Identify, Interpret, Integrate

Sabine Lake Watershed, Texas and Louisiana

2D Base Level Engineering and Mapping

Contract #HSFE60-15-D0003, Task Order # 70FBR620F00000047
November 2021

Prepared for:

DHS/FEMA (Federal Emergency Management Agency)
Attn: Sable Bell, Compass Contracting Officer Representative (COR)
FEMA Region VI
400 C Street Southwest
Washington, DC

Submitted by:

Compass PTS JV
3101 Wilson Boulevard
Suite 900
Arlington, VA 22201

Compass PTS JV
3101 Wilson Boulevard, Suite 900
Arlington, VA 22201
T: 703.682.9100; F: 703.682.4901

DOCUMENT HISTORY

DOCUMENT LOCATION

K:/FY2020/20-06-0094S/Hydraulics - Sabine Lake (Jefferson County, TX)|BLE (FY20) 12/Hydraulic Data Capture - Hydraulic Data Capture|Sabine Lake (Jefferson County, TX) - 01

REVISION HISTORY

Version Number	Version Date	Summary Changes	Team/Author
2	November 2021	Final Submittal (addressed R6 comments to the initial submittal)	Compass

APPROVALS

This document requires the approval of the following persons:

Role	Name	Review Date	Approved Date
Project Manager	Sean Sutton	November 1, 2021	November 30, 2021

CLIENT DISTRIBUTION

Name	Title/Organization	Location
FEMA's MIP	Region VI	See path above
Diane Howe	FEMA Region VI	Denton, Texas
Larry Voice	FEMA Region VI	Denton, Texas

Table of Contents

1. Introduction

BLE is a riverine hydrologic and hydraulic modeling approach that builds on lessons learned to produce a baseline understanding of flood risk to communities, produced to support the assessment and maintenance of the national flood hazard inventory. Engineering models are created during a Base Level Engineering assessment, producing information that meets the mapping Standards for Flood Risk Projects (FEMA Policy Memo FP 204-078-1) to produce Zone A (1-percent-annual-chance flood) information. BLE data is intended to represent the base level of investment needed for all flood study efforts FEMA will undertake.

Base Level Engineering (BLE) provides technically credible flood data for various geographies - community, county, watershed and/or state level. BLE data can be shared with Federal, State, local and tribal governments, this data sharing provides stakeholders at all levels the necessary data to make informed decisions to reduce future flood losses. Without the mapping of flood prone areas, there can be a lack of information to effectively communicate flood risk to community officials, citizens, and businesses.

BLE practices leverage high-resolution topography that meets or exceeds the United States Geological Survey (USGS) 3-D Elevation Program standards and often applies flood engineering at a large scale as opposed to targeting stream reaches within a watershed. BLE can be conducted at any scale, commonly for larger areas (HUC-8 watershed) but may be produced at the county or local level too. It is encouraged to do BLE for wider areas in order to build on efficiencies in modeling and ensure cost efficiency. Using current technologies, multiple watersheds or watersheds with large land areas can be analyzed at a more efficient rate to produce water-surface elevations and site-specific hazard data replacing outdated flood studies shown in existing Flood Insurance Rate Maps (FIRMs). All flood prone areas within a watershed will have an engineering model calculating multiple flood recurrence intervals and defining floodplains with elevation grids using high-resolution topography.

For floodplain management purposes, BLE data shall be used as best available information in areas that are designated as Zone A floodplain. It may also be used to regulate development in areas where no Special Flood Hazard Area (SFHA) has been mapped before. Communities should be encouraged to adopt BLE data to support local regulations. Adoption of BLE data facilitates use of the data in local floodplain management activities, including in the post disaster environment where a need for updated and/or enhanced flood hazard information may be necessary.

Per standards #84 and #133, BLE will include all recurrence intervals (0.2-percent, 1-percent, 1-percent plus, 1-percent minus, 2-percent, 4-percent, and 10-percent-annual-chance floods). As such, hydrologic and hydraulic analysis should be performed to determine the expected water surface elevations for each of the seven recurrence intervals previously identified.

The intent of BLE is to provide communities technically credible flood hazard information in a cost efficient and timely manner. Additionally, BLE provides communities a chance to review draft modeling information, reflecting the potential changes in risk within their community. Providing additional flood risk datasets, like water surface elevation grids and flood depth grids, delivers alternative information that reinforces the variability of flood risk within a designated floodplain and supports historic community requests for a source to determine a Base Flood Elevation in Zone A areas.

BLE provides information to communities who are currently unmapped and provides a digital entry to communities that are currently un-modernized. BLE acts as a measuring tool to allow FEMA to assess the current Zone A inventory identified as unknown or unverified in FEMA's Coordinated Needs

Management Strategy (CNMS). BLE modeling is intended to be scalable, meaning that the model produced during the BLE assessment may be refined to produce a more enhanced model with additional manual correction and on the ground survey. If BLE modeling exists, FEMA will recommend that it be used as the base model for any detailed studies performed in those areas.

Base Level Engineering benefits Federal, State, local and tribal governments by providing an expansive stream network of available modeling and providing a range of flood risk data that can broaden and expand risk awareness conversations with local communities.

This report details the 2D BLE modeling approach and products derived for the Sabine Lake Watershed BLE Project contracted by FEMA Region VI to the Compass JV.

In an effort to increase and enhance the flood risk products in Texas and Louisiana, FEMA Region VI contracted the Compass JV to perform a BLE analysis for the Sabine Lake Watershed. This report documents the BLE process, products, and results for this watershed. Figure 1 depicts the Watershed footprint.

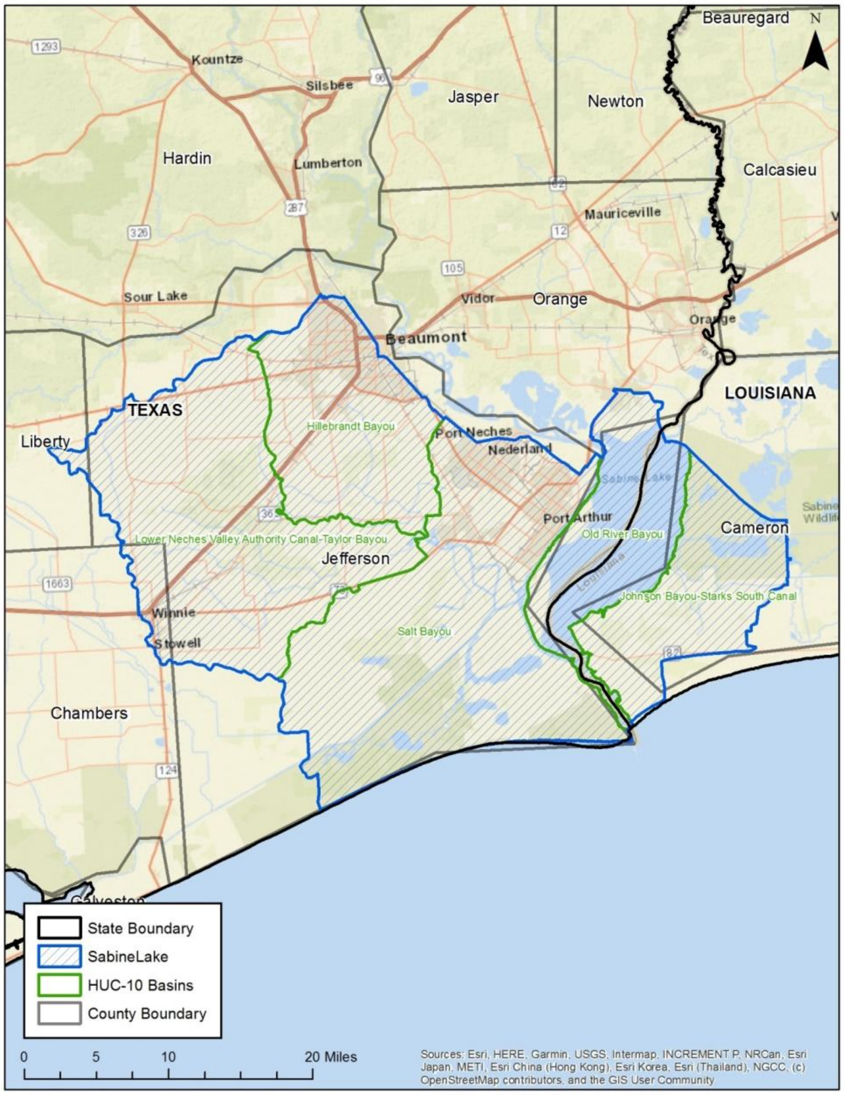


Figure 1: Sabine Lake Watershed

2. 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2-dimensional (2D) hydraulic engineering analysis for the Sabine Lake Watershed. Inputs such as elevation data, hydrology from rain-on-grid and inflow hydrographs, and hydraulic analyses and variables are defined herein. HEC-RAS 5.0.7 rain-on-grid utility was applied in the production of the 2D BLE products produced for this watershed.

2.1 Topographic Data

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

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

Documentation regarding leveraged data including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables and text within Section 2.1.2. All vertical accuracy specifications were obtained from the metadata or survey reports provided with the leverage datasets. All available metadata, survey reports, and other leverage documentation are included in the FEMA Data Capture Technical Reference compliant submittal content for the Sabine Lake Watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the Sabine Lake BLE watershed footprint. Figure 2 depicts the datasets identified and leveraged across the project area. FEMA, National Oceanic and Atmospheric Administration (NOAA), United States Geological Survey (USGS), and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

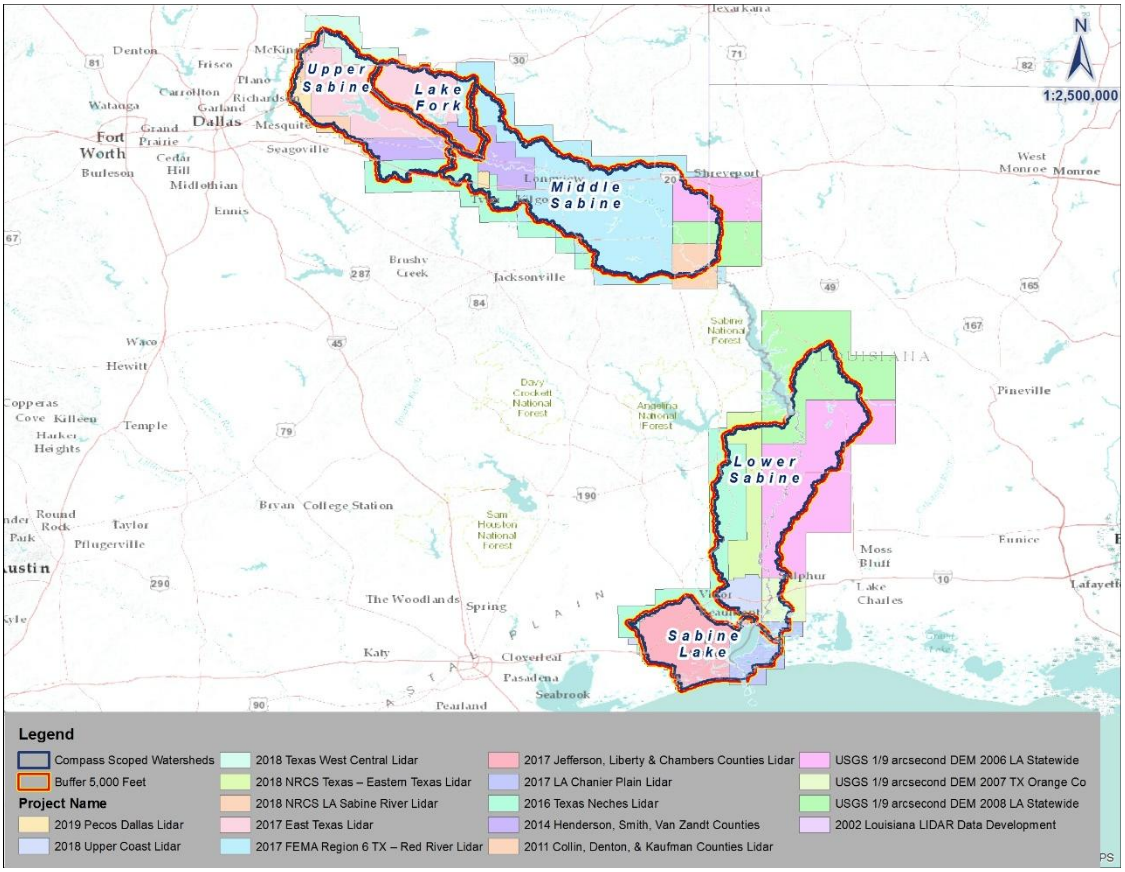


Figure 2: Sabine Lake HUC8 Topographic Input Data Sources

2.1.2 Evaluation

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

- Data meet FEMA vertical accuracy standards (Table 1)
- Date of origination
- Data density and coverage

