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Paint Watershed, Texas
2D Base Level Engineering and Mapping Methods and Results

Texas Water Development Board Contract No. 2101792542, Task Order 1

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Texas Water Development Board
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Table of Contents

List of Figures

List of Tables

1. Introduction

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 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 BLE 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. The Paint watershed BLE documented here was designed to use two-dimensional (2D) modeling techniques with enhancements and calibration to develop products that can be communicated and shared with stakeholders, and transitioned into FEMA regulatory data development workflows.

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 (WSEL) 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.

For floodplain management purposes, BLE data may 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 may adopt BLE data to support local regulations, which 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.

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), which FEMA is required to evaluate once every five years, as described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e). 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. Another important goal of the BLE process is scalability of the results, 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.

BLE practices leverage high-resolution topography that meets or exceeds the United States Geological Survey (USGS) 3-D Elevation Program (3DEP) 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 (Hydrologic Unit Code (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.

Per standard identification SID #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 WSELs for each of the seven recurrence intervals previously identified.

The Paint watershed 2D BLE project was scoped as described in the Texas Water Development Board (TWDB) Task Order 1 (Contract 2101792542). In an effort to increase and enhance the flood risk products in Texas, the study was contracted through the TWDB's Cooperative Technical Partner (CTP) program to AECOM Technical Services, Inc. This report documents the BLE process, products, and results for this watershed. Figure 1 depicts the Paint watershed footprint.

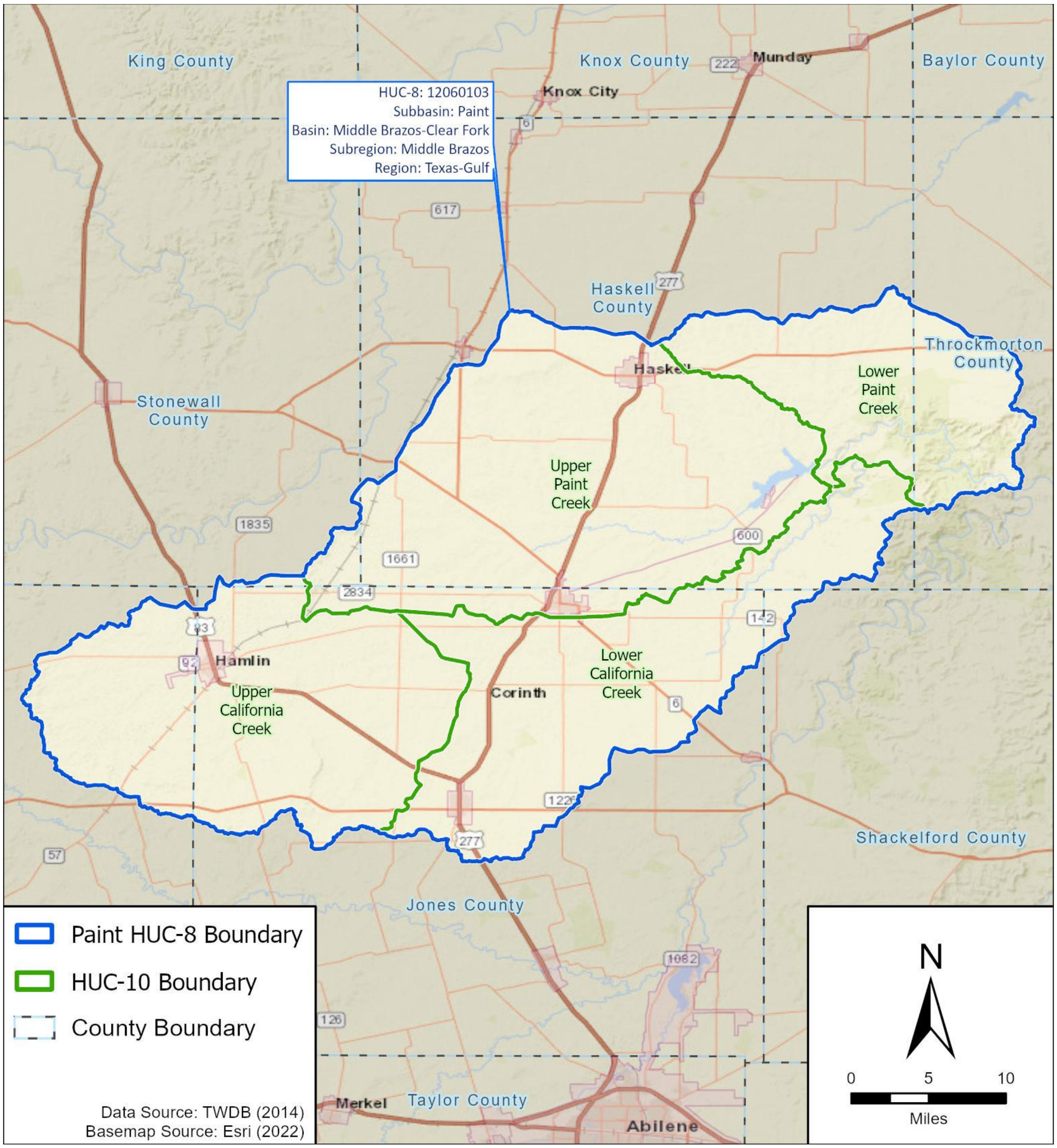


Figure 1: Paint Watershed

2. 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2D hydraulic engineering analysis for the Paint watershed using Hydrologic Engineering Center's River Analysis System (HEC-RAS) version 6.1 (HEC-RAS). Inputs such as elevation data, hydrology from rain-on-grid and inflow hydrographs, and hydraulic analyses and variables are defined herein. HEC-RAS 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 2D engineering analyses by providing a detailed representation of the surface for hydraulic routing through the model area. As such, DEMs were developed for the Task Order 1 project by leveraging available high resolution gridded elevation data derived from Light Detection and Ranging (LiDAR) collections throughout the States of Texas. Task Order 1 watersheds include Double Mountain Fork Brazos (Hydrologic Unit Code (HUC) 8 No. 12050004), Hubbard (HUC8 12060105), Lower Clear Fork Brazos (HUC8 12060104), and Paint (HUC8 12060103). The 1 meter DEM developed to support the 2D BLE modeling and analysis, within the Paint 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 Geographic Information Systems (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 Paint watershed.

2.1.1 Inventory

An inventory of existing topographic data was conducted for the Paint BLE watershed footprint. Figure 2 depicts the datasets identified and leveraged across the project area. FEMA, National Oceanic and Atmospheric Administration (NOAA), USGS, Texas Natural Resources Information System (TNRIS) and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

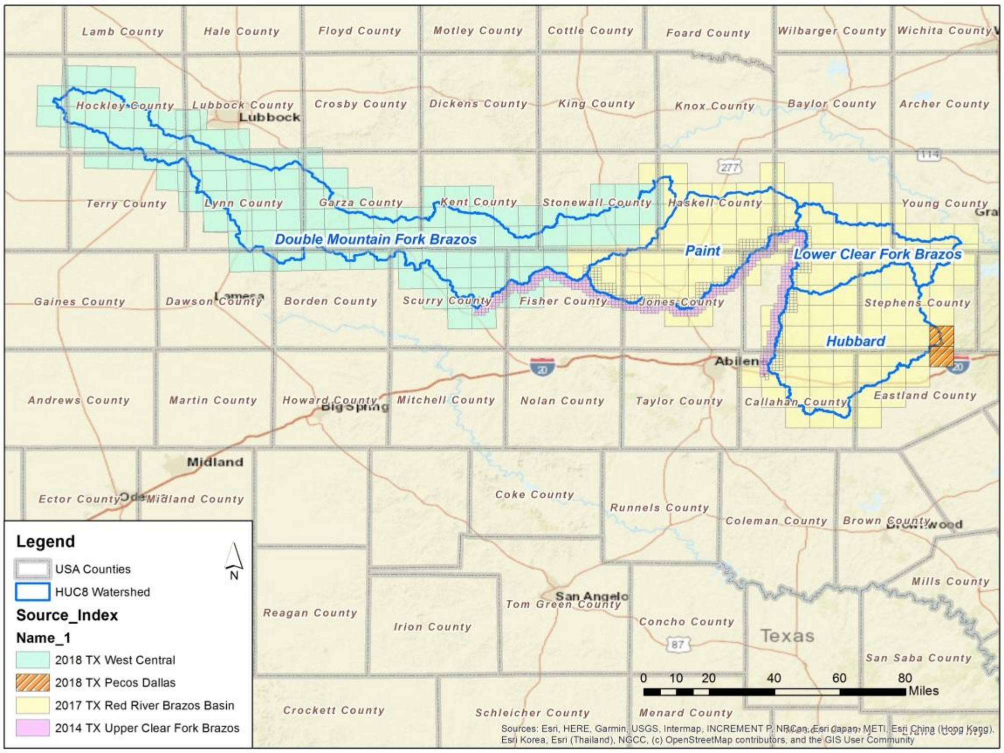


Figure 2: Task Order 1 BLE Source Terrain Data

2.1.2 Evaluation

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

- Data 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 Paint 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 Paint Watershed

Year	Description	Source/Owner	Accuracy[1]	Approximate Footprint (mi^2)[2]
2018	2018 FEMA Texas West Central LiDAR	USGS/FEMA	9.1 cm	464
2017	2017 Texas Red River Basin LiDAR	FEMA	18.8 cm	1,314
2014	2014 Texas Upper Clear Fork Brazos LiDAR	FEMA	6.7cm	37

[1]RMSEz reported at the 95% confidence level

[2]Size of LiDAR DEM footprint utilized for BLE study

2.1.2.1 Paint Watershed Source Terrain Data

The source elevation data for the Paint watershed are DEMs derived from the 2018 FEMA Texas West Central; the 2017 Texas Red River Basin LiDAR; and the 2014 Texas Upper Clear Fork Brazos LiDAR. Only points classified as "ground" points (i.e., bare earth) were imported from the LiDAR and used for development of the project DEMs. Bare-earth LiDAR data are typically made by filtering non-ground returns (e.g. buildings, vegetation, etc.) from the raw laser returns. Figure 2 depicts the extent of the data defined in Table 2.

