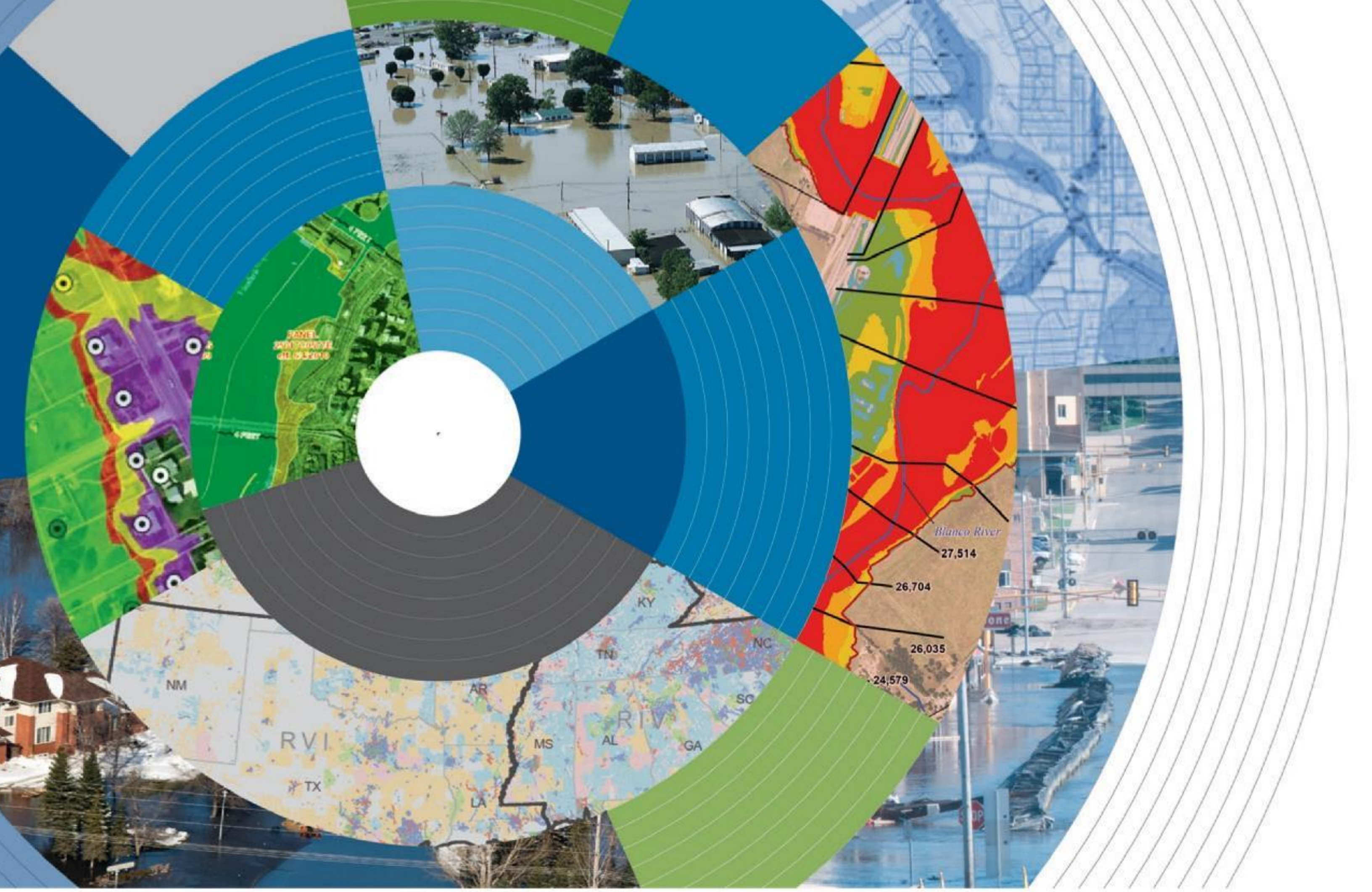

Base Level Engineering Report

Lower Brazos San Gabriel (HUC8 12070205)

SEPTEMBER 2024

Version 2.4

Texas Water Development Board

Report Prepared for:

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

Report Prepared by:

Freese & Nichols, Inc Team
Doucet & Associates, Inc.
7401 B Hwy 71 West, Suite 160
Austin, Texas 78735

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DRAFT

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DOUCET & ASSOCIATES, INC.

TEXAS REGISTERED ENGINEERING FIRM F-3937

Table of Contents

Executive Summary

The Texas Water Development Board (TWDB) contracted with the Freese and Nichols, Inc. (FNI) team in September 2021 to develop Base Level Engineering for multiple HUC8 Watersheds within the State. Doucet & Associates, Inc. (Doucet), as a subcontractor and member of the FNI Team, will complete a Base Level Engineering (BLE) analysis for the Lower Brazos San Gabriel watershed in Central Texas, to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). This BLE study will provide significant data for several Texas counties previously lacking modernized flood models.

The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory-quality 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.

Flood discharges and water surface elevations for this study were calculated by utilizing the rain-on-grid two-dimensional (2-D) modeling capabilities of the Hydrologic Engineering Center's River Analysis System (HEC-RAS), which translates rainfall into runoff based on an underlying terrain and various other physically based parameters. 2D HEC-RAS models were developed in accordance with the 2019 FEMA Region 6 Base Level Engineering Submittal Guidance, which relies heavily on *HEC-RAS River Analysis System, 2D Modeling Users' Manual 5.0* (Bruner, 2016). All models were ran in the HEC-RAS program version 6.3.

FEMA's Community Needs Management Strategy (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. Based on the validation assessments and BLE comparison results described in this report, the CNMS inventory of Zone A studies in the Lower Brazos San Gabriel Watershed study area has been updated. Total miles in each validation category are summarized in **Table 1**.

Table 1: Zone A Validation Results

Validation Status	Status Type	Total Mileage
Valid	Being Studied	426
Unverified	Being Studied	654
Assessed	Being Studied	388

1.0 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 traditional model development procedures to produce regulatory quality 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 Coordinated Needs Management Strategy (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 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.

TWDB contracted the Freese and Nichols team to complete a BLE analysis for the Lower Brazos San Gabriel Watershed in Central Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The Lower Brazos San Gabriel Watershed Phase 0 project consists of performing BLE modeling and analyses for the Lower Brazos San Gabriel River Watershed (HUC-12070205) located in Central Texas. The total area for the watershed is approximately 1,358 square miles and has an estimated population of 600,000 (2019 Census).

The Lower Brazos San Gabriel Watershed originates in hill country of Burnet County and drains through Williamson County into the coastal plains of Milam County, where it discharges into the Litter River. It is a long, narrow watershed, generally sloping from the west to the east. The upper half of the watershed west of IH-35 is generally characterized by steep, hill country terrain, and the lower half of the watershed east of IH-35 is mostly flat. The upper and lower thirds of the watershed are sparsely populated, with the central IH-35 corridor and communities of Cedar Park, Leander, Round Rock, Austin, Liberty Hill, Jarrell, and Georgetown being the population center within the watershed. The study area consists of five HUC10 basins: North Fork San Gabriel River, South Fork San Gabriel River, Berry Creek, Turkey Creek-Brushy Creek, and Granger Lake-San Gabriel River. Figure 1 shows the location of the Lower Brazos San Gabriel River Watershed HUC-10 basins with respect to the counties and communities mentioned above.

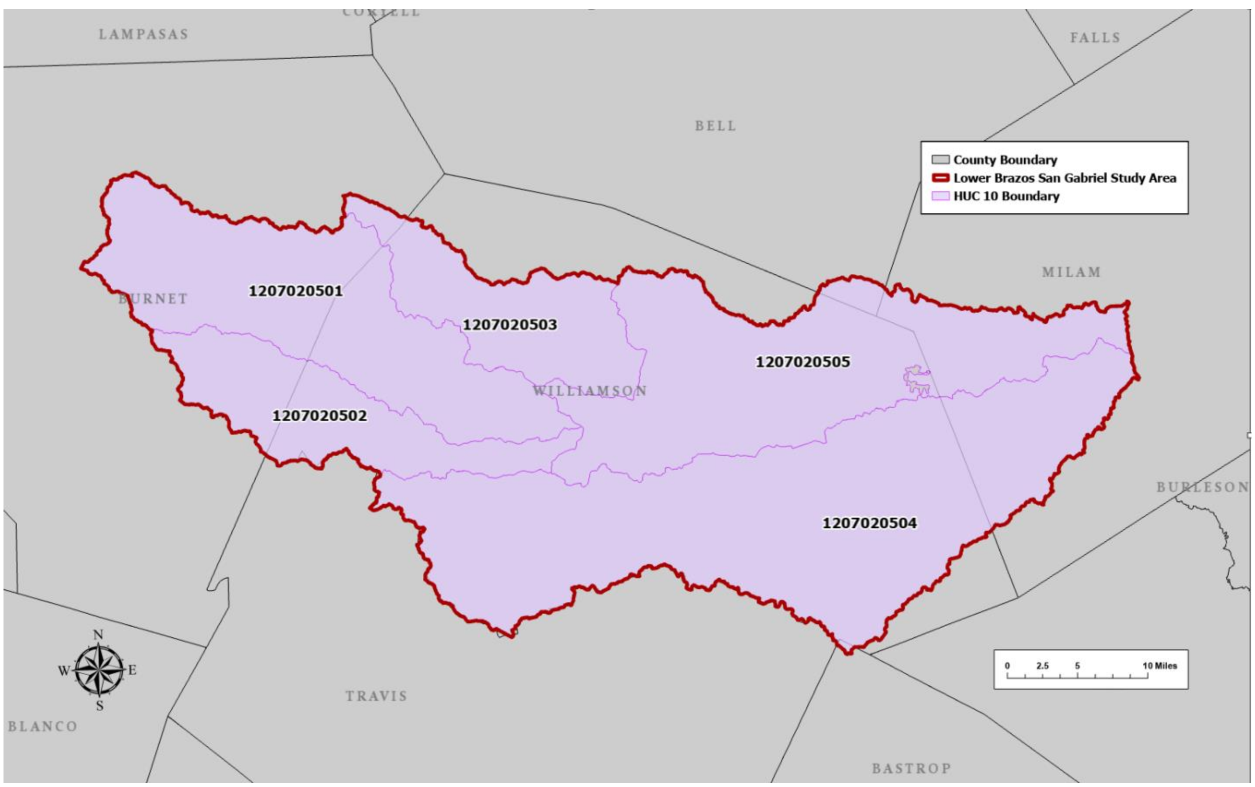

Figure 1: Lower Brazos San Gabriel watershed – HUC-10 Basins

The Base Level Engineering assessment prepared cursory engineering analysis for approximately 1,460 miles of stream reaches within the Lower Brazos San Gabriel watershed with a minimum drainage area tolerance of one square mile. The selection and extent of stream reaches studied was based upon the number of stream miles with minimum drainage area of one square mile and not the number of effective Zone A stream miles. Study reaches were extended above this one square mile threshold as appropriate to ensure all effective Zone A floodplain received an updated analysis. The following sections will summarize the BLE process and will discuss the results along with their recommended use.

2.0 2D BLE Modeling Input and Controls

This Section discusses the fundamental components required to execute a 2D BLE analysis for the Lower Brazos San Gabriel Watershed. Inputs including elevation data, hydrology from rain-on-grid and inflow hydrographs, and hydraulic analyses and variables are defined in the following sections. The HEC-RAS 6.3 rain-on-grid utility was applied in the production of these 2D BLE products.

2.1. Topographic Data

A high-resolution Digital Elevation Model (DEM) derived from Light Detection and Ranging (LiDAR) provides a detailed representation of the Earth's surface. DEMs are one of the fundamental components for 2D engineering analyses and are used to direct excess rainfall-runoff (hydrology) through the model area to develop water surface elevations (hydraulics) and resulting floodplain inundation boundaries. The seamless DEMs developed to support the 2D BLE modeling and analysis within the Lower Brazos San Gabriel Watershed were developed using the following steps:

- Available 1-meter DEMs within each watershed were gathered from the USGS National Map;
- Seamless DEMs were produced using GIS spatial analyst and 3D analyst tools and resampled to 10-foot resolution; and,
- Quality Assurance (QA) and Quality Control (QC) measures were implemented to ensure topographic data meets quality standards of the project.