Table 1 depicts the Risk MAP SID #43 vertical accuracy requirements based on flood risk and terrain slope within the floodplain being mapped.

Table 1: FEMA Vertical Accuracy Requirements for Leveraged Data

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

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

Table 2 depicts the complete list of source elevation data and attributes leveraged for the Sabine Lake Watershed. All datasets used for hydraulic analyses and mapping meet the highest specification level defined in Table 1. The following datasets were evaluated and prioritized as best available:

Table 2: LiDAR Topographic Data Available for the Sabine Lake Watershed

Year	Description	Source/Owner	Accuracy[1]	Approximate Footprint (Sq. Mi.)[2]
2018	Upper Coast LiDAR 1 Meter DEM	TNRIS/TWDB	0.098 m	42.4
2017	Jefferson, Liberty, & Chambers Counties 1 Meter DEM	TNRIS/TWDB	0.116 m	847.8
2017	LA Chenier Plain LiDAR 1 Meter DEM	USGS	0.122 m	280.5
2016	Texas Neches LiDAR 1 Meter DEM	USGS	0.129 m	92.3

1. [1]RMSEz reported at the 95% confidence level
2. [2]Size of LiDAR DEM footprint utilized for BLE study

2.1.2.1 Processing Leverage Data

2.1.2.1.1 2018 Upper Coast LiDAR 1 Meter DEM

Fugro was tasked to collect and process a LiDAR-derived elevation dataset for the Texas counties of Austin, Brazoria, Calcasieu, Cameron, Chambers, Colorado, Fort Bend, Galveston, Grimes, Harris, Houston, Jasper, Jefferson, Liberty, Madison, Matagorda, Montgomery, Newton, Orange, Polk, San Jacinto, Trinity, Walker, Waller, Washington, and Wharton with QL 2 Specification.

The 2018 Upper Coast LiDAR was available as 1 meter rasters from TNRIS (https://data.tnris.org/collection/b5bd2b96-8ba5-4dc6-ba88-d88133eb6643). The data was downloaded on September 9, 2020. The data was in NAD83 UTM Zone 15 projection with elevations in NAVD88 with units in meters. The data was collected from January 13, 2018 to March 22, 2018.

Data Specification:

Modern era LiDAR data collection is typically expected to meet specifications of the NGP - LBS. The national LBS have been modified through a series of revisions throughout time and can be accessed at 'LiDAR Base Specification Online' for reference (https://www.usgs.gov/core-science-systems/ngp/ss/LiDAR-base-specification-online). This LiDAR survey and derivative products produced in compliance with the task order are based on:

- USGS LiDAR Base Specifications v1.2
- ASPRS Positional Accuracy Standards for Digital Geospatial Data

The measured accuracy was 0.098 meters for NVA at 95% confidence level and the VVA measured as 0.116 meters.

Figure 3: 2018 Upper Coast LiDAR 1 Meter DEM

2.1.2.1.2 2017 Jefferson, Liberty and Chambers Counties 1 Meter DEM

Sanborn was tasked to collect and process a LiDAR-derived elevation dataset for the Texas counties of Jefferson, Liberty, and Chambers with QL 2 Specification for the Jefferson County Area of Interest (AOI) and QL0 Specification for the Liberty and Chambers Counties AOI.

The Jefferson, Liberty, and Chambers Counties LiDAR data was available as 1 meter rasters from TNRIS (https://data.tnris.org/collection/12342f12-2d74-44c4-9f00-a5c12ac2659c). The data was downloaded on September 9, 2020. The data was in NAD83 UTM Zone 15 projection with elevations in NAVD88 with units in meters. The data was collected from February 22, 2017 to March 23, 2017.

Data Specification:

Modern era LiDAR data collection is typically expected to meet specifications of the NGP - LBS. The national LBS have been modified through a series of revisions throughout time and can be accessed at 'LiDAR Base Specification Online' for reference (https://www.usgs.gov/core-science-systems/ngp/ss/LiDAR-base-specification-online). This LiDAR survey and derivative products produced in compliance with the task order are based on:

- USGS LiDAR Base Specifications v1.2
- ASPRS Positional Accuracy Standards for Digital Geospatial Data

The measured accuracy was 0.196 meters for NVA at 95% confidence level and the VVA measured as 0.286 meters.

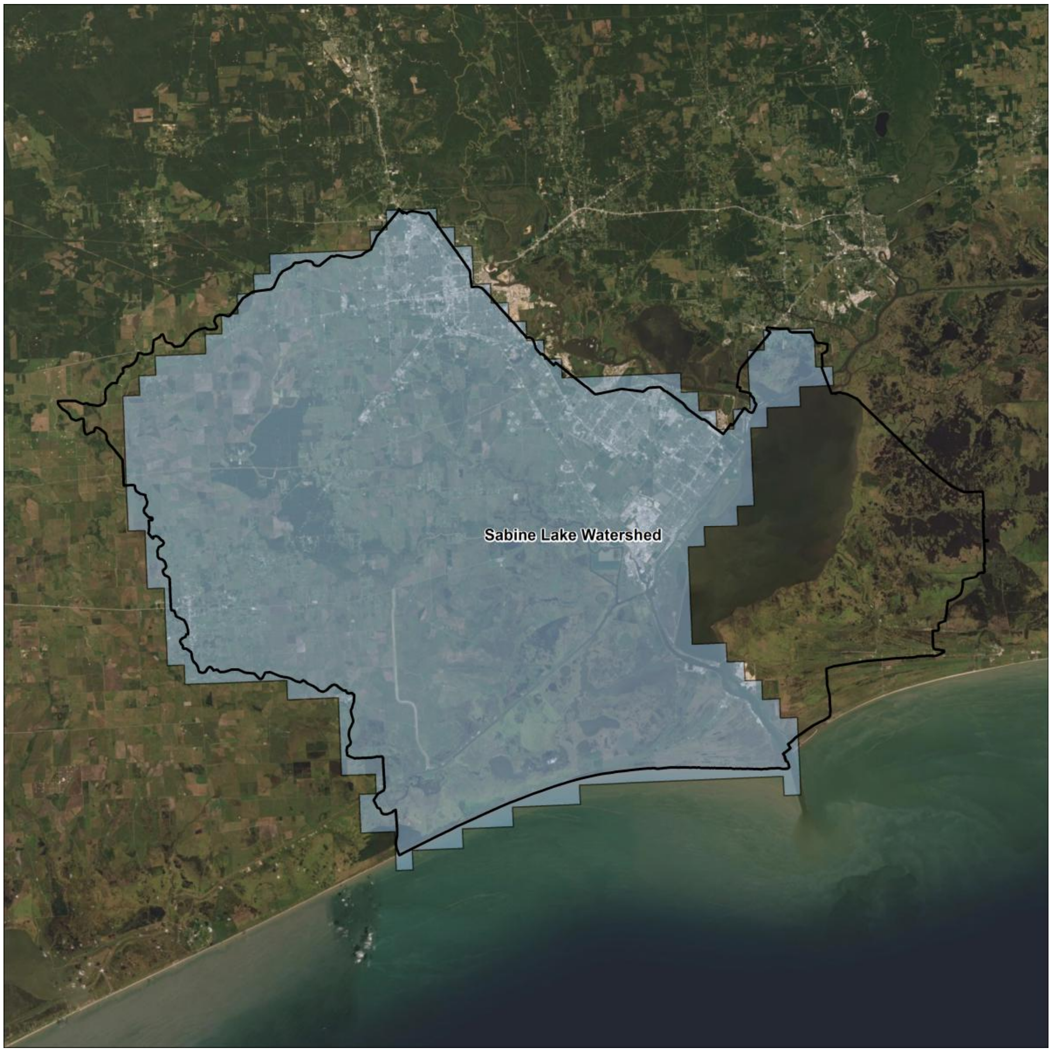


Figure 4: 2017 Jefferson, Liberty and Chambers Counties 1 Meter DEM

2.1.2.1.3 2017 LA Chenier Plain LiDAR 1 Meter DEM

Woolpert and Aerial Services, Inc. were tasked to collect and process a LiDAR-derived elevation dataset for the Louisiana parishes of Calcasieu, Cameron, Vermillion, Iberia, and St. Mary with QL 2 Specification.

The 2017 LA Chenier Plain data was available as 1 meter rasters from the USGS National Map (ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Elevation/1m/Projects/LA_Chenier_Plain_2017/). The data was downloaded on September 9, 2020. The data was in NAD83 UTM Zone 15 projection with elevations in NAVD88 with units in meters. The data was collected from January 8, 2017 to March 3, 2017.

Data Specification:

Modern era LiDAR data collection is typically expected to meet specifications of the NGP - LBS. The national LBS have been modified through a series of revisions throughout time and can be accessed at 'LiDAR Base Specification Online' for reference (https://www.usgs.gov/core-science-systems/ngp/ss/LiDAR-base-specification-online). This LiDAR survey and derivative products produced in compliance with the task order are based on:

- USGS LiDAR Base Specifications v1.2
- ASPRS Positional Accuracy Standards for Digital Geospatial Data

The measured accuracy was 0.122 meters for NVA at 95% confidence level and the VVA measured as 0.121 meters.

