San Ambrosia – Santa Isabel HUC-8 Watershed, Texas
Base Level Engineering (BLE) Results

MAS No. FY20-CTP-FRP-MAST #5 T.O. No. 11

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Executive Summary

The Texas Water Development Board (TWDB) contracted Halff Associates (Halff) to complete a Base Level Engineering (BLE) analysis for the HUC-08 watershed No. 13080002 – San Ambrosia – Santa Isabel in South 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 regulatory-quality flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals.

The source digital terrain data used for surface model development in support of hydrologic and hydraulic analysis as well as mapping activities were leveraged from various local, State, and Federal partners. Details regarding the different datasets used are provided below in Section 2.1.

Precipitation depths for this study were established using NOAA Atlas 14 rainfall. An average precipitation depth was computed for the study area. The Hydrologic Engineering Center's (HEC) Hydrologic Modeling System (HMS) was used to develop a simplified hydrologic model to compute excess rainfall which was then used in a rain-on-grid, 2D hydraulic model using HEC-RAS. The hydraulic model was used to compute flood depths and peak water surface elevations within the study area.

The stream mile network that was validated for this watershed was compiled using FEMA's Community Needs Management Strategy (CNMS) inventory. CNMS is an inventory of flood hazard studies and flood hazard mapping needs for areas where a study is needed. This data is helpful for community officials in analyzing and depicting flood hazards to enhance the understanding of flood risks. Communities may use this information to make informed decisions on their planning and flood mitigation efforts. Table ES-1.1 lists the stream miles associated with this validation analysis.

Table ES-1.1: Summary of Stream Miles

Source	San Ambrosia – Santa Isabel Stream Miles
CNMS	5,341

The full inventory of Zone A studies in the watershed were classified in CNMS. Total miles validated in CNMS are summarized in Table ES-1.2.

Table ES-1.2: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	3.5
UNVERIFIED	BEING STUDIED	1,803.8

01 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 standard 2-dimensional (2D) model development procedures to produce flood hazard boundaries for the 1-percent annual chance event as well as estimates of flood hazard boundaries for multiple recurrence intervals. The cost for developing the data and estimates resulting from the BLE process is lower than standard flood production costs. The BLE results may be used for eventual production of regulatory and non-regulatory products.

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

In addition to the need for Zone A validation guidance, FEMA standards require flood risk data to be provided in the early stages of a flood risk project. FEMA Program Standard SID #29 requires that during Discovery, data must be identified that illustrates potential changes in flood elevation and mapping that may result from the proposed project scope. If available data does not clearly illustrate the likely changes, an analysis is required that estimates the likely changes. This data and any associated analyses should be shared, and results should be discussed with stakeholders.

An important goal of the BLE process is the scalability of the results. Scalability means that the results of a BLE analysis can not only be used for CNMS evaluations of Zone A studies but can also be leveraged throughout the Risk Mapping, Assessment and Planning (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 Halff Associates (Halff) to complete a BLE analysis for the San Ambrosia – Santa Isabel Watershed in South Texas to support FEMA's Discovery process and validation of effective Zone A Special Flood Hazard Areas (SFHA). The study extents include portions of Maverick, Dimmit, and Webb Counties, and include the following communities: The Cities of El Cenizo, Rio Bravo, Laredo, and Eagle Pass, and the Census-Designated Places of El Indio, Chula Vista, and Rosita. The study area consists of all or parts of eight HUC-10 basins on the United States side: Rosita Creek – Rio Grande, Indio Creek – Rio Grande, San Ambrosia Creek, San Lorenzo – Rio Grande, Espada Creek – Rio Grande, Cuchara Creek – Santa Isabel Creek, Santa Isabel Creek, and Chacon Creek – Rio Grande. Figure 1.1 shows the orientation of the San Ambrosia – Santa Isabel HUC-8 Watershed with respect to the Texas counties and Mexico.

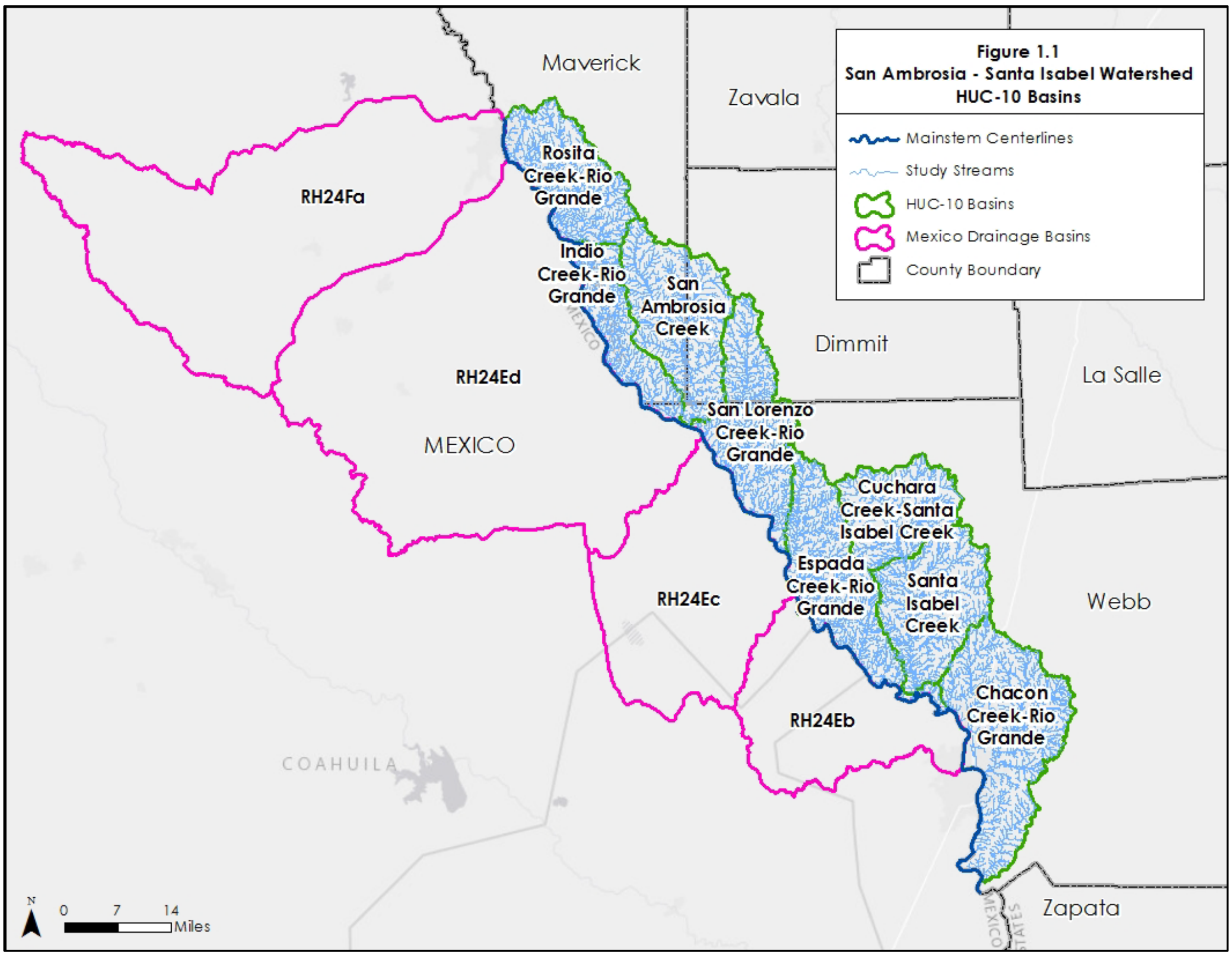

Figure 1.1: San Ambrosia – Santa Isabel Watershed

02 2D BLE Modeling Inputs and Controls

Section 2 presents fundamental components required to execute a 2D hydraulic engineering analysis for the San Ambrosia – Santa Isabel Watershed. Inputs such as elevation data, hydrology used to develop rain-on-grid data and inflow hydrographs, and hydraulic analyses and requisite model parameters are defined herein. HEC-RAS, Version 6.1 rain-on-grid utility was applied in the production of the 2D BLE products produced for this watershed.

2.1 Topographic Data

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

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

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

2.1.1 Inventory

An inventory of existing topographic data was conducted for the San Ambrosia – Santa Isabel BLE project footprint. Figure 2.1 depicts the datasets identified for leverage across the project area. FEMA, National Oceanic and Atmospheric Administration (NOAA), U.S. Geological Survey (USGS), and other State and Federal agencies were queried to build the inventory with the most current and available data sources.

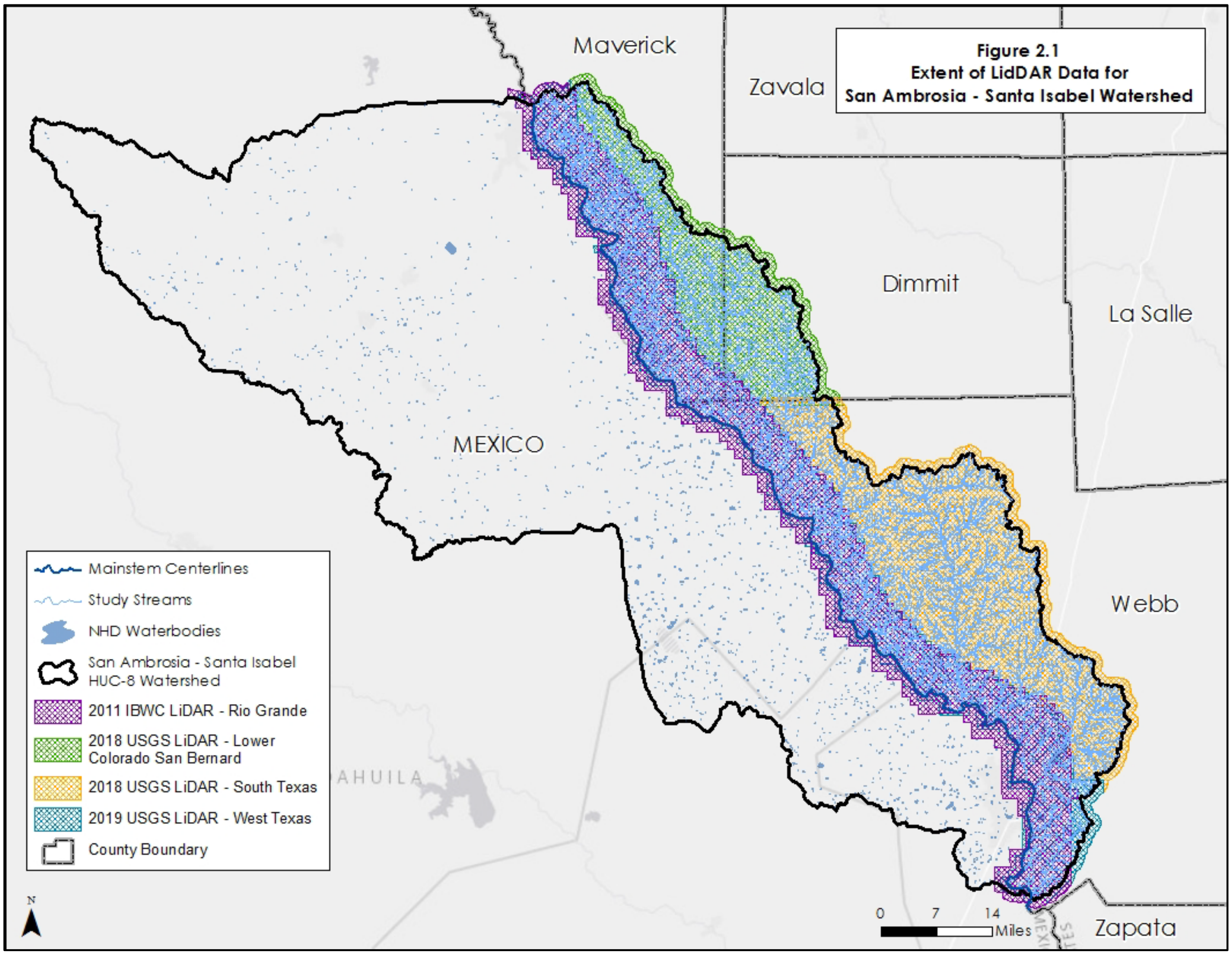

Figure 2.1: San Ambrosia – Santa Isabel Watershed BLE Source Terrain Data

2.1.2 Evaluation

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

- Data meets FEMA vertical accuracy standards (Table 2.1)
- Date of origination
- Data density and coverage

Table 2.1 depicts the Risk Map SID #43 vertical accuracy requirements based on flood risk and terrain slope within the floodplain being mapped.