Additional documentation regarding DEMs including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables, and text in the sections below.

2.1.1 Inventory

DEMs were obtained for the for the Lower Brazos San Gabriel Watershed, which included an approximate 1-mile buffer around the watershed boundary. **Figure** 2 depicts the datasets identified and leveraged for each watershed. Data from FEMA and USGS were queried to build the inventory with the most current and available data sources.

2.1.2 Evaluation

A data coverage assessment was conducted to check for data gaps, extent, accuracy, and completeness. Additionally, a review of related documentation, reports, indexes, and metadata associated with the leveraged datasets were conducted. **Table 2** depicts the complete list of source elevation data and attributes leveraged for this BLE project. **Figure 2** depicts the extent of the data defined in **Table 2**.

Table 2: LiDAR Data Sources

Watershed	Year	Description	Data Type	3DEP Quality Level	RMSE	Source/Owner
Lower Brazos San Gabriel River Watershed	2018	USGS Eastern Texas LiDAR	Airborne LiDAR	2	5.1 cm	USGS
	2020	Stratmap North and Central Texas LiDAR	Airborne LiDAR	2	3.9 cm	TNRIS
	2017	Stratmap Central Texas LiDAR	Airborne LiDAR	2	5.4 cm	TNRIS
	2015	Stratmap Georgetown LiDAR	Airborne LiDAR	2	3.7 cm	TNRIS
	2014	Stratmap Lampasas Texas LiDAR	Airborne LiDAR	2	6.2 cm	TNRIS

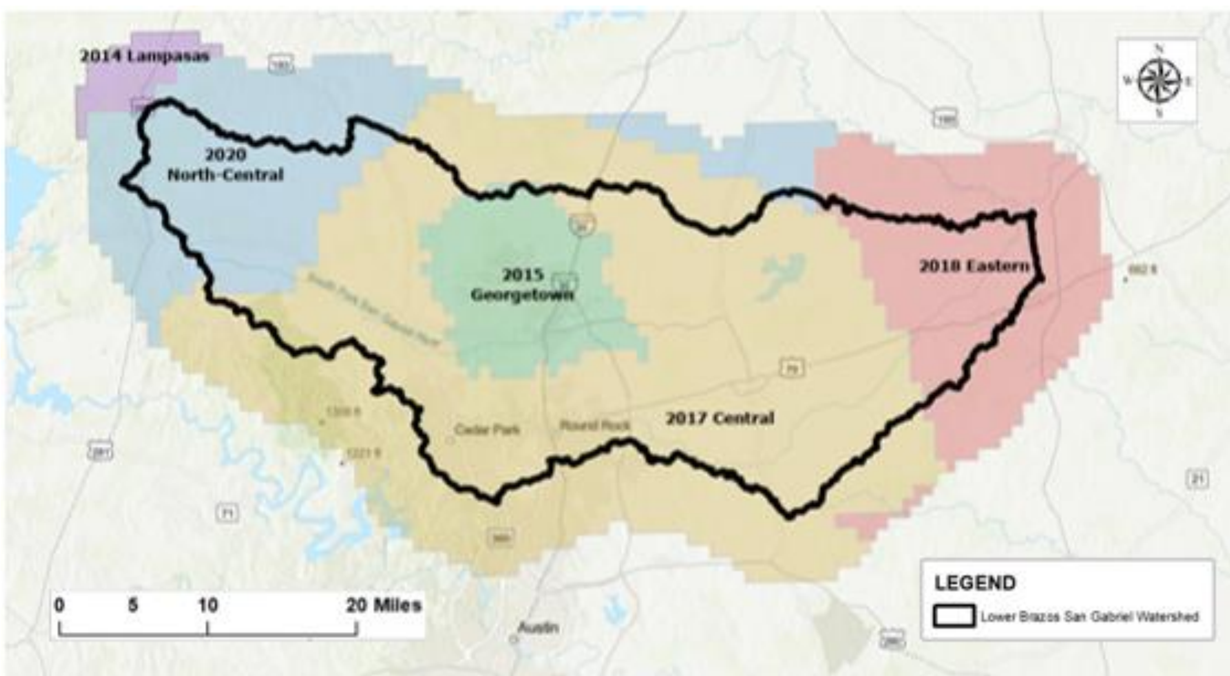

Figure 2: Extent of LiDAR Data

2.1.3 LiDAR Data Sources

USGS 2018 Eastern Texas LiDAR

The USGS 2018 Eastern Texas LiDAR was acquired between March 6, 2018 to March 21, 2018. The vertical accuracy for the dataset is reported to be 5.1 cm RMSEz at a 95% confidence level, which meets project accuracy specifications of the National Standard for Spatial Data Accuracy (NSSDA). These accuracies meet FEMA standards for floodplain reevaluation studies and map modernization programs designed to update the Flood Insurance Rate Maps (FIRM).

Stratmap 2020 North and Central Texas LiDAR

The Stratmap 2020 North and Central Texas LiDAR was acquired between January and June 2020. The vertical accuracy for the dataset is reported to be 3.9 cm RMSEz at a 95% confidence level, which meets project accuracy specifications of the NSSDA. These accuracies meet FEMA standards for floodplain reevaluation studies and map modernization programs designed to update the Flood Insurance Rate Maps (FIRM).

Stratmap 2017 Central Texas LiDAR

The Stratmap 2017 Central Texas LiDAR was acquired between January 20, 2017, and March 22, 2017. The vertical accuracy for the dataset is reported to be 5.4 cm RMSEz at a 95% confidence level, which meets project accuracy specifications of the NSSDA. These accuracies meet FEMA standards for floodplain reevaluation studies and map modernization programs designed to update the Flood Insurance Rate Maps (FIRM).

Stratmap 2015 Georgetown LiDAR

The Stratmap 2015 Georgetown LiDAR was acquired on December 29, 2014. The vertical accuracy for the dataset is reported to be 3.7 cm RMSEz at a 95% confidence level, which meets project accuracy specifications of the NSSDA. These accuracies meet FEMA standards for floodplain reevaluation studies and map modernization programs designed to update the Flood Insurance Rate Maps (FIRM).

Stratmap 2014 Lampasas LiDAR

The Stratmap 2014 Lampasas LiDAR was acquired between December 18, 2013 and January 25, 2014. The vertical accuracy for the dataset is reported to be 6.2 cm RMSEz at a 95% confidence level, which meets project accuracy specifications of the NSSDA. These accuracies meet FEMA standards for floodplain reevaluation studies and map modernization programs designed to update the Flood Insurance Rate Maps (FIRM).

2.1.4 Data Development and Methodology

DEMs were processed for the watershed for the BLE modeling efforts. Tools within ArcGIS were used to mosaic and reproject the source data. The mosaicked DEM was projected horizontally to North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS) Texas Central (4203) with units of US Survey Foot. The vertical datum for this project is set to North American Vertical Datum of 1988 (NAVD88) with units of US Survey Foot.

During the model refinement and calibration process, the terrain modification tool was utilized at bridge/culvert crossings that were not removed from the terrain. The terrain modification tool was delineated at the crossing location and used the lower terrain elevation to cut an opening for flow to pass through to reduce pooling. The widths of the openings ranged from 3 – 20 feet, depending on the crossing size, with a side slope of 0.001, to mimic a box culvert shape and control the amount of flow passing through the opening. The terrain modifications kept the 10’x10’ cell grid spacing.

2.1.5 DEM QA/QC

A Seamless DEM for use on the BLE analyses was developed and independently assured to meet quality assurance (QA) standards of the project. Quality assurance during the data development process included, but was not limited to the following:

- Horizontal Projection Check (NAD83 SPCS 4203 FT)
- Vertical Datum Check (NAVD88 FT)
- Resolution Check (1-meter to 10-foot resolution)
- Seamless Data Check to develop DEM files that are consistent and seamless along source data
- Review and resolution of LiDAR Project transition edge

Quality control (QC) measures were implemented following the development process of the seamless DEMs and included visual observations using hillshade, color rendering, and/or other visual aids to review and identify potential impactful anomalies within the DEM surfaces. This QC step included, but was not limited to the following:

- Seamless Data Check to eliminate voids along the edges and between the prioritized datasets
- NoData Value Check to eliminate no null values
- Manual Elevation Check using hillshade rasters to find erroneous elevation issues

Following these QA/QC steps, the final DEM data developed for the Lower Brazos San Gabriel Watershed was considered of sufficient quality 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 methodology used in the 2D BLE analysis of the Lower Brazos San Gabriel Watershed. This section includes discussion regarding the overall approach along with hydrologic and hydraulic methodologies and results.

2.2.1 Model Areas

The Lower Brazos San Gabriel Watershed covers a total area of approximately 1,358 square miles. While possible to model the entire HUC8 in a single 2D HEC-RAS model, the large area would lead to excessively long model run times and inhibit the model's usability for future users. To combat this issue and simplify model development, the study team divided the watershed into several smaller models, consisting of a single HUC10 within the larger HUC8. Table 3 and Figure 3 present the grouping of HUC-10s for each 2D model. As described in Section 2.2.2, these models remain interconnected via external boundary conditions, so no runoff volume is lost through the subdivision of the HUC8.

Table 3: Lower Brazos San Gabriel Model Areas

Model	HUC10(s)	HUC10 Name(s)	Area (Sq. Mi.)
501	1207020501	North Fork San Gabriel River	268
502	1207020502	South Fork San Gabriel River	134
503	1207020503	Berry Creek	127
504	1207020504	Turkey Creek-Brushy Creek	520
505	1207020505	Granger Lake-San Gabriel River	318

2.2.2 Model and Boundary Condition Setup

HEC-RAS 2D rain-on-grid modeling requires two main components, a 2D computational mesh and inflow hydrology. HUC10 boundaries were used to establish the 2D computational mesh boundaries within the watershed, according to the groupings presented in Table 3. Inflow hydrology can be applied through various methods in HEC-RAS 2D modeling, but hydrology methods are limited to two categories for the watershed. These are flow hydrographs and precipitation time-series. Section 2.2.4 describes the development the precipitation data applied to each model. Precipitation, rather than excess precipitation, was applied directly to the 2D mesh because simplistic hydrologic losses can be accounted for entirely within HEC-RAS version 6.3.

External boundary conditions were applied along each model area's boundary where a transfer of flow (inflow or outflow) may occur. The upstream area of each model, where applicable, has an inflow hydrograph applied at the outflow of the upstream model area . For example, the 505 model has an inflow hydrograph that applies the outflow from the other four upgradient models. The outflow boundary condition flow from the upstream models were used for these inflow hydrographs.

A normal depth boundary condition was utilized along all basin outflows that uses an approximate energy grade-line slope estimated from the LiDAR terrain data.

2.2.3 2D Computational Mesh and Settings

The HEC-RAS 2D computational mesh defines both the extent and level of detail of 2D hydraulic results. The density and detail of the 2D mesh is the primary component that defines the resolution of hydraulic results (e.g., more detail-finer results, less detail-coarser results). A more detailed mesh may provide finely resolved and accurate results, but it can lead excessively long computation times which are prohibitive to future use of BLE models. To provide a balance between mesh detail and model performance, the base mesh for each model was developed using 200'x200' cells. To add detail to dense urban areas, refinement regions that enforced 100'x100' cells were added in over urban areas in TxDOT's municipalities layer. The mesh was refined through the addition of breaklines along roadways, reservoirs, stream centerlines, and other topographically significant features. The mesh for each model area was developed in a manner that allows for automatic regeneration of the mesh by future users, without the need for manual cell edits.

Hydraulic results are also influenced by the many computational settings used in each HEC-RAS simulation. Of the available settings, the two most influential to results are the computational timestep and the equation set. Each model uses a 30-second computational timestep and applies the Diffusion Wave equation set. All other computational settings were kept at their default values as sensitivity analyses were conducted early in the modeling process and showed little to no impact on model results.

