

Lake O'the Pines Watershed, Texas Base Level Engineering (BLE) Results

MAS No. FY20-CTP-FRP-MAS-26

Case No. 21-06-0029S

August 2022

Prepared for:

Federal Emergency Management Agency &
Department of Homeland Security
FEMA Region VI
800 North Loop 288
Denton, TX 76209



FEMA

Submitted by:

Texas Water Development Board
1700 North Congress Avenue
Austin, TX 78701

Table of Contents

Executive Summary	iii
01 Introduction	1-1
02 2D BLE Modeling Inputs and Controls.....	2-3
2.1 Topographic Data	2-3
2.1.1 Inventory.....	2-3
2.1.2 Evaluation	2-5
2.1.3 Data Development Methodology	2-6
2.1.4 DEM QA/QC	2-6
2.2 2D BLE Methods	2-8
2.2.1 2D Computational Mesh and Settings	2-8
2.2.2 Model and Boundary Condition Setup	2-8
2.2.3 Hydrology	2-9
2.2.4 Hydraulics	2-13
2.2.5 Special Assumptions	2-15
2.3 Model Results	2-21
2.3.1 Calibration & Sensitivity Analysis.....	2-21
2.4 Challenges	2-25
2.5 Recommendations	2-26
03 Floodplain Mapping and Effective Zone A Validation	3-27
3.1 Special Flood Hazard Area.....	3-27
3.1.1 Model Outputs.....	3-27
3.1.2 Methodology	3-27
3.1.3 Flood Hazard Area Layer.....	3-28
3.1.4 Mapping Considerations.....	3-28
3.2 Validation of Effective Zone A SFHA	3-28
3.2.1 Initial Assessment A1 – Significant Topography Update Check.....	3-28
3.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes	3-28
3.2.3 Initial Assessment A3 – Check for Significant Development.....	3-29
3.2.4 Validation Check A4 – Check of Studies Backed by Technical Data	3-29
3.2.5 Validation Check A5 – Comparison of BLE and Effective Zone A	3-29
3.2.6 Validation Results	3-30
3.3 Flood Risk Analysis	3-33
04 References	4-34

List of Tables

Table ES-1.1: Summary of Stream Miles	iii
Table ES-1.2: Aggregated Zone A Validation Results	iii
Table 2.1: FEMA Vertical Accuracy Requirements for Leveraged Data	2-5
Table 2.2: Source Topographic Data Available for the Lake O’the Pines Watershed	2-5
Table 2.3: USGS Peak Streamflow Gages	2-10
Table 2.4: USGS Peak Streamflow Gage Analysis Results	2-10
Table 2.5: Land Use-Soils-CN Matrix for Computing Initial Curve Numbers	2-11
Table 2.6: Rainfall-Runoff Parameters (Curve Number, Lag Time)	2-11
Table 2.7: Precipitation Rainfall Depths for Estimating Excess Precipitation for HEC-RAS 2D Computational Mesh	2-12
Table 2.8: NLCD 2019-Manning’s N Roughness Matrix	2-13
Table 2.9: Lake O’the Pines Watershed Dam Summary	2-15
Table 2.10: Effective and Model BFE Comparison	2-21
Table 2.11: 1% Annual Chance Reasonability Comparisons	2-21
Table 2.12: Sensitivity Analysis Results at USGS Gage 07344486	2-22
Table 2.13: Sensitivity Analysis Results at USGS Gage 07344500	2-23
Table 2.14: Sensitivity Analysis Results at USGS Gage 07345000	2-24
Table 2.15: Sensitivity Analysis Results at USGS Gage 07344482	2-25
Table 3.1: Mapping Threshold Matrix	3-27
Table 3.2: A1-A3 Validation Results	3-29
Table 3.3: Aggregated Zone A Validation Results	3-30
Table 3.4: HUC 12 Zone A Validation Results	3-31
Table 3.5: Hazus 5.1 (SP02) Results for 1-percent-annual-chance (100 year) scenario for Lake O’the Pines Watershed, Texas	3-33

List of Figures

Figure 1.1: Lake O’the Pines Watershed	1-2
Figure 2.1: Lake O’the Pines Watershed BLE Source Terrain Data	2-4
Figure 2.2: HEC-RAS 2D Computational Mesh and USGS Peak Streamflow Gages	2-9
Figure 2.3: Excess Precipitation Hyetographs Applied to the Computational Mesh	2-12
Figure 2.4 : V-Notch Breakline Approach at Bridge Crossing	2-14
Figure 2.5: Franklin County Dam Service Spillway Discharge Rating Curve	2-16
Figure 2.6: Franklin County Dam Emergency Spillway Discharge Rating Curve	2-16
Figure 2.7: Ellison Creek Dam Service Spillway Discharge Rating Curve	2-17
Figure 2.8: Ellison Creek Dam Emergency Spillway Discharge Rating Curve	2-18
Figure 2.9: Monticello Dam Service Spillway Discharge Rating Curve	2-19
Figure 2.10: Monticello Dam Emergency Spillway Discharge Rating Curve	2-19
Figure 2.11: Ferrells Bridge Dam Outlet Works Discharge Rating Curve	2-20
Figure 2.12: Cupping Examples	2-26
Figure 3.1: Lake O’the Pines Watershed CNMS Validation Results	3-32

Executive Summary

The Texas Water Development Board (TWDB) contracted Halff Associates (Halff) to complete a Base Level Engineering (BLE) analysis for the HUC-08 watershed No. 11140305 – Lake O'the Pines in Northeast Texas, to support the U.S. Department of Homeland Security's Federal Emergency Management Agency's (FEMA) Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). The BLE process involves using best available data and incorporating automated techniques with standard 2-dimensional (2D) model development procedures to produce flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development in support of hydrologic and hydraulic analysis as well as mapping activities were leveraged from various local, State, and Federal partners. Details regarding the different datasets used are provided below in Section 2.1.

Precipitation depths for this study were established using National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall. An average precipitation depth was computed for the study area. The Hydrologic Engineering Center's (HEC) Hydrologic Modeling System (HMS) was used to develop a simplified hydrologic model to compute excess rainfall which was then used in a rain-on-grid, 2D hydraulic model using HEC-RAS. The hydraulic model was used to compute flood depths and peak water surface elevations within the study area.

The stream mile network that was validated for this watershed was compiled using FEMA's Community Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risks. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-1.1 lists the stream miles associated with this validation analysis.

Table ES-1.1: Summary of Stream Miles

Source	Lake O'the Pines Stream Miles
CNMS	2,575

The full inventory of Zone A studies in the watershed were classified in CNMS. Total miles validated in CNMS are summarized in Table ES-1.2.

Table ES-1.2: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	179.1
UNVERIFIED	BEING STUDIED	400.5

01 Introduction

Recent innovations and efficiencies in floodplain mapping have allowed the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop a process called Base Level Engineering (BLE), which can be used to address current program challenges, including the validation of Zone A studies and the availability of flood risk data in the early stages of a flood risk project. The BLE process involves using best available data and incorporating automated techniques with standard 2-dimensional (2D) model development procedures to produce flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals. The cost for developing the data and estimates resulting from the BLE process are lower than standard flood production costs. The BLE results may be used for eventual production of regulatory and non-regulatory products.

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every five years, FEMA must evaluate whether the information on Flood Insurance Rate Maps (FIRMs) reflects the current risks in flood-prone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the CNMS Technical Reference. The CNMS Validation Checklist provides a series of critical and secondary checks to determine the validity of flood hazard areas studied by detailed methods (e.g., Zone AE, AH, or AO). While the critical and secondary elements in CNMS provide a comprehensive method of evaluating the validity of Zone AE studies, a cost-effective approach for evaluating Zone A studies has been lacking.

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the early stages of a flood risk project. FEMA Program Standard SID #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses should be shared, and results should be discussed with stakeholders.

An important goal of the BLE process is the scalability of the results. Scalability means that the results of a BLE analysis can not only be used for CNMS evaluations of Zone A studies but can also be leveraged throughout the Risk Mapping, Assessment and Planning (Risk MAP) program. The data resulting from a BLE analysis can be updated as needed and used for the eventual production of regulatory and non-regulatory products, outreach and risk communication, and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

The Texas Water Development Board (TWDB) contracted Halff Associates (Halff) to complete a BLE analysis for the Lake O'the Pines Watershed in Northeast Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Hopkins, Franklin, Titus, Morris, Wood, Camp, Upshur, Cass, Marion, and Harrison Counties, and include the following communities: the Cities of Daingerfield, Mt Pleasant, Pittsburg, and Winnsboro, the Towns of Avinger, Lone Star, Miller's Cove, Omaha, Ore City, Rocky Mound, and Winfield. The study area consists of four HUC-10 basins: Glade Branch – Big Cypress Creek, Brushy Creek – Big Cypress Creek, Boggy Creek, and Alley Creek – Big Cypress Creek. Figure 1.1 shows the orientation of the Lake O'the Pines HUC-8 basin with respect to the counties.

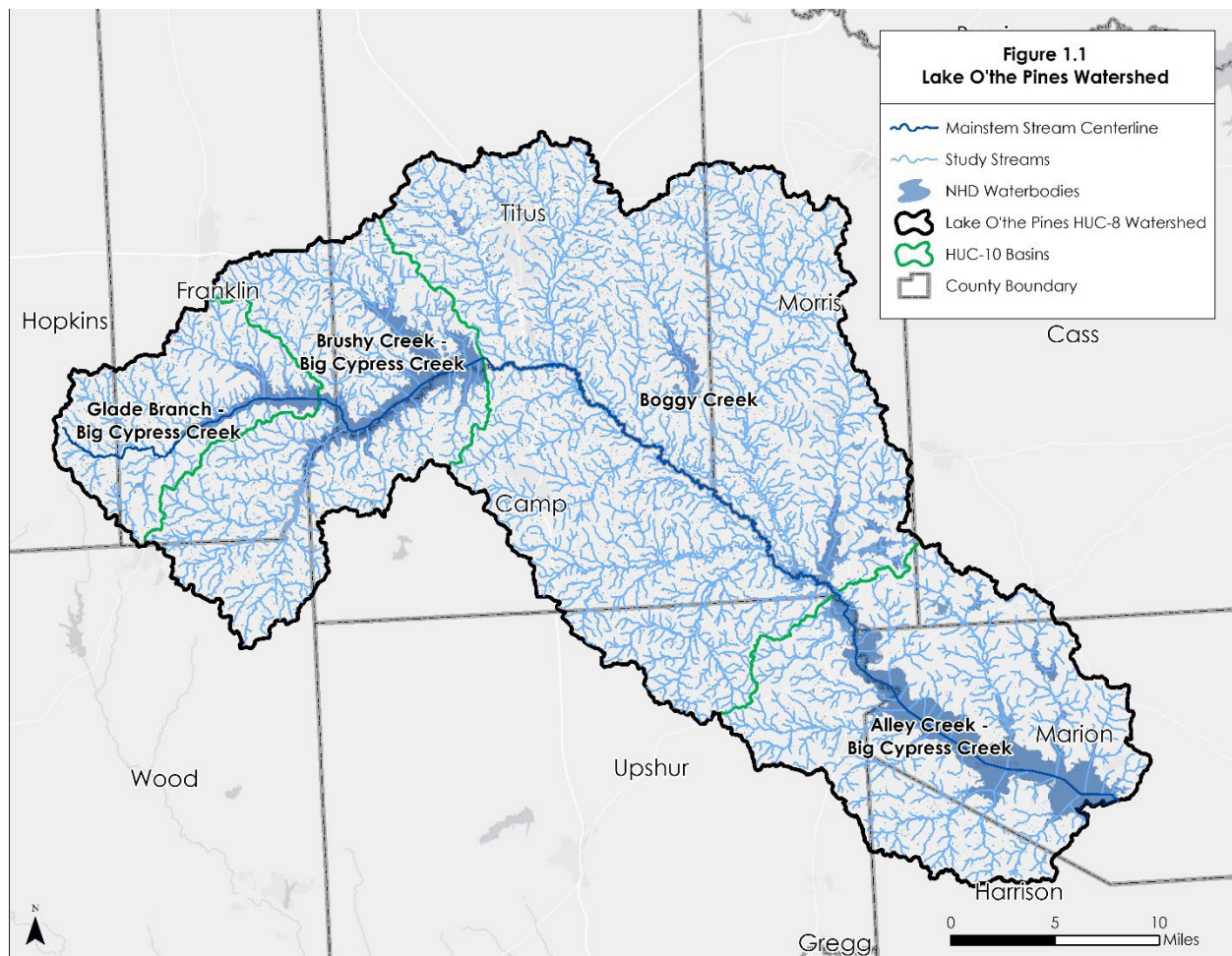


Figure 1.1: Lake O'the Pines Watershed

02 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2D hydraulic engineering analysis for the Lake O'the Pines Watershed. Inputs such as elevation data, hydrology from rain-on-grid data and inflow hydrographs, and hydraulic analyses and variables are defined herein. HEC-RAS, Version 6.1 rain-on-grid utility was applied in the production of these Texas 2D BLE products.