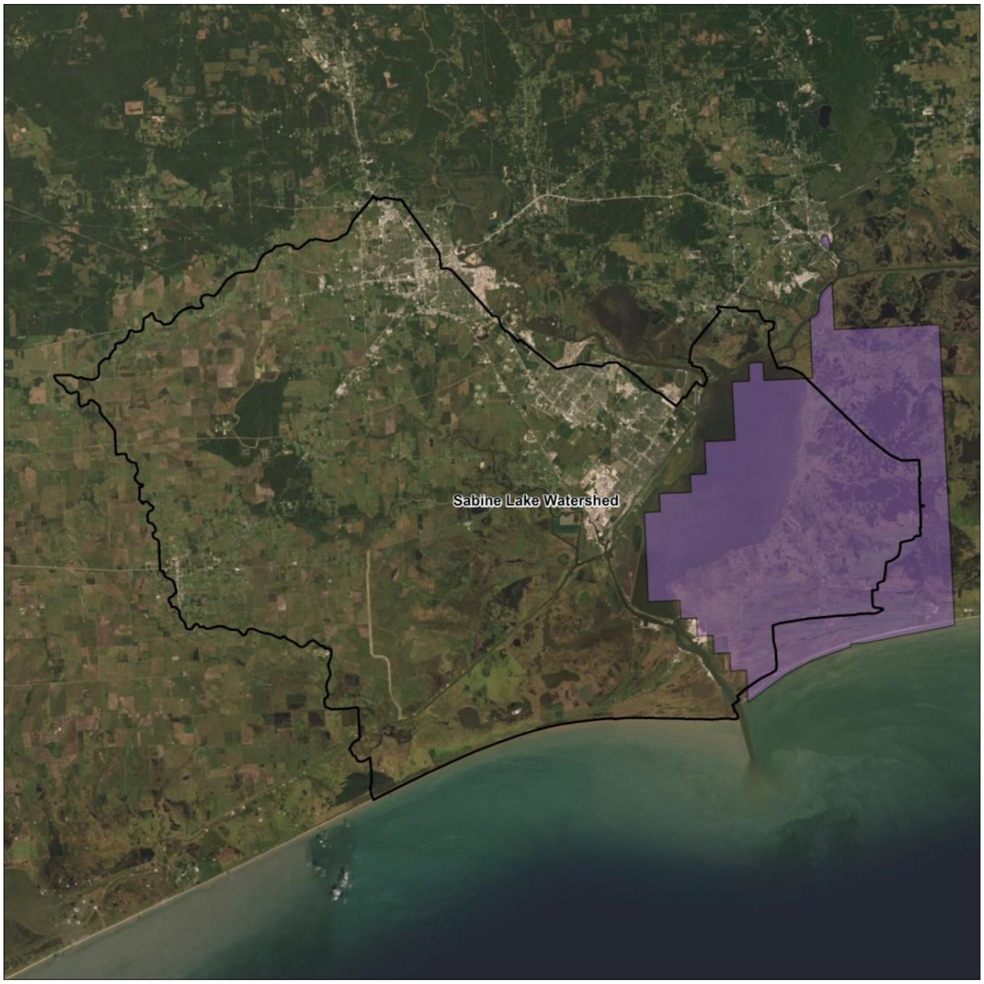


Figure 5: 2017 LA Chenier Plain LiDAR 1 Meter DEM

2.1.2.1.4 2016 Texas Neches LiDAR 1 Meter DEM

Dewberry was tasked to collect and process a LiDAR-derived elevation dataset for the USGS Texas Neches Project Area with QL 2 Specification. Quantum Spatial and Precision Aerial Reconnaissance completed LiDAR data acquisition and data calibration for the project area which includes the Texas counties of Kaufman, Navarro, Freestone, Leon, Madison, Van Zandt, Henderson, Smith, Anderson, Cherokee, Rusk, Shelby, Nacogdoches, Houston, Trinity, Angelina, San Augustine, Sabine, Newton, Jasper, Tyler, Hardin, Polk, Liberty, Jefferson, and Orange.

The 2016 Texas Neches LiDAR data was available as 1 meter rasters from the USGS National Map (ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Elevation/1m/Projects/TX_Neches_B5_2016/ and ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Elevation/1m/Projects/TX_Neches_B1_2016/ and ftp://rockyftp.cr.usgs.gov/vdelivery/Datasets/Staged/Elevation/1m/Projects/TX_Neches_B2_2016/) The data was downloaded on September 9, 2020. The data was in NAD83 UTM Zone 15 projection with elevations in NAVD88 with units in meters. The data was collected from March 3, 2016 to February 25, 2017.

Data Specification:

Modern era LiDAR data collection is typically expected to meet specifications of the NGP - LBS. The national LBS have been modified through a series of revisions throughout time and can be accessed at 'LiDAR Base Specification Online' for reference (https://www.usgs.gov/core-science-systems/ngp/ss/LiDAR-base-specification-online). This LiDAR survey and derivative products produced in compliance with the task order are based on:

- USGS LiDAR Base Specifications v1.2
- ASPRS Positional Accuracy Standards for Digital Geospatial Data

The measured accuracy was 0.129 meters for NVA at 95% confidence level and the VVA measured as 0.167 meters.

Figure 6: 2016 Texas Neches LiDAR 1 Meter DEM

2.1.3 Data Processing

ArcGIS software was utilized in order to create a digital surface model for the Sabine Lake HUC 8 Watershed project area. The LiDAR datasets were added to a mosaic dataset and prioritized by date with the most recent dataset taking the first priority. If two datasets are from the same year or flown at similar dates, the accuracy was reviewed to determine the priority. The mosaic dataset was exported to make a seamless bare earth DEM.

The exported DEM was reviewed through automated QC to check for anomalies and outlier locations based on slope and cells that exceed z value differences from surrounding cells. Visual review was also performed to check for ground differences at the extents of the datasets for differences in ground values. Where necessary, minor adjustments were made to represent a more accurate bare earth surface using aerial imagery. A shapefile with specific notes has been included for reference for modified locations.

2.1.4 DEM QA/QC

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

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

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

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

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

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

2.2 2D BLE Methods

HEC-RAS 5.0.7 (RAS5) rain-on-grid utility was applied in the Texas 2D Base Level Engineering (BLE) products workflow. The following sections describe the engineering methods and model inputs used.

2.2.1 2D Computational Mesh and Settings

The RAS5 2D computational mesh was created for the Sabine Lake model area were created using ArcGIS toolsets, which reduce the need for manual edits to mesh cells within RAS5 that result in error generation. The model’s 2D mesh contains 1,573,451 cells with a default cell size of 200 feet and with 50 foot cells within community boundaries and 500 foot cells in the lakes using refinement regions. Profile lines were used for all flow extractions. There are no 2D connections in the model. An adaptive 30-second time step was used to allow the model to lower the time step, as necessary, to keep the maximum courant number under 3 for the duration of the simulation. The time step was allowed to reach 60 seconds for a maximum and 7.5 seconds for the minimum. A theta value of 0.6 was used due to the models alignment with the coast. The RAS5 model was ran with Diffusion Wave (simplified Full Momentum) equations.

2.2.2 Model and Boundary Condition Setup

Using RAS5 rain-on-grid modeling requires a 2D computational mesh boundary and often requires defining inflow boundary conditions and application of excess precipitation. Excess precipitation was applied to the 2D mesh as a precipitation boundary condition. The process to determine the excess precipitation to be applied is outlined in the hydrology section. Figure 7 below depicts the Sabine Lake model boundaries, tidal gages and inflow locations.

Outflow boundary conditions (from the computational 2D mesh) were used along model boundaries without an inflow boundary condition. Unique outflow boundaries were established for obvious riverine outflows, while the remaining boundaries were defined as continuous boundaries to allow drainage to adjacent basins leave the model area freely. Normal depth was used for all non-unique outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain data.

A stage hydrograph was used for boundary conditions along the coast. The water elevation was determined by the Mean Higher High Water (MHHW) of the nearby tide station. The tide stations referenced for these boundary conditions are Sabine Pass TX (8770822). On April 15th 2021 the MHWW value of 0.81 ft was obtained from NOAA.