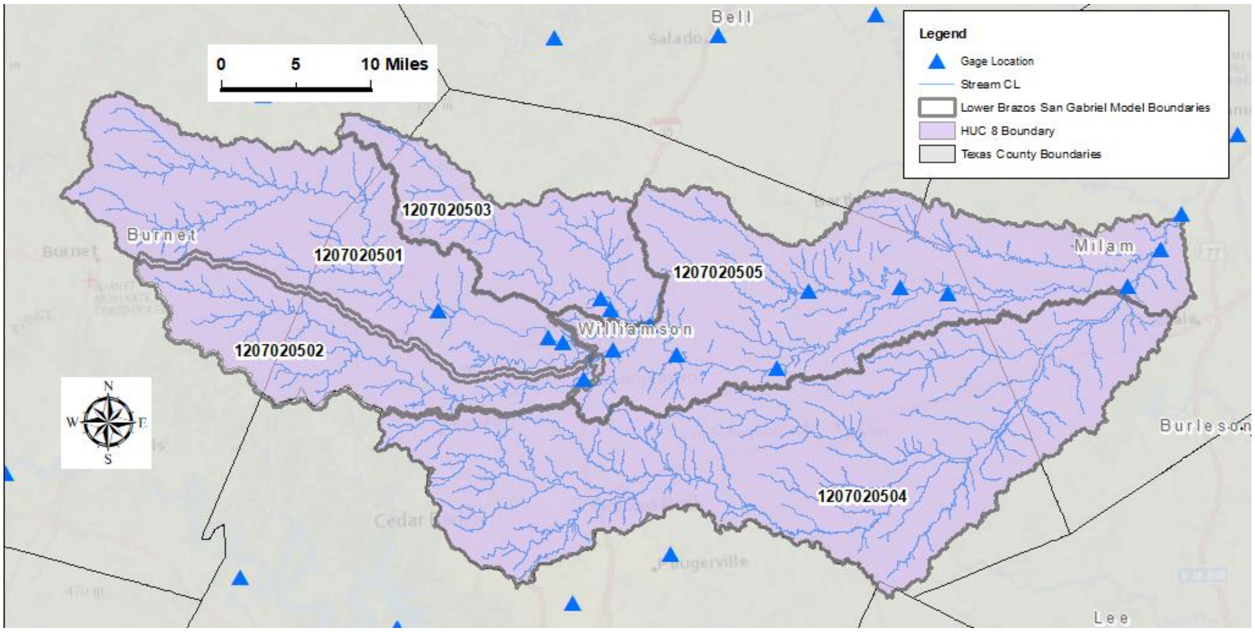

Figure 3: Lower Brazos San Gabriel Model Configuration Overview

2.2.4 Hydrology

Hydrologic data for the Lower Brazos San Gabriel Watershed was derived from NOAA Atlas 14, Volume 11 Version 2.0 precipitation data, which was obtained from NOAA's Precipitation Frequency Data Server. Spatial variation of precipitation depths was accounted for by developing area-weighted average depths for each model area. The 10%, 4%, 2%, 1%-minus, 1%, 1%-plus, and 0.2% annual exceedance probability events were simulated in the Lower Brazos San Gabriel Watershed.

2.2.4.1 Precipitation Data

Precipitation data for this study were based on the National Oceanic and Atmospheric Association's (NOAA) Atlas 14 Precipitation Frequency Data Server in the form of point precipitation grids. The ESRI ArcGIS Pro zonal statistics tool was used to process point grids and develop subbasin-averaged partial duration depths for all frequency storm events analyzed within each of the five 5) model work areas, which were based on HUC10 delineations. Each frequency storm utilized the parameters listed in Table 4. HEC-HMS version 4.10 was used to generate a precipitation hyetograph using frequency storm meteorological models for each work area. The 1% plus and minus events are defined to be one standard deviation above and below the 1%-annual-chance event. The NOAA Atlas 14 90% confidence intervals correspond to +/- 1.645 standard deviations. The 1%-minus and 1%-plus events utilize the 1% precipitation depths +/- 1.645 standard deviations. Computed precipitation hyetographs were then applied to the HEC-RAS 2D mesh as a precipitation boundary condition in the unsteady flow editor. The precipitation-frequency depths for each model area and simulation event are summarized in **Table 4- 8**.

Table 4: HEC-HMS Frequency Storm Parameters

Parameter	Value
Annual-Partial Conversion	None
Storm Duration	1-day
Intensity Duration	5-minute
Intensity Position	50%
Area Reduction	None
Storm Area	

Table 5: 1207020501 - Precipitation Frequency Depths

Duration (min)	BASIN 1207020501 - Percent Annual Chance Precipitation Depth (in)						
	10%	4%	2%	1%-	1%	1%+	0.2%
5	0.75	0.91	1.04	0.90	1.17	1.44	1.51
15	1.50	1.82	2.07	1.79	2.33	2.86	2.99
60	2.75	3.34	3.80	3.30	4.29	5.29	5.65
120	3.46	4.31	5.00	4.47	5.77	7.07	7.92
180	3.90	4.93	5.79	5.26	6.77	8.28	9.52
360	4.65	5.94	7.07	6.53	8.35	10.16	11.99
720	5.36	6.84	8.12	7.56	9.59	11.63	13.84
1440	6.09	7.74	9.13	8.52	10.74	12.96	15.45

Table 6: 1207020502 - Precipitation Frequency Depths

Duration (min)	BASIN 1207020502 - Percent Annual Chance Precipitation Depth (in)						
	10%	4%	2%	1%-	1%	1%+	0.2%
5	0.76	0.93	1.06	0.93	1.21	1.49	1.57
15	1.52	1.85	2.12	1.85	2.40	2.95	3.10
60	2.79	3.41	3.91	3.42	4.44	5.47	5.90
120	3.53	4.42	5.15	4.62	5.98	7.33	8.28
180	3.98	5.06	5.97	5.44	7.01	8.59	9.96
360	4.76	6.12	7.30	6.75	8.65	10.56	12.56
720	5.49	7.05	8.41	7.81	9.97	12.13	14.55
1440	6.24	7.98	9.46	8.80	11.17	13.54	16.25

Table 7: 1207020503 - Precipitation Frequency Depths

Duration (min)	BASIN 1207020503 - Percent Annual Chance Precipitation Depth (in)						
	10%	4%	2%	1%-	1%	1%+	0.2%
5	0.76	0.92	1.05	0.91	1.18	1.46	1.52
15	1.51	1.83	2.09	1.81	2.35	2.89	3.01
60	2.78	3.38	3.84	3.34	4.34	5.35	5.72
120	3.52	4.39	5.10	4.56	5.89	7.23	8.13
180	3.98	5.04	5.94	5.41	6.96	8.50	9.84
360	4.76	6.10	7.27	6.73	8.60	10.48	12.41
720	5.48	7.01	8.34	7.77	9.87	11.96	14.24
1440	6.23	7.92	9.36	8.73	11.01	13.29	15.77

Table 8: 1207020504 - Precipitation Frequency Depths

Duration (min)	BASIN 1207020504 - Percent Annual Chance Precipitation Depth (in)						
	10%	4%	2%	1%-	1%	1%+	0.2%
5	0.76	0.91	1.04	0.90	1.17	1.44	1.48
15	1.51	1.82	2.06	1.78	2.32	2.85	2.93
60	2.79	3.36	3.82	3.31	4.30	5.30	5.58
120	3.55	4.38	5.06	4.49	5.81	7.12	7.87
180	4.03	5.05	5.89	5.30	6.84	8.37	9.50
360	4.84	6.15	7.27	6.66	8.54	10.42	12.18
720	5.60	7.16	8.50	7.88	10.05	12.21	14.57
1440	6.38	8.16	9.70	9.05	11.47	13.90	16.70

Table 9: 1207020505 - Precipitation Frequency Depths

Duration (min)	BASIN 1207020505 - Percent Annual Chance Precipitation Depth (in)						
	10%	4%	2%	1%-	1%	1%+	0.2%
5	0.75	0.91	1.03	0.88	1.15	1.42	1.46
15	1.50	1.80	2.04	1.75	2.28	2.81	2.88
60	2.76	3.33	3.76	3.25	4.22	5.20	5.47
120	3.51	4.33	4.99	4.42	5.72	7.01	7.75
180	3.98	4.98	5.81	5.24	6.75	8.26	9.38
360	4.77	6.06	7.16	6.57	8.42	10.26	11.99
720	5.51	7.03	8.34	7.73	9.84	11.96	14.18
1440	6.27	8.00	9.48	8.83	11.17	13.52	16.10

An areal reduction factor (ARF) is generally defined as the ratio of the mean precipitation depth over a watershed resulting from a storm to the maximum point depth of the storm. ARFs range from 0.0 to 1.0 and vary according to storm characteristics such as watershed size, shape, and geographic location.

Based on models results, the averaged areal reduction factors were considered too general for this BLE study and would not be appropriate for the smaller flowpaths within the work areas. Areal reduction factors will be considered for future detailed study.

2.2.4.2 Hydrologic Losses

HEC-RAS version 6.3 was used to apply the SCS Curve Number method to calculate losses and define excess precipitation for each model work area. Initial Curve Numbers (i.e., prior to calibration) were computed by intersecting the National Land Cover Dataset (NLCD) 2019 coverage and NRCS soils data based on the matrix presented in Table 10.

Table 10: Land Use-Soils-CN Matrix

Land Use (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 1%-minus and 1%-plus events utilize CNs that correspond to dry (ARC1.5) and wet (ARCIII) antecedent moisture conditions. The values presented in Table 10 were adjusted according to the methodology presented in NRCS's National Engineering Handbook and referenced in Appendix A of FEMA Region 6's BLE Submittal Guidance. CN1.5 and CNIII values are documented in **Table 11** and **Table 12**, respectively. The initial abstraction ratio for the CN1.5 and CNIII layers was set to 0.20.

Table 11: Land Use-Soils-CN 1.5 Matrix

Land Use (LU) GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	96	96	96	96
21	Developed Open Space	39	60	71	77
22	Developed Low Intensity	51	66	76	81
23	Developed Medium Intensity	73	82	86	88
24	Developed High Intensity	83	87	90	91
31	Barren Land	30	51	65	72
41	Deciduous Forest	22	45	61	69
42	Evergreen Forest	22	45	61	69
43	Mixed Forest	22	45	61	69
52	Shrub Scrub	22	38	55	64
71	Herbaceous	39	52	65	78
81	Hay Pasture	30	51	65	77
82	Cultivated Crops	41	57	68	72
90	Woody Wetlands	63	72	81	88
95	Emergent Herbaceous Wetlands	63	72	81	88

Table 12: Land Use-Soils-CN III Matrix

Land Use (LU) GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	99	99	99	99
21	Developed Open Space	69	85	91	94
22	Developed Low Intensity	79	89	93	95
23	Developed Medium Intensity	92	95	96	97
24	Developed High Intensity	96	97	97	98
31	Barren Land	59	79	88	92
41	Deciduous Forest	48	74	86	90
42	Evergreen Forest	48	74	86	90
43	Mixed Forest	48	74	86	90
52	Shrub Scrub	48	68	82	88
71	Herbaceous	69	80	88	94
81	Hay Pasture	59	79	88	94
82	Cultivated Crops	71	84	89	92
90	Woody Wetlands	87	92	95	97
95	Emergent Herbaceous Wetlands	87	92	95	97

2.3.1 Hydraulics

Hydraulic analysis of the Lower Brazos San Gabriel Watershed was conducted in HEC-RAS 6.3 using a rain-on-grid modeling approach. This section describes the development of hydraulic input data and its implementation in the 2D model. The precipitation data for each modeling area is outlined in **Figure 4-8**.