2018 FEMA Texas West Central LiDAR

The 2018 FEMA Texas West Central Quality Level (QL) 2 Lidar project covers portions of Borden, Callahan, Cochran, Crosby, Dawson, Eastland, Fisher, Garza, Haskell, Hockley, Jones, Kent, Lubbock, Lynn, Palo Pinto, Scurry, Shackelford, Stephens, Stonewall, Taylor, Terry, Throckmorton, and Young Counties, Texas intersecting the Double Mountain Fork Brazos HUC8 study area and along the boundary of the Paint HUC8 watershed in Fisher, Haskell, Jones, and Stonewall Counties, Texas (see Figure 3). The USGS awarded this project to support the FEMA Risk MAP program. The acquisition was conducted from February 1, 2018 through May 27, 2018. Reflights were collected on November 5, 2018. Airborne Imaging, AXIS, Eagle, LEG, and Precision Aerial Reconnaissance completed Lidar data acquisition and data calibration for the project area. Dewberry served as the prime contractor for the project. In addition to project management, Dewberry was responsible for LAS classification, all Lidar products, breakline production, DEM production, and quality assurance. The source 1-meter bare earth DEM data was in Universal Transverse Mercator (UTM) Zone 13N, North American Datum of 1983 (NAD83) (2011), meters with elevations in North American Vertical Datum of 1988 (NAVD88) (GEOID 12B), meters.

For the 2018 FEMA Texas West Central QL2 Lidar Project, the tested RMSEz of the classified Lidar data vertical accuracy for checkpoints in non-vegetated terrain equaled 4.7 cm compared with the 10 cm specification; and the Non-vegetated Vertical Accuracy (NVA) of the classified Lidar data computed using RMSEz x 1.9600 was equal to 9.1 cm, compared with the 19.6 cm specification. Using National Standard for Spatial Data Accuracy (NSSDA) methodology, the horizontal accuracy at the 95 percent confidence level was reported as 61.4 cm (target was 100 cm).

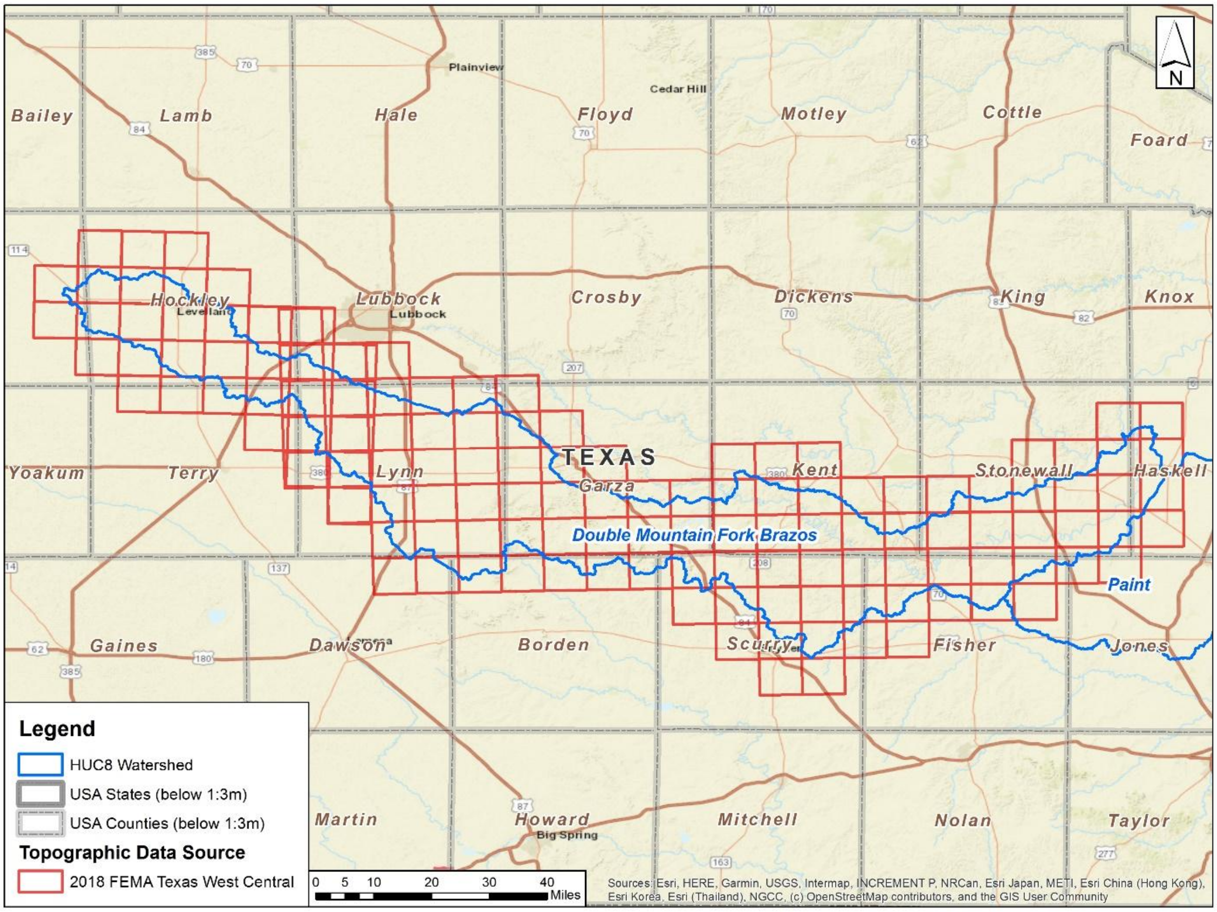


Figure 3: 2018 FEMA Texas West Central LiDAR

2017 Texas Red River Brazos Basin LiDAR

The 2017 Texas Red River Brazos Basin Lidar project covers Callahan, Eastland, Fisher, Haskell, Jones, Shackelford, Stephens, Stonewall, Throckmorton, and Young Counties, Texas (see Figure 4). This data set covers the majority of the Paint, Lower Clear Fork Brazos, and Hubbard HUC8 Watersheds. Dewberry served as the prime contractor for the project, and Leading Edge Geomatics Ltd. completed the Lidar data acquisition and data calibration for the project area. Lidar was collected between November 17, 2016 and May 28, 2018. The 1-meter bare earth DEM data was delivered in NAD83 (2011) UTM Zone 14N horizontal datum, NAVD88 vertical datum (GEOID12B), with horizontal and vertical units in meters.

The tested Root Mean Square Error (RMSEz) of the classified Lidar data vertical accuracy for checkpoints in non-vegetated terrain equaled 9.6 cm compared with the 10 cm specification. The NVA of the classified Lidar data computed using RMSEz x 1.9600 was equal to 18.8 cm, compared with the 19.6 cm specification. The tested VVA of the classified Lidar data computed using the 95th percentile was equal to 21.6 cm, compared with the 29.4 cm specification.

The horizontal accuracy, tested using NSSDA methodology at the 95 percent confidence level was computed as 88.4 cm (target was 100 cm).

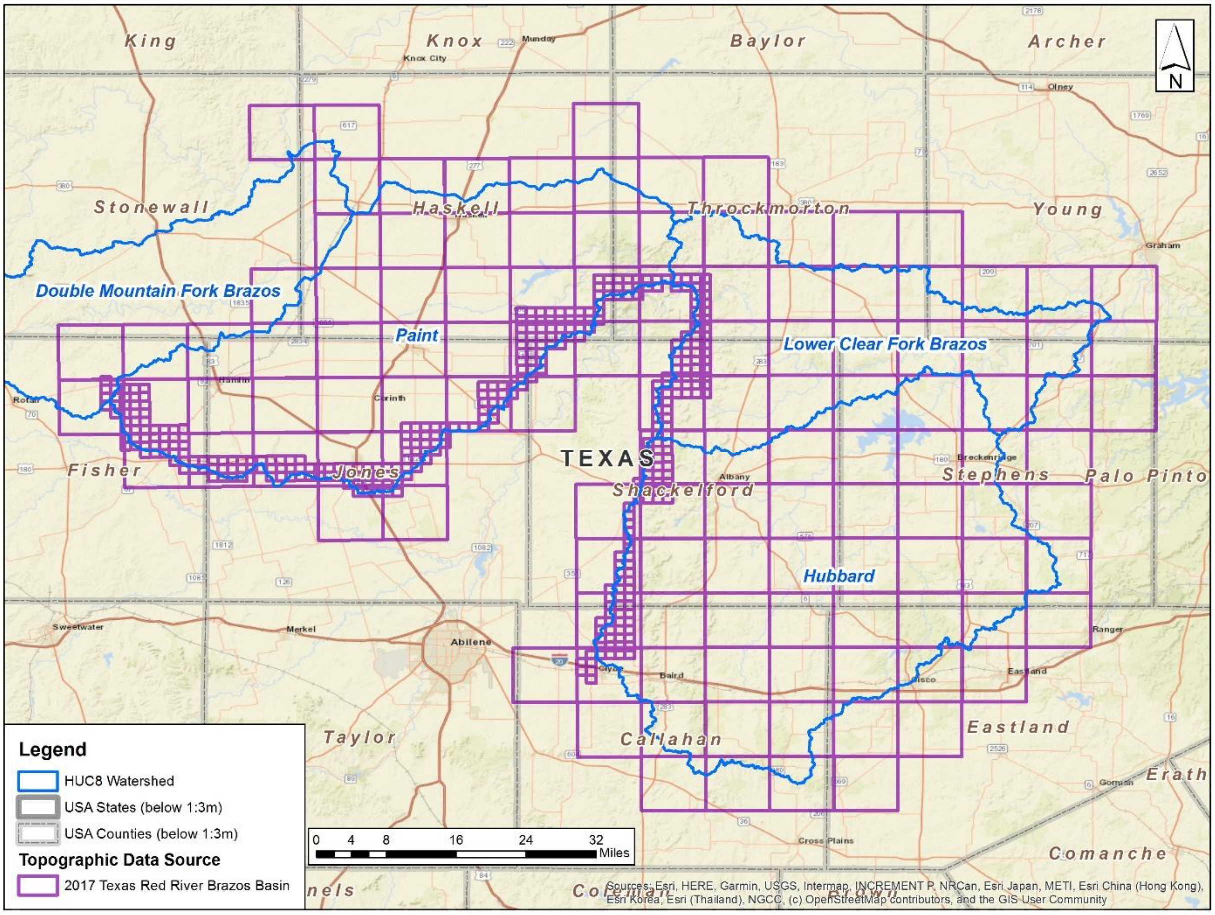


Figure 4: 2017 Texas Red River Brazos Basin LiDAR

2014 Texas Upper Clear Fork Brazos LiDAR

The 2014 Texas Upper Clear Fork Brazos QL2 Lidar project covers the buffer coverage along the southern border of the Double Mountain Fork Brazos and Paint HUC8 Watersheds within Fisher, Jones, and Scurry Counties, TX. The data set also covers a small area in Callahan and Shackelford Counties, TX to provide adequate buffer coverage for the Hubbard HUC8 Watershed (see Figure 5). Digital Aerial Solutions, LLC performed the Lidar data acquisition and data calibration for the project area. The data was collected December 12, 2014 through December 22, 2014. The 1-meter bare earth DEM data was delivered in NAD83 UTM Zone 14N horizontal datum, NAVD88 vertical datum, with horizontal and vertical units in meters.