Table 2.1: FEMA Vertical Accuracy Requirements for Leveraged Data

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

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

Table 2.2 depicts the complete list of source elevation data and attributes leveraged for the San Ambrosia – Santa Isabel Watershed BLE project. All datasets used for hydraulic analyses and mapping meet the highest specification level defined in Table 2.1. Further explanation of the Table 2.2 datasets can be referenced in section 2.1.2.1.

Table 2.2: Source Topographic Data Available for the San Ambrosia – Santa Isabel Watershed

Year	Description	Data Type	RMSE	Source/Owner
2011	2011 IBWC	Airborne LiDAR	NVA 0.03m	IBWC
2018	2018 USGS Lower Colorado San Bernard	Airborne LiDAR	NVA 0.0096m	USGS
2018	2018 USGS South TX LiDAR (Aransas, Dewitt, Calhoun, Goliad, Karnes, Refugio, Victoria)	Airborne LiDAR	NVA 0.0089m	USGS
2018	2018 Mexico	Airborne LiDAR	Best Available	Mexico
2019	2019 USGS West Texas	Airborne LiDAR	Less than 10 cm	USGS

2.1.2.1 San Ambrosia – Santa Isabel Watershed Source Terrain Data

The source elevation data for the San Ambrosia – Santa Isabel Watershed are DEMs derived from USGS, TWDB and FEMA LiDAR data. Preprocessed Bare-earth Hydro-enforced DEMs from the acquiring entity (via TNRIS) were projected and adjusted as needed into one seamless DEM in Texas State Plane 4204 NAD83, Vertical Feet NAVD88. Bare-earth LiDAR data are typically made by filtering non-ground returns (e.g. buildings, vegetation, etc.) from the processed LiDAR returns. Figure 2.1 depicts the extent of the data defined in Table 2.2. Please see brief descriptions of the LiDAR sources below. For more detailed information, please see the attached LiDAR project report for each individual project.

2011 IBWC LiDAR– The 2011 IBWC LiDAR was acquired from December 2010 to August 2011. The measured RMSE was documented at 0.03m Non-Vegetated Accuracy.

2018 USGS Lower Colorado San Bernard LiDAR– The 2018 USGS Lower Colorado San Bernard LiDAR was acquired from February 2018 to April 2018. The measured RMSE was documented at 0.0096m. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2018 USGS South TX LiDAR, Aransas, Dewitt, Calhoun, Goliad, Karnes, Refugio, Victoria – The 2018 USGS LiDAR was acquired from January 2018 to February 2019 and was collected with a point spacing of 70 cm. The measured RMSE was documented at 0.089 Non-Vegetative Accuracy. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2019 USGS West Texas LiDAR– The 2019 USGS West Texas LiDAR was acquired from February 2019 to April 2019. The measured RMSE was documented at less than 10 cm. The reported Z (vertical) Accuracy meets the 19.6 cm or better Non-Vegetated Vertical Accuracy at 95% confidence level using RMSE(z) x 1.9600 as defined by the National Standards for Spatial Data Accuracy (NSSDA) and was assessed and reported following National Digital Elevation Program (NDEP)/ASRPS Guidelines.

2.1.3 Data Development Methodology

The source topographic data were processed for an area covering the San Ambrosia – Santa Isabel Watershed for the San Ambrosia – Santa Isabel BLE modeling efforts. The topographic data for San Ambrosia – Santa Isabel Watershed was projected horizontally, as needed, to North American Datum of 1983 (NAD83), State Plane Coordinate System (SPCS) Texas S Central in feet (4204-SPC83). All topographic data were adjusted vertically, as needed, to NAVD88 in feet. Halff used a combination of ArcGIS and other software tools to apply any vertical datum shifts and/or any horizontal projection transformations to the topographic data.

2.1.4 DEM QA/QC

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

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

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

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

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

The final DEM data developed for the San Ambrosia – Santa Isabel Watershed are assured to meet FEMA standards and present a representative surface developed from leveraged elevation data for the purposes of this BLE project.

2.2 2D BLE Methods

The following sections describe the 2D computational mesh and program setting considerations, followed by discussion and tabulation of hydrologic and hydraulic engineering methods and model inputs.

2.2.1 2D Computational Mesh and Settings

The HEC-RAS 2D computational mesh defines the extents of the 2D flow and can affect the accuracy of the 2D calculations. A denser mesh may provide more accurate results, but it can dramatically increase model run times. The original 2D mesh for the model was established as evenly spaced cells at approximately 200 feet. The mesh was further refined by placing breaklines along roads, berms, ridges, and other high ground that can impede flow as well as stream centerlines to allow flow conveyance. The San Ambrosia – Santa Isabel HUC-8 was bisected into North and South study areas, and a separate RAS model was created for each. The North model included the following HUC-10 basins: Rosita Creek – Rio Grande, Indio Creek – Rio Grande, San Ambrosia Creek, San Lorenzo Creek – Rio Grande, and Espada Creek – Rio Grande; the South model included the following HUC-10 basins: Cuchara Creek – Santa Isabel Creek, Espada Creek – Rio Grande, Santa Isabel Creek, and Chacon Creek – Rio Grande.

The HEC-RAS 2D computational mesh was created for San Ambrosia – Santa Isabel Watershed based on the USGS HUC boundaries using ArcGIS toolsets, such as smoothing and simplification routines, significantly reducing the need for manual edits to mesh cells within HEC-RAS. The 2D mesh consists of 948,236 cells in the North model and 882,480 cells in the South model, with a 200-foot nominal mesh cell size. Factors that result in either larger or smaller cell sizes included:

- Proximity to the edge of the 2D mesh
- Presence of breaklines
- Refinement of mesh for significant flood control features (levees, dams, etc.)

To ensure the entire San Ambrosia – Santa Isabel Watershed, including adjacent flows, was represented, a 1-mile buffer was initially added to the HUC boundaries for each model's 2D computational mesh area. This buffer was expanded where the southern Elm – Sycamore model tied into the northern San Ambrosia – Santa Isabel model, as well as between where the two San Ambrosia – Santa Isabel models tied into each other. The buffer was also extended at the Rio Grande to create a larger overlap, allowing for flows to be transferred seamlessly between models. The mesh was further extended into Mexico as needed to capture the entire flood extents of the Rio Grande.

An alternating 30-second and 15-second time step was used in both HEC-RAS models to lower the Courant values. Both models applied the Diffusion Wave (simplified Full Momentum) equations.

2.2.2 Model and Boundary Condition Setup

Using HEC-RAS rain-on-grid modeling requires establishing a 2D computational mesh boundary as discussed previously, and often requires defining inflow boundary conditions in addition to excess precipitation applied to the mesh. For the San Ambrosia – Santa Isabel Watershed, inflow hydrographs from four inflow points along the Mexico border and two inflow points to transfer between models were used, along with excess precipitation applied to the mesh. Figure 2.2 shows the 2D computational mesh for the San Ambrosia – Santa Isabel Watershed, along with USGS peak streamflow gages pertinent to the study.

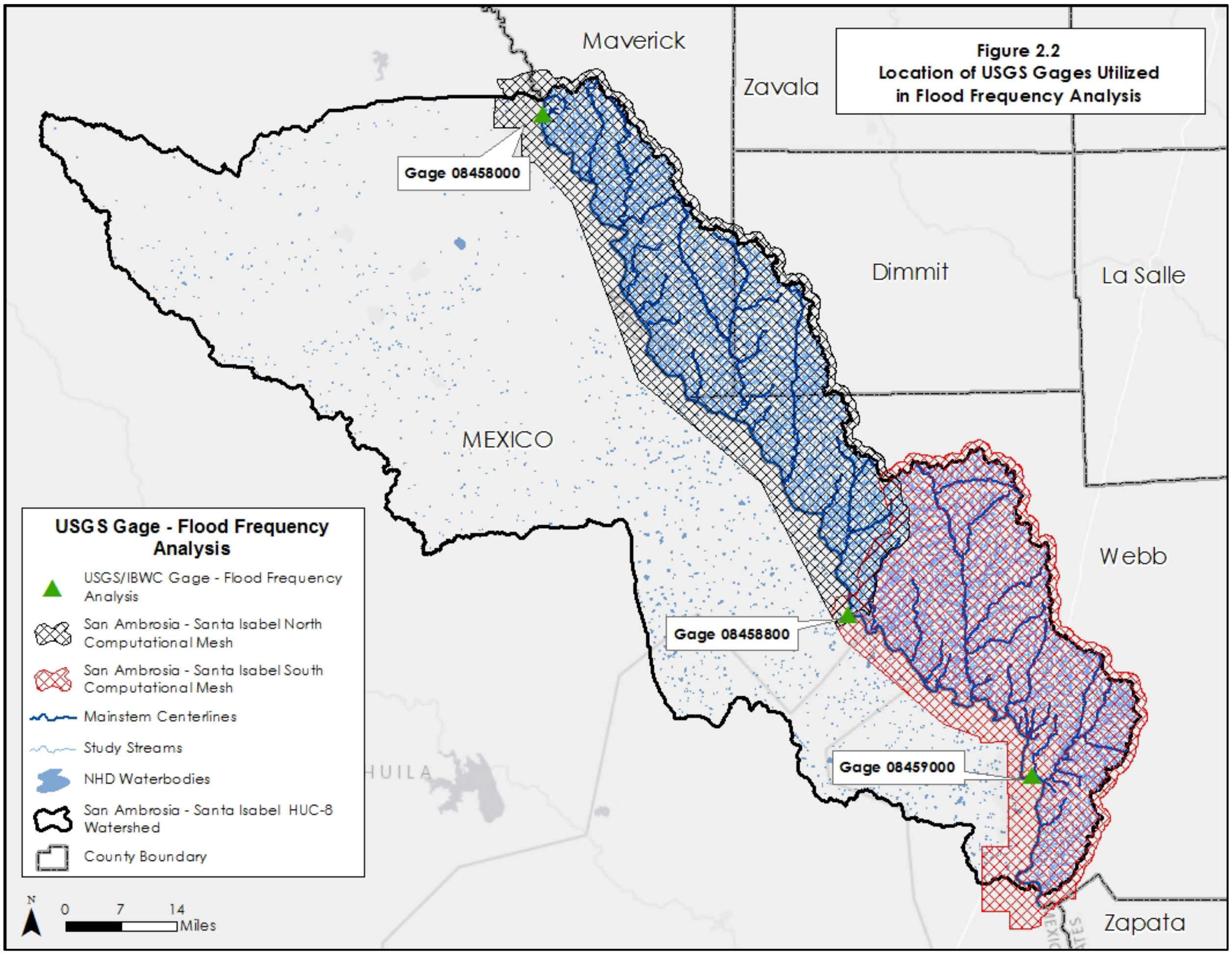

Figure 2.2: HEC-RAS 2D Computational Mesh and USGS Peak Streamflow Gages

Figure 2.3 shows the inflow boundary condition locations for the San Ambrosia – Santa Isabel Watershed. The development of the inflow hydrographs, and excess precipitation hyetographs for the 2D mesh, is described in Section 2.2.3.3.

A flow hydrograph representing outflow from the upstream Elm – Sycamore RAS model was used for the boundary condition along the Rio Grande. The remaining boundaries on the U.S side were defined as continuous boundaries to allow drainage from adjacent basins to leave the model area freely. Normal depth was used for non-unique outflow boundary conditions using approximate energy grade-line slopes estimated from the LiDAR terrain data.