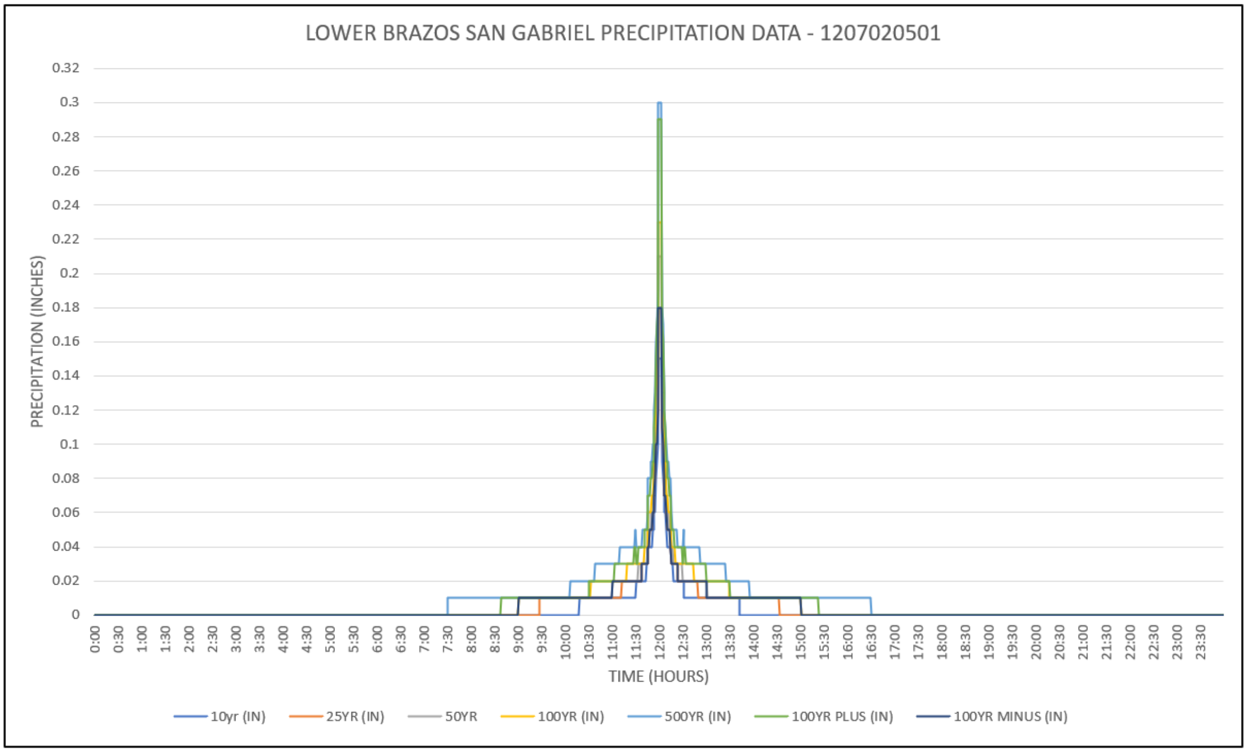

Figure 4: Lower Brazos San Gabriel Precipitation Data – 12070501

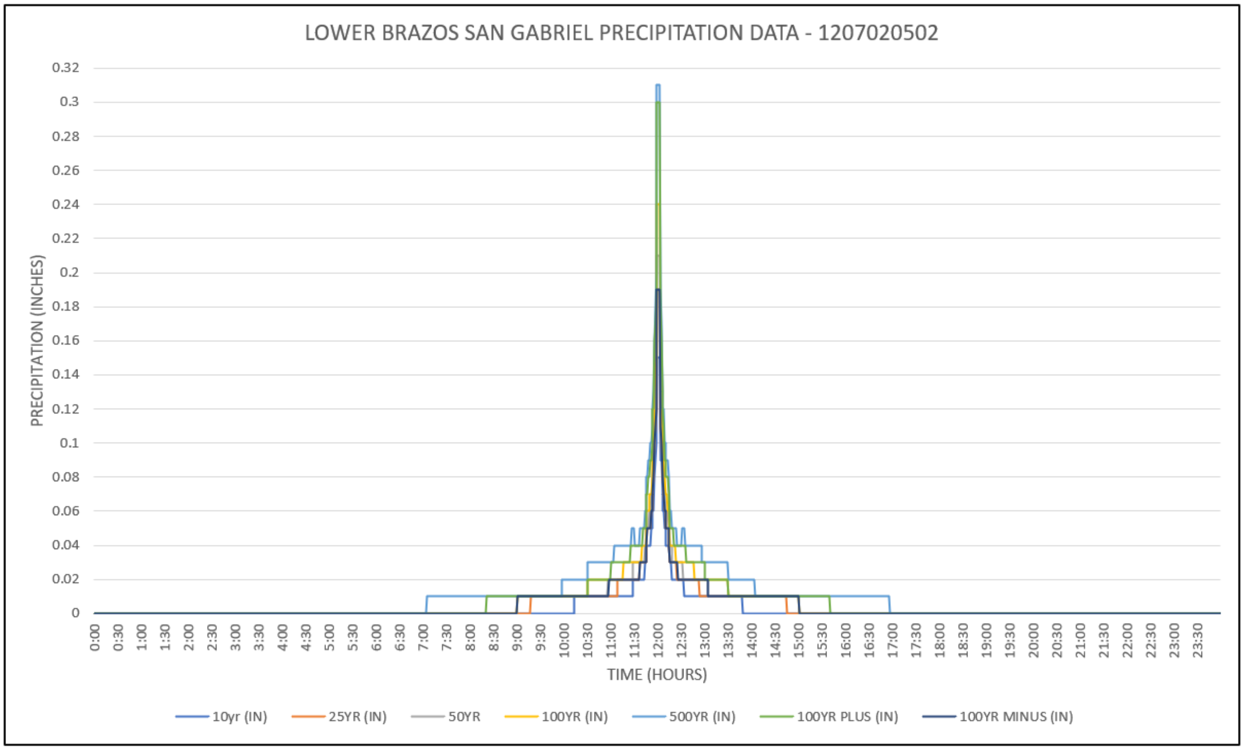

Figure 5: Lower Brazos San Gabriel Precipitation Data – 12070502

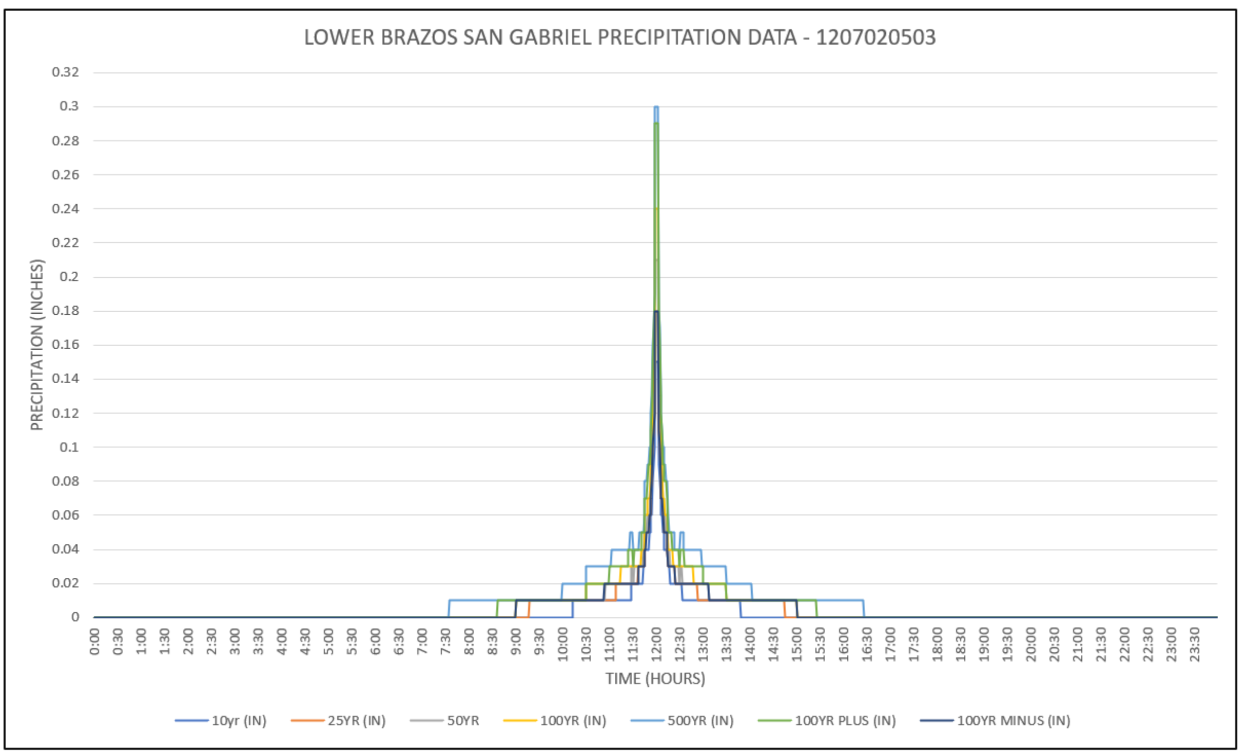

Figure 6: Lower Brazos San Gabriel Precipitation Data - 12070503

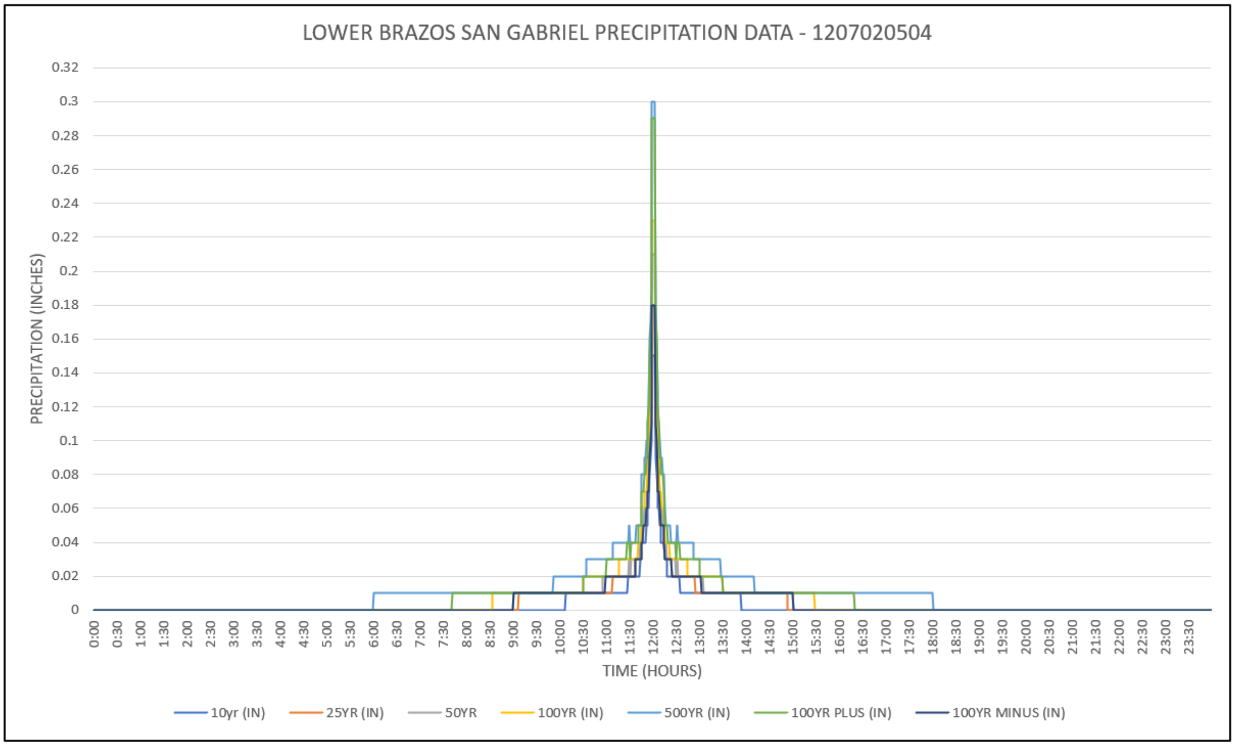

Figure 7: Lower Brazos San Gabriel Precipitation Data - 12070504

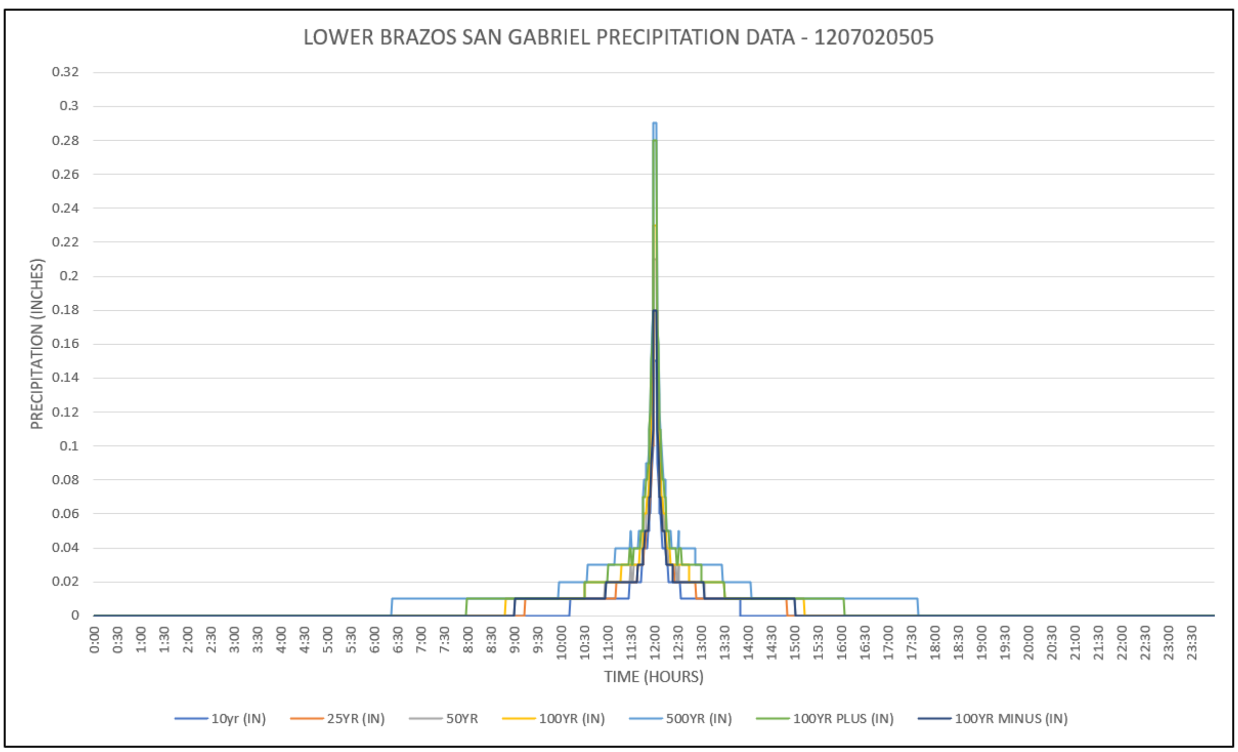

Figure 8: Lower Brazos San Gabriel Precipitation Data - 12070505

2.3.1.1 Roughness Coefficients

A manning's roughness layer was developed for the 2D mesh by applying typical values associated with NLCD land cover classifications. In addition to the base manning's roughness layer from the NLCD data, manning's roughness values were refined along stream centerlines to override excessively high channel roughness values resulting from the NLCD layer. Channel roughness values were assigned according to a review of aerial imagery. For simplicity, a n value of 0.06 was used for the channel stream buffer layer throughout the models. The stream buffer was developed using the stream centerline breaklines with a 40-foot buffer layer for the main stem reaches, and a 20-foot buffer for the tributary branches. Theses buffer lengths were determined based on reviews of aerial imagery and terrain to determine a reasonable width to encompass the stream channels. Table 13 documents the typical roughness values assigned to each NLCD land cover classification.

Table 13: Manning's N Values

Classification	Selected Manning's n	Minimum	Maximum
Open Water	0.03	0.025	0.05
Developed, Open Space	0.04	0.03	0.05
Developed, Low Intensity	0.06	0.06	0.12
Developed, Medium Intensity	0.08	0.08	0.16
Developed, High Intensity	0.12	0.12	0.20
Barren Land	0.03	0.023	0.03
Deciduous Forest	0.10	0.10	0.20
Evergreen Forest	0.10	0.08	0.16
Mixed Forest	0.10	0.08	0.20
Scrub/Shrub	0.07	0.07	0.16
Grassland/Herbaceous	0.035	0.025	0.05
Pasture/Hay	0.035	0.025	0.05
Cultivated Crops	0.045	0.020	0.05
Woody Wetlands	0.10	0.045	0.15
Emergent Herbaceous Wetland	0.07	0.05	0.085
Stream Buffer	0.06	0.05	0.07

2.3.1.2 Breaklines and Hydraulic Structures

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including, road embankments and hydraulic structures, including more than twenty Upper Brushy Creek Water Control Improvement District (WCID) dams within work area 1207020504. Road embankments were defined in GIS and imported into HEC-RAS 6.3 as breaklines to ensure that water was not routed past roads without passing through a structure until it was deep enough to overtop the road. Additionally, stream centerlines were added as breaklines to reflect the terrain more accurately within the banks.

Bridge or culvert crossings that were not processed out of the terrain data were modeled by creating a "V" notch at the crossing (**Figure 9**) or through terrain modification (**Figure 10**) outlined in Section 1.1.4 above to allow flow to pass through the crossing. New terrain modification tools were also used in select areas to cut a near vertical walled channel with a nominal width (typically 3-5 feet) based on review of aerial imagery. Additionally, a reference line was added to every dam in the TCEQ inventory within the model boundaries to improve model usability for future users.

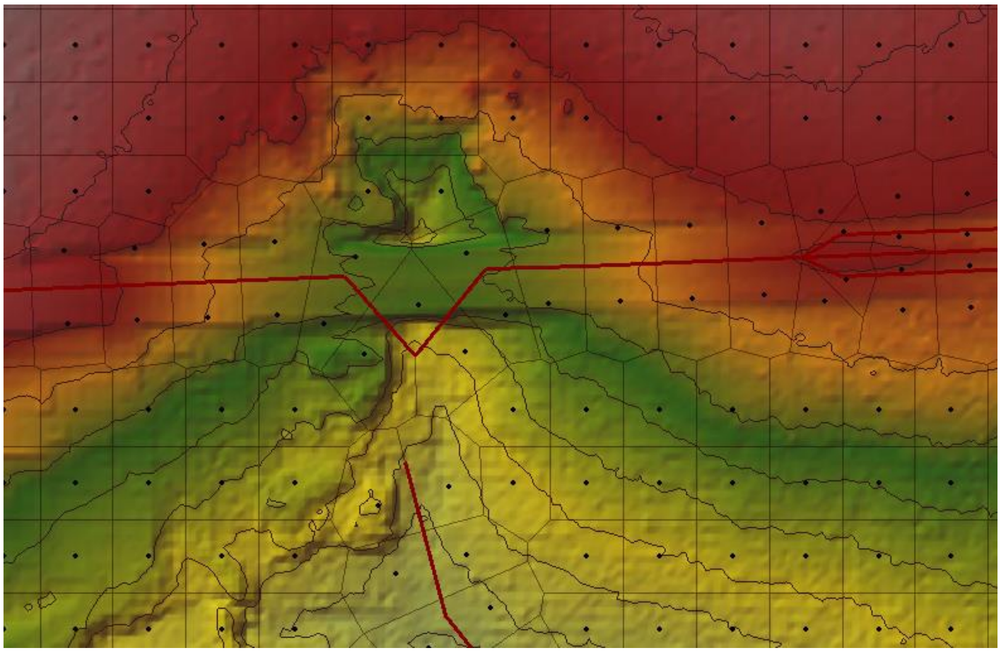

Figure 9: V-Notch Breakline Example

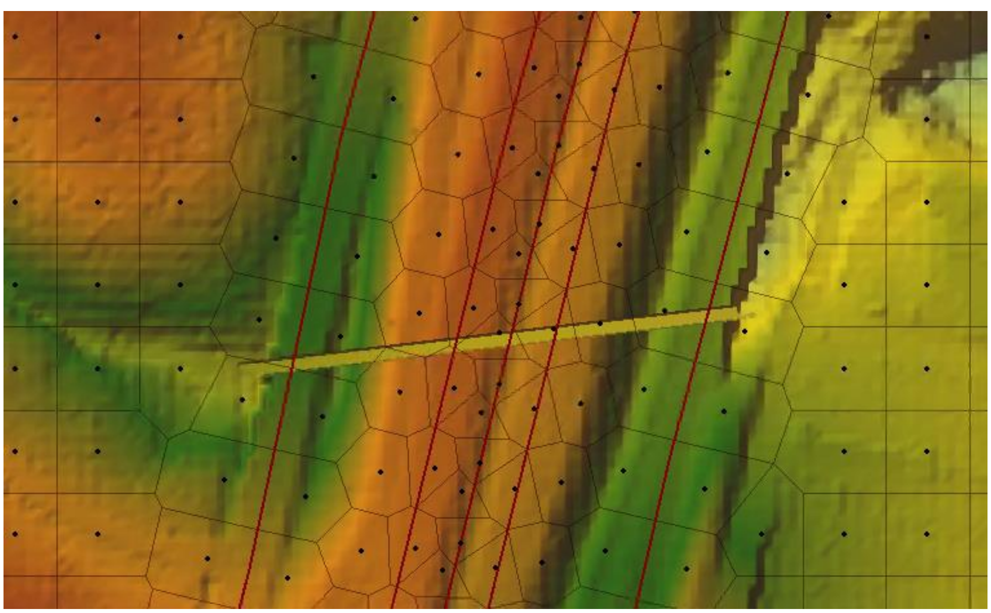

Figure 10: Terrain Modification Example

2.3.1.3 Initial Conditions