2.1 Topographic Data

A high-resolution Digital Elevation Model (DEM) is a fundamental component for two-dimensional engineering analyses by providing a detailed representation of the surface for hydraulic routing through the model area. As such, DEMs were developed for the Lake O'the Pines BLE project by leveraging available high-resolution gridded elevation data derived from Light Detection and Ranging (LiDAR) collections throughout the entire State of Texas. The 10-foot DEM developed to support the 2D BLE modeling and analysis, within the Lake O'the Pines Watershed, was executed using the following steps:

1. Available elevation data for the project area were inventoried and collected.
2. Leveraged elevation data were evaluated and prioritized based on source vertical accuracy, year of collection, and resolution.
3. Seamless DEMs were processed using GIS.
4. Quality was assured using quantitative and qualitative assessment.

Documentation regarding leveraged data including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables, and text within the following sections. All vertical accuracy specifications were obtained from the metadata or survey reports provided with the leverage datasets. All available metadata, survey reports, and other leverage documentation are included in the FEMA Data Capture Technical Reference compliant submittal content for the Lake O'the Pines Watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the Lake O'the Pines BLE project footprint. Figure 2.1 depicts the datasets identified for leverage across the project area. FEMA, National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

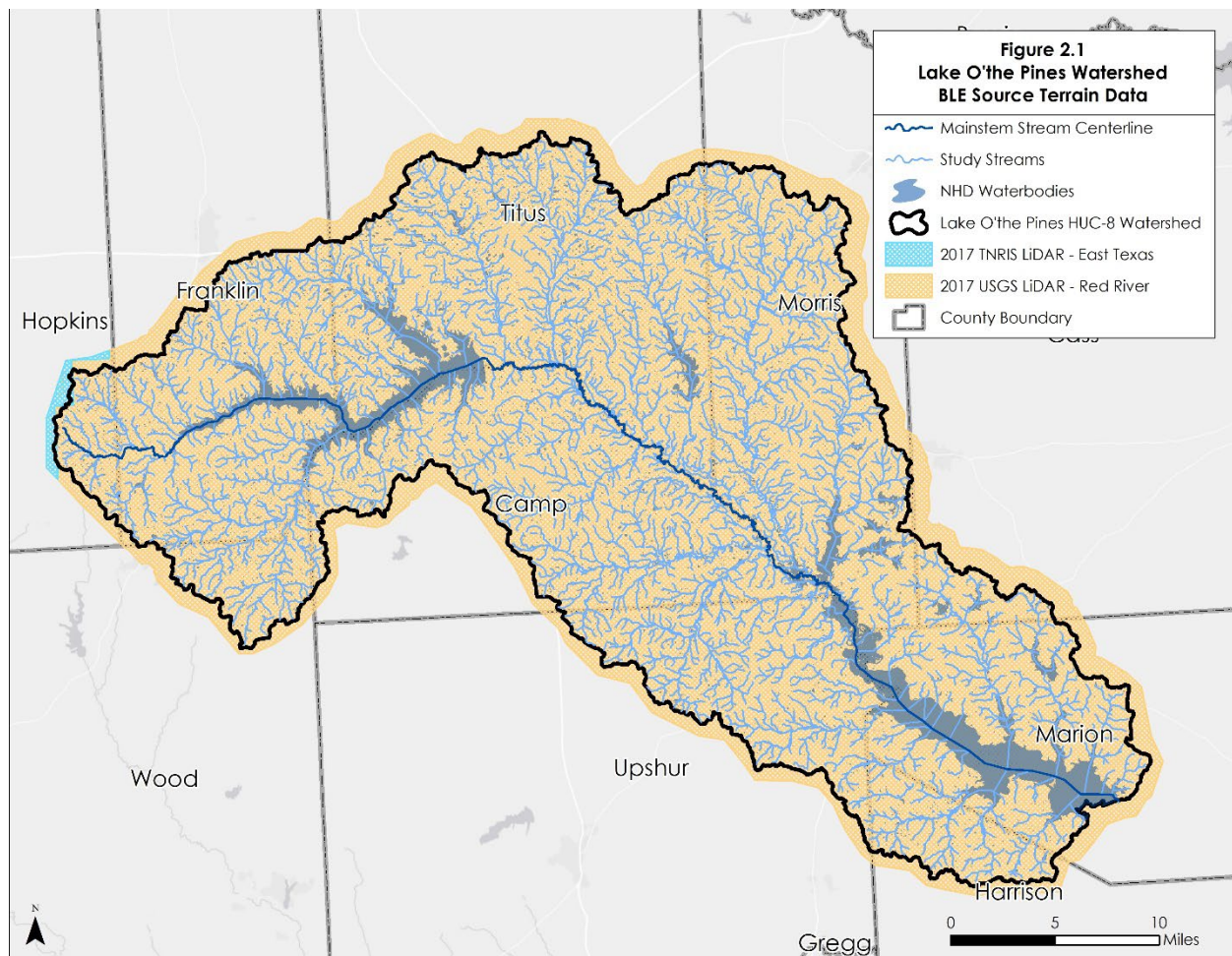


Figure 2.1: Lake O'the Pines Watershed BLE Source Terrain Data

2.1.2 Evaluation

A data coverage assessment was conducted to check for data gaps, extent, accuracy, and completeness. A review of related documentation, reports, indexes, and metadata associated with the leveraged datasets ensured each dataset meets FEMA accuracy requirements for topographic data. Decisions to leverage or exclude a dataset (or portion of it), were based generally on the following criteria coupled with engineering judgment:

- Data meets FEMA vertical accuracy standards (Table 2.1)
- Date of origination
- Data density and coverage

Table 2.1 depicts the Risk Map SID #43 vertical accuracy requirements based on flood risk and terrain slope within the floodplain being mapped.

Table 2.1: FEMA Vertical Accuracy Requirements for Leveraged Data

Level of Flood Risk	Typical Slopes	Specification Level	Vertical Accuracy*	LiDAR Nominal Pulse Spacing (NPS)
High (Deciles 1,2,3)	Flattest	Highest	24.5 cm / 36.3 cm	≤ 2 meters
High (Deciles 1,2,3)	Rolling or Hilly	High	49.0 cm / 72.6 cm	≤ 2 meters
High (Deciles 2,3,4,5)	Hilly	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Flattest	High	49.0 cm / 72.6 cm	≤ 2 meters
Medium (Deciles 3,4,5,6,7)	Rolling	Medium	98.0 cm / 145 cm	≤ 3.5 meters
Medium (Deciles 3,4,5,6,7)	Hilly	Low	147 cm / 218 cm	≤ 5 meters
Low (Deciles 7,8,9,10)	All	Low	147 cm / 218 cm	≤ 5 meters

*Vertical Accuracy at 95% Confidence Level (FVA or NVA)/ (CVA or VVA)

Table 2.2 depicts the complete list of source elevation data and attributes leveraged for the Lake O'the Pines Watershed BLE project. All datasets used for hydraulic analyses and mapping meet the highest specification level defined in Table 2.1. Further explanation of the Table 2.2 datasets can be referenced in Section 2.1.2.1.

Table 2.2: Source Topographic Data Available for the Lake O'the Pines Watershed

Year	Description	Data Type	RMSE	Source/Owner
2017	East Texas Lidar 2017	Airborne LiDAR	<10cm NVA	TNRIS
2017	Red River Lidar 2017	Airborne LiDAR	10.9 NVA	USGS

2.1.2.1 Lake O'the Pines Watershed Source Terrain Data

The source elevation data for the Lake O'the Pines Watershed are DEMs derived from USGS, TWDB and FEMA LiDAR data. Preprocessed Bare-earth Hydro-enforced DEMs from the acquiring entity (via TNRIS) were projected and adjusted as needed into one seamless DEM in Texas State Plane 4204 NAD83, Vertical Feet NAVD88. Bare-earth LiDAR data are typically made by filtering non-ground returns (e.g. buildings, vegetation, etc.) from the processed LiDAR returns. Figure 2.1 depicts the extent of the data defined in Table 2.2. Please see brief descriptions of the lidar sources below. For more detailed information, please see the attached LiDAR project report for each individual project.

2017 TNRIS East Texas LiDAR– The 2017 East Texas LiDAR was acquired from December 2016 through February 2017 with limited reflights in April 2017. The measured RMSE was documented as less than 10 cm Non-Vegetative Accuracy. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2017 TNRIS Red River LiDAR– The 2017 Red River LiDAR was acquired from January 2017 to March 2017. The measured RMSE was documented at 10.9 cm Non-Vegetative Accuracy. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using $RMSE(z) \times 1.9600$ as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2.1.3 Data Development Methodology

The source topographic data were processed for an area covering the Lake O'the Pines Watershed and contributing drainage areas for the Lake O'the Pines BLE modeling efforts. The topographic data for Lake O'the Pines Watershed was projected horizontally, as needed, to North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS) Texas N Central in feet (4202-SPC83). All topographic data were adjusted vertically, as needed, to NAVD88 in feet. Halff used a combination of ArcGIS and other software tools to apply any vertical datum shifts and/or any horizontal projection transformations to the topographic data.

2.1.4 DEM QA/QC

DEMs developed for use in the Lake O'the Pines Watershed BLE analysis were developed using a controlled process, evaluated, and assured by a topographic data development team and were evaluated and assured by the engineering team to meet the quality standards of the project. Quality assurance during the data development process includes, but is not limited to the following QC checks:

- Horizontal Projection Check
- Vertical Datum Check
- Resolution Check
- Format Check
- Seamless Data Check to ensure the DEM files are consistent and seamless along source data edges

The quality control after the development process by the topographic data development team included visual observations using hillshade, contouring, color rendering, and/or other visual aids to review and identify potential impactful anomalies within the DEM surface. This QC step included, but were not limited to the following QC checks:

- Seamless Data Check to ensure no voids along the edges and between the prioritized datasets
- NoData Value Check to ensure no null values
- Manual Elevation Check using hillshade rasters to find erroneous elevation issues
- Unit Consistency Check
- Legacy Cell Value Anomalies

Quality assurance conducted after the seamless DEM development conducted by the engineering team included visual and automated assessments to identify potentially impactful anomalies or slope changes that may adversely impact hydraulic computations.

The final DEM data developed for the Lake O'the Pines Watershed are assured to meet FEMA standards and present a representative surface developed from leveraged elevation data for the purposes of this BLE project.

2.2 2D BLE Methods

The following sections describe the 2D computational mesh and program setting considerations, followed by discussion and tabulation of hydrologic and hydraulic engineering methods and model inputs.

2.2.1 2D Computational Mesh and Settings

The HEC-RAS 2D computational mesh defines the extents of the 2D flow and can affect the accuracy of the 2D calculations. A denser mesh may provide more accurate results, but it can dramatically increase model run times. The original 2D mesh for the model was set as evenly spaced cells at approximately 200 feet. The mesh was further refined by placing breaklines along roads, berms, ridges, and other high ground that can impede flow as well as stream centerlines to allow flow conveyance. To ensure the entire Lake O'the Pines Watershed, including adjacent inflows, was represented accurately, an approximately 5,000-foot buffer was added to the HUC boundary. This buffer was used to capture inflows and produce mapping through the full extents of the HUC-8 boundary. It should be noted, the buffer was applied to the USGS HUC-8 boundary that was not modified based on topography. A hydro-corrected HUC-8 boundary was not used to meet FEMA's requirement to provide mapping through the full extent of the USGS HUC-8 watershed.

