San Miguel Watershed, TX
Base Level Engineering (BLE) Results

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FEMA’s MIP	Region VI	See path above
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Executive Summary

FEMA Region VI contracted Compass to complete a Base Level Engineering (BLE) analysis for the San Miguel HUC-8 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. 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	San Miguel Stream Miles
CNMS	359.28

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	4.44
UNVERIFIED	BEING STUDIED	354.84

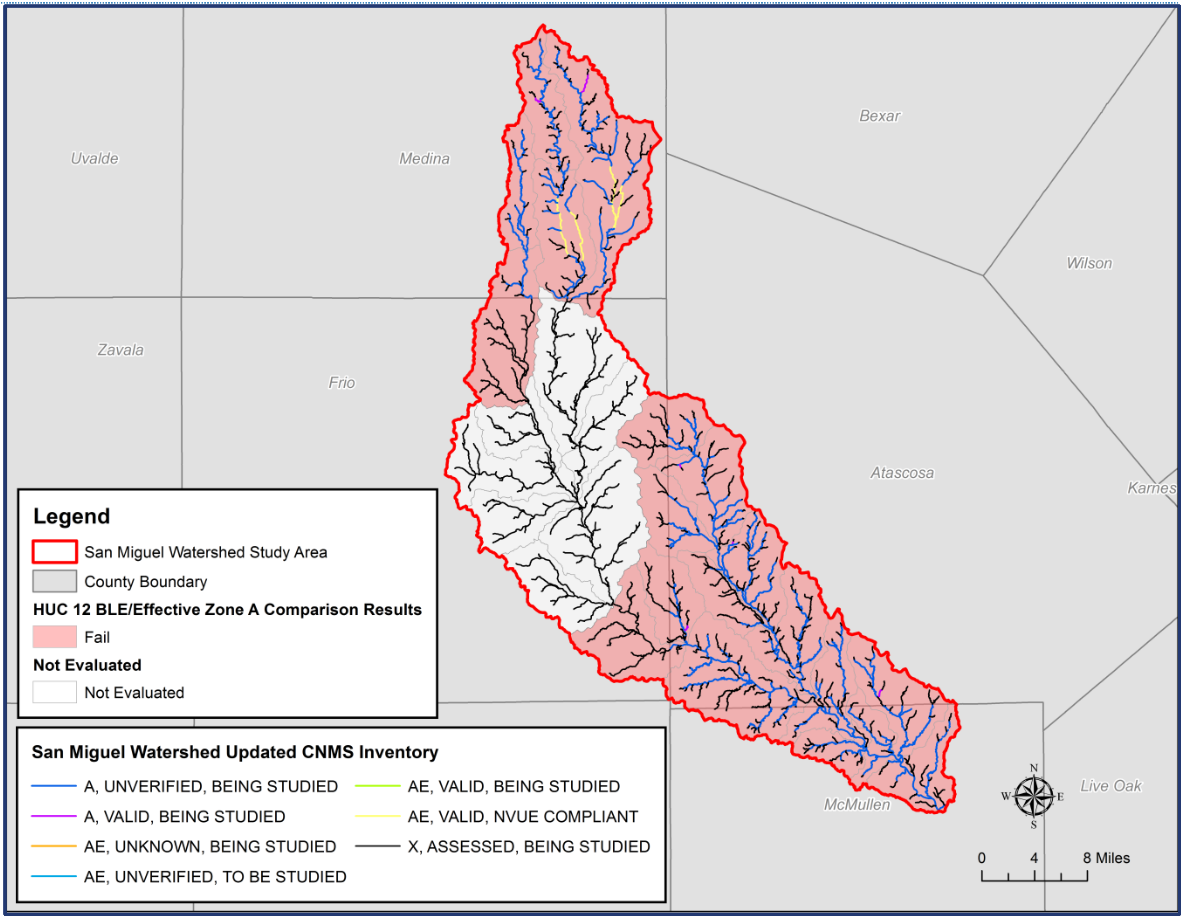

Figure ES-1: San Miguel Watershed CNMS Validation Results

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 effective to determine the priority score. Figure ES-2 below shows the range of the San Miguel HUC-8 priority scores which can be used to initiate discussions during the Discovery phase.

Horse Creek-Black Creek HUC-12 was determined to have the highest priority score and the most need while Liveoak Creek HUC-12 had the lowest scores.