The Lower Brazos San Gabriel Watershed includes two major USACE-operated reservoirs: Lake Georgetown located west of the City of Georgetown along the North Fork San Gabriel River, and Granger Lake located east of the City of Granger along the San Gabriel River. The USACE regulates both dams and has published data on the maximum gate release rates[5]. The applicability of an initial water surface elevation within the reservoirs was considered during model setup. Since the 2D BLE analysis relies on the LiDAR terrain to account for storage, the LiDAR elevations within the reservoirs were compared to the conservation pool elevations published by USACE. While the terrain elevations within Granger Lake were within 0.2 feet of its conservation pool elevation of 504.00 ft NGVD29, the terrain elevation within Lake Georgetown was several feet lower than its conservation pool elevation of 791.00 ft NVGD29, which could overestimate available storage for a design storm. For this reason, the RAS Mapper terrain modification tool was used to raise terrain elevations within Lake Georgetown to the conservation pool level and appropriately establish initial conditions. Reference lines were placed at the downstream end of both dams and compared to the maximum release rates to compare water surface elevation and discharge, shown in **Table 14.**

Table 14: Lower Brazos San Gabriel Watershed Dam Water Surface Elevation and Discharge Comparison

Scenario	Lake Georgetown		Granger Lake	
	Discharge (cfs)	WSE (ft)	Discharge (cfs)	WSE (ft)
USACE MAX GATE RELEASE	3,000	757.5-834.0	6,000	518-528
Williamson County FIS 1%	-	-	11,467	-
USGS Streamstats Max WSE	-	819.18	-	520.63
BLE Results				
-1%	805	821.9	425.7	519.9
1%	1,954	822.5	1,175	520.0
+1%	6,996	836.6	8,311	520.8
0.2%	8,450	836.6	10,185	521.0

The table shows the while the 1% event falls within the maximum release rate, the 0.2% event exceeds the rate by over 5,450 cfs at Lake Georgetown and over 4,185 cfs at Granger Lake. It should be noted that the Granger and Lake Georgetown reservoir control gates that were not modeled for this study, and this is likely contributing to the higher discharge rates in the 0.2% event. The Williamson County FIS report included discharge data downstream of Granger Lake, it is unknown with the reservoir gate was modeled in this study. The USGS Streamstats gages did not have discharge records for the lakes but had 22 years of water surface elevation records for Lake Georgetown (USGS 08104650) and 16 years of records for Granger Lake (USGS 08105600). The maximum recorded elevations are shown above to be in a reasonable range of the study results. After taking this into consideration it was determined that the discharge rates were within enough reason for the level of detail of this study to be acceptable. Further calibration of the dams will require a more detailed study in the future.

2.3. Model Results

The 2D BLE results for the study produced a Special Flood Hazard Area (SFHA) that was reasonable and generally compared favorably to effective FEMA SFHAs previously studied areas within the basin. A comparison of intersecting FEMA Effective Base Flood Elevation contours with the produced BLE Base Flood Elevation contours was performed. This comparison produced an average increase of 1.04 feet in elevation between the BLE and FEMA results. The largest difference in elevation was 5 feet, the smallest 0 feet, and the most repeated difference being 1 foot. Due to the contour values being rounded to the nearest foot and the level of detail of each study, these results are reasonable and expected. 2D BLE results provide estimated SFHAs in areas that have not been studied. 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 to a regulatory product.

