

FY18 Lower Brazos Little Brazos Watershed, TX Base Level Engineering (BLE) Results

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Table of Contents

Executive Summary	i
Base Level Engineering (BLE) Methodology	1
1.1 Topographic Data	2
1.1.1 Source Terrain Data	3
1.1.2 Terrain Data Processing.....	6
1.2 Hydrology.....	7
1.2.1 Regression Analysis.....	8
1.2.2 Stream Gage Analysis.....	9
1.3 Hydraulics.....	11
1.4 Quality Control	14
1.5 One-percent Special Flood Hazard Area Delineation.....	15
Challenges	16
Results and Recommendations.....	18
3.1 CNMS Validation of Effective Zone A SFHA	18
3.2 Flood Risk Analysis.....	24
References	25
Appendix A BLE Map.....	A-1

Executive Summary

Texas Water Development Board (TWDB) contracted AECOM to complete a Base Level Engineering (BLE) analysis for the Lower Brazos Little Brazos HUC-8 in East Central Texas, to support FEMA's 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 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. Details regarding the different datasets used are provided below in Section 1.1.

Flood discharges for this study were calculated using both the United States Geological Survey (USGS) regression equations and gage analysis, where stream gages with sufficient record exist. Regression equations were obtained from the USGS Scientific Investigations Report (SIR) 2009-5087, *Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach* (2009).

The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 5.0.5 was used to compute water surface elevations on a stream by stream basis. All hydraulic models were computed using 1-D steady state analysis.

The stream mile network that was validated for these watersheds 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 lists the Zone A stream miles associated with this validation analysis.

Table ES-1: Summary of Stream Miles

Source	Lower Brazos Little Brazos Stream Miles
CNMS	1,681.9

The full inventory of Zone A studies in the watershed were classified in CNMS. Total miles validated in CNMS are summarized in Table ES-2 and illustrated in Figure ES-1 below.

Table ES-2: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	485.8
UNVERIFIED	BEING STUDIED	1,196.1

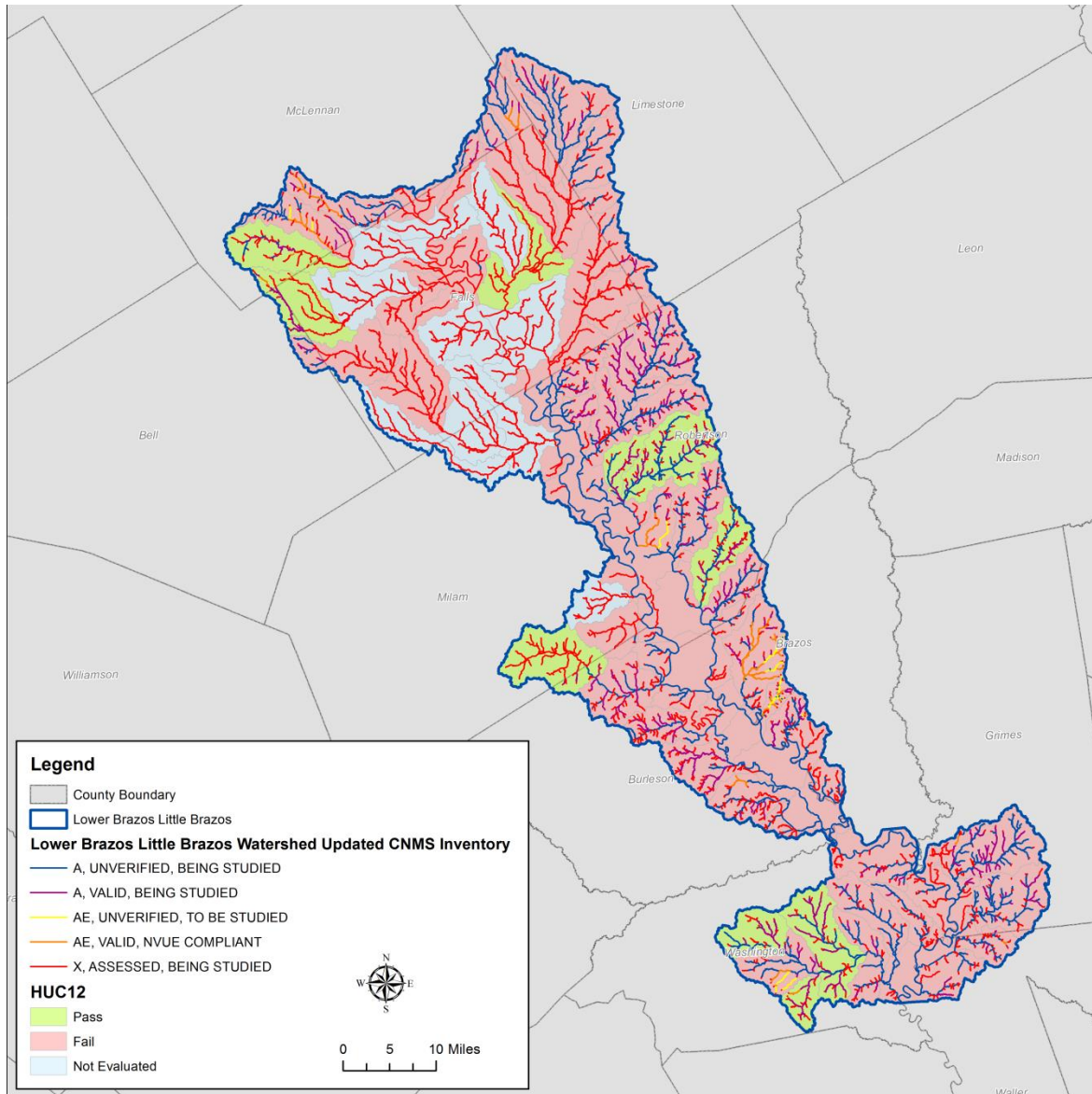


Figure ES-1: Lower Brazos Little Brazos Watershed CNMS Validation Results

An overall risk for each HUC-12 watershed was calculated using the National Flood Risk Percentages Dataset and its proportional area. The weighted risk was multiplied by the percentage of points in the watershed that failed the CNMS comparison to effectively determine the priority score. Figure ES-2 below shows the range of the Lower Brazos Little Brazos HUC-8 priority scores which can be used to initiate discussions during the Discovery phase.

Perry Creek – Brazos River HUC-12 was determined to have the highest priority score and the most need while Keechi Creek HUC-12 had the lowest score.

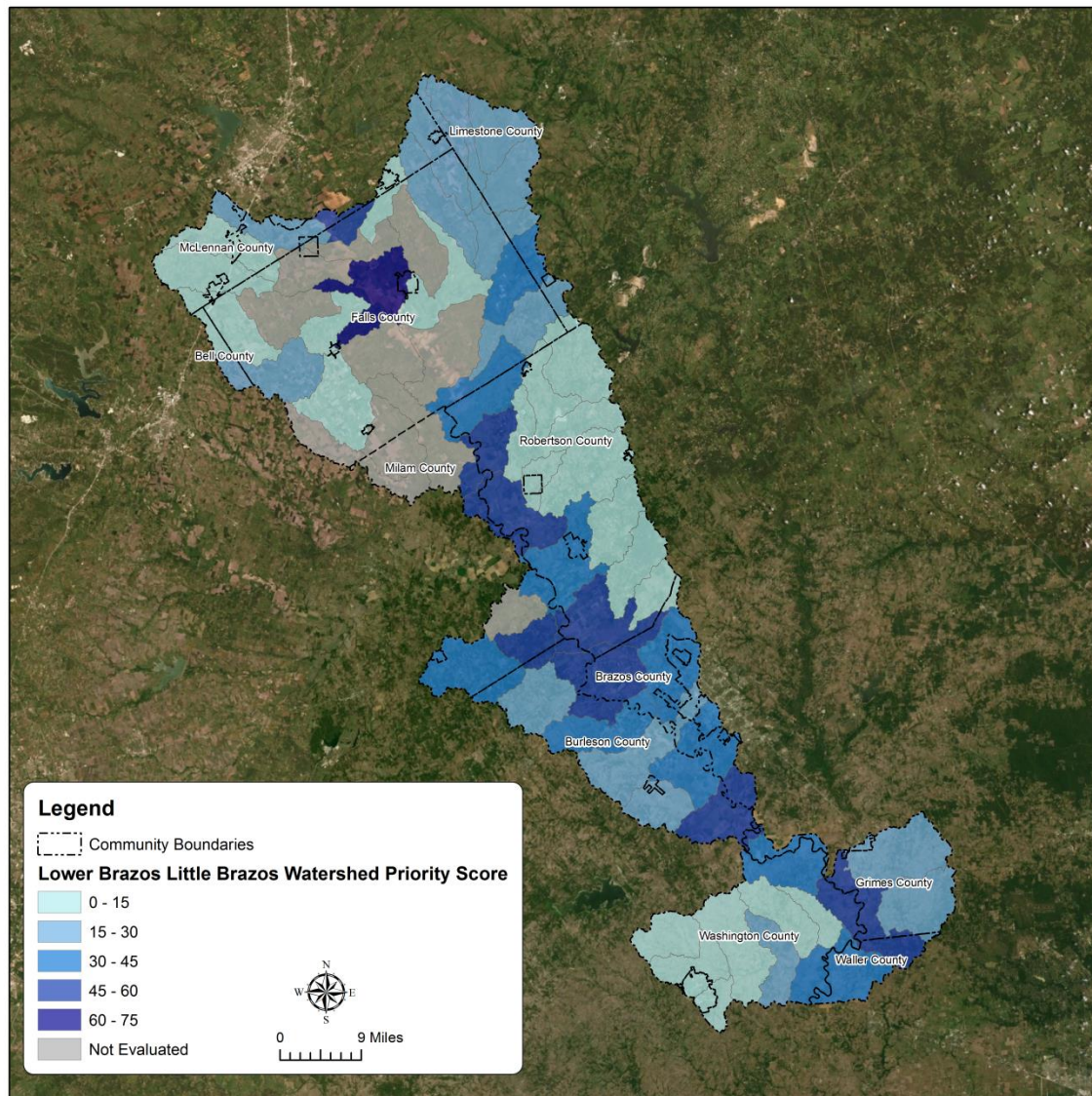


Figure ES-2: Ranking of Lower Brazos Little Brazos Watershed HUC-12s

Base Level Engineering (BLE) Methodology

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 AECOM to complete a BLE analysis for the Lower Brazos Little Brazos Watershed in East Central Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Bell, Brazos, Burleson, Falls, Grimes Limestone, McLennan, Milam, Robertson, Waller and Washington Counties, and include the following communities: the Cities of Bremond, Brenham, Bruceville-Eddy, Bryan, Calvert, College Station, Franklin, Golinda, Hearne, Hewitt, Lott, Marlin, Mart, Milano, Navasota, Robinson, Rosebud, Snook and Waco and Towns of Kosse, Lorena, Moody and Riesel. The study area consists of nine HUC-10 basins: Beason Creek – Brazos River, Brushy Creek – Big Creek, Cedar Creek – Brazos River, Deer Creek – Brazos River, Little Brazos River – Brazos River, New Year Creek – Brazos River, Old River – Brazos River, Pond Creek and Walnut Creek –

Brazos River. Figure 1 shows the orientation of the Lower Brazos Little Brazos HUC-10 basins with respect to the counties.

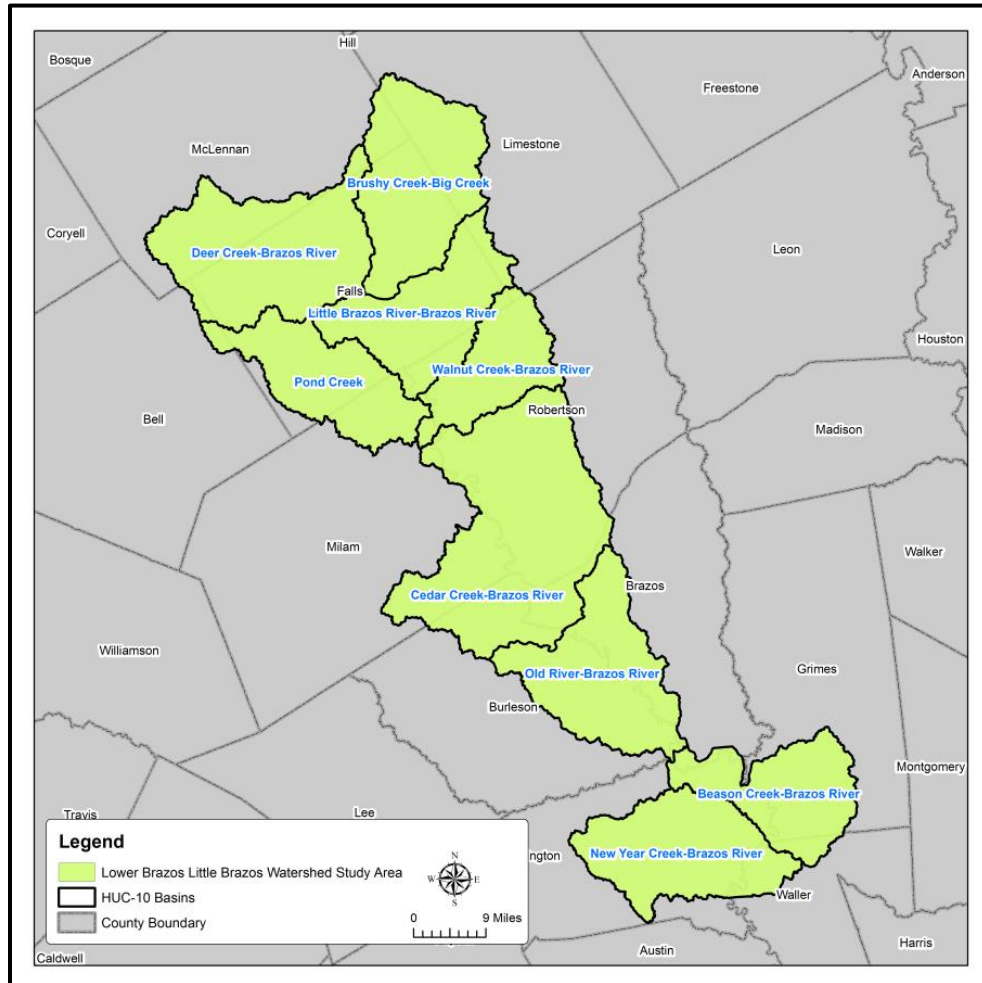


Figure 1: Lower Brazos Little Brazos Watershed HUC-10 Basins

AECOM studied approximately 3,500 miles of stream reaches within the Lower Brazos Little Brazos Watershed with a minimum drainage area tolerance of one square mile outside of population centers and half a square mile inside population centers. The selection and extent of stream reaches studied were based upon the number of stream miles with a minimum drainage area of one square mile and not the number of effective Zone A stream miles. Study reaches were extended above this threshold as appropriate to ensure all effective Zone A flood areas received an updated analysis. Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. The following sections summarize the BLE process and discuss the results along with their recommended use.

1.1 Topographic Data

Topographic data from multiple sources were used to determine the hydrologic and hydraulic characteristics of the watershed. Topographic data was obtained from the Texas Natural Resources Information System (TNRIS), and the United States Geological Survey (USGS).

All available metadata, survey reports, and other leverage documentation are available with the source dataset. Figure 2 shows the extents of the source Digital Terrain Model (DTM) data used for the Lower Brazos Little Brazos Watershed.

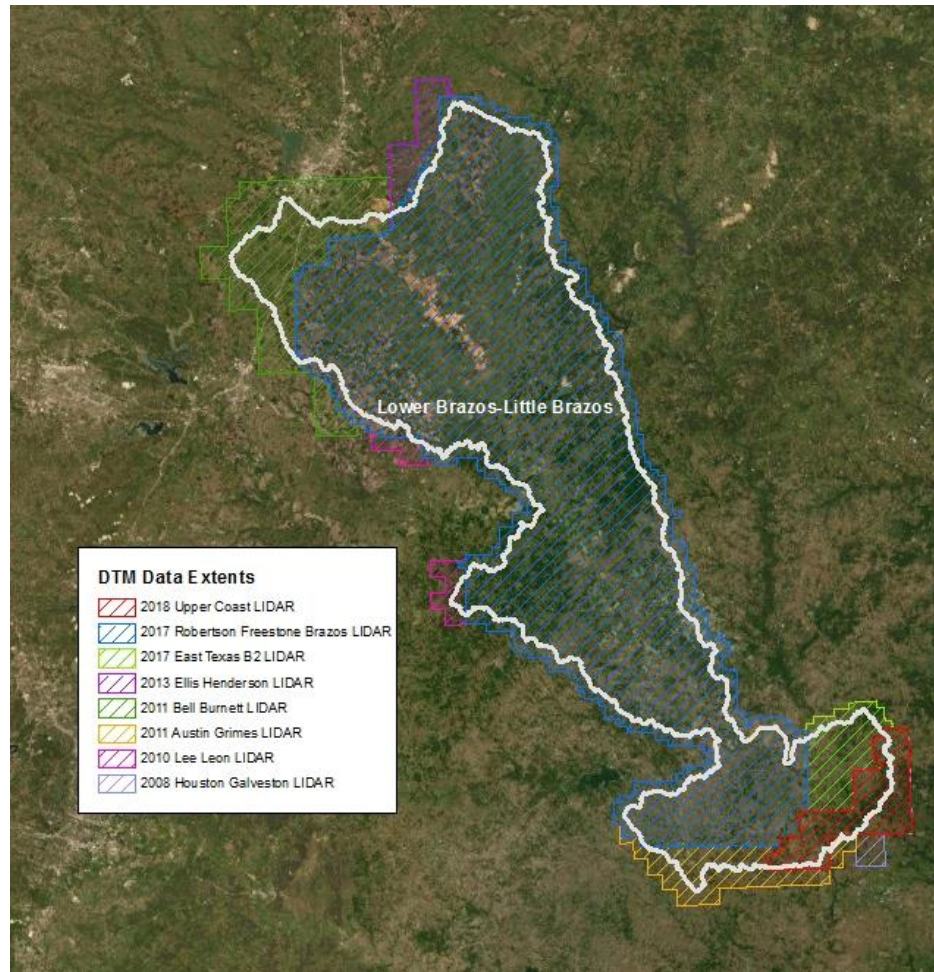


Figure 2: Extent of LiDAR Data for Lower Brazos Little Brazos Watershed

1.1.1 Source Terrain Data

Eight topographic datasets were used in the development of the BLE hydraulic models. Details on each dataset are outlined below.

1.1.1.1 2018 Upper Coast LiDAR

The Texas Water Development Board (TWDB) in cooperation with their project partners tasked Fugro Geospatial, Inc. (Fugro) under the Department of Information Resources (DIR) Geographic Information Systems (GIS) Hardware, Software and Services contract also known as the Texas Strategic Mapping (StratMap) Contract to acquire high resolution elevation data and associated products from airborne LiDAR systems during the 2017-2018 leaf-off season. The StratMap Program promotes inter-governmental collaboration and partnerships to purchase geospatial data products that provide cost savings and project efficiencies. Both the StratMap Program and the StratMap Contract are administered by the Texas Natural Resources Information System

(TNRIS), a division of TWDB. Project partners include: Houston-Galveston Area Council (H-GAC), Harris County Flood Control District (HCFCD), and the United States Geological Survey (USGS). This Coastal Texas project consists of approximately 9,758 DO4Q tiles and is located on the Texas Coast covering much of Orange to Matagorda County along with Harris County and the surrounding area. The project includes large metropolitan areas as well as coastal areas. The Urban and Coastal AOIs consist of approximately 4,045 square miles and were acquired between January 12 and March 22, 2018 utilizing both Riegl LMS-Q680i and Riegl LMS-Q780 sensors; collecting multiple return x, y, and z as well as intensity data. Specialized in-house and commercial software processes the native LiDAR data into 3-dimensional positions that can be imported into GIS software for visualization and further analysis. The horizontal datum for the data is the North American Datum of 1983 (NAD83, 2011) in meters and the vertical datum is the North American Vertical Datum of 1988 (NAVD88) in meters realized with GEOID12B.

1.1.1.2 2017 Robertson Freestone Brazos LiDAR

Digital Aerial Solutions (DAS) collected 5,445 square miles in the Texas counties of Brazos, McLennan, Freestone, Washington, Falls, Grimes, Navarro, Milam, Limestone, Hill, Robertson, and Burleson. The purpose of this LiDAR data was to produce high accuracy 3D elevation products, including tiled LiDAR in LAS 1.4 format, 3D breaklines, and 1 meter cell size hydro flattened Digital Elevation Models (DEMs). All products follow and comply with USGS LiDAR Base Specification Version 1.2. The nominal pulse spacing for this project was 1 point every 0.7 meters. Dewberry used proprietary procedures to classify the LAS according to project specifications: 1-Unclassified, 2-Ground, 7-Low Noise, 9-Water, 10-Ignored Ground due to breakline proximity, 17- Bridges, 18-High Noise. Dewberry produced 3D breaklines and combined these with the final LiDAR data to produce seamless hydro flattened DEMs for the project area. The data was formatted according to the USNG tile naming convention with each tile covering an area of 1,500 meters by 1,500 meters.

1.1.1.3 2017 East Texas B2 LiDAR

Project stakeholders included the Texas Natural Resources Information System (TNRIS) and Texas Commission of Environmental Quality (TCEQ). The project AOI (~2,763 square miles) is located in East Texas encompassing much of San Jacinto County and the surrounding area. The AOI includes large portions of Lake Livingston and the Sam Houston National Forrest. This region is dominated by dense forest. The data acquired will be used for floodplain planning and management, dam safety, feature extraction, water quality modeling, stream restoration analysis, change detection, wildfire mitigation, and habitat identification/modeling for endangered species. The data acquired will become part of an ongoing geospatial data collection program by the State of Texas to support regional and local mapping needs". - From TWDB Project Solicitation #580170829. An additional 755 mi² was appended to the project as part of an optional task award.

All raw and derived LiDAR data products were acquired and processed by Fugro Geospatial ("Fugro"). from December 2016 to September 2017. LiDAR derivative products included Hydro Breaklines, Hydro-flattened DEM Rasters, and Intensity Rasters.

1.1.1.4 2013 StratMap Ellis Henderson Hill Johnson Navarro LiDAR

The Texas Water Development Board contracted with Gorrondona & Associates, Inc. (Gorrondona) team, which consisted of the following firms; Gorrondona, Williams Aerial and

Mapping (WAM), and McKim & Creed, Inc. For the purposes of this project the LiDAR points were gridded 3 foot by 3 foot in an effort to save processing time and space due to the density of the original LiDAR points. The purpose of this project is to support the ongoing data collection efforts by the State of Texas to facilitate the mapping and modeling of flood plains, hydrography, and terrain. Aerial LiDAR data was collected for this project, encompassing two distinct Areas of Interest (AOIs) within the State of Texas. These AOIs were designated as the Northern and Central AOIs. The Northern AOI covered portions of the following counties in TX: Parker, Hood, Johnson, Ellis, Hill, Navarro, Henderson, McLennan, Limestone, Kaufmann, and Falls. The Central AOI covered portions of the following counties in TX: Guadalupe, Atascosa, Wilson, Gonzales, Karnes, DeWitt, Live Oak, and Bee. The LiDAR collected was calibrated and processed to produce digital elevation model (DEM), LiDAR intensity image, classified LAS point cloud, and hydro-breakline files for the geographic areas covered by the AOIs.

1.1.1.5 2011 StratMap Bell Burnett McLennan 50 cm LiDAR

The Photo Science, Inc. acquisition team collected ALS50-II, and Optech Gemini derived LiDAR over the Texas AOI in the State of Texas with a 1m, nominal post spacing using a Piper Navajo aircraft. The collection for the entire project area was accomplished from March 11, 2011 through July 31, 2011. The collection was performed using a Leica ALS50-II MPiA LiDAR system, serial numbers ALS019 and Optech Gemini systems, serial numbers 240 246 and 247, including an inertial measuring unit (IMU) and a dual frequency GPS receiver. This project required 62 lifts of flight lines to be collected. The lines were flown at an average of 6,000 feet above mean terrain using a maximum pulse rate frequency of 127,500 Hz. The sensor had a 32 degree FOV and a swath width of 1032 meters.

Leica software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning of the sensor during all flights. This software suite includes Applanix's PosPac and Waypoint's GrafNav solutions. PosPac provides the smoothed best estimate of trajectory (SBET) that is necessary for Leica's post processor to develop the point cloud from the LiDAR missions. The point cloud is the mathematical three dimensional collection of all returns from all laser pulses as determined from the aerial mission. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are removed from the data set. The point cloud was processed within the Leica software; GeoCue, TerraScan, and TerraModeler software was used for the automated data classification, manual cleanup, and bare earth generation from this data. Project specific macros were used to classify the ground and to remove the side overlap between parallel flight lines. All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. QT Modeler and QT Reader was used to review the surfaces a second time to ensure the bare earth surface model.

1.1.1.6 2011 StratMap Austin Grimes Walker 50 cm LiDAR

The project area is 840 tiles covering approximately 3300 square miles in the Austin / Walker counties of Texas. The project design of the LiDAR data acquisition was developed to support a nominal post spacing of 0.5 meter. The AeroMetric, Inc. acquisition covered 440 flights lines in 51 lifts from January 8, 2011 through February 3, 2011. LiDAR data collection was performed with a Piper Navajo aircraft, utilizing an Optech Gemini sensor, Serial Number 07SEN201, collecting multiple return x, y, and z data as well as intensity data. Keystone Aerial Surveys was sub-contracted by AeroMetric, Inc. to complete a portion of the acquisition of this area. Keystone

completed 26 of the 51 lifts, utilizing an Optech Gemini sensor, Serial Number 05SEN191, in a Cessna 310. The LiDAR data was processed to achieve a bare ground surface. LiDAR data is remotely sensed high-resolution elevation data collected by an airborne collection platform. Using a combination of laser range finding, GPS positioning and inertial measurement technologies, LiDAR instruments are able to make highly detailed Digital Elevation Models (DEMs) of the earth's terrain, man-made structures and vegetation.

1.1.1.7 2010 StratMap Lee Leon Madison Milam 1m LiDAR

TNRIS contracted with Photo Science Inc to provide high density elevation map data for the AOI in Texas. This LiDAR operation was designed to provide a high density set of masspoints within the defined areas. The data sets are suitable for the development of contours for use in hydraulic/hydrologic model development, and for assessing environmental impacts. Typical uses for the data set include: FEMA Flood Plain Map Modernization. DFIRM map updates. Watersheds and other hydro studies per FEMA specifications. County Mapping projects which include several uses, in addition to Flood mitigation assessment. The data was collected between January 18, 2010 and January 22, 2010. In order to post process the LiDAR data to meet task order specifications, Photo Science established a total of 64 QA control points that were used to calibrate the LiDAR to known ground locations established throughout the project area.

Leica software was used in the post processing of the airborne GPS and inertial data that is critical to the positioning of the sensor during all flights. This software suite includes Applanix's PosPac and Waypoint's GrafNav solutions. PosPac provides the smoothed best estimate of trajectory (SBET) that is necessary for Leica's post processor to develop the point cloud from the LiDAR missions. The point cloud is the mathematical three dimensional collection of all returns from all laser pulses as determined from the aerial mission. At this point this data is ready for analysis, classification, and filtering to generate a bare earth surface model in which the above ground features are removed from the data set. The point cloud was processed within the Leica software; GeoCue, TerraScan, and TerraModeler software was used for the automated data classification, manual cleanup, and bare earth generation from this data. Project specific macros were used to classify the ground and to remove the side overlap between parallel flight lines. All data was manually reviewed and any remaining artifacts removed using functionality provided by TerraScan and TerraModeler. QT Modeler and QT Reader was used to review the surfaces a second time to ensure the bare earth surface model.

1.1.1.8 2008 Houston Galveston Area Council (HGAC) LiDAR

The 2008 Houston Galveston Area Council LiDAR was acquired between February 1, 2008 and March 4, 2008 with a publication date of November 3, 2008. Merrick & Company (Merrick) performed a LiDAR survey for the HGAC. In order to post process the LiDAR data to meet task order specifications, Merrick established a total of 296 QA control points that were used to calibrate the LiDAR to known ground locations established throughout the project area. The NVA reported for the 2012 East Central Texas LiDAR was .22 feet at the 95% confidence level, which meets project accuracy specifications of the National Standard for Spatial Data Accuracy (NSSDA).

1.1.2 Terrain Data Processing

The LiDAR data were processed in Environmental System Research Institute (ESRI) ArcGIS software to create a composite Digital Terrain Model (DTM) dataset for the project area. The

outputs from the processing described below were used during the hydrology, hydraulics, floodplain mapping and CNMS processes and validations.

The Watershed Information System (WISE) software platform was utilized in order to create a digital surface model for the project area. This module allows source data from a variety of sources to be prioritized based on level of accuracy or preference of the user.

For the Lower Brazos Little Brazos Watershed, the 2018 Upper Coast LiDAR was highest priority followed by the 2017 Robertson Freestone Brazos LiDAR, 2017 East Texas B2 LiDAR, 2013 StratMap Ellis Henderson Hill Johnson Navarro LiDAR, 2011 StratMap Bell Burnett McLennan 50cm LiDAR, 2011 StratMap Austin Grimes Walker 50cm LiDAR, 2010 StratMap Lee Leon Madison Milam 1m LiDAR, and 2008 Houston Galveston Area Council (HGAC) LiDAR data was the lowest priority dataset. These datasets were used as the data sources for creating the 10-ft and 50-ft DEMs.

The DEMs created from the LiDAR datasets mentioned above were compiled in order of vertical accuracy into a mosaic dataset using ArcMap. From this mosaic, a tile index was created for the project area and the mosaic was clipped into 50,000-foot tiles, converted to asciis and imported into WISE Terrain Analyst (WTA). Visual inspection of the 10-foot DEMs was performed to ensure no voids and/or artifacts were present in the DEM. The DEM surface model was affirmed to be suitable for hydraulic takeoffs and supporting other hydraulic analyses.

Stream centerlines were manually digitized using the 10-foot DEMs as a source for horizontal alignment and vertical elevation. These stream centerlines are created for use in the hydraulic analysis, hydro-enforcement of the 50-foot DEMs, and visual reference on the FIRM products. Several routines were then used to take localized elevations from the source topographic data and apply them to the streams. This gave the stream vertices elevation information along the Z axis. The resulting elevations ensure that the streams are lower in elevation than any overbank sums. A separate routine was then used to ensure that the elevations of these vertices descend in height down to an outfall. The final streams file is then “burned” into the 50-foot DEMs to force flow through structures while preventing it from jumping out of the channel banks.

After the DEM was imported, an additional 50-foot DEM was created from the same mosaic and tile index used for the 10-foot DEM. This 50-foot DEM was used for hydro enforcement of the project areas. Proprietary software was used to identify natural sinks, peaks and flat areas in the 50-foot DEM surface. Elevations of the cells in the DEM were algorithmically calculated and the best path to route flow was determined without filling sinks in the DEM. Once all calculations were completed, the flow was checked confirming that all drainage flowed downstream correctly and routed to outside of the project area.

In addition to the quantitative assessment of the source digital terrain, a qualitative visual inspection of the composite DEM was performed using a hillshade derived from the 10-foot DEM. The visual inspection indicated that no unusual or non-terrestrial features were observed in the composite DEM, assuring the surface files used for hydrologic and hydraulic analyses and floodplain mapping activities are sufficient for BLE analysis.

1.2 Hydrology

Flood discharges for this study were calculated using both the United States Geological Survey (USGS) regression equations and gage analysis, where stream gages with sufficient record exist. Regression equations obtained from the USGS Scientific Investigations Report (SIR) 2009-5087,

Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment Based, PRESS-Minimized, Residual-Adjusted Approach (2009) contain the most recent regression equations for Texas. USGS Peak FQ Version 7.1 was used to perform the Flood Frequency Analysis (FFA) for the gages within the Lower Brazos Little Brazos Watershed (see below for further discussion).

1.2.1 Regression Analysis

The Watershed Information System (WISE) software was used to delineate drainage basins in shapefile format using the 50-foot DEM. WISE was also used to calculate the main-channel slope for each basin. The basin shapefile attribution was automated by WISE with drainage area, main-channel slope, precipitation, and OmegaEM.

Table 1 shows the published equations used in this study. In these equations, Q_i represents peak streamflow for i -recurrence interval (annual chance exceedance (a.c.e.)) in cubic feet per second (cfs), P represents mean annual precipitation in inches, S represents dimensionless main-channel slope, Ω represents the OmegaEM parameter, and A represents cumulative drainage area in square miles.

Table 1: Summary of Regression Equations in Texas (SIR 2009-5087)

Recurrence Interval	Equation
$Q_{10\%}$	$P^{1.203} \times S^{0.403} \times 10^{[0.918\Omega + 13.62 - 11.97A^{(-0.0289)}]}$
$Q_{4\%}$	$P^{1.140} \times S^{0.446} \times 10^{[0.945\Omega + 11.79 - 9.819A^{(-0.0374)}]}$
$Q_{2\%}$	$P^{1.105} \times S^{0.476} \times 10^{[0.961\Omega + 11.17 - 8.997A^{(-0.0424)}]}$
$Q_{1\%}$	$P^{1.071} \times S^{0.507} \times 10^{[0.969\Omega + 10.82 - 8.448A^{(-0.0467)}]}$
$Q_{0.2\%}$	$P^{0.988} \times S^{0.569} \times 10^{[0.976\Omega + 10.40 - 7.605A^{(-0.0554)}]}$
Variables: Q_i , peak flow for i recurrence interval (a.c.e.), in cubic feet per second; P , mean annual precipitation, in inches; S , Main-channel slope (dimensionless); Ω , OmegaEM parameter; A , cumulative drainage area, in square miles	

Discharges for the 1-percent plus and 1-percent minus a.c.e. were calculated as well. These values were computed as $Q_{1\% \pm} = Q_{1\%} \times (10^{\pm 0.30})$ where 0.30 is the residual standard error in $\log_{10}$ -unit of cubic feet per second for the $Q_{1\%}$ equation (Table 3 in SIR 2009-5087). In other words, these values were computed by multiplying the $Q_{1\%}$ discharges by 1.995 and 0.501 respectively, which account for the $\log_{10}$ format residual standard error of 0.30 associated with the $Q_{1\%}$ regression equation.

The mean annual precipitation values were determined based on a shapefile coverage obtained from the Texas Water Development Board (TWDB) and available for download at the following location: <https://www.twdb.texas.gov/mapping/gisdata.asp>.

The annual precipitation values reflect data for the climatological period 1981-2010 as recorded by the Natural Resources Conservation Service (NRCS).

Main-channel slope was calculated in WISE. An automated routine determined the longest flowpath from upstream of a reach to the outlet of the sub-basin of interest. Two points along the channel, one at 0 percent and the other at 100 percent of the channel length, determined the endpoints of the segment used in the main-channel slope calculation. The elevations for those endpoints were based on the 10-foot DEM developed from the LiDAR.

From USGS SIR 2009-5087, the OmegaEM parameter is a generalized terrain and climate index that expresses relative differences in peak-streamflow potential. A shapefile was developed and populated with OmegaEM values based on Figure 2 in SIR 2009-5087. This shapefile was used to determine Omega EM values on a sub-basin basis. For sub-basins spanning more than one OmegaEM grid, the sub-basin's centroid determined its OmegaEM parameter.

Drainage area for each sub-basin was determined based on automated basin delineations performed by WISE. Basin break points were set by the user with a sub-basin target size of one square mile. This criterion was adjusted for the main stem of the Brazos River to avoid excessive and unnecessary discharge breaks. Break points were also set immediately upstream of stream confluences. Cumulative drainage area was determined based on these automated delineations performed by WISE in combination with a stream connectivity routine that defined the stream reach segments with upstream and downstream neighbors.

The sub-basin shapefile was attributed with the computed discharges, and those discharges were incorporated into the HEC-RAS models using an automated routine in WISE. Discharges, as well as water surface elevation results, were associated with the hydraulic cross sections prior to generation of floodplain boundaries and grid mapping. Those results are available in GIS format as part of this BLE submittal package.

1.2.2 Stream Gage Analysis

Figure 3 shows the location of the eight active USGS stream gages along the Brazos River mainstem in the Lower Brazos Little Brazos watershed used to develop weighted discharges for the study (

Table 2). In addition to those within the Lower Brazos Little Brazos watershed, additional gages just upstream and further downstream of this watershed were also considered for the analysis and shown in Figure 3. Flood frequency analyses (FFA) were performed for all eight gages, according to Bulletin 17B guidelines. USGS WRIR 96-4307 was used as a reference during the stream gage analysis; however, the flood frequency data for these gages were not weighted with the regression-developed discharges using the procedure described by this USGS report due to the large size of the basin and because this report's analysis was based on natural flow record prior to any regulation. Since post-regulation records were used for this BLE study, the USGS WRIR 96-4307 procedure doesn't apply.

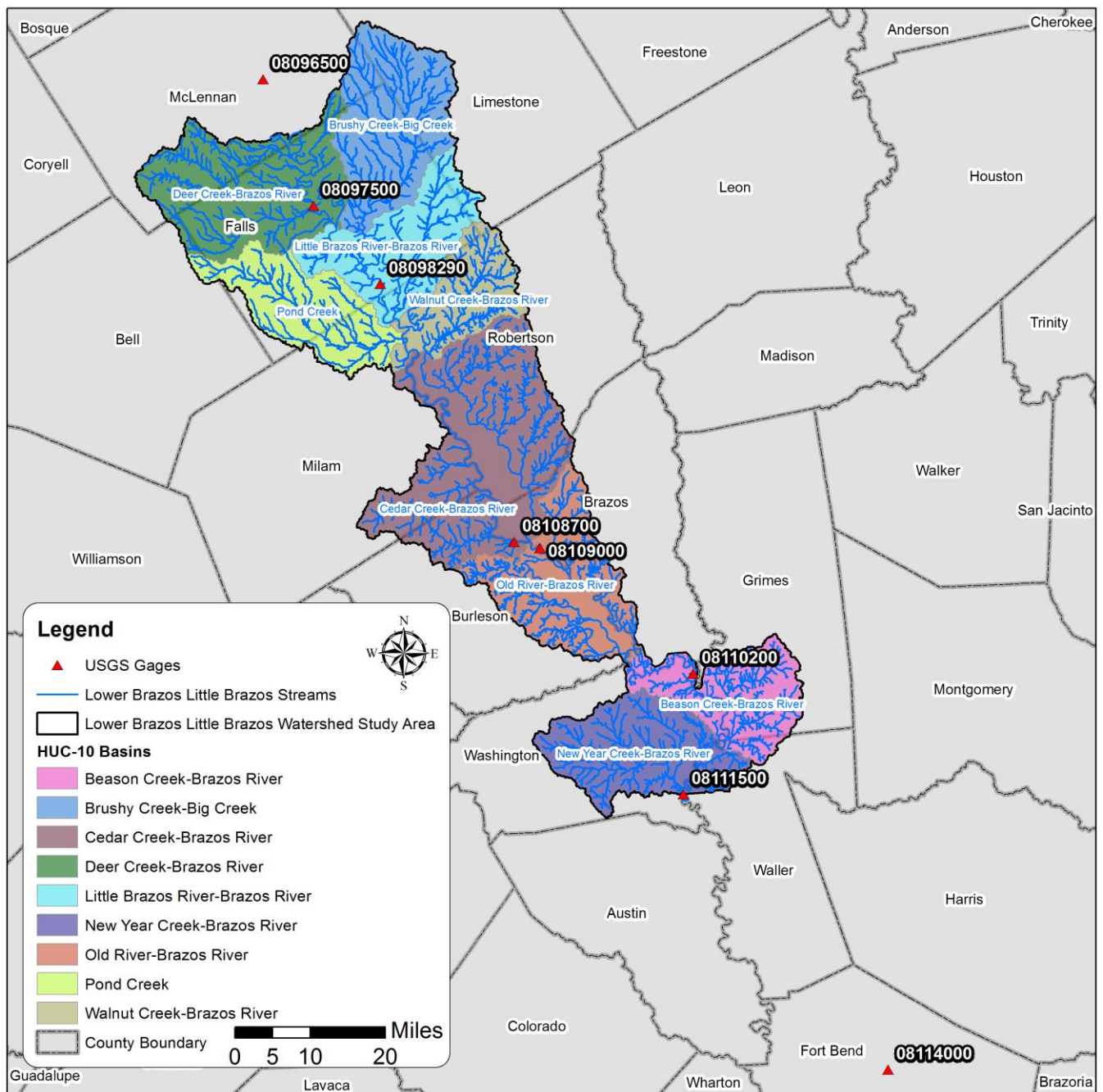


Figure 3: Locations of USGS Gages Utilized in Flood Frequency Analyses

Table 2: USGS Stream Gages in Lower Brazos Little Brazos Watershed

Gage ID	Flooding Source and Location	Computed Drainage Area (mi. ²)	Published Drainage Area (mi. ²)	Period of Record
08096500	Brazos Rv at Waco, TX	237.48	29,559	1941-2017
08097500	Brazos River near Marlin, TX	237.48	30,211	1939-1951
08098290	Brazos River near Highbank, TX	781.18	30,436	1966-2017
08108700	Brazos River at SH21 near Bryan, TX	1,466.88	39,049	1994-2017
08109000	Brazos River near Bryan, TX	1,475.1	39,515	1941-1993
08110200	Brazos River at Washington, TX	1,820.86	41,192	1966-1996
08111500	Brazos River near Hempstead, TX	2,293.29	43,880	1899, 1939-2017
08114000	Brazos River near Richmond, TX	NA	45,107	1936-2017

Flood Frequency Analysis for gage 08114000 was discarded due to distance downstream. Discharges for the Brazos River estimated by gage analysis are presented in Table 3.

Table 3: Discharges at USGS Stream Gages in Lower Brazos Little Brazos Watershed

Gage ID	10PCT (cfs)	4PCT (cfs)	2PCT (cfs)	1PCT (cfs)	0.2PCT (cfs)
08096500	66,100	93,700	117,000	143,000	172,000
08097500	68,463	96,217	119,442	145,085	173,465
08098290	69,298	97,102	120,296	145,812	173,974
08108700	102,000	130,000	151,000	171,000	191,000
08109000	103,000	132,000	153,000	173,000	193,000
08110200	103,399	131,195	151,385	170,162	188,932
08111500	104,000	130,000	149,000	166,000	183,000

1.3 Hydraulics

The hydraulic approach for this BLE analysis of the Lower Brazos Little Brazos Watershed consisted of using the terrain model described in Section 1.1 in combination with the hydrologic outputs from Section 1.2 to establish water surface elevations using 1-D steady state analysis. The Hydrologic Engineering Center's River Analysis System (HEC-RAS) program version 5.0.5 was chosen as the computer model to compute water surface elevations on a stream by stream basis. The WISE software was used to establish model stream orientation, generate initial hydraulic cross section layout and stationing, assign n-values to cross sections, and develop all input files for

the HEC-RAS program. ESRI's ArcMap program was used to review and refine cross-section layout orientation.

First pass cross-section layout was performed using an automated routine in WISE that varies cross section spacing based on the cumulative drainage area at the cross section location. A first draft model was created based on this initial cross-section layout, and draft boundaries were developed. Next, a second pass inspection for cross-section placement and alignment occurred. Significant refinement occurred during this step. To improve the hydraulic models, additional cross-sections were added as needed to better define the BLE floodplain boundary. Cross-sections were extended in locations where overtopping occurred. Orientation of cross-sections was refined to improve on the perpendicular orientation to flow. Additional cross-sections were added at floodplain constrictions and at downstream portions of tributaries to ensure a proper tie-in with receiving streams. Cross-sections were adjusted to remove sections that intersected hydraulic crossings in the floodplain. For some of the largest studied streams, cross-sections were laid out manually in order to have more reasonable spacing and better capture the constrictions in the floodplain.

Cross-sections were not drawn on top of roadways or railroads but were placed at the upstream and downstream face of major roads and railroads. Ineffective flow stations were placed in the hydraulic models as appropriate to account for flow constrictions and other locations deemed by the engineer to be ineffective at conveying flow downstream.

Cross-sections were drawn on dam crests for dams with well-defined spillways in order to better represent ponded water upstream of the structures. In so doing, it was assumed that the vast majority of the flow during a flood event would pass the spillway and that the hydraulic model would reasonably estimate flow across the spillway as represented in the hydraulic cross-section. The elevations used in the modeling were checked against effective Zone A boundaries, and the results were deemed reasonable.

The relationship between cumulative drainage area and assigned channel geometry is shown in Table 4. These default values for dimensions and spacing were subject to change based on engineering judgment.

Table 4: Cross-Section Default Parameters

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
1.0	500	7	6	0.8
2.0	500	8	7	0.8
4.0	500	11	10	0.8
8.0	500	12	11	0.8
10.0	500	13	12	0.8
15.0	500	18	13	0.8
20.0	500	19	14	0.8
25.0	500	20	15	0.8
30.0	500	21	16	0.8
40.0	500	25	17	0.8
50.0	600	28	18	0.8
75.0	600	30	19	1
100.0	750	33	20	1
150.0	750	36	21	1

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
250.0	1000	38	22	2
500.0	1500	40	23	2
1000.0	2500	100	50	3
2000.0	2500	150	75	3
5000.0	2500	100	100	3

In typical BLE projects, Manning's roughness coefficients (n-values) are determined using the 2016 National Land Cover Data (NLCD) dataset in combination with n-values from Chow (1959) and Calenda et al. (2005). For this watershed, the n-values for the developed areas indicated an underestimation of the roughness coefficients when compared to the aerial imagery and were adjusted accordingly. The association between the n-values and the NLCD Classification is shown in Table 5. Manning's n-value takeoffs are performed by WISE (default values taken from the "Normal" column). N-values within channel banks are constrained by the automated routine to a range of 0.030 to 0.070. Then, overbank and channel n-values are manually adjusted in certain locations based on engineering judgment.

Table 5: Manning's "n" Roughness Based on 2016 NLCD Classification (Moore, 2011)

NLCD Classification	Selected Manning's n	Minimum	Normal	Maximum	Source
Open Water	0.033	0.025	0.03	0.033	Chow 1959
Developed, Open Space	0.04	0.01	0.013	0.016	Calenda et al. 2005
Developed, Low Intensity	0.08	0.038	0.05	0.063	Calenda et al. 2005
Developed, Medium Intensity	0.1	0.056	0.075	0.094	Calenda et al. 2005
Developed, High Intensity	0.15	0.075	0.1	0.125	Calenda et al. 2005
Barren Land	0.025	0.025	0.03	0.035	Chow 1959
Deciduous Forest	0.16	0.1	0.12	0.16	Chow 1959
Evergreen Forest	0.16	0.1	0.12	0.16	Chow 1959
Mixed Forest	0.16	0.1	0.12	0.16	Chow 1959
Scrub/Shrub	0.1	0.035	0.05	0.1	Chow 1959
Grassland/Herbaceous	0.035	0.025	0.03	0.035	Chow 1959
Pasture/Hay	0.03	0.03	0.04	0.05	Chow 1959
Cultivated Crops	0.035	0.025	0.035	0.045	Chow 1959
Woody Wetlands	0.12	0.08	0.1	0.12	Chow 1959
Emergent Herbaceous Wetland	0.07	0.07	0.1	0.15	Chow 1959

The downstream boundary condition used for the majority of the study streams was normal depth with a default value of 0.005 ft/ft. For streams with large drainage areas (generally greater than eight square miles), the normal depth slope was calculated based on the channel inverts of the downstream cross sections.

Several HUC-10s within this watershed are located in urban areas with storm drain systems, which are unaccounted for in the BLE models. Implications of these systems may considerably affect risk.

1.4 Quality Control

Following the initial hydraulic model analysis in each watershed, the resulting flood hazard area delineations were reviewed for areas where the results were not ideal.

QC results indicated that some of the models should be extended to cover the scope of effective flood hazard data. Those streams were extended farther upstream to match the extents of the effective SFHA.

Typical revisions resulting from reasonability checks included adding cross-sections, adjusting orientation of cross-sections, trimming cross-sections and reduction of the default “V” angle of cross-sections. Examples of default “V” angled cross-sections are shown in Figure 4. It is estimated that 75 percent of cross-sections were adjusted in some work areas while other areas did not require as much editing. Other examples of manual editing included the addition of cross-sections at confluence areas (see Figure 5 below), modifications to improve perpendicular orientation at the channel, adjustment of discharge breaks to better represent flow addition points, revisions to cross sections at dams, additional cross-sections bounding major hydraulic structures, and revisions to n-values.

A major component of the QC process was an automated check that identified locations where the 1-percent a.c.e profile was crossed by any other frequency profile. Significant effort was made to reasonably resolve all of these instances. Another automated check identified locations where there was a drawdown of greater than 0.5 foot on the 1-percent a.c.e. water surface profile. This check is particularly useful for identifying errors in the model such as a channel that is too wide, a poorly placed cross-section, or a need for additional cross-sections. Again, significant effort was made to reasonably resolve these drawdown situations.

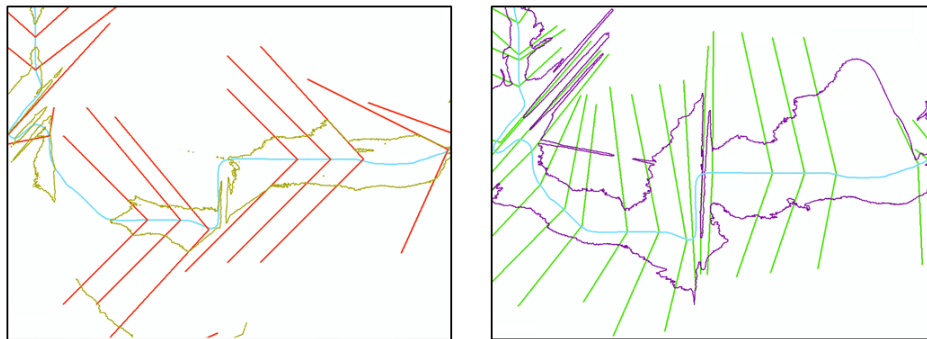


Figure 4: Default “V” angle cross-sections automated by WISE (left). Manually edited cross-sections to more accurately capture terrain (right). Resulting flood boundaries shown in gold (left) or purple (right) for clarity.

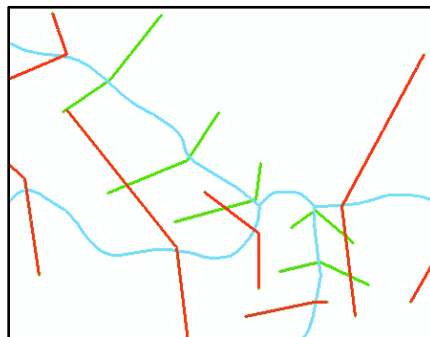


Figure 5: Manually added cross-sections (green) to improve accuracy of tie-ins at confluences.

1.5 One-percent Special Flood Hazard Area Delineation

The 1-percent and 0.2-percent boundaries were mapped using a routine that develops water surface elevation grids based on the 10-foot cell size DEM developed from the LiDAR dataset used for this project (see Section 1.1). This product was converted to a polygon for cleaning. The cleaning routine involved manual inspection of the polygons to identify and remove areas of disconnected flooding. In general, all polygons greater than 5,000 square feet are investigated, but all polygons, including those less than 5,000 square feet that intersect the stream line are included in the final output. This investigation was aided by the ground DEM and aerial imagery. Manual adjustments to the polygons were made to account for spillways on dams which could not be accurately modeled using HEC-RAS as well as disconnected areas along the flooding source that should reasonably be connected.

Following the removal of disconnected flooding areas and other boundary adjustments, the small islands in the floodplain were filled. In general, islands less than 20,000 square feet were inspected and filled.

Once the island filling process was complete, the water surface raster mapping routine was run and set to conform to the polygon boundary. This ensures that the water surface raster and the floodplain boundary are consistent with each other. 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.

Challenges

The Lower Brazos Little Brazos Watershed is located in East Central Texas, an area known for flat terrain. In some of the wide and flat floodplains, small tributaries run parallel to large streams. Parallel streams with shared floodplains were modeled by moving the combined discharge upstream to the cross-section that begins the shared floodplain.

A significant effort was made to achieve proper 1%-a.c.e. water surface elevation tie-ins at stream confluences. Cross-sections were manually added on the downstream end of nearly every stream, some of which traverse the receiving stream; so that the water surface elevation of the tributary would be lower than that of the receiving stream.

There are a significant number of dams of varying sizes throughout the watershed. Discharges calculated with the regression equations do not take into account the impact of these structures. There may be need for further investigation, particularly for those dams designed for flood control, when upgrading these models for detailed studies.

There are a few containment issues across the study area. In some areas the 0.2%- a.c.e. flows overtopped cross section. For these situations, additional investigation is recommended when upgrading these models for detailed study.

Area-specific challenges follow:

For the Brazos River Mainstem (BRMS), the most challenging area was along the reach where the Lower Brazos River Mainstem (LBRMS) runs parallel to the BRMS and the two mainstems share a floodplain in between them. Based on the initial individual analyses for these two mainstems, the BRMS experiences split-flow along this shared floodplain. At the same time, individual analysis of the LBRMS suggests an overtopping towards the upstream end of this shared floodplain with the BRMS. The final modeling approach was to simulate both mainstems separately with bank stations defined to delineate the main channel for the river being modeled and ineffective areas set within the shared floodplain along the reach where both rivers run parallel to each other. A set of cross-sections were cut for LRRMS which are nearly identical to the BRMS cross-sections for comparison purposes. The final output rasters were created based on the maximum water surface elevation between these two mainstems. The peak flows for the LBRMS were calculated based on the regression equation analysis as mentioned in Section 1.2, and the peak flows for the BRMS were calculated based on the gage analysis, also discussed above in Section 1.2. For the area where the two mainstems run parallel to each other, the BRMS is assumed to convey the combined flow, as measured at the downstream gage where BRMS meets with LBRMS (i.e. the combined flow of the two mainstem basins are used at this location).

In the Brushy Creek HUC-10, UNT 020 from upstream station 26,710 to downstream station 25,210 in Brushy Creek Watershed, were not able to contain 0.2%- a.c.e. flooding.

In the Cedar Creek HUC-10, UNT 031 in Cedar Creek Watershed was not able to contain in the 0.2%- a.c.e. flooding.

In Little Brazos River HUC-10, Alligator Creek from upstream station 49,343 to downstream station 45, 474, were not able to contain 0.2%- a.c.e. flooding. In addition, Bee Branch from upstream station 34,698 to downstream station 26,679 and Alligator Creek Tributary 1 at its most upstream cross-sections were not able to contain 0.2%- a.c.e. flooding.

In Pond Creek HUC-10, UNT 017 in PCW runs parallel to Live Oak Creek. The cross-sections for Live Oak Creek have been trimmed to the basin extent to prevent conflux of flows, thus 0.2%- a.c.e. flooding is not contained. Moreover, in UNT 036 in PCW there were multiple spots between upstream station 23,983 and downstream station 17,221 where the stream made right angle turns and which 0.2%- a.c.e. flooding was not contained, further detailed study is suggested.

In the Walnut Creek HUC-10 there are multiple areas with several streams running parallel along with multiple confluences nearby. These areas would be an ideal candidate for 2D modeling due to the interconnectedness of the system. For example, the area where Gnats Creek meets with Walnut Creek, and WNC Trib 26 meets with Barton Br E in close proximity. WNC Trib 4_1 may need further study to verify higher water surface elevation near the confluence with WNC Trib 4. There is potential interconnected flow between WNC Trib 14 and WNC Trib 16 near the confluences with Walnut Creek. Barton Br W Trib 4 shows overflows which need further detailed study.

In the Old River – Brazos River HUC-10 there are multiple areas where the basin containing the stream has an adjacent basin running parallel to it with relatively shallow land, the available high ground to tie in the cross sections was not sufficient, hence creating a challenge to contain the floodplain within the basin boundaries. A few such areas can be found near Old River, Bethel Creek, UNT 192 in Old River Watershed, UNT 166 in Old River Watershed, UNT 143 in Old River Watershed, UNT 124 in Old River Watershed, UNT 126 in Old River Watershed, and UNT 210 in Old River Watershed, UNT 211 in Old River Watershed. All the above mentioned areas were added to the S_AOMI_Ar shapefile as potential area of mitigation interest which may require further study.

Results and Recommendations

The BLE results for this study produced a SFHA that compares favorably with the effective SFHA and adds SFHA for flooding sources up to 1 square mile. These boundaries provide an estimated SFHA in areas that have not been previously studied and therefore do not currently have an SFHA mapped. These results provide context for flood risk communication as part of the Discovery process, and should be verified through community work map meetings before being applied to a regulatory product.

A map showing the BLE results is included as Appendix A.

3.1 CNMS Validation of Effective Zone A SFHA

The inventory of Zone A studies (1,681.9 miles) in the Lower Brazos Little Brazos Watershed were classified in CNMS with validation status of “UNVERIFIED” (1,203.8 miles) or “VALID” (488.2 miles), and with status type of “BEING STUDIED.” 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.

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 study area in the Lower Brazos Little Brazos Watershed, the effective Zone A topographic data leveraged was based upon United States Interagency Elevation Inventory. The LiDAR sources discussed in Section 1.1 are a significant improvement from the effective Zone A topographic source for the entire study area. Therefore, all reaches failed this check.

INITIAL ASSESSMENT A2 – CHECK FOR SIGNIFICANT HYDROLOGY CHANGES

This check involves first determining 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 annual chance flow.

Regression equations are only known to have been used for the effective studies in Limestone County. Significantly newer equations were published in 2009 causing these reaches to fail this check. The hydrology methods for all effective Zone A study areas outside of Limestone County within the Lower Brazos Little Brazos watershed are either unknown or known to not be regression equations and, therefore, pass this assessment check.

INITIAL ASSESSMENT A3 – CHECK FOR SIGNIFICANT DEVELOPMENT

This check involves using the National Urban Change Indicator (NUCI) dataset to assess increased urbanization in the watershed of the Zone A study. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15% or more, and has increased by 50% or more since the effective analysis, the study would fail this check. Although the NUCI data provide year-to-year changes in urbanization, the NLCD also is needed to establish a baseline of urban land cover for this analysis. The check for significant development in this watershed was

completed by evaluating percentage of urban change at the HUC-12 level. The entire study area is still classified as rural, so all reaches pass this check.

All of the initial assessment results are shown in Table 6.

Table 6: Zone A Initial Assessment Results

Assessment Check	Pass / Fail	Notes
A1 – Topography	Fail	LiDAR sources available are a significant improvement from effective topography
A2 – Hydrology	Fail/Pass	New equations published/Effective hydrology methods used are unknown or known to not use regression equations
A3 – Development	Pass	HUC12 watershed is still rural

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. All Zone A studies within the Lower Brazos Little Brazos Watershed are not model-backed. Therefore, all reaches failed this check.

VALIDATION CHECK A5 – COMPARISON OF BLE AND EFFECTIVE ZONE A

The BLE /effective Zone A comparison method leverages the existing Floodplain Boundary Standard (FBS) certification procedures described in FEMA SID 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 FEMA’s Automated Engineering guidance document dated May 2016. For the comparison of BLE and effective Zone A in the Lower Brazos Little Brazos Texas study area, the following vertical and horizontal tolerances were used to conduct the modified FBS procedure. One point was placed every 200 feet along the floodplain boundaries for comparison.

- Vertical Tolerance: +/- 10 feet (one-half contour interval of assumed effective topographic source).
- Horizontal Tolerance: +/- 75 feet (standard horizontal tolerance for BLE comparison testing).

Comparison results for these streams were grouped at the HUC-12 level and are summarized in Table 7 to better understand the general health of the HUC-12 watershed, but the validation check was performed at the stream level. Streams where the percentage of passing FBS sample points is greater than or equal to 85% are marked as “Pass”, otherwise marked as “Fail”.

Table 7: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Lower Brazos Little Brazos	All Streams	95,544	35,434	60,110	63%	Fail	
Able Lake-Sandy Creek	120701010103	605	94	511	84%	Fail	8.9
Barton Branch-Brazos River	120701010504	1,431	844	587	41%	Fail	47.0
Beason Creek	120701010803	2,716	820	1,896	70%	Fail	23.3
Beck Creek-Walnut Creek	120701010501	2,687	489	2,198	82%	Fail	13.0
Bethel Creek	120701010704	1,905	673	1,232	65%	Fail	28.3
Big Sandy Creek-New Year Creek	120701010902	1,601	305	1,296	81%	Fail	14.3
Big Willow Creek-Walnut Creek	120701010502	1,738	401	1,337	77%	Fail	14.6
Bull Hide Creek	120701010101	1,629	305	1,324	81%	Fail	15.1
Bull Hide Creek-Brazos River	120701010102	193	138	55	28%	Fail	50.2
Campbells Creek	120701010609	1,555	332	1,223	79%	Fail	13.6
Carrington Creek-Old River	120701010703	3,871	1,306	2,565	66%	Fail	28.9
Cedar Creek-Brazos River	120701010706	2,871	1,766	1,105	38%	Fail	48.4
Coles Creek-Brazos River	120701010801	2,552	1,428	1,124	44%	Fail	41.5
Cottonwood Creek-Big Creek	120701010203	1,439	297	1,142	79%	Fail	16.5
Damn Branch-Brazos River	120701010613	6,242	4,640	1,602	26%	Fail	56.0
Doe Run	120701010907	1,031	201	830	81%	Fail	15.0
Donahoe Creek-Brazos River	120701010908	3,018	1,612	1,406	47%	Fail	42.7
Dunn Creek-Spring Creek	120701010608	2,083	311	1,772	85%	Pass	9.6
Foster Branch-Cedar Creek	120701010611	399	44	355	89%	Pass	33.3
Hardin Slough-Brazos River	120701010305	1,613	626	987	61%	Fail	34.3
Headwaters Pond Creek	120701010401	372	75	297	80%	Fail	28.3
Hogpen Creek-Big Creek	120701010201	1,477	295	1,182	80%	Fail	15.2
Indian Camp Creek	120701010202	1,644	550	1,094	67%	Fail	26.8
Keechi Creek	120701010208	14	0	14	100%	Pass	0.0
Little Brazos River	120701010303	222	78	144	65%	Fail	35.3
Little Elm Creek-Big Elm Creek	120701010204	1,205	326	879	73%	Fail	21.6
Little Mud Creek-Mud Creek	120701010602	3,575	518	3,057	86%	Pass	7.3
Little Pin Oak Creek-Pin Oak Creek	120701010604	2,333	464	1,869	80%	Fail	11.3
Lost Creek-Brazos River	120701010606	1,424	906	518	36%	Fail	43.2
Lower Deer Creek	120701010110	49	10	39	80%	Fail	10.2

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Mud Creek-Little Brazos River	120701010603	4,180	2,859	1,321	32%	Fail	45.7
North Cow Bayou	120701010105	1,594	299	1,295	81%	Fail	9.4
Peach Creek-Brazos River	120701010610	2,726	1,747	979	36%	Fail	46.7
Peach Creek-New Year Creek	120701010905	1,690	456	1,234	73%	Fail	21.2
Perry Creek-Brazos River	120701010111	255	174	81	32%	Fail	70.1
Pin Oak Creek-Brushy Creek	120701010206	700	140	560	80%	Fail	16.0
Polecat Creek	120701010304	226	44	182	81%	Fail	21.2
Reed Creek-Brazos River	120701010701	3,763	1,427	2,336	62%	Fail	30.4
Rocky Creek-Big Creek	120701010205	241	69	172	71%	Fail	22.9
Rocky Creek-Brazos River	120701010804	3,611	2,252	1,359	38%	Fail	52.9
Rocky Creek-New Year Creek	120701010904	2,645	340	2,305	87%	Pass	10.3
Sand Branch-Jackson Creek	120701010906	1,676	315	1,361	81%	Fail	13.2
Sandy Creek-Grassy Creek	120701010802	4,407	1,656	2,751	62%	Fail	30.0
South Cow Bayou	120701010106	996	148	848	85%	Pass	8.9
South Walnut Creek	120701010503	2,888	630	2,258	78%	Fail	12.8
Storm Branch-Cedar Creek	120701010612	2,542	622	1,920	76%	Fail	18.6
Thompsons Creek	120701010702	1,473	616	857	58%	Fail	37.3
Tidwell Creek-Sandy Creek	120701010601	914	128	786	86%	Pass	7.0
Tommelson Creek-New Year Creek	120701010901	1,118	141	977	87%	Pass	6.2
Upper Deer Creek	120701010108	615	61	554	90%	Pass	6.3
Upper Pond Creek	120701010402	27	10	17	63%	Fail	0.5
Webb Branch-Sixmile Creek	120701010607	207	151	56	27%	Fail	58.4
White Creek-Brazos River	120701010705	2,898	1,239	1,659	57%	Fail	44.0
Woodward Creek	120701010903	658	56	602	91%	Pass	3.7

VALIDATION RESULTS

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Lower Brazos Little Brazos Watershed has been updated as summarized in Table 8 and illustrated in Figure 6 below.

Table 8: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	485.8
UNVERIFIED	BEING STUDIED	1,196.1

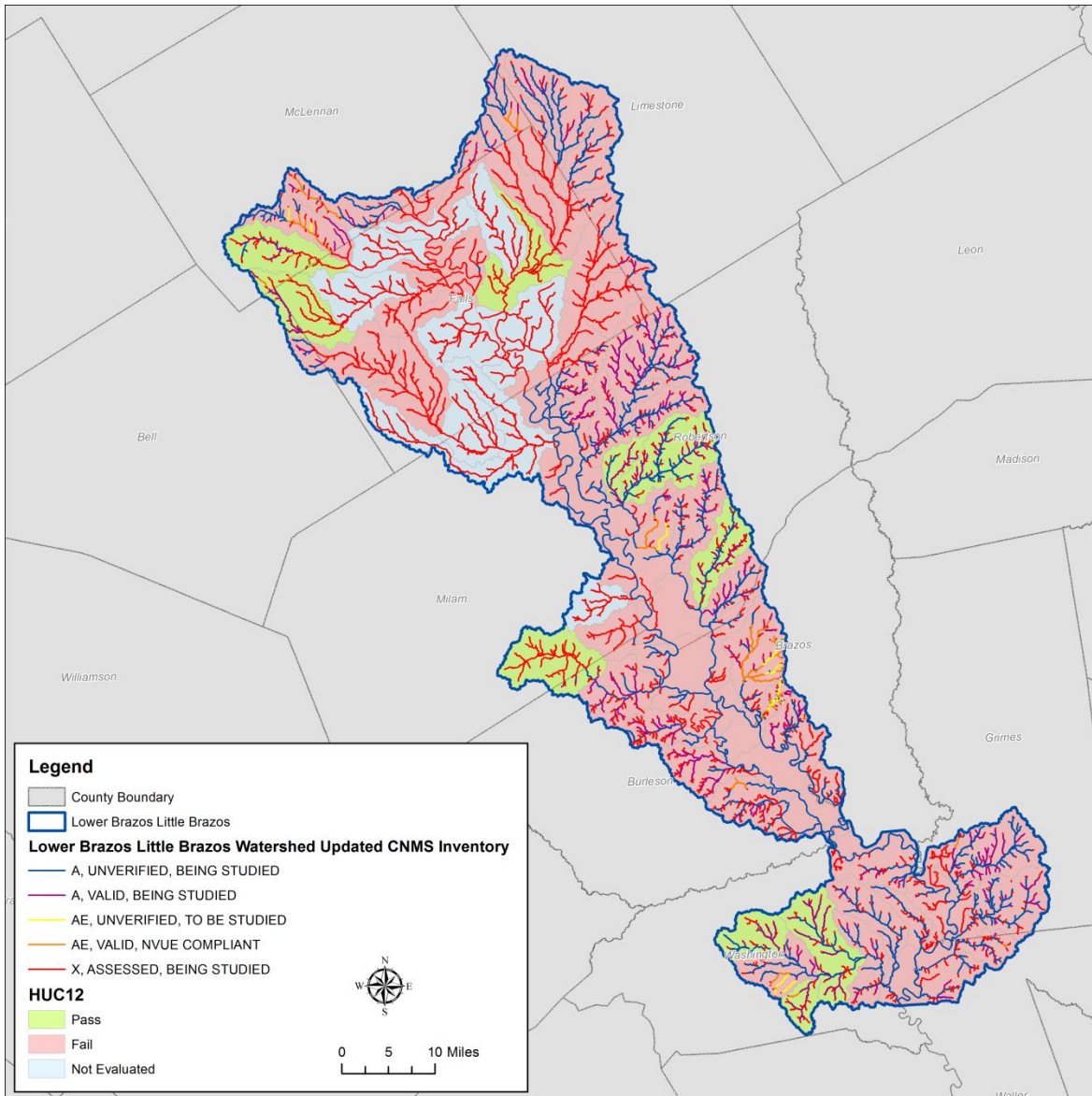


Figure 6: Lower Brazos Little Brazos Watershed CNMS Validation Results

An overall risk for each HUC-12 watershed was calculated using the National Flood Risk Percentages Dataset and its proportional area. The weighted risk was multiplied by the percentage of points in the watershed that failed the CNMS comparison to effectively determine the priority score. Figure 7 below shows the range of the HUC-12 priority scores which can be used to initiate discussions during the Discovery phase.

Perry Creek – Brazos River HUC-12 was determined to have the highest priority score and the most need while Keechi Creek HUC-12 had the lowest score.

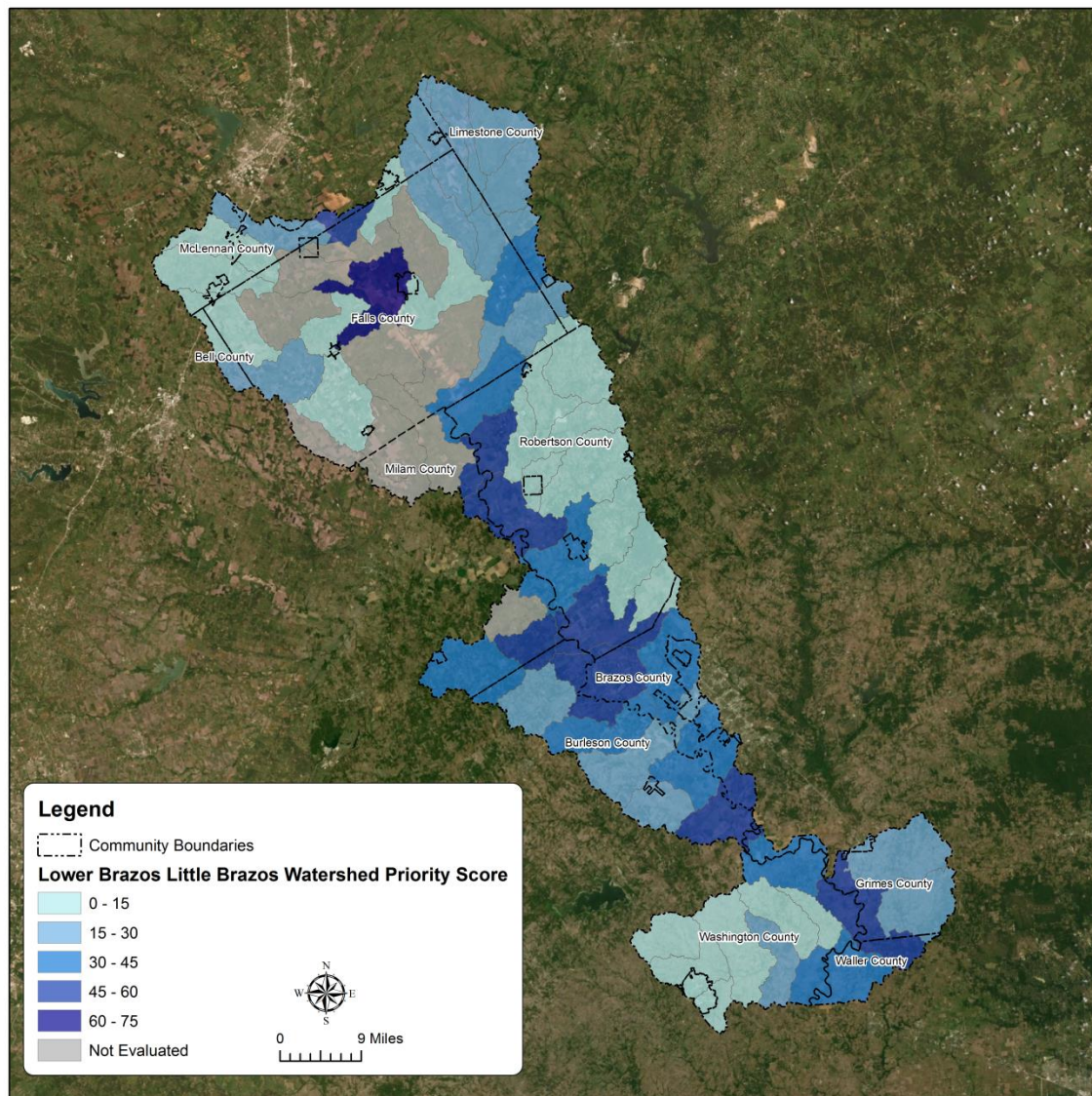


Figure 7: Ranking of Lower Brazos Little Brazos Watershed HUC-12s

3.2 Flood Risk Analysis

An advanced flood risk analysis was performed using the updated 1-percent-annual-chance grid (known as ‘refined base level engineering grid’) created for this project. The loss analysis uses 2010 census data and the subsequent results are stored in the L_RA_Results table.

Hazus version 4.2 was used for the loss analysis.

The losses are reported via census blocks. It is important to note that Hazus version 4.0 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](#).

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Appendix A BLE Map