The vertical accuracy tested RMSEz at the 95 percent confidence level was 3.10 cm compared to required accuracy of 9.25 cm. The NVA of the TIN tested RMSEz of 6.7 cm and 13.1 cm at the 95 percent confidence level in open terrain. The NVA of the DEM tested at an RMSEz of 6.7 cm and 13.0 cm at the 95 percent confidence level in open terrain. The tested horizontal accuracy was not provided within the Lidar project report.

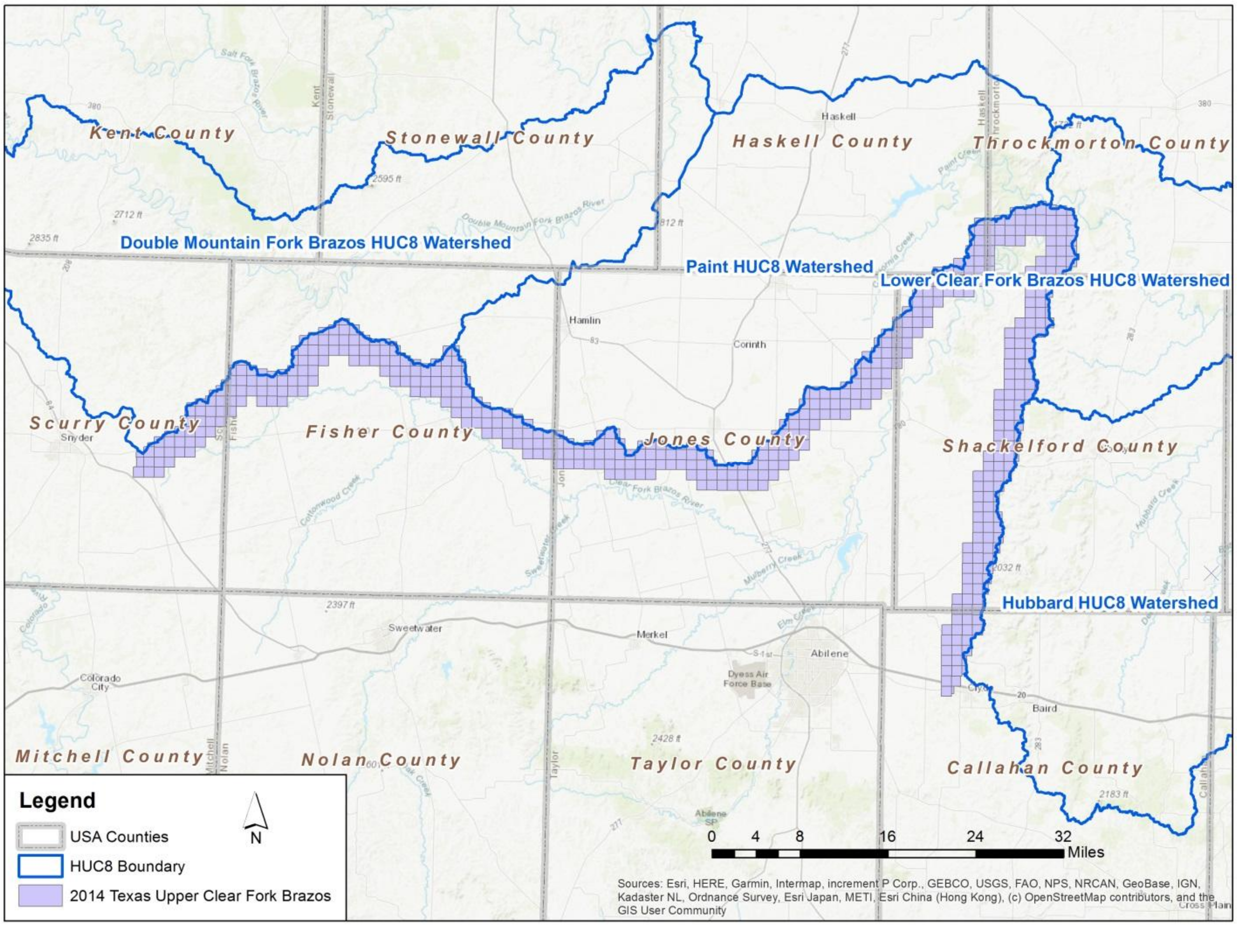


Figure 5: 2014 Texas Upper Clear Fork Brazos LiDAR

2.1.3 Data Processing

ArcGIS software was utilized in order to create a digital surface model for the Paint 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 quality control (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.

2.1.4 DEM QA/QC

DEMs developed for use in the Paint 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 (QA) 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 QC 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 was 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

QA 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 analysis.

The final DEM data developed for the Paint 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 2D hydraulic modeling and rain-on-grid utility was applied in the Texas 2D BLE products workflow. The following sections describe the engineering methods and model inputs used.

2.2.1 2D Computational Mesh and Settings

Due to the size of the Paint watershed (approximately 1,065 sqmi), the presence of two separate creeks, and to account for computational and modeling limitations, the HUC-8 was split into two separate HEC-RAS geometries as shown in Figure 6. The HUC-8 was split into the California Creek and Paint Creek modeling areas. Initially, model area footprints were aligned with HUC-10 boundaries, combining some where the size of the smaller HUC-10s allowed. Minor adjustments were made to those initial model area footprints to improve modeling and/or mapping efficiency. The HEC-RAS boundaries were created for the Paint model areas using ArcGIS toolsets, which reduce the need for manual edits to mesh cells within HEC-RAS that result in error generation. The California Creek and Paint Creek 2D meshes contain 597,270 and 523,847 cells, respectively, consisting of 200 foot cells, with the exception of 100 foot along the 1 square mile streams and 50 foot cells within population center boundaries using refinement regions. Within community boundaries the streamlines were also extended to the 0.5 square mile extent and assigned 50 foot cell spacing in order to be more detailed. Internal connections were used to extract flow readings for gage locations throughout the model, while profile lines were used for all other flow extractions. An adaptive 1 minute 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 240 seconds for a maximum and 7.50 seconds for the minimum. A theta value of 0.6 was used. The HEC-RAS model was run with Diffusion Wave (Simplified Full Momentum) equations.

2.2.2 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires a 2D computational mesh boundary and often requires defining inflow boundary conditions and application of precipitation values. Spatially varying precipitation DSS values were applied as a meteorological data boundary condition. The process to determine the spatially varied precipitation DSS values to be applied is outlined in the hydrology section. Figure 6 depicts the California Creek and Paint Creek model boundaries, flow transition points between models, and USGS stream gages found near and within the study area.

Because the Paint HUC-8 was split into two work areas, the outflow from the California Creek model was used as an inflow hydrograph for the Paint Creek work area. This hydrograph was extracted from the Calfornia Creek model using a 2D connection, and then placed as a flow hydrograph external boundary condition for the Paint Creek model.

Outflow boundary conditions (from the computational 2D mesh) were used along model boundaries. Outflow boundaries were established as normal depth using approximate energy grade-line slope estimated from the LiDAR data. This allowed the boundary conditions defined as continuous boundaries to allow drainage to leave the model area freely to adjacent basins.

