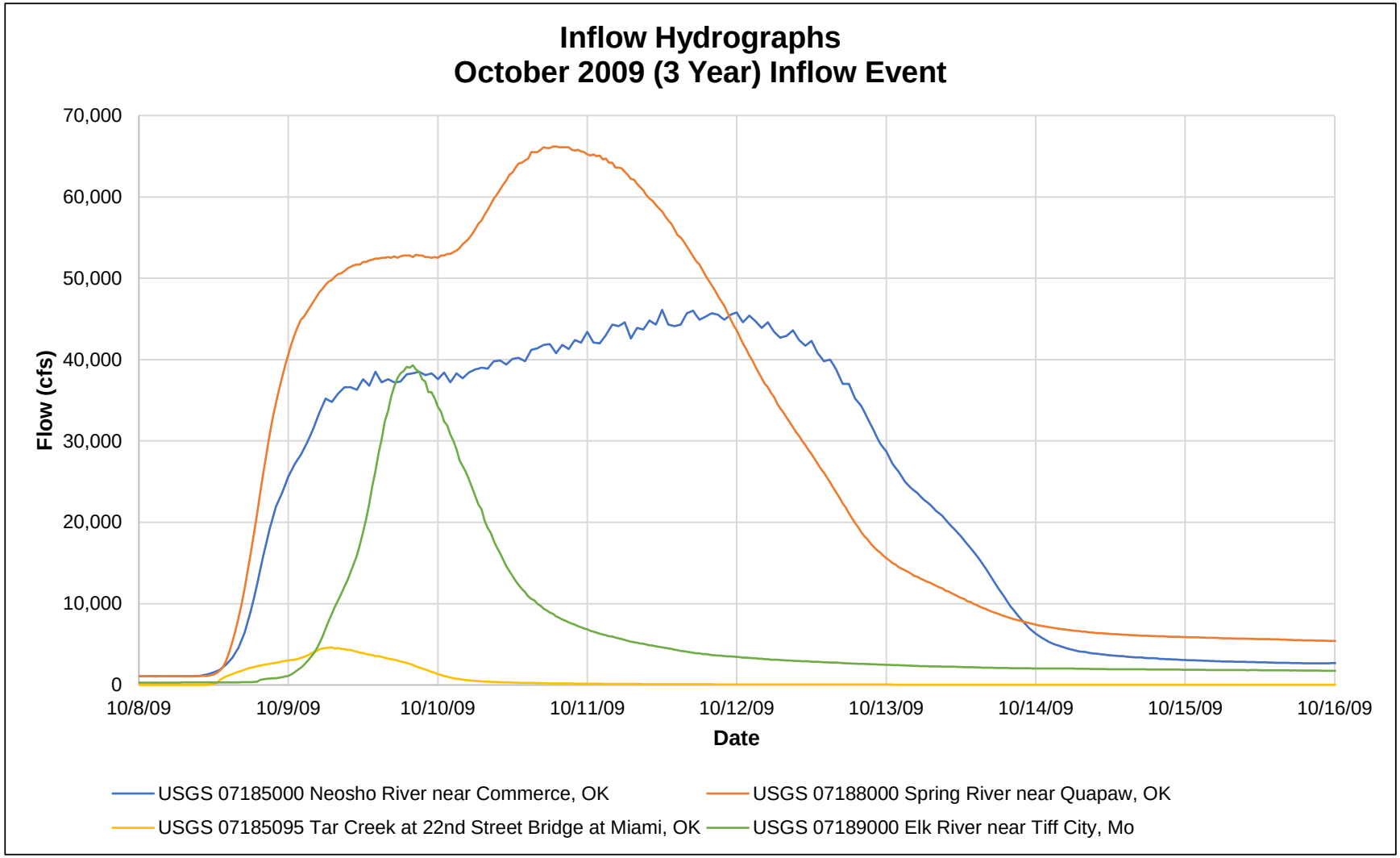


Figure C.4. Inflow hydrographs for the October 2009 (3 year) inflow event upstream of Pensacola Dam.

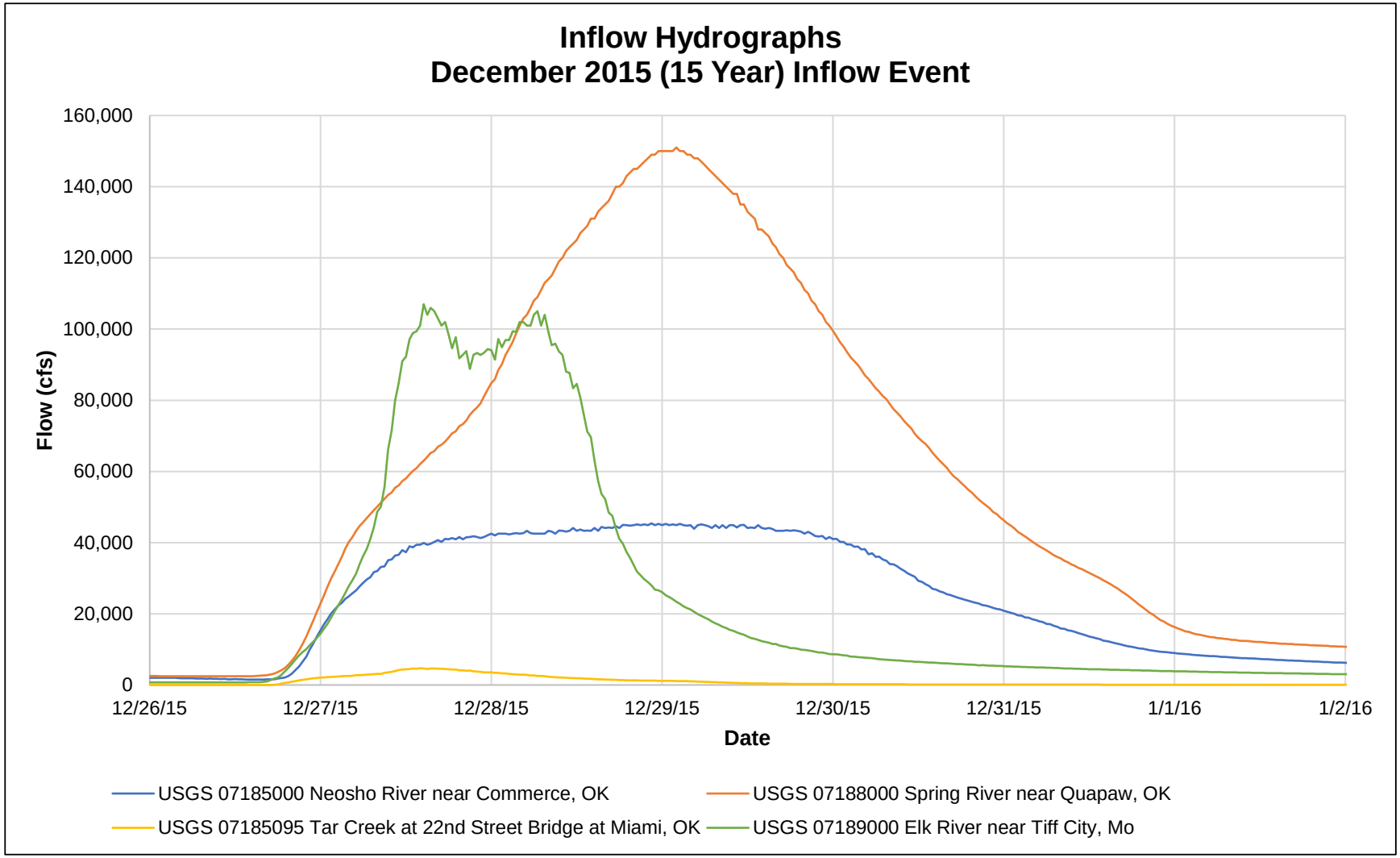


Figure C.5. Inflow hydrographs for the December 2015 (15 year) inflow event upstream of Pensacola Dam.

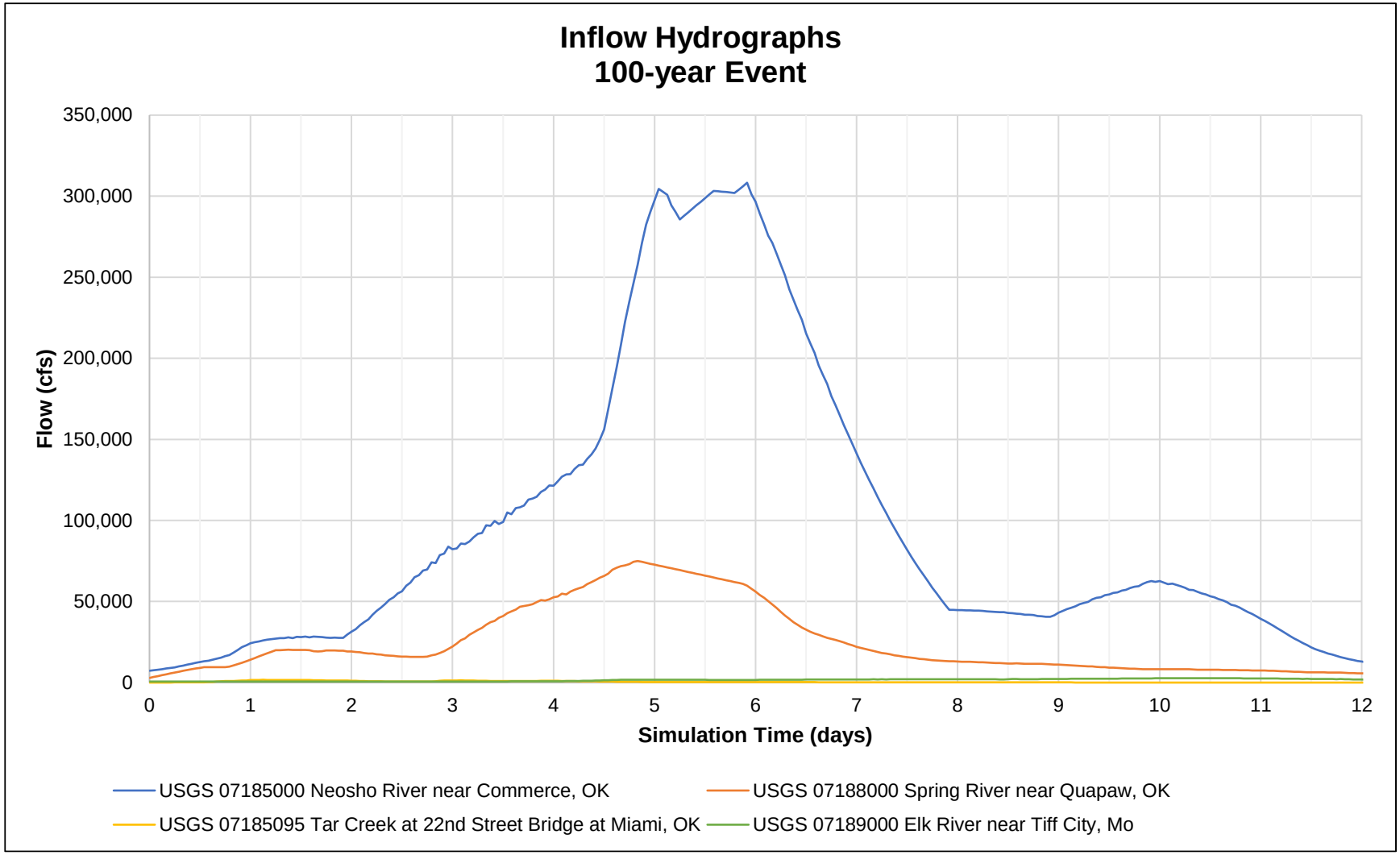


Figure C.6. Inflow hydrographs for the 100-year event upstream of Pensacola Dam.

Note: Because the 100-year event is synthetic, there is no historical start or end date, so stage hydrographs for the 100-year event are presented as a function of simulation time rather than date.

APPENDIX C.2:
STAGE HYDROGRAPHS

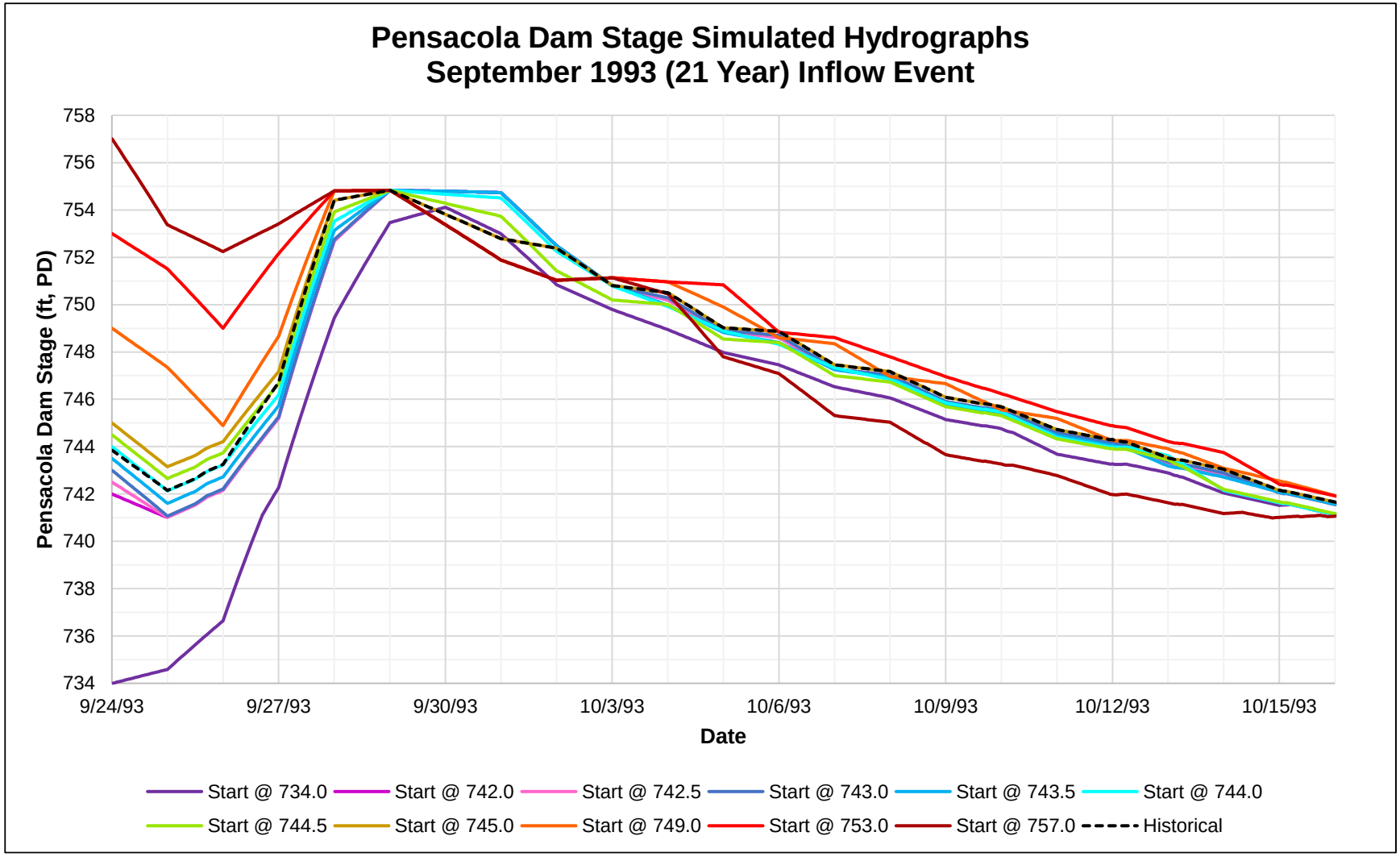


Figure C.7. Simulated stage hydrographs for the September 1993 (21 year) inflow event upstream of Pensacola Dam.

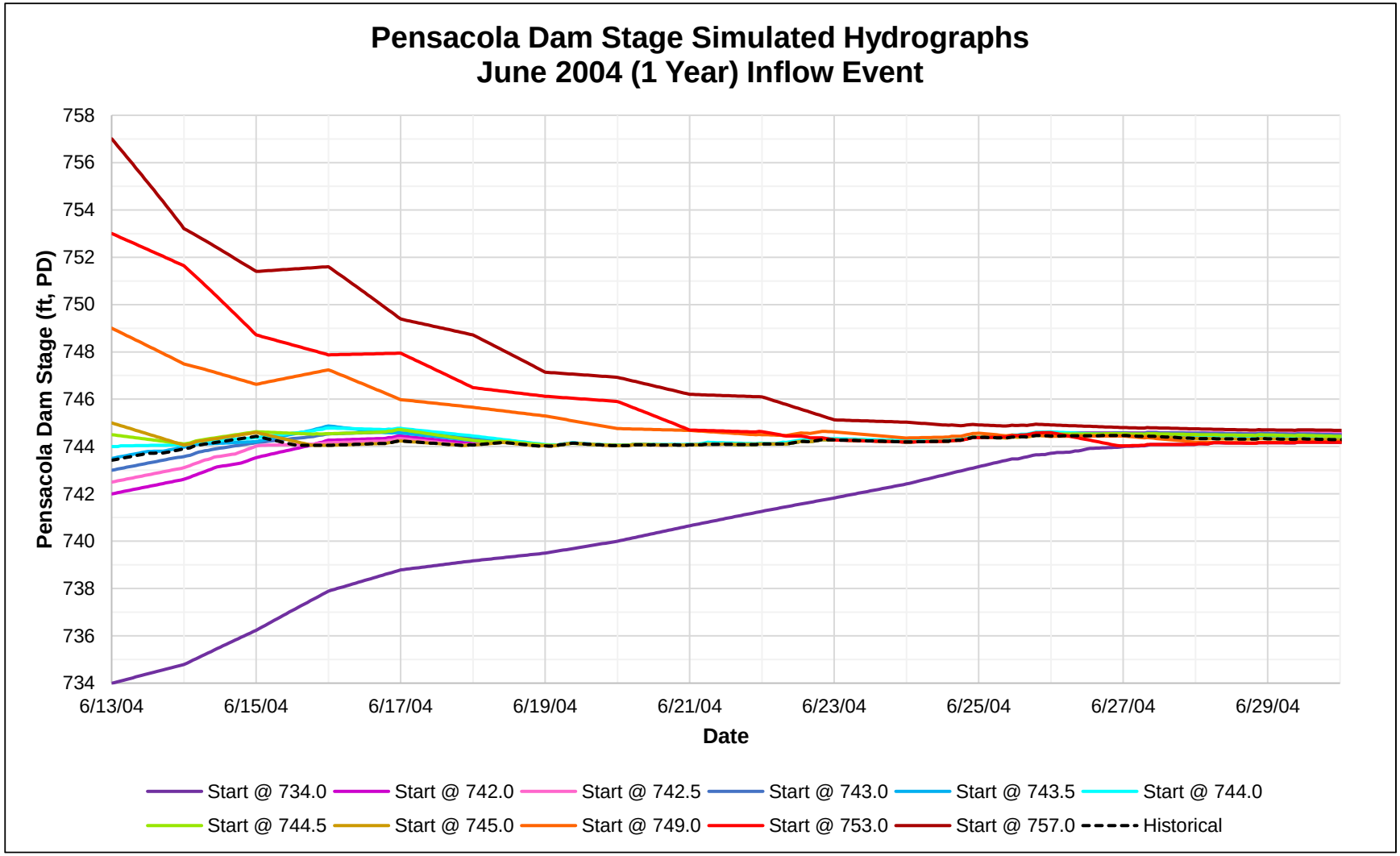


Figure C.8. Simulated stage hydrographs for the June 2004 (1 year) inflow event upstream of Pensacola Dam.

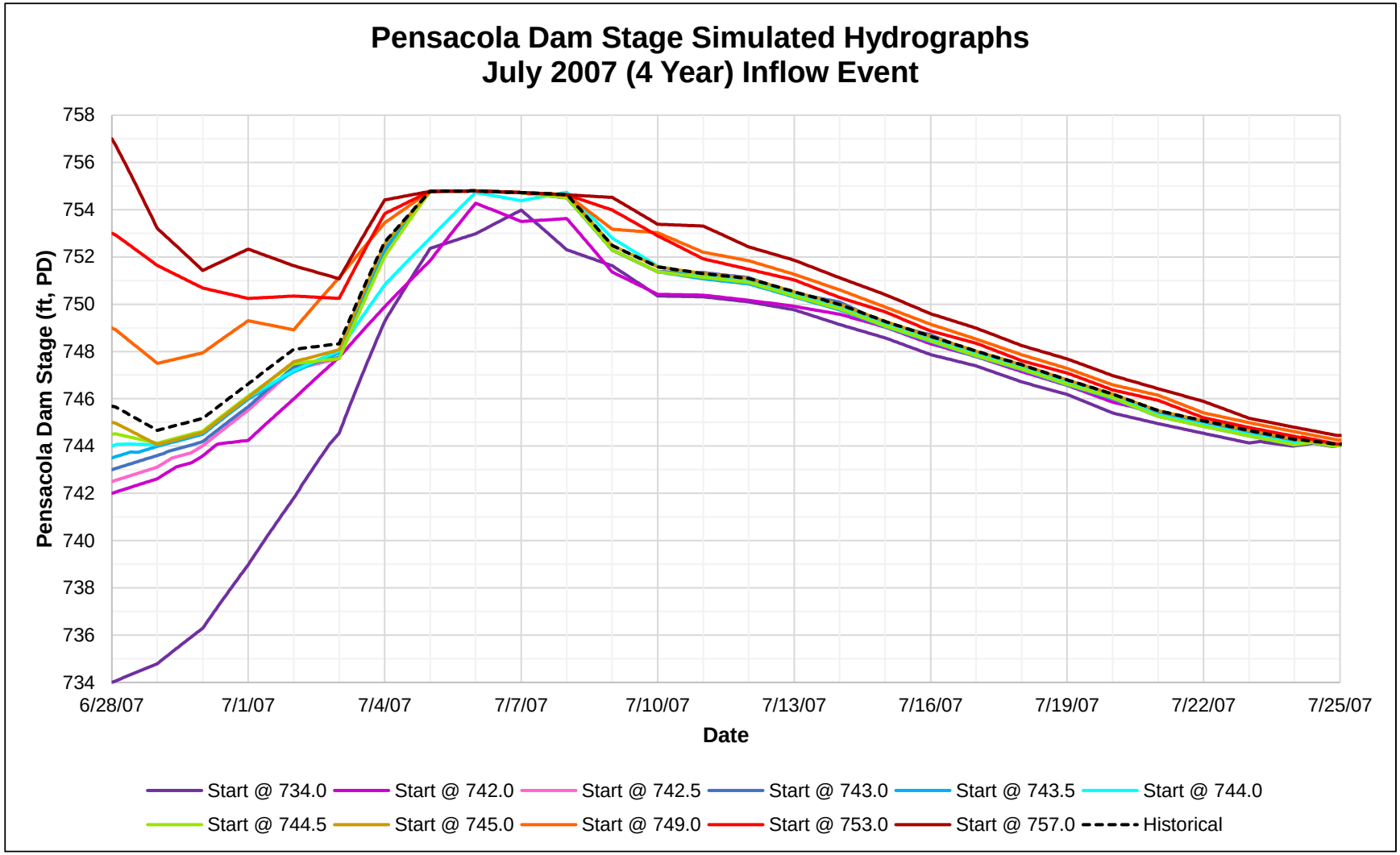


Figure C.9. Simulated stage hydrographs for the July 2007 (4 year) inflow event upstream of Pensacola Dam.

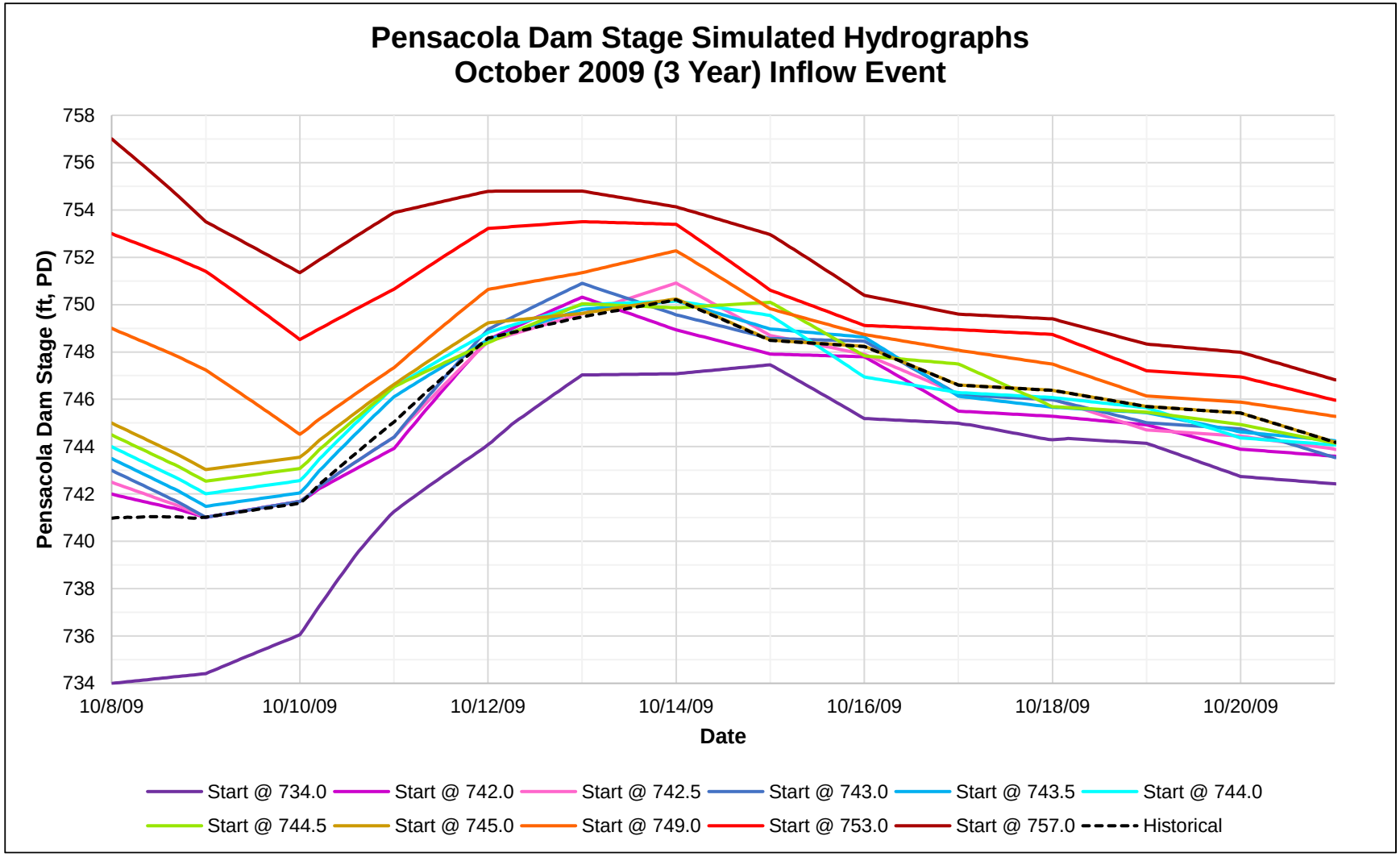


Figure C.10. Simulated stage hydrographs for the October 2009 (3 year) inflow event upstream of Pensacola Dam.

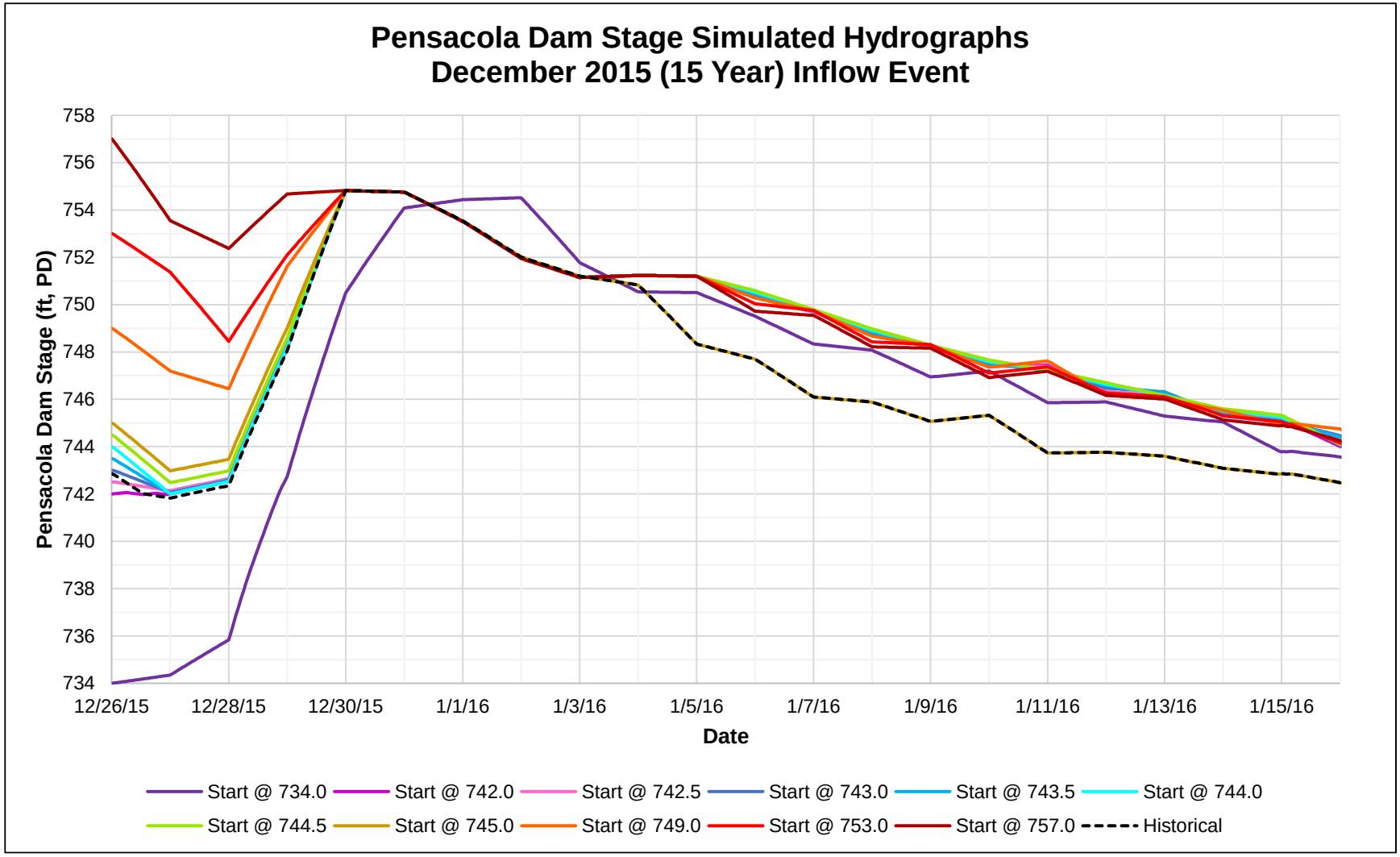


Figure C.11. Simulated stage hydrographs for the December 2015 (15 year) inflow event upstream of Pensacola Dam.

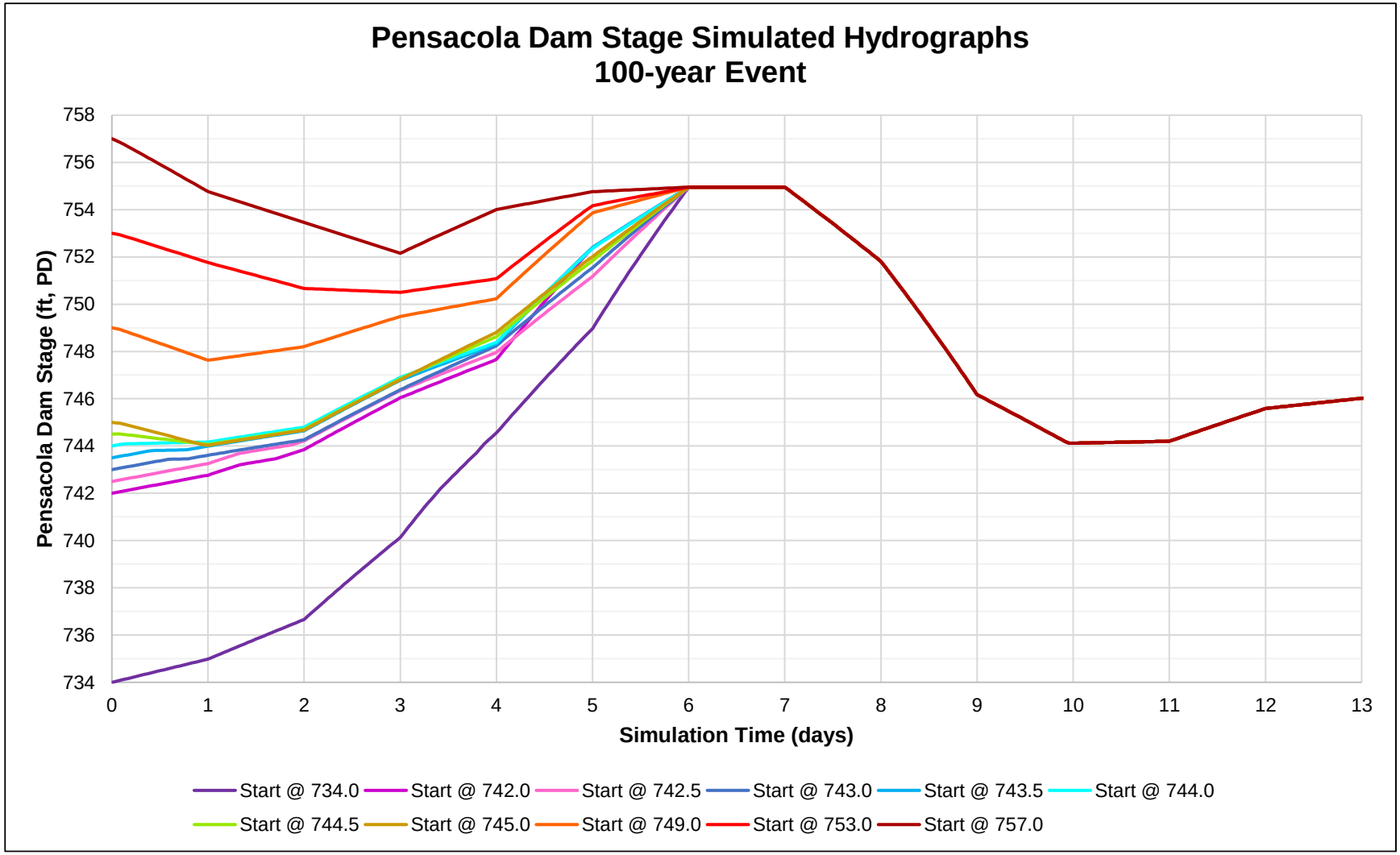


Figure C.12. Simulated stage hydrographs for the 100-year event upstream of Pensacola Dam.

Note: Because the 100-year event is synthetic, there is no historical start or end date, so stage hydrographs for the 100-year event are presented as a function of simulation time rather than date.

APPENDIX D:
MAXIMUM WATER SURFACE ELEVATIONS

APPENDIX D.1:
SEPTEMBER 1993 (21 YEAR) INFLOW EVENT
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - SEP 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
152.175	Upstream end of model													
152.175	752.29	780.71	780.71	780.71	780.71	780.71	780.71	780.71	780.71	780.71	780.71	780.71	0.00	0.00
151.000	748.53	777.94	777.94	777.94	777.94	777.94	777.94	777.94	777.94	777.94	777.94	777.95	0.00	0.00
150.000	748.47	776.66	776.66	776.66	776.66	776.66	776.66	776.66	776.66	776.66	776.66	776.67	0.00	0.01
149.000	750.14	775.12	775.12	775.12	775.12	775.12	775.12	775.12	775.12	775.13	775.14	775.14	0.00	0.02
148.000	749.29	774.25	774.25	774.25	774.25	774.25	774.25	774.25	774.25	774.26	774.28	774.30	0.00	0.05
147.000	747.76	772.70	772.71	772.71	772.71	772.71	772.72	772.72	772.72	772.74	772.78	772.82	0.01	0.12
145.500	745.12	771.59	771.61	771.61	771.62	771.62	771.63	771.63	771.64	771.67	771.74	771.81	0.03	0.22
145.480	E 60 Road Bridge													
145.400	748.01	771.52	771.55	771.55	771.55	771.55	771.56	771.57	771.58	771.60	771.68	771.74	0.03	0.22
144.000	743.43	770.48	770.53	770.53	770.53	770.55	770.56	770.57	770.59	770.62	770.72	770.80	0.05	0.32
143.000	737.95	769.99	770.06	770.06	770.06	770.08	770.09	770.11	770.13	770.17	770.28	770.37	0.07	0.37
142.000	742.91	769.62	769.70	769.70	769.70	769.72	769.73	769.75	769.78	769.82	769.94	770.03	0.08	0.41
141.000	741.01	769.47	769.56	769.56	769.56	769.58	769.59	769.61	769.64	769.68	769.80	769.90	0.08	0.43
140.000	736.33	769.42	769.51	769.51	769.52	769.53	769.55	769.57	769.59	769.64	769.76	769.86	0.08	0.43
139.000	743.99	769.38	769.47	769.47	769.47	769.49	769.50	769.52	769.55	769.60	769.72	769.81	0.08	0.44
138.000	736.48	769.29	769.38	769.38	769.39	769.40	769.42	769.44	769.47	769.52	769.64	769.74	0.08	0.45
137.000	733.33	768.95	769.06	769.06	769.07	769.09	769.11	769.13	769.16	769.21	769.34	769.44	0.09	0.48
135.950	731.18	768.21	768.35	768.35	768.35	768.37	768.40	768.43	768.46	768.52	768.65	768.76	0.11	0.55
135.941	Highway 69 Bridge													
135.940	731.21	768.20	768.34	768.34	768.34	768.37	768.39	768.42	768.46	768.52	768.65	768.76	0.12	0.56
135.590	731.77	768.03	768.19	768.19	768.19	768.21	768.24	768.27	768.31	768.37	768.51	768.62	0.12	0.59
135.586	BN RR Bridge													
135.580	731.07	767.85	768.00	768.00	768.01	768.03	768.06	768.09	768.13	768.19	768.33	768.44	0.13	0.59
135.470	732.63	767.79	767.95	767.95	767.95	767.98	768.01	768.04	768.08	768.14	768.28	768.39	0.13	0.60
135.460	Highway 125 Bridge													
135.440	731.60	767.84	767.99	767.99	767.99	768.02	768.05	768.08	768.12	768.18	768.32	768.43	0.13	0.59
135.000	732.64	767.54	767.70	767.70	767.71	767.73	767.76	767.80	767.84	767.91	768.05	768.16	0.14	0.62

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - SEP 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
134.610	728.75	767.01	767.20	767.20	767.20	767.23	767.27	767.30	767.35	767.41	767.55	767.67	0.15	0.66
134.599	Abandonded RR Bridge													
134.595	728.58	766.71	766.91	766.91	766.91	766.94	766.97	767.01	767.05	767.12	767.25	767.35	0.14	0.64
134.000	727.23	766.31	766.53	766.53	766.53	766.56	766.60	766.64	766.69	766.76	766.90	767.01	0.16	0.70
133.973	Tar Creek													
133.900	727.72	766.08	766.31	766.31	766.32	766.35	766.39	766.43	766.48	766.55	766.69	766.80	0.17	0.71
133.800	Interstate 44 Bridge													
133.700	728.57	765.88	766.12	766.12	766.12	766.16	766.19	766.23	766.29	766.36	766.50	766.61	0.17	0.73
133.000	727.70	765.15	765.43	765.43	765.44	765.48	765.52	765.57	765.63	765.72	765.86	765.98	0.20	0.83
132.000	727.96	764.19	764.54	764.54	764.54	764.59	764.64	764.69	764.77	764.86	765.01	765.12	0.23	0.93
131.000	726.82	763.37	763.77	763.77	763.78	763.83	763.89	763.95	764.03	764.14	764.29	764.41	0.26	1.04
130.000	723.18	762.41	762.88	762.88	762.88	762.95	763.02	763.09	763.19	763.31	763.47	763.61	0.31	1.20
129.000	719.79	761.76	762.00	762.00	762.01	762.09	762.18	762.27	762.38	762.52	762.71	762.96	0.38	1.19
128.000	719.69	761.62	761.70	761.70	761.71	761.73	761.75	761.78	761.81	761.93	762.32	762.62	0.11	1.00
126.710	715.94	761.46	761.55	761.55	761.55	761.57	761.59	761.62	761.66	761.77	762.16	762.45	0.11	0.99
126.700	S 590 Road Bridge													
126.670	715.61	761.44	761.52	761.52	761.53	761.55	761.57	761.60	761.64	761.74	762.14	762.43	0.12	0.99
126.000	720.35	761.41	761.50	761.50	761.50	761.52	761.55	761.57	761.61	761.72	762.12	762.41	0.12	1.00
125.000	717.08	761.32	761.40	761.40	761.40	761.43	761.45	761.48	761.51	761.62	762.03	762.33	0.11	1.01
124.000	715.62	761.27	761.36	761.36	761.36	761.38	761.41	761.44	761.47	761.58	761.99	762.29	0.11	1.02
123.000	713.34	761.19	761.28	761.28	761.28	761.30	761.33	761.36	761.39	761.50	761.91	762.21	0.11	1.02
122.580	711.08	761.14	761.23	761.23	761.23	761.25	761.28	761.31	761.34	761.45	761.87	762.17	0.11	1.03
122.570	Highway 60 Bridge													
122.550	709.97	761.14	761.22	761.22	761.23	761.25	761.27	761.30	761.33	761.44	761.85	762.15	0.11	1.01
122.350	Spring River													
122.000	710.64	760.03	760.12	760.12	760.12	760.15	760.18	760.21	760.25	760.37	760.79	761.05	0.13	1.02
121.980	709.90	759.56	759.66	759.66	759.66	759.68	759.71	759.75	759.79	759.91	760.28	760.52	0.13	0.96
121.970	BN RR Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - SEP 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
121.960	710.89	756.82	756.92	756.92	756.93	756.95	756.98	757.02	757.06	757.21	758.06	758.75	0.14	1.93
120.000	717.63	755.14	755.59	755.59	755.58	755.59	755.59	755.60	755.95	756.26	756.85	757.68	0.37	2.54
118.000	720.29	754.40	755.36	755.36	755.36	755.36	755.36	755.36	755.51	755.84	755.86	757.10	0.15	2.70
116.000	725.99	754.34	755.25	755.25	755.25	755.25	755.25	755.26	755.30	755.63	755.63	757.09	0.05	2.75
114.000	718.27	754.24	755.07	755.07	755.07	755.07	755.07	755.06	755.06	755.29	755.26	757.08	0.01	2.85
112.000	714.31	754.19	754.98	754.98	754.98	754.98	754.97	754.97	754.97	755.12	755.08	757.07	0.01	2.88
110.000	719.24	754.16	754.94	754.94	754.94	754.94	754.93	754.93	754.93	755.03	754.99	757.06	0.01	2.90
108.000	710.68	754.13	754.88	754.88	754.88	754.88	754.87	754.87	754.86	754.92	754.87	757.05	0.02	2.92
106.000	700.35	754.13	754.88	754.88	754.87	754.87	754.87	754.86	754.86	754.89	754.86	757.04	0.02	2.91
105.350	Elk River													
105.000	701.60	754.13	754.88	754.88	754.87	754.87	754.87	754.86	754.86	754.89	754.86	757.04	0.02	2.91
104.000	696.61	754.13	754.87	754.87	754.87	754.87	754.86	754.86	754.86	754.88	754.86	757.03	0.01	2.90
102.000	688.58	754.12	754.86	754.86	754.86	754.86	754.85	754.85	754.85	754.85	754.85	757.02	0.01	2.90
101.750	685.91	754.12	754.85	754.85	754.85	754.85	754.85	754.85	754.85	754.85	754.85	757.02	0.00	2.90
101.730	Highway 59 (Sailboat Bridge)													
101.710	682.31	754.11	754.84	754.84	754.84	754.84	754.84	754.84	754.84	754.84	754.84	757.01	0.00	2.90
100.000	702.62	754.11	754.84	754.84	754.84	754.84	754.84	754.84	754.84	754.84	754.84	757.01	0.00	2.89
90.000	681.52	754.11	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	757.00	0.00	2.89
80.000	657.03	754.11	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	757.00	0.00	2.89
78.000	653.11	754.11	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	757.00	0.00	2.89
77.000	Pensacola Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.2**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - SEP 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
21.000	Upstream end of model													
21.000	762.67	805.10	805.10	805.10	805.10	805.10	805.10	805.10	805.10	805.10	805.10	805.10	0.00	0.00
20.000	760.13	804.41	804.41	804.41	804.41	804.41	804.41	804.41	804.41	804.41	804.41	804.41	0.00	0.00
19.000	759.04	803.09	803.09	803.09	803.09	803.09	803.09	803.09	803.09	803.09	803.09	803.09	0.00	0.00
18.000	753.18	800.93	800.93	800.93	800.93	800.93	800.93	800.93	800.93	800.93	800.93	800.93	0.00	0.00
17.000	750.54	799.10	799.10	799.10	799.10	799.10	799.10	799.10	799.10	799.10	799.10	799.10	0.00	0.00
16.000	749.28	796.17	796.17	796.17	796.17	796.17	796.17	796.17	796.17	796.17	796.17	796.17	0.00	0.00
15.000	746.37	794.15	794.15	794.15	794.15	794.15	794.15	794.15	794.15	794.15	794.15	794.15	0.00	0.00
14.170	741.32	791.71	791.71	791.71	791.71	791.71	791.71	791.71	791.71	791.71	791.71	791.71	0.00	0.00
14.160	E 57 Road													
14.120	744.21	789.81	789.81	789.81	789.81	789.81	789.81	789.81	789.81	789.81	789.81	789.81	0.00	0.00
13.510	744.59	786.79	786.79	786.79	786.79	786.79	786.79	786.79	786.79	786.79	786.79	786.79	0.00	0.00
13.500	Interstate 44 Bridge													
13.450	745.52	784.91	784.91	784.91	784.91	784.91	784.91	784.91	784.91	784.91	784.91	784.91	0.00	0.00
12.000	742.72	780.13	780.13	780.13	780.13	780.13	780.13	780.13	780.13	780.13	780.13	780.13	0.00	0.00
11.000	742.23	778.45	778.45	778.45	778.45	778.45	778.45	778.45	778.45	778.45	778.45	778.45	0.00	0.00
10.000	737.62	776.97	776.97	776.97	776.97	776.97	776.97	776.97	776.97	776.97	776.97	776.97	0.00	0.00
9.000	733.92	774.02	774.02	774.02	774.02	774.02	774.02	774.02	774.02	774.02	774.02	774.03	0.00	0.00
8.020	733.14	772.73	772.73	772.73	772.73	772.73	772.73	772.73	772.73	772.73	772.72	772.74	0.00	0.02
8.010	OK Highway 10 Bridge													
7.970	731.28	771.27	771.29	771.29	771.29	771.29	771.30	771.30	771.31	771.33	771.64	771.70	0.02	0.43
7.000	730.33	769.20	769.23	769.23	769.23	769.23	769.24	769.25	769.26	769.29	769.48	769.69	0.03	0.49
6.000	727.95	767.84	767.88	767.88	767.88	767.88	767.89	767.90	767.92	767.96	768.19	768.43	0.04	0.59
5.000	722.10	766.48	766.52	766.52	766.52	766.53	766.54	766.56	766.57	766.62	766.90	767.17	0.05	0.70
4.000	720.00	765.58	765.62	765.62	765.63	765.64	765.65	765.66	765.68	765.74	766.06	766.34	0.06	0.76
3.000	723.22	764.30	764.36	764.36	764.36	764.37	764.39	764.41	764.43	764.50	764.85	765.16	0.07	0.86
2.000	723.73	763.43	763.50	763.50	763.50	763.51	763.53	763.55	763.58	763.66	764.04	764.36	0.08	0.93
1.000	728.44	762.56	762.63	762.63	762.63	762.65	762.67	762.70	762.72	762.81	763.21	763.53	0.09	0.97
0.580	716.17	760.58	760.66	760.66	760.66	760.68	760.71	760.74	760.77	760.88	761.26	761.54	0.11	0.96
0.570	Highway 60 Bridge													
0.560	713.76	760.09	760.18	760.18	760.18	760.20	760.23	760.26	760.30	760.41	760.80	761.07	0.12	0.98
0.460	715.35	760.74	760.83	760.83	760.83	760.85	760.87	760.90	760.94	761.05	761.44	761.72	0.11	0.98
0.000	Downstream end of Spring River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.3**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - SEP 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
19.590	Upstream end of model													
19.590	771.15	787.52	787.52	787.52	787.52	787.52	787.52	787.52	787.52	787.52	787.52	787.52	0.00	0.00
19.000	767.51	785.42	785.42	785.42	785.42	785.42	785.42	785.42	785.42	785.42	785.42	785.42	0.00	0.00
18.000	765.41	781.77	781.77	781.77	781.77	781.77	781.77	781.77	781.77	781.77	781.77	781.77	0.00	0.00
17.000	762.53	777.78	777.78	777.78	777.78	777.78	777.78	777.78	777.78	777.78	777.78	777.78	0.00	0.00
16.000	756.63	773.42	773.42	773.42	773.42	773.42	773.42	773.42	773.42	773.42	773.42	773.42	0.00	0.00
15.000	754.26	769.55	769.55	769.55	769.55	769.55	769.55	769.55	769.55	769.55	769.55	769.55	0.00	0.00
14.240	750.52	766.33	766.33	766.33	766.33	766.33	766.33	766.33	766.33	766.33	766.33	766.33	0.00	0.00
14.220	Highway 43 Bridge													
14.200	750.12	766.08	766.08	766.08	766.08	766.08	766.08	766.08	766.08	766.08	766.08	766.08	0.00	0.00
14.000	747.07	764.91	764.91	764.91	764.91	764.91	764.91	764.91	764.91	764.91	764.92	764.92	0.00	0.01
13.000	745.41	760.77	760.77	760.77	760.77	760.77	760.77	760.77	760.77	760.77	760.78	760.82	0.00	0.05
12.000	741.15	757.41	757.41	757.41	757.41	757.41	757.41	757.41	757.41	757.41	757.45	757.66	0.00	0.25
11.910	OK/MO State Line													
11.000	741.93	754.15	754.94	754.94	754.94	754.93	754.93	754.90	754.89	755.06	754.94	757.11	0.05	2.96
10.000	734.62	754.14	754.93	754.93	754.92	754.91	754.91	754.89	754.87	755.03	754.91	757.10	0.06	2.96
9.000	734.66	754.14	754.92	754.92	754.91	754.90	754.90	754.88	754.87	755.01	754.90	757.09	0.05	2.95
8.000	724.21	754.14	754.91	754.91	754.91	754.90	754.90	754.88	754.87	754.99	754.89	757.09	0.04	2.95
7.000	728.21	754.14	754.91	754.91	754.90	754.89	754.89	754.88	754.87	754.96	754.89	757.08	0.04	2.94
6.000	727.13	754.13	754.90	754.90	754.90	754.89	754.89	754.87	754.87	754.96	754.88	757.07	0.03	2.94
5.000	721.05	754.13	754.90	754.90	754.89	754.89	754.88	754.87	754.86	754.94	754.88	757.07	0.04	2.94
4.700	716.13	754.13	754.90	754.90	754.89	754.89	754.88	754.87	754.86	754.93	754.88	757.07	0.04	2.94
4.670	OK Highway 10 Bridge													
4.640	715.21	754.13	754.90	754.90	754.89	754.88	754.88	754.87	754.86	754.94	754.88	757.06	0.04	2.93
4.000	716.61	754.13	754.89	754.89	754.89	754.88	754.88	754.87	754.86	754.93	754.87	757.06	0.03	2.93
3.000	714.74	754.13	754.89	754.89	754.88	754.88	754.87	754.87	754.86	754.92	754.87	757.05	0.03	2.92
2.000	709.09	754.13	754.88	754.88	754.88	754.88	754.87	754.87	754.86	754.91	754.86	757.05	0.02	2.92
1.000	705.82	754.13	754.88	754.88	754.87	754.87	754.87	754.86	754.86	754.90	754.86	757.04	0.02	2.91
0.320	706.36	754.13	754.88	754.88	754.87	754.87	754.87	754.86	754.86	754.89	754.86	757.04	0.02	2.91
0.000	Downstream end of Elk River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.4**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - SEP 1993 (21 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
4.152	Upstream end of model													
4.152	762.17	776.77	776.77	776.77	776.77	776.77	776.77	776.77	776.77	776.77	776.77	776.77	0.00	0.00
3.900	760.10	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	775.76	0.00	0.00
3.840	22nd Ave Bridge													
3.800	762.30	774.50	774.50	774.50	774.50	774.50	774.50	774.50	774.50	774.50	774.50	774.50	0.00	0.00
3.300	759.46	772.27	772.27	772.27	772.27	772.27	772.27	772.27	772.27	772.27	772.27	772.27	0.00	0.00
2.800	756.73	768.46	768.46	768.46	768.46	768.46	768.46	768.46	768.46	768.46	768.46	768.47	0.00	0.00
2.710	BN RR Bridge													
2.700	755.72	767.11	767.11	767.11	767.11	767.11	767.11	767.11	767.11	767.12	767.14	767.19	0.00	0.08
2.500	754.95	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
2.300	754.15	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
2.200	Rockdale Blvd Bridge													
2.100	751.51	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
1.900	750.02	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
1.700	749.58	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
1.660	Central Ave Bridge													
1.600	746.47	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
1.500	744.29	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
1.400	OK Highway 10 Bridge													
1.300	742.00	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
1.000	739.34	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
0.700	737.06	766.21	766.43	766.43	766.44	766.47	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
0.300	736.42	766.22	766.44	766.44	766.44	766.48	766.51	766.55	766.60	766.67	766.81	766.92	0.16	0.71
0.041	735.85	766.20	766.42	766.42	766.43	766.46	766.50	766.53	766.59	766.66	766.80	766.91	0.16	0.71
0.000	Downstream end of Tar Creek													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX D.2:
JUNE 2004 (1 YEAR) INFLOW EVENT
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUN 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
152.175	Upstream end of model													
152.175	752.29	773.78	773.78	773.79	773.79	773.79	773.79	773.79	773.79	773.80	773.83	773.85	0.00	0.07
151.000	748.53	772.51	772.52	772.52	772.52	772.52	772.52	772.52	772.52	772.54	772.56	772.59	0.01	0.08
150.000	748.47	771.80	771.81	771.81	771.82	771.82	771.82	771.82	771.82	771.83	771.87	771.90	0.01	0.09
149.000	750.14	770.43	770.44	770.44	770.44	770.44	770.44	770.44	770.44	770.46	770.50	770.54	0.00	0.11
148.000	749.29	768.73	768.75	768.76	768.76	768.76	768.76	768.76	768.76	768.80	768.85	768.89	0.01	0.17
147.000	747.76	766.90	766.93	766.93	766.93	766.94	766.94	766.94	766.94	766.99	767.07	767.12	0.01	0.23
145.500	745.12	764.66	764.70	764.70	764.71	764.71	764.72	764.72	764.72	764.79	764.92	765.00	0.02	0.34
145.480	E 60 Road Bridge													
145.400	748.01	764.55	764.60	764.60	764.61	764.61	764.61	764.62	764.62	764.69	764.82	764.90	0.02	0.35
144.000	743.43	763.27	763.33	763.33	763.34	763.34	763.35	763.35	763.35	763.44	763.60	763.69	0.02	0.42
143.000	737.95	762.10	762.16	762.17	762.18	762.18	762.19	762.19	762.19	762.30	762.48	762.62	0.03	0.52
142.000	742.91	761.17	761.24	761.25	761.26	761.27	761.27	761.27	761.27	761.39	761.61	761.77	0.03	0.60
141.000	741.01	759.97	760.07	760.09	760.10	760.11	760.11	760.12	760.12	760.27	760.58	760.81	0.05	0.84
140.000	736.33	758.57	758.73	758.75	758.77	758.78	758.79	758.79	758.79	759.03	759.50	759.90	0.07	1.33
139.000	743.99	756.44	756.70	756.73	756.76	756.78	756.79	756.80	756.80	757.09	757.80	758.38	0.10	1.94
138.000	736.48	754.95	755.28	755.33	755.37	755.39	755.41	755.41	755.41	755.80	756.63	757.44	0.13	2.50
137.000	733.33	752.67	753.22	753.31	753.37	753.40	753.43	753.47	753.47	754.08	755.23	757.09	0.25	4.42
135.950	731.18	752.01	752.62	752.72	752.78	752.81	752.84	752.89	752.88	753.56	754.86	757.08	0.27	5.07
135.941	Highway 69 Bridge													
135.940	731.21	751.71	752.38	752.48	752.55	752.59	752.62	752.67	752.66	753.40	754.79	757.08	0.29	5.37
135.590	731.77	751.79	752.45	752.55	752.61	752.65	752.68	752.73	752.72	753.44	754.79	757.08	0.28	5.29
135.586	BN RR Bridge													
135.580	731.07	751.84	752.48	752.58	752.64	752.68	752.71	752.76	752.75	753.46	754.80	757.07	0.28	5.23
135.470	732.63	751.71	752.37	752.47	752.54	752.57	752.61	752.66	752.65	753.37	754.75	757.07	0.29	5.36
135.460	Highway 125 Bridge													
135.440	731.60	751.78	752.43	752.53	752.59	752.63	752.66	752.71	752.70	753.41	754.77	757.07	0.28	5.29
135.000	732.64	751.39	752.12	752.23	752.30	752.33	752.37	752.42	752.42	753.18	754.65	757.07	0.31	5.68

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUN 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
134.610	728.75	751.21	751.95	752.06	752.13	752.17	752.21	752.26	752.25	753.03	754.55	757.07	0.31	5.86
134.599	Abandonded RR Bridge													
134.595	728.58	751.10	751.86	751.97	752.04	752.08	752.12	752.17	752.16	752.95	754.50	757.07	0.31	5.97
134.000	727.23	750.38	751.23	751.36	751.44	751.47	751.52	751.58	751.57	752.44	754.20	757.06	0.35	6.68
133.973	Tar Creek													
133.900	727.72	750.13	751.02	751.15	751.22	751.26	751.31	751.37	751.36	752.25	754.08	757.06	0.36	6.92
133.800	Interstate 44 Bridge													
133.700	728.57	749.72	750.68	750.82	750.90	750.94	750.98	751.05	751.04	751.98	753.93	757.05	0.38	7.33
133.000	727.70	748.16	749.45	749.63	749.71	749.76	749.82	749.90	749.89	750.99	753.40	757.04	0.45	8.88
132.000	727.96	746.45	748.15	748.37	748.47	748.52	748.59	748.70	748.68	750.03	753.07	757.03	0.55	10.58
131.000	726.82	745.65	746.99	747.26	747.37	747.42	747.51	747.65	747.62	749.39	753.05	757.03	0.66	11.38
130.000	723.18	745.51	746.66	746.94	747.05	747.11	747.20	747.35	747.32	749.26	753.05	757.02	0.69	11.51
129.000	719.79	745.29	746.12	746.43	746.54	746.60	746.70	746.86	746.83	749.14	753.04	757.02	0.74	11.73
128.000	719.69	745.25	746.00	746.31	746.43	746.49	746.59	746.75	746.72	749.14	753.04	757.02	0.75	11.77
126.710	715.94	745.13	745.70	746.02	746.14	746.20	746.31	746.47	746.44	749.13	753.04	757.02	0.77	11.89
126.700	S 590 Road Bridge													
126.670	715.61	745.12	745.68	746.00	746.12	746.18	746.29	746.45	746.42	749.13	753.04	757.02	0.77	11.90
126.000	720.35	745.08	745.57	745.89	746.01	746.08	746.18	746.35	746.32	749.13	753.04	757.02	0.78	11.94
125.000	717.08	745.01	745.36	745.69	745.81	745.88	745.99	746.16	746.13	749.13	753.04	757.02	0.80	12.01
124.000	715.62	744.95	745.31	745.55	745.67	745.74	745.85	746.02	745.99	749.12	753.03	757.02	0.71	12.07
123.000	713.34	744.90	745.26	745.42	745.54	745.62	745.73	745.90	745.87	749.12	753.03	757.02	0.63	12.12
122.580	711.08	744.89	745.25	745.38	745.50	745.59	745.69	745.86	745.83	749.12	753.03	757.02	0.61	12.13
122.570	Highway 60 Bridge													
122.550	709.97	744.44	744.80	744.93	745.06	745.15	745.25	745.43	745.40	749.01	753.01	757.01	0.63	12.57
122.350	Spring River													
122.000	710.64	744.44	744.80	744.92	745.05	745.14	745.23	745.41	745.38	749.01	753.01	757.01	0.61	12.57
121.980	709.90	744.43	744.80	744.91	745.04	745.13	745.22	745.40	745.37	749.01	753.01	757.01	0.60	12.58
121.970	BN RR Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUN 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
121.960	710.89	744.42	744.79	744.89	745.02	745.12	745.21	745.39	745.36	749.01	753.00	757.00	0.60	12.58
120.000	717.63	744.37	744.74	744.73	744.83	745.04	745.02	745.20	745.17	749.01	753.00	757.00	0.48	12.63
118.000	720.29	744.32	744.70	744.69	744.75	745.00	744.92	745.07	745.04	749.00	753.00	757.00	0.38	12.68
116.000	725.99	744.29	744.68	744.67	744.75	744.98	744.89	744.98	745.01	749.00	753.00	757.00	0.34	12.71
114.000	718.27	744.23	744.64	744.63	744.74	744.93	744.84	744.79	744.99	749.00	753.00	757.00	0.36	12.77
112.000	714.31	744.21	744.62	744.61	744.73	744.91	744.82	744.74	744.99	749.00	753.00	757.00	0.38	12.79
110.000	719.24	744.20	744.62	744.60	744.73	744.90	744.81	744.74	745.00	749.00	753.00	757.00	0.40	12.80
108.000	710.68	744.19	744.61	744.59	744.72	744.89	744.80	744.73	745.00	749.00	753.00	757.00	0.41	12.81
106.000	700.35	744.19	744.61	744.59	744.72	744.89	744.79	744.73	745.01	749.00	753.00	757.00	0.42	12.81
105.350	Elk River													
105.000	701.60	744.19	744.61	744.59	744.72	744.89	744.79	744.73	745.01	749.00	753.00	757.00	0.42	12.81
104.000	696.61	744.19	744.60	744.59	744.72	744.88	744.79	744.73	745.01	749.00	753.00	757.00	0.42	12.81
102.000	688.58	744.18	744.60	744.58	744.71	744.88	744.79	744.72	745.02	749.00	753.00	757.00	0.44	12.82
101.750	685.91	744.18	744.60	744.58	744.71	744.88	744.79	744.72	745.03	749.00	753.00	757.00	0.45	12.82
101.730	Highway 59 (Sailboat Bridge)													
101.710	682.31	744.18	744.60	744.58	744.71	744.87	744.78	744.72	745.02	749.00	753.00	757.00	0.44	12.82
100.000	702.62	744.18	744.60	744.58	744.71	744.87	744.78	744.72	745.01	749.00	753.00	757.00	0.43	12.82
90.000	681.52	744.18	744.60	744.58	744.71	744.87	744.78	744.72	745.00	749.00	753.00	757.00	0.42	12.82
80.000	657.03	744.18	744.60	744.58	744.71	744.87	744.78	744.72	745.00	749.00	753.00	757.00	0.42	12.82
78.000	653.11	744.18	744.60	744.58	744.71	744.87	744.78	744.72	745.00	749.00	753.00	757.00	0.42	12.82
77.000	Pensacola Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.6**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - JUN 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
21.000	Upstream end of model													
21.000	762.67	773.88	773.88	773.88	773.88	773.88	773.88	773.88	773.88	773.88	773.88	773.88	0.00	0.00
20.000	760.13	771.04	771.04	771.04	771.04	771.04	771.04	771.04	771.04	771.04	771.04	771.04	0.00	0.00
19.000	759.04	768.52	768.52	768.52	768.52	768.52	768.52	768.52	768.52	768.52	768.53	768.54	0.00	0.02
18.000	753.18	764.57	764.57	764.57	764.57	764.57	764.57	764.57	764.57	764.58	764.62	764.71	0.00	0.14
17.000	750.54	762.75	762.75	762.75	762.75	762.75	762.75	762.75	762.75	762.77	762.87	763.03	0.00	0.28
16.000	749.28	760.33	760.33	760.34	760.34	760.34	760.34	760.34	760.34	760.39	760.66	761.04	0.01	0.71
15.000	746.37	758.32	758.33	758.33	758.33	758.34	758.34	758.34	758.34	758.44	758.97	759.60	0.02	1.27
14.170	741.32	757.45	757.45	757.45	757.46	757.46	757.47	757.47	757.47	757.61	758.27	759.03	0.02	1.58
14.160	E 57 Road													
14.120	744.21	757.47	757.48	757.48	757.48	757.49	757.49	757.50	757.50	757.63	758.30	759.05	0.02	1.58
13.510	744.59	756.82	756.83	756.83	756.84	756.84	756.85	756.85	756.86	757.03	757.83	758.70	0.03	1.88
13.500	Interstate 44 Bridge													
13.450	745.52	756.56	756.57	756.57	756.57	756.58	756.59	756.59	756.60	756.78	757.65	758.57	0.03	2.01
12.000	742.72	753.20	753.26	753.28	753.31	753.34	753.36	753.39	753.41	754.19	756.21	757.70	0.15	4.50
11.000	742.23	751.43	751.58	751.63	751.69	751.77	751.81	751.85	751.90	753.19	755.72	757.46	0.32	6.03
10.000	737.62	749.79	750.11	750.20	750.31	750.43	750.51	750.59	750.66	752.47	755.39	757.44	0.55	7.65
9.000	733.92	748.61	749.11	749.24	749.39	749.56	749.65	749.75	749.84	752.00	755.18	757.44	0.73	8.83
8.020	733.14	747.09	747.98	748.19	748.38	748.56	748.68	748.81	748.93	751.51	754.96	757.44	0.95	10.35
8.010	OK Highway 10 Bridge													
7.970	731.28	744.73	745.75	745.97	746.16	746.31	746.42	746.55	746.67	749.27	753.01	757.01	0.92	12.28
7.000	730.33	744.48	745.27	745.52	745.73	745.88	745.95	746.03	746.11	749.02	753.01	757.01	0.84	12.53
6.000	727.95	744.47	744.87	745.17	745.39	745.54	745.62	745.73	745.70	749.02	753.01	757.01	0.86	12.54
5.000	722.10	744.46	744.83	745.10	745.28	745.41	745.51	745.63	745.60	749.02	753.01	757.01	0.80	12.55
4.000	720.00	744.46	744.82	745.05	745.20	745.32	745.41	745.55	745.52	749.01	753.01	757.01	0.73	12.55
3.000	723.22	744.46	744.82	745.03	745.17	745.28	745.38	745.52	745.50	749.01	753.01	757.01	0.70	12.55
2.000	723.73	744.46	744.82	745.01	745.14	745.23	745.34	745.50	745.47	749.01	753.01	757.01	0.68	12.55
1.000	728.44	744.45	744.82	744.99	745.12	745.20	745.31	745.48	745.45	749.01	753.01	757.01	0.66	12.56
0.580	716.17	744.45	744.82	744.98	745.11	745.19	745.30	745.48	745.45	749.01	753.01	757.01	0.66	12.56
0.570	Highway 60 Bridge													
0.560	713.76	744.45	744.82	744.98	745.11	745.19	745.30	745.47	745.44	749.01	753.01	757.01	0.65	12.56
0.460	715.35	744.45	744.82	744.98	745.11	745.19	745.30	745.47	745.44	749.01	753.01	757.01	0.65	12.56
0.000	Downstream end of Spring River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.7**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - JUN 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
19.590	Upstream end of model													
19.590	771.15	774.17	774.17	774.17	774.17	774.17	774.17	774.17	774.17	774.17	774.17	774.17	0.00	0.00
19.000	767.51	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	0.00	0.00
18.000	765.41	769.18	769.18	769.18	769.18	769.18	769.18	769.18	769.18	769.18	769.18	769.18	0.00	0.00
17.000	762.53	766.13	766.13	766.13	766.13	766.13	766.13	766.13	766.13	766.13	766.13	766.13	0.00	0.00
16.000	756.63	761.16	761.16	761.16	761.16	761.16	761.16	761.16	761.16	761.16	761.16	761.16	0.00	0.00
15.000	754.26	757.92	757.92	757.92	757.92	757.92	757.92	757.92	757.92	757.92	757.92	757.92	0.00	0.00
14.240	750.52	753.18	753.18	753.18	753.18	753.18	753.18	753.18	753.18	753.18	753.31	757.03	0.00	3.85
14.220	Highway 43 Bridge													
14.200	750.12	753.10	753.10	753.10	753.10	753.10	753.10	753.10	753.10	753.10	753.28	757.02	0.00	3.92
14.000	747.07	752.78	752.78	752.78	752.78	752.78	752.78	752.78	752.78	752.78	753.22	757.02	0.00	4.24
13.000	745.41	749.01	749.01	749.01	749.01	749.01	749.01	749.01	749.01	749.40	753.02	757.00	0.00	8.00
12.000	741.15	746.01	746.06	746.06	746.03	746.01	746.01	746.01	746.01	749.03	753.01	757.00	0.05	10.99
11.910	OK/MO State Line													
11.000	741.93	744.92	744.79	744.79	744.96	745.12	745.06	745.02	745.14	749.00	753.00	757.00	0.35	12.21
10.000	734.62	744.21	744.64	744.61	744.74	744.92	744.83	744.75	745.05	749.00	753.00	757.00	0.44	12.79
9.000	734.66	744.21	744.64	744.61	744.74	744.92	744.83	744.75	745.03	749.00	753.00	757.00	0.42	12.79
8.000	724.21	744.21	744.63	744.61	744.74	744.91	744.82	744.75	745.02	749.00	753.00	757.00	0.41	12.79
7.000	728.21	744.20	744.63	744.60	744.74	744.91	744.81	744.75	745.00	749.00	753.00	757.00	0.40	12.80
6.000	727.13	744.20	744.62	744.60	744.73	744.90	744.81	744.74	745.00	749.00	753.00	757.00	0.40	12.80
5.000	721.05	744.20	744.62	744.60	744.73	744.90	744.81	744.74	745.00	749.00	753.00	757.00	0.40	12.80
4.700	716.13	744.20	744.61	744.60	744.73	744.90	744.81	744.74	745.00	749.00	753.00	757.00	0.40	12.80
4.670	OK Highway 10 Bridge													
4.640	715.21	744.20	744.61	744.60	744.73	744.90	744.80	744.74	745.00	749.00	753.00	757.00	0.40	12.80
4.000	716.61	744.19	744.61	744.59	744.73	744.89	744.80	744.74	745.00	749.00	753.00	757.00	0.41	12.81
3.000	714.74	744.19	744.61	744.59	744.73	744.89	744.80	744.74	745.00	749.00	753.00	757.00	0.41	12.81
2.000	709.09	744.19	744.61	744.59	744.72	744.89	744.80	744.74	745.00	749.00	753.00	757.00	0.41	12.81
1.000	705.82	744.19	744.61	744.59	744.72	744.89	744.80	744.73	745.01	749.00	753.00	757.00	0.42	12.81
0.320	706.36	744.19	744.61	744.59	744.72	744.89	744.79	744.73	745.01	749.00	753.00	757.00	0.42	12.81
0.000	Downstream end of Elk River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.8**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - JUN 2004 (1 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
4.152	Upstream end of model													
4.152	762.17	768.17	768.17	768.17	768.17	768.17	768.17	768.17	768.17	768.17	768.17	768.17	0.00	0.00
3.900	760.10	767.29	767.29	767.29	767.29	767.29	767.29	767.29	767.29	767.29	767.29	767.29	0.00	0.00
3.840	22nd Ave Bridge													
3.800	762.30	766.05	766.05	766.05	766.05	766.05	766.05	766.05	766.05	766.05	766.05	766.05	0.00	0.00
3.300	759.46	764.09	764.09	764.09	764.09	764.09	764.09	764.09	764.09	764.09	764.09	764.09	0.00	0.00
2.800	756.73	760.95	760.95	760.95	760.95	760.95	760.95	760.95	760.95	760.95	760.96	760.96	0.00	0.01
2.710	BN RR Bridge													
2.700	755.72	760.45	760.45	760.45	760.45	760.45	760.45	760.45	760.45	760.45	760.46	760.46	0.00	0.01
2.500	754.95	759.30	759.30	759.30	759.30	759.30	759.30	759.30	759.30	759.30	759.30	759.33	0.00	0.03
2.300	754.15	757.47	757.47	757.47	757.47	757.47	757.47	757.47	757.47	757.47	757.49	757.63	0.00	0.16
2.200	Rockdale Blvd Bridge													
2.100	751.51	754.83	754.83	754.84	754.84	754.84	754.84	754.84	754.84	754.87	755.19	757.06	0.00	2.23
1.900	750.02	753.18	753.21	753.21	753.22	753.22	753.23	753.23	753.23	753.40	754.46	757.06	0.02	3.87
1.700	749.58	750.72	751.23	751.33	751.39	751.43	751.47	751.52	751.51	752.38	754.21	757.06	0.29	6.34
1.660	Central Ave Bridge													
1.600	746.47	750.30	751.16	751.29	751.36	751.40	751.44	751.51	751.50	752.38	754.19	757.06	0.35	6.76
1.500	744.29	750.29	751.16	751.29	751.36	751.40	751.44	751.51	751.50	752.38	754.18	757.06	0.35	6.76
1.400	OK Highway 10 Bridge													
1.300	742.00	750.29	751.16	751.29	751.36	751.40	751.44	751.51	751.50	752.38	754.18	757.06	0.35	6.76
1.000	739.34	750.29	751.16	751.29	751.36	751.40	751.44	751.51	751.50	752.38	754.17	757.06	0.35	6.77
0.700	737.06	750.29	751.16	751.29	751.36	751.40	751.44	751.51	751.50	752.38	754.17	757.06	0.35	6.77
0.300	736.42	750.29	751.16	751.29	751.36	751.40	751.44	751.51	751.50	752.38	754.16	757.06	0.35	6.77
0.041	735.85	750.29	751.15	751.28	751.36	751.40	751.44	751.50	751.49	752.37	754.16	757.06	0.35	6.77
0.000	Downstream end of Tar Creek													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX D.3:
JULY 2007 (4 YEAR) INFLOW EVENT
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.9**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUL 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
152.175	Upstream end of model													
152.175	752.29	784.43	784.43	784.43	784.43	784.43	784.43	784.43	784.43	784.43	784.43	784.43	0.00	0.00
151.000	748.53	780.33	780.33	780.33	780.33	780.33	780.33	780.33	780.33	780.33	780.33	780.33	0.00	0.00
150.000	748.47	778.90	778.90	778.90	778.90	778.90	778.90	778.90	778.90	778.90	778.90	778.90	0.00	0.00
149.000	750.14	777.44	777.45	777.46	777.46	777.46	777.45	777.45	777.46	777.47	777.48	777.49	0.01	0.05
148.000	749.29	777.07	777.08	777.09	777.09	777.09	777.09	777.08	777.09	777.10	777.11	777.13	0.01	0.06
147.000	747.76	776.19	776.21	776.22	776.22	776.22	776.22	776.22	776.23	776.25	776.26	776.28	0.02	0.09
145.500	745.12	775.69	775.71	775.73	775.73	775.73	775.72	775.73	775.74	775.77	775.78	775.81	0.03	0.11
145.480	E 60 Road Bridge													
145.400	748.01	775.65	775.67	775.69	775.69	775.69	775.68	775.69	775.70	775.72	775.74	775.76	0.02	0.11
144.000	743.43	775.05	775.07	775.10	775.10	775.10	775.09	775.10	775.11	775.14	775.16	775.19	0.04	0.14
143.000	737.95	774.77	774.79	774.83	774.83	774.83	774.81	774.82	774.83	774.87	774.89	774.92	0.04	0.15
142.000	742.91	774.53	774.56	774.60	774.60	774.60	774.57	774.59	774.60	774.64	774.66	774.69	0.05	0.16
141.000	741.01	774.40	774.43	774.47	774.47	774.47	774.45	774.46	774.48	774.52	774.54	774.57	0.05	0.17
140.000	736.33	774.36	774.39	774.43	774.43	774.43	774.41	774.42	774.44	774.48	774.50	774.53	0.05	0.17
139.000	743.99	774.33	774.36	774.40	774.40	774.40	774.37	774.39	774.41	774.45	774.47	774.50	0.05	0.17
138.000	736.48	774.26	774.29	774.33	774.33	774.33	774.31	774.32	774.34	774.38	774.40	774.43	0.05	0.17
137.000	733.33	774.04	774.07	774.12	774.12	774.12	774.09	774.11	774.12	774.17	774.19	774.22	0.06	0.18
135.950	731.18	773.38	773.41	773.47	773.47	773.48	773.43	773.46	773.48	773.53	773.55	773.59	0.07	0.21
135.941	Highway 69 Bridge													
135.940	731.21	773.41	773.44	773.50	773.50	773.50	773.46	773.49	773.51	773.56	773.58	773.62	0.07	0.21
135.590	731.77	773.23	773.26	773.32	773.32	773.32	773.28	773.31	773.33	773.38	773.40	773.44	0.07	0.21
135.586	BN RR Bridge													
135.580	731.07	773.16	773.19	773.25	773.25	773.26	773.21	773.24	773.26	773.31	773.34	773.38	0.07	0.22
135.470	732.63	773.08	773.11	773.18	773.18	773.18	773.14	773.17	773.19	773.24	773.26	773.30	0.08	0.22
135.460	Highway 125 Bridge													
135.440	731.60	773.13	773.16	773.23	773.23	773.23	773.19	773.22	773.24	773.29	773.31	773.35	0.08	0.22
135.000	732.64	772.80	772.83	772.90	772.90	772.90	772.86	772.89	772.91	772.96	772.99	773.03	0.08	0.23

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.9**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUL 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
134.610	728.75	772.32	772.35	772.44	772.44	772.44	772.39	772.43	772.46	772.51	772.54	772.58	0.11	0.26
134.599	Abandonded RR Bridge													
134.595	728.58	772.06	772.09	772.19	772.19	772.19	772.12	772.17	772.20	772.25	772.28	772.32	0.11	0.26
134.000	727.23	771.78	771.81	771.92	771.92	771.92	771.85	771.91	771.93	771.99	772.02	772.06	0.12	0.28
133.973	Tar Creek													
133.900	727.72	771.46	771.49	771.61	771.61	771.61	771.53	771.59	771.62	771.68	771.71	771.75	0.13	0.29
133.800	Interstate 44 Bridge													
133.700	728.57	771.12	771.15	771.27	771.27	771.27	771.19	771.25	771.28	771.34	771.37	771.41	0.13	0.30
133.000	727.70	770.43	770.46	770.61	770.61	770.61	770.51	770.59	770.62	770.68	770.72	770.76	0.16	0.33
132.000	727.96	769.24	769.27	769.46	769.46	769.46	769.33	769.44	769.47	769.54	769.57	769.63	0.20	0.39
131.000	726.82	768.26	768.28	768.52	768.52	768.53	768.36	768.51	768.54	768.61	768.65	768.70	0.25	0.43
130.000	723.18	766.95	766.97	767.27	767.27	767.27	767.07	767.25	767.29	767.37	767.41	767.47	0.32	0.52
129.000	719.79	765.69	765.71	766.10	766.10	766.10	765.83	766.08	766.12	766.20	766.24	766.31	0.41	0.62
128.000	719.69	764.58	764.59	765.06	765.06	765.07	764.73	765.05	765.08	765.16	765.21	765.28	0.49	0.70
126.710	715.94	762.70	762.67	763.36	763.36	763.36	762.88	763.34	763.38	763.45	763.50	763.57	0.71	0.90
126.700	S 590 Road Bridge													
126.670	715.61	762.65	762.61	763.31	763.31	763.32	762.83	763.30	763.33	763.41	763.45	763.53	0.72	0.92
126.000	720.35	762.00	761.95	762.74	762.74	762.74	762.19	762.72	762.75	762.83	762.87	762.95	0.80	0.99
125.000	717.08	760.46	760.36	761.36	761.36	761.37	760.69	761.35	761.38	761.44	761.48	761.56	1.02	1.20
124.000	715.62	758.81	758.71	759.97	759.98	759.98	759.13	759.96	759.99	760.04	760.08	760.15	1.28	1.44
123.000	713.34	756.90	757.22	758.37	758.37	758.37	757.55	758.36	758.38	758.43	758.46	758.51	1.16	1.61
122.580	711.08	755.56	756.26	757.22	757.22	757.22	756.62	757.21	757.22	757.26	757.28	757.32	0.96	1.76
122.570	Highway 60 Bridge													
122.550	709.97	755.51	756.21	757.22	757.22	757.22	756.59	757.21	757.23	757.26	757.29	757.33	1.02	1.82
122.350	Spring River													
122.000	710.64	755.13	755.96	756.93	756.93	756.94	756.36	756.93	756.94	756.97	756.99	757.04	0.98	1.91
121.980	709.90	755.04	755.84	756.78	756.78	756.79	756.24	756.78	756.79	756.82	756.84	757.02	0.95	1.98
121.970	BN RR Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.9**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - JUL 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
121.960	710.89	754.84	755.51	756.29	756.29	756.29	755.89	756.28	756.29	756.31	756.32	757.01	0.78	2.17
120.000	717.63	754.52	755.04	755.72	755.72	755.72	755.46	755.72	755.72	755.73	755.74	757.01	0.68	2.49
118.000	720.29	754.35	754.81	755.43	755.43	755.43	755.24	755.43	755.43	755.44	755.44	757.01	0.62	2.66
116.000	725.99	754.27	754.70	755.30	755.30	755.30	755.13	755.29	755.30	755.30	755.31	757.00	0.60	2.73
114.000	718.27	754.14	754.52	755.07	755.07	755.07	754.96	755.07	755.07	755.07	755.07	757.00	0.55	2.86
112.000	714.31	754.08	754.43	754.96	754.96	754.96	754.87	754.96	754.96	754.95	754.95	757.00	0.54	2.92
110.000	719.24	754.05	754.38	754.91	754.91	754.90	754.83	754.91	754.90	754.89	754.90	757.00	0.53	2.95
108.000	710.68	754.01	754.32	754.83	754.83	754.83	754.78	754.84	754.83	754.82	754.82	757.00	0.52	2.99
106.000	700.35	754.00	754.31	754.82	754.82	754.82	754.77	754.82	754.82	754.82	754.82	757.00	0.51	3.00
105.350	Elk River													
105.000	701.60	754.00	754.31	754.82	754.82	754.82	754.77	754.82	754.82	754.82	754.82	757.00	0.51	3.00
104.000	696.61	754.00	754.31	754.82	754.82	754.82	754.76	754.82	754.82	754.82	754.82	757.00	0.51	3.00
102.000	688.58	754.00	754.29	754.81	754.81	754.81	754.75	754.81	754.81	754.81	754.81	757.00	0.52	3.00
101.750	685.91	753.99	754.29	754.81	754.81	754.81	754.75	754.81	754.81	754.81	754.81	757.00	0.52	3.01
101.730	Highway 59 (Sailboat Bridge)													
101.710	682.31	753.98	754.28	754.80	754.80	754.80	754.74	754.80	754.80	754.80	754.80	757.00	0.52	3.02
100.000	702.62	753.98	754.28	754.80	754.80	754.80	754.74	754.80	754.80	754.80	754.80	757.00	0.52	3.01
90.000	681.52	753.98	754.27	754.79	754.79	754.79	754.74	754.79	754.79	754.79	754.79	757.00	0.52	3.02
80.000	657.03	753.98	754.27	754.79	754.79	754.79	754.74	754.79	754.79	754.79	754.79	757.00	0.52	3.02
78.000	653.11	753.98	754.27	754.79	754.79	754.79	754.74	754.79	754.79	754.79	754.79	757.00	0.52	3.02
77.000	Pensacola Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.10**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - JUL 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
21.000	Upstream end of model													
21.000	762.67	783.49	783.49	783.49	783.49	783.49	783.49	783.49	783.49	783.49	783.49	783.50	0.00	0.01
20.000	760.13	780.70	780.70	780.70	780.70	780.70	780.70	780.70	780.70	780.70	780.70	780.70	0.00	0.00
19.000	759.04	777.52	777.52	777.52	777.52	777.52	777.52	777.52	777.52	777.52	777.52	777.52	0.00	0.00
18.000	753.18	774.19	774.20	774.20	774.20	774.20	774.20	774.20	774.20	774.20	774.20	774.20	0.00	0.01
17.000	750.54	772.20	772.20	772.20	772.20	772.20	772.20	772.20	772.20	772.21	772.21	772.21	0.00	0.01
16.000	749.28	770.00	770.00	770.00	770.00	770.00	770.00	770.00	770.00	770.00	770.00	770.02	0.00	0.02
15.000	746.37	767.51	767.51	767.51	767.51	767.51	767.51	767.51	767.51	767.52	767.52	767.54	0.01	0.03
14.170	741.32	765.96	765.96	765.96	765.96	765.96	765.96	765.96	765.96	765.97	765.97	766.01	0.00	0.05
14.160	E 57 Road													
14.120	744.21	766.18	766.18	766.18	766.18	766.18	766.18	766.18	766.18	766.19	766.19	766.22	0.00	0.04
13.510	744.59	765.30	765.30	765.30	765.30	765.30	765.30	765.30	765.30	765.31	765.31	765.35	0.00	0.05
13.500	Interstate 44 Bridge													
13.450	745.52	764.98	764.98	764.98	764.98	764.98	764.98	764.98	764.98	764.99	764.99	765.03	0.00	0.05
12.000	742.72	762.16	762.16	762.16	762.16	762.16	762.16	762.16	762.16	762.20	762.19	762.29	0.00	0.13
11.000	742.23	760.39	760.39	760.39	760.39	760.39	760.39	760.39	760.40	760.47	760.44	760.62	0.01	0.23
10.000	737.62	758.86	758.86	758.87	758.87	758.87	758.87	758.87	758.87	759.21	759.27	759.55	0.01	0.69
9.000	733.92	757.29	757.55	758.52	758.52	758.53	757.89	758.52	758.53	758.58	758.72	759.03	0.98	1.74
8.020	733.14	756.72	757.52	758.47	758.47	758.48	757.85	758.47	758.48	758.52	758.55	758.78	0.96	2.06
8.010	OK Highway 10 Bridge													
7.970	731.28	755.66	756.33	757.38	757.38	757.39	756.71	757.38	757.39	757.44	757.47	757.66	1.06	2.00
7.000	730.33	755.62	756.30	757.35	757.35	757.35	756.68	757.34	757.36	757.40	757.43	757.50	1.06	1.88
6.000	727.95	755.59	756.29	757.33	757.34	757.34	756.67	757.33	757.34	757.39	757.41	757.47	1.05	1.88
5.000	722.10	755.58	756.28	757.32	757.32	757.33	756.66	757.32	757.33	757.37	757.40	757.45	1.05	1.87
4.000	720.00	755.57	756.27	757.32	757.32	757.32	756.66	757.31	757.33	757.37	757.39	757.45	1.06	1.88
3.000	723.22	755.57	756.27	757.31	757.31	757.32	756.65	757.31	757.32	757.36	757.39	757.44	1.05	1.87
2.000	723.73	755.56	756.26	757.31	757.31	757.31	756.65	757.30	757.32	757.36	757.38	757.44	1.06	1.88
1.000	728.44	755.56	756.26	757.31	757.31	757.31	756.65	757.30	757.32	757.36	757.38	757.43	1.06	1.87
0.580	716.17	755.56	756.26	757.30	757.30	757.31	756.64	757.30	757.31	757.35	757.38	757.43	1.05	1.87
0.570	Highway 60 Bridge													
0.560	713.76	755.55	756.25	757.30	757.30	757.30	756.64	757.29	757.31	757.35	757.37	757.42	1.06	1.87
0.460	715.35	755.55	756.25	757.30	757.30	757.30	756.64	757.29	757.31	757.35	757.37	757.42	1.06	1.87
0.000	Downstream end of Spring River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.11**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - JUL 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
19.590	Upstream end of model													
19.590	771.15	775.57	775.57	775.57	775.57	775.57	775.57	775.57	775.57	775.57	775.57	775.57	0.00	0.00
19.000	767.51	774.03	774.03	774.03	774.03	774.03	774.03	774.03	774.03	774.03	774.03	774.03	0.00	0.00
18.000	765.41	770.46	770.46	770.46	770.46	770.46	770.46	770.46	770.46	770.46	770.46	770.46	0.00	0.00
17.000	762.53	767.01	767.01	767.01	767.01	767.01	767.01	767.01	767.01	767.01	767.01	767.01	0.00	0.00
16.000	756.63	762.78	762.78	762.78	762.78	762.78	762.78	762.78	762.78	762.78	762.78	762.78	0.00	0.00
15.000	754.26	759.23	759.23	759.23	759.23	759.23	759.23	759.23	759.23	759.23	759.24	759.24	0.00	0.00
14.240	750.52	754.93	755.05	755.42	755.42	755.42	755.57	755.42	755.51	755.50	755.50	757.02	0.52	2.09
14.220	Highway 43 Bridge													
14.200	750.12	754.89	755.02	755.39	755.39	755.39	755.55	755.39	755.48	755.47	755.47	757.01	0.53	2.12
14.000	747.07	754.74	754.90	755.25	755.25	755.25	755.40	755.25	755.33	755.32	755.32	757.01	0.50	2.27
13.000	745.41	754.13	754.45	754.95	754.94	754.93	754.89	754.95	754.94	754.90	754.90	757.00	0.50	2.87
12.000	741.15	754.05	754.39	754.90	754.90	754.89	754.84	754.91	754.89	754.85	754.85	757.00	0.52	2.95
11.910	OK/MO State Line													
11.000	741.93	754.03	754.37	754.89	754.88	754.87	754.82	754.89	754.88	754.84	754.83	757.00	0.52	2.97
10.000	734.62	754.03	754.36	754.88	754.87	754.86	754.81	754.88	754.87	754.83	754.83	757.00	0.52	2.97
9.000	734.66	754.02	754.35	754.87	754.87	754.86	754.81	754.87	754.86	754.83	754.83	757.00	0.52	2.98
8.000	724.21	754.02	754.35	754.86	754.86	754.85	754.80	754.86	754.85	754.83	754.83	757.00	0.51	2.98
7.000	728.21	754.02	754.34	754.86	754.85	754.85	754.80	754.86	754.85	754.83	754.83	757.00	0.52	2.98
6.000	727.13	754.02	754.34	754.85	754.85	754.85	754.79	754.85	754.85	754.82	754.82	757.00	0.51	2.98
5.000	721.05	754.01	754.33	754.85	754.84	754.84	754.79	754.85	754.84	754.82	754.82	757.00	0.52	2.99
4.700	716.13	754.01	754.33	754.84	754.84	754.84	754.79	754.84	754.84	754.82	754.82	757.00	0.51	2.99
4.670	OK Highway 10 Bridge													
4.640	715.21	754.01	754.33	754.84	754.84	754.84	754.79	754.84	754.84	754.82	754.82	757.00	0.51	2.99
4.000	716.61	754.01	754.33	754.84	754.84	754.84	754.78	754.84	754.83	754.82	754.82	757.00	0.51	2.99
3.000	714.74	754.01	754.32	754.84	754.84	754.83	754.78	754.84	754.83	754.82	754.82	757.00	0.52	2.99
2.000	709.09	754.01	754.32	754.83	754.83	754.83	754.78	754.83	754.83	754.82	754.82	757.00	0.51	2.99
1.000	705.82	754.00	754.32	754.83	754.83	754.82	754.77	754.83	754.82	754.82	754.82	757.00	0.51	3.00
0.320	706.36	754.00	754.31	754.82	754.82	754.82	754.77	754.82	754.82	754.82	754.82	757.00	0.51	3.00
0.000	Downstream end of Elk River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.12**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - JUL 2007 (4 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
4.152	Upstream end of model													
4.152	762.17	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
3.900	760.10	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
3.840	22nd Ave Bridge													
3.800	762.30	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
3.300	759.46	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
2.800	756.73	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
2.710	BN RR Bridge													
2.700	755.72	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
2.500	754.95	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
2.300	754.15	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
2.200	Rockdale Blvd Bridge													
2.100	751.51	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
1.900	750.02	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
1.700	749.58	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
1.660	Central Ave Bridge													
1.600	746.47	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
1.500	744.29	771.86	771.89	772.00	772.00	772.00	771.93	771.99	772.01	772.07	772.10	772.15	0.12	0.29
1.400	OK Highway 10 Bridge													
1.300	742.00	771.86	771.89	772.00	772.00	772.00	771.93	771.98	772.01	772.07	772.10	772.14	0.12	0.29
1.000	739.34	771.85	771.88	771.99	771.99	771.99	771.92	771.98	772.00	772.06	772.09	772.14	0.12	0.29
0.700	737.06	771.84	771.88	771.98	771.98	771.98	771.91	771.97	772.00	772.05	772.08	772.13	0.12	0.29
0.300	736.42	771.78	771.81	771.92	771.92	771.92	771.85	771.90	771.93	771.99	772.02	772.06	0.12	0.29
0.041	735.85	771.69	771.73	771.83	771.83	771.84	771.76	771.82	771.85	771.90	771.93	771.98	0.12	0.29
0.000	Downstream end of Tar Creek													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX D.4:
OCTOBER 2009 (3 YEAR) INFLOW EVENT
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - OCT 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
152.175	Upstream end of model													
152.175	752.29	778.47	778.47	778.47	778.47	778.47	778.47	778.47	778.47	778.47	778.47	778.47	0.00	0.00
151.000	748.53	776.35	776.35	776.35	776.35	776.35	776.35	776.35	776.35	776.35	776.35	776.35	0.00	0.00
150.000	748.47	775.17	775.17	775.17	775.17	775.17	775.17	775.17	775.17	775.17	775.17	775.18	0.00	0.00
149.000	750.14	773.78	773.78	773.78	773.78	773.78	773.78	773.78	773.78	773.78	773.78	773.78	0.00	0.00
148.000	749.29	772.40	772.40	772.40	772.40	772.40	772.40	772.40	772.40	772.40	772.40	772.40	0.00	0.01
147.000	747.76	770.52	770.52	770.52	770.52	770.52	770.52	770.52	770.52	770.52	770.52	770.53	0.00	0.02
145.500	745.12	768.34	768.34	768.34	768.34	768.35	768.35	768.35	768.35	768.35	768.36	768.39	0.00	0.05
145.480	E 60 Road Bridge													
145.400	748.01	768.23	768.23	768.23	768.23	768.24	768.24	768.24	768.24	768.24	768.25	768.28	0.00	0.05
144.000	743.43	766.45	766.46	766.46	766.46	766.46	766.46	766.46	766.46	766.47	766.50	766.56	0.01	0.11
143.000	737.95	764.99	765.00	765.01	765.01	765.01	765.01	765.01	765.02	765.03	765.10	765.23	0.01	0.24
142.000	742.91	763.80	763.83	763.83	763.83	763.84	763.85	763.84	763.85	763.87	764.00	764.21	0.02	0.41
141.000	741.01	763.13	763.18	763.18	763.19	763.19	763.20	763.19	763.21	763.25	763.44	763.72	0.03	0.59
140.000	736.33	762.76	762.83	762.83	762.84	762.85	762.86	762.85	762.87	762.92	763.17	763.49	0.04	0.73
139.000	743.99	762.21	762.31	762.31	762.33	762.34	762.35	762.34	762.36	762.44	762.77	763.17	0.05	0.96
138.000	736.48	761.75	761.88	761.88	761.91	761.91	761.93	761.91	761.94	762.04	762.42	762.88	0.06	1.13
137.000	733.33	760.65	760.85	760.84	760.88	760.88	760.90	760.88	760.92	761.05	761.56	762.11	0.07	1.45
135.950	731.18	759.95	760.18	760.18	760.22	760.21	760.24	760.21	760.26	760.41	760.97	761.57	0.08	1.62
135.941	Highway 69 Bridge													
135.940	731.21	759.91	760.14	760.14	760.18	760.17	760.20	760.17	760.22	760.37	760.94	761.54	0.08	1.63
135.590	731.77	759.84	760.08	760.07	760.12	760.11	760.13	760.11	760.15	760.31	760.89	761.49	0.08	1.65
135.586	BN RR Bridge													
135.580	731.07	759.82	760.05	760.05	760.09	760.08	760.11	760.08	760.13	760.29	760.86	761.46	0.08	1.64
135.470	732.63	759.73	759.97	759.96	760.01	760.00	760.03	760.00	760.05	760.21	760.79	761.40	0.09	1.67
135.460	Highway 125 Bridge													
135.440	731.60	759.78	760.01	760.01	760.05	760.04	760.07	760.04	760.09	760.25	760.82	761.43	0.08	1.65
135.000	732.64	759.64	759.89	759.89	759.93	759.92	759.95	759.92	759.97	760.14	760.73	761.36	0.08	1.72