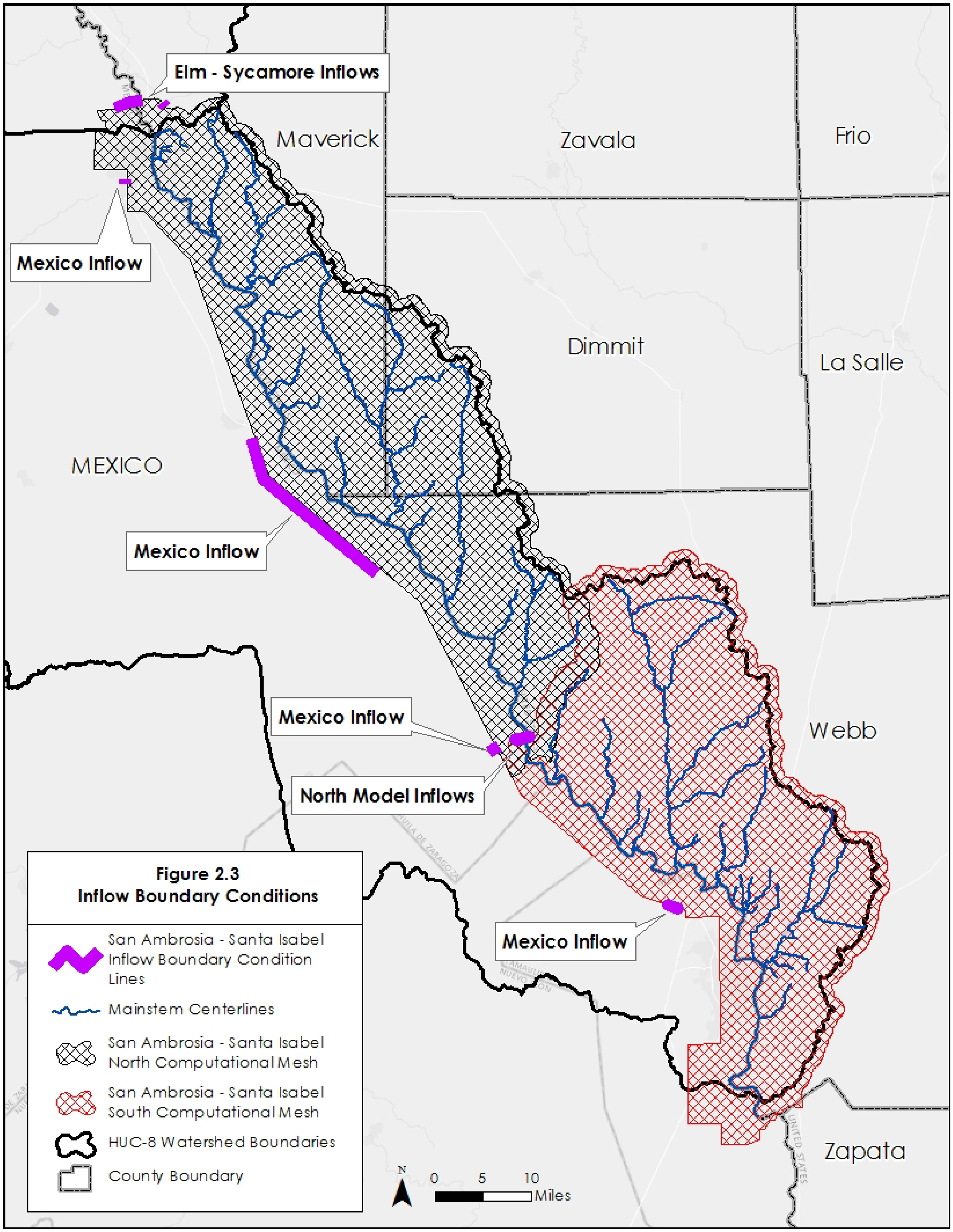

Figure 2.3: HEC-RAS 2D Computational Mesh and Inflow Boundary Conditions

2.2.3 Hydrology

The San Ambrosia – Santa Isabel Watershed contains the Rio Grande with contributing drainage area from both the United States and Mexico, with the greater portion from Mexico. The following sections discuss the approach for the hydrologic modeling in the United States and in Mexico.

2.2.3.1 United States Hydrology

HEC-HMS, Version 4.3, was used for the development of excess precipitation hyetographs which were applied to the 2D mesh in the United States. Precipitation frequency data published in NOAA Atlas 14, Volume 11 Version 2.0 (NOAA, 2018) were used for this study. These data were obtained from NOAA's Precipitation Frequency Data Server (PFDS) (http://hdsc.nws.noaa.gov/hdsc/pfds/index.html). The 10-, 4-, 2-, 1-, and 0.2-percent annual chance 24-hour precipitation depths for the watershed were determined by area-weighted intersection of gridded PFDS data within the study area. Excess precipitation for the 2D mesh was developed as described in Section 2.2.3.1.1.

Inflow hydrograph boundary conditions for the 2D mesh were derived from the Elm – Sycamore model and from the Mexico hydrology model (discussed in Section 2.2.3.3).

USGS streamflow gage data were leveraged to estimate peak flows for gages within the San Ambrosia – Santa Isabel Watershed for model validation purposes, as discussed in Section 2.3.1. The gages located in this watershed are presented in Table 2.3.

Table 2.3: USGS/IBWC Peak Streamflow Gages

Gage ID	Flooding Source and Location	Published Drainage Area (mi^2)	Period of Record
08458000	USIBW Rio Grande at Eagle Pass, TX	127,311	1931-2006
08458800	Rio Grande at Palafox near Laredo, TX	131,538	1960-1986
08459000	Rio Grande at Laredo, TX	132,578	1899-2020

Annual chance peak flows were calculated at each gage using USGS Bulletin 17C methodology. Calculated discharges for the 1-percent, 1-percent plus, and 1-percent minus events are presented in Table 2.4 for each gage utilized in this study. Gage 08458800 (Rio Grande at Palafox near Laredo, TX) was relocated along the Rio Grande in 1976 and discontinued in 1986. With limited data available at the new location on the river, this gage not utilized for this study because of the unreliability of the data and the relatively short period of record.

Table 2.4: USGS/IBWC Peak Streamflow Gage Analysis Results

Gage ID	Flooding Source and Location	1% Peak Q (cfs)	1%- Peak Q (cfs)	1%+ Peak Q (cfs)
08458000	USIBW Rio Grande at Eagle Pass, TX	438,241	272,873	497,219
08459000	Rio Grande at Laredo, TX	380,124	250,169	499,427

2.2.3.1.1 <u>Excess Precipitation for 2D Computational Mesh</u>

HEC-HMS, Version 4.3, was used to apply the SCS Curve Number method to calculate losses and define excess precipitation for each watershed. Temporal distributions of point rainfall totals were defined using frequency storm distributions. The plus and minus standard error for the 1-percent annual chance precipitation depths were determined as the upper and lower 84% confidence limits on the nominal 1-percent depth, assuming a normal distribution of the logarithms for the precipitation depths.

In addition to recurrence interval precipitation estimates, NOAA Atlas 14 provides 90% confidence intervals of reported precipitation values. On a normal distribution curve, 90% confidence intervals (i.e. the upper and lower 95% confidence limits) correspond to +/- 1.645 standard deviations. The 1-percent plus and minus events are defined to be one standard deviation above and below the 1-percent event.

Curve Numbers were computed by intersecting the National Land Cover Dataset (NLCD) 2016 coverage and NRCS soils data based on the matrix presented in Table 2.5. A portion of the modeled area was outside the coverage of the NLCD, and these areas were assumed to be NLCD classification of 11 (open water) since they were located in and near the Rio Grande.

Table 2.5: Land Use-Soils-CN Matrix for Computing Initial Curve Numbers

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

The time of concentration (in hours) for the study area was approximated as the square root of the drainage area (in square miles). Time of concentration was multiplied by 0.6 to compute the lag time. The lag time does not impact the excess rainfall hyetograph, so it was not necessary to compute a more accurate basin travel time. Table 2.6 below shows the curve number and lag time values used in this study.

Table 2.6: U.S. Rainfall-Runoff Parameters (Curve Number, Lag Time)

Sub-basin Description	CN	Lag Time (min)
San Ambrosia – Santa Isabel - North	65	1,069
San Ambrosia – Santa Isabel - South	66	1,049

NRCS rainfall-runoff methods were used to define excess precipitation applied to the 2D mesh, including curve numbers for defining rainfall losses and lag time for transforming the runoff temporally. No routing was considered in the rainfall-runoff modeling. Frequency storm distributions were used for defining temporal distributions of point rainfall totals. Weighted average rainfall depths were calculated for the 10-, 4-, 2-, 1-, and 0.2-percent ACEs. The weighted average rainfall depths for 1-percent plus and 1-percent minus rasters were also calculated using the upper and lower confidence intervals for the 1-percent event. These steps were performed for durations of 5-min, 15-min, 1-hr, 2-hr, 3-hr, 6-hr, 12-hr, and 24-hr. The weighted average rainfall depths were used to determine the excess precipitation in the HEC-HMS model. Areal reduction was not applied to the US portion of the watershed based on the sensitivity analysis described in Section 2.3.1. Table 2.7 provides the rainfall depths for a 24-hour storm duration used for determining excess precipitation.

Table 2.7: Precipitation Rainfall Depths for Estimating Excess Precipitation for HEC-RAS 2D Computational Mesh

Sub-basin Description	Percent Annual Chance Exceedance	Rainfall Duration (in)							
		5 min	15 min	1 hr	2 hr	3 hr	6 hr	12 hr	24 hr
San Ambrosia – Santa Isabel	10%	0.83	1.64	3.07	3.77	4.18	4.83	5.36	5.89
	4%	1.02	2.06	3.77	4.75	5.33	6.23	6.90	7.54
	2%	1.16	2.41	4.31	5.54	6.30	7.43	8.23	8.97
	1%	1.32	2.77	4.89	6.41	7.38	8.79	9.74	10.58
	1% minus	1.01	2.13	3.77	4.97	5.74	6.88	7.68	8.39
	1% plus	1.57	3.41	6.01	7.85	9.02	10.70	11.80	12.76
	0.2%	1.72	3.60	6.49	8.87	10.46	12.63	13.91	14.89

Figure 2.4 and Figure 2.5 show the hyetographs applied to the 2D computational mesh.

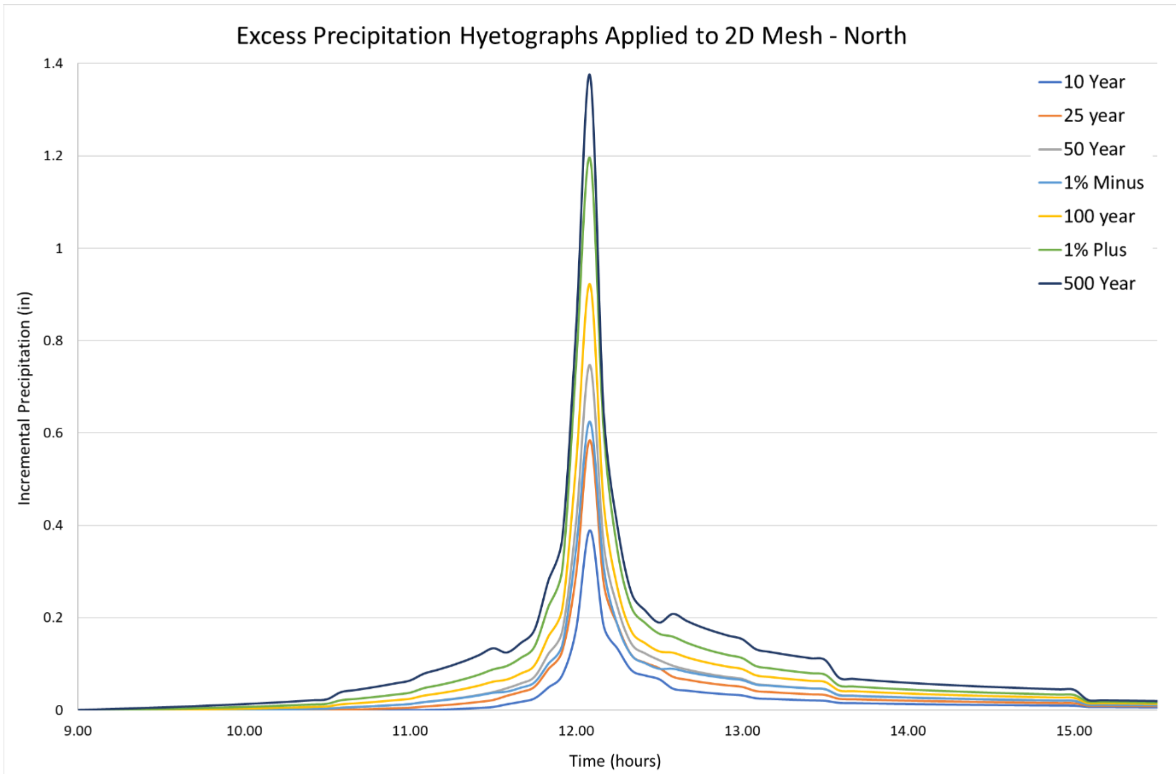

Figure 2.4: Precipitation Hyetographs Applied to the Computational Mesh in San Ambrosia – Santa Isabel - North