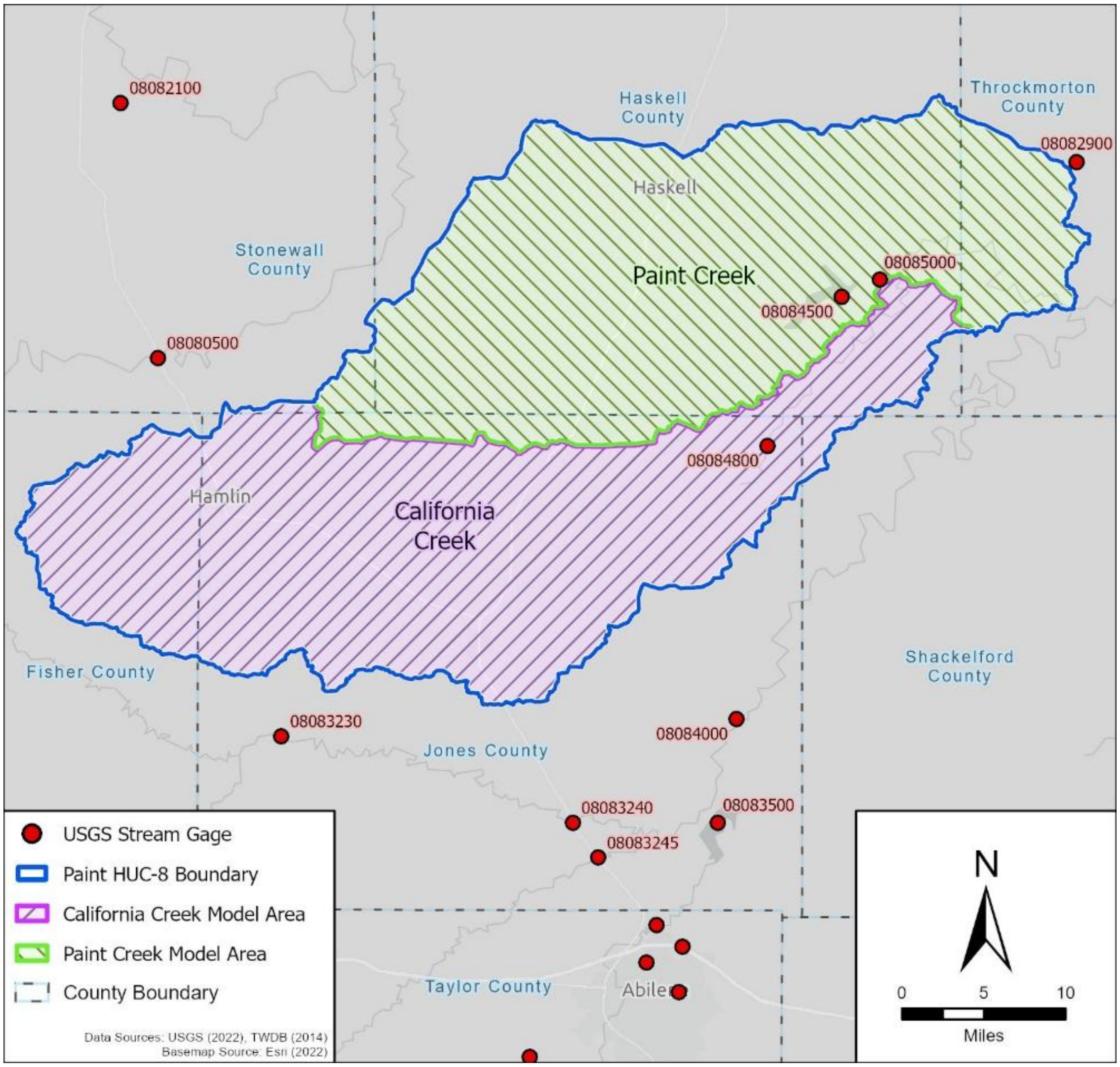


Figure 6: HEC-RAS 2D Computational Mesh and Boundary Conditions and USGS Peak Streamflow Gages

2.2.3 Hydrology

HEC-RAS (specifically version 6.1, used for this analysis) can implement spatial precipitation and infiltration methods. This capability has improved the efficiency and hydrologic representation of a study area. HEC-RAS version 6.1 cannot directly import ASCII format gridded precipitation data. Therefore, spatially varied precipitation Data Storage System (DSS) files were used for the precipitation hyetograph boundary condition in the HEC-RAS hydraulic models.

2.2.3.1 Precipitation Frequencies

Precipitation frequency data from NOAA's Atlas 14 Precipitation Frequency Data Server (PFDS) was used for this study (NOAA, 2018). The 10-, 4-, 2-, 1-, and 0.2-percent-annual-chance precipitation depths for the 24-hr duration were determined by area-weighted intersection of the gridded PFDS data with the model area boundaries. Specifically, precipitation depths for return periods as rare as 1-in-1,000 annual chance for the state of Texas are available as raster data with 1/12-degree spatial resolution. No areal reduction factors were applied to these depths for any of the model areas since it would be inappropriate for the majority of smaller-sized tributaries within each model; however, flow and stage results throughout the model area were analyzed against historic gage and previous study data as discussed later in the Calibration and Validation section of the report.

The 1-percent-plus flood elevation is defined as the flood elevation using discharges at the upper 84% confidence limit for the 1-percent-annual-chance flood. Similarly, the 1-percent-plus flood elevation is derived using discharges at the lower 84% confidence limit for the 1-percent-annual-chance-flood. The plus and minus standard error was determined as the upper and lower 84% confidence limits (i.e., the 68-percent confidence interval) on the nominal 1-percent depth. In addition to recurrence interval precipitation estimates, 90% confidence intervals of reported Atlas 14 precipitation values are provided on the PFDS (NOAA, 2018). 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, so the provided 95% confidence limits were used to determine the 84% confidence limits using this relationship.

The 1%-plus and 1%-minus storm events were defined by utilizing a 68% confidence interval around the 1% event. The 68% confidence interval was estimated using the following equations:

$$\widehat{\sigma} = \frac{X_{95} - X_{05}}{Z_{95} - Z_{05}}$$

$$CI_{68} = (X - \widehat{\sigma}, X + \widehat{\sigma})$$

Where :

1. $\widehat{\sigma}$ represents the standard deviation of an assumed normal distribution around the NOAA Atlas 14 frequency estimates.

2. X95 and X05 represent the upper and lower estimates of the 90% confidence interval, respectively.

3. Z95 and Z05 represent the corresponding z-scores of the upper and lower estimates, respectively (i.e., Z95 = 1.645; Z05 = -1.645).

4. CI68 the 68% confidence interval is approximated by applying one standard deviation above and below the baseline 1% storm event.

files were used for the precipitation hyetograph boundary condition in the HEC-RAS hydraulic models.

2.2.3.2 Temporal Rainfall Distribution

Temporal rainfall distributions were computed for the Paint HUC8 model areas following the NRCS synthetic rainfall distribution procedure as described in the National Engineering Handbook Part 630 – Chapter 4 (NRCS, 2019). NOAA Atlas 14 data was extracted for the areas, and a unique 24-hour temporal distribution was computed for each recurrence interval. The temporal distributions are expressed in probability terms as cumulative percentages of precipitation totals at various time steps. The NOAA Atlas 14 precipitation-frequency grids only provide total depths for each frequency. Precipitation grids were spatially distributed across the 24-hour duration using a 6-minutes time series data shown in Figure 7. The resulting 6-minute interval precipitation grids were used to develop spatially distributed precipitation DSS data for the model areas. The "Meteorological Data" tab under the Unsteady Flow Boundary Conditions editor in HEC-RAS was used to import the spatial precipitation DSS data into the 2D hydraulic model.

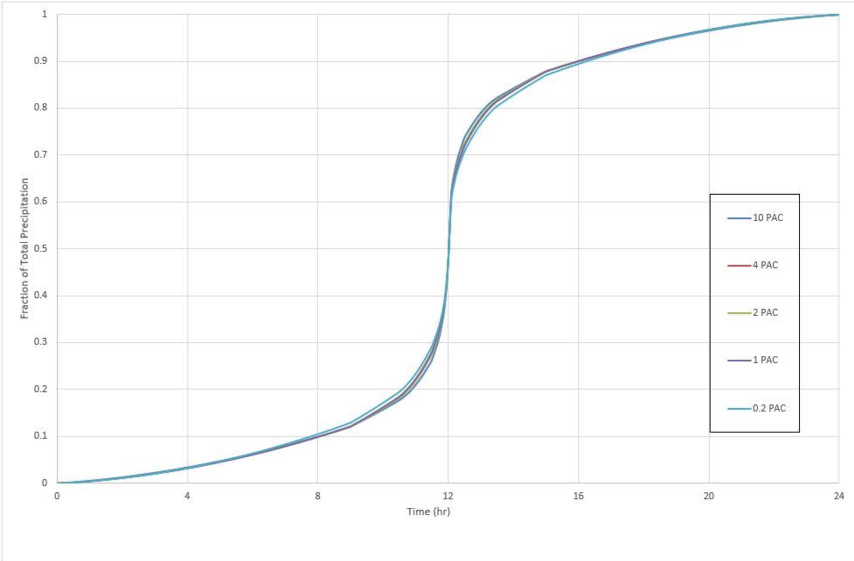


Figure 7: NRCS Nested Rainfall Distributions for the Paint HUC-8 Watershed BLE Study

2.2.3.3 Infiltration Parameters

The infiltration layer containing attributes for Soil Conservation Survey (SCS; now the Natural Resources Conservation Survey (NRCS)) curve numbers (CN), abstraction ratio, and minimum infiltration rate was initially calculated in ArcGIS using the National Land Cover Database (NLCD, 2019) and NRCS soil data. This infiltration layer was then imported to the HEC-RAS 2D hydraulic model where it is then used to estimate rainfall-runoff losses and surface runoff used in the hydraulic calculations.

A land use-soils-CN matrix can be used to determine CN for a particular study area. Table 3 details soil-water balance model lookup table for determining CN's for the intersection of soils and land use. The CN values are sourced from the NRCS's TR-55 (USDA, 1986). This matrix is intended as a general guide and then adjusted based on engineering judgment, as well as during calibrations and validation of the model, for a given study area.

Table 3: Land Use(LU)-Soils-CN Matrix for Defining Initial Curve Number

LU_GridCode	NLCD LU Description	Hydrologic Soil Group			
		A	B	C	D
11	Open Water	100	100	100	100
12	Perennial ice/snow	40	40	40	40
21	Developed Open Space	49	69	79	84
22	Developed Low Intensity	77	86	91	94
23	Developed Medium Intensity	89	92	94	95
24	Developed High Intensity	98	98	98	98
31	Barren Land	77	86	91	94
41	Deciduous Forest	32	48	57	63
42	Evergreen Forest	39	58	73	80
43	Mixed Forest	46	60	68	74
52	Shrub Scrub	49	68	79	84
71	Herbaceous	64	71	81	89
81	Hay Pasture	49	69	79	84
82	Cultivated Crops	71	80	87	90
90	Woody Wetlands	88	89	90	91
95	Emergent Herbaceous Wetlands	89	90	91	92

2.2.3.4 USGS Gage Analysis

The models were compared to known USGS streamflow gage data (peak flow) to validate model results. USGS stream gages with less than 10 years of record were not considered for this study. The gage used for analysis in this study is listed in Table 4.

Table 4: USGS Peak Streamflow Gages

Gage ID	Flooding Source and Location	Published Drainage Area (mi^2)	Period of Record
08084800	California Ck nr Stamford, TX	478	1963-2021

2.2.3.5 Inflow Hydrograph Boundary Conditions

Outflow from the California Creek model was used as an inflow into the Paint Creek model. The inflow hydrograph was derived by utilizing the results of the HEC-RAS model for California Creek directly upstream. By using upstream model results as inflow hydrographs to the downstream model, this allows the two separate hydraulic models to act as one continuous model of the larger Paint HUC-8 watershed area. The inflow hydrograph was extracted from the California Creek model using a 2D connection. The inflow hydrograph applied to Paint Creek model is represented in Figure 8.