The HEC-RAS 2D computational mesh was created for Lake O'the Pines Watershed based on the USGS HUC boundaries using ArcGIS toolsets, such as smoothing and simplification routines; ultimately, significantly reducing the need for manual edits to mesh cells within HEC-RAS that happen to generate errors. The 2D mesh consists of 767,336 cells with a 200-foot nominal mesh cell size. Factors that result in either larger or smaller cell sizes included:

- Proximity to the edge of the 2D mesh
- Presence of breaklines
- Refinement of mesh for significant flood control features (levees, dams, etc.)

A 30-second time step was used in the HEC-RAS model, applying the Diffusion Wave (simplified Full Momentum) equations.

2.2.2 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires establishing a 2D computational mesh boundary as discussed previously, and often requires defining inflow boundary conditions in addition to excess precipitation applied to the mesh. For the Lake O'the Pines Watershed, excess precipitation was applied to the mesh and no additional inflows were required to be accounted for. Figure 2.2 shows the 2D computational mesh for the Lake O'the Pines Watershed, along with USGS peak streamflow gages pertinent to the study area. The development of the excess precipitation hyetographs for the 2D mesh is described in Section 2.2.3.

Outflow boundary conditions, allowing flow to leave the computational 2D mesh were utilized along basin boundaries. Unique outflow normal depth boundary conditions were established for riverine flows, while the remaining boundaries were added to allow flow to leave the model area freely. Normal depth was used for non-unique outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain data.

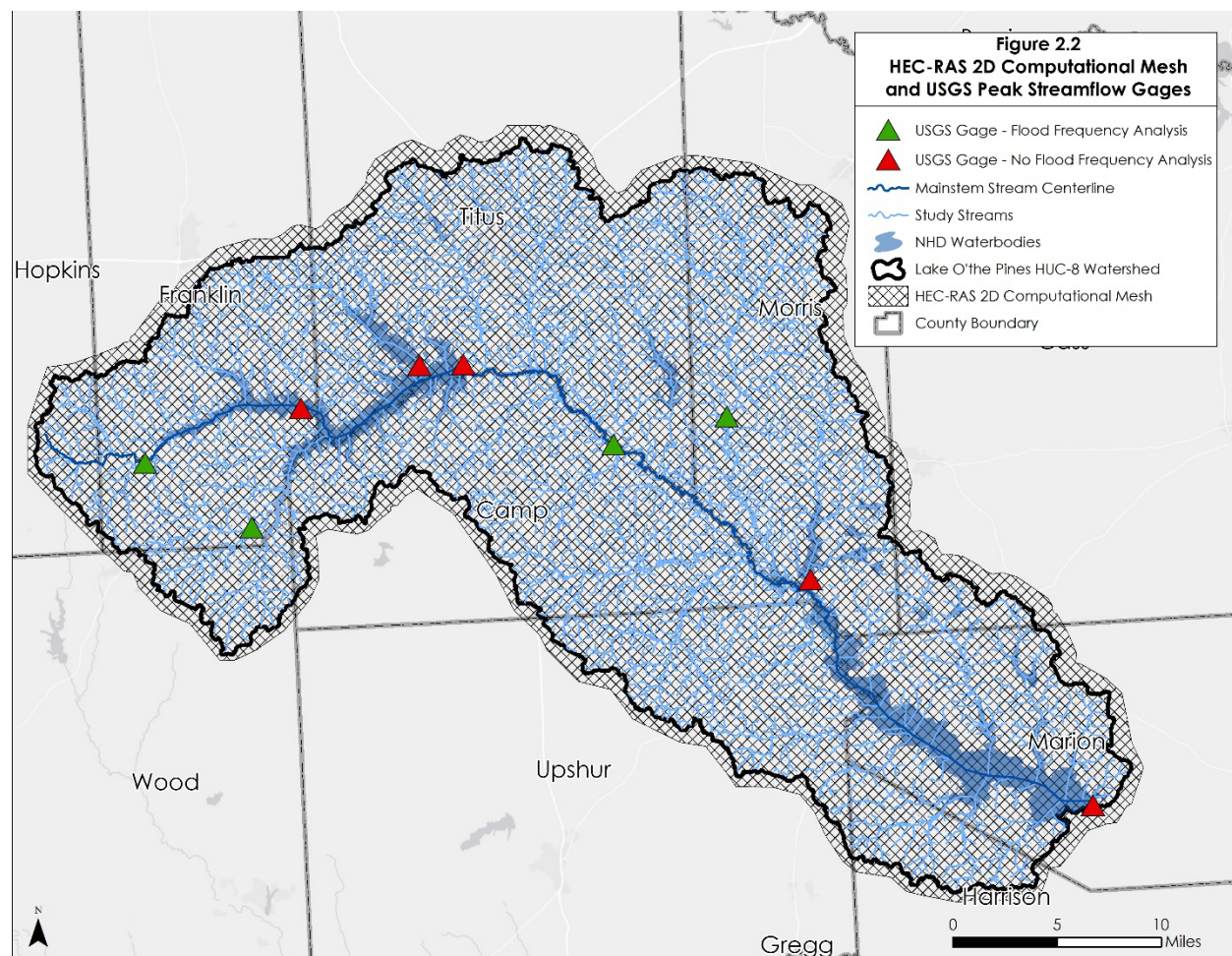


Figure 2.2: HEC-RAS 2D Computational Mesh and USGS Peak Streamflow Gages

2.2.3 Hydrology

HEC-HMS, Version 4.8, was used solely for the development of excess precipitation hyetographs which were applied to the 2D mesh. Precipitation frequency data published in NOAA Atlas 14, Volume 11 Version 2.0 (NOAA, 2018) were used for this study. These data were obtained from NOAA's Precipitation Frequency Data Server (PFDS) (<http://hdsc.nws.noaa.gov/hdsc/pfds/index.html>). The 10-, 4-, 2-, 1-, and 0.2-percent annual chance 24-hour precipitation depths for the watershed were determined by area-weighted intersection of gridded PFDS data within the study area. Excess precipitation for the 2D mesh was developed as described in Section 2.2.3.1. Lake O'the Pines is a headwater basin, so no inflow hydrographs were used.

A total of nine (9) USGS gages are found within Lake O'the Pines Watershed. No peak flow record data was found for USGS gage No. 07345900 – Lake O'the Pines near Jefferson, TX, USGS gage No. 07345500 – Ellison Creek Reservoir near Lone Star, TX, USGS gage No. 07344489 – Lake Bob Sandlin near Mount Pleasant, TX, USGS gage No. 07344488 – Monticello Reservoir near Mount Pleasant, TX, and USGS gage No. 07344484 – Lake Cypress Springs near Mount Vernon, TX. These five gages were excluded from the analysis. The streamflow gage data from the four remaining USGS gages were leveraged to estimate peak

flows for model validation purposes, as discussed in Section 2.3.1. The gages utilized for this study are presented in Table 2.3.

Table 2.3: USGS Peak Streamflow Gages

Gage ID	Flooding Source and Location	Published Drainage Area (mi ²)	Period of Record
07344482	Big Cypress Ck nr Winnsboro, TX	27	1974-1991
07344486	Brushy Ck at Scroggins, TX	23	1979-2004
07344500	Big Cypress Ck nr Pittsburg, TX	370	1943-2020
07345000	Boggy Ck nr Daingerfield, TX	72	1944-1977

Annual chance peak flows were calculated at each gage using USGS Bulletin 17B and 17C (EMA) methodology. The peak flows were computed using both methodologies and evaluated based on confidence of the gage analysis. Calculated discharges for the 1%, 1% plus, and 1% minus events used for comparison of flow validation within the upper (1% plus) and lower (1% minus) confidence intervals are presented in Table 2.4 for each gage utilized in this study.

Table 2.4: USGS Peak Streamflow Gage Analysis Results

Gage ID	Flooding Source and Location	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
07344482	Big Cypress Ck nr Winnsboro, TX	10,070	7,7702	14,530
07344486	Brushy Ck at Scroggins, TX	11,840	8,866	17,130
07344500	Big Cypress Ck nr Pittsburg, TX	21,970	19,200	25,930
07345000	Boggy Ck nr Daingerfield, TX	19,200	14,660	26,800

2.2.3.1 Excess Precipitation for 2D Computational Mesh

HEC-HMS, Version 4.8 was used to apply the SCS Curve Number method to calculate losses and define excess precipitation for each watershed. Temporal distributions of point rainfall totals were defined using frequency storm distributions. The plus and minus standard error for the 1-percent annual chance precipitation depths were determined as the upper and lower 84% confidence limits on the nominal 1-percent depth, assuming a normal distribution of the logarithms for the precipitation depths.

In addition to recurrence interval precipitation estimates, NOAA Atlas 14 provides 90% confidence intervals of reported precipitation values. On a normal distribution curve, 90% confidence intervals (i.e. the upper and lower 95% confidence limits) correspond to +/- 1.645 standard deviations. The 1% plus and minus events are defined to be one standard deviation above and below the 1% event.

Curve Numbers were computed by intersecting the National Land Cover Dataset (NLCD) 2019 coverage and NRCS soils data based on the matrix presented in Table 2.5.

Table 2.5: Land Use-Soils-CN Matrix for Computing Initial Curve Numbers

LU_GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	99	99	99	99
21	Developed Open Space	49	69	79	84
22	Developed Low Intensity	61	75	83	87
23	Developed Medium Intensity	81	88	91	93
24	Developed High Intensity	89	92	94	95
31	Barren Land	39	61	74	80
41	Deciduous Forest	30	55	70	77
42	Evergreen Forest	30	55	70	77
43	Mixed Forest	30	55	70	77
52	Shrub Scrub	30	48	65	73
71	Herbaceous	49	62	74	85
81	Hay Pasture	39	61	74	84
82	Cultivated Crops	51	67	76	80
90	Woody Wetlands	72	80	87	93
95	Emergent Herbaceous Wetlands	72	80	87	93

The time of concentration for the study area was approximated as the square root of the drainage area, then multiplied by 0.6 to compute the lag time. The lag time does not impact the excess rainfall hyetograph, so it was not necessary to compute a more accurate basin travel time. The table below shows the curve number and lag time values used in this study.

Table 2.6: Rainfall-Runoff Parameters (Curve Number, Lag Time)

Basin Description	CN	Tlag (min)
Lake O'the Pines	74	1,071

NRCS rainfall-runoff methods were used to define excess precipitation applied to the 2D mesh, including curve numbers for defining rainfall losses and lag time for transforming the runoff temporally. No routing was considered in the rainfall-runoff modeling. Frequency storm distributions were used for defining temporal distributions of point rainfall totals. Weighted average rainfall depths were calculated for the 10-, 4, 2, 1, and 0.2-percent ACEs. The weighted average rainfall depths for 1-percent plus and 1-percent minus rasters were also calculated using the upper and lower confidence intervals for the 1-percent event. These steps were performed for durations of 5-min, 15-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr and 24-hr. The weighted average rainfall depths were used to determine the excess precipitation in the HEC-HMS model.

Areal reduction was applied using TP40 curves and an assumption of storm area equivalent to approximately one half of the total study area. Table 2.7 provides the total rainfall depth for a 24-hour storm duration used for determining excess precipitation.

Table 2.7: Precipitation Rainfall Depths for Estimating Excess Precipitation for HEC-RAS 2D Computational Mesh

Sub-basin Description	Percent Annual Chance Precipitation Total (in)	Rainfall Duration (in)							
		5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
Lake O'the Pines	10yr	0.70	1.39	2.54	3.21	3.64	4.40	5.22	6.13
	25yr	0.81	1.62	2.96	3.79	4.32	5.28	6.30	7.42
	50yr	0.90	1.80	3.28	4.23	4.85	5.97	7.16	8.46
	100yr	0.99	1.97	3.60	4.69	5.40	6.70	8.08	9.57
	100yr minus	0.77	1.52	2.79	3.66	4.24	5.30	6.45	7.70
	100yr plus	1.21	2.41	4.42	5.71	6.57	8.10	9.71	11.43
	500yr	1.20	2.38	4.41	5.85	6.83	8.60	10.49	12.52

Figure 2.3 show the excess precipitation hyetographs applied to the 2D computational mesh.