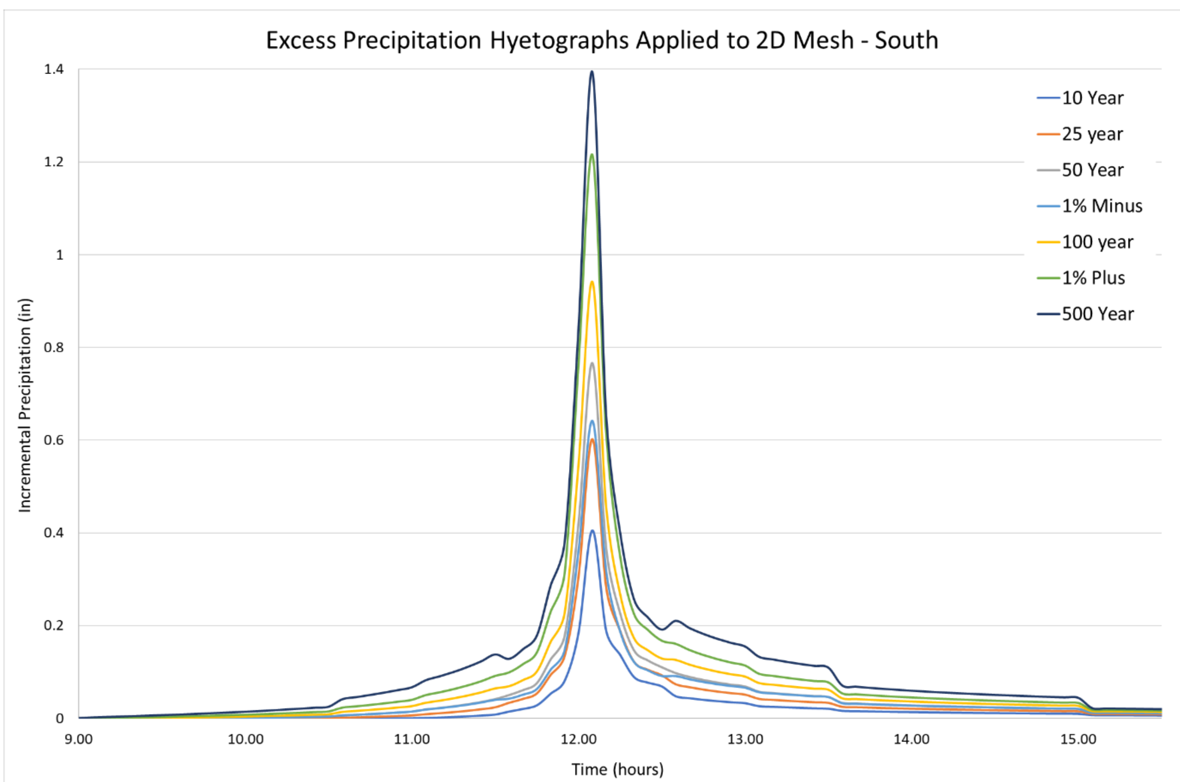

Figure 2.5: Precipitation Hyetographs Applied to the Computational Mesh in San Ambrosia – Santa Isabel - South

2.2.3.2 Mexico Hydrology

The hydrology in Mexico utilized drainage areas obtained from the *Instituto Nacional de Estadística, Geografía y Informatica* (INEGI) website, specifically, the "*Simulador de Flujos de Agua de Cuencas Hidrograficas*". These basins were merged or adjusted based on location and engineering judgement. Figure 2.6 shows the final boundaries of the Mexico drainage basins used, as well as the U.S HUC-10 boundaries.

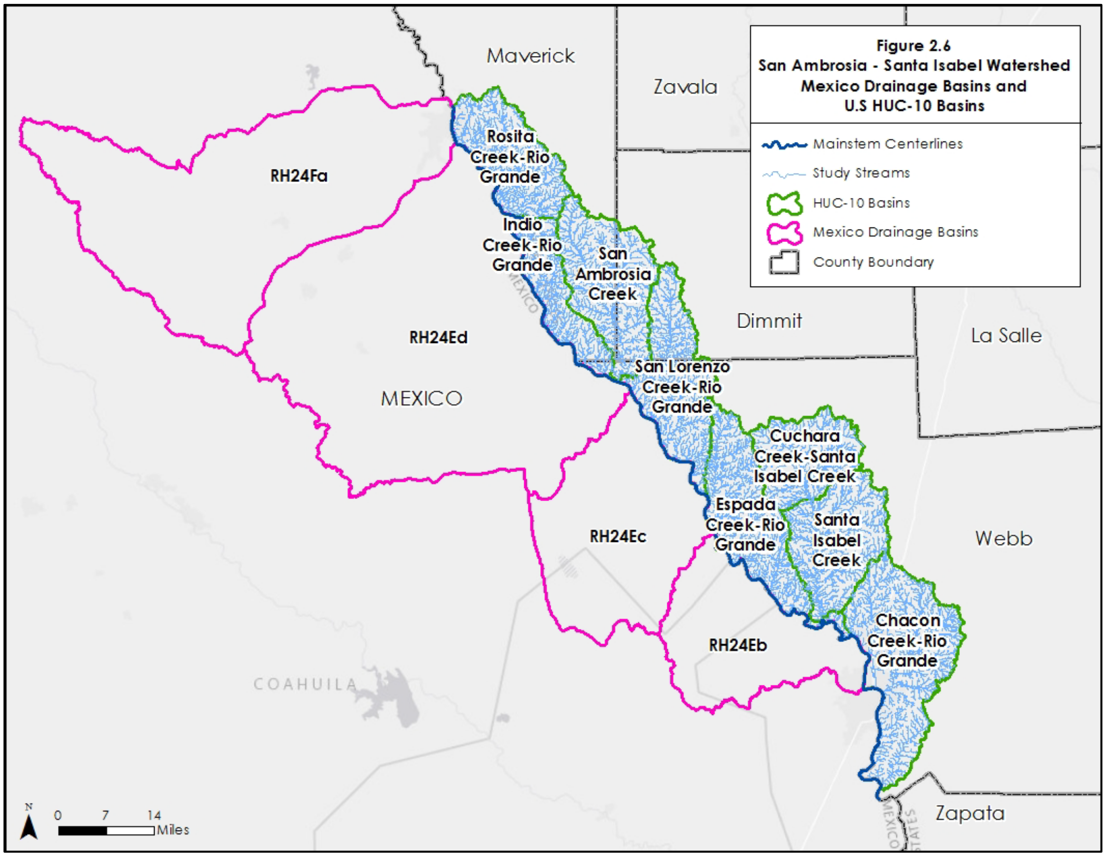

Figure 2.6: Mexico Drainage Basins and U.S. HUC-10 Basins in San Ambrosia - Santa Isabel

Mexico land use data was based on the North American Land Change Monitoring System (NALCMS) 2015 land cover 30-meter resolution map. The NALCMS land cover categories were converted to NLCD codes according to Table 2.8 below.

Table 2.8: Mexico Landcover

NALCMS 2015 Land Cover Values and Description		NLCD Code	NLCD Description
Value 1	Temperate or sub-polar needleleaf forest	42	Evergreen Forest
Value 2	Sub-polar taiga needleleaf forest	42	Evergreen Forest
Value 3	Tropical or sub-tropical broadleaf evergreen forest	42	Evergreen Forest
Value 4	Tropical or sub-tropical broadleaf deciduous forest	41	Deciduous Forest
Value 5	Temperate or sub-polar broadleaf deciduous forest	41	Deciduous Forest
Value 6	Mixed forest	43	Mixed Forest
Value 7	Tropical or sub-tropical shrubland	52	Shrub Scrub
Value 8	Temperate or sub-polar shrubland	52	Shrub Scrub
Value 9	Tropical or sub-tropical grassland	71	Herbaceous
Value 10	Temperate or sub-polar grassland	71	Herbaceous
Value 14	Wetland	95	Emergent Herbaceous Wetlands
Value 15	Cropland	82	Cultivated Crops
Value 16	Barren lands	31	Barren Land
Value 17	Urban	23	Developed Medium Intensity
Value 18	Water	11	Open Water

The time of concentration for the Mexico sub-basins was calculated using velocity-based methods. The flow was split into five major categories: overland flow, shallow concentrated flow, channel – mountainous, channel – hills, and channel – plains. Each of the channel sections were drawn and had an estimated slope. The velocities for channel sections were calculated using the open channel sections in Bentley's FlowMaster software. Table 2.9 shows the curve number and lag time values used in this study.

Table 2.9: Mexico Rainfall-Runoff Parameters (Curve Number, Lag Time)

Sub-basin Description	CN	Lag Time (min)
RH24Eb	71	792
RH24Ec	68	694
RH24Ed	69	796
RH24Fa	68	971

Precipitation data for Mexico was obtained from Centro Nacional de Prevencíon de Desastres in Mexico (http://www.atlasnacionalderiesgos.gob.mx/portal/fenomenos). Isohyets were available for the 24-hr storm event and treated like contours to create a precipitation raster. Rainfall depths were available only for 1-hour and 24-hour storm durations, so depths for the other durations (5-min, 15-min, 2-hr, 3-hr, 6-hr, and 12-hr) were computed based on average ratios established from the depth-durations in the U.S.

hydrology. Additionally, rainfall depths were not available for the 4-percent, 1-percent plus, and 1-percent minus frequency events, so depths were interpolated based on ratios established from the U.S. hydrology.

Areal reduction was applied to the Mexico subbasins using the USGS areal reduction curves (USGS WRI Report 99-4267). Areal reduction was applied to the Mexico basins and not the U.S. basins in order to align with the gage analyses on the Rio Grande and to ensure that the International Falcon Reservoir stage did not exceed the top of the dam in the 0.2-percent storm event.

2.2.3.3 Rainfall-Runoff Hydrograph Boundary Conditions

This section discusses the drainage areas for which inflow hydrographs, developed from rainfall-runoff modeling, were used as boundary conditions to the 2D computational mesh. The following figures show the inflow hydrographs for each contributing flooding source applied to the 2D computational mesh. Note that Figure 2.7 and Figure 2.8 include the Elm – Sycamore drainage area from two locations contributing inflow hydrographs to San Ambrosia – Santa Isabel. Figure 2.9, Figure 2.10, Figure 2.11, and Figure 2.12 include the Mexico tributaries drainage area contributing inflow hydrograph to San Ambrosia – Santa Isabel.