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - OCT 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
134.610	728.75	759.36	759.63	759.62	759.67	759.65	759.68	759.65	759.71	759.88	760.50	761.14	0.09	1.78
134.599	Abandonded RR Bridge													
134.595	728.58	759.17	759.44	759.43	759.49	759.47	759.50	759.47	759.52	759.70	760.33	760.97	0.09	1.80
134.000	727.23	758.52	758.83	758.82	758.88	758.86	758.90	758.86	758.92	759.12	759.82	760.52	0.10	2.00
133.973	Tar Creek													
133.900	727.72	758.26	758.59	758.58	758.65	758.62	758.65	758.62	758.68	758.89	759.62	760.33	0.10	2.07
133.800	Interstate 44 Bridge													
133.700	728.57	757.97	758.32	758.31	758.38	758.35	758.39	758.35	758.41	758.64	759.41	760.14	0.11	2.17
133.000	727.70	756.70	757.15	757.13	757.22	757.17	757.22	757.17	757.25	757.54	758.46	759.31	0.13	2.61
132.000	727.96	755.29	755.84	755.81	755.94	755.87	755.93	755.86	755.97	756.33	757.46	758.45	0.16	3.16
131.000	726.82	754.10	754.73	754.71	754.85	754.78	754.84	754.77	754.91	755.33	756.65	757.77	0.20	3.66
130.000	723.18	753.64	754.29	754.27	754.41	754.35	754.40	754.34	754.48	754.93	756.34	757.52	0.21	3.87
129.000	719.79	752.93	753.60	753.59	753.76	753.68	753.79	753.68	753.92	754.51	756.04	757.26	0.33	4.33
128.000	719.69	752.65	753.32	753.31	753.48	753.40	753.52	753.42	753.66	754.27	755.85	757.20	0.35	4.54
126.710	715.94	752.11	752.77	752.76	752.94	752.88	753.00	752.91	753.14	753.79	755.48	757.20	0.38	5.09
126.700	S 590 Road Bridge													
126.670	715.61	752.09	752.75	752.74	752.92	752.86	752.98	752.89	753.12	753.77	755.46	757.20	0.38	5.11
126.000	720.35	752.05	752.71	752.70	752.89	752.82	752.95	752.85	753.09	753.75	755.44	757.21	0.39	5.16
125.000	717.08	751.74	752.40	752.39	752.58	752.53	752.66	752.57	752.80	753.49	755.24	757.20	0.41	5.46
124.000	715.62	751.56	752.22	752.21	752.40	752.36	752.49	752.41	752.62	753.34	755.13	757.20	0.41	5.64
123.000	713.34	751.32	751.97	751.95	752.16	752.13	752.26	752.19	752.39	753.13	754.98	757.20	0.44	5.88
122.580	711.08	751.23	751.88	751.86	752.07	752.05	752.17	752.11	752.30	753.05	754.91	757.19	0.44	5.96
122.570	Highway 60 Bridge													
122.550	709.97	750.96	751.63	751.61	751.83	751.81	751.94	751.87	752.07	752.85	754.77	757.24	0.46	6.28
122.350	Spring River													
122.000	710.64	750.51	751.37	751.35	751.75	751.47	751.62	751.51	751.81	752.63	754.62	757.24	0.46	6.73
121.980	709.90	750.30	751.23	751.21	751.70	751.31	751.47	751.34	751.67	752.52	754.52	757.23	0.49	6.93
121.970	BN RR Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - OCT 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
121.960	710.89	750.20	751.19	751.13	751.67	751.23	751.39	751.24	751.60	752.44	754.36	757.25	0.54	7.05
120.000	717.63	748.31	750.87	751.00	751.39	750.43	750.59	750.63	750.74	752.34	753.94	757.24	0.96	8.93
118.000	720.29	747.87	750.71	750.98	751.25	750.26	750.42	750.46	750.34	752.32	753.74	757.22	0.99	9.35
116.000	725.99	747.69	750.63	750.97	751.18	750.22	750.33	750.37	750.30	752.32	753.67	757.19	0.96	9.50
114.000	718.27	747.48	750.50	750.95	751.06	750.19	750.20	750.23	750.27	752.30	753.60	757.17	0.87	9.69
112.000	714.31	747.47	750.43	750.94	751.00	750.18	750.17	750.15	750.26	752.29	753.55	757.14	0.85	9.67
110.000	719.24	747.47	750.40	750.94	750.97	750.17	750.17	750.12	750.26	752.29	753.54	757.11	0.85	9.64
108.000	710.68	747.47	750.36	750.93	750.94	750.17	750.16	750.10	750.25	752.28	753.52	757.09	0.84	9.62
106.000	700.35	747.46	750.35	750.93	750.93	750.17	750.16	750.10	750.25	752.28	753.51	757.06	0.83	9.60
105.350	Elk River													
105.000	701.60	747.46	750.35	750.93	750.93	750.17	750.16	750.10	750.25	752.28	753.51	757.06	0.83	9.60
104.000	696.61	747.46	750.34	750.92	750.92	750.17	750.16	750.10	750.25	752.28	753.51	757.05	0.82	9.59
102.000	688.58	747.46	750.33	750.92	750.91	750.16	750.16	750.10	750.25	752.28	753.51	757.02	0.82	9.56
101.750	685.91	747.46	750.33	750.92	750.91	750.16	750.16	750.10	750.24	752.27	753.51	757.02	0.82	9.56
101.730	Highway 59 (Sailboat Bridge)													
101.710	682.31	747.46	750.33	750.91	750.91	750.16	750.15	750.10	750.24	752.27	753.50	757.02	0.81	9.56
100.000	702.62	747.46	750.32	750.91	750.90	750.16	750.15	750.10	750.24	752.27	753.50	757.00	0.81	9.54
90.000	681.52	747.46	750.32	750.91	750.90	750.16	750.15	750.10	750.24	752.27	753.50	757.00	0.81	9.54
80.000	657.03	747.46	750.32	750.91	750.90	750.16	750.15	750.10	750.24	752.27	753.50	757.00	0.81	9.54
78.000	653.11	747.46	750.32	750.91	750.90	750.16	750.15	750.10	750.24	752.27	753.50	757.00	0.81	9.54
77.000	Pensacola Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.14**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - OCT 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
21.000	Upstream end of model													
21.000	762.67	790.77	790.77	790.77	790.77	790.77	790.77	790.77	790.77	790.77	790.77	790.77	0.00	0.00
20.000	760.13	788.92	788.92	788.92	788.92	788.92	788.92	788.92	788.92	788.92	788.92	788.92	0.00	0.00
19.000	759.04	785.68	785.68	785.68	785.68	785.68	785.68	785.68	785.68	785.68	785.68	785.68	0.00	0.00
18.000	753.18	782.60	782.60	782.60	782.60	782.60	782.60	782.60	782.60	782.60	782.60	782.60	0.00	0.00
17.000	750.54	780.53	780.53	780.53	780.53	780.53	780.53	780.53	780.53	780.53	780.53	780.54	0.00	0.01
16.000	749.28	778.12	778.12	778.12	778.12	778.12	778.12	778.12	778.12	778.12	778.12	778.13	0.00	0.01
15.000	746.37	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.16	775.18	0.00	0.02
14.170	741.32	772.80	772.81	772.81	772.81	772.81	772.81	772.81	772.81	772.81	772.82	772.84	0.00	0.04
14.160	E 57 Road													
14.120	744.21	773.22	773.22	773.22	773.22	773.22	773.22	773.22	773.22	773.22	773.23	773.25	0.00	0.03
13.510	744.59	772.08	772.08	772.08	772.08	772.08	772.08	772.08	772.08	772.08	772.09	772.12	0.00	0.04
13.500	Interstate 44 Bridge													
13.450	745.52	771.61	771.61	771.61	771.61	771.61	771.61	771.61	771.61	771.61	771.63	771.66	0.00	0.05
12.000	742.72	767.89	767.89	767.89	767.89	767.89	767.89	767.89	767.89	767.90	767.93	767.99	0.00	0.10
11.000	742.23	765.97	765.98	765.98	765.98	765.98	765.98	765.99	765.99	765.99	766.04	766.16	0.01	0.19
10.000	737.62	764.45	764.46	764.46	764.46	764.46	764.47	764.47	764.47	764.48	764.56	764.75	0.01	0.30
9.000	733.92	762.26	762.28	762.28	762.28	762.29	762.30	762.30	762.31	762.32	762.46	762.79	0.03	0.54
8.020	733.14	760.73	760.75	760.76	760.76	760.78	760.78	760.79	760.80	760.82	761.04	761.55	0.05	0.82
8.010	OK Highway 10 Bridge													
7.970	731.28	759.41	759.44	759.45	759.45	759.47	759.49	759.49	759.50	759.53	759.80	760.43	0.06	1.02
7.000	730.33	756.98	757.04	757.06	757.06	757.12	757.15	757.16	757.17	757.23	757.74	758.81	0.12	1.83
6.000	727.95	755.40	755.50	755.52	755.52	755.63	755.68	755.69	755.70	755.80	756.60	758.01	0.20	2.61
5.000	722.10	754.09	754.24	754.27	754.28	754.45	754.51	754.51	754.54	754.69	755.78	757.42	0.29	3.34
4.000	720.00	753.26	753.46	753.50	753.51	753.71	753.79	753.79	753.83	754.03	755.44	757.25	0.37	3.99
3.000	723.22	752.50	752.76	752.81	752.82	753.05	753.14	753.13	753.19	753.51	755.23	757.25	0.43	4.76
2.000	723.73	751.87	752.22	752.28	752.32	752.54	752.64	752.62	752.71	753.26	755.08	757.25	0.49	5.38
1.000	728.44	751.40	751.91	751.91	752.10	752.17	752.29	752.24	752.39	753.09	754.96	757.25	0.48	5.85
0.580	716.17	750.97	751.70	751.68	751.90	751.84	751.97	751.89	752.13	752.91	754.83	757.24	0.45	6.27
0.570	Highway 60 Bridge													
0.560	713.76	750.92	751.66	751.65	751.88	751.80	751.93	751.84	752.10	752.88	754.80	757.24	0.45	6.32
0.460	715.35	750.95	751.69	751.67	751.89	751.83	751.96	751.88	752.12	752.90	754.82	757.24	0.45	6.29
0.000	Downstream end of Spring River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.15**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - OCT 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
19.590	Upstream end of model													
19.590	771.15	793.77	793.77	793.77	793.77	793.77	793.77	793.77	793.77	793.77	793.77	793.77	0.00	0.00
19.000	767.51	791.13	791.13	791.13	791.13	791.13	791.13	791.13	791.13	791.13	791.13	791.13	0.00	0.00
18.000	765.41	787.17	787.17	787.17	787.17	787.17	787.17	787.17	787.17	787.17	787.17	787.17	0.00	0.00
17.000	762.53	783.91	783.91	783.91	783.91	783.91	783.91	783.91	783.91	783.91	783.91	783.91	0.00	0.00
16.000	756.63	779.22	779.22	779.22	779.22	779.22	779.22	779.22	779.22	779.22	779.22	779.22	0.00	0.00
15.000	754.26	775.00	775.00	775.00	775.00	775.00	775.00	775.00	775.00	775.00	775.00	775.00	0.00	0.00
14.240	750.52	771.70	771.70	771.70	771.70	771.70	771.70	771.70	771.70	771.70	771.70	771.70	0.00	0.00
14.220	Highway 43 Bridge													
14.200	750.12	771.20	771.20	771.20	771.20	771.20	771.20	771.20	771.20	771.20	771.20	771.20	0.00	0.00
14.000	747.07	770.02	770.02	770.02	770.02	770.02	770.02	770.02	770.02	770.02	770.02	770.02	0.00	0.00
13.000	745.41	764.84	764.84	764.84	764.84	764.84	764.84	764.84	764.84	764.84	764.84	764.85	0.00	0.01
12.000	741.15	761.15	761.15	761.15	761.15	761.15	761.15	761.15	761.15	761.15	761.17	761.22	0.00	0.07
11.910	OK/MO State Line													
11.000	741.93	755.16	755.17	755.17	755.17	755.17	755.17	755.18	755.18	755.21	755.44	757.14	0.01	1.98
10.000	734.62	750.86	750.88	751.07	751.09	750.89	750.91	750.93	750.96	752.30	753.53	757.13	0.21	6.27
9.000	734.66	747.82	750.40	750.95	750.97	750.18	750.17	750.11	750.26	752.30	753.52	757.13	0.86	9.31
8.000	724.21	747.47	750.39	750.95	750.97	750.17	750.17	750.11	750.26	752.29	753.52	757.12	0.86	9.65
7.000	728.21	747.47	750.38	750.94	750.96	750.17	750.17	750.11	750.26	752.29	753.52	757.11	0.85	9.64
6.000	727.13	747.47	750.38	750.94	750.96	750.17	750.17	750.11	750.26	752.29	753.52	757.11	0.85	9.64
5.000	721.05	747.47	750.37	750.94	750.95	750.17	750.16	750.11	750.26	752.29	753.52	757.10	0.84	9.63
4.700	716.13	747.47	750.37	750.94	750.95	750.17	750.16	750.11	750.26	752.29	753.52	757.10	0.84	9.63
4.670	OK Highway 10 Bridge													
4.640	715.21	747.47	750.37	750.94	750.95	750.17	750.16	750.11	750.25	752.29	753.52	757.10	0.84	9.63
4.000	716.61	747.47	750.37	750.94	750.94	750.17	750.16	750.11	750.25	752.29	753.52	757.09	0.83	9.62
3.000	714.74	747.46	750.36	750.93	750.94	750.17	750.16	750.10	750.25	752.28	753.52	757.08	0.84	9.62
2.000	709.09	747.46	750.36	750.93	750.94	750.17	750.16	750.10	750.25	752.28	753.52	757.08	0.84	9.62
1.000	705.82	747.46	750.35	750.93	750.93	750.17	750.16	750.10	750.25	752.28	753.51	757.07	0.83	9.61
0.320	706.36	747.46	750.35	750.93	750.93	750.17	750.16	750.10	750.25	752.28	753.51	757.06	0.83	9.60
0.000	Downstream end of Elk River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.16**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - OCT 2009 (3 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
4.152	Upstream end of model													
4.152	762.17	775.04	775.04	775.04	775.04	775.04	775.04	775.04	775.04	775.04	775.04	775.04	0.00	0.00
3.900	760.10	774.11	774.11	774.11	774.11	774.11	774.11	774.11	774.11	774.11	774.11	774.11	0.00	0.00
3.840	22nd Ave Bridge													
3.800	762.30	772.86	772.86	772.86	772.86	772.86	772.86	772.86	772.86	772.86	772.86	772.86	0.00	0.00
3.300	759.46	770.57	770.57	770.57	770.57	770.57	770.57	770.57	770.57	770.57	770.57	770.57	0.00	0.00
2.800	756.73	766.52	766.52	766.52	766.52	766.52	766.52	766.52	766.52	766.52	766.53	766.53	0.00	0.00
2.710	BN RR Bridge													
2.700	755.72	765.50	765.50	765.50	765.50	765.50	765.50	765.50	765.50	765.50	765.50	765.50	0.00	0.01
2.500	754.95	764.13	764.13	764.13	764.13	764.13	764.13	764.13	764.13	764.13	764.13	764.14	0.00	0.01
2.300	754.15	762.23	762.23	762.23	762.23	762.23	762.23	762.23	762.23	762.23	762.24	762.29	0.00	0.07
2.200	Rockdale Blvd Bridge													
2.100	751.51	759.49	759.50	759.50	759.50	759.50	759.50	759.51	759.51	759.54	759.74	760.43	0.01	0.94
1.900	750.02	758.40	758.72	758.71	758.77	758.75	758.78	758.75	758.81	759.01	759.73	760.43	0.10	2.03
1.700	749.58	758.40	758.72	758.71	758.77	758.75	758.78	758.75	758.81	759.01	759.73	760.43	0.10	2.03
1.660	Central Ave Bridge													
1.600	746.47	758.40	758.72	758.71	758.77	758.75	758.78	758.75	758.81	759.01	759.73	760.43	0.10	2.03
1.500	744.29	758.40	758.72	758.71	758.77	758.75	758.78	758.75	758.81	759.01	759.73	760.43	0.10	2.03
1.400	OK Highway 10 Bridge													
1.300	742.00	758.40	758.72	758.71	758.77	758.75	758.78	758.75	758.81	759.01	759.73	760.43	0.10	2.03
1.000	739.34	758.40	758.72	758.71	758.77	758.75	758.78	758.75	758.81	759.01	759.73	760.43	0.10	2.03
0.700	737.06	758.40	758.72	758.71	758.77	758.75	758.78	758.75	758.81	759.01	759.73	760.43	0.10	2.03
0.300	736.42	758.41	758.73	758.72	758.78	758.75	758.79	758.75	758.81	759.02	759.74	760.44	0.10	2.03
0.041	735.85	758.39	758.71	758.70	758.77	758.74	758.78	758.74	758.80	759.01	759.72	760.42	0.10	2.03
0.000	Downstream end of Tar Creek													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX D.5:
DECEMBER 2015 (15 YEAR) INFLOW EVENT
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - DEC 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
152.175	Upstream end of model													
152.175	752.29	778.38	778.38	778.38	778.38	778.38	778.38	778.38	778.38	778.38	778.38	778.38	0.00	0.00
151.000	748.53	776.27	776.27	776.27	776.27	776.27	776.27	776.27	776.27	776.27	776.27	776.27	0.00	0.00
150.000	748.47	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	0.00	0.00
149.000	750.14	773.76	773.76	773.76	773.76	773.76	773.76	773.76	773.76	773.76	773.76	773.76	0.00	0.00
148.000	749.29	772.37	772.37	772.37	772.37	772.37	772.37	772.37	772.37	772.37	772.37	772.38	0.00	0.01
147.000	747.76	770.49	770.50	770.50	770.50	770.50	770.50	770.50	770.50	770.50	770.51	770.53	0.00	0.03
145.500	745.12	768.33	768.34	768.34	768.34	768.34	768.34	768.34	768.34	768.36	768.37	768.43	0.00	0.10
145.480	E 60 Road Bridge													
145.400	748.01	768.22	768.23	768.23	768.23	768.23	768.23	768.23	768.23	768.25	768.26	768.32	0.00	0.10
144.000	743.43	766.48	766.51	766.51	766.51	766.51	766.51	766.51	766.52	766.57	766.60	766.73	0.01	0.25
143.000	737.95	765.14	765.23	765.23	765.23	765.23	765.23	765.24	765.25	765.37	765.41	765.64	0.03	0.50
142.000	742.91	764.13	764.31	764.31	764.31	764.31	764.31	764.33	764.34	764.51	764.56	764.87	0.04	0.74
141.000	741.01	763.63	763.91	763.92	763.92	763.91	763.91	763.93	763.95	764.13	764.20	764.54	0.04	0.91
140.000	736.33	763.40	763.75	763.75	763.75	763.75	763.75	763.77	763.79	763.98	764.05	764.42	0.04	1.02
139.000	743.99	763.08	763.52	763.53	763.52	763.52	763.52	763.54	763.56	763.77	763.84	764.25	0.04	1.17
138.000	736.48	762.79	763.31	763.32	763.31	763.31	763.31	763.33	763.35	763.56	763.64	764.07	0.04	1.28
137.000	733.33	762.04	762.74	762.75	762.75	762.75	762.75	762.76	762.79	762.99	763.07	763.53	0.04	1.50
135.950	731.18	761.52	762.34	762.35	762.35	762.34	762.34	762.36	762.38	762.58	762.66	763.12	0.04	1.60
135.941	Highway 69 Bridge													
135.940	731.21	761.49	762.32	762.33	762.32	762.32	762.32	762.34	762.36	762.56	762.63	763.10	0.04	1.61
135.590	731.77	761.44	762.28	762.29	762.28	762.28	762.28	762.30	762.32	762.52	762.59	763.06	0.04	1.62
135.586	BN RR Bridge													
135.580	731.07	761.42	762.26	762.26	762.26	762.26	762.26	762.28	762.30	762.49	762.57	763.04	0.04	1.62
135.470	732.63	761.36	762.21	762.22	762.22	762.22	762.22	762.23	762.26	762.45	762.52	763.00	0.05	1.64
135.460	Highway 125 Bridge													
135.440	731.60	761.39	762.24	762.25	762.25	762.24	762.24	762.26	762.28	762.48	762.55	763.03	0.04	1.64
135.000	732.64	761.32	762.19	762.20	762.20	762.20	762.20	762.21	762.24	762.43	762.51	762.98	0.05	1.66

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - DEC 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
134.610	728.75	761.12	762.03	762.03	762.03	762.03	762.03	762.05	762.07	762.26	762.33	762.81	0.04	1.69
134.599	Abandonded RR Bridge													
134.595	728.58	760.96	761.91	761.91	761.91	761.91	761.91	761.93	761.95	762.13	762.20	762.68	0.04	1.72
134.000	727.23	760.55	761.59	761.60	761.59	761.59	761.59	761.61	761.63	761.80	761.87	762.37	0.04	1.82
133.973	Tar Creek													
133.900	727.72	760.37	761.45	761.46	761.46	761.45	761.45	761.48	761.49	761.66	761.73	762.23	0.04	1.86
133.800	Interstate 44 Bridge													
133.700	728.57	760.20	761.32	761.33	761.33	761.33	761.33	761.35	761.36	761.52	761.59	762.10	0.04	1.90
133.000	727.70	759.44	760.77	760.77	760.77	760.77	760.77	760.79	760.80	760.94	761.01	761.56	0.03	2.12
132.000	727.96	758.64	760.20	760.20	760.20	760.20	760.20	760.21	760.23	760.34	760.40	761.01	0.03	2.37
131.000	726.82	758.01	759.76	759.76	759.76	759.76	759.76	759.77	759.78	759.87	759.93	760.63	0.02	2.62
130.000	723.18	757.78	759.61	759.61	759.61	759.61	759.61	759.61	759.62	759.70	759.76	760.45	0.01	2.67
129.000	719.79	757.54	759.46	759.46	759.46	759.46	759.46	759.46	759.48	759.54	759.60	760.30	0.02	2.77
128.000	719.69	757.40	759.38	759.38	759.38	759.38	759.38	759.38	759.39	759.44	759.49	760.23	0.02	2.82
126.710	715.94	757.13	759.22	759.22	759.22	759.22	759.22	759.22	759.23	759.25	759.31	760.07	0.01	2.94
126.700	S 590 Road Bridge													
126.670	715.61	757.12	759.20	759.20	759.20	759.20	759.20	759.20	759.21	759.23	759.28	760.06	0.01	2.94
126.000	720.35	757.10	759.18	759.17	759.17	759.17	759.17	759.17	759.18	759.21	759.27	760.03	0.01	2.94
125.000	717.08	756.94	759.09	759.08	759.08	759.08	759.08	759.08	759.09	759.09	759.16	759.94	0.01	3.00
124.000	715.62	756.86	759.04	759.04	759.04	759.04	759.04	759.04	759.05	759.04	759.11	759.90	0.01	3.04
123.000	713.34	756.76	758.97	758.97	758.97	758.97	758.97	758.97	758.98	758.95	759.00	759.82	0.01	3.07
122.580	711.08	756.69	758.93	758.93	758.93	758.93	758.93	758.93	758.94	758.90	758.95	759.78	0.01	3.09
122.570	Highway 60 Bridge													
122.550	709.97	756.62	758.92	758.92	758.92	758.92	758.92	758.92	758.93	758.89	758.94	759.77	0.01	3.15
122.350	Spring River													
122.000	710.64	756.04	758.41	758.41	758.41	758.41	758.41	758.41	758.42	758.41	758.44	759.17	0.01	3.13
121.980	709.90	755.77	758.18	758.18	758.18	758.18	758.18	758.18	758.19	758.19	758.23	758.92	0.01	3.15
121.970	BN RR Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - DEC 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
121.960	710.89	755.07	757.25	757.26	757.25	757.25	757.25	757.26	757.26	757.26	757.25	757.53	0.01	2.46
120.000	717.63	754.72	756.52	756.52	756.52	756.52	756.52	756.53	756.53	756.57	756.59	757.23	0.01	2.51
118.000	720.29	754.54	756.01	756.01	756.01	756.01	756.01	756.01	756.02	756.06	756.07	757.21	0.01	2.67
116.000	725.99	754.53	755.76	755.77	755.76	755.76	755.76	755.77	755.76	755.80	755.81	757.19	0.01	2.66
114.000	718.27	754.52	755.34	755.35	755.35	755.35	755.34	755.36	755.39	755.38	755.39	757.17	0.05	2.64
112.000	714.31	754.52	755.15	755.16	755.16	755.16	755.16	755.19	755.20	755.17	755.17	757.14	0.05	2.62
110.000	719.24	754.52	755.06	755.08	755.08	755.07	755.07	755.10	755.09	755.06	755.06	757.11	0.04	2.59
108.000	710.68	754.52	754.97	754.98	754.98	754.98	754.98	754.97	754.95	754.92	754.92	757.09	0.03	2.57
106.000	700.35	754.52	754.95	754.94	754.95	754.95	754.95	754.94	754.93	754.90	754.90	757.06	0.02	2.54
105.350	Elk River													
105.000	701.60	754.52	754.94	754.94	754.94	754.94	754.94	754.94	754.93	754.90	754.90	757.06	0.02	2.54
104.000	696.61	754.52	754.93	754.92	754.92	754.92	754.92	754.92	754.92	754.89	754.89	757.05	0.01	2.53
102.000	688.58	754.51	754.88	754.88	754.88	754.88	754.88	754.88	754.88	754.87	754.87	757.02	0.00	2.51
101.750	685.91	754.51	754.87	754.87	754.87	754.87	754.87	754.87	754.87	754.86	754.86	757.02	0.00	2.51
101.730	Highway 59 (Sailboat Bridge)													
101.710	682.31	754.51	754.86	754.86	754.86	754.86	754.86	754.86	754.86	754.84	754.84	757.02	0.00	2.51
100.000	702.62	754.51	754.84	754.84	754.84	754.84	754.84	754.84	754.84	754.84	754.84	757.00	0.00	2.49
90.000	681.52	754.51	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	754.83	757.00	0.00	2.49
80.000	657.03	754.51	754.82	754.82	754.82	754.82	754.82	754.82	754.82	754.82	754.82	757.00	0.00	2.49
78.000	653.11	754.51	754.82	754.82	754.82	754.82	754.82	754.82	754.82	754.82	754.82	757.00	0.00	2.49
77.000	Pensacola Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.18**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - DEC 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
21.000	Upstream end of model													
21.000	762.67	800.70	800.69	800.69	800.69	800.69	800.69	800.69	800.69	800.69	800.68	800.66	0.00	0.04
20.000	760.13	799.50	799.50	799.50	799.50	799.50	799.50	799.50	799.50	799.50	799.50	799.51	0.00	0.01
19.000	759.04	797.69	797.69	797.69	797.69	797.69	797.69	797.69	797.69	797.69	797.69	797.69	0.00	0.00
18.000	753.18	795.45	795.45	795.45	795.45	795.45	795.45	795.45	795.45	795.45	795.45	795.45	0.00	0.00
17.000	750.54	793.52	793.52	793.52	793.52	793.52	793.52	793.52	793.52	793.51	793.51	793.51	0.00	0.01
16.000	749.28	790.74	790.74	790.74	790.74	790.74	790.74	790.74	790.74	790.74	790.74	790.74	0.00	0.00
15.000	746.37	788.26	788.26	788.26	788.26	788.26	788.26	788.26	788.26	788.26	788.26	788.26	0.00	0.00
14.170	741.32	785.82	785.82	785.82	785.82	785.82	785.82	785.82	785.82	785.82	785.82	785.82	0.00	0.00
14.160	E 57 Road													
14.120	744.21	784.98	784.97	784.97	784.97	784.97	784.97	784.97	784.97	784.96	784.95	784.95	0.00	0.03
13.510	744.59	783.35	783.33	783.32	783.32	783.32	783.32	783.32	783.32	783.29	783.27	783.19	0.01	0.16
13.500	Interstate 44 Bridge													
13.450	745.52	782.65	782.64	782.64	782.63	782.64	782.64	782.64	782.63	782.57	782.56	782.46	0.01	0.19
12.000	742.72	777.95	777.94	777.94	777.94	777.94	777.94	777.94	777.93	777.91	777.90	777.84	0.01	0.11
11.000	742.23	776.26	776.26	776.26	776.26	776.26	776.26	776.26	776.26	776.25	776.25	776.24	0.00	0.02
10.000	737.62	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.15	775.14	0.00	0.00
9.000	733.92	773.56	773.56	773.56	773.56	773.56	773.56	773.56	773.56	773.55	773.54	773.53	0.00	0.02
8.020	733.14	772.72	772.72	772.72	772.72	772.72	772.72	772.72	772.72	772.87	772.87	772.87	0.00	0.15
8.010	OK Highway 10 Bridge													
7.970	731.28	767.78	767.85	767.86	767.86	767.85	767.85	767.87	767.89	768.05	768.09	768.36	0.04	0.58
7.000	730.33	765.08	765.23	765.24	765.24	765.23	765.23	765.26	765.30	765.58	765.66	766.09	0.07	1.02
6.000	727.95	763.48	763.70	763.72	763.71	763.71	763.71	763.75	763.81	764.18	764.27	764.83	0.10	1.36
5.000	722.10	761.95	762.29	762.31	762.30	762.30	762.30	762.35	762.41	762.88	763.00	763.68	0.12	1.73
4.000	720.00	760.88	761.34	761.37	761.36	761.35	761.35	761.41	761.48	762.01	762.15	762.92	0.13	2.03
3.000	723.22	759.52	760.33	760.34	760.33	760.33	760.33	760.34	760.35	760.92	761.06	761.93	0.02	2.42
2.000	723.73	758.53	759.86	759.87	759.86	759.86	759.86	759.87	759.88	760.19	760.35	761.27	0.02	2.74
1.000	728.44	757.63	759.45	759.45	759.45	759.45	759.45	759.45	759.46	759.61	759.76	760.64	0.01	3.01
0.580	716.17	756.47	758.73	758.72	758.72	758.72	758.72	758.72	758.73	758.73	758.74	759.55	0.01	3.08
0.570	Highway 60 Bridge													
0.560	713.76	756.34	758.58	758.58	758.58	758.58	758.58	758.59	758.59	758.61	758.60	759.33	0.01	2.99
0.460	715.35	756.51	758.79	758.78	758.78	758.78	758.78	758.78	758.79	758.79	758.81	759.61	0.01	3.10
0.000	Downstream end of Spring River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.19**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - DEC 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
19.590	Upstream end of model													
19.590	771.15	800.12	800.12	800.12	800.12	800.12	800.12	800.12	800.12	800.12	800.12	800.12	0.00	0.00
19.000	767.51	797.92	797.92	797.92	797.92	797.92	797.92	797.92	797.92	797.92	797.92	797.92	0.00	0.00
18.000	765.41	794.01	794.01	794.01	794.01	794.01	794.01	794.01	794.01	794.01	794.01	794.01	0.00	0.00
17.000	762.53	790.87	790.87	790.87	790.87	790.87	790.87	790.87	790.87	790.87	790.87	790.87	0.00	0.00
16.000	756.63	786.22	786.22	786.22	786.22	786.22	786.22	786.22	786.22	786.22	786.22	786.22	0.00	0.00
15.000	754.26	782.38	782.38	782.38	782.38	782.38	782.38	782.38	782.38	782.38	782.38	782.38	0.00	0.00
14.240	750.52	779.28	779.28	779.28	779.28	779.28	779.28	779.28	779.28	779.28	779.28	779.28	0.00	0.00
14.220	Highway 43 Bridge													
14.200	750.12	776.85	776.85	776.85	776.85	776.85	776.85	776.85	776.85	776.85	776.85	776.85	0.00	0.00
14.000	747.07	775.82	775.82	775.82	775.82	775.82	775.82	775.82	775.82	775.82	775.82	775.82	0.00	0.00
13.000	745.41	769.73	769.73	769.73	769.73	769.73	769.73	769.73	769.73	769.73	769.73	769.74	0.00	0.01
12.000	741.15	765.85	765.86	765.86	765.86	765.86	765.86	765.86	765.86	765.86	765.86	765.89	0.00	0.04
11.910	OK/MO State Line													
11.000	741.93	760.17	760.18	760.18	760.18	760.18	760.18	760.18	760.18	760.23	760.30	760.62	0.00	0.45
10.000	734.62	756.33	756.38	756.38	756.38	756.38	756.38	756.39	756.41	756.61	756.84	757.78	0.03	1.45
9.000	734.66	754.53	755.08	755.06	755.07	755.06	755.06	755.02	755.07	754.98	754.97	757.12	0.06	2.59
8.000	724.21	754.53	755.05	755.04	755.05	755.04	755.04	755.00	755.04	754.96	754.95	757.11	0.05	2.58
7.000	728.21	754.53	755.04	755.03	755.03	755.03	755.03	755.00	755.02	754.95	754.94	757.11	0.04	2.58
6.000	727.13	754.53	755.04	755.02	755.03	755.03	755.03	754.99	755.01	754.95	754.94	757.10	0.05	2.57
5.000	721.05	754.53	755.02	755.01	755.02	755.01	755.01	754.99	754.99	754.94	754.93	757.10	0.03	2.57
4.700	716.13	754.52	755.01	755.00	755.01	755.01	755.01	754.98	754.98	754.93	754.93	757.09	0.03	2.57
4.670	OK Highway 10 Bridge													
4.640	715.21	754.52	755.01	755.00	755.01	755.01	755.01	754.98	754.98	754.93	754.92	757.09	0.03	2.57
4.000	716.61	754.52	755.00	754.99	755.00	755.00	755.00	754.98	754.97	754.93	754.92	757.09	0.03	2.57
3.000	714.74	754.52	754.99	754.98	754.99	754.98	754.98	754.97	754.96	754.92	754.91	757.08	0.03	2.56
2.000	709.09	754.52	754.98	754.97	754.97	754.97	754.97	754.96	754.95	754.91	754.91	757.07	0.03	2.55
1.000	705.82	754.52	754.96	754.95	754.96	754.96	754.96	754.95	754.94	754.91	754.90	757.07	0.02	2.55
0.320	706.36	754.52	754.95	754.94	754.95	754.95	754.95	754.94	754.93	754.90	754.90	757.06	0.02	2.54
0.000	Downstream end of Elk River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.20**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - DEC 2015 (15 YEAR) EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
4.152	Upstream end of model													
4.152	762.17	775.09	775.09	775.09	775.09	775.09	775.09	775.09	775.09	775.09	775.09	775.09	0.00	0.00
3.900	760.10	774.16	774.16	774.16	774.16	774.16	774.16	774.16	774.16	774.16	774.16	774.16	0.00	0.00
3.840	22nd Ave Bridge													
3.800	762.30	772.90	772.90	772.90	772.90	772.90	772.90	772.90	772.90	772.90	772.90	772.90	0.00	0.00
3.300	759.46	770.62	770.62	770.62	770.62	770.62	770.62	770.62	770.62	770.62	770.62	770.62	0.00	0.00
2.800	756.73	766.58	766.58	766.58	766.58	766.58	766.58	766.58	766.58	766.58	766.59	766.59	0.00	0.00
2.710	BN RR Bridge													
2.700	755.72	765.54	765.54	765.54	765.54	765.54	765.54	765.54	765.54	765.54	765.54	765.54	0.00	0.01
2.500	754.95	764.16	764.16	764.16	764.16	764.16	764.16	764.16	764.16	764.16	764.17	764.18	0.00	0.02
2.300	754.15	762.23	762.24	762.24	762.24	762.24	762.24	762.24	762.24	762.25	762.33	762.45	0.00	0.22
2.200	Rockdale Blvd Bridge													
2.100	751.51	760.47	761.53	761.54	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
1.900	750.02	760.47	761.53	761.54	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
1.700	749.58	760.47	761.53	761.53	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
1.660	Central Ave Bridge													
1.600	746.47	760.47	761.53	761.53	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
1.500	744.29	760.47	761.53	761.53	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
1.400	OK Highway 10 Bridge													
1.300	742.00	760.47	761.53	761.53	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
1.000	739.34	760.47	761.53	761.53	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
0.700	737.06	760.47	761.53	761.53	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
0.300	736.42	760.47	761.53	761.54	761.53	761.53	761.53	761.55	761.57	761.74	761.81	762.31	0.04	1.84
0.041	735.85	760.46	761.52	761.53	761.53	761.52	761.52	761.54	761.56	761.73	761.80	762.30	0.04	1.84
0.000	Downstream end of Tar Creek													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX D.6:
100-YEAR EVENT
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
152.175	Upstream end of model													
152.175	752.29	791.90	791.91	791.91	791.91	791.91	791.91	791.91	791.91	791.92	791.92	791.93	0.00	0.02
151.000	748.53	788.12	788.13	788.13	788.13	788.13	788.13	788.13	788.13	788.14	788.15	788.16	0.01	0.05
150.000	748.47	787.42	787.44	787.43	787.43	787.44	787.44	787.44	787.44	787.45	787.46	787.47	0.01	0.05
149.000	750.14	786.89	786.91	786.90	786.91	786.91	786.91	786.91	786.91	786.93	786.93	786.95	0.01	0.06
148.000	749.29	786.82	786.84	786.83	786.83	786.84	786.84	786.84	786.84	786.85	786.86	786.88	0.01	0.06
147.000	747.76	786.45	786.47	786.46	786.47	786.47	786.47	786.47	786.47	786.49	786.49	786.51	0.01	0.05
145.500	745.12	786.21	786.23	786.22	786.22	786.23	786.23	786.23	786.23	786.24	786.25	786.27	0.01	0.06
145.480	E 60 Road Bridge													
145.400	748.01	786.19	786.21	786.20	786.20	786.20	786.20	786.21	786.20	786.22	786.22	786.24	0.01	0.06
144.000	743.43	785.80	785.82	785.81	785.81	785.82	785.82	785.82	785.81	785.83	785.84	785.85	0.01	0.06
143.000	737.95	785.60	785.62	785.61	785.62	785.62	785.62	785.62	785.62	785.64	785.64	785.66	0.01	0.06
142.000	742.91	785.44	785.46	785.45	785.45	785.46	785.46	785.46	785.45	785.47	785.48	785.50	0.01	0.06
141.000	741.01	785.31	785.33	785.32	785.32	785.33	785.33	785.33	785.32	785.34	785.35	785.37	0.01	0.06
140.000	736.33	785.27	785.29	785.28	785.28	785.28	785.28	785.29	785.28	785.30	785.31	785.32	0.01	0.06
139.000	743.99	785.23	785.25	785.24	785.24	785.24	785.24	785.25	785.24	785.26	785.26	785.28	0.01	0.06
138.000	736.48	785.16	785.18	785.17	785.17	785.18	785.18	785.18	785.18	785.19	785.20	785.22	0.01	0.06
137.000	733.33	785.02	785.04	785.03	785.03	785.04	785.04	785.04	785.03	785.05	785.06	785.08	0.01	0.06
135.950	731.18	784.61	784.63	784.62	784.62	784.63	784.63	784.63	784.62	784.64	784.65	784.67	0.01	0.06
135.941	Highway 69 Bridge													
135.940	731.21	784.50	784.52	784.51	784.51	784.52	784.52	784.52	784.51	784.53	784.54	784.56	0.01	0.06
135.590	731.77	784.39	784.41	784.40	784.41	784.41	784.41	784.41	784.41	784.43	784.43	784.45	0.01	0.06
135.586	BN RR Bridge													
135.580	731.07	784.26	784.28	784.27	784.27	784.27	784.27	784.28	784.27	784.29	784.30	784.31	0.01	0.05
135.470	732.63	784.19	784.21	784.20	784.20	784.21	784.21	784.21	784.21	784.22	784.23	784.25	0.01	0.06
135.460	Highway 125 Bridge													
135.440	731.60	784.24	784.26	784.25	784.25	784.25	784.25	784.26	784.25	784.27	784.27	784.29	0.01	0.05
135.000	732.64	784.03	784.05	784.04	784.04	784.04	784.04	784.05	784.04	784.06	784.06	784.08	0.01	0.05

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
134.610	728.75	783.79	783.81	783.80	783.81	783.81	783.81	783.81	783.81	783.83	783.83	783.85	0.01	0.06
134.599	Abandonded RR Bridge													
134.595	728.58	783.59	783.61	783.60	783.61	783.61	783.61	783.61	783.61	783.63	783.63	783.65	0.01	0.06
134.000	727.23	783.17	783.19	783.18	783.18	783.18	783.18	783.19	783.18	783.20	783.20	783.22	0.01	0.06
133.973	Tar Creek													
133.900	727.72	782.61	782.63	782.62	782.63	782.63	782.63	782.63	782.63	782.65	782.65	782.67	0.01	0.06
133.800	Interstate 44 Bridge													
133.700	728.57	781.92	781.94	781.93	781.94	781.94	781.94	781.94	781.94	781.96	781.96	781.98	0.01	0.06
133.000	727.70	781.10	781.12	781.11	781.12	781.12	781.12	781.12	781.12	781.14	781.14	781.16	0.01	0.06
132.000	727.96	779.46	779.48	779.47	779.47	779.48	779.48	779.48	779.48	779.50	779.50	779.52	0.01	0.06
131.000	726.82	777.63	777.65	777.64	777.64	777.65	777.65	777.65	777.65	777.66	777.67	777.69	0.01	0.06
130.000	723.18	776.29	776.31	776.30	776.30	776.31	776.31	776.31	776.30	776.32	776.33	776.35	0.01	0.06
129.000	719.79	775.16	775.18	775.17	775.17	775.18	775.18	775.18	775.18	775.19	775.20	775.22	0.01	0.06
128.000	719.69	774.10	774.12	774.11	774.12	774.12	774.12	774.12	774.12	774.14	774.14	774.16	0.01	0.06
126.710	715.94	772.60	772.62	772.61	772.61	772.62	772.62	772.62	772.62	772.64	772.64	772.66	0.01	0.06
126.700	S 590 Road Bridge													
126.670	715.61	772.24	772.26	772.25	772.25	772.26	772.26	772.26	772.26	772.27	772.28	772.30	0.01	0.06
126.000	720.35	771.56	771.58	771.57	771.58	771.58	771.58	771.58	771.58	771.60	771.60	771.62	0.01	0.06
125.000	717.08	769.64	769.66	769.65	769.65	769.66	769.66	769.66	769.66	769.67	769.68	769.70	0.01	0.05
124.000	715.62	767.95	767.97	767.96	767.96	767.97	767.97	767.97	767.96	767.98	767.99	768.01	0.01	0.06
123.000	713.34	765.51	765.52	765.51	765.51	765.52	765.52	765.52	765.51	765.53	765.54	765.56	0.01	0.05
122.580	711.08	762.55	762.55	762.55	762.55	762.55	762.55	762.55	762.55	762.55	762.55	762.55	0.00	0.00
122.570	Highway 60 Bridge													
122.550	709.97	762.32	762.37	762.35	762.35	762.37	762.37	762.37	762.36	762.40	762.41	762.45	0.02	0.13
122.350	Spring River													
122.000	710.64	762.40	762.47	762.44	762.44	762.46	762.46	762.46	762.45	762.51	762.52	762.58	0.03	0.18
121.980	709.90	761.87	761.95	761.91	761.92	761.94	761.94	761.94	761.93	762.00	762.02	762.08	0.04	0.21
121.970	BN RR Bridge													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
121.960	710.89	761.16	761.17	761.17	761.17	761.17	761.17	761.17	761.17	761.18	761.19	761.20	0.00	0.04
120.000	717.63	759.87	759.88	759.87	759.87	759.87	759.87	759.88	759.87	759.88	759.88	759.89	0.00	0.03
118.000	720.29	758.57	758.58	758.57	758.57	758.57	758.57	758.57	758.57	758.58	758.58	758.59	0.00	0.02
116.000	725.99	757.93	757.93	757.93	757.93	757.93	757.93	757.93	757.93	757.94	757.94	757.94	0.00	0.01
114.000	718.27	756.68	756.68	756.68	756.68	756.68	756.68	756.68	756.68	756.68	756.68	757.00	0.00	0.33
112.000	714.31	756.01	756.01	756.01	756.01	756.01	756.01	756.01	756.01	756.01	756.01	757.00	0.00	0.99
110.000	719.24	755.66	755.66	755.66	755.66	755.66	755.66	755.66	755.66	755.66	755.66	757.00	0.00	1.34
108.000	710.68	755.19	755.17	755.18	755.17	755.17	755.17	755.17	755.17	755.16	755.16	757.00	0.01	1.84
106.000	700.35	755.13	755.11	755.12	755.12	755.11	755.11	755.11	755.12	755.11	755.10	757.00	0.01	1.90
105.350	Elk River													
105.000	701.60	755.14	755.13	755.13	755.13	755.13	755.13	755.13	755.13	755.13	755.12	757.00	0.01	1.88
104.000	696.61	755.12	755.11	755.11	755.11	755.11	755.11	755.11	755.11	755.11	755.11	757.00	0.00	1.89
102.000	688.58	755.07	755.06	755.06	755.06	755.06	755.06	755.06	755.06	755.06	755.06	757.00	0.00	1.94
101.750	685.91	755.03	755.02	755.02	755.02	755.02	755.02	755.02	755.02	755.02	755.02	757.00	0.00	1.98
101.730	Highway 59 (Sailboat Bridge)													
101.710	682.31	755.00	754.99	755.00	754.99	754.99	754.99	754.99	754.99	754.99	754.99	757.00	0.01	2.01
100.000	702.62	755.02	755.02	755.02	755.02	755.02	755.02	755.02	755.02	755.02	755.02	757.00	0.00	1.98
90.000	681.52	754.98	754.98	754.98	754.98	754.98	754.98	754.98	754.98	754.98	754.98	757.00	0.00	2.02
80.000	657.03	754.95	754.95	754.95	754.95	754.95	754.95	754.95	754.95	754.95	754.95	757.00	0.00	2.05
78.000	653.11	754.95	754.95	754.95	754.95	754.95	754.95	754.95	754.95	754.95	754.95	757.00	0.00	2.05
77.000	Pensacola Dam													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.22**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
21.000	Upstream end of model													
21.000	762.67	791.80	791.80	791.80	791.80	791.80	791.80	791.80	791.80	791.80	791.80	791.80	0.00	0.00
20.000	760.13	790.14	790.14	790.14	790.14	790.14	790.14	790.14	790.14	790.15	790.15	790.15	0.00	0.01
19.000	759.04	786.91	786.91	786.91	786.91	786.91	786.91	786.91	786.91	786.91	786.91	786.91	0.01	0.01
18.000	753.18	783.88	783.88	783.88	783.88	783.88	783.88	783.88	783.88	783.88	783.89	783.89	0.00	0.01
17.000	750.54	781.90	781.91	781.91	781.91	781.91	781.91	781.91	781.91	781.92	781.92	781.93	0.00	0.03
16.000	749.28	779.42	779.43	779.43	779.43	779.43	779.43	779.43	779.43	779.44	779.44	779.46	0.00	0.04
15.000	746.37	776.44	776.46	776.45	776.45	776.46	776.46	776.46	776.46	776.47	776.48	776.50	0.01	0.06
14.170	741.32	773.95	773.98	773.97	773.97	773.98	773.98	773.98	773.98	774.01	774.02	774.05	0.01	0.10
14.160	E 57 Road													
14.120	744.21	774.41	774.44	774.43	774.43	774.44	774.44	774.44	774.44	774.46	774.47	774.50	0.01	0.09
13.510	744.59	773.23	773.26	773.25	773.26	773.26	773.26	773.26	773.26	773.29	773.30	773.34	0.01	0.11
13.500	Interstate 44 Bridge													
13.450	745.52	772.71	772.74	772.73	772.74	772.75	772.75	772.74	772.75	772.78	772.79	772.83	0.02	0.12
12.000	742.72	768.85	768.96	768.91	768.92	768.96	768.96	768.93	768.94	769.06	769.09	769.15	0.05	0.30
11.000	742.23	767.46	767.59	767.53	767.55	767.59	767.59	767.57	767.57	767.68	767.70	767.76	0.06	0.29
10.000	737.62	766.63	766.68	766.66	766.67	766.68	766.68	766.67	766.67	766.73	766.75	766.80	0.02	0.17
9.000	733.92	765.63	765.67	765.65	765.66	765.67	765.67	765.67	765.67	765.70	765.71	765.73	0.02	0.10
8.020	733.14	765.18	765.22	765.20	765.21	765.22	765.22	765.22	765.21	765.25	765.26	765.29	0.02	0.11
8.010	OK Highway 10 Bridge													
7.970	731.28	764.51	764.56	764.54	764.54	764.55	764.55	764.55	764.55	764.58	764.59	764.63	0.02	0.12
7.000	730.33	764.20	764.25	764.23	764.23	764.24	764.24	764.24	764.24	764.27	764.28	764.32	0.02	0.12
6.000	727.95	764.08	764.12	764.10	764.11	764.12	764.12	764.12	764.11	764.15	764.16	764.19	0.02	0.12
5.000	722.10	763.99	764.03	764.01	764.02	764.03	764.03	764.03	764.02	764.06	764.07	764.10	0.02	0.12
4.000	720.00	763.94	763.98	763.96	763.97	763.98	763.98	763.98	763.97	764.01	764.02	764.05	0.02	0.11
3.000	723.22	763.88	763.92	763.90	763.91	763.92	763.92	763.92	763.91	763.95	763.96	764.00	0.02	0.12
2.000	723.73	763.84	763.89	763.87	763.87	763.88	763.88	763.88	763.88	763.91	763.92	763.96	0.02	0.12
1.000	728.44	763.81	763.86	763.83	763.84	763.85	763.85	763.85	763.84	763.88	763.89	763.93	0.03	0.12
0.580	716.17	763.74	763.78	763.76	763.77	763.78	763.78	763.78	763.77	763.81	763.82	763.86	0.02	0.12
0.570	Highway 60 Bridge													
0.560	713.76	763.71	763.76	763.74	763.74	763.75	763.75	763.75	763.75	763.79	763.80	763.83	0.02	0.12
0.460	715.35	763.73	763.77	763.75	763.76	763.77	763.77	763.77	763.76	763.80	763.81	763.85	0.02	0.12
0.000	Downstream end of Spring River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.23**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
19.590	Upstream end of model													
19.590	771.15	777.77	777.77	777.77	777.77	777.77	777.77	777.77	777.77	777.77	777.77	777.77	0.00	0.00
19.000	767.51	776.22	776.22	776.22	776.22	776.22	776.22	776.22	776.22	776.22	776.22	776.22	0.00	0.00
18.000	765.41	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	772.64	0.00	0.00
17.000	762.53	768.77	768.77	768.77	768.77	768.77	768.77	768.77	768.77	768.77	768.77	768.77	0.00	0.00
16.000	756.63	764.95	764.95	764.95	764.95	764.95	764.95	764.95	764.95	764.95	764.95	764.95	0.00	0.00
15.000	754.26	761.27	761.27	761.27	761.27	761.27	761.27	761.27	761.27	761.27	761.27	761.27	0.00	0.00
14.240	750.52	756.89	756.89	756.89	756.89	756.89	756.89	756.89	756.89	756.89	756.89	757.07	0.00	0.18
14.220	Highway 43 Bridge													
14.200	750.12	756.83	756.83	756.83	756.83	756.83	756.83	756.83	756.83	756.83	756.83	757.07	0.00	0.24
14.000	747.07	756.37	756.37	756.37	756.37	756.37	756.37	756.37	756.37	756.37	756.37	757.05	0.00	0.68
13.000	745.41	755.43	755.35	755.38	755.38	755.35	755.36	755.37	755.37	755.34	755.34	757.01	0.03	1.67
12.000	741.15	755.32	755.23	755.26	755.26	755.23	755.24	755.25	755.25	755.21	755.19	757.00	0.03	1.81
11.910	OK/MO State Line													
11.000	741.93	755.28	755.19	755.22	755.22	755.19	755.20	755.21	755.21	755.16	755.15	757.00	0.03	1.85
10.000	734.62	755.26	755.18	755.21	755.21	755.18	755.19	755.20	755.20	755.16	755.14	757.00	0.03	1.86
9.000	734.66	755.24	755.17	755.20	755.20	755.17	755.18	755.19	755.19	755.15	755.14	757.00	0.03	1.86
8.000	724.21	755.23	755.17	755.19	755.19	755.17	755.18	755.18	755.18	755.15	755.14	757.00	0.02	1.86
7.000	728.21	755.21	755.16	755.18	755.18	755.16	755.17	755.17	755.17	755.14	755.14	757.00	0.02	1.86
6.000	727.13	755.21	755.16	755.18	755.17	755.16	755.16	755.17	755.17	755.14	755.13	757.00	0.02	1.87
5.000	721.05	755.19	755.15	755.17	755.16	755.15	755.16	755.16	755.16	755.14	755.13	757.00	0.02	1.87
4.700	716.13	755.19	755.15	755.17	755.16	755.15	755.15	755.16	755.16	755.14	755.13	757.00	0.02	1.87
4.670	OK Highway 10 Bridge													
4.640	715.21	755.19	755.15	755.17	755.16	755.15	755.15	755.16	755.16	755.14	755.13	757.00	0.02	1.87
4.000	716.61	755.18	755.15	755.16	755.16	755.15	755.15	755.15	755.15	755.13	755.13	757.00	0.01	1.87
3.000	714.74	755.17	755.14	755.15	755.15	755.15	755.14	755.15	755.15	755.13	755.13	757.00	0.01	1.87
2.000	709.09	755.16	755.14	755.15	755.14	755.14	755.14	755.14	755.14	755.13	755.13	757.00	0.01	1.87
1.000	705.82	755.15	755.14	755.14	755.14	755.14	755.14	755.14	755.14	755.13	755.13	757.00	0.00	1.87
0.320	706.36	755.15	755.13	755.14	755.14	755.13	755.13	755.13	755.13	755.13	755.12	757.00	0.01	1.88
0.000	Downstream end of Elk River													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.

2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE D.24**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - 100-YEAR EVENT

River Mile	Bed El. (ft, PD)	Pensacola Dam Starting Stage (ft, PD)											Anticipated Operation Range WSE Difference[1] (ft)	Extreme, Hypothetical Range WSE Difference[2] (ft)
		El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)		
4.152	Upstream end of model													
4.152	762.17	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
3.900	760.10	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.65	0.01	0.06
3.840	22nd Ave Bridge													
3.800	762.30	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
3.300	759.46	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
2.800	756.73	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
2.710	BN RR Bridge													
2.700	755.72	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
2.500	754.95	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
2.300	754.15	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
2.200	Rockdale Blvd Bridge													
2.100	751.51	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
1.900	750.02	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
1.700	749.58	783.59	783.61	783.60	783.60	783.61	783.61	783.61	783.60	783.62	783.63	783.64	0.01	0.06
1.660	Central Ave Bridge													
1.600	746.47	783.59	783.61	783.60	783.60	783.60	783.60	783.61	783.60	783.62	783.62	783.64	0.01	0.06
1.500	744.29	783.58	783.60	783.59	783.60	783.60	783.60	783.60	783.60	783.62	783.62	783.64	0.01	0.06
1.400	OK Highway 10 Bridge													
1.300	742.00	783.56	783.58	783.57	783.58	783.58	783.58	783.58	783.58	783.60	783.60	783.62	0.01	0.06
1.000	739.34	783.52	783.54	783.53	783.53	783.54	783.54	783.54	783.53	783.55	783.56	783.58	0.01	0.06
0.700	737.06	783.48	783.50	783.49	783.49	783.49	783.49	783.50	783.49	783.51	783.51	783.53	0.01	0.06
0.300	736.42	783.25	783.27	783.26	783.26	783.27	783.27	783.27	783.26	783.28	783.29	783.30	0.01	0.06
0.041	735.85	783.04	783.07	783.06	783.06	783.06	783.06	783.06	783.06	783.08	783.08	783.10	0.01	0.06
0.000	Downstream end of Tar Creek													

1 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in Max WSEL from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX D.7:
HISTORICAL STARTING STAGE
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE D.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 (21 Year)	June 2004 (1 Year)	July 2007 (4 Year)	Oct 2009 (3 Year)	Dec 2015 (15 Year)	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
152.175	Upstream end of model						
152.175	752.29	780.71	773.79	784.43	778.47	778.38	10.65
151.000	748.53	777.94	772.52	780.33	776.35	776.27	7.81
150.000	748.47	776.66	771.82	778.90	775.17	775.15	7.09
149.000	750.14	775.12	770.44	777.46	773.78	773.76	7.01
148.000	749.29	774.25	768.76	777.09	772.40	772.37	8.33
147.000	747.76	772.72	766.94	776.23	770.52	770.50	9.29
145.500	745.12	771.64	764.71	775.74	768.34	768.33	11.03
145.480	E 60 Road Bridge						
145.400	748.01	771.57	764.61	775.70	768.23	768.23	11.09
144.000	743.43	770.58	763.34	775.11	766.46	766.51	11.77
143.000	737.95	770.12	762.18	774.84	765.01	765.23	12.65
142.000	742.91	769.77	761.27	774.61	763.83	764.31	13.34
141.000	741.01	769.63	760.11	774.48	763.18	763.91	14.37
140.000	736.33	769.58	758.78	774.44	762.84	763.74	15.66
139.000	743.99	769.54	756.78	774.41	762.33	763.52	17.63
138.000	736.48	769.46	755.40	774.34	761.90	763.31	18.94
137.000	733.33	769.15	753.43	774.13	760.86	762.74	20.70
135.950	731.18	768.45	752.84	773.49	760.19	762.34	20.65
135.941	Highway 69 Bridge						
135.940	731.21	768.45	752.62	773.51	760.15	762.32	20.89
135.590	731.77	768.30	752.67	773.34	760.09	762.28	20.67
135.586	BN RR Bridge						
135.580	731.07	768.12	752.71	773.27	760.07	762.25	20.56
135.470	732.63	768.07	752.60	773.20	759.98	762.21	20.60
135.460	Highway 125 Bridge						
135.440	731.60	768.10	752.65	773.24	760.02	762.24	20.59
135.000	732.64	767.83	752.37	772.92	759.90	762.19	20.55
134.610	728.75	767.33	752.21	772.46	759.64	762.03	20.25
134.599	Abandonded RR Bridge						
134.595	728.58	767.04	752.12	772.20	759.45	761.90	20.08
134.000	727.23	766.68	751.51	771.94	758.84	761.59	20.42
133.973	Tar Creek						
133.900	727.72	766.47	751.31	771.63	758.60	761.45	20.32

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 (21 Year)	June 2004 (1 Year)	July 2007 (4 Year)	Oct 2009 (3 Year)	Dec 2015 (15 Year)	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
133.800	Interstate 44 Bridge						
133.700	728.57	766.28	750.98	771.29	758.33	761.32	20.31
133.000	727.70	765.62	749.82	770.63	757.15	760.77	20.81
132.000	727.96	764.75	748.60	769.48	755.85	760.20	20.88
131.000	726.82	764.02	747.53	768.55	754.76	759.76	21.02
130.000	723.18	763.18	747.22	767.30	754.32	759.61	20.08
129.000	719.79	762.37	746.72	766.13	753.65	759.46	19.41
128.000	719.69	761.77	746.61	765.09	753.37	759.38	18.47
126.710	715.94	761.61	746.33	763.38	752.83	759.22	17.05
126.700	S 590 Road Bridge						
126.670	715.61	761.59	746.31	763.34	752.81	759.20	17.03
126.000	720.35	761.56	746.21	762.76	752.77	759.18	16.55
125.000	717.08	761.47	746.01	761.38	752.47	759.09	15.46
124.000	715.62	761.42	745.88	759.99	752.28	759.04	15.54
123.000	713.34	761.34	745.75	758.39	752.03	758.97	15.60
122.580	711.08	761.29	745.71	757.23	751.94	758.93	15.58
122.570	Highway 60 Bridge						
122.550	709.97	761.29	745.27	757.23	751.70	758.92	16.02
122.350	Spring River						
122.000	710.64	760.20	745.26	756.94	751.43	758.42	14.94
121.980	709.90	759.73	745.25	756.79	751.29	758.18	14.48
121.970	BN RR Bridge						
121.960	710.89	757.01	745.23	756.29	751.22	757.26	12.03
120.000	717.63	755.95	745.05	755.72	750.30	756.52	11.47
118.000	720.29	755.51	744.91	755.43	750.27	756.01	11.10
116.000	725.99	755.30	744.81	755.30	750.26	755.76	10.96
114.000	718.27	755.06	744.61	755.07	750.24	755.35	10.74
112.000	714.31	754.97	744.53	754.96	750.22	755.16	10.63
110.000	719.24	754.93	744.49	754.90	750.22	755.06	10.57
108.000	710.68	754.86	744.48	754.83	750.21	754.95	10.47
106.000	700.35	754.86	744.48	754.82	750.21	754.95	10.47
105.350	Elk River						
105.000	701.60	754.86	744.48	754.82	750.21	754.95	10.47
104.000	696.61	754.86	744.47	754.82	750.21	754.93	10.46

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 (21 Year)	June 2004 (1 Year)	July 2007 (4 Year)	Oct 2009 (3 Year)	Dec 2015 (15 Year)	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
102.000	688.58	754.85	744.47	754.81	750.21	754.89	10.42
101.750	685.91	754.85	744.47	754.81	750.20	754.88	10.41
101.730	Highway 59 (Sailboat Bridge)						
101.710	682.31	754.84	744.47	754.80	750.20	754.86	10.39
100.000	702.62	754.84	744.47	754.80	750.20	754.84	10.37
90.000	681.52	754.83	744.47	754.79	750.20	754.83	10.36
80.000	657.03	754.83	744.47	754.79	750.20	754.82	10.36
78.000	653.11	754.83	744.47	754.79	750.20	754.82	10.36
77.000	Pensacola Dam						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.26**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 (21 Year)	June 2004 (1 Year)	July 2007 (4 Year)	Oct 2009 (3 Year)	Dec 2015 (15 Year)	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
21.000	Upstream end of model						
21.000	762.67	805.10	773.88	783.49	790.77	800.69	31.22
20.000	760.13	804.41	771.04	780.70	788.92	799.50	33.37
19.000	759.04	803.09	768.52	777.52	785.68	797.69	34.58
18.000	753.18	800.93	764.57	774.20	782.60	795.45	36.37
17.000	750.54	799.10	762.75	772.20	780.53	793.52	36.34
16.000	749.28	796.17	760.34	770.00	778.12	790.74	35.83
15.000	746.37	794.15	758.33	767.51	775.15	788.26	35.81
14.170	741.32	791.71	757.46	765.96	772.81	785.82	34.25
14.160	E 57 Road						
14.120	744.21	789.81	757.49	766.18	773.22	784.97	32.32
13.510	744.59	786.79	756.84	765.30	772.08	783.33	29.95
13.500	Interstate 44 Bridge						
13.450	745.52	784.91	756.58	764.98	771.61	782.64	28.33
12.000	742.72	780.13	753.34	762.17	767.89	777.94	26.80
11.000	742.23	778.45	751.75	760.40	765.98	776.26	26.70
10.000	737.62	776.97	750.41	758.87	764.46	775.15	26.56
9.000	733.92	774.02	749.53	758.54	762.29	773.56	24.50
8.020	733.14	772.73	748.52	758.49	760.76	772.72	24.21
8.010	OK Highway 10 Bridge						
7.970	731.28	771.30	746.31	757.40	759.45	767.85	24.99
7.000	730.33	769.24	745.90	757.36	757.08	765.22	23.34
6.000	727.95	767.90	745.58	757.35	755.55	763.69	22.32
5.000	722.10	766.55	745.48	757.34	754.32	762.28	21.07
4.000	720.00	765.65	745.40	757.33	753.57	761.33	20.25
3.000	723.22	764.40	745.37	757.33	752.89	760.33	19.03
2.000	723.73	763.54	745.35	757.32	752.37	759.86	18.19
1.000	728.44	762.68	745.33	757.32	752.01	759.45	17.35
0.580	716.17	760.72	745.32	757.32	751.77	758.73	15.40
0.570	Highway 60 Bridge						
0.560	713.76	760.25	745.32	757.31	751.73	758.59	14.93
0.460	715.35	760.89	745.32	757.31	751.75	758.79	15.57
0.000	Downstream end of Spring River						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.27**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 (21 Year)	June 2004 (1 Year)	July 2007 (4 Year)	Oct 2009 (3 Year)	Dec 2015 (15 Year)	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
19.590	Upstream end of model						
19.590	771.15	787.52	774.17	775.57	793.77	800.12	25.95
19.000	767.51	785.42	772.64	774.03	791.13	797.92	25.28
18.000	765.41	781.77	769.18	770.46	787.17	794.01	24.83
17.000	762.53	777.78	766.13	767.01	783.91	790.87	24.74
16.000	756.63	773.42	761.16	762.78	779.22	786.22	25.06
15.000	754.26	769.55	757.92	759.23	775.00	782.38	24.46
14.240	750.52	766.33	753.18	755.51	771.70	779.28	26.10
14.220	Highway 43 Bridge						
14.200	750.12	766.08	753.10	755.48	771.20	776.85	23.75
14.000	747.07	764.91	752.78	755.33	770.02	775.82	23.04
13.000	745.41	760.77	749.01	754.92	764.84	769.73	20.72
12.000	741.15	757.41	746.01	754.87	761.15	765.86	19.85
11.910	OK/MO State Line						
11.000	741.93	754.89	744.91	754.86	755.17	760.18	15.27
10.000	734.62	754.87	744.49	754.85	750.88	756.37	11.88
9.000	734.66	754.87	744.49	754.85	750.23	755.09	10.60
8.000	724.21	754.87	744.48	754.84	750.22	755.06	10.58
7.000	728.21	754.87	744.48	754.84	750.22	755.04	10.56
6.000	727.13	754.86	744.48	754.84	750.22	755.04	10.56
5.000	721.05	754.86	744.48	754.83	750.22	755.02	10.54
4.700	716.13	754.86	744.48	754.83	750.22	755.01	10.53
4.670	OK Highway 10 Bridge						
4.640	715.21	754.86	744.48	754.83	750.22	755.01	10.53
4.000	716.61	754.86	744.48	754.83	750.21	755.00	10.52
3.000	714.74	754.86	744.48	754.83	750.21	754.99	10.51
2.000	709.09	754.86	744.48	754.83	750.21	754.97	10.49
1.000	705.82	754.86	744.48	754.82	750.21	754.96	10.48
0.320	706.36	754.86	744.48	754.82	750.21	754.95	10.47
0.000	Downstream end of Elk River						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

PENSACOLA DAM **TABLE D.28**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - HISTORICAL STARTING STAGES

River Mile	Bed El. (ft, PD)	Historical Inflow Event					Max WSEL Difference* (ft)
		Sept 1993 (21 Year)	June 2004 (1 Year)	July 2007 (4 Year)	Oct 2009 (3 Year)	Dec 2015 (15 Year)	
		Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	Max WSEL (ft, PD)	
4.152	Upstream end of model						
4.152	762.17	776.77	768.17	772.02	775.04	775.09	8.60
3.900	760.10	775.76	767.29	772.02	774.11	774.16	8.47
3.840	22nd Ave Bridge						
3.800	762.30	774.50	766.05	772.02	772.86	772.90	8.45
3.300	759.46	772.27	764.09	772.02	770.57	770.62	8.17
2.800	756.73	768.46	760.95	772.02	766.52	766.58	11.06
2.710	BN RR Bridge						
2.700	755.72	767.11	760.45	772.02	765.50	765.54	11.56
2.500	754.95	766.59	759.30	772.02	764.13	764.16	12.72
2.300	754.15	766.59	757.47	772.02	762.23	762.24	14.55
2.200	Rockdale Blvd Bridge						
2.100	751.51	766.59	754.84	772.02	759.50	761.53	17.18
1.900	750.02	766.59	753.22	772.02	758.73	761.53	18.80
1.700	749.58	766.59	751.46	772.02	758.73	761.53	20.56
1.660	Central Ave Bridge						
1.600	746.47	766.59	751.44	772.02	758.73	761.53	20.58
1.500	744.29	766.59	751.44	772.02	758.73	761.53	20.58
1.400	OK Highway 10 Bridge						
1.300	742.00	766.59	751.44	772.02	758.73	761.53	20.58
1.000	739.34	766.59	751.44	772.01	758.73	761.53	20.57
0.700	737.06	766.59	751.44	772.00	758.73	761.53	20.56
0.300	736.42	766.59	751.44	771.94	758.74	761.53	20.50
0.041	735.85	766.58	751.44	771.85	758.72	761.52	20.42
0.000	Downstream end of Tar Creek						

*Difference between the highest and lowest Max WSELs from the simulations with historical starting stages.