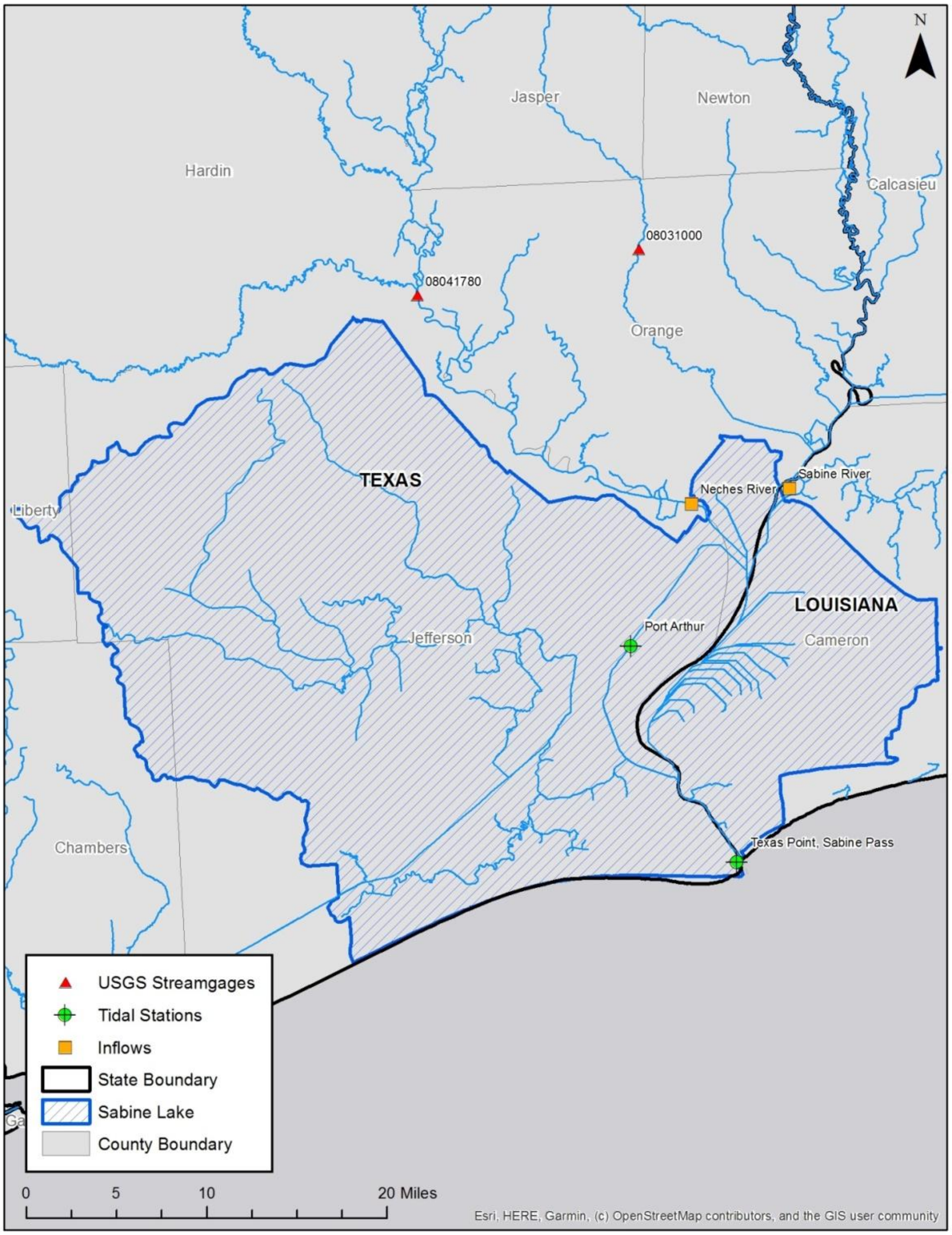


Figure 7: RAS5 2D Computational Mesh and Boundary Conditions

2.2.3 Hydrology

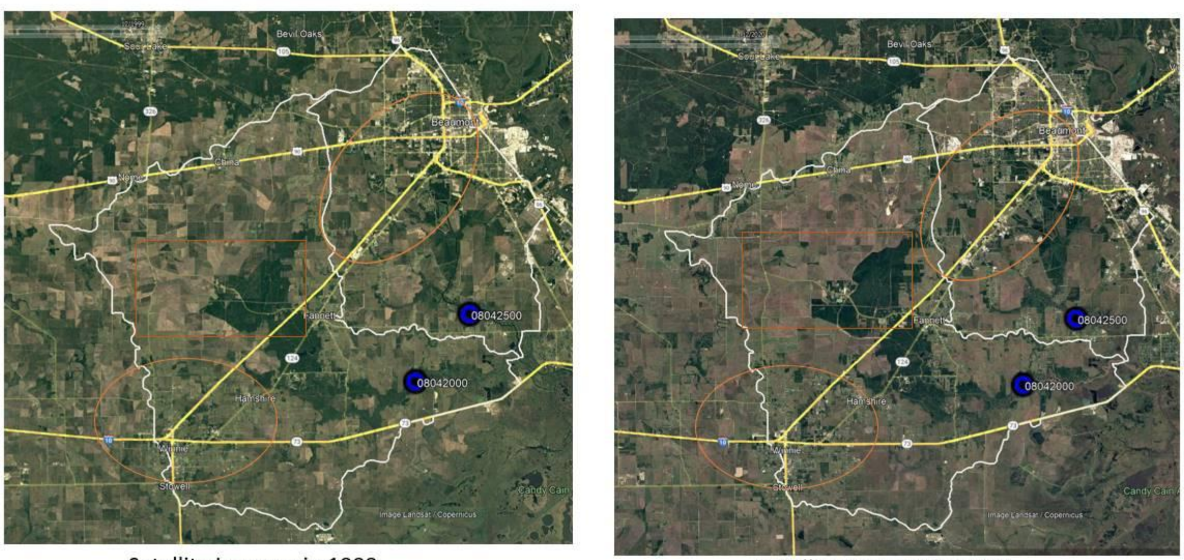
Precipitation frequency data (NOAA, 2018) was used for this study. These data were obtained from NOAA's Precipitation Frequency Data Server (PFDS) (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html), and appropriate values for all sub-basin elements were determined considering spatial variation and a representative total for Sabine Lake. Excess precipitation for the 2D mesh was developed as described in Section 2.2.3.1. USGS streamflow gage data were leveraged to estimate peak flows for downstream gages within each work area for calibration purposes, as discussed in Section 3. The 10-, 4-, 2-, 1-, and 0.2-percent annual chance 24-hour precipitation depths for all sub-basin elements were determined by area-weighted intersection of gridded PFDS data with sub-basins.

USGS streamflow gage data are leveraged to estimate peak flows for downstream gages within each model for calibration purposes. USGS stream gages with less than 10 years of continuous record, and gages without any recent data were not considered for this study. No gages fit these criteria for this watershed. USGS stream gages listed in Table 3 are within the scoped area, but were not considered for this analysis.

Table 3: USGS Peak Streamflow Gages

Gage ID	Flooding Source and Location	Published Drainage Area (mi^2)	Period of Record
08042500	Hillebrandt Bayou near Lovell Lake, TX	128	1954-2000
08042000	Taylor Bayou near LaBelle, TX	262	1952-2000

Figure 8 shows the Drainage area (white outlines) for gages 08042500 and 08042000. From Google Earth historical satellite imagery, the urban development changes between 1999 and 2019 are visible in those circled areas. The Multi-Resolution Land Characteristics (MRLC) National Land Cover Database (NLCD) Enhanced Visualization and Analysis (EVA) tool shows the land cover change from 2001 to 2019, and the report for Jefferson County shows that overall 6.58%, or 73 square miles, of the County land use changed. Per FEMA guidance (General Hydrologic Considerations Guidance Feb 2019), "*Note that gage record analyses are valid only for homogeneous periods of record in which the hydrologic response of the watershed is unchanged*". Therefore, the two gages with period of records ending before 2000 are not representing current watershed condition, and therefore the gage data was not used.



Satellite Imagery in 1999

Satellite Imagery in 2019

Figure 8: Comparison of Satellite Imageries from 1999 to 2019

2.2.3.1 Excess Precipitation for 2D Computational Mesh

HEC-HMS version 4.6 was used to apply the Soil Conservation Service (SCS) Curve Number method to calculate losses and define excess precipitation for this watershed. Temporal distributions of point rainfall totals were defined using 24-hour, frequency-based storm distributions. The plus and minus standard error for the 1% annual chance precipitation depths were determined as the upper and lower 84% confidence limits on the nominal 1% depth, assuming a normal distribution of the logarithms for the precipitation depths. An areal reduction as per Technical Paper 40 (TP-40) was used in HEC-HMS on all recurrence interval total precipitation depths in order to determine the effective precipitation for the sub-basin representing 2D mesh.

In addition to recurrence interval precipitation estimates, NOAA Atlas 14 provides 90% confidence intervals of reported precipitation values. On a normal distribution curve, 90% confidence intervals (i.e. the upper and lower 95% confidence limits) correspond to +/- 1.645 standard deviations. The 1% plus and minus events are defined to be one standard deviation above and below the 1% event. It should be noted that the standard errors for the 1% rainfall depth were based on the depth used post-areal reduction.

Curve numbers were computed by intersecting the NLCD 2016 coverage and NRCS soils data based on the matrix presented in Table 4.

Table 4: Land Use-Soils-CN Matrix for Defining Initial Curve Number

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

A Curve Number (CN) can be considered a parameter, exhibiting variability that follows some frequency distribution. While Antecedent Runoff Condition (ARC) II CNs were used for a 1% event, the range between ARC I and ARC III for the ARC II CN was assumed to correspond to an 80% confidence interval of the ARC II CN. The CN loss method assumes a maximum potential retention parameter, S, is inversely related to a CN by S = 1000 / CN – 10; this relationship is based on a median value of S determined from plotting a large number of observations.

Chapter 5 of the NRCS National Engineering Handbook (NEH) Part 630 provides an example of computing a CN for a watershed based on annual peak gage observations. The example involves computing a CN and corresponding S value for each event, then taking the logarithms of the S values. Further, the logarithm of S is assumed to vary normally, and the mean of the logarithms corresponds to the arithmetic median. Therefore, 10% (S10) and 90% (S90) extremes of lognormally distributed S values can be assumed to correspond to ARC III and ARC I condition CN values, respectively. This range represents an 80% confidence interval, corresponding to +/- 1.282 standard deviations from the mean. The following procedure was used to estimate one standard deviation of a given CN (in fact, one standard deviation of the logarithm of S) for the purposes of modeling 1% plus and minus events. First, ARC III (corresponding to S10) and ARC I (corresponding to S90) CN values can be estimated from a 1% CN (ARC II) by:

$$CNI = 4.2 * CNII / (10 - 0.058 * CNII)$$

$$CNIII = 23 * CNII / (10 + 0.13 * CNII)$$

Next, S90 and S10 can be computed by:

$$S10 = 1000 / CNIII - 10$$

$$S90 = 1000 / CNI - 10$$

The following relationship can then be used to compute one standard deviation of the logarithm of S:

$$\log (S10) = \text{mean} (\log(S)) + 1.282 \text{ std. dev.} (\log(S))$$

$$\log (S90) = \text{mean} (\log(S)) - 1.282 \text{ std. dev.} (\log(S))$$

$$1 \text{ std. dev.} (\log S) = (\log S10 - \log S90) / 1.282$$

Therefore, 1% plus and minus S values can be estimated by:

$$\log SPlus = \log S + [1 \text{ std. dev.} (\log S)]$$

$$\log SMinus = \log S - [1 \text{ std. dev.} (\log S)]$$

Finally, 1% plus and minus CNs can be computed by:

$$CNPlus = 1000 / (SPlus + 10)$$

$$CNMinus = 1000 / (SMinus + 10)$$

Since the 1% plus and minus events represent plus and minus one standard deviation of a 1% event, CNs used in a rainfall-runoff simulation for modeling 1% plus and minus events were developed, as described above.

The table below shows the curve numbers both initially computed and revised values based on reasonability check revisions.

Table 5: Rainfall-Runoff Curve Numbers

Sub-basin Description	CN (initial)	CN (verified)	CN 1% Minus	CN 1% Plus
Sabine Lake	89.5	89.5	82.1	94.14

NRCS rainfall-runoff methods were used to define excess precipitation applied to the 2D mesh, including curve numbers for defining rainfall losses. No routing was considered in the rainfall-runoff modeling. Frequency-based storms, with 50% storm centering, were used for defining temporal distributions of point rainfall totals. An Areal Reduction Factor (ARF) of 0.91 was used on all recurrence interval total precipitation depths in order to determine the effective precipitation for the sub-basin representing the 2D mesh. Table 6 provides the precipitation totals used for determining excess precipitation.

Table 6: Precipitation Totals Estimated in HEC-HMS (post ARF)

Percent Annual Chance Precipitation Depths (in.)							
Sub-Basin Description	1%	0.2%	2%	4%	10%	1% Plus	1% Minus
Sabine Lake	18.2	27.7	15.1	12.4	9.4	22.18	14.22

Table 7 shows the excess precipitation totals determined from the HMS model. These values are a factor of the average curve number and precipitation depths for each model area. Note that CNs were modified during the calibration process and the excess precipitation depths were recalculated to match actual conditions and install confidence in the final model results.

Table 7: Total Excess Precipitation Applied to 2D Mesh

Percent Annual Chance Precipitation Depths (in.)							
Sub-Basin Description	1%	0.2%	2%	4%	10%	1% Plus	1% Minus
Sabine Lake	15.23	23.85	12.43	9.99	7.26	19.46	10.65

Figure 9 shows the excess precipitation hyetograph used for Sabine Lake. Curve Number and precipitation depth are the two factors used by the HMS model to determine the magnitude of the excess precipitation event. The excess precipitation hyetograph is calculated in 6-minute increments. All models in this study have excess hyetograph shapes that closely resemble this one, but with varying maximum excess precipitation values.