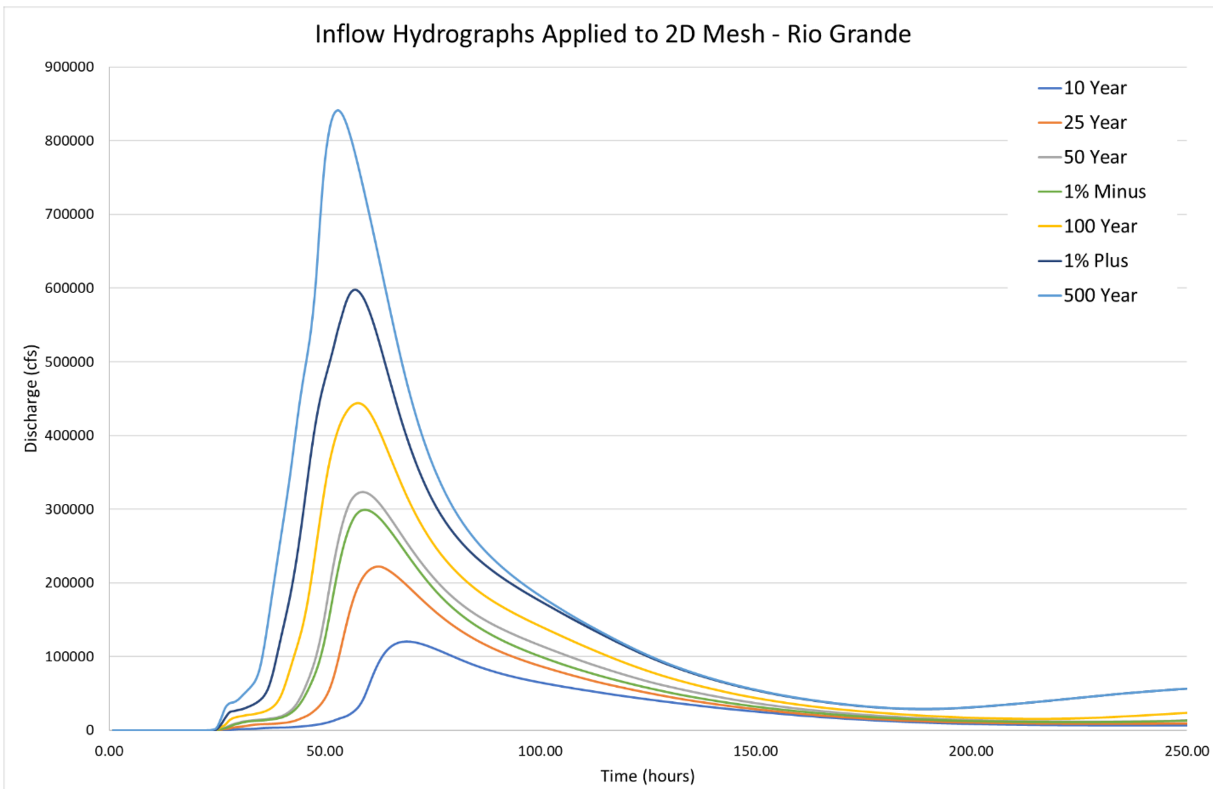

Figure 2.7: Elm – Sycamore Basin – Rio Grande Drainage Area Inflow Hydrographs

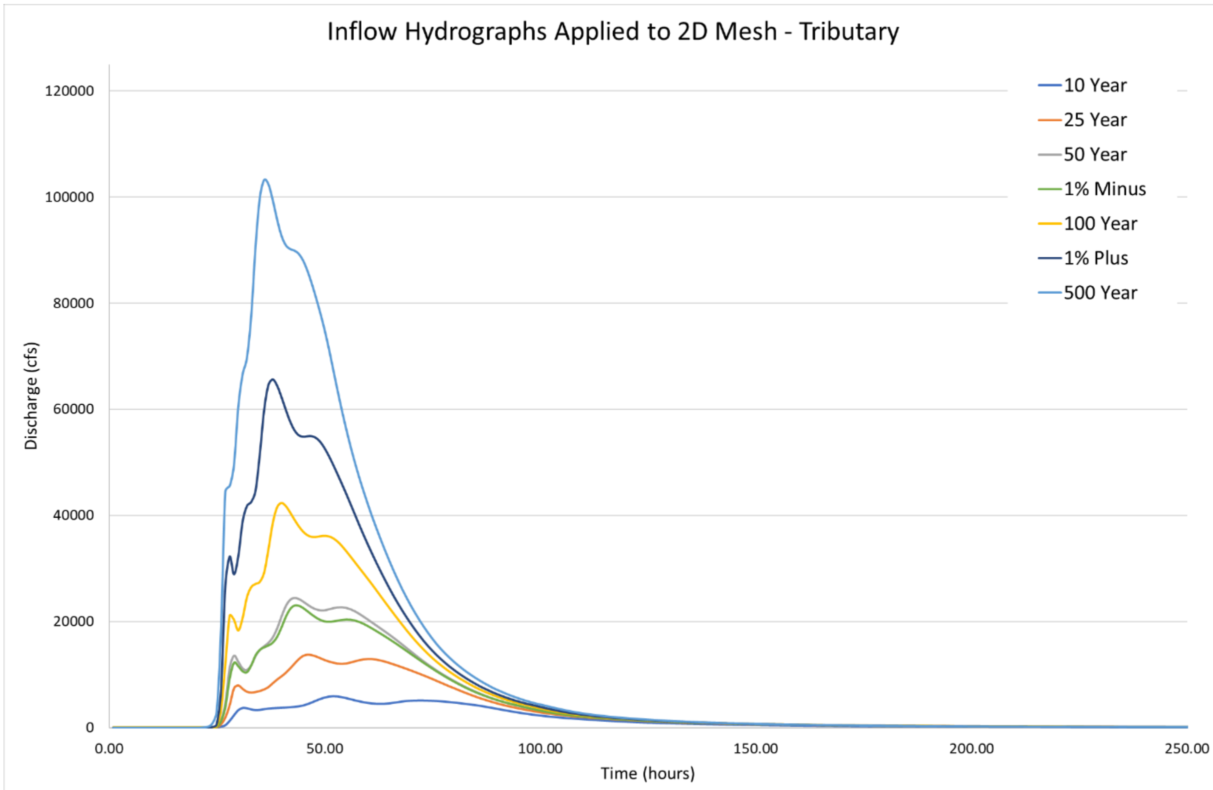

Figure 2.8: Elm – Sycamore Basin – Tributary Drainage Area Inflow Hydrographs

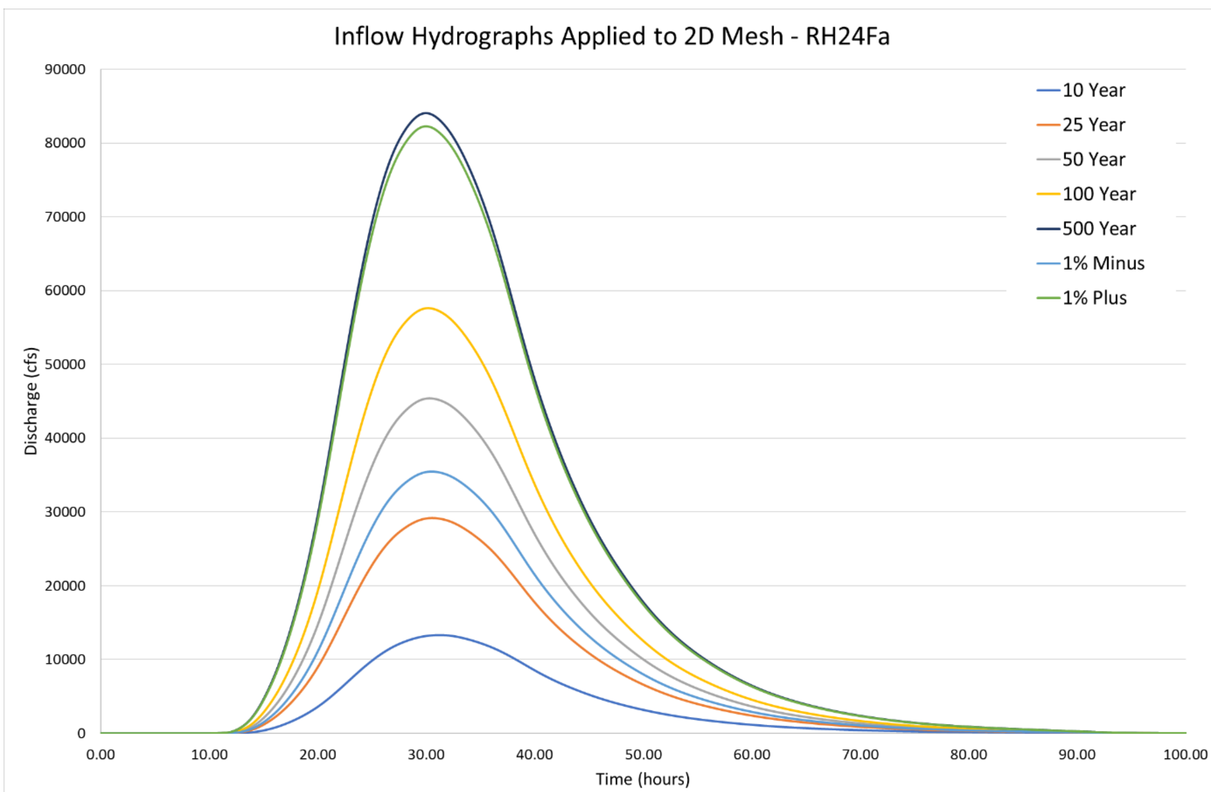

Figure 2.9: RH24Fa – Rio Escondido Basin Contributing Drainage Area Inflow Hydrographs