APPENDIX E:
WATER SURFACE ELEVATION PROFILES

APPENDIX E.1:
SEPTEMBER 1993 (21 YEAR) INFLOW EVENT
WATER SURFACE ELEVATION PROFILES

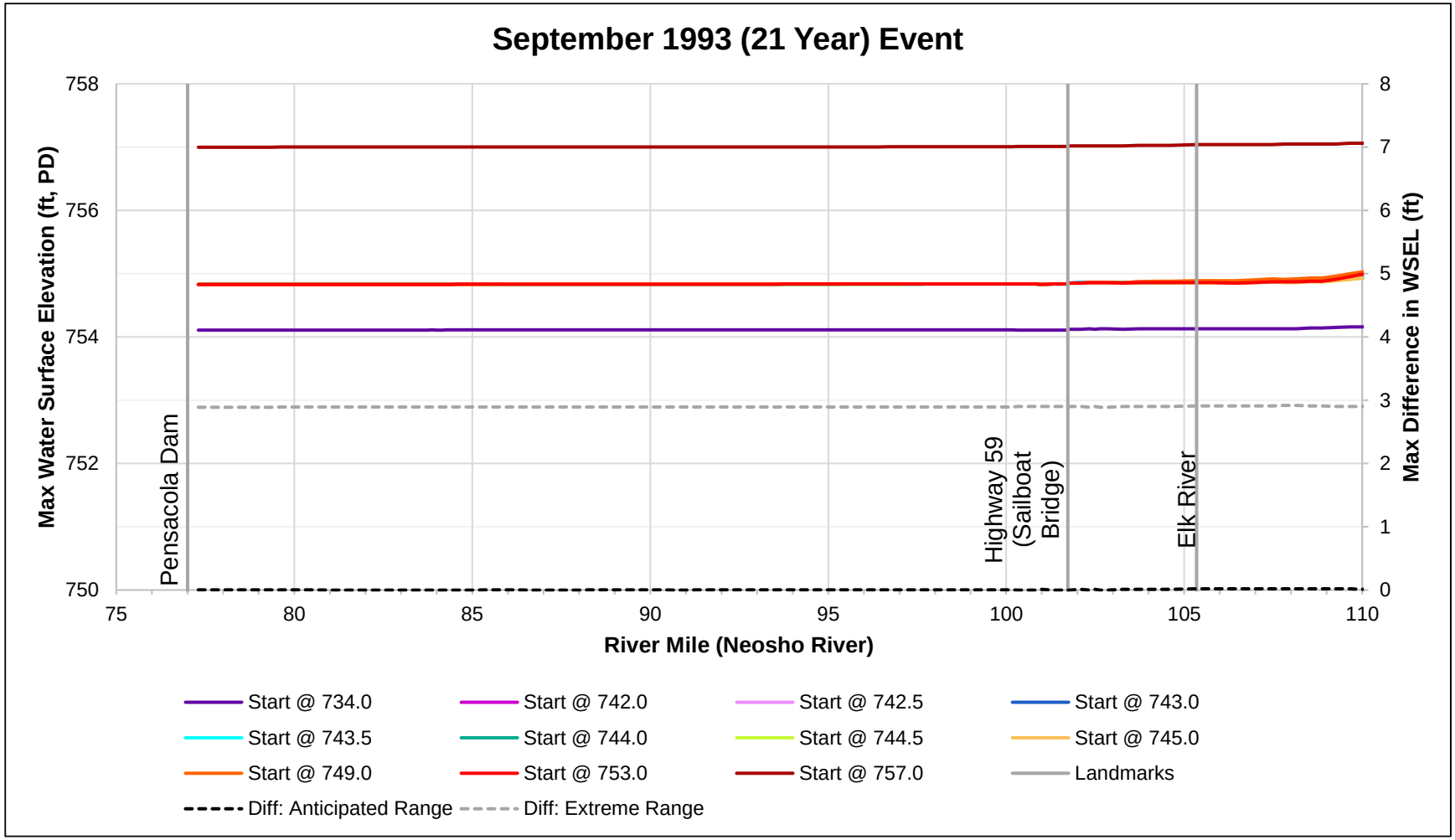


Figure E.1. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

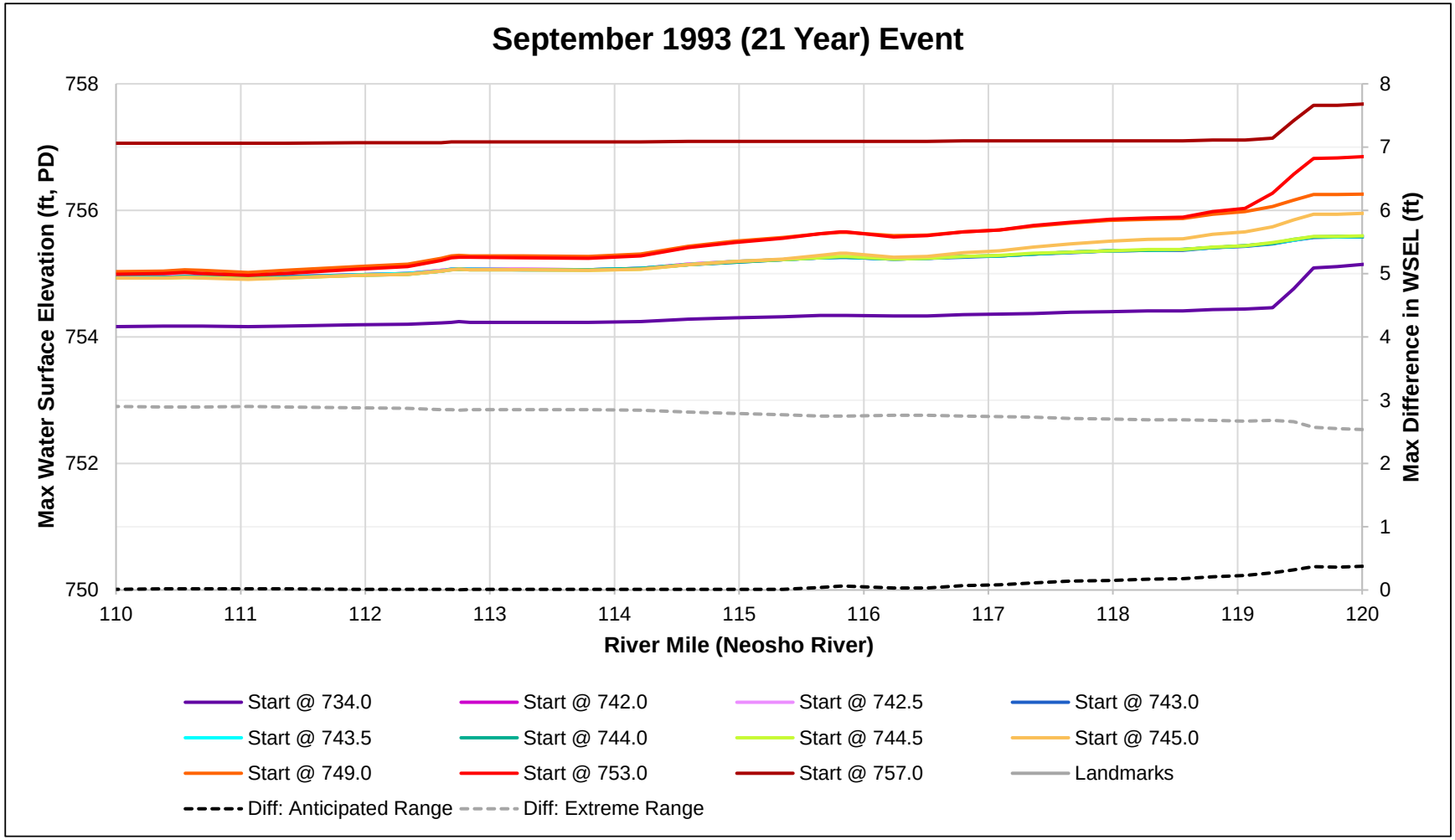


Figure E.2. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

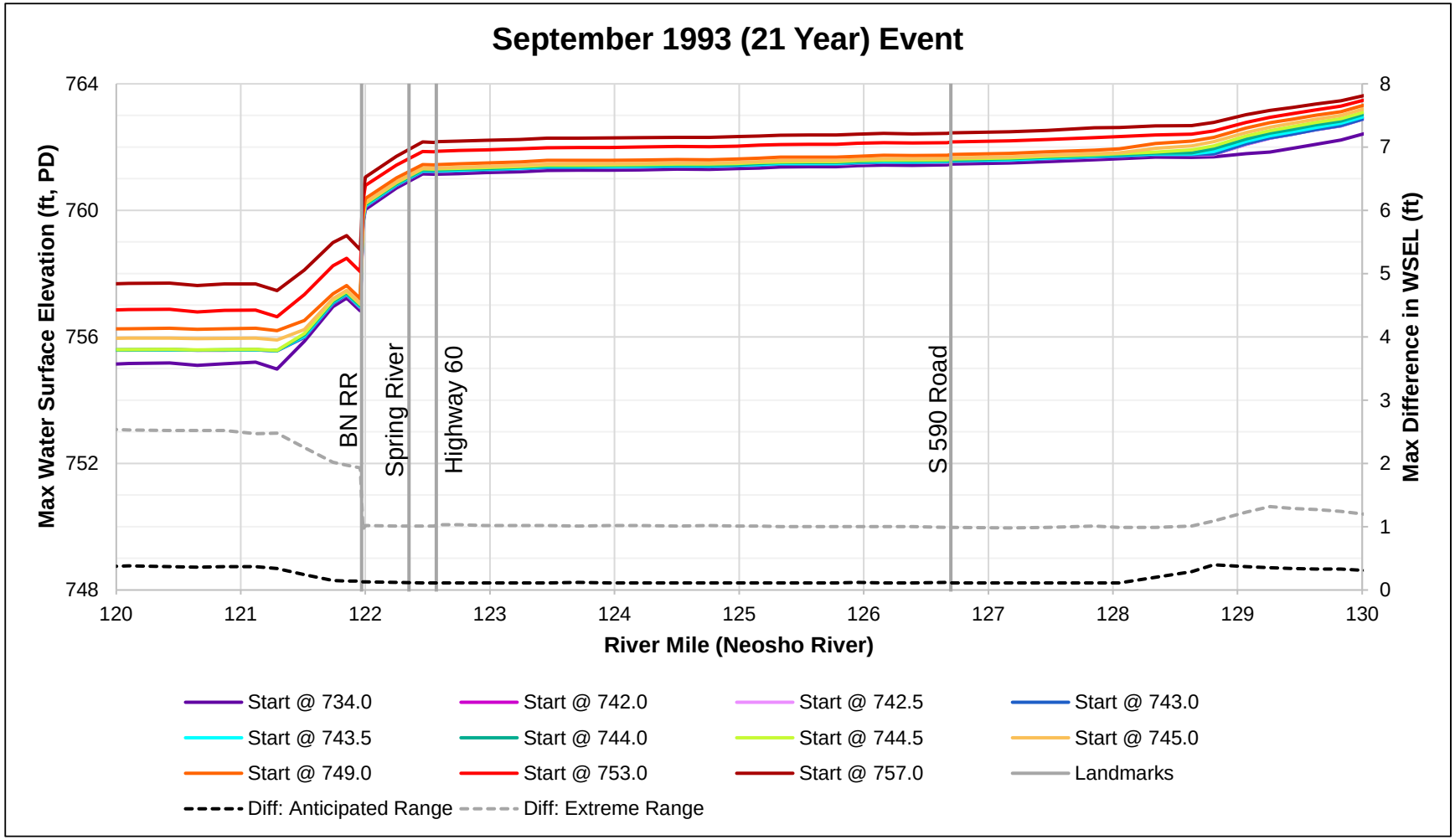


Figure E.3. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

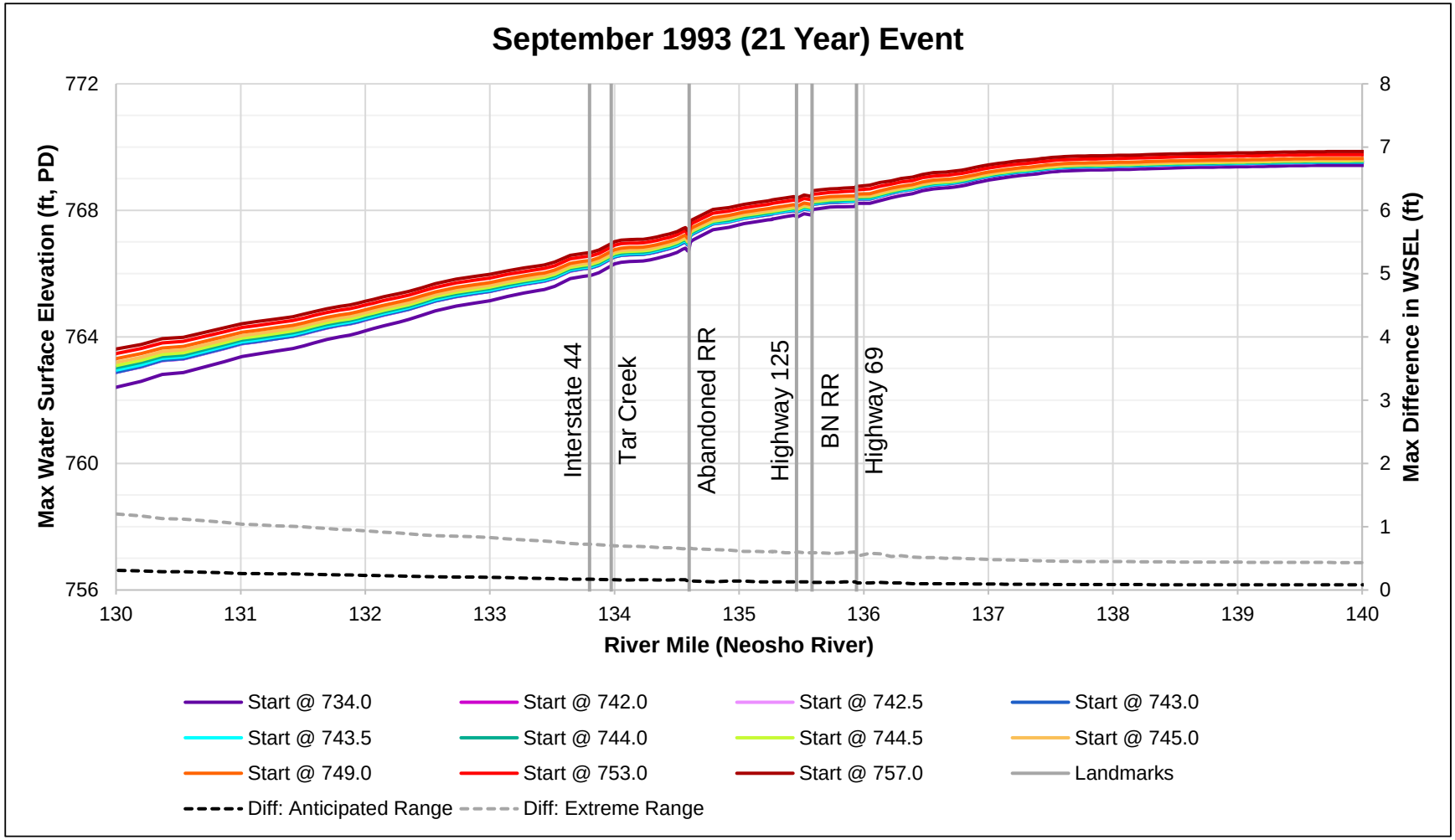


Figure E.4. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

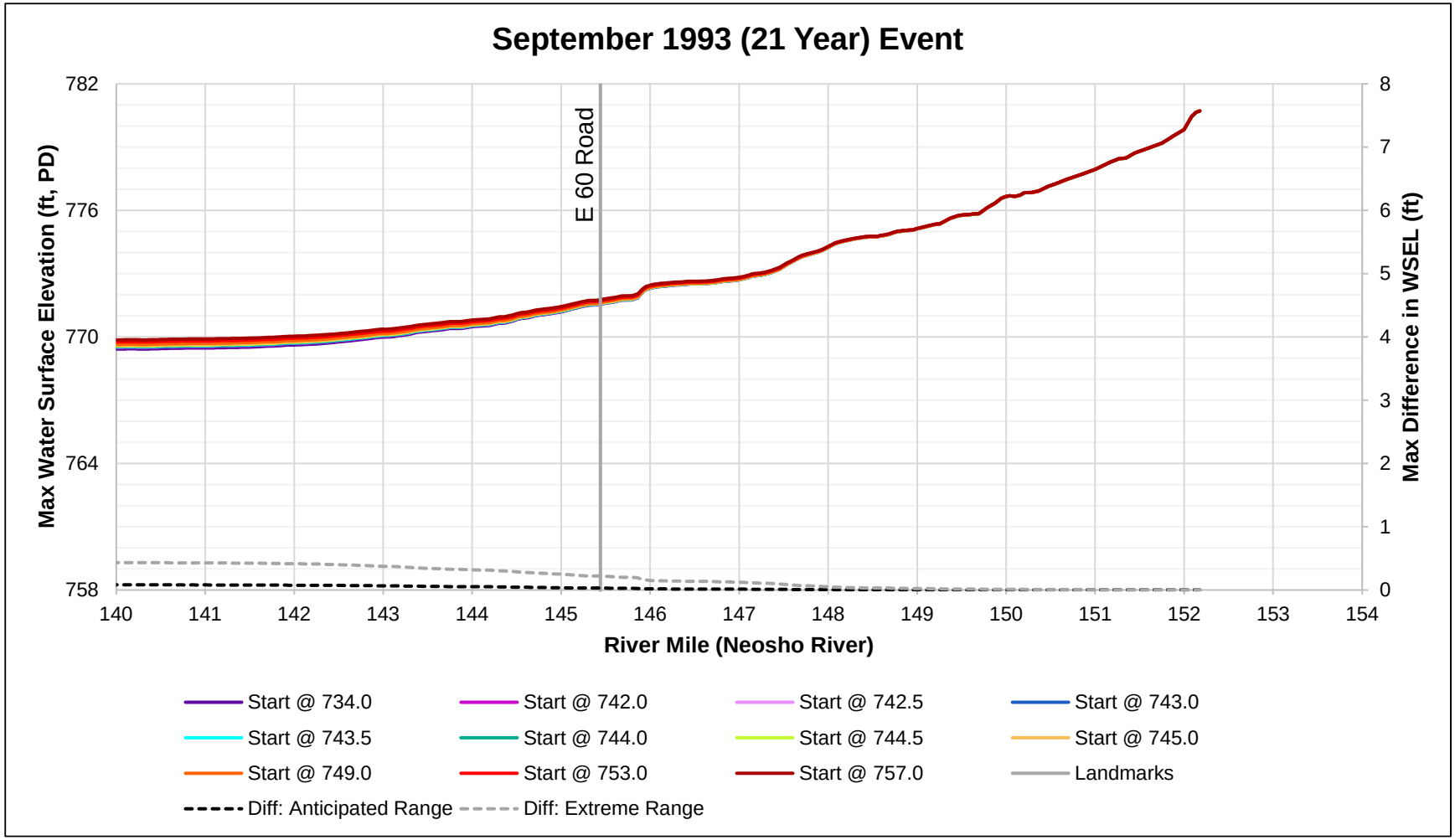


Figure E.5. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

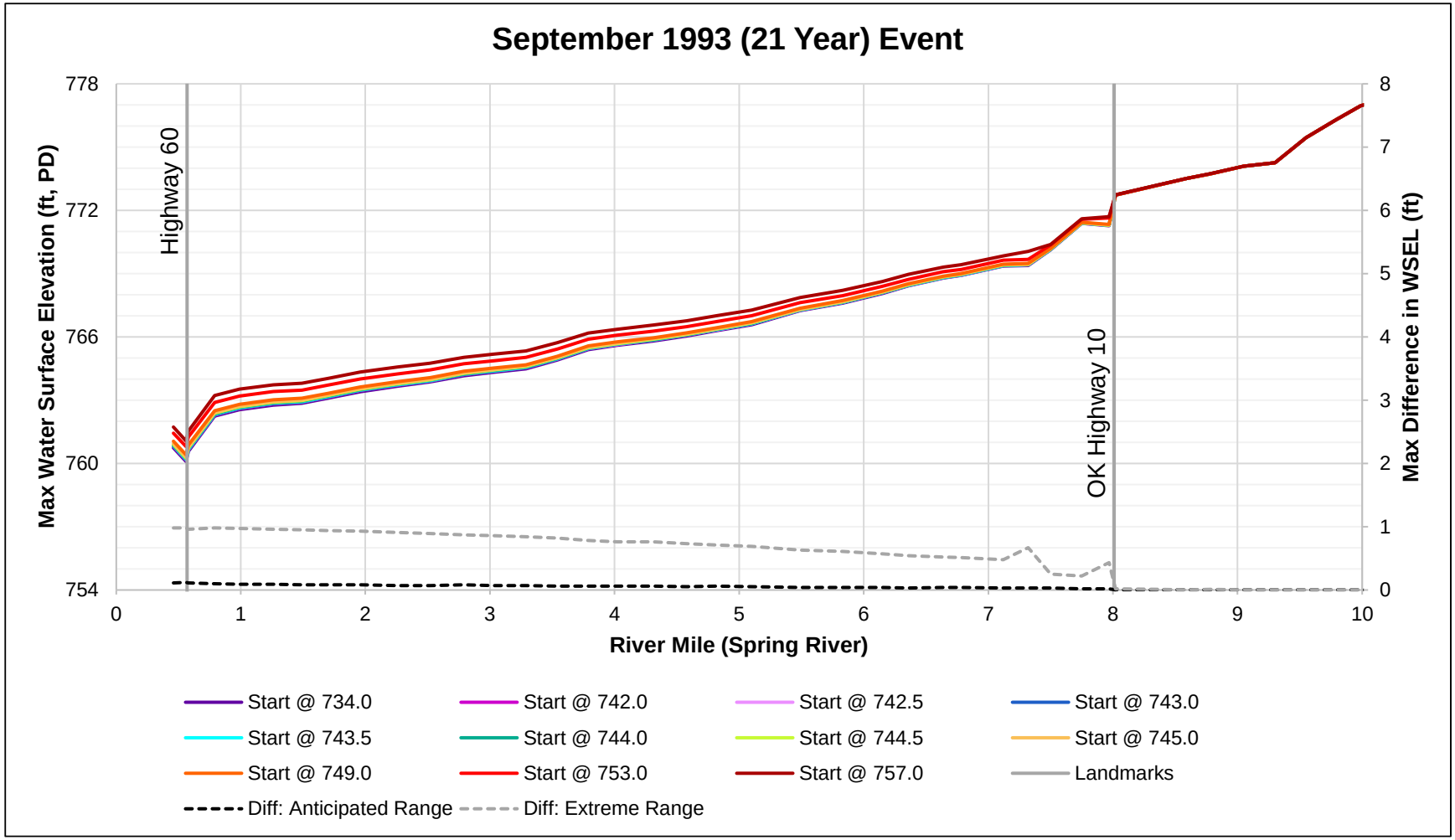


Figure E.6. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

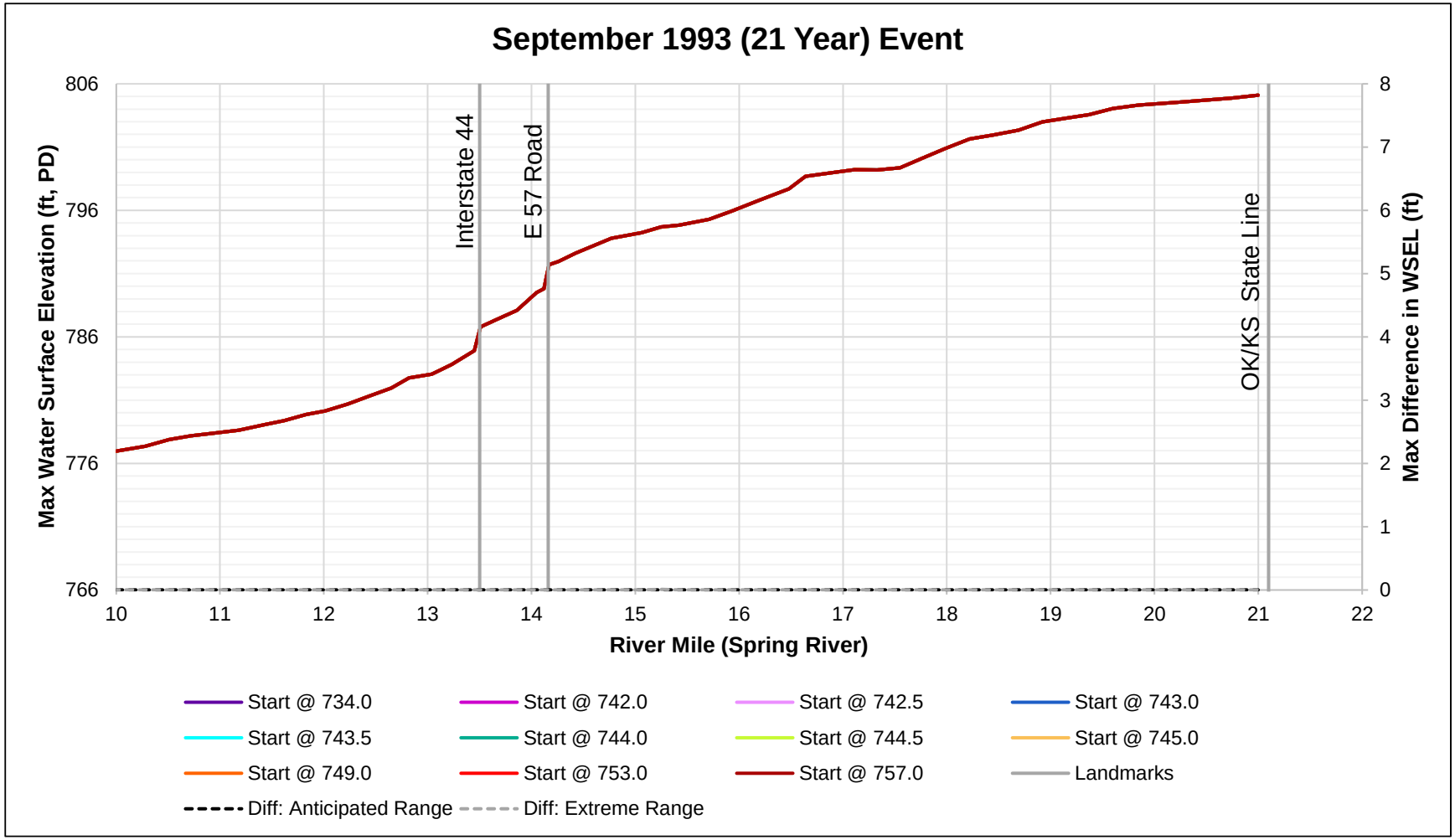


Figure E.7. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

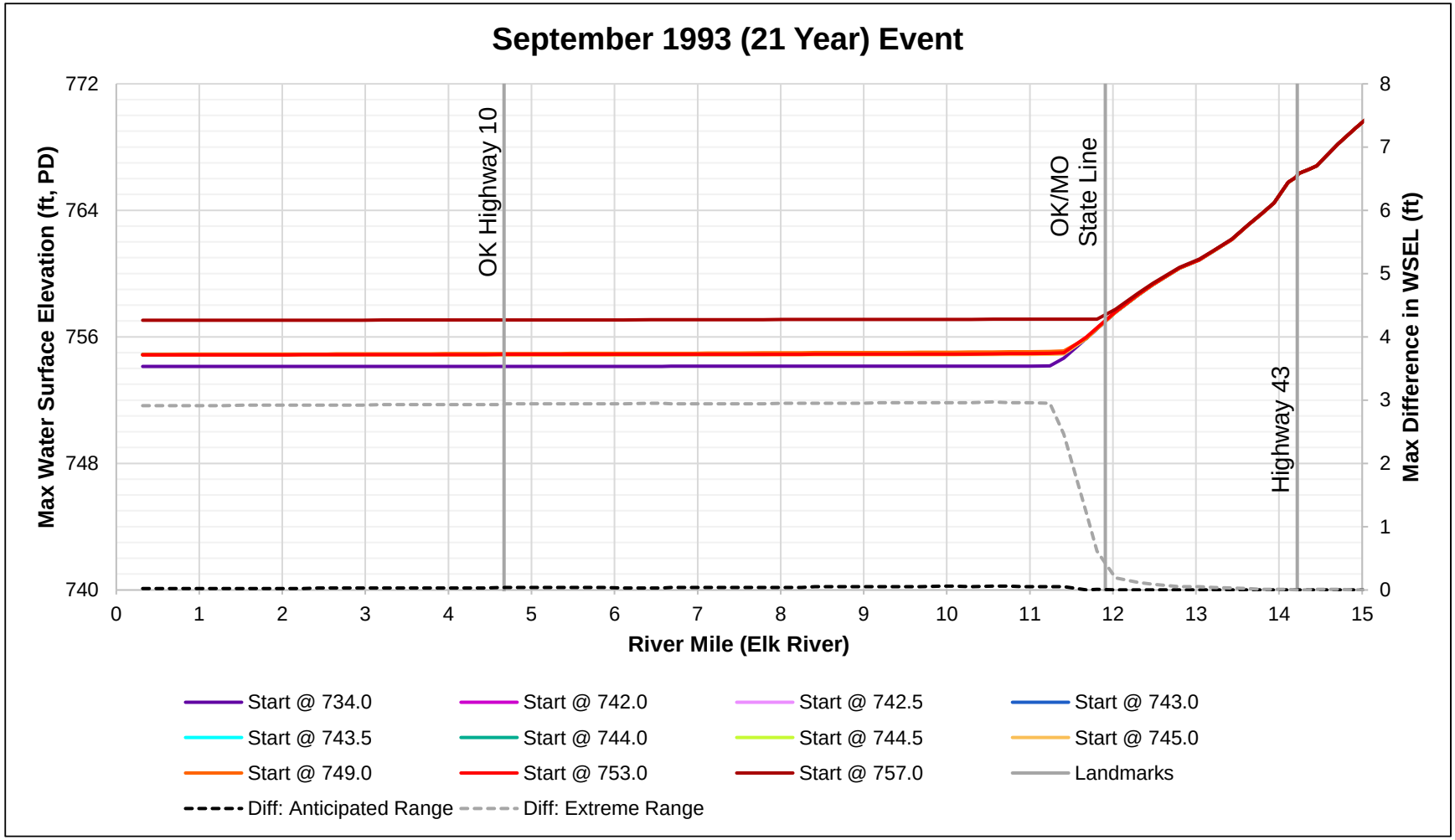


Figure E.8. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

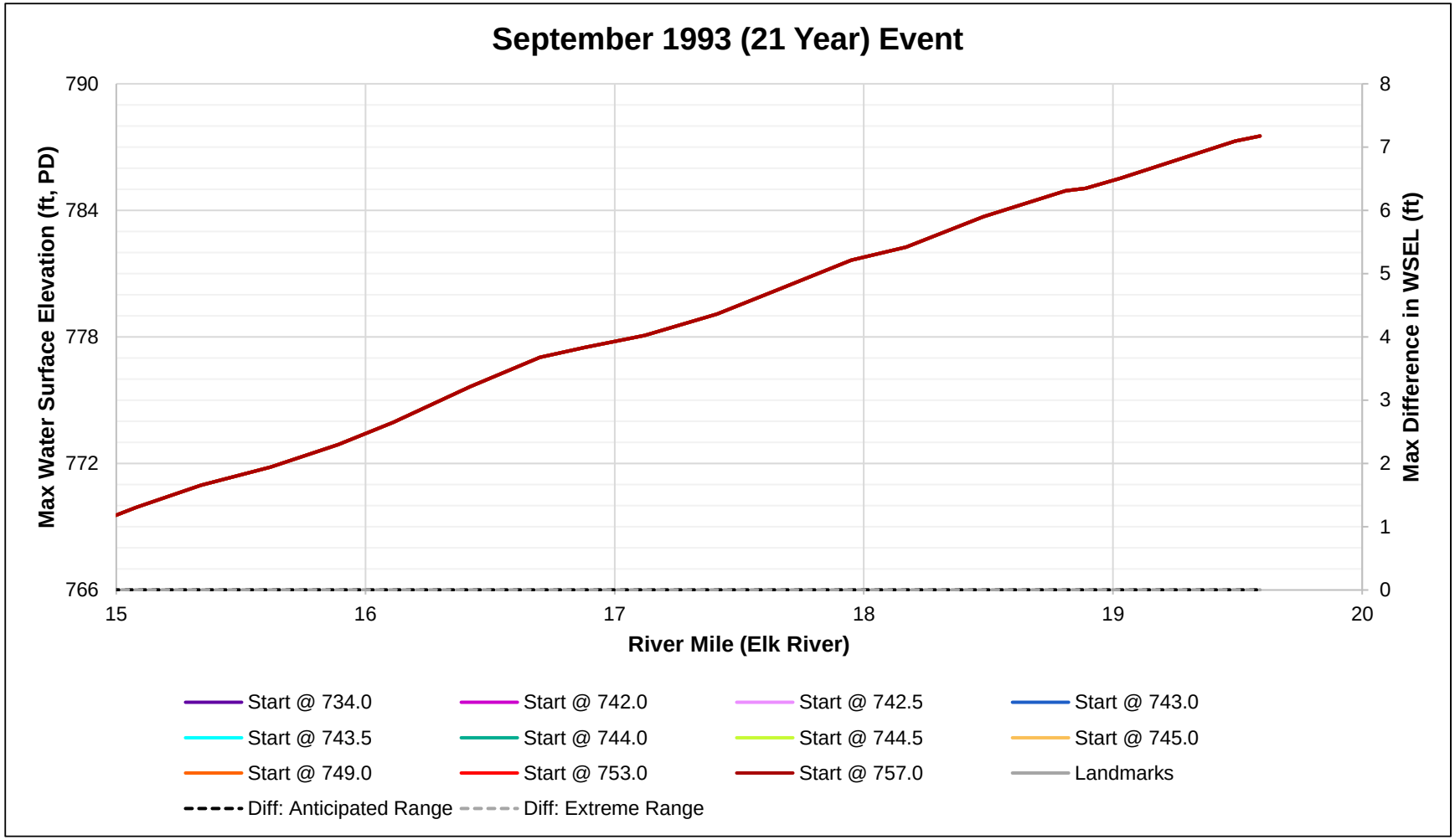


Figure E.9. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

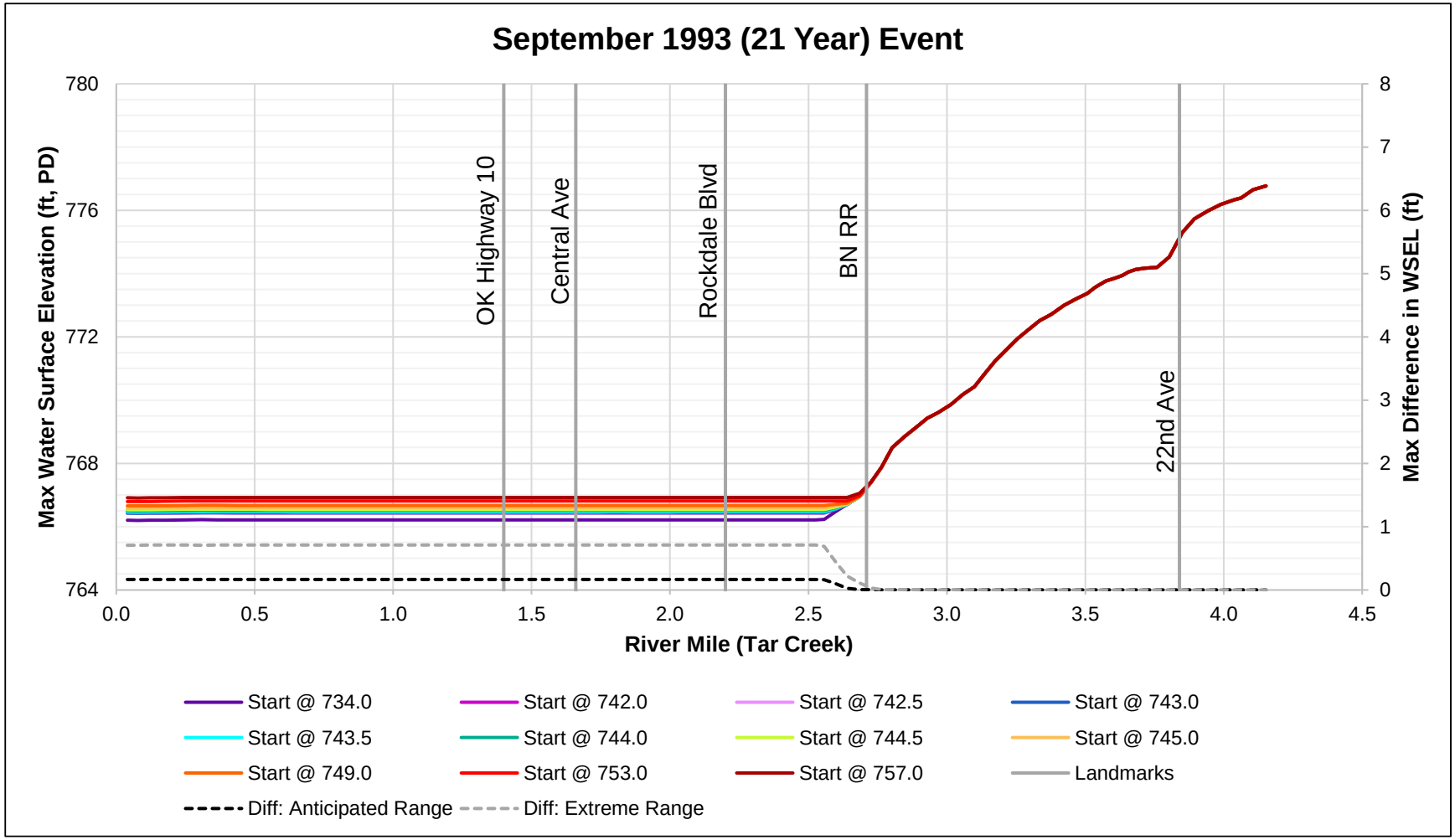


Figure E.10. Water surface elevations for the September 1993 (21 year) inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