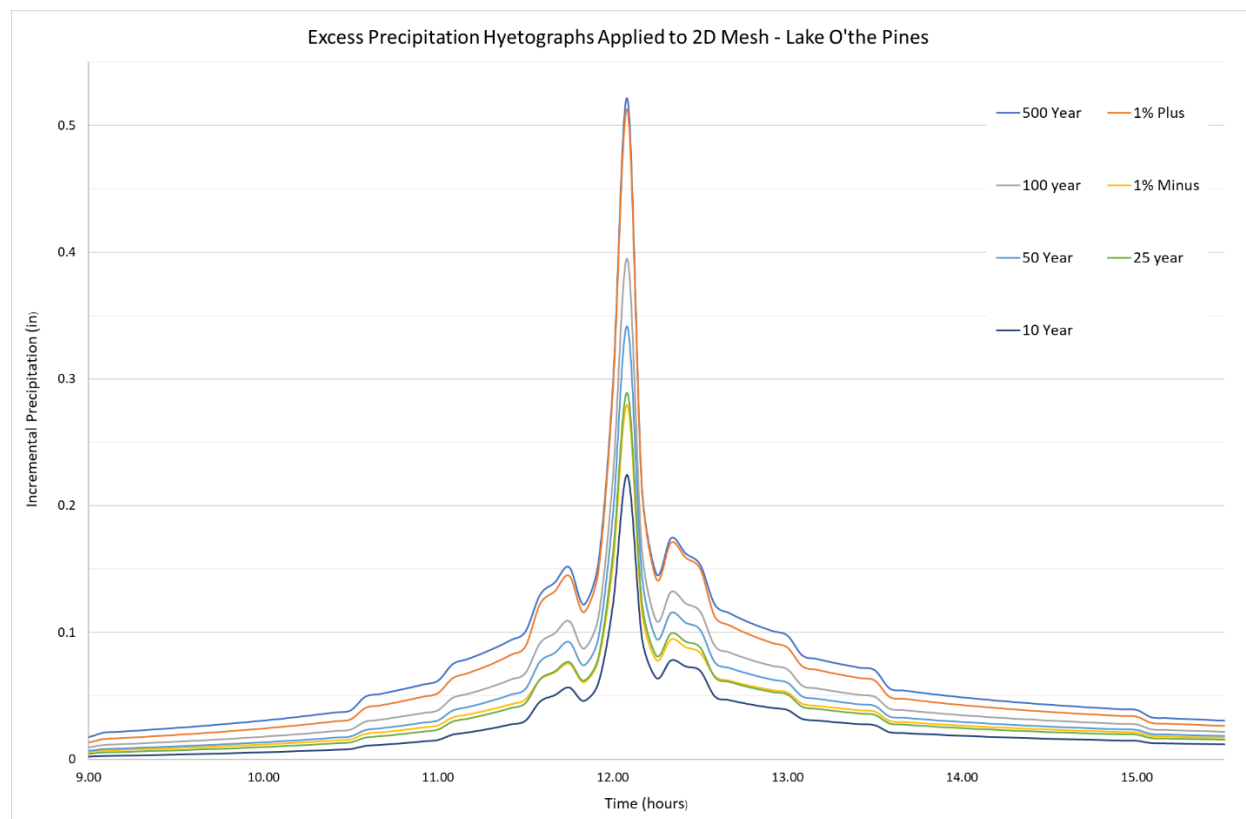


Figure 2.3: Excess Precipitation Hyetographs Applied to the Computational Mesh

2.2.3.2 Rainfall-Runoff Hydrograph Boundary Conditions

Inflow hydrographs were not used in the Lake O'the Pines 2D BLE model.

2.2.4 Hydraulics

This section describes the remaining hydraulic modeling considerations, including implementation of Manning's roughness values, breaklines, and hydraulic structures within the 2D computational mesh.

2.2.4.1 Roughness Coefficients

A Manning's n roughness coverage was developed for the 2D computational mesh using typical values for roughness for given NLCD land classifications. In several areas, the channel section land use indicated a Manning's n-value inappropriate for channel conveyance. A 20-foot buffer zone was created by automated processes around each stream centerline (mainstem and tributaries) to create a main channel roughness zone. The channel roughness zone was given a Manning's n value of 0.045, obtained from the HEC-RAS User's Manual, to ensure the channel 2D cells have appropriate conveyance. The table below shows a typical land use-roughness matrix used in defining the roughness coverage for the study area as well as the final Manning's roughness used based on the model validation. The final Manning n values for developed low intensity, developed medium intensity, developed high intensity, and shrub scrub were updated to more closely reflect current aerial imagery based on regionally accepted values and are thus lower than the HEC-RAS User's Manual range, provided below in Table 2.8.

Table 2.8: NLCD 2019-Manning's N Roughness Matrix

NLCD Classification	Manning's N	Minimum	Normal	Maximum
Open Water	0.025	0.025	0.038	0.050
Developed, Open Space	0.030	0.030	0.040	0.050
Developed, Low Intensity	0.040	0.060	0.090	0.120
Developed, Medium Intensity	0.060	0.080	0.120	0.160
Developed, High Intensity	0.075	0.120	0.160	0.20
Barren Land	0.025	0.023	0.025	0.030
Deciduous Forest	0.100	0.100	0.150	0.200
Evergreen Forest	0.100	0.080	0.120	0.160
Mixed Forest	0.100	0.080	0.140	0.20
Scrub/Shrub	0.035	0.070	0.115	0.160
Grassland/Herbaceous	0.025	0.025	0.038	0.050
Pasture/Hay	0.030	0.025	0.038	0.050
Cultivated Crops	0.025	0.020	0.035	0.050
Woody Wetlands	0.080	0.045	0.098	0.150
Emergent Herbaceous Wetland	0.075	0.050	0.068	0.085
Main Channel ¹	0.045			

Source: HEC-RAS 2D Modeling User's Manual

¹ Clean, winding, some pools and shoals, some weeds and stones, lower stages, more ineffective slopes and sections with a default 20 feet buffer from centerlines

2.2.4.2 Breaklines

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including, road embankments and hydraulic structures as well as stream centerlines. Road embankments were identified in ArcGIS and imported into HEC-RAS as breaklines to ensure that water was not routed past roads until it was deep enough to overtop the road. County, interstate, state recognized, and U.S. roads were incorporated for road breaklines from the ESRI North America Detailed Streets layer. The stream centerlines were input as breaklines to ensure cells lined up perpendicular to the stream and to capture stream conveyance. Stream centerlines were simplified to speed up editing and run times in HEC-RAS. Levees from the National Levee Inventory, and railroads from the TIGER Railroads layer were also incorporated. Additionally, several private dams and embankments were added as breaklines to better represent flow patterns through and around these structures.

2.2.4.2.1 Roads

Culvert crossings specifically were identified by intersections of the stream centerlines and road lines by automated processes and were modeled by burning channels through the embankment in the DEM to prevent unnecessary impoundment of water. This approach was used for most hydraulic structures because it could be implemented in ArcGIS on a large scale with much less effort than alternative methods. Since this an automated process, it was not possible to isolate specific culverts to burn through the DEM, thus conservative assumptions on width of opening were applied to not overestimate the release of water through the crossing.

Bridge/culvert crossings that were not processed out of the terrain data were modeled by inserting v-notches into the road breaklines at the points of intersection with the bridge/culvert crossings. The v-notches cause the grid cells to realign around the embankment and allow water to be routed across the embankment without creating artificial backwater. An example of the v-notch breakline approach is shown below.

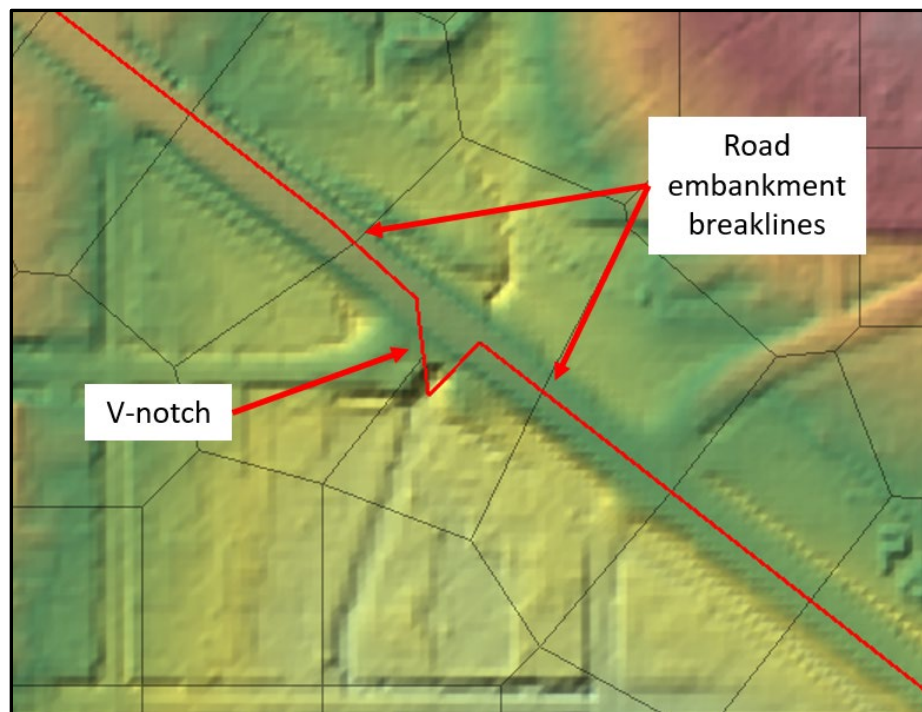


Figure 2.4 : V-Notch Breakline Approach at Bridge Crossing

2.2.4.3 Initial Conditions

Initial conditions were not used in the Lake O’the Pines 2D BLE model.

2.2.5 Special Assumptions

Within the Lake O’the Pines watershed five dams provide significant flood protection within the watershed and thus required a more detailed modeling approach than typically used in BLE. These dams include Franklin County Dam (Lake Cypress Springs), Ellison Creek Dam (Ellison Creek Reservoir), Monticello Dam (Lake Monticello), Fort Sherman Dam (Lake Bob Sandlin), and Ferrells Bridge Dam (Lake O’the Pines). Data for the dams was obtained from the Texas Commission on Environmental Quality (TCEQ) Central Registry for the Dam Safety Program and the United States Army Corps of Engineers (USACE) National Inventory of Dams (NID). To model the dam structures in HEC-RAS, 2D connection lines were used for each dam outflow structure.

Due to limited information and the high-level modeling approached used for BLE, additional information was not acquired for the gate operations of these structures. Future detailed studies in this area may consider coordination with TCEQ, USACE, and the dam owners to represent the spillway discharges more accurately. Further information about the dams modeled in the Lake O’the Pines Watershed can be found in Table 2.9 and the following sections.

Table 2.9: Lake O’the Pines Watershed Dam Summary

Dam Name	ID Number	Source of Information	Owner	County	Outfall Structure Type	Top of Dam Elevation (ft)
Franklin County Dam	TX03288	TCEQ	Franklin County	Franklin	Morning glory service spillway and emergency spillway	395.0
Ellison Creek Dam	TX04010	TCEQ	Lone Star Steel Company	Morris	Service spillway and emergency spillway	279.6
Monticello Dam	TX04013	TCEQ	Texas Utilities Electric Company	Titus	Gated service spillway and emergency spillway	352.0
Fort Sherman Dam	TX04785	NID	Titus County and TWDB	Titus	Gated service spillway and emergency spillway	349.0
Ferrells Bridge Dam	TX00020	NID	USACE	Marion	Gated service spillway and emergency spillway	277.0

2.2.5.1 Franklin County Dam (Lake Cypress Springs)

Franklin County Dam consists of a 10-foot diameter morning glory uncontrolled service spillway at crest elevation 378 ft-msl and an earthen uncontrolled emergency spillway that is 1,000 feet wide with a crest elevation of 387 ft-msl. The top of dam is at elevation 395 ft-msl. The service and emergency spillways were modeled using discharge rating curves developed outside of HEC-RAS using the weir equation and maximum discharge capacity values obtained from the TCEQ Central Registry. The weir/embankments for the 2D connectors with rating curves were based on the top of dam elevation since flows will be accounted

for through the rating curve. Figures 2.5 and 2.6 show the discharge-elevation curves used to model the service and emergency spillways, respectively.