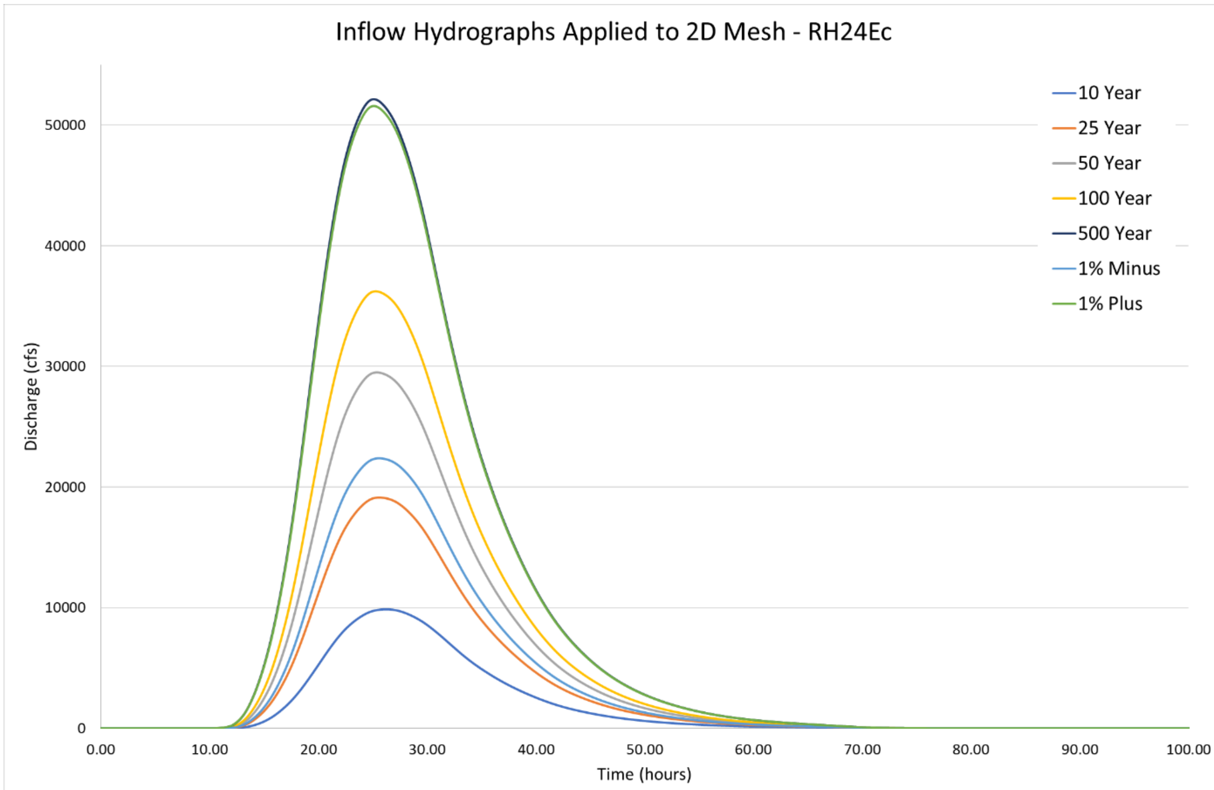

Figure 2.10: RH24Ec Basin Contributing Drainage Area Inflow Hydrographs

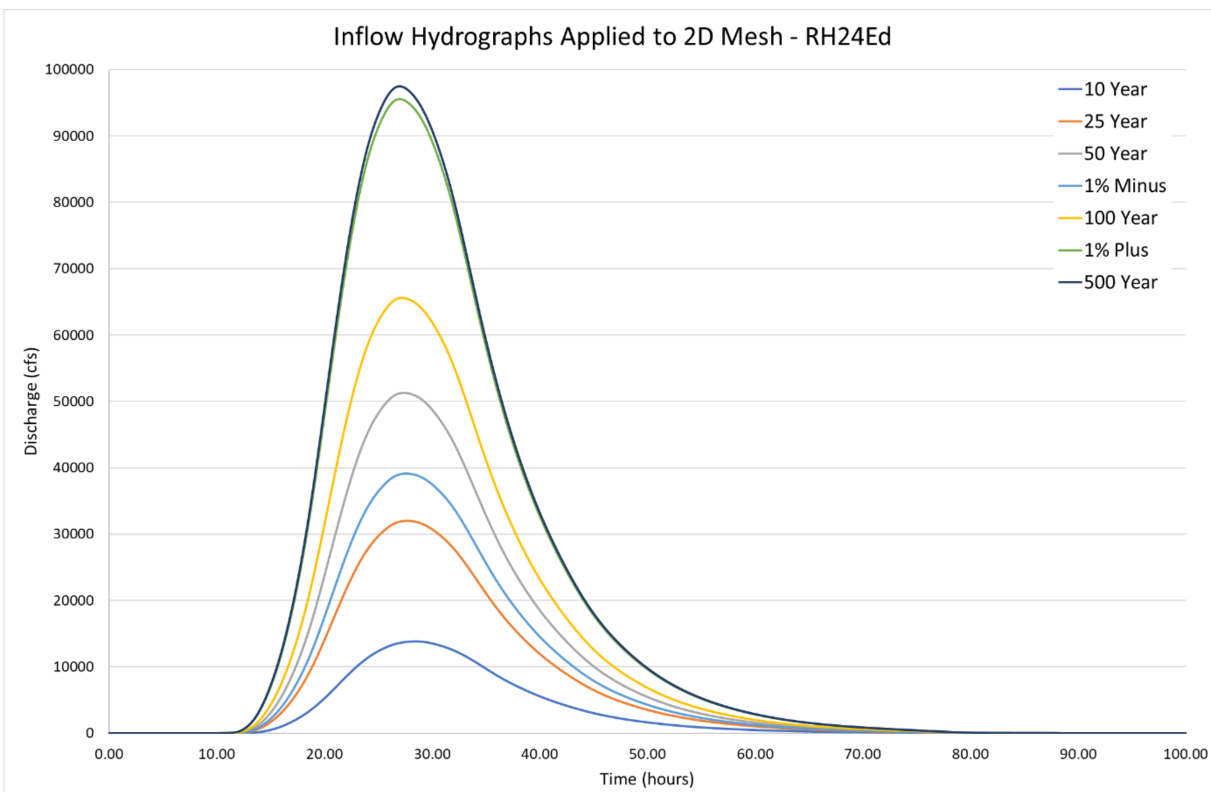

Figure 2.11: RH24Ed Basin Contributing Drainage Area Inflow Hydrographs

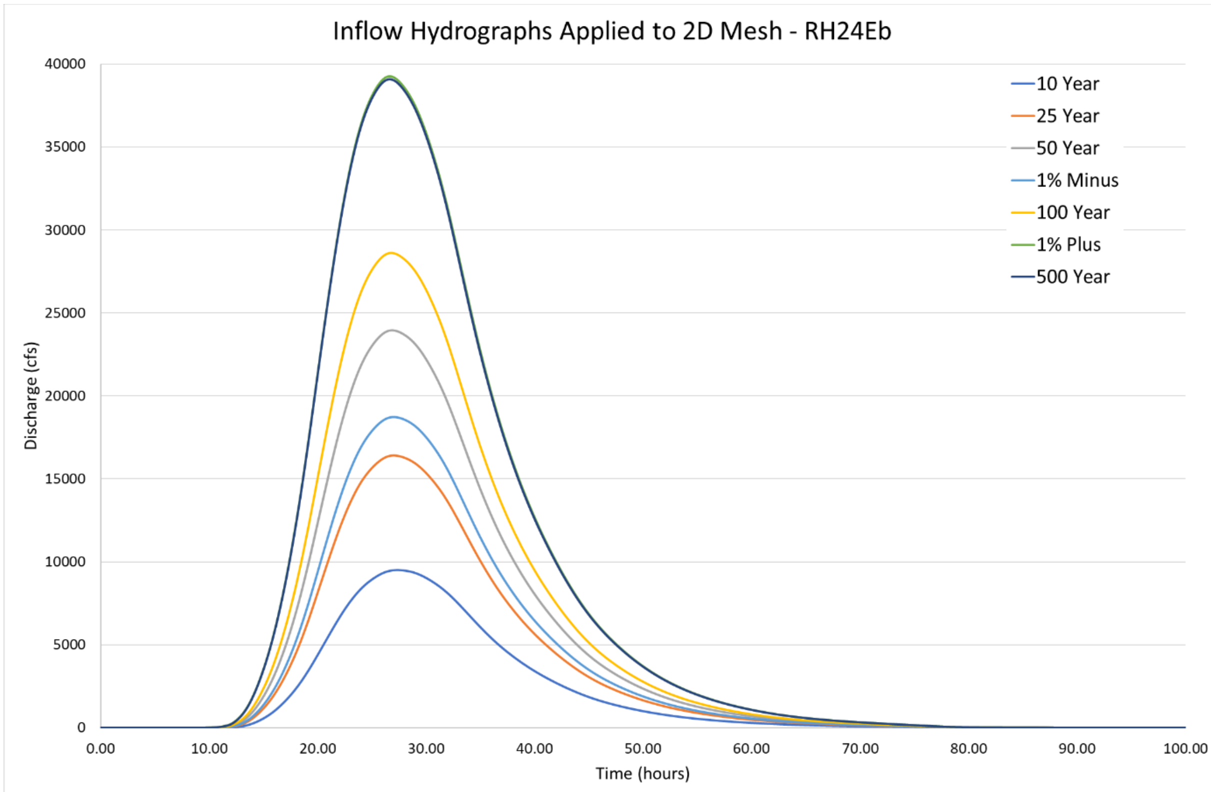

Figure 2.12: RH24Eb Basin Contributing Drainage Area Inflow Hydrographs

2.2.4 Hydraulics

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

2.2.4.1 Roughness Coefficients

A Manning's n roughness coverage was developed for the 2D computational mesh using typical values for roughness for given NLCD land classifications. In several areas, the channel section land use indicated a Manning's n-value inappropriate for channel conveyance. A 20-foot buffer zone was created by automated processes around each stream centerline (mainstem and tributaries) to create a main channel roughness zone. The channel roughness zone was given a Manning's n value of 0.045, obtained from the HEC-RAS User's Manual, to ensure the channel 2D cells have appropriate conveyance. The table below shows a typical land use-roughness matrix used in defining the roughness coverage for the study area.

Table 2.10: NLCD 2016-Manning's N Roughness Matrix

NLCD Classification	Manning's N	Minimum	Normal	Maximum
Open Water	0.030	0.025	0.038	0.050
Developed, Open Space	0.040	0.030	0.040	0.050
Developed, Low Intensity	0.060	0.060	0.090	0.120
Developed, Medium Intensity	0.080	0.080	0.120	0.160
Developed, High Intensity	0.120	0.120	0.160	0.200
Barren Land	0.030	0.023	0.025	0.030
Deciduous Forest	0.120	0.100	0.150	0.200
Evergreen Forest	0.120	0.080	0.120	0.160
Mixed Forest	0.120	0.080	0.140	0.200
Scrub/Shrub	0.060	0.070	0.115	0.160
Grassland/Herbaceous	0.030	0.025	0.038	0.050
Pasture/Hay	0.040	0.025	0.038	0.050
Cultivated Crops	0.040	0.020	0.035	0.050
Woody Wetlands	0.100	0.045	0.098	0.150
Emergent Herbaceous Wetland	0.080	0.050	0.068	0.085
Main Channel[1]	0.045			

[1] Clean, winding, some pools and shoals, some weeds and stones, lower stages, more ineffective slopes and sections

2.2.4.2 Breaklines

Breaklines align grid cell faces and were used within the 2D mesh area to define prominent features including road embankments and hydraulic structures as well as stream centerlines. Road embankments were identified in ArcGIS and imported into HEC-RAS as breaklines to ensure that water was not routed past roads until it was deep enough to overtop the road. County, interstate, state recognized, and U.S. roads were incorporated for road breaklines from the ESRI North America Detailed Streets layer. The stream centerlines were input as breaklines to ensure cells lined up perpendicular to the stream and to capture stream conveyance. Stream centerlines were simplified to speed up editing and run times in HEC-RAS. Railroads from the TIGER Railroads layer were also incorporated. Additionally, several private dams and embankments were added as breaklines to better represent flow patterns through and around these structures.

2.2.4.2.1 Roads

Culvert crossings specifically were identified by intersections of the stream centerlines and road lines by automated processes and were modeled by burning channels through the embankment in the DEM to prevent unnecessary impoundment of water. This approach was used for most hydraulic structures because it could be implemented in ArcGIS on a large scale with much less effort than alternative methods. Since this an automated process, it was not possible to isolate specific culverts to burn through the DEM, thus conservative assumptions on width of opening were applied to not overestimate the release of water through the crossing.

Bridge/culvert crossings that were not processed out of the terrain data were modeled by inserting v-notches into the road breaklines at the points of intersection with the bridge/culvert crossings. The v-notches cause the grid cells to realign around the embankment and allow water to be routed across the embankment without creating artificial backwater. An example of the v-notch breakline approach is shown below.

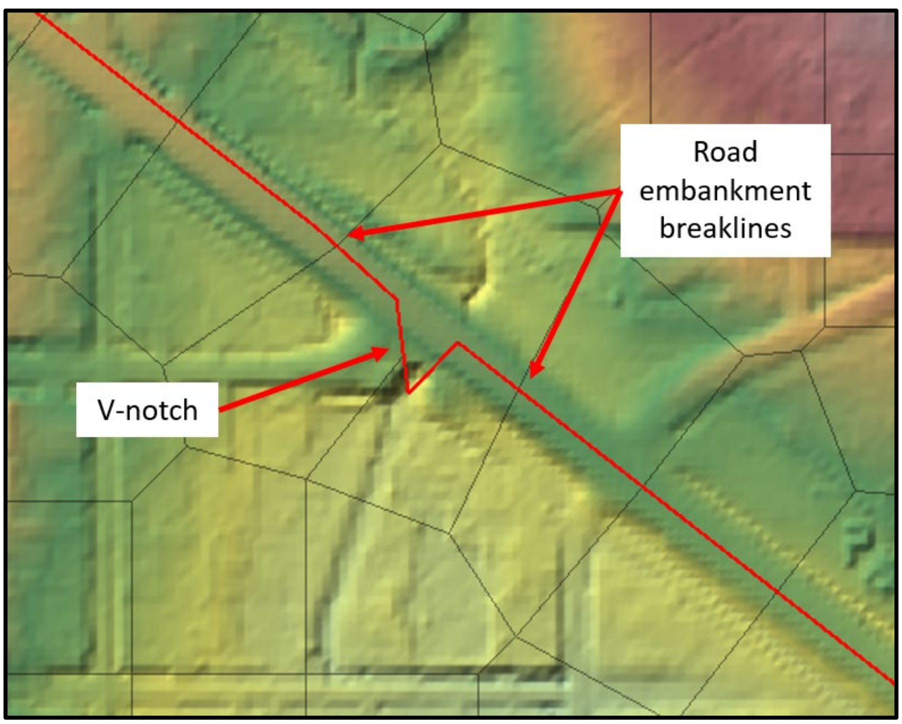

Figure 2.13: V-notch Breakline Approach at Bridge Crossing

2.2.4.3 Initial Conditions

Initial conditions were not used in the San Ambrosia – Santa Isabel 2D BLE model.

2.2.5 Special Assumptions

Due to the large size of the San Ambrosia – Santa Isabel HUC, it was deemed necessary to split the HUC-8 into a North and South RAS model. The models were split approximately 1.5 miles upstream of Gage No. 08458800. There were some differences in the North and South models such as necessary boundary conditions, but computational parameters, nominal mesh cell size, and land use n-values remained constant between the two models. Flow hydrographs on the Rio Grande were used to transfer flow from the North model to the South model. Figure 2.14 below shows the two model boundaries with respective buffers used in the RAS models.