APPENDIX E.2:
JUNE 2004 (1 YEAR) INFLOW EVENT
WATER SURFACE ELEVATION PROFILES

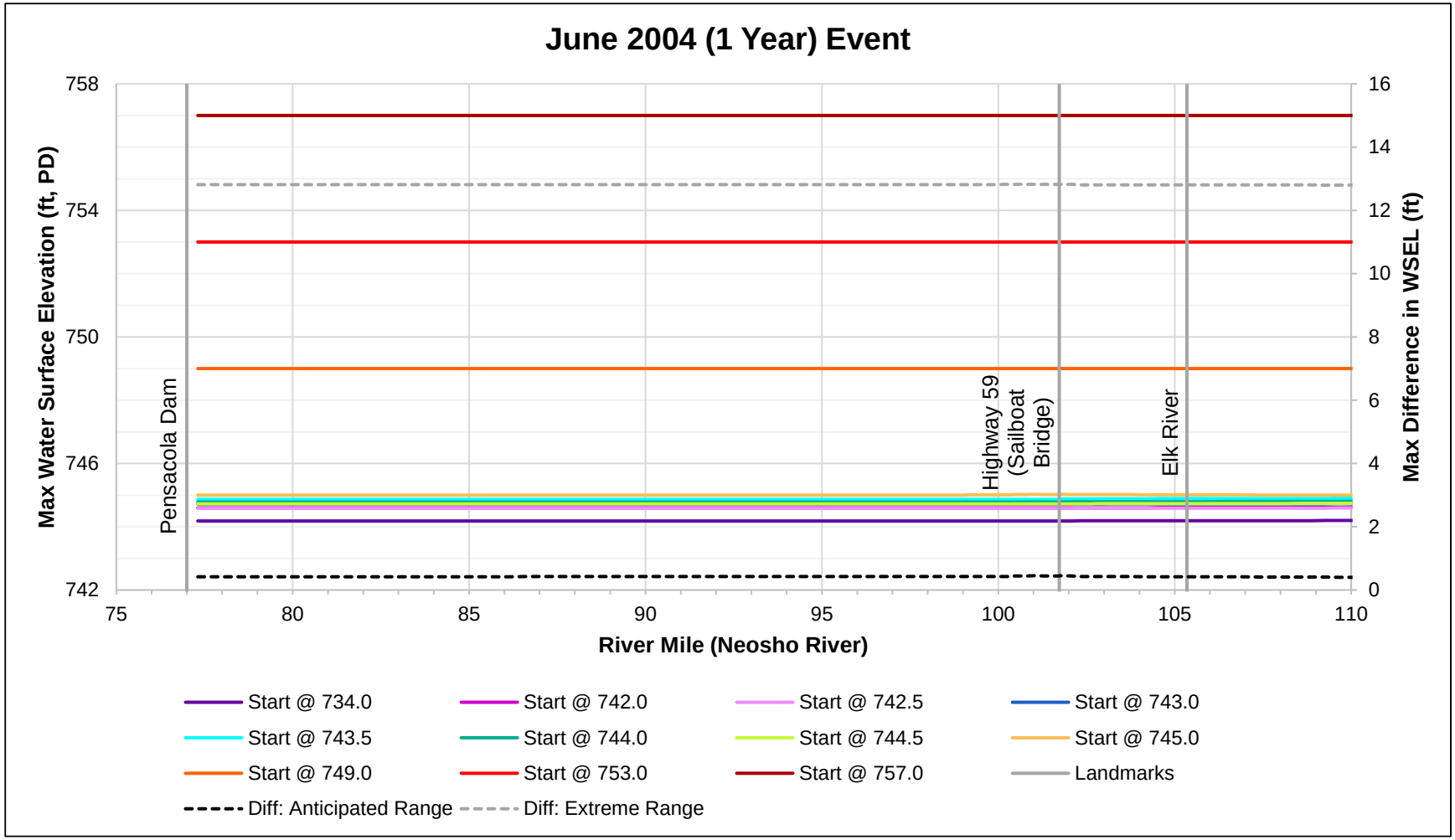


Figure E.11. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

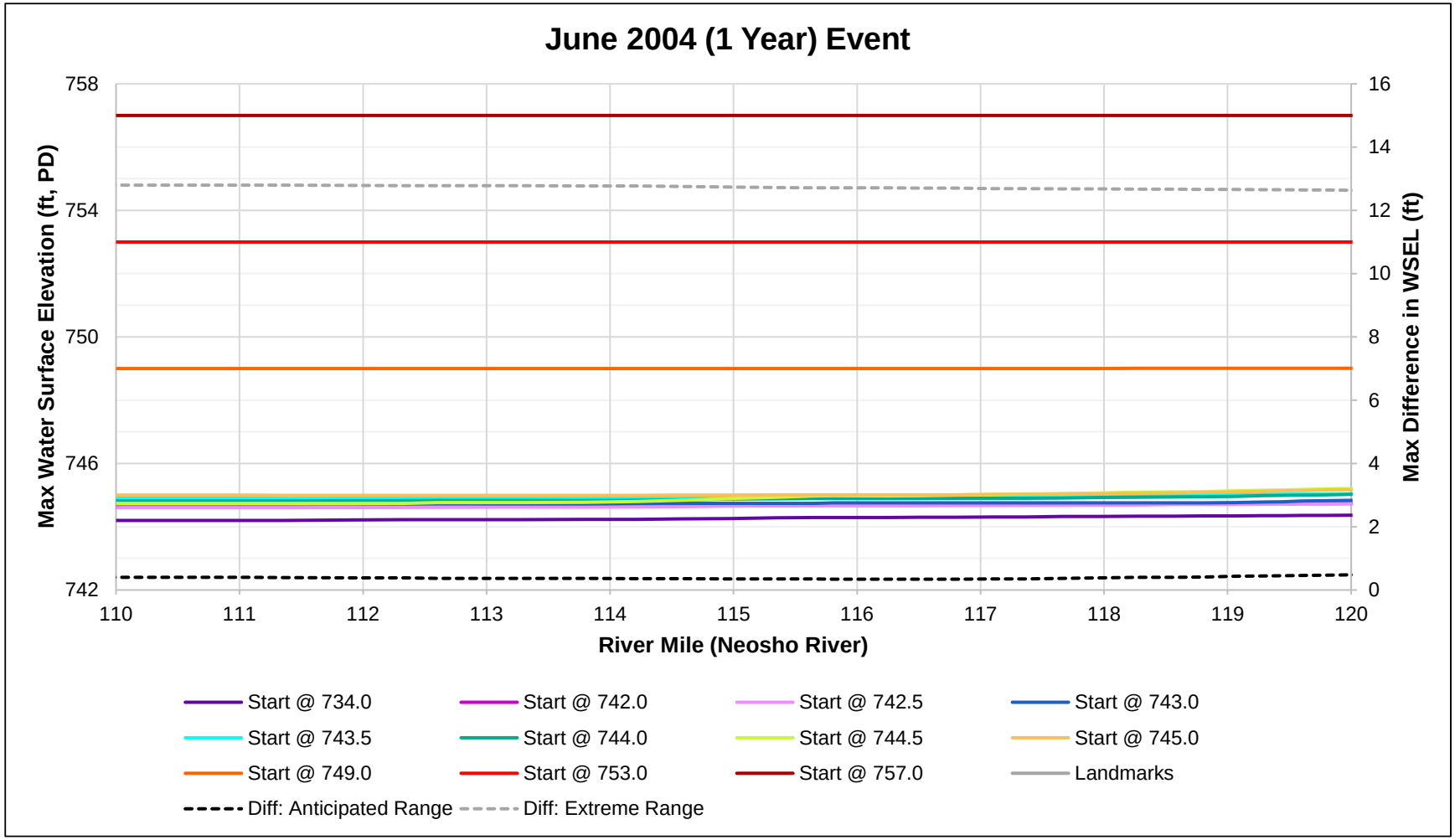


Figure E.12. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

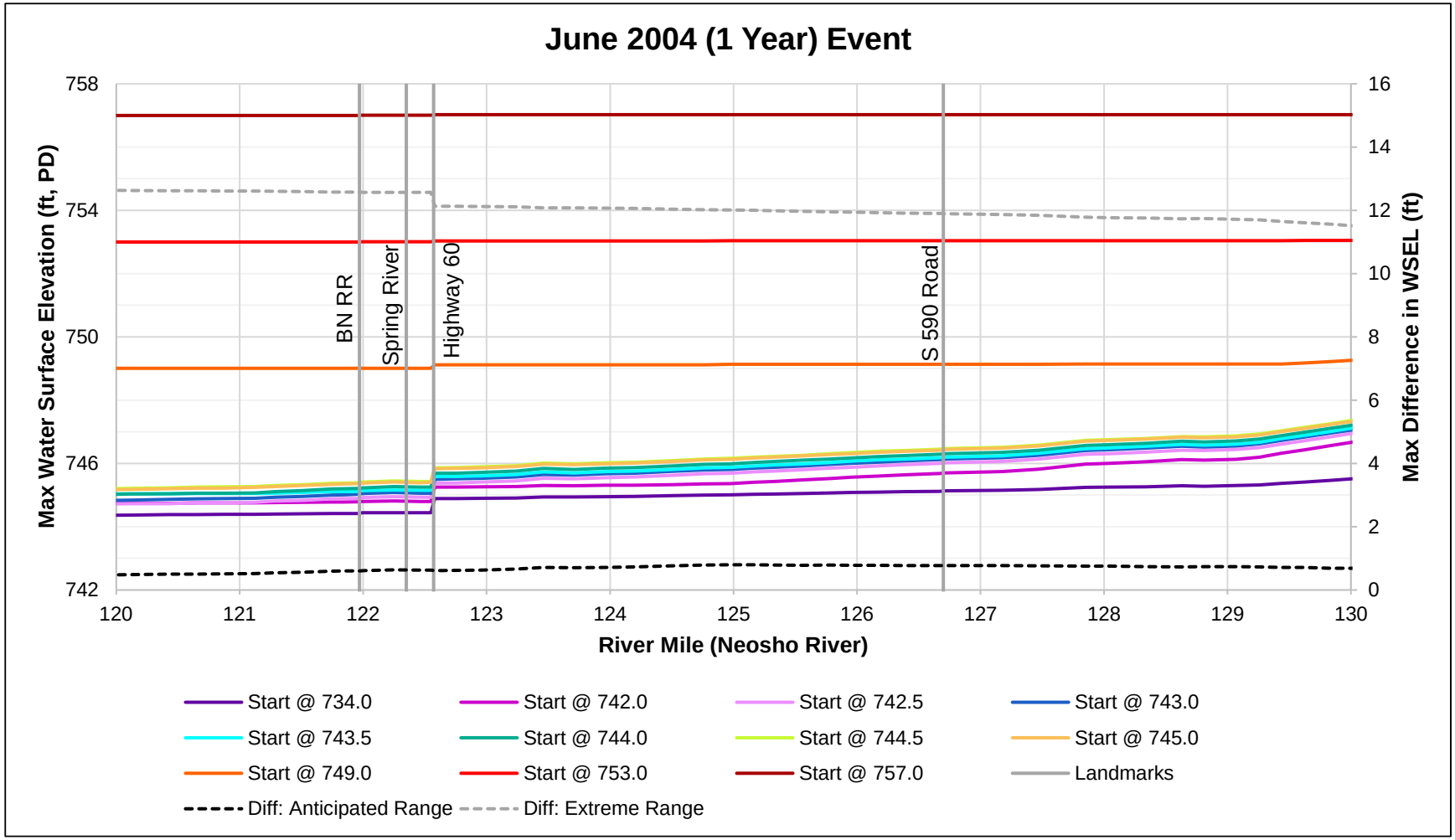


Figure E.13. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

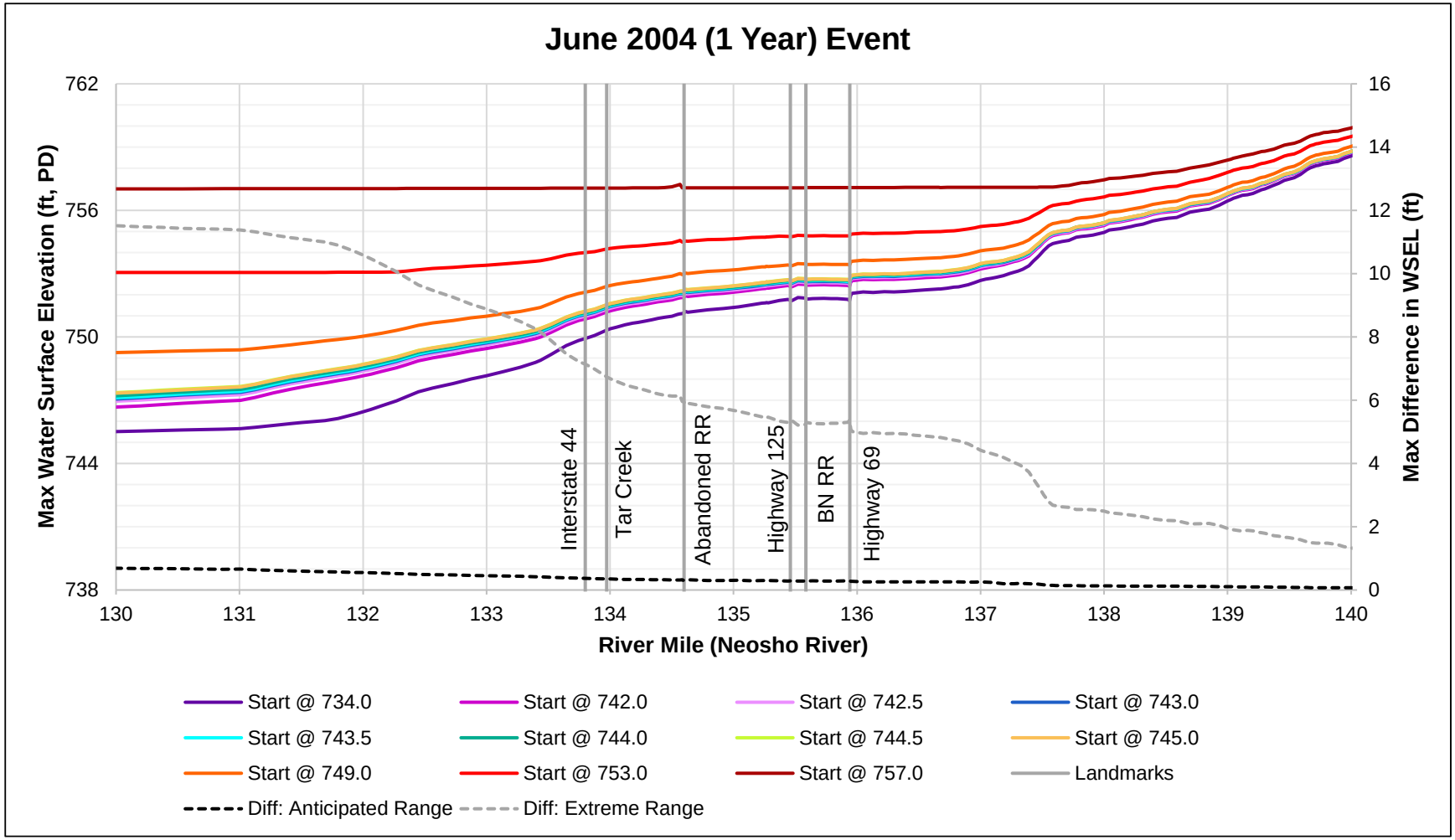


Figure E.14. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

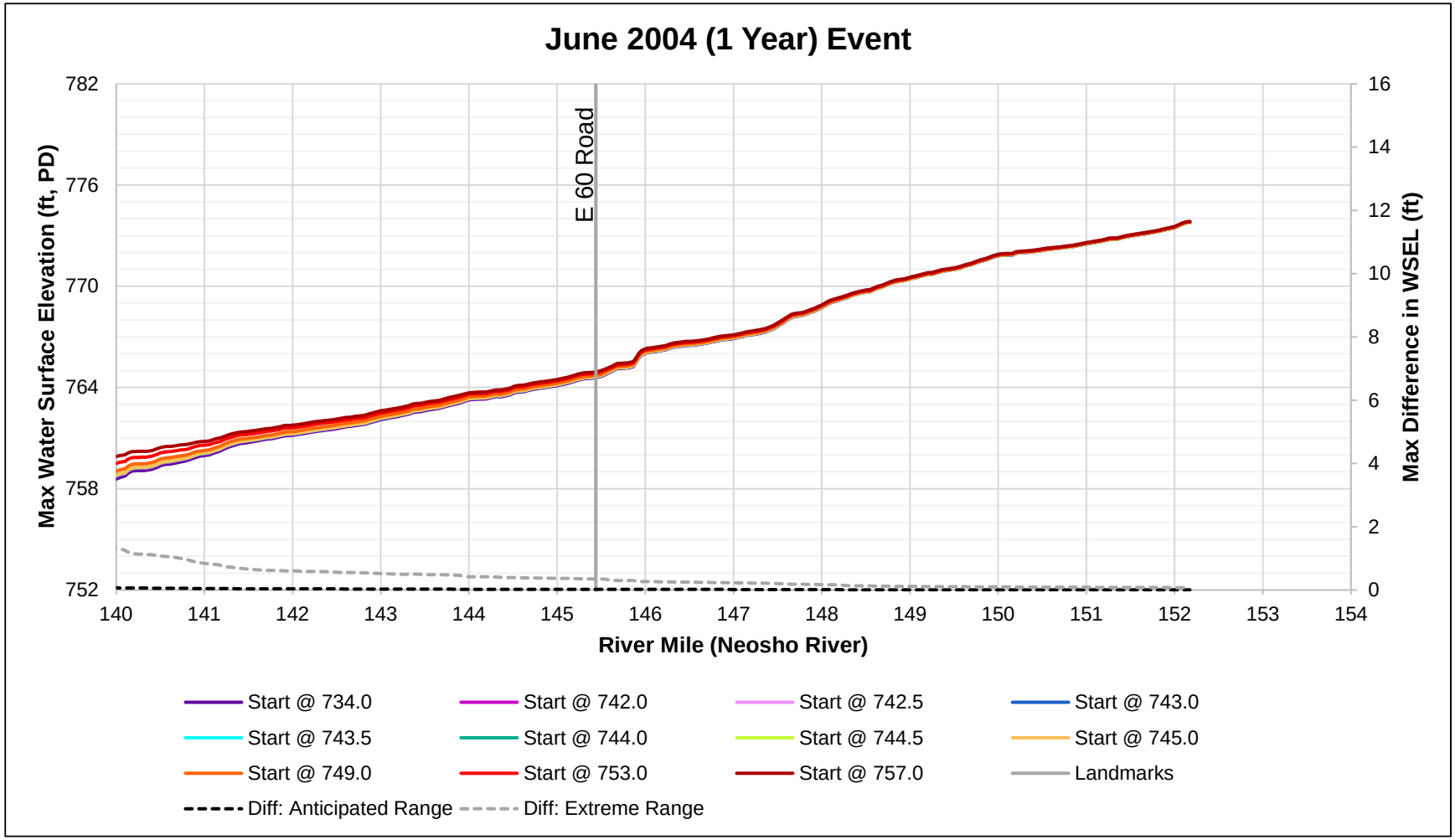


Figure E.15. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

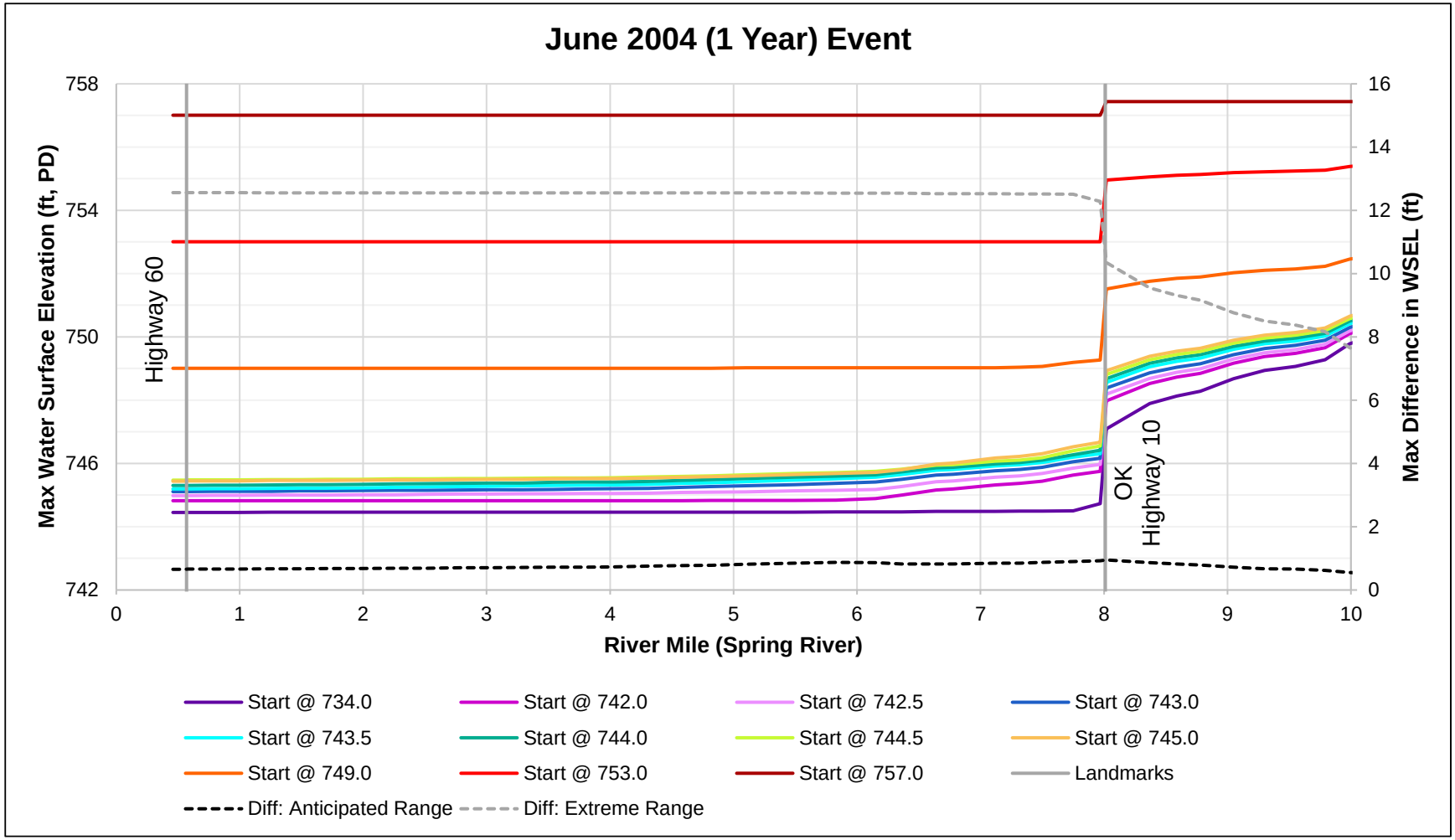


Figure E.16. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

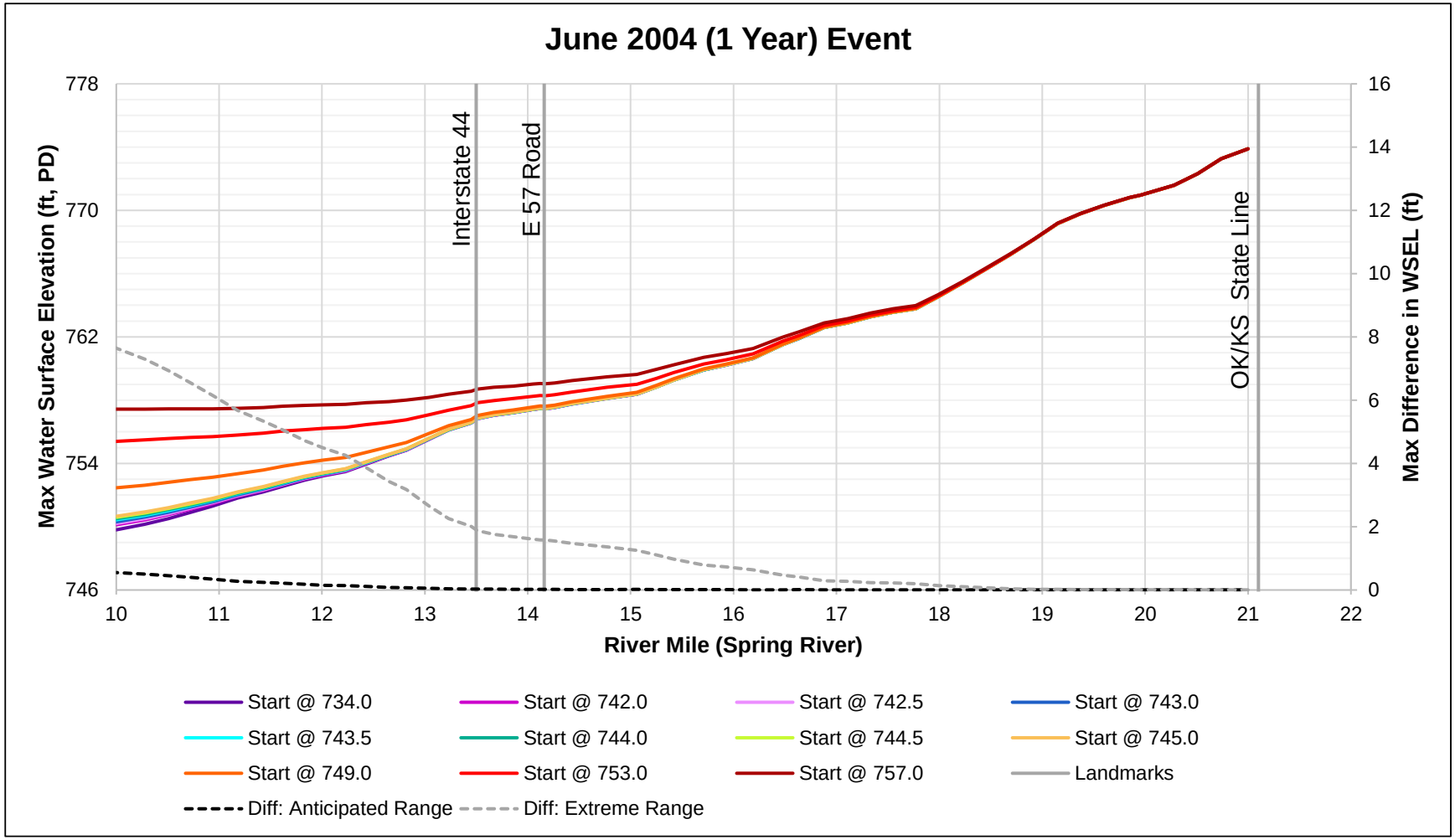


Figure E.17. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

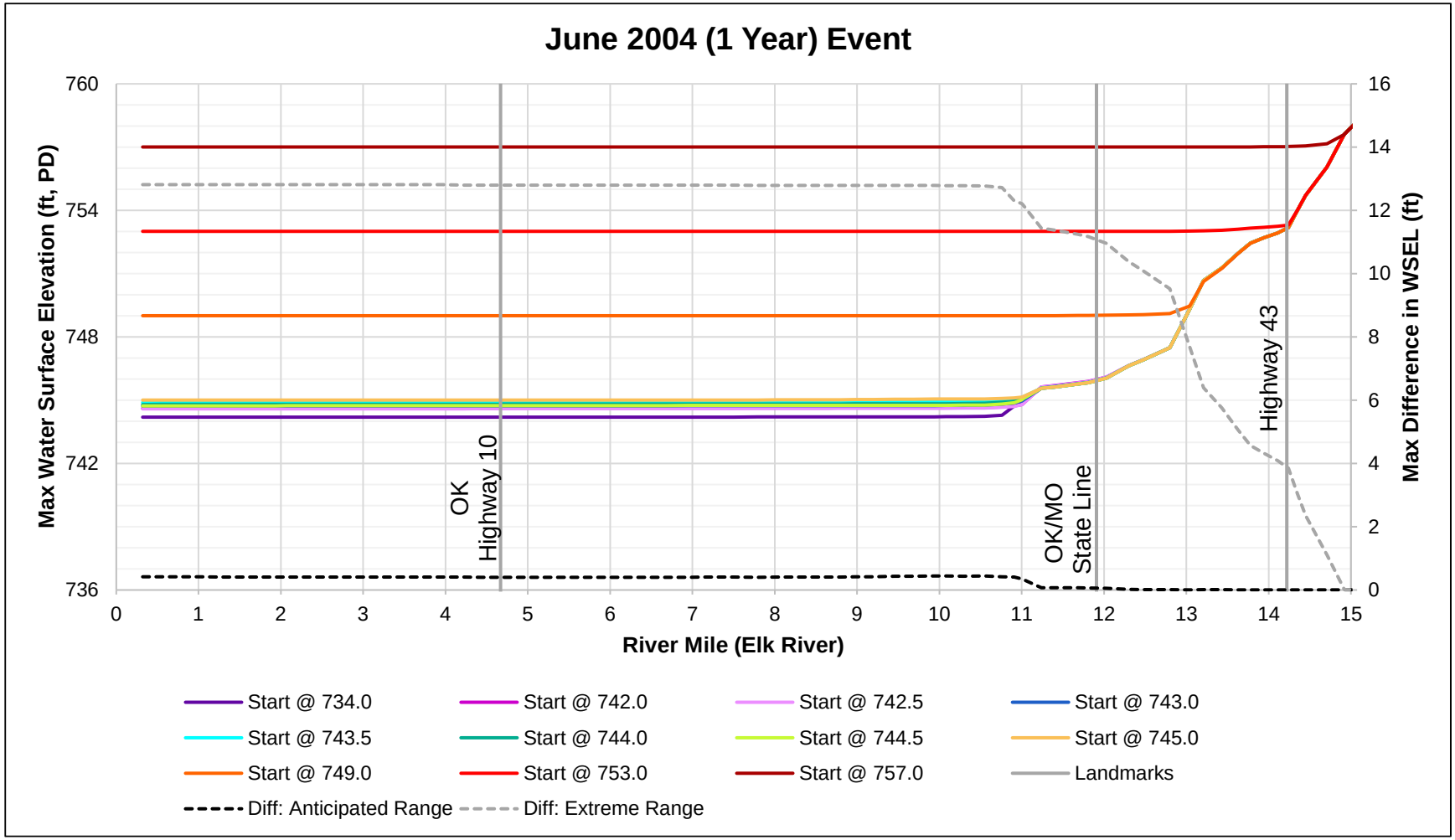


Figure E.18. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

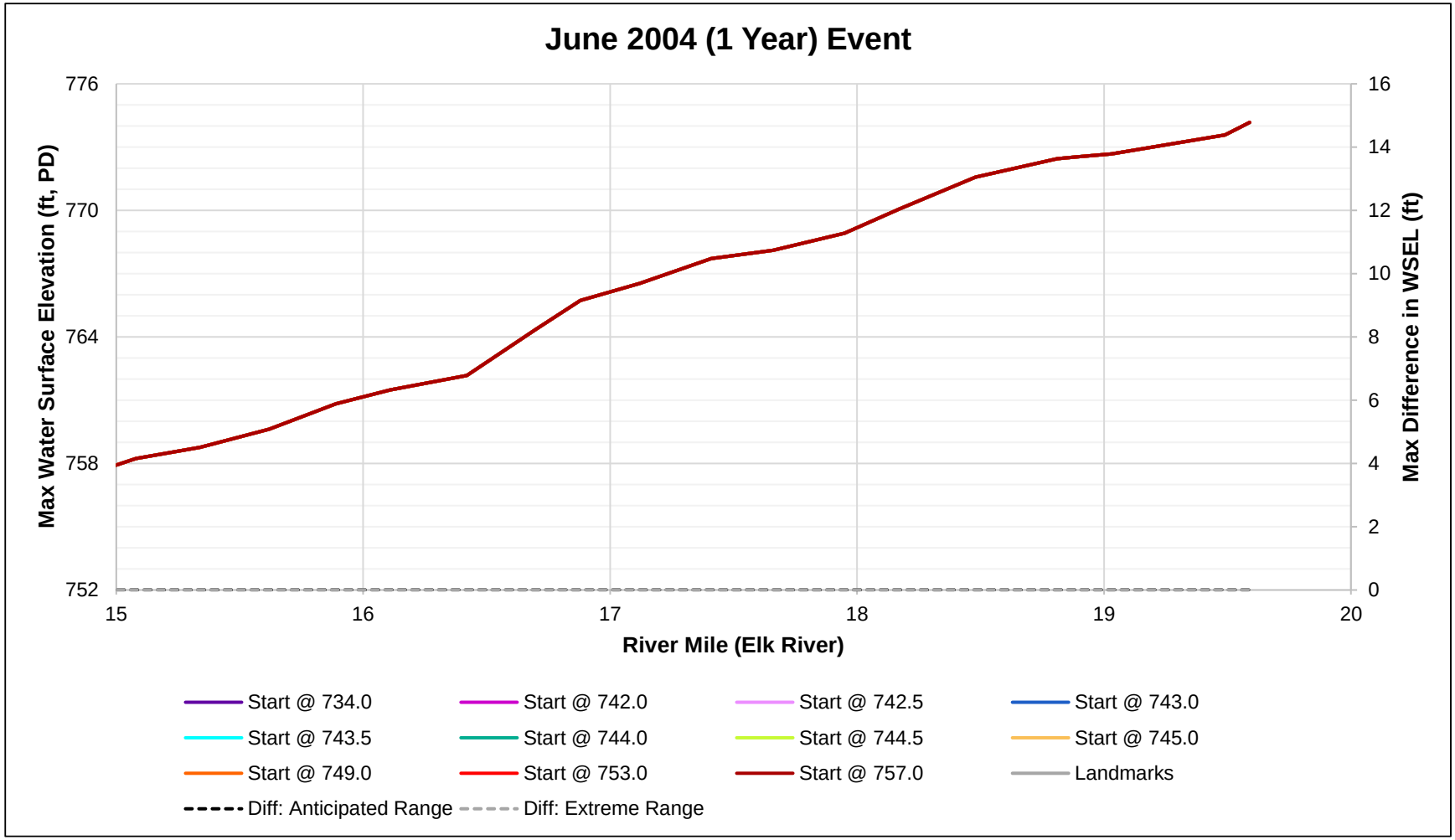


Figure E.19. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

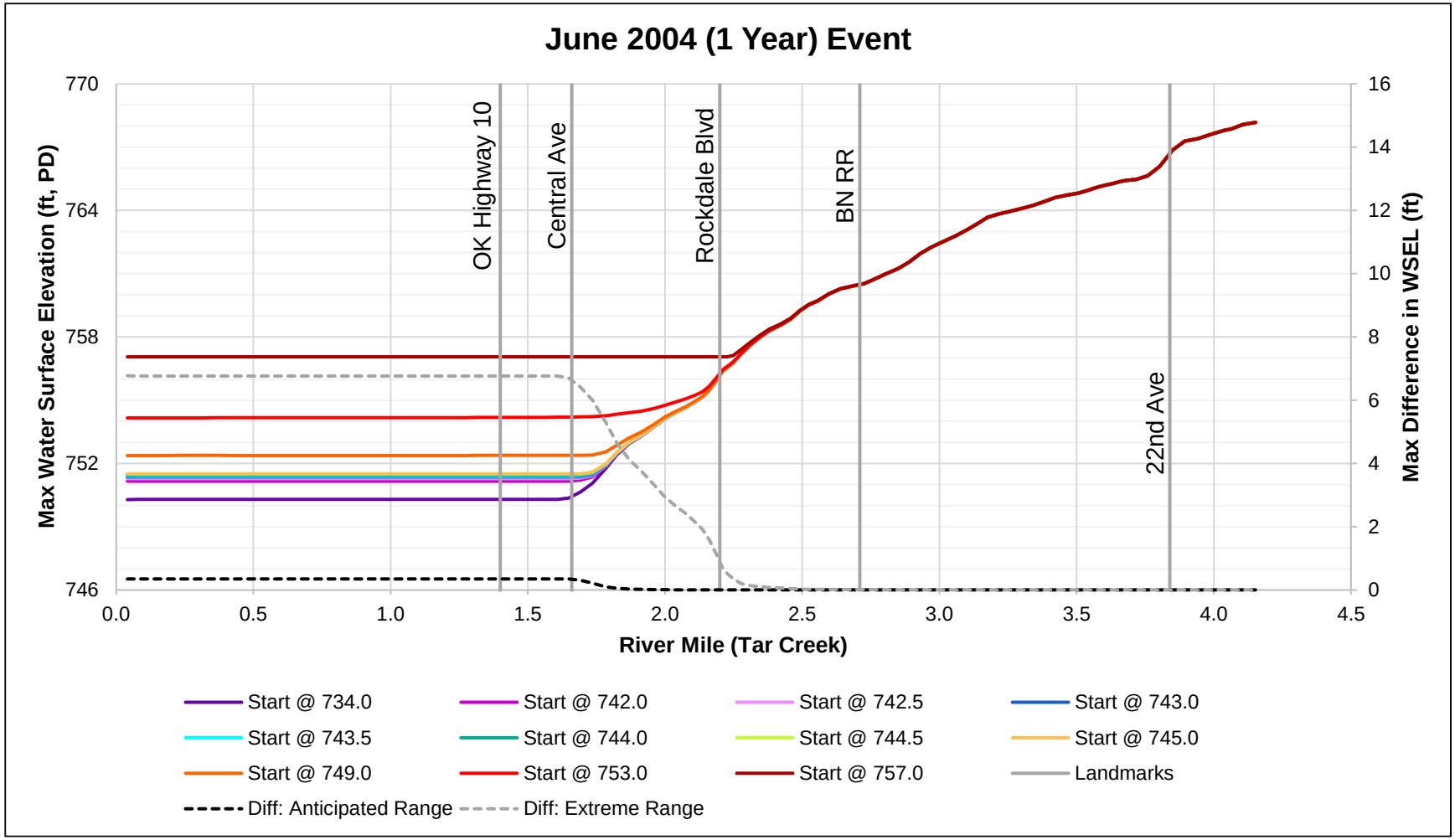


Figure E.20. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

APPENDIX E.3:
JULY 2007 (4 YEAR) INFLOW EVENT
WATER SURFACE ELEVATION PROFILES

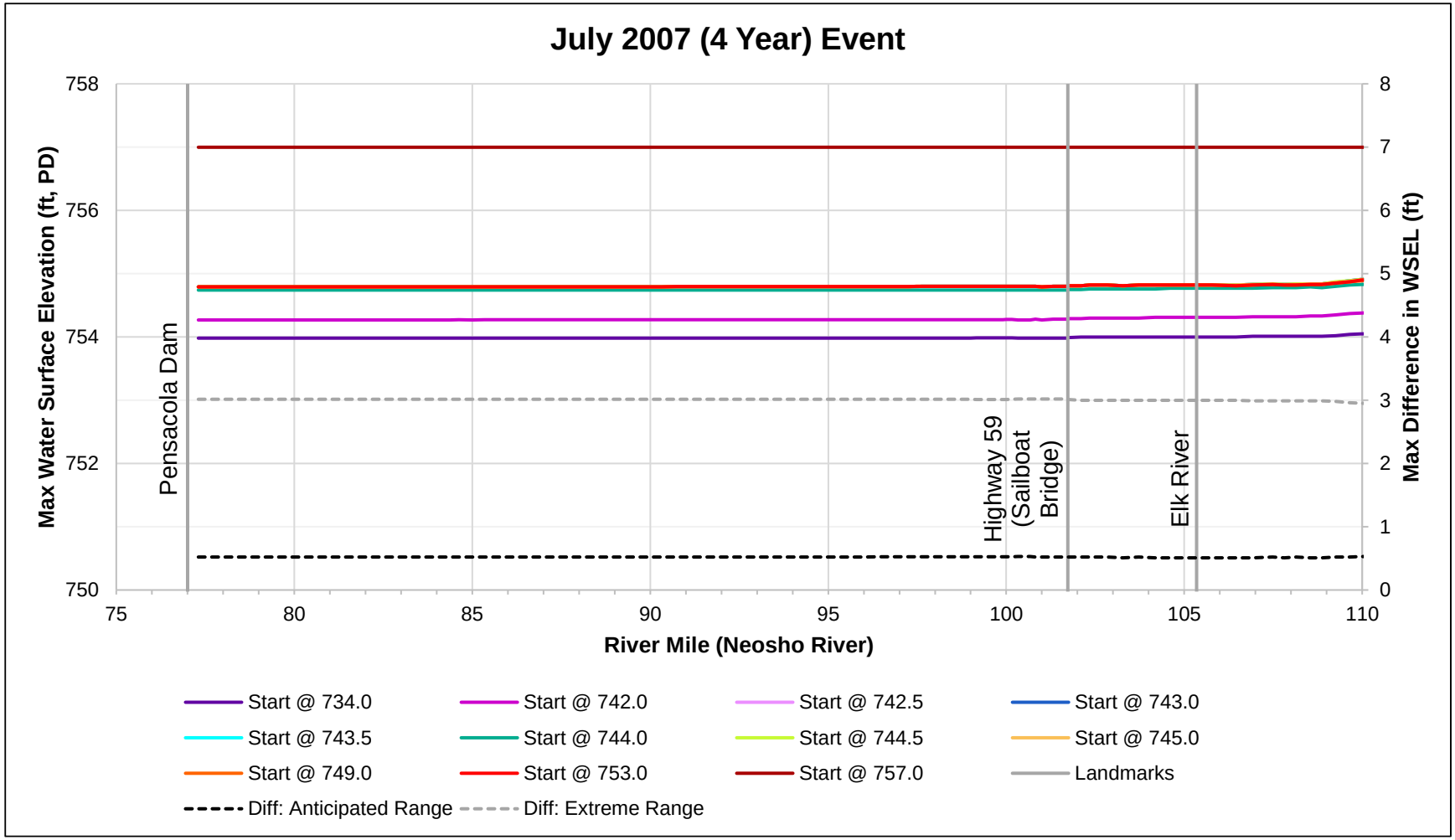


Figure E.21. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

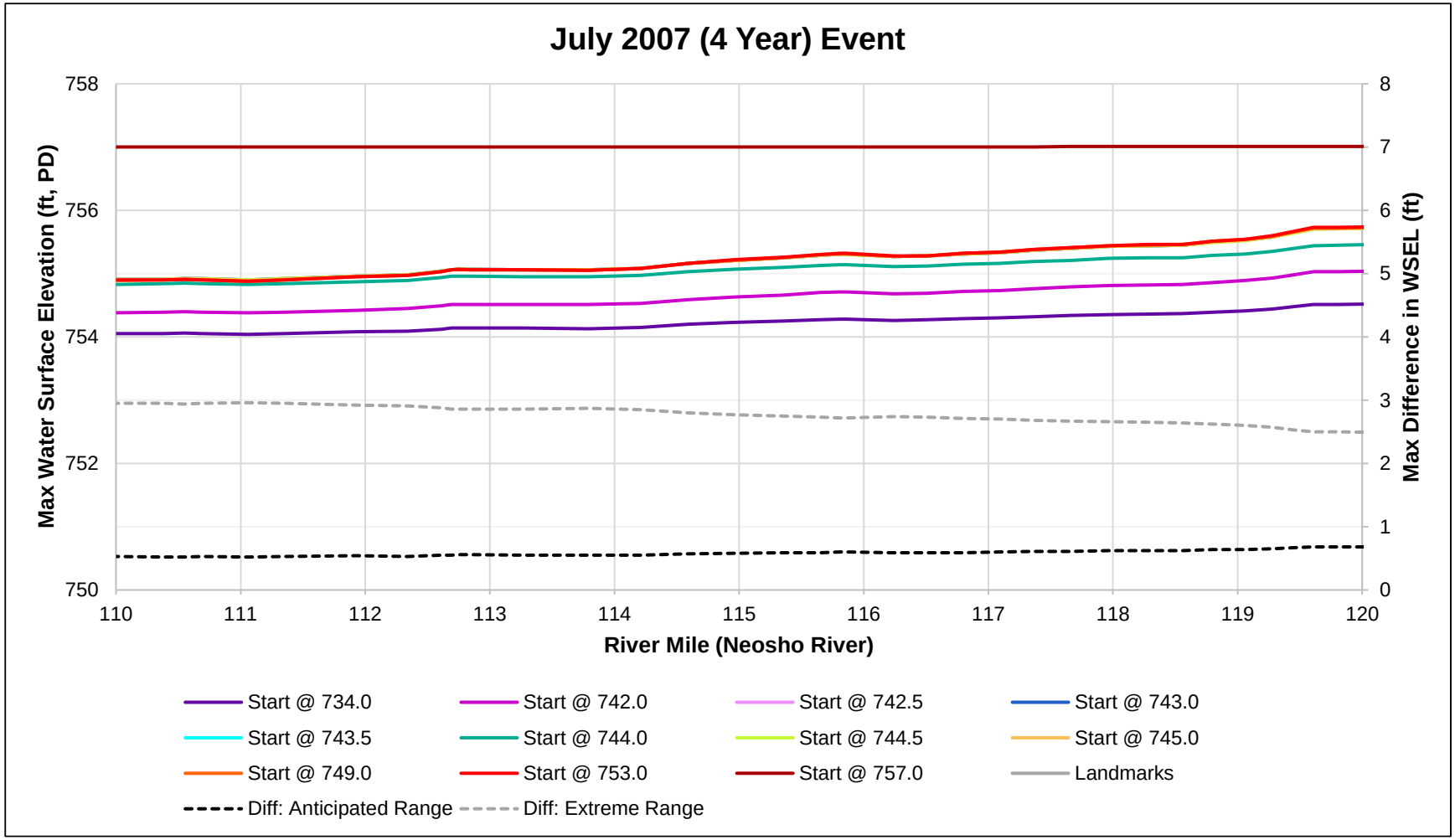


Figure E.22. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

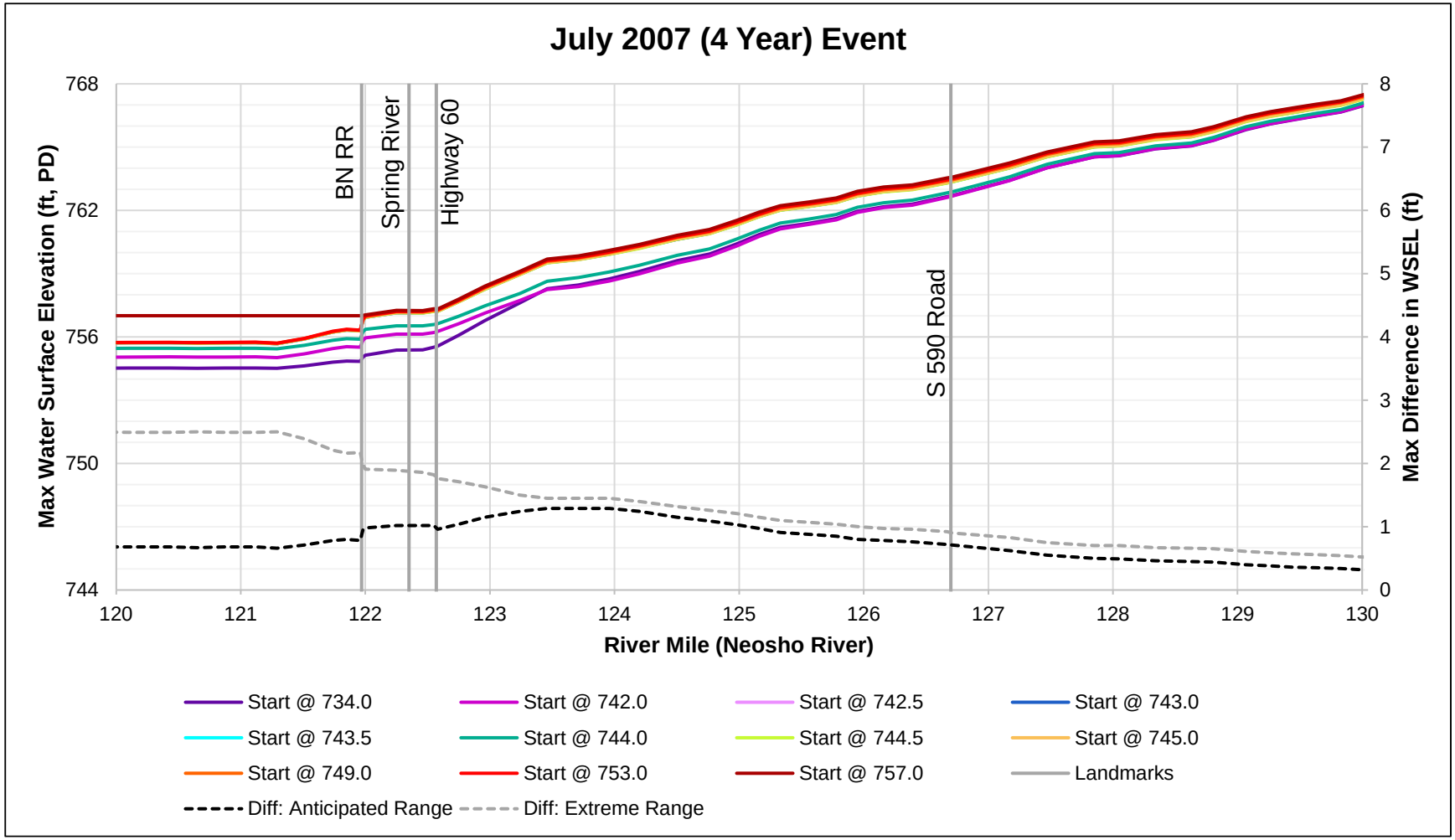


Figure E.23. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

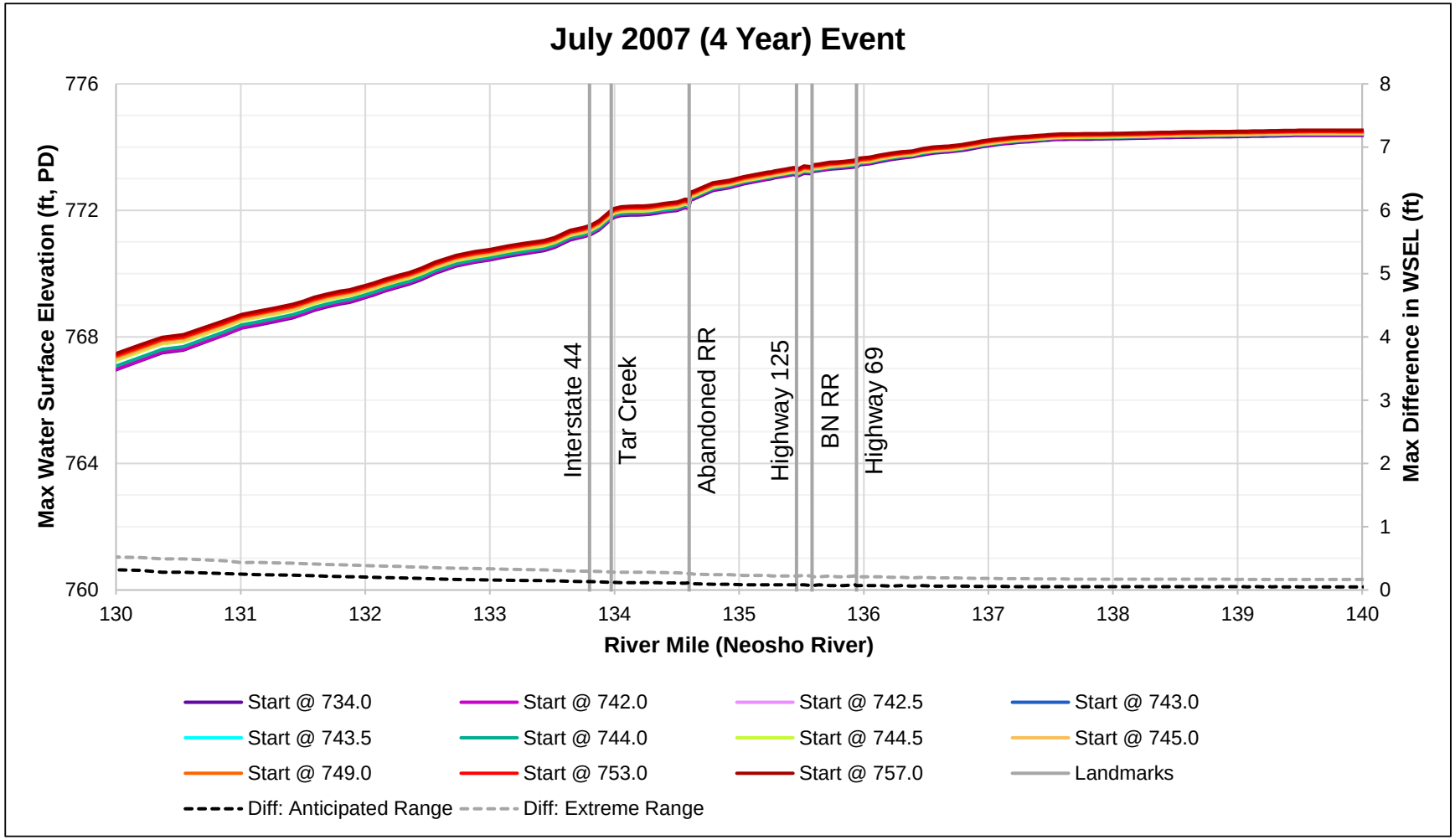


Figure E.24. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

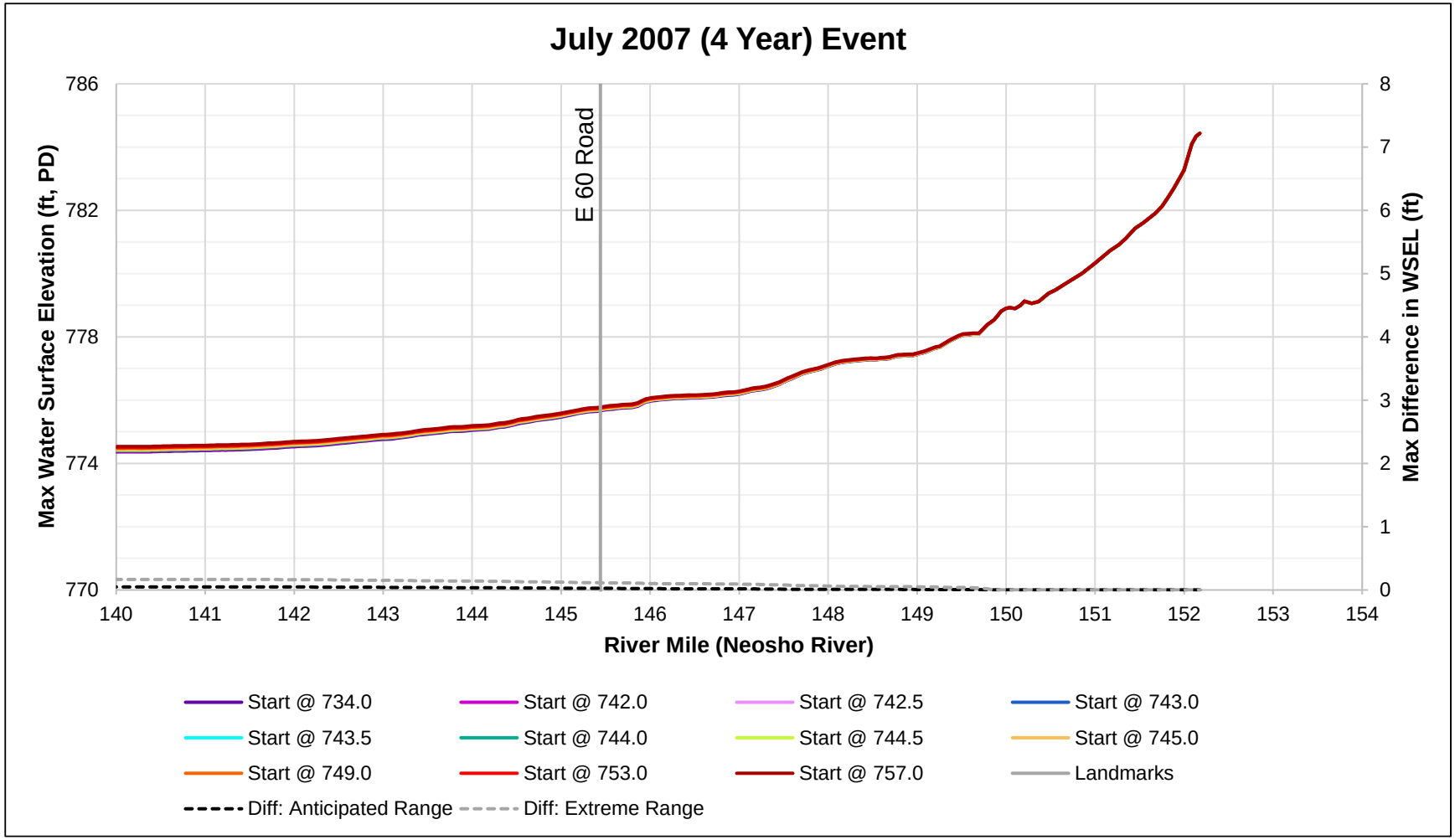


Figure E.25. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

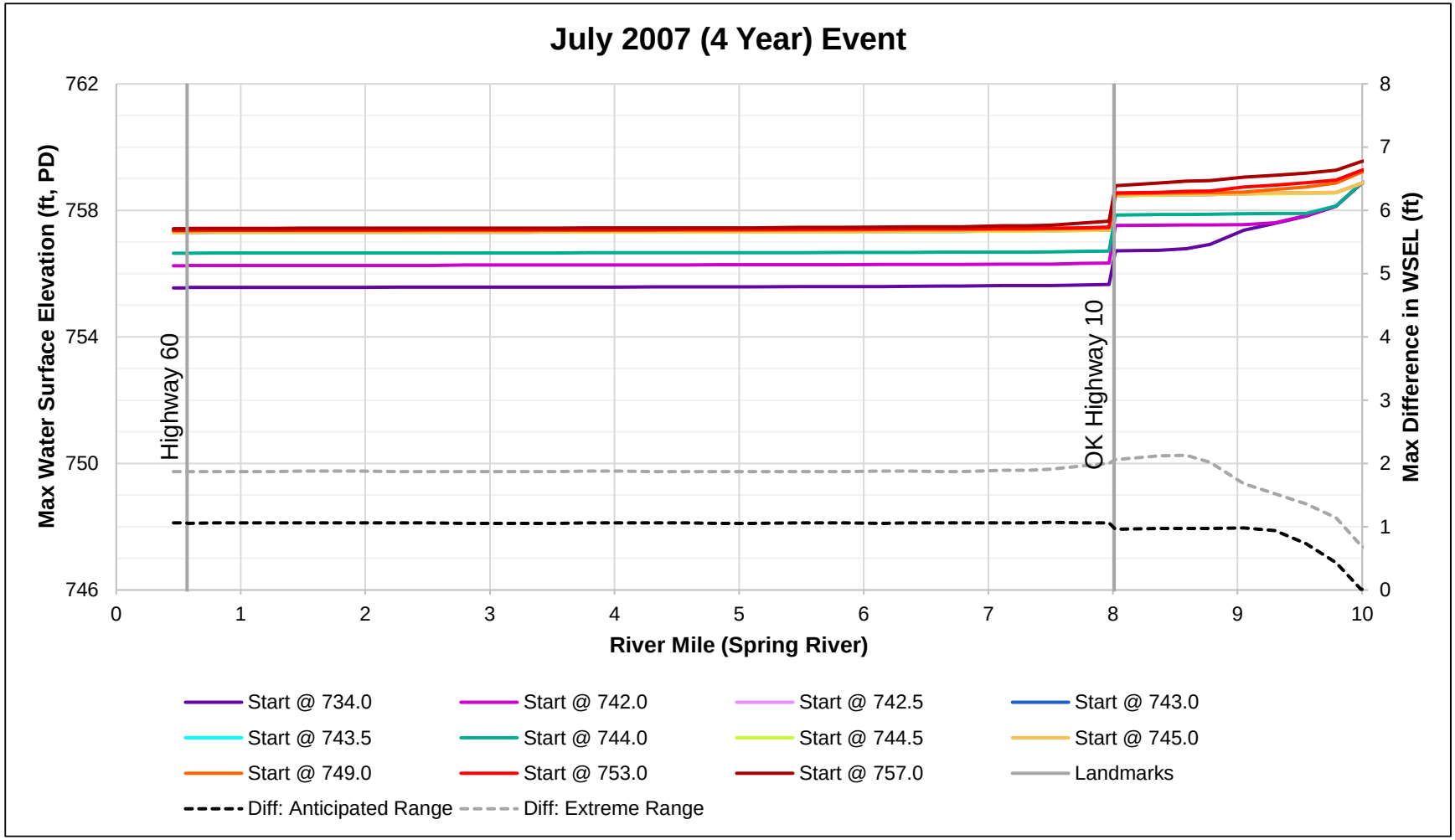


Figure E.26. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

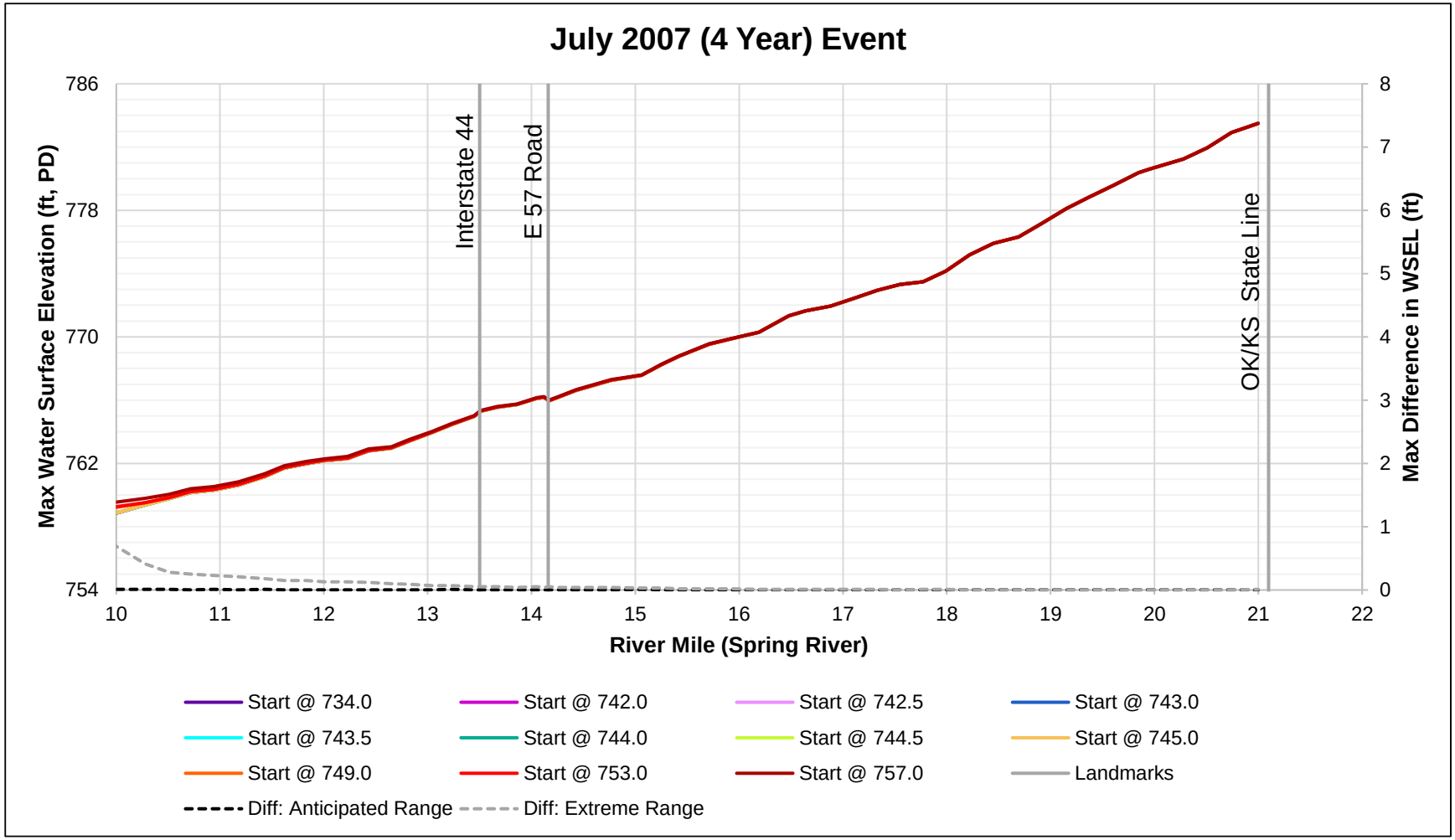


Figure E.27. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

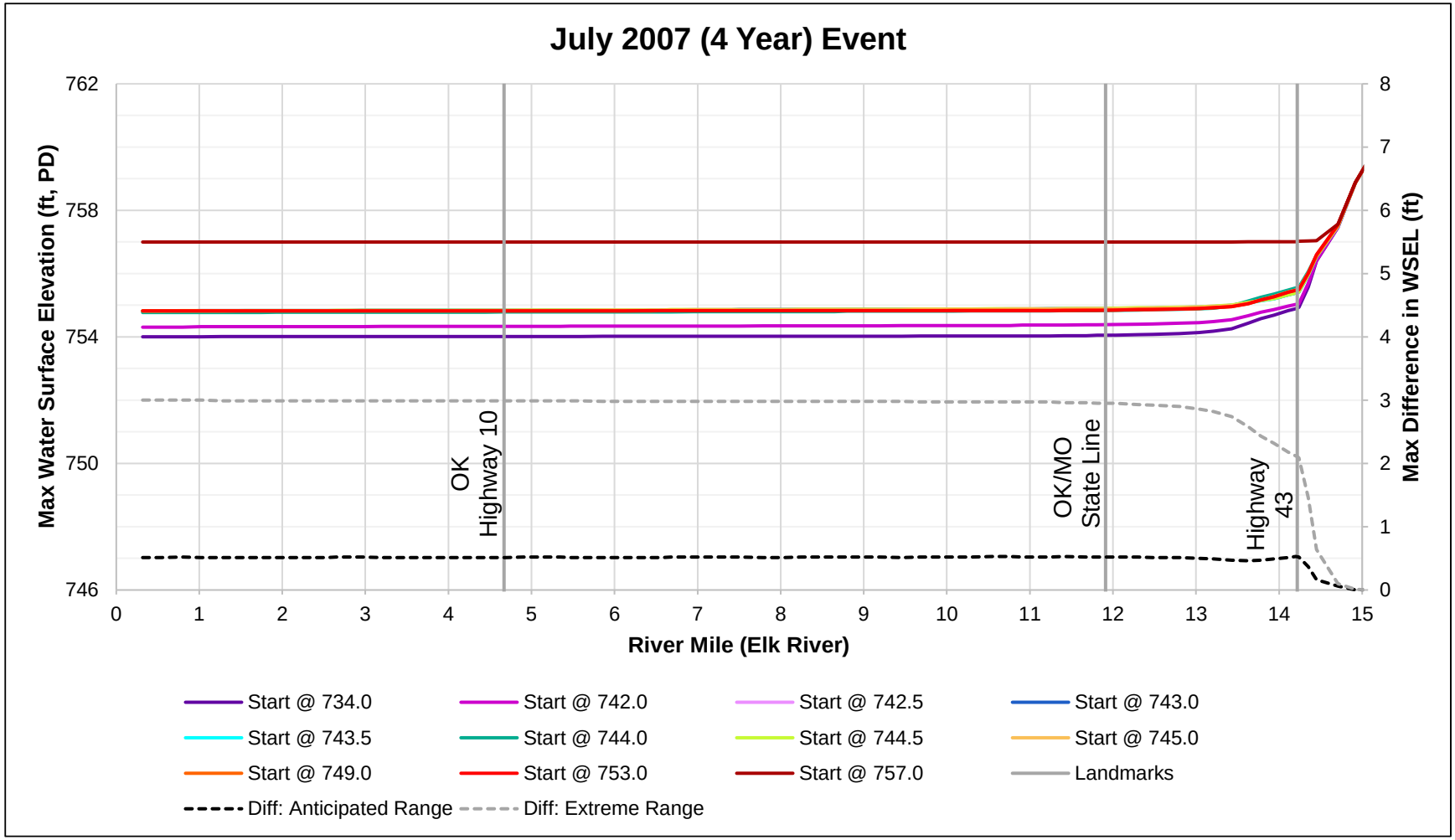


Figure E.28. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

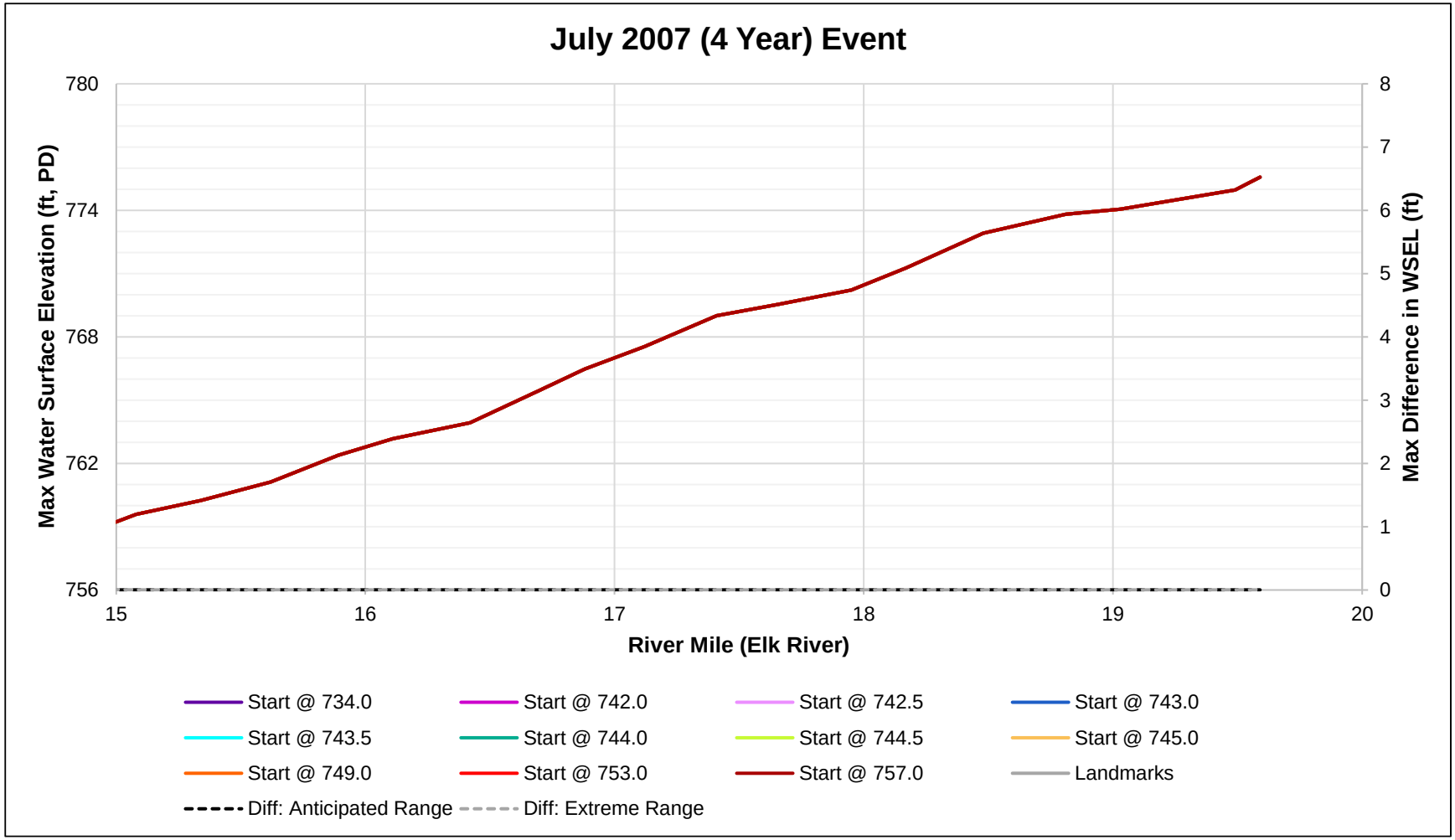


Figure E.29. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

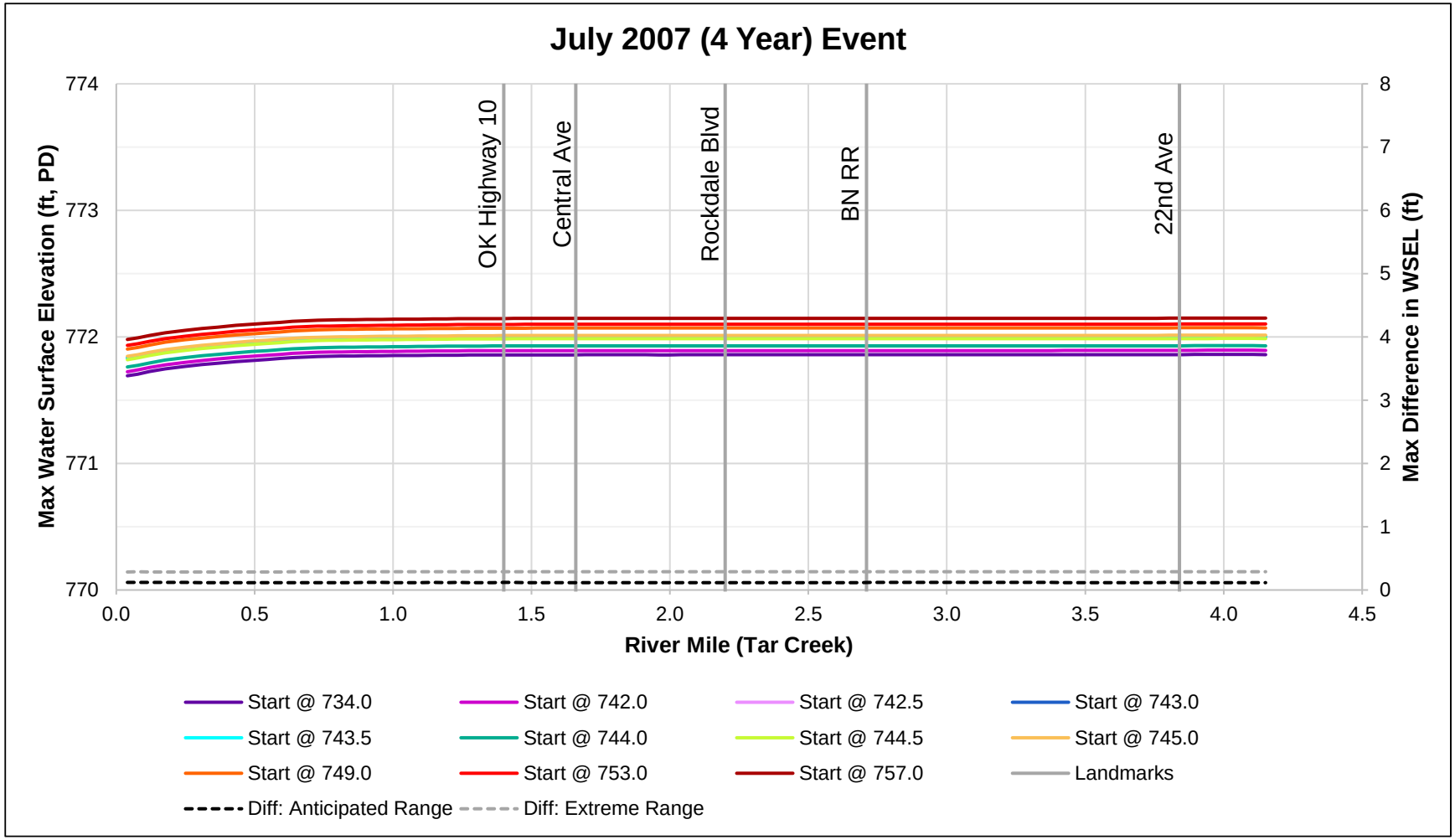


Figure E.30. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

APPENDIX E.4:
OCTOBER 2009 (3 YEAR) INFLOW EVENT
WATER SURFACE ELEVATION PROFILES

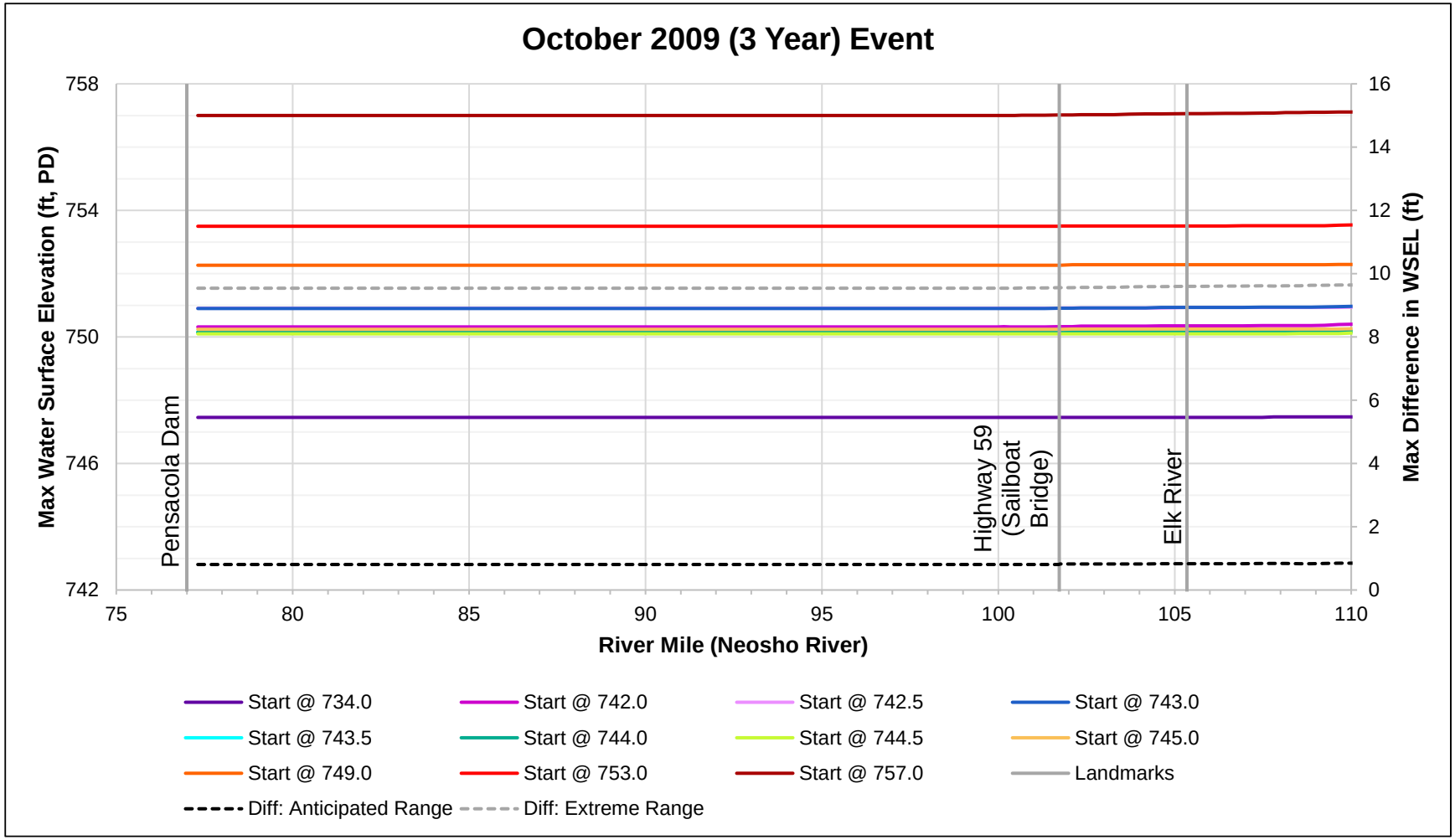


Figure E.31. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

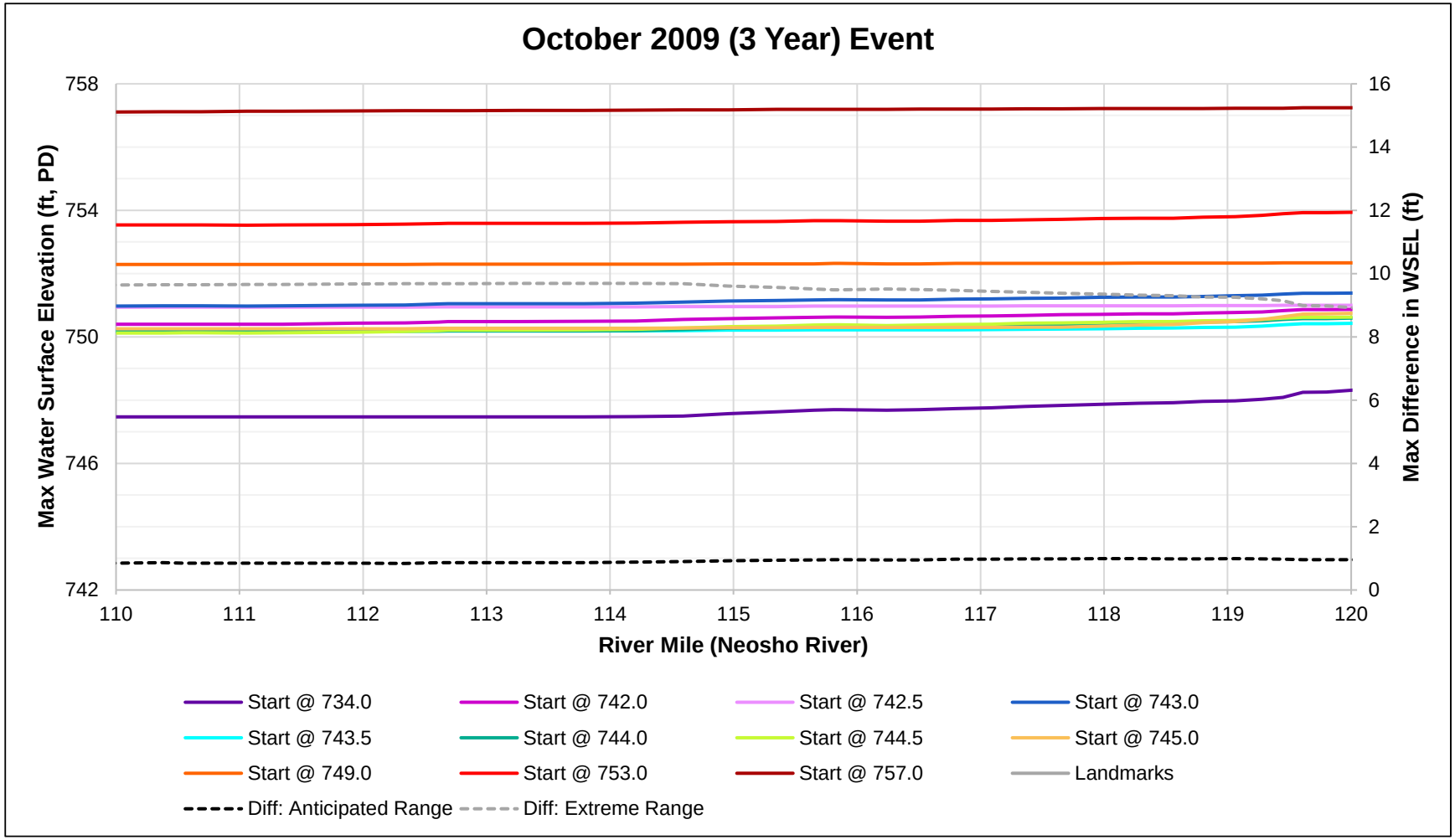


Figure E.32. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

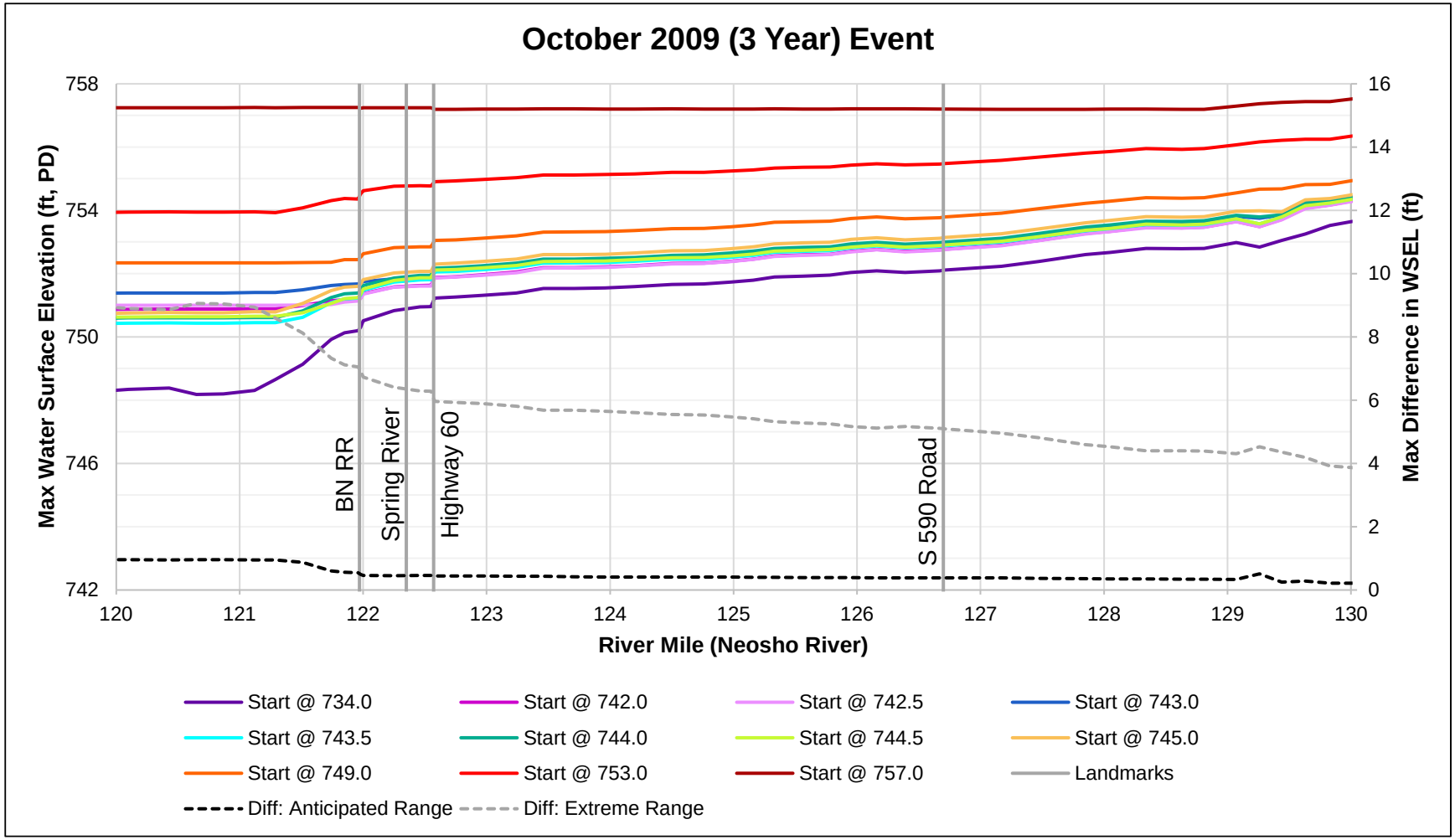


Figure E.33. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

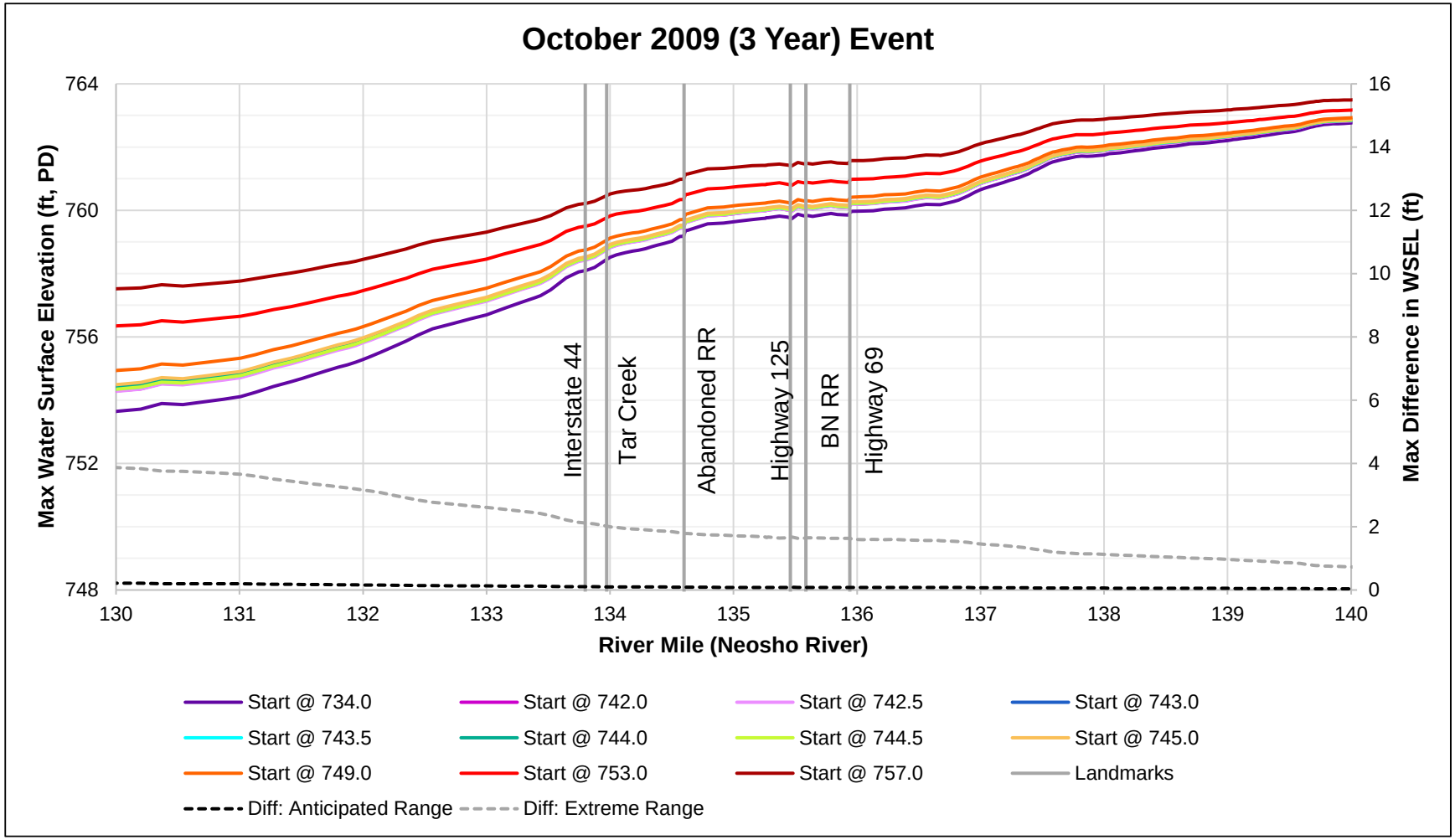


Figure E.34. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

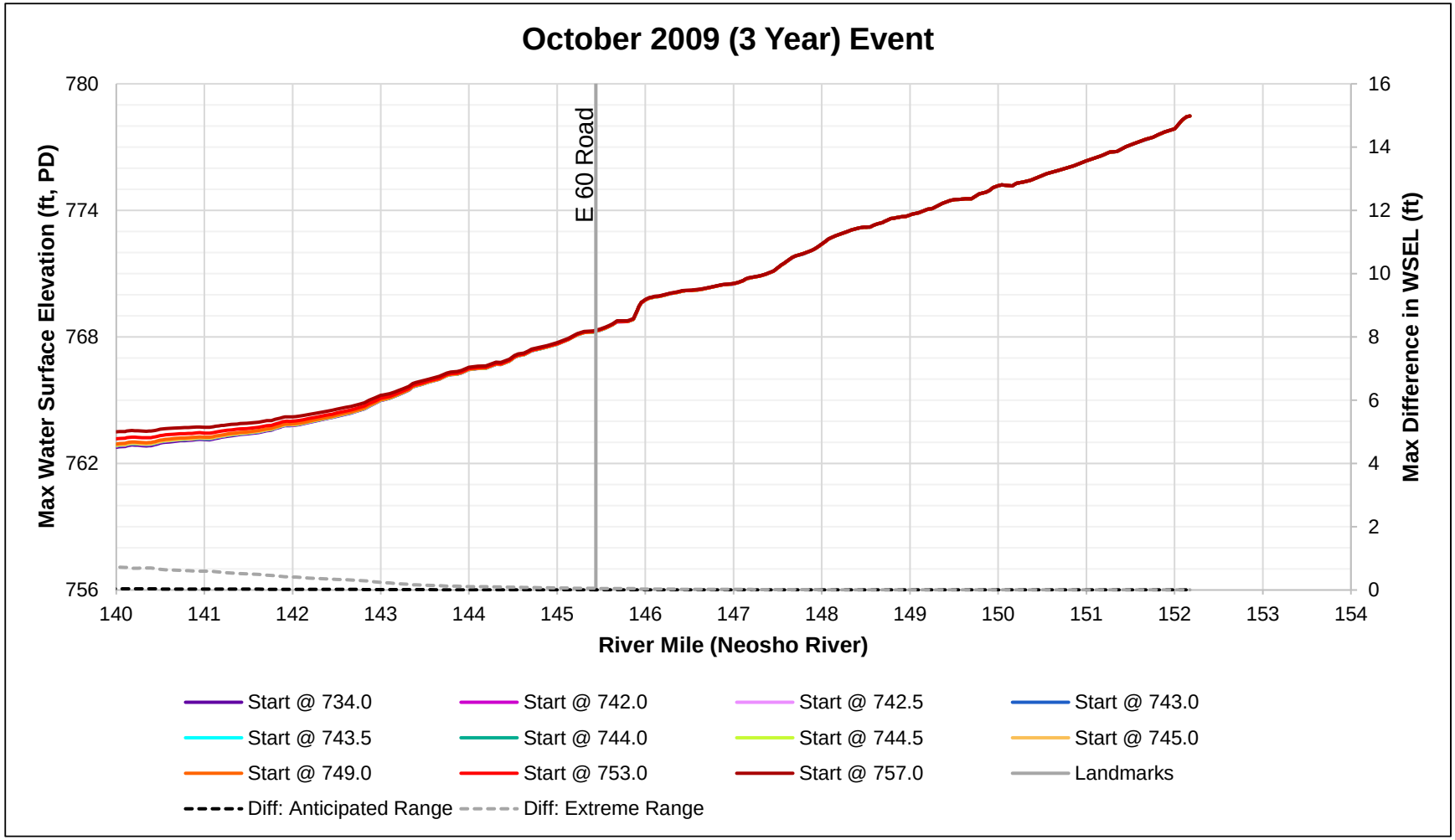


Figure E.35. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

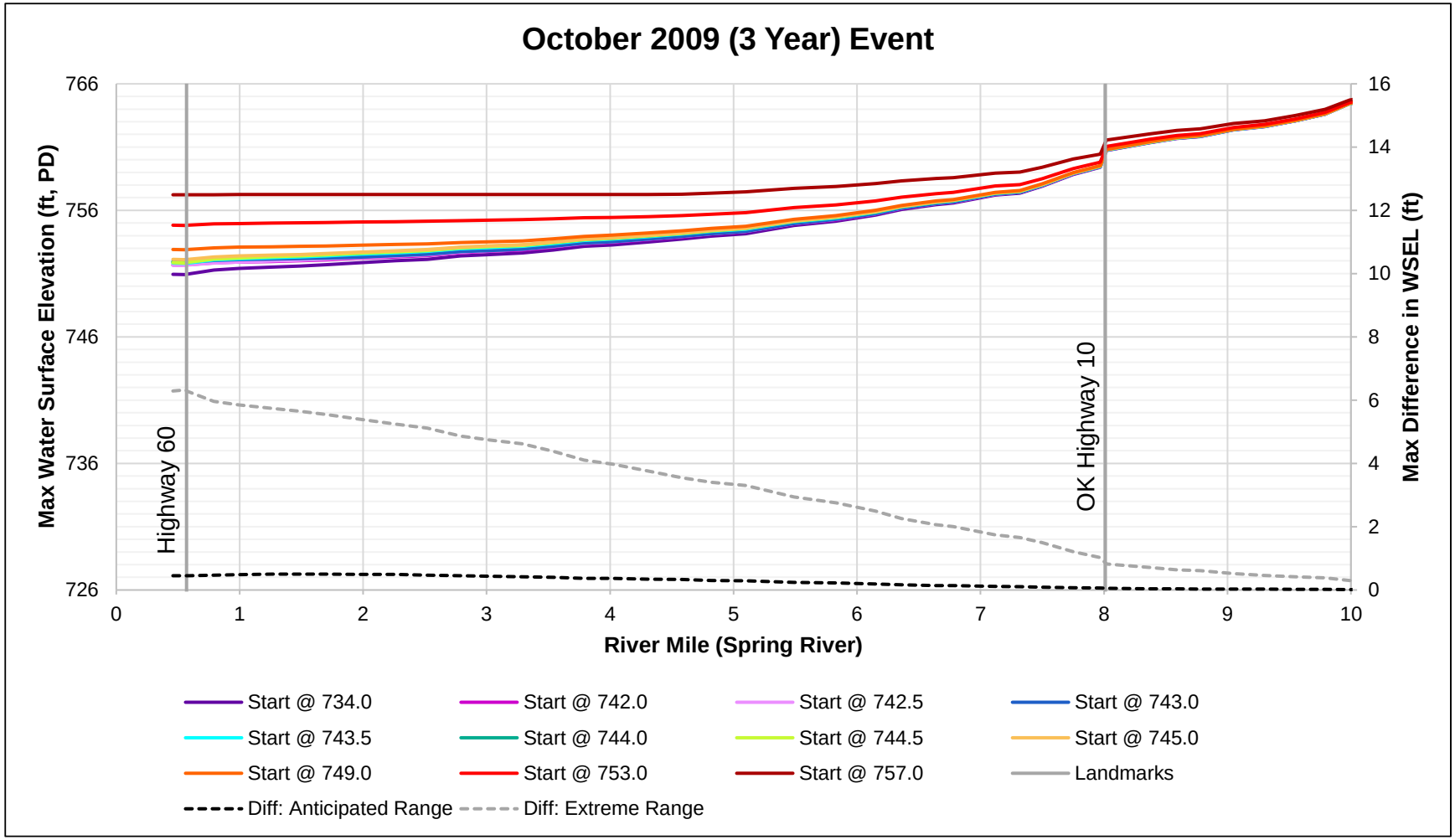


Figure E.36. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

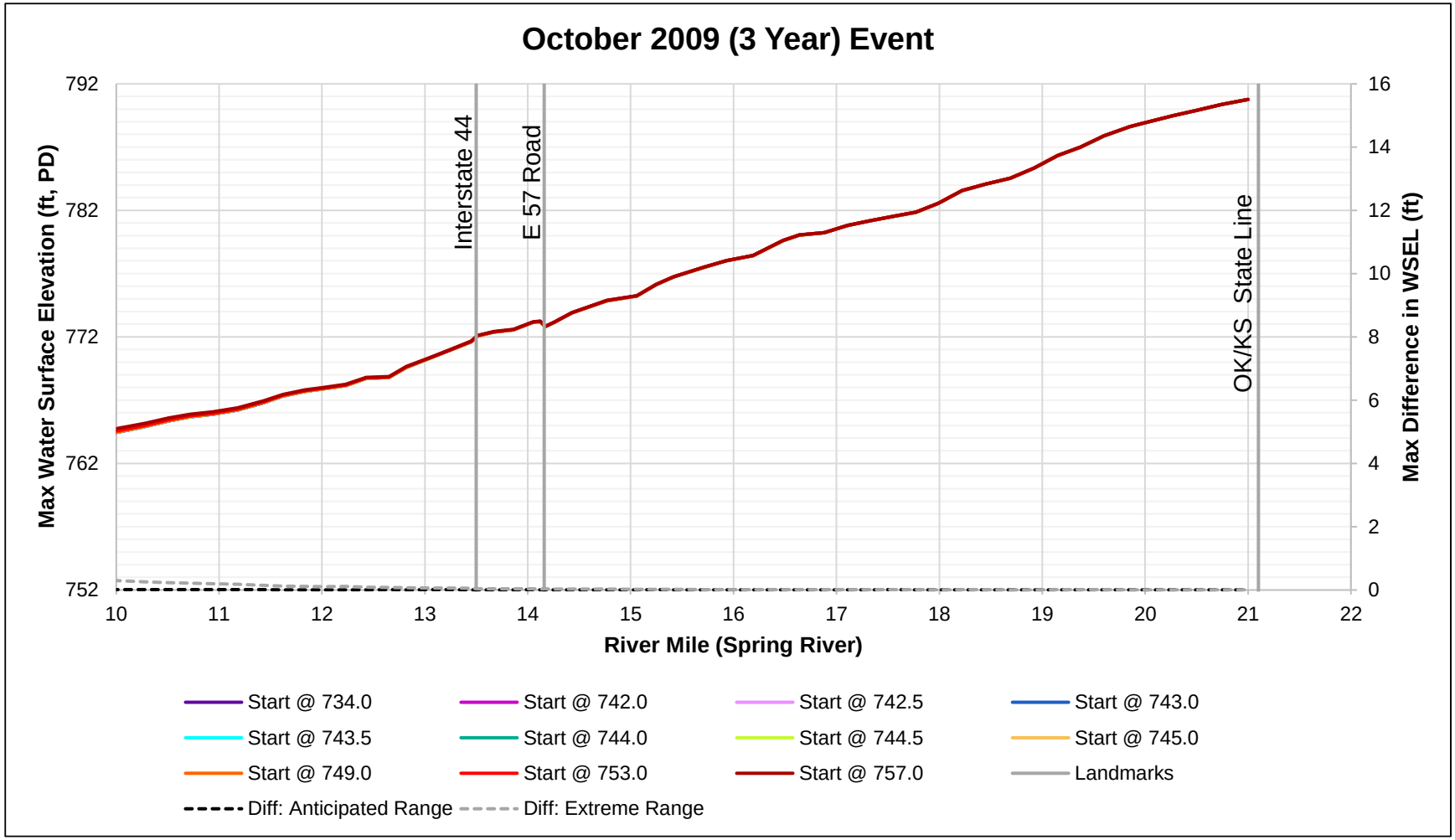


Figure E.37. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

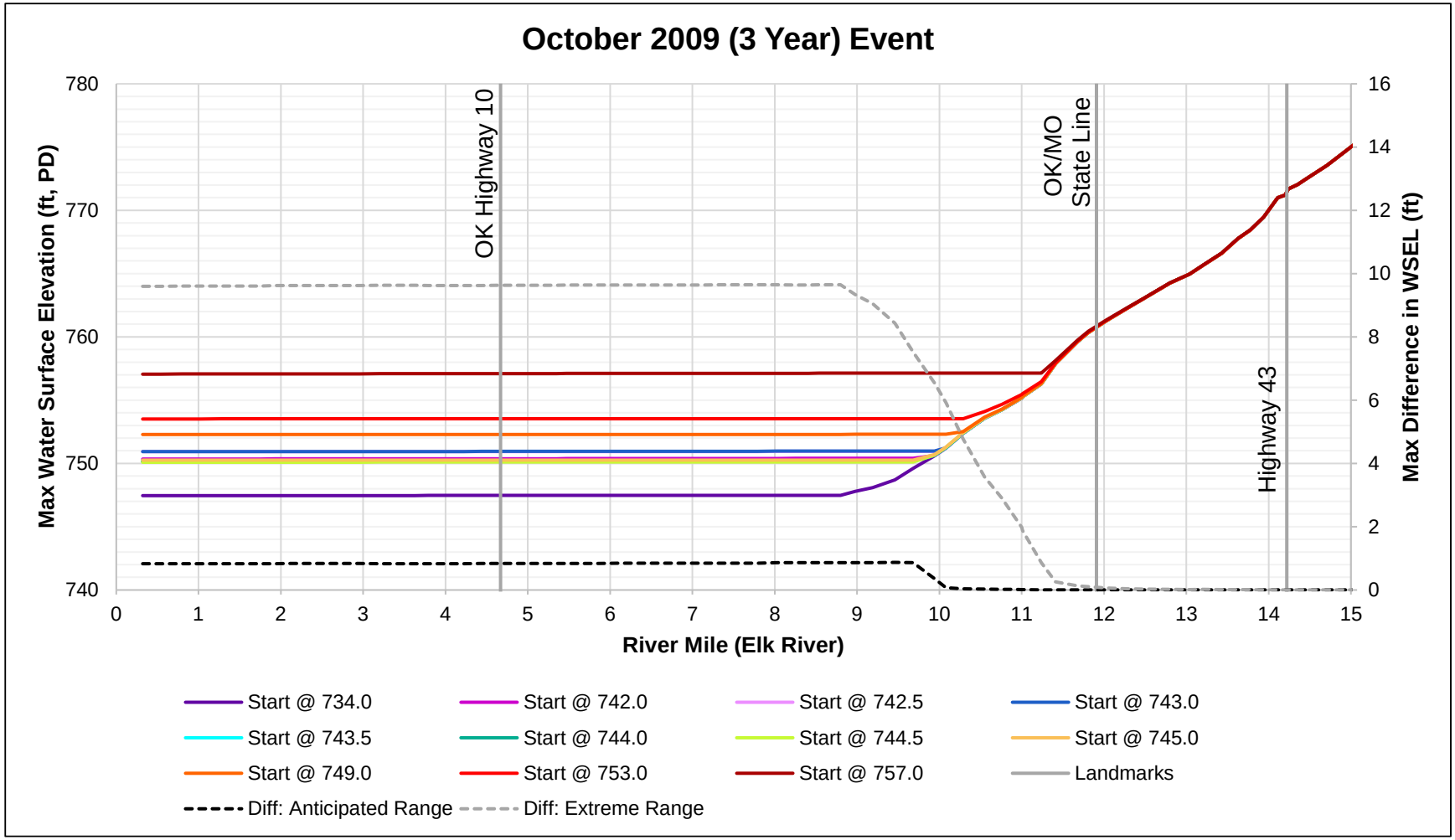


Figure E.38. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

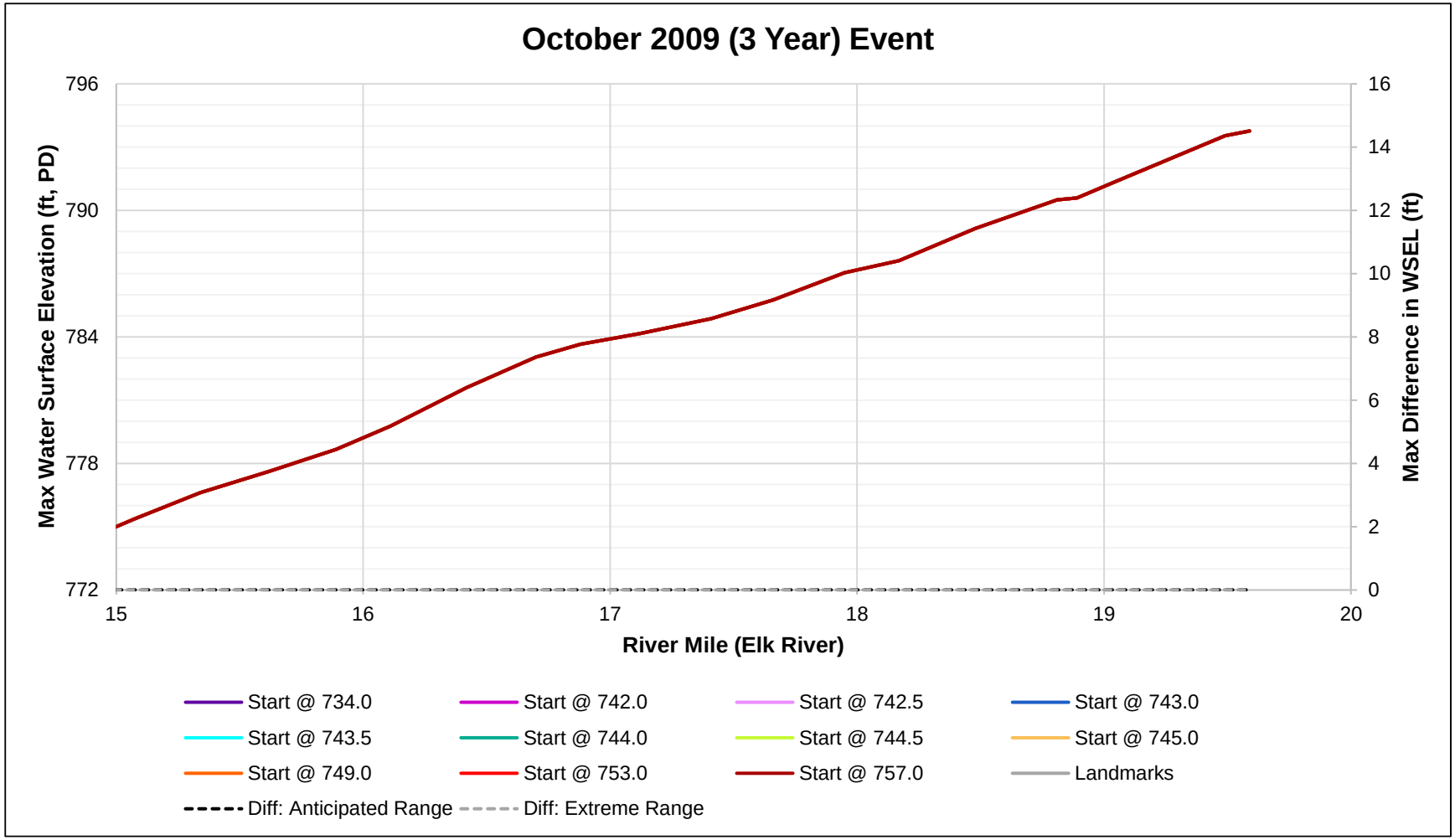


Figure E.39. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

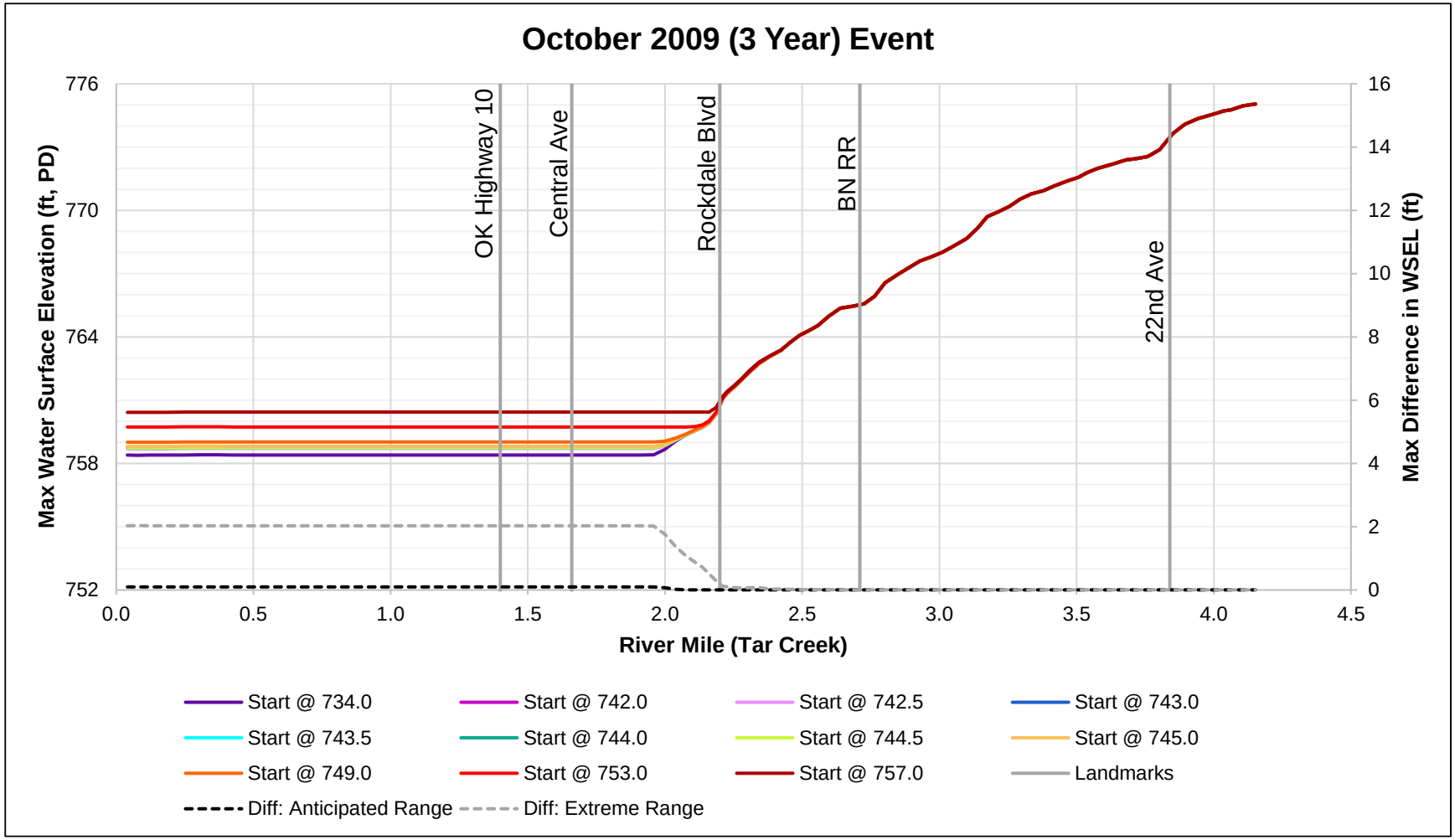


Figure E.40. Water surface elevations for the October 2009 (3 year) inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

APPENDIX E.5:
DECEMBER 2015 (15 YEAR) INFLOW EVENT
WATER SURFACE ELEVATION PROFILES

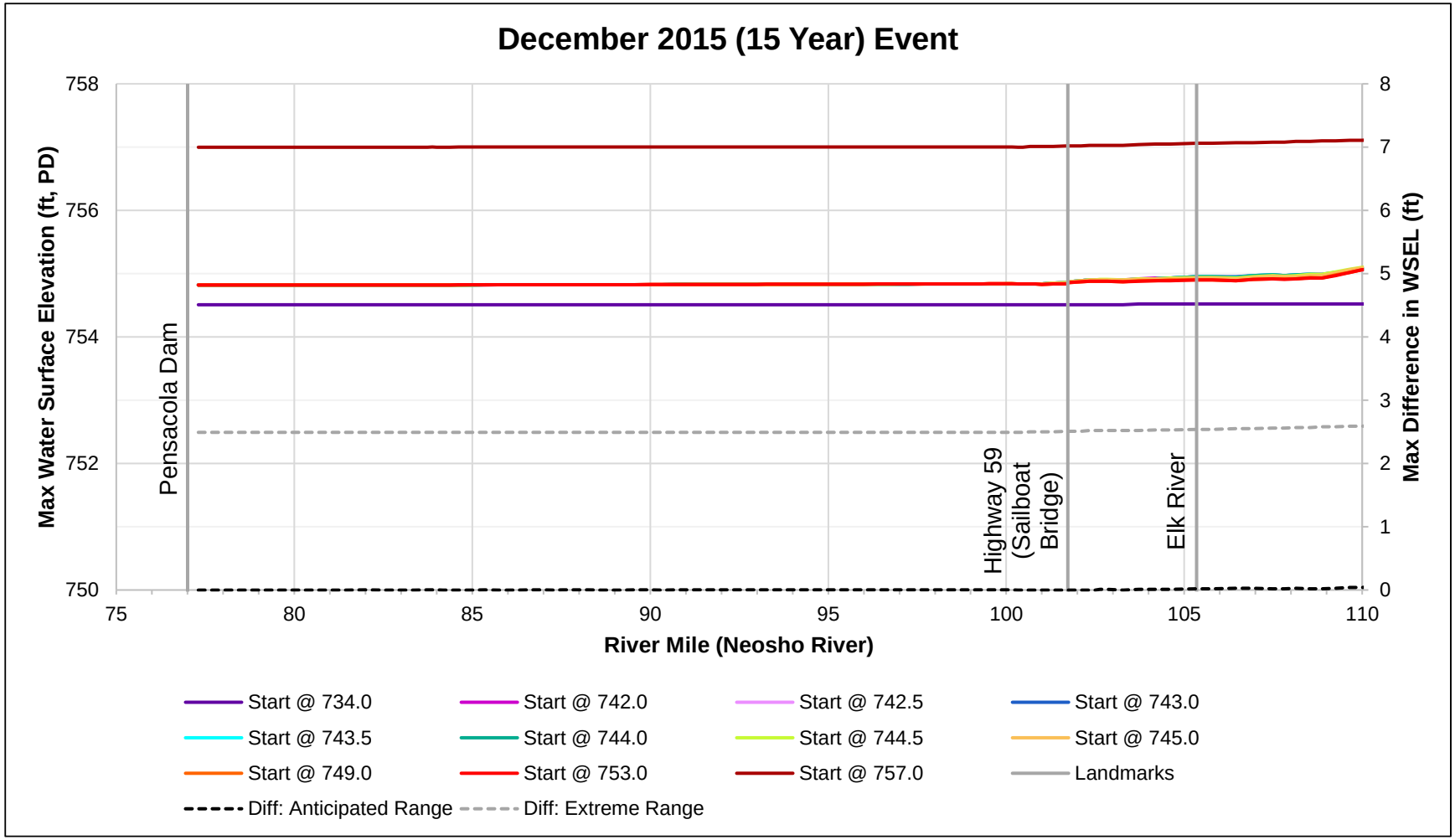


Figure E.41. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

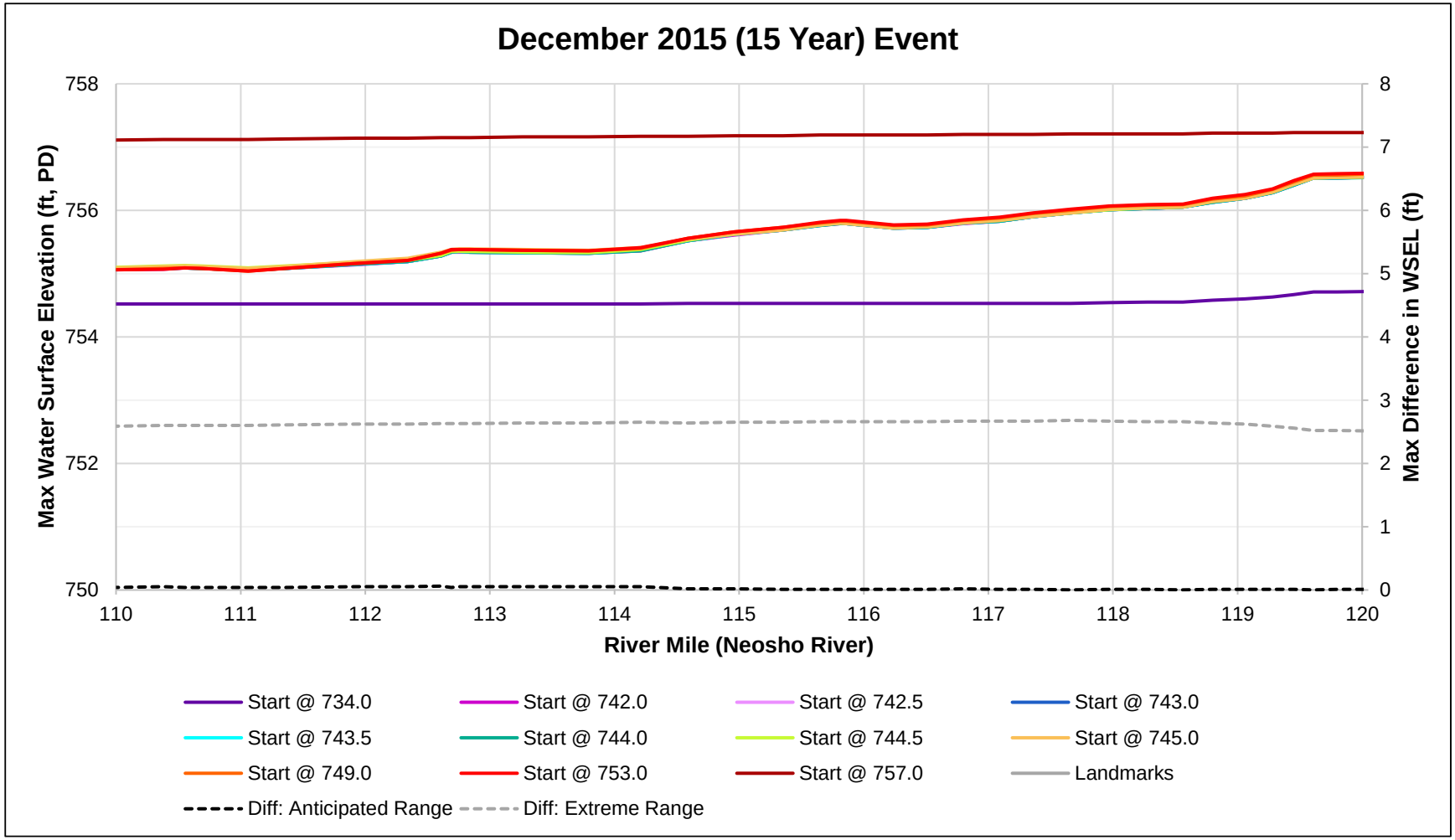


Figure E.42. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

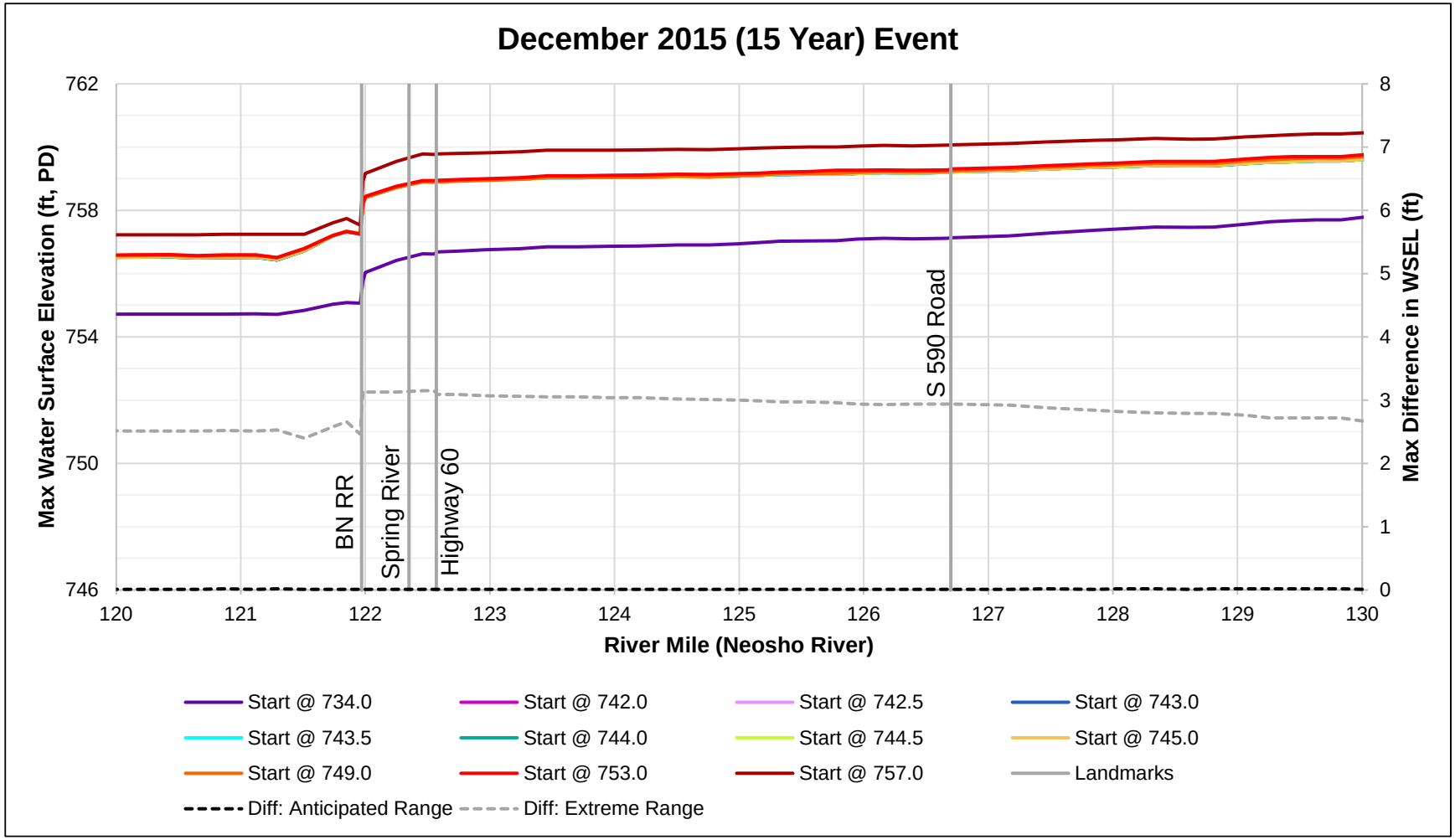


Figure E.43. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

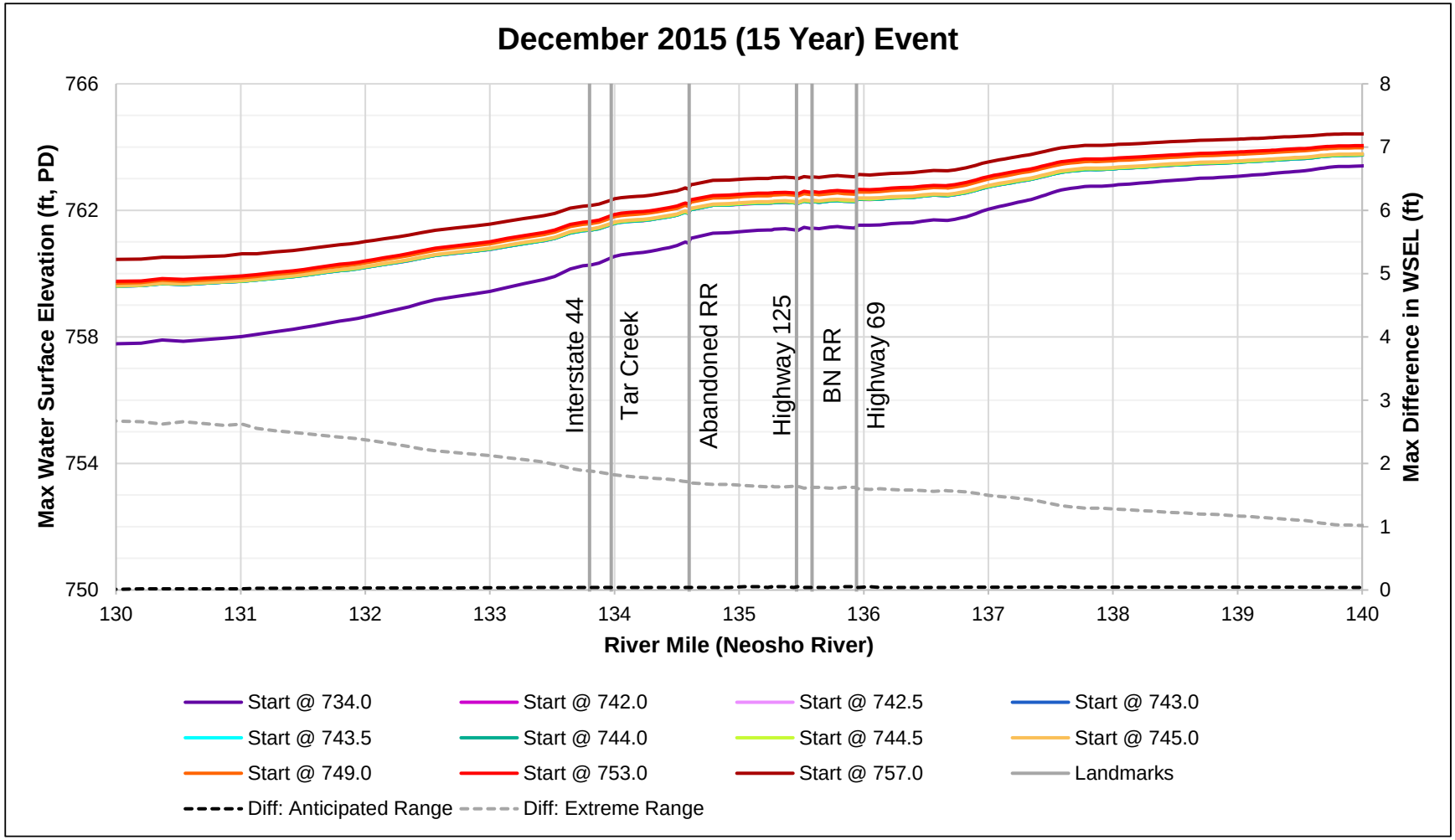


Figure E.44. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

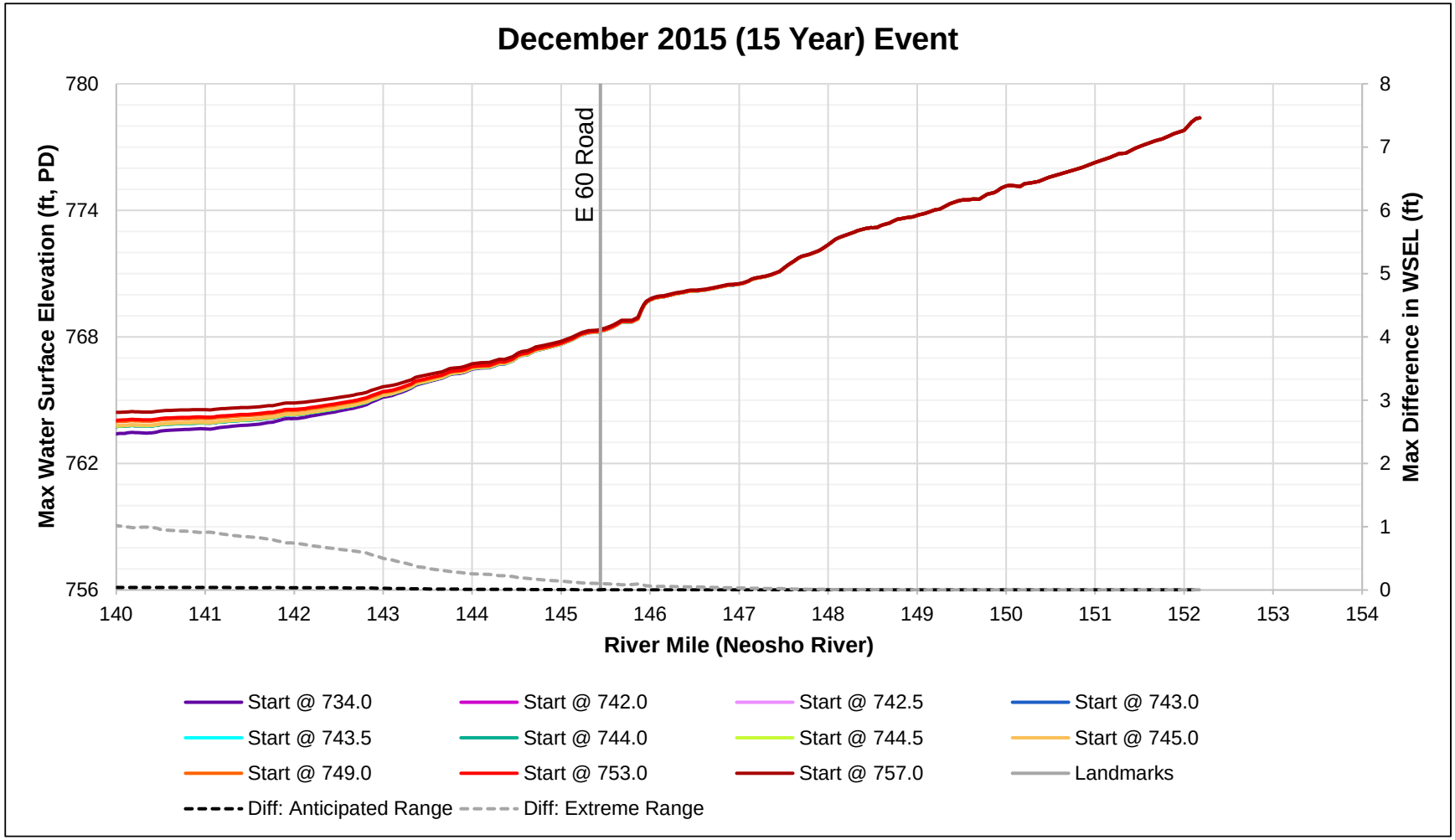


Figure E.45. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

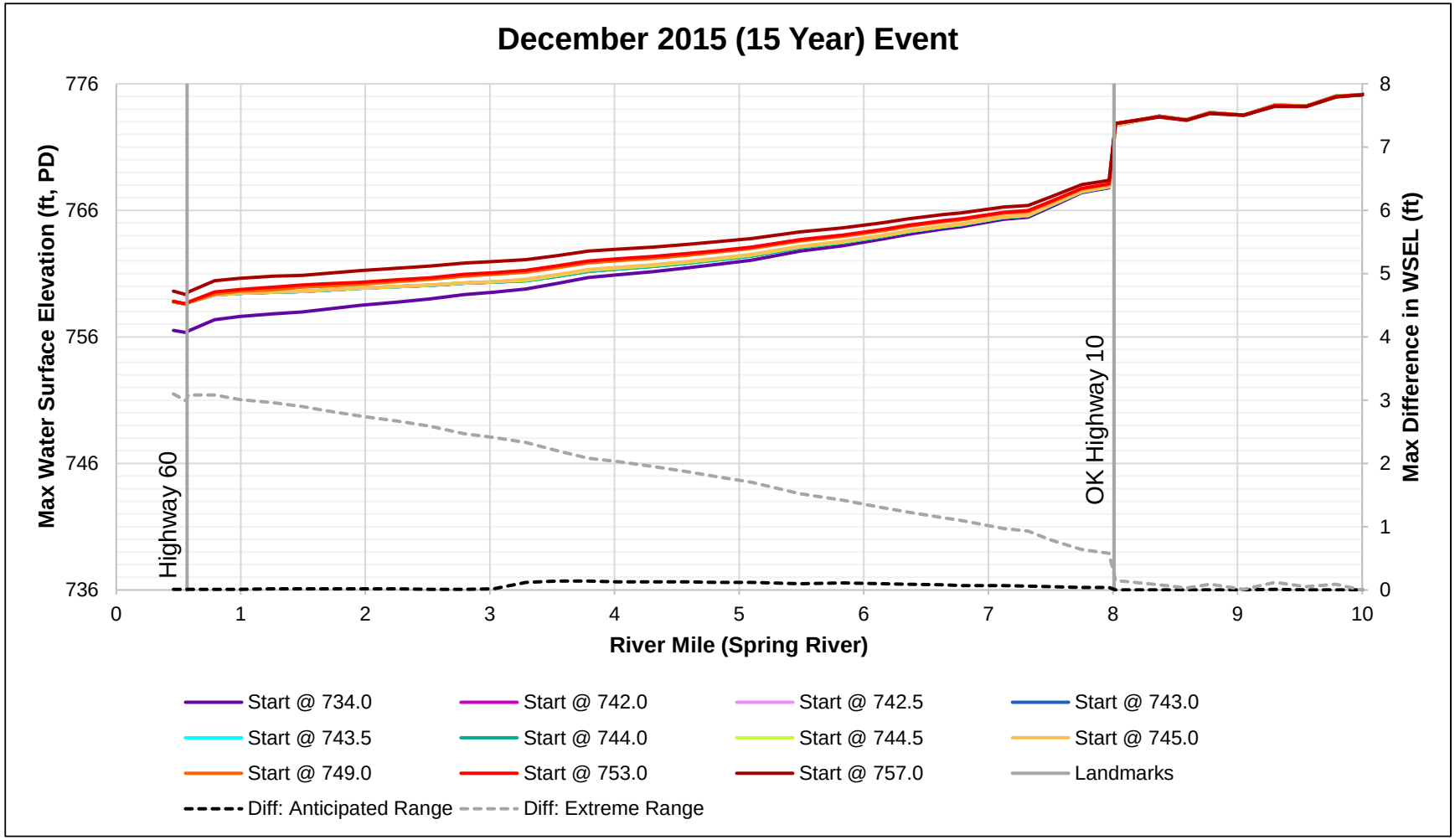


Figure E.46. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

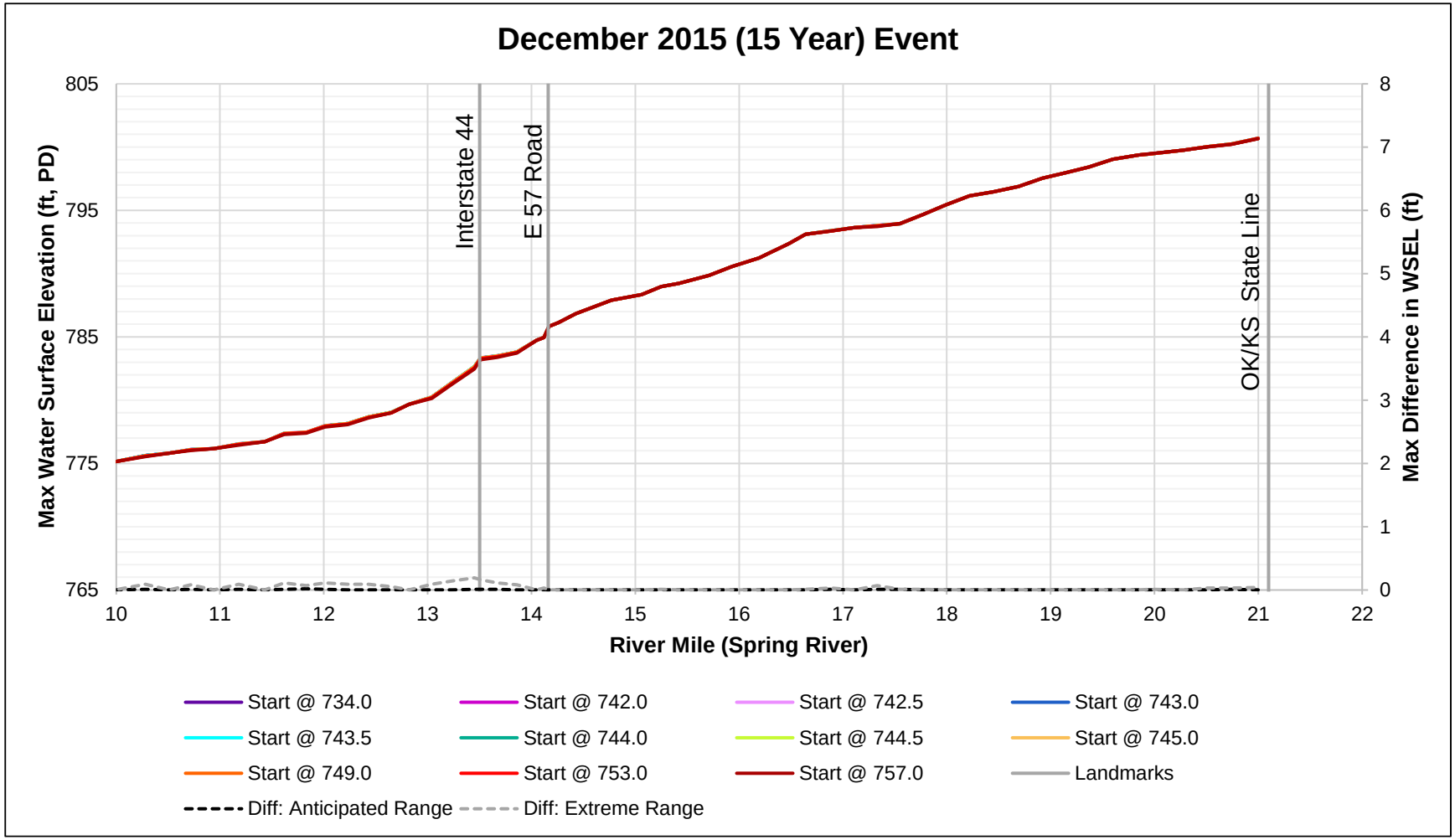


Figure E.47. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

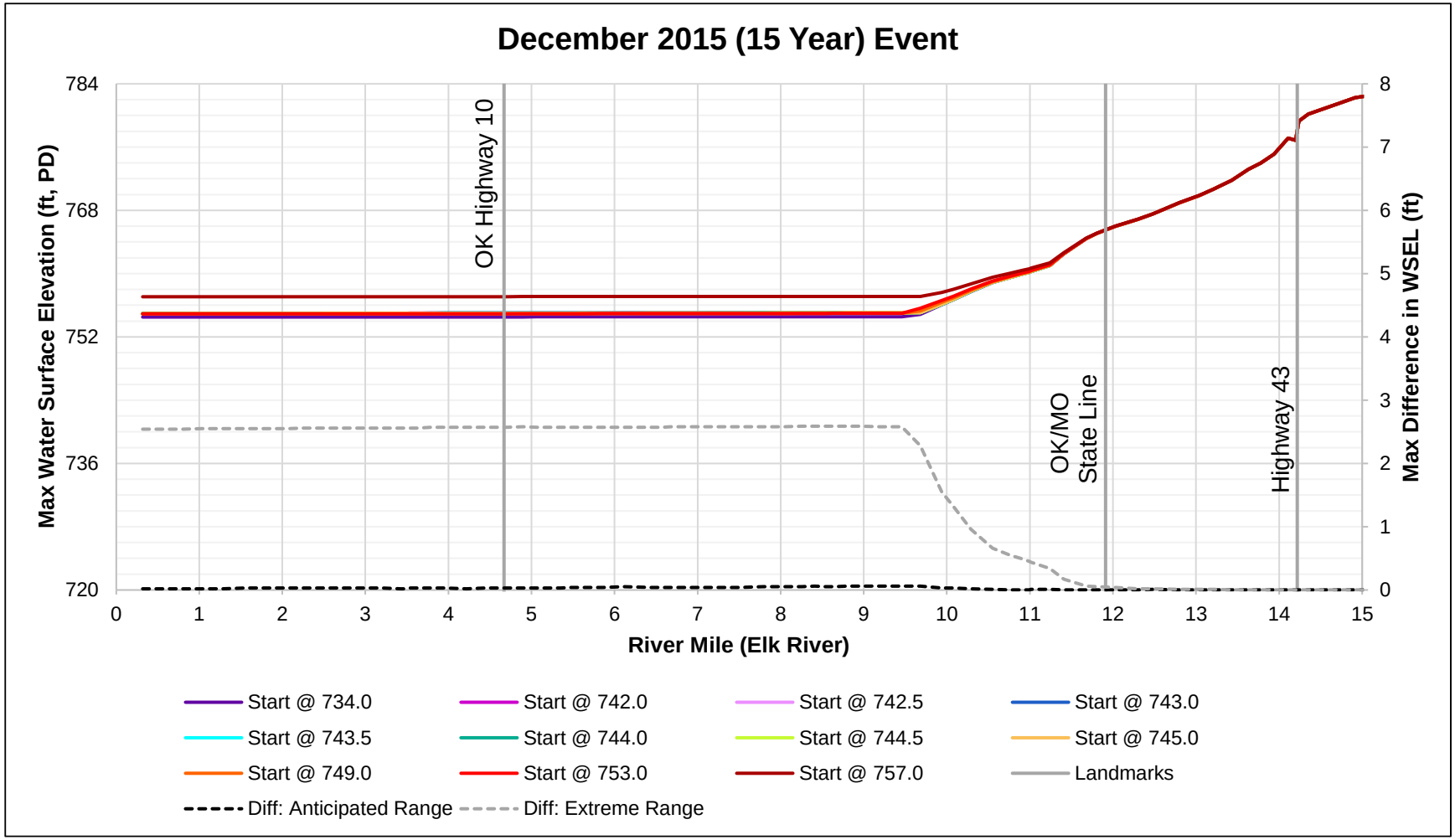


Figure E.48. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

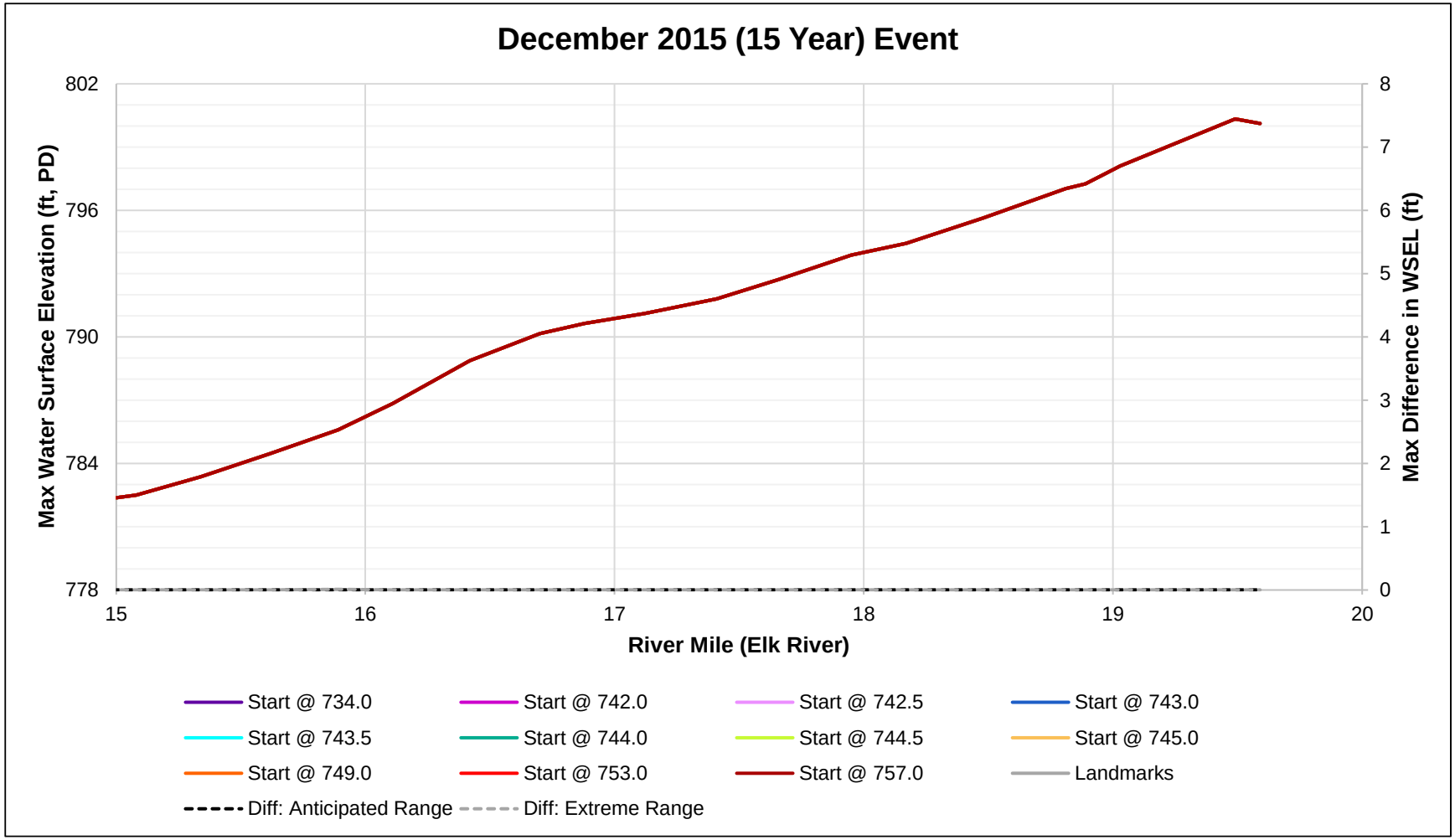


Figure E.49. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

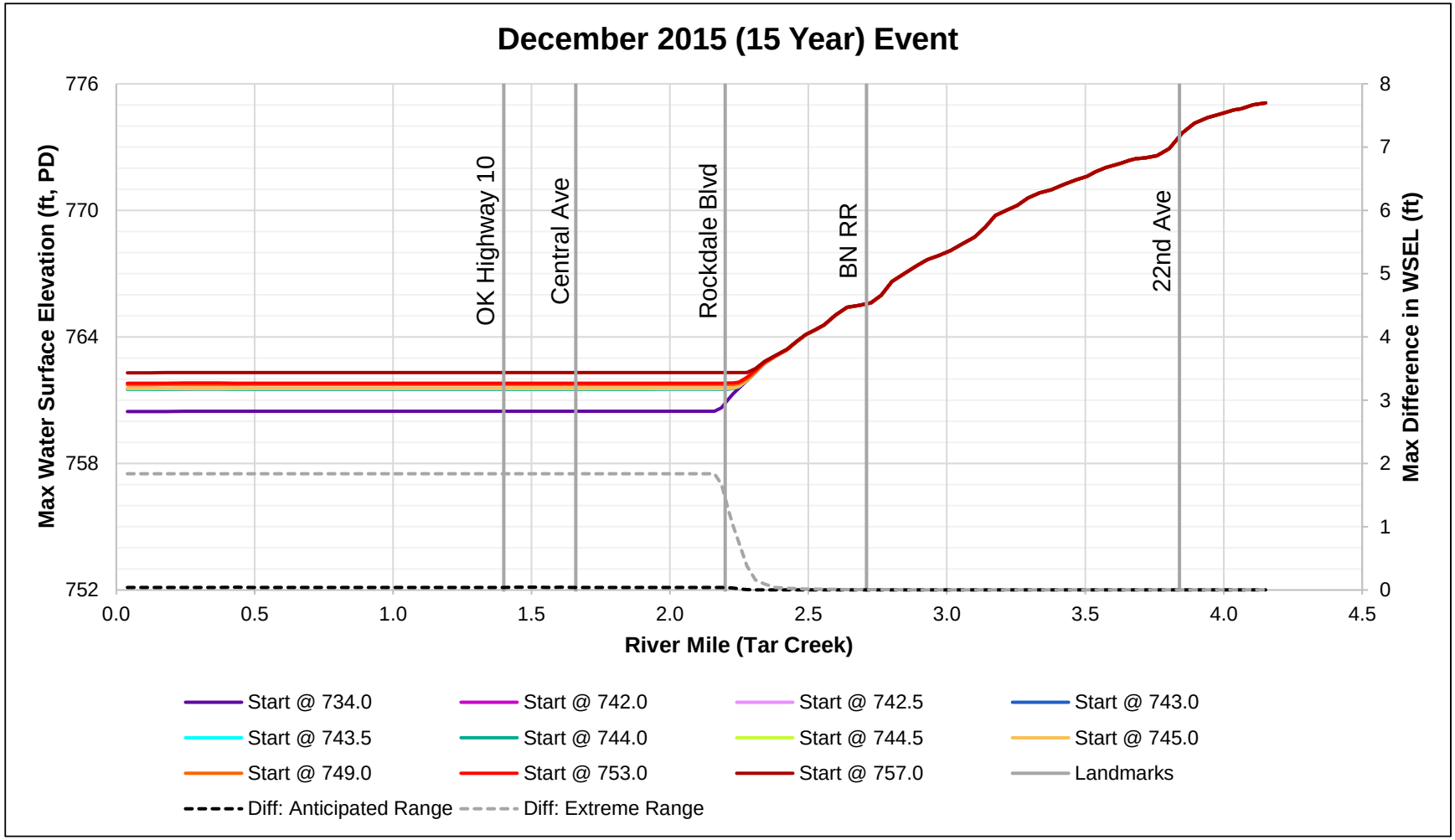


Figure E.50. Water surface elevations for the December 2015 (15 year) inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