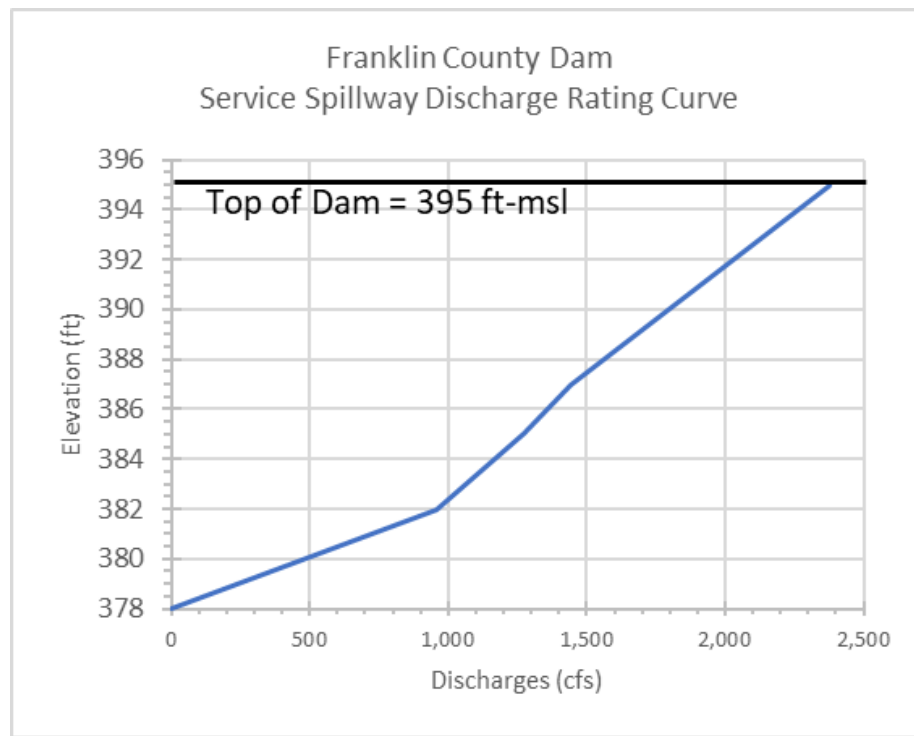


Figure 2.5: Franklin County Dam Service Spillway Discharge Rating Curve

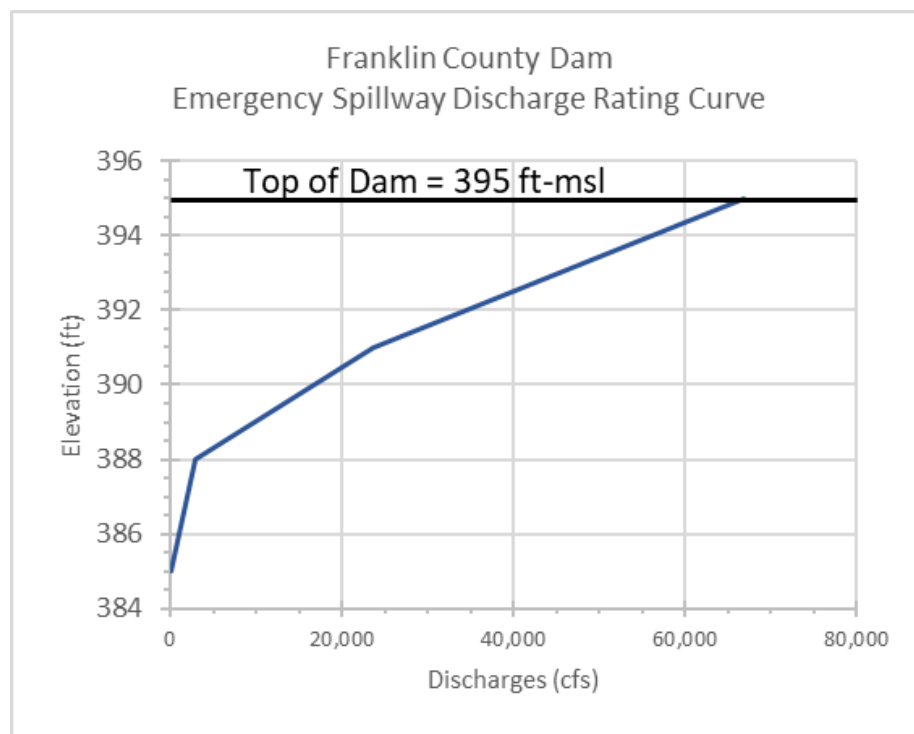


Figure 2.6: Franklin County Dam Emergency Spillway Discharge Rating Curve

2.2.5.2 Ellison Creek Dam

Ellison Creek Dam consists of a 300-foot-wide concrete broad-crested service/primary spillway at crest elevation 268 ft-msl and an earthen emergency spillway that is 530 feet wide with a crest elevation of 274.3 ft-msl. The top of dam is at elevation 279.6 ft-msl. The service and emergency spillways were modeled using a discharge rating curve developed outside of HEC-RAS using the weir equation and maximum discharge capacity values obtained from the TCEQ Central Registry. The weir/embankments for the 2D connectors with rating curves were based on the top of dam elevation since flows will be accounted for through the rating curve. Figures 2.7 and 2.8 show the discharge-elevation curves used to model the service and emergency spillways, respectively.

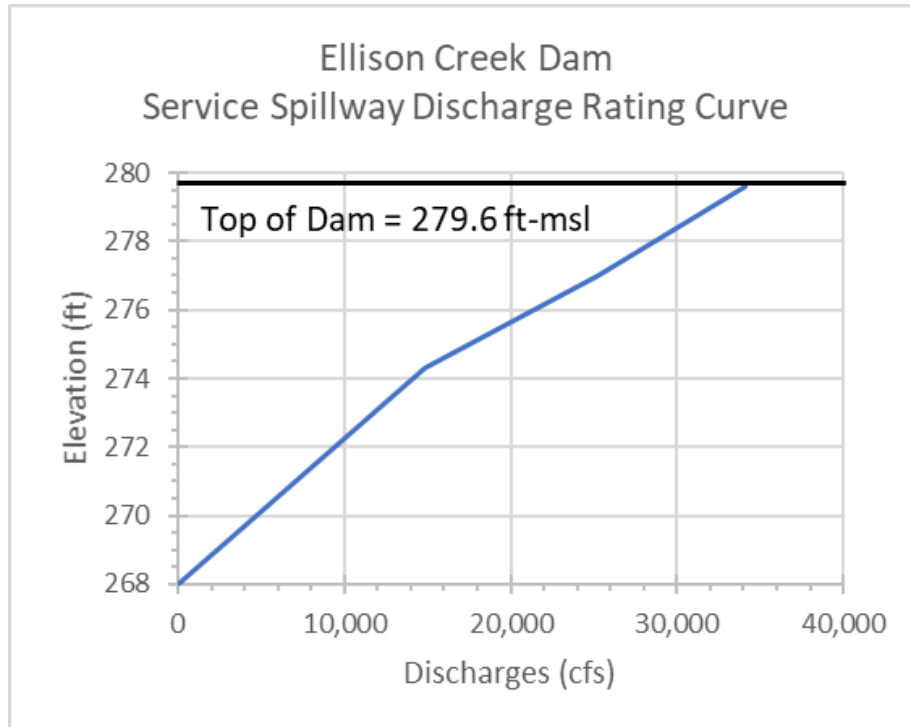


Figure 2.7: Ellison Creek Dam Service Spillway Discharge Rating Curve

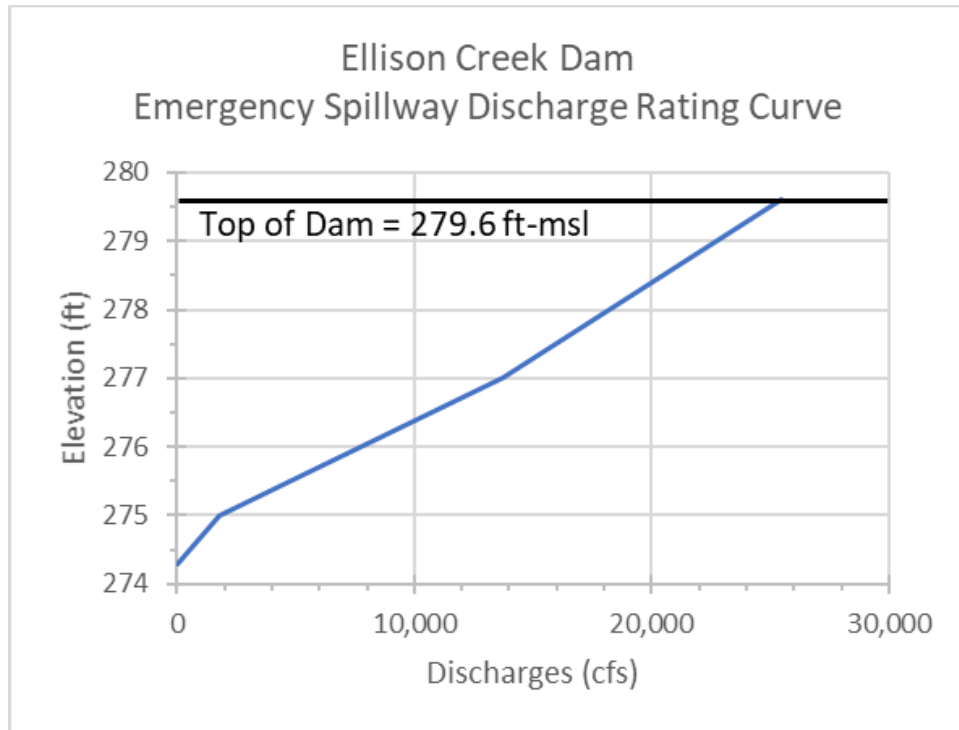


Figure 2.8: Ellison Creek Dam Emergency Spillway Discharge Rating Curve

2.2.5.3 Monticello Dam

Monticello Dam consists of a 160-foot-wide concrete ogee-crested service spillway at crest elevation 328 ft-msl and an earthen broad-crested emergency spillway that is 1,000 feet wide with a crest elevation of 343.5 ft-msl. The service spillway is controlled by four tainter gates, each 14 feet tall and 40 feet wide with a top of flood gate elevation of 342 ft-msl. The top of dam is at elevation 352 ft-msl. The service and emergency spillways were modeled using a discharge rating curve developed outside of HEC-RAS using the weir equation and data gathered from the NID. The weir/embankments for the 2D connectors with rating curves were based on the top of dam elevations since flows will be accounted for through the rating curve. For the service spillway, the gates were assumed to be fully open above elevation 342 ft-msl and no gate operations were modeled. Figures 2.9 and 2.10 show the discharge-elevation curves used to model Monticello Dam.