2.2.1. Stream Gage Analysis

Active USGS gages within the model area with at least about 20-years of flow record were used for calibration of the 1% annual chance event. All gages within the model area can be seen in **Figure 11** Williamson County FIS (Effective December 2019) also had available flow data. Zone AE studies performed within the last 15 years were prioritized in determining calibration locations from the FIS. Reference lines were added at the approximate gage locations and computed discharge hydrographs and peaks were used to calibrate the model. Table 15 shows a summary of relevant gage data within the Lower Brazos San Gabriel watershed. The only gage still currently active is 08104900 at the South Fork San Gabriel, and the remaining gages have no records for at least 20 years. The four gages with sufficient years of record were also analyzed using a SSP (version 2.2) Bulletin 17B and 17C analysis as well.

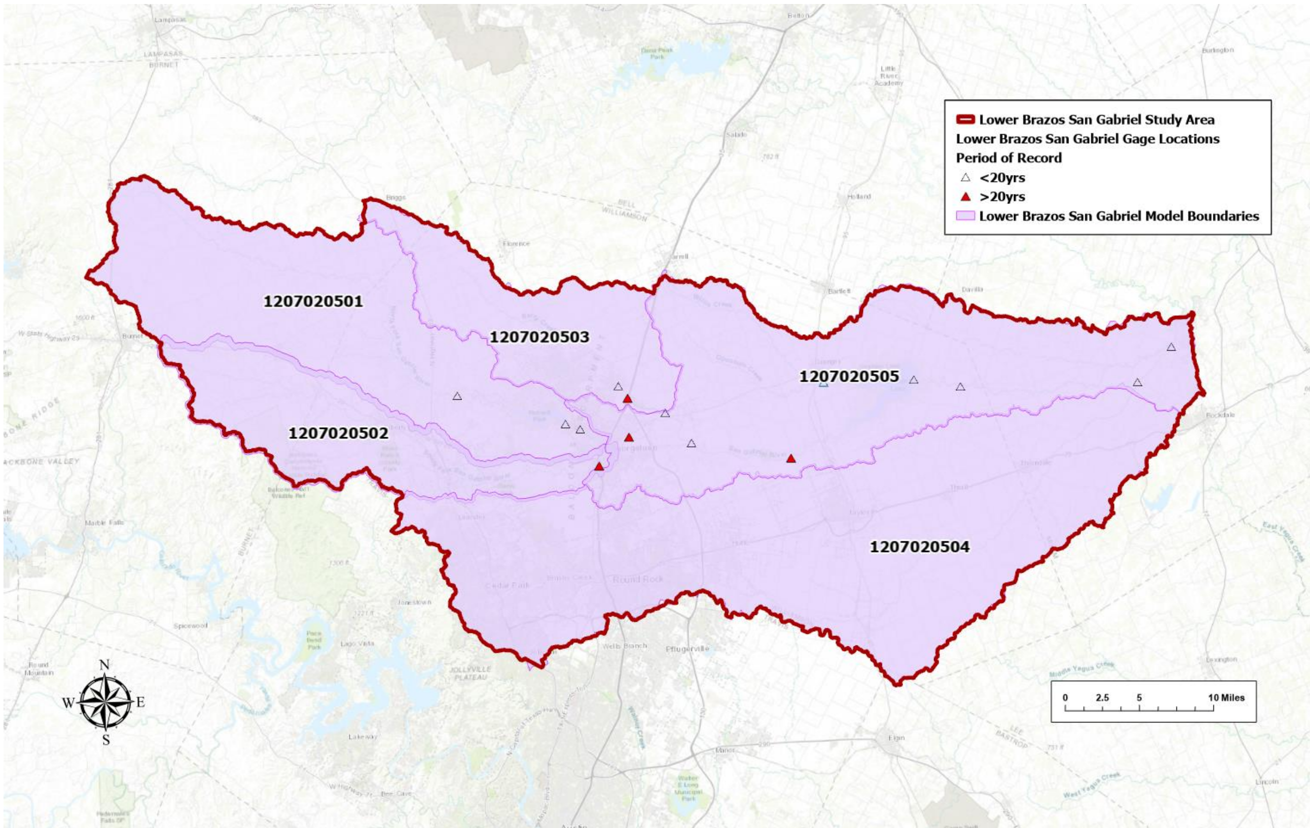

Figure 11: Lower Brazos San Gabriel Watershed Gage Locations

Table 15: Lower Brazos San Gabriel USGS Gage Data

Calibration Location	Source	Period of Record	Percent Annual Exceedance Probability Discharge				
			10%	4%	2%	1%	0.2%
USGS 08105100 Berry Ck nr Georgetown, TX	Streamstats	1967-2003	9,976	13,102	15,355	17,535	22,537
USGS 08105000 San Gabriel Rv at Georgetown, TX	Streamstats	1924-1987	41,993	65,562	89,557	118,464	212,361
USGS 08104900 S Fk San Gabriel Rv at Georgetown, TX	Streamstats	1957-2023	22,373	33,448	43,590	55,338	89,607
USGS 08105400 San Gabriel Rv nr Circleville, TX	Streamstats	1924-1976	46,097	59,071	69,841	80,855	92,289
San Gabriel River Confluence with N Fork San Gabriel at State Route 29	Williamson County FIS	2011	72,964	*	101,987	116,737	165,736
Lake Creek at Confluence with Lake Creek Tributary 1	Williamson County FIS	2015	3,134	4,646	6,564	10,330	18,604
Chandler Branch at confluence with Brushy Creek	Williamson County FIS	2015	3,207	4,365	5,439	7,135	10,894
USGS 08105100 Berry Ck nr Georgetown, TX	HEC-SSP Bulletin 17C	1968-2008	12,830	19,292	26,166	30,049	37,095
USGS 08104900 S Fk San Gabriel Rv at Georgetown, TX	HEC-SSP Bulletin 17C	1968-2021	16,210	24,617	36,121	44,821	71,888
USGS 08105000 San Gabriel Rv at Georgetown, TX	HEC-SSP Bulletin 17C	1921-1973	30,087	44,163	64,326	80,582	139,141
USGS 08105400 San Gabriel Rv nr Circleville, TX	HEC-SSP Bulletin 17B	1925-1976	31,326	44,813	64,516	80,879	144,241

**Value not provided in FIS Report*

2.2.2. Sensitivity Analysis

When calibrating the models, primary focus was placed on the South Fork gage. This is the only gage still currently active and has a 55 year period of record. The remaining gages within the San Gabriel Watershed had significantly shorter periods of record with the most recent record ranging from 1976 to 2003. Within this time period there has been a significant increase in development in this watershed, particularly in Williamson County, would cause discrepancies in modeling for current conditions. For these reasons Gage 08104900 was determined to the most reliable calibration gage.

To determine which factors were significantly impacting the model results, a sensitivity analysis was performed using the USGS Gage 08104900 in the 1207020502 HUC 10 work area (South Fork San Gabriel River) to evaluate the impact of multiple parameters including Manning's roughness values, Curve Numbers, time step intervals, and cell mesh size, detailed in **Table 16**.

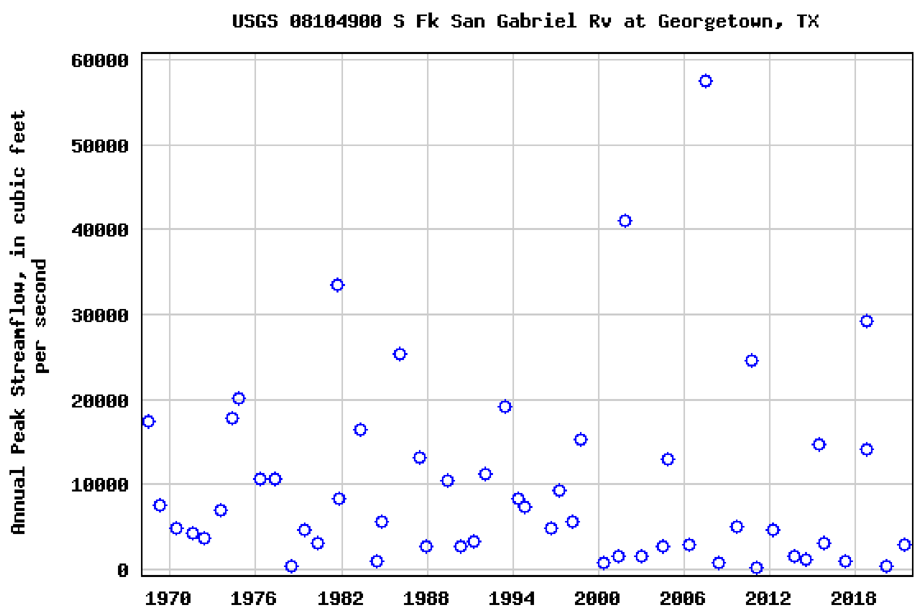

Figure 12: USGS Gage 08104900, South Fork San Gabriel River – Annual Peak Streamflow

Table 16: Model Sensitivity Analysis Summary

Scenario	Sensitivity/Calibration Parameter			USGS 08104900 - South Fork San Gabriel @ Georgetown		Additional Notes
	CN	Time Step Interval	Manning's n	Time to Peak	1% APE Peak Flow (cfs)	
USGS Statistical Analysis 1% ACE Discharge					**55,338**	
1	ARC II	1 MIN		01 Jan 2021, 17:00	101,350	
2	ARC 1.5	1 MIN		01 Jan 2021, 17:40	81,391	
3	ARC III	1 MIN		01 Jan 2021, 16:20	131,599	
4	ARC II	1 MIN	+50%	01 Jan 2021, 19:00	75,049	
5	ARC II	1 MIN	-50%	01 Jan 2021, 15:00	156,815	
6	CN - 15	1 MIN		01 Jan 2021, 18:00	66,706	250-ft Cells
7	CN - 15	1 MIN		01 Jan 2021, 17:40	68,725	200-ft Cells, 100-ft Refinement Regions
8	CN - 20	1 MIN		01 Jan 2021, 18:00	56,824	
9	CN - 15	30 SEC		01 Jan 2021, 17:40	67,668	30s Time Step Interval
10	CN - 15	30 SEC		01 Jan 2021, 17:40	67,668	30s Time Step, Courant variant

2.2.3. Recommendations

Table 16 shows that the CN and roughness adjustments had the most significant impacted on the results and changes in time step interval had relatively minor impacts in peak discharges and timing. It was determined that the CN – 15 adjustment produced the most reasonable results compared to statistical gage data and regional regression equation-based discharges included in the FIS, while maintaining reasonableness in losses. Although scenario 8 resulted in a peak flow that was closer to the gage and HEC-SSP results, it was decided to follow the recommended CN adjustment of CN-15 based on the climate and soil conditions for the study area (see **Figure 5**). These adjusted CN values can be seen in Table 10. The 1%-minus and 1%-plus events utilized the CNs presented in Table 11 and Table 12. This adjustment is also consistent with the regionally appropriate climactic adjustment factor for Central Texas recommended by TxDOT in **Figure 4-20** of the TxDOT Hydraulic Design Manual, shown in **Figure 13**. Therefore, it was determined that Scenario 7 would be used as the basis for all work areas and multi-frequency simulations. No changes were made to initial precipitation applications. Appendix A provides a summary of model results for multi-frequency simulations within each work area.

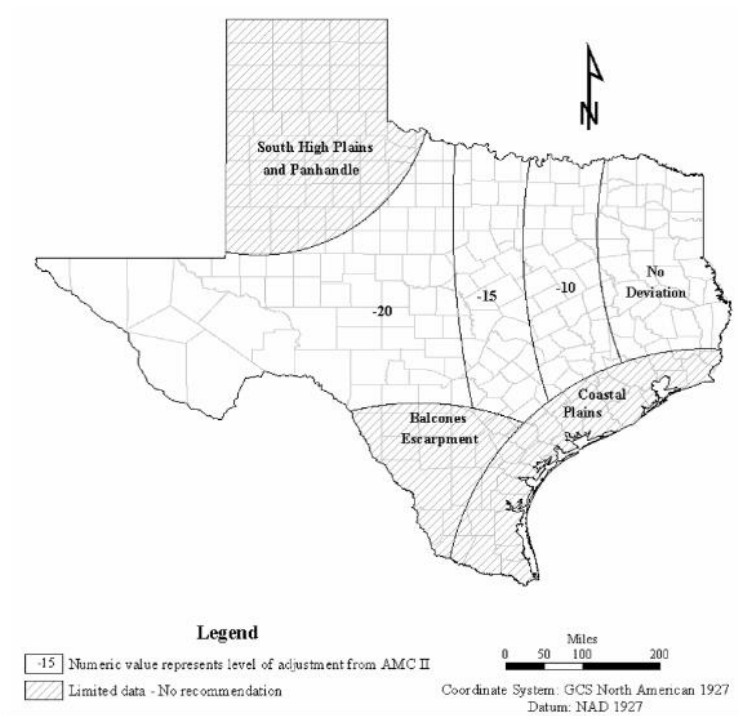

Figure 4-20. Climatic adjustment factor CN_{dev}

Figure 13: TXDOT Climatic Adjustment Factor CN

2.2.4. Challenges

The LBSG_504 area included many challenges due to the size of the model and the number of reservoirs within the area. To reduce the number of cells in the model population centers that were defined as refinement regions were compared with aerial imagery. In areas where the refinement regions covered undeveloped space or open water, the boundary was adjusted so that the cell sizing in these areas could be increased from 100X100 feet to 200X200 feet. This was done to decrease the total cell count in the model and reduce the model run time.