APPENDIX E.6:
100-YEAR INFLOW EVENT
WATER SURFACE ELEVATION PROFILES

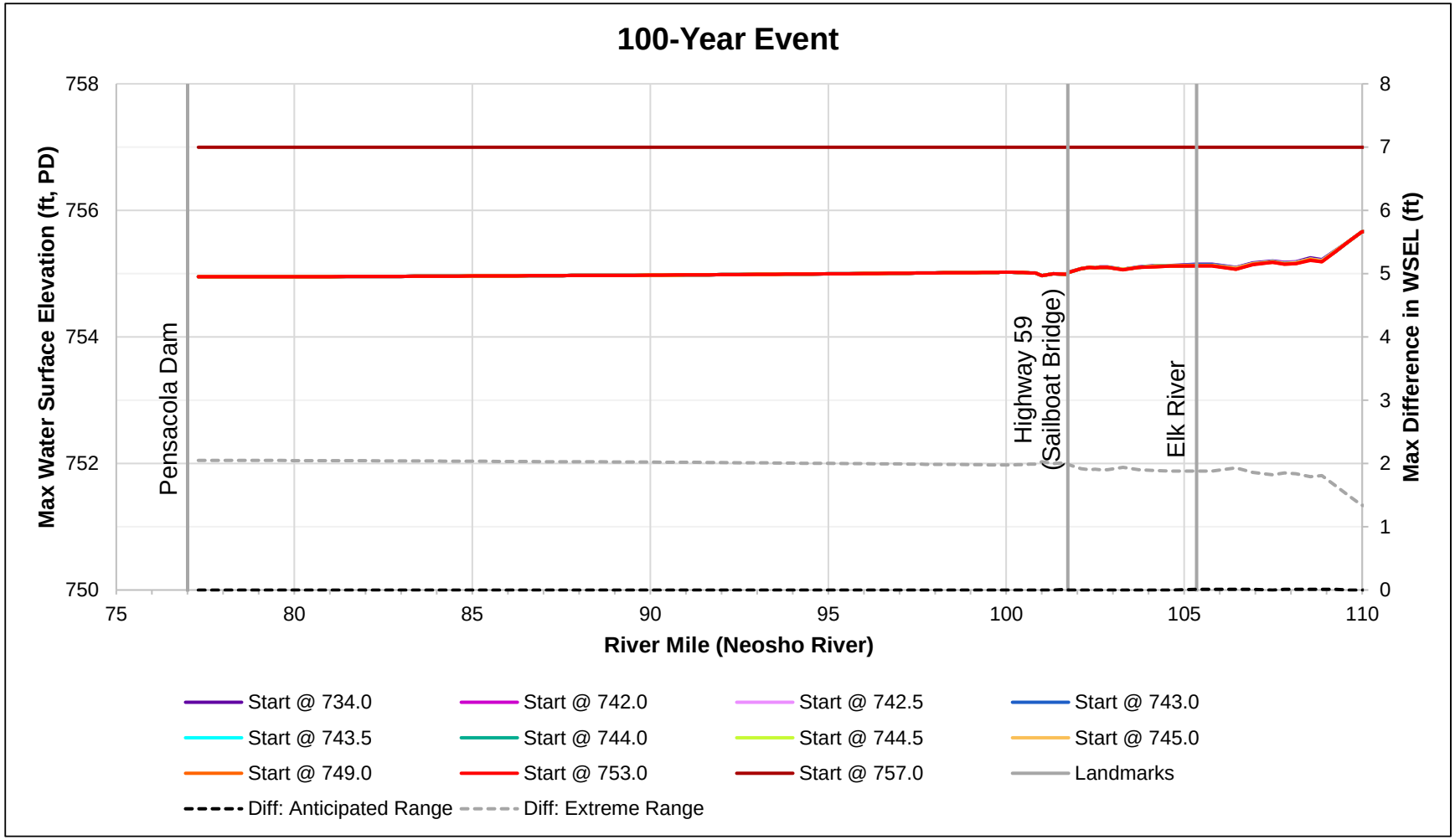


Figure E.51. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

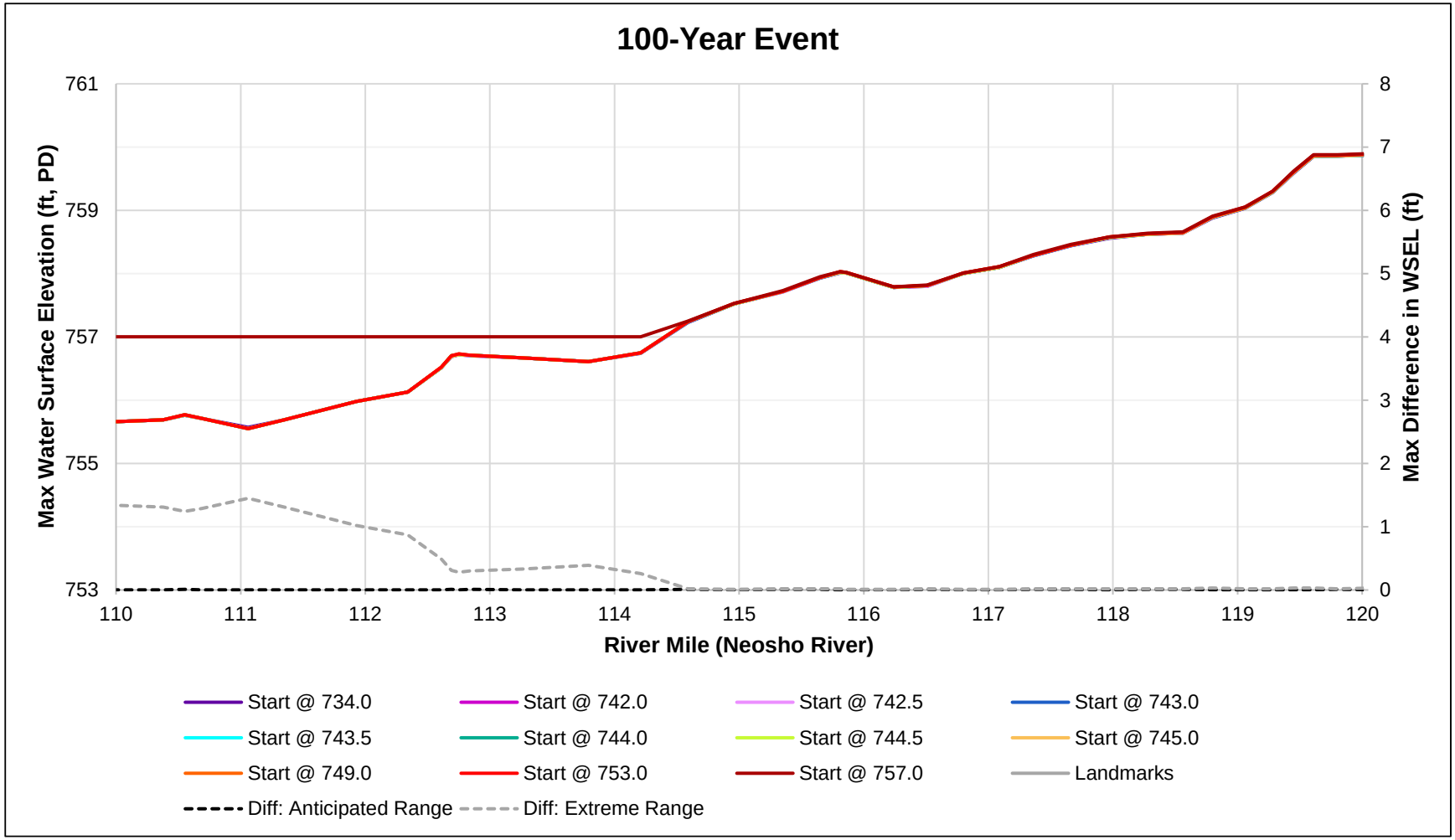


Figure E.52. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

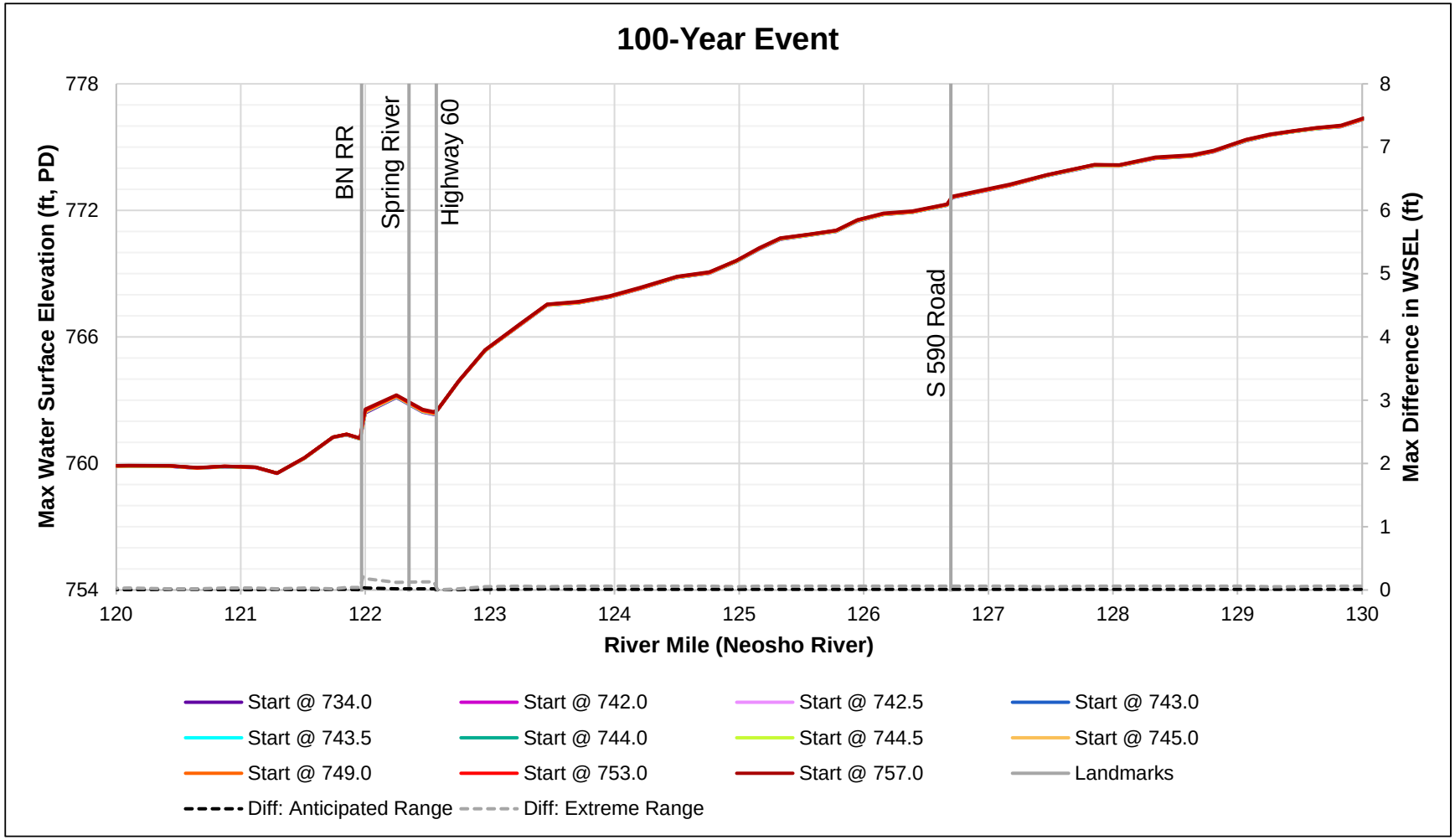


Figure E.53. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

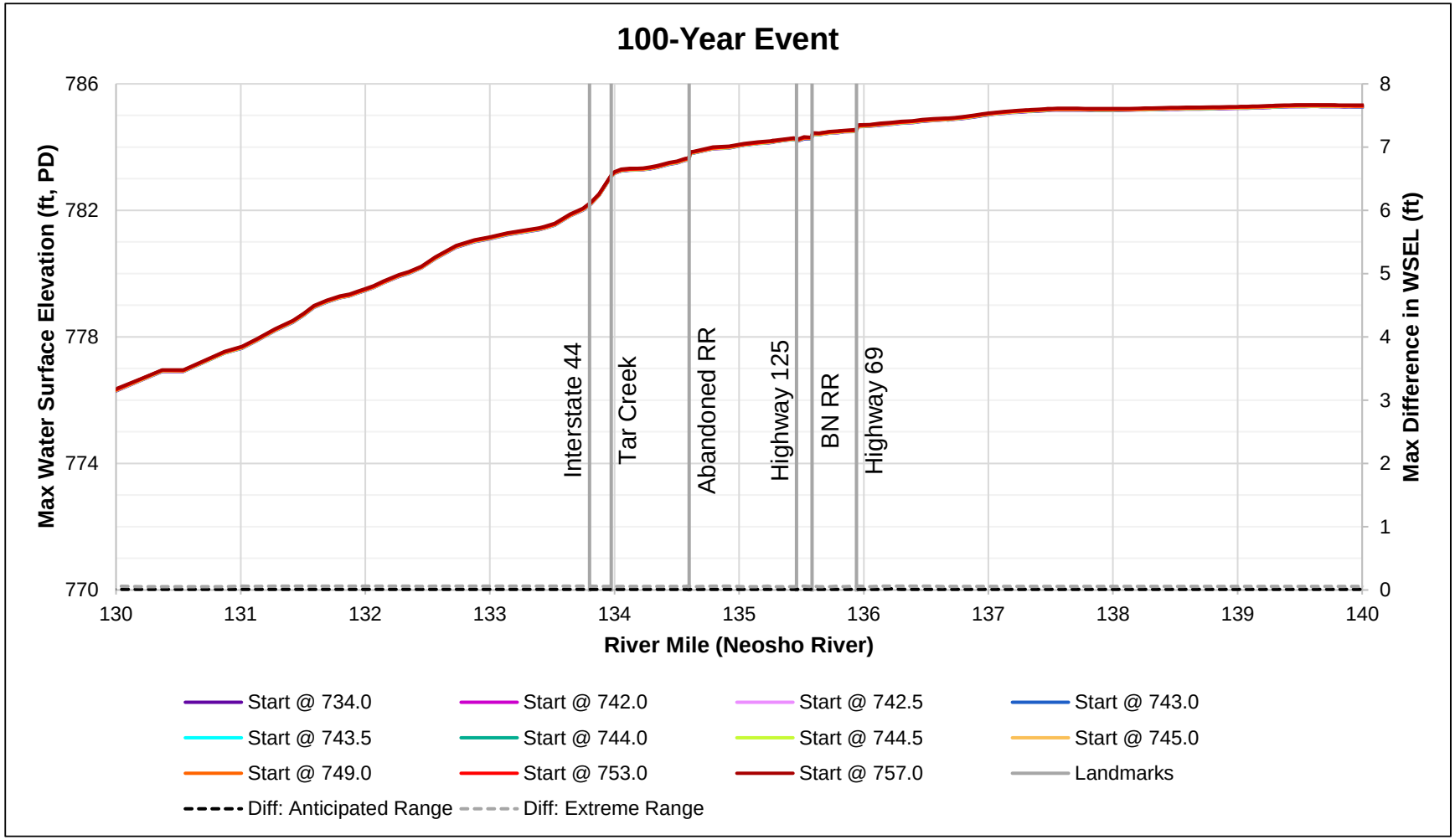


Figure E.54. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

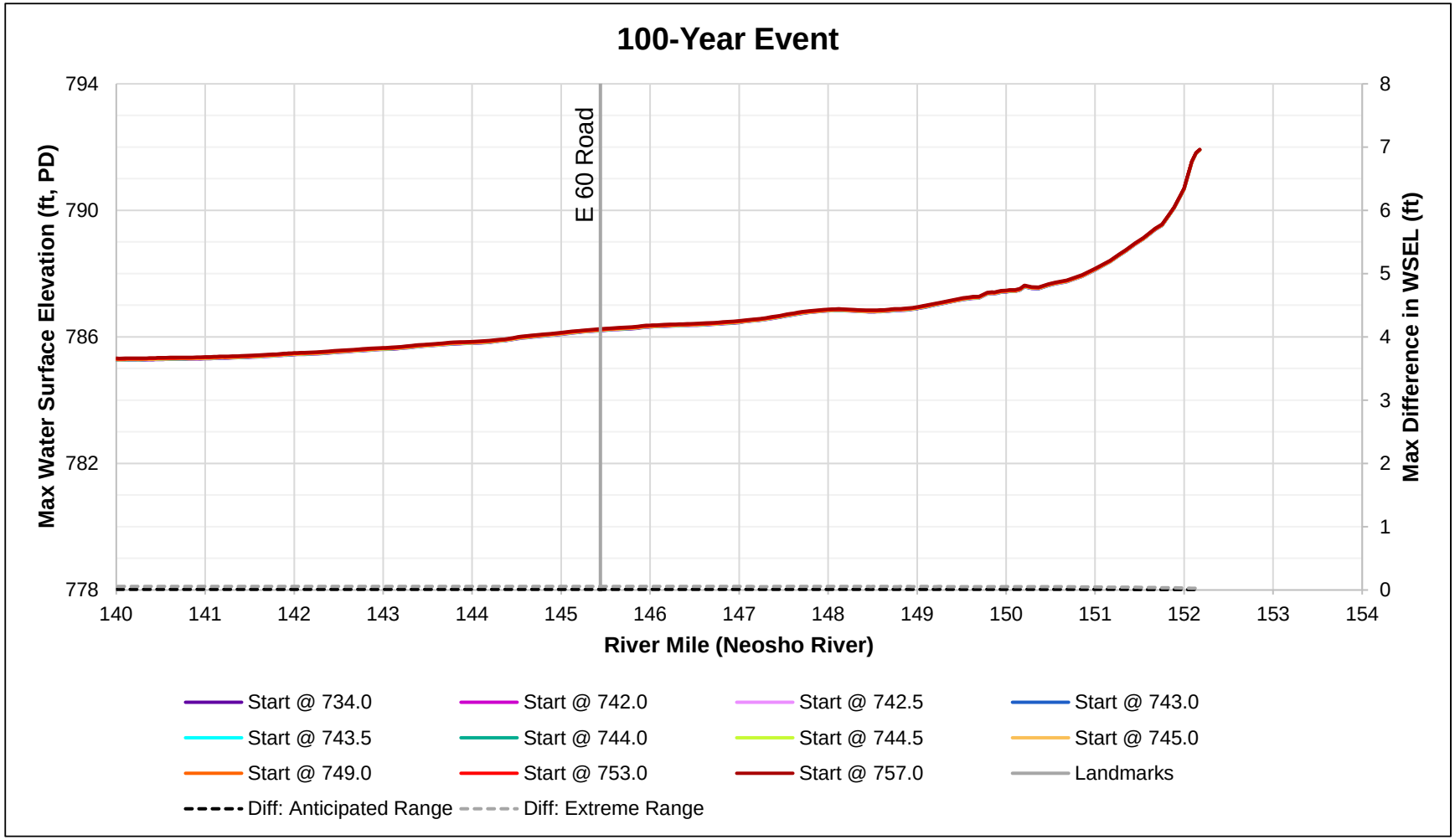


Figure E.55. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

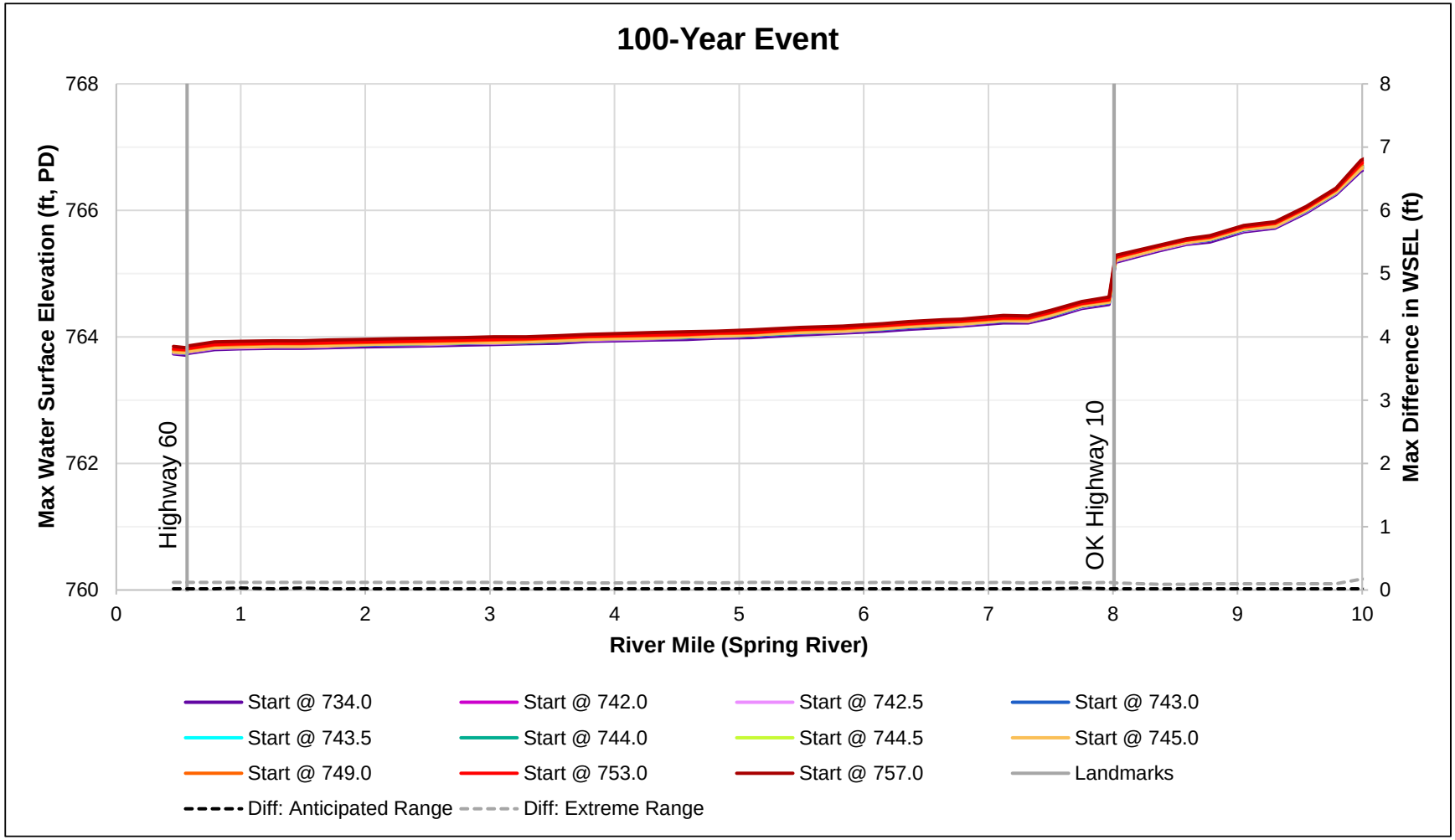


Figure E.56. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: *1. The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.

3. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.

4. For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.

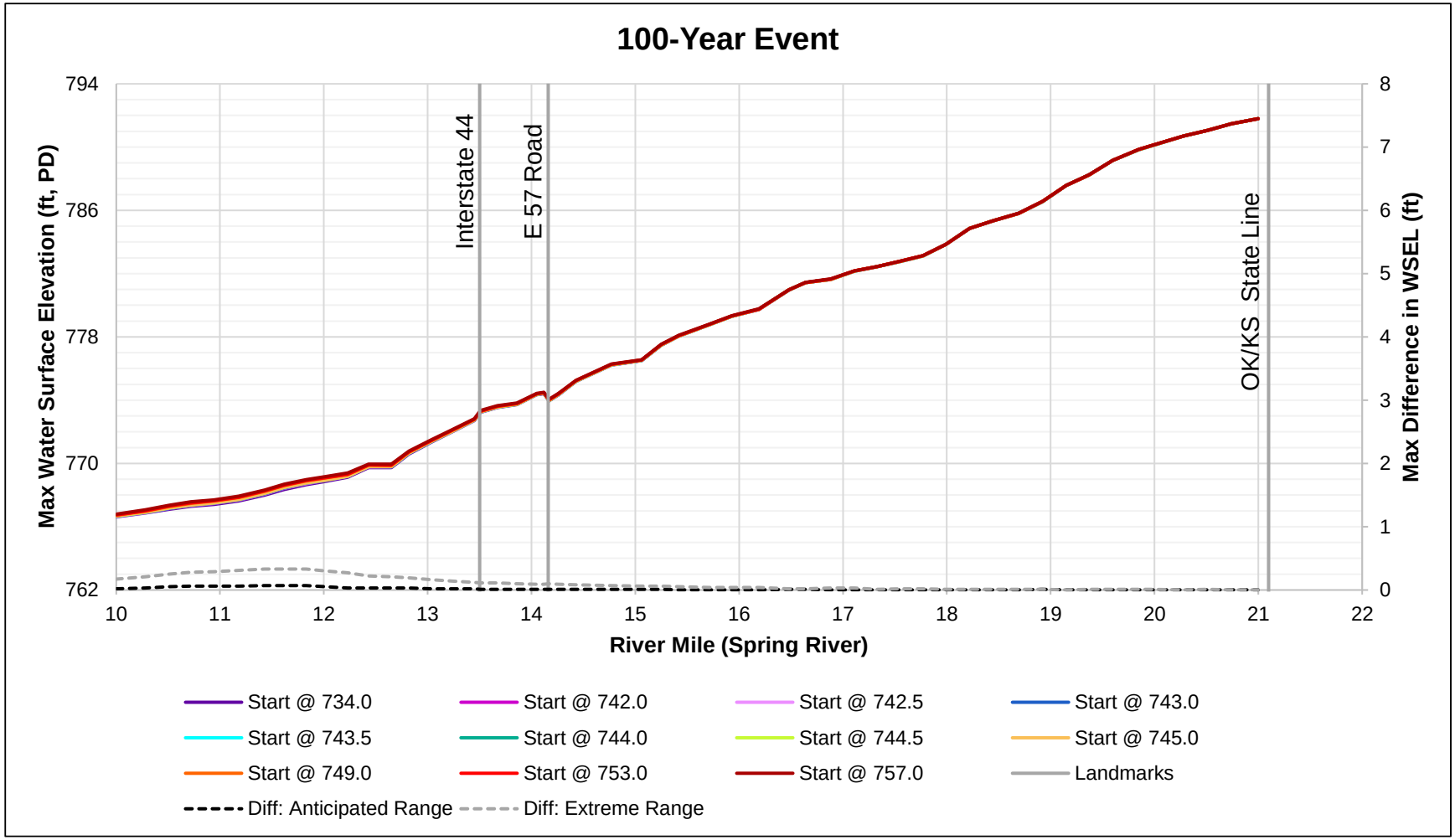


Figure E.57. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

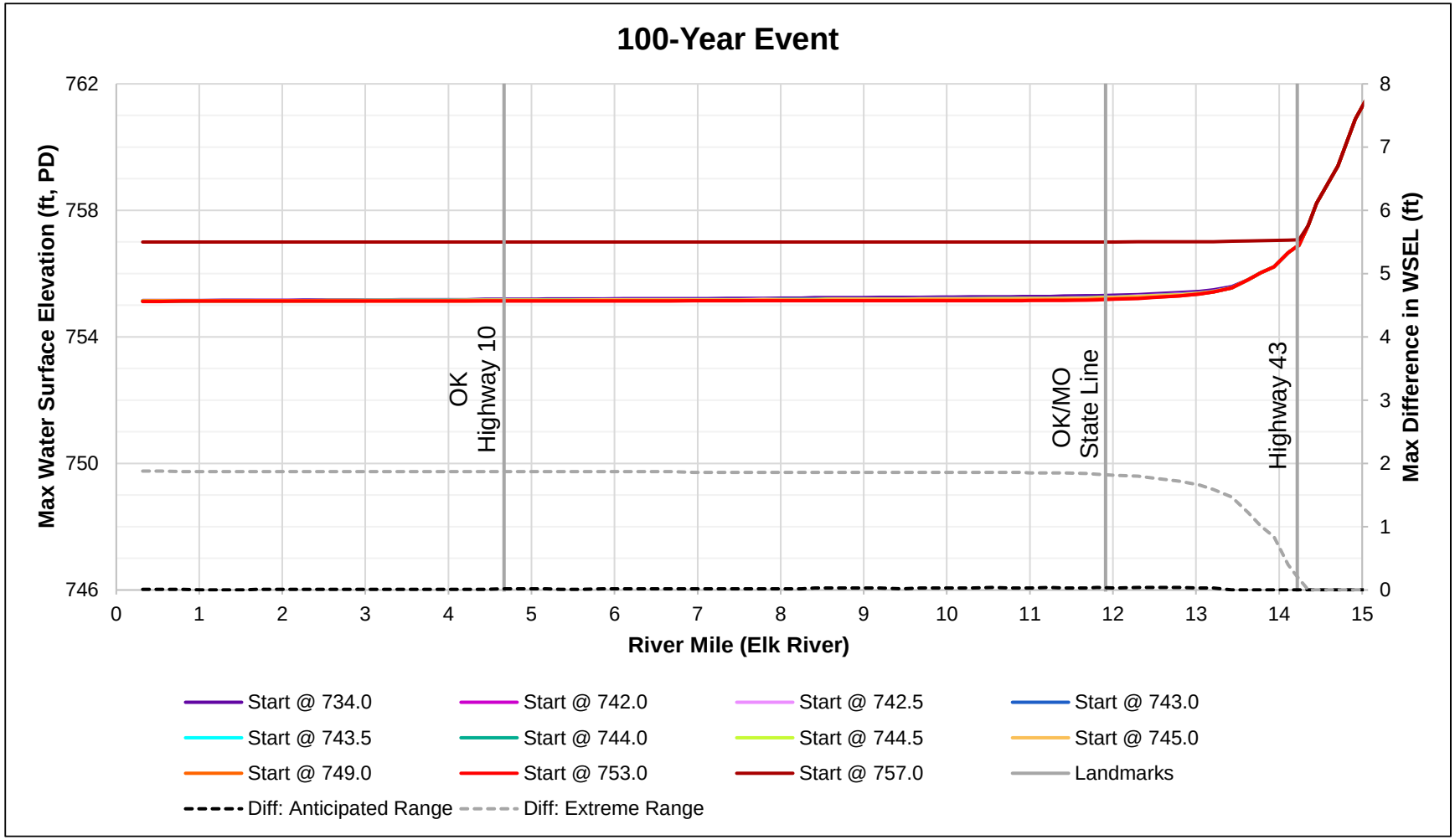


Figure E.58. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

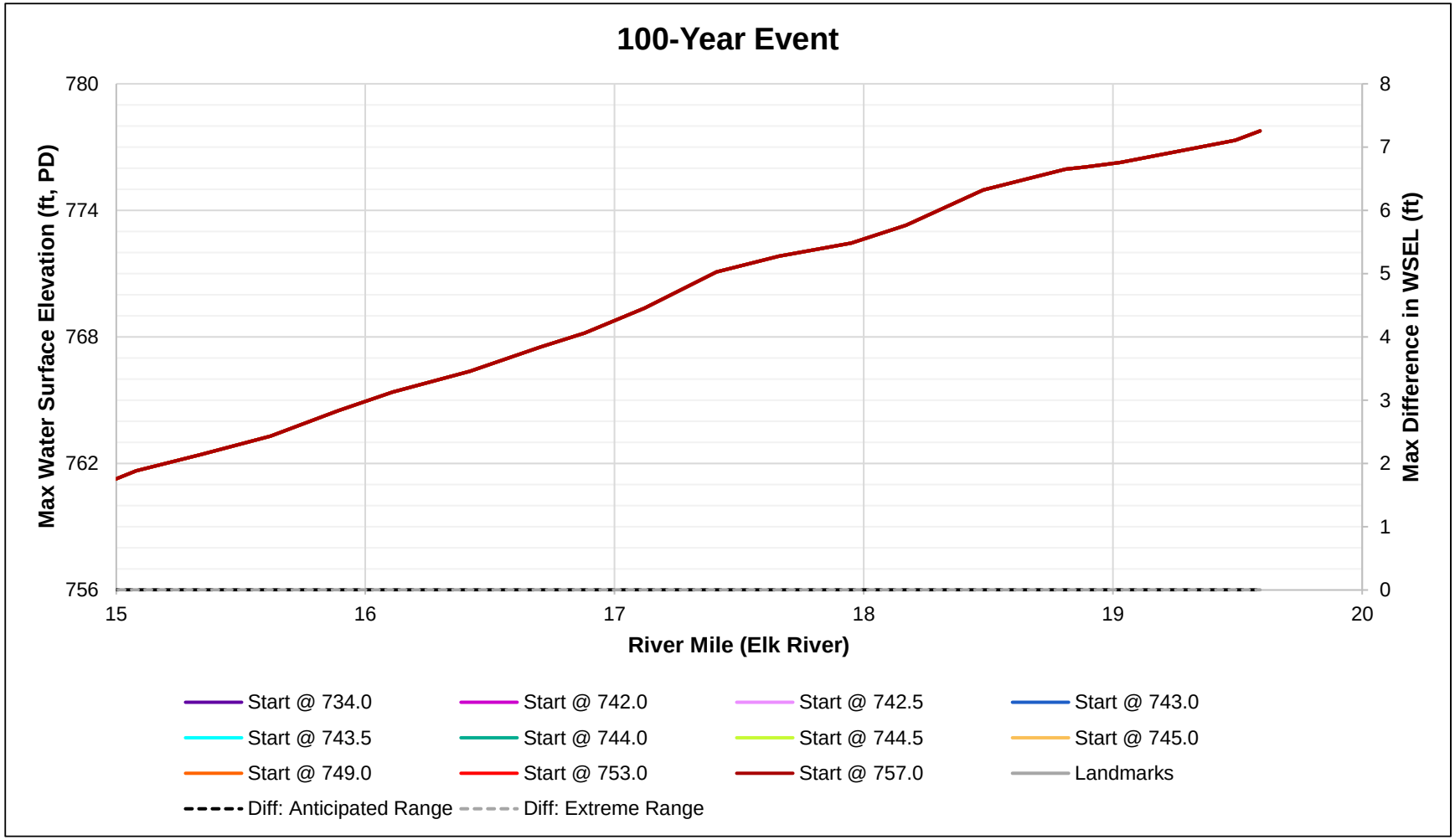


Figure E.59. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*
2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

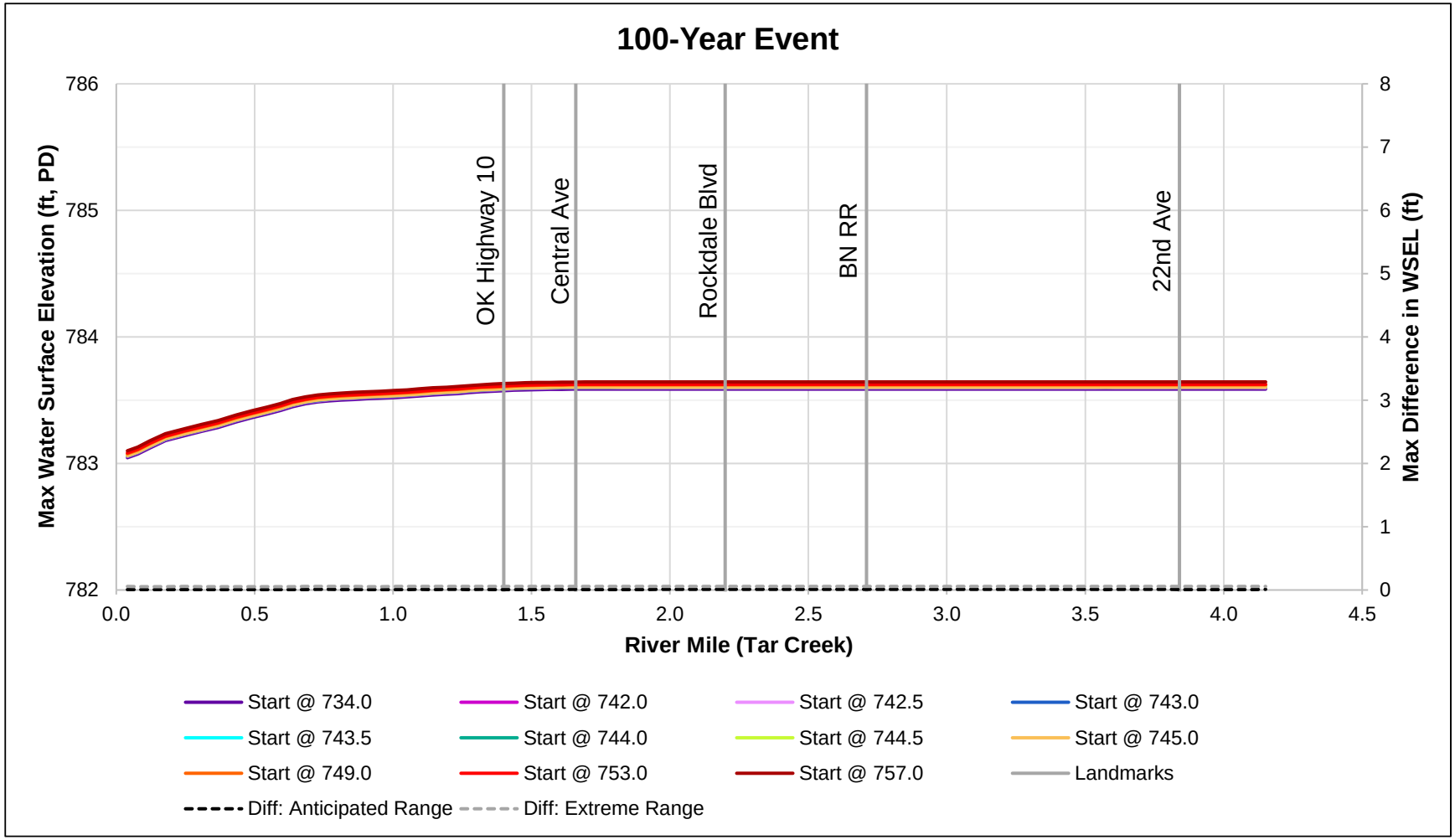


Figure E.60. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. *The first set of series' names refers to starting pool elevation at Pensacola Dam. For example, "Start @ 742" means a starting pool elevation of 742 ft PD.*

2. *The black dashed line plotted against the right y-axis represents the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range (742 to 745 feet PD). The gray dashed line represents the maximum difference in WSEL for simulations with starting stages at extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*

3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*

4. *For portions of the reach where only the highest starting elevation WSEL profile is visible, the WSEL profiles for the other starting elevations are nearly identical.*

APPENDIX E.7:
HISTORICAL STARTING STAGE
WATER SURFACE ELEVATION PROFILES

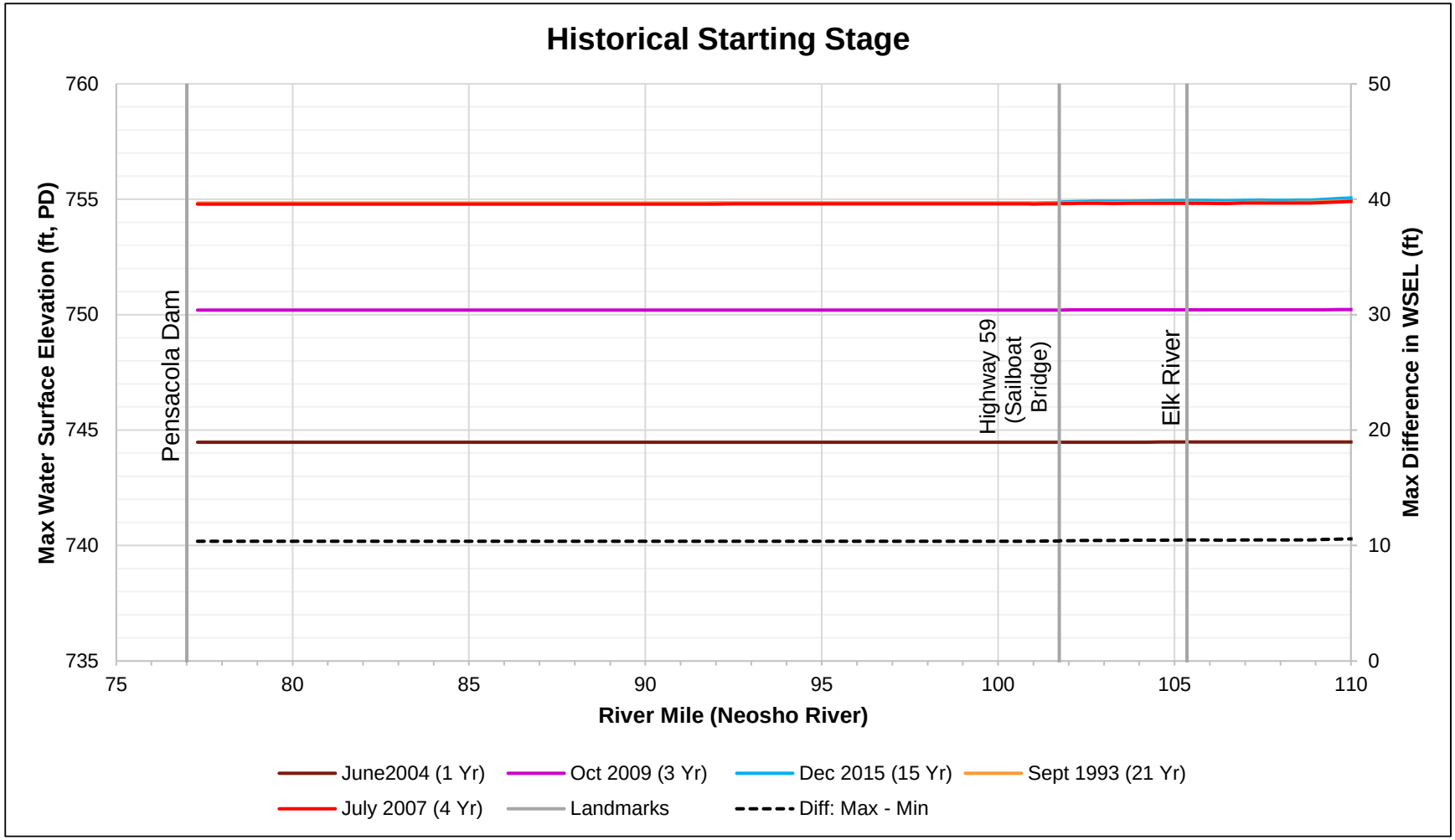


Figure E.61. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.

2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

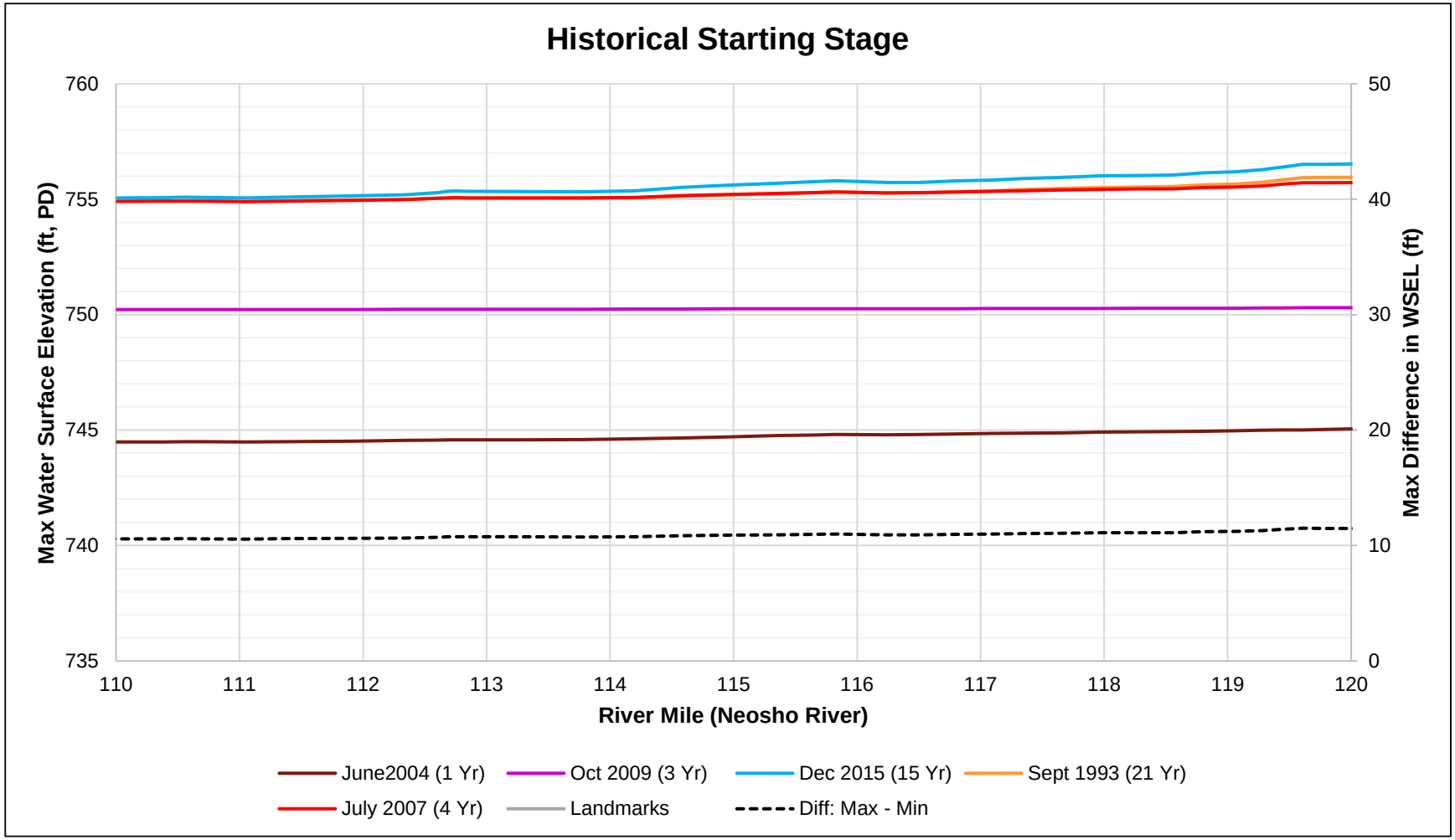


Figure E.62. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

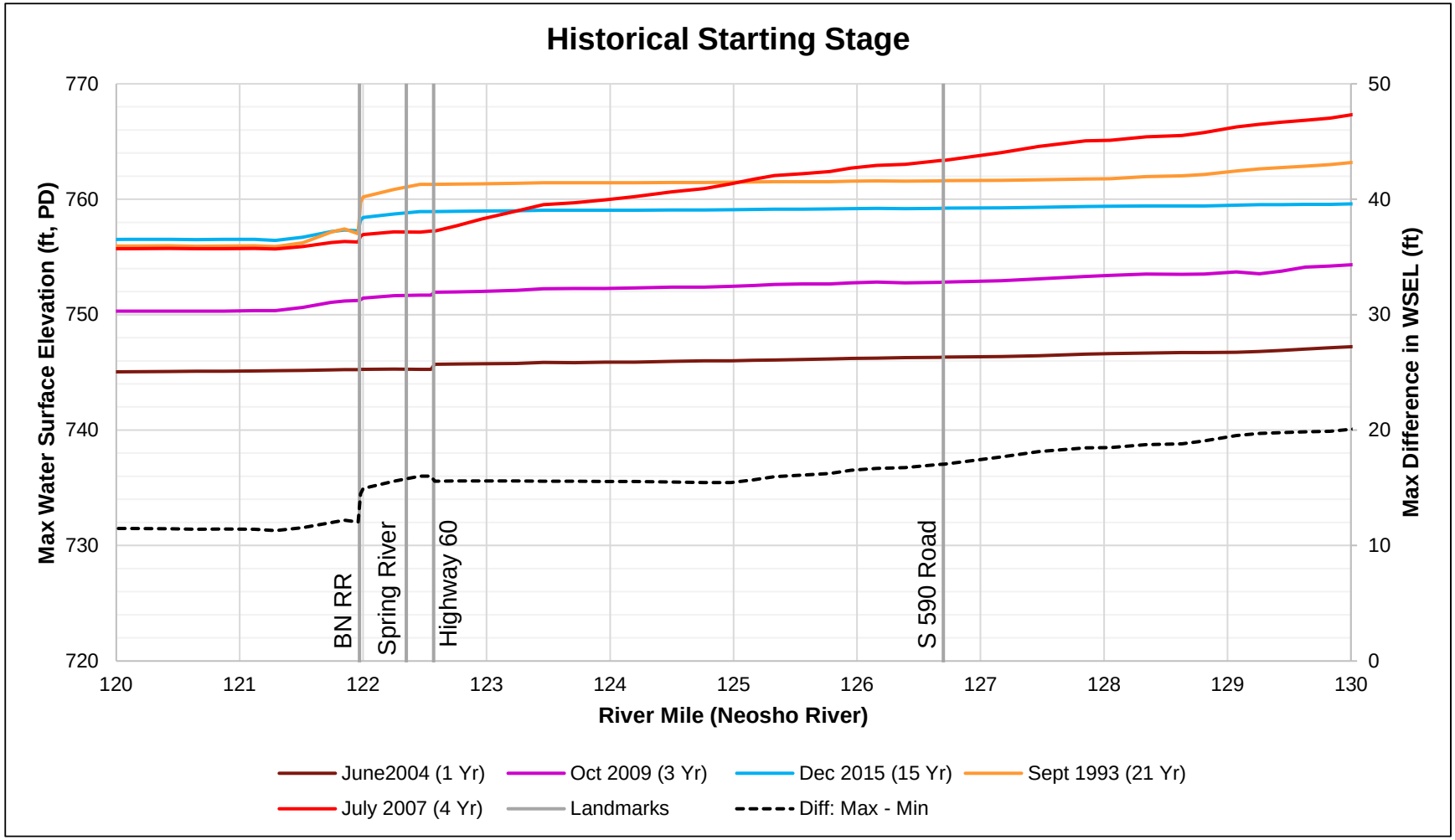


Figure E.63. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

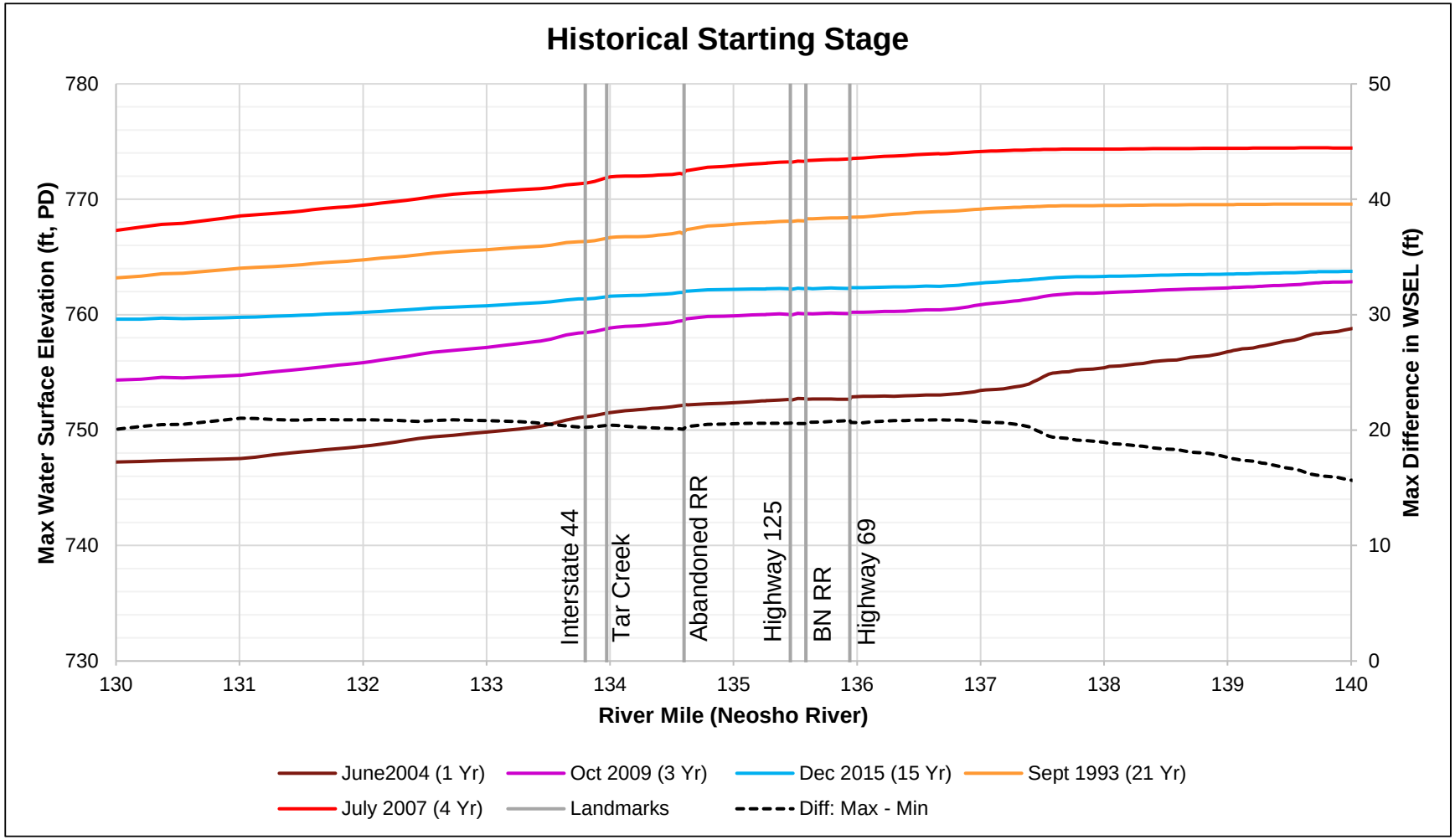


Figure E.64. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

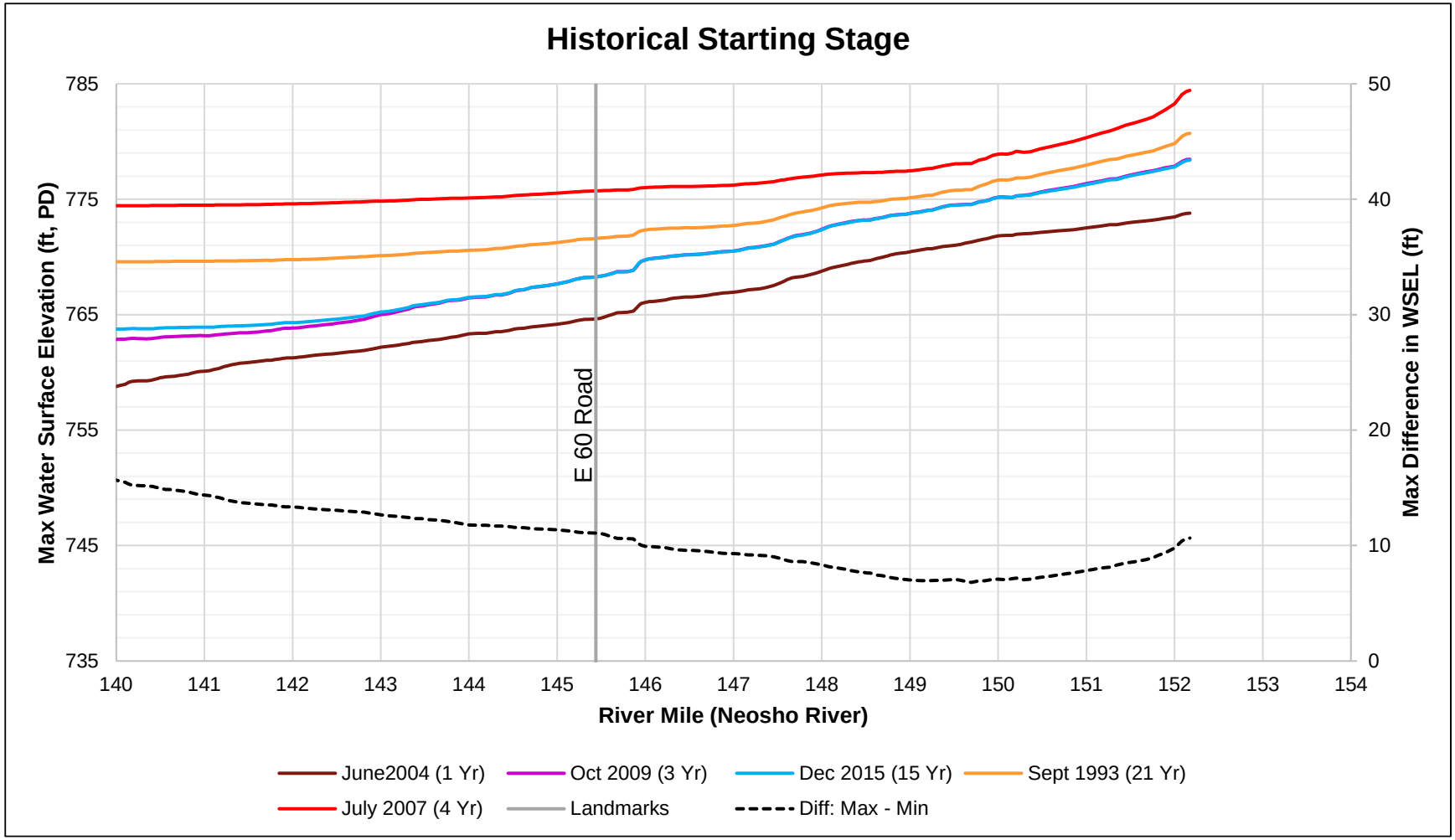


Figure E.65. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

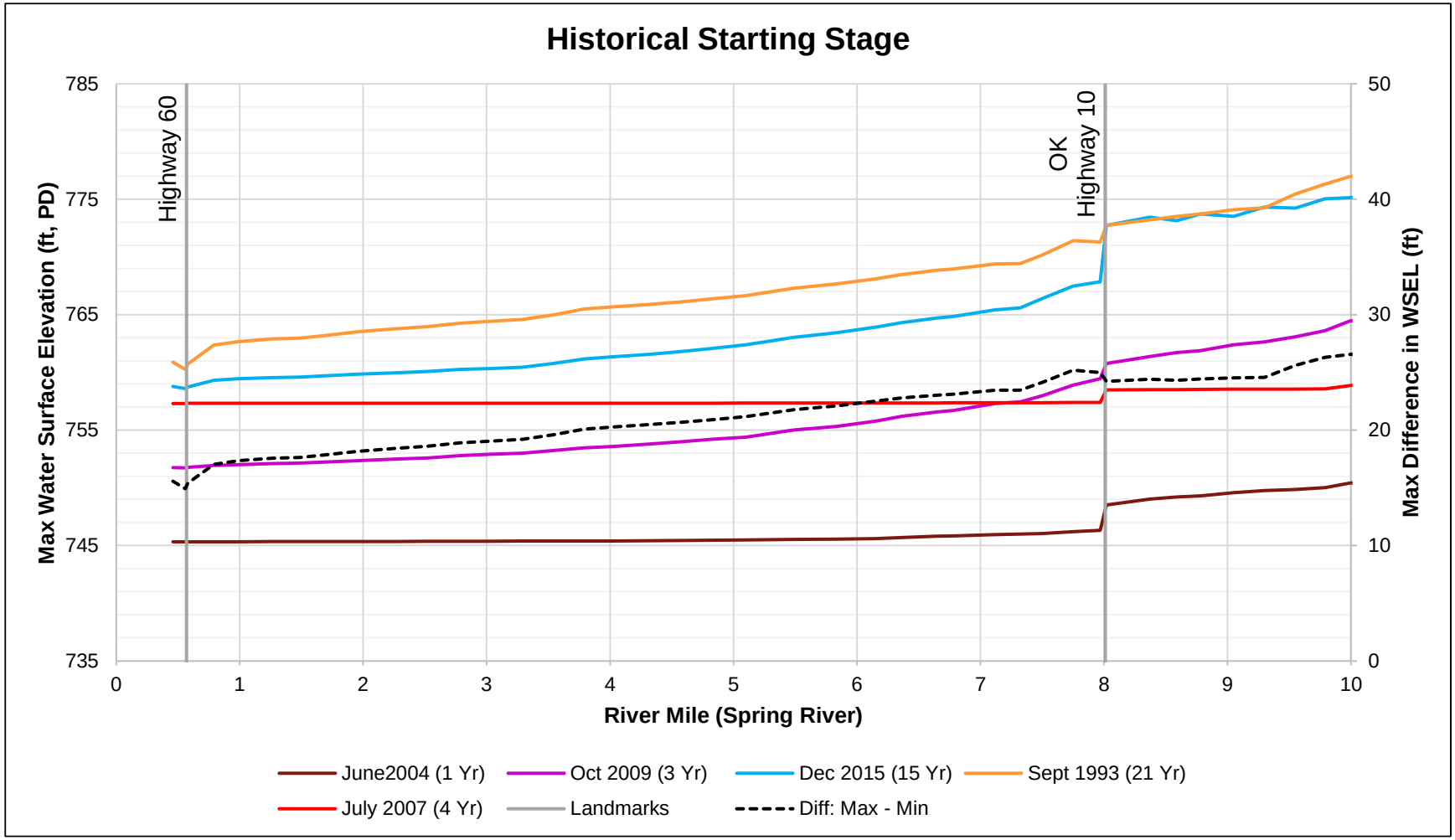


Figure E.66. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

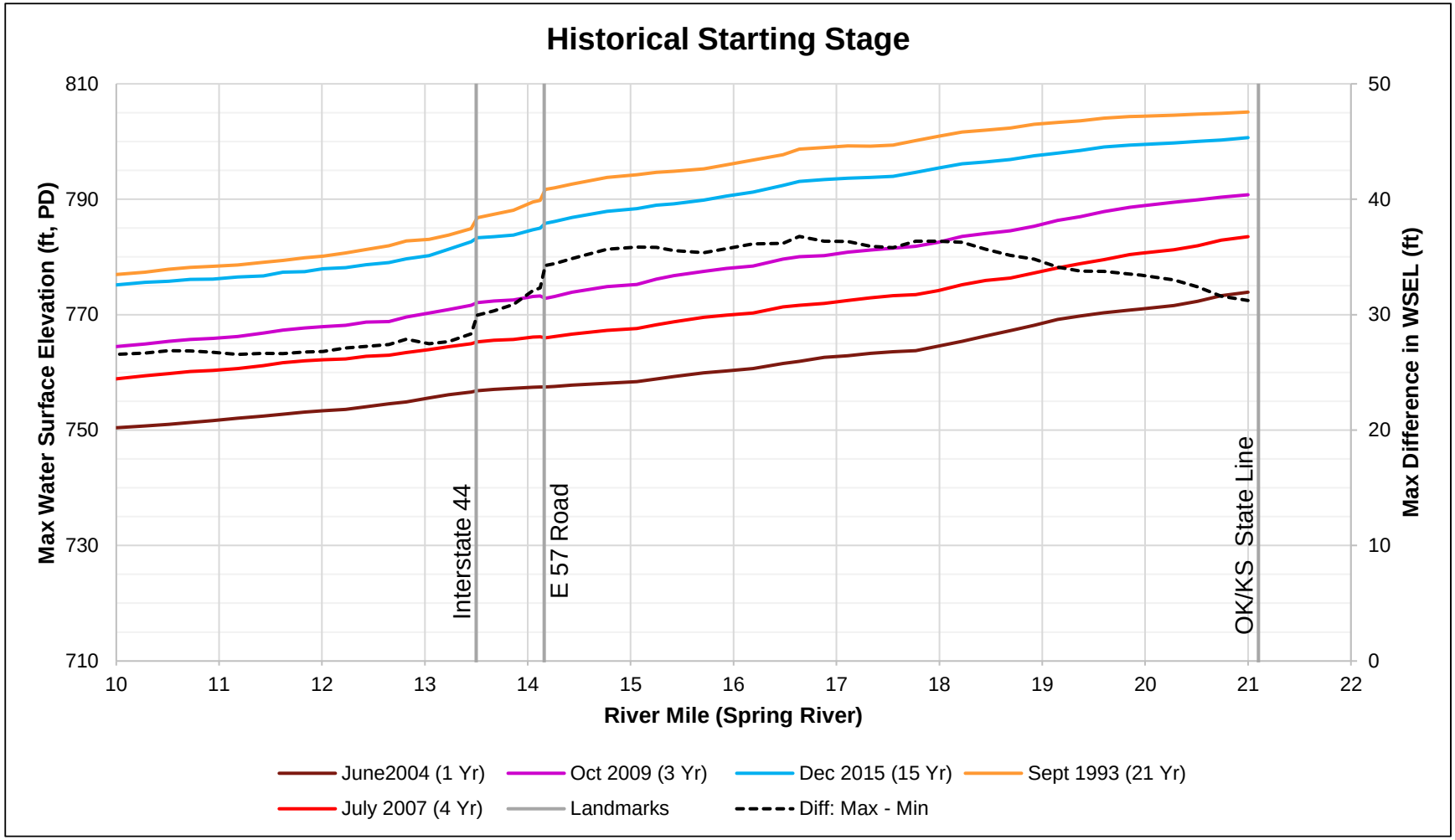


Figure E.67. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

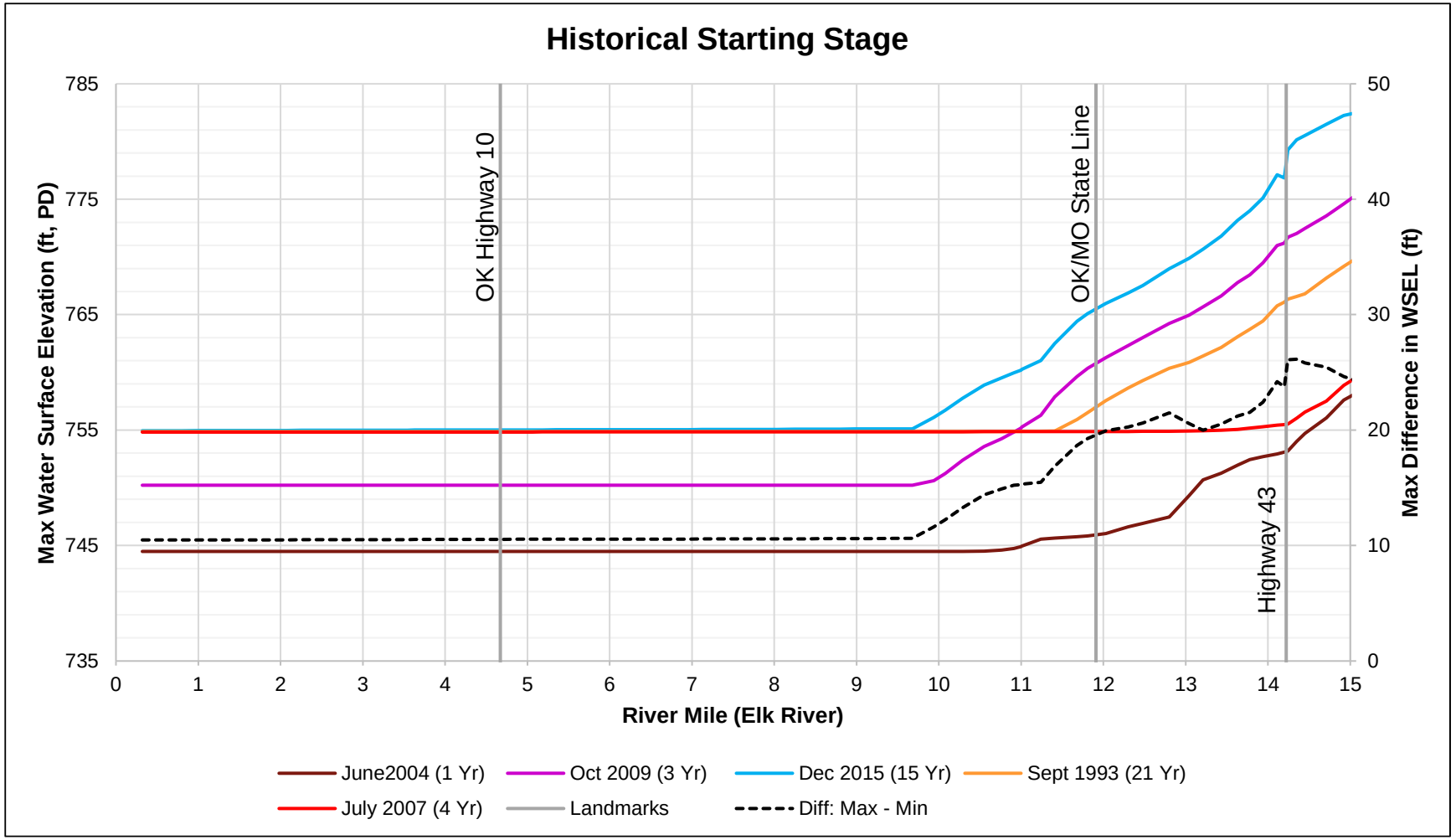


Figure E.68. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

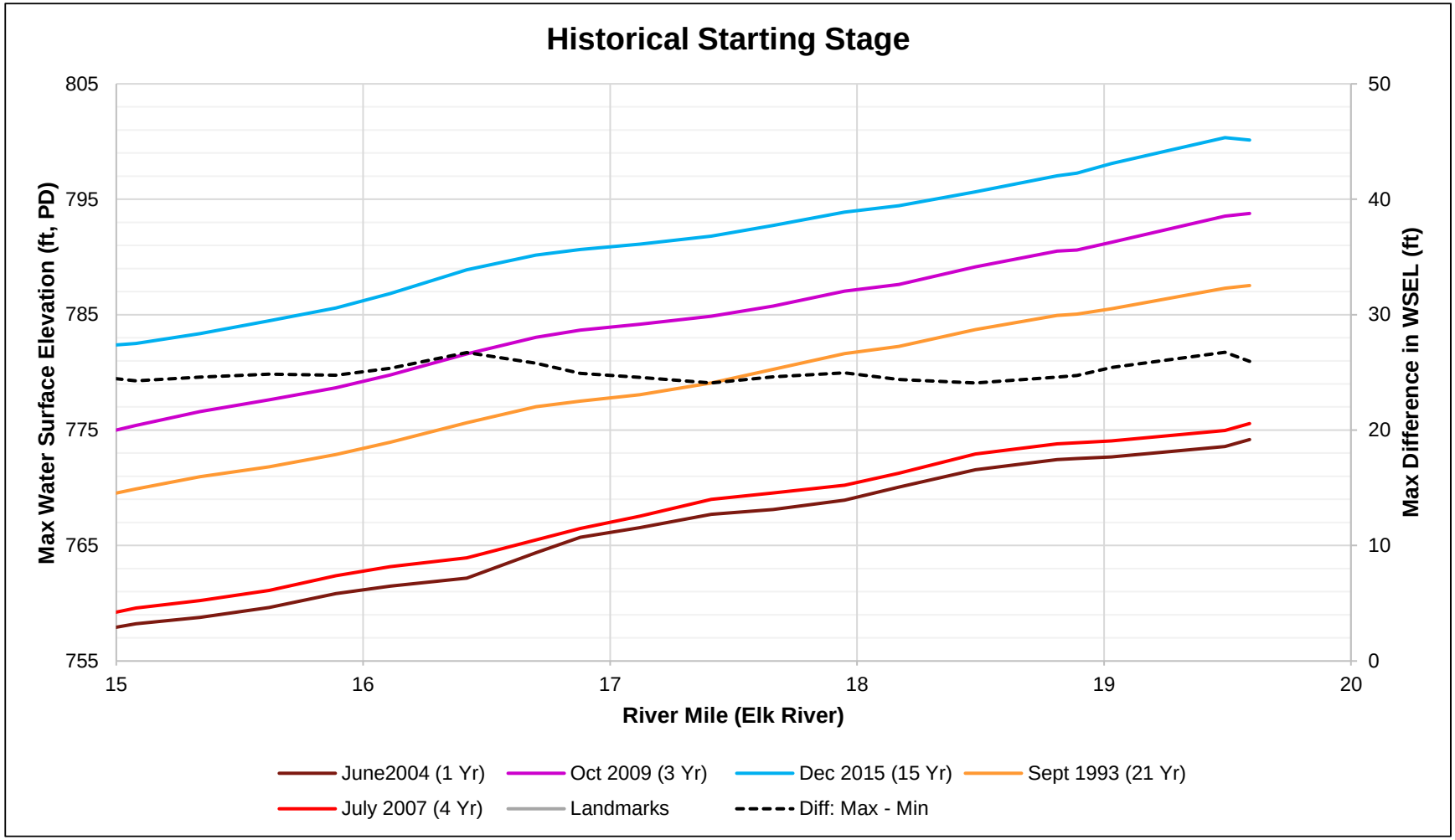


Figure E.69. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

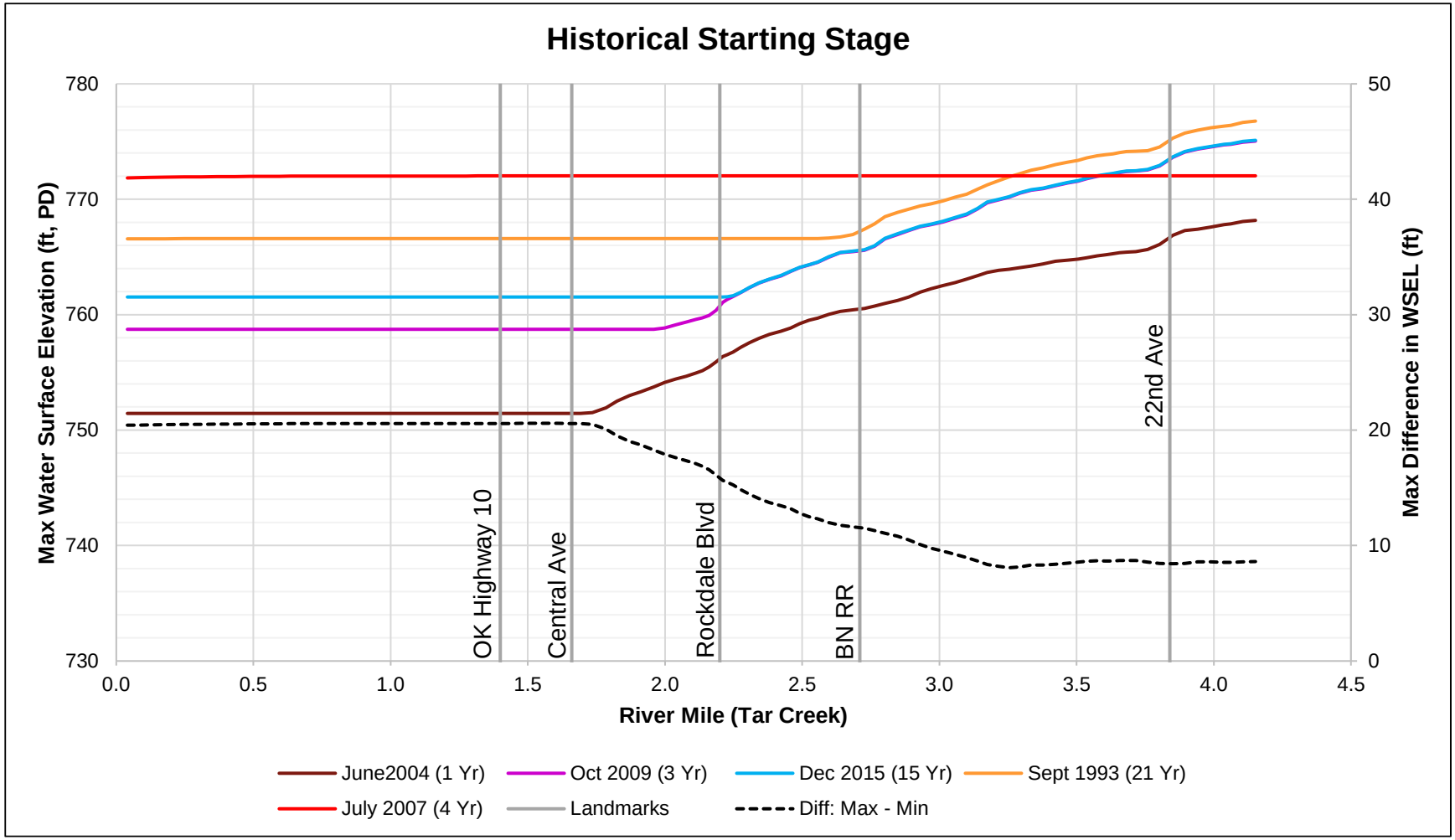


Figure E.70. Water surface elevations for events with historical starting stages upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. The dashed line is plotted against the right y-axis and represents the difference between the highest and lowest max WSEL displayed on the figure.
2. Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles displayed.

APPENDIX E.8:
COMPARISON OF MAXIMUM DIFFERENCES

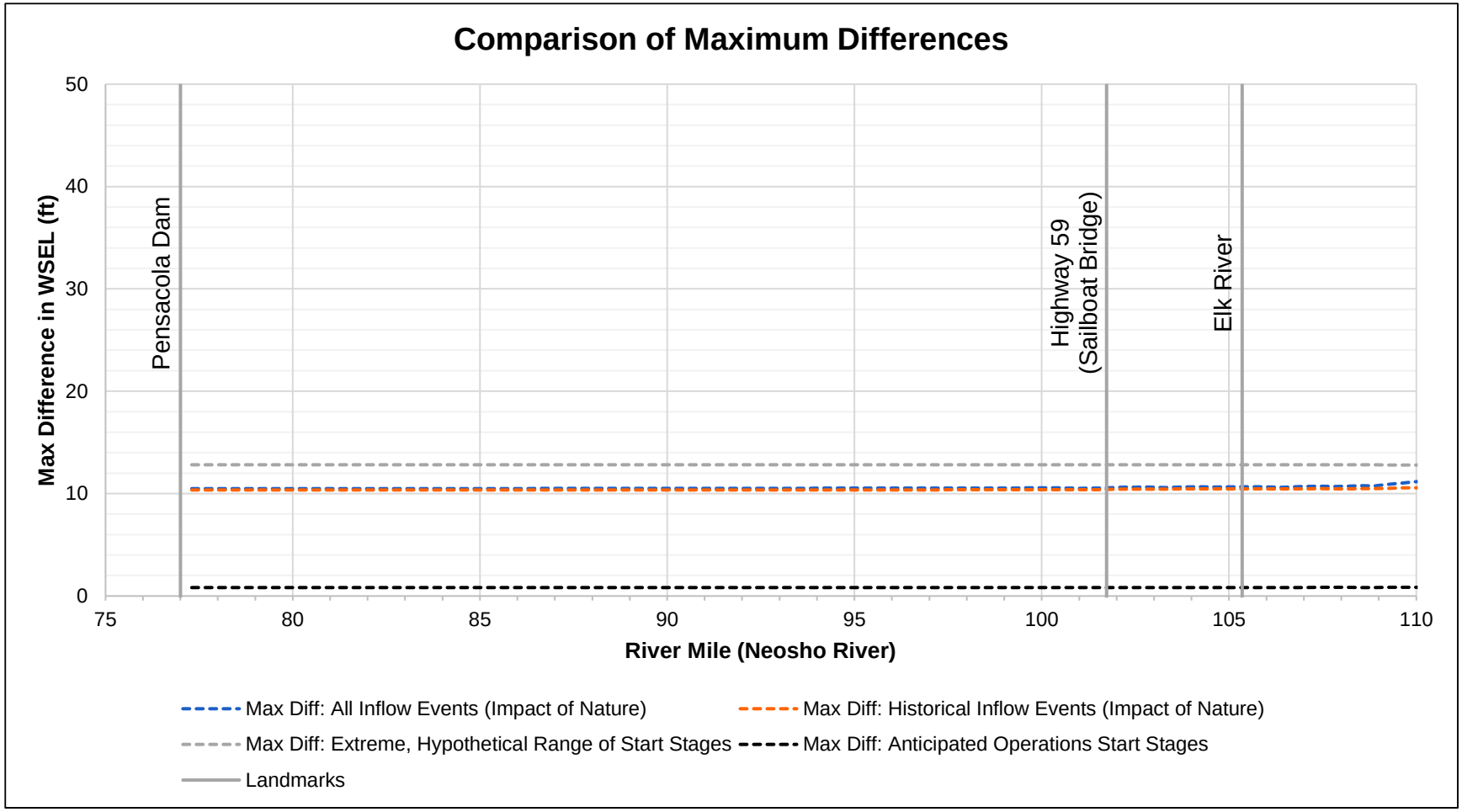


Figure E.71. Comparison of maximum water surface elevation differences along the Neosho River profile (1 of 5).

Notes:

1. *The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. *The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.*
3. *The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
4. *The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.*

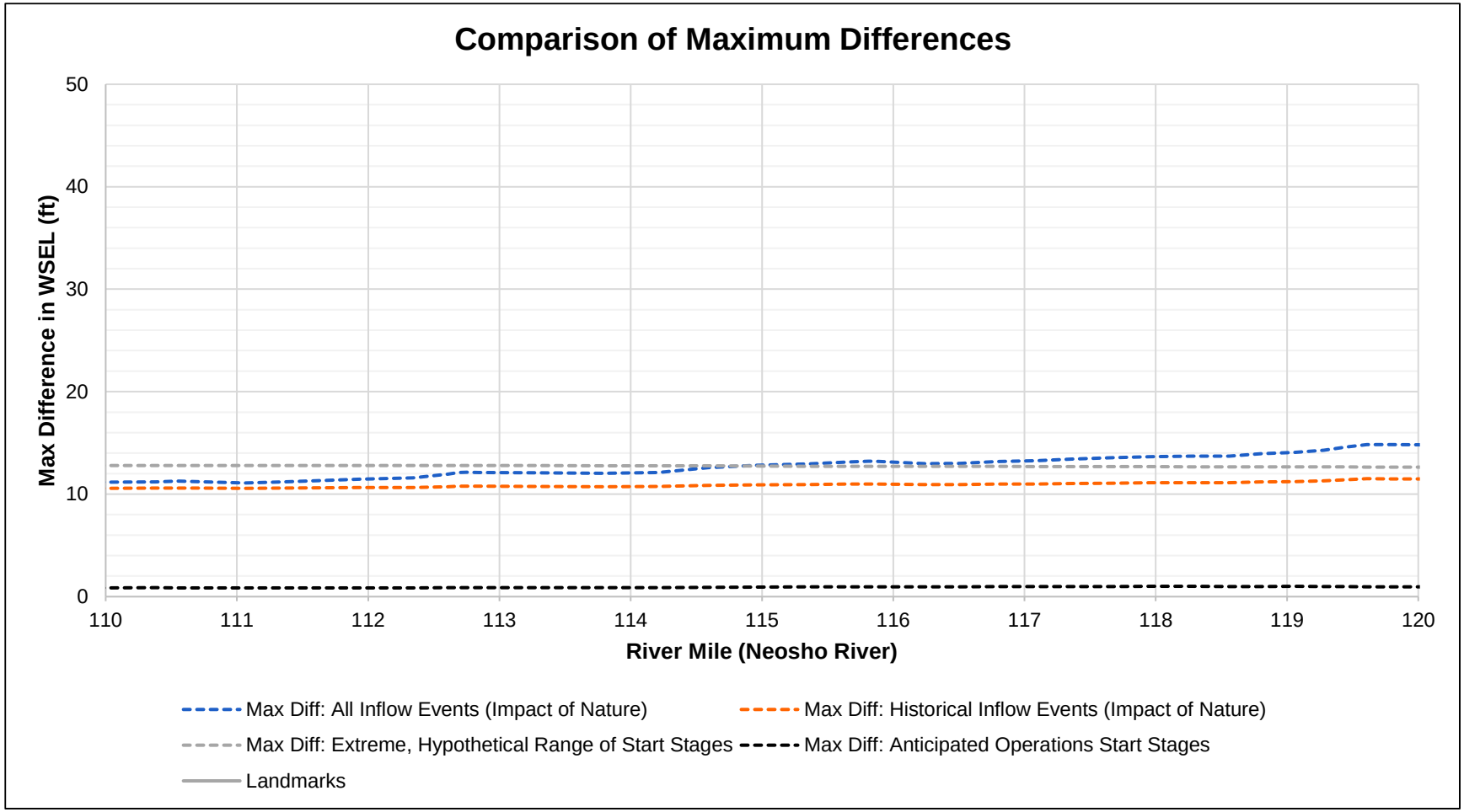


Figure E.72. Comparison of maximum water surface elevation differences along the Neosho River profile (2 of 5).