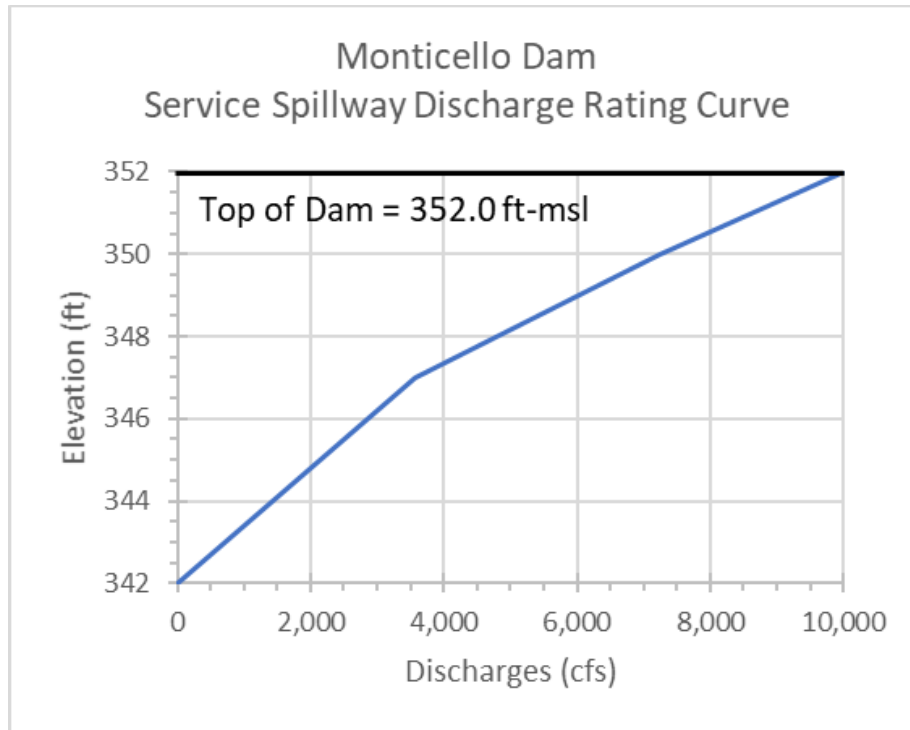


Figure 2.9: Monticello Dam Service Spillway Discharge Rating Curve

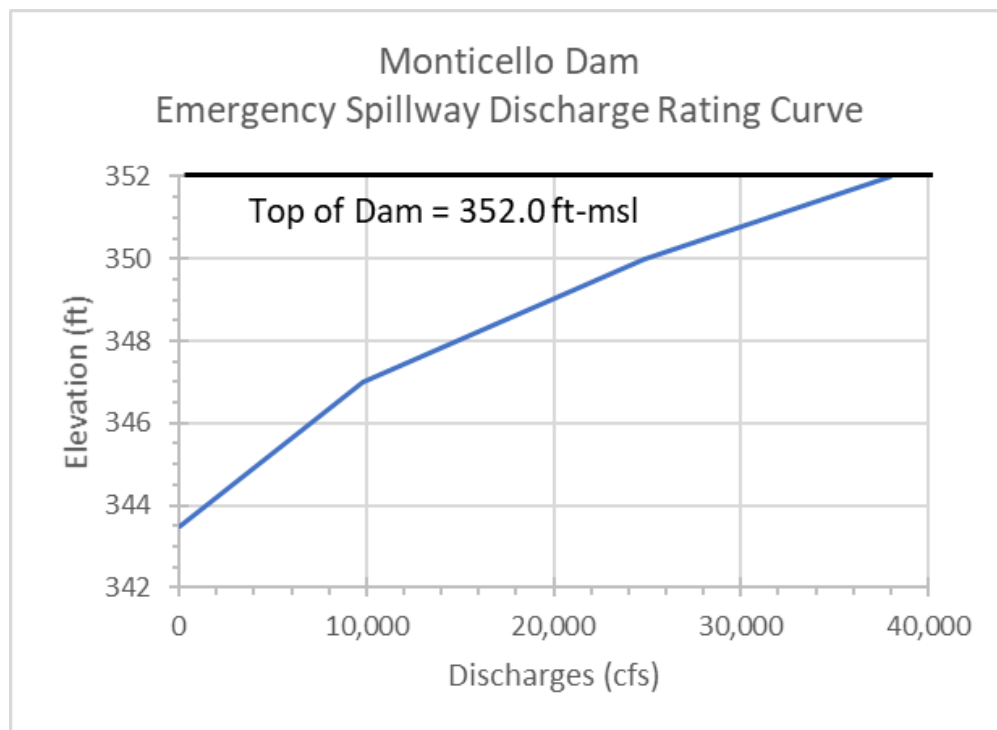


Figure 2.10: Monticello Dam Emergency Spillway Discharge Rating Curve

2.2.5.4 Fort Sherman Dam

Fort Sherman Dam consists of a 160-foot-wide concrete ogee-crested service spillway at crest elevation 316.5 ft-msl and an earthen broad-crested emergency spillway that is 4,500 feet wide with a crest elevation of 341.3 ft-msl. The service spillway is controlled by four tainter gates, each 22.5 feet tall and 40 feet wide. The top of dam is at elevation 349 ft-msl. The service and emergency spillways were modeled using the weir equation within HEC-RAS, each with a weir coefficient of 3.0 and 3.1 for the service and emergency spillways, respectively.

2.2.5.5 Ferrells Bridge Dam (Lake O'the Pines)

Ferrells Bridge Dam consists of an outlet works with two gate-controlled 10-foot-diameter conduits at and an uncontrolled ogee-crested spillway that is 200 feet wide with a crest elevation of 249.5 ft-msl. The top of dam is at elevation 277 ft-msl. The outlet works was modeled using a discharge rating curve developed from USACE data up to elevation 269.9 ft-msl when the outlet works is closed. To provide stability in the model, a gradual increase in discharge was used from elevation 228.5 ft-msl to 230.5 ft-msl. Figures 2.11 show the discharge-elevation curve used to model the Ferrells Bridge Dam outlet works. The spillway was modeled using the weir equation within HEC-RAS with a weir coefficient of 3.1 representative of the ogee-crested spillway shape.

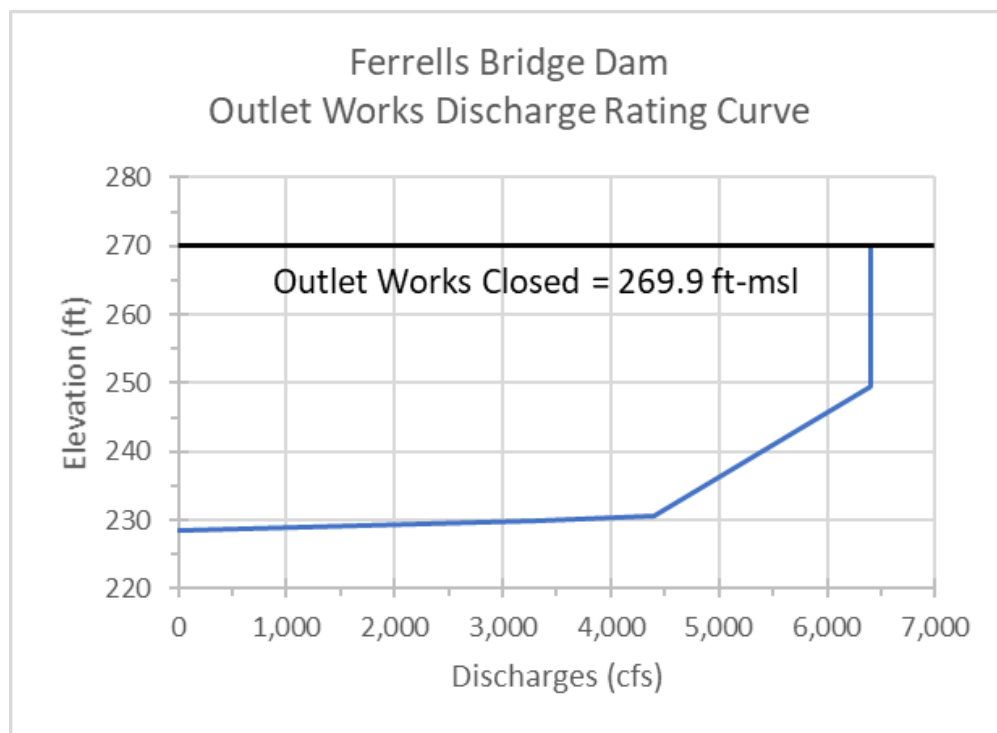


Figure 2.11: Ferrells Bridge Dam Outlet Works Discharge Rating Curve

2.3 Model Results

The 2D BLE results for the study produced flood risk mapping that compared reasonably well with the effective SFHA in most cases and provides additional estimated flood risk in areas that do not currently have an SFHA mapped. Additionally, the application of rain-on-grid modeling allowed for the identification of localized flood risk beyond the extents of the traditional SFHAs. Table 2.10 shows a comparison of some the effective BFE data with the model results. While the results provide context for flood risk communication as part of the Discovery process, and are scalable, the results require further analysis to be used for regulatory purposes. The validity of the 2D BLE results should be verified through community work map meetings before being applied as a regulatory product. The effective BFE for Hart Creek Tributary and Tributary 1 is lower than the model BFE, which is largely due land use changes, topographic differences, and the change of rainfall data.

Table 2.10: Effective and Model BFE Comparison

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
Hart Creek Tributary	18450	401	399.32	-1.68
Hart Creek Tributary	14750	373	372.26	-0.74
Hart Creek Tributary	10650	346	344.9	-1.1
Hart Creek Tributary	6117	328	326.03	-1.97
Tributary 3	570	380	380.17	0.17
Tributary 2	330	360	360.39	0.39
Tributary 1	1320	344	341.64	-2.36

2.3.1 Calibration & Sensitivity Analysis

Known USGS gages within the model area with more than 10-years of flow record were used for calibration and validation of the 1-percent ACE. Peak flows within the model were compared with Bulletin 17B analyses and EMA (Bulletin 17C) analyses of the gage data using PeakFQ, Version 7.3. Results of the flow comparisons are presented in Table 2.11.

Table 2.11: 1% Annual Chance Reasonability Comparisons

Flooding Source	USGS Gage Used for Verification	HEC-RAS 6.1 (2D)		Reference	
		WSEL (ft)	Discharge (cfs)	WSEL (ft) ¹	Discharge (cfs)
Brushy Creek at Scroggins, TX	07344486	359.57	11,201	359.06	11,840
Big Cypress Creek near Pittsburg, TX	07344500	265.10	17,544	264.71	21,970
Boggy Creek near Daingerfield, TX	07345000	275.87	19,516	276.21	19,200
Big Cypress Creek near Winnsboro, TX	07344482	389.20	12,029	388.74	10,070

¹ Water surface elevation is approximate based on PeakFQ input data and adjusted to NAVD 88 Datum.

To determine which factors were significantly impacting the model results, a sensitivity analysis was run to evaluate the impact of five specific parameters: Manning's roughness values, breaklines, hydrologic losses, initial conditions, and boundary conditions. Further discussion of the roughness coefficients can be found in Section 2.2.4.1. It was determined that enforced breaklines at major roads and centerlines were needed and are discussed further in Section 2.2.4.2. No changes were made to the precipitation. Table 2.12, Table 2.13, Table 2.14, and Table 2.15 summarizes the results of each run at each of the USGS gages.

Table 2.12: Sensitivity Analysis Results at USGS Gage 07344486

Iteration	Manning's N Zones	Breaklines	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	10,480	360.5
2	Woody Wetlands 0.12	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	9,865	360.65
3	Open water 0.025, Mixed Forest 0.12, Woody Wetlands 0.12, Deciduous Forest 0.12, Emergent Herbaceous Wetland 0.15	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	8,949	360.45
4	Open water 0.025, pasture/hay 0.04	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	10,948	359.7
5	Open water 0.025, pasture/hay 0.03, scrub/shrub 0.05	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	11,154	359.5
6 ¹	Minimum N values	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	11,201	359.57
					Gage Analysis:	11,840	359.06 ²

¹ Parameters from Iteration 6 were used for the final model² Water surface elevation is approximate based on PeakFQ input data.

Table 2.13: Sensitivity Analysis Results at USGS Gage 07344500

Iteration	Manning's N Zones	Breaklines	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	16,744	265.85
2	Woody Wetlands 0.12	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	15,079	266.15
3	Open water 0.025, Mixed Forest 0.12, Woody Wetlands 0.12, Deciduous Forest 0.12, Emergent Herbaceous Wetland 0.15	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	12,860	265.41
4	Open water 0.025, pasture/hay 0.04	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	16,915	264.94
5	Open water 0.025, pasture/hay 0.03, scrub/shrub 0.05	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	17,287	264.95
6 ¹	Minimum N values	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	17,544	265.1
					Gage Analysis:	21,970	264.71 ²

¹ Parameters from Iteration 6 were used for the final model.² Water surface elevation is approximate based on PeakFQ input data.

Table 2.14: Sensitivity Analysis Results at USGS Gage 07345000

Iteration	Manning's N Zones	Breaklines	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	16,895	276.0
2	Woody Wetlands 0.12	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	15,302	276.3
3	Open water 0.025, Mixed Forest 0.12, Woody Wetlands 0.12, Deciduous Forest 0.12, Emergent Herbaceous Wetland 0.15	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	14,615	276.14
4	Open water 0.025, pasture/hay 0.04	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	19,103	274.4
5	Open water 0.025, pasture/hay 0.03, scrub/shrub 0.05	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	19,490	273.5
6 ¹	Minimum N values	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	19,516	275.87
					Gage Analysis:	19,200	276.21 ²

¹ Parameters from Iteration 6 were used for the final model.² Water surface elevation is approximate based on PeakFQ input data.