Within the watershed, there are several populated areas and agricultural fields that appear to be trapping water which prevents runoff from reaching the channel in the model. Various v-notches were applied to represent cross culverts and improve conveyance. Further detail and study of the flow patterns and likely runoff conveyance would be recommended as part of a future study if more detailed flood risk information was needed in these areas. Additionally, several breaklines and refinement regions representing population centers increased the total number of cells and thereby increased the model runtime. This was specifically an issue in the LBSG_504 model area where a large portion of the model contained dense population centers that required a mesh with finer cell spacing to model more accurately.

The discharges at the USGS stream gage used for calibration in this model were significantly higher for the Berry Creek 08105100 and Circleville 08105400 gages. Conversely, the discharges at the San Gabriel River 0810500 gage was 47% lower than the model results. Additional model detail, such as adjusting the n-values in the model in the areas upstream and downstream of the gage with override regions, could improve the model results relative to the gage, but due to limitations for this approximate BLE study this was not done for this project. The gage with the closest results to the model results was the South Fork-San Gabriel 08104900 gage, which is the only gage still currently active that was used for calibration. Curve numbers were reduced by 15 across the entire watershed for modeling consistency. While this helped to calibrate flows in some areas, it adversely impacted the calibration of other locations. Adjusting curve numbers at a HUC-10 level instead of at the HUC-8 level could help to add additional detail to the study to improve model results, but due to limitations for this approximate BLE study this was not done for this project.

While relevant statistical gage data were available for four (4) USGS gages with a period of record more than 20 years, challenges were encountered in matching predicted discharge ranges at all four gages. In light of these challenges, the selected CN adjustments are aimed at producing the most reasonable results within the basin with a comprehensive view of available gage data and FIS reported discharges., comparison shown in Appendix B.

Additionally, there was limited reliable data in regards to discharge rates of both Lake Georgetown and Granger Lake. Both reservoirs have controlled gates, which the maximum release rate is provided, but limited info of the spillway. Water surface elevation records of the lakes is available, but are more difficult to calibrate as they are not tied to a storm event like other gage data has available. Due to these limitations, the two lakes within the Lower Brazos San Gabriel watershed proved challenging to accurately model.

2.2.5 Frequency Event Results

The results of the analysis are summarized in **Table 17** for the 1% frequency event, the remaining scenario results are provided in Appendix B.

Table 17: 1% Event Peak Discharge Summary (cfs)

Location	Gage Analysis Method	Discharge (cfs)	BLE HEC-RAS Model (cfs)	Percent Difference
USGS 08105100 Berry Ck nr Georgetown, TX	Bulletin 17C	30,049	47,820	59%
USGS 08104900 S Fk San Gabriel Rv at Georgetown, TX	Bulletin 17C	44,821	68,150	52%
USGS 08105000 San Gabriel Rv at Georgetown, TX	Bulletin 17C	80,582	47,820	-41%
USGS 08105400 San Gabriel Rv nr Circleville, TX	Bulletin 17B	80,879	120,537	49%

3.0 Quality Control

Throughout the BLE analysis, multiple quality checks were performed. These included checks to review the terrain data processing prior to hydraulic model development; hydrologic discharge and model parameter checks; hydraulic checks for complete model coverage, addition of “v-notch” locations to allow for hydraulic connectivity through structures, revisions to dam spillways and top of dams, and revisions to Manning’s “n” values; floodplain mapping cleanup; database quality checks and review; and final submittal reviews. Significant efforts were made to reasonably resolve all items noted prior to submittal. Please see the information included in the Reporting and Documentation > Internal Reviews folder for additional details on the hydraulic review documentation.

4.0 Floodplain Delineation (10%, 1% and 0.2% events)

Following the HEC-RAS analysis, the model results were then imported into the HEC-RAS 6.3 RAS Mapper tool to map floodplain boundaries for the model extent. This tool uses a routine that develops water surface elevation grids based on the 10-foot cell size DEM. The sloping rendering mode was used with the "shallow depth reduces to horizonal" mapping option selected. While the horizontal render mode produces "bathtubs" of isolated ponding per cell, the sloping render mode produces "cupping." Cupping is a ramp up of the depth in the overbanks occurring most often in areas of significant topographic relief. The USACE HEC is aware of this issue which is an error caused by the WSE projecting to the adjacent cell's average elevation. However, the timeframe for a solution to this error by HEC is unknown. For this BLE analysis, mapping results were developed for three (3) events. These events were the 10-, 1-, and 0.2-percent-events. The results of these analyses were used to perform an updated Flood Loss Analysis using the HAZUS program.

Shallow depth mapping was removed from the 10-percent event using the mapping threshold matrix defined in **Table 18**. The 1-percent and 0.2-percent mapping was refined to remove a depth of 0.33 ft or less and then merged with the 10 percent mapping. To remove further "noise" and produce cleaner final product, polygons with an area < 1 acre within the 1-percent and 0.2-percent and did not intersect the WTR_LN were removed. The resulting floodplain spatial data were smoothed with smoothing tolerance 2x input raster cell size and simplified with a 5-foot tolerance. After the initial boundary edits, the resulting floodplain boundaries were merged into a single watershed map boundary.

Once the map boundaries were cleaned, the resulting rasters (Water Surface Elevation, Depth, etc.) were developed with the raster set to correspond in extent to the cleaned polygon boundary. This ensures that the water surface raster and the floodplain boundary are consistent with each other. The backwater WSE at HUC10 watershed boundaries was extended upstream to produce clean tie-ins, with no drawdowns. The depth raster product was created at the end of the process by performing a raster subtraction with the water surface elevation raster and the ground DEM.

Table 18: Mapping Clean-Up 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

5.0 CNMS Validation of Effective Zone A Special Flood Hazard Area (SFHA)

A large portion of the Zone A studies (654 miles) in the Watershed Name were classified in CNMS with a validation status of "UNVERIFIED" and status type of "TO BE STUDIED." Another 426 miles of Zone A studies were classified in CNMS with a validation status of "VALID" and status type of "NVUE COMPLIANT." The following is a summary of the results of the CNMS validation assessment for the effective Zone A studies in the study area. Initial Assessment checks A1-A3 were evaluated for the CNMS inventory of Zone A studies.

5.1 Initial Assessment A1 – Significant Topography Update Check

This check involves determining whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping.

For the Lower Brazos San Gabriel Watershed, the effective Zone A topographic data was based upon multiple LiDAR and non-LIDAR topographic sources with varying levels of accuracy. Approximately 15% of the streams passed this check.

5.2 Initial Assessment A2 – Check for Significant Hydrology Changes

This check involves first determining whether regression equations were used in the effective study. If they were, then it needs to be determined if 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-annual-chance flow.

For the Lower Brazos San Gabriel Watershed, the effective Zone A data is based on counties that went through FEMA's Map Modernization (Map Mod) and those that have the original Flood Hazard Boundary Maps (FHBMs) that were first issued. For the Map Mod studies, they are based upon 1995 Regional Regression equations, while it is unknown how the Zone A hydrologic data may have been developed for each stream shown in the old, existing studies. Since that time, new regression equations have been released statewide and all reaches were set to FAIL this assessment.

5.3 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 watershed was completed by evaluating percentage of urban change at the HUC-12 level. In this check 97% of the reaches were set to PASS this assessment after a spatial analysis.

5.4 Initial Assessment 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. While this 2D analysis is backed by technical data, some of the original modeling is lacking documentation. This watershed has varied PASS and FAIL reaches.

5.5 Initial Assessment A5 – Comparison of BLE and Effective Zone A Floodplains

The BLE/effective Zone A comparison method leverages the existing Floodplain Boundary Standard (FBS) certification procedures described in FEMA Standards ID 113, but with a slight modification. This modified FBS comparison approach uses the 1-percent plus and 1-percent minus flood profiles and horizontal and vertical tolerances described in the First Order Approximation - Methodology, Validation, and Scalability Guidance Procedures (Version 1.5). For the comparison of BLE and effective Zone A in the study area, the following vertical and horizontal tolerances were used to conduct the modified FBS procedure.

Vertical Tolerance: +/- 5 feet (one-half contour interval of assumed effective topographic source).

Horizontal Tolerance: +/-75 feet (standard horizontal tolerance for BLE comparison testing).

The effective Zone A comparison was performed at the full extent of the Lower Brazos San Gabriel 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 Zone A boundaries were compiled using the National Flood Hazard Layer. These data were dissolved into one continuous Zone A layer, which then had test points placed along its perimeter every 500 feet.

For each test point, a vertical test and horizontal test were performed. These tests compare the 1% plus and 1% minus against the DEM at the test point locations. These 1% plus and 1% minus values are products of the new 2D BLE study. If the point fails either the vertical test or horizontal test, then the point fails and is assigned a value of "F". If the point passes both the vertical and horizontal test, then the point passes and is assigned a value of "P".

For the vertical test the following must be true. (1-percent-minus WSEL – vertical tolerance) is less than or equal to the topographic elevation at study point and the topographic elevation at study point is less than or equal to the (1-percent-plus WSEL + vertical tolerance). The vertical tolerance is defined by half the contour interval of the USGS 24K Quad for the study area. For this study we used a vertical tolerance of 5ft since the contour interval was 10ft.

For the horizontal test the following must be true. 1-percent-plus WSEL is greater than or equal to the minimum topographic elevation within a 75-foot radius of the validation point AND 1-percent-minus WSEL is less than or equal to the maximum topographic elevation within a 75-foot radius of the validation point.

Points were then grouped by HUC-12 watersheds. A pass percentage was calculated for each HUC based on the number of passing points divided by total number of points within that watershed. The Passing threshold used to determine if the HUC-12 watershed passed or failed the check was based on the risk class. The Lower Brazos San Gabriel Watershed had 3 risk classes: A, B, and C. Since multiple risk classes were present the most conservative passing threshold of 95% was used. If the watershed had 95% or higher passing points than all the effective Zone A reaches within that HUC passed. If the watershed had less than 95% passing points, then all the reaches within that watershed failed.

5.6 CNMS Validation Results

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Lower Brazos San Gabriel Watershed study area has been updated. Total miles in each of these categories are summarized in **Table 18** and illustrated in **Figure 14** below.

Table 19: Zone A Validation Results

Validation Status	Status Type	Total Mileage
Valid	Being Studied	426
Unverified	Being Studied	654
Assessed	Being Studied	388

While all of the HUC-12 watersheds did not pass the Initial Assessment checks, this information has been provided as additional background data. For the study area, there was a total of 28 HUC-12 areas that were reviewed, shown in **Table 20** and **Figure 14**. Of these areas, the highest Pass/Fail percentage for any area was 90% while the lowest was 43%. However, the overall average for all areas was 30%. Based on these results, 7 HUC-12 areas at a passing score, which is expected when dealing with mapping derived from USGS 24K map products versus that or mapping derived from high resolution LiDAR data.