Notes:
1. *The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. *The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.*
3. *The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
4. *The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.*

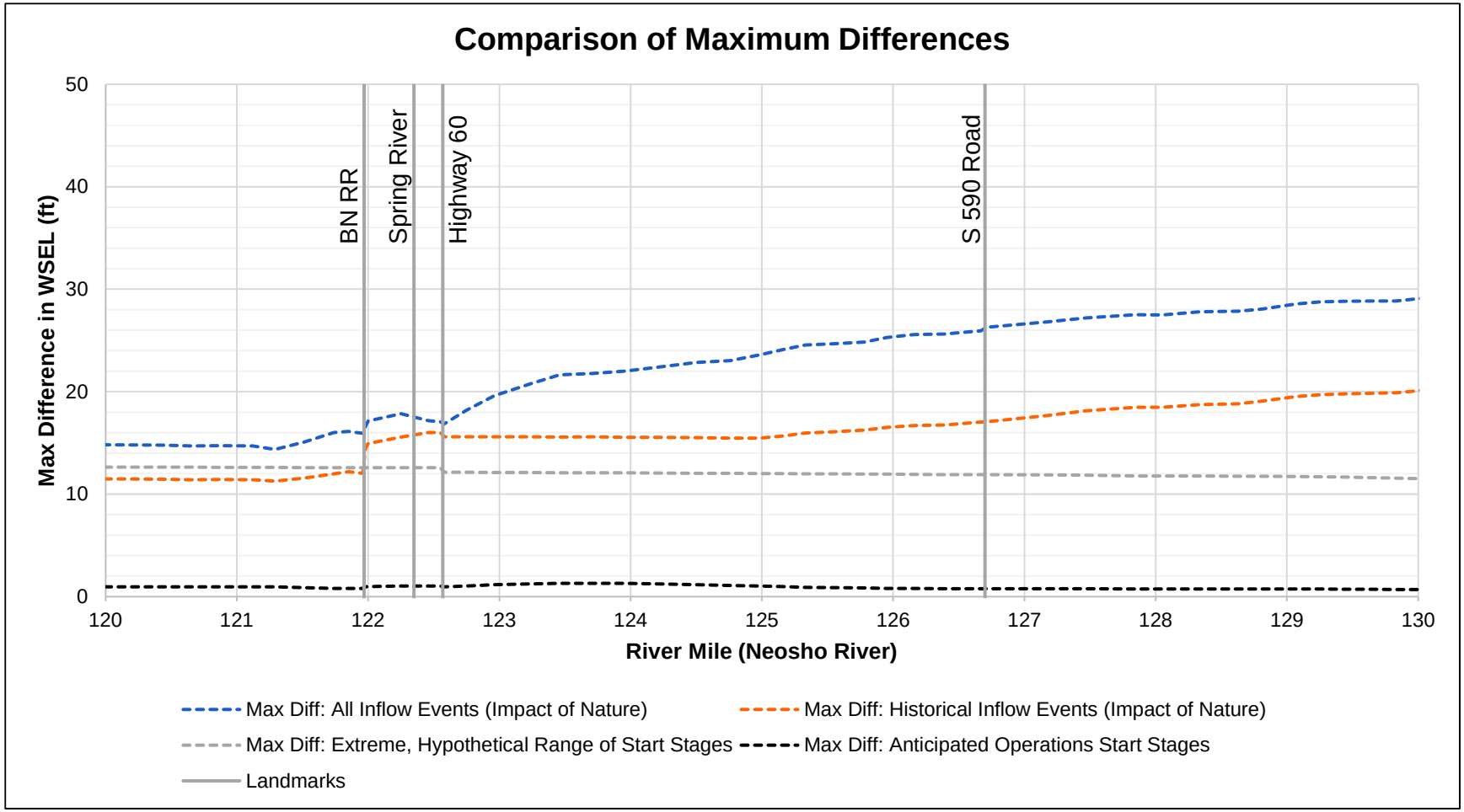


Figure E.73. Comparison of maximum water surface elevation differences along the Neosho River profile (3 of 5).

Notes: 1. *The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. *The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.*
3. *The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
4. *The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.*

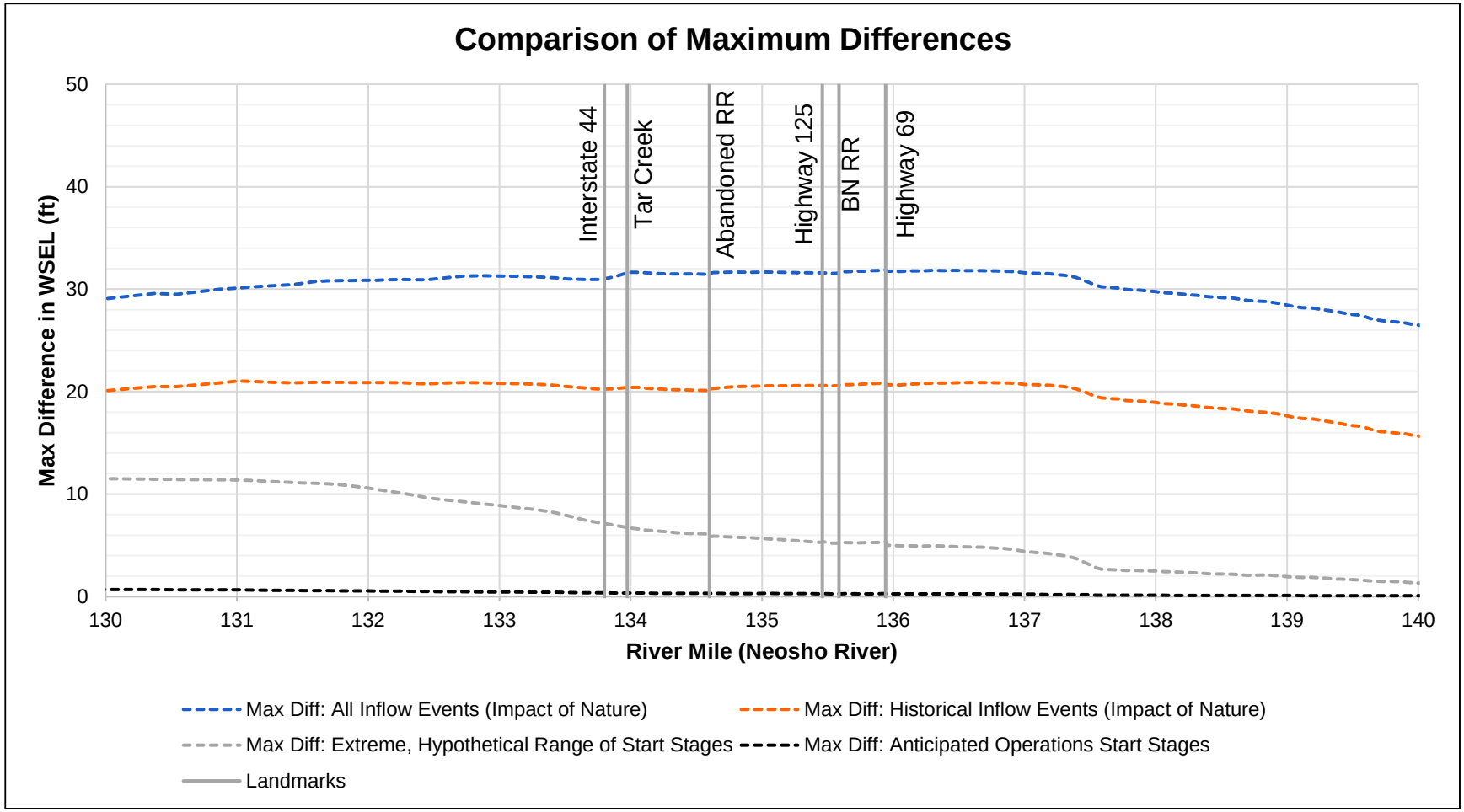


Figure E.74. Comparison of maximum water surface elevation differences along the Neosho River profile (4 of 5).

Notes:

1. *The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. *The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.*
3. *The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
4. *The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.*

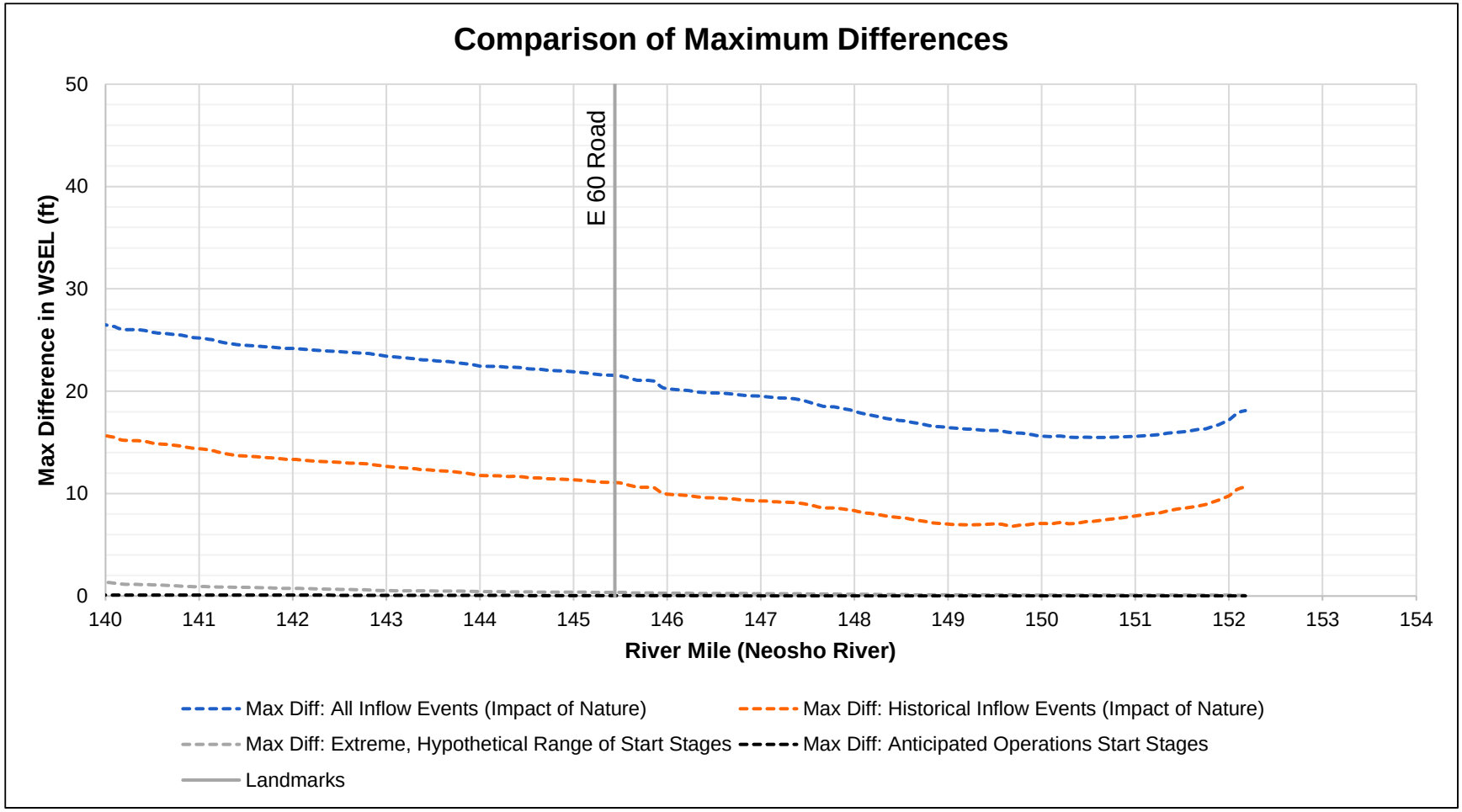


Figure E.75. Comparison of maximum water surface elevation differences along the Neosho River profile (5 of 5).

Notes:
1. *The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. *The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.*
3. *The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
4. *The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.*

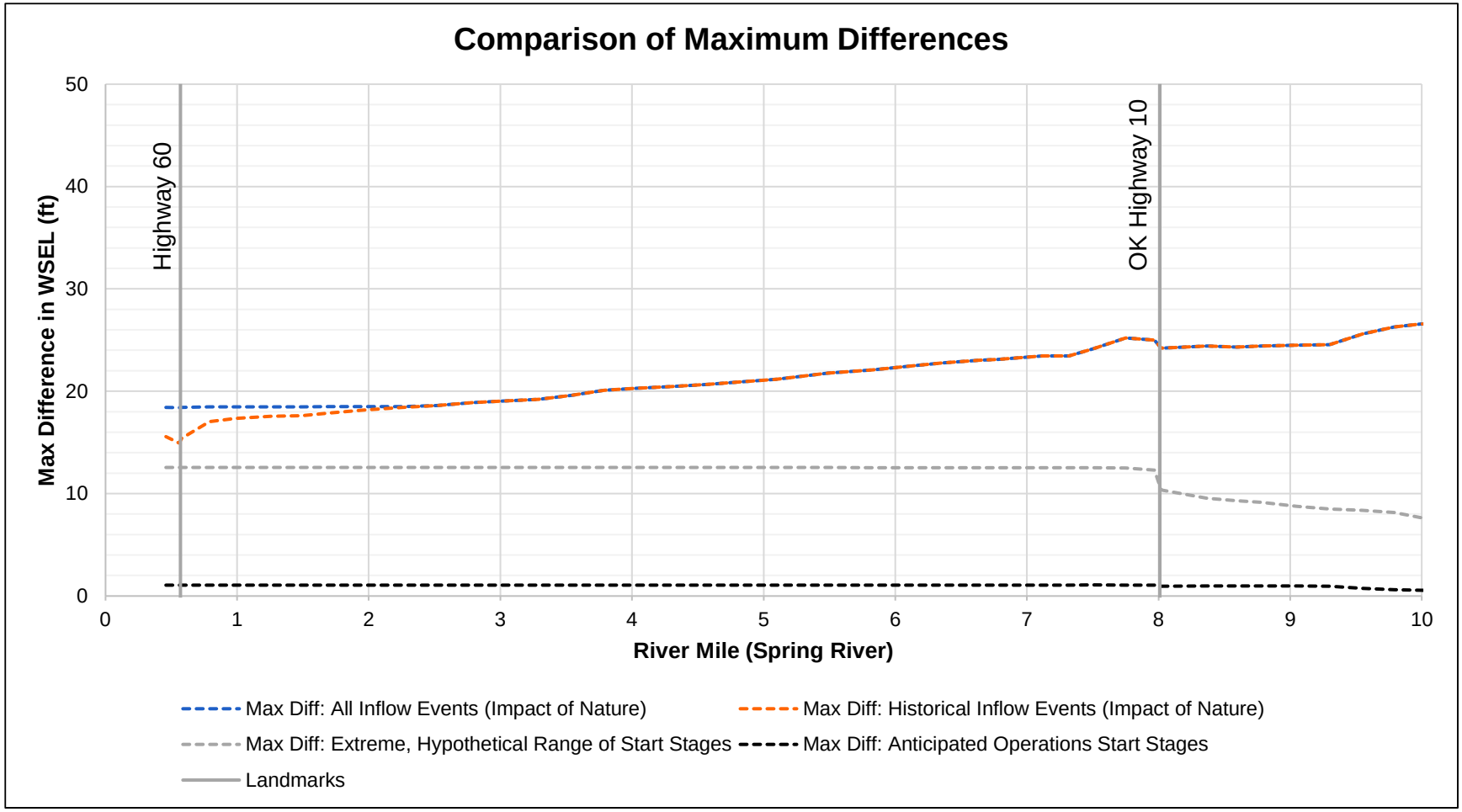


Figure E.76. Comparison of maximum water surface elevation differences along the Spring River profile (1 of 2).

Notes:
1. *The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. *The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.*
3. *The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
4. *The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.*

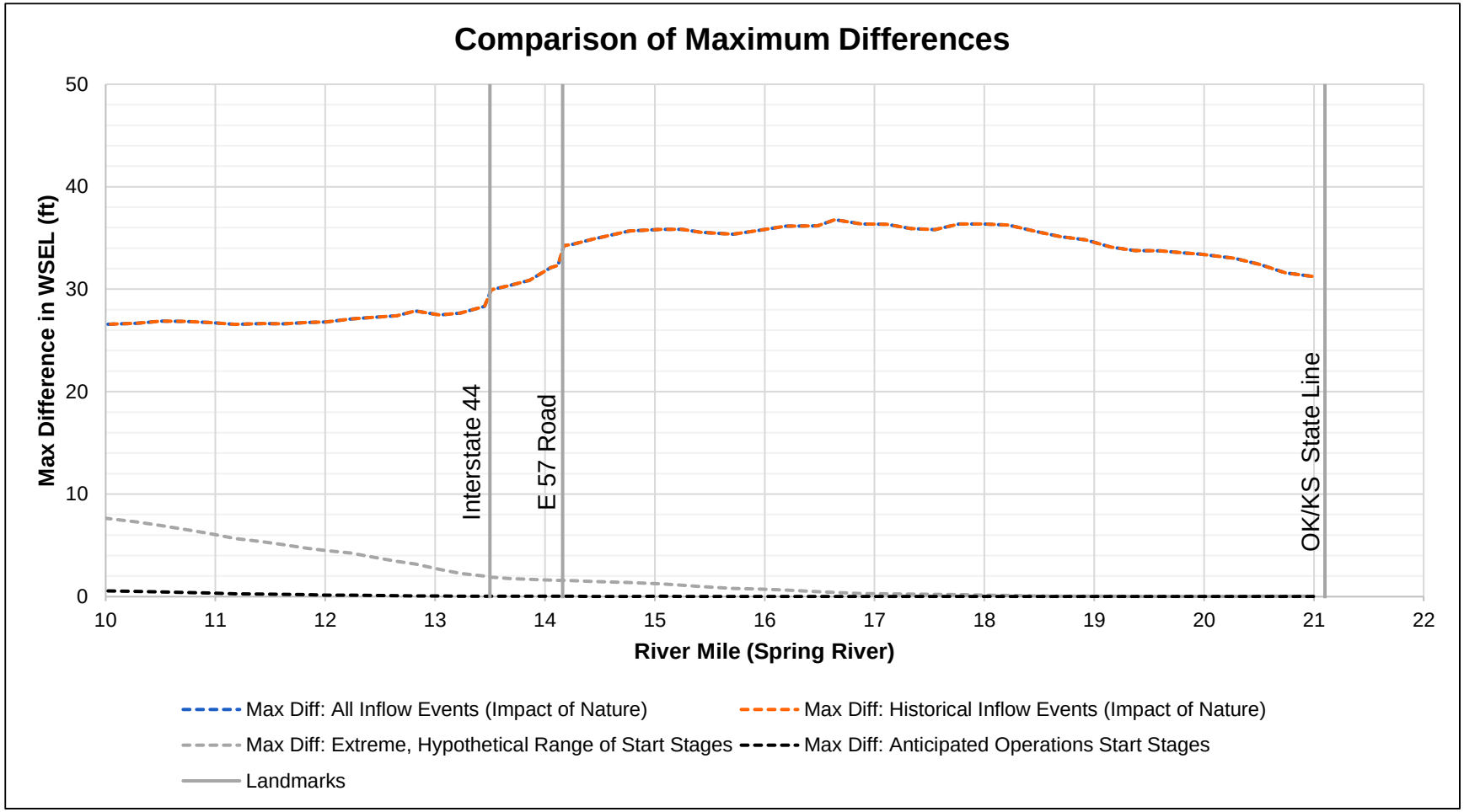


Figure E.77. Comparison of maximum water surface elevation differences along the Spring River profile (2 of 2).

Notes:

1. *The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. *The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.*
3. *The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.*
4. *The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.*

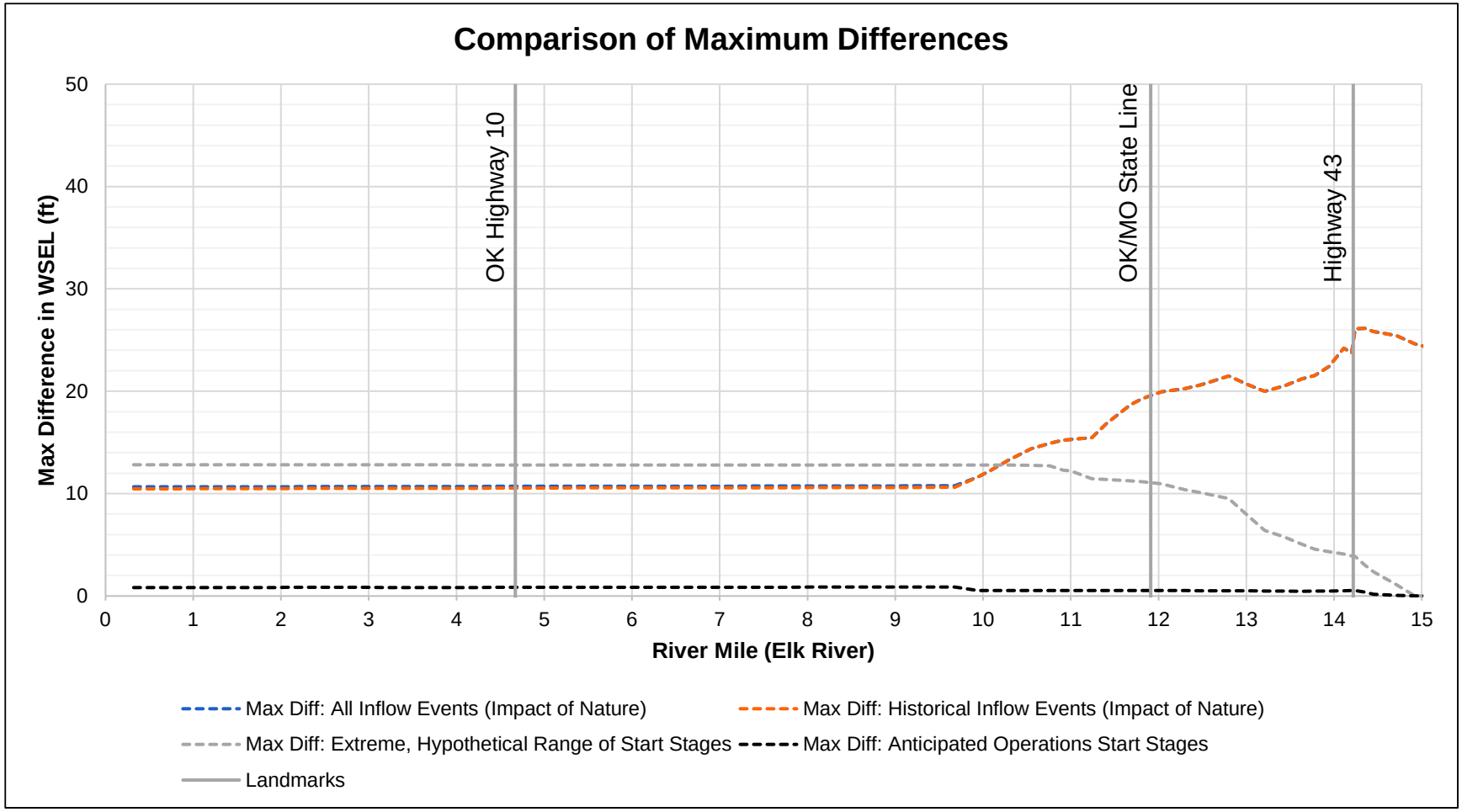


Figure E.78. Comparison of maximum water surface elevation differences along the Elk River profile (1 of 2).

Notes: *1. The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.
3. The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.
4. The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.

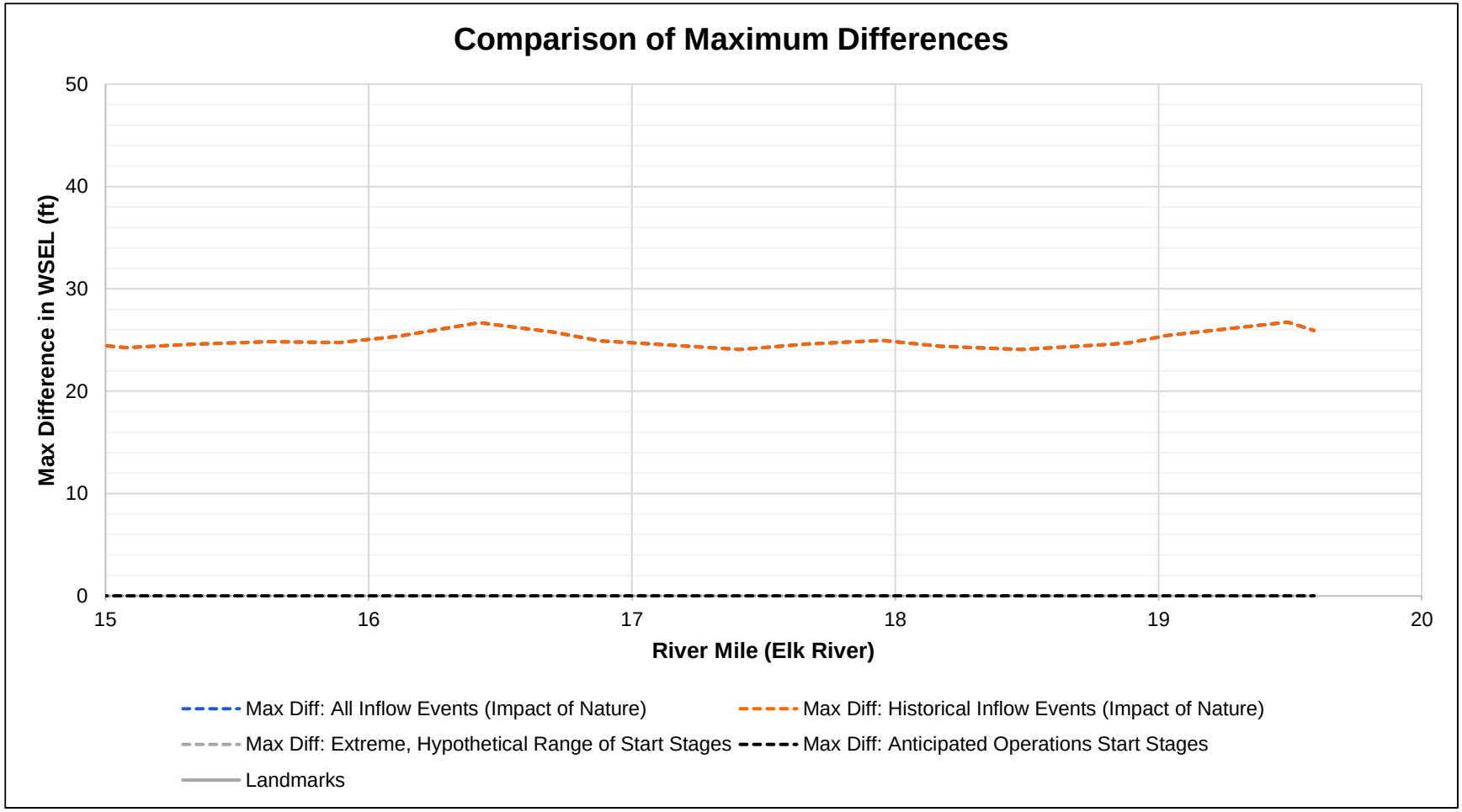


Figure E.79. Comparison of maximum water surface elevation differences along the Elk River profile (2 of 2).

Notes: *1. The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.
3. The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.
4. The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.

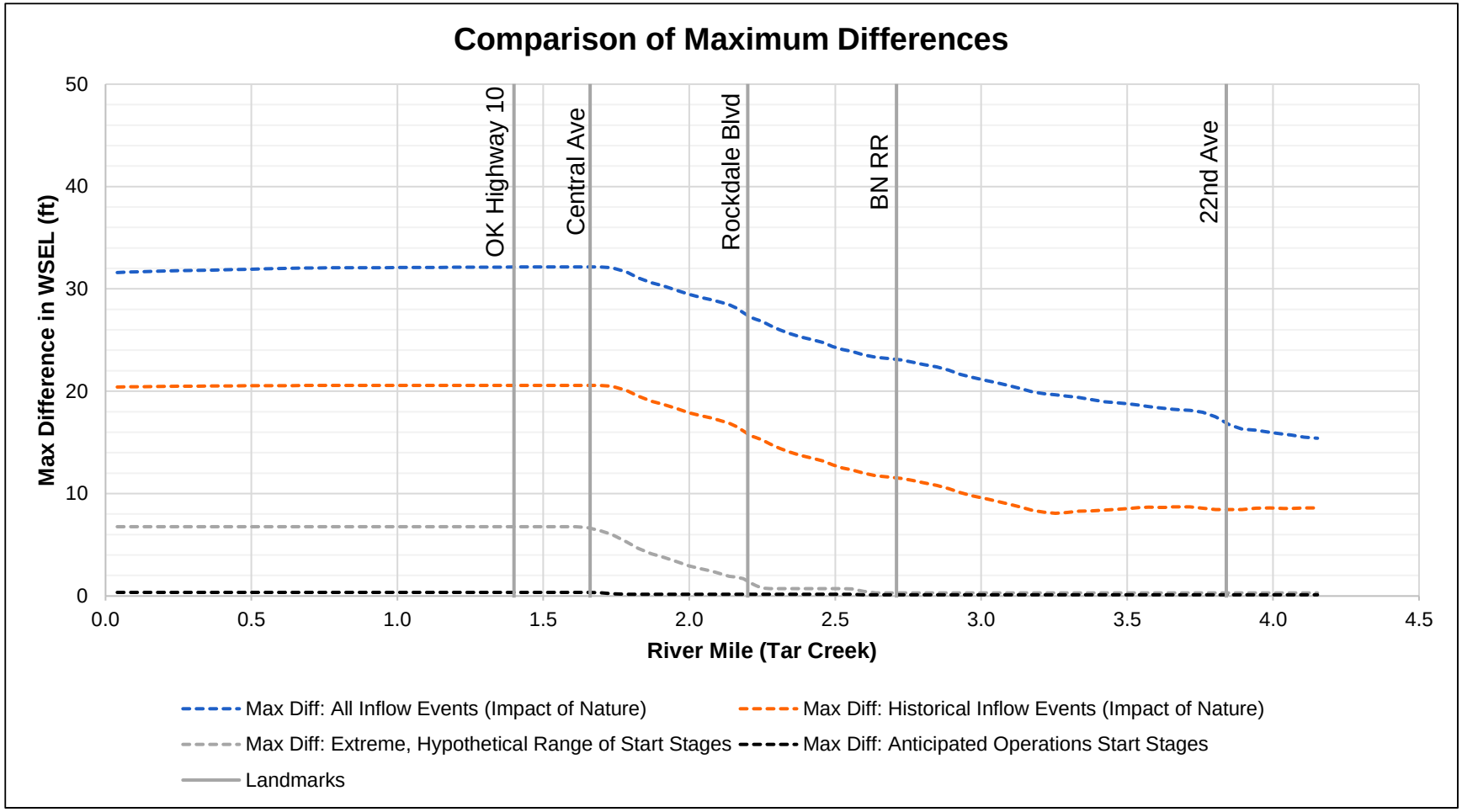


Figure E.80. Comparison of maximum water surface elevation differences along the Tar Creek profile (1 of 1).

Notes: *1. The blue dotted line "Max Diff: All Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all inflow events (including the 100-year inflow event).*
2. The orange dashed line "Max Diff: Historical Inflow Events (Impact of Nature)" plots the maximum difference in WSEL for all historical inflow events.
3. The grey dashed line "Max Diff: Extreme, Hypothetical Range of Start Stages" plots the maximum difference in WSEL for simulations with all FERC-required starting elevations, including extreme, hypothetical values (734 to 757 feet PD) outside GRDA's anticipated operational range.
4. The black dashed line "Max Diff: Anticipated Operations Start Stages" plots the maximum difference in WSEL for simulations with starting stages within GRDA's anticipated operational range.

APPENDIX F:
INUNDATION MAPS

Due to the size of inundation map files, maps are included as a set of separate PDFs.

*The following maps serve a dual purpose for both (A) the **Hydrologic and Hydraulic Modeling: Upstream Hydraulic Model** report and (B) the **Infrastructure** report:*

1. *September 1993 (21 Year) Inundation Scenario*
2. *June 2004 (1 Year) Inundation Scenario*
3. *July 2007 (4 Year) Inundation Scenario*
4. *October 2009 (3 Year) Inundation Scenario*
5. *December 2015 (15 Year) Inundation Scenario*

*And the remaining maps are only for the **Hydrologic and Hydraulic Model: Upstream Hydraulic Model** report:*

6. *100-Year Inundation Scenario*
7. *Historical Inundation Scenarios*

APPENDIX G:
DURATION OF INUNDATION

APPENDIX G.1:
SEPTEMBER 1993 (21 YEAR) INFLOW EVENT
DURATION OF INUNDATION

PENSACOLA DAM **TABLE G.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - SEP 1993 (21 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
152.175	Upstream end of model												
152.175	137	137	137	137	137	137	137	137	137	137	137	0	0
151.000	117	117	117	117	117	117	117	117	117	117	117	0	0
150.000	144	145	145	145	145	145	145	145	145	145	145	0	1
149.000	142	142	142	142	142	142	142	142	142	142	142	0	0
148.000	143	144	144	144	144	144	144	144	144	144	144	0	1
147.000	138	138	138	138	138	138	138	138	138	138	138	0	0
145.500	154	155	155	155	155	155	155	155	154	154	155	0	1
145.480	E 60 Road Bridge												
145.400	153	154	154	154	154	154	153	153	154	154	154	1	1
144.000	159	160	160	160	160	160	160	160	160	161	162	0	3
143.000	153	153	153	153	153	153	153	153	153	154	155	0	2
142.000	171	172	172	172	172	172	172	171	171	172	173	1	2
141.000	169	169	169	169	169	169	169	169	169	171	172	0	3
140.000	163	164	164	164	164	164	163	163	164	166	169	1	6
139.000	149	150	150	150	150	150	150	150	151	154	158	0	9
138.000	143	145	145	145	145	145	145	145	145	148	153	0	10
137.000	136	138	138	138	139	138	138	138	138	142	146	1	10
135.950	134	136	136	136	136	135	135	136	136	139	144	1	10
135.941	Highway 69 Bridge												
135.940	134	136	136	136	136	135	135	134	135	139	143	2	9
135.590	133	135	135	135	135	135	135	134	135	139	143	1	10
135.586	BN RR Bridge												
135.580	133	135	135	135	135	135	135	134	135	139	143	1	10
135.470	133	135	135	135	135	135	135	134	135	138	143	1	10
135.460	Highway 125 Bridge												
135.440	133	135	135	135	135	135	135	134	135	139	143	1	10
135.000	133	134	134	134	135	135	134	134	135	138	143	1	10

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - SEP 1993 (21 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
134.610	131	134	134	134	134	134	133	133	133	136	141	1	10
134.599	Abandonded RR Bridge												
134.595	131	132	132	132	132	132	132	132	133	136	141	0	10
134.000	129	130	130	130	130	130	129	129	129	132	138	1	9
133.973	Tar Creek												
133.900	127	129	129	129	129	128	128	128	128	131	135	1	8
133.800	Interstate 44 Bridge												
133.700	127	128	128	128	128	128	127	127	127	130	135	1	8
133.000	122	124	124	124	124	124	123	123	122	124	128	1	6
132.000	117	120	120	120	120	120	119	118	118	120	123	2	6
131.000	114	116	116	116	116	116	115	114	113	115	119	2	6
130.000	109	114	114	114	114	114	112	111	109	112	115	3	6
129.000	104	110	110	110	110	110	108	106	103	106	109	4	7
128.000	97	104	104	104	105	105	101	97	95	97	100	8	10
126.710	72	83	83	83	83	82	82	81	80	82	86	2	14
126.700	S 590 Road Bridge												
126.670	71	82	82	82	82	81	81	80	79	82	85	2	14
126.000	39	76	76	76	76	76	75	75	75	77	81	1	42
125.000	29	45	45	45	50	56	59	63	64	67	70	18	41
124.000	24	26	26	26	26	27	33	46	50	53	56	20	32
123.000	21	22	22	22	22	23	23	24	33	44	47	2	26
122.580	20	21	21	21	21	21	22	22	25	38	42	1	22
122.570	Highway 60 Bridge												
122.550	20	21	21	21	21	21	22	22	25	38	42	1	22
122.350	Spring River												
122.000	13	13	13	13	13	14	14	15	16	26	37	2	24
121.980	10	10	10	10	11	11	11	12	12	21	31	2	21
121.970	BN RR Bridge												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - SEP 1993 (21 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
121.960	0	0	0	0	0	0	0	0	0	0	0	0	0
120.000	0	0	0	0	0	0	0	0	0	0	0	0	0
118.000	0	0	0	0	0	0	0	0	0	0	0	0	0
116.000	0	0	0	0	0	0	0	0	0	0	0	0	0
114.000	0	0	0	0	0	0	0	0	0	0	0	0	0
112.000	0	0	0	0	0	0	0	0	0	0	0	0	0
110.000	0	0	0	0	0	0	0	0	0	0	0	0	0
108.000	0	0	0	0	0	0	0	0	0	0	0	0	0
106.000	0	0	0	0	0	0	0	0	0	0	0	0	0
105.350	Elk River												
105.000	0	0	0	0	0	0	0	0	0	0	0	0	0
104.000	0	0	0	0	0	0	0	0	0	0	0	0	0
102.000	0	0	0	0	0	0	0	0	0	0	0	0	0
101.750	0	0	0	0	0	0	0	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)												
101.710	0	0	0	0	0	0	0	0	0	0	0	0	0
100.000	0	0	0	0	0	0	0	0	0	0	0	0	0
90.000	0	0	0	0	0	0	0	0	0	0	0	0	0
80.000	0	0	0	0	0	0	0	0	0	0	0	0	0
78.000	0	0	0	0	0	0	0	0	0	0	0	0	0
77.000	Pensacola Dam												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.2**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - SEP 1993 (21 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
21.000	Upstream end of model												
21.000	54	54	54	54	54	54	54	54	54	54	54	0	0
20.000	52	52	52	52	52	52	52	52	52	52	52	0	0
19.000	70	70	70	70	70	70	70	70	70	70	70	0	0
18.000	70	70	70	70	70	70	70	70	70	70	70	0	0
17.000	72	72	72	72	72	72	72	72	72	72	72	0	0
16.000	79	79	79	79	79	79	79	79	79	79	79	0	0
15.000	74	75	75	75	75	75	75	75	75	75	75	0	1
14.170	92	92	92	92	92	92	92	92	92	92	92	0	0
14.160	E 57 Road												
14.120	93	93	93	93	93	93	93	93	93	93	94	0	1
13.510	93	93	93	93	93	93	93	93	93	93	94	0	1
13.500	Interstate 44 Bridge												
13.450	92	93	93	93	93	93	93	93	93	93	93	0	1
12.000	92	93	93	93	93	93	93	93	93	93	94	0	2
11.000	110	112	112	112	112	112	112	112	112	113	114	0	4
10.000	104	107	107	107	107	108	108	108	107	108	109	1	5
9.000	95	99	99	99	99	99	99	99	100	102	105	0	10
8.020	85	91	91	91	91	91	91	91	92	95	97	0	12
8.010	OK Highway 10 Bridge												
7.970	72	78	78	78	78	79	80	80	82	83	85	2	13
7.000	60	64	64	64	65	66	67	69	70	71	73	5	13
6.000	53	57	57	57	58	59	60	62	64	64	67	5	14
5.000	46	49	49	49	50	51	53	54	57	59	61	5	15
4.000	43	46	46	46	47	48	50	52	54	55	58	6	15
3.000	40	41	41	41	42	42	43	47	51	52	53	6	13
2.000	33	37	37	37	38	39	40	41	46	49	50	4	17
1.000	29	30	30	30	31	31	32	36	38	45	49	6	20
0.580	16	18	18	18	18	19	19	19	21	35	40	1	24
0.570	Highway 60 Bridge												
0.560	13	15	15	15	15	15	15	16	18	33	38	1	25
0.460	18	19	19	19	19	19	19	20	22	36	41	1	23
0.000	Downstream end of Spring River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.3**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - SEP 1993 (21 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
19.590	Upstream end of model												
19.590	10	10	10	10	10	10	10	10	10	10	10	0	0
19.000	0	0	0	0	0	0	0	0	0	0	0	0	0
18.000	7	7	7	7	7	7	7	7	7	7	7	0	0
17.000	56	56	56	56	56	56	56	56	56	56	56	0	0
16.000	61	62	62	62	62	62	62	62	62	62	62	0	1
15.000	48	48	48	48	48	48	48	48	48	48	49	0	1
14.240	18	18	18	18	18	18	18	18	19	19	19	0	1
14.220	Highway 43 Bridge												
14.200	18	18	18	18	18	18	18	18	18	18	18	0	0
14.000	12	12	12	12	12	12	12	12	12	12	12	0	0
13.000	14	14	14	14	14	14	14	14	14	14	15	0	1
12.000	0	0	0	0	0	0	0	0	0	0	0	0	0
11.910	OK/MO State Line												
11.000	0	0	0	0	0	0	0	0	0	0	0	0	0
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.000	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.700	0	0	0	0	0	0	0	0	0	0	0	0	0
4.670	OK Highway 10 Bridge												
4.640	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.320	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Elk River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.4**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - SEP 1993 (21 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
4.152	Upstream end of model												
4.152	25	25	25	25	25	25	25	25	25	25	25	0	0
3.900	32	32	32	32	32	32	32	32	32	32	32	0	0
3.840	22nd Ave Bridge												
3.800	36	36	36	36	36	36	36	36	36	36	36	0	0
3.300	28	28	28	28	28	28	28	28	29	29	29	0	1
2.800	20	20	20	20	20	20	20	20	20	20	21	0	1
2.710	BN RR Bridge												
2.700	130	133	133	133	133	133	132	131	131	131	131	2	3
2.500	140	142	142	142	142	142	141	140	140	140	140	2	2
2.300	143	145	145	145	145	145	144	144	143	143	143	1	2
2.200	Rockdale Blvd Bridge												
2.100	157	159	159	159	159	159	158	158	157	157	158	1	2
1.900	143	146	146	146	146	146	145	145	144	146	148	1	5
1.700	129	131	131	131	132	132	131	131	132	138	144	1	15
1.660	Central Ave Bridge												
1.600	128	131	131	131	131	131	130	130	130	135	143	1	15
1.500	128	131	131	131	131	131	130	130	130	135	143	1	15
1.400	OK Highway 10 Bridge												
1.300	128	130	130	130	130	130	129	129	129	133	139	1	11
1.000	128	130	130	130	130	130	129	129	129	133	138	1	10
0.700	128	130	130	130	130	130	129	129	129	132	138	1	10
0.300	128	130	130	130	130	130	129	129	129	132	137	1	9
0.041	127	130	130	130	130	130	129	129	129	132	137	1	10
0.000	Downstream end of Tar Creek												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX G.2:
JUNE 2004 (1 YEAR) INFLOW EVENT
DURATION OF INUNDATION

PENSACOLA DAM **TABLE G.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - JUN 2004 (1 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
152.175	Upstream end of model												
152.175	0	0	0	0	0	0	0	0	0	0	0	0	0
151.000	0	0	0	0	0	0	0	0	0	0	0	0	0
150.000	0	0	0	0	0	0	0	0	0	0	0	0	0
149.000	0	0	0	0	0	0	0	0	0	0	0	0	0
148.000	0	0	0	0	0	0	0	0	0	0	0	0	0
147.000	0	0	0	0	0	0	0	0	0	0	0	0	0
145.500	0	0	0	0	0	0	0	0	0	0	7	0	7
145.480	E 60 Road Bridge												
145.400	0	0	0	0	0	0	0	0	0	0	0	0	0
144.000	17	18	18	18	18	19	19	19	21	26	31	1	14
143.000	0	0	0	0	0	0	0	0	0	0	0	0	0
142.000	42	42	42	43	43	43	43	43	44	47	53	1	11
141.000	31	33	33	33	33	34	34	34	37	42	49	1	18
140.000	0	0	0	0	0	0	0	0	9	27	41	0	41
139.000	0	0	0	0	0	0	0	0	0	0	0	0	0
138.000	0	0	0	0	0	0	0	0	0	0	0	0	0
137.000	0	0	0	0	0	0	0	0	0	0	0	0	0
135.950	0	0	0	0	0	0	0	0	0	0	0	0	0
135.941	Highway 69 Bridge												
135.940	0	0	0	0	0	0	0	0	0	0	0	0	0
135.590	0	0	0	0	0	0	0	0	0	0	0	0	0
135.586	BN RR Bridge												
135.580	0	0	0	0	0	0	0	0	0	0	0	0	0
135.470	0	0	0	0	0	0	0	0	0	0	0	0	0
135.460	Highway 125 Bridge												
135.440	0	0	0	0	0	0	0	0	0	0	0	0	0
135.000	0	0	0	0	0	0	0	0	0	0	0	0	0

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - JUN 2004 (1 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
134.610	0	0	0	0	0	0	0	0	0	0	0	0	0
134.599	Abandonded RR Bridge												
134.595	0	0	0	0	0	0	0	0	0	0	0	0	0
134.000	0	0	0	0	0	0	0	0	0	0	0	0	0
133.973	Tar Creek												
133.900	0	0	0	0	0	0	0	0	0	0	0	0	0
133.800	Interstate 44 Bridge												
133.700	0	0	0	0	0	0	0	0	0	0	0	0	0
133.000	0	0	0	0	0	0	0	0	0	0	0	0	0
132.000	0	0	0	0	0	0	0	0	0	0	0	0	0
131.000	0	0	0	0	0	0	0	0	0	0	0	0	0
130.000	0	0	0	0	0	0	0	0	0	0	0	0	0
129.000	0	0	0	0	0	0	0	0	0	0	0	0	0
128.000	0	0	0	0	0	0	0	0	0	0	0	0	0
126.710	0	0	0	0	0	0	0	0	0	0	0	0	0
126.700	S 590 Road Bridge												
126.670	0	0	0	0	0	0	0	0	0	0	0	0	0
126.000	0	0	0	0	0	0	0	0	0	0	0	0	0
125.000	0	0	0	0	0	0	0	0	0	0	0	0	0
124.000	0	0	0	0	0	0	0	0	0	0	0	0	0
123.000	0	0	0	0	0	0	0	0	0	0	0	0	0
122.580	0	0	0	0	0	0	0	0	0	0	0	0	0
122.570	Highway 60 Bridge												
122.550	0	0	0	0	0	0	0	0	0	0	0	0	0
122.350	Spring River												
122.000	0	0	0	0	0	0	0	0	0	0	0	0	0
121.980	0	0	0	0	0	0	0	0	0	0	0	0	0
121.970	BN RR Bridge												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - JUN 2004 (1 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
121.960	0	0	0	0	0	0	0	0	0	0	0	0	0
120.000	0	0	0	0	0	0	0	0	0	0	0	0	0
118.000	0	0	0	0	0	0	0	0	0	0	0	0	0
116.000	0	0	0	0	0	0	0	0	0	0	0	0	0
114.000	0	0	0	0	0	0	0	0	0	0	0	0	0
112.000	0	0	0	0	0	0	0	0	0	0	0	0	0
110.000	0	0	0	0	0	0	0	0	0	0	0	0	0
108.000	0	0	0	0	0	0	0	0	0	0	0	0	0
106.000	0	0	0	0	0	0	0	0	0	0	0	0	0
105.350	Elk River												
105.000	0	0	0	0	0	0	0	0	0	0	0	0	0
104.000	0	0	0	0	0	0	0	0	0	0	0	0	0
102.000	0	0	0	0	0	0	0	0	0	0	0	0	0
101.750	0	0	0	0	0	0	0	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)												
101.710	0	0	0	0	0	0	0	0	0	0	0	0	0
100.000	0	0	0	0	0	0	0	0	0	0	0	0	0
90.000	0	0	0	0	0	0	0	0	0	0	0	0	0
80.000	0	0	0	0	0	0	0	0	0	0	0	0	0
78.000	0	0	0	0	0	0	0	0	0	0	0	0	0
77.000	Pensacola Dam												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.6**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - JUN 2004 (1 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
21.000	Upstream end of model												
21.000	0	0	0	0	0	0	0	0	0	0	0	0	0
20.000	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	0	0	0	0	0	0	0	0	0	0	0	0	0
18.000	0	0	0	0	0	0	0	0	0	0	0	0	0
17.000	0	0	0	0	0	0	0	0	0	0	0	0	0
16.000	0	0	0	0	0	0	0	0	0	0	0	0	0
15.000	0	0	0	0	0	0	0	0	0	0	0	0	0
14.170	0	0	0	0	0	0	0	0	0	0	0	0	0
14.160	E 57 Road												
14.120	0	0	0	0	0	0	0	0	0	0	0	0	0
13.510	0	0	0	0	0	0	0	0	0	0	0	0	0
13.500	Interstate 44 Bridge												
13.450	0	0	0	0	0	0	0	0	0	0	0	0	0
12.000	0	0	0	0	0	0	0	0	0	0	0	0	0
11.000	0	0	0	0	0	0	0	0	0	0	0	0	0
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.020	0	0	0	0	0	0	0	0	0	0	0	0	0
8.010	OK Highway 10 Bridge												
7.970	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.580	0	0	0	0	0	0	0	0	0	0	0	0	0
0.570	Highway 60 Bridge												
0.560	0	0	0	0	0	0	0	0	0	0	0	0	0
0.460	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Spring River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.7**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - JUN 2004 (1 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
19.590	Upstream end of model												
19.590	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	0	0	0	0	0	0	0	0	0	0	0	0	0
18.000	0	0	0	0	0	0	0	0	0	0	0	0	0
17.000	0	0	0	0	0	0	0	0	0	0	0	0	0
16.000	0	0	0	0	0	0	0	0	0	0	0	0	0
15.000	0	0	0	0	0	0	0	0	0	0	0	0	0
14.240	0	0	0	0	0	0	0	0	0	0	0	0	0
14.220	Highway 43 Bridge												
14.200	0	0	0	0	0	0	0	0	0	0	0	0	0
14.000	0	0	0	0	0	0	0	0	0	0	0	0	0
13.000	0	0	0	0	0	0	0	0	0	0	0	0	0
12.000	0	0	0	0	0	0	0	0	0	0	0	0	0
11.910	OK/MO State Line												
11.000	0	0	0	0	0	0	0	0	0	0	0	0	0
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.000	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.700	0	0	0	0	0	0	0	0	0	0	0	0	0
4.670	OK Highway 10 Bridge												
4.640	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.320	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Elk River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.8**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - JUN 2004 (1 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
4.152	Upstream end of model												
4.152	0	0	0	0	0	0	0	0	0	0	0	0	0
3.900	0	0	0	0	0	0	0	0	0	0	0	0	0
3.840	22nd Ave Bridge												
3.800	0	0	0	0	0	0	0	0	0	0	0	0	0
3.300	0	0	0	0	0	0	0	0	0	0	0	0	0
2.800	0	0	0	0	0	0	0	0	0	0	0	0	0
2.710	BN RR Bridge												
2.700	0	0	0	0	0	0	0	0	0	0	0	0	0
2.500	0	0	0	0	0	0	0	0	0	0	0	0	0
2.300	0	0	0	0	0	0	0	0	0	0	0	0	0
2.200	Rockdale Blvd Bridge												
2.100	0	0	0	0	0	0	0	0	0	0	0	0	0
1.900	0	0	0	0	0	0	0	0	0	0	0	0	0
1.700	0	0	0	0	0	0	0	0	0	0	0	0	0
1.660	Central Ave Bridge												
1.600	0	0	0	0	0	0	0	0	0	0	0	0	0
1.500	0	0	0	0	0	0	0	0	0	0	0	0	0
1.400	OK Highway 10 Bridge												
1.300	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.700	0	0	0	0	0	0	0	0	0	0	0	0	0
0.300	0	0	0	0	0	0	0	0	0	0	0	0	0
0.041	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Tar Creek												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX G.3:
JULY 2007 (4 YEAR) INFLOW EVENT
DURATION OF INUNDATION

PENSACOLA DAM **TABLE G.9**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - JUL 2007 (4 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
152.175	Upstream end of model												
152.175	193	193	193	193	193	193	193	193	193	193	193	0	0
151.000	143	143	144	144	144	143	144	144	143	143	143	1	1
150.000	213	213	213	213	213	213	213	213	213	213	214	0	1
149.000	208	208	208	208	208	208	208	208	208	209	209	0	1
148.000	209	209	209	209	209	209	209	209	210	210	211	0	2
147.000	193	193	193	193	193	193	193	193	193	193	193	0	0
145.500	228	228	228	228	228	228	228	228	229	229	230	0	2
145.480	E 60 Road Bridge												
145.400	226	227	228	228	228	228	228	228	228	229	230	1	4
144.000	236	236	236	237	237	237	237	237	237	238	239	1	3
143.000	221	223	223	223	223	223	223	223	223	225	226	0	5
142.000	252	252	253	253	253	253	253	253	254	256	260	1	8
141.000	248	248	249	249	249	249	249	249	250	253	255	1	7
140.000	237	238	239	239	239	239	239	239	241	245	249	1	12
139.000	204	206	208	208	208	208	208	208	213	220	225	2	21
138.000	186	189	190	190	191	192	191	192	197	202	208	3	22
137.000	170	172	174	174	174	174	174	174	177	180	186	2	16
135.950	164	166	168	168	168	169	168	168	171	173	178	3	14
135.941	Highway 69 Bridge												
135.940	164	165	167	167	167	167	167	167	171	173	178	2	14
135.590	163	165	167	167	167	167	167	167	170	172	177	2	14
135.586	BN RR Bridge												
135.580	163	165	167	167	167	167	167	167	170	172	177	2	14
135.470	162	164	166	166	166	166	166	166	168	171	175	2	13
135.460	Highway 125 Bridge												
135.440	162	165	166	166	166	166	167	167	169	172	177	2	15
135.000	161	164	165	166	165	166	166	166	168	171	175	2	14

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.9**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - JUL 2007 (4 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
134.610	158	161	162	163	162	163	163	163	166	168	172	2	14
134.599	Abandonded RR Bridge												
134.595	156	158	161	161	161	161	161	161	163	166	169	3	13
134.000	149	152	153	153	153	153	154	154	156	159	162	2	13
133.973	Tar Creek												
133.900	146	148	150	150	150	150	150	150	154	155	159	2	13
133.800	Interstate 44 Bridge												
133.700	145	148	149	150	150	150	150	150	152	154	157	2	12
133.000	137	139	140	140	140	141	140	141	142	143	144	2	7
132.000	132	132	134	134	134	134	134	135	135	136	137	3	5
131.000	126	128	130	130	130	130	130	130	131	132	132	2	6
130.000	120	122	126	126	126	126	125	126	127	127	127	4	7
129.000	112	116	119	119	119	120	119	120	122	121	122	4	10
128.000	103	107	113	113	113	114	113	114	116	115	116	7	13
126.710	84	85	92	92	93	90	92	93	95	95	96	8	12
126.700	S 590 Road Bridge												
126.670	83	83	91	91	91	90	91	91	94	93	95	8	12
126.000	75	76	84	84	84	81	84	84	87	86	88	8	13
125.000	53	59	67	67	67	64	66	67	70	70	72	8	19
124.000	0	0	41	41	41	23	40	43	47	49	51	43	51
123.000	0	0	0	0	0	0	0	0	0	0	0	0	0
122.580	0	0	0	0	0	0	0	0	0	0	0	0	0
122.570	Highway 60 Bridge												
122.550	0	0	0	0	0	0	0	0	0	0	0	0	0
122.350	Spring River												
122.000	0	0	0	0	0	0	0	0	0	0	0	0	0
121.980	0	0	0	0	0	0	0	0	0	0	0	0	0
121.970	BN RR Bridge												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.9**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - JUL 2007 (4 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
121.960	0	0	0	0	0	0	0	0	0	0	0	0	0
120.000	0	0	0	0	0	0	0	0	0	0	0	0	0
118.000	0	0	0	0	0	0	0	0	0	0	0	0	0
116.000	0	0	0	0	0	0	0	0	0	0	0	0	0
114.000	0	0	0	0	0	0	0	0	0	0	0	0	0
112.000	0	0	0	0	0	0	0	0	0	0	0	0	0
110.000	0	0	0	0	0	0	0	0	0	0	0	0	0
108.000	0	0	0	0	0	0	0	0	0	0	0	0	0
106.000	0	0	0	0	0	0	0	0	0	0	0	0	0
105.350	Elk River												
105.000	0	0	0	0	0	0	0	0	0	0	0	0	0
104.000	0	0	0	0	0	0	0	0	0	0	0	0	0
102.000	0	0	0	0	0	0	0	0	0	0	0	0	0
101.750	0	0	0	0	0	0	0	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)												
101.710	0	0	0	0	0	0	0	0	0	0	0	0	0
100.000	0	0	0	0	0	0	0	0	0	0	0	0	0
90.000	0	0	0	0	0	0	0	0	0	0	0	0	0
80.000	0	0	0	0	0	0	0	0	0	0	0	0	0
78.000	0	0	0	0	0	0	0	0	0	0	0	0	0
77.000	Pensacola Dam												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.10**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - JUL 2007 (4 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
21.000	Upstream end of model												
21.000	0	0	0	0	0	0	0	0	0	0	0	0	0
20.000	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	0	0	0	0	0	0	0	0	0	0	0	0	0
18.000	0	0	0	0	0	0	0	0	0	0	0	0	0
17.000	0	0	0	0	0	0	0	0	0	0	0	0	0
16.000	0	0	0	0	0	0	0	0	0	0	0	0	0
15.000	0	0	0	0	0	0	0	0	0	0	0	0	0
14.170	0	0	0	0	0	0	0	0	0	0	0	0	0
14.160	E 57 Road												
14.120	0	0	0	0	0	0	0	0	0	0	0	0	0
13.510	0	0	0	0	0	0	0	0	0	0	0	0	0
13.500	Interstate 44 Bridge												
13.450	0	0	0	0	0	0	0	0	0	0	0	0	0
12.000	0	0	0	0	0	0	0	0	0	0	0	0	0
11.000	38	39	45	45	45	40	44	47	53	56	63	8	25
10.000	0	0	0	0	0	0	0	0	31	15	41	0	41
9.000	0	0	0	0	0	0	0	0	0	0	8	0	8
8.020	0	0	0	0	0	0	0	0	0	0	0	0	0
8.010	OK Highway 10 Bridge												
7.970	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.580	0	0	0	0	0	0	0	0	0	0	0	0	0
0.570	Highway 60 Bridge												
0.560	0	0	0	0	0	0	0	0	0	0	0	0	0
0.460	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Spring River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.11**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - JUL 2007 (4 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
19.590	Upstream end of model												
19.590	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	0	0	0	0	0	0	0	0	0	0	0	0	0
18.000	0	0	0	0	0	0	0	0	0	0	0	0	0
17.000	0	0	0	0	0	0	0	0	0	0	0	0	0
16.000	0	0	0	0	0	0	0	0	0	0	0	0	0
15.000	0	0	0	0	0	0	0	0	0	0	0	0	0
14.240	0	0	0	0	0	0	0	0	0	0	0	0	0
14.220	Highway 43 Bridge												
14.200	0	0	0	0	0	0	0	0	0	0	0	0	0
14.000	0	0	0	0	0	0	0	0	0	0	0	0	0
13.000	0	0	0	0	0	0	0	0	0	0	0	0	0
12.000	0	0	0	0	0	0	0	0	0	0	0	0	0
11.910	OK/MO State Line												
11.000	0	0	0	0	0	0	0	0	0	0	0	0	0
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.000	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.700	0	0	0	0	0	0	0	0	0	0	0	0	0
4.670	OK Highway 10 Bridge												
4.640	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.320	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Elk River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.12**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - JUL 2007 (4 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
4.152	Upstream end of model												
4.152	0	0	0	0	0	0	0	0	0	0	0	0	0
3.900	0	0	0	0	0	0	0	0	0	0	0	0	0
3.840	22nd Ave Bridge												
3.800	32	33	35	35	35	33	35	35	36	36	37	2	5
3.300	46	46	48	48	48	47	48	48	49	49	50	2	4
2.800	80	82	83	83	83	82	83	83	83	83	84	1	4
2.710	BN RR Bridge												
2.700	110	110	112	112	112	112	112	112	112	113	113	2	3
2.500	118	120	122	122	122	122	122	122	122	122	123	2	5
2.300	127	128	129	129	129	129	129	129	130	130	131	1	4
2.200	Rockdale Blvd Bridge												
2.100	148	151	153	153	153	153	153	153	156	159	161	2	13
1.900	148	151	153	153	153	153	153	153	156	158	161	2	13
1.700	148	151	153	153	153	153	153	153	156	158	161	2	13
1.660	Central Ave Bridge												
1.600	148	151	153	153	153	153	153	153	156	158	161	2	13
1.500	148	151	153	153	153	153	153	153	156	158	161	2	13
1.400	OK Highway 10 Bridge												
1.300	148	151	153	153	153	153	153	153	156	158	161	2	13
1.000	148	151	153	153	153	153	153	153	156	158	161	2	13
0.700	148	151	153	153	153	153	153	153	156	158	161	2	13
0.300	148	151	153	153	153	153	153	153	156	158	161	2	13
0.041	148	151	153	153	153	153	153	153	156	158	161	2	13
0.000	Downstream end of Tar Creek												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX G.4:
OCTOBER 2009 (3 YEAR) INFLOW EVENT
DURATION OF INUNDATION

PENSACOLA DAM **TABLE G.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - OCT 2009 (3 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
152.175	Upstream end of model												
152.175	90	90	90	90	90	90	90	90	90	90	90	0	0
151.000	42	42	42	42	42	42	42	42	42	42	42	0	0
150.000	95	95	95	95	95	95	95	95	95	95	95	0	0
149.000	92	93	93	93	93	93	93	93	93	94	94	0	2
148.000	95	95	95	95	95	95	95	95	95	95	95	0	0
147.000	87	87	87	87	87	87	87	87	87	87	89	0	2
145.500	104	104	104	104	104	104	104	104	104	104	105	0	1
145.480	E 60 Road Bridge												
145.400	102	102	102	102	102	102	102	102	103	104	105	0	3
144.000	107	107	107	107	107	108	108	108	108	110	110	1	3
143.000	100	100	100	100	100	100	100	100	100	102	103	0	3
142.000	117	117	117	117	117	117	117	117	119	121	123	0	6
141.000	114	115	114	115	114	115	115	114	116	118	121	1	7
140.000	108	108	109	110	109	110	109	109	111	114	117	2	9
139.000	91	93	93	93	93	93	93	93	95	101	108	0	17
138.000	80	81	81	82	82	82	82	82	85	92	100	1	20
137.000	57	60	59	60	60	60	61	61	63	74	88	2	31
135.950	44	48	48	49	49	49	49	50	53	63	77	2	33
135.941	Highway 69 Bridge												
135.940	43	47	46	47	48	49	49	49	51	62	76	3	33
135.590	42	46	45	46	46	47	47	47	50	62	75	2	33
135.586	BN RR Bridge												
135.580	42	45	45	46	46	46	47	47	50	61	75	2	33
135.470	39	44	43	45	45	45	45	46	49	59	74	3	35
135.460	Highway 125 Bridge												
135.440	40	44	45	46	45	46	46	46	50	61	75	2	35
135.000	37	41	42	43	43	43	43	44	47	58	72	3	35

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - OCT 2009 (3 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
134.610	28	34	35	36	36	37	37	37	42	54	69	3	41
134.599	Abandonded RR Bridge												
134.595	22	30	29	32	32	33	33	33	37	50	66	4	44
134.000	0	0	0	0	0	0	0	0	16	38	59	0	59
133.973	Tar Creek												
133.900	0	0	0	0	0	0	0	0	0	32	54	0	54
133.800	Interstate 44 Bridge												
133.700	0	0	0	0	0	0	0	0	0	30	54	0	54
133.000	0	0	0	0	0	0	0	0	0	0	30	0	30
132.000	0	0	0	0	0	0	0	0	0	0	0	0	0
131.000	0	0	0	0	0	0	0	0	0	0	0	0	0
130.000	0	0	0	0	0	0	0	0	0	0	0	0	0
129.000	0	0	0	0	0	0	0	0	0	0	0	0	0
128.000	0	0	0	0	0	0	0	0	0	0	0	0	0
126.710	0	0	0	0	0	0	0	0	0	0	0	0	0
126.700	S 590 Road Bridge												
126.670	0	0	0	0	0	0	0	0	0	0	0	0	0
126.000	0	0	0	0	0	0	0	0	0	0	0	0	0
125.000	0	0	0	0	0	0	0	0	0	0	0	0	0
124.000	0	0	0	0	0	0	0	0	0	0	0	0	0
123.000	0	0	0	0	0	0	0	0	0	0	0	0	0
122.580	0	0	0	0	0	0	0	0	0	0	0	0	0
122.570	Highway 60 Bridge												
122.550	0	0	0	0	0	0	0	0	0	0	0	0	0
122.350	Spring River												
122.000	0	0	0	0	0	0	0	0	0	0	0	0	0
121.980	0	0	0	0	0	0	0	0	0	0	0	0	0
121.970	BN RR Bridge												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.13**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - OCT 2009 (3 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
121.960	0	0	0	0	0	0	0	0	0	0	0	0	0
120.000	0	0	0	0	0	0	0	0	0	0	0	0	0
118.000	0	0	0	0	0	0	0	0	0	0	0	0	0
116.000	0	0	0	0	0	0	0	0	0	0	0	0	0
114.000	0	0	0	0	0	0	0	0	0	0	0	0	0
112.000	0	0	0	0	0	0	0	0	0	0	0	0	0
110.000	0	0	0	0	0	0	0	0	0	0	0	0	0
108.000	0	0	0	0	0	0	0	0	0	0	0	0	0
106.000	0	0	0	0	0	0	0	0	0	0	0	0	0
105.350	Elk River												
105.000	0	0	0	0	0	0	0	0	0	0	0	0	0
104.000	0	0	0	0	0	0	0	0	0	0	0	0	0
102.000	0	0	0	0	0	0	0	0	0	0	0	0	0
101.750	0	0	0	0	0	0	0	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)												
101.710	0	0	0	0	0	0	0	0	0	0	0	0	0
100.000	0	0	0	0	0	0	0	0	0	0	0	0	0
90.000	0	0	0	0	0	0	0	0	0	0	0	0	0
80.000	0	0	0	0	0	0	0	0	0	0	0	0	0
78.000	0	0	0	0	0	0	0	0	0	0	0	0	0
77.000	Pensacola Dam												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.14**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - OCT 2009 (3 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
21.000	Upstream end of model												
21.000	0	0	0	0	0	0	0	0	0	0	0	0	0
20.000	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	28	28	28	28	28	28	28	28	28	28	28	0	0
18.000	29	29	29	29	29	29	29	29	29	29	29	0	0
17.000	32	32	32	32	32	32	32	32	32	32	32	0	0
16.000	59	59	59	59	59	59	59	59	59	59	59	0	0
15.000	39	39	39	39	39	39	39	39	39	39	39	0	0
14.170	75	75	75	75	75	75	75	75	75	75	76	0	1
14.160	E 57 Road												
14.120	76	76	76	76	76	76	76	76	76	76	76	0	0
13.510	76	76	76	76	76	76	76	76	76	76	77	0	1
13.500	Interstate 44 Bridge												
13.450	74	74	74	74	74	74	74	74	74	76	76	0	2
12.000	75	75	75	75	75	75	75	75	75	76	76	0	1
11.000	87	87	87	87	87	87	87	87	89	91	94	0	7
10.000	81	82	82	82	82	82	82	82	84	86	89	0	8
9.000	73	74	74	74	74	74	74	74	75	79	84	0	11
8.020	53	55	55	55	55	56	56	56	59	68	76	1	23
8.010	OK Highway 10 Bridge												
7.970	20	21	22	22	22	22	22	22	23	30	39	1	19
7.000	0	0	0	0	0	0	0	0	0	0	3	0	3
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.580	0	0	0	0	0	0	0	0	0	0	0	0	0
0.570	Highway 60 Bridge												
0.560	0	0	0	0	0	0	0	0	0	0	0	0	0
0.460	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Spring River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.15**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - OCT 2009 (3 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
19.590	Upstream end of model												
19.590	24	24	24	24	24	24	24	24	24	24	24	0	0
19.000	19	19	19	19	19	19	19	19	19	19	19	0	0
18.000	22	22	22	22	22	22	22	22	22	22	22	0	0
17.000	56	56	56	56	56	56	56	56	56	56	56	0	0
16.000	58	58	58	58	58	58	58	58	58	58	58	0	0
15.000	51	51	51	51	51	51	51	51	51	51	51	0	0
14.240	31	31	31	31	31	31	31	31	31	31	31	0	0
14.220	Highway 43 Bridge												
14.200	30	30	30	30	30	30	30	30	30	30	30	0	0
14.000	25	25	25	25	25	25	25	25	25	25	25	0	0
13.000	27	27	27	27	27	27	27	27	27	27	28	0	1
12.000	15	15	15	15	15	15	15	15	15	15	15	0	0
11.910	OK/MO State Line												
11.000	0	0	0	0	0	0	0	0	0	0	0	0	0
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.000	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.700	0	0	0	0	0	0	0	0	0	0	0	0	0
4.670	OK Highway 10 Bridge												
4.640	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.320	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Elk River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.16**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - OCT 2009 (3 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
4.152	Upstream end of model												
4.152	1	1	1	1	1	1	1	1	1	1	1	0	0
3.900	12	12	12	12	12	12	12	12	12	12	12	0	0
3.840	22nd Ave Bridge												
3.800	18	18	18	18	18	18	18	18	18	18	18	0	0
3.300	7	7	7	7	7	7	7	7	7	7	7	0	0
2.800	0	0	0	0	0	0	0	0	0	0	0	0	0
2.710	BN RR Bridge												
2.700	20	20	20	20	20	20	20	20	20	20	20	0	0
2.500	14	14	14	14	14	14	14	14	14	14	14	0	0
2.300	6	6	6	6	6	6	6	6	6	7	7	0	1
2.200	Rockdale Blvd Bridge												
2.100	10	10	10	10	10	10	11	11	84	95	101	1	91
1.900	0	0	0	0	0	0	0	0	12	36	57	0	57
1.700	0	0	0	0	0	0	0	0	12	36	57	0	57
1.660	Central Ave Bridge												
1.600	0	0	0	0	0	0	0	0	12	36	57	0	57
1.500	0	0	0	0	0	0	0	0	12	36	57	0	57
1.400	OK Highway 10 Bridge												
1.300	0	0	0	0	0	0	0	0	12	36	57	0	57
1.000	0	0	0	0	0	0	0	0	12	36	57	0	57
0.700	0	0	0	0	0	0	0	0	12	36	57	0	57
0.300	0	0	0	0	0	0	0	0	12	36	57	0	57
0.041	0	0	0	0	0	0	0	0	12	36	57	0	57
0.000	Downstream end of Tar Creek												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX G.5:
DECEMBER 2015 (15 YEAR) INFLOW EVENT
DURATION OF INUNDATION

PENSACOLA DAM **TABLE G.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - DEC 2015 (15 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
152.175	Upstream end of model												
152.175	74	74	74	74	74	74	74	74	74	74	74	0	0
151.000	47	47	47	47	47	47	47	47	47	47	48	0	1
150.000	80	80	80	80	80	80	80	80	80	80	81	0	1
149.000	79	79	79	79	79	79	79	79	79	79	79	0	0
148.000	80	80	80	80	80	80	80	80	81	81	81	0	1
147.000	73	74	74	74	74	74	74	74	74	75	75	0	2
145.500	91	92	92	92	92	92	92	92	92	92	94	0	3
145.480	E 60 Road Bridge												
145.400	90	91	91	91	91	91	91	91	92	92	92	0	2
144.000	96	98	98	98	98	98	98	98	99	99	100	0	4
143.000	88	90	90	90	90	90	90	90	90	91	93	0	5
142.000	113	114	114	114	114	114	114	114	114	115	116	0	3
141.000	109	110	110	110	110	110	110	110	111	112	114	0	5
140.000	102	105	105	105	105	105	105	105	106	107	109	0	7
139.000	87	89	89	89	89	89	90	90	91	94	98	1	11
138.000	78	82	82	82	82	82	82	82	83	86	92	0	14
137.000	68	72	72	72	72	72	72	72	73	76	84	0	16
135.950	62	67	67	67	67	67	67	67	69	72	80	0	18
135.941	Highway 69 Bridge												
135.940	62	67	67	67	67	67	67	67	69	72	80	0	18
135.590	62	67	67	67	67	67	67	67	69	72	80	0	18
135.586	BN RR Bridge												
135.580	62	66	67	66	66	66	67	67	69	71	80	1	18
135.470	61	65	65	65	65	65	65	65	68	71	78	0	17
135.460	Highway 125 Bridge												
135.440	61	66	66	66	66	66	66	67	68	71	79	1	18
135.000	60	65	65	65	65	65	65	65	68	71	78	0	18

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - DEC 2015 (15 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
134.610	57	63	63	63	63	63	63	63	65	68	77	0	20
134.599	Abandonded RR Bridge												
134.595	56	61	61	61	61	61	61	62	65	67	75	1	19
134.000	49	57	57	57	57	57	57	57	60	62	71	0	22
133.973	Tar Creek												
133.900	44	53	53	53	53	53	54	54	57	60	69	1	25
133.800	Interstate 44 Bridge												
133.700	42	51	52	52	51	51	52	52	57	59	68	1	26
133.000	28	40	40	40	40	40	41	41	48	50	60	1	32
132.000	0	30	30	30	30	30	31	32	38	40	52	2	52
131.000	0	20	20	20	20	20	21	23	32	33	45	3	45
130.000	0	15	16	15	15	15	16	18	28	30	43	3	43
129.000	0	11	12	11	11	11	13	14	25	28	41	3	41
128.000	0	9	10	10	9	9	10	10	23	26	38	1	38
126.710	0	5	6	5	5	5	7	6	17	22	35	2	35
126.700	S 590 Road Bridge												
126.670	0	5	5	5	5	5	5	5	17	20	33	0	33
126.000	0	5	5	5	5	5	5	5	15	20	33	0	33
125.000	0	3	3	3	3	3	3	3	9	16	30	0	30
124.000	0	2	2	2	2	2	2	3	4	14	29	1	29
123.000	0	0	0	0	0	0	0	0	0	2	27	0	27
122.580	0	0	0	0	0	0	0	0	0	1	26	0	26
122.570	Highway 60 Bridge												
122.550	0	0	0	0	0	0	0	0	0	0	25	0	25
122.350	Spring River												
122.000	0	0	0	0	0	0	0	0	0	0	14	0	14
121.980	0	0	0	0	0	0	0	0	0	0	0	0	0
121.970	BN RR Bridge												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.17**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - DEC 2015 (15 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
121.960	0	0	0	0	0	0	0	0	0	0	0	0	0
120.000	0	0	0	0	0	0	0	0	0	0	0	0	0
118.000	0	0	0	0	0	0	0	0	0	0	0	0	0
116.000	0	0	0	0	0	0	0	0	0	0	0	0	0
114.000	0	0	0	0	0	0	0	0	0	0	0	0	0
112.000	0	0	0	0	0	0	0	0	0	0	0	0	0
110.000	0	0	0	0	0	0	0	0	0	0	0	0	0
108.000	0	0	0	0	0	0	0	0	0	0	0	0	0
106.000	0	0	0	0	0	0	0	0	0	0	0	0	0
105.350	Elk River												
105.000	0	0	0	0	0	0	0	0	0	0	0	0	0
104.000	0	0	0	0	0	0	0	0	0	0	0	0	0
102.000	0	0	0	0	0	0	0	0	0	0	0	0	0
101.750	0	0	0	0	0	0	0	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)												
101.710	0	0	0	0	0	0	0	0	0	0	0	0	0
100.000	0	0	0	0	0	0	0	0	0	0	0	0	0
90.000	0	0	0	0	0	0	0	0	0	0	0	0	0
80.000	0	0	0	0	0	0	0	0	0	0	0	0	0
78.000	0	0	0	0	0	0	0	0	0	0	0	0	0
77.000	Pensacola Dam												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.18**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - DEC 2015 (15 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
21.000	Upstream end of model												
21.000	54	54	54	54	54	54	54	54	54	54	54	0	0
20.000	52	52	52	52	52	52	52	52	52	52	52	0	0
19.000	76	76	76	76	76	76	76	76	76	76	76	0	0
18.000	77	77	77	77	77	77	77	77	77	77	77	0	0
17.000	79	79	79	79	79	79	79	79	79	79	79	0	0
16.000	86	86	86	86	86	86	86	86	86	86	86	0	0
15.000	82	82	82	82	82	82	82	82	82	82	82	0	0
14.170	96	97	97	97	97	97	97	97	97	97	98	0	2
14.160	E 57 Road												
14.120	98	98	98	98	98	98	98	98	98	98	98	0	0
13.510	99	99	99	99	99	99	99	99	99	99	99	0	0
13.500	Interstate 44 Bridge												
13.450	97	97	97	97	97	97	97	97	97	97	97	0	0
12.000	97	97	97	97	97	97	97	98	98	98	98	1	1
11.000	112	111	111	111	111	111	112	112	112	113	113	1	2
10.000	108	108	108	108	108	108	108	108	108	108	109	0	1
9.000	100	101	101	101	101	101	101	101	102	103	104	0	4
8.020	92	93	93	93	93	93	93	93	93	95	97	0	5
8.010	OK Highway 10 Bridge												
7.970	78	81	81	81	81	81	81	81	82	83	85	0	7
7.000	61	65	65	65	65	65	65	65	66	67	71	0	10
6.000	51	57	57	57	57	57	57	57	58	58	61	0	10
5.000	41	49	49	49	49	49	49	49	50	51	54	0	13
4.000	28	38	38	38	38	38	38	38	43	45	50	0	22
3.000	15	32	32	32	32	32	33	33	35	37	45	1	30
2.000	0	25	25	25	25	25	26	27	31	32	41	2	41
1.000	0	8	8	8	8	8	8	10	25	27	35	2	35
0.580	0	0	0	0	0	0	0	0	0	0	23	0	23
0.570	Highway 60 Bridge												
0.560	0	0	0	0	0	0	0	0	0	0	19	0	19
0.460	0	0	0	0	0	0	0	0	0	0	24	0	24
0.000	Downstream end of Spring River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.19**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - DEC 2015 (15 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
19.590	Upstream end of model												
19.590	58	58	58	58	58	58	58	58	58	58	58	0	0
19.000	51	51	51	51	51	51	51	51	51	51	51	0	0
18.000	55	55	55	55	55	55	55	55	55	55	55	0	0
17.000	111	111	111	111	111	111	111	111	111	111	111	0	0
16.000	118	118	118	118	118	118	118	118	118	118	118	0	0
15.000	103	104	104	104	104	104	104	104	104	104	104	0	1
14.240	68	68	68	68	68	68	68	68	68	68	68	0	0
14.220	Highway 43 Bridge												
14.200	67	67	67	67	67	67	67	67	67	67	67	0	0
14.000	59	59	59	59	59	59	59	59	59	59	59	0	0
13.000	62	62	62	62	62	62	62	62	63	64	65	0	3
12.000	46	46	46	46	46	46	46	46	46	46	48	0	2
11.910	OK/MO State Line												
11.000	21	21	21	21	21	21	21	21	21	21	23	0	2
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.000	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.700	0	0	0	0	0	0	0	0	0	0	0	0	0
4.670	OK Highway 10 Bridge												
4.640	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.320	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Elk River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.20**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - DEC 2015 (15 YEAR) EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
4.152	Upstream end of model												
4.152	4	4	4	4	4	4	4	4	4	4	4	0	0
3.900	15	15	15	15	15	15	15	15	15	15	15	0	0
3.840	22nd Ave Bridge												
3.800	21	21	21	21	21	21	21	21	21	21	21	0	0
3.300	9	9	9	9	9	9	9	9	9	9	9	0	0
2.800	0	0	0	0	0	0	0	0	0	0	0	0	0
2.710	BN RR Bridge												
2.700	24	24	24	24	24	24	24	24	24	24	24	0	0
2.500	17	17	17	17	17	17	17	17	17	17	17	0	0
2.300	8	8	8	8	8	8	8	8	8	9	67	0	59
2.200	Rockdale Blvd Bridge												
2.100	84	89	89	89	89	89	89	89	90	90	92	0	8
1.900	49	56	56	56	56	56	56	56	60	62	74	0	25
1.700	48	55	56	55	55	55	56	56	60	62	72	1	24
1.660	Central Ave Bridge												
1.600	48	55	55	55	55	55	56	56	60	62	72	1	24
1.500	48	55	55	55	55	55	56	56	60	62	72	1	24
1.400	OK Highway 10 Bridge												
1.300	48	55	55	55	55	55	56	56	59	62	71	1	23
1.000	48	55	55	55	55	55	55	56	59	62	70	1	22
0.700	48	55	55	55	55	55	55	56	59	62	70	1	22
0.300	48	55	55	55	55	55	55	56	59	62	70	1	22
0.041	48	55	55	55	55	55	55	56	59	62	70	1	22
0.000	Downstream end of Tar Creek												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX G.6:
100-YEAR INFLOW EVENT
DURATION OF INUNDATION

PENSACOLA DAM **TABLE G.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - 100-YEAR EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
152.175	Upstream end of model												
152.175	221	221	221	221	221	221	221	221	221	221	221	0	0
151.000	209	209	209	209	209	209	209	209	209	209	209	0	0
150.000	227	227	227	227	227	227	227	227	233	234	235	0	8
149.000	227	227	227	227	227	227	227	227	227	227	227	0	0
148.000	229	229	229	229	229	229	229	229	229	229	229	0	0
147.000	225	225	225	225	225	225	225	225	225	225	225	0	0
145.500	253	254	254	254	254	254	254	254	254	255	257	0	4
145.480	E 60 Road Bridge												
145.400	252	253	253	253	253	253	253	253	253	254	256	0	4
144.000	261	262	262	262	262	262	262	262	262	264	266	0	5
143.000	242	243	243	243	244	244	244	244	246	250	254	1	12
142.000	275	275	275	275	275	276	276	276	276	278	284	1	9
141.000	272	272	272	272	272	272	272	272	273	275	280	0	8
140.000	261	263	263	263	263	263	263	263	266	270	276	0	15
139.000	238	239	239	239	239	239	239	239	241	245	263	0	25
138.000	230	231	231	231	231	231	231	231	233	235	243	0	13
137.000	223	224	224	224	224	224	224	224	225	226	230	0	7
135.950	220	221	221	221	221	221	221	221	222	223	226	0	6
135.941	Highway 69 Bridge												
135.940	220	220	221	221	221	221	221	221	222	223	226	1	6
135.590	219	220	220	220	220	221	220	220	222	223	226	1	7
135.586	BN RR Bridge												
135.580	219	220	220	220	220	220	220	220	222	223	226	0	7
135.470	219	220	220	220	220	220	220	220	221	222	225	0	6
135.460	Highway 125 Bridge												
135.440	219	220	220	220	220	220	220	220	221	223	225	0	6
135.000	219	220	220	220	220	220	220	220	221	222	225	0	6

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - 100-YEAR EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
134.610	217	218	218	218	218	218	218	218	219	220	223	0	6
134.599	Abandonded RR Bridge												
134.595	216	217	217	217	217	217	217	217	219	220	222	0	6
134.000	210	211	212	212	212	212	212	212	213	215	217	1	7
133.973	Tar Creek												
133.900	209	210	210	210	211	211	211	211	212	213	216	1	7
133.800	Interstate 44 Bridge												
133.700	208	209	209	209	209	209	209	209	211	212	214	0	6
133.000	202	203	203	203	204	204	204	204	205	205	207	1	5
132.000	196	197	197	197	197	197	197	197	198	198	200	0	4
131.000	191	191	191	191	192	192	192	192	193	193	195	1	4
130.000	180	181	181	181	181	181	181	181	182	183	184	0	4
129.000	156	157	157	157	157	157	157	157	158	159	161	0	5
128.000	134	136	136	136	136	136	136	136	138	138	141	0	7
126.710	114	115	116	116	116	116	116	116	118	119	124	1	10
126.700	S 590 Road Bridge												
126.670	113	115	115	115	116	116	116	116	118	119	124	1	11
126.000	108	110	110	110	110	110	110	110	112	114	119	0	11
125.000	96	98	98	98	98	99	98	99	101	102	108	1	12
124.000	84	87	86	87	87	87	87	87	90	91	96	1	12
123.000	70	72	71	71	72	72	71	72	74	75	80	1	10
122.580	59	61	61	61	62	62	61	62	64	65	68	1	9
122.570	Highway 60 Bridge												
122.550	60	63	62	62	63	63	62	63	65	66	69	1	9
122.350	Spring River												
122.000	59	61	61	61	62	62	61	61	63	63	65	1	6
121.980	57	60	59	59	60	60	59	60	61	62	63	1	6
121.970	BN RR Bridge												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.21**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - 100-YEAR EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0	El. 742.0	El. 742.5	El. 743.0	El. 743.5	El. 744.0	El. 744.5	El. 745.0	El. 749.0	El. 753.0	El. 757.0		
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)		
121.960	37	41	39	39	41	40	40	40	43	44	46	2	9
120.000	25	27	26	27	27	27	27	27	29	30	32	1	7
118.000	0	0	0	0	0	0	0	0	0	0	0	0	0
116.000	0	0	0	0	0	0	0	0	0	0	0	0	0
114.000	0	0	0	0	0	0	0	0	0	0	0	0	0
112.000	0	0	0	0	0	0	0	0	0	0	0	0	0
110.000	0	0	0	0	0	0	0	0	0	0	0	0	0
108.000	0	0	0	0	0	0	0	0	0	0	0	0	0
106.000	0	0	0	0	0	0	0	0	0	0	0	0	0
105.350	Elk River												
105.000	0	0	0	0	0	0	0	0	0	0	0	0	0
104.000	0	0	0	0	0	0	0	0	0	0	0	0	0
102.000	0	0	0	0	0	0	0	0	0	0	0	0	0
101.750	0	0	0	0	0	0	0	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)												
101.710	0	0	0	0	0	0	0	0	0	0	0	0	0
100.000	0	0	0	0	0	0	0	0	0	0	0	0	0
90.000	0	0	0	0	0	0	0	0	0	0	0	0	0
80.000	0	0	0	0	0	0	0	0	0	0	0	0	0
78.000	0	0	0	0	0	0	0	0	0	0	0	0	0
77.000	Pensacola Dam												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.22**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - 100-YEAR EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
21.000	Upstream end of model												
21.000	0	0	0	0	0	0	0	0	0	0	0	0	0
20.000	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	40	40	40	40	40	40	40	40	40	40	40	0	0
18.000	41	41	41	41	41	41	41	41	41	41	41	0	0
17.000	43	43	43	43	43	43	43	43	43	43	44	0	1
16.000	55	55	55	55	55	55	55	55	55	55	55	0	0
15.000	49	49	49	49	49	49	49	49	49	49	49	0	0
14.170	72	72	72	72	72	72	72	72	72	72	72	0	0
14.160	E 57 Road												
14.120	73	73	73	73	73	73	73	73	73	73	73	0	0
13.510	75	75	75	75	75	75	75	75	75	75	75	0	0
13.500	Interstate 44 Bridge												
13.450	73	73	73	73	73	73	73	73	73	73	73	0	0
12.000	84	84	84	84	84	84	84	84	84	84	85	0	1
11.000	115	115	115	115	115	115	115	115	116	116	117	0	2
10.000	110	110	111	111	111	111	111	111	111	111	112	1	2
9.000	103	103	103	103	103	104	104	104	105	105	107	1	4
8.020	94	96	96	96	96	96	96	96	98	99	103	0	9
8.010	OK Highway 10 Bridge												
7.970	81	82	82	82	82	82	82	83	84	85	92	1	11
7.000	70	74	73	74	74	74	74	74	77	78	84	1	14
6.000	65	70	69	69	71	71	70	70	74	75	80	2	15
5.000	63	67	66	66	67	67	67	67	71	72	77	1	14
4.000	63	66	65	65	66	66	66	66	69	71	76	1	13
3.000	62	64	63	63	64	64	64	64	67	68	75	1	13
2.000	62	64	63	63	64	64	64	64	67	68	73	1	11
1.000	62	64	63	63	64	64	64	64	66	67	71	1	9
0.580	62	64	63	63	64	64	64	64	65	66	69	1	7
0.570	Highway 60 Bridge												
0.560	62	63	63	63	64	64	64	64	65	66	69	1	7
0.460	62	64	63	63	64	64	64	64	66	66	70	1	8
0.000	Downstream end of Spring River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.23**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - 100-YEAR EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
19.590	Upstream end of model												
19.590	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	0	0	0	0	0	0	0	0	0	0	0	0	0
18.000	0	0	0	0	0	0	0	0	0	0	0	0	0
17.000	0	0	0	0	0	0	0	0	0	0	0	0	0
16.000	0	0	0	0	0	0	0	0	0	0	0	0	0
15.000	0	0	0	0	0	0	0	0	0	0	0	0	0
14.240	0	0	0	0	0	0	0	0	0	0	0	0	0
14.220	Highway 43 Bridge												
14.200	0	0	0	0	0	0	0	0	0	0	0	0	0
14.000	0	0	0	0	0	0	0	0	0	0	0	0	0
13.000	0	0	0	0	0	0	0	0	0	0	0	0	0
12.000	0	0	0	0	0	0	0	0	0	0	0	0	0
11.910	OK/MO State Line												
11.000	0	0	0	0	0	0	0	0	0	0	0	0	0
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.000	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.700	0	0	0	0	0	0	0	0	0	0	0	0	0
4.670	OK Highway 10 Bridge												
4.640	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.320	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Elk River												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

PENSACOLA DAM **TABLE G.24**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - 100-YEAR EVENT

River Mile	Pensacola Dam Starting Stage (ft, PD)											Anticipated Op Range Duration Difference[1] (hours)	Extreme, Hypothetical Range Duration Difference[2] (hours)
	El. 734.0 Duration (hours)	El. 742.0 Duration (hours)	El. 742.5 Duration (hours)	El. 743.0 Duration (hours)	El. 743.5 Duration (hours)	El. 744.0 Duration (hours)	El. 744.5 Duration (hours)	El. 745.0 Duration (hours)	El. 749.0 Duration (hours)	El. 753.0 Duration (hours)	El. 757.0 Duration (hours)		
4.152	Upstream end of model												
4.152	70	70	70	70	70	70	70	70	70	70	70	0	0
3.900	79	80	80	80	80	80	80	80	80	80	80	0	1
3.840	22nd Ave Bridge												
3.800	91	92	92	92	92	92	92	92	92	92	93	0	2
3.300	97	97	97	97	97	97	97	97	98	98	99	0	2
2.800	120	120	120	120	120	120	121	121	121	121	123	1	3
2.710	BN RR Bridge												
2.700	171	171	171	171	171	171	171	171	172	172	173	0	2
2.500	184	184	185	185	185	185	185	185	185	186	187	1	3
2.300	193	194	194	194	194	194	194	194	195	195	196	0	3
2.200	Rockdale Blvd Bridge												
2.100	210	212	212	212	212	212	212	212	214	215	217	0	7
1.900	210	211	211	211	212	212	212	212	213	214	217	1	7
1.700	210	211	211	211	211	212	211	211	213	214	217	1	7
1.660	Central Ave Bridge												
1.600	210	211	211	211	211	211	211	211	213	214	217	0	7
1.500	210	211	211	211	211	211	211	211	213	214	217	0	7
1.400	OK Highway 10 Bridge												
1.300	210	211	211	211	211	211	211	211	213	214	217	0	7
1.000	210	211	211	211	211	211	211	211	213	214	217	0	7
0.700	210	211	211	211	211	211	211	211	213	214	217	0	7
0.300	210	211	211	211	211	211	211	211	213	214	217	0	7
0.041	210	211	211	211	211	211	211	211	213	214	217	0	7
0.000	Downstream end of Tar Creek												

1 Max difference in duration from simulations with Pensacola Dam starting stages of El. 742.0 to El. 745.0 ft.
2 Max difference in duration from simulations with Pensacola Dam starting stages of El. 734.0 to El. 757.0 ft.

APPENDIX G.7:
HISTORICAL STARTING STAGES
DURATION OF INUNDATION

PENSACOLA DAM **TABLE G.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - HISTORICAL STARTING STAGES

River Mile	Historical Inflow Event					Max Duration Difference* (hours)
	Sept 1993 (21 year)	June 2004 (1 year)	July 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	
152.175	Upstream end of model					
152.175	137	0	193	90	74	193
151.000	117	0	143	42	47	143
150.000	145	0	213	95	80	213
149.000	142	0	208	93	79	208
148.000	144	0	209	95	80	209
147.000	138	0	193	87	74	193
145.500	155	0	228	104	92	228
145.480	E 60 Road Bridge					
145.400	153	0	228	102	91	228
144.000	160	18	237	107	98	219
143.000	153	0	223	100	90	223
142.000	171	43	253	117	114	210
141.000	169	34	249	114	110	215
140.000	163	0	239	108	105	239
139.000	150	0	209	92	89	209
138.000	145	0	192	81	82	192
137.000	138	0	175	59	71	175
135.950	135	0	168	48	67	168
135.941	Highway 69 Bridge					
135.940	134	0	168	47	67	168
135.590	134	0	167	46	67	167
135.586	BN RR Bridge					
135.580	134	0	167	45	66	167
135.470	134	0	167	43	65	167
135.460	Highway 125 Bridge					
135.440	134	0	167	45	65	167
135.000	134	0	166	42	65	166
134.610	133	0	163	35	63	163

* Max difference in duration from simulations with historical starting stages.

PENSACOLA DAM **TABLE G.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - HISTORICAL STARTING STAGES

River Mile	Historical Inflow Event					Max Duration Difference* (hours)
	Sept 1993 (21 year)	June 2004 (1 year)	July 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	
134.599	Abandonded RR Bridge					
134.595	131	0	162	30	61	162
134.000	129	0	154	0	56	154
133.973	Tar Creek					
133.900	127	0	151	0	53	151
133.800	Interstate 44 Bridge					
133.700	127	0	150	0	51	150
133.000	123	0	141	0	40	141
132.000	118	0	135	0	30	135
131.000	114	0	130	0	20	130
130.000	111	0	126	0	15	126
129.000	106	0	121	0	11	121
128.000	97	0	114	0	9	114
126.710	80	0	93	0	5	93
126.700	S 590 Road Bridge					
126.670	79	0	92	0	5	92
126.000	74	0	84	0	5	84
125.000	62	0	67	0	3	67
124.000	45	0	44	0	2	45
123.000	23	0	0	0	0	23
122.580	22	0	0	0	0	22
122.570	Highway 60 Bridge					
122.550	22	0	0	0	0	22
122.350	Spring River					
122.000	14	0	0	0	0	14
121.980	11	0	0	0	0	11
121.970	BN RR Bridge					
121.960	0	0	0	0	0	0
120.000	0	0	0	0	0	0

* Max difference in duration from simulations with historical starting stages.

PENSACOLA DAM **TABLE G.25**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - HISTORICAL STARTING STAGES

River Mile	Historical Inflow Event					Max Duration Difference* (hours)
	Sept 1993 (21 year)	June 2004 (1 year)	July 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	
118.000	0	0	0	0	0	0
116.000	0	0	0	0	0	0
114.000	0	0	0	0	0	0
112.000	0	0	0	0	0	0
110.000	0	0	0	0	0	0
108.000	0	0	0	0	0	0
106.000	0	0	0	0	0	0
105.350	Elk River					
105.000	0	0	0	0	0	0
104.000	0	0	0	0	0	0
102.000	0	0	0	0	0	0
101.750	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)					
101.710	0	0	0	0	0	0
100.000	0	0	0	0	0	0
90.000	0	0	0	0	0	0
80.000	0	0	0	0	0	0
78.000	0	0	0	0	0	0
77.000	Pensacola Dam					

* Max difference in duration from simulations with historical starting stages.

PENSACOLA DAM **TABLE G.26**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - HISTORICAL STARTING STAGES

River Mile	Historical Inflow Event					Max Duration Difference* (hours)
	Sept 1993 (21 year)	June 2004 (1 year)	July 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	
21.000	Upstream end of model					
21.000	54	0	0	0	54	54
20.000	52	0	0	0	52	52
19.000	70	0	0	28	76	76
18.000	70	0	0	29	77	77
17.000	72	0	0	32	79	79
16.000	79	0	0	59	86	86
15.000	75	0	0	39	82	82
14.170	92	0	0	75	97	97
14.160	E 57 Road					
14.120	93	0	0	76	98	98
13.510	93	0	0	76	99	99
13.500	Interstate 44 Bridge					
13.450	93	0	0	74	97	97
12.000	93	0	0	75	97	97
11.000	112	0	47	87	111	112
10.000	107	0	0	82	108	108
9.000	99	0	0	74	101	101
8.020	91	0	0	55	93	93
8.010	OK Highway 10 Bridge					
7.970	80	0	0	22	81	81
7.000	69	0	0	0	65	69
6.000	61	0	0	0	57	61
5.000	54	0	0	0	49	54
4.000	52	0	0	0	38	52
3.000	46	0	0	0	32	46
2.000	40	0	0	0	25	40
1.000	33	0	0	0	8	33
0.580	19	0	0	0	0	19
0.570	Highway 60 Bridge					
0.560	15	0	0	0	0	15
0.460	19	0	0	0	0	19
0.000	Downstream end of Spring River					

* Max difference in duration from simulations with historical starting stages.

PENSACOLA DAM **TABLE G.27**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - HISTORICAL STARTING STAGES

River Mile	Historical Inflow Event					Max Duration Difference* (hours)
	Sept 1993 (21 year)	June 2004 (1 year)	July 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	
19.590	Upstream end of model					
19.590	10	0	0	24	58	58
19.000	0	0	0	19	51	51
18.000	7	0	0	22	55	55
17.000	56	0	0	56	111	111
16.000	62	0	0	58	118	118
15.000	48	0	0	51	104	104
14.240	18	0	0	31	68	68
14.220	Highway 43 Bridge					
14.200	18	0	0	30	67	67
14.000	12	0	0	25	59	59
13.000	14	0	0	27	62	62
12.000	0	0	0	15	46	46
11.910	OK/MO State Line					
11.000	0	0	0	0	21	21
10.000	0	0	0	0	0	0
9.000	0	0	0	0	0	0
8.000	0	0	0	0	0	0
7.000	0	0	0	0	0	0
6.000	0	0	0	0	0	0
5.000	0	0	0	0	0	0
4.700	0	0	0	0	0	0
4.670	OK Highway 10 Bridge					
4.640	0	0	0	0	0	0
4.000	0	0	0	0	0	0
3.000	0	0	0	0	0	0
2.000	0	0	0	0	0	0
1.000	0	0	0	0	0	0
0.320	0	0	0	0	0	0
0.000	Downstream end of Elk River					

* Max difference in duration from simulations with historical starting stages.

PENSACOLA DAM **TABLE G.28**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - HISTORICAL STARTING STAGES

River Mile	Historical Inflow Event					Max Duration Difference* (hours)
	Sept 1993 (21 year)	June 2004 (1 year)	July 2007 (4 year)	Oct 2009 (3 year)	Dec 2015 (15 year)	
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	
4.152	Upstream end of model					
4.152	25	0	0	1	4	25
3.900	32	0	0	12	15	32
3.840	22nd Ave Bridge					
3.800	36	0	36	18	21	36
3.300	28	0	49	7	9	49
2.800	20	0	83	0	0	83
2.710	BN RR Bridge					
2.700	131	0	112	20	24	131
2.500	140	0	122	14	17	140
2.300	144	0	130	6	8	144
2.200	Rockdale Blvd Bridge					
2.100	158	0	154	10	89	158
1.900	145	0	154	0	56	154
1.700	131	0	154	0	55	154
1.660	Central Ave Bridge					
1.600	130	0	154	0	55	154
1.500	130	0	154	0	55	154
1.400	OK Highway 10 Bridge					
1.300	129	0	154	0	55	154
1.000	129	0	154	0	55	154
0.700	129	0	154	0	55	154
0.300	129	0	154	0	55	154
0.041	129	0	153	0	55	153
0.000	Downstream end of Tar Creek					

* Max difference in duration from simulations with historical starting stages.

APPENDIX H:
ANTICIPATED OPERATIONS ANALYSIS

APPENDIX H.1:
ANTICIPATED OPERATIONS ANALYSIS
STAGE HYDROGRAPHS

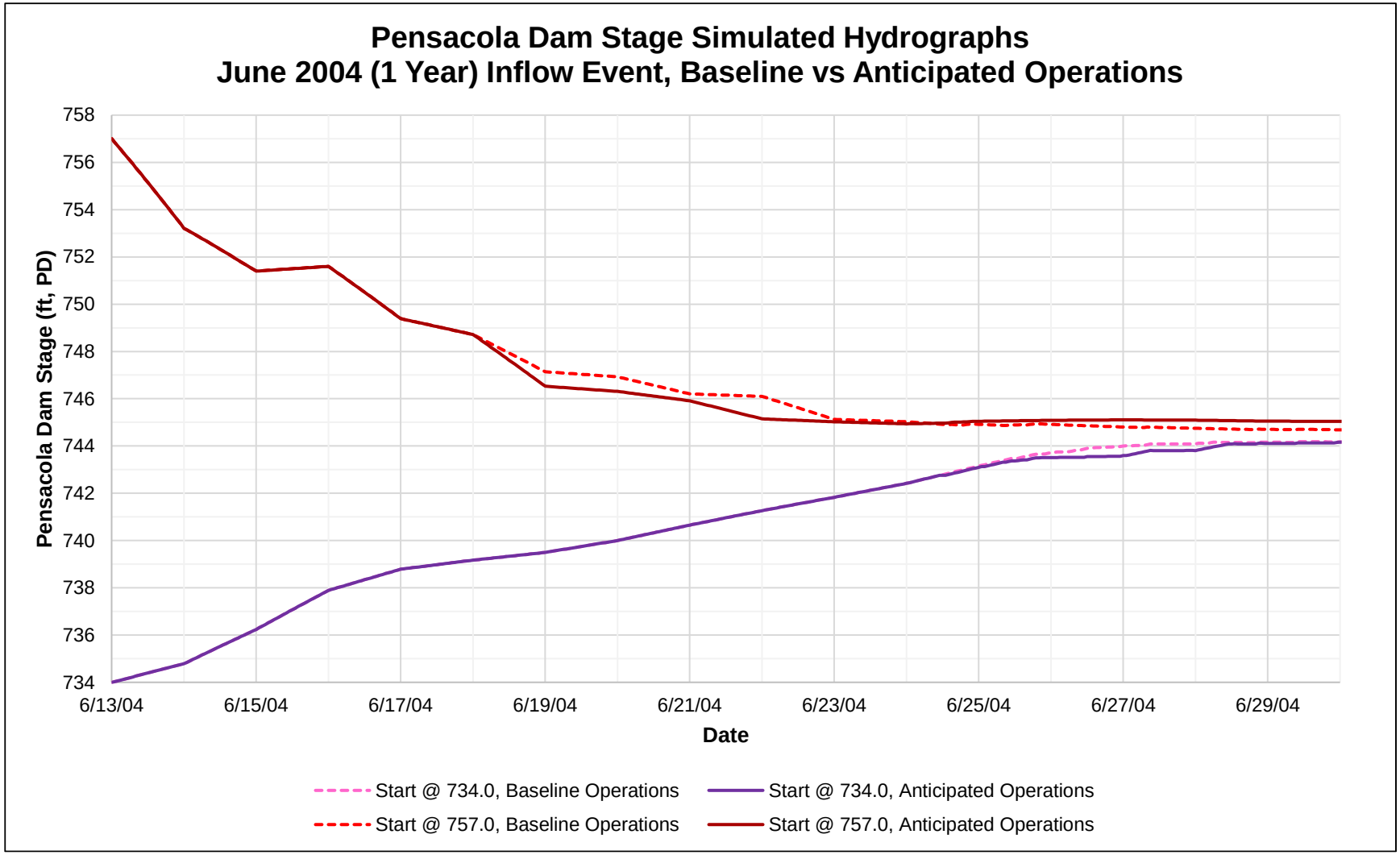


Figure H.1. Simulated stage hydrographs for the June 2004 (1 year) inflow event upstream of Pensacola Dam.

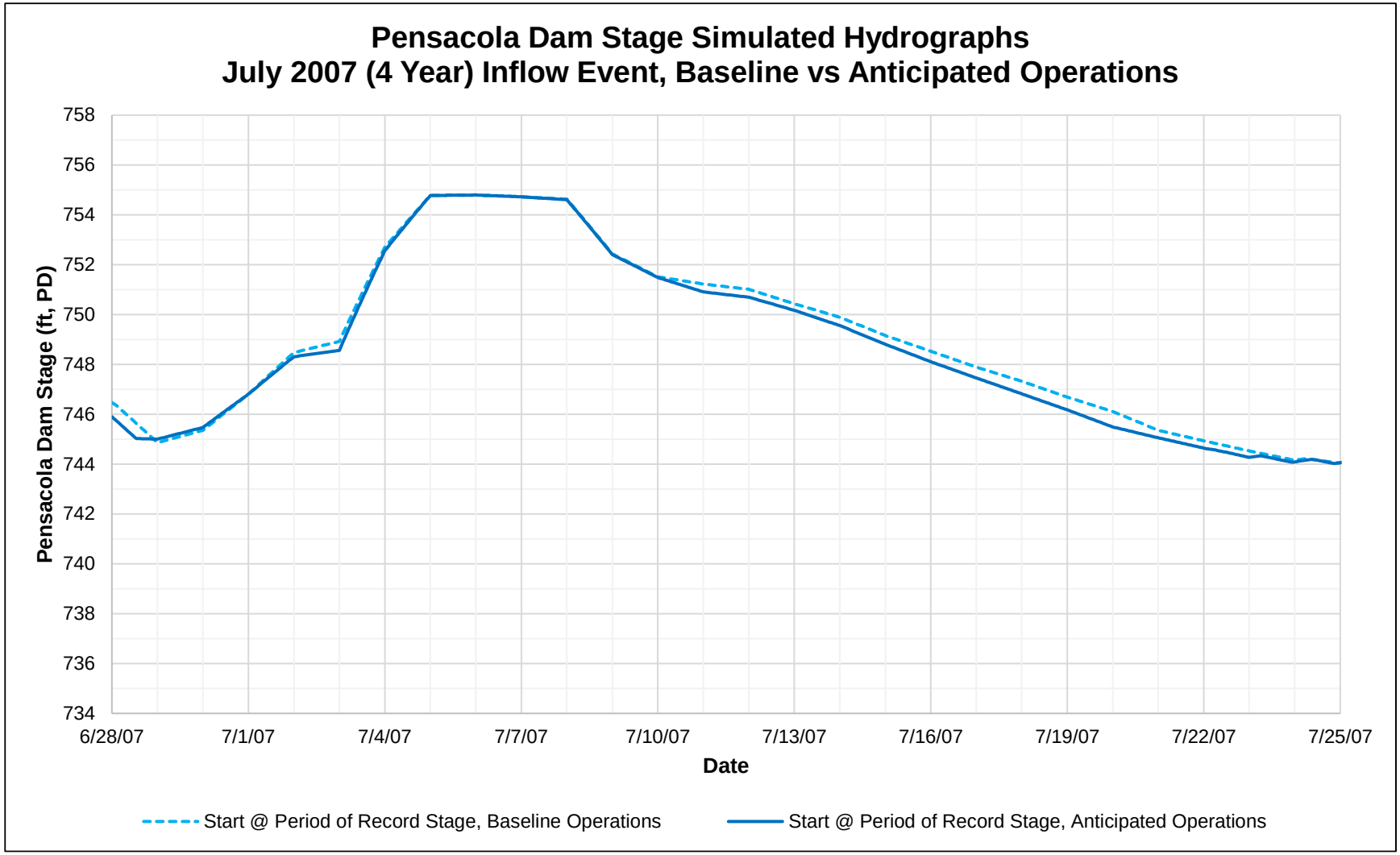


Figure H.2. Simulated stage hydrographs for the July 2007 (4 year) inflow event upstream of Pensacola Dam.

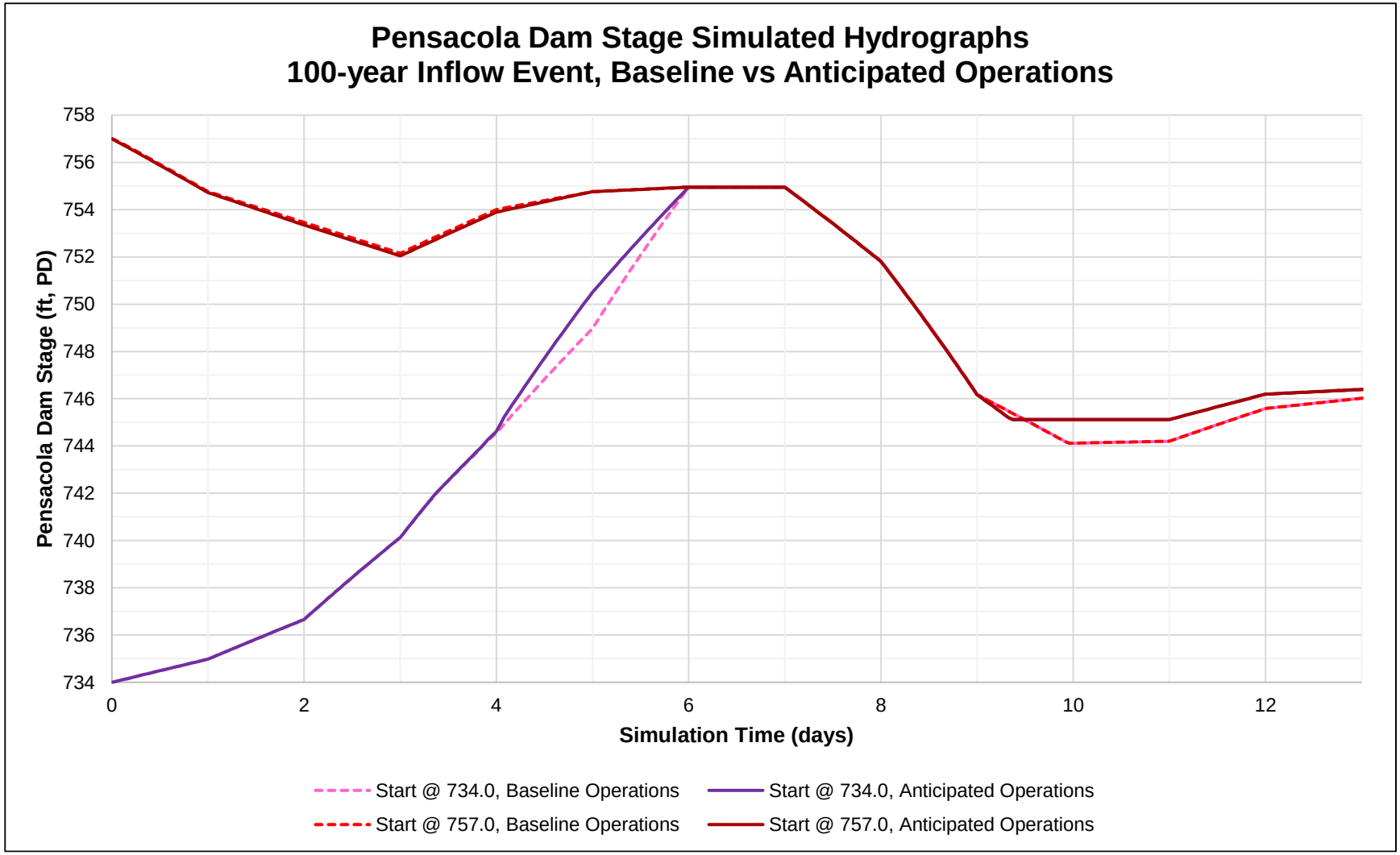


Figure H.3. Simulated stage hydrographs for the 100-year event upstream of Pensacola Dam.

Note: Because the 100-year event is synthetic, there is no historical start or end date, so stage hydrographs for the 100-year event are presented as a function of simulation time rather than date.

APPENDIX H.2:
ANTICIPATED OPERATIONS ANALYSIS
MAXIMUM WATER SURFACE ELEVATIONS

PENSACOLA DAM **TABLE H.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
152.175	Upstream end of model													
152.175	752.29	773.78	773.85	784.43	791.90	791.93	773.78	773.85	784.43	791.91	791.93	0.00	0.00	0.00
151.000	748.53	772.51	772.59	780.33	788.12	788.16	772.51	772.59	780.33	788.12	788.16	0.00	0.00	0.00
150.000	748.47	771.80	771.90	778.90	787.42	787.47	771.80	771.90	778.90	787.43	787.47	0.00	0.00	0.00
149.000	750.14	770.43	770.54	777.46	786.89	786.95	770.43	770.54	777.46	786.90	786.95	0.00	0.00	0.01
148.000	749.29	768.73	768.89	777.10	786.82	786.88	768.73	768.89	777.09	786.83	786.88	0.00	0.00	0.00
147.000	747.76	766.90	767.12	776.23	786.45	786.51	766.90	767.12	776.23	786.46	786.51	0.00	0.00	0.01
145.500	745.12	764.66	765.00	775.75	786.21	786.27	764.66	765.00	775.74	786.22	786.27	0.00	0.00	0.01
145.480	E 60 Road Bridge													
145.400	748.01	764.55	764.90	775.71	786.19	786.24	764.55	764.90	775.70	786.19	786.24	0.00	0.00	0.01
144.000	743.43	763.27	763.69	775.12	785.80	785.85	763.27	763.69	775.12	785.80	785.85	0.00	0.00	0.00
143.000	737.95	762.10	762.62	774.84	785.60	785.66	762.10	762.62	774.84	785.61	785.66	0.00	0.00	0.00
142.000	742.91	761.17	761.77	774.61	785.44	785.50	761.17	761.77	774.61	785.44	785.49	0.00	0.00	0.00
141.000	741.01	759.97	760.81	774.49	785.31	785.37	759.97	760.81	774.49	785.32	785.37	0.00	0.00	0.01
140.000	736.33	758.57	759.90	774.45	785.27	785.32	758.57	759.90	774.45	785.27	785.32	0.00	0.00	0.00
139.000	743.99	756.44	758.38	774.42	785.23	785.28	756.44	758.38	774.41	785.23	785.28	0.00	0.00	0.00
138.000	736.48	754.95	757.44	774.35	785.16	785.22	754.95	757.44	774.35	785.17	785.22	0.00	0.00	0.00
137.000	733.33	752.67	757.09	774.14	785.02	785.08	752.67	757.09	774.13	785.02	785.07	0.00	0.00	0.00
135.950	731.18	752.01	757.08	773.50	784.61	784.67	752.01	757.08	773.49	784.61	784.67	0.00	-0.01	0.00
135.941	Highway 69 Bridge													
135.940	731.21	751.71	757.08	773.52	784.50	784.56	751.70	757.08	773.52	784.51	784.56	0.00	0.00	0.01
135.590	731.77	751.79	757.08	773.35	784.39	784.45	751.79	757.08	773.34	784.40	784.45	0.00	-0.01	0.01
135.586	BN RR Bridge													
135.580	731.07	751.84	757.07	773.28	784.26	784.31	751.84	757.07	773.27	784.26	784.31	0.00	-0.01	0.00
135.470	732.63	751.71	757.07	773.20	784.19	784.25	751.71	757.07	773.20	784.20	784.25	0.00	0.00	0.01
135.460	Highway 125 Bridge													
135.440	731.60	751.78	757.07	773.25	784.24	784.29	751.78	757.07	773.25	784.24	784.29	0.00	0.00	0.00

1 Max increase in max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
135.000	732.64	751.39	757.07	772.93	784.03	784.08	751.39	757.07	772.92	784.03	784.08	0.00	-0.01	0.00
134.610	728.75	751.21	757.07	772.47	783.79	783.85	751.21	757.07	772.46	783.80	783.85	0.00	-0.01	0.01
134.599	Abandonded RR Bridge													
134.595	728.58	751.10	757.07	772.21	783.59	783.65	751.10	757.07	772.20	783.60	783.65	0.00	-0.01	0.01
134.000	727.23	750.38	757.06	771.95	783.17	783.22	750.38	757.06	771.94	783.17	783.22	0.00	-0.01	0.01
133.973	Tar Creek													
133.900	727.72	750.13	757.06	771.63	782.61	782.67	750.13	757.06	771.63	782.62	782.67	0.00	-0.01	0.01
133.800	Interstate 44 Bridge													
133.700	728.57	749.72	757.05	771.30	781.92	781.98	749.72	757.05	771.29	781.93	781.98	0.00	-0.01	0.01
133.000	727.70	748.16	757.04	770.64	781.10	781.16	748.16	757.04	770.63	781.11	781.16	0.00	-0.01	0.00
132.000	727.96	746.45	757.03	769.49	779.46	779.52	746.45	757.03	769.48	779.47	779.52	0.00	-0.01	0.01
131.000	726.82	745.65	757.03	768.56	777.63	777.69	745.61	757.03	768.55	777.64	777.69	0.00	-0.01	0.01
130.000	723.18	745.51	757.02	767.31	776.29	776.35	745.47	757.02	767.30	776.30	776.35	0.00	-0.01	0.01
129.000	719.79	745.29	757.02	766.14	775.16	775.22	745.25	757.02	766.13	775.17	775.22	0.00	-0.01	0.01
128.000	719.69	745.25	757.02	765.10	774.10	774.16	745.20	757.02	765.09	774.11	774.16	0.00	-0.01	0.01
126.710	715.94	745.13	757.02	763.39	772.60	772.66	745.09	757.02	763.38	772.61	772.66	0.00	-0.01	0.01
126.700	S 590 Road Bridge													
126.670	715.61	745.12	757.02	763.35	772.24	772.30	745.08	757.02	763.34	772.25	772.30	0.00	-0.01	0.01
126.000	720.35	745.08	757.02	762.77	771.56	771.62	745.03	757.02	762.76	771.57	771.62	0.00	-0.01	0.01
125.000	717.08	745.01	757.02	761.39	769.64	769.70	744.96	757.02	761.38	769.65	769.70	0.00	-0.01	0.00
124.000	715.62	744.95	757.02	760.00	767.95	768.01	744.91	757.02	759.99	767.95	768.01	0.00	-0.01	0.00
123.000	713.34	744.90	757.02	758.39	765.51	765.56	744.85	757.02	758.38	765.51	765.56	0.00	-0.01	0.00
122.580	711.08	744.89	757.02	757.23	762.55	762.55	744.84	757.02	757.22	762.55	762.55	0.00	-0.01	0.00
122.570	Highway 60 Bridge													
122.550	709.97	744.44	757.01	757.23	762.32	762.45	744.39	757.01	757.23	762.34	762.45	0.00	0.00	0.02
122.350	Spring River													
122.000	710.64	744.44	757.01	756.95	762.40	762.58	744.39	757.01	756.94	762.42	762.57	0.00	-0.01	0.02

1 Max increase in max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.1**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
121.980	709.90	744.43	757.01	756.80	761.87	762.08	744.39	757.01	756.79	761.90	762.08	0.00	-0.01	0.03
121.970	BN RR Bridge													
121.960	710.89	744.42	757.00	756.29	761.16	761.20	744.38	757.00	756.29	761.16	761.20	0.00	0.00	0.00
120.000	717.63	744.37	757.00	755.72	759.87	759.89	744.33	757.00	755.72	759.87	759.89	0.00	0.00	0.01
118.000	720.29	744.32	757.00	755.43	758.57	758.59	744.29	757.00	755.43	758.57	758.59	0.00	0.00	0.01
116.000	725.99	744.29	757.00	755.30	757.93	757.94	744.27	757.00	755.30	757.93	757.94	0.00	0.00	0.00
114.000	718.27	744.23	757.00	755.07	756.68	757.00	744.22	757.00	755.07	756.68	757.00	0.00	0.00	0.00
112.000	714.31	744.21	757.00	754.96	756.01	757.00	744.19	757.00	754.96	756.01	757.00	0.00	0.01	0.00
110.000	719.24	744.20	757.00	754.90	755.66	757.00	744.18	757.00	754.91	755.66	757.00	0.00	0.01	0.00
108.000	710.68	744.19	757.00	754.83	755.19	757.00	744.17	757.00	754.83	755.18	757.00	0.00	0.00	0.00
106.000	700.35	744.19	757.00	754.82	755.13	757.00	744.17	757.00	754.82	755.12	757.00	0.00	0.00	0.00
105.350	Elk River													
105.000	701.60	744.19	757.00	754.82	755.14	757.00	744.17	757.00	754.82	755.14	757.00	0.00	0.00	0.00
104.000	696.61	744.19	757.00	754.82	755.12	757.00	744.17	757.00	754.82	755.11	757.00	0.00	0.00	0.00
102.000	688.58	744.18	757.00	754.81	755.07	757.00	744.17	757.00	754.81	755.07	757.00	0.00	0.00	0.00
101.750	685.91	744.18	757.00	754.81	755.03	757.00	744.16	757.00	754.81	755.03	757.00	0.00	0.00	0.00
101.730	Highway 59 (Sailboat Bridge)													
101.710	682.31	744.18	757.00	754.80	755.00	757.00	744.16	757.00	754.80	755.00	757.00	0.00	0.00	0.00
100.000	702.62	744.18	757.00	754.80	755.02	757.00	744.16	757.00	754.80	755.02	757.00	0.00	0.00	0.00
90.000	681.52	744.18	757.00	754.79	754.98	757.00	744.16	757.00	754.79	754.98	757.00	0.00	0.00	0.00
80.000	657.03	744.18	757.00	754.79	754.95	757.00	744.16	757.00	754.79	754.95	757.00	0.00	0.00	0.00
78.000	653.11	744.18	757.00	754.79	754.95	757.00	744.16	757.00	754.79	754.95	757.00	0.00	0.00	0.00
77.000	Pensacola Dam													

1 Max increase in max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.2**

GRAND RIVER DAM AUTHORITY SPRING RIVER MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
21.000	Upstream end of model													
21.000	762.67	773.88	773.88	783.49	791.80	791.80	773.88	773.88	783.49	791.80	791.80	0.00	0.00	0.00
20.000	760.13	771.04	771.04	780.70	790.14	790.15	771.04	771.04	780.70	790.14	790.15	0.00	0.00	0.00
19.000	759.04	768.52	768.54	777.52	786.91	786.91	768.52	768.54	777.52	786.91	786.91	0.00	0.00	0.00
18.000	753.18	764.57	764.71	774.20	783.88	783.89	764.57	764.71	774.20	783.88	783.89	0.00	0.00	0.00
17.000	750.54	762.75	763.03	772.20	781.90	781.93	762.75	763.03	772.20	781.91	781.93	0.00	0.00	0.01
16.000	749.28	760.33	761.04	770.00	779.42	779.46	760.33	761.04	770.00	779.42	779.46	0.00	0.00	0.00
15.000	746.37	758.32	759.60	767.52	776.44	776.50	758.32	759.60	767.51	776.44	776.50	0.00	0.00	0.00
14.170	741.32	757.45	759.03	765.96	773.95	774.05	757.45	759.03	765.96	773.96	774.05	0.00	0.00	0.01
14.160	E 57 Road													
14.120	744.21	757.47	759.05	766.18	774.41	774.50	757.47	759.05	766.18	774.42	774.50	0.00	0.00	0.01
13.510	744.59	756.82	758.70	765.30	773.23	773.34	756.82	758.70	765.30	773.24	773.34	0.00	0.00	0.01
13.500	Interstate 44 Bridge													
13.450	745.52	756.56	758.57	764.98	772.71	772.83	756.56	758.57	764.98	772.72	772.83	0.00	0.00	0.01
12.000	742.72	753.20	757.70	762.17	768.85	769.15	753.20	757.70	762.17	768.87	769.15	0.00	0.00	0.02
11.000	742.23	751.43	757.46	760.40	767.46	767.76	751.43	757.46	760.40	767.51	767.76	0.00	0.00	0.04
10.000	737.62	749.79	757.44	758.88	766.63	766.80	749.79	757.44	758.88	766.65	766.80	0.00	0.00	0.02
9.000	733.92	748.61	757.44	758.54	765.63	765.73	748.61	757.44	758.54	765.64	765.73	0.00	0.00	0.01
8.020	733.14	747.09	757.44	758.49	765.18	765.29	747.09	757.44	758.49	765.20	765.29	0.00	0.00	0.02
8.010	OK Highway 10 Bridge													
7.970	731.28	744.73	757.01	757.40	764.51	764.63	744.73	757.01	757.40	764.53	764.62	0.00	0.00	0.02
7.000	730.33	744.48	757.01	757.37	764.20	764.32	744.43	757.01	757.36	764.21	764.31	0.00	-0.01	0.01
6.000	727.95	744.47	757.01	757.35	764.08	764.19	744.42	757.01	757.35	764.09	764.19	0.00	0.00	0.02
5.000	722.10	744.46	757.01	757.34	763.99	764.10	744.42	757.01	757.33	764.00	764.10	0.00	-0.01	0.02
4.000	720.00	744.46	757.01	757.33	763.94	764.05	744.41	757.01	757.33	763.95	764.05	0.00	0.00	0.01
3.000	723.22	744.46	757.01	757.33	763.88	764.00	744.41	757.01	757.32	763.89	763.99	0.00	-0.01	0.01
2.000	723.73	744.46	757.01	757.33	763.84	763.96	744.41	757.01	757.32	763.86	763.96	0.00	-0.01	0.02
1.000	728.44	744.45	757.01	757.33	763.81	763.93	744.41	757.01	757.32	763.82	763.93	0.00	-0.01	0.01
0.580	716.17	744.45	757.01	757.32	763.74	763.86	744.41	757.01	757.32	763.75	763.86	0.00	0.00	0.01
0.570	Highway 60 Bridge													
0.560	713.76	744.45	757.01	757.31	763.71	763.83	744.41	757.01	757.31	763.73	763.83	0.00	0.00	0.02
0.460	715.35	744.45	757.01	757.32	763.73	763.85	744.41	757.01	757.31	763.74	763.85	0.00	-0.01	0.01
0.000	Downstream end of Spring River													

1 Max increase in max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.3**

GRAND RIVER DAM AUTHORITY ELK RIVER MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
19.590	Upstream end of model													
19.590	771.15	774.17	774.17	775.57	777.77	777.77	774.17	774.17	775.57	777.77	777.77	0.00	0.00	0.00
19.000	767.51	772.64	772.64	774.03	776.22	776.22	772.64	772.64	774.03	776.22	776.22	0.00	0.00	0.00
18.000	765.41	769.18	769.18	770.46	772.64	772.64	769.18	769.18	770.46	772.64	772.64	0.00	0.00	0.00
17.000	762.53	766.13	766.13	767.01	768.77	768.77	766.13	766.13	767.01	768.77	768.77	0.00	0.00	0.00
16.000	756.63	761.16	761.16	762.78	764.95	764.95	761.16	761.16	762.78	764.95	764.95	0.00	0.00	0.00
15.000	754.26	757.92	757.92	759.23	761.27	761.27	757.92	757.92	759.23	761.27	761.27	0.00	0.00	0.00
14.240	750.52	753.18	757.03	755.50	756.89	757.07	753.18	757.03	755.48	756.89	757.07	0.00	-0.02	0.00
14.220	Highway 43 Bridge													
14.200	750.12	753.10	757.02	755.47	756.83	757.07	753.10	757.02	755.45	756.83	757.07	0.00	-0.02	0.00
14.000	747.07	752.78	757.02	755.32	756.37	757.05	752.78	757.02	755.30	756.37	757.05	0.00	-0.02	0.00
13.000	745.41	749.01	757.00	754.93	755.43	757.01	749.01	757.00	754.94	755.40	757.01	0.00	0.01	0.00
12.000	741.15	746.01	757.00	754.88	755.32	757.00	746.01	757.00	754.90	755.29	757.00	0.00	0.02	0.00
11.910	OK/MO State Line													
11.000	741.93	744.92	757.00	754.87	755.28	757.00	744.92	757.00	754.88	755.25	757.00	0.00	0.01	0.00
10.000	734.62	744.21	757.00	754.86	755.26	757.00	744.21	757.00	754.87	755.23	757.00	0.00	0.01	0.00
9.000	734.66	744.21	757.00	754.85	755.24	757.00	744.20	757.00	754.87	755.22	757.00	0.00	0.02	0.00
8.000	724.21	744.21	757.00	754.85	755.23	757.00	744.20	757.00	754.86	755.21	757.00	0.00	0.01	0.00
7.000	728.21	744.20	757.00	754.84	755.21	757.00	744.19	757.00	754.86	755.19	757.00	0.00	0.02	0.00
6.000	727.13	744.20	757.00	754.84	755.21	757.00	744.19	757.00	754.85	755.19	757.00	0.00	0.01	0.00
5.000	721.05	744.20	757.00	754.83	755.19	757.00	744.18	757.00	754.85	755.18	757.00	0.00	0.02	0.00
4.700	716.13	744.20	757.00	754.83	755.19	757.00	744.18	757.00	754.84	755.17	757.00	0.00	0.01	0.00
4.670	OK Highway 10 Bridge													
4.640	715.21	744.20	757.00	754.83	755.19	757.00	744.18	757.00	754.84	755.17	757.00	0.00	0.01	0.00
4.000	716.61	744.19	757.00	754.83	755.18	757.00	744.18	757.00	754.84	755.17	757.00	0.00	0.01	0.00
3.000	714.74	744.19	757.00	754.83	755.17	757.00	744.18	757.00	754.84	755.16	757.00	0.00	0.01	0.00
2.000	709.09	744.19	757.00	754.82	755.16	757.00	744.18	757.00	754.83	755.15	757.00	0.00	0.01	0.00
1.000	705.82	744.19	757.00	754.82	755.15	757.00	744.17	757.00	754.82	755.14	757.00	0.00	0.00	0.00
0.320	706.36	744.19	757.00	754.82	755.15	757.00	744.17	757.00	754.82	755.14	757.00	0.00	0.00	0.00
0.000	Downstream end of Elk River													

1 Max increase in max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.4**

GRAND RIVER DAM AUTHORITY TAR CREEK MAX WSELs - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Bed El. (ft, PD)	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
		Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (ft)	July 2007 (4 year) Difference (ft)	100-Year Difference (ft)
		Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)	Max WSE (ft, PD)			
4.152	Upstream end of model													
4.152	762.17	768.17	768.17	772.03	783.59	783.64	768.17	768.17	772.02	783.59	783.64	0.00	-0.01	0.01
3.900	760.10	767.29	767.29	772.03	783.59	783.65	767.29	767.29	772.02	783.59	783.64	0.00	-0.01	0.01
3.840	22nd Ave Bridge													
3.800	762.30	766.05	766.05	772.03	783.59	783.64	766.05	766.05	772.02	783.59	783.64	0.00	-0.01	0.01
3.300	759.46	764.09	764.09	772.03	783.59	783.64	764.09	764.09	772.02	783.59	783.64	0.00	-0.01	0.01
2.800	756.73	760.95	760.96	772.03	783.59	783.64	760.95	760.96	772.02	783.59	783.64	0.00	-0.01	0.01
2.710	BN RR Bridge													
2.700	755.72	760.45	760.46	772.03	783.59	783.64	760.45	760.46	772.02	783.59	783.64	0.00	-0.01	0.00
2.500	754.95	759.30	759.33	772.03	783.59	783.64	759.30	759.33	772.02	783.59	783.64	0.00	-0.01	0.00
2.300	754.15	757.47	757.63	772.03	783.59	783.64	757.47	757.63	772.02	783.59	783.64	0.00	-0.01	0.01
2.200	Rockdale Blvd Bridge													
2.100	751.51	754.83	757.06	772.03	783.59	783.64	754.83	757.06	772.02	783.59	783.64	0.00	-0.01	0.00
1.900	750.02	753.18	757.06	772.03	783.59	783.64	753.18	757.06	772.02	783.59	783.64	0.00	-0.01	0.00
1.700	749.58	750.72	757.06	772.03	783.59	783.64	750.72	757.06	772.02	783.59	783.64	0.00	-0.01	0.01
1.660	Central Ave Bridge													
1.600	746.47	750.30	757.06	772.03	783.59	783.64	750.30	757.06	772.02	783.59	783.64	0.00	-0.01	0.01
1.500	744.29	750.29	757.06	772.03	783.58	783.64	750.29	757.06	772.02	783.59	783.64	0.00	-0.01	0.01
1.400	OK Highway 10 Bridge													
1.300	742.00	750.29	757.06	772.03	783.56	783.62	750.29	757.06	772.02	783.57	783.62	0.00	-0.01	0.01
1.000	739.34	750.29	757.06	772.02	783.52	783.58	750.29	757.06	772.01	783.53	783.57	0.00	-0.01	0.01
0.700	737.06	750.29	757.06	772.01	783.48	783.53	750.29	757.06	772.00	783.48	783.53	0.00	-0.01	0.01
0.300	736.42	750.29	757.06	771.95	783.25	783.30	750.29	757.06	771.94	783.25	783.30	0.00	-0.01	0.01
0.041	735.85	750.29	757.06	771.86	783.04	783.10	750.29	757.06	771.85	783.05	783.10	0.00	-0.01	0.01
0.000	Downstream end of Tar Creek													

1 Max increase in max WSEL for the simulated inflow event listed. Baseline operations max WSEL is subtracted from anticipated operations max WSEL to assess the impact of anticipated operations.

APPENDIX H.3:
ANTICIPATED OPERATIONS ANALYSIS
WATER SURFACE ELEVATION PROFILES

JUNE 2004 (1 YEAR) INFLOW EVENT
ANTICIPATED OPERATIONS ANALYSIS
WATER SURFACE ELEVATION PROFILES

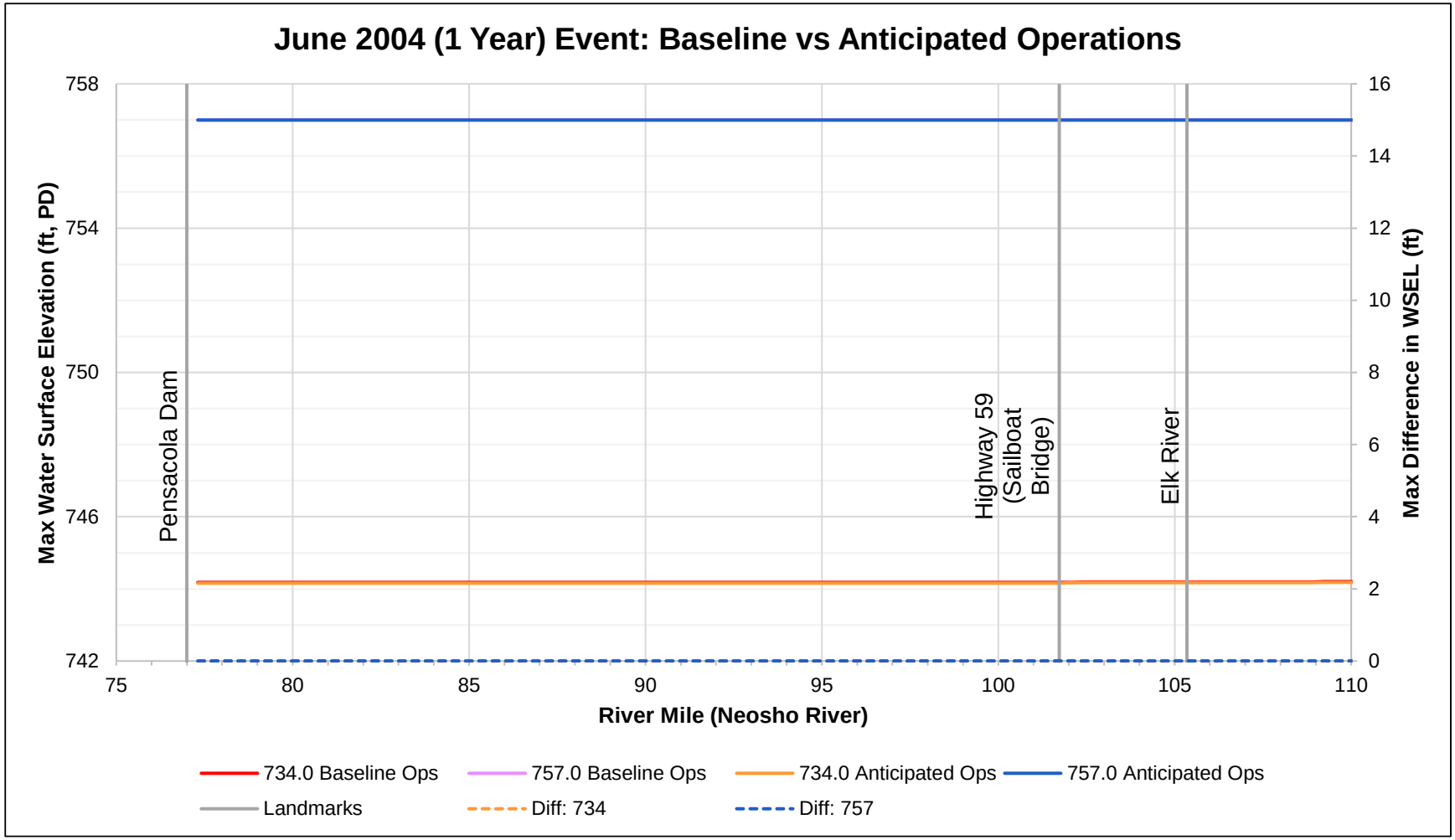


Figure H. 1. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

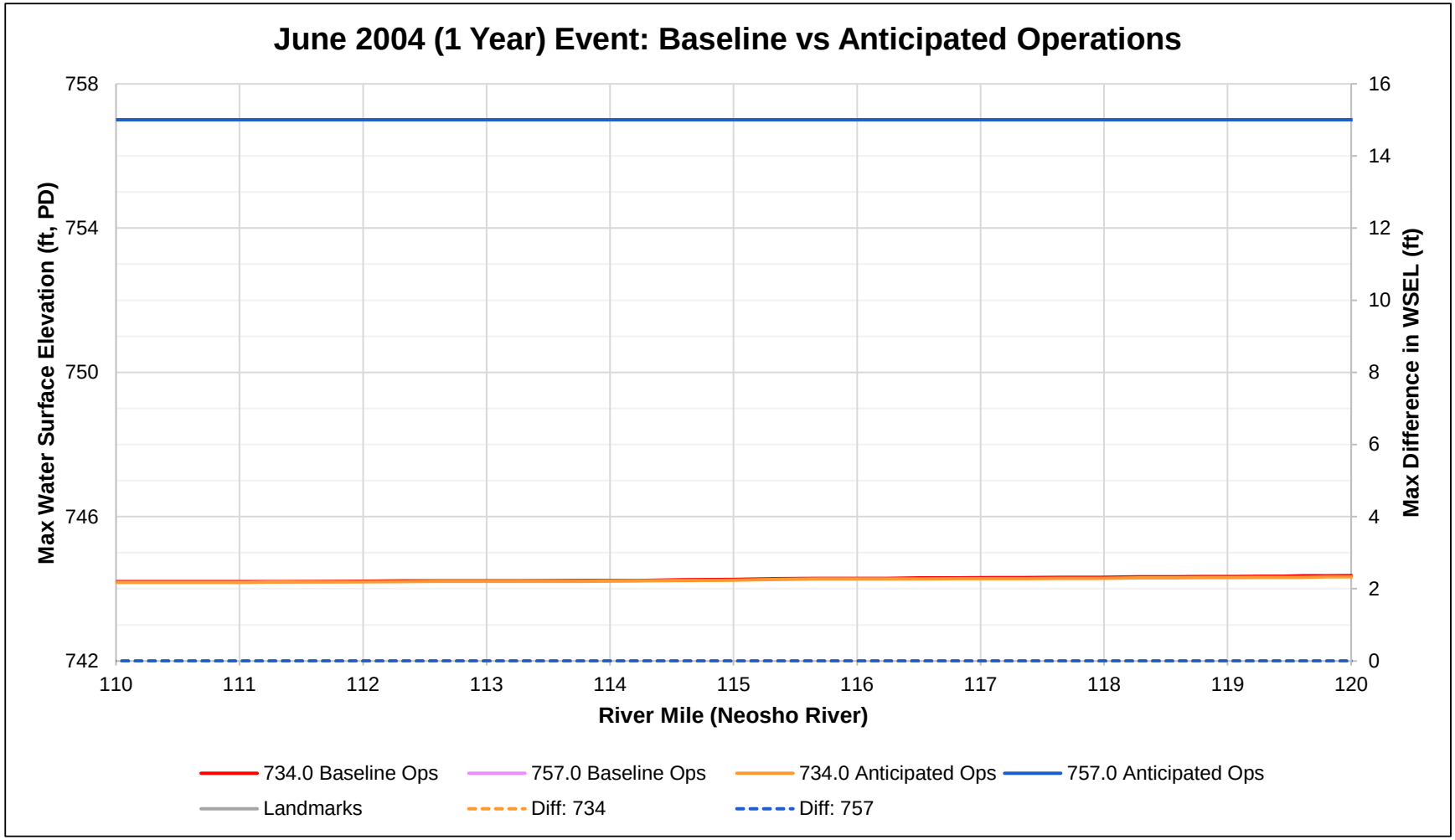


Figure H. 2. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

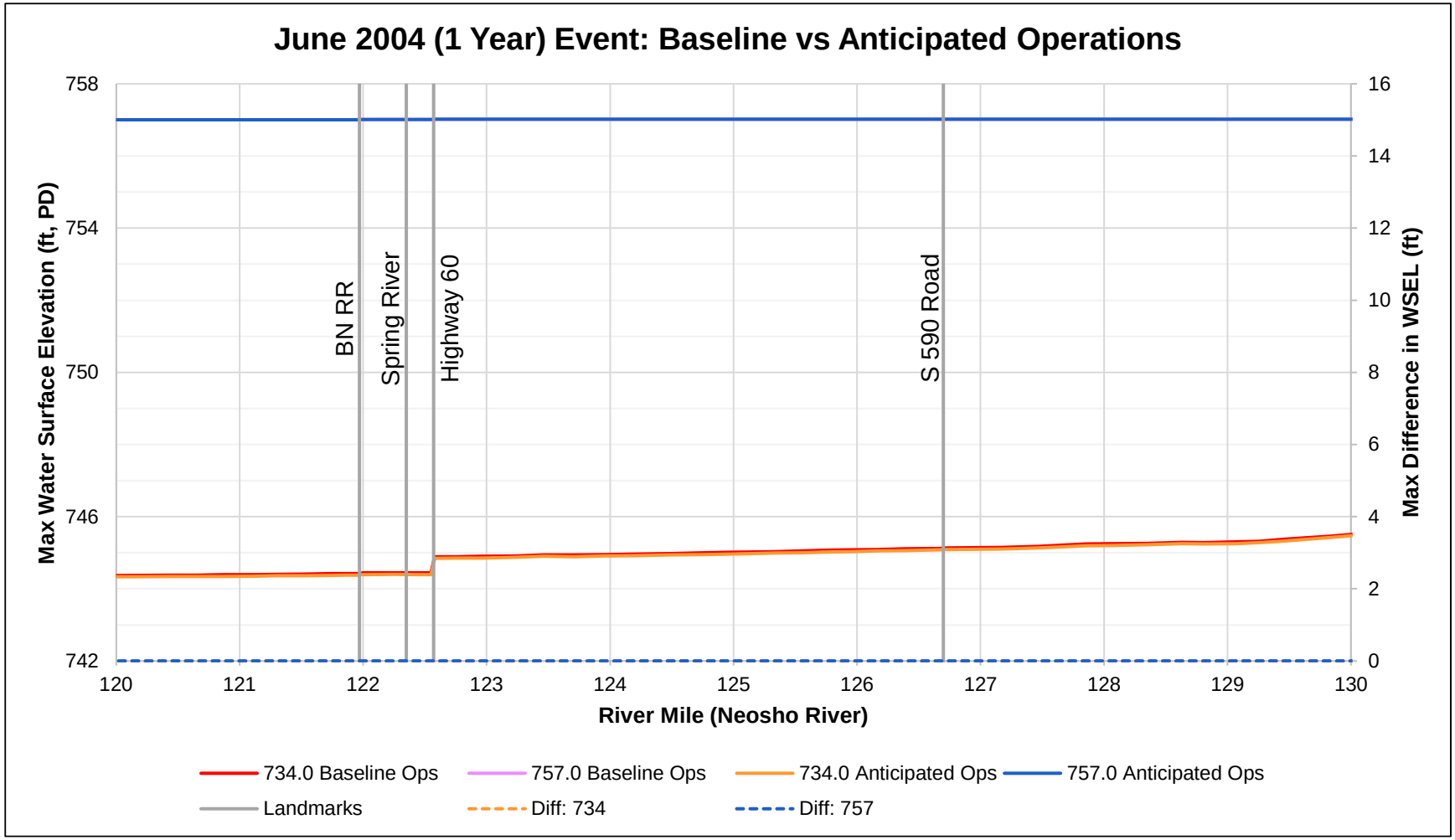


Figure H. 3. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

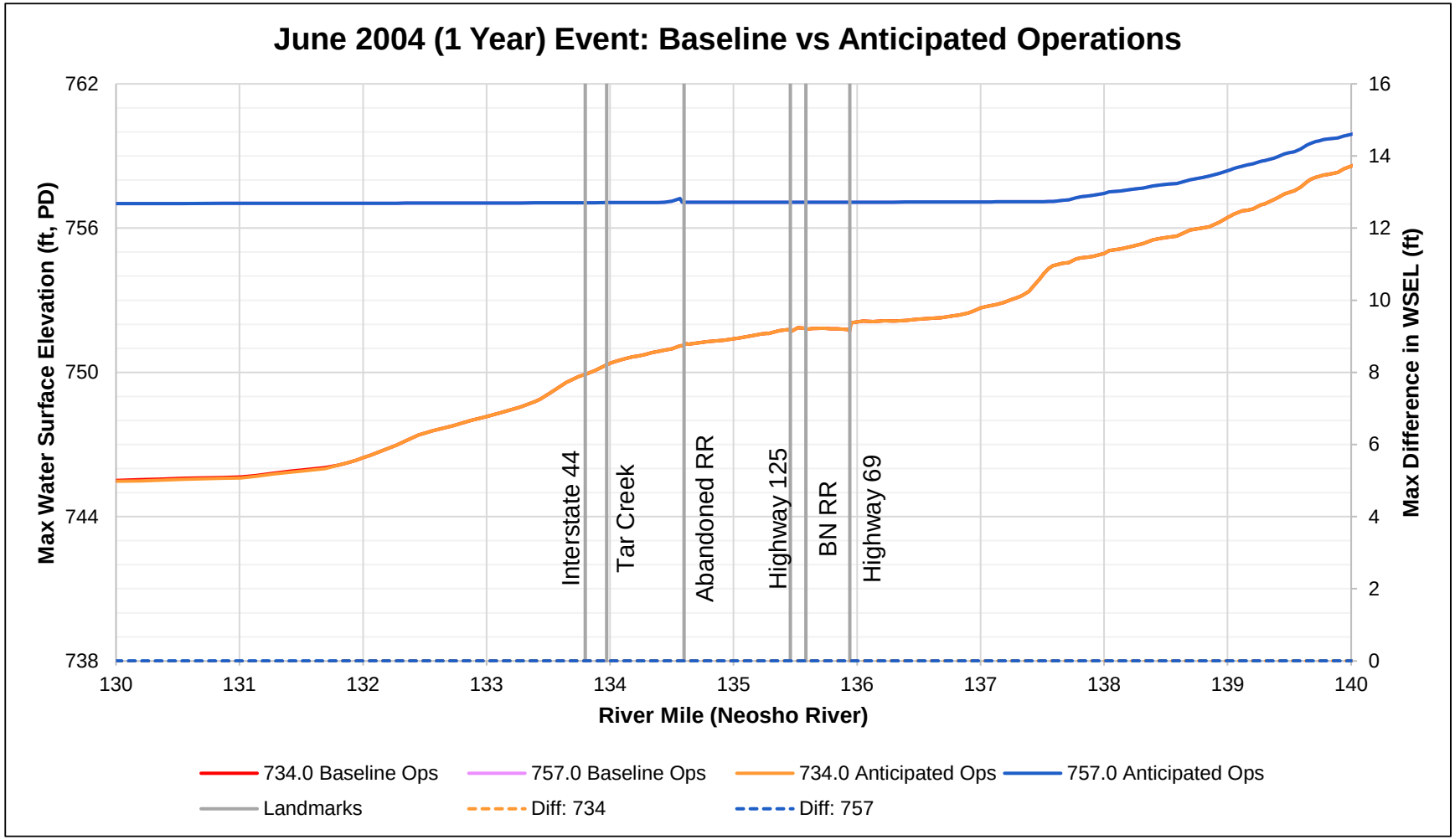


Figure H. 4. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

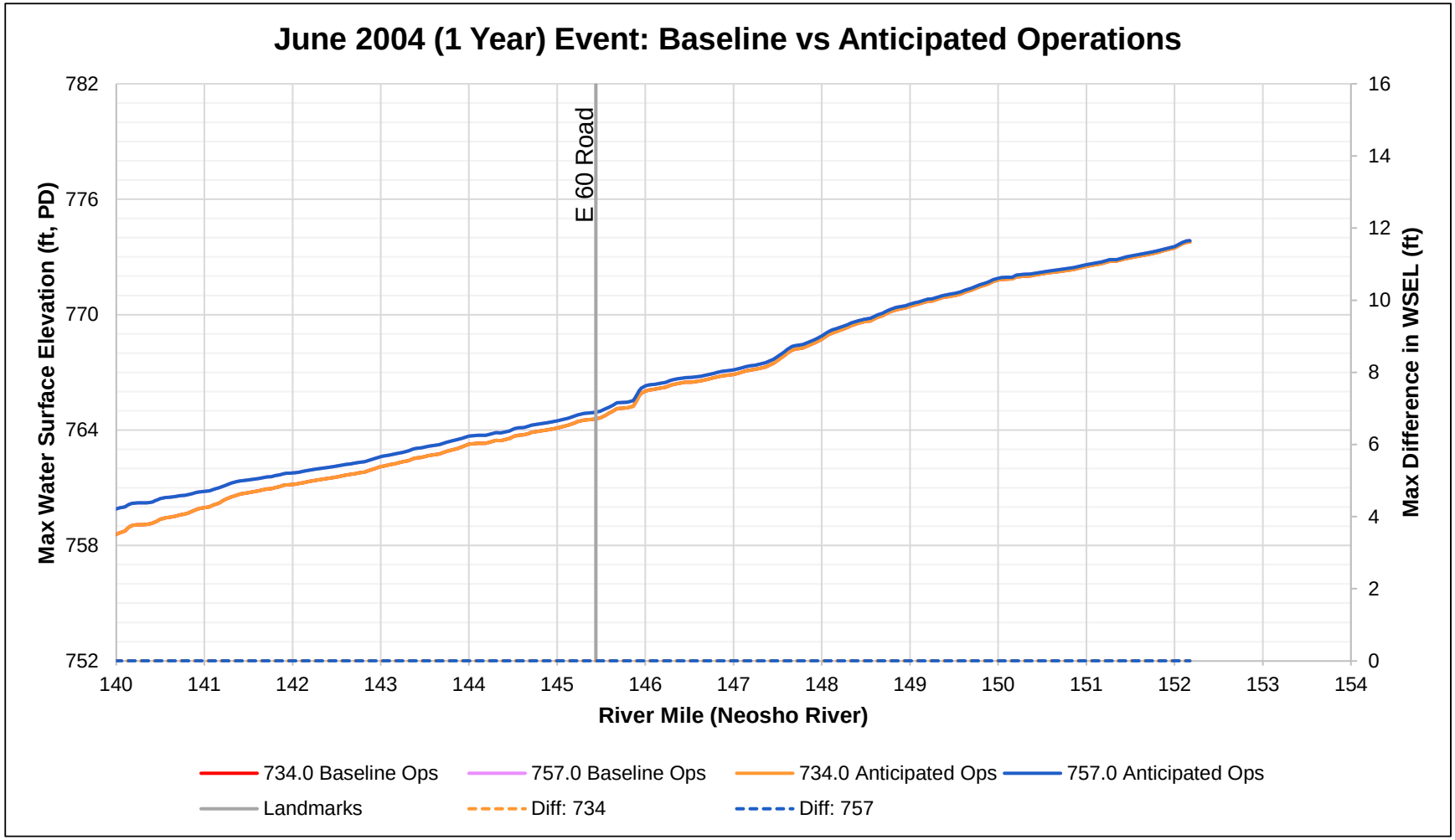


Figure H. 5. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

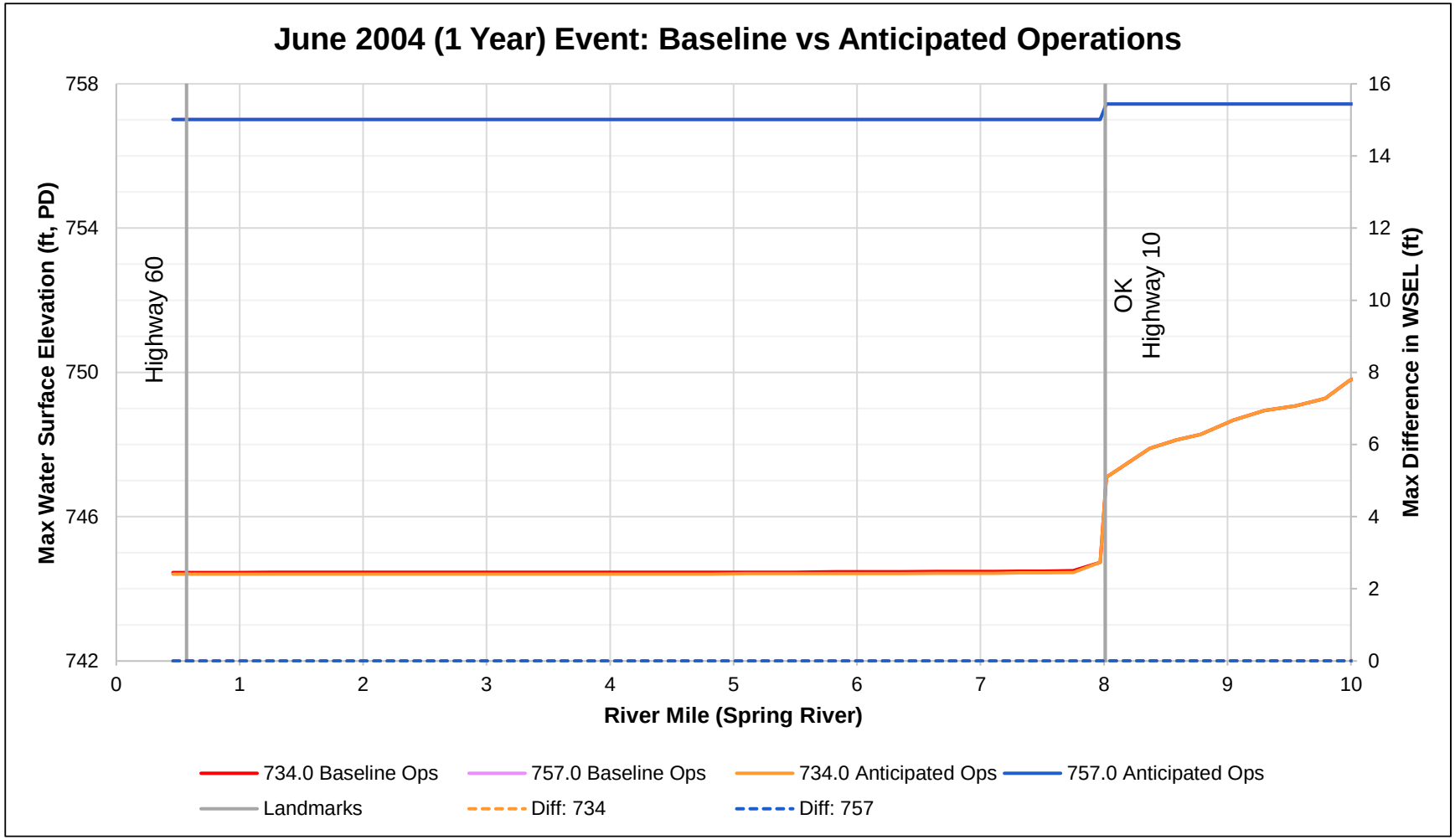


Figure H. 6. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

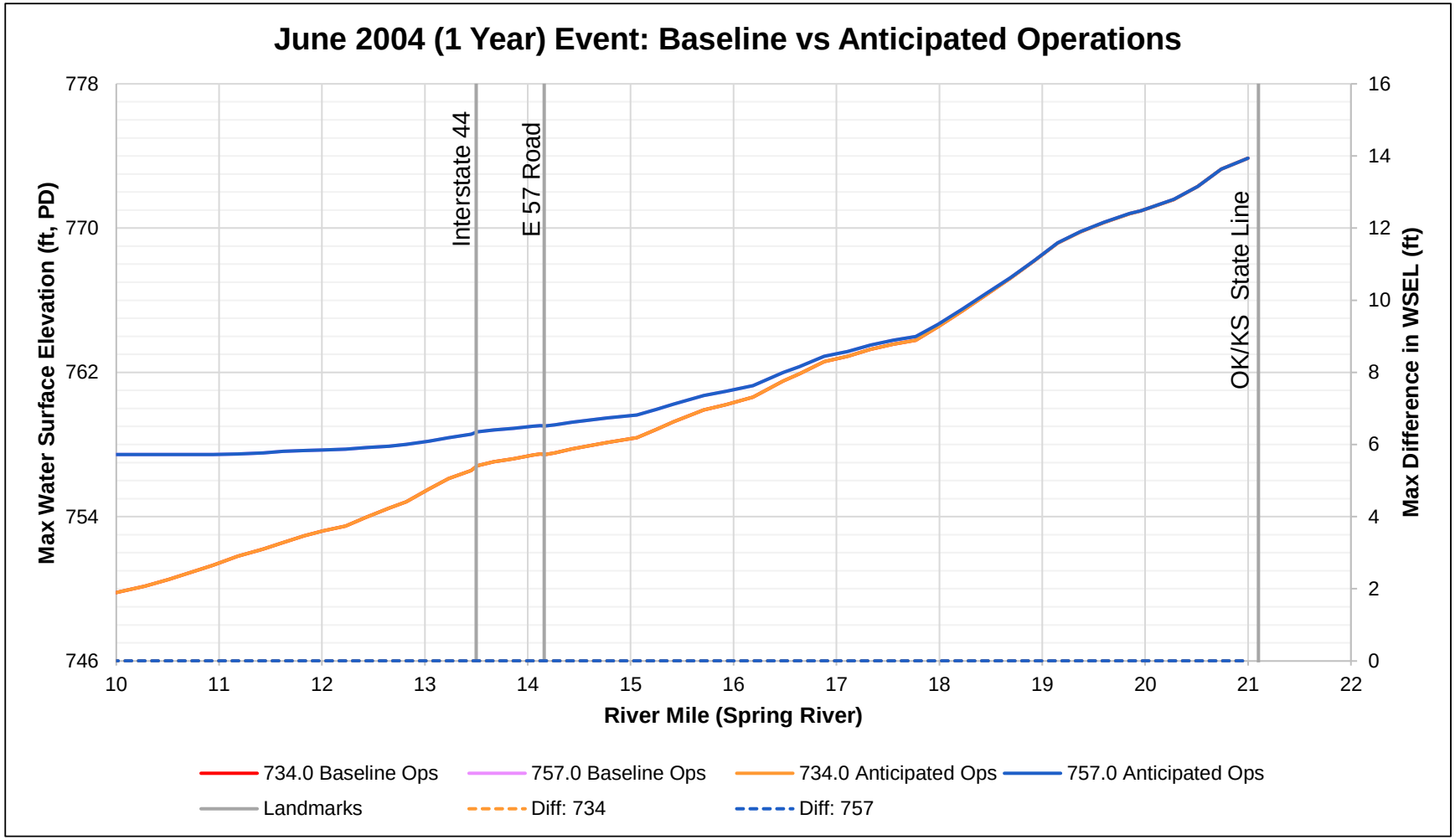


Figure H. 7. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

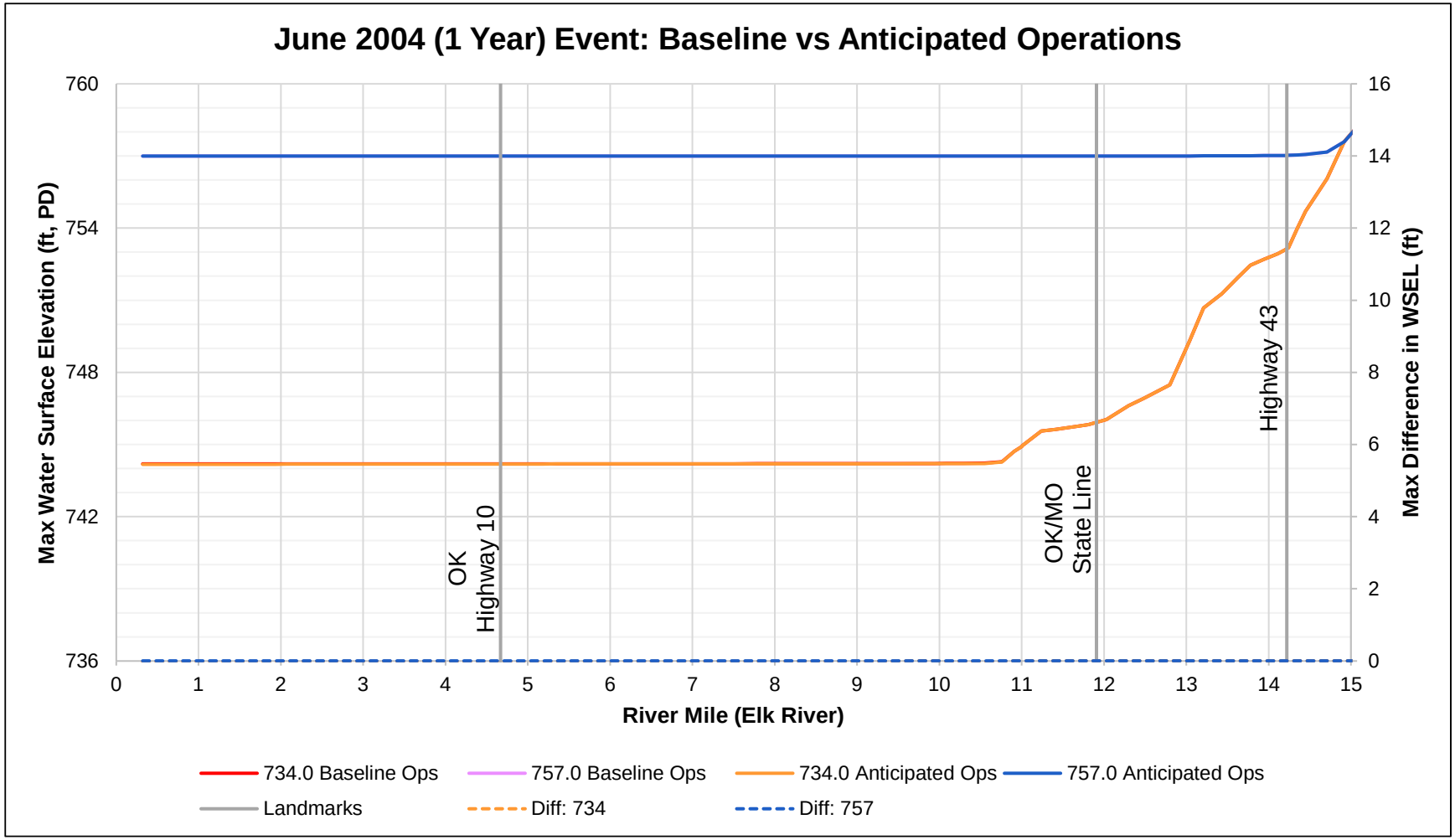


Figure H. 8. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

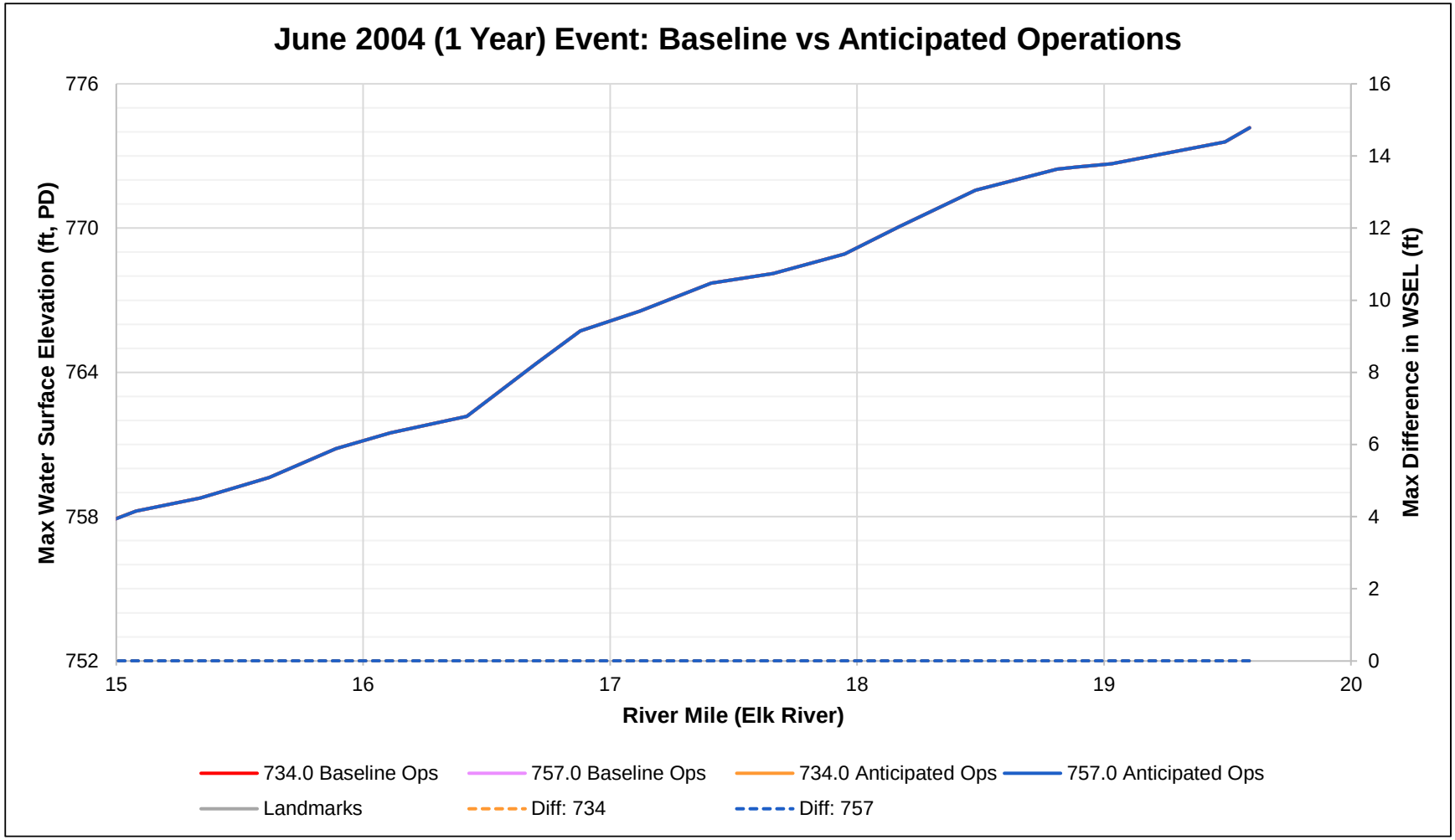


Figure H. 9. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

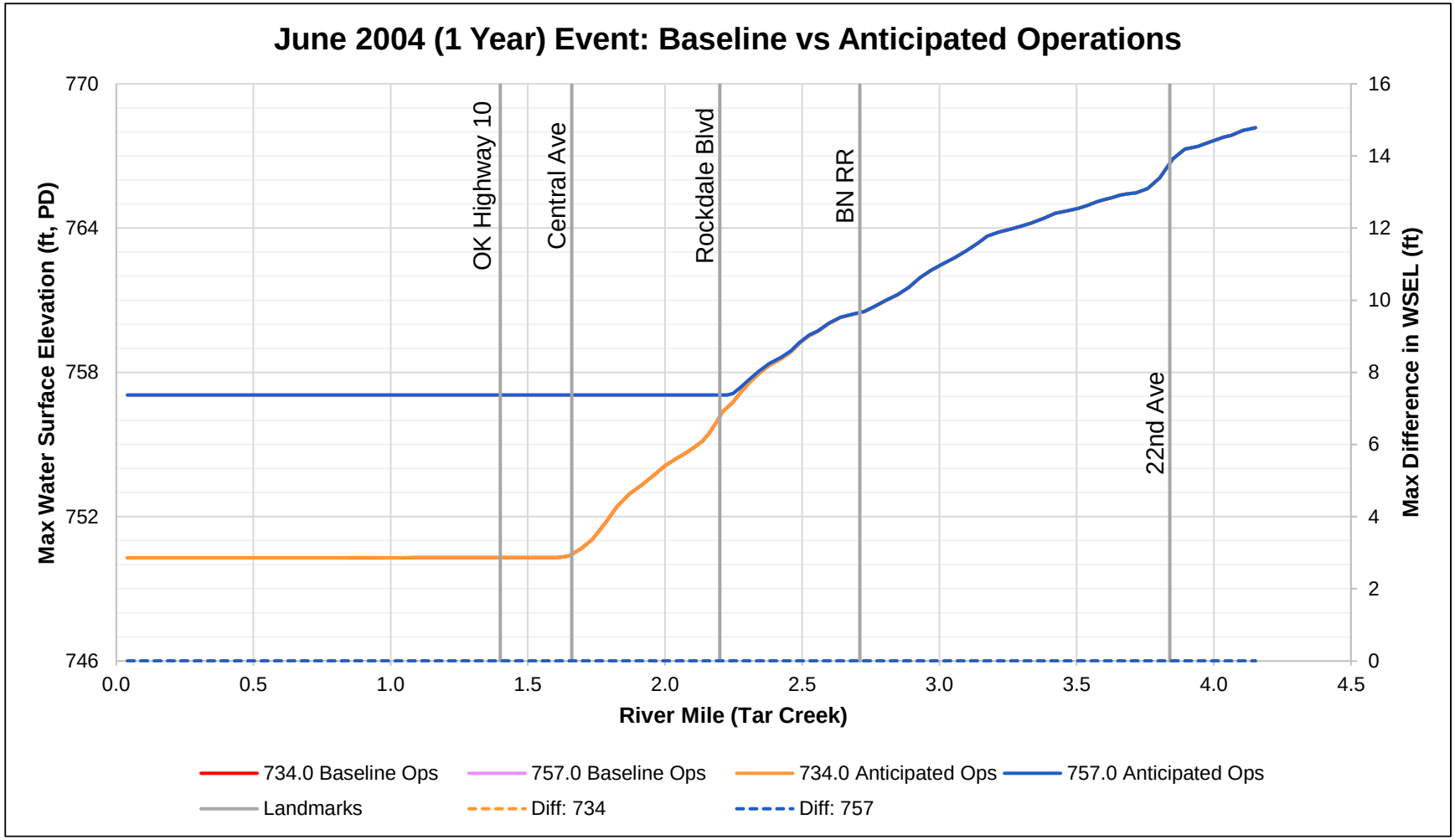


Figure H. 10. Water surface elevations for the June 2004 (1 year) inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

JULY 2007 (4 YEAR) INFLOW EVENT
ANTICIPATED OPERATIONS ANALYSIS
WATER SURFACE ELEVATION PROFILES

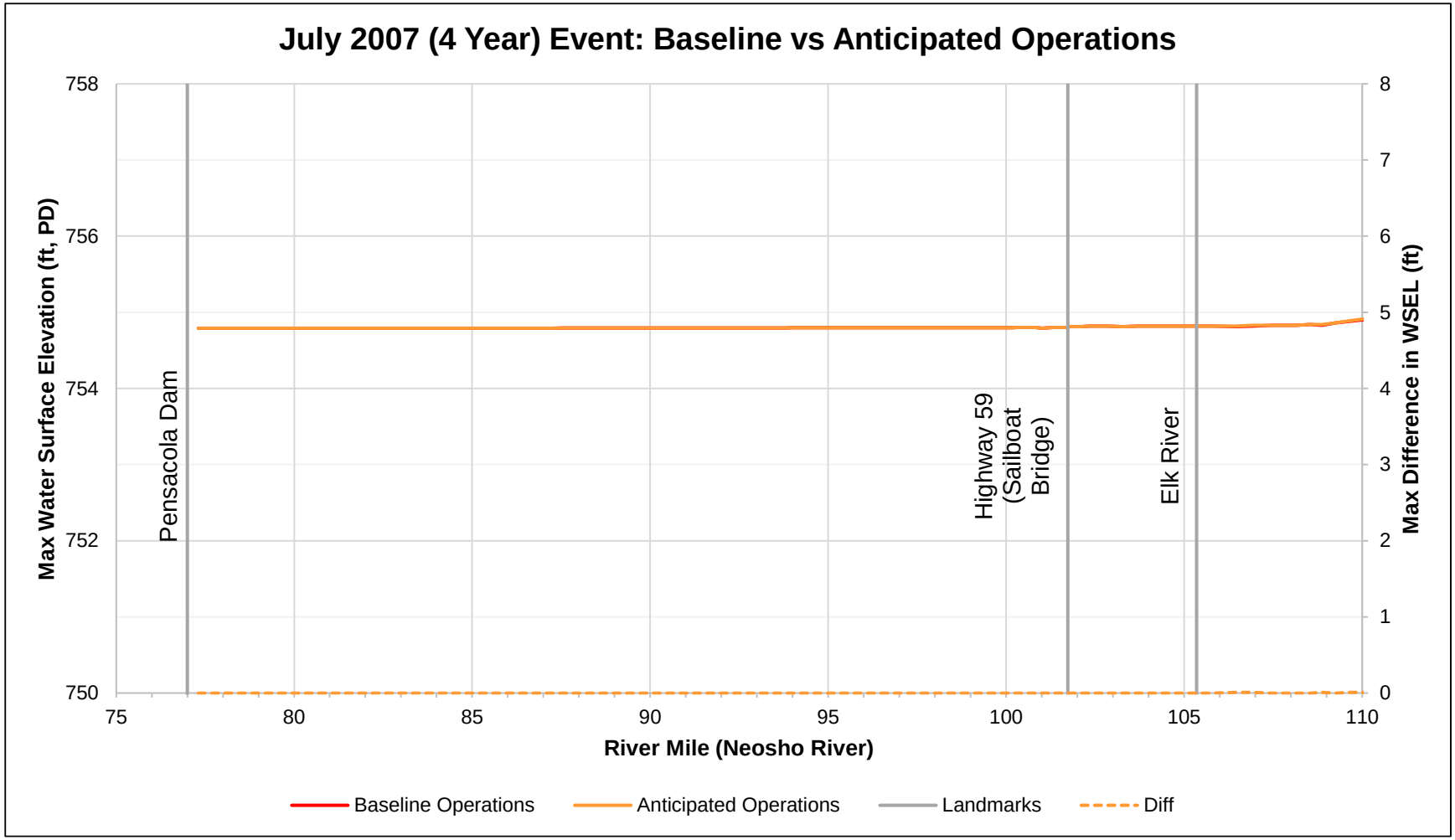


Figure H. 11. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes: 1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

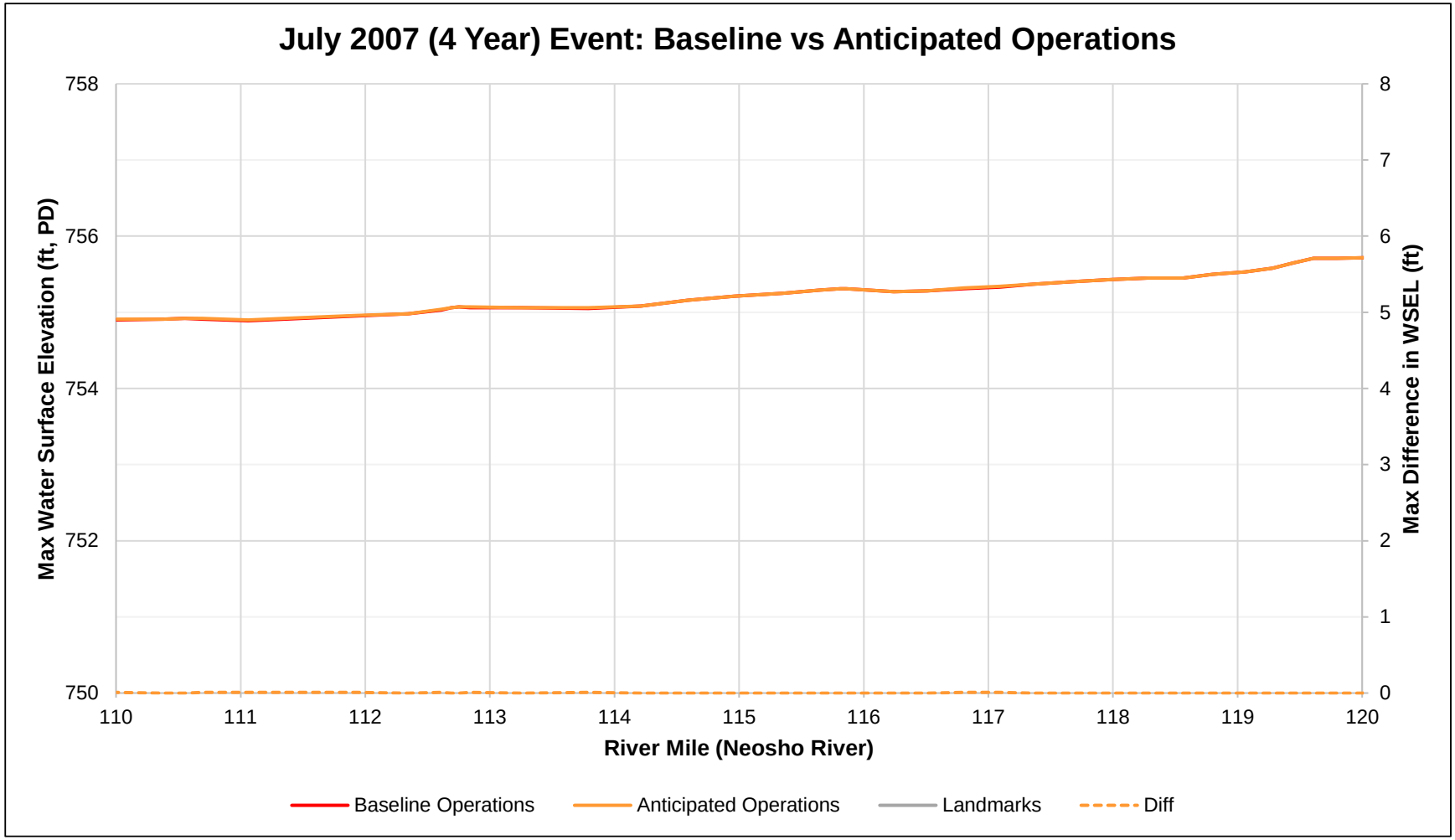


Figure H. 12. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:
1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

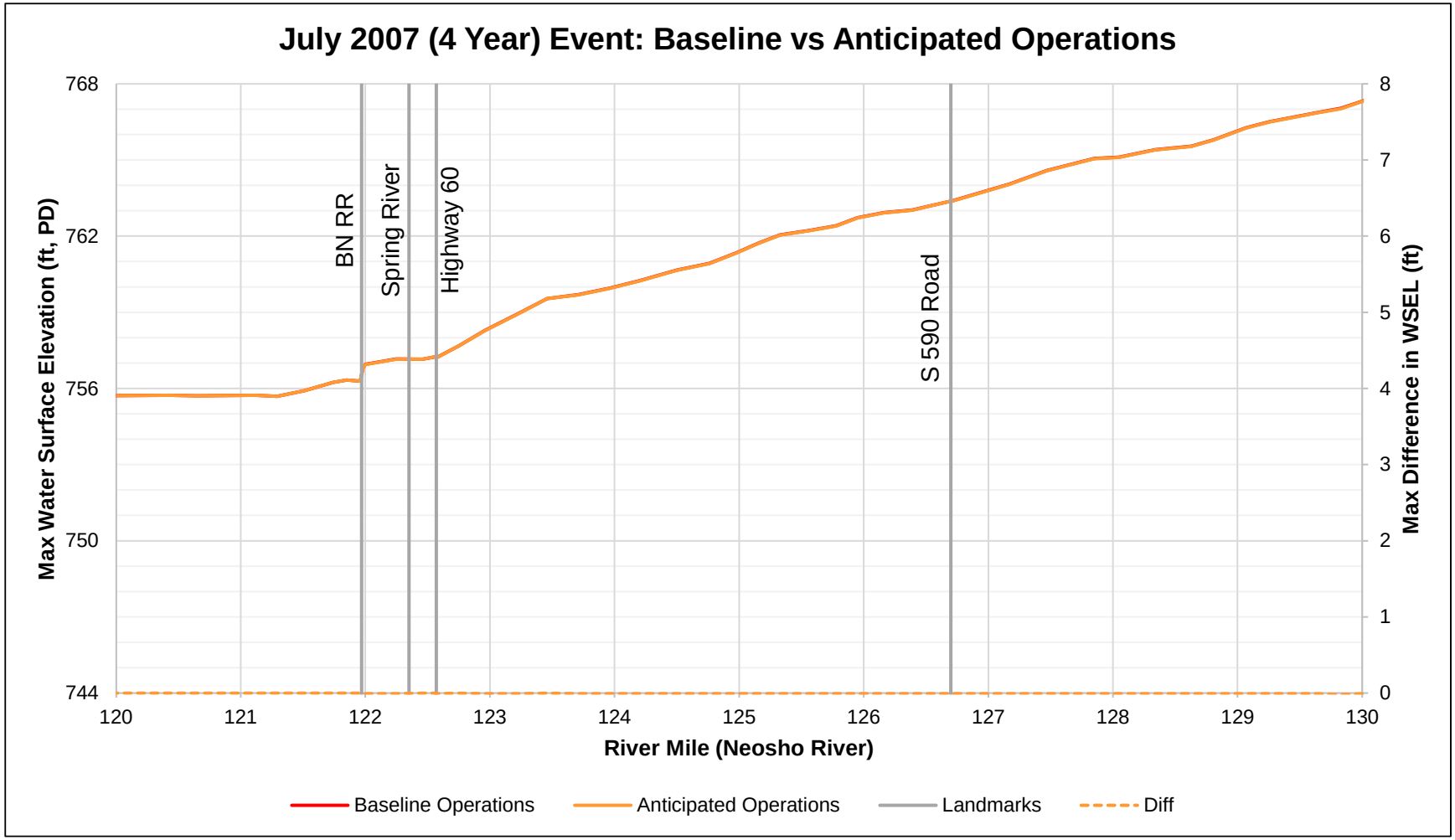


Figure H. 13. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes: 1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

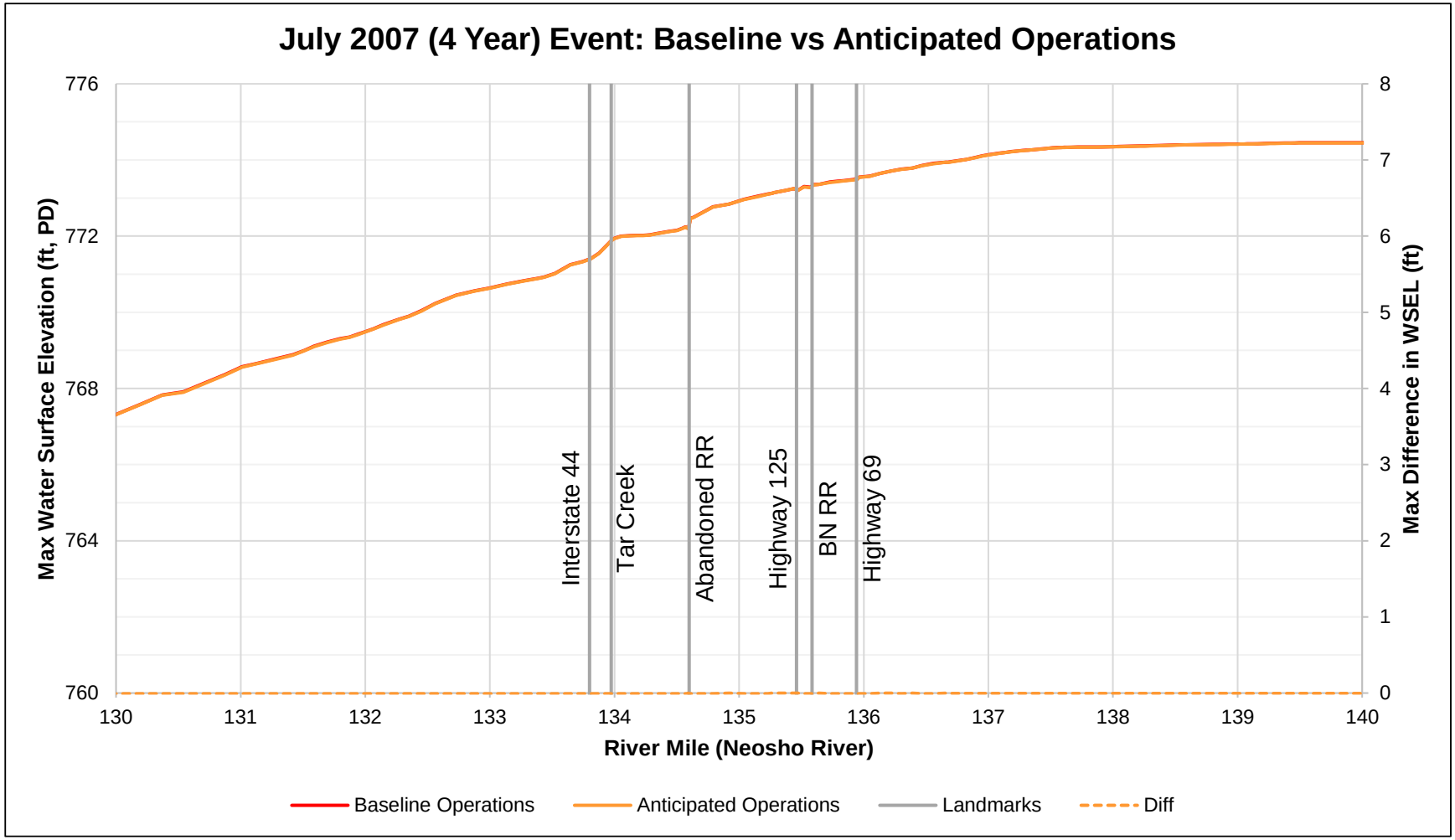


Figure H. 14. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes: 1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

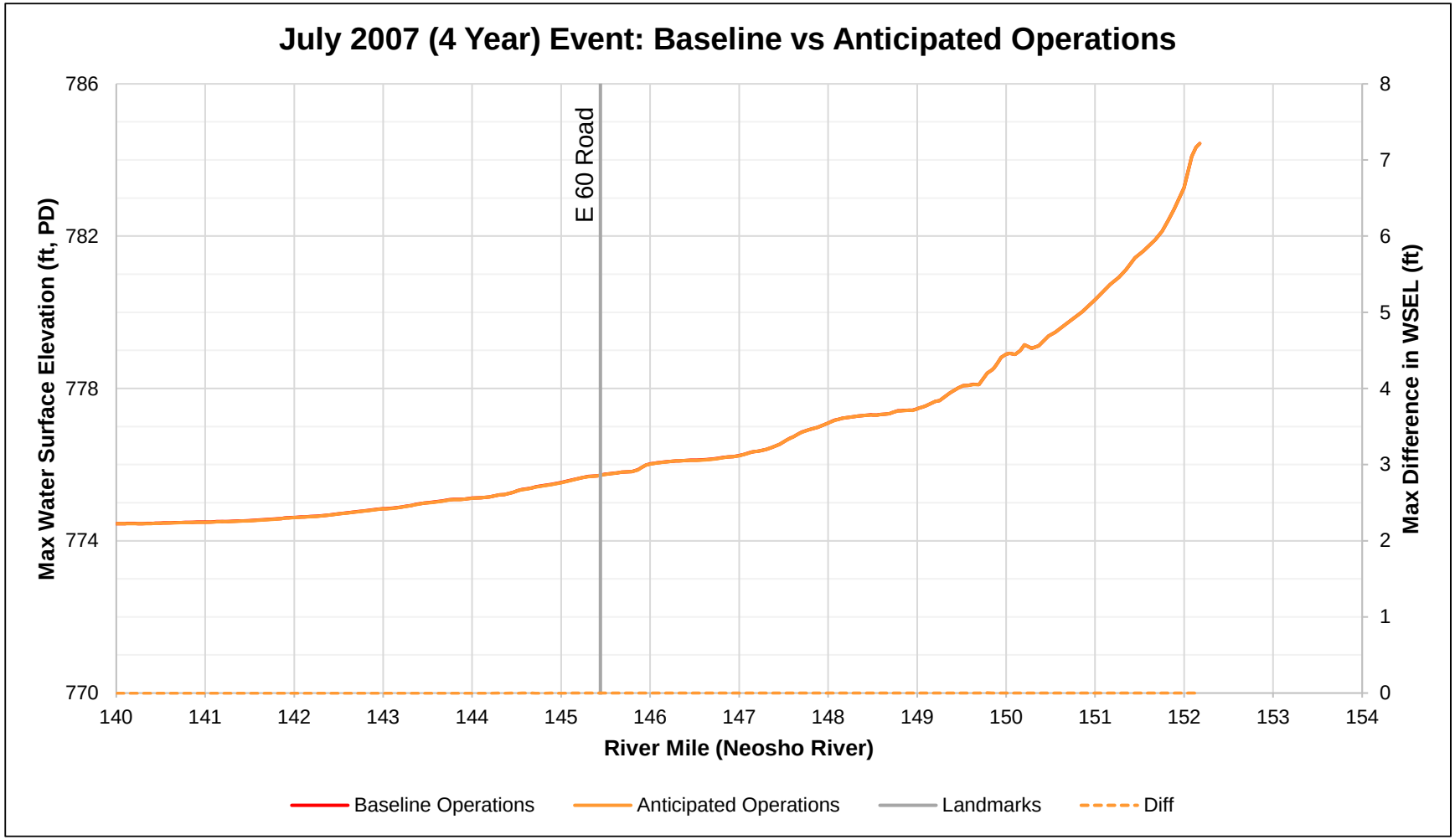


Figure H. 15. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:
1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

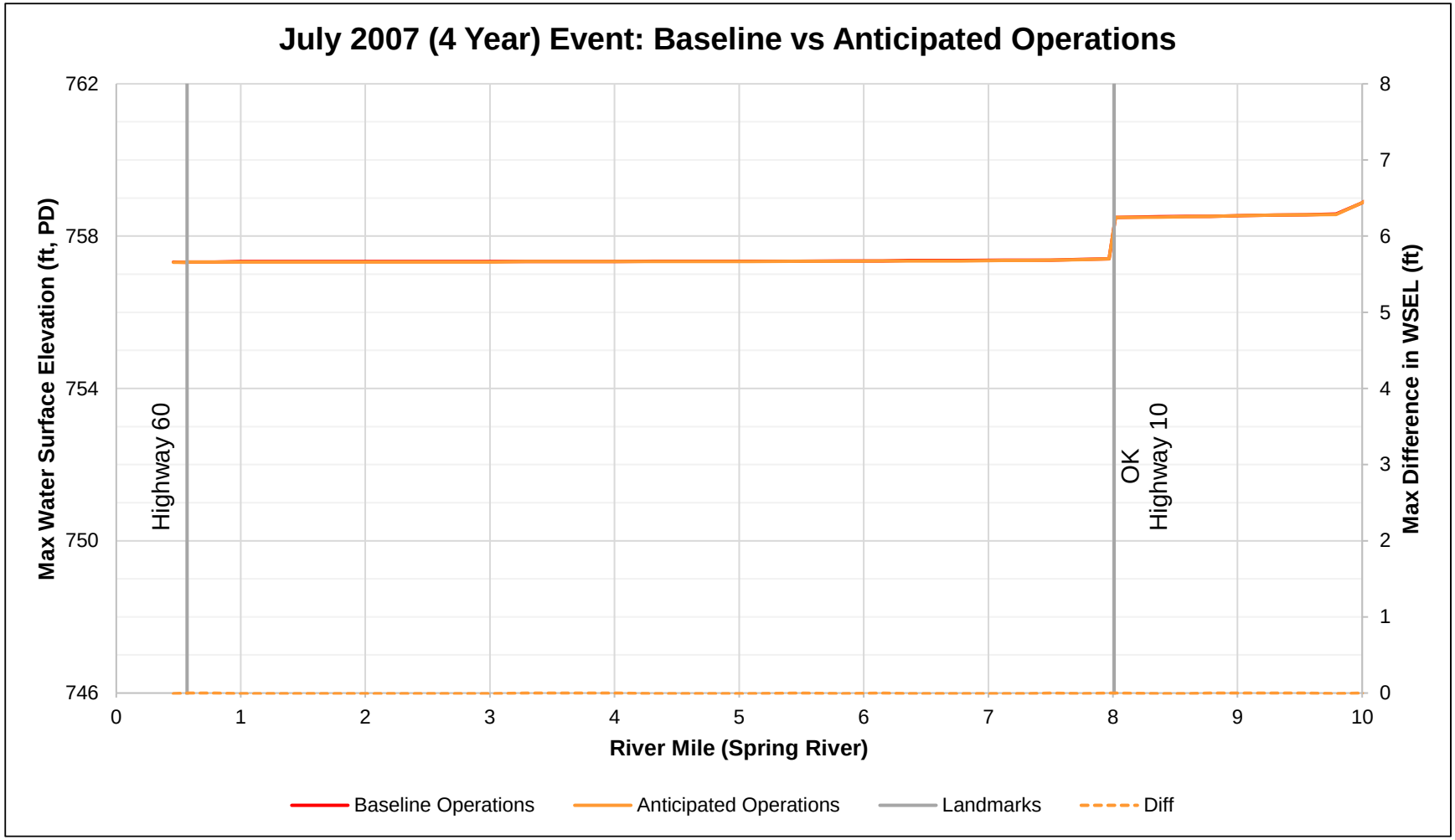


Figure H. 16. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes: 1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

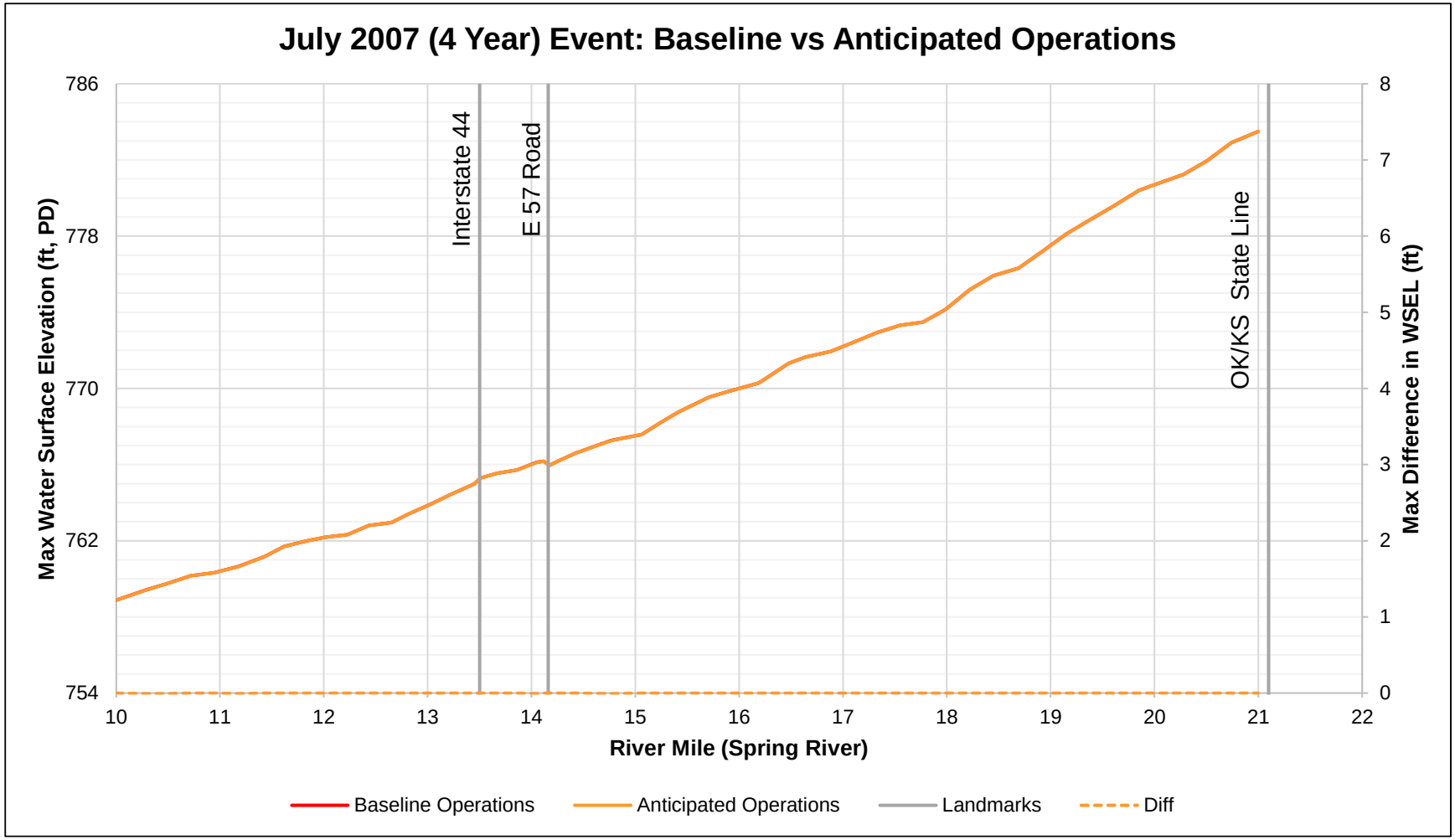


Figure H. 17. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:
1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

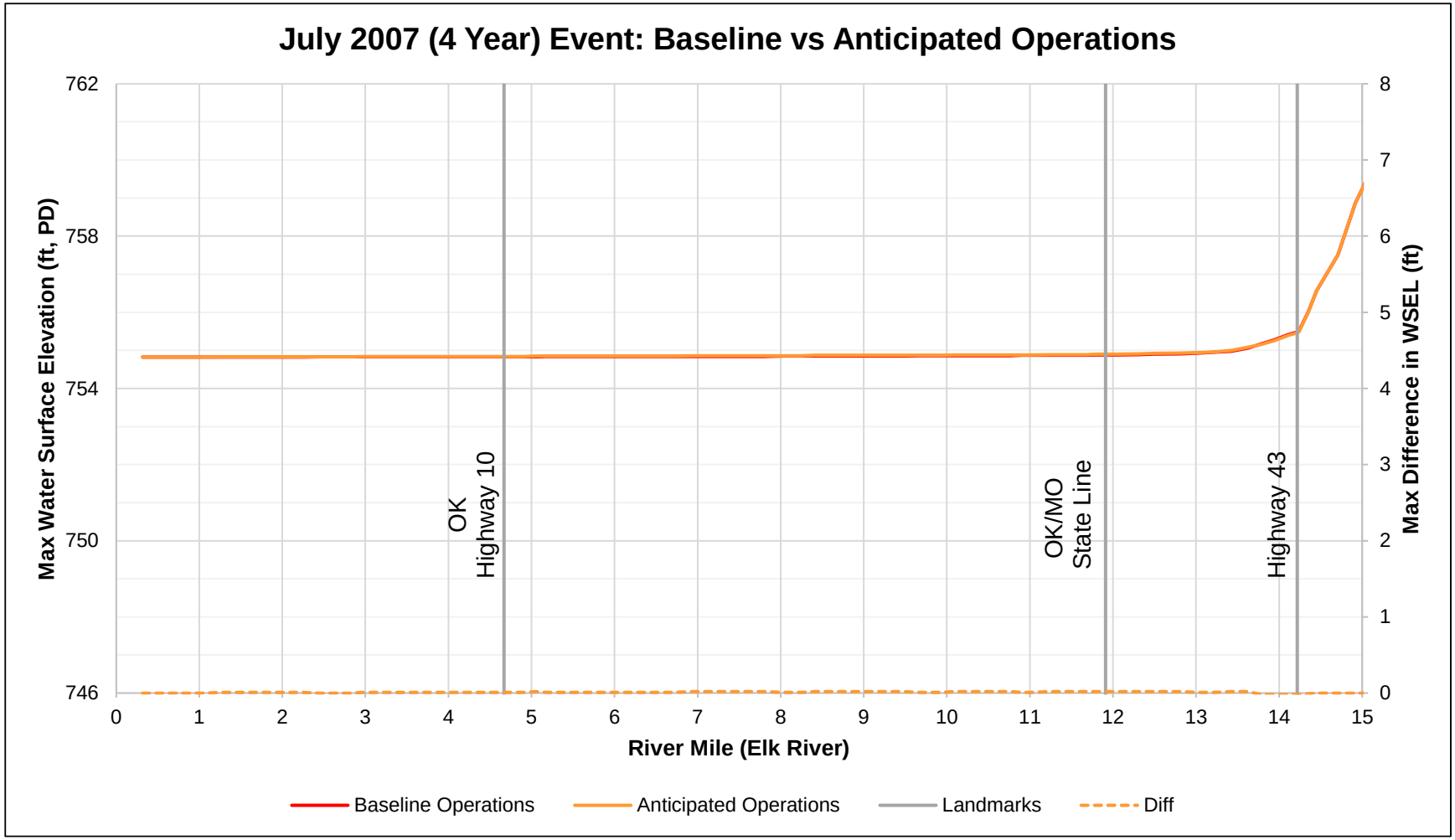


Figure H. 18. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes: 1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

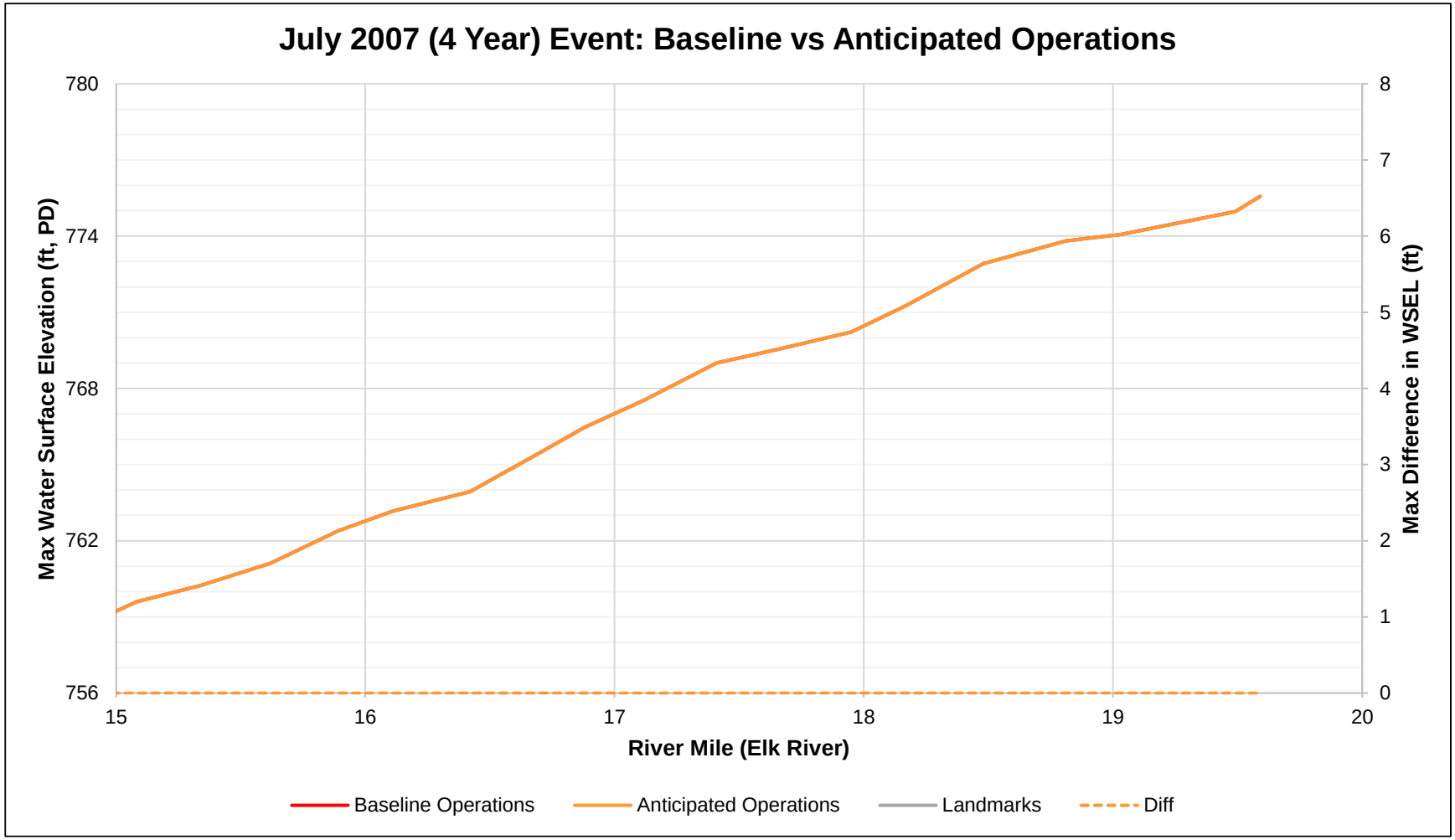


Figure H. 19. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:
1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

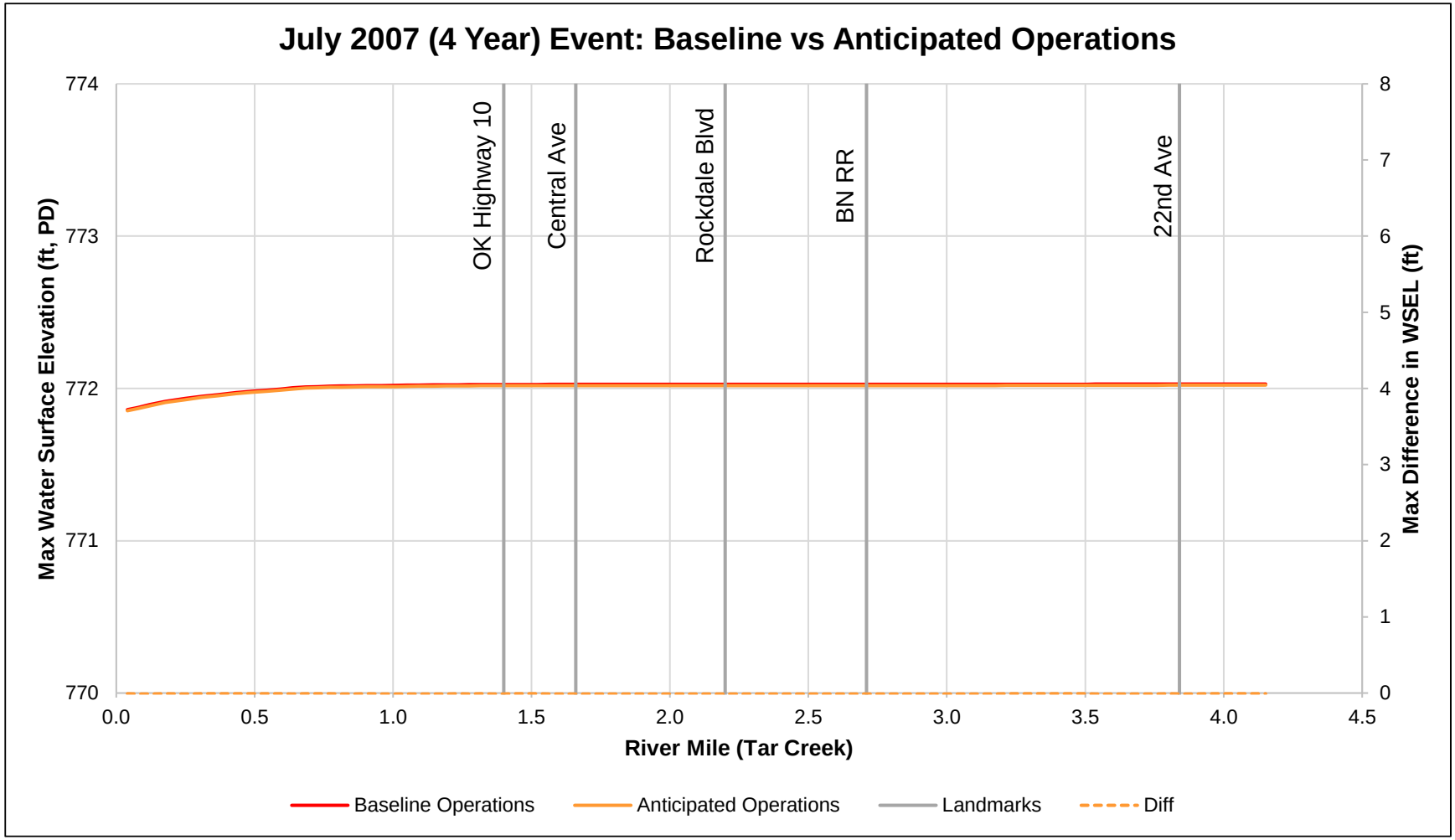


Figure H. 20. Water surface elevations for the July 2007 (4 year) inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes: 1. *Both the baseline operations and anticipated operations simulations used their respective period of record stage as the simulation starting stage.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

100-YEAR INFLOW EVENT
ANTICIPATED OPERATIONS ANALYSIS
WATER SURFACE ELEVATION PROFILES

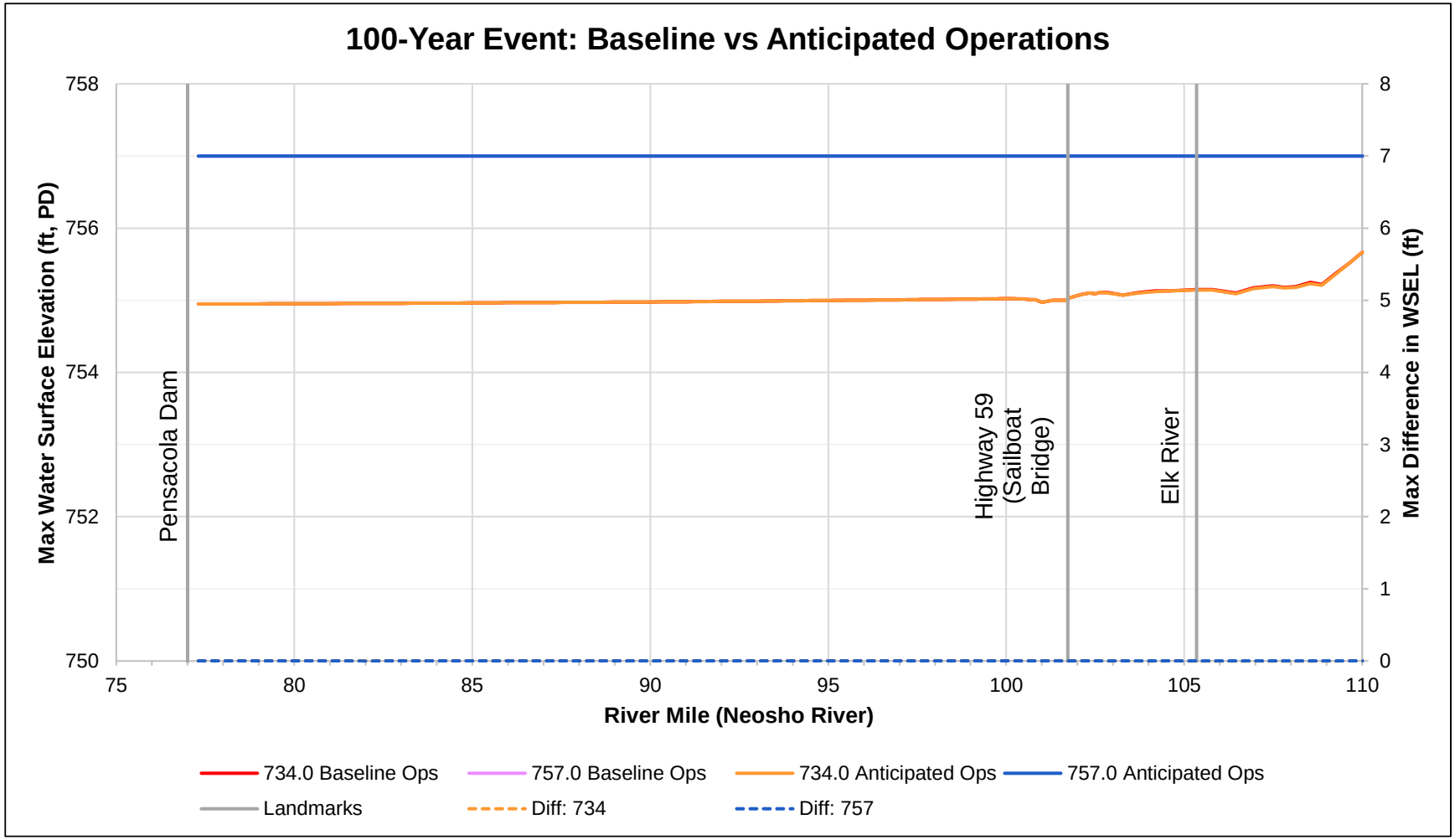


Figure H. 21. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (1 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

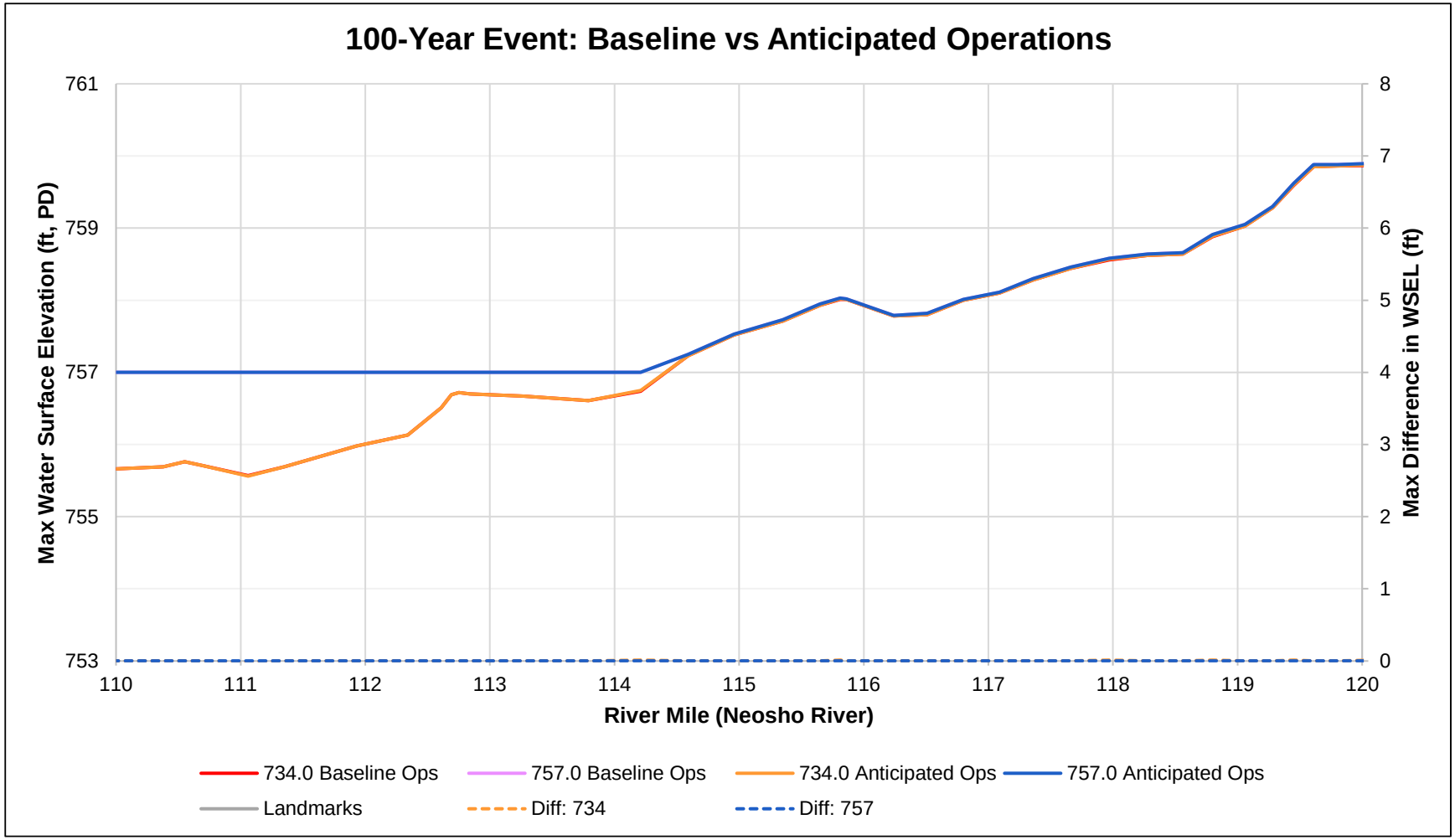


Figure H. 22. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (2 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

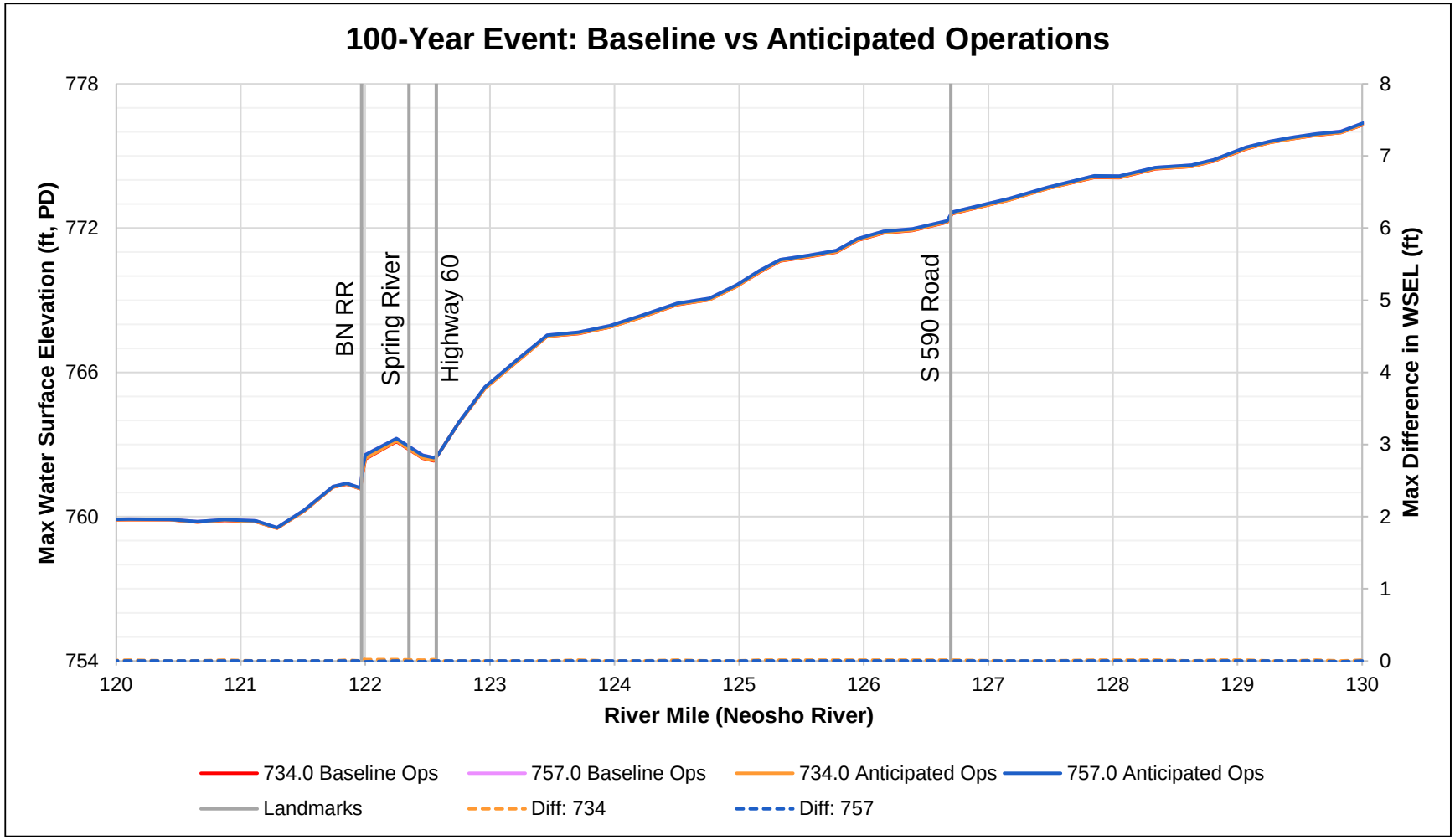


Figure H. 23. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (3 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

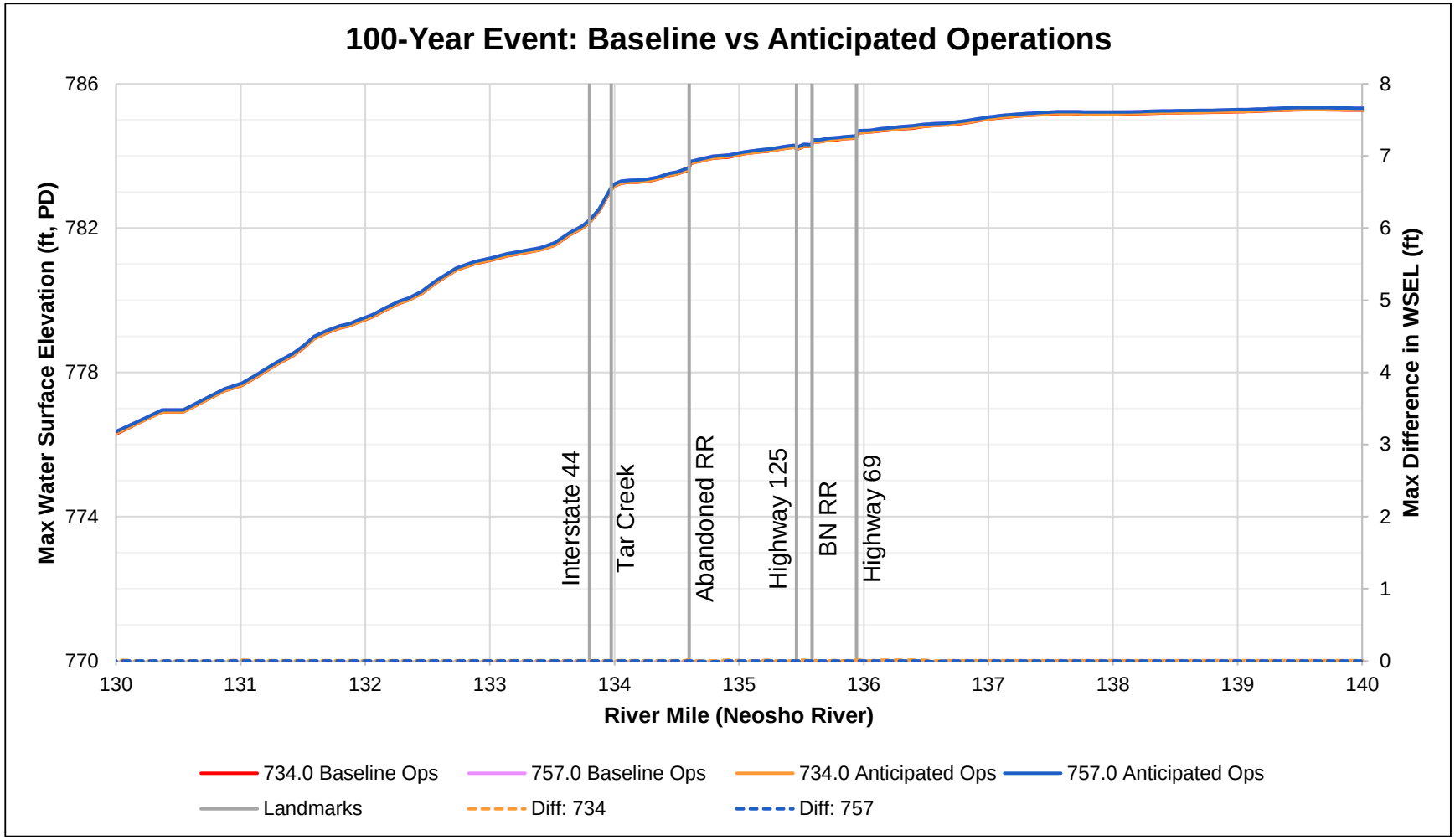


Figure H. 24. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (4 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

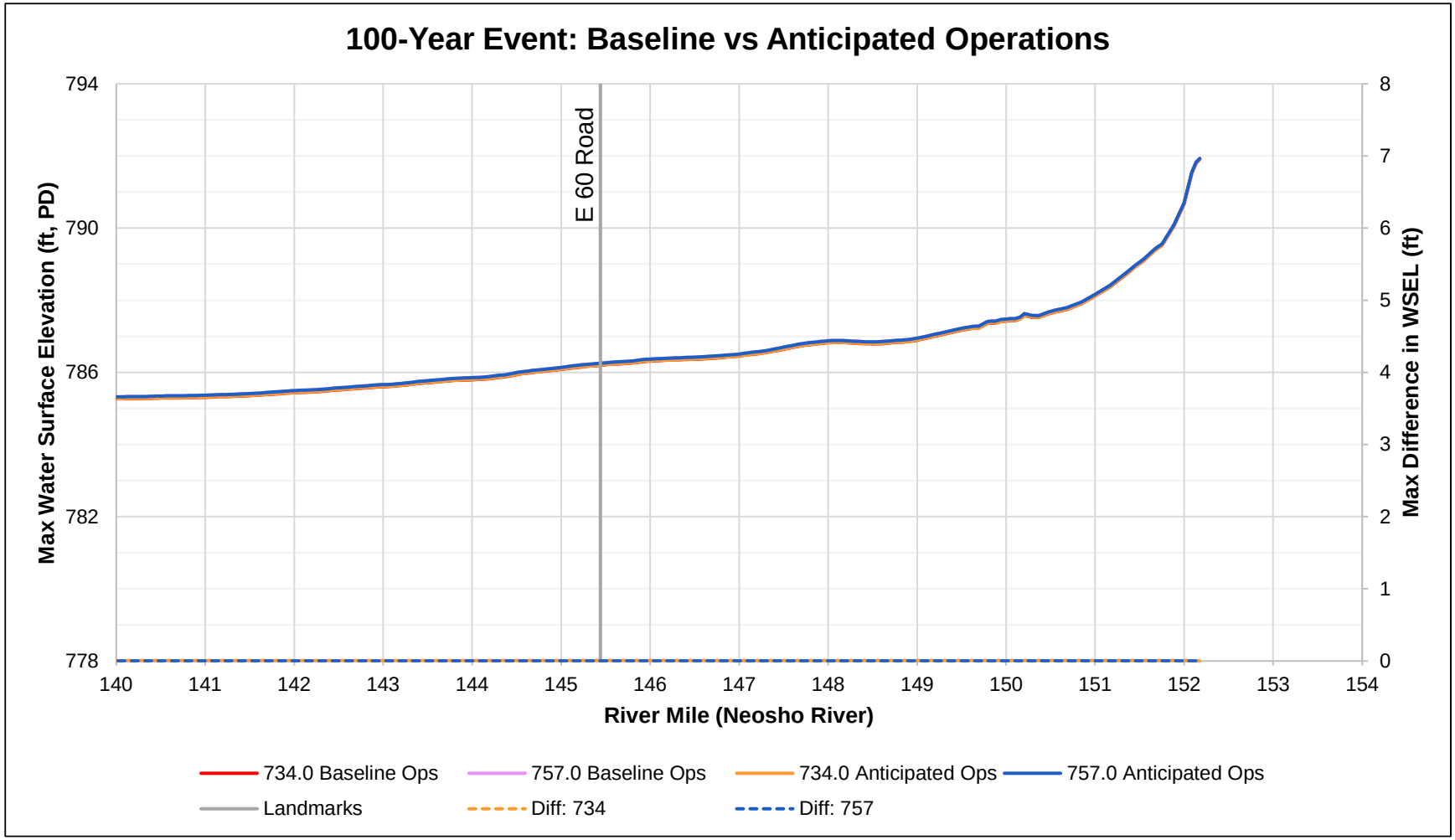


Figure H. 25. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Neosho River profile (5 of 5).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

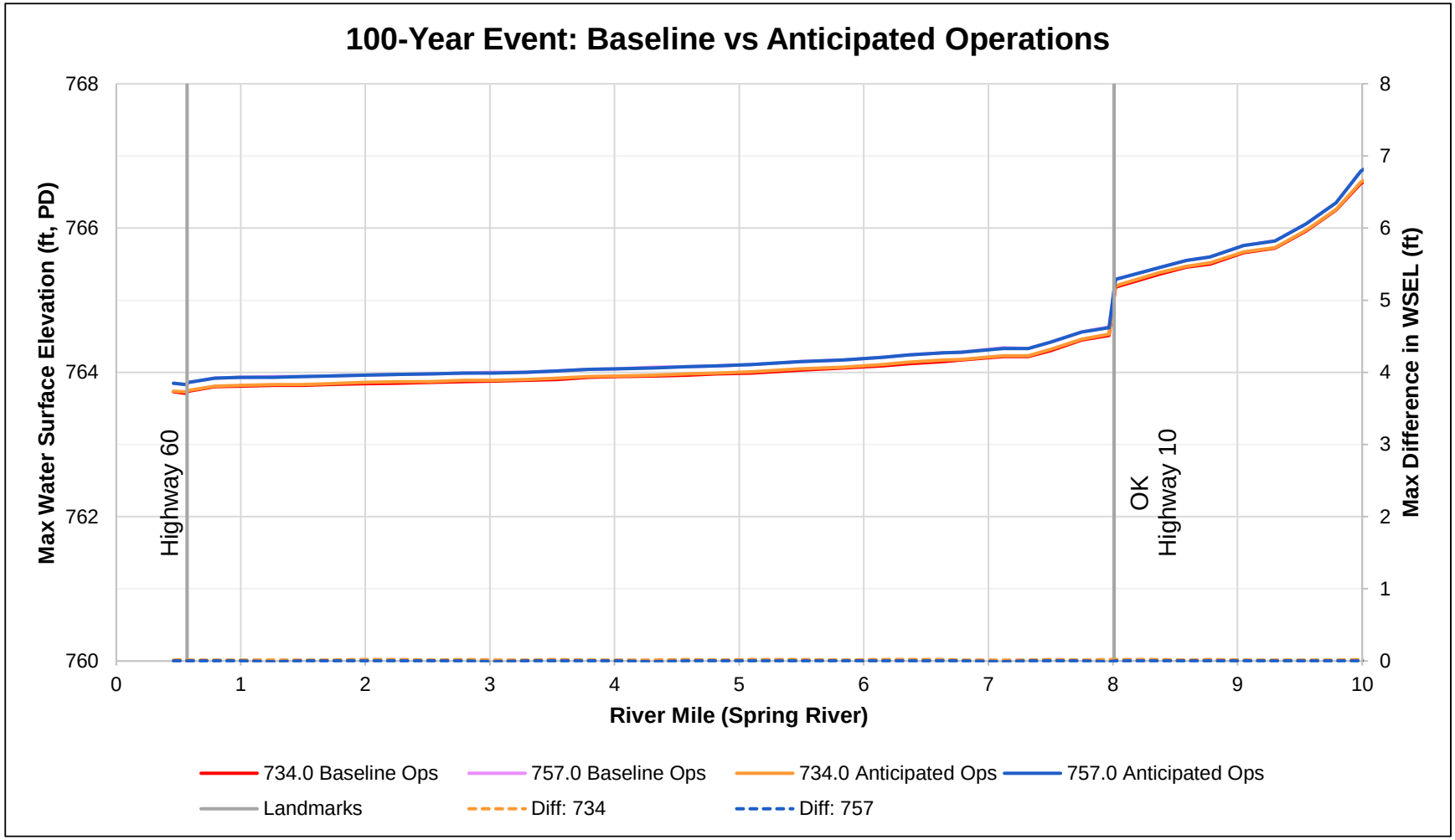


Figure H. 26. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Spring River profile (1 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

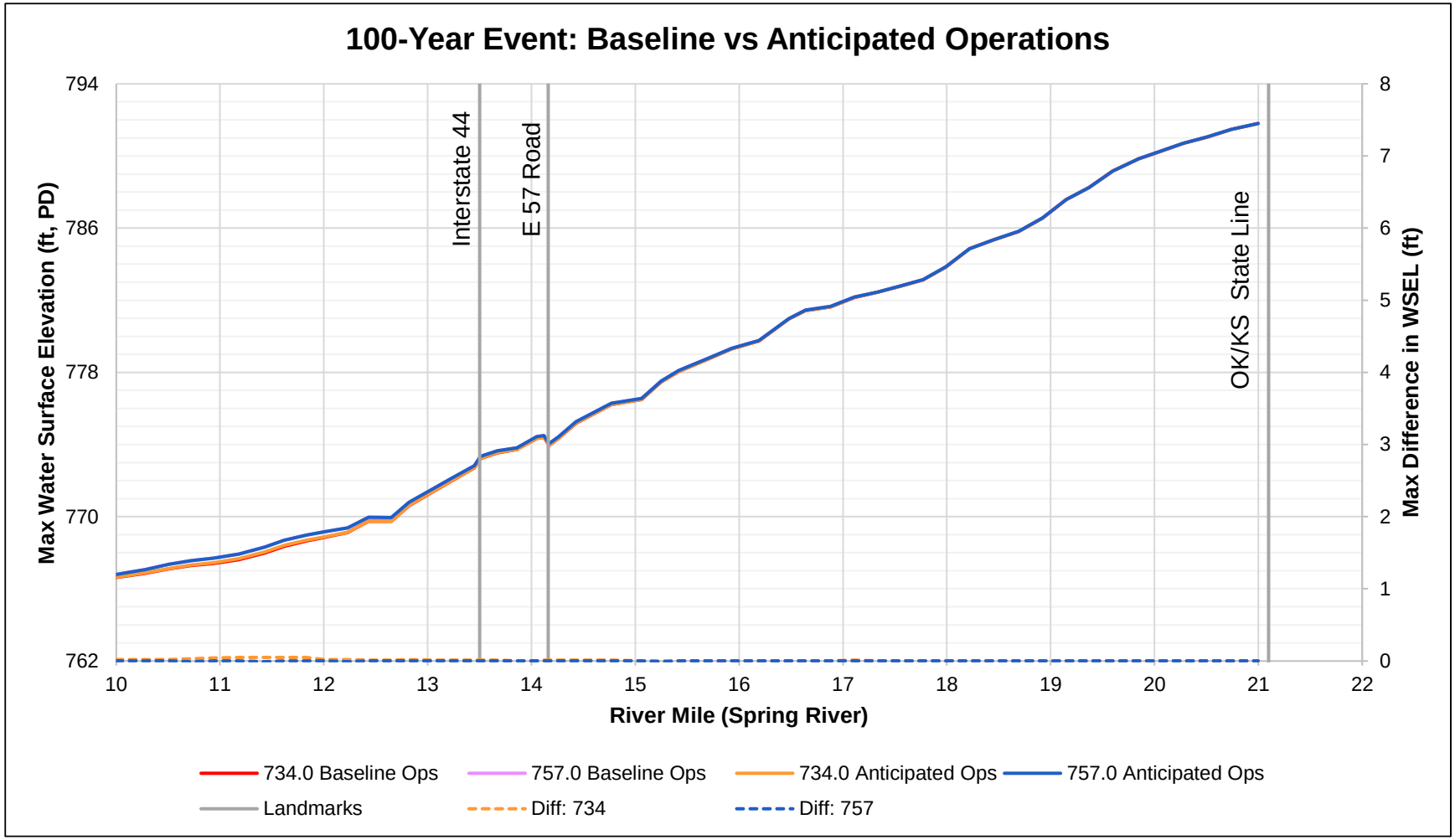


Figure H. 27. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Spring River profile (2 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

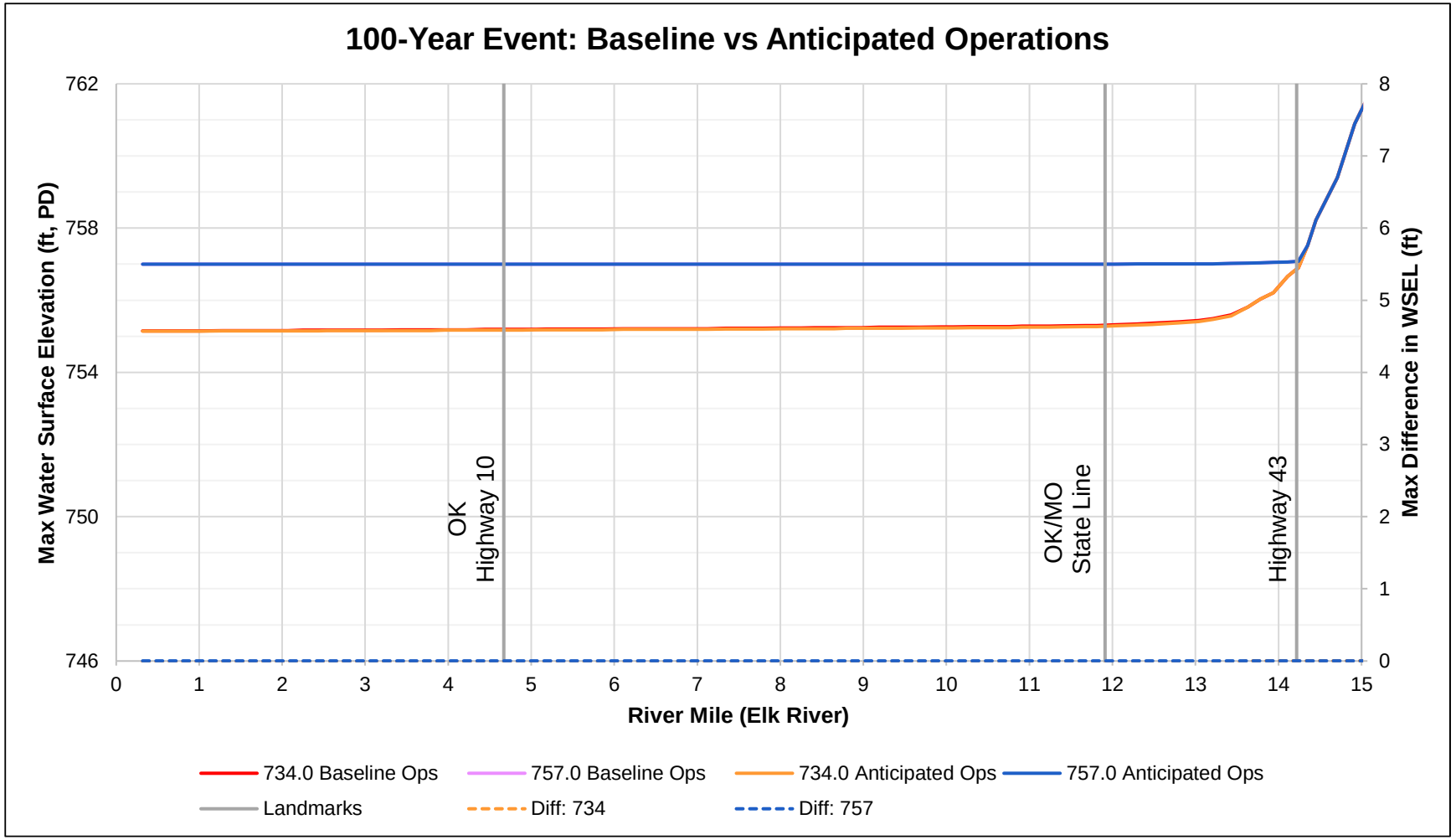


Figure H. 28. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Elk River profile (1 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

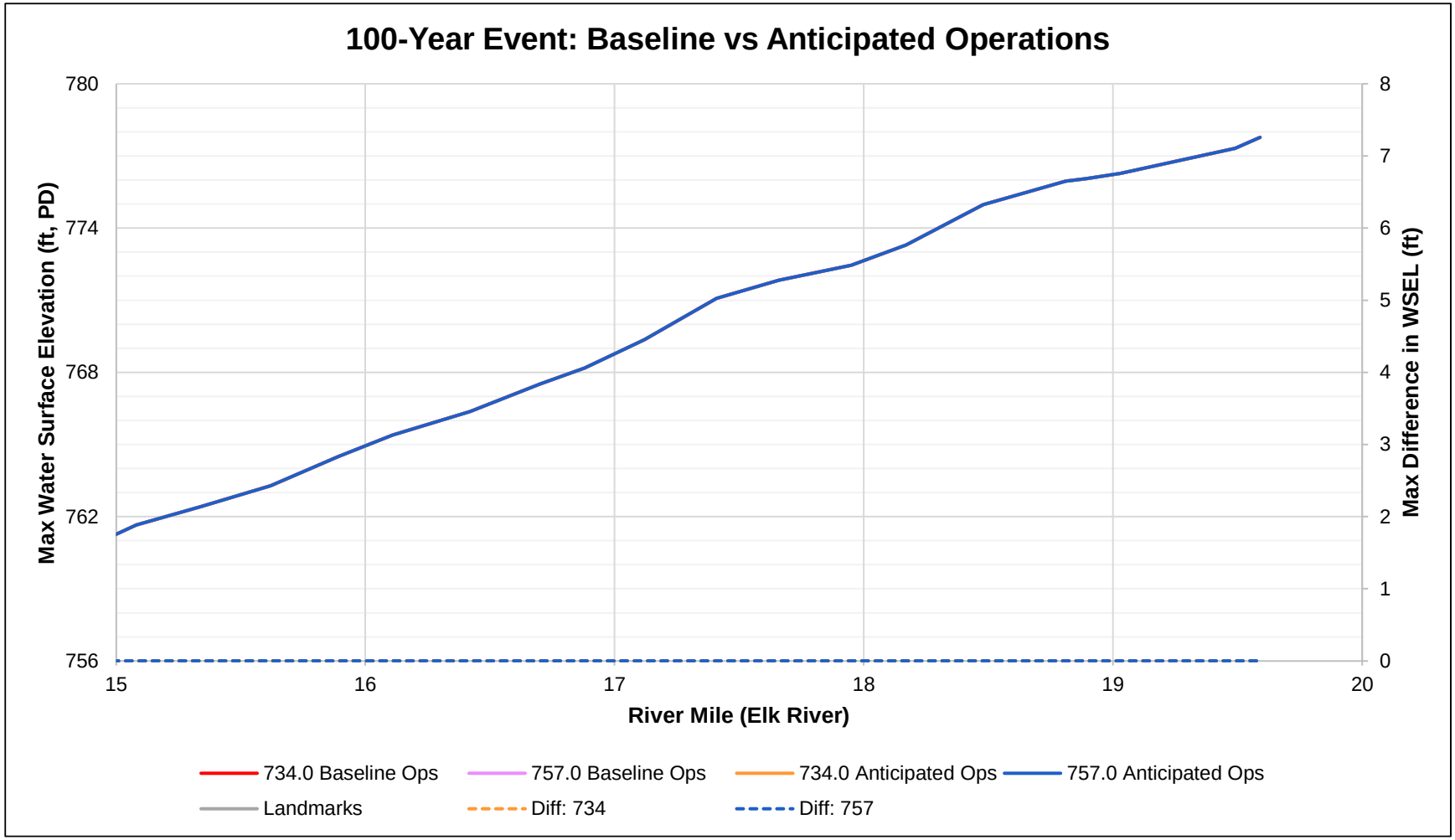


Figure H. 29. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Elk River profile (2 of 2).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

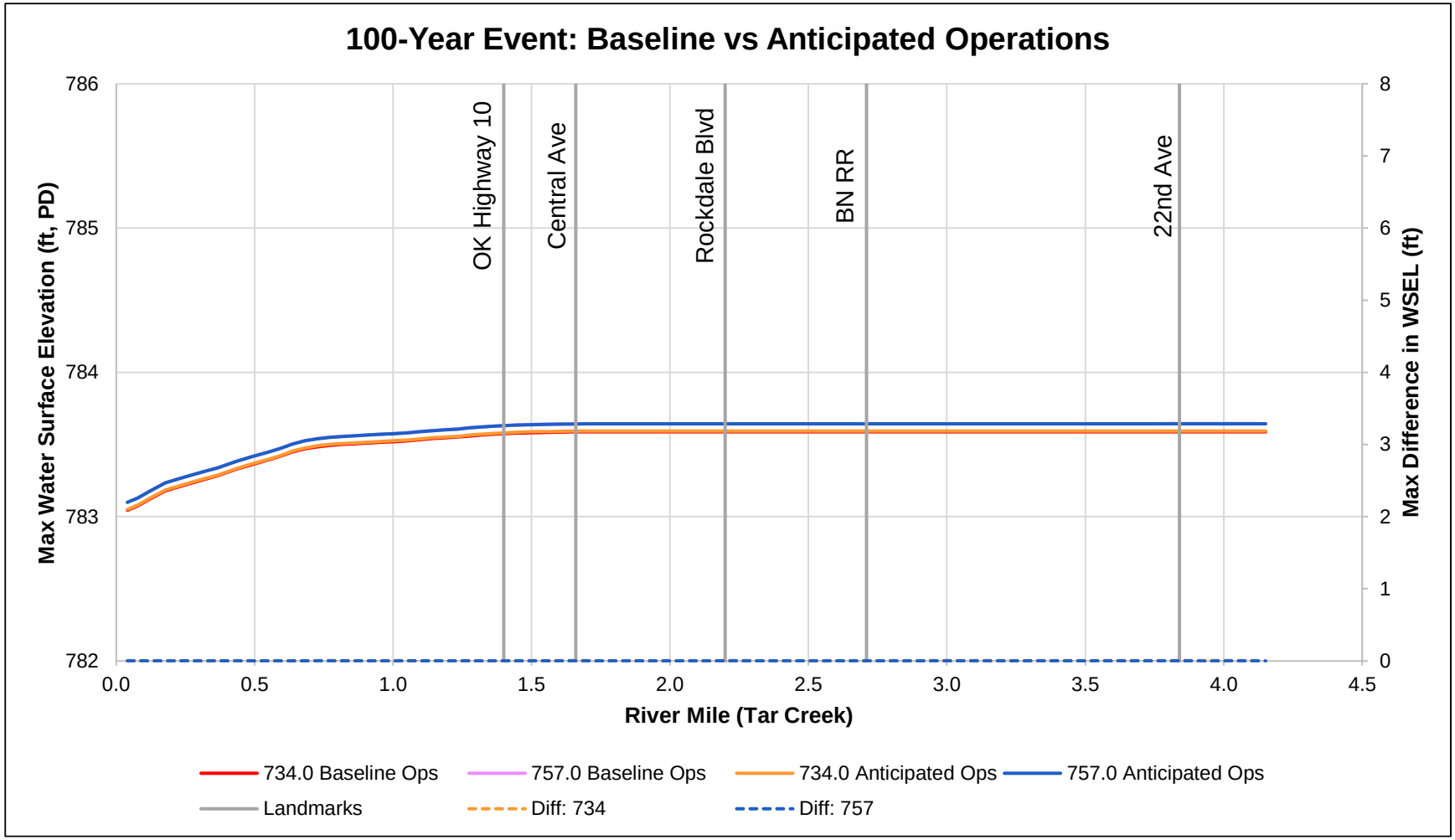


Figure H. 30. Water surface elevations for the 100-year inflow event upstream of Pensacola Dam along the Tar Creek profile (1 of 1).

Notes:

1. *The start of series' names refers to starting pool elevation at Pensacola Dam. For example, "734.0" means a starting pool elevation of 734 ft PD.*
2. *The orange dashed line plotted against the right y-axis represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 734 feet PD. The blue dashed line represents the maximum difference in WSEL between baseline and anticipated operations at a starting elevation of 757 feet PD.*
3. *Vertical and horizontal scales vary between plots based on the slope of the WSEL profiles and maximum differences displayed.*
4. *For portions of the reach where only the anticipated operations WSEL profile is visible, the WSEL profile for the baseline operations is nearly identical.*

APPENDIX H.4:
ANTICIPATED OPERATIONS ANALYSIS
DURATION OF INUNDATION

PENSACOLA DAM **TABLE H.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (hours)	July 2007 (4 year) Difference (hours)	100-Year Difference (hours)
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)			
152.175	Upstream end of model												
152.175	0	0	193	221	221	0	0	193	221	221	0	0	0
151.000	0	0	143	209	209	0	0	143	209	209	0	0	0
150.000	0	0	213	227	235	0	0	213	227	235	0	0	0
149.000	0	0	208	227	227	0	0	208	227	227	0	0	0
148.000	0	0	209	229	229	0	0	209	229	229	0	0	0
147.000	0	0	193	225	225	0	0	193	225	225	0	0	0
145.500	0	7	228	253	257	0	7	228	253	257	0	0	0
145.480	E 60 Road Bridge												
145.400	0	0	228	252	256	0	0	228	252	256	0	0	0
144.000	17	31	237	261	266	17	31	237	261	266	0	0	0
143.000	0	0	223	242	254	0	0	223	242	254	0	0	0
142.000	42	53	253	275	284	42	53	253	275	284	0	0	0
141.000	31	49	249	272	280	31	49	249	272	280	0	0	0
140.000	0	41	240	261	276	0	41	240	261	276	0	0	0
139.000	0	0	209	238	263	0	0	209	238	262	0	0	0
138.000	0	0	192	230	243	0	0	192	230	242	0	0	0
137.000	0	0	175	223	230	0	0	175	223	230	0	0	0
135.950	0	0	169	220	226	0	0	168	220	226	0	-1	0
135.941	Highway 69 Bridge												
135.940	0	0	168	220	226	0	0	168	220	226	0	0	0
135.590	0	0	168	219	226	0	0	168	219	225	0	0	0
135.586	BN RR Bridge												
135.580	0	0	168	219	226	0	0	168	219	225	0	0	0
135.470	0	0	167	219	225	0	0	167	219	225	0	0	0
135.460	Highway 125 Bridge												
135.440	0	0	167	219	225	0	0	167	219	225	0	0	0
135.000	0	0	166	219	225	0	0	166	219	225	0	0	0

1 Max increase in duration for the simulated inflow event listed. Baseline operations duration is subtracted from anticipated operations duration to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (hours)	July 2007 (4 year) Difference (hours)	100-Year Difference (hours)
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)			
134.610	0	0	163	217	223	0	0	163	218	224	0	0	1
134.599	Abandonded RR Bridge												
134.595	0	0	162	216	222	0	0	162	216	222	0	0	0
134.000	0	0	155	210	217	0	0	155	210	217	0	0	0
133.973	Tar Creek												
133.900	0	0	151	209	216	0	0	151	209	216	0	0	0
133.800	Interstate 44 Bridge												
133.700	0	0	151	208	214	0	0	150	208	214	0	-1	0
133.000	0	0	142	202	207	0	0	141	202	207	0	-1	0
132.000	0	0	135	196	200	0	0	135	196	200	0	0	0
131.000	0	0	130	191	195	0	0	130	191	195	0	0	0
130.000	0	0	126	180	184	0	0	126	180	184	0	0	0
129.000	0	0	121	156	161	0	0	121	158	163	0	0	2
128.000	0	0	115	134	141	0	0	113	134	141	0	-2	0
126.710	0	0	93	114	124	0	0	93	114	124	0	0	0
126.700	S 590 Road Bridge												
126.670	0	0	92	113	124	0	0	92	113	124	0	0	0
126.000	0	0	85	108	119	0	0	84	108	119	0	-1	0
125.000	0	0	67	96	108	0	0	67	96	108	0	0	0
124.000	0	0	44	84	96	0	0	44	84	96	0	0	0
123.000	0	0	0	70	80	0	0	0	70	80	0	0	0
122.580	0	0	0	59	68	0	0	0	60	67	0	0	1
122.570	Highway 60 Bridge												
122.550	0	0	0	60	69	0	0	0	61	69	0	0	1
122.350	Spring River												
122.000	0	0	0	59	65	0	0	0	60	65	0	0	1
121.980	0	0	0	57	63	0	0	0	58	63	0	0	1
121.970	BN RR Bridge												

1 Max increase in duration for the simulated inflow event listed. Baseline operations duration is subtracted from anticipated operations duration to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.5**

GRAND RIVER DAM AUTHORITY NEOSHO RIVER DURATIONS - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (hours)	July 2007 (4 year) Difference (hours)	100-Year Difference (hours)
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)			
121.960	0	0	0	37	46	0	0	0	38	46	0	0	1
120.000	0	0	0	25	32	0	0	0	26	32	0	0	1
118.000	0	0	0	0	0	0	0	0	0	0	0	0	0
116.000	0	0	0	0	0	0	0	0	0	0	0	0	0
114.000	0	0	0	0	0	0	0	0	0	0	0	0	0
112.000	0	0	0	0	0	0	0	0	0	0	0	0	0
110.000	0	0	0	0	0	0	0	0	0	0	0	0	0
108.000	0	0	0	0	0	0	0	0	0	0	0	0	0
106.000	0	0	0	0	0	0	0	0	0	0	0	0	0
105.350	Elk River												
105.000	0	0	0	0	0	0	0	0	0	0	0	0	0
104.000	0	0	0	0	0	0	0	0	0	0	0	0	0
102.000	0	0	0	0	0	0	0	0	0	0	0	0	0
101.750	0	0	0	0	0	0	0	0	0	0	0	0	0
101.730	Highway 59 (Sailboat Bridge)												
101.710	0	0	0	0	0	0	0	0	0	0	0	0	0
100.000	0	0	0	0	0	0	0	0	0	0	0	0	0
90.000	0	0	0	0	0	0	0	0	0	0	0	0	0
80.000	0	0	0	0	0	0	0	0	0	0	0	0	0
78.000	0	0	0	0	0	0	0	0	0	0	0	0	0
77.000	Pensacola Dam												

1 Max increase in duration for the simulated inflow event listed. Baseline operations duration is subtracted from anticipated operations duration to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.6**

GRAND RIVER DAM AUTHORITY SPRING RIVER DURATIONS - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (hours)	July 2007 (4 year) Difference (hours)	100-Year Difference (hours)
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)			
21.000	Upstream end of model												
21.000	0	0	0	0	0	0	0	0	0	0	0	0	0
20.000	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	0	0	0	40	40	0	0	0	40	40	0	0	0
18.000	0	0	0	41	41	0	0	0	41	41	0	0	0
17.000	0	0	0	43	44	0	0	0	43	44	0	0	0
16.000	0	0	0	55	55	0	0	0	55	55	0	0	0
15.000	0	0	0	49	49	0	0	0	49	49	0	0	0
14.170	0	0	0	72	72	0	0	0	72	72	0	0	0
14.160	E 57 Road												
14.120	0	0	0	73	73	0	0	0	73	73	0	0	0
13.510	0	0	0	75	75	0	0	0	75	75	0	0	0
13.500	Interstate 44 Bridge												
13.450	0	0	0	73	73	0	0	0	73	73	0	0	0
12.000	0	0	0	84	85	0	0	0	84	85	0	0	0
11.000	0	0	48	115	117	0	0	47	115	117	0	-1	0
10.000	0	0	0	110	112	0	0	0	110	112	0	0	0
9.000	0	0	0	103	107	0	0	0	103	107	0	0	0
8.020	0	0	0	94	103	0	0	0	94	103	0	0	0
8.010	OK Highway 10 Bridge												
7.970	0	0	0	81	92	0	0	0	81	91	0	0	0
7.000	0	0	0	70	84	0	0	0	72	84	0	0	2
6.000	0	0	0	65	80	0	0	0	67	80	0	0	2
5.000	0	0	0	63	77	0	0	0	64	77	0	0	1
4.000	0	0	0	63	76	0	0	0	64	76	0	0	1
3.000	0	0	0	62	75	0	0	0	62	74	0	0	0
2.000	0	0	0	62	73	0	0	0	62	73	0	0	0
1.000	0	0	0	62	71	0	0	0	62	71	0	0	0
0.580	0	0	0	62	69	0	0	0	62	69	0	0	0
0.570	Highway 60 Bridge												
0.560	0	0	0	62	69	0	0	0	62	69	0	0	0
0.460	0	0	0	62	70	0	0	0	62	70	0	0	0
0.000	Downstream end of Spring River												

1 Max increase in duration for the simulated inflow event listed. Baseline operations duration is subtracted from anticipated operations duration to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.7**

GRAND RIVER DAM AUTHORITY ELK RIVER DURATIONS - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (hours)	July 2007 (4 year) Difference (hours)	100-Year Difference (hours)
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)			
19.590	Upstream end of model												
19.590	0	0	0	0	0	0	0	0	0	0	0	0	0
19.000	0	0	0	0	0	0	0	0	0	0	0	0	0
18.000	0	0	0	0	0	0	0	0	0	0	0	0	0
17.000	0	0	0	0	0	0	0	0	0	0	0	0	0
16.000	0	0	0	0	0	0	0	0	0	0	0	0	0
15.000	0	0	0	0	0	0	0	0	0	0	0	0	0
14.240	0	0	0	0	0	0	0	0	0	0	0	0	0
14.220	Highway 43 Bridge												
14.200	0	0	0	0	0	0	0	0	0	0	0	0	0
14.000	0	0	0	0	0	0	0	0	0	0	0	0	0
13.000	0	0	0	0	0	0	0	0	0	0	0	0	0
12.000	0	0	0	0	0	0	0	0	0	0	0	0	0
11.910	OK/MO State Line												
11.000	0	0	0	0	0	0	0	0	0	0	0	0	0
10.000	0	0	0	0	0	0	0	0	0	0	0	0	0
9.000	0	0	0	0	0	0	0	0	0	0	0	0	0
8.000	0	0	0	0	0	0	0	0	0	0	0	0	0
7.000	0	0	0	0	0	0	0	0	0	0	0	0	0
6.000	0	0	0	0	0	0	0	0	0	0	0	0	0
5.000	0	0	0	0	0	0	0	0	0	0	0	0	0
4.700	0	0	0	0	0	0	0	0	0	0	0	0	0
4.670	OK Highway 10 Bridge												
4.640	0	0	0	0	0	0	0	0	0	0	0	0	0
4.000	0	0	0	0	0	0	0	0	0	0	0	0	0
3.000	0	0	0	0	0	0	0	0	0	0	0	0	0
2.000	0	0	0	0	0	0	0	0	0	0	0	0	0
1.000	0	0	0	0	0	0	0	0	0	0	0	0	0
0.320	0	0	0	0	0	0	0	0	0	0	0	0	0
0.000	Downstream end of Elk River												

1 Max increase in duration for the simulated inflow event listed. Baseline operations duration is subtracted from anticipated operations duration to assess the impact of anticipated operations.

PENSACOLA DAM **TABLE H.8**

GRAND RIVER DAM AUTHORITY TAR CREEK DURATIONS - BASELINE VS ANTICIPATED OPERATIONS

River Mile	Baseline Operations					Anticipated Operations					Anticipated vs. Baseline[1]		
	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 Year), Start @ 734 ft	Jun 2004 (1 Year), Start @ 757 ft	Jul 2007 (4 Year), Period of Record	100-Year, Start @ 734 ft	100-Year, Start @ 757 ft	Jun 2004 (1 year) Difference (hours)	July 2007 (4 year) Difference (hours)	100-Year Difference (hours)
	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)	Duration (hours)			
4.152	Upstream end of model												
4.152	0	0	0	70	70	0	0	0	70	70	0	0	0
3.900	0	0	0	79	80	0	0	0	79	80	0	0	0
3.840	22nd Ave Bridge												
3.800	0	0	36	91	93	0	0	36	91	93	0	0	0
3.300	0	0	49	97	99	0	0	49	97	99	0	0	0
2.800	0	0	83	120	123	0	0	83	120	123	0	0	0
2.710	BN RR Bridge												
2.700	0	0	112	171	173	0	0	112	171	173	0	0	0
2.500	0	0	122	184	187	0	0	122	184	187	0	0	0
2.300	0	0	130	193	196	0	0	130	193	196	0	0	0
2.200	Rockdale Blvd Bridge												
2.100	0	0	154	210	217	0	0	154	210	217	0	0	0
1.900	0	0	154	210	217	0	0	154	210	217	0	0	0
1.700	0	0	154	210	217	0	0	154	210	217	0	0	0
1.660	Central Ave Bridge												
1.600	0	0	154	210	217	0	0	154	210	217	0	0	0
1.500	0	0	154	210	217	0	0	154	210	217	0	0	0
1.400	OK Highway 10 Bridge												
1.300	0	0	154	210	217	0	0	154	210	217	0	0	0
1.000	0	0	154	210	217	0	0	154	210	217	0	0	0
0.700	0	0	154	210	217	0	0	154	210	217	0	0	0
0.300	0	0	154	210	217	0	0	154	210	216	0	0	0
0.041	0	0	154	210	217	0	0	154	210	216	0	0	0
0.000	Downstream end of Tar Creek												

1 Max increase in duration for the simulated inflow event listed. Baseline operations duration is subtracted from anticipated operations duration to assess the impact of anticipated operations.

APPENDIX I:
SUPPORTING MAPS FOR OTHER STUDIES

Due to the size of map files, maps are included as a set of separate PDFs.