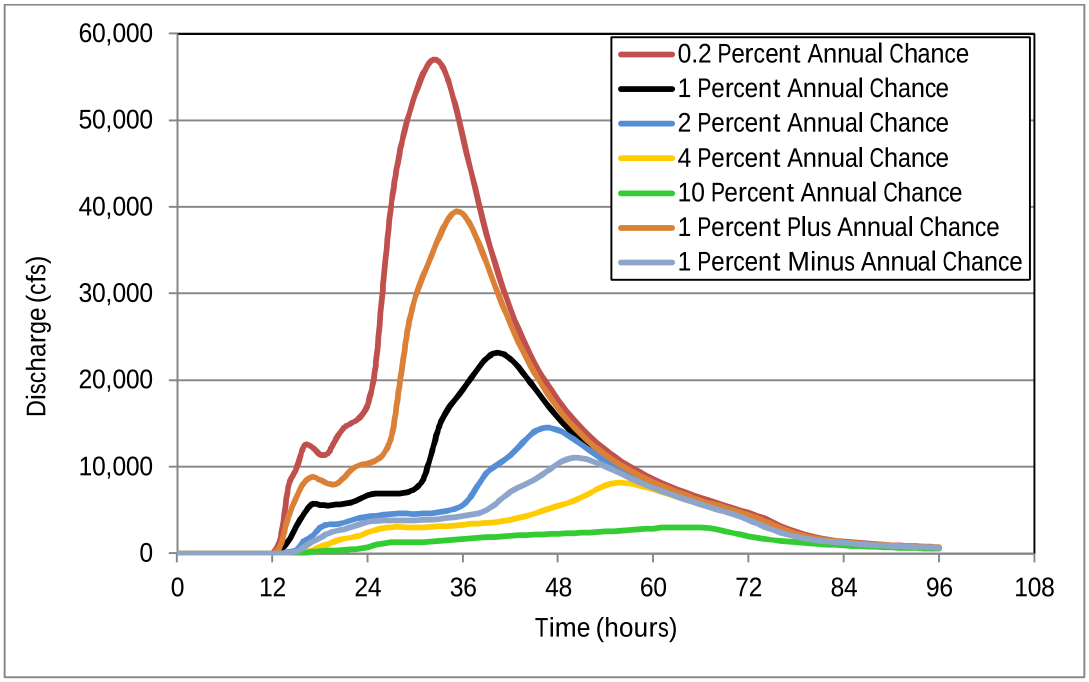


Figure 8: Inflow Hydrograph for Paint Creek

In order to achieve a seamless flood hazard result at a transition location (locations where flow is exchanged between 2D model areas), the water surface elevation (WSE) and inundation tie-ins between models must be made as close as possible. A 1,000 feet buffer was applied to each model work area for the mesh boundary. This is done so that the inflow boundary condition of the downstream model and the normal depth outlet boundary condition of the upstream model are far enough away from the work area transition location that they do not impact the WSE tie-ins between models in an undesired way. To make this overlap work without double accounting for rainfall, an internal 2D connection is placed in the upstream model at the exact same location as the inflow boundary condition for the downstream model. Approximately halfway between the model overlap is the actual model area boundaries where the mapped floodplain products switch from the upstream model results to the downstream model results. This transition location is the targeted area to have the water surface elevation and inundation tie-in as closely as possible.

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. Manning's n values were used for all areas outside of the channels of the stream network, with one Manning's n value assigned to the stream channels. The channel layer was created using a 100 foot 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. Sources cited in the table were used to associate typical n values with the NLCD classifications.

Table 5: NLCD 2016 Manning's n Roughness Matrix

NLCD Classification	N Value	Source
Stream Channel	0.04	NRCS KS Dam Breach, 2016, Chow, 1959
Open Water	0.04	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, Open Space	0.04	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, Low Intensity	0.08	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, Medium Intensity	0.1	NRCS KS Dam Breach, 2016, Chow, 1959
Developed, High Intensity	0.15	NRCS KS Dam Breach, 2016, Chow, 1959
Barren Land	0.025	NRCS KS Dam Breach, 2016, Chow, 1959
Deciduous Forest	0.16	NRCS KS Dam Breach, 2016 , Chow, 1959
Evergreen Forest	0.16	NRCS KS Dam Breach, 2016, Chow, 1959
Mixed Forest	0.16	NRCS KS Dam Breach, 2016, Chow, 1959
Scrub/Shrub	0.1	NRCS KS Dam Breach, 2016, Chow, 1959
Grassland/Herbaceous	0.035	NRCS KS Dam Breach, 2016 , Chow, 1959
Pasture/Hay	0.03	NRCS KS Dam Breach, 2016, Chow, 1959
Cultivated Crops	0.035	NRCS KS Dam Breach, 2016 , Chow, 1959
Woody Wetlands	0.12	NRCS KS Dam Breach, 2016, Chow, 1959
Emergent Herbaceous Wetland	0.07	NRCS KS Dam Breach, 2016, Chow, 1959

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 HEC-RAS 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 9.

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.

A SA/2D connection was added to represent Stamford Dam which is at the downstream end of Paint HUC-8 watershed. Per 2018 National Inventory of Dams, no additional public owned dams were present in the HUC-8 watershed. 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 that could be created in the future as a result of this study. The study area does not include any FEMA accredited levees.

Breaklines were also used along all the stream centerlines of streams draining greater than one square mile of drainage area, and 0.5 square miles of drainage area within densely populated areas. Each streamline was topo-derived and the stream centerline was enforced with 100 feet cell spacing in order to align cells along the stream line and capture more detail along the one square mile stream network. Streamline alignment was also hand checked with the terrain by the modeler to ensure accuracy. Stream names were referenced from other sources such as NFHL and NHD datasets. In the California Creek and Paint Creek models, streams that passed through densely populated regions were enforced as breaklines using 50ft cell spacing.

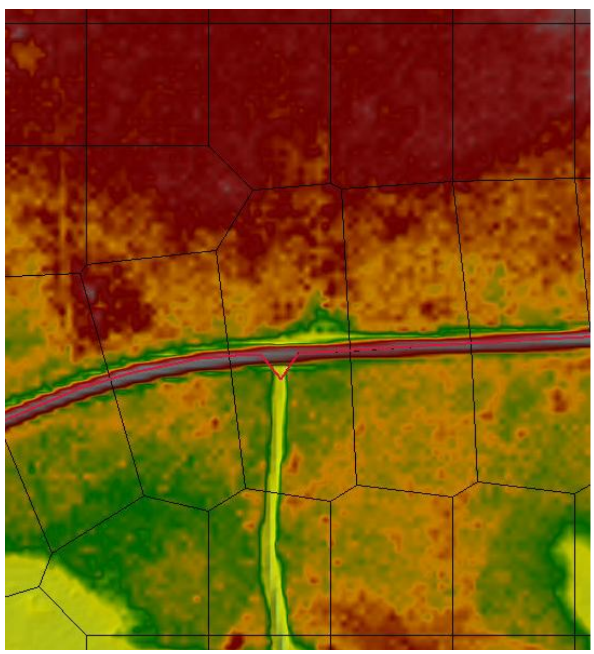


Figure 9: V-notch Breakline Approach at Bridge Crossing

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. Table 6 shows the communities contained within Paint HUC-8 watershed that were modeled with refinement regions as well as the square mileage of the refinement region.

Table 6: Communities with 2D Mesh Refinement

Community Name	Area (mi^2)
Hamlin	5.28
Anson	2.59
Corinth	0.03
Avoca	0.24
Stamford	3.70
Haskell	3.61
Stamford Lake	0.16

2.2.5 Quality Control

The 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 0, 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 areas that compared reasonably well with AECOM-provided Corelogic layers, which represent georeferenced and digitized FIRM maps, 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 1 hour, mapping output interval of 1 hour and the detailed output interval of 1 hour. The Paint HUC-8 2D BLE 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.

To further check the accuracy of the model, additional profile lines were added to the Paint Creek model and compared to Base Flood Elevations (BFEs) that were available in the City of Haskell Flood Insurance Study (FIS), dated September 18, 1987. The FIS BFEs were estimated using FIS Table 2 as well as flood profiles 01P – 04P. Stream reach distances were estimated using the BLE stream lines, since the age of the City of Haskell data meant that no centerline or cross-section location data was available. No other effective FIS or Base Flood elevations were available in the Paint HUC-8 watershed 2D BLE study footprint. The comparison is shown below in Table 8. It is noted from the comparison that the BLE WSEs for Rice Spring Branch are all lower than the estimated effective BFEs, with varied ranges from -2.5 to -3.9 feet. The Stream RS-1s BLE WSEs are lower than effective BFEs downstream of Highway 277, and higher than effective BFEs upstream of Highway 277. It is assumed that reasons for the WSE differences are most likely related to much newer terrain used in the 2D BLE study, as well as the lack of detailed hydraulic structure data used in the BLE study, which is assumed to slightly over-estimate the WSEs upstream of significant structures such as highway crossings, like the ones located along Highway 277. The 2D BLE results should be verified through community work map meetings as part of the regulatory workflow.

Table 7: Effective and Model Base Flood Elevation(BFE) Comparison After Calibration

Model Area	Location Description	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
Paint	44240[1]	1559.8	1555.9	-3.9
Paint	46650	4566.5	1564.2	-2.3
Paint	47825	1570.2	1567.7	-2.5
Paint	48800	1574.7	1572.1	-2.6
Paint	49850	1577.5	1575.2	-2.3
Paint	50650	1581.3	1578.3	-3.0
Paint	52000	1584.3	1581.4	-2.9
Paint	53225	1586.7	1583.7	-3.0
Paint	54710	1590.9	1587.8	-3.1
Paint	11202	1562.9	1560.8	-2.1
Paint	2120	1567.6	1565.8	-1.8
Paint	2720	1570.5	1569.7	-0.8
Paint	3660	1572.9	1574.2	1.3
Paint	4500	1577.2	1578.2	1.0
Paint	4850	1578.0	1578.8	0.8

3.1 Calibration

Known USGS gages within the model area with more than 10-years of flow record were used as the first priority for calibration of the 1-percent annual chance event. Discharges at gages were compared to discharges in the 2D models at the exact same locations.