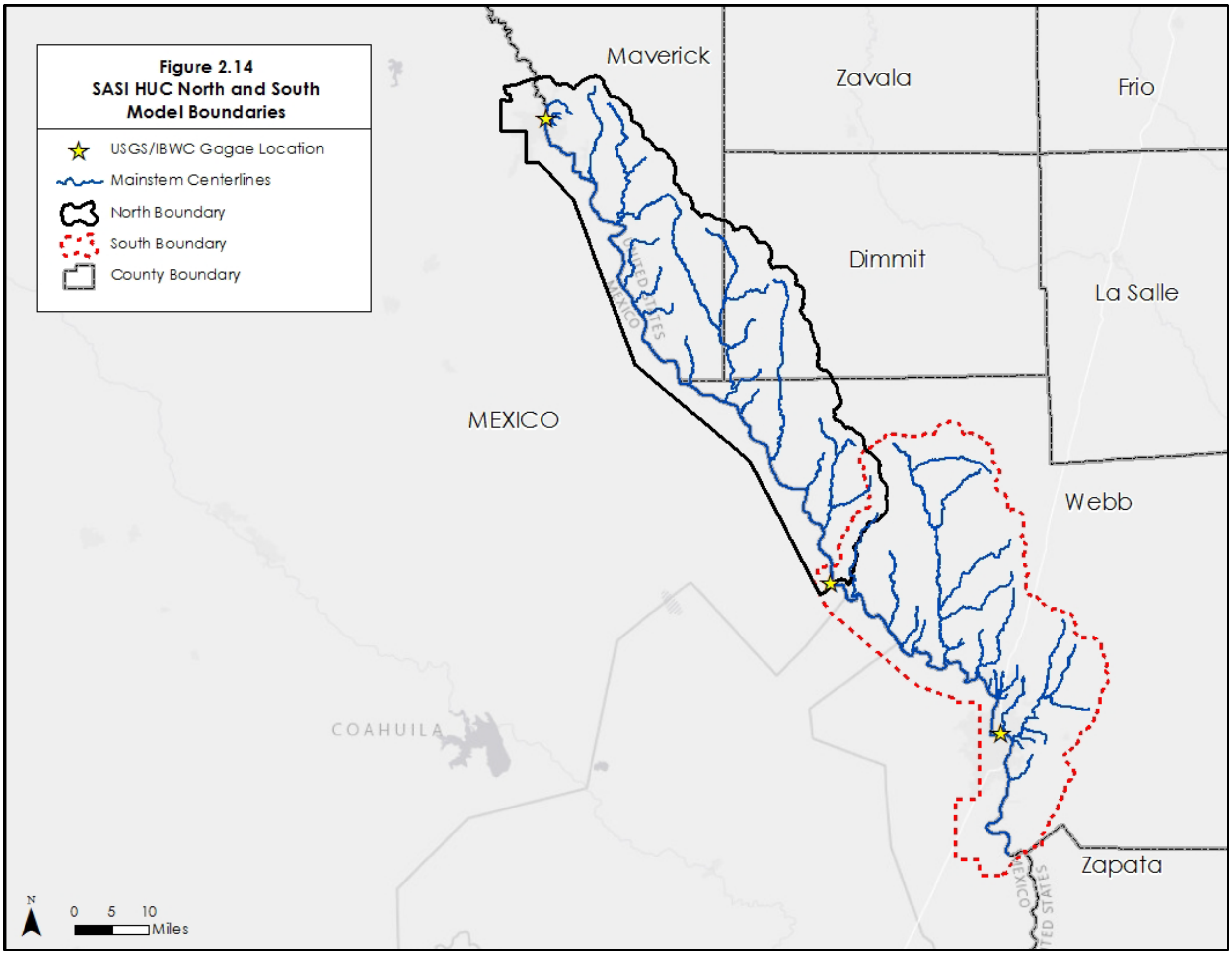

Figure 2.14: San Ambrosia – Santa Isabel Model Boundaries

Many irrigation canals were present in the San Ambrosia – Santa Isabel Watershed that required two unique approaches to maintain the integrity of the floodplain mapping. The first approach was for canals that had an elevated water surface. For these, a partial burn was performed between the berms, keeping the berms intact. This ensured that water leaked through the canal at a lower, more desirable elevation and ponding within the canal was disconnected from the main stem's ponding. An example of the first approach can be seen below in Figure 2.15.

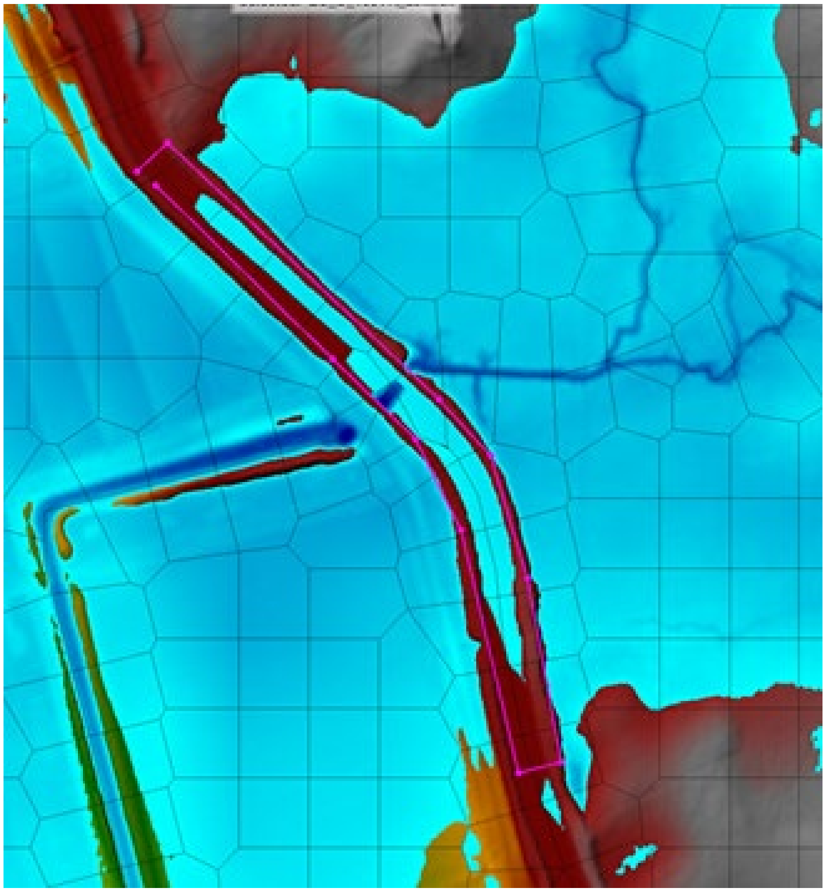

Figure 2.15: First Canal Burn Approach

The second approach was for canals that were as deep as the natural ground surrounding the berm and had significant leakage across the canal. For these, breaklines were revised from following the center of the canal to one breakline along each berm. These new breaklines were spaced 100 feet apart as opposed to the 200-foot spacing present in the rest of the model. Next, a full burn was performed across the canal, and the canal ends were capped, preventing flow exchange between the stream and canal. The caps were made 200 feet wide in the direction of the canal. An example of the second approach can be seen below in Figure 2.16.

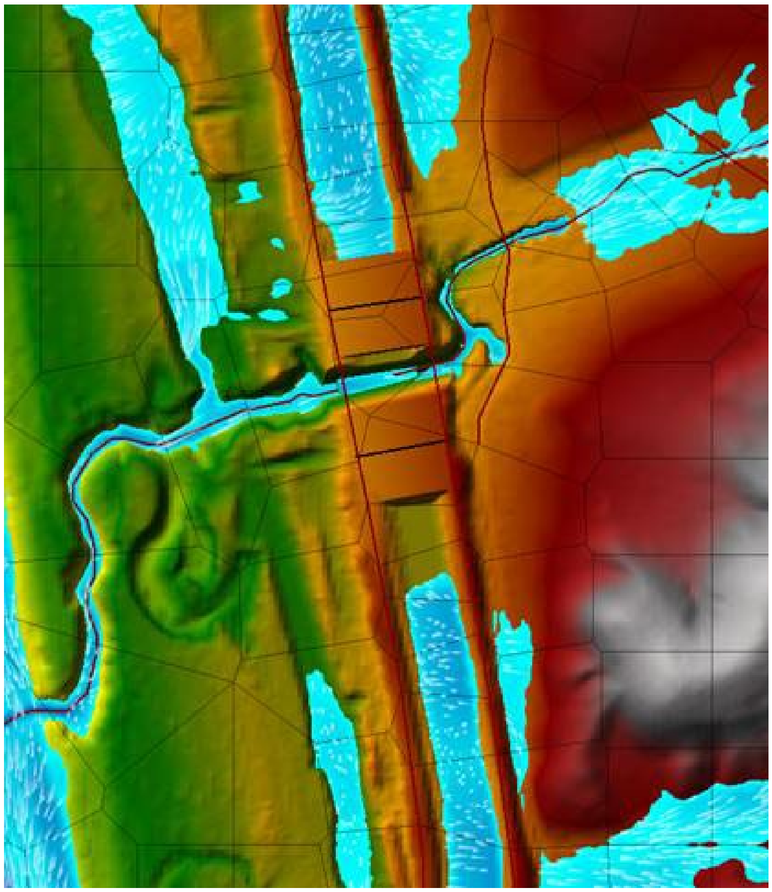

Figure 2.16: Second Canal Burn Approach

2.3 Model Results

The 2D BLE results for the study produced flood risk mapping that compared reasonably well with the effective SFHA in most cases and provides additional estimated flood risk in areas that do not currently have an 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. Table 2.11 shows a comparison of some the effective BFE data with the model results. In general, model BFEs are higher than the effective BFEs, with the exception of Unnamed Tributary to Arroyo Linda Tributary. The differences can be attributed to the effective study dates (which range from 2008 to 2011 in the San Ambrosia – Santa Isabel Watershed), the availability of newer digital topography, the change in rainfall data, and the 2D nature of this BLE study. While there are differences in water surface elevation, the modeled flood extents align well to the effective mapping.

While the results provide context for flood risk communication as part of the Discovery process, and are scalable, the results require further analysis to be used for regulatory purposes. The validity of the 2D BLE results should be verified through community work map meetings before being applied as a regulatory product.

Table 2.11: Effective and Model BFE Comparison

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
Arroyo Linda Tributary to Chacon Creek	2993	602.6	603.8	1.2
Arroyo Linda Tributary to Chacon Creek	3097	603.7	604.9	1.2
Arroyo Linda Tributary to Chacon Creek	3325	603.8	605.4	1.6
Arroyo Linda Tributary to Chacon Creek	3457	603.9	605.6	1.7
Arroyo Linda Tributary to Chacon Creek	3662	604.2	605.8	1.6
Arroyo Linda Tributary to Chacon Creek	3879	604.8	606.0	1.2
Arroyo Linda Tributary to Chacon Creek	4273	606.1	606.9	0.8
Arroyo Linda Tributary to Chacon Creek	4699	607.4	608.1	0.7
Arroyo Linda Tributary to Chacon Creek	4898	608.0	608.7	0.7
Arroyo Linda Tributary to Chacon Creek	5093	608.9	609.6	0.7
Arroyo Linda Tributary to Chacon Creek	5307	609.7	610.7	1.0
Arroyo Linda Tributary to Chacon Creek	5429	610.4	612.0	1.6
Arroyo Linda Tributary to Chacon Creek	5551	612.7	613.3	0.6
Arroyo Linda Tributary to Chacon Creek	5721	612.7	613.6	0.9
Arroyo Linda Tributary to Chacon Creek	5828	612.8	613.9	1.1
Arroyo Linda Tributary to Chacon Creek	6147	613.1	614.4	1.3
Arroyo Linda Tributary to Chacon Creek	6328	613.5	615.0	1.5
Arroyo Linda Tributary to Chacon Creek	6545	614.0	615.5	1.5
Arroyo Linda Tributary to Chacon Creek	6730	614.1	615.8	1.7
Arroyo Linda Tributary to Chacon Creek	7166	614.8	616.7	1.9
Arroyo Linda Tributary to Chacon Creek	7597	616.3	617.6	1.3
Arroyo Linda Tributary to Chacon Creek	8193	618.5	619.9	1.4
Arroyo Linda Tributary to Chacon Creek	8406	619.3	620.7	1.4
Arroyo Linda Tributary to Chacon Creek	8597	620.0	621.4	1.4

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
Arroyo Linda Tributary to Chacon Creek	8810	621.1	622.4	1.3
Arroyo Linda Tributary to Chacon Creek	9002	622.1	623.3	1.2
Arroyo Linda Tributary to Chacon Creek	9215	623.0	624.2	1.2
Arroyo Linda Tributary to Chacon Creek	9413	623.7	625.0	1.3
Arroyo Linda Tributary to Chacon Creek	9599	624.5	625.8	1.3
Arroyo Linda Tributary to Chacon Creek	9781	625.5	626.7	1.2
Arroyo Linda Tributary to Chacon Creek	10003	626.5	627.8	1.3
Arroyo Linda Tributary to Chacon Creek	10178	627.3	628.9	1.6
Eagle Pass Creek	11792	758.5	761.0	2.5
Eagle Pass Creek	13164	768.2	770.6	2.4
Eagle Pass Creek	13965	776.3	777.3	1.0
Eagle Pass Creek	14731	784.1	785.9	1.8
Eagle Pass Creek Tributary 1	1670	735.7	736.2	0.5
Eagle Pass Creek Tributary 1	2227	740.0	741.2	1.2
Eagle Pass Creek Tributary 2	638	747.1	749.2	2.1
Eagle Pass Creek Tributary 2	3648	761.0	763.2	2.2
Eagle Pass Creek Tributary 2	4751	768.0	769.1	1.1
Eagle Pass Creek Tributary 2	6491	781.2	782.7	1.5
Eagle Pass Creek Tributary 2	7091	784.4	785.2	0.8
Eagle Pass Creek Tributary 2	7691	791.2	790.0	-1.2
Las Manadas Creek	3446	561.2	563.4	2.2
Las Manadas Creek	3447	548.2	550.4	2.2
Las Manadas Creek	3449	552.6	554.2	1.6
Las Manadas Creek	3450	548.0	549.9	1.9
Las Manadas Creek	3467	515.6	517.9	2.3
Las Manadas Creek	3514	503.2	501.5	-1.7
Las Manadas Creek	3547	493.8	491.9	-1.9
Las Manadas Creek	3562	478.7	479.1	0.4
Tordillo Creek	97	689.7	690.0	0.4
Tordillo Creek	197	690.2	690.4	0.2
Tordillo Creek	229	690.5	690.5	0.0
Tordillo Creek	355	690.9	691.0	0.1
Tordillo Creek	570	691.4	691.9	0.5
Tordillo Creek	794	692.4	692.6	0.2
Tordillo Creek	1158	693.9	693.8	-0.2
Tordillo Creek	1409	694.9	694.5	-0.4
Tordillo Creek	1828	696.3	696.1	-0.2
Tordillo Creek	2081	697.2	697.3	0.1
Tributary to Seco Creek	2714	740.7	743.3	2.6
Tributary to Seco Creek	3444	743.6	746.3	2.7