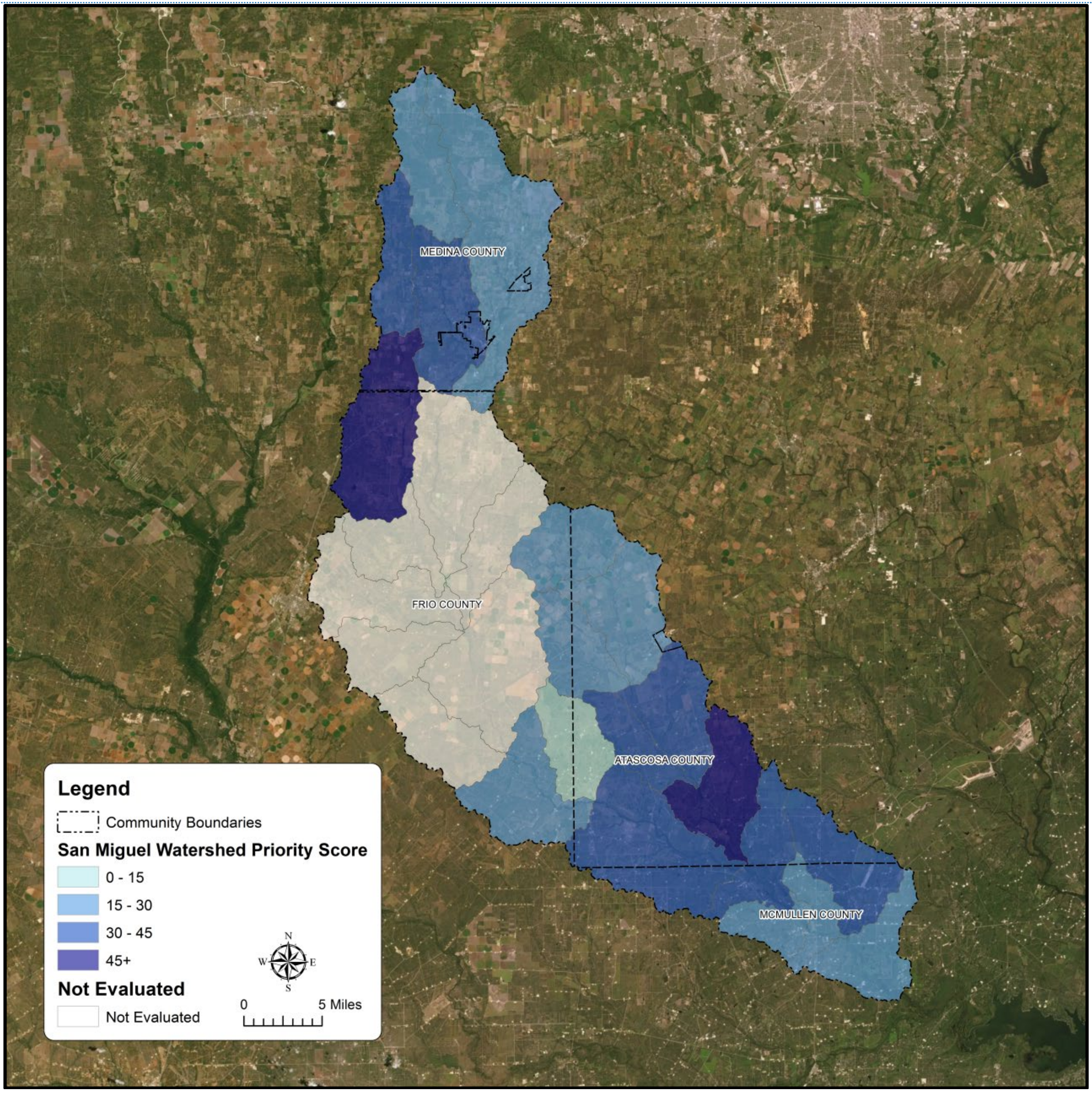

Figure ES-2: Ranking of San Miguel Watershed HUC-12s

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.

FEMA Region VI contracted Compass to complete a BLE analysis for the San Miguel Watershed in 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 Atascosa, Frio, McMullen, Medina Counties, and include the following communities: the Cities of Charlotte, Devine, and Natalia.The study area consists of five HUC-10 basins: Raccoon Creek, Lagunillas Creek, Black Creek, la Jarita Creek, and Headwaters. Figure 1 shows the orientation of the San Miguel HUC-10 basins with respect to the counties.

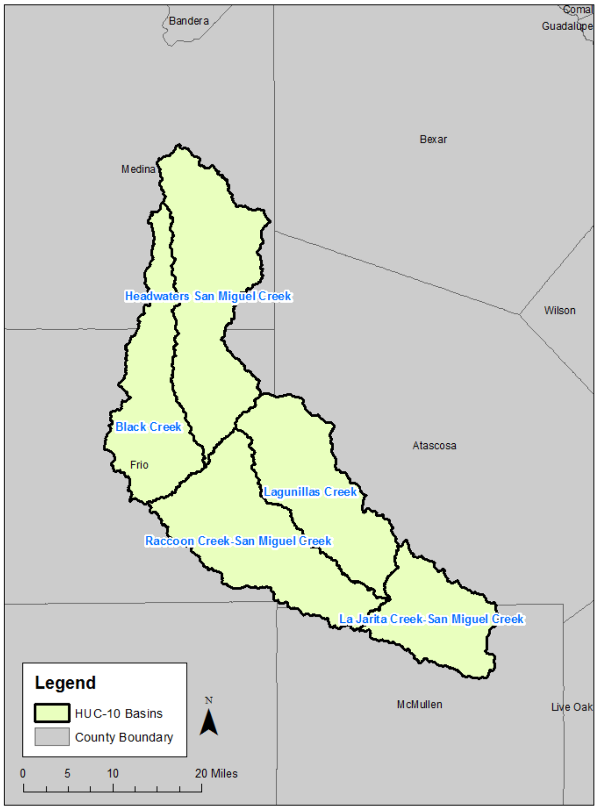

Figure 1: San Miguel Watershed HUC-10 Basins

AECOM studied approximately 925 miles of stream reaches within the San Miguel 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 were 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 San Miguel Watershed.

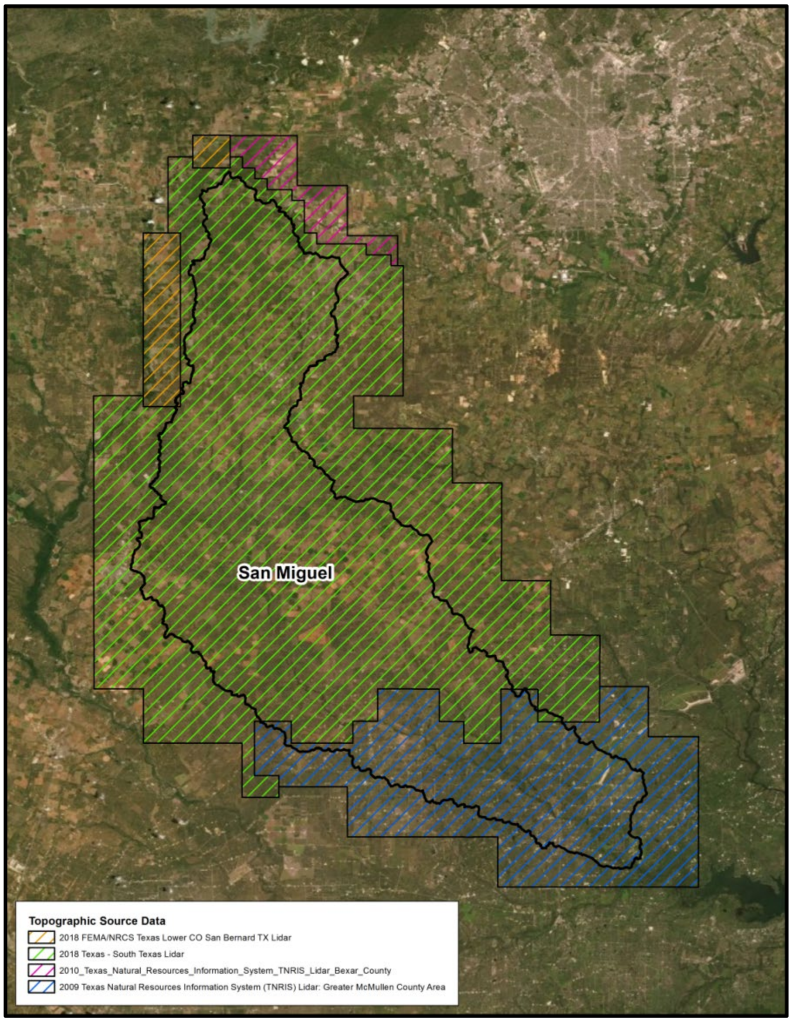

Figure 2: Extent of LiDAR Data for San Miguel Watershed

1.1.1 Source Terrain Data

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

1.1.1.1 2018 FEMA/NRCS Texas Lower CO San Bernard TX LiDAR

The 2018 FEMA/NRCS Texas Lower CO San Bernard TX LiDAR was acquired from the United States Geological Survey (USGS). The LiDAR data was collected from February 12th to April 22nd of 2018. This task order requires LiDAR data to be acquired over approximately 17,942 square miles of LiDAR, for the area of interest (AOI) collected at a nominal pulse spacing (NPS) of 0.571 meters. The LiDAR data was acquired and processed in compliance with USGS National Geospatial Program LiDAR Base Specification version 1.2. The Root Mean Square Error (RMSE)z reported for the dataset was 4.9 cm at the 95% confidence level which meets project accuracy specifications of the National Standard for Spatial Data Accuracy (NSSDA).

1.1.1.2 2018 Texas - South Texas LiDAR

The USGS LiDAR project covers Dimmit, Frio, La Salle, Live Oak and Zavala counties. The project was developed to create a consistent and accurate surface elevation dataset for the USGS FEMA VI Red River, Texas Project Area. The acquisition was conducted from January 4, 2018 to January 22, 2018. Dewberry served as the prime contractor for the project and was responsible for LAS classification, all LiDAR products, breakline production, DEM production, and quality assurance. The RMSEz reported for the dataset was 8.9 cm at the 95% confidence level which meets project accuracy specifications of the NSSDA.

LiDAR acquired from this project will be used for floodplain management and planning, feature extraction, water quality modeling, stream restoration potential analysis, change detection, 9-1-1, wildfire mitigation, habitat identification/modeling for endangered species, and hurricane recovery projects.

Further details regarding this acquisition can be found by downloading the USGS 2018 South Central Project Reports.

1.1.1.3 2010 Texas Natural Resources Information System (TNRIS) LiDAR: Bexar County

This dataset contains 50 centimeter LAS tiles and 1 meter DEM tiles for areas in Bexar County, Texas. The project AOI was defined by NQQQ tiles. The outside tiles were buffered by 300 meters on all sides and the interior tiles were buffered by 50 meters on all sides. The project design of the LiDAR data acquisition was developed to support a nominal post spacing of 4 points/meter.

Data was acquired by Terrapoint from May 20, 2010 through August 4, 2010. LiDAR data collection was performed with a Cessna 375 aircraft, utilizing a Leica ALS50-II MPiA sensor and a Cessna 210 aircraft, utilizing an Optech Sensor collecting multiple return x, y, and z data as well as intensity data. LiDAR data was processed to achieve a bare ground surface.

1.1.1.4 2009 Texas Natural Resources Information System (TNRIS) LiDAR: Greater McMullen County Area

The StratMap LiDAR collection covers portions of Atascosa, Frio, La Salle, Live Oak and McMullen counties, Texas. Data was captured by Photoscience, Inc. from June 19-20, 2009. The purpose of this project was to develop new flood hazard information that would be used in the update and creation of accurate flood zone maps in support of the National Flood Insurance Program.

The data products became part of ongoing data collection by the State of Texas to support mapping and modeling of floodplains, hydrography, and terrain. This project was procured through the Council on Competitive Government's HPIDS contract.

1.1.2 Terrain Data Processing

The LiDAR data were processed in Environmental System Research Institute (ESRI) ArcGIS software to create a composite 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 San Miguel Watershed 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. The 2018 FEMA/NRCS Texas Lower CO San Bernard TX LiDAR dataset was prioritized as the best data source for the San Miguel Watershed followed by the 2018 Texas - South Texas LiDAR, 2010 Texas Natural Resources Information System (TNRIS) LiDAR: Bexar County, and lastly the 2009 Texas Natural Resources Information System (TNRIS) LiDAR: Greater McMullen County Area.

The 10-foot DEMs created from the LiDAR datasets described in Section 2.2 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 40,000-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. 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-and hydro-enforcement of the 50-foot DEMs. 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 sumps. 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-ft DEM. This 50-foot DEM was used for hydro enforcement of the project area. 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 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 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.

Flood discharges for San Miguel mainstem 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 Water-Resources Investigations Report (WRIR) 96-4307, *REGIONAL EQUATIONS FOR ESTIMATION OF PEAK-STREAMFLOW FREQUENCY FOR NATURAL BASINS IN TEXAS* (1996) contain the regression equations for Texas. USGS Peak FQ Version 7.1 was used to perform the Flood Frequency Analysis (FFA) for the USGS gage 08206700 within the San Miguel Watershed.

1.2.1 Regression Analysis

The 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, all inputs for the USGS regression equations.

Table 1 shows the published 2009 L-moment regression 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
$Q_{10\%}$	$P^{1.203} \times S^{0.403} \times 10^{[0.918\Omega + 13.62 - 11.97A\text{^}(-0.0289)]}$
$Q_{4\%}$	$P^{1.140} \times S^{0.446} \times 10^{[0.945\Omega + 11.79 - 9.819A\text{^}(-0.0374)]}$
$Q_{2\%}$	$P^{1.105} \times S^{0.476} \times 10^{[0.961\Omega + 11.17 - 8.997A\text{^}(-0.0424)]}$
$Q_{1\%}$	$P^{1.071} \times S^{0.507} \times 10^{[0.969\Omega + 10.82 - 8.448A\text{^}(-0.0467)]}$
$Q_{0.2\%}$	$P^{0.988} \times S^{0.569} \times 10^{[0.976\Omega + 10.40 - 7.605A\text{^}(-0.0554)]}$
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 $Q_{1\%+/-} = Q_{1\%} \pm 10^{1.6*0.30}$, where 0.30 is the mean residual standard error for the $Q_{1\%}$ equation.

The mean annual precipitation values were determined based on a shapefile coverage obtained from the TWDB and is 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 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 OmegaEM 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 San Miguel 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 regression discharges, and those discharges were incorporated into the Hydrologic Engineering Center's River Analysis System (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.

Table 2 shows the published equations used for the San Miguel Creek mainstem 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), SL represents dimensionless main-channel slope, and A represents cumulative drainage area in square miles.

Table 2: Summary of Regression Equations for Region 6 in Texas (WRIR 96-4307)

Recurrence Interval	Equation[1]
$Q_{10\%}$	$1720*A^{0.410}*SL^{-0.419}$
$Q_{4\%}$	$3290*A^{0.398}*SL^{-0.428}$
$Q_{2\%}$	$4970*A^{0.391}*SL^{-0.434}$
$Q_{1\%}$	$4970*A^{0.440}$

Recurrence Interval	Equation[1]
$Q_{0.2\%}$	N/A

Variables:

Q_i, peak flow for i recurrence interval (a.c.e.), in cubic feet per second;

A, Contributing drainage area in square miles;

SL, Stream slope in feet per mile, ratio of change in elevation of (1) longest mapped channel from site (or station) to headwater to (2) length of longest mapped channel.

Discharges for the 1-percent plus and 1-percent minus a.c.e. were calculated as well. These values were computed as $Q_{1\%+/-} = Q_{1\%} \times (10^{\pm 0.29})$ where 0.29 is the weighted standard error of estimate in $\log_{10}$-unit of cubic feet per second for the $Q_{1\%}$ equation (Table 2 in WRIR 96-4307, Region 6).

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.

Drainage area for each sub-basin was determined based on automated basin delineations performed by WISE. Basin break points were set at by the user starting from downstream at the confluence with Frio River. The entire San Miguel watershed was delineated into 9 basins. This criterion was adjusted for the main stem of the San Miguel Creek 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 5.0.5 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 active USGS stream gage on the San Miguel Creek mainstem used to develop weighted discharges for the study. The Flood Frequency analyses (FFA) were performed for both gages, according to USGS Bulletin 17C (EMA) guidelines.

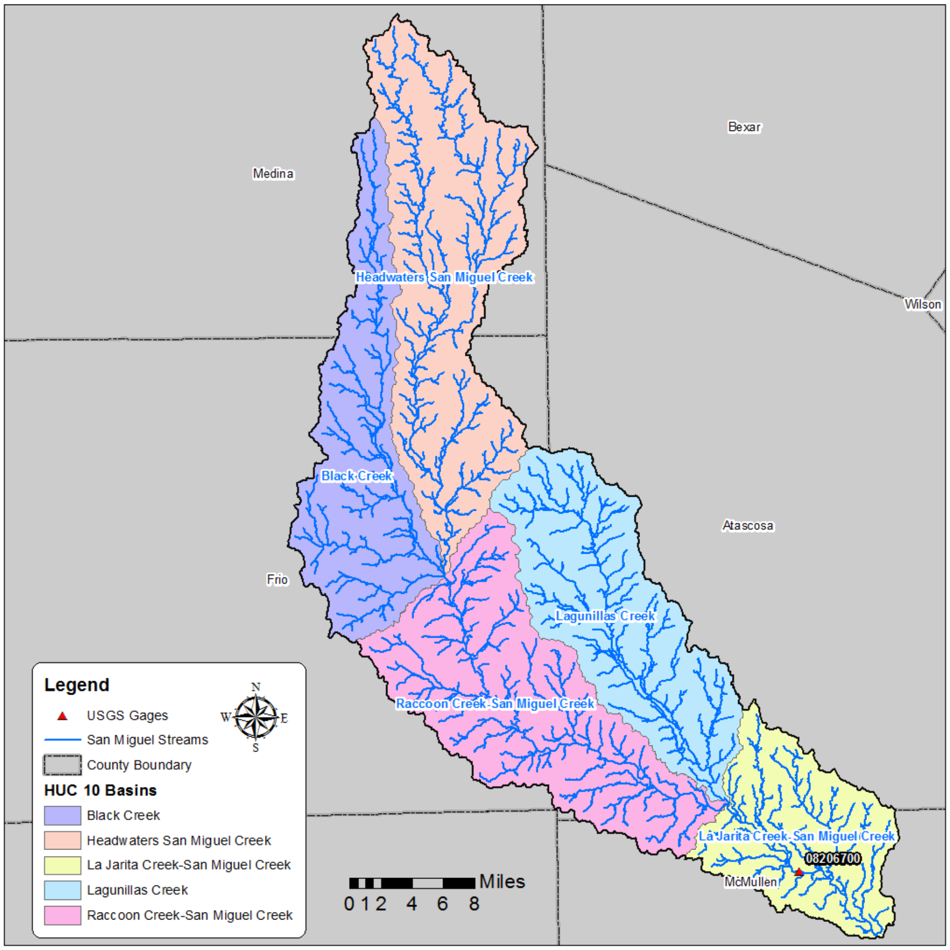

Figure 3: Locations of USGS Gages Utilized in Flood Frequency Analyses

Table 3: USGS Stream Gage in San Miguel Creek Watershed

Gage ID	Flooding Source and Location	Computed Drainage Area (mi.^{2})	Published Drainage Area (mi.^{2})	Period of Record
08206700	San Miguel Creek near Tilden, TX	782.59	783	1925-2019

The flood flow frequency data from these gages were weighted with the regression developed discharges using the procedure described in SIR 2009-5087. Adjusted discharges were held constant if the adjustment resulted in flows decreasing in the downstream direction.

The initial effort was to use the 2009-5087 L-moment based regression equations. However, because the watershed overlays the OmegaEM grids with sharp values change, the L-moment based regression equation flows are decreasing with the drainage area increasing. There is no obviously evidence to verify that, then a decision made to use the 1996 regression equations (WRI 96-4307). According to a study by Asquith and Slade (1995), eleven hydrologic regions of Texas were identified. These regions are based on areas of the State with similar physiographic and climatic characteristics. The San Miguel watershed is located in Region 6, and the available regression equations for the region are listed in Table 2.

One issue with the 1996-4307 regression equations is that there is no equation for the 500-year event. An extrapolation formula was introduced for 500-year flow determination, which is provided below:

Log ($Q_{0.002}$) = [Log ($Q_{0.01}$) – log ($Q_{0.02}$)] / [log (0.01) – log (0.02)] * [log (0.002) – log(0.01)] + log ($Q_{0.01}$)

Where:

$Q_{0.002}$ is for 500-year peak flow, in cubic feet per second;

$Q_{0.01}$ is for 100-year peak flow, in cubic feet per second;

$Q_{0.02}$ is for 50-year peak flow, in cubic feet per second.

The flood flow frequency data from USGS Gage 08206700 was weighted with the regression developed discharges using the procedure described in WRI 98-4178 and WRI 98-4015. Adjusted discharges were held constant when flows decreased in the downstream direction. The formula used to determine the weighted peak discharges (WRI 98-4015 page 10, equation 6, WRI 98-4178, Page 12 equation 4):

$$Q_{TW} = \frac{SE_{TR}^2 Q_{TS} + SE_{TS}^2 Q_{TR}}{SE_{TR}^2 + SE_{TS}^2}$$

Where:

SE_{TS}, standard error of the log-Pearson Type III distribution at recurrence interval T, in log-cubic feet per second;

SE_{TR}, standard error of prediction of the regression at recurrence interval T, in log-cubic feet per second;

Q_{TW}, weighted peak discharge at recurrence interval T, in cubic feet per second;

Q_{TS}, log-Pearson Type III peak discharge at recurrence interval T, in cubic feet per second

Q_{TR}, regression peak discharge at recurrence interval T, in cubic feet per second;

The weighted factor for the regression is the square of the standard error of estimation of the regression, which can be found at WRI 96-4307, Page 64 (Table 2, Region 6, Weighted standards error of estimate in $\log_{10}$ units). The standard error of estimation for 500 year was estimated from the relationship between 10 year and 50 year standard error of estimate, as 0.34 in Table 4.

The weighted factor for the Log-Pearson Type III distribution is the square of the standard error, or the variance error of estimate. It is computed using the 67-percent prediction interval in a USGS computer program PEAKFQ (to estimate peak-discharge frequency on the basis of the Log-Pearson Type III distribution). The 67-percent prediction interval of the regression equation is equivalent to the {100-(100-67)/2} = 83.5-percent interval in PEAKFQ. Thus, the standard error and the variance error of estimate can be determined from the program PEAKFQ by setting the confidence limits at 83.5 percent.

Gage variances for each storm event were used to develop weighted discharges. These variances are provided in Table 4.

Table 4: Summary of Standard Error and Variances at Gage 08206700

	10PCT (cfs)	4PCT (cfs)	2PCT (cfs)	1PCT (cfs)	0.2PCT (cfs)
Variance from PEAKFQ	0.0062	0.0090	0.0131	0.0188	0.0383
SE_{TS}	0.079	0.095	0.114	0.137	0.196
SE_{TR}	0.20	0.21	0.25	0.29	0.34

Weighted discharges were adjusted using a gage adjustment factor developed from a comparison between the rural and gage discharges and rounded to determine final discharges. Final discharges for the San Miguel Creek determined by gage analysis are presented in Table 5.

Table 5: Final Discharges at USGS Stream Gage in San Miguel Watershed

Gage ID	10PCT (cfs)	4PCT (cfs)	2PCT (cfs)	1PCT (cfs)	0.2PCT (cfs)
08206700	12,200	19,200	25,200	31,300	47,800

1.3 Hydraulics

The hydraulic approach for this BLE analysis of the San Miguel 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. 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 ArcGIS 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 6. These default values for dimensions and spacing were subject to change based on engineering judgment.

Table 6: Cross-Section Default Parameters

Drainage area (upper limit)	XS Spacing	Channel Top Width	Channel Bottom Width	Channel Depth
1	300	6	5	0.8
2	300	7	6	0.8
4	300	10	8	0.8
8	400	12	11	0.8
10	500	13	12	0.8
15	500	18	13	0.8
20	500	19	14	0.8
25	500	20	15	0.8
30	500	21	16	0.8
40	500	25	17	0.8
50	600	28	18	0.8
75	600	30	19	1
100	750	33	20	1
150	750	36	21	1
250	1000	38	22	2
500	1500	40	23	2
1000	2500	100	50	3
2000	2500	150	75	3
5000	2500	200	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 7. 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 7: 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 8 square miles), the normal depth slope was calculated based on the channel inverts of the downstream cross sections.

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 data.

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.

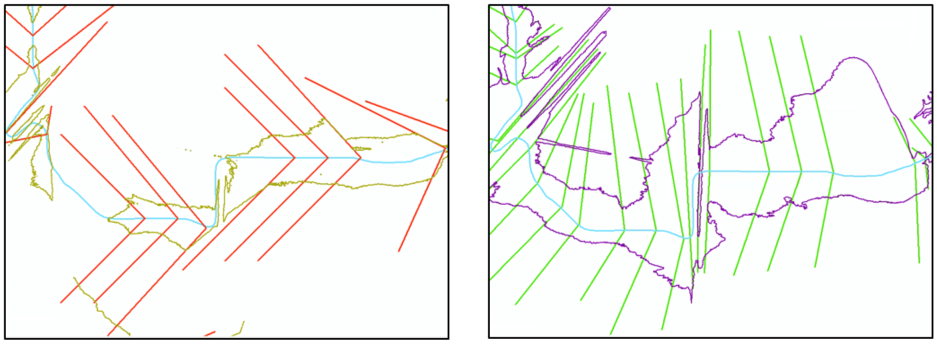

Figure 4: Default "V" angle cross-sections automated by WISE (left). Manually edited cross-sections to more accurately capture terrain (right). Resulting flood boundaries shown in gold (left) or purple (right) for clarity.

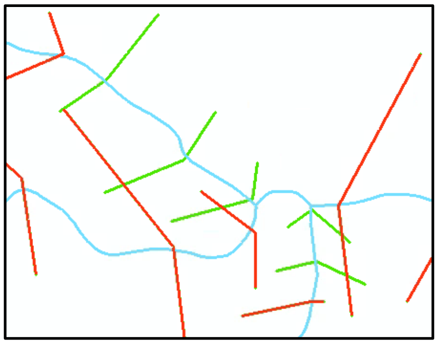

Figure 5: Manually added cross-sections (green) to improve accuracy of tie-ins at confluences.

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 lines were 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 2 acres 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 San Miguel Creek Watershed is located in 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.

The Choke Canyon Reservoir is downstream of the San Miguel Creek study area in the Lower Frio HUC-8 watershed. The large flows on the Frio River may result in differing BFEs at the downstream end of the study area. The Choke Canyon Reservoir has been modeled in the Lower Frio BLE study with a 1%-acf water surface elevation of 225.4'. Coordination efforts were made with the Lower Frio BLE study to ensure a tie-in. Incorporating this tie-in may result in water surface elevation data within the modeling to be less than what is shown in the grids/floodplain results.

A significant effort was made to achieve proper 1%-acf 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%-acf flows overtopped cross section. For these situations, additional investigation is recommended when upgrading these models for detailed study.

For San Miguel mainstem, because the watershed overlays the OmegaEM grids with sharp values change, the L-moment based regression equation flows (2009) are decreasing with the drainage area increasing at some important locations. There is no obvious evidence to verify that, but we decided to use the 1996 regression equations (WRI 96-4307). One challenge is that the 1996-4307 regression equations do not have an equation for the 500-year event. An extrapolation formula was introduced for 500-year flow determination, which is based on the relationship between 50-year peak flows and 100-year peaks flows, and was described in section 1.2.2.

In Black Creek HUC-10, there were a few areas where detailed study is recommended. UNT 024 in BCW runs parallel to UNT 021 in BCW towards the downstream and due to their shared floodplains some cross sections were overtopped.

In Headwaters HUC-10, the floodwater overtopped from the cross sections of UNT 022 in HW. Cross sections were clipped at the basin extent and suggested a need for the further study.

In Lagunillas Creek HUC-10 watershed, multiple streams may require further study as cross sections are overtopped: UNT 58 in Lagunillas Cr Wtrshd, UNT 144 in Lagunillas Cr Wtrshd, UNT 145 in Lagunillas Cr Wtrshd, UNT 158 in Lagunillas Cr Wtrshd, UNT in Lagunillas Cr Wtrshd, UNT 69 in Lagunillas Cr Wtrshd, UNT 98 in Lagunillas Cr Wtrshd, UNT 91 in Lagunillas Cr Wtrshd, UNT

135 in Lagunillas Cr Wtrshd, UNT 171 in Lagunillas Cr Wtrshd, UNT 175 in Lagunillas Cr Wtrshd UNT 150 in Lagunillas Cr Wtrshd, UNT 167 in Lagunillas Cr Wtrshd, UNT 42 in Lagunillas Cr Wtrshd, UNT 35 in Lagunillas Cr Wtrshd, UNT 65 in Lagunillas Cr Wtrshd , UNT 151 in Lagunillas Cr Wtrshd, UNT 167 in Lagunillas Cr Wtrshd, LAGUNILLAS Cr, Ellis Br, Lake Br, Elm Cr, Bear Br, Chiltipin Creek, Macho Creek, UNT 179 SanMiguel Cr Watershed, UNT 181 SanMiguel Cr Watershed, and UNT 195 SanMiguel Cr Watershed. Cross sections were clipped at the basin extent and further study is required.

Results and Recommendations

The BLE results for this study produced an SFHA that conforms to the existing topography and compares favorably with the effective SFHA. These boundaries provide an approximate 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 (359.28 miles) in the San Miguel Watershed were classified in CNMS with validation status of “UNVERIFIED” (354.84 miles) or “VALID” (4.44 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 San Miguel Watershed, the effective Zone A topographic data leveraged were not LiDAR sources. 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 if regression equations were used for the effective study. Next, it must be determined 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 were not used for any effective Zone A study areas located in the San Miguel watershed 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 8.

Table 8: 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	Pass	Regression equations used in effective study
A3 – Development	Pass	HUC-12 watershed does not meet urban threshold

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. None of the Zone A studies in the San Miguel HUC-8 Watershed are backed by technical data and, therefore, fail 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 Atascosa 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 8 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 they are marked as "Fail".

Table 9: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
San Miguel Watershed	All Streams	23,560	10,015	13,545	57%	FAIL	
Black Creek Cemetery-Black	121101090201	924	444	480	52%	FAIL	38.4
Bruce Branch-San Miguel Creek	121101090503	906	340	566	62%	FAIL	23.7
Calf Creek-San Miguel Creek	121101090303	127	50	77	61%	FAIL	21.0
Chacon Creek	121101090101	2,800	1,043	1,757	63%	FAIL	29.1
Chiltipin Creek	121101090403	710	321	389	55%	FAIL	22.7
Clear Creek-San Miguel Creek	121101090501	1,716	758	958	56%	FAIL	34.2
Far Live Oak Creek-San Miguel	121101090502	1,209	399	810	67%	FAIL	16.5
Headwaters Lagunillas Creek	121101090401	538	238	300	56%	FAIL	22.1
Horse Creek-Black Creek	121101090202	343	180	163	48%	FAIL	47.6
Indian Creek-Raccoon Creek	121101090305	3,011	1,281	1,730	57%	FAIL	30.5
La Jarita Creek	121101090504	1,390	704	686	49%	FAIL	34.0
Lake Branch	121101090405	575	309	266	46%	FAIL	43.0
Liveoak Creek	121101090304	598	153	445	74%	FAIL	13.0
Lower Lagunillas Creek	121101090406	1,515	865	650	43%	FAIL	45.7
Lower San Francisco Perez	121101090103	1,131	485	646	57%	FAIL	35.8
Middle Lagunillas Creek	121101090404	1,864	739	1,125	60%	FAIL	31.7
Mustang Branch-San Miguel Creek	121101090505	1,790	854	936	52%	FAIL	23.9
Upper Lagunillas Creek	121101090402	1,288	467	821	64%	FAIL	19.0
Upper San Francisco Perez	121101090102	1,125	385	740	66%	FAIL	27.4

VALIDATION RESULTS

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the San Miguel Watershed has been updated as summarized in Table 9 and illustrated in Figure 6 below.

Table 10: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	4.44
UNVERIFIED	BEING STUDIED	354.84

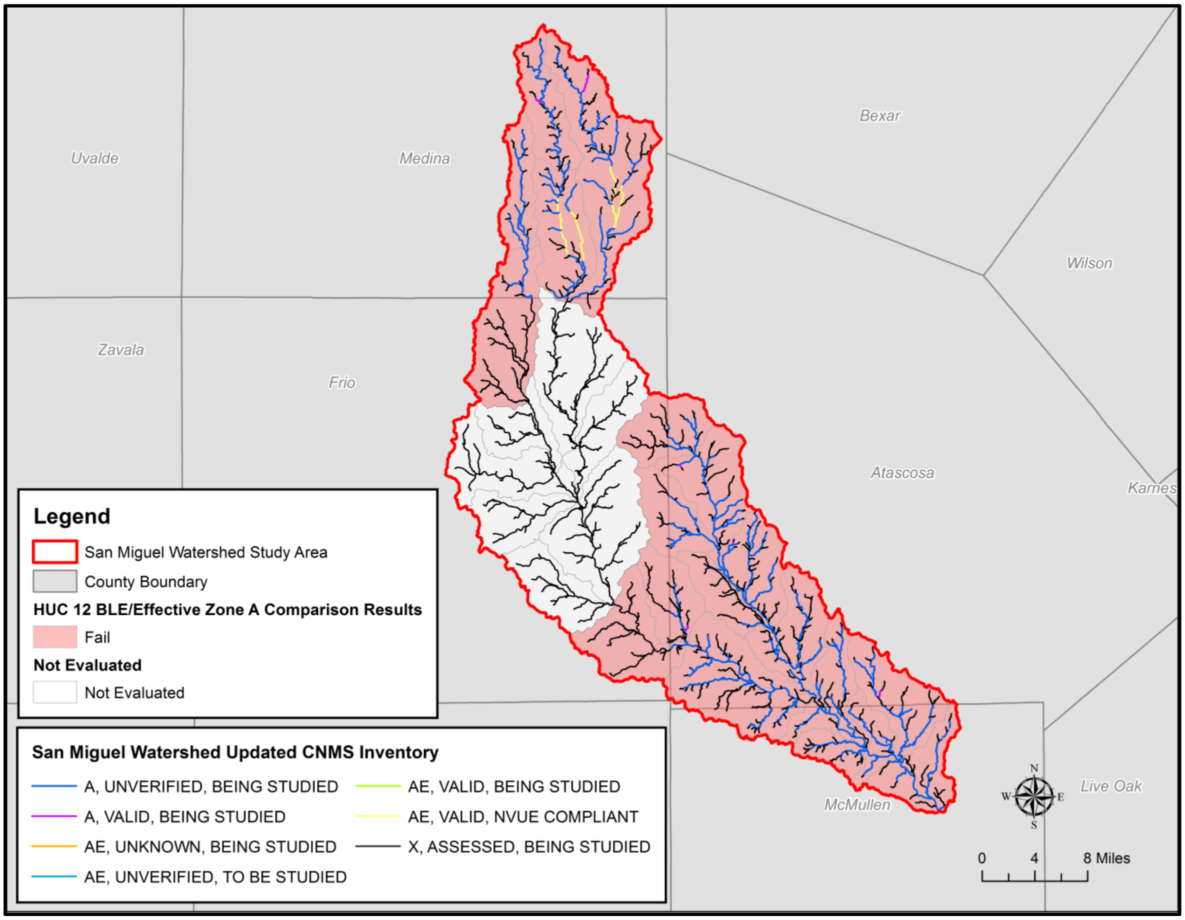

Figure 4: San Miguel Watershed CNMS Validation Results

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 effective to 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.

Horse Creek-Black Creek HUC-12 was determined to have the highest priority score and the most need while Liveoak Creek HUC-12 had the lowest scores.

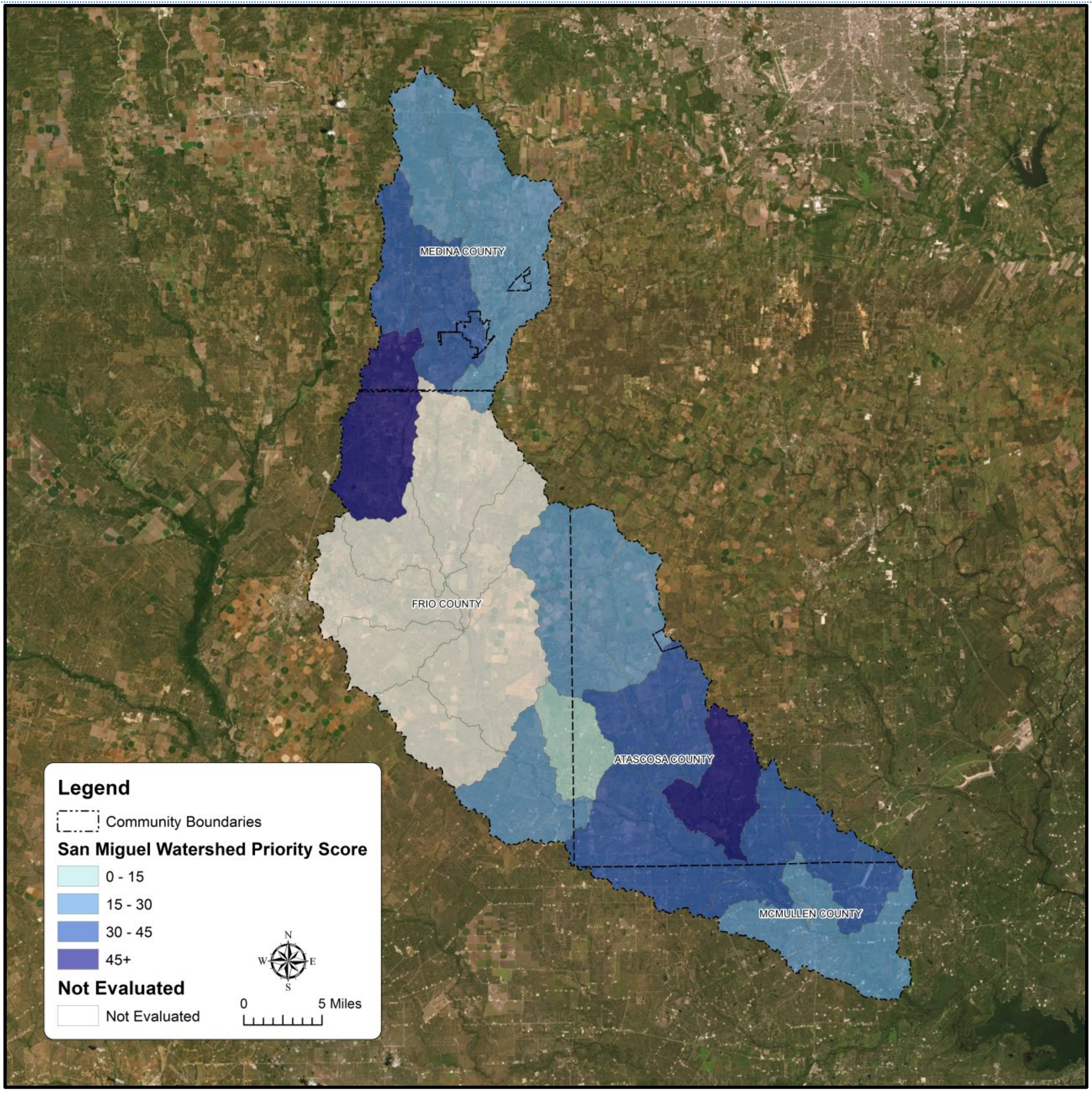

Figure 5: Ranking of San Miguel Watershed HUC-12s

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 4.2 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