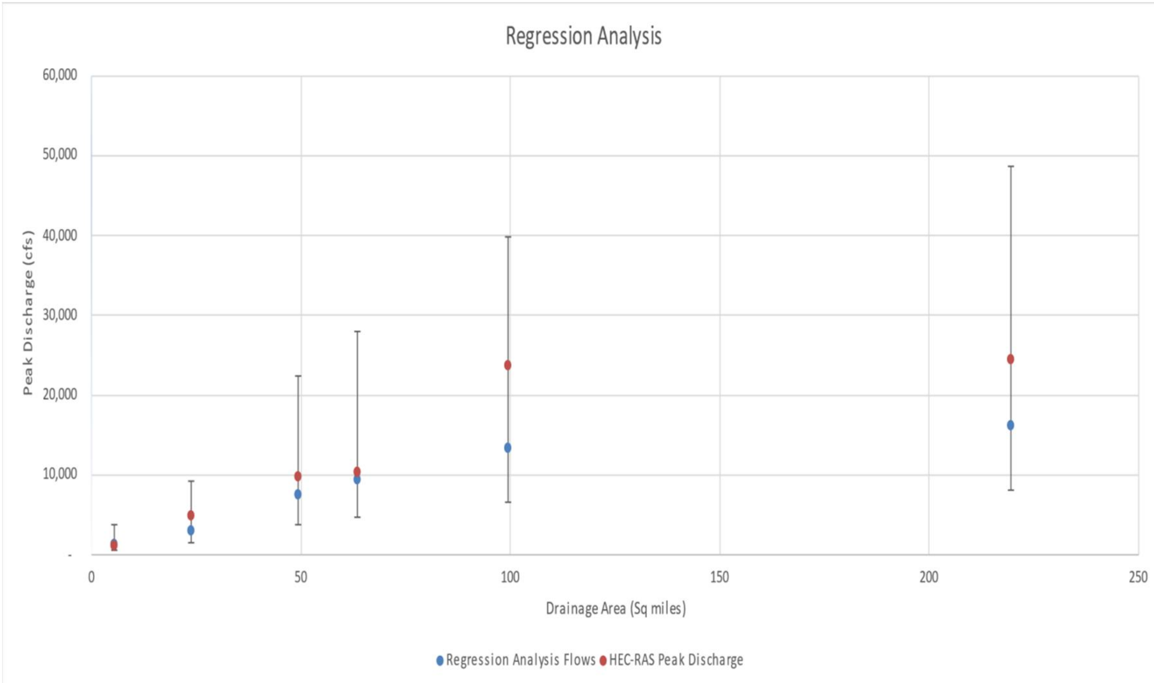
One usable USGS gage fell within the boundary of the California Creek model area and was utilized for calibration purposes. Regression equations were used for secondary calibration in the California Creek model and used as primary in the Paint Creek model area. The regression analysis was performed as 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 multiple locations with varying contributing drainage area to ensure a reasonable amount of excess precipitation was being applied to the 2D mesh.

Adjustments to hydraulic features within the model were made until the flows in the model matched closely with the peak flows determined from gage and regression equations. Specifically, adjustments were focused on modifying curve numbers uniformly across the model area, and the models were then re-run until the modified results compared closely to the gage and/or regression equation results, falling within the estimated upper and lower limits. For the Paint Creek model area, adjusted curve numbers were reduced by approximately 18 from their original values (calculated using the relationship described by Table 3, above), while for the California Creek model area curve numbers were reduced by approximately 16 from their initial values. Final results following model calibration at the calibration locations are presented in Table 8.

Table 8: Calibration Results

Model Area	Calibration Location	Source	Method Used in Original Study	Reference			HEC-RAS 6.1 (2D) (cfs)
				Lower Limit (cfs)	1-percent (cfs)	Upper Limit (cfs)	
Paint Creek	Paint Creek Upper 1	SIR 2009-5087	Regression Equations	628	1,254	2,502	1,052
Paint Creek	Paint Creek Upper 2	SIR 2009-5087	Regression Equations	1,544	3,080	6,146	4,955
Paint Creek	Paint Creek Upper 3	SIR 2009-5087	Regression Equations	3,735	7,453	14,870	9,746
Paint Creek	Paint Creek Upper 4	SIR 2009-5087	Regression Equations	8,131	16,223	32,368	24,519
Paint Creek	Mule Creek	SIR 2009-5087	Regression Equations	4,671	9,320	18,595	10,430
Paint Creek	North Paint Creek	SIR 2009-5087	Regression Equations	6,664	13,296	26,530	23,586
California Creek	Headwaters California	SIR 2009-5087	Regression Equations	5,253	10,482	20,914	12,403
California Creek	Dry California Creek	SIR 2009-5087	Regression Equations	3,368	6,720	13,409	5,985
California Creek	Thompson Creek	SIR 2009-5087	Regression Equations	2,560	5,109	10,193	3,701
California Creek	Upper Redmud Creek	SIR 2009-5087	Regression Equations	3,411	6,805	13,579	10,514
California Creek	USGS Gage 08084800	California Ck nr Stamford, TX	USGS	17,240	22,730	33,080	23,603

Figure 10 shows the final results of the calibration locations compared to modeled flows throughout the Paint HUC-8 watershed along with error bars created using the difference between 1-percent and 1-percent plus discharges and 1-percent and 1-percent minus discharge as minimum and maximum values. Ten 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.



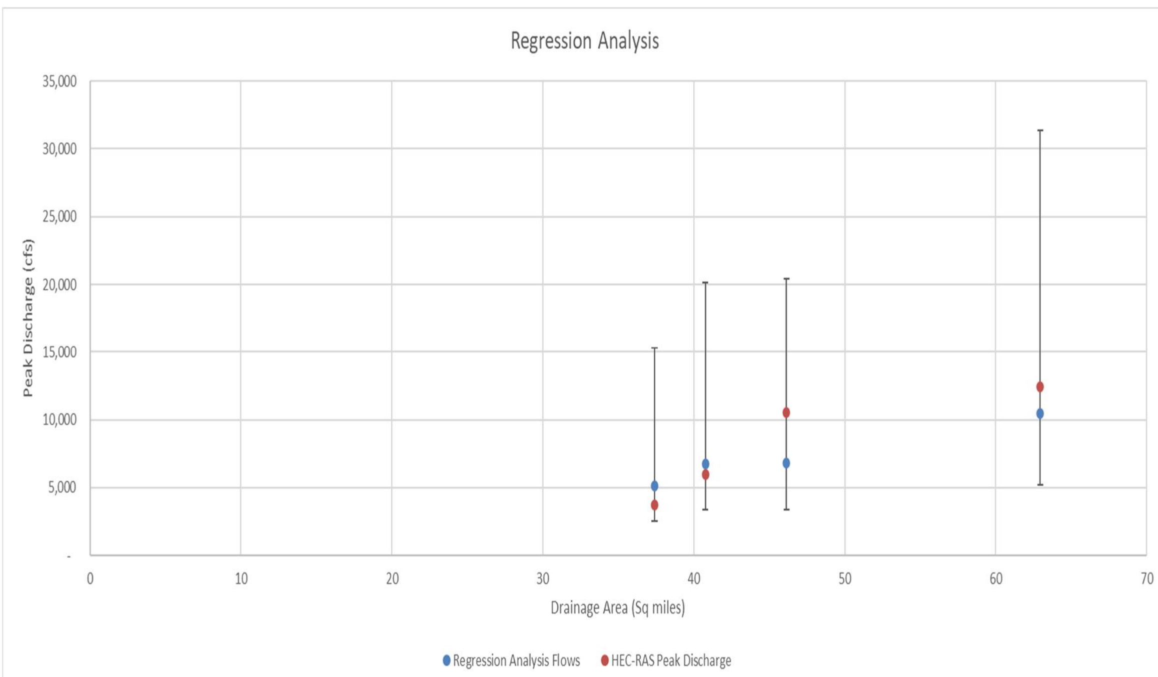


Figure 10: Calibration Comparison Paint Creek (Top) & California Creek (Bottom)

3.2 Challenges

A considerable challenge for the Paint watershed was the size of the HUC-8 basin. In order to create this model without creating runtime or cell number issues, it was decided that the watershed would be split into two working models. The outflow from the upstream Paint Creek model area was then used as an inflow boundary condition to the downstream model. The Paint HUC-8 watershed contains the Stamford Dam at the downstream end of the Upper Paint Creek HUC-10. A 2D connection was built to represent the dam and the outlet structures. The HUC-8 also included a medium size urbanized area.

Per TWDB's *Volumetric Survey of Lake Stamford* (TWDB, 2000), Stamford Dam and appurtenant structures consist of an earth fill embankment approximately 3,600 feet in length, with a maximum height of 78 feet and a top of dam elevation of 1436.8 feet NGVD29. The service spillway is an excavated channel cut through limestone rock located approximately 900 feet to the left of the dam. The uncontrolled spillway crest is 100 feet in length at elevation 1,416.8 feet NGVD29, the same as the conservation pool elevation. The low-flow outlet consists of a 24 inch diameter concrete pipe that is 442 feet in length bisects the embankment approximately 500 feet south of the old Paint Creek channel. The Invert elevation is 1382.8 feet NGVD29. The emergency spillway is a natural channel located at the right end of the embankment with a crest elevation of 1425.8 feet NGVD29. The datum was converted to NGVD88 using NOAA's Online Vertical Datum Transformation tool, which is 0.48 feet higher than NGVD29.

The dam was modeled using a 2D Connection, all elevations or inverts were converted to NAVD88. For simulating a reasonable water surface elevation at Stamford Lake, at start of the model simulation, the lake WSE was assumed to be equal to the conservation pool elevaion, which is 1417.28 feet NAVD88. The Lidar data shows the terrain at Stamford Lake is 1413.22 feet, implying that when the LiDAR was acquired, the water level was lower than normal pool elevation. Using HEC-RAS terrain modification capability, a clone terrain (Virtual) method was applied to update the surface elevation at lake to 1417.28 feet. Assessment of the model results for the 1 percent-annual-chance WSE (1423.82) and the 0.2 percent-annual-chance WSE (1427.85) at the dam concluded that both corresponded reasonably well with the elevations of the service and emergency spillways, 1417.28 and 1426.28, respectively.

Within the watershed, there are several populated areas and agricultural fields that appear to be trapping water which prevents runoff from reaching the channel in the model. Various v-notches were applied to represent cross culverts and improve conveyance. Further detail and study of the flow patterns and likely runoff conveyance would be recommended as part of a future study if more detailed flood risk information was needed in these areas. In addition, several breaklines and refinement regions increased the total number of cells and thereby increasing the model runtime.

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 hydraulic model, nominal 200 foot cells are utilized with refinement areas (and smaller cell sizes) implemented in specific areas of interest, as described in the modeling sections above. For detailed modeling and further improvements, smaller sized model is recommended to allow further refinement of infiltration parameters as well as use of a smaller cell sizes, along with addition of 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 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 Area

4.1.1 Model Outputs

The HEC acknowledged RAS Mapper may not render water surface elevation values and/or delineate inundation extent appropriately for direct use in FEMA regulatory mapping products. To maintain a high level of consistency between modeling results and final mapping, minimal map clean up was performed while maintaining identification of both fluvial and pluvial flood risk as reflected by the models. Additional processing may be required to make the mapping products FEMA compliant.

4.1.2 Methodology

The sloping render mode plots water surface elevation (WSE) by interpolating the WSE between the 2D cell faces, producing a more continuous flood inundation extent. Depth rasters from the sloping render mode were exported for the 10-percent, 1-percent, and 0.2-percent flood events with a tolerance of 0.001 feet. To reduce the extent of disconnected flood areas, raster grid processing is used to filter and remove disconnected, small, or shallow areas of flooding by processing through the 'Mapping Threshold Matrix' shown in Table 9.

Table 9: Mapping Threshold Matrix

Area (acres)	Average Depth (feet)
< 0.33	-
0.33 – 0.5	< 0.5
0.5 – 1.0	< 0.33
1.0 – 2.0	<0.1

Polygon outputs from the 'Mapping Threshold Matrix' also fill in minor areas of high ground (islands) that are less than 0.33 acre. The outputs are then modified through a Simplication and Smoothing process to reduce unnecessary/erroneous vertices, remove rough edges and reduce the size and complexity of the raw floodplain polygons for the 1-percent, and 0.2-percent flood events. For the Paint watershed, the polygon outputs were simplified by retaining critical points at a 5 foot tolerance. The simplified polygon outputs were then smoothed utilizing the PAEK algorithm and the tolerance was set to 25 feet. The 10-percent flood event polygons are not modified through the simplification and smoothing process and are delivered in the rasterized polygon shape.

Due to topographic differences within a lake footprint, these areas sometimes appear partially mapped in the flood extents from the model results. Lakes and reservoirs larger than 40 acres are reviewed to ensure full inundation on the 1-percent, and 0.2-percent polygon extents. If necessary, lake boundaries were copied into the flood event polygons to make sure they are fully mapped.

Once the final polygon flood extents are complete, it is necessary to merge the 10-percent boundaries into the 1-percent and the 1-percent extents into the 0.2-percent extents. This step ensures that the extents of the 10-percent floodplain is smaller than the 1-percent floodplain, and the 1-percent is smaller than the extents of the 0.2-percent floodplain.

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 BLE schema agreement. The 10-percent boundaries have been included in the BLE TENPCT_FP feature class.

4.1.4 Additional 1-Percent Features

Once the final floodplain polygons were created, it is required that the depth and WSEL grids match the full extents of the flood inundation polygons. Because of the processing of the floodplain polygon boundaries through the above mentioned steps, there are areas in the model produced raster grids that no longer match the polygons. Final grids are interpolated for areas filled in with surrounding cell values and then clipped to the polygon extents to create the final water surface and depth grids for the 1-percent and 0.2-percent flood events.

4.2 Validation of Effective Zone A SFHA

The inventory of Zone A studies (455.9 miles) in the Paint Watershed were classified in CNMS with validation status of "UNVERIFIED" (342.4 miles) or "VALID" (113.5 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.

4.2.1 Intial 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 within Paint Watershed, LIDAR sources were not used for and of the effective studies. New LiDAR sources are now available in this area and are considered significant improvements from the effective zone A topographic sources. Therefore, all reaches in the study area fail this check.

4.2.2 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.

For Zone A streams in Jones County, USGS Regional Studies were used. However, even though the current effective equations were published in June 2009, the equations used for the effective study which was completed in 2009 is unclear. Therefore, this assessment check fails for reaches in this county. For the rest of the Zone A streams in Paint Watershed, regression equations were not known to be used for any effective studies and, therefore, pass this assessment check.

4.2.3 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. All effective studies in the Paint HUC-8 are in rural watersheds and pass this check for that reason.

All of the initial assessment results are shown in Table 10.

Table 10: Zone A Initial Assessment Results

Assessment Check	Pass / Fail	Notes
A1 – Topography	Fail	Effective Study did not utilize LiDAR source and LiDAR is now available
A2 – Hydrology	Pass/Fail	Regression equations not used in effective study / New regression equations published since those used in the effective
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. Streams in Jones County are model-backed and pass this check. All other streams in Paint HUC-8 are not known to be model-backed and fail this 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. For the comparison of BLE and effective Zone A in the 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: +/- 2.5 - 10 feet (one-half contour interval of effective topographic source).
- Horizontal Tolerance: +/- 75 feet (standard horizontal tolerance for BLE comparison testing).

Comparison results for thse streams were grouped at the HUC-12 level and are summarized in Table 11 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 11: BLE Comparison Results

HUC-12 Watershed		Total FBS points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)	Priority Score
Watershed Name	Watershed Number						
Paint Watershed	All Streams	19,666	4,618	15,048	77%	Fail	
120601030104	120601030104	763	191	572	75%	Fail	6.3
Buffalo Creek-Lake Stamford	120601030207	578	105	473	82%	Fail	14.5
Coon Creek-Paint Creek	120601030201	1299	285	1014	78%	Fail	11.0
Dry California Creek	120601030102	530	48	482	91%	Pass	2.4
Flag Branch-California Creek	120601030304	1144	262	882	77%	Fail	11.5
Flat Paint Creek-Paint Creek	120601030205	1867	408	1459	78%	Fail	13.1
Headwaters California Creek	120601030101	25	3	22	88%	Pass	3.0
Lake Stamford	120601030208	1090	119	971	89%	Pass	8.7
Little Timber Creek	120601030204	413	112	301	73%	Fail	20.2
Lower Redmud Creek	120601030302	295	98	197	67%	Fail	16.6
Moore Lake-California Creek	120601030103	458	62	396	86%	Pass	4.1
North Paint Creek	120601030402	1721	394	1327	77%	Fail	18.3
Outlet California Creek	120601030306	888	400	488	55%	Fail	36.0
Red Creek	120601030401	955	291	664	70%	Fail	24.4
Rice Springs Branch-Mule Creek	120601030206	1383	381	1002	72%	Fail	20.9
Rockdale Cemetery-California Creek	120601030305	973	216	757	78%	Fail	13.2
Skinout Creek-California Creek	120601030106	595	154	441	74%	Fail	8.5
Thompson Creek	120601030105	80	5	75	94%	Pass	3.1
Town of Corinth-California Creek	120601030303	476	61	415	87%	Pass	6.4
Turkey Bend-Paint Creek	120601030403	1456	373	1083	74%	Fail	20.5
Turkey Paint Creek-Paint Creek	120601030203	1727	381	1346	78%	Fail	11.0
Upper Redmud Creek	120601030301	142	5	137	96%	Pass	1.1
Willow Creek	120601030202	808	264	544	67%	Fail	16.3

4.2.6 Validation Results

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the Paint watershed has been updated as summarized in Table 12 and illustrated in Figure 11.

Table 12: Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	113.5
UNVERIFIED	BEING STUDIED	342.4

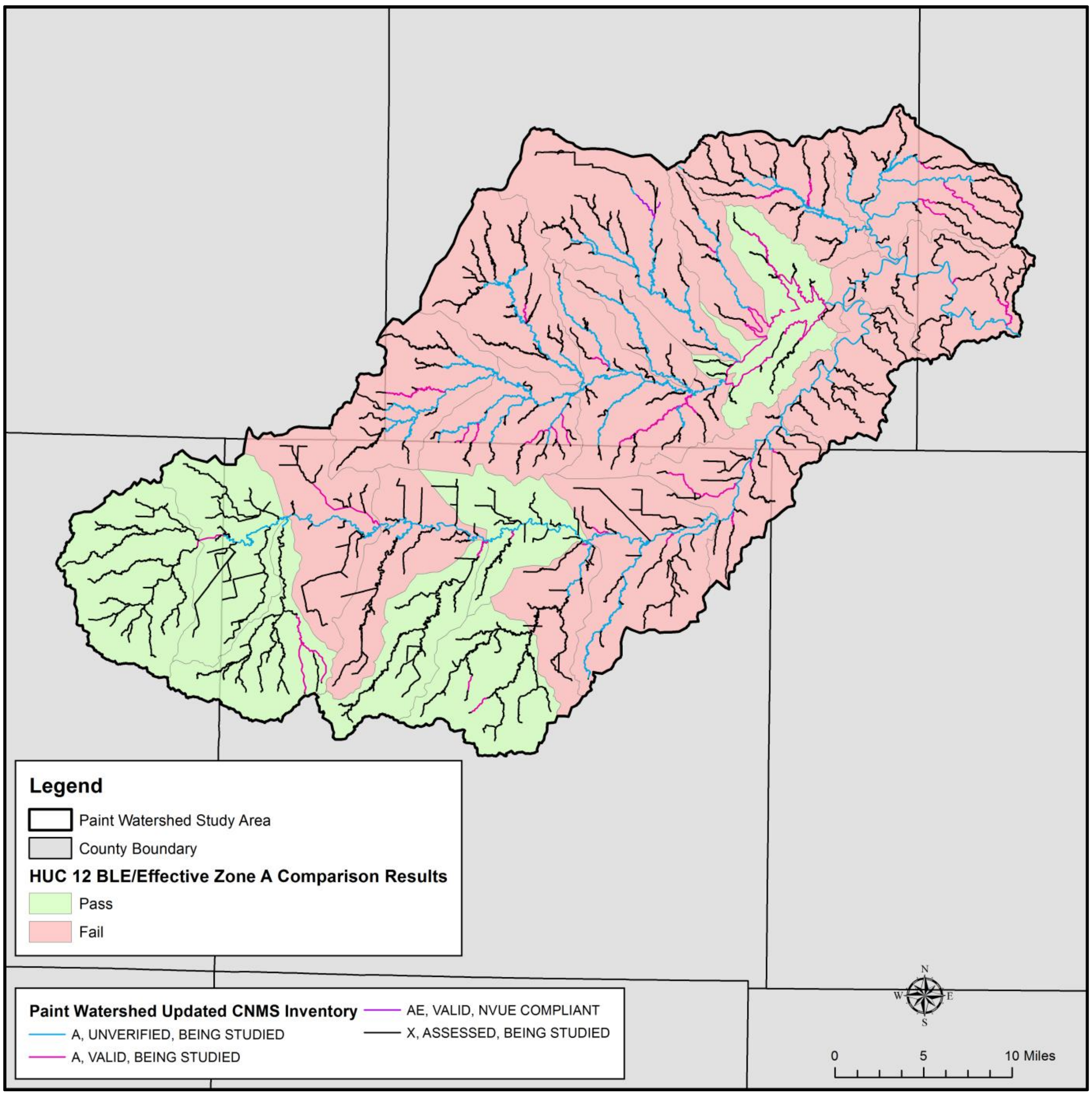


Figure 11: Paint Watershed CNMS Validation Results

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 12 below shows the range of the HUC-12 priority scores which can be used to initiate discussions during the Discovery phase.

Outlet California Creek HUC-12 was determined to have the highest priority score and the most need while Upper Redmud Creek HUC-12 had the lowest score.

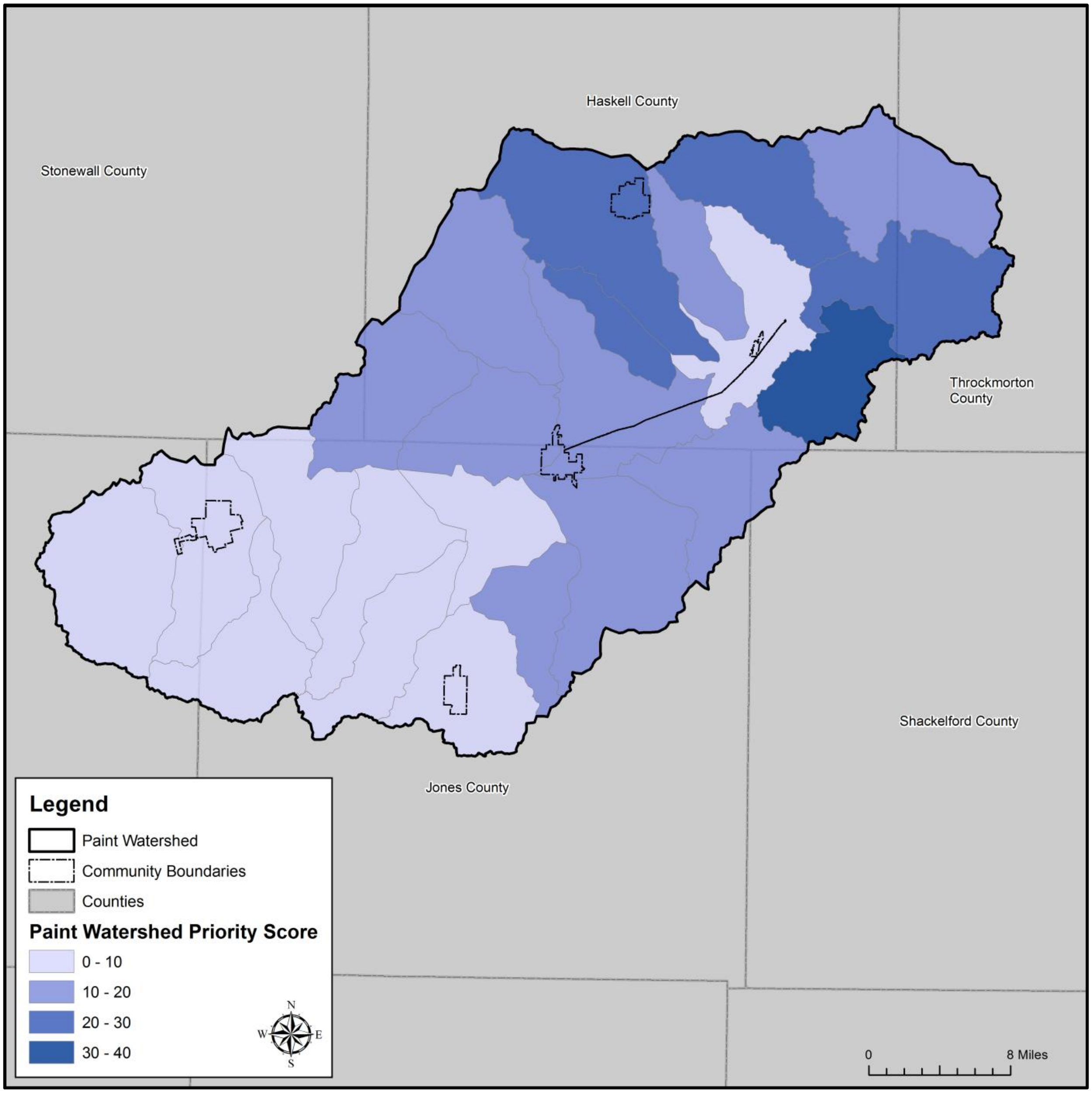


Figure 12: Ranking of Paint Watershed HUC-12s

4.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent annual chance and 0.2-percent 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 5.1 was used for the basic and refined loss analysis.

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

Hazus analysis was performed by watershed extents for each return period to ensure proper model processing. A summary of results for counties within the watershed for the 1-percent annual chance scenarios are shown in Table 13. Totals only reflect data for those census tracts/blocks included in the user's study region and will reflect the entire county only if all of the census blocks for that county/state were selected at the time of study region creation.

Table 13: Hazus 5.1 Results for 1-Percent-Annual-Chance (100 year) Scenario

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Fisher	$31,513,000	$16,373,000	$1,145,000
Haskell	$456,296,000	$279,282,000	$69,247,000
Jones	$984,976,000	$636,309,000	$154,965,000
Shackelford	$1,265,000	$729,000	$2,000
Stonewall	$409,000	$204,000	$0
Throckmorton	$1,634,000	$818,000	$5,000
Total	$1,476,093,000	$933,715,000	$225,364,000

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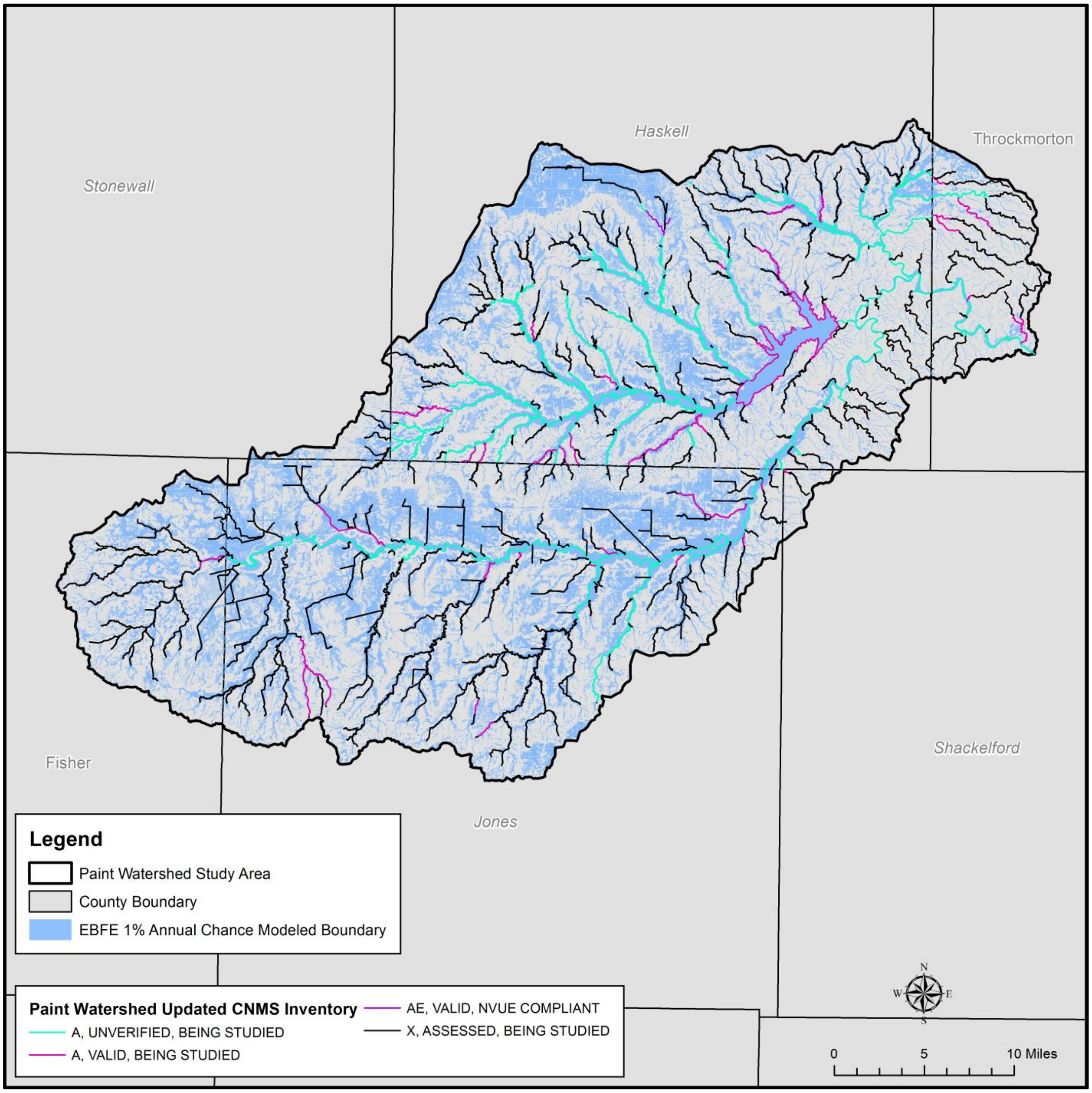
Appendix A BLE Map



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