Table 2.15: Sensitivity Analysis Results at USGS Gage 07344482

Iteration	Manning's N Zones	Breaklines	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	10,470	391.50
2	Woody Wetlands 0.12	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	9,630	392.00
3	Open water 0.025, Mixed Forest 0.12, Woody Wetlands 0.12, Deciduous Forest 0.12, Emergent Herbaceous Wetland 0.15	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	9,525	391.70
4	Open water 0.025, pasture/hay 0.04	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	11,730	390.60
5	Open water 0.025, pasture/hay 0.03, scrub/shrub 0.05	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	11,947	390.80
6 ¹	Minimum N values	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 30 sec	Normal Depth	12,070	389.20
					Gage Analysis:	10,070	388.74 ²

¹ Parameters from Iteration 6 were used for the final model.² Water surface elevation is approximate based on PeakFQ input data.

2.4 Challenges

Major challenges included a lack of peak streamflow records within the watershed. There were only four gages with significant data to validate model results. With limited gage data, the resulting mapping was compared to the FEMA effective mapping to ensure validity of the model. Within the watershed, there are two distinct terrain types: high ground with distinct channels mainly in the northern half of the watershed and low, flat ground (mostly lakes) at the southern portion of the watershed. The difference in terrain caused the time step used to be a factor in model stability. It was determined that a smaller time step (30 second) would be needed to stabilize the model in the Lake portion of the watershed, which caused longer model runtimes.

The estimation of the discharge rating curves for the dams within Lake O'the Pines Watershed was another significant challenge. Multiple iterations were performed to stabilize the model and complete the model validation. Due to limited information on the five dams within the study area and the high-level modeling approach used for BLE, additional information was not acquired for the dam operations of any of the included flood control structures.

Structures have not been added to the BLE model despite evidence of cross structures which allow the streams to convey water through numerous structures. In these locations, the model may be overestimating the water surface elevation upstream of the road until the road is overtopped and underestimating the water surface elevation downstream of the road.

HEC-RAS, Version 6.1, has an apparent bug that was identified in reviewing isolated areas of flooding. In these areas, the lower frequency events (ex. 10-percent) showed higher water surface elevations than the higher frequency events (ex. 0.2-percent). This was reviewed in multiple versions of HEC-RAS and was confirmed to occur in Version 5.7, 6.1 and 6.2. It is unknown why this may occur; however, the model does not experience instabilities and the mainstem floodplains have not shown this occurring when reviewing profile lines. In review of the model setup, stability and results, the flood extent results appear appropriate and impacts due to the bug are likely negligible.

HEC-RAS, Version 6.1 has a known error in the rain on mesh interpolation of flood depths between adjacent cells in the overbank area. This error produces artificially higher depths of flooding on the flood fringe referred to as cupping. Since this is a known issue in HEC-RAS and HEC is working on a solution, effort to remove these errors from the flood extents was not performed. Figure 2.12 below provides an example of cupping for reference. Once a solution is provided by HEC, it may be possible to update mapping to reduce and/or remove the cupping effects on the fringe of the floodplains.

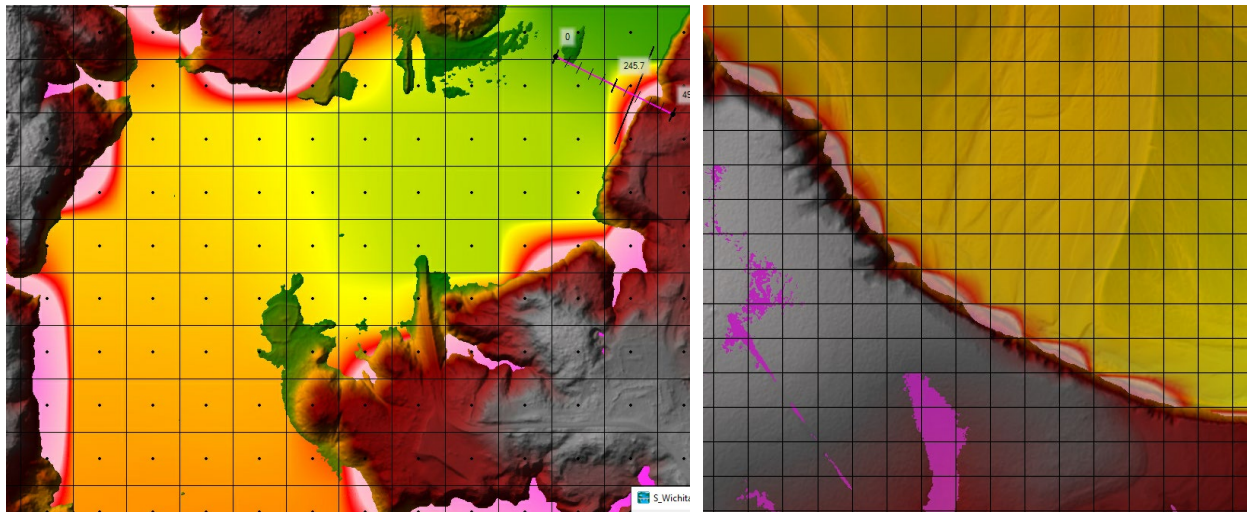


Figure 2.12: Cupping Examples

2.5 Recommendations

This study provides significant information useful for flood identification and communication among those affected. The study is highly scalable, and stakeholder input and further analysis would enhance the product and inform implementation of regulatory flood hazard areas. In addition, the validity of the 2D BLE results should be verified through community work map meetings before being applied as a regulatory product.

03 Floodplain Mapping and Effective Zone A Validation

The following sections provide a synopsis of how raw modeled depths were translated into SFHAs. In addition to developing a new SFHA, the BLE model data was leveraged to validate the effective zone A studies within the project footprint. The results of the validation effort can be found below in section 3.2.

3.1 Special Flood Hazard Area

3.1.1 Model Outputs

The floodplains are derived from the raw modeled depth grids using the maximum value. These depth grids are exported from HEC-RAS as TIFF format rasters with an interpolated rendering that slope values at the center and along the faces/edges of the computational mesh cells. Using GIS, the TIFF rasters are post processed into a 10-percent non-regulatory feature class, 1-percent ACE SFHA and 0.2-percent shaded X polygons.

3.1.2 Methodology

The use of 2D modeling methods results in water surface elevation values at every cell in the model's computational mesh. In order to represent the desired model results and eliminate extraneous disconnected cells, post processing of the depth grids is required. For the purposes of the Lake O'the Pines BLE study, floodplain mapping delineation was completed using connected raster cells at the extent of the CNMS mapped and unmapped features in the project footprint. Converting the raster data to polygon features enabled an intersection of modeled results to the CNMS and effective zones to create the SFHA and 0.2-percent shaded X features. Because the new mapping, based on gridded engineering, retains the blocky shape of a raster, a simplification process was applied using GIS to smooth the boundaries using a 10-foot smoothing threshold. These processes remove unnecessary points, bends, and angles while preserving the natural shape of the polygon. Furthermore, small voids, or "holes" inside of the floodplain footprint were aggregated with the larger surrounding polygons to merge them and make the floodplain complete. In alignment with the TWDB's 2D BLE Guidelines (May 2022) floodplain polygons were cleaned against the criteria provided below in Table 3.1 which provides thresholds for mapping removal based on depth and area of flood risk.

Table 3.1: Mapping Threshold Matrix

Area (ac)	Depth (ft)
< 0.33	-
0.33 - 0.5	< 0.33
0.5 - 1.0	< 0.25
1.0 - 2.0	<0.1

For example, if flooding polygons were disconnected from a flooding source and less than two acres in area and 0.1 feet of depth, the polygon was removed from the SFHA. These edits align to the mapping standards adopted by the TWDB and those required by FEMA.

In addition to the SFHA, all other flooding associated with the 1- and 0.2-percent raw results were retained as "on the shelf" data that may be leveraged for future needs and analysis. This information is available in the included Supplemental Data associated with this study.

3.1.3 Flood Hazard Area Layer

Special Flood Hazard Areas (SFHA), as noted above, were developed to at least the extent of the CNMS features and up to 0.1 square mile drainage area and effective zone A study locations. The Regional CNMS database, National Flood Hazard Layer, and paper inventory were used as reference data to ensure extent of the BLE results represents appropriate current flooding extent coverage, at a minimum.

The 0.2%-percent flood areas were produced using the same methods as the 1-percent SFHA. After both layers were developed, a union of the two products was performed to develop the deliverable format EBF_E_FLD_HAZ_AR.

3.1.4 Mapping Considerations

3.1.4.1 Ponds

Numerous ponds exist throughout the Lake O'the Pines Watershed. Due to the nature of 2D BLE and the large mesh cells used for modeling, the entire extent of smaller, isolated ponding areas is not always fully mapped in the raw model output. To identify flood risk in these areas, the pond footprints were merged in by automated processes using the best available National Hydrography Dataset. This dataset has its own limitations in that it is not current to current topography or LiDAR and may not align completely to the present-day pond footprints. However, it was used as the best available at the time of the study. A nominal depth of 0.1-foot was used for any areas merged into the floodplain that were not in the raw model results and the water surface elevation was interpolated. The water surface elevations in these areas should not be considered correct and would require further study to refine the correct water surface elevation based on detailed modeling.

3.1.4.2 Mapping Tie-Ins

Watershed tie-ins required manual review and coordination between HUCs to ensure tie-ins could be met within the required 0.5-foot FEMA requirement. For Lake O'the Pines, a significant tie-in occurs downstream of the Lake O'the Pines watershed, on the downstream side of the Ferrells Bridge Dam at Lake O'the Pines. This area downstream of the dam is located in the Caddo Lake Watershed, however, is modeled as part of the Lake O'the Pines BLE model using an overlapping mesh to determine the appropriate mapping tie-in location and the mapping is incorporated into the Caddo Lake mapping.

3.1.4.3 Centerline Alignment

After completion of the FLD_HAZ_AR, the S_WTR_LNs (centerlines) were reviewed for containment within the 1-percent ACE floodplain. Any centerlines that were 50-feet or greater in length outside of the 1-percent floodplain extent were realigned for containment.

3.2 Validation of Effective Zone A SFHA

The following summarizes the results of the CNMS validation assessments for the effective Zone A studies in the Lake O'the Pines Watershed.

3.2.1 Initial Assessment A1 – Significant Topography Update Check

The significant topography update check determines whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. If the effective studies were based on topographic data derived from LiDAR then A1 is set to PASS. If the effective studies were not based on LiDAR then A1 is set to FAIL. If the topographic data source was not provided, then an

assumption of studies with effective dates prior to 2000 were assumed to be non-LiDAR based studies and studies completed after 2000 were assumed to have used LiDAR.

3.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

The significant hydrology changes check determines whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent ACE flow. New regression equations were made available for Texas in 2009. Thus, effective studies completed prior to 2009 are assumed to FAIL the A2 assessment while studies completed after 2009 are assumed to PASS the A2 assessment. If already attributed as PASS in the CNMS database, then A2 classification was maintained as such.

3.2.3 Initial Assessment A3 – Check for Significant Development

The significant development check, using the National Urban Change Indicator (NUCI) dataset, assesses increased urbanization in the watershed of the BLE. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15 percent or more and has increased by 50 percent or more since the effective analysis, the study would fail this check. The check for significant development in the Lake O'the Pines Watershed was completed by evaluating percentage of urban change at the HUC-12 level. The entire watershed is classified as rural, and all reaches were set to PASS for this assessment.

Table 3.2 presents the summarized results of checks A1 through A3.

Table 3.2: A1-A3 Validation Results

Assessment Checks	Pass / Fail	Notes
A1 – Topography	Pass / Fail	LiDAR significantly better than effective USGS topo source/Effective mapping leveraged LiDAR data.
A2 – Hydrology	Pass / Fail	Effective hydrology methods are unknown
A3- Development	Pass / Fail	Less than 15% of study area is under urban cover/>50% increase in urban area in an urban HUC-12

3.2.4 Validation Check A4 – Check of Studies Backed by Technical Data

Zone A studies that pass all initial assessment checks described above may be categorized as “Valid” in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If the effective Zone A study passes all initial assessment checks, but is not supported by modeling, or if the original engineering method used is unsupported or undocumented, a comparison of the BLE results and effective Zone A's is performed.

If the effective study was model backed, then A4 is set to PASS. If the effective study was not model backed, then A4 is set to FAIL. If it was unknown if the study was model backed or not, then it was assumed it was not model backed and the A4 assessment was set to FAIL.

Due to lack of documentation of the original engineering methods in the Lake O'the Pines Watershed, check A4 has been marked as FAIL for most parts of this study and left as PASS if it was already identified as such in previous CNMS.

3.2.5 Validation Check A5 – Comparison of BLE and Effective Zone A

The effective Zone A comparison was performed at the full extent of the Lake O'the Pines Watershed. The validation of the effective Zone A boundaries using 2D flood hazard products differ from the standard 1D

methods due to the lack of cross sections and their use with standard FBS methodology. For this 2D study, the effective A zone boundaries were compiled using the National Flood Hazard Layer and Core Logic effective digital uplift product. These data were dissolved to one continuous A-zone layer, which then had points placed along its perimeter every 200 feet.

For each test point, a 75-foot buffer polygon was created. Using this buffer, the minimum and maximum values of the DEM were extracted, as a proxy for the effective base flood elevation. The minimum value of the 1% minus raster, and the maximum value of the 1% plus raster are also extracted. These 1% plus maximum and 1% minus minimum values are products of the new 2D BLE study and act as the vertical tolerance. The test point passes if the DEM maximum value is less than or equal to the 1% plus maximum value and the DEM minimum value is greater than or equal to the 1% minus minimum value. This can be visualized as a short 75-foot radius cylinder, with a height of 1% plus maximum – 1% minus minimum. This test verifies that at least one point from the ground surface (i.e. proxy BFE) falls both vertically and horizontally within this range.

3.2.6 Validation Results

All 579.6 total miles of available CNMS features representing the effective Zone A studies were categorized as shown in Table 3.3 and illustrated in Figure 3.1. Table 3.4 summarizes the validation results based on the individual HUC 12 watersheds within Lake O'the Pines Watershed.

Table 3.3: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	179.1
UNVERIFIED	BEING STUDIED	400.5

Table 3.4: HUC 12 Zone A Validation Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)
Watershed Name	Watershed Number					
Glade Branch-Big Cypress Creek	111403050101	416	36	380	91.3	PASS
South Fork Brushy Creek-Brushy Creek	111403050201	1,556	260	1,296	83.3	FAIL
Brushy Creek-Big Cypress Creek	111403050202	431	184	247	57.3	FAIL
Jakes Creek-Big Cypress Creek	111403050203	701	173	528	75.3	FAIL
Blundell Creek-Big Cypress Creek	111403050204	2,125	655	1,470	69.2	FAIL
Tankersley Creek-Big Cypress Creek	111403050301	2,167	414	1,753	80.9	FAIL
Hart Creek	111403050302	2,819	418	2,401	85.2	PASS
Walkers Creek-Big Cypress Creek	111403050303	1,188	358	830	69.9	FAIL
Welsh Reservoir-Big Cypress Creek	111403050304	2,781	709	2,072	74.5	FAIL
Little Boggy Creek-Boggy Creek	111403050305	2,261	570	1,691	74.8	FAIL
Whitmore Branch-Boggy Creek	111403050306	2,160	698	1,462	67.7	FAIL
Kitchen Branch-Prairie Creek	111403050307	395	45	350	88.6	PASS
Headwaters Greasy Creek	111403050308	2,113	336	1,777	84.1	FAIL
Brutons Creek	111403050309	2,662	752	1,910	71.8	FAIL
Little Creek-Big Cypress Creek	111403050310	1,146	463	683	59.6	FAIL
Jones Creek-Big Cypress Creek	111403050401	980	386	594	60.6	FAIL
Meddlin Creek-Big Cypress Creek	111403050402	1,614	289	1,325	82.1	FAIL

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)
Watershed Name	Watershed Number					
Alley Creek	111403050403	656	142	514	78.4	FAIL
Sandy Creek-Big Cypress Creek	111403050404	340	51	289	85.0	FAIL
Johnson Creek	111403050405	235	32	203	86.4	PASS
Arms Creek-Big Cypress Creek	111403050406	986	222	764	77.5	FAIL
Hurricane Creek-Big Cypress Creek	111403050407	229	33	196	85.6	PASS

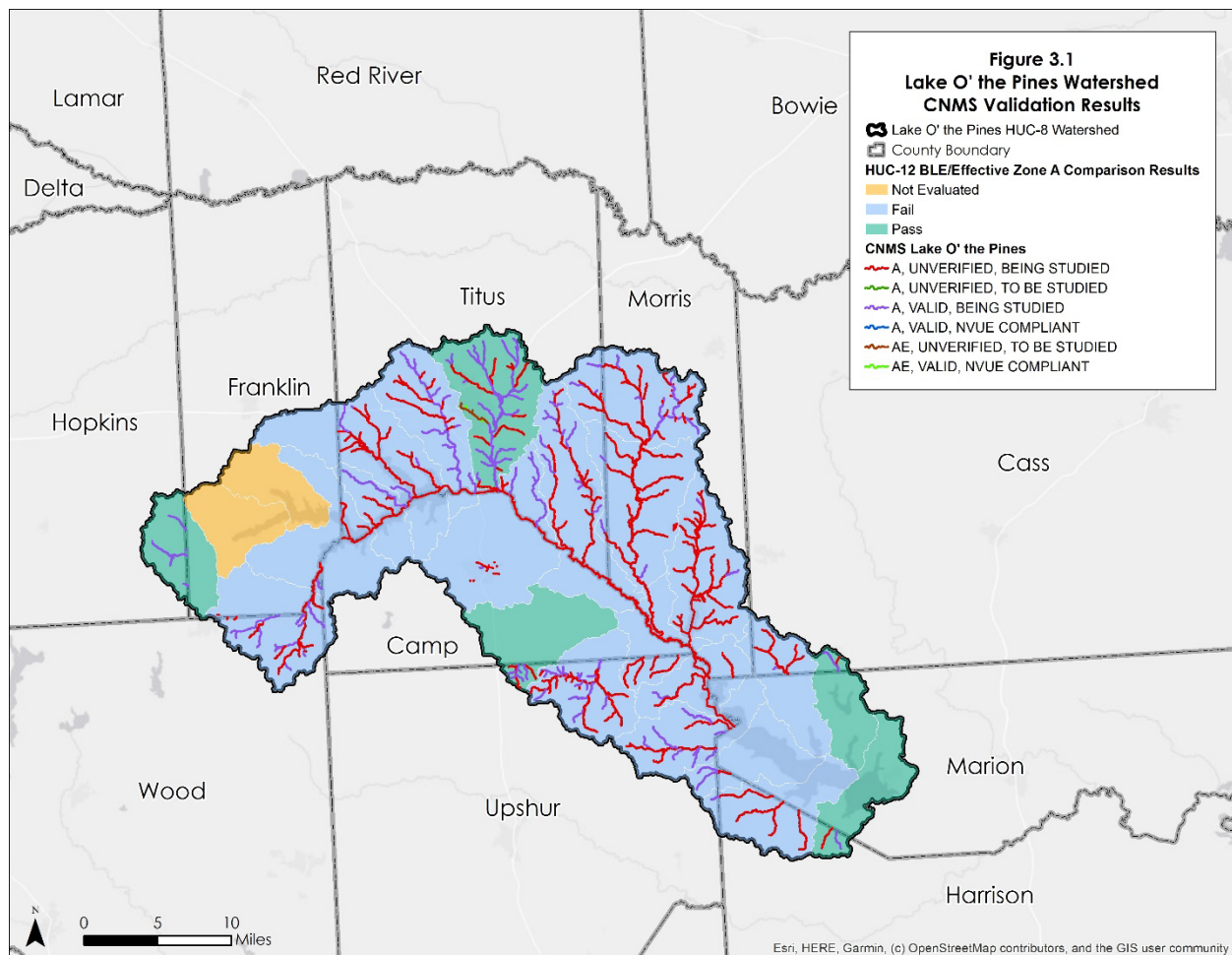


Figure 3.1: Lake O' the Pines Watershed CNMS Validation Results

3.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent ACE depth grid was used to calculate the potential flood losses. The loss results are stored in the S_FRAC_AR spatial file within the FRD geodatabase. All results are reported in whole dollar values.

Hazus Version 5.1 (SP02) was used for the basic and refined loss analysis.

The losses are reported via census blocks. It is important to note that Hazus Version 5.1 (SP02) uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by bodies of water, wetlands, or forests) from the census blocks, changing their shape and reducing their size in these areas. For more information on dasymetric data visit FEMA's Media Library for the Hazus-MH Data Inventories: Dasymetric vs. Homogenous, or Hazus 3.0 Dasymetric Data Overview.

Hazus analysis was performed by county within the project watershed extents for the 1-percent return period to ensure proper model processing. A summary of results per county for the 1-percent ACE scenario is shown in Table 3.5.

Table 3.5: Hazus 5.1 (SP02) Results for 1-percent-annual-chance (100 year) scenario for Lake O'the Pines Watershed, Texas

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Cass	\$43,605,000.00	\$900,796,000.00	\$583,232,000.00
Camp	\$1,366,000.00	\$35,243,000.00	\$17,840,000.00
Franklin	\$19,263,000.00	\$585,024,000.00	\$309,519,000.00
Harrison	\$2,651,000.00	\$94,174,000.00	\$49,173,000.00
Hopkins	\$622,000.00	\$51,416,000.00	\$26,625,000.00
Marion	\$8,142,000.00	\$256,435,000.00	\$133,971,000.00
Morris	\$48,864,000.00	\$791,642,000.00	\$505,717,000.00
Titus	\$137,509,000.00	\$1,936,072,000.00	\$1,373,602,000.00
Upshur	\$11,289,000.00	\$280,262,000.00	\$165,541,000.00
Wood	\$3,202,000.00	\$110,867,000.00	\$62,393,000.00
Total	\$276,513,000.00	\$5,041,931,000.00	\$3,227,613,000.00

04 References

1. Chow, Ven T. "Development of Uniform Flow and It Formulas." *Open Channel Hydraulics*. Caldwell, NJ: Blackburn, 1959. 109-113. Print.
2. City of Dallas, "Drainage Design Manual." September 2019 (https://dallascityhall.com/departments/public-works/DCH%20Documents/Public%20Works/pdf/Drainage%20Design%20Manual_091019.pdf).
3. FEMA, "Coordinated Needs Management Strategy (CNMS) Technical Reference", November 2021 (https://www.fema.gov/sites/default/files/documents/fema_CNMS-technical-reference_112021.pdf).
4. FEMA, "Data Capture Technical Reference", November 2021, (https://www.fema.gov/sites/default/files/documents/fema_data-capture-technical-reference_112021.pdf).
5. FEMA, "Flood Risk Database Technical Reference", February 2018 (https://www.fema.gov/sites/default/files/2020-02/Flood_Risk_Database_Technical_Reference_Feb_2018.pdf).
6. FEMA, "Guidance for Flood Risk Analysis and Mapping – Base Level Engineering (BLE) Analyses and Mapping", February 2018. (https://www.fema.gov/media-library-data/1526489690918-2862bece100f28564c4167aaf4b2378b/Base_Level_Engineering_Guidance_Feb_2018.pdf).
7. NOAA, "NOAA Atlas 14 Precipitation-Frequency Atlas of the United States", 2013. Volume 9, Version 2.0. (https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume9.pdf).
8. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (March 2019). HEC-RAS River Analysis System, Version 5.0.7 Davis, California.
9. USGS, "Estimating Magnitude and Frequency of Floods Using PeakFQ Program: USGS Fact Sheet", 2006.
10. USGS, "Estimating Magnitude and Frequency of Floods Using PeakFQ Program: USGS Fact Sheet", 2006.
11. USGS. Multi-Resolution Land Characteristics Consortium. *National Land Cover Database 2019*. (<https://www.mrlc.gov/data/nlcd-2019-land-cover-conus>).