Table 20: BLE Comparison Results

HUC-12 Watershed		Total FBS Points	Fail	Pass	% Pass	BLE Comparison Pass? (>85%)
Watershed Name	HUC12 ID					
Lake Georgetown	120702050105	536	206	330	62%	FAIL
Alligator Creek	120702050506	305	128	177	58%	FAIL
South Brushy Creek-Brushy Creek	120702050401	1626	248	1378	85%	PASS
Chandler Branch-Brushy Creek	120702050403	857	150	707	82%	FAIL
Mileham Branch-San Gabriel River	120702050502	810	198	612	76%	FAIL
Middle South Fork San Gabriel River	120702050202	679	143	536	79%	FAIL
Granger Lake	120702050505	1517	858	659	43%	FAIL
Pecan Creek-San Gabriel River	120702050507	541	172	369	68%	FAIL
Lower South Fork San Gabriel River	120702050203	961	227	734	76%	FAIL
Dry Brushy Creek-Brushy Creek	120702050407	707	256	451	64%	FAIL
Clear Creek-North Fork San Gabriel River	120702050104	667	192	475	71%	FAIL
Smith Branch-San Gabriel River	120702050501	604	131	473	78%	FAIL
Upper Berry Creek	120702050301	576	253	323	56%	FAIL
Lower Berry Creek	120702050303	965	339	626	65%	FAIL
Middle Fork San Gabriel River-North Fork San Gabriel River	120702050106	573	79	494	86%	PASS
Bear Creek	120702050103	402	50	352	88%	PASS
Mustang Creek	120702050405	1188	311	877	74%	FAIL
Boggy Creek-Brushy Creek	120702050406	971	391	580	60%	FAIL
Pecan Branch-San Gabriel River	120702050504	705	291	414	59%	FAIL
Berry Branch-Brushy Creek	120702050408	789	331	458	58%	FAIL
Turkey Creek	120702050409	952	288	664	70%	FAIL
Dry Berry Creek	120702050302	683	179	504	74%	FAIL
Opossum Creek-Willis Creek	120702050503	891	256	635	71%	FAIL
Lake Creek-Brushy Creek	120702050402	1363	180	1183	87%	PASS
Cottonwood Creek-Brushy Creek	120702050404	1304	277	1027	79%	FAIL
Pool Branch-North Fork San Gabriel River	120702050102	851	117	734	86%	PASS
Russell Fork San Gabriel River	120702050101	894	134	760	85%	PASS
Upper South Fork San Gabriel River	120702050201	467	45	422	90%	PASS

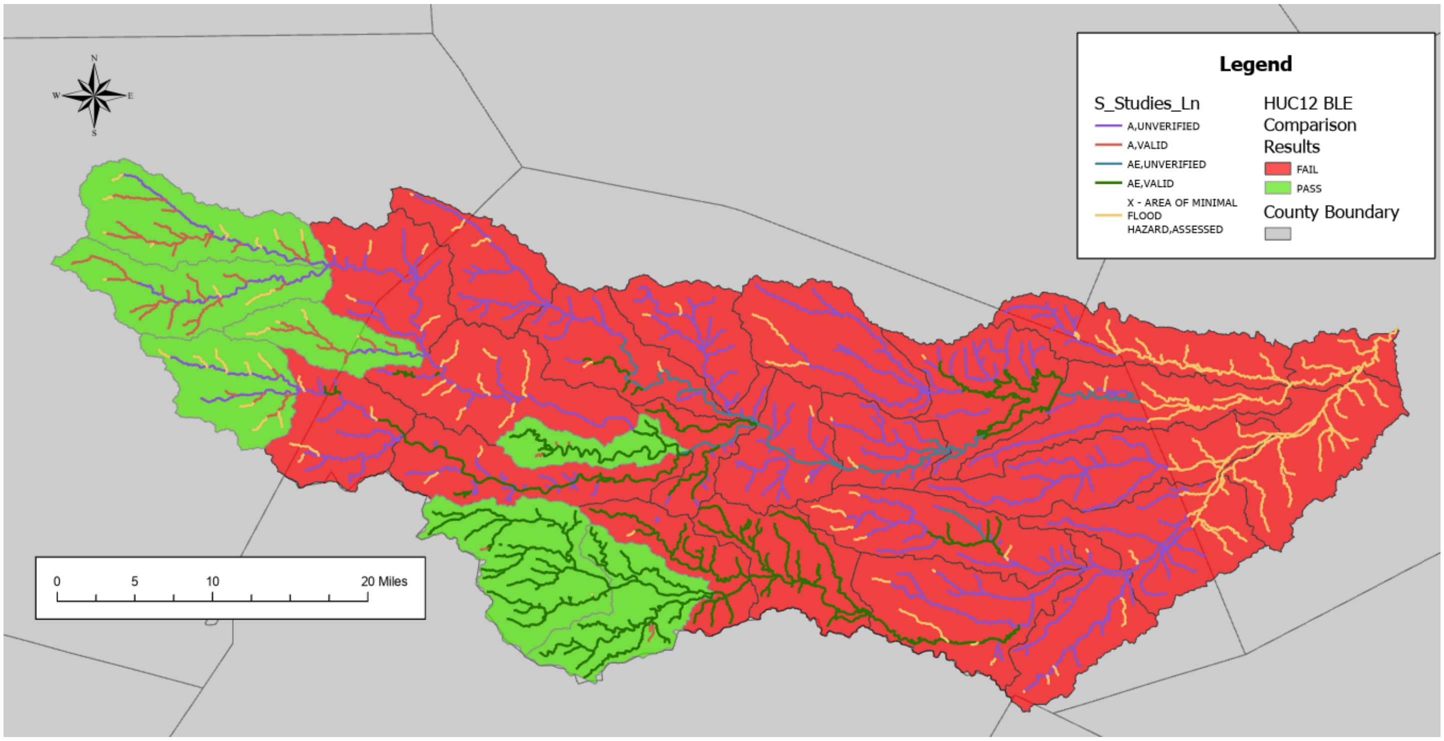

Figure 14: CNMS Validation Results

6.0 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent annual chance 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 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 uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by other 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 watershed extents for each return period to ensure proper model processing. A summary of results for counties within the watershed for the 1-percent annual chance scenarios are shown in **Table 21**. Totals only reflect data for those census tracts/blocks included in the user's study region and will reflect the entire county only if all of the census blocks for that county/state were selected at the time of study region creation. The losses are reported via census blocks. It is important to note that Hazus version 4.2 (SP02) uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by other 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.

Table 21: HAZUS Results for 1% Annual Chance Scenario

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Bastrop	$0	$0	$0
Bell	$50,000	$31,000	$14,000
Burnet	$11,980,000	$5,379,000	$3,317,000
Milam	$25,629,000	$6,590,000	$4,896,000
Travis	$128,000	$4,000	$4,000
Williamson	$1,182,127,000	$415,949,000	$350,534,000
Total	**$1,219,914,000**	**$427,953,000**	**$358,765,000**

7.0 References

Bibliography list of references used and referred to throughout document.

1. USGS. Multi-Resolution Land Characteristics Consortium. National Land Cover Database 2011. (http://www.mrlc.gov/nlcd2011.php).

2. Chow, Ven T. "Development of Uniform Flow and Its Formulas." Open Channel Hydraulics. Caldwell, NJ: Blackburn, 1959. 109-113. Print.

3. FEMA, "Guidance for Flood Risk Analysis and Mapping – First Order Approximation", November 2014. (http://www.fema.gov/media-library-data/1420849667914-c1656173985d814d0e62f80818505969/FOA_Guidance_Nov_2014.pdf).

4. FEMA Region 6, "Base Level Engineering Submittal Guidance", June 2017. (https://rmd.msc.fema.gov/Regions/VI/Ph0_Investment/1/Base%20Level%20Engineering/Submittal%20Guidance/20170615_BLE%20Submittal%20Guidance_R6.pdf).

5. USACE. Reservoir Regulation Tables (https://www.swf-wc.usace.army.mil/pertdata/BRAZOS.htm) .

Appendix A – Summary of Peak Flow Values (Q)

Stream Name	Drainage Area (Sq. Miles)	1% Peak Q (cfs)	1% minus Peak Q (cfs)	1% plus Peak Q (cfs)
North Fork San Gabriel River	250.3	4,281	1,547	6,998
North Fork San Gabriel River	248.0	1,952	800	7,053
South Fork San Gabriel River	86.3	68,160	27,687	133,052
Berry Creek	59.8	44,292	18,629	77,981
Berry Creek	80.5	47,182	21,262	83,944
Berry Creek	80.5	48,312	22,156	89,329
Chandler Branch	22.9	8,891	3,998	17,841
Lake Creek	27.4	12,069	4,405	24,409
Brushy Creek	33.5	17,239	8,417	31,825
Mustang Creek	34.1	25,838	11,783	51,925
Brushy Creek	61.4	34,322	16,159	60,039
Brushy Creek	138.8	62,730	27,644	112,326
Brushy Creek	188.5	78,115	34,612	141,154
Berry Creek	126.8	55,008	26,132	101,516
San Gabriel River	404.9	65,296	28,278	128,601
San Gabriel River	562.8	110,076	49,827	205,497
San Gabriel River	618.2	113,196	51,137	206,204
San Gabriel River	730.0	913	321	8,411
San Gabriel River	730.0	113,958	51,805	208,122

Appendix B – Exhibits – Base Level Engineering Results

Location	HUC10 / Work Area	Percent Annual Exceedance Probability					
		10%			4%		
		USGS Gage (cfs)	BLE RAS (cfs)	Difference (%)	USGS Gage (cfs)	BLE RAS (cfs)	Difference (%)
USGS 08105100 Berry Ck nr Georgetown, TX	503	9,976	14,058	41%	13,102	23,663	81%
USGS 08104900 S Fk San Gabriel Rv at Georgetown, TX	502	22,373	17,381	-22%	33,448	32,534	-3%
USGS 08105000 San Gabriel Rv at Georgetown, TX	505	41,993	18,685	-56%	65,562	33,222	-49%
USGS 08105400 San Gabriel Rv nr Circleville, TX	505	46,097	33,030	-28%	59,071	60,668	3%
FIS Study Location - San Gabriel River Confluence with N Fork San Gabriel at State Route 29	505	72,964	32,722	-55%	*	60,412	-
FIS Study Location - Lake Creek at Confluence with Lake Creek Tributary 1	504	3,134	2,691	-14%	4,646	5,057	9%
FIS Study Location - Chandler Branch at confluence with Brushy Creek	504	3,207	2,027	-37%	4,365	3,549	-19%

Location	HUC10 / Work Area	Percent Annual Exceedance Probability					
		2%			1%		
		USGS Gage (cfs)	BLE RAS (cfs)	Difference (%)	USGS Gage (cfs)	BLE RAS (cfs)	Difference (%)
USGS 08105100 Berry Ck nr Georgetown, TX	503	15,355	34,744	128%	17,535	47,820	173%
USGS 08104900 S Fk San Gabriel Rv at Georgetown, TX	502	43,590	49,948	12%	55,338	68,150	23%
USGS 08105000 San Gabriel Rv at Georgetown, TX	505	89,557	47,870	-48%	118,464	65,356	-45%
USGS 08105400 San Gabriel Rv nr Circleville, TX	505	69,841	87,863	18%	80,855	120,537	49%
FIS Study Location - San Gabriel River Confluence with N Fork San Gabriel at State Route 29	505	101,987	87,922	-14%	116,737	118,295	1%
FIS Study Location - Lake Creek at Confluence with Lake Creek Tributary 1	504	6,564	7,278	11%	10,330	9,764	-5%
FIS Study Location - Chandler Branch at confluence with Brushy Creek	504	5,439	4,326	-20%	7,135	6,669	-7%

Location	HUC10 / Work Area	Percent Annual Exceedance Probability		
		0.2%		
		USGS Gage (cfs)	BLE RAS (cfs)	Difference (%)
USGS 08105100 Berry Ck nr Georgetown, TX	503	22,537	93,237	314%
USGS 08104900 S Fk San Gabriel Rv at Georgetown, TX	502	89,607	135,540	51%
USGS 08105000 San Gabriel Rv at Georgetown, TX	505	212,361	125,804	-41%
USGS 08105400 San Gabriel Rv nr Circleville, TX	505	108,259	232,467	115%
FIS Study Location - San Gabriel River Confluence with N Fork San Gabriel at State Route 29	505	165,736	229,123	38%
FIS Study Location - Lake Creek at Confluence with Lake Creek Tributary 1	504	18,604	20,469	10%
FIS Study Location - Chandler Branch at confluence with Brushy Creek	504	10,894	14,450	33%