Stream	Comparison Point Effective Station	Effective BFE (feet)	Model BFE (feet)	Difference (feet)
Unnamed Tributary of Rio Grande	50	739.8	741.1	1.3
Unnamed Tributary of Rio Grande	1063	742.8	743.7	0.9
Unnamed Tributary of Rio Grande	2260	747.1	749.2	2.1
Unnamed Tributary of Rio Grande	2972	749.2	750.7	1.5
Unnamed Tributary of Rio Grande	4433	754.6	753.9	-0.7
Unnamed Tributary of Rio Grande	7650	765.0	766.1	1.1
Unnamed Tributary of Rio Grande	9291	772.0	773.9	1.9
Unnamed Tributary to Arroyo Linda Tributary	17	614.1	616.0	1.9
Unnamed Tributary to Arroyo Linda Tributary	526	616.2	616.9	0.7
Unnamed Tributary to Arroyo Linda Tributary	753	617.4	617.6	0.2
Unnamed Tributary to Arroyo Linda Tributary	1001	618.9	619.0	0.1
Unnamed Tributary to Arroyo Linda Tributary	1151	619.9	619.9	0.0
Unnamed Tributary to Arroyo Linda Tributary	1376	621.8	621.4	-0.5
Unnamed Tributary to Arroyo Linda Tributary	1541	623.2	622.6	-0.6
Unnamed Tributary to Arroyo Linda Tributary	1757	625.2	624.6	-0.6
Unnamed Tributary to Arroyo Linda Tributary	1991	627.3	626.9	-0.4
Unnamed Tributary to Arroyo Linda Tributary	2199	629.4	629.4	-0.1
Unnamed Tributary to Arroyo Linda Tributary	2412	631.2	631.0	-0.2
Unnamed Tributary to Arroyo Linda Tributary	2546	632.6	631.9	-0.7
Unnamed Tributary to Arroyo Linda Tributary	2721	634.6	633.3	-1.3
Unnamed Tributary to Arroyo Linda Tributary	2886	636.4	635.8	-0.6
Unnamed Tributary to Arroyo Linda Tributary	3040	637.8	637.0	-0.8
Unnamed Tributary to Arroyo Linda Tributary	3234	640.1	639.2	-0.9
Unnamed Tributary to Arroyo Linda Tributary	3434	642.3	640.9	-1.4
Unnamed Tributary to Arroyo Linda Tributary	3614	645.6	643.9	-1.7
Unnamed Tributary to Arroyo Linda Tributary	3779	647.9	647.1	-0.8
Unnamed Tributary to Arroyo Linda Tributary	3899	649.6	649.2	-0.4
Wonder Tank	3581	470.4	471.4	1.0
Zacate Creek	14935	418.3	420.9	2.7
Zacate Creek	15126	418.8	421.4	2.6
Zacate Creek	15637	419.6	422.5	2.8
Zacate Creek	15731	420.2	422.5	2.3
Zacate Creek	16289	421.7	424.2	2.6
Zacate Creek	18340	429.6	431.3	1.7

2.3.1 Model Validation & Sensitivity Analysis

Known USGS and IBWC gages within the model area with more than 20-years of combined flow record were used for calibration and validation of the 1-percent annual chance event. Peak flows within the model were compared with Bulletin 17C Analyses of the gage data using HEC-SSP, Version 2.2. Results of the flow comparisons are presented in Table 2.12.

There are three USGS/IBWC gages in the San Ambrosia – Santa Isabel Watershed. Of these gages, 08458000 and 08459000 were used for calibration of the hydraulic model. USGS/IBWC gage 08458800 was not used for calibration due to unreliable peak flow data. Gage 08458800 moved locations in 1976 and only 11 years of peak flow data are available at the new location.

Table 2.12: 1-percent Annual Chance Reasonability Comparisons

Flooding Source	USGS/IBWC Gage Used for Verification	**HEC-RAS 6.1** (2D)		Reference	
		WSEL (ft)	**Discharge (cfs)**	**WSEL (ft)**	**Discharge (cfs)**
Rio Grande	08458000	741.70	428,241	---[1]	531,082
Rio Grande	08459000	411.48	380,124	441.01[2]	395,740

[1] Water surface elevation information was not available with Mexico data.

[2] Water surface elevation is approximate based on HEC-SSP input data and adjusted to NAVD 88 Datum.

To determine which factors were significantly impacting the model results, a sensitivity analysis was run to evaluate the impact of four specific parameters: Manning's n-values, hydrologic losses, computation interval, and boundary conditions. Table 2.13 and Table 2.14 summarize the results of each run at each of the USGS/IBWC gages.

The sensitivity analysis on both gages demonstrated that river flows are highly dependent on hydrologic losses. In order to align with the gage analysis, areal reduction was not applied to the U.S. basins, while areal reduction was applied to the Mexico basins. Additionally, the extension of the 2D computational mesh into Mexico to cover the entire flood extent of the Rio Grande was accounted for by subtracting that drainage area from the Mexico subbasins in HEC-HMS (described as "no hydrologic overlap" in the tables below).

Table 2.13: Sensitivity Analysis Results at IBWC Gage 08458000

Iteration	Manning's N Zones	Breaklines	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	156,251	
2	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR[3]	Dry / 30 sec	Normal Depth	456,028	
3	Land Use with Shrub/Scrub 0.07	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR	Dry / 30 sec	Normal Depth	451,463	
4	Land Use with DOS 0.05, DLI 0.0.063, DMI 0.094 and DHI 0.125	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR	Dry / 30 sec	Normal Depth	453,406	
5	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR in US, AR in MX, NHO[4]	Dry / 30 sec	Stage Hydrograph	431,438	741.84
6[1]	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR in US, AR in MX, NHO	Dry / 30 sec	Normal Depth	438,241	741.70
					Gage Analysis:	531,082	---[2]

[1] Parameters from Iteration 6 were used for the final model, however additional computational mesh was implemented following the results of the sensitivity analysis.
[2] Water surface elevation information was not available with Mexico data.
[3]AR – areal reduction
[4]NHO – no hydrologic overlap

Table 2.14: Sensitivity Analysis Results at USGS/IBWC Gage 08459000

Iteration	Manning's N Zones	Breaklines	Hydrologic Losses	Initial Conditions/ Computational Interval	Boundary Conditions	Peak Flow (cfs)	Peak Elevation (ft)
1	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation	Dry / 1 min	Normal Depth	164,991	
2	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR[3]	Dry / 30 sec	Normal Depth	515,538	
3	Land Use with Shrub/Scrub 0.07	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR	Dry / 30 sec	Normal Depth	497,360	
4	Land Use with DOS 0.05, DLI 0.0.063, DMI 0.094 and DHI 0.125	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR	Dry / 30 sec	Normal Depth	506,888	
5	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR in US, AR in MX, NHO[4]	Dry / 30 sec	Stage Hydrograph	380,526	411.87
6[1]	Original Land Use	Major Roads w/Centerlines Enforced - Simplified	Excess Precipitation, No AR in US, AR in MX, NHO	Dry / 30 sec	Normal Depth	380,124	411.48
					Gage Analysis:	395,740	441.01[2]

[1] Parameters from Iteration 6 were used for the final model, however additional computational mesh was implemented following the results of the sensitivity analysis.
[2] Water surface elevation is approximate based on HEC-SSP input data.
[3]AR – areal reduction
[4]NHO – no hydrologic overlap

2.4 Challenges

Major challenges included a lack of peak streamflow records in Mexico, though sufficient data was available to provide confidence in the results.

The Mexico hydrology was established using best available soils and land use data as well as topographic information. Runoff estimates were not able to be validated for the Mexico hydrology.

Structures have not been added to the BLE model despite evidence of cross structures which allow the streams to convey water through numerous structures. In these locations, the model may be overestimating the water surface elevation upstream of the road until the road is overtopped and underestimating the water surface elevation downstream of the road.

HEC-RAS, Version 6.1, has an apparent bug that was identified in reviewing isolated areas of flooding. In these areas, the lower frequency events (ex. 10-percent) showed higher water surface elevations than the higher frequency events (ex. 0.2-percent). This was reviewed in multiple versions of HEC-RAS and was confirmed to occur in Version 5.7, 6.1 and 6.2. It is unknown why this may occur; however, the model does not experience instabilities and the mainstem floodplains have not shown this occurring when reviewing profile lines. In review of the model setup, stability and results, the flood extent results appear appropriate and impacts due to the bug are likely negligible.

HEC-RAS, Version 6.1 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. Since this is a known issue in HEC-RAS and HEC is working on a solution, effort to remove these errors from the flood extents was not performed. Figure 2.17 below provides an example of cupping for reference. Once a solution is provided by HEC, it may be possible to update mapping to reduce and/or remove the cupping effects on the fringe of the floodplains.

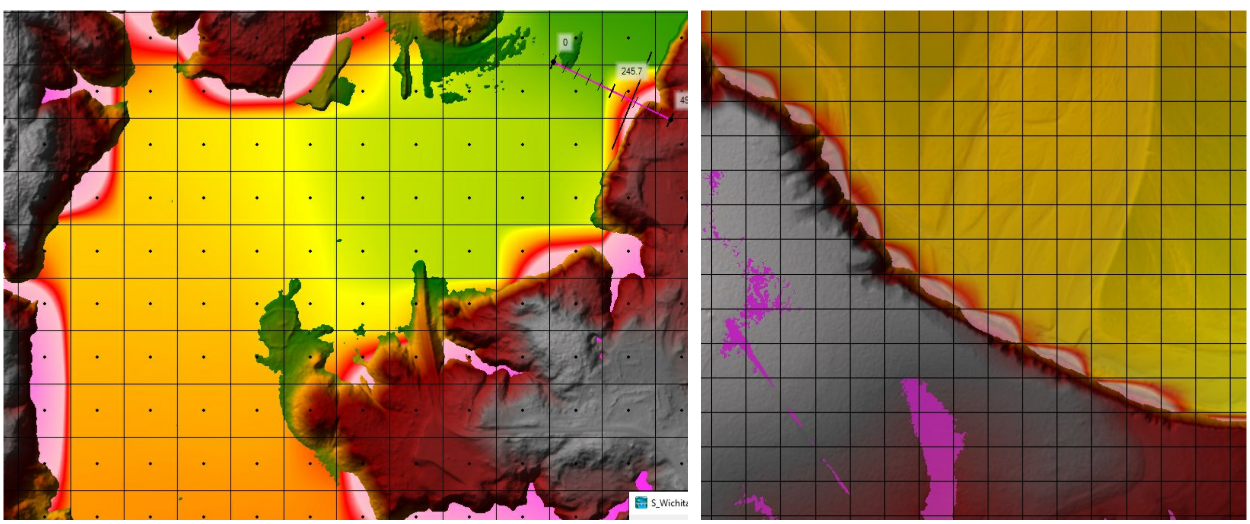

Figure 2.17: Cupping Examples

2.5 Recommendations

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

03 Floodplain Mapping and Effective Zone A Validation

The following sections provide a synopsis of how raw modeled depths were translated into SFHAs. In addition to developing a new SFHA, the BLE model data was leveraged to validate the effective zone A studies within the project footprint. The results of the validation effort can be found below in Section 3.2.

3.1 Special Flood Hazard Area

3.1.1 Model Outputs

The floodplains are derived from the raw modeled depth grids using the maximum value. These depth grids are exported from HEC-RAS as TIFF format rasters with an interpolated rendering that slope values at the center and along the faces/edges of the computational mesh cells. Using GIS, the TIFF rasters are post processed into a 10-percent non-regulatory feature class, 1-percent ACE SFHAs and 0.2-percent shaded X polygons.

3.1.2 Methodology

The use of 2D modeling methods results in water surface elevation values at every cell in the model's computational mesh. In order to represent the desired model results and eliminate extraneous disconnected cells, post processing of the depth grids is required. For the purposes of the San Ambrosia – Santa Isabel BLE study, floodplain mapping delineation was completed using connected raster cells at the extent of the CNMS mapped and unmapped features in the project footprint. Converting the raster data to polygon features enabled an intersection of modeled results to the CNMS and effective zones to create the SFHA and 0.2-percent shaded X features. