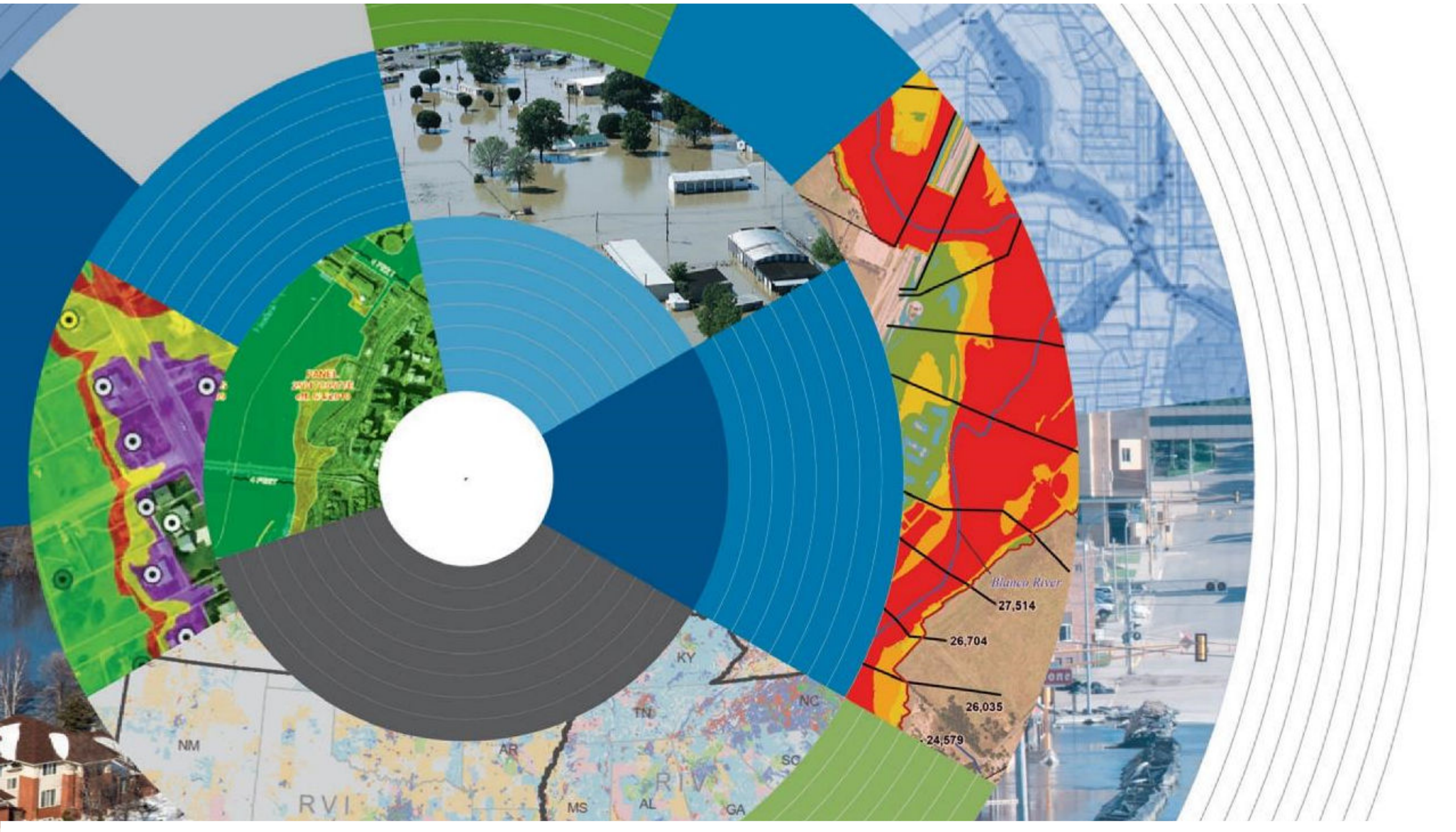

Base Level Engineering Report

Coyanosa-Hackberry Draws (13070006)

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Texas Water Development Board

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FINAL REPORT FOR COYANOSA-HACKBERRY DRAWS (13070006)

PREPARED FOR:

Texas Water Development Board

Prepared By:

AtkinsRéalis USA, Inc.

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06/12/2025

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Executive Summary

The Texas Water Development Board (TWDB) contracted with AtkinsRéalis USA, Inc. (AtkinsRéalis) to complete a Base Level Engineering (BLE) analysis for the Coyanosa-Hackberry Draws HUC-8 watershed (13070006) in West Texas to support the U.S. Department of Homeland Security's Federal Emergency Management Agency's (FEMA) Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHAs). The BLE process involves using best available data and incorporating automated techniques with standard 2-dimensional (2D) model development procedures to produce flood hazard boundaries for the 1% annual chance event (ACE) as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development supporting hydrologic and hydraulic analysis and mapping activities were leveraged from local, State, and Federal partners. Details regarding the different datasets used are provided below in section 2.

Precipitation depths for this study were established using National Oceanic and Atmospheric Administration (NOAA) Atlas 14 rainfall data. The Hydrologic Engineering Center's (HEC) Hydrologic Modeling System (HMS) was used to develop a simplified hydrologic model to compute rainfall that was then used in a rain-on-grid, 2D hydraulic HEC River Analysis System (HEC-RAS) model. The hydraulic model was used to compute flood depths and peak water surface elevations (WSELs) within the study area.

The stream mile network that was validated for this watershed was compiled using FEMA's Coordinated Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risk. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-0-1 lists the stream miles associated with this validation analysis.

Table ES-0-1: Summary of stream miles

Source	Watershed Name Stream Miles
CNMS	304.6
New Study Streams - CNMS	623.6

The full inventory of Zone A studies in the watershed were classified in CNMS. The total miles validated in CNMS are summarized in Table ES-0-2.

Table ES-0-2: Aggregated Zone A validation results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	0
UNVERIFIED	BEING STUDIED	292.5

1 Introduction

Recent innovations and efficiencies in floodplain mapping have allowed the U.S. Department of Homeland Security's Federal Emergency Management Agency (FEMA) to develop a process called Base Level Engineering (BLE), which can be used to address current program challenges, including the validation of Zone A studies and the availability of flood risk data in the early stages of a Flood Risk Project. The BLE process involves using best available data and incorporating automated techniques with traditional model development procedures to produce regulatory-quality flood hazard boundaries for the 1% annual chance event (ACE) as well as estimates of flood hazard boundaries for other recurrence intervals. The cost for developing the data and estimates resulting from the BLE process are lower than standard flood production costs. The BLE results may be used for eventual production of regulatory and non-regulatory products.

As described in Title 42 of the Code of Federal Regulations, Chapter III, Section 4101(e), once every five years, FEMA must evaluate whether the information on its Flood Insurance Rate Maps (FIRMs) reflects the current risks in flood prone areas. FEMA makes this determination of flood hazard data validity by examining flood study attributes and change characteristics, as specified in the Validation Checklist of the Coordinated Needs Management Strategy (CNMS) Technical Reference. The CNMS Validation Checklist provides a series of critical and secondary checks to determine the validity of flood hazard areas studied by detailed methods (e.g., Zone AE, AH, or AO). While the critical and secondary elements in CNMS provide a comprehensive method of evaluating the validity of Zone AE studies, a cost-effective approach for evaluating Zone A studies has been lacking.

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the initial stages of a Flood Risk Project. FEMA Program Standard SID #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevations and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses should be shared and results should be discussed with stakeholders. An important goal of the BLE process is the scalability of the results. Scalability means that the results of a BLE analysis cannot only be used for CNMS evaluations of Zone A studies, but can also be leveraged throughout the Risk MAP program. The data resulting from a BLE analysis can be updated as needed and used for the eventual production of regulatory and non-regulatory products, outreach and risk communication, and MT-1 processing. Leveraging this data outside the Risk MAP program may also be valuable to external stakeholders.

The Texas Water Development Board (TWDB) contracted with AtkinsRéalis USA, Inc. (AtkinsRéalis) to complete a BLE analysis for the Coyanosa-Hackberry Draws watershed. This arid watershed is mostly rural with minimal development. There are scattered agricultural and energy extraction activities present. The watershed is located in Brewster, Jeff Davis, Pecos, Presidio, and Reeves counties. The City of Alpine is the only community in the watershed with a population of more than 1,000 residents. This report documents the BLE process, products, and results for this watershed. Figure 1-1 below depicts the Coyanosa-Hackberry Draws watershed's footprint.

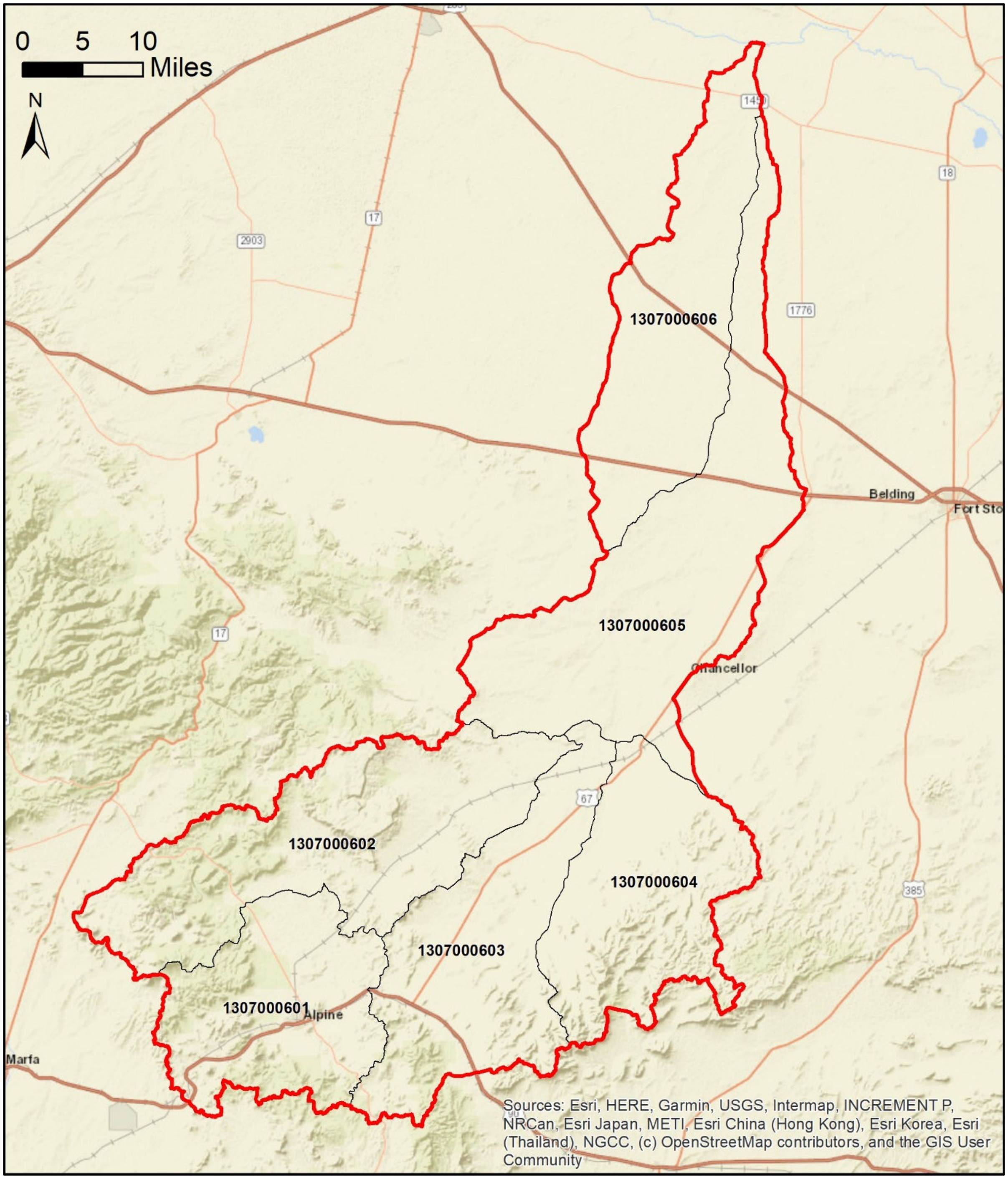

Figure 1-1: Coyanosa-Hackberry Draws HUC-8 watershed with HUC-10 basins labeled

The BLE study for the Coyanosa-Hackberry Draws watershed was completed under a single Task Order (TO) for the TWDB that also included BLE studies for six other nearby watersheds. Figure 1-2 below shows the seven HUC-8 watersheds studied under this TO.

Figure 1-2: HUC-8 watersheds studied by AtkinsRéalis for the TWDB

Typically, the hydrologic and hydraulic (H&H) modeling footprint and the floodplain mapping footprint for a BLE study are both aligned with the HUC-8 watershed boundary. For the Coyanosa-Hackberry Draws BLE study, the floodplain mapping footprint remains aligned with the HUC-8 watershed boundary, and the mapping deliverables cover the extent of the HUC-8 watershed. However, in some locations the H&H modeling footprint deviates from the extents of the HUC-8 boundary. These adjustments were made to limit the number of flow transfers between hydraulic models and minimize the number of floodplain mapping tie-ins across model domain boundaries.

Where feasible, model extent boundaries were placed where preliminary model results indicated there would be minimal or no floodplain mapping.

Figure 1-3 below shows the BLE hydraulic model extents of the 10 hydraulic models developed under this TO.

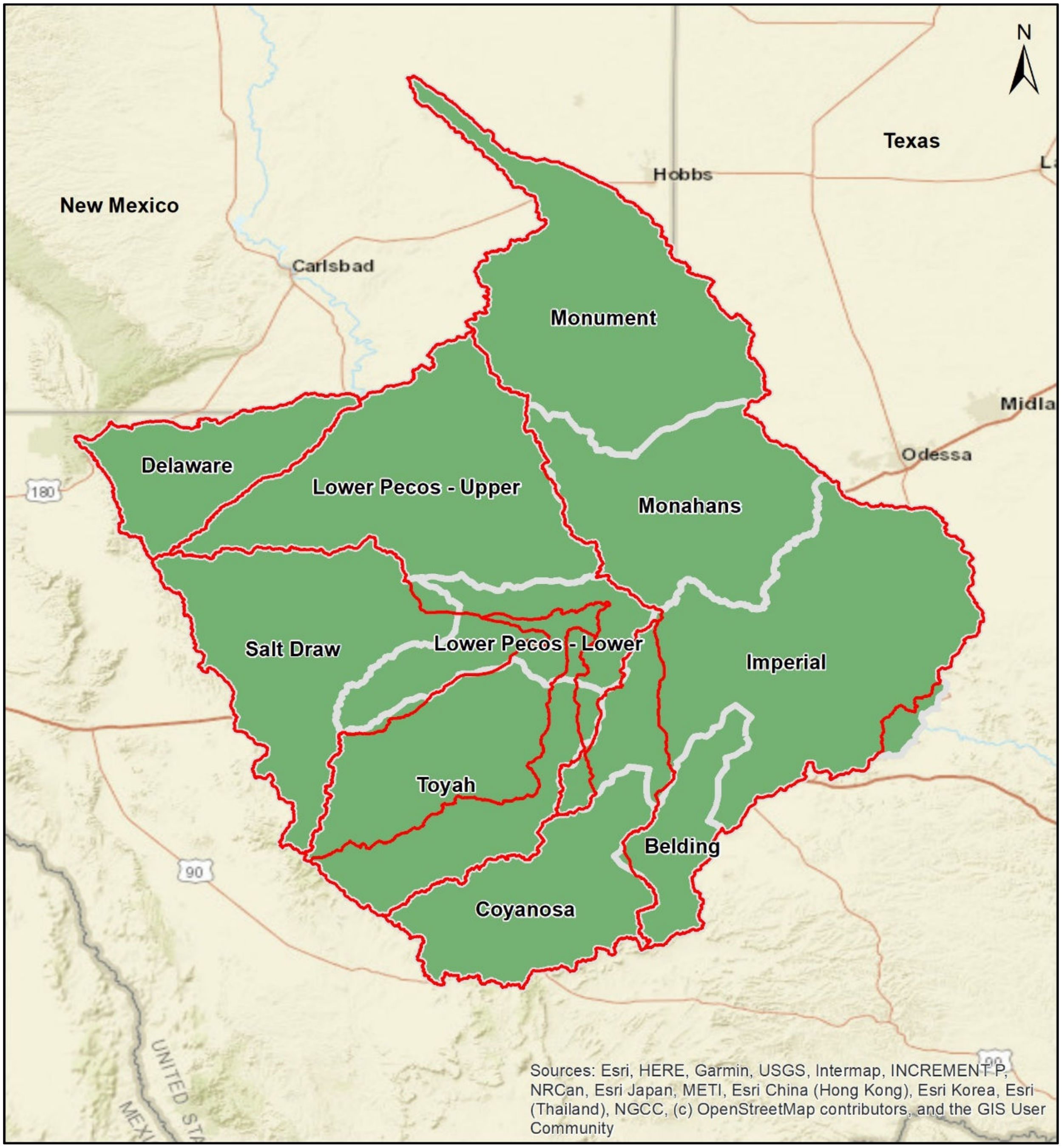

Figure 1-3: HUC-8 watersheds (red polygons) and BLE model extents (green polygons) studied by AtkinsRéalis

The TWDB, in coordination with FEMA, is storing the BLE studies for Texas on the Estimate Base Flood Elevation (estBFE) Viewer accessible at https://webapps.usgs.gov/infrm/estbfe/. This viewer is organized by HUC-8 watershed. Typically, there is one BLE HEC-RAS model for each watershed. However, for this task order, because there are 7 HUC-8 watersheds and 10 HEC-RAS models, most watersheds are modeled by more than one HEC-RAS model. In addition, the TWDB, for versioning control purposes, does not want more than one copy of a BLE HEC-RAS model on the estBFE viewer. Therefore, the BLE HEC-RAS models for this task order have been stored on the viewer under the watersheds catalogued in Table 1-1.

Table 1-1: Location of BLE HEC-RAS models on the estBFE viewer

Watershed	HEC-RAS Models Stored on the Viewer under This Watershed
Barrilla Draw	None
Coyanosa-Hackberry Draws	Coyanosa
Delaware	Delaware
Landreth-Monument Draws	Belding, Imperial, Monahans, and Monument
Lower Pecos-Red Bluff Reservoir	Lower Pecos-Lower and Lower Pecos-Upper
Salt Draw	Salt Draw
Toyah	Toyah

Because the model and mapping footprints for the Coyanosa-Hackberry Draws watershed BLE study are not identical, the mapping for the Coyanosa-Hackberry Draws watershed was derived from the model output of more than one BLE model. For the Coyanosa-Hackberry Draws watershed, the models used to model the watershed were the Belding, Coyanosa, and Imperial models. The floodplain mapping deliverables for the Coyanosa-Hackberry Draws watershed have been trimmed to align with the HUC-8 boundaries for this watershed.

2 2D BLE Modeling Inputs and Controls

Section 2 presents the fundamental components required to execute a 2D hydraulic engineering analysis for the Coyanosa-Hackberry Draws watershed. Inputs such as elevation data, the hydrology used to develop the rain-on-grid data, inflow hydrographs, and the hydraulic analysis and its requisite model parameters are defined herein. HEC-RAS, Version 6.4.1 and its rain-on-grid utility were 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 that provides a detailed representation of the ground surface for hydraulic routing through the model area. As such, DEMs were developed for the Coyanosa-Hackberry Draws watershed by leveraging available high-resolution pre-processed hydro-enforced digital elevation models derived from Light Detection and Ranging (LiDAR) collections throughout the entire State of Texas. The 10-foot DEMs developed to support the 2D BLE modeling and analysis within the Coyanosa-Hackberry Draws watershed were created by executing the following steps:

1. Download LiDAR data for the entire study area from the USGS's National Map Downloader.
2. Identify the sources of the LiDAR data that were downloaded.
3. Evaluate the LiDAR sources to confirm each met the minimum requirements for use in this study.
4. Process the datasets in GIS to create seamless DEMs. A seamless DEM was created for each HUC-8 watershed and each model domain described in section 1.
5. Assess the quality of the seamless DEMs by applying a quality control (QC) checklist developed for terrain processing tasks.

Documentation regarding leveraged data including coverage, accuracy, acquisition dates, and source contact/agency are presented in the figures, tables, and text below. All vertical accuracy specifications were obtained from the metadata or survey reports provided with the leveraged datasets. All available metadata, survey reports, and other leveraged documentation are included in the submittal content for the Coyanosa-Hackberry Draws watershed. This content is compliant with FEMA's Data Capture Technical Reference.

2.2 Inventory

The sources of LiDAR data downloaded from the National Map Downloader were catalogued using LiDAR coverage datasets available from the Texas Geographic Information Office (TxGIO). Figure 2-1 below depicts these datasets for the Coyanosa-Hackberry Draws watershed. This watershed was modeled using the Lower Pecos-Lower, Salt Draw, and Toyah hydraulic models. Figure 2-2 below depicts the terrain datasets used to develop the meshes for these models.

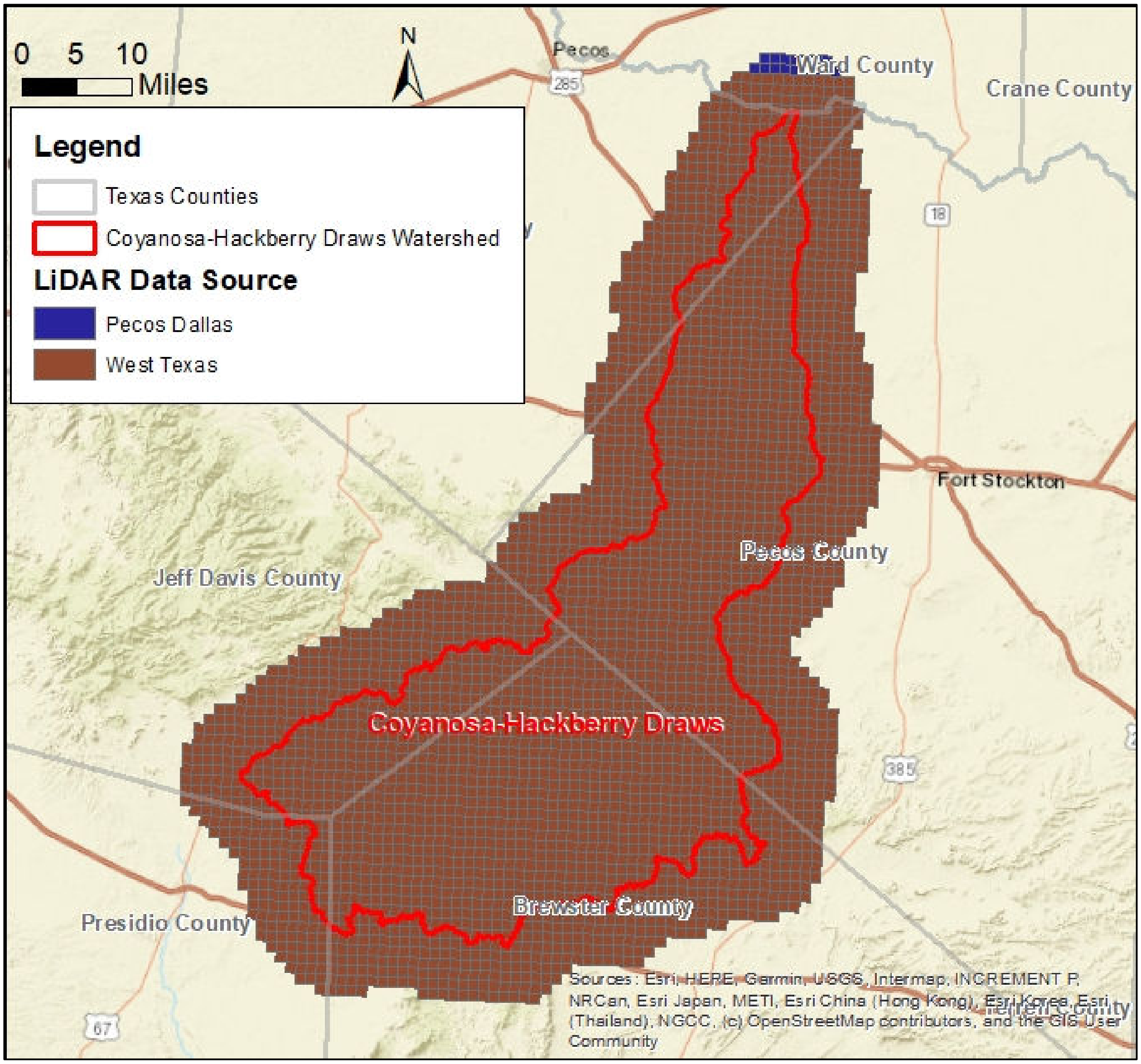

Figure 2-1: LiDAR data sources in the Coyanosa-Hackberry Draws watershed

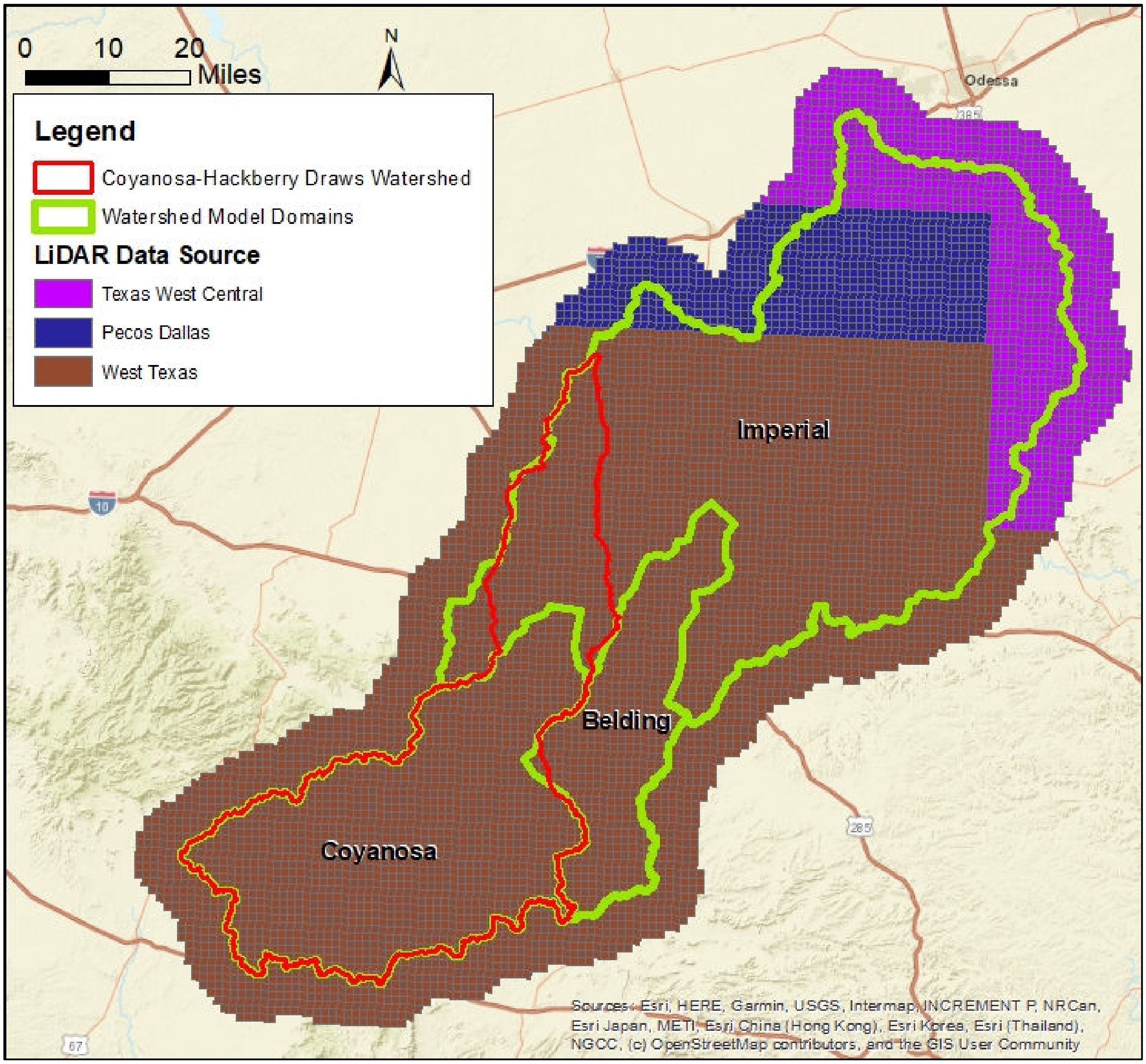

Figure 2-2: LiDAR data sources in the Belding, Coyanosa, and Imperial model domains

2.3 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 confirmed each dataset met FEMA's 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 met FEMA vertical accuracy standards (Table 2-2)
- Date of origination
- Data density and coverage

A description of each LiDAR data source is in

Table 2-1. Additional information about these sources is available in sections 2.3.1 and 2.3.2.

Table 2-1: Topographic data sources in the Coyanosa-Hackberry Draws watershed

Year	Description	Data Type	$RMSE_z$ (cm)	Vertical Accuracy (cm)	Source/Owner
2019	West Texas	LiDAR data	5.7	11.3	USGS

The vertical accuracy presented in

Table 2-1 for each LiDAR dataset is the Non-vegetated Vertical Accuracy (NVA) of the dataset. NVA is defined as 1.96 * RMSEz, which is the root mean square error of the LiDAR data in the z direction.

FEMA Region 6's BLE guidance states that BLE should be prepared only where high-resolution ground elevation data is available for at least 90% of the study area. The guidance also states that the ground elevation data must comply with the vertical accuracy requirements detailed in SID 43. These requirements have been reproduced in Table 2-2. Note that the vertical accuracy criteria in the table are the minimum NVA requirements for the elevation data at the 95% confidence level.

Table 2-2: 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)

Both requirements were met for this project. First, LiDAR data was available for the entire study area, so the 90% coverage criterion was met. Second, the NVAs of the LiDAR datasets that were leveraged to complete the BLE for this watershed (

Table 2-1) are less than 24.5 centimeters, which is the most stringent NVA requirement in Table 2-2.

2.3.1 Watershed and Source Terrain Data

The source elevation data for the Coyanosa-Hackberry Draws watershed are DEMs derived from the USGS's 2019 Pecos Dallas, and 2019 West Texas LiDAR DEM tiles in .TIF format. For development of bare earth DEMs, USGS utilized only points classified as "ground" points and filtered non-ground returns such as buildings, vegetation, etc. from the raw laser returns. Figure 2-1 and Figure 2-2 depict the extent of the data defined in

Table 2-1.

The source elevation data for the Coyanosa-Hackberry Draws watershed was downloaded from the National Map Downloader as pre-processed bare-earth, hydro-enforced DEMs. One HUC-8-wide DEM was created for the Coyanosa-Hackberry Draws watershed and one DEM was created for each model domain. The DEMs acquired from the National Map Downloader were projected and adjusted as needed into seamless DEMs projected to the Texas State Plane Zone 3 (Central) projection (North American Datum of 1983 (NAD 83)) with units of U.S. feet (FIPS 4202). The elevation data is referenced to the North American Vertical Datum of 1988 (NAVD 88). Bare-earth LIDAR data is typically made by filtering non-ground returns (e.g., buildings, vegetation, etc.) from the processed LiDAR returns. See the following subsection for brief descriptions of the LiDAR sources.

2.3.2 Data Sets

An overview of each of the topographic datasets leveraged for this study follows. The vertical datum for each dataset is NAVD 88.

Dataset One – Pecos Dallas LiDAR

The USGS's Pecos Dallas LiDAR dataset captured in 2019 contains data for 9,557 square miles across 21 counties in Texas. In the Coyanosa-Hackberry Draws watershed, this dataset includes parts of Culberson and Reeves counties. The NVA of this dataset is 14.2 centimeters. The RMSEz of the dataset is 7.2 centimeters. The horizontal accuracy is 78.3 centimeters. The ANPS was not available, but the LiDAR project report stated that the specifications for the LiDAR data required ANPS to be less than 71 centimeters. The native cell size of the data is 1 square meter.

Dataset Two – West Texas LiDAR

The USGS's West Texas LiDAR dataset captured in 2019 contains data for 32,494 square miles across 17 counties in Texas. In the Coyanosa-Hackberry Draws watershed, this dataset includes parts of Culberson, Jeff Davis, and Reeves counties. The NVA of this dataset is 11.3 centimeters. The RMSEz of the dataset is 5.7 centimeters. The horizontal accuracy was not available. The ANPS was not available, but the LiDAR project report stated that the specifications for the LiDAR data required ANPS to be less than 71 centimeters. The native cell size of the data is 1 square meter.

2.4 Data Processing

The above-mentioned LiDAR data sets were processed to create a seamless set of tiled 10-foot DEMs for the Coyanosa-Hackberry Draws watershed; the Belding, Coyanosa, and Imperial model domains; and a buffered area around the watershed/domains. Each DEM tile measured 6,000 feet by 6,000 feet. This tile size was used because tiles this size can easily be resampled by other users to 1-, 2-, 3-, 5-, 10-, 20-, or 25-foot rasters, since 6,000 feet is evenly divisible by all of these numbers. A five-mile buffer was included around the watershed and the model domains since the watershed divide was outside the HUC-8 watershed extents in some areas. In addition, a large buffer was applied to facilitate clean floodplain and Base Flood Elevation (BFE) transitions between watersheds and model domains. A 10-foot cell size was used in accordance with the 10-foot cell size criterion outlined in FEMA's Region 6 BLE guidance. After projecting the terrain horizontally into the Texas State Plane Zone 3 (Central) projection (NAD 83) with units of U.S. feet (FIPS 4202), the tiles were mosaicked into single DEMs, one for the watershed and one for each model domain that touched the watershed. A combination of ArcGIS software and custom scripts was applied to process the data.

2.5 DEM QA/QC

DEMs developed for use in the Coyanosa-Hackberry Draws watershed BLE analysis were developed and independently reviewed to confirm they met the quality standards of the project. The data was developed using a controlled process, was evaluated by a topographic data development team, and was evaluated by the engineering team. Quality assurance (QA) during the data development process included, but was not limited to, the following QC checks:

- Horizontal projection check
- Vertical datum check
- Resolution check
- Format check
- Seamless data check to verify the DEM files were consistent and seamless along source data edges

The QC after the development process by the DEM development team included visual observations 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 to find erroneous elevation issues
- Unit consistency check
- Legacy cell value anomalies

QA conducted after development of the seamless DEMs conducted by the engineering team included visual or automated assessments to identify potentially impactful anomalies that may adversely impact hydraulic analysis. The final DEM data developed for the Coyanosa-Hackberry Draws watershed met FEMA standards and presented a representative surface developed from leveraged elevation data for the purposes of this BLE project.

2.6 2D BLE Methods

The following sections describe the modeling methodology, including leveraged studies, the 2D computational mesh, and program setting considerations. Model parameters are also discussed and tabulated for the hydrologic and hydraulic engineering methods and model inputs. Results are provided with comparisons to FEMA effective studies and available USACE studies, if any were available.

2.6.1 2D Computational Mesh and Settings

The Coyanosa-Hackberry Draws watershed is approximately 1,958 square miles in size. The original 2D computational mesh for each model was established as evenly spaced 300-foot cells. The mesh was then further refined by placing breaklines along roads, berms, ridges, and other high ground that can impede flow. Breaklines were also placed along stream centerlines to allow proper flow conveyance across the terrain surface. The nominal cell spacing in the models is 300 feet, except along breaklines, where a nominal cell spacing of 150 feet was used. Additionally, refinement regions were placed along stream centerlines down to a drainage area of 0.3 square miles and within communities with more than 1,000 residents. This was done to refine the model output and promote continuity in the floodplain mapping along the centerlines. Similar to stream centerline refinement regions, stream breaklines were extended down to a drainage area of 0.3 square miles.

As discussed at the end of section 1, the watershed was modeled with three HEC-RAS models, shown in Figure 1-3. After computational mesh refinements and adjustments, the Belding 2D mesh contained 210,938 cells, the Coyanosa 2D mesh contained 567,805 cells, and the Imperial 2D mesh contained 1,303,362 cells.

In some locations, the model domain extents overlap to support floodplain mapping tie-ins between neighboring models. Once draft results of the modeling were available, the model domains were reviewed and iteratively buffered where needed to facilitate flow transfers and mapping tie-ins across model domain extents.

It should be noted that although the modeling footprints do not align with the Coyanosa-Hackberry Draws watershed boundary, the mapped floodplains and other datasets in the mapping database will adhere to the original HUC-8 boundaries. Internal SA/2D connections were used to extract flow readings for gage locations throughout the models. An adaptive 30-second time step was used to allow the models to lower the time step, as necessary, to keep the maximum courant number under 2 for the duration of the simulation. The time step was allowed to reach a maximum of 1 minute and a minimum of 15 seconds. A theta value of 1.0 was used. The HEC-RAS models were run with Diffusion Wave (simplified Full Momentum) equations.

2.6.2 Model and Boundary Conditions

Using HEC-RAS's rain-on-grid functionality typically requires the definition of precipitation, inflow hydrograph, and outflow normal depth slope boundary conditions in order to execute the model. Precipitation boundary conditions in the HEC-RAS models were applied by linking the HEC-HMS outputs into the HEC-RAS unsteady flow data editor via DSS files. The process to determine the precipitation values to be applied is outlined in section 2.7. Figure 2-3 depicts the model layout for the Coyanosa-Hackberry Draws watershed, flow transition points between models, and the USGS stream gages leverage by the study.

As a headwater watershed, the Coyanosa-Hackberry Draws watershed does not receive inflows from upstream of the watershed. However, there are three flow transfer locations within the watershed. The first is at the downstream end of the Coyanosa model, where it drains into the Imperial model. The second is a breakout from the Coyanosa model into the Toyah model at Hackberry Draw. The third is a breakout from the Imperial model into the Lower Pecos-Lower model at US 285. The Coyanosa-Hackberry Draws watershed drains into the Landreth-Monument Draws HUC-8 watershed (13070007).

The Coyanosa-Hackberry Draws watershed was modeled with the Belding, Coyanosa, and Imperial hydraulic models. In this watershed, the Coyanosa models drains into the Imperial model. The outflow from the Coyanosa model was used as an inflow hydrograph into the Imperial model. The outflow hydrographs from the Coyanosa model was extracted using an SA/2D connection and then transferred downstream as a flow hydrograph internal boundary condition in the Imperial model.

Normal depth boundary conditions were applied at main riverine outflows to allow the flow to exit the model domain. Around the rest of the model perimeter, continuous normal depth boundary conditions were applied to allow sheet flow and minor tributary drainage to leave the model area freely and prevent water from ponding along the perimeter. Generally, at the main river outflow locations, a separate boundary condition was created by splitting the boundary condition lines around the main river outflow. For the perimeter outflows, longer boundary condition lines were used, which were generally split at locations with significant changes in topography, at main outflows and at other significant overflows, and where there were major mapping tie-ins. Normal depth was used for all outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain. In some cases, the energy slope was adjusted to achieve acceptable tie-ins with the downstream model.

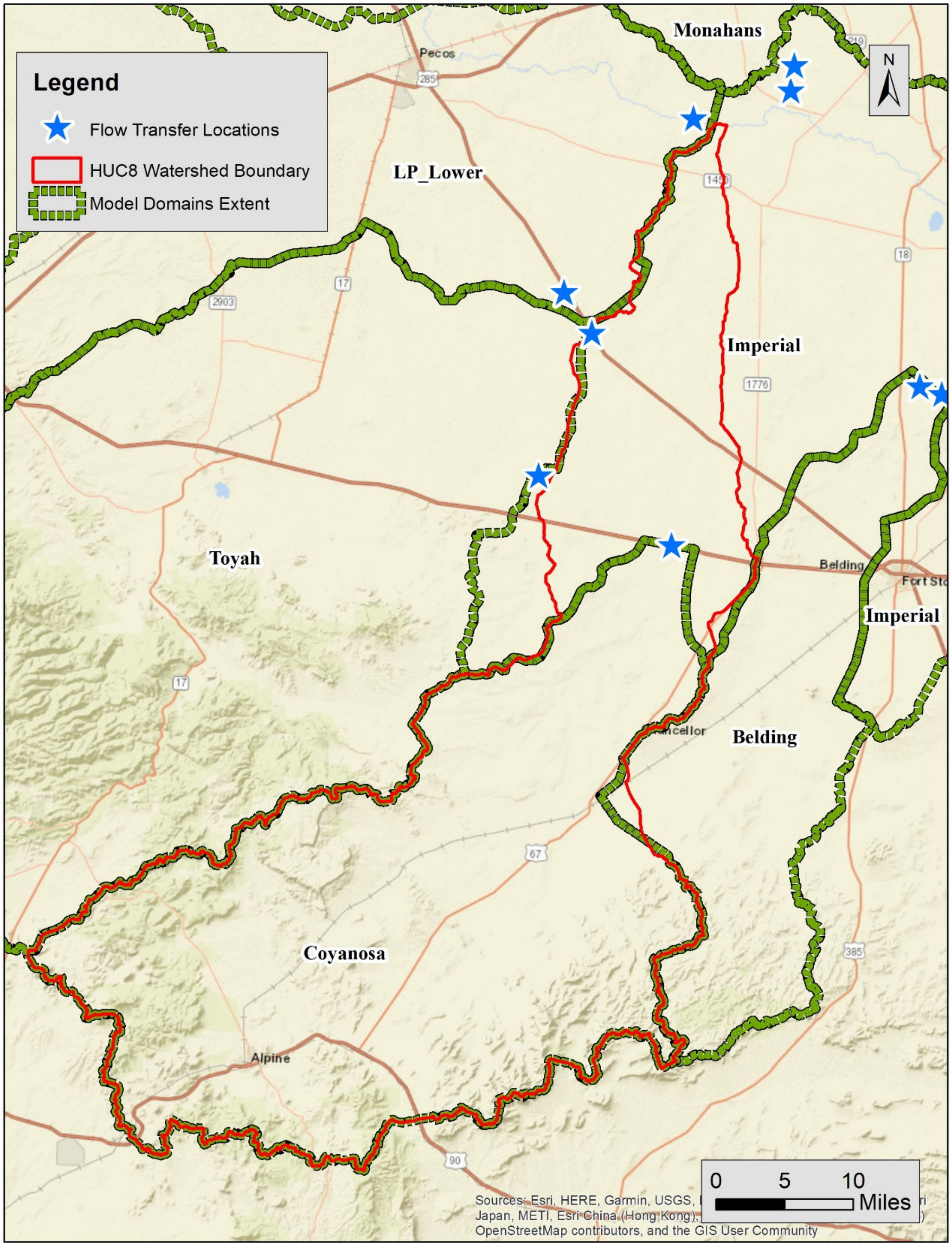

Figure 2-3: HEC-RAS 2D computational mesh extents, flow transfer locations, and USGS streamflow gages

2.7 Hydrology

HEC-HMS, Version 4.11 was used solely for the development of precipitation hyetographs that were applied to the 2D mesh in HEC-RAS. Precipitation frequency data published in NOAA Atlas 14, Volume 11, Version 2.0 (NOAA, 2018) was used for this study. The data was obtained from NOAA's Precipitation Frequency Data Server (PFDS) (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html). The 10%, 4%, 2%, 1%, and 0.2% ACE 24-hour precipitation depths for the watershed were determined by the area-weighted intersection of gridded PFDS data within the study area. Precipitation for the 2D mesh was developed as described in section 2.7.1.

2.7.1 Precipitation for 2D Computational Mesh

The precipitation inputs for the HEC-RAS models were computed using NOAA Atlas 14 rainfall data. The HEC-RAS models included seven events, which were the 10%, 4%, 2%, 1%, 0.2%, 1% plus, and 1% minus ACEs. For each model in the Coyanosa-Hackberry Draws watershed, a hyetograph was required for each event. The TWDB's 2D BLE guidelines state that the duration of each hyetograph should be 24 hours.

The TWDB directed the team to apply spatially uniform rainfall in each model domain if the 1%, 24-hour maximum and minimum point rainfall totals in the domain were within 10% or so of the average 1%, 24-hour point rainfall total. In the Coyanosa-Hackberry Draws watershed, the Belding, Coyanosa, and Imperial model domains met these criteria and spatially uniform rainfall was applied.

The hyetographs for the Belding, Coyanosa, and Imperial models were developed using the following process:

- Download the NOAA Atlas 14 rainfall grids. For each event, grids were acquired for storms with durations of 5 minutes, 15 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, and 24 hours. Each cell in a grid stored the rainfall total in the cell for that duration.
- For the 10%, 4%, 2%, 1%, and 0.2% ACEs, intersect the rainfall grid for each event with each HEC-RAS model extent. This process produced an average point rainfall total for each duration of each event in each model domain.
- NOAA's rainfall datasets did not include rainfall totals for the 1% plus and 1% minus ACEs. Instead, NOAA has calculated rainfall grids for the upper and lower 90% confidence intervals of the 1% ACE. These grids were downloaded for each duration and processed as described below.

- For the 1% plus and 1% minus ACEs, intersect the rainfall grids with the HEC-RAS extent for each model domain. Compute an average point rainfall total for each model domain for the upper and lower 90% confidence intervals for the 1% ACE. Complete this computation for each duration. The 1% plus and 1% minus rainfall totals, for each duration, were determined using the following equations:

$$1\%\ plus\ precip = 1\%\ precip + \frac{Upper\ 90\%\ Limit - Lower\ 90\%\ Limit}{3.29}$$

$$1\%\ minus\ precip = 1\%\ precip - \frac{Upper\ 90\%\ Limit - Lower\ 90\%\ Limit}{3.29}$$

Figure 2-4: Equations for determining 1% plus and 1% minus rainfall totals

- Build the hyetographs for each domain using HEC-HMS, version 4.11. Load the domain extent into HEC-HMS. For each domain, create frequency-based hypothetical storms for the 10%, 4%, 2%, 1%, 0.2%, 1% plus, and 1% minus ACEs using average rainfall totals in the domain for storm durations of 5 minutes, 15 minutes, 1 hour, 2 hours, 3 hours, 6 hours, 12 hours, and 24 hours. The hyetographs in HEC-HMS assumed a one-minute time step. The final hyetograph for each event had a duration of 24 hours.
- Transfer the hyetographs into HEC-RAS by linking DSS file paths.
- Rainfall losses were not computed in HEC-HMS. Instead, rainfall losses were computed in HEC-RAS. See section 2.7.3 for more information.

As an example, Figure 2-5 and Figure 2-6 show the hyetograph computed in HEC-HMS for the 1% ACE and the cumulative 1% rainfall totals for the Toyah model domain. The 1% rainfall total for this domain, for the 5-minute duration, was 0.914 inches. Note how the maximum rainfall in the hyetograph is 0.914 inches. The 1% rainfall total for this domain for the 24-hour duration was 4.99 inches. Note how the total cumulative rainfall in the domain for the 24-hour hyetograph is 4.99 inches.

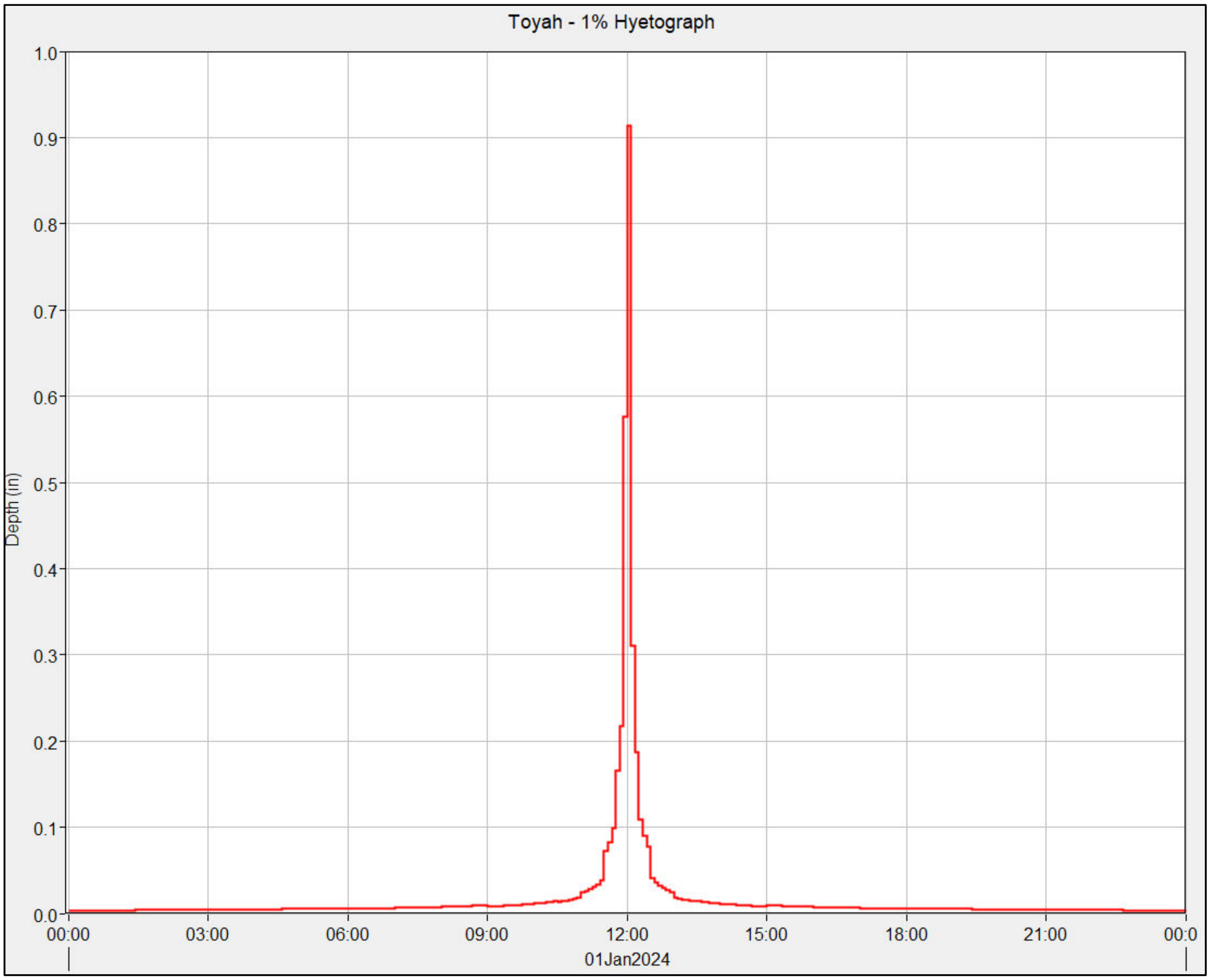

Figure 2-5: 1% hyetograph for the Toyah model domain

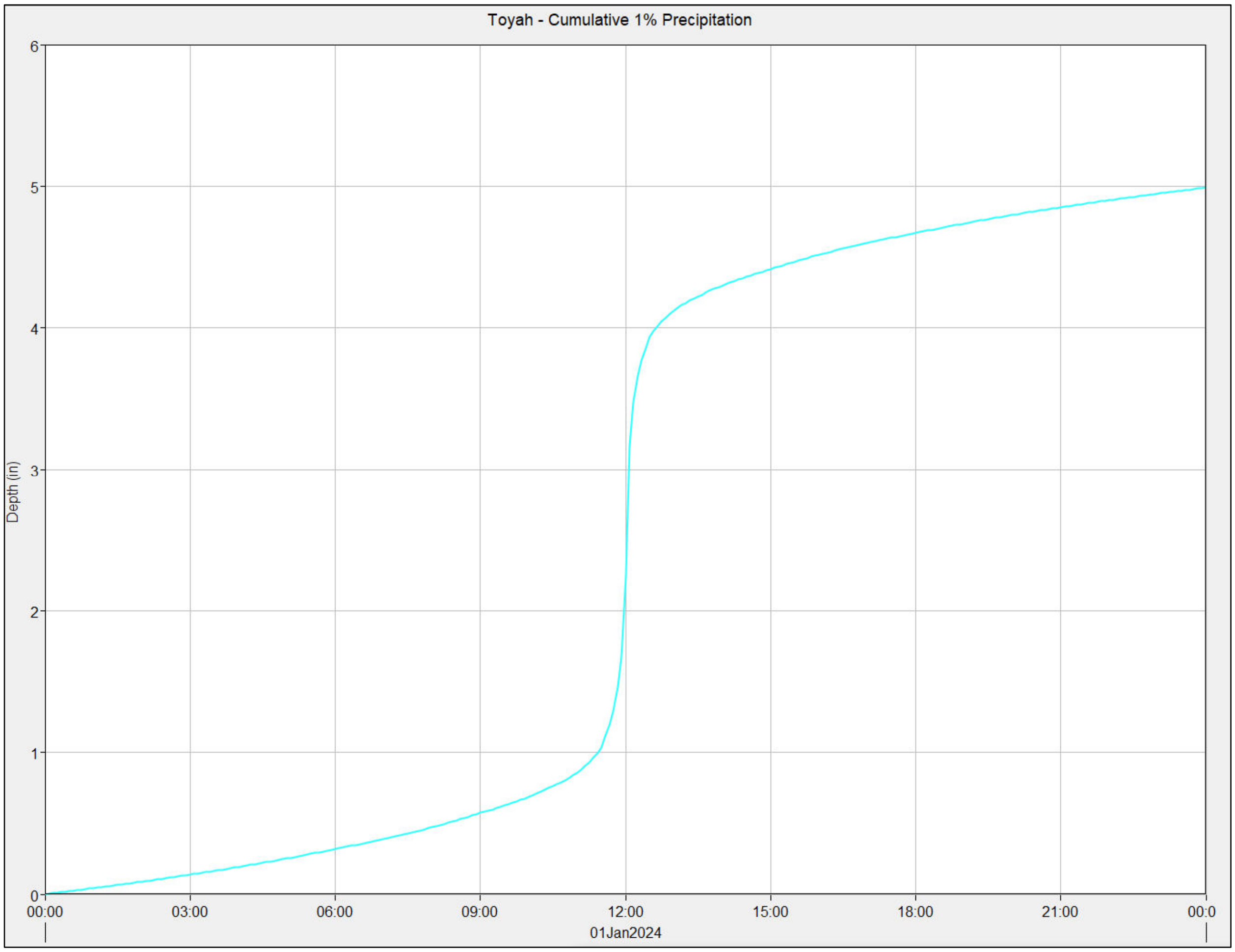

Figure 2-6: Cumulative 1% rainfall totals for the Toyah model domain

Once the hyetographs were available for all events in a domain, the cumulative rainfall totals were plotted in Excel to confirm that no profiles crossed. In limited instances, the 1% plus or the 1% minus rainfall curve intersected one of the curves for the 10%, 4%, 2%, 1%, or 0.2% ACEs. However, no adjustments were made to the curves since any crossings occurred significantly far away from the hyetograph peaks.

Figure 2-7 through Figure 2-9 show the precipitation hyetographs applied to the 2D computational meshes for the Belding, Coyanosa, and Imperial model domains, respectively.

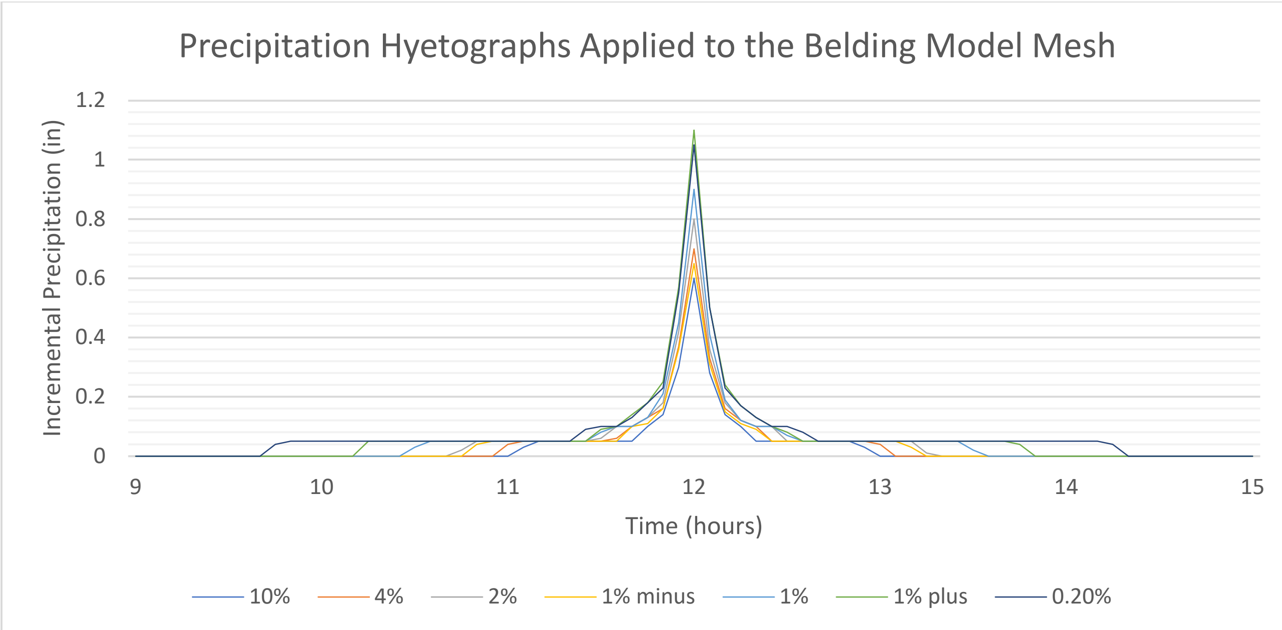

Figure 2-7: Precipitation hyetographs applied to the computational mesh for the Belding model domain

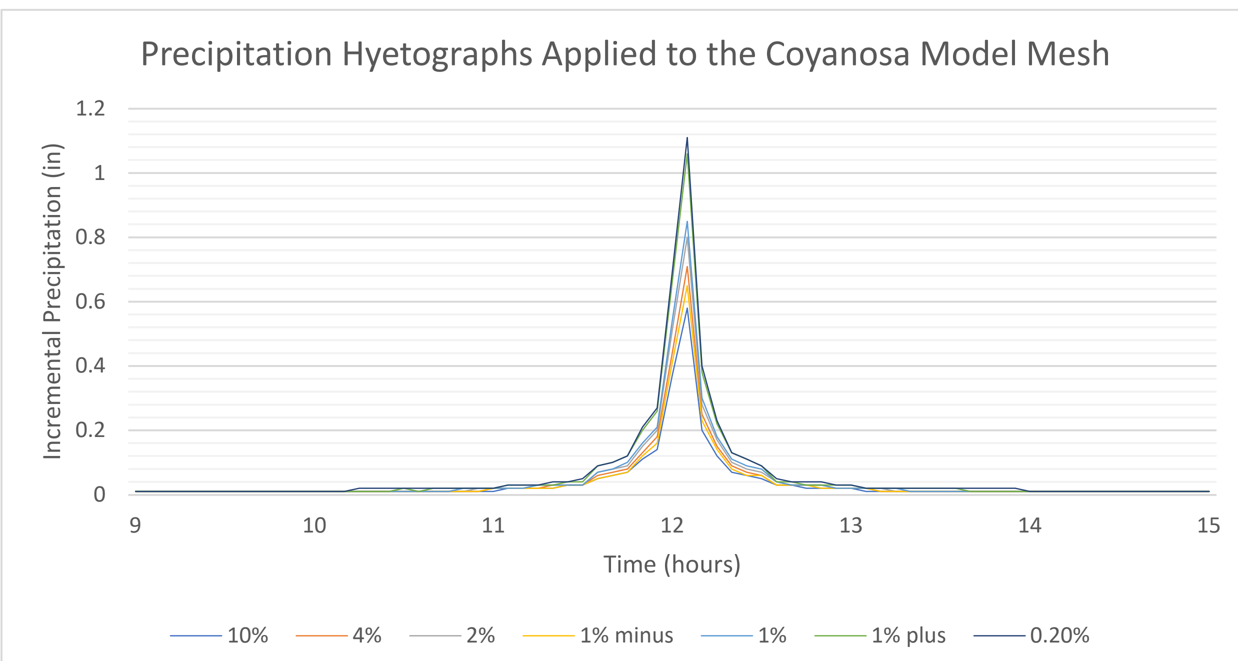

Figure 2-8: Precipitation hyetographs applied to the computational mesh for the Coyanosa model domain

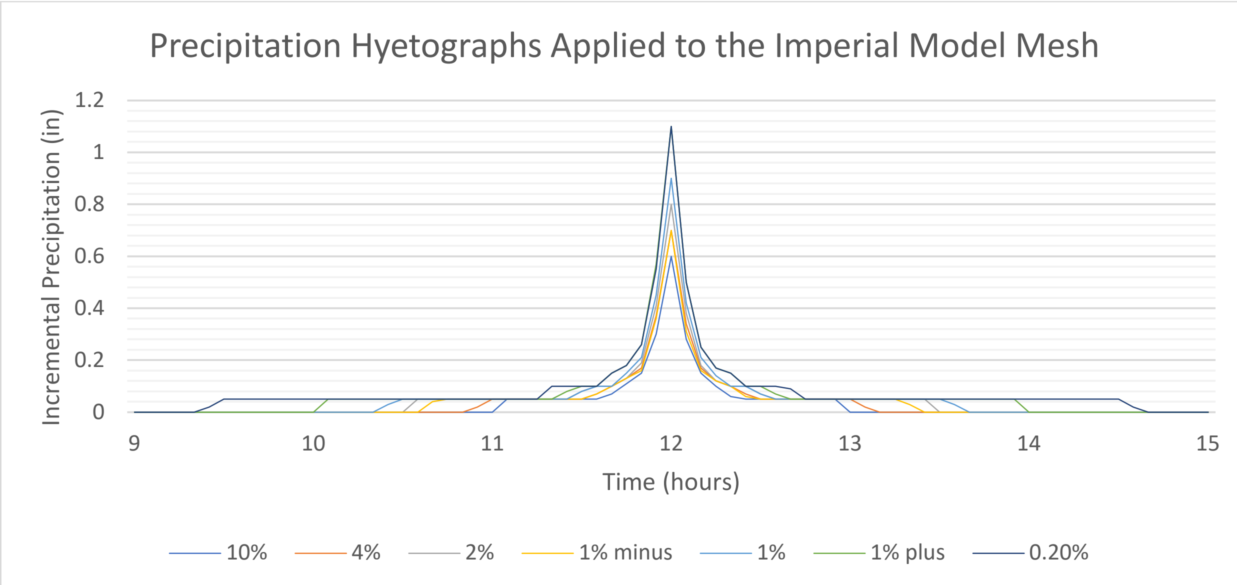

Figure 2-9: Precipitation hyetographs applied to the computational mesh for the Imperial model domain

Table 2-3 through Table 2-5 provide the depth – duration values used to develop the precipitation hyetographs in the Belding, Coyanosa, and Imperial model domains.

Table 2-3: Rainfall depths (inches) for estimating precipitation for the Belding HEC-RAS model

Model Domain	Percent ACE	Rainfall Duration							
		5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
Belding	10%	0.59	1.18	1.96	2.32	2.52	2.88	3.24	3.64
	4%	0.71	1.41	2.34	2.79	3.05	3.51	4.00	4.53
	2%	0.80	1.58	2.62	3.14	3.44	3.99	4.59	5.25
	1%	0.88	1.74	2.89	3.48	3.83	4.48	5.20	6.01
	1% minus	0.67	1.34	2.22	2.70	2.99	3.52	4.12	4.80
	1% plus	1.08	2.14	3.56	4.26	4.67	5.44	6.28	7.22
	0.2%	1.06	2.12	3.50	4.29	4.79	5.72	6.77	7.96

Table 2-4: Rainfall depths (inches) for estimating precipitation for the Coyanosa HEC-RAS model

Model Domain	Percent ACE	Rainfall Duration							
		5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
Coyanosa	10%	0.58	1.15	1.88	2.16	2.31	2.59	2.91	3.28
	4%	0.71	1.40	2.29	2.61	2.77	3.09	3.48	3.96
	2%	0.80	1.59	2.60	2.94	3.11	3.46	3.91	4.47
	1%	0.85	1.69	2.76	3.10	3.28	3.63	4.12	4.74
	1% minus	0.65	1.29	2.09	2.38	2.54	2.83	3.25	3.77
	1% plus	1.06	2.10	3.42	3.81	4.02	4.43	5.00	5.71
	0.2%	1.11	2.20	3.56	4.01	4.25	4.73	5.39	6.24

Table 2-5: Rainfall depths (inches) for estimating precipitation for the Imperial HEC-RAS model

Model Domain	Percent ACE	Rainfall Duration							
		5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
Imperial	10%	0.61	1.19	2.01	2.38	2.60	2.97	3.34	3.74
	4%	0.72	1.43	2.40	2.88	3.15	3.64	4.15	4.69
	2%	0.81	1.60	2.69	3.24	3.58	4.16	4.80	5.47
	1%	0.90	1.77	2.97	3.61	4.00	4.71	5.48	6.30
	1% minus	0.69	1.36	2.29	2.80	3.12	3.69	4.33	5.01
	1% plus	1.10	2.17	3.66	4.43	4.89	5.72	6.63	7.58
	0.2%	1.09	2.15	3.63	4.51	5.08	6.10	7.25	8.49

2.7.2 Flow-Frequency Analysis of USGS Streamflow Gages

There were a number of USGS flow gages with a sufficient period of record throughout the BLE TO completed by AtkinsRéalis, including two in the Coyanosa-Hackberry Draws watershed. To facilitate the validation of the BLE outcomes throughout the footprint of the BLE TO, the USGS's Bulletin 17-C methodology was applied to develop flow-frequency analyses of the 1% ACE at these gages. See Figure 2-10 for a map of the model domains in the BLE TO footprint and the USGS gages that received a flow-frequency analysis.

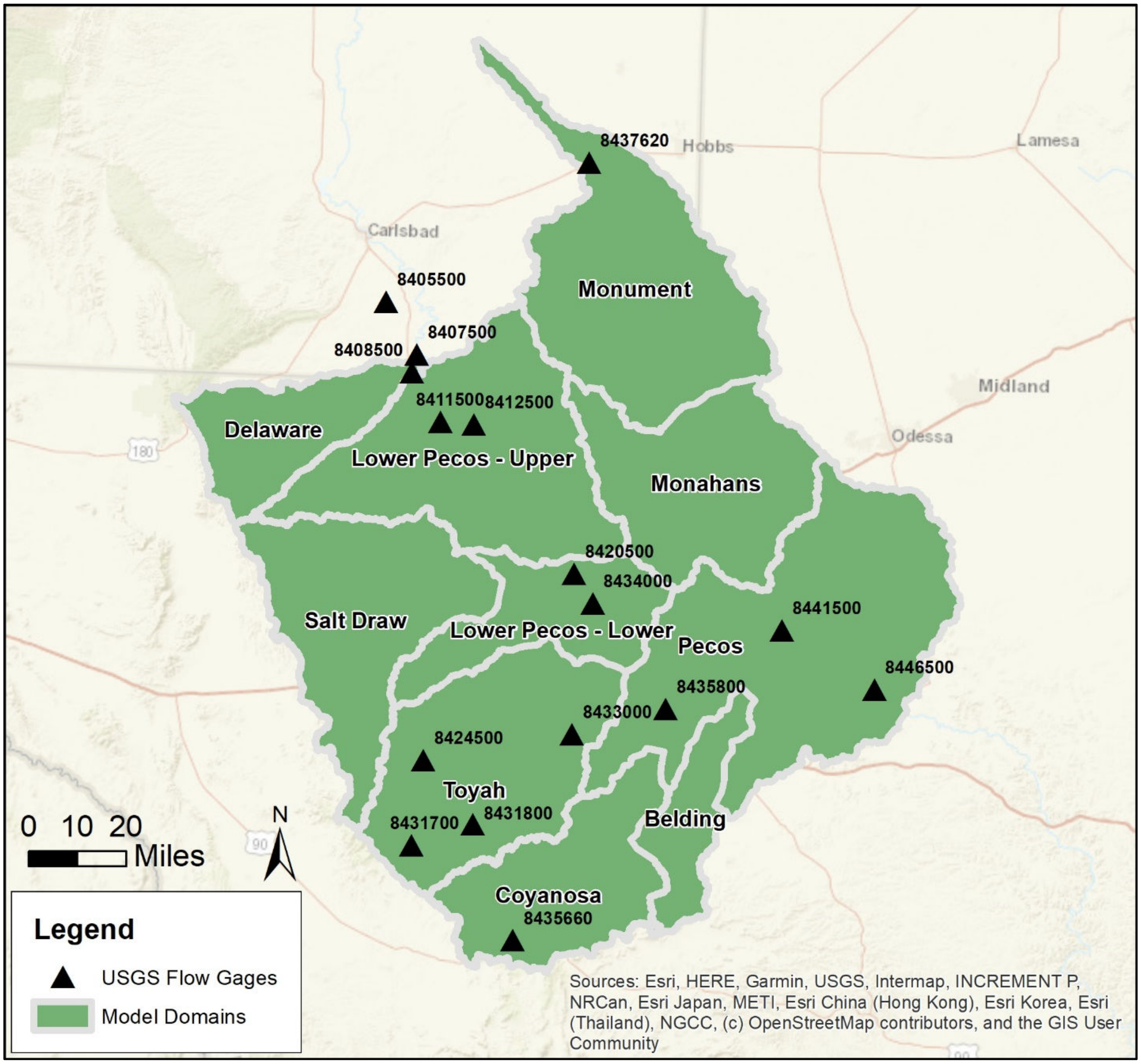

Figure 2-10: USGS gages where a flow-frequency analysis was performed

For those watersheds without any gages, such as the Salt Draw watershed, a discharge-drainage area chart could be created from these Bulletin 17-C flow-frequency analysis and BLE outcomes could be validated by comparing the discharge-drainage area values at the ungaged validation points in the watershed with the discharge-drainage area outcomes from the flow-frequency analyses.

Table 2-6 summarizes the results of the Bulletin 17-C flow-frequency analyses that were completed. Data about each gage is presented as well as the computed 1% minus, 1%, and 1% plus gage discharges. The column "Pecos River or Tributary" indicates whether the gage was located along the Pecos River or one of its tributaries.

Table 2-6: Outcomes of the flow-frequency analysis of the USGS streamflow gages

USGS Gages				Bulletin 17-C Flow-Frequency Analysis				
Site No.	Site Name	Drainage Area (mi^2)	Period of Record (years)	Pecos River or Tributary	Station Skew	1% Minus Discharge (cfs)	1% Discharge (cfs)	1% Plus Discharge (cfs)
08405500	Black River Above Malaga, NM	371	78	Trib	-0.345	36,730	53,140	84,760
08408500	Delaware River Nr Red Bluff, NM	783	86	Trib	-0.34	51,310	71,830	111,000
08411500	Salt Screwbean Draw nr Orla, TX	498	15	Trib	-0.34	22,180	38,010	91,880
08424500	Madera Canyon nr Toyahvale, TX	56	18	Trib	-0.25	7,453	11,450	21,410
08431700	Limpia Ck abv Ft Davis, TX	37	26	Trib	-0.23	11,180	20,860	61,360
08431800	Limpia Ck bl Ft Davis, TX	213	17	Trib	-0.25	8,327	11,400	17,180
08433000	Barrilla Draw nr Saragosa, TX	570	28	Trib	-0.29	9,608	16,950	43,040
08434000	Toyah Ck bl Toyah Lk nr Pecos, TX	3,218	12	Trib	-0.32	12,260	35,440	184,700
08435660	Moss Ck nr Alpine, TX	10	19	Trib	-0.225	1,876	2,806	5,328
08435800	Coyanosa Draw nr Ft Stockton, TX	1,163	14	Trib	-0.31	8,412	14,980	37,650
08437620	Monument Draw Trib nr Monument, NM	17	14	Trib	-0.35	552	1,223	4,495

USGS Gages				Bulletin 17-C Flow-Frequency Analysis				
Site No.	Site Name	Drainage Area (mi^2)	Period of Record (years)	Pecos River or Tributary	Station Skew	1% Minus Discharge (cfs)	1% Discharge (cfs)	1% Plus Discharge (cfs)
08407500	Pecos River at Red Bluff, NM After 1987	19,540	36	Pecos River	n/a	31,540	75,390	300,000
08412500	Pecos Rv nr Orla, TX (After 1987)	21,229	36	Pecos River	n/a	5,848	10,900	29,550
08420500	Pecos Rv at Pecos, TX (All records)	22,100	30	Pecos River	n/a	13,100	20,500	47,340
08441500	Pecos Rv bl Grandfalls, TX (All records)	26,110	20	Pecos River	n/a	5,831	10,220	25,440
08446500	Pecos Rv nr Girvin, TX (All records)	29,560	84	Pecos River	n/a	7,017	11,560	25,790

2.7.3 Infiltration Parameters

The National Resource Conservation Service's (NRCS) Curve Number (CN) loss rate method was used in HEC-RAS to quantify the infiltration losses in the watershed. The CN at a given point in the watershed is a function of the hydrologic soil group (HSG) of the soil and the land cover type at that location. Therefore, a spatially varying infiltration layer for each model domain was developed in HEC-RAS using gridded soils and gridded land cover datasets.

To develop the soils dataset for a model domain, the 2021 Gridded Soils Survey Geographic (gSSURGO) database was downloaded from the NRCS website (https://data.nal.usda.gov/dataset/gridded-soil-survey-geographic-database-gssurgo). The SSURGO database included the HSG of each soil type in the study area. The HSGs varied from Group A (low runoff potential when thoroughly wet) to Group D (high runoff potential when thoroughly wet). Figure 2-11 through Figure 2-13 show the distribution of the HSGs in the three model domains in the watershed.

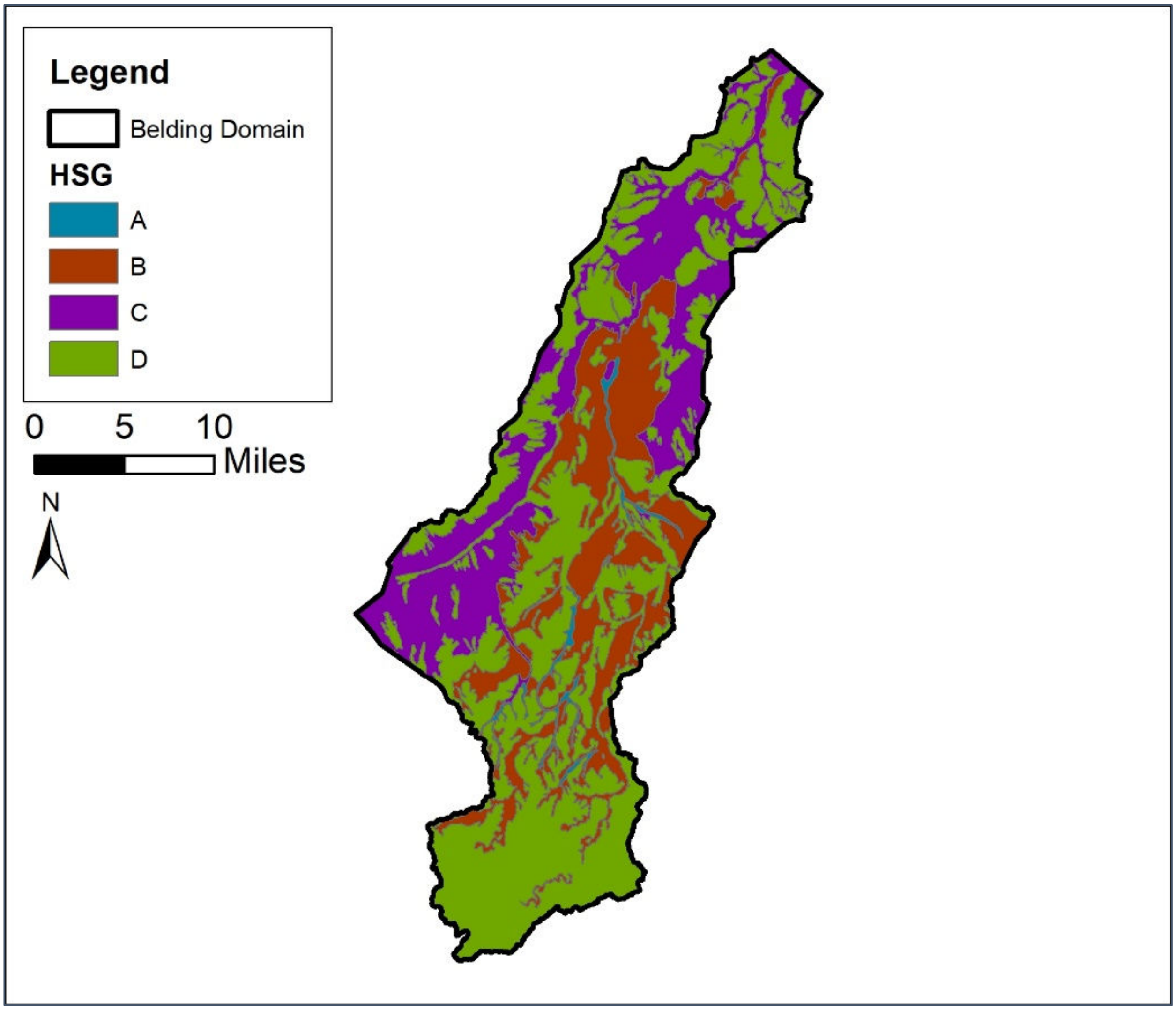

Figure 2-11: HSGs in the Belding model domain

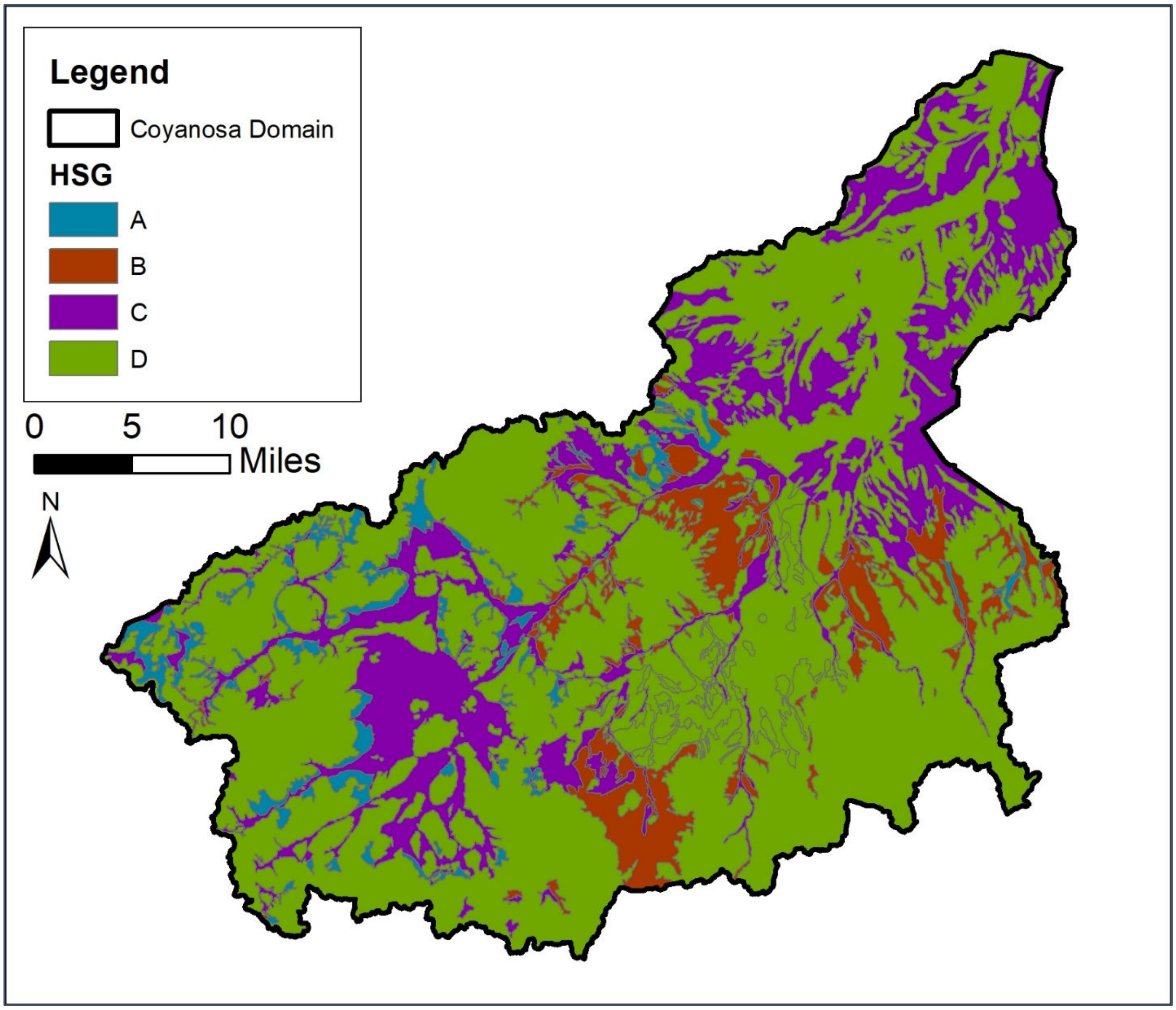

Figure 2-12: HSGs in the Coyanosa model domain

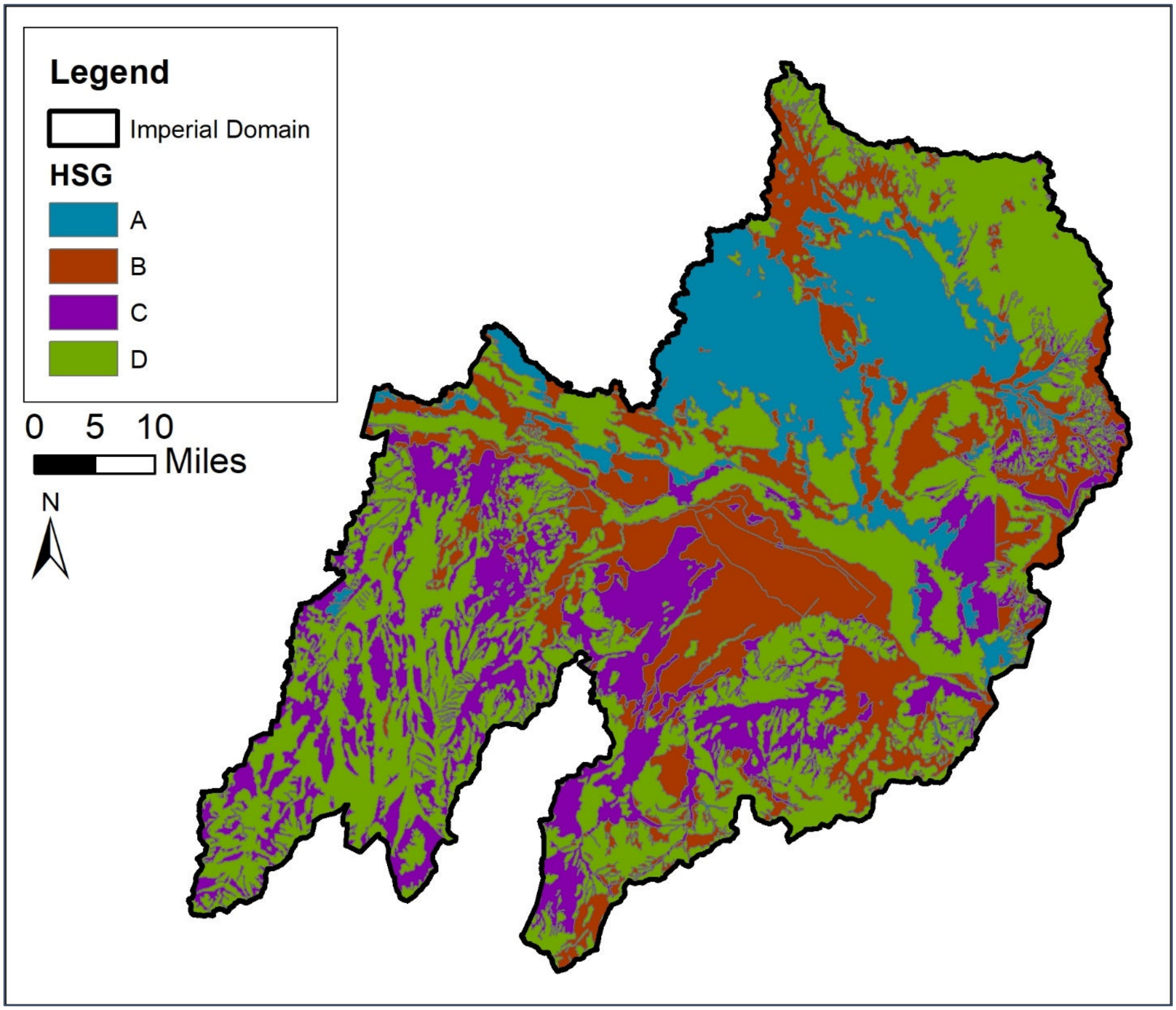

Figure 2-13: HSGs in the Imperial model domain

To develop the land cover dataset for a model domain, the 2021 National Land Cover Database (NLCD) was downloaded from the Multi-Resolution Land Characteristics Consortium (MRLC) website (https://www.usgs.gov/centers/eros/news/nlcd-2021-now-available). The land cover dataset provided land use classification codes and the extent of each land use. This information was used to create the gridded land cover dataset. Figure 2-14 through Figure 2-16 show the Land Cover Types present in the three model domains in the watershed.

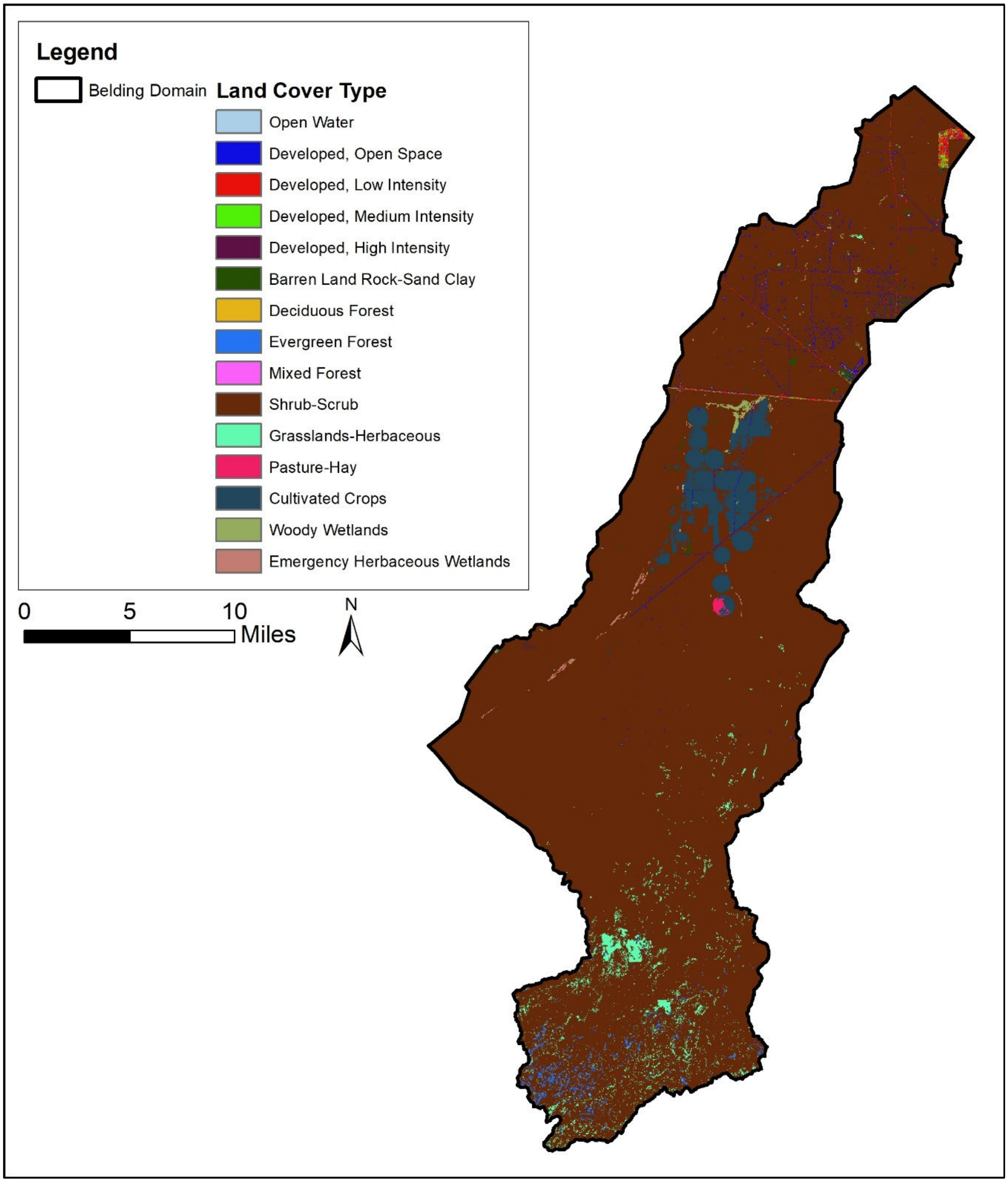

Figure 2-14: Land cover types in the Belding model domain

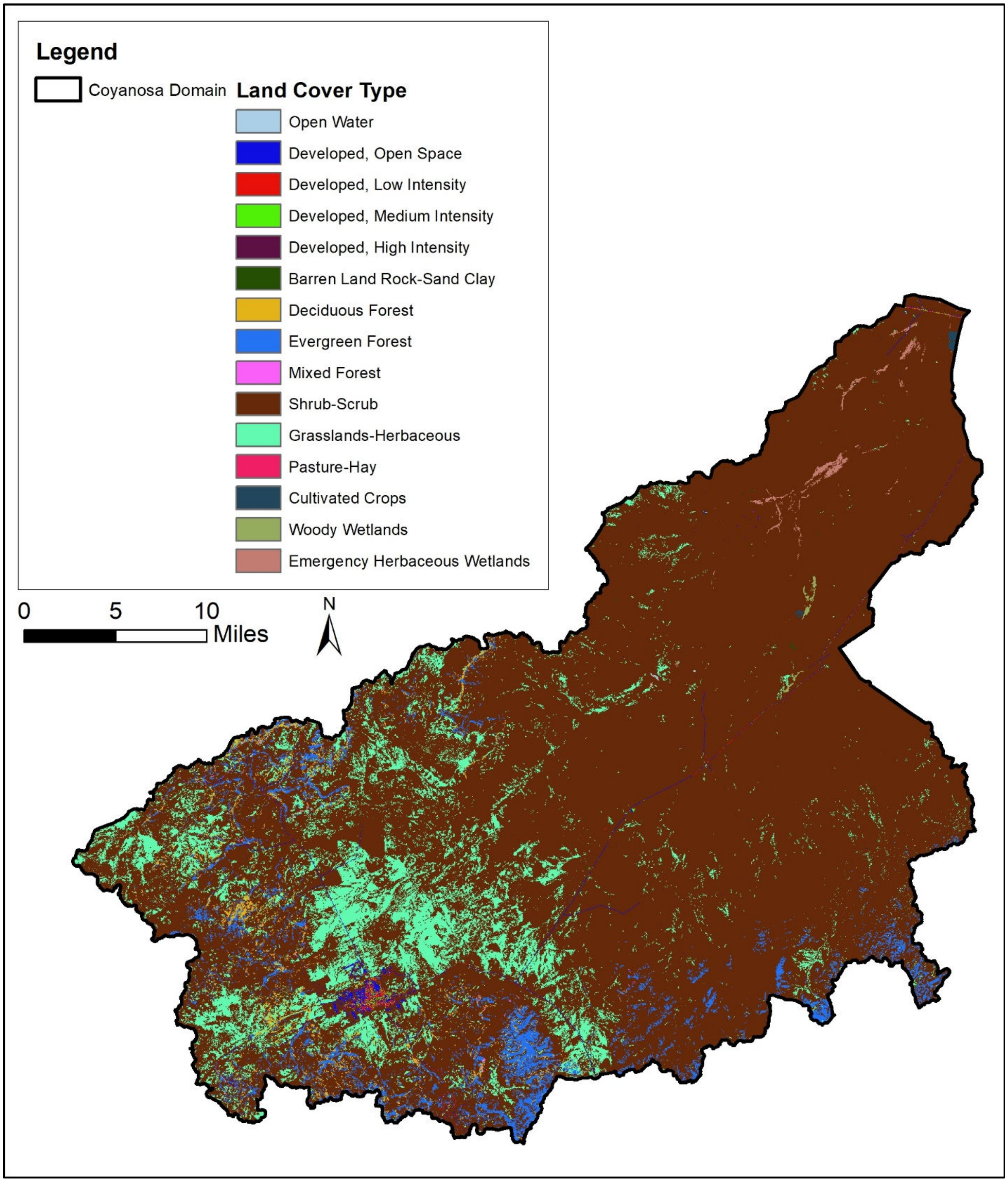

Figure 2-15: Land cover types in the Coyanosa model domain

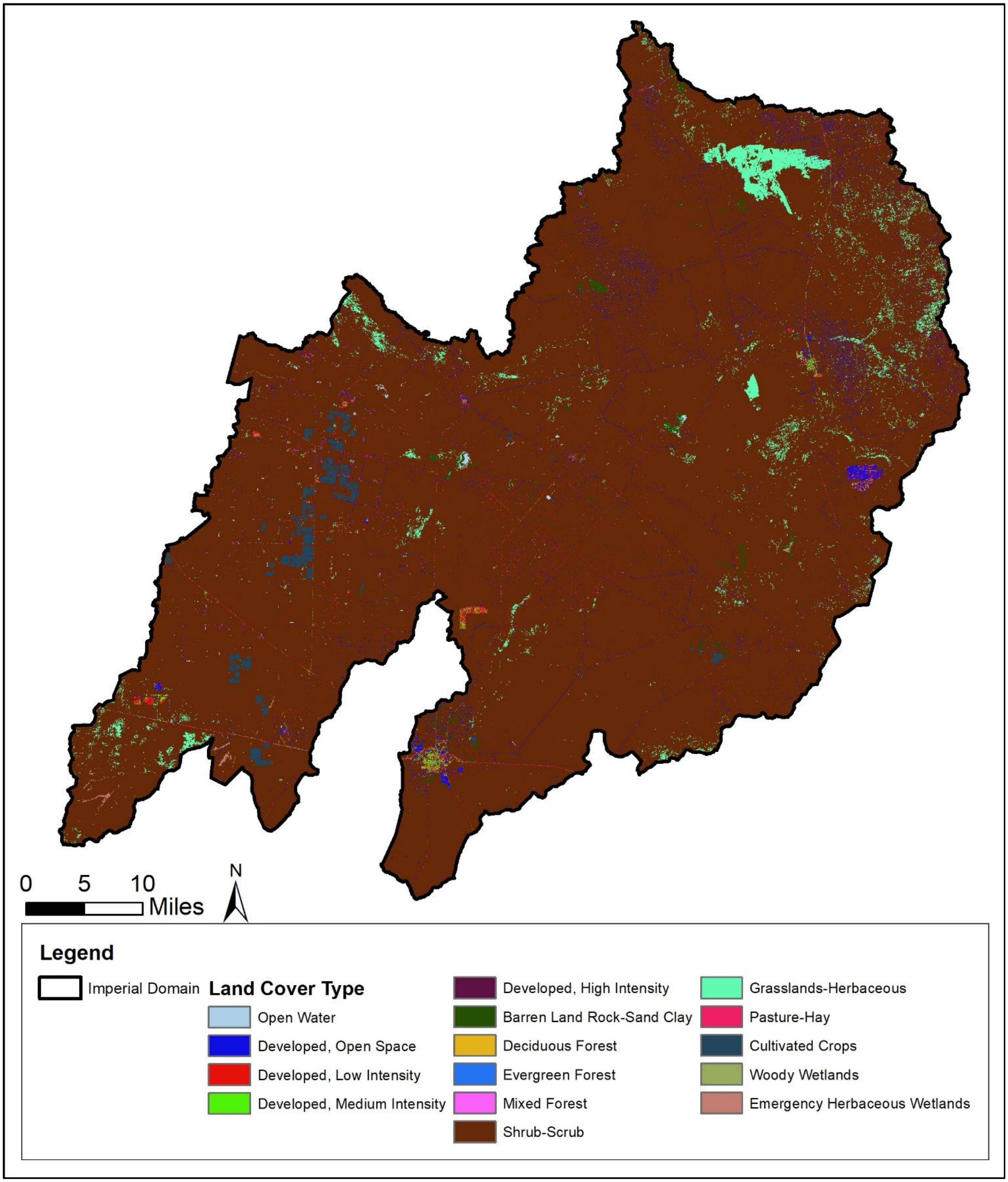

Figure 2-16: Land cover types in the Imperial model domain

The infiltration layer was created in HEC-RAS by combining the soils and land cover gridded datasets. The CN values required for the loss rate computations were obtained from Table 2.4 of the TWDB's *2D Base Level Engineering* Guidance *Version 1.0* (May 2022) and are shown below in Table 2-7.

An initial abstraction ratio of 0.2 was used to obtain the initial loss during the model validation phase. The CN values presented in Table 2-7 are based on average Antecedent Moisture Condition I (AMC I). Any CN values less than 30 were rounded up to 30 to avoid overestimating the infiltration losses.

Table 2-7: AMC I and AMC II Curve Number values

Land Use Grid Code	NLCD Land Use Description	CN for Each Hydrologic Soil Group (AMC I)				CN for Each Hydrologic Soil Group (AMC II)				Percent Impervious
		A	B	C	D	A	B	C	D	
11	Open Water	98	98	98	98	99	99	99	99	n/a
21	Developed, Open Space	29*	48	61	69	49	69	79	84	n/a
22	Developed, Low Intensity	21*	40	54	63	39	61	74	80	38
23	Developed, Medium Intensity	21*	40	54	63	39	61	74	80	72
24	Developed, High Intensity	21*	40	54	63	39	61	74	80	85
31	Barren Land	21*	40	54	63	39	61	74	80	n/a
41	Deciduous Forest	15*	34	49	58	30	55	70	77	n/a
42	Evergreen Forest	15*	34	49	58	30	55	70	77	n/a
43	Mixed Forest	15*	34	49	58	30	55	70	77	n/a
52	Shrub Scrub	15*	28*	44	53	30	48	65	73	n/a
71	Herbaceous	29*	41	54	70	49	62	74	85	n/a
81	Hay Pasture	21*	40	54	63	39	61	74	80	n/a
82	Cultivated Crops	30	46	57	63	51	67	76	80	n/a
90	Woody Wetlands	52	63	74	85	72	80	87	93	n/a
95	Emergent Herbaceous Wetlands	52	63	74	85	72	80	87	93	n/a

*CN increased to 30 in the HEC-RAS model to avoid overestimating the infiltration losses.

2.7.4 Inflow Hydrograph Boundary Conditions

As a headwater watershed, the Coyanosa-Hackberry Draws watershed does not receive inflows from upstream of the watershed. However, there are three flow transfer locations within the watershed. The first is at the downstream end of the Coyanosa model, where it drains into the Imperial model. The second is a breakout from the Coyanosa model into the Toyah model at Hackberry Draw. The third is a breakout from the Imperial model into the Lower Pecos-Lower model at US 285. The Coyanosa-Hackberry Draws watershed drains into the Landreth-Monument Draws HUC-8 watershed (13070007).

The Coyanosa-Hackberry Draws watershed was modeled with the Belding, Coyanosa, and Imperial hydraulic models. The Coyanosa model drains into the Imperial model. In addition, there are the three flow transfer locations described in the previous paragraph. A direct-flow approach was used to transfer flows from upstream domains to downstream domains. In the direct-inflow method, the precipitation and upstream inflows assume the same annual-chance event is occurring simultaneously. So, for each event, the outflows from the upstream domains were directly applied as inflows to the model of interest without adjustments to the timing of the peaks.

SA/2D connections were added near the main channel outflow location in the upstream HEC-RAS model to compute the outflow from the upstream model. A flow boundary condition (BC) line was then added in the downstream model at a location that coincided with the SA/2D line to maintain consistency. Breaklines were enforced at the SA/2D connections and flow BC lines to align the cell faces with the boundary. The purpose of adding SA/2D connections was to limit the impact of the boundary conditions on the inflow applied to the downstream model and to clearly document the flow transfer locations and hydrographs, as this information is stored in the DSS output files. The alignments of the SA/2D connections were based on the layout of the terrain, the water surface elevation contours, and engineering judgment.

Typically, an SA/2D connection line only intersects one stream centerline. However, in this study area, there are locations where an SA/2D connection crosses multiple stream centerlines. The reason for this is that some parts of the study areas include broad areas with minimal topographic relief, which leads to wide, shallow floodplains. An example of this scenario is presented in Figure 2-17. Note the SA/2D connection in the middle of the image, represented by the vertical black line. Also note the red breaklines, which include the centerlines in the floodplain. At the SA/2D connection, the floodplain is more than 2.5 miles wide, and three line segments are needed to capture the stream centerlines in this broad floodplain. Even though it is unusual for more than one centerline to cross an SA/2D connection, in this instance, this approach was preferred to splitting the SA/2D connections in the middle of floodplain. This approach was approved by the TWDB's independent technical review team.

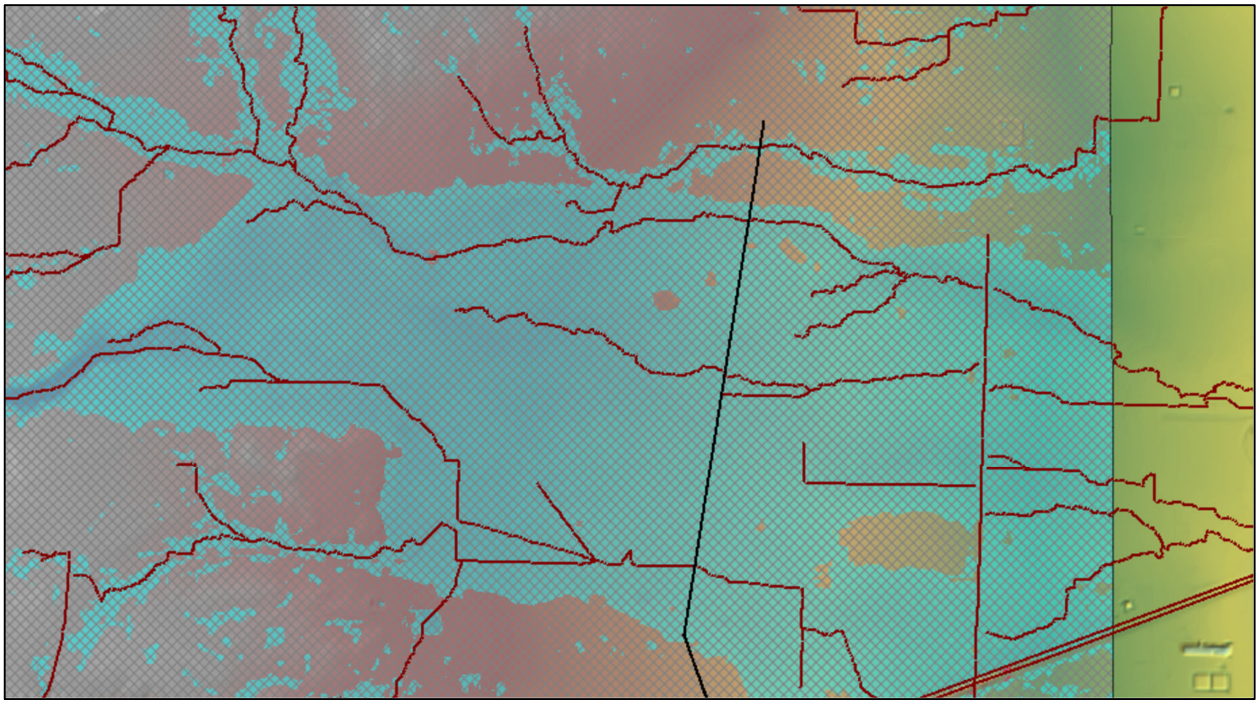

Figure 2-17: Example of an SA/2D connection crossing more than one stream centerline

In areas where the floodplain was wide and the topographic relief was minimal, the orientation of the WSEL contours indicated which way the floodwaters were flowing. Therefore, the SA/2D connections in these areas were drawn by following the WSEL contours instead of drawing them as straight lines.

The outflows from the Coyanosa model were used as inflow hydrographs into the Imperial model. The outflow hydrographs from the Coyanosa model were extracted using SA/2D connections and then placed as a flow hydrograph internal boundary condition in the Imperial model. Additionally, in order match the flow distribution between the upstream and downstream models, the SA/2D connections were split into multiple connections. Higher ground elevations that were outside of the 0.2% ACE floodplain guided the placement of the end points of the SA/2D connections. In areas where the 0.2% ACE floodplain was continuous, local high ground locations were used occasionally to split the SA/2D connections where the discharges were relatively low and the depths were shallow.

The lengths of each pair of co-located SA/2D connection and BC line were not the same. Instead, the BC line was shorter than the SA/2D connection, typically somewhere between the width of the 10% ACE floodplain and the 1% ACE floodplain. This was done to prevent the floodplain from being distributed along the full length of the SA/2D connection, which often is not realistic, especially for more frequent events. Figure 2-18 shows the location of a typical SA/2D connection. Note how the connection extends across the entire valley. In Figure 2-19, the BC line has been placed so that it is as long as the SA/2D connection. This placement results in a significantly larger floodplain than what is shown in Figure 2-18, which is not realistic. In Figure 2-20, the BC line has been shortened. Note how the width of the floodplain in Figure 2-20 is better aligned with the width shown in

Figure 2-18. Using a BC line that was shorter than the SA/2D connection produced floodplain widths that were consistent in the upstream and downstream domains.

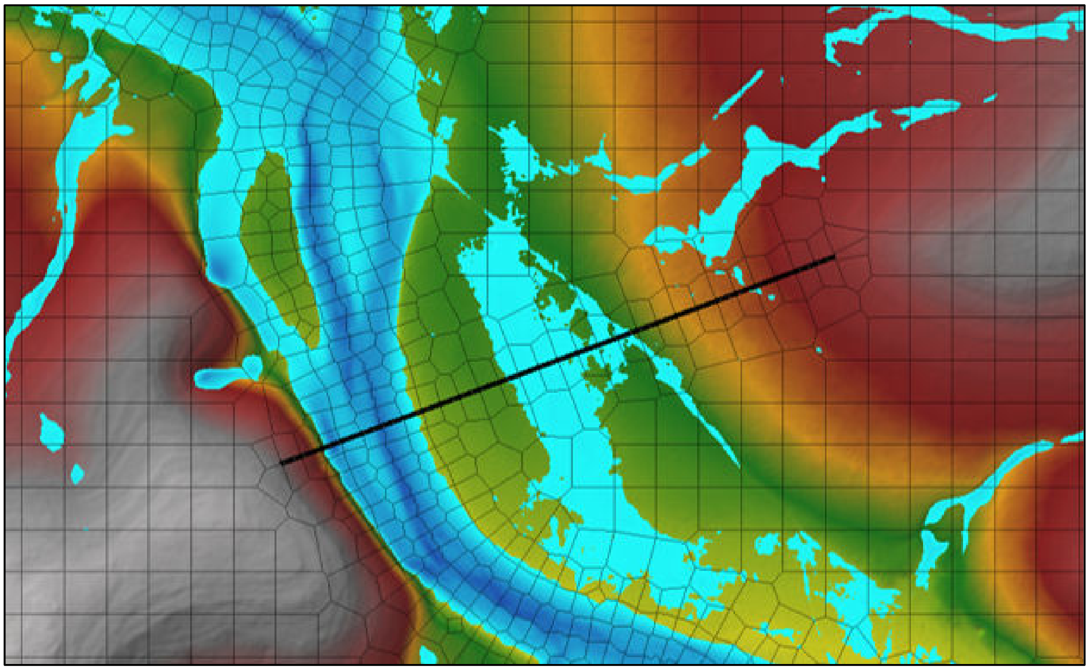

Figure 2-18: Placement of the SA/2D connection line across the entire valley

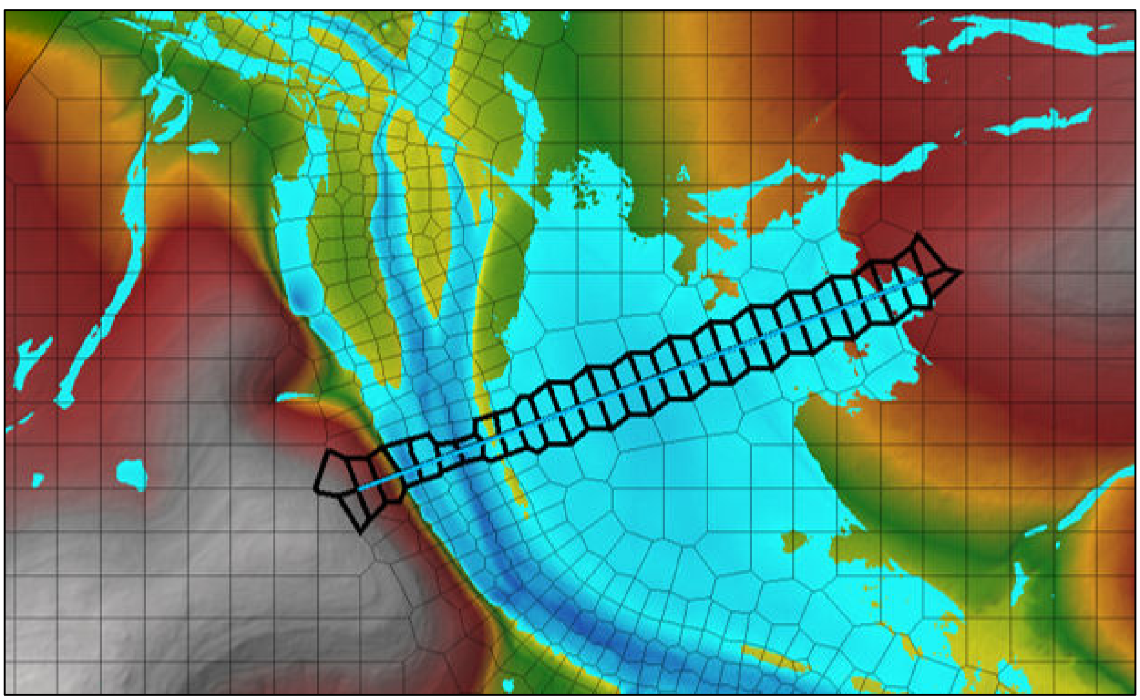

Figure 2-19: BC line with a length equal to the SA/2D connection line

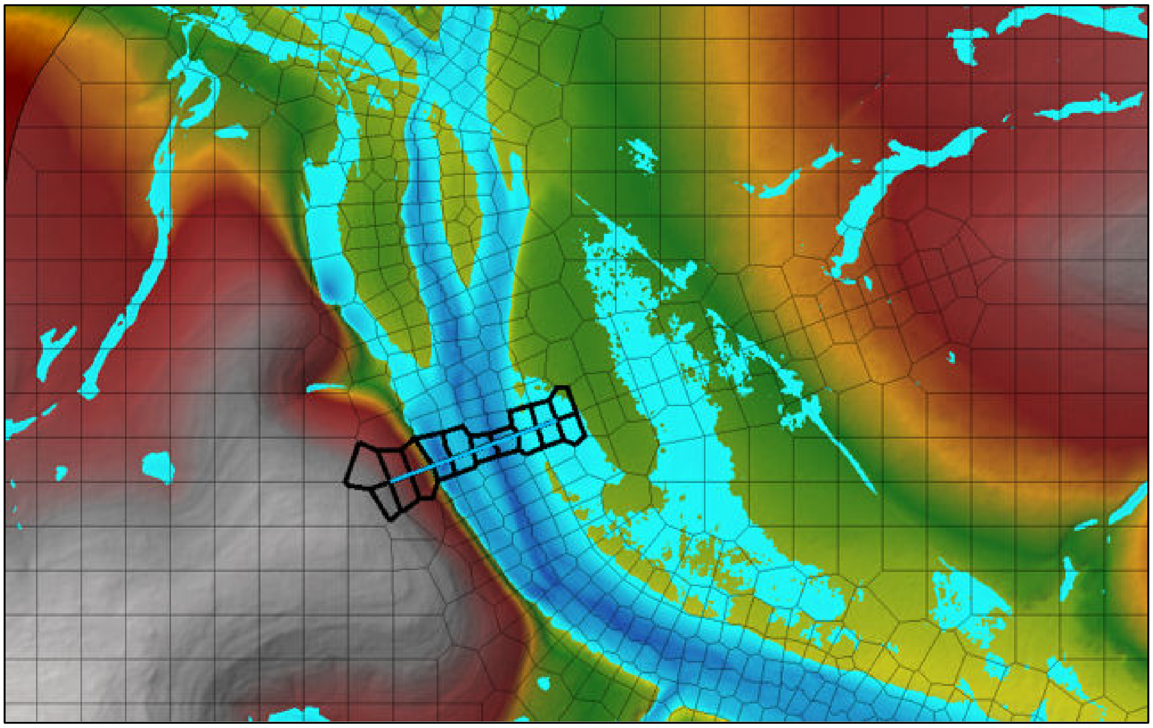

Figure 2-20: BC line with a length similar to the width of the flooding

Where one model drains into another, the water surface elevations (WSELs) for the 10%, 1%, and 0.2% ACEs must tie-in within 0.5 feet. To achieve these tie-ins, a Normal Depth boundary condition was applied at the main stem outflow location. The ground slope was used to estimate an initial normal depth. The upstream model was run and the outflow hydrograph was extracted using the SA/2D connection. This hydrograph was placed as an inflow hydrograph in the downstream model. The computed WSEL in each model were compared. If they were not within 0.5 feet, the normal depth slope was revised, and the process was repeated until the WSELs met the 0.5-foot criterion.

There are three flow transfer locations within Coyanosa-Hackberry Draws watershed where one domain drains into another. The first is at the downstream end of the Coyanosa model, where it drains into the Imperial model. The second is a breakout from the Coyanosa model into the Toyah model at Hackberry Draw. The third is a breakout from the Imperial model into the Lower Pecos-Lower model at US 285. See Figure 2-3 for these locations.

At each of these locations, there is a model overlap to facilitate the mapping tie-in. To verify the 1% WSELs between the upstream and downstream models tied-in within 0.5 feet, a difference raster was computed in the model domain overlap region by subtracting the 1% WSELs in the upper model from those in the lower model. An example of a flow transfer location is shown in Figure 2-21. The purple mapping is associated with the upper model domain and the dark green mapping is associated with the lower model domain.

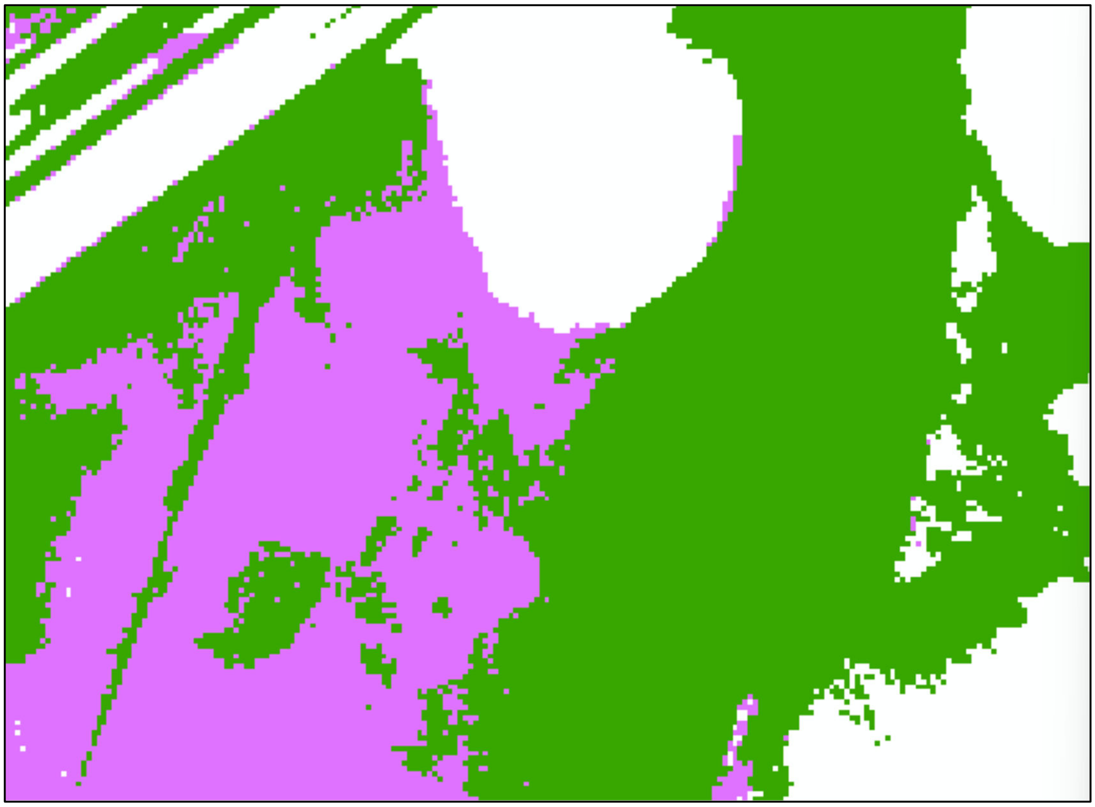

Figure 2-21: Example of overlapping mapping at a flow transfer location

Figure 2-22 shows what the difference raster looks like for this area. Light green means the WSELs are within 0.5 feet of each other and red means they are not. The blue-black line is what is known as a split line. The split line demarcates where the mapping from the upstream model will transition to the downstream model. Since this split line can be drawn so that it crosses the difference raster without touching any of the red areas, a successful WSEL tie-in with 0.5 feet can be demonstrated at this flow transfer location.

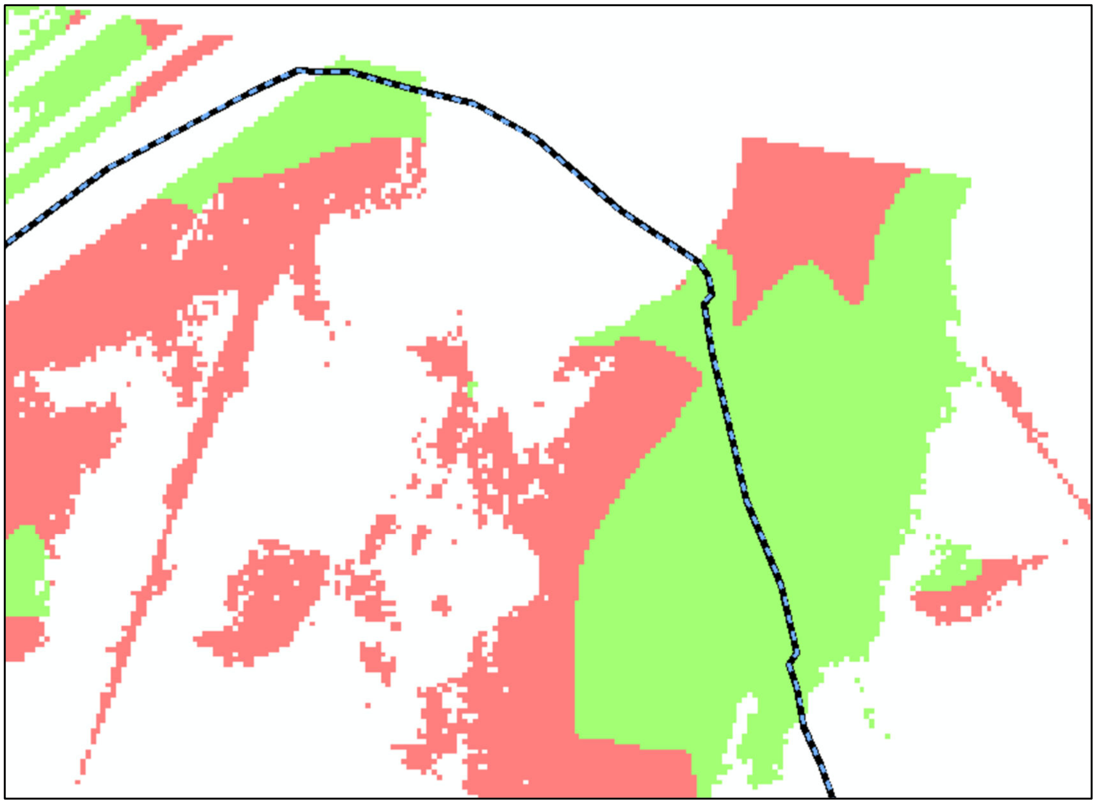

Figure 2-22: WSEL difference raster in the overlap area

At each flow transfer location, difference rasters were created for the 10%, 1%, and 0.2% ACEs to confirm that the WSELs between the models tied-in within 0.5 feet for each event.

2.8 Hydraulics

The Coyanosa-Hackberry Draws watershed was modeled using the Belding, Coyanosa, and Imperial HEC-RAS models. The hydraulic approach for the BLE analysis for the Coyanosa-Hackberry Draws watershed consisted of using the terrain model described in sections 2.1 through 2.5 in combination with the hydrology inputs described in section 2.7 to establish WSELs using a 2D analysis. HEC-RAS version 6.4.1 was chosen as the computer model to compute WSELs throughout the watershed.

2.8.1 Roughness Coefficients

Manning's roughness coefficients (n values) were defined within the infiltration layer. These values were used to compute the energy losses as the flow was routed through the 2D computational mesh in the HEC-RAS model. For this study, the overbank Manning's n values were obtained from Table 2.2 of the TWDB's *2D Base Level Engineering Guidance Version 1.0* (May 2022), as shown in Table 2-8. Manning's n values for the main channel areas were refined by adding Manning's n override regions. The extents of the override regions in the channels were established by adding a typical buffer of 150 feet to the streamlines. For larger streams, where the channel polygon widths were wider than 300 feet, the channel polygons were adjusted by reviewing the typical channel widths on the terrain surface and aerial photography. Manning's n values in the main channels were initially assumed to be 0.04 but ended up being revised in some locations during the validation task.

Table 2-8: Manning's n values for overland and overbank areas

Land Use Grid Code	NLCD Land Use Description	Typical N Value	N Value Range
11	Open Water	0.038	0.025–0.050
21	Developed, Open Space	0.040	0.030–0.050
22	Developed, Low Intensity	0.090	0.060–0.12
23	Developed, Medium Intensity	0.12	0.080–0.16
24	Developed, High Intensity	0.16	0.12–0.20
31	Barren Land	0.025	0.023–0.030
41	Deciduous Forest	0.15	0.10–0.20
42	Evergreen Forest	0.12	0.080–0.16
43	Mixed Forest	0.14	0.080–0.20
52	Shrub Scrub	0.115	0.070–0.16
71	Herbaceous	0.038	0.025–0.050
81	Hay Pasture	0.038	0.025–0.050
82	Cultivated Crops	0.035	0.020–0.050
90	Woody Wetlands	0.098	0.045–0.15
95	Emergent Herbaceous Wetlands	0.068	0.050–0.085

2.8.2 Breaklines

Breaklines were used within the 2D mesh areas 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. The purpose of breaklines is to spilt cells and align cell faces along breakline features, which prevents flow from bypassing high ground and eliminates mesh leaking.

Similarly, significant bridge and culvert crossings that were not processed out of the terrain data were modeled by modifying the terrain using burn lines that were incorporated into the HEC-RAS terrain as terrain modification features. Terrain modifications, when applied, allowed flow to pass through the bridges and culverts along the roadways. An example of a terrain modification at a culvert crossing is shown in Figure 2-23.

County, interstate, common name, state recognized, and U.S. roads were incorporated for road breaklines from the Texas Department of Transportation's (TxDOT) road database. 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 applied along the centerlines of streams with a drainage area greater than 0.3 square miles. Experience has shown that adding breaklines to a drainage area as low as 0.3 square miles leads to more continuous floodplain mapping in the upper reaches of the stream network. Although the lower stream breakline threshold increases the number of cells and leads to longer model run times, the 0.3-square-mile threshold balances computational efficiency with model refinement along the larger and better defined stream corridors.

Each streamline was topo-derived and was enforced with a cell spacing of 150 feet to align cells along the streamline and capture more detail along the stream network. Streamline alignment was also hand checked with the terrain by the modeler to verify accuracy. Stream names were referenced from other sources such as the National Flood Hazard Layer (NFHL) and the National Hydrography Dataset (NHD) datasets. In the HEC-RAS model, streams that passed through populated regions were enforced as breaklines using 150-foot cell spacing.

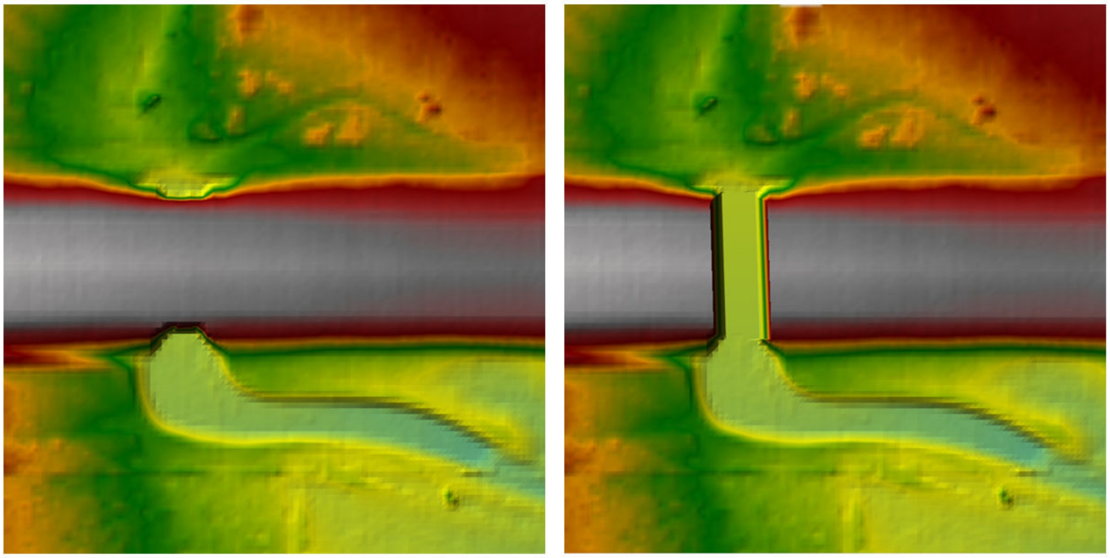

Figure 2-23: HEC-RAS terrain modification at a culvert crossing to allow flow through a roadway

Terrain modifications that were completed to hydro-enforce the terrain DEM were added using the "clone terrain" feature in HEC-RAS. This feature creates a virtual copy of the terrain that is then modified, which establishes openings through the embankments in the terrain where the hydraulic structures are located. Burn lines and other terrain adjustments are strictly for modeling purposes. The original, non-burned terrain has been used to develop the floodplain mapping. In the *Terrain* folder for each model, the original DEM has been included as a TIF file. HEC-RAS creates the file *Terrain.HDF* to work with the TIF file. The "cloned" terrain data may be found in the file *Terrain_Hydroenforced.HDF*.

2.8.3 Refinement Regions

Refinement regions were added along the stream centerlines that had a drainage area of at least 0.3 square miles. The refinements regions were inserted by buffering the centerline by 150 feet on either side of the centerline and placing a refinement region in that polygon.

Refinement regions were created for each community within the model that had a population greater than 1,000 residents. TxDOT's "cities" shapefile was used to identify such communities and their political boundaries. In the Coyanosa-Hackberry Draws watershed, the City of Alpine was the only community with a population greater than 1,000. In addition, in cases where large urban areas were not captured in the TxDOT cities extents, refinement region polygons were created by reviewing the aerial photos.

2.8.4 Special Assumptions

There were no special assumptions for the portions of the Belding, Coyanosa, and Imperial models that resided within the Coyanosa-Hackberry Draws watershed.

3 Model Results

In the Coyanosa-Hackberry Draws watershed, there was no effective mapping present in the National Flood Hazard Layer. However, there were sporadic locations throughout the watershed that were mapped with a Zone A Special Flood Hazard Area (SFHA) on FEMA's paper maps. The BLE results for the Coyanosa-Hackberry Draws watershed were compared with the digitized SFHAs. In most cases, the new BLE mapping compared reasonably well with the effective SFHAs and provided additional estimated flood risk in areas that do not currently have a SFHA mapped. Additionally, the application of rain-on-grid modeling allowed for the identification of localized flood risk beyond the extents of the traditional SFHAs.

Figure 3-1 shows a part of the watershed that has been mapped with a Zone A SFHA. This area is near the upper end of the watershed, in the vicinity of the City of Alpine. The 1% BLE mapping is blue with a 35% transparency and the SFHA is black. Overall, the SFHA mapping tends to be wider than the BLE mapping. The SFHA mapping appears to be based on 24K quad maps with contour intervals of 20 feet and 40 feet. The vertical accuracy requirement for a 40-foot contour interval is +/- 20 feet and for a 20-foot contour internal it is +/- 10 feet, so the terrain used to map the SFHA is much less accurate than the LiDAR data used to map the BLE model results. In addition, the SFHA mapping only floods the primary stream corridors, whereas the BLE mapping, derived from a 2D HEC-RAS model, includes a number of breakouts, which are common in flat arid environments. Overall, the BLE mapping is based on higher quality data that is more accurate, so it is not surprising to see some deviations.

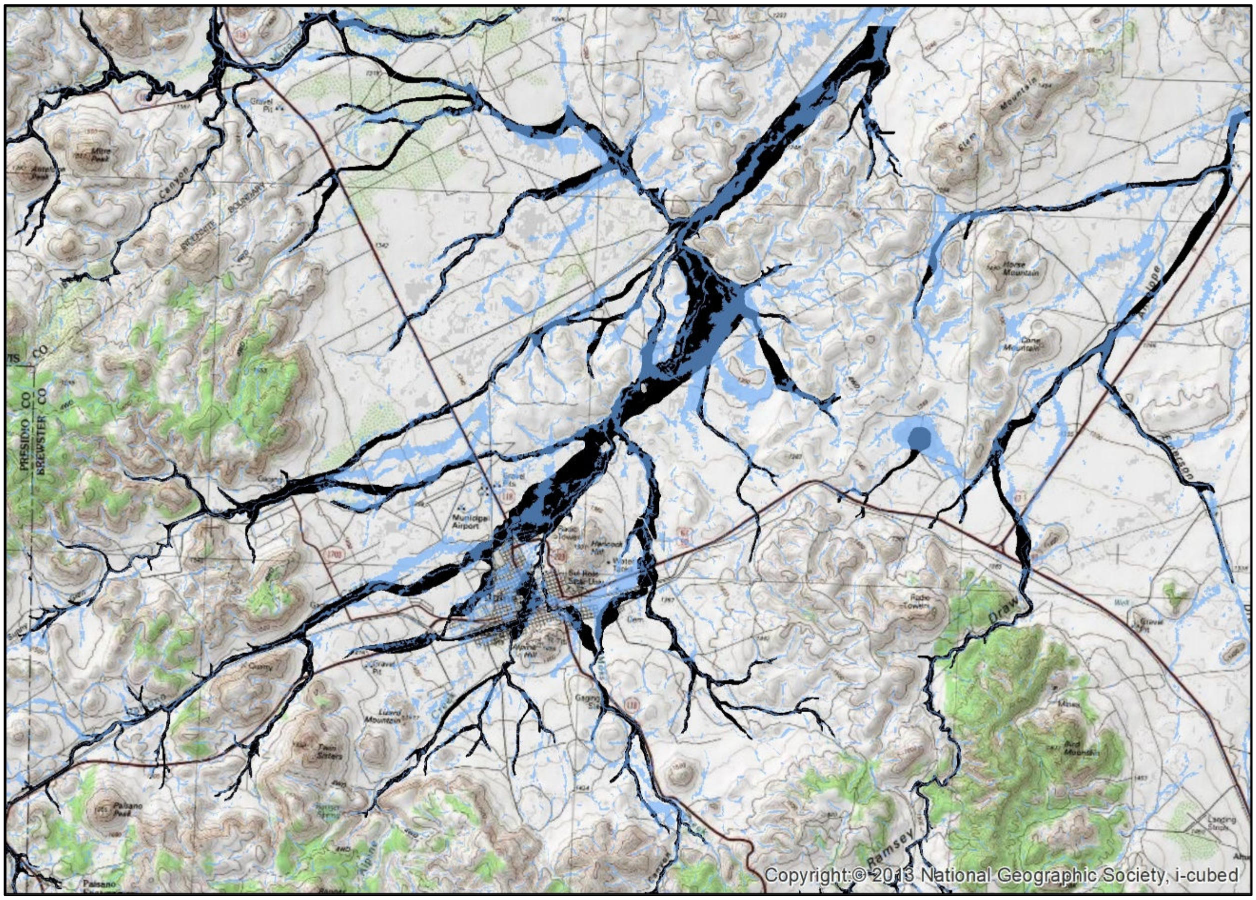

Figure 3-1: Comparison of 1% BLE mapping (light blue with 50% transparency) with digitized effective Zone A SFHA

Floodplain mapping for the Coyanosa-Hackberry Draws watershed was also available from a contractor called Fathom. The TWDB acquired cursory floodplain data from Fathom to fill gaps in areas where no floodplain mapping was available in Texas. The Fathom floodplain dataset included pluvial, fluvial, and coastal storm surges produced using models developed at a 30-meter resolution for the entire state of Texas. The 30-meter Fathom models incorporated LiDAR data provided by the TWDB and NOAA Atlas 14 rainfall data in all areas of the state. Fathom model results were mapped to a 3-meter resolution. Fluvial and pluvial cells with depths less than 0.5 feet were removed from the results of the mapping dataset. The use of this dataset should be limited to areas where no other data source has been identified or areas where flood hazard information is outdated or unreliable. Limited use of this dataset is recommended due to limitations with accuracy, resolution, and age of the underlying datasets.

The 2D BLE results for the Coyanosa-Hackberry Draws watershed were compared with the Fathom floodplain mapping. Figure 3-2 shows the 1% BLE mapping in blue with a transparency applied and the 1% Fathom mapping in black near the downstream end of the Salt Draw model domain. In general, there was good agreement between the mapping from these two sources. The mapping results line up well along the primary channel corridors. Along most of the tributaries to the main channels, there is good agreement as well. The primary difference between the two mapping sources is in the breakouts between the primary channels, where the BLE mapping shows more breakouts than the Fathom mapping does. Finally, the pluvial mapping in the BLE mapping is a little bit more extensive than what is shown in the Fathom mapping.

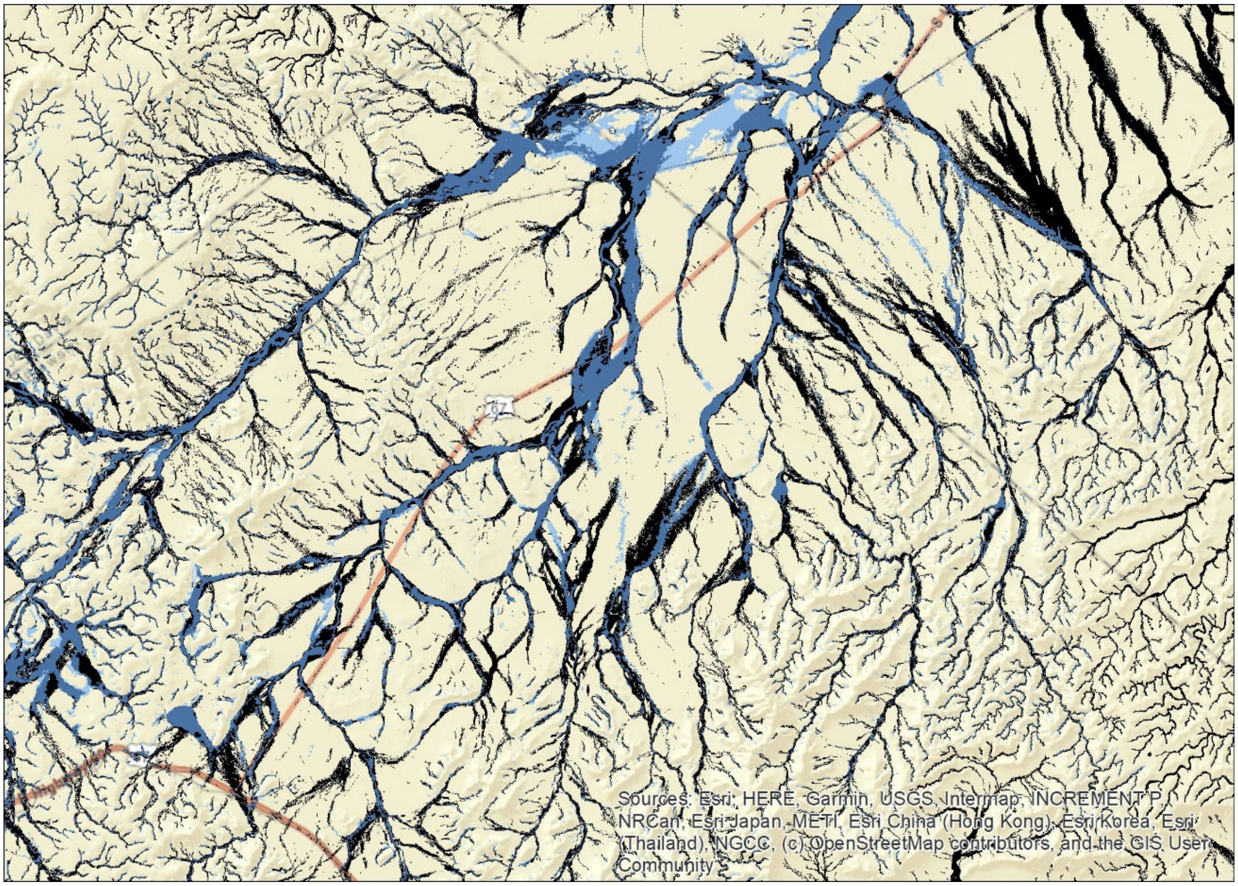

Figure 3-2: Comparison of 1% BLE mapping (light blue with 50% transparency) with Fathom 1% mapping (black) in the Coyanosa-Hackberry Draws watershed

The Coyanosa-Hackberry Draws watershed was reviewed to identify areas where SFHAs with BFEs were mapped so that a comparison could be made between the BLE model results and the effective BFEs. Within the city limits of Alpine, Texas, a number of streams were studied by FEMA using detailed methods. According to the 1990 effective FIS report for the city, the effective hydrologic analysis was performed in 1977 using a combination of TR-20 and regional regression equations. The effective hydraulic analysis was performed using WSP-2 using 2-foot topography developed in 1967.

A comparison between the effective 1% ACE peak discharge/WSELs and the BLE results revealed that the effective 1% discharge and BFEs were significantly higher than the BLE outcomes. USGS gage 08435660 on Moss Creek near Alpine is located approximately 2,500 feet upstream of the detailed study reach along Moss Creek. At the gage, the 1% BLE flow rate of 3,725 cfs compared favorably to the 1% flow rate of 2,806 cfs computed by the flow-frequency analysis of the gage. The effective discharge nearby was significantly higher at 6,329 cfs.

Unsurprisingly, this is causing the effective BFEs to be much higher than the BLE WSELs. Other differences between the effective and BLE mapping are in the vicinity of the roadway embankments in the city, where the 2D BLE model does a much better job modeling the complex flow patterns near the embankments.

The BLE results should be considered more reliable in this area because the effective study uses outdated information and techniques, while the BLE efforts incorporated superior data and modeling software whose results have been validated using the outcomes of the gage flow-frequency analysis.

Table 3-1: Effective study data vs BLE outcomes in the Coyanosa-Hackberry Draws watershed

Location	1% ACE Peak Discharge (cfs)		1% ACE Peak WSEL (ft, NAVD 88)	
	Effective Study	BLE Study	Effective Study[1]	BLE Study
Alpine Creek @ Loop Road	11,182	1,165	4,423.5	4,412.5
Moss Creek @ Avenue I	6,329	3,673	4,516.5	4,505.5
Taranto Creek @ State Route 118	10,120	1,395	4,450.5	4,446.0

1. NGVD 29 to NAVD 88 conversion of +1.45 feet.

Figure 3-3 shows the differences between the effective 1% mapping and the BLE 1% mapping in the vicinity of Alpine, Texas.

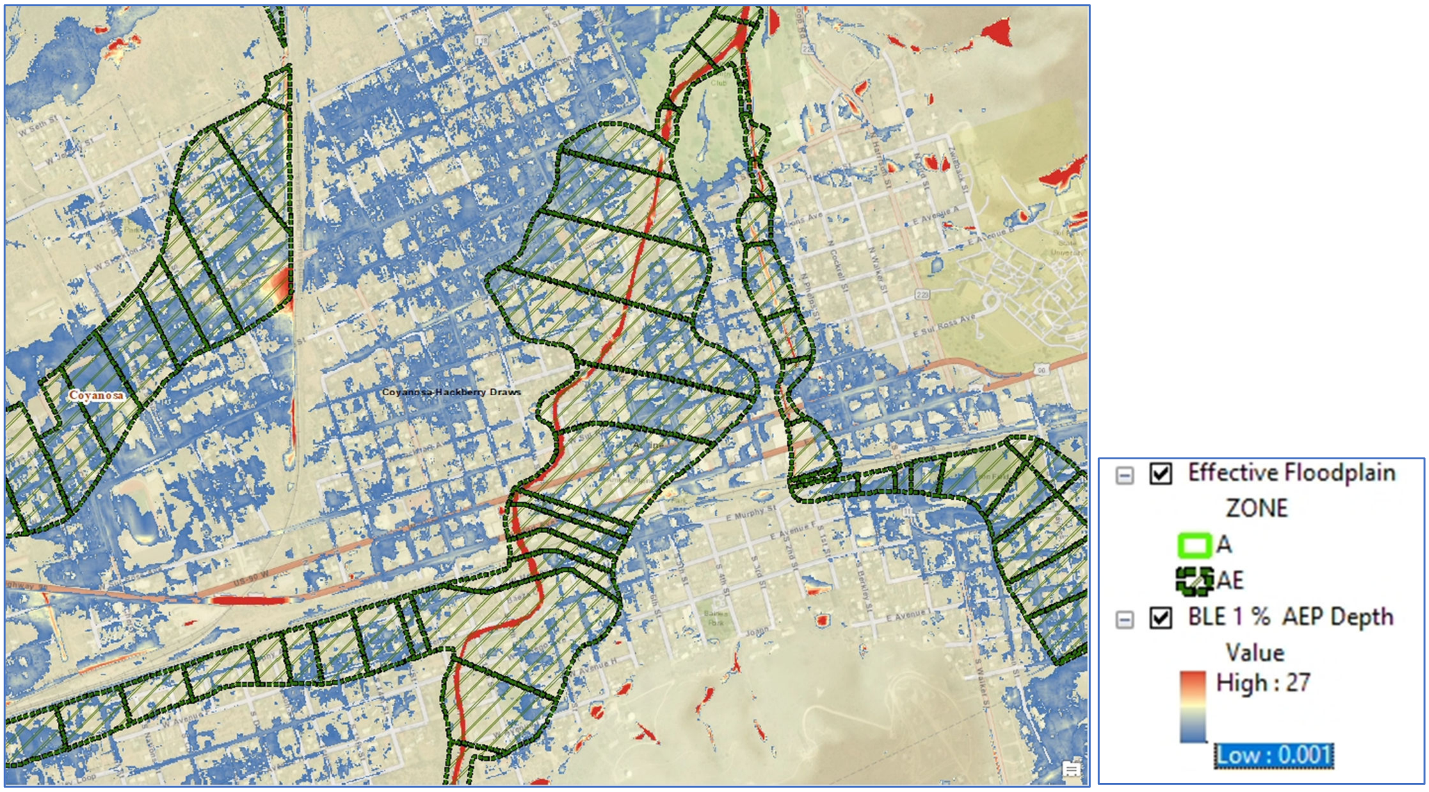

Figure 3-3: Effective SFHA and BLE 1% mapping near Alpine, Texas

Following the initial BLE hydraulic analysis in each watershed, the models were reviewed to confirm the output was reasonable. Results were reviewed to look for abnormally high velocities, mass/volume balance errors, and instabilities/oscillations. Model adjustments were made to resolve any issues that had been identified.

3.1 Validation and Sensitivity Analysis

The BLE models developed in the study area (see Figure 1-2) were validated using two approaches. The first approach was a gage flow-frequency analysis of a number of USGS streamflow gages located within the study area. The second approach leveraged the outcomes of this flow-frequency analysis to develop discharge-drainage area curves that were applied to select ungaged streams in the study area.

3.1.1 Validation of BLE Results Using a Gage Flow-Frequency Analysis

The AtkinsRéalis BLE study area for this task order included the Pecos River main steam from approximately the Texas-New Mexico state border to Girvin, TX and the watersheds that drained into this reach of the Pecos River. The study area included a network of ten interconnected HEC-RAS 2D BLE models where outflows from each model were applied as inflows into the downstream model to obtain the combined discharge for the Pecos River near Girvin, TX. The model validation effort first focused on validating the results along the tributaries to the Pecos River and then a global validation approach was applied to achieve valid results along the Pecos River through the downstream end of the study area. The validation process was iterative with a goal of generating BLE 1% discharges that were within the bounds of the gage 1% plus and 1% minus discharges in the study area.

Three primary model validation parameters were selected for this study. These are the model parameters that were varied to improve the validation outcomes of this BLE assessment. The parameters were the rainfall areal reduction factor (ARF), the NRCS Curve Numbers (CN), and the channel Manning's n values. The rainfall ARF was the primary validation parameter since it had the greatest effect on BLE outcomes. A rainfall ARF of 5% was applied to all model domains except for three model domains in the Landreth-Monument Draws HUC-8 watershed (Monument, Monahans, and Imperial).

The CNs were the second model parameter that was adjusted to refine the validation results. Since this West Texas study area is arid (10 to 15 inches of rain per year), the CNs were typically based on AMC I conditions. However, for the high-altitude mountainous areas in the headwaters of some of the watersheds, AMC II conditions were assumed since the AMC I CNs led to modeled discharges that were too low in the Coyanosa, Lower Pecos-Upper, and Toyah models. AMC II CNs were applied in the mountainous upper reaches of these models to improve the model results. The areas where these adjustments from AMC I to AMC II were made are shown on Figure 3-4.

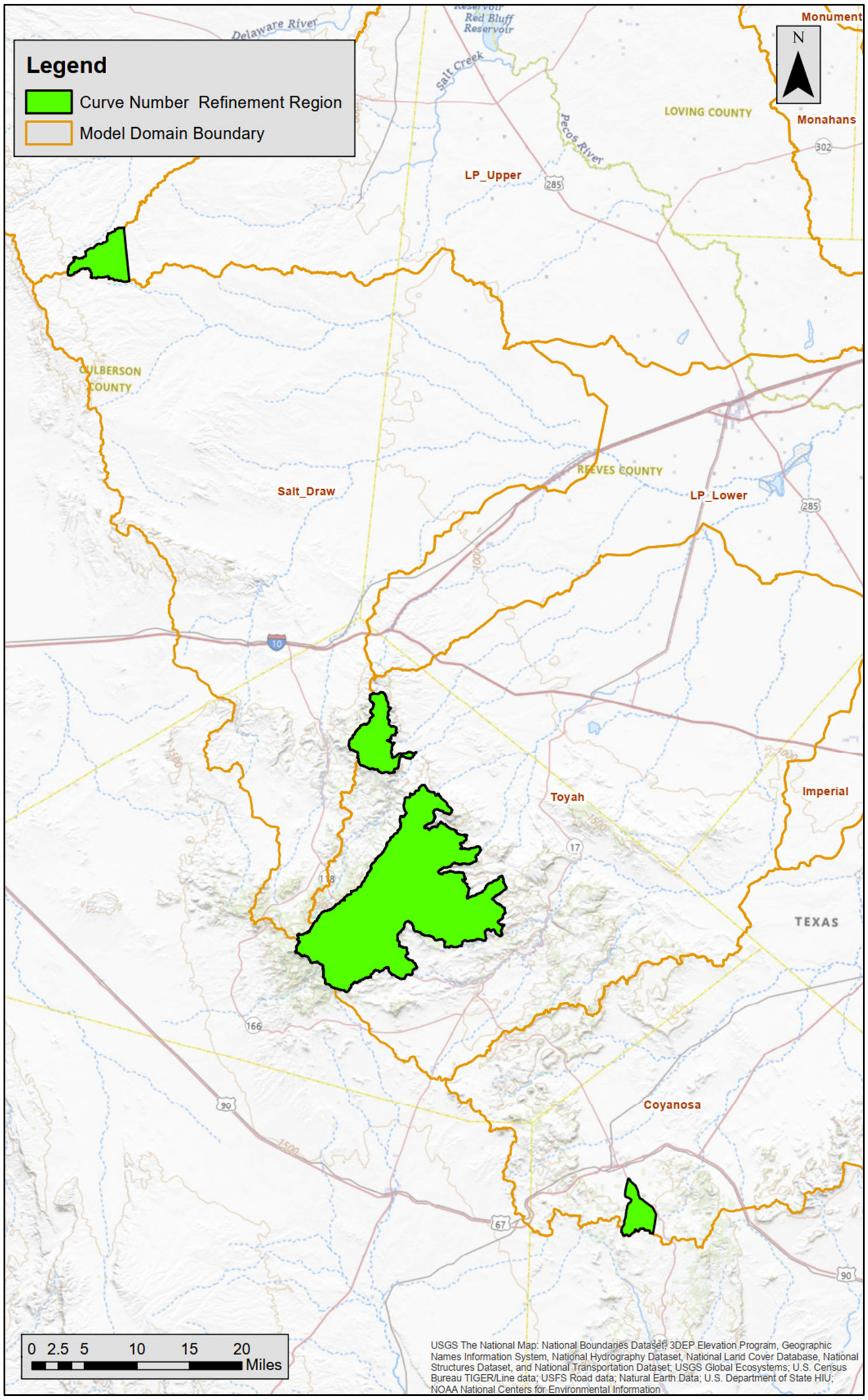

Figure 3-4: Mountainous areas where AMC II conditions were assumed

Throughout the study area, the model results were sensitive to the CN assignments, and adjusting the CNs to AMC II from AMC I conditions significantly increased the computed discharges.

Therefore, AMC II CNs (shown in Table 2-7) were applied only in limited parts of the study area to prevent excessive increases in the discharges along the larger rivers.

The channel Manning's n values were the third model parameter that was revised to improve the validation results. These revisions were applied mostly to adjust the timing of the runoff hydrographs in the models instead of the magnitude of the discharges in these hydrographs. The channel Manning's n values were increased from their default value of 0.04 to between 0.045 and 0.055. These adjustments shifted the timing of the runoff hydrographs to prevent the hydrographs from unrealistically peaking at the same time and to improve the alignment of the modeled discharges with the discharges computed by the gage flow-frequency analysis.

After the initial BLE model runs, before any adjustments were made to the rainfall ARF, the CNs, or the channel Manning's n values, the discharges along the tributaries to the Pecos River were generally reasonable, if a little low, but they were significantly overestimated at the gages along the Pecos River and at the gages located in the downstream reaches of Toyah Creek, Barilla Draw, and Coyanosa Draw. To lower the discharges along these larger rivers, the model parameters were revised as shown in Table 3-2. These adjustments lowered the discharges along both the Pecos River and the tributaries that drain into the river. Therefore, care was applied when making these revisions to lower the discharges along the Pecos River below the 1% plus gage discharges along the river while also keeping the discharges along the tributaries above the 1% minus gage discharges along the tributaries.

However, after adjusting the three primary validation parameters, the discharges along the Pecos River main stem downstream of the confluence of Salt Draw and the Toyah watershed (near Pecos, Texas) remained too high. Further adjustments to the rainfall ARFs, CNs, or Manning's n values were considered unacceptable since they would lead to parameters that were unrealistic. To identify options to lower the discharges along the Pecos River further, research was completed to understand how the runoff discharges were combining as they left the different models and entered the Pecos River. It was observed that the runoff from the Salt Draw, Toyah, and Lower Pecos-Upper models were peaking at roughly the same time in the river, leading to an overprediction of flows in the river. These simultaneous peaks were not realistic since it would require a storm large enough to flood southern New Mexico and the Delaware, Lower Pecos-Upper, Lower Pecos-Lower, Salt Draw, and Toyah models simultaneously. Through trial and error, it was observed that delaying the hydrograph from the Lower Pecos-Upper model that enters the Lower Pecos-Lower model by 24 hours and the hydrograph from the Salt Draw model that enters the Lower Pecos-Lower model by 12 hours produced results that satisfactorily lowered the discharges along the Pecos River so they aligned better with the outcomes of the gage flow-frequency analysis.

Table 3-2: Summary of adjustments made to the BLE models to support validation

Model Domain	Precipitation Adjustment	Curve Number [1]	Channel Manning's n	Outflow Hydrograph Shift
Delaware	5% ARF	AMC I	All channels - 0.04	0
LP Upper	5% ARF	AMC I - Majority of domain AMC II - In mountain headwaters	Pecos River Main Stem - 0.05 River Tribs - 0.045	24 hours
LP Lower	5% ARF	AMC I	Pecos River Main Stem - 0.055 River Tribs - 0.045	0
Salt Draw	5% ARF	AMC I	All channels - 0.05	12 hours
Toyah	5% ARF	AMC I – Majority of domain AMC II – In the steep parts of the Davis Mountains	All channels - 0.04	0
Coyanosa	5% ARF	AMC I - Majority of domain AMC II – In the steep parts of the Puertacita Mountains	All channels - 0.04	0
Belding	5% ARF	AMC I	All channels - 0.04	0
Monument	No reduction	AMC I	All channels - 0.04	0
Monahans	No reduction	AMC I	All channels - 0.04	0
Imperial	No reduction	AMC I	All channels - 0.04	0

Notes:
1. A minimum AMC I CN value of 30 was used per guidance from the USGS.

The BLE models were validated by comparing the model discharges to the discharges computed by a flow-frequency analysis of the USGS flow gages in the study area. A comparison of the BLE 1% discharges versus the 1%, 1% plus, and 1% minus discharges from the gage flow-frequency analysis is shown in Table 3-3 on the following page.

The information in this table was leveraged to create discharge-drainage area plots for the gages along the tributaries to the Pecos River (Figure 3-5) and for the gages along the river (Figure 3-6). As seen in Table 3-3, along the Pecos River tributaries, the computed BLE 1% discharges were between the 1% plus and 1% minus gage discharges at 8 out of 10 gages. Along the Pecos River, the BLE 1% flow was between the 1% plus and 1% minus gage discharges at 3 out of 4 gages.

Table 3-3: Comparison of BLE 1% discharges with the gage 1%, 1% minus, and 1% plus discharges

USGS Gage ID	Gage Location	Drainage Area at Gage (mi^2)	No. of Records for Gage Analysis	BLE 1% Flow (cfs)	Gage 1%- Flow (cfs)	Gage 1% Flow (cfs)	Gage 1%+ Flow (cfs)
Pecos River Tributaries							
08408500	Delaware River nr Red Bluff, NM	783	86	65,698	51,310	71,830	111,000
08411500	Salt Screwbean Draw nr Orla, TX	498	15	21,968	22,180	38,010	91,880
08424500	Madera Canyon nr Toyahvale, TX	56	18	13,845	7,453	11,450	21,410
08431700	Limpia Ck abv Ft Davis, TX	37	26	8,212	11,180	20,860	61,360
08431800	Limpia Ck bl Ft Davis, TX	213	17	15,832	8,327	11,400	17,180
08433000	Barrilla Draw nr Saragosa, TX	570	28	19,523	9,608	16,950	43,040
08434000	Toyah Ck bl Toyah Lk nr Pecos, TX	3,218	12	21,692	12,260	35,440	184,700
08435660	Moss Ck nr Alpine, TX	10	19	3,730	1,876	2,806	5,328
08435800	Coyanosa Draw nr Ft Stockton, TX	1,163	14	11,398	8,412	14,980	37,650
08437620	Monument Draw Trib nr Monument, TX	17	14	994	552	1,223	4,495
Pecos River Main Stem							
08412500 [1]	Pecos Rv nr Orla, TX (After 1987)	21,229	36	19,540	5,848	10,900	29,550
08420500 [2]	Pecos Rv at Pecos, TX (All Records)	22,100	30	19,082	13,100	20,500	47,340
08441500 [2]	Pecos Rv bl Grandfalls, TX (All Records)	26,110	20	26,351	5,831	10,220	25,440
08446500 [2]	Pecos Rv nr Girvin, TX (All Records)	29,560	84	24,528	7,017	11,560	25,790
Number of gages evaluated						**14**	
Number of gages within bounds (Valid)						**11**	
Number of gages outside of bounds (Not Valid)						**3**	

Notes:

1. For USGS gage 08412500 on the Pecos River at Orla TX, only flow records after 1987 were used due to the construction of Brantley Dam, which regulates flows this part of the Pecos River.
2. For the USGS gages on the Pecos River at Pecos, Grandfalls, and Girvin, TX, the flow rates along this part of the Pecos River are controlled by the runoff from the Toyah, Salt Draw and Barrilla Draw HUC-8 watersheds and not the discharges that exit Brantley Dam. Therefore all gage records, including those prior to the construction of Brantley Dam, were applied in the flow-frequency analyses of these gages.

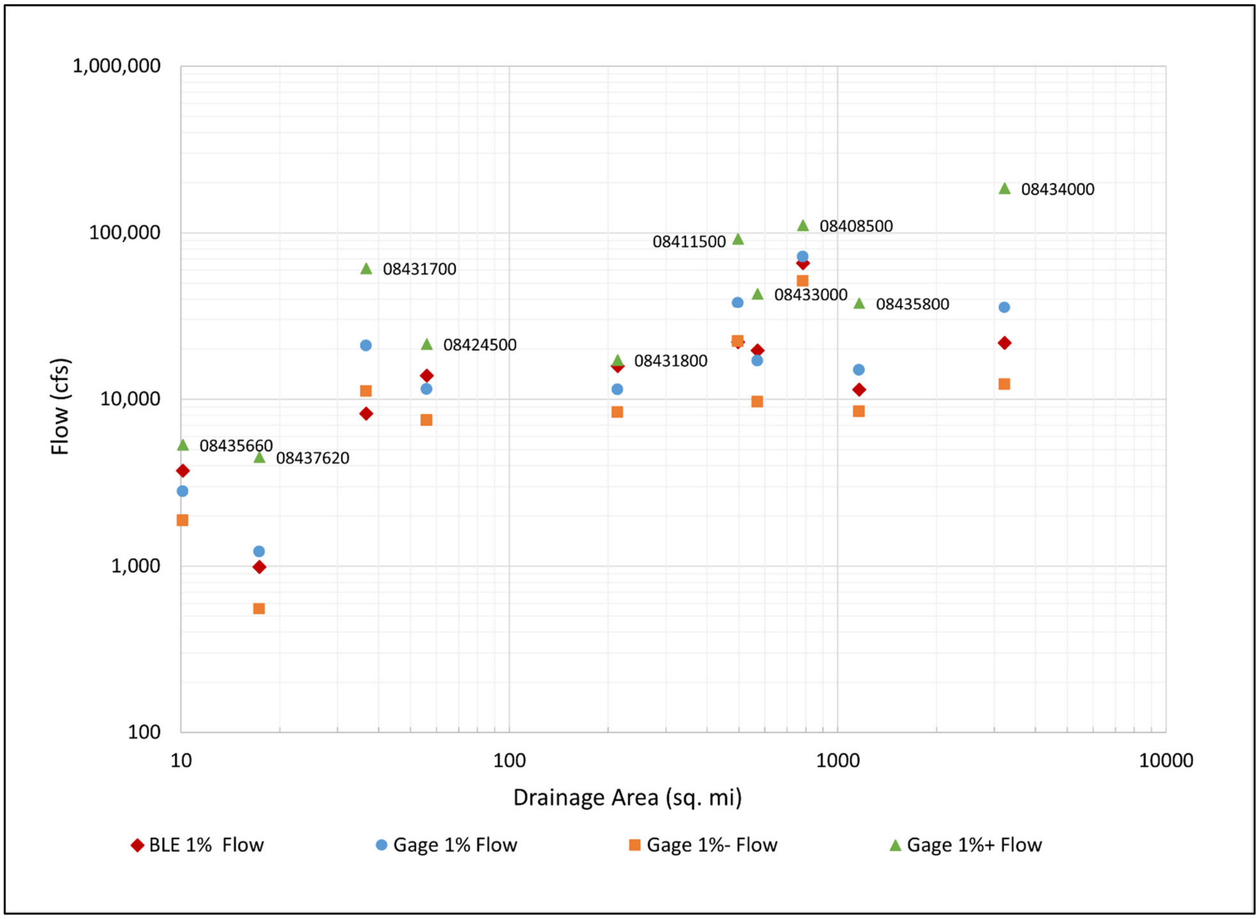

Figure 3-5: Comparison of BLE 1% discharges with the gage 1%, 1% minus, and 1% plus discharges for the gages along the Pecos River tributaries

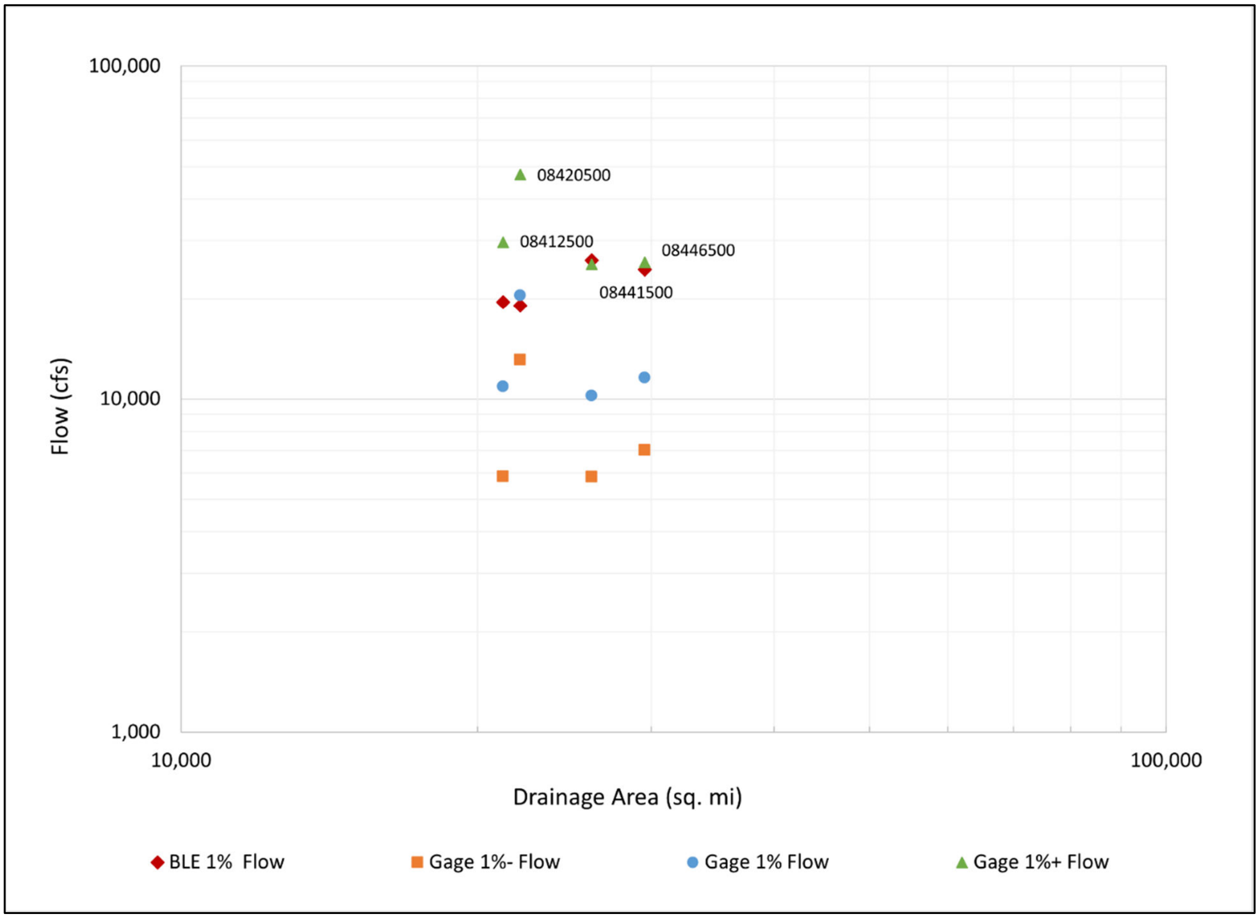

Figure 3-6: Comparison of BLE 1% discharges with the gage 1%, 1% minus, and 1% plus discharges for the gages along the Pecos River

At 3 of the 14 gages, the BLE 1% discharge was outside of the bounds between the 1% plus and 1% minus discharges computed by the flow-frequency analysis. Explanations for why this is happening follow.

- Gage 08411500 (Salt Screwbean Draw nr Orla, TX) – The flow-frequency discharges computed at this gage appear to be overestimated. The flow record at this gage is heavily skewed by the October 1955 peak of 40,600 cfs. USGS gage 08412500 (Pecos River at Orla, TX) is located just downstream of the confluence of Salt Screwbean Draw and the Pecos River. During the same event in October 1955, a much lower peak discharge of 8,050 cfs was recorded at the Pecos River at Orla gage. Therefore, the BLE model was validated against a 1% minus discharge of approximately 22,000 cfs at the Salt Screwbean Draw gage, which excluded the peak discharge of 40,600 cfs from the flow-frequency calculations. Including the October 1955 event in the analysis produced a 1% minus discharge of 38,000 cfs, which was concluded to be too high.

- Gage 08431700 (Limpia Ck abv Ft Davis, TX) - The flow-frequency discharges computed at this gage appear to be overestimated for the following reasons:

    - The drainage area for gage 08431700 is 37 square miles. There is another USGS gage on Limpia Creek downstream of Fort Davis (08431800) where the drainage area is 213 square miles. The 1% discharge computed by the flow-frequency analysis for gage 08431700 was 20,860 cfs, while the 1% discharge computed for the downstream gage was 11,400 cfs. A review of the terrain and aerial photography data for this area did not see any reason why the flow would decrease so significantly as it moves downstream.

    - Gage 08424500 (Madera Canyon nr Toyahvale, TX), also located in the vicinity of gage 08431700, has a contributing area that is larger than that of gage 08431700 (56 square miles versus 37 square miles). Even though its contributing area is larger, the flow-frequency analysis computed a 1% discharge of 11,450 cfs compared to the 1% discharge of 20,806 cfs at gage 08431700.

    - Because there were 2 gages near gage 08431700 with drainages areas greater than the drainage area at gage 08141700 yet had 1% gage discharges that were less than the 1% discharge at gage 08141700, it was concluded that the flow-frequency analysis for gage 08431700 produced discharges that were unrealistically high.

- Gage 08441500 (Pecos Rv bl Grandfalls, TX) – The BLE 1% discharge of 26,110 cfs was only slightly above the 1% plus gage discharge of 25,440 cfs. This difference is less than 3%. After adjusting the rainfall ARFs, the CNs, and the channel Manning's n values upstream of this gage, the peak discharges in this reach of the Pecos River were still significantly higher than the 1% plus flow rates along the river. Additional adjustments to the rainfall ARFs or the CN values to lower the discharges along the Pecos River were not considered feasible since they would have led to rainfall totals or CNs that were unrealistic. In addition, these adjustments would also start to lower the BLE 1% discharges along the Pecos River tributaries below the 1% minus discharges from the gage flow-frequency analysis. Therefore, the outflow hydrographs from the Lower Pecos-Upper and Salt model domains were shifted as described above to reduce the peak discharges for the USGS gages below Grandfalls, TX and at Girvin, TX. This produced BLE 1% discharges just above the gage 1% plus discharge at Grandfalls, TX and just below the gage 1% plus discharge at Girvin, TX, which was considered acceptable.

Figure 3-7 includes a map showing where the 14 gages included in the flow-frequency analysis are located. It also documents where the BLE 1% discharge fell between the gage 1% plus and gage 1% minus discharges (green dots), where the BLE 1% discharge was higher than the gage 1% plus discharge (blue dot), and where the BLE 1% discharge was lower than the gage 1% plus discharge (red dot).

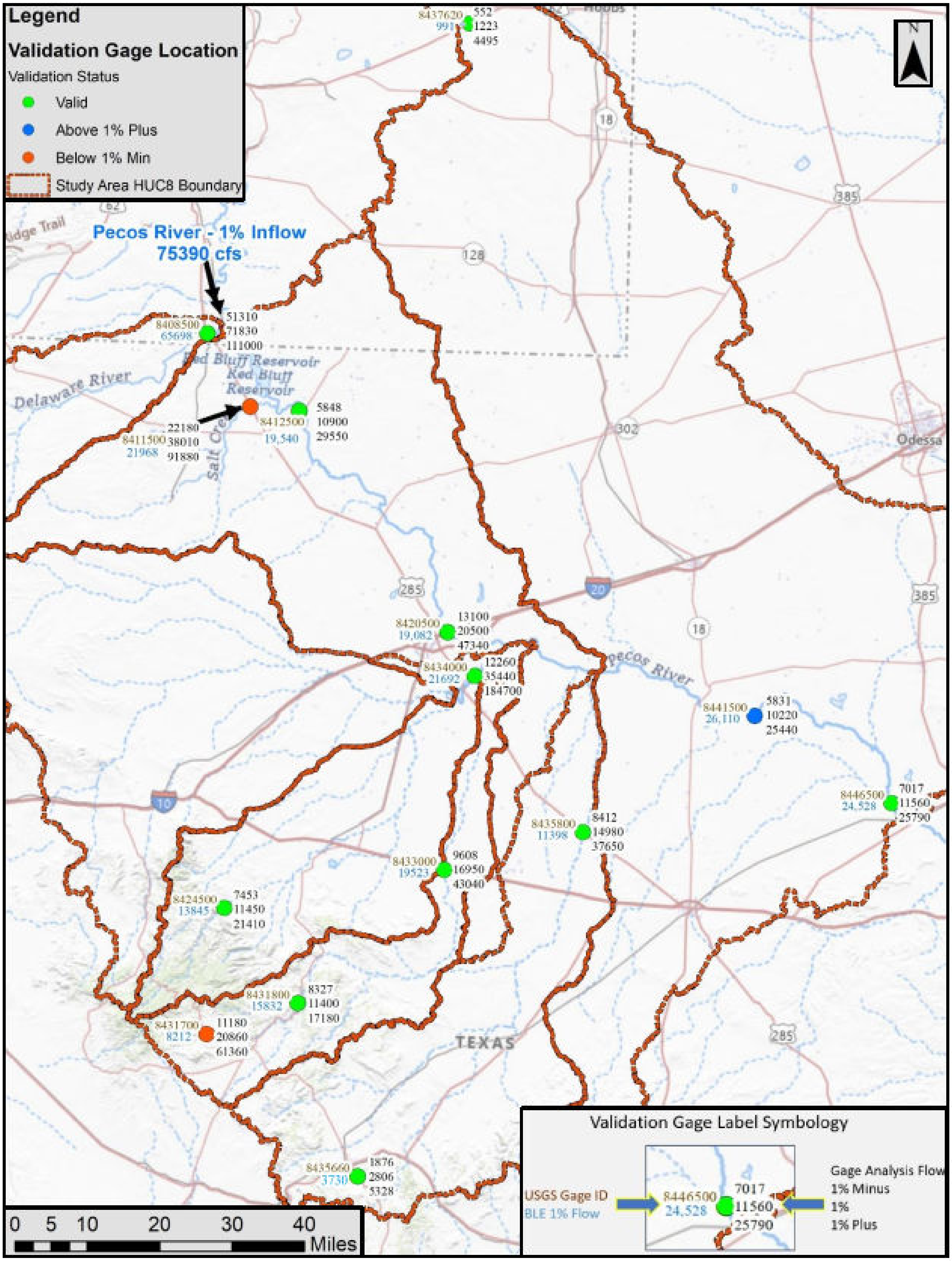

Figure 3-7: Map of the USGS gages used in the flow-frequency analysis and their validation outcomes

3.1.2 Validation of BLE Results Using Discharge-Drainage Area Curves

Even though the study area is nearly 15,000 square miles, because of the area's rural nature, there were only 14 USGS gages that had a flow record adequate for a flow-frequency analysis. To validate the BLE discharges in the parts of the study area where gage data was not available, a second validation approach was applied. Oftentimes, USGS regression equations can be applied to validate BLE outcomes. However, USGS regression equations include drainage area as a parameter, and it was difficult to compute reliable drainage areas in significant parts of this study area because of the unpredictable flow paths caused by the flat terrain. In addition, the extensive presence of playa-like features throughout the Landreth-Monument Draws watershed, which capture runoff and prevent it from heading downstream, invalidated the results of the regression equations in the eastern half of the study area.

Instead of using regression equations to validate ungaged portions of the study area, discharge versus drainage area curves were developed using the outcomes of the flow-frequency analysis of the 14 USGS gages. These curves were then used to validate the BLE 1% discharges in ungaged areas.

To develop the curves, the gage 1% plus and 1% minus discharges were plotted against the gage drainage areas. Only those gages with more than 15 years of record were included. The gage results were carefully screened to account for regulated discharges, outlier discharges, and the topography of the area that contributed to the gage. Trendlines for the 1% plus and 1% minus gage discharges were computed using the trendline option in Microsoft Excel. The intent of these trendlines was to establish 1% plus and 1% minus discharges for ungaged locations in the BLE study area.

Next, the BLE 1% discharges at the ungaged model validation locations shown in Figure 3-10 were plotted against the drainage areas upstream of the validation points. Then the Excel trendlines for the 1% plus and 1% minus gage discharges were added to the plot. See Figure 3-8 for the plot of the 1% BLE discharges at the ungaged model validation locations and the trendlines.

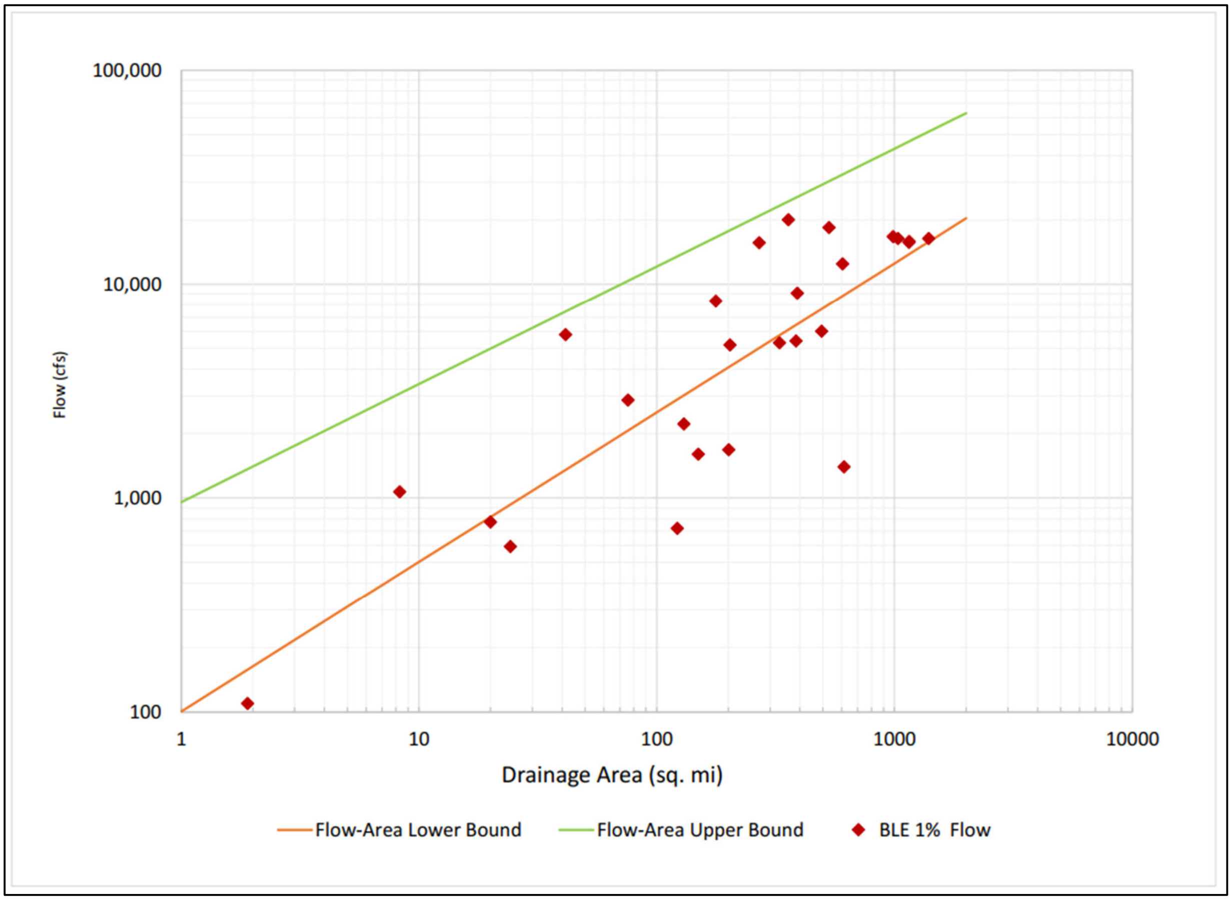

Figure 3-8: BLE 1% discharges at ungaged validation locations with 1% plus and 1% minus trendlines from the USGS gage flow-frequency analysis

Figure 3-8 was created using Table 3-4, where the BLE 1% discharges and drainage areas are documented for each ungaged validation location. The lower bound discharge is the 1% discharge along the trendline derived from the gage 1% minus discharges at the drainage area of the validation location. Likewise, the upper bound discharge is the 1% discharge along the trendline derived from the gage 1% plus discharges at the drainage area of the validation location. Ideally, the BLE 1% discharges would fall between the lower bound and upper bound discharges derived from the 1% minus and 1% plus gage discharges.

Table 3-4: BLE 1% discharges at ungaged validation locations with estimated 1% plus and 1% minus discharges derived from the USGS gage flow-frequency analysis

ID	Location Name (BLE Model and Validation Point)	Contributing Drainage Area (mi²)	BLE 1% Flow (cfs)	Flow Area - Lower Bound (cfs)	Flow Area - Upper Bound (cfs)	HUC-8 Watershed
1	Toyah: OF3_BRLLDRW_003	177	8,329	3,744	16,593	Barrilla Draw
2	Coyanosa: OF1_COYA_006	1,150	15,719	13,827	46,493	Coyanosa-Hackberry Draws
3	Coyanosa: ValidationPT2	390	9,091	6,495	25,620	Coyanosa-Hackberry Draws
4	Coyanosa: ValidationPT4	130	2,218	3,018	13,998	Coyanosa-Hackberry Draws
5	Delaware: 8407800	41	5,800	1,357	7,451	Delaware
6	Delaware: SA2D Conn 1	8.3	1,068	442	3,075	Delaware
7	Monument: 08436000	20 [1]	772	816	4,991	Landreth-Monument Draws
8	Monument: Outflow_MONU_007	613 [1]	1,397	8,913	32,883	Landreth-Monument Draws
9	Monument: SA2D Conn 1	201 [1]	1,681	4,085	17,772	Landreth-Monument Draws
10	Monument: SA2D Conn 3	24 [1]	593	934	5,548	Landreth-Monument Draws
11	Monahans: SA2D Conn 3	1.9 [1]	110	158	1,365	Landreth-Monument Draws
12	Belding: SA2D1_FM2037_007	203	5,180	4,124	17,908	Landreth-Monument Draws
13	Belding: SA2D2_I-10_007	385	5,415	6,444	25,461	Landreth-Monument Draws
14	Belding: SA2D4_LEONCR_007	494	6,012	7,665	29,195	Landreth-Monument Draws
15	LP Upper: SA2D4_CR433_001	76	2,866	2,068	10,390	Lower Pecos - Red Bluff Reservoir
16	LP Upper: SA2D5_FM2119_001	270	15,652	5,019	20,907	Lower Pecos - Red Bluff Reservoir
17	LP Upper: SA2D6_US285_001	122	721	2,886	13,515	Lower Pecos - Red Bluff Reservoir

ID	Location Name (BLE Model and Validation Point)	Contributing Drainage Area (mi²)	BLE 1% Flow (cfs)	Flow Area - Lower Bound (cfs)	Flow Area - Upper Bound (cfs)	HUC-8 Watershed
18	Salt Draw: OF1_SLDR_004	1,152	15,834	13,844	46,539	Salt Draw
19	Salt Draw: OF4_CTWD_004	530	18,433	8,049	30,342	Salt Draw
20	Salt Draw: SLDR_valid_loc_1	605	12,446	8,830	32,640	Salt Draw
21	Salt Draw: SLDR_valid_loc_2	358	20,014	6,121	24,448	Salt Draw
22	Salt Draw: SLDR_valid_loc_3	328	5,299	5,761	23,309	Salt Draw
23	LP Lower: SA2D1_FM2903_001	150	1,602	3,328	15,119	Salt Draw
24	LP Lower: SA2D2_SLDRW_001	1,394	16,349	15,813	51,683	Salt Draw
25	LP Lower: SA2D3_TYHCR_001	1,034	16,359	12,838	43,849	Toyah
26	Toyah: OF1_TYHCRK_003	986	16,712	12,419	42,716	Toyah
Number of locations evaluated						**26**
Number of locations within bounds (Valid)						**15**
Number of locations outside of bounds (Not Valid)						**11**

Notes:

1. Contributing area at this location was estimated by reviewing topography and floodplain extents as portions of the upstream watershed are not contributing flow.

Table 3-4 shows that the BLE 1% discharges fell between the lower and upper bounds of the gage discharge curves at 15 of the 26 ungaged validation locations. However, if the validation locations for the Landreth-Monument Draws watershed are removed from the totals, the results improve, and the BLE 1% discharges are between the lower and upper bounds at 14 out of 18 validation locations. Achieving valid BLE 1% discharges at 14 out of the 18 ungaged validation locations was considered acceptable for a BLE study.

For the Landreth-Monument Draws watershed, Table 3-4 shows that the BLE 1% discharges at 7 of the 8 ungaged validation locations in the watershed are below the lower bound discharges. While this might initially appear to be a negative validation outcome, these results are actually realistic because of the unusual features in the watershed. First, the low rainfall totals caused by the arid climate and the high infiltration rates of the soils that are common in the watershed lead to depressed runoff volumes. Second, the terrain in the watershed causes the flows to be lower than would be expected. Throughout the watershed are numerous playa-like features that intercept runoff and decrease the peak discharges in the watershed. See Figure 3-9, which shows part of the Monument model domain, for a representative example of how prevalent the playa-like features are in the watershed.

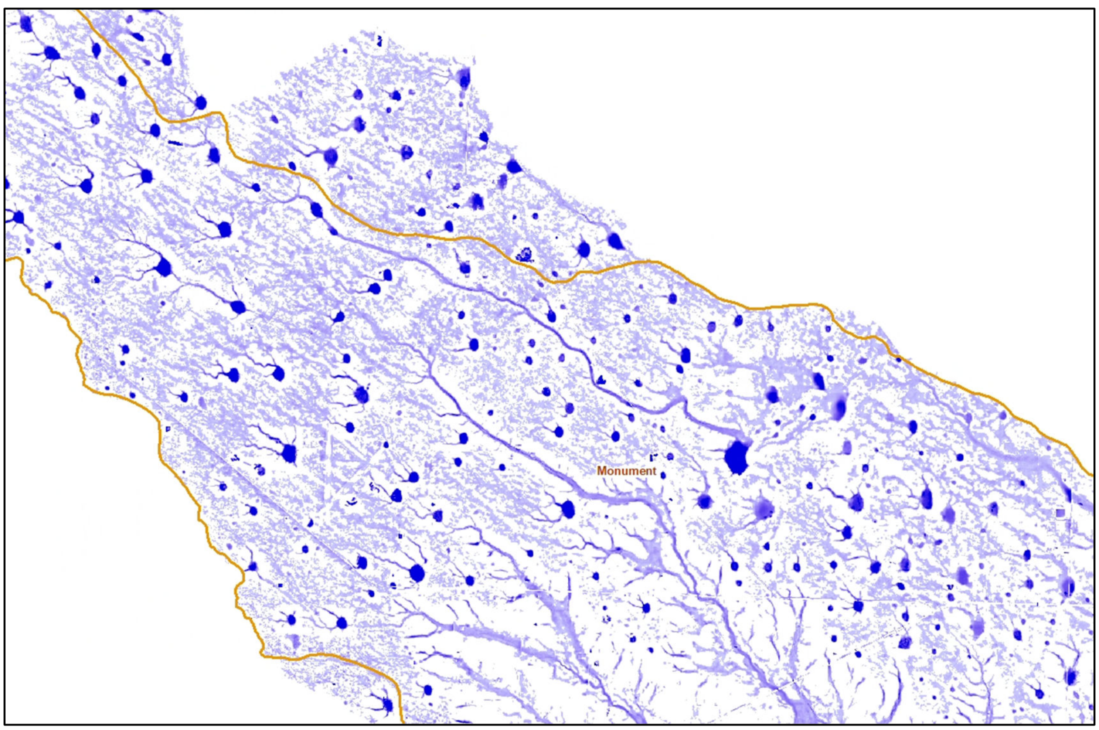

Figure 3-9: Playa-like features in the Monument model domain within the Landreth-Monument Draws watershed

In addition, many parts of the watershed are flat, leading to wide, shallow floodplains that move slowly and experience significant attenuation. Taken together, these characteristics in the Landreth-Monument Draws watershed cause the flows to be lower than what is predicted by the lower discharge curve derived from the gage flow-frequency analysis. These low flows in the watershed were considered acceptable since they led to BLE 1% discharges in the Pecos River at gage 08446500 (Pecos Rv nr Given, TX) and gage 08441500 (Pecos Rv Grandfalls, TX), which are located near the downstream end of the Landreth-Monument Draws watershed, that agree well with the 1% discharges from the flow-frequency analyses for these gages.

See Figure 3-10 for a summary of the validation outcomes for the ungaged validation location in the BLE study area.

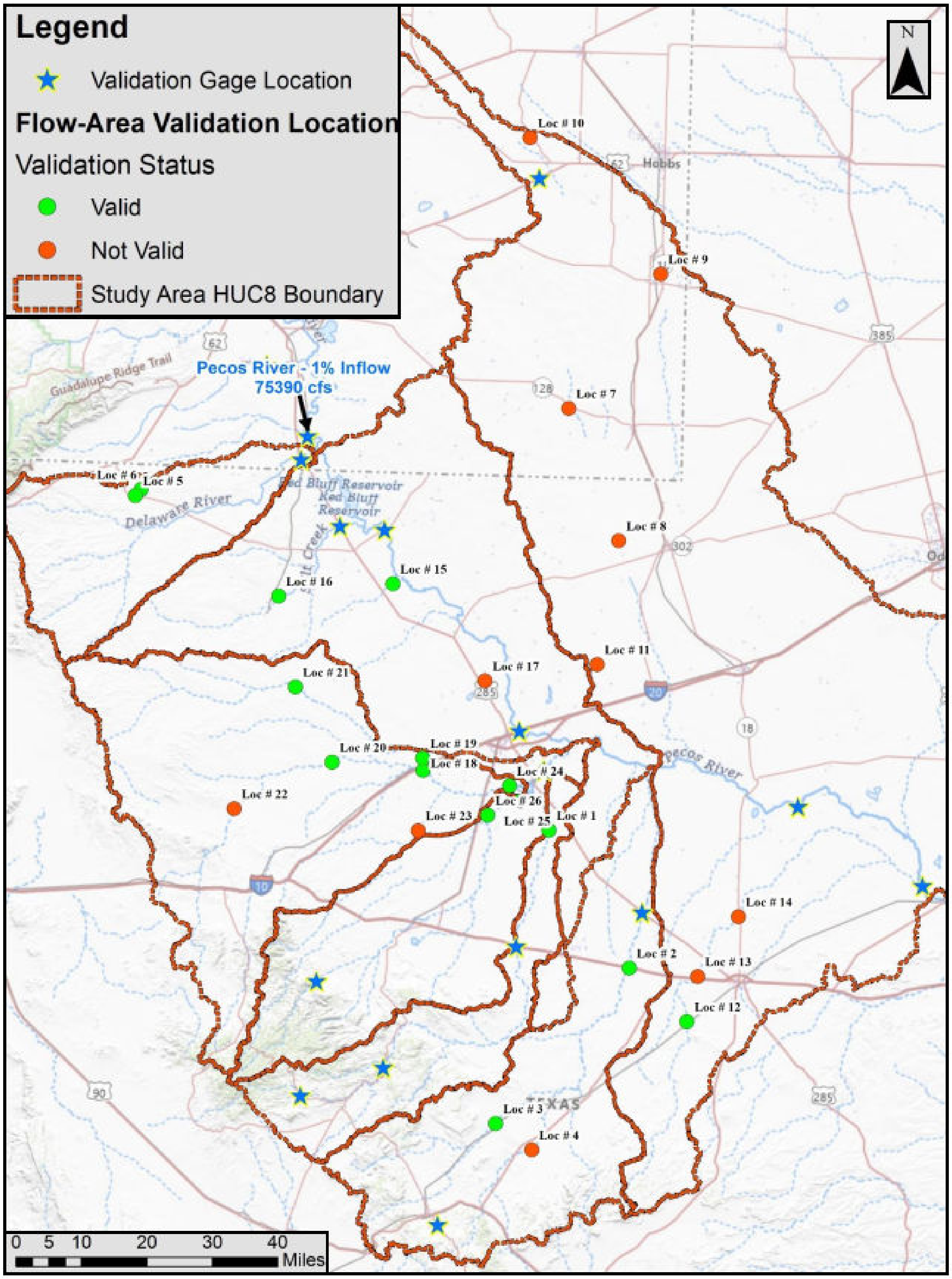

Figure 3-10: Summary of validation outcomes at the ungaged validation locations

Validation Summary

The BLE models developed in the study area (see Figure 1-2) were validated using two approaches. The first approach was a gage flow-frequency analysis of a number of USGS gages located within the study area. The second approach leveraged the outcomes of this flow-frequency analysis to develop discharge-drainage area curves that were applied to select ungaged streams in the study area.

Three primary model validation parameters were selected for this study. These are the model parameters that were varied to improve the validation outcomes of this BLE assessment. The parameters were the rainfall ARF, the NRCS CNs, and the channel Manning's n values. In addition, outflow hydrographs from the Lower Pecos-Upper and Salt Draw models were shifted to produce more realistic timing of the flood waves in the study area. A summary of the adjustments that were applied to the models is in Table 3-2.

A comparison of the BLE 1% discharges with the 1%, 1% minus, and 1% plus discharges from the flow-frequency analysis is in Table 3-3. Overall, there was good agreement between the BLE 1% outcomes and the discharges calculated by the flow-frequency analysis. There were 14 USGS flow gages in the study area with sufficient data for a flow-frequency analysis. At 11 gages, the BLE 1% discharge was between the gage 1% minus and 1% plus discharges. At the 3 gages where the BLE 1% discharges fell outside of the range between the gage 1% minus and 1% plus discharges, the flow data was questionable at 2 of the gages. At the third gage, the 1% BLE discharge was only slightly above the 1% plus discharge.

A set of discharge-drainage area curves was created to validate the BLE results at 26 ungaged locations in the study area. These curves were derived from the results of the flow-frequency analysis of the USGS flow gages. Again, there was good agreement between the BLE 1% outcomes and discharge-drainage area curves. At 15 of these locations, the BLE 1% discharge fell between the lower and upper bounds of the curves. At 11 locations, the BLE 1% discharges fell outside of the range between the lower and upper bounds of the curves. While 11 locations may seem like a lot, in reality this result was expected because the 11 locations were clustered in the Landreth-Monument Draws watershed, which receives less rain since it is the most arid watershed in the study area. In addition, there are many playa-like features in the watershed that intercept and store runoff, which further depresses the discharges in this watershed.

3.2 Challenges

A number of challenges were encountered during the Coyanosa-Hackberry Draws watershed BLE analysis. These challenges are summarized in the following paragraphs.

3.2.1 Cupping

HEC-RAS, Version 6.4.1 has a known error in the rain-on-mesh interpolation of flood depths between adjacent cells in the overbank area. This error produces artificially higher depths of flooding on the flood fringe, referred to as cupping. In narrower floodplains, the cupping effect becomes more significant due to the 300-foot cell size and the changes in elevation through the channel banks. At the direction of the TWDB, since this is a known issue in HEC-RAS and the HEC is working on a solution, these errors were not removed from the flood extents. Figure 3-11 below provides an example of cupping for reference. Once a solution is provided by the HEC, it may be possible to update the mapping to reduce and/or remove the cupping effects on the fringe of the floodplains.

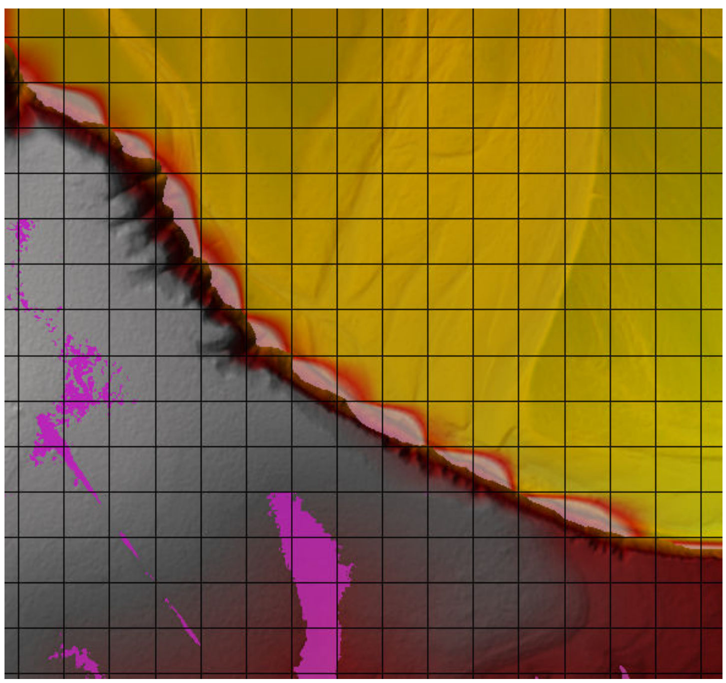

Figure 3-11: Cupping examples

3.2.2 Abnormally Deep Floodplains in the Mountainous Areas

During a review of the mapping results, deep floodplains were discovered near the upstream ends of streams that resided in the mountainous areas. An example of these deep floodplains is shown in Figure 3-12. Yellow represents depths between 10 and 15 feet, while red represents depths between 15 and 50 feet.

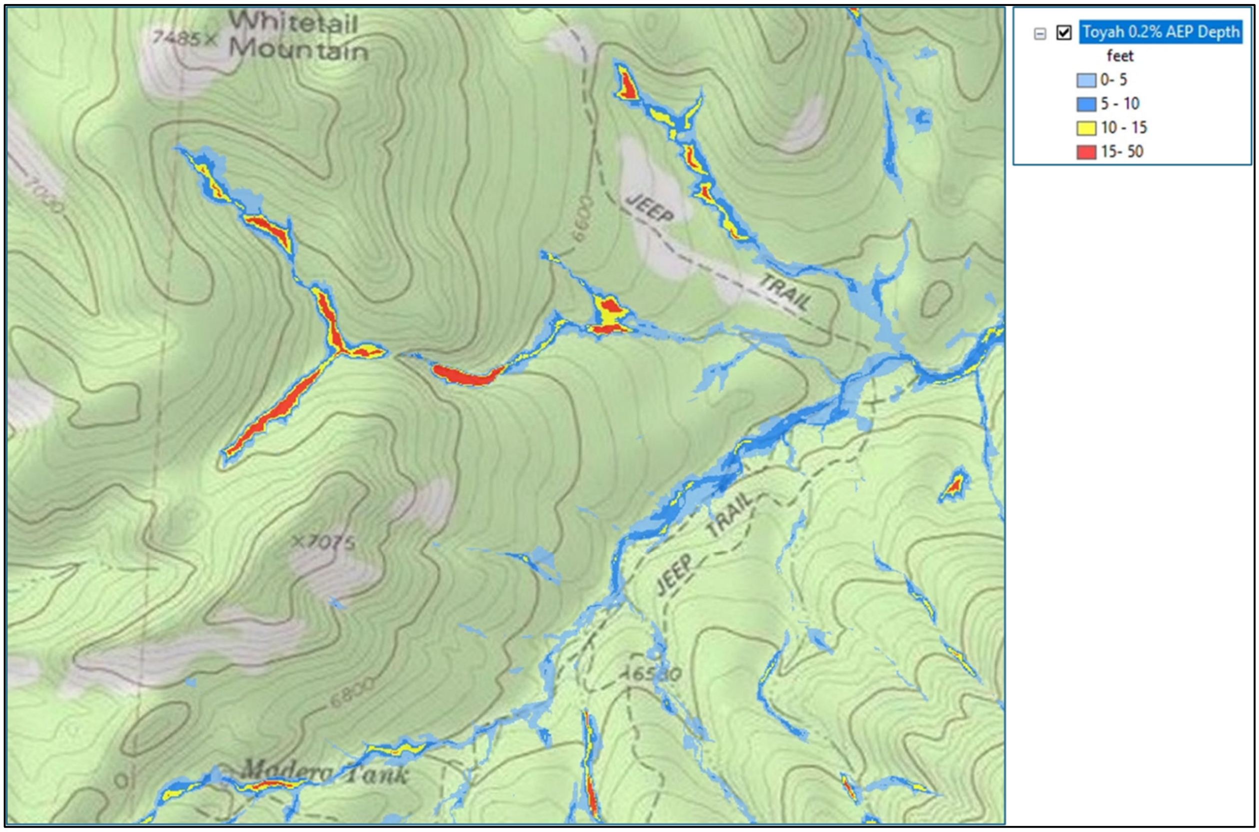

Figure 3-12: Deep floodplains in the mountainous region of the Toyah watershed

Research completed by AtkinsRéalis concluded that these excessive depths were caused by the large cell size (300 feet) in the HEC-RAS model and the steep terrain present in the mountains. When HEC-RAS completed its interpolation routines when exporting the model results, it had a difficult time determining the WSELs along these streams. This was happening because the ground elevations were changing rapidly but the WSELs were not because the cell sizes were large. As a result, HEC-RAS produced excessive depths in the exported WSEL and depth grids.

AtkinsRéalis met with the TWDB and its ITR team to discuss this issue. Resolving the issue would have required reducing the cell sizes throughout the mountainous areas. This would have significantly increased the number of cells in the models, leading to long run times. This outcome was considered untenable since it would have severely compromised the usability of the models. Instead, the TWDB directed AtkinsRéalis to leave the modeling and mapping as is and document the areas where these excessive depths were present as Areas of Mitigation Interest (AOMI). Refer to the AOMI feature class in the mapping database to learn where the excessive depths are occurring.

3.2.3 Development of WTR_LN Feature Class

Typically the WTR_LN feature class in the mapping geodatabase includes all stream centerlines that drain an area of at least 1 square mile in undeveloped areas and 0.5 square miles in urban areas. In this watershed, the WTR_LN feature class does not include all of the streams that meet these criteria.

Because of the arid conditions in this watershed, there is not a lot of runoff in some parts of the watershed. The limited runoff in these areas has caused gaps in the floodplain mapping. Since the mapping requirements state that there must be 1% ACE mapping along all centerlines in WTR_LN, it did not make sense to include linework in WTR_LN in areas where there were extensive gaps in the floodplain mapping. In addition, the terrain in parts of this watershed is flat, leading to extensive shallow overland flow and the absence of distinct channels. In areas where channels were not present, no centerlines were added to the WTR_LN feature class.

During the hydro-conditioning task for this watershed, a complete set of stream centerlines was created for this watershed. This dataset provided the foundational linework for the stream network included in the WTR_LN feature class. See the *Supplemental Data* folder for this dataset.

3.2.4 Terrain Adjustments in Mining Areas

This watershed included some mining operations. These sites included large depressions that were present in the terrain data. In some instances, the sites were located near streams and had elevations lower than the stream channel's thalweg.

Initially, the HEC-RAS models diverted flow from the streams into these depressions. Since mining areas are not intended for flood control purposes, the terrain was modified to remove these pits so they would not influence the floodplain mapping. This was done by using the terrain modification feature in HEC-RAS. The fill elevation for each pit was determined by reviewing the topography around the depression and selecting an elevation similar to the surrounding area. A shapefile identifying where the terrain was modified to remove the depressions has been included in the *Supplemental Data* folder of this submittal. A screenshot showing the pre- and post-modified terrain for one pit is shown on Figure 3-13.

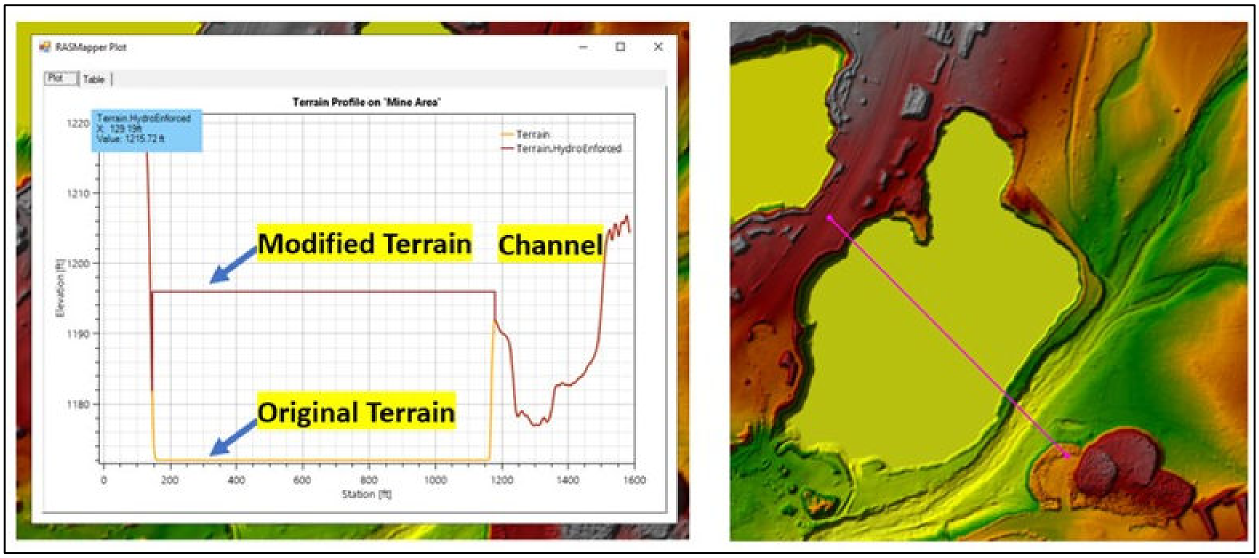

Figure 3-13: Example of a terrain modification at a mining pit

3.2.5 Velocity Hotspots

In the mountainous parts of the watershed, there are some isolated locations where the velocities computed by the HEC-RAS model are high (i.e., 10 to 15+ feet per second). These high velocities are caused by the combination of steep terrain, large cell sizes, and the orientation of the cell faces in the model mesh. While the model was being built, the initial results were reviewed for velocity hot spots. Where hot spots were identified, cell alignments were adjusted and/or additional cells were added to resolve them. Although, many hot spots were able to be resolved, some of them persisted.

An example of a hot spot in the watershed is shown in Figure 3-14.

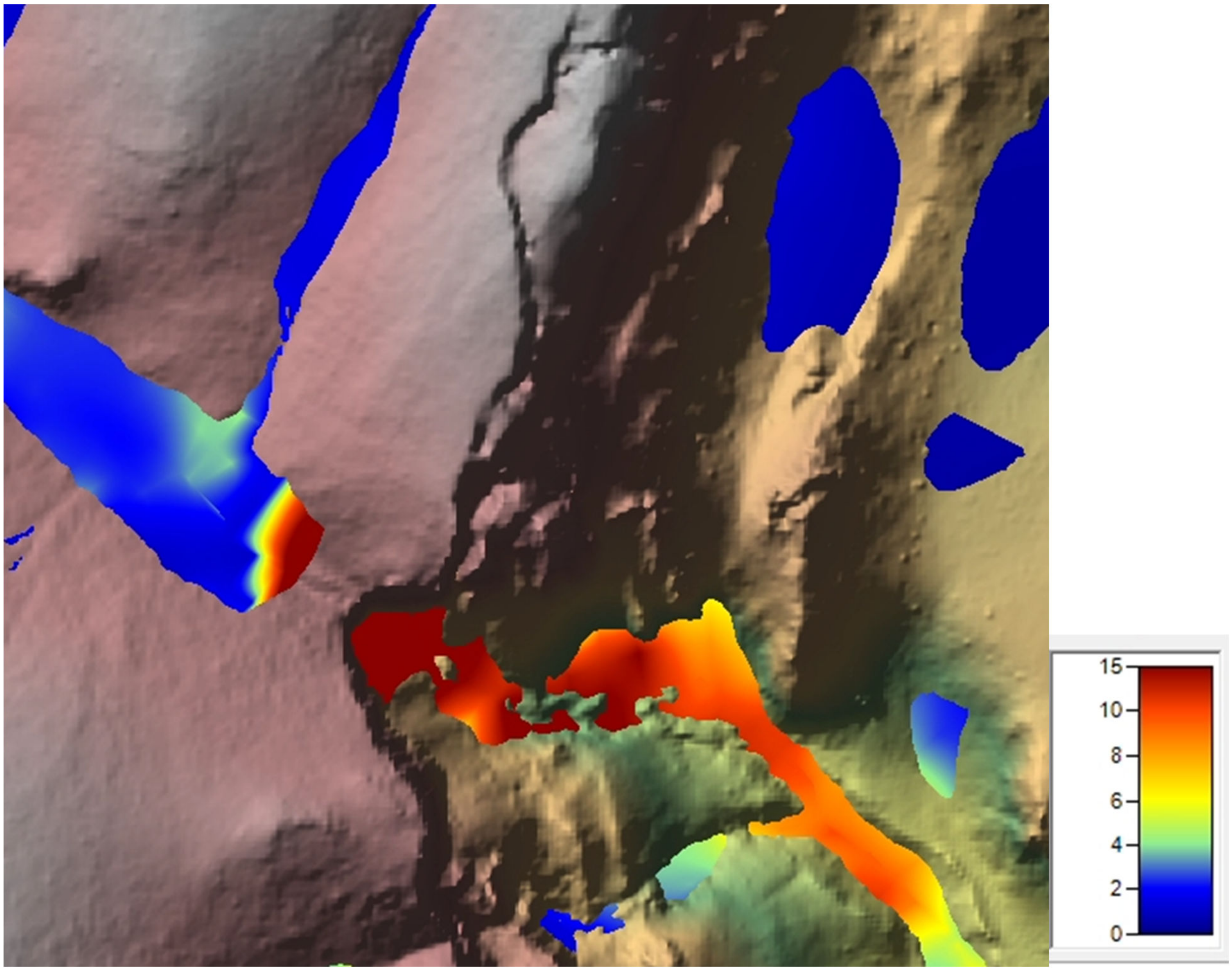

Figure 3-14: Example of a velocity hot spot in the mountains

3.2.6 Validation of BLE Model Results

The validation of the BLE model results was challenging. BLE 1% discharges were validated using the results of a flow-frequency analysis of a number of USGS streamflow gages in the study areas. In addition, flows were validated using discharge-drainage area curves that were developed using the outcomes of the flow-frequency analysis. The validation effort also involved shifting the outflow hydrographs for two of the models to produce more realistic results at the downstream end of the task order study area. This effort required extensive research and many model runs. See Section 3.1 for more details about the validation effort that was completed for this task order.

3.3 Results and Recommendations

The BLE results for the Coyanosa-Hackberry Draws watershed produced 1% BLE floodplain mapping that compares reasonably well with the effective SFHA in most locations. In addition, the 1% BLE floodplain mapping provides an additional estimated flood hazard in areas that 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 has been included in Appendix A.

As a part of the BLE assessment effort, a point file was prepared to detail areas where model refinements may be warranted. The file S_AOMI identifies these locations and includes recommendations for model refinement.

4 Floodplain Mapping and Effective Zone A Validation

Floodplains were delineated throughout the entire watershed for the 10%, 1%, and 0.2% ACEs using output from the Belding, Coyanosa, and Imperial HEC-RAS models. The 1% and 0.2% ACE floodplains may be found in the FLD_HZD_AR feature class in the flood risk database. The 10% ACE floodplain may be found in the TENPCT_FP feature class in the database.

This section describes the process that was followed to delineate the floodplains.

4.1 Development of the Flood Hazard Area Layers

4.1.1 Model Outputs

The floodplains were derived from the raw modeled grids using the maximum water surface elevation and depth values in each cell of the mesh. These grids were exported from HEC-RAS as rasters in TIF format with an interpolated rendering that slopes values at the center and along the faces/edges of the computational mesh cells. Using GIS software, the TIF rasters were post-processed into 10%, 1%, and 0.2% ACE floodplains.

4.1.2 Methodology

The following general steps were completed to delineate the floodplains:

- Export the depth rasters and WSEL rasters for the 10%, 1%, and 0.2% ACEs from the HEC-RAS models using a sloping water surface elevation render mode to a GIS environment. When exporting the model results, the "Raster based on terrain" parameter in HEC-RAS was changed from "Terrain.HydroEnforced" to "Terrain." This change was made so the original terrain surface was used to develop the floodplain mapping, not the hydro-enforced terrain surface. Using the hydro-enforced terrain would have led to mapping that would have incorrectly shown the roadway as being overtopped where the hydro-enforced culverts had been added.
- For each ACE, merge the raw WSEL rasters into a single raster that covers the entire watershed. Do the same for the depth rasters. Where the floodplain mapping needed to tie-in across two model domains, the model domain boundaries overlapped. Tie-in locations were identified in these overlap areas using split line shapefiles. Three split line shapefiles were created, one for each of the mapped events (i.e., 10%, 1%, and 0.2%). Split line alignments for each event were determined by creating difference rasters that subtracted the WSEL rasters from one another in the model domain overlap areas. Split lines were then drawn around the entire perimeter of each model domain through areas where the WSELs in the difference rasters were within 0.5 feet of each other. See the split line shapefiles in the *Supplemental Data* folder to understand where the mapping tie-ins are located.

  To understand how a split line is placed, consider Figure 4-1, which shows two floodplains that overlap along a model domain boundary. The split line must be placed where the WSELs are within 0.5 feet of one another in the overlap area. To determine where the WSELs meet this criterion, a WSEL difference raster was created.

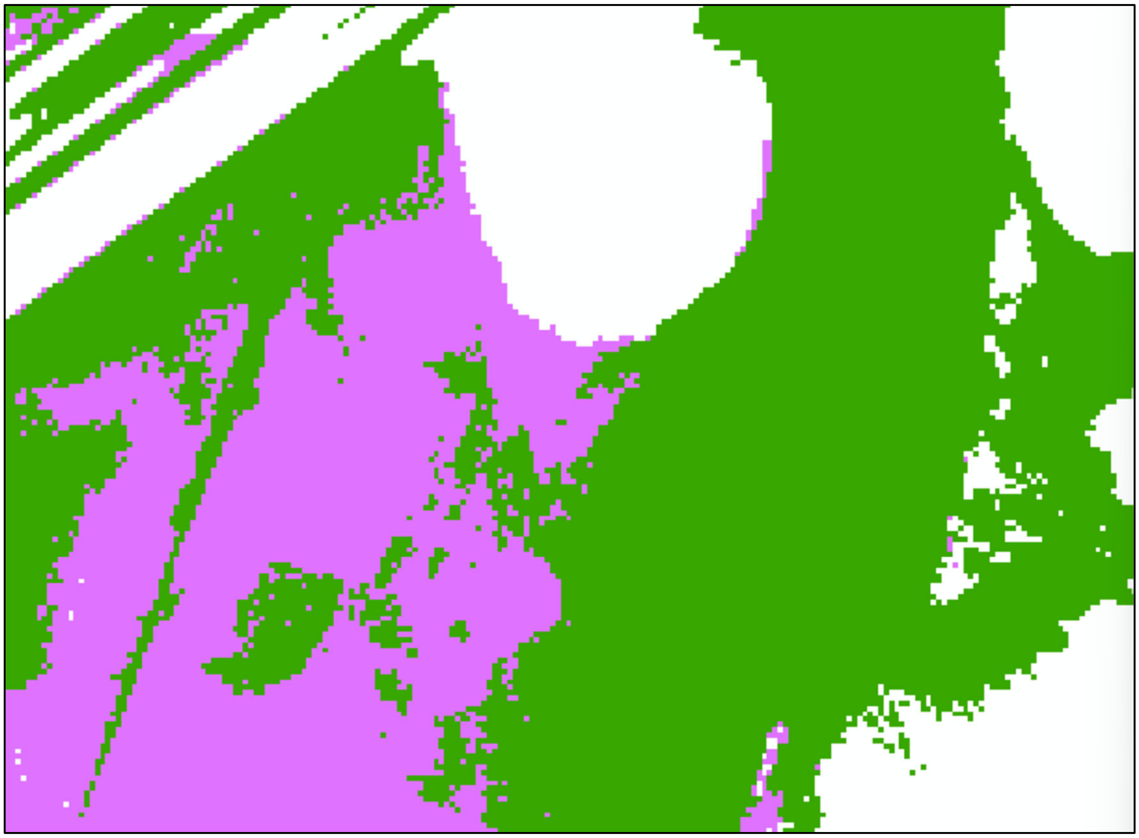

Figure 4-1: Example of overlapping mapping along a model domain boundary

Figure 4-2 shows what the difference raster looks like for the area in Figure 4-1. Light green means the WSELs are within 0.5 feet of each other and red means they are not. The blue-black line is the split line. It has been aligned so that it crosses the difference raster where the raster is light green. To the south of this line, the purple raster in Figure 4-1 is the source of the floodplain mapping. To the north of the split line, the dark green raster is the source of the floodplain mapping. Along the split line is where the source of the mapping transitions from the purple mapping to the dark green mapping.

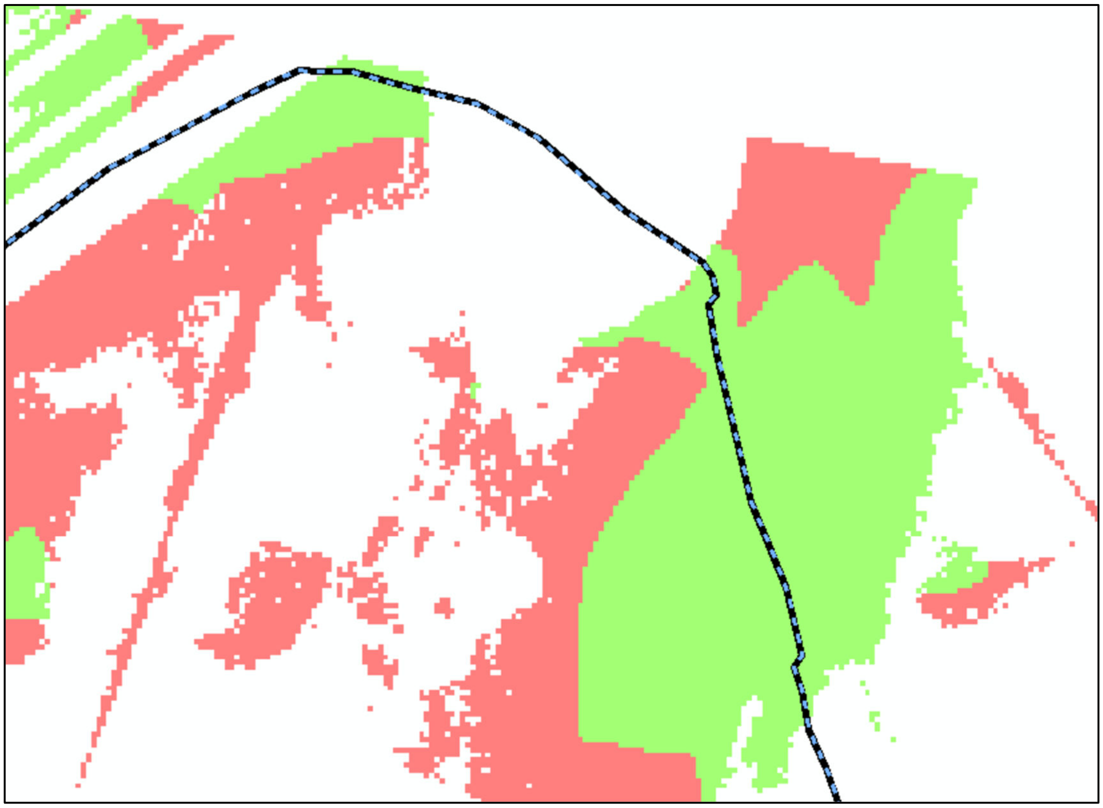

Figure 4-2: WSEL difference raster and split line for the overlap area

- The merged raw raster grids included connected and disconnected areas of potential flood hazard. To reduce the extent of these disconnected flood areas, process the rasters to filter and remove disconnected small, shallow areas of flooding. To do this, apply the TWDB's mapping threshold matrix to remove shallow depths, small areas of flood risk, and disconnected areas. According to Figure 3.1 in TWDB's 2D BLE guidelines, the Coyanosa-Hackberry Draws watershed falls in the Inland Areas of Texas. Therefore, disconnected areas were removed if they met ***both*** of the criteria in Table 4-1.

Table 4-1: Inland mapping threshold matrix

Area (ac)	Depth (ft)
< 0.33	-
0.33 - 0.5	< 0.33
0.5 - 1.0	< 0.25
1.0 - 2.0	<0.1

- Convert each WSEL raster to a floodplain polygon. Fill all holes in the 1% and 0.2% floodplain polygons with an area less than 2 acres.
- Fill all holes in the 10% floodplain polygon with an area less than 0.5 acres.
- Many ponding areas were present throughout the watershed. Due to the large mesh cells used in the 2D modeling, the extent of the smaller ponds was not always mapped properly in the model output. To properly identify the flood hazard in these areas, transfer the ponding extents available in the National Hydrography Dataset into the 1% and 0.2% floodplain polygons. Do not transfer them into the 10% floodplain polygon.

- If any dams are present that have been catalogued by the National Inventory of Dams and include a normal pool storage of 200 acre-feet or more, review the spillway mapping along each dam. If the 1% and/or the 0.2% model output did not include any flooding along the spillway, manually revise the floodplain polygon(s) to flood the spillway.
- Add waterbodies of lake and reservoir inundation areas of 20 acres or greater to the WTR_AR and FLD_HAZ_AR feature classes. The National Inventory of Dams was used to identify dams with inundation areas greater than 20 acres. The areas of inundation were computed by measuring the areas of the normal pools visible on the aerial photography.
- Clean up each polygon by simplifying it and smoothing it. The intent of the simplify and smooth processes is to eliminate unnecessary/erroneous vertices, remove rough edges, and reduce the size and complexity of the raw floodplain polygons. Apply professional judgement to determine the appropriate tolerance for simplifying and smoothing the floodplain polygons. Set initial thresholds to 5 feet for simplifying and 25 feet for smoothing.
- Merge the 1%, and 0.2% ACE polygons into one feature class. Keep the 10% ACE polygon as a separate feature class.
- The extents of the final depth and WSEL grids must match the extents of the flood inundation polygons. Because of the clipping and smoothing procedures applied to the floodplain polygons, they will no longer match the extents of the rasters. Apply Elevation Void Fill raster interpolation to expand depth and WSEL grids without changing grid values. Clip the depth and WSEL grids to each respective flood frequency inundation polygon to align the extents of the rasters with the extents of the floodplain polygons.
- Clip the rasters and the floodplain polygons using the Coyanosa-Hackberry Draws HUC-8 watershed boundary.

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

All of the Zone A studies (292.5 miles) in the Coyanosa-Hackberry Draws watershed were classified in CNMS with a validation status of "UNVERIFIED" and 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-A5 were evaluated for the CNMS inventory of Zone A studies.

4.2.1 Initial Assessment A1 – Significant Topography Update Check

This check involved determining whether a topographic data source was available that was significantly better than what was used for the effective Zone A modeling and mapping. For the Coyanosa-Hackberry Draws watershed, the effective Zone A topographic data source is unknown due to the age of the studies. The LiDAR data used in the BLE analysis was a significant improvement over the effective data. Therefore, the A1 check failed for all effective Zone A reaches.

4.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

This check involved first determining whether regression equations were used in the effective study. If they were, then it was determined whether new regression equations had become available since the date of the effective Zone A study. If newer regression equations existed for the area of interest, then an engineer determined whether these regression equations would significantly affect the 1% annual-chance flow. The effective hydrologic analysis was not based on a regression analysis, therefore the A2 check was set to pass.

4.2.3 Initial Assessment A3 – Check for Significant Development

This check involved using the National Urban Change Indicator (NUCI) dataset to assess increased urbanization in the HUC-12 watersheds with Zone A studies. If the percentage of urban area within the watershed containing the effective Zone A study was 15% or more, and had increased by 50% or more since the effective analysis, then the study would fail this check. Although the NUCI data provided year-to-year changes in urbanization, the NLCD also was needed to establish a baseline of urban land cover for this analysis. This watershed is generally rural with limited development. A significant development check for the study areas was carried out using the NUCI dataset, which did not meet the urban change criteria. Therefore, the A3 check was set to pass for all reaches.

Table 4-2 presents the summarized results of checks A1 through A3.

Table 4-2: Zone A initial assessment results

Assessment Check	Pass/Fail	Comments/Notes
A1 - Topography	Fail	The LiDAR terrain data is a significant improvement over the terrain data used to develop the effective mapping.
A2 - Hydrology	Pass	The effective hydrologic analysis was not regression based.
A3 - Development	Pass	No significant development has occurred in the study area.

4.2.4 Initial Assessment A4 – Check of Studies Backed by Technical Data

Zone A studies that passed all of the initial assessment checks described above were categorized as "Valid" in the CNMS Inventory when the effective Zone A study was supported by modeling or sound engineering judgment and all regulatory products were in agreement. If the effective Zone A study passed all initial assessment checks but was not supported by modeling, or if the original engineering method used was unsupported or undocumented, then a comparison of the BLE results and effective Zone A mapping was performed. There was no adequate documentation regarding how the engineering analysis supporting the effective study was performed. Therefore, the A4 check was set to fail for all reaches in this study.

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

The BLE/effective Zone A comparison method leveraged the existing Floodplain Boundary Standard (FBS) certification procedures described in FEMA SID 113, but with a slight modification. This modified FBS comparison approach used the 1% plus and 1% minus flood extents and the horizontal and vertical tolerances described in the *CNMS Technical Reference*. For the comparison of the BLE mapping and effective Zone A mapping in the study area, the following vertical and horizontal tolerances were used to conduct the modified FBS procedure. These comparisons were made at points spaced at a 100-foot interval along the outer extents of the effective Zone A mapping.

Vertical Tolerance: Plus or minus 5, 10, or 20 feet (one-half contour interval of assumed effective topographic source). See the shapefile USGS_24K_Index.shp in the Supplemental data folder to see how the vertical tolerance varied throughout the watershed.

Horizontal Tolerance: Plus or minus 75 feet (standard horizontal tolerance for BLE comparison testing).

The effective Zone A comparison was performed at the full extent of the watershed. The validation of the effective Zone A boundaries using 2D flood hazard products differs from the standard 1D methods due to the lack of cross sections. For this 2D study, the effective Zone A boundaries were compiled using the National Flood Hazard Layer and any mapping data that was digitized from FEMA's paper FIRMs. This data was dissolved to one continuous Zone A layer, which then had test points placed along its perimeter every 100 feet.

For each test point, a vertical test and a horizontal test were performed. These tests compared the 1% plus and 1% minus WSELs against the DEM ground elevation at the test point locations. These

1% plus and 1% minus values were products of the new 2D BLE study. If the point failed either the vertical test or the horizontal test, then the point failed and was assigned a value of 0. If the point passed both the vertical and horizontal tests, then the point passed and was assigned a value of 1.

For the vertical test the following must be true to pass the test:

(1% minus WSEL – vertical tolerance) is less than or equal to the topographic elevation at the study point and the topographic elevation at the study point is less than or equal to (1% plus WSEL + vertical tolerance).

The vertical tolerance is defined by half the contour interval of the USGS 24K Quad for the study area. For this study a vertical tolerance of 5, 10, or 20 feet was applied.

For the horizontal test the following must be true to pass the test:

(1% plus WSEL) is greater than or equal to the minimum topographic elevation within a 75-foot radius of the validation point AND (1% minus WSEL) is less than or equal to the maximum topographic elevation within a 75-foot radius of the validation point.

Points were then grouped by HUC-12 watersheds. A passing percentage was calculated for each HUC-12 watershed based on the number of passing points divided by the total number of points within that watershed. Due to the rural nature of this study area, a passing threshold of 85% was used to determine whether the HUC-12 watershed passed or failed the check. If 85% or more of the test points in the watershed passed, then all the effective Zone A reaches within that HUC passed. If fewer than 85% of the test points in the watershed passed, then all the reaches within that watershed failed.

4.2.6 CNMS Validation Results

Based on the validation assessments and BLE comparison results described above, the CNMS inventory of Zone A studies in the watershed has been updated and the total miles in each of these categories are summarized in Table 4-3 and illustrated on Figure 4-3.

Table 4-4 summarizes the validation results based on the individual HUC-12 watersheds within the Coyanosa-Hackberry Draws HUC-8 watershed.

Table 4-3: Zone A validation results

Validation Status	CNMS Validation Status	CNMS Project Start	CNMS Post-BLE Assessment	Total Miles
VALID	BEING STUDIED	0	0	0
UNVERIFIED	BEING STUDIED	302.9	292.5	292.5

Table 4-4: BLE comparison results

HUC-12 Watershed		Total FBS Points	Fail	Pass	% Pass	BLE Comparison Pass? (>85%)
Watershed Name	HUC12 ID					
Headwaters Alpine Creek	130700060101	4066	1078	2988	73.5%	Fail
Ramirez Tank-Alpine Creek	130700060102	2162	510	1652	76.4%	Fail
Moss Creek	130700060103	2585	559	2026	78.4%	Fail
Merriwether Ranch	130700060104	2808	718	2090	74.4%	Fail
Alpine Creek	130700060105	2177	450	1727	79.3%	Fail
Headwaters Musquiz Creek	130700060201	3143	850	2293	73.0%	Fail
Barillos Creek	130700060202	2620	941	1679	64.1%	Fail
Upper Musquiz Creek	130700060203	939	200	739	78.7%	Fail
Middle Musquiz Creek	130700060204	949	204	745	78.5%	Fail
Ramsey Draw	130700060301	2565	716	1849	72.1%	Fail
Emerson Draw	130700060302	544	139	405	74.4%	Fail
House Mountain-Antelope Draw	130700060303	1441	377	1064	73.8%	Fail
Mah Pe Tank-Mah Pe Draw	130700060304	811	389	422	52.0%	Fail
McClary Hill-Antelope Draw	130700060305	102	41	61	59.8%	Fail
Moose Draw	130700060401	1084	538	546	50.4%	Fail
Christmas Tank-Gilliland Canyon	130700060402	1642	1111	531	32.3%	Fail
Upper Burnt House Creek	130700060403	856	396	460	53.7%	Fail

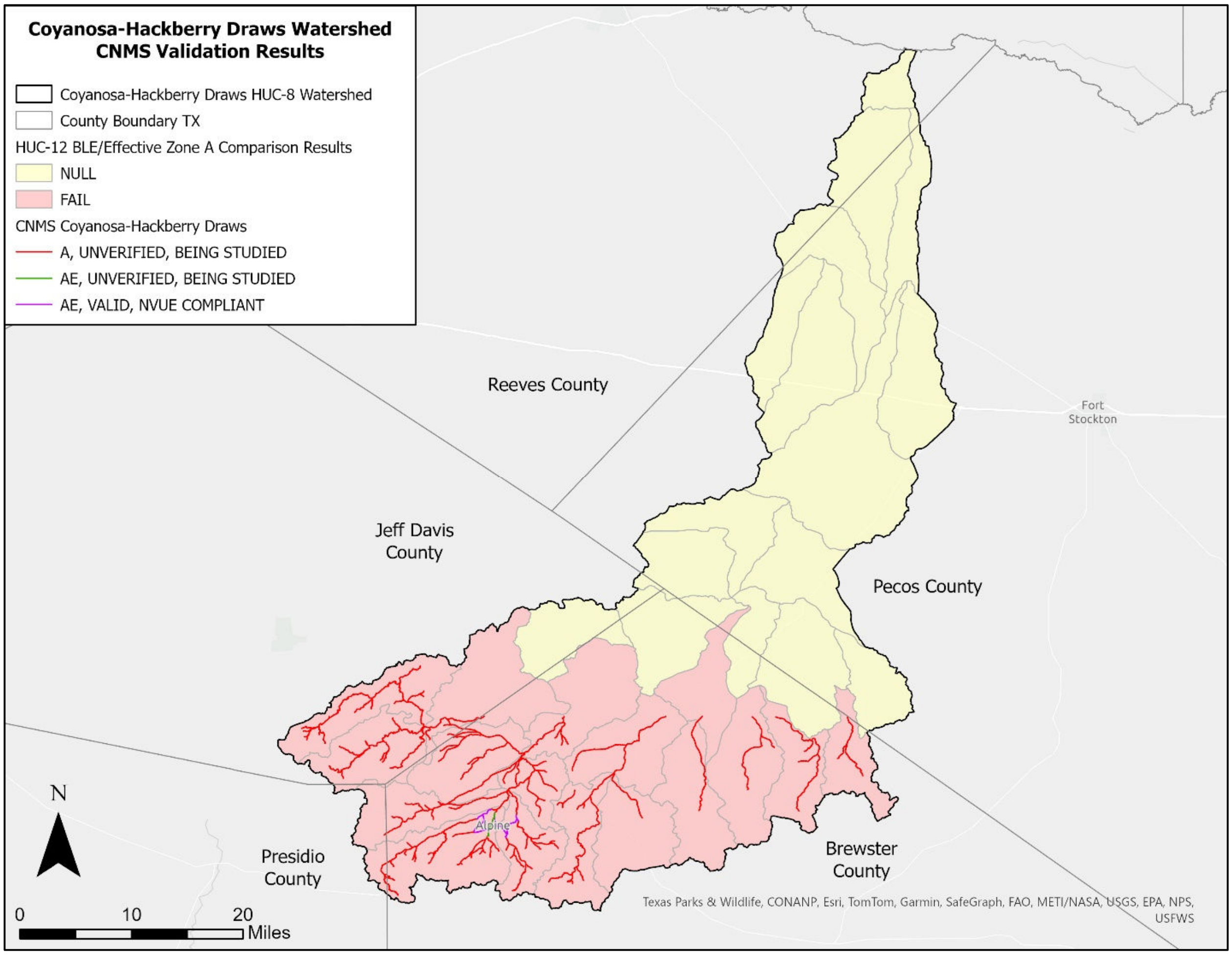

Figure 4-3: Coyanosa-Hackberry Draws watershed CNMS validation results

4.3 Flood Risk Analysis

A flood risk analysis was performed for Coyanosa-Hackberry Draws watershed. The updated 1% ACE depth grid was used to calculate the potential flood losses. The loss results are stored in the S_FRAC_AR spatial file within the FRD geodatabase. All results were reported in whole dollar values.

Hazus version 6.1 was used for the basic and refined loss analysis.

The losses were reported via census blocks. It is important to note that Hazus version 6.1 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.

The Hazus analysis was performed by county within the project watershed extents. A summary of results by county for the 1% ACE scenarios are shown in Table 4-5.

Table 4-5: Hazus 6.1 results for 1% ACE scenario for the Coyanosa-Hackberry Draws watershed

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Brewster County	$257,981,000	$9,888,000	$9,934,000
Jeff Davis County	$2,070,000	$236,000	$532,000
Pecos County	$7,103,000	$247,000	$467,000
Presidio County	$26,000	$11,000	$6,000
Reeves County	$3,000	$1,000	$0
Total	**$267,183,000**	**$10,383,000**	**$10,939,000**

5 References

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Appendix A – BLE MAP

This map includes the 1% ACE polygon boundary and the CNMS inventory lines.