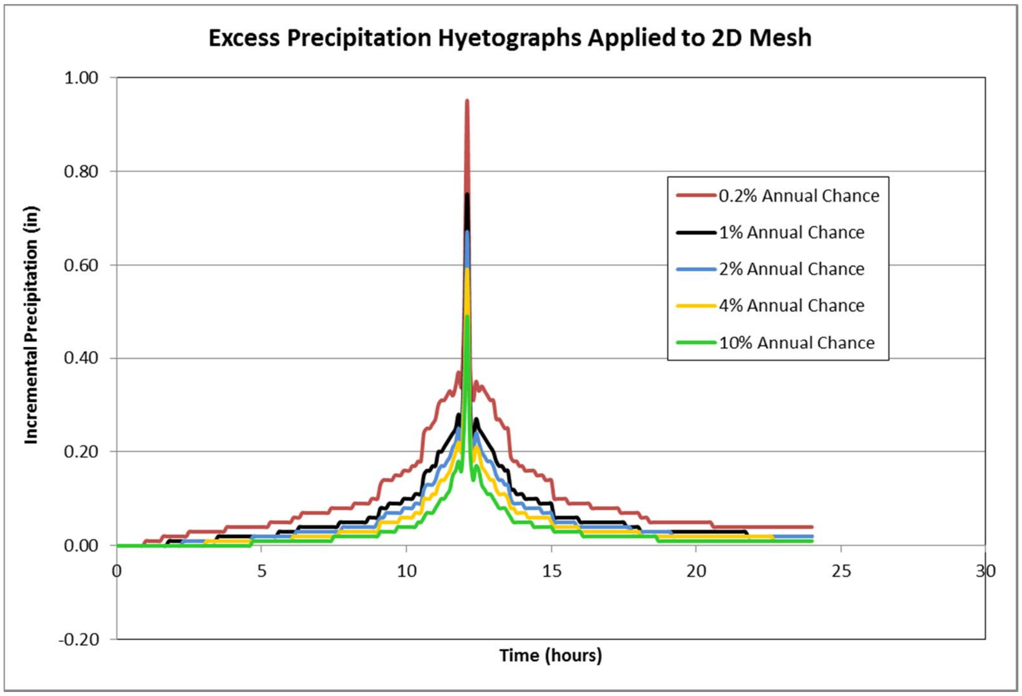


Figure 9: Excess Precipitation Hyetograph

2.2.3.2 Inflow Hydrograph Boundary Conditions

There are two major inflows for Sabine Lake watershed, Sabine River and Neches River. See Figure 7 for the inflow locations. For both of the inflow hydrographs development, the approach of Unit Hydrograph (UH) were applied.

- Neches River developed the UH from gage records at site 08031000, and the peak values are from 2019 BLE study.
- Sabine River developed the UH from gage records at site 08041780, and the peak values are from the on-going FEMA Region 6 FY20 Lower Sabine River 1D BLE study.

The resultant hydrographs are shown in the figures below.

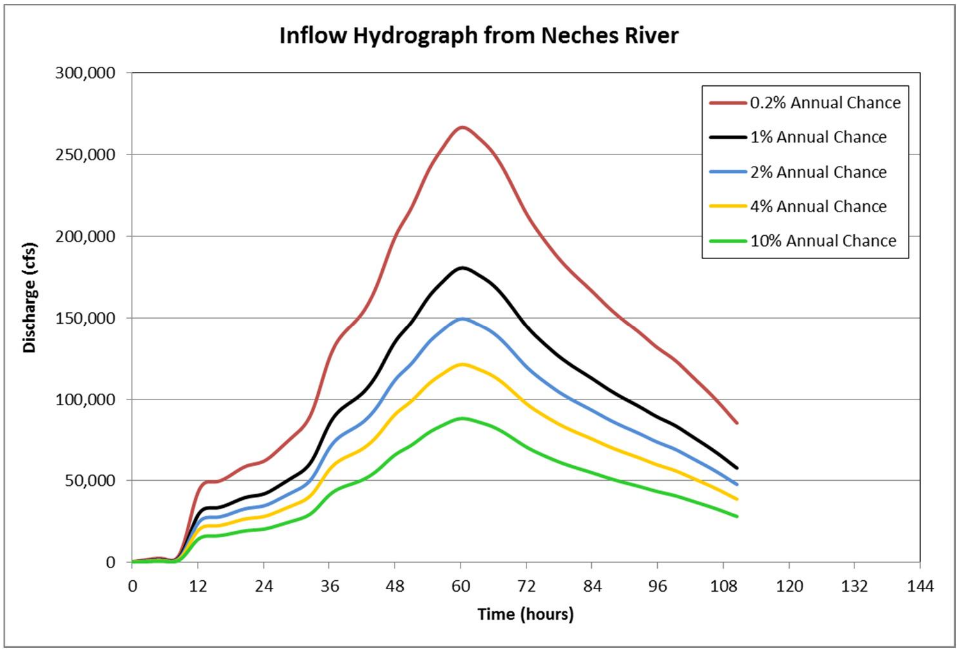


Figure 10: Inflow Hydrograph from Neches River

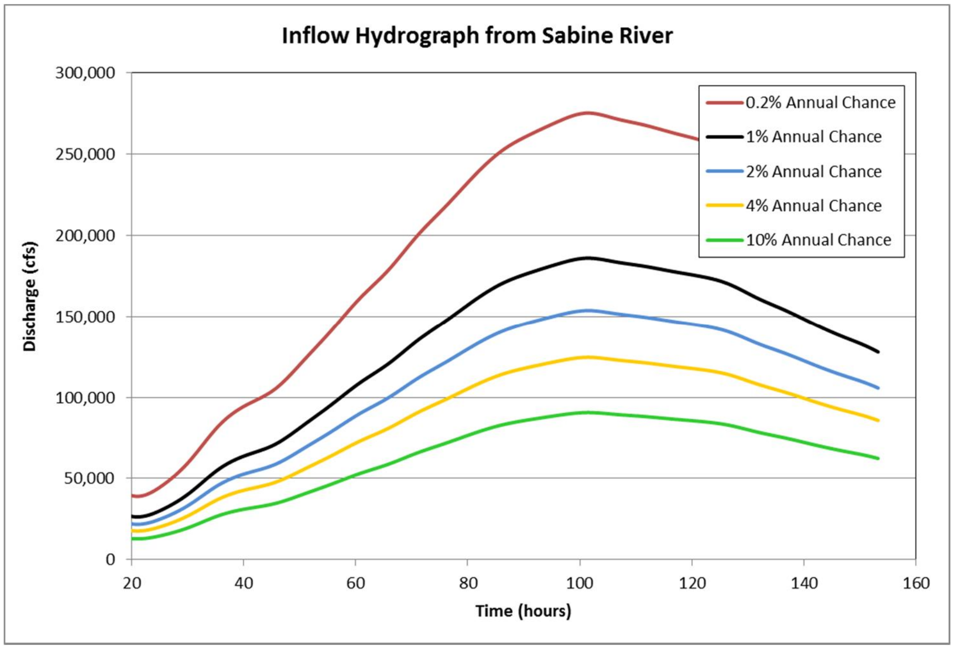


Figure 11: Inflow Hydrograph from Sabine River

2.2.4 Hydraulics

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

2.2.4.1 Roughness Coefficients

Manning's (n) roughness coverage was developed for the 2D computational mesh using typical roughness values for given NLCD land classifications. Two different sets of Manning's N values were used for areas within the channel and all other areas outside of the channels of the stream network. The channel layers were created using a 100-ft buffer. This allows for the model to accurately represent deep, swift flow within the channel and shallow overland flow outside of the channel areas. The table below shows a typical landuse-roughness matrix used in defining the roughness coverage for the study area for areas both inside and outside of the channel.

Table 8: NLCD 2016 Manning's N Roughness Matrix

NLCD Classification	Channel		Overbank	
	N Value	Source	N Value	Source
Open Water	0.03	Chow, 1959	0.03	Chow 1959
Developed, Open Space	0.035	Chow, 1959	0.04	NRCS KS Dam Breach, 2016
Developed, Low Intensity	0.035	Chow, 1959	0.08	NRCS KS Dam Breach, 2016
Developed, Medium Intensity	0.035	Chow, 1959	0.1	NRCS KS Dam Breach, 2016
Developed, High Intensity	0.035	Chow, 1959	0.15	NRCS KS Dam Breach, 2016
Barren Land	0.03	Chow, 1959	0.03	NRCS KS Dam Breach, 2016
Deciduous Forest	0.05	Chow, 1959	0.16	NRCS KS Dam Breach, 2016
Evergreen Forest	0.05	Chow, 1959	0.16	NRCS KS Dam Breach, 2016
Mixed Forest	0.05	Chow, 1959	0.15	NRCS KS Dam Breach, 2016
Scrub/Shrub	0.04	Chow, 1959	0.1	NRCS KS Dam Breach, 2016
Grassland/Herbaceous	0.04	Chow, 1959	0.15	HCFCD modeling Guidelines
Pasture/Hay	0.04	Chow, 1959	0.15	HCFCD modeling Guidelines, 2018
Cultivated Crops	0.04	Chow, 1959	0.1	HCFCD modeling Guidelines, 2018
Woody Wetlands	0.04	Chow, 1959	0.12	NRCS KS Dam Breach, 2016
Emergent Herbaceous Wetland	0.04	Chow, 1959	0.07	NRCS KS Dam Breach, 2016

2.2.4.2 Breaklines

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including road embankments and hydraulic structures. Road embankment features were delineated in GIS and imported into RAS5 as breaklines to contain water where appropriate. Similarly, significant bridge/culvert crossings that were not processed out of the terrain data were modeled by v-notch breaklines adjacent to the road embankment to align grid cells around the embankment and allow water to be routed through the embankment without creating artificial backwater. An example of the v-notch breakline approach is shown in Figure 12.

County, interstate, common name, state recognized, and U.S. roads were incorporated for road breaklines from the U.S. Census Bureau TIGER/Line road layer.

Any publicly owned dams, according to the 2018 National Inventory of Dams, were modeled with breaklines to provide protection. This method allows water to flow out of the spillway, if it reaches that elevation. Private dams were not modeled as showing protection. This is to lessen the burden on private dam owners to maintain their dams in order to sustain the regulatory products created as a result of this study.

Breaklines were also used along all the stream centerlines of streams draining greater than one square mile of drainage area. Each stream centerline was enforced with 100 foot cell spacing in order to align cells along the stream line and capture more detail along the one square mile stream network.

The study area included multiple levee systems. The accredited levee system, Port Arthur Hurricane Flood Protection, was represented by breaklines running along the top. The non-accredited levee systems used breaklines running along the low point at the bottom so as to allow water to pass.

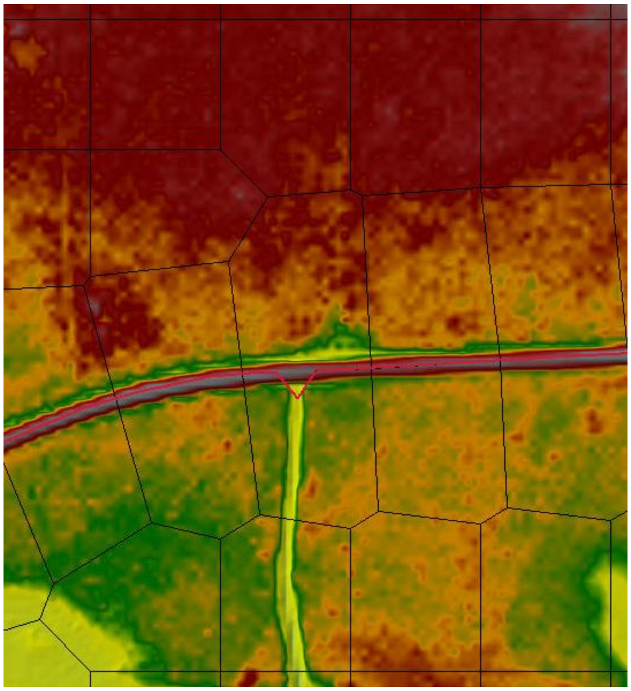


Figure 12: V-notch Breakline Approach at Bridge Crossing

2.2.4.3 Refinement Regions

Refinement regions were created for each community within the model. The political boundary was used to determine the shape of the refinement region. The regions were assigned a cell spacing of 50 feet by 50 feet. This finer cell spacing allows for more hydraulic calculations and mapping detail near areas where there are likely to be more structures. The table below shows the communities contained within Sabine Lake watershed that were modeled with refinement regions as well as the square mileage of the refinement region.

Table 9: Communities with 2D Mesh Refinement

Community Name	Area (mi^2)
Beaumont City	54.9
Bridge City	1.8
Central Gardens CDP	2.5
China City	1.0
Fannett CDP	6.2
Groves City	5.2
Nederland City	5.4
Nome City	5.4
Port Arthur City	30.4
Port Neches City	5.2
Stowell CDP	3.2
Taylor Landing City	0.1
Winnie CDP	3.3

Refinement regions were also used in a few of the largest lakes, including Sabine Lake, where the terrain does not have a slope. A cell size of 500ft was used for the body of the lake. Due to the flat surface in these lakes, no detail was lost by having larger cell sizes. This was done to lower to total model cell count, ensuring shorter runtimes and decreasing chance of error.

2.2.5 Quality Control

The results of 2D BLE results were independently assured to meet quality standards of the project. Standard checklists complying with FEMA standards were used to review hydrology and hydraulics results, the resulting flood hazard area delineations and CNMS dataset. Quality assurance during the data development process includes, but is not limited to the following QC checks:

- Hydrological QC – included checks for curve number calculation, input precipitation, flood events, areal reduction factor and human error.
- Hydraulic QC – included checks for RAS geometry, breakline placement, v-notch placement to ensure water conveyance at crossings, refinement regions, roughness coefficients, boundary/initial conditions, timestep and mapping outputs
- Mapping – included checks for spot checking flood inundation accuracies based on floodplain mapping criteria described in Section 4, ensuring flood extents from higher frequency events did not exceed lower frequency extents due to GIS smoothing algorithms, and topological overlap and cluster tolerance errors were resolved

- CNMS - Included review of the A1-A5 analysis for all effective approximate reaches in the HUC, geometry updates to newly studied reaches added as Zone X, and removal of scoped areas which lie outside of the final BLE footprint.

3. Results

The 2D BLE results for the study produced flood hazard area that compared reasonably well with effective special flood hazard area (SFHA) in most cases, and provides additional estimated flood hazard risk area where not previously mapped. The HEC-RAS peak (max) results were exported for mapping and the HEC-RAS model was run with a hydrograph output interval of 30 minutes, mapping output interval of 1 hour and the detailed output interval of 1 hour. The Sabine Lake Watershed is sufficient to facilitate FEMA regulatory processes while also providing the best available information for planning purposes. The 2D BLE results should be verified through community work map meetings as part of the regulatory workflow.

Table 10: Effective and Model BFE Comparison

Location	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
Willow Marsh Bayou Effective XS Letter A	9.7	10	0.3
Green Pond Gully Effective XS Letter C	30.7	30	0.7
South Fork Taylor Bayou Effective XS Letter E	17.8	18	0.2
Channel to Janes Gully Effective XS Letter F	25.6	26	0.4

3.1 Calibration

For calibration purposes, none of the USGS gages fit the criteria due to insufficient length of record or outdated record dates. There also existed only a limited amount of reliable effective data within the study area; therefore, regression estimates were utilized in different locations throughout the model to ensure accurate results. The specific locations for calculating regression were chosen based on their proximity to communities, defined streamflow, and to achieve a variety of drainage area sizes between the points. With this criteria in mind, the points chosen all fall in the Texas portion of the study area.

The regression analysis was performed as per regional regression equations using the drainage area, dimensionless main channel slope (S), OmegaEM parameter and mean annual precipitation (P) (USGS-SIR 2009-5087). Regression comparisons were made in four locations with varying contributing drainage area to ensure a reasonable amount of excess precipitation was being applied to the 2D mesh.

Adjustments to curve number and hydraulic features within the model were made until the flows in the model matched closely with the peak flows determined from gage and effective data. Final results following model calibration at the calibration locations are presented in Table 11.

Table 11: Calibration Results

Calibration Location	Source	Method Used in Original Study	Drainage Area (Square Miles)	Reference			HEC-RAS 5.0.7 (2D)
				Lower Limit	1%	Upper Limit	
Basin 1	Regression	USGS Report 77-110 methodologies	13	1,608	3,209	6,403	4,714
Basin 2	Regression	USGS Report 77-110 methodologies	280	6,369	12,707	25,355	13,535
Basin 4	Regression	USGS Report 77-110 methodologies	160	4,511	9,001	17,958	8,777
Basin 6	Regression	USGS Report 77-110 methodologies	16	1,074	2,144	4,278	3,797

Figure 13 shows the final results of the calibration locations compared to modeled flows throughout the Sabine Lake watershed. Four comparisons were made with varying drainage areas to ensure the calibration of excess precipitation for different points over the entire watershed area. This large collection of calibration points provides confidence in results throughout the entire Watershed.

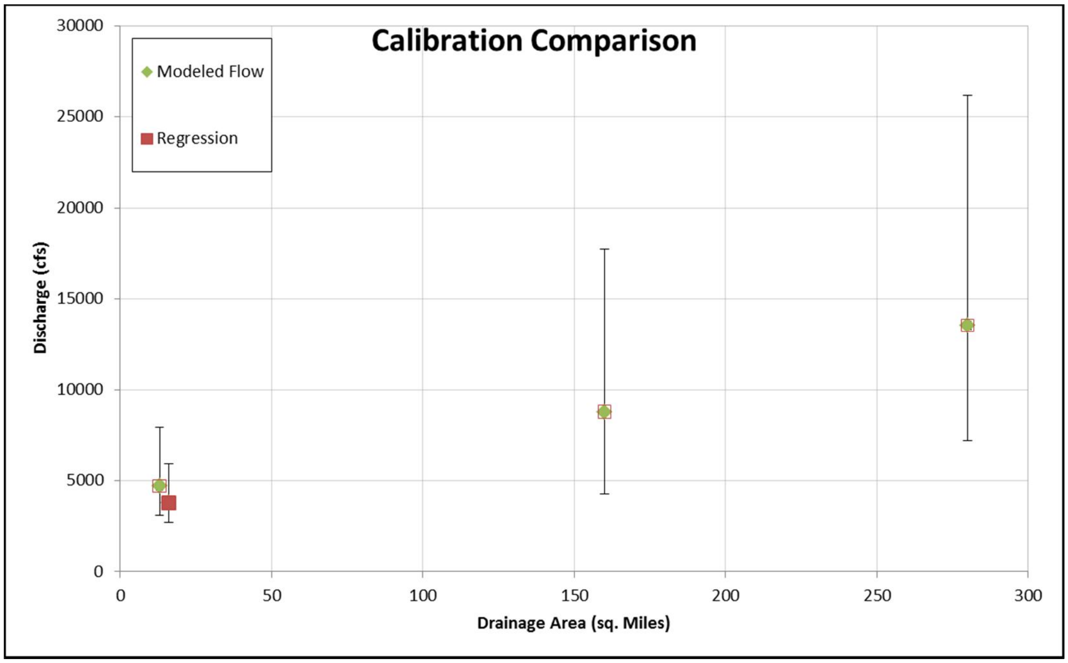


Figure 13: Calibration Comparison

3.2 Challenges

In order to mimic the normal pool condition for Sabine Lake, the team conducted tests to see how much impact the empty lake may have in terms of the discharge and WSEL. Below are the three simulation scenarios that were tested:

- Restart: unrevised terrain (-1.3ft), using a restart file starts which ran for 12 hours prior to the real simulation. This allows the model starts with wet conditions.
- Original: unrevised terrain (-1.3ft), no restart file.
- Mod terrain: revised terrain (0.67ft), no restart file. 0.67ft is the MHHW value at gage 08770475.

Table 12: Simulation Comparison

Items	Restart Plan	Original Plan	Modified Terrain
WSE(Max)	4.58	4.28	4.5
Depth(Max)	5.89	5.57	5.05
percent error	0.000171	0.000235	0.000236
Starting Volume	875,742	235,603	109,645

The comparison profile lines were pulled from the mid-point through the lake. Table 12 lists the comparisons between the three plans, and below are some findings:

- The flow/volume/WSEL/Depth comparisons look reasonable.
- Start volume for restart plan is higher because more volume had been added into the model before the real simulation and that plan yields to the lowest percent error among those three.
- The discharge from the modified terrain is significantly lower than the other two.

Due to the lack of a riverine gage, it could not be determined which flow is closest to reality. However, this area will be fully under coastal impact, so this is not a concern at the moment. In conclusion, the original terrain is used for the model without a restart file because there is not enough available data to support otherwise.

3.3 Recommendations

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

Due to the size of the HEC-RAS model, point source Atlas 14 rainfall data was used. For detailed modeling and further improvements smaller sized model is recommended which will have less rainfall and curve number variability. The hydraulic model can further be improved by using a smaller cell size than 200 ft along with adding structural and survey data for each crossing.

4. Floodplain Mapping and Effective Zone A Validation

The following sections provide a synopsis of how raw modeled depths were translated into Special Flood Hazard Areas (SFHA). In addition to developing a new SFHA, the BLE model data was leveraged to validate the effective Zone A studies within the project footprint.

4.1 Special Flood Hazard Areas

4.1.1 Model Outputs

The HEC acknowledged that RAS Mapper may not render water surface elevation values and/or delineate inundation extent appropriately for direct use in FEMA regulatory mapping products. As a result, Compass created a workflow to export model water surface elevation values for each 2D mesh cell to develop regulatory-ready water surface elevation grids and subsequent flood hazard area mapping features.

4.1.2 Methodology

Maximum water surface elevation values were exported for each model's two-dimensional computational mesh cell centroid. Densified points along the floodplain fringe of the sloping raster extents and areas of zero slope (ponds) from the DEM were added to the cell centroid points to help meet FEMA regulatory mapping product requirements. A triangular irregular network (TIN) was created from the points, and water surface elevation and depth grids were created from the TIN to match the resolution of the input terrain DEM.

Discussion with Compass partners, FEMA Region 6, and the Texas Water Development Board determined that floodplain outputs in coastal areas should reduce the overall inundation using statistical analysis of flood hazard depths and areas. For the Sabine Lake watershed, the following parameters were applied to remove or reduce floodplain inundation:

- Removal of all depths below 1/3rd of a foot across the watershed
- Removal of all polygons smaller than 10,890 square feet, regardless of depth
- Removal of polygons between 10,890 and 21,780 square feet, with an average depth between 1/3rd and ½ foot.

The final polygons were smoothed and simplified in order to meet FEMA regulatory mapping specifications. Small islands less than 13,068 square feet in the polygons were filled in.

Minor adjustments were made to the floodplain boundaries along open water rivers, ponds and other waterways to ensure floodplain connectivity in situations that were removed based on the parameters mentioned above. Minor tributaries or roadside ditches that aren't fully inundated have not been adjusted. The watershed does contain open water detention ponds that are elevated compared to surrounding areas. These ponds have not been included in the floodplain boundaries in situations that the sloping model raster did not show inundation.

Mapping for the 0.2% annual chance was mapped in a similar manner as mentioned above in regard to removal of depths and areas. Due to methodologies and tolerances applied in the ArcGIS smoothing tool, minor differences between 1% and 0.2% boundaries where the extent of the 1% boundary would exceed the 0.2% have been resolved by copying the 1% boundaries into the 0.2% boundaries and merging the boundaries together.

Mapping for the 10% annual chance was mapped as well in a similar manner in regard to removal of depths and areas. No adjustments were made beyond the removal of very minor differences that could result from the smoothing methodologies and tolerances as mentioned previously. In locations that the 10% boundary exceeded the 1% boundary, those areas have been removed.

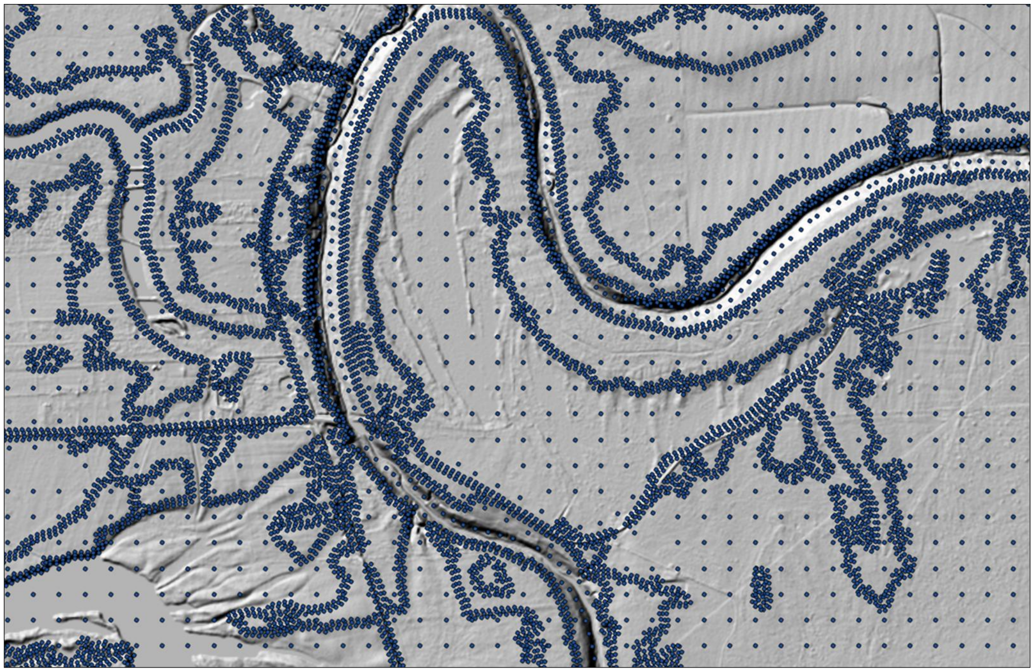


Figure 14: 2D BLE Model Points for Mapping Workflow

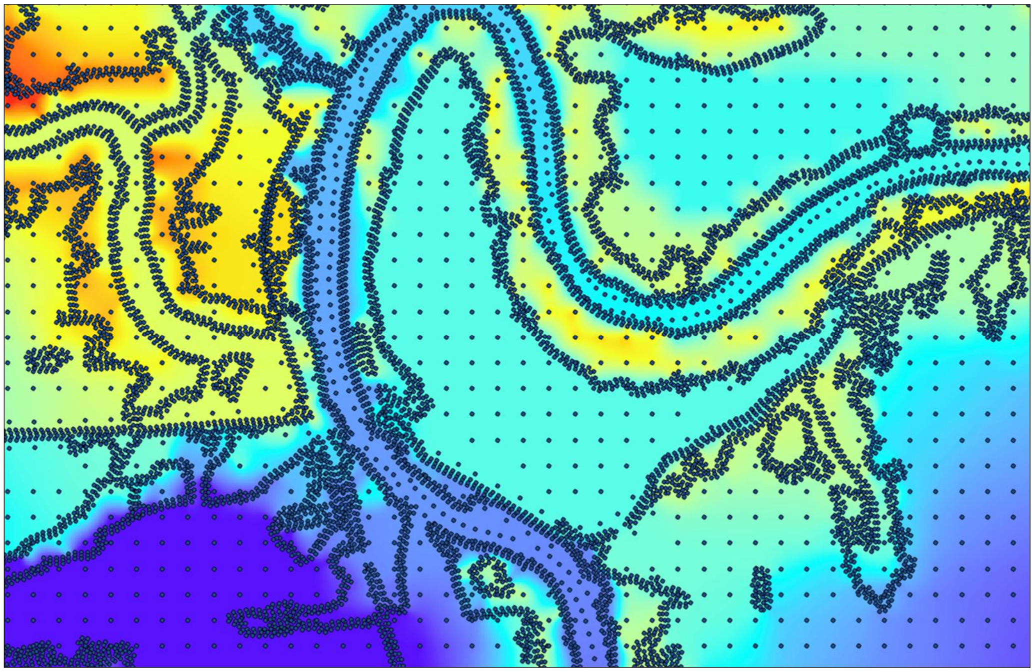


Figure 15: 2D BLE Model Points to Water Surface Elevation TIN

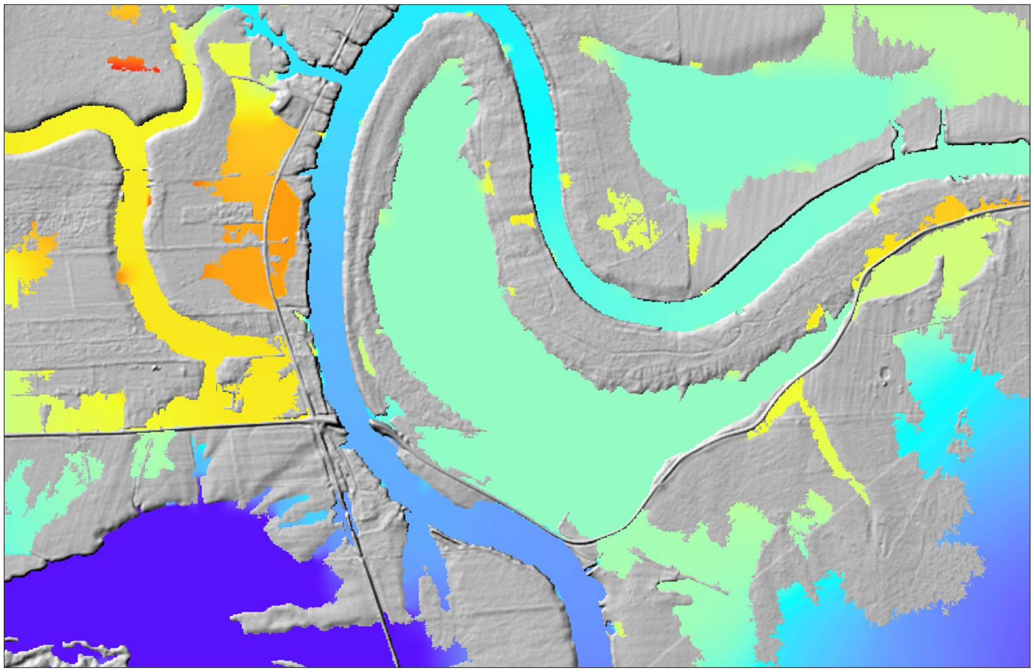


Figure 16: Water Surface Elevation TIN to Grid

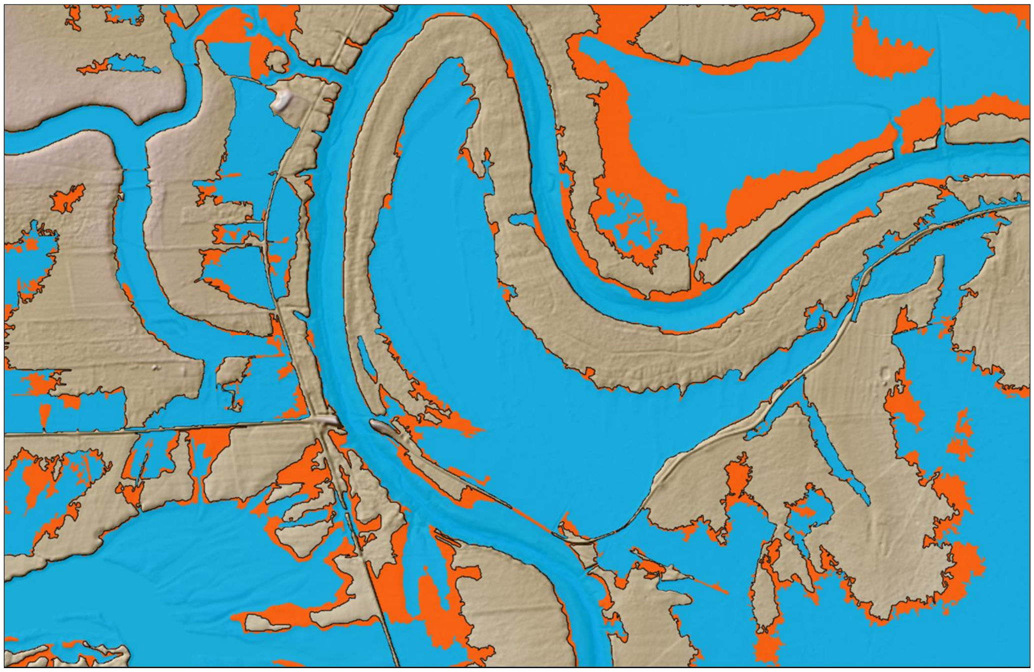


Figure 17: Water Surface Elevation Grid to Mapping Products

4.1.3 BLE Flood Hazard Layer

BLE database format FLD_HAZ_AR feature classes were developed and attributed with Zone A and Shaded Zone X features. The BLE FLD_HAZ_AR feature class was tested for topological errors described in the FIRM Database Technical Reference and all errors were fixed for data integrity and schema agreement. The 10% boundaries have been included in the BLE TENPCT_FP feature class.

4.1.4 Additional 1-Percent Features

The BLE results for this study produced a SFHA that compares favorably with the effective SFHA. 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 .

4.2 Validation of Effective Zone A SFHA

The inventory of Zone A studies (102.7 miles) in the Sabine Lake Watershed were classified in CNMS with validation status of “UNVERIFIED” (97.8 miles) or “VALID” (4.9 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. Note, there is no CNMS linework in the Louisiana portion of the Sabine Lake HUC watershed (or in the lower portion of Jefferson County, Texas as well) as those are coastally influenced areas that are Zone V, Zone AE, or Zone AE with static BFEs (coastal). Coastally influenced areas are not included or tracked in CNMS.

4.2.1 Initial Assessment A1 – Significant Topography Update Check

This check involves determining whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. For the study area in the Sabine Lake Watershed, the effective Zone A topographic data consisted of USGS 7.5 Minute Series Topo Maps. The LiDAR sources used in this BLE study are considered significant improvements from the effective zone A topographic sources; therefore, all reaches FAIL this check.

4.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

The significant hydrology changes check determines whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1% annual chance flow. New equations have not been issued since that time. For this reason, all reaches in the study area PASS this check.

4.2.3 Initial Assessment A3 – Check for Significant Development

The significant development check, using the National Urban Change Indicator (NUCI) dataset, assesses increased urbanization in the watershed. If the percentage of urban area within the HUC-12 watershed containing the effective Zone A study is 15 percent or more, and has increased by 50 percent or more since the effective analysis, the study would fail this check. The check for significant development in the Sabine Lake Watershed was completed by evaluating percentage of urban change at the HUC-12 level. None of the HUC-12 polygons within the study area met the threshold of 15% or more urban cover, therefore, all reaches were set to PASS this element.

Table 13 presents the summarized results of checks A1 through A3.

Table 13: Zone A Initial Assessment Results

Assessment Check	Pass / Fail	Notes
A1 – Topography	Fail	LiDAR sources available are considered significant improvements from the effective zone A topographic sources.
A2 – Hydrology	Pass	Regression equations are not known used in effective study
A3 – Development	Pass	Watershed does not meet urban threshold

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

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

All zone A streams within this watershed are not supported by technical data and fail this assessment check.

4.2.5 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. Within the Louisiana portion of the study area, there are no effective Zone A areas or CNMS lines, and therefore no A5 validation check. For the comparison of BLE and effective Zone A in the Texas portion of the 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: +/- 2.5 - 5 feet (one-half contour interval of effective topographic source).
- Horizontal Tolerance: +/- 75 feet (standard horizontal tolerance for BLE comparison testing).

Comparison results, in Texas, for these streams were grouped at the HUC-12 level and are summarized in Table 14 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 14: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Sabine Lake	All Streams	6182	3525	2657	43%	Fail	
Hillebrandt Bayou	120402010200	5232	3079	2153	41%	Fail	48.2
Lower Neches Valley Authority Canal-Taylor Bayou	120402010100	2944	1308	1636	55.6%	Fail	46.3
Salt Bayou	120402010300	78	5	73	94%	Pass	6.1

4.2.6 Validation Results

All 102.7 total miles of available CNMS features representing the effective Zone A studies were categorized as VALID – BEING STUDIED and UNVERIFIED – BEING STUDIED. Total miles in each of these categories are summarized in Table 15 and illustrated in Figure 18 below. Please note again, these do not include the coastally influenced areas in the Louisiana portion of the HUC-8 watershed since these are not tracked in CNMS.

Table 15: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	4.9
UNVERIFIED	BEING STUDIED	97.8

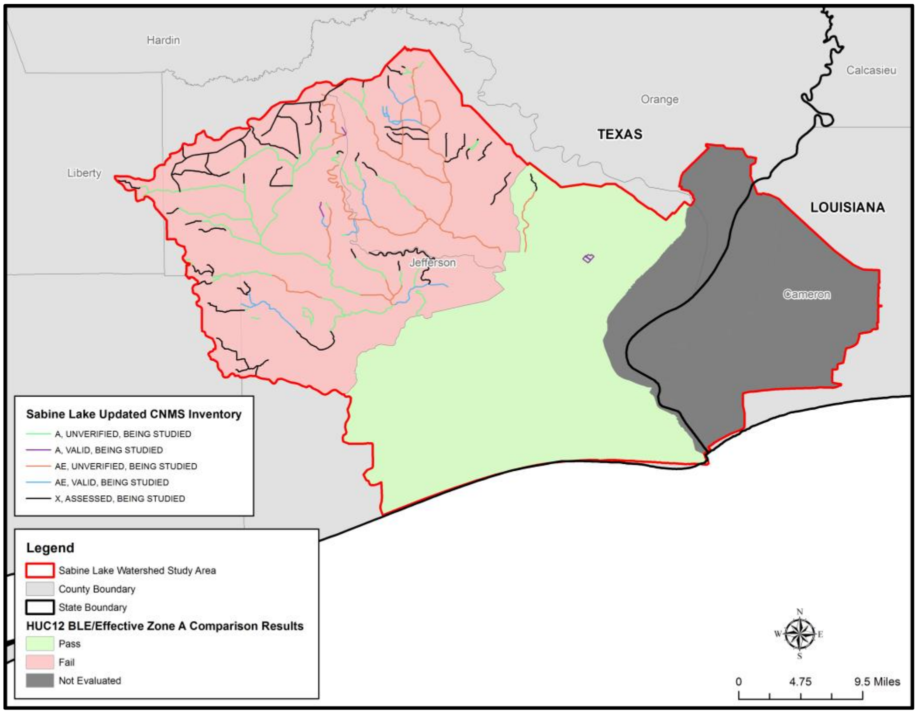


Figure 18: Sabine Lake Watershed CNMS Validation Results

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 19 below shows the range of the HUC-12 priority scores which can be used to initiate discussions during the Discovery phase. Priority scores not determined for the coastally influenced areas in the Louisiana portion of the HUC-8 watershed since these areas not tracked in CNMS.

Hillebrandt Bayou HUC-12 was determined to have the highest priority score and the most need while Salt Bayou HUC-12 had the lowest scores.

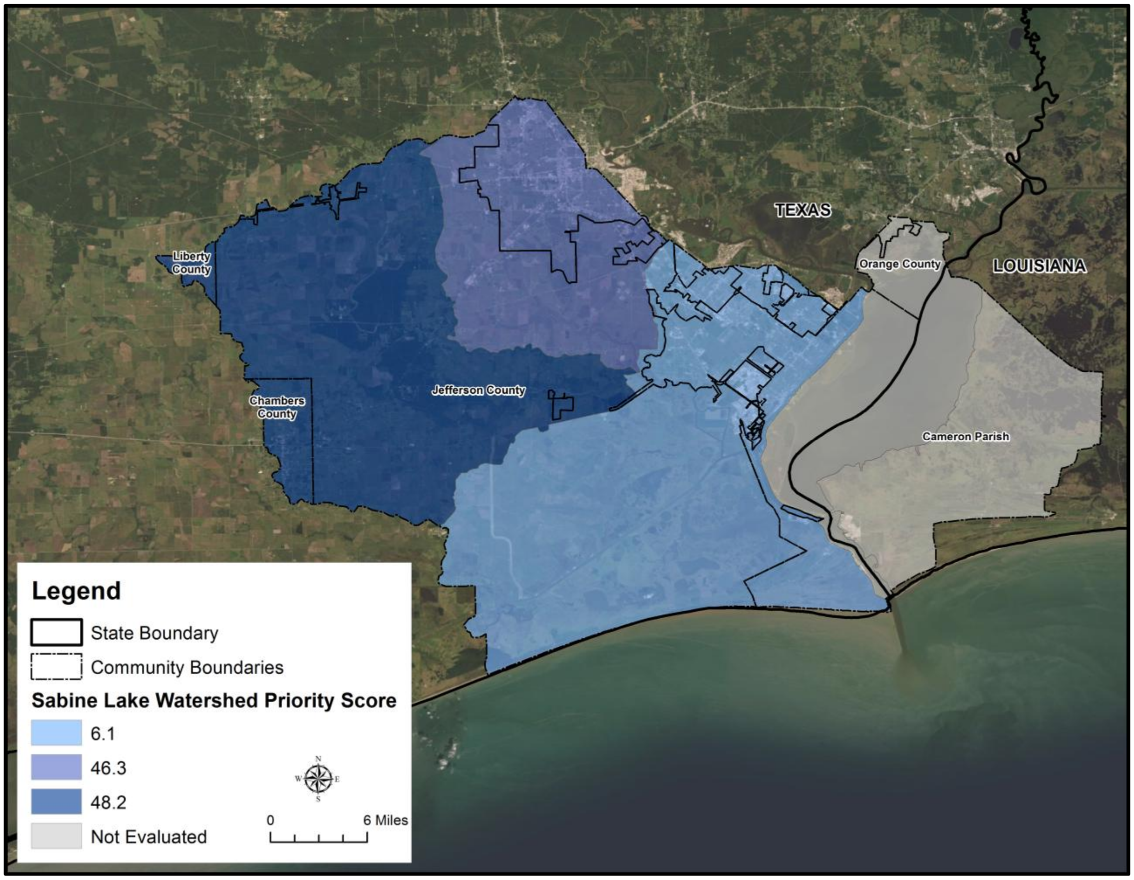


Figure 19: Ranking of Sabine Lake Watershed HUC-12s

4.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1% annual chance and 0.2% annual chance depth grids were used to calculate the potential flood losses. The loss results are stored in the S_FRAC_AR spatial file within the FRD geodatabase. All results are reported in whole dollar values.

Hazus version 4.2 (SP03) was used for the basic and refined loss analysis.

The losses are reported via census blocks. It is important to note that Hazus version 4.2 (SP03) uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by other bodies of water, wetlands, or forests) from the census blocks, changing their shape and reducing their size in these areas. For more information on dasymetric data visit FEMA's Media Library for the Hazus-MH Data Inventories: Dasymetric vs. Homogenous, or Hazus 3.0 Dasymetric Data Overview.

Hazus analysis was performed by county within the project watershed extents for each return period to ensure proper model processing. A summary of results for the 1-percent a.c.e. scenarios are shown in Table 16.

Table 16: Hazus 4.2 (SP03) Results for 1-percent-annual-chance (100 year) scenario for Sabine Lake Watershed, Texas and Louisiana

County/Parish	Full Replacement - Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Cameron	50,413,000	5,128,000	5,082,000
Chambers	58,762,000	409,718,000	249,953,000
Jefferson	18,806,877,000	22,981,242,000	146,496,328,000
Liberty	81,000	1,314,000	658,000
Orange	42,293,000	375,515,000	221,607,000
Total	18,908,013,000	23,767,789,000	146,968,546,000

5. References

1. Asquith, William H. and Roussel, Meghan C., “Regression Equations for Estimation of Annual Peak-Streamflow Frequency for Undeveloped Watersheds in Texas Using an L-moment-Based, PRESS-Minimized, Residual-Adjusted Approach,” United States Geological Survey Scientific Investigations Report 2009-5087, 2009.
2. Chow, Ven T., "Development of Uniform Flow and It Formulas." *Open Channel Hydraulics*. Caldwell, NJ: Blackburn, 1959. 109-113. Print.
3. Homer, C.G., Dewitz, J.A., Yang, L., Jin, S., Danielson, P., Xian, G., Coulston, J., Herold, N.D., Wickham, J.D., and Megown, K., 2015, Completion of the 2016 National Land Cover Database for the conterminous United States-Representing a decade of land cover change information. Photogrammetric Engineering and Remote Sensing, v. 81, no. 5, p. 345-354
4. FEMA, “Guidance for Flood Risk Analysis and Mapping – Automated Engineering”, May 2016. (https://www.fema.gov/media-library-data/1469144112748-f3c4ecd90cb927cd200b6a3e9da80d8a/Automated_Engineering_Guidance_May_2016.pdf).
5. FEMA, “Guidance for Flood Risk Analysis and Mapping-General Hydrologic Considerations”, Feb 2019. (https://www.fema.gov/sites/default/files/2020-02/General_Hydrologic_Considerations_Guidance_Feb_2019.pdf)
6. National Oceanic and Atmospheric Administration. NOAA Atlas 14, Volume 11 Version 2.0, Precipitation-Frequency Atlas of the United States. Silver Spring, Maryland, 2018.
7. Region 6 Neches River Watershed-Lower Neches (HUC8-12020003) Base Level Engineering Analysis. *STARRII 2019.*
8. Texas Precipitation – Average monthly and annual precipitation for the climatological period 1981-2010. Data from NRCS. Retrieved July 2019. (https://www.twdb.texas.gov/mapping/gisdata.asp/).
9. United States Army Corps of Engineers, Hydrologic Engineering Center. (March 2019). HEC-RAS River Analysis System, Version 5.0.7. Davis, California.
10. United States Geological Survey, Multi-Resolution Land Characteristics Consortium. *National Land Cover Database 2016*. (http://www.mrlc.gov/nlcd2011.php).

Appendix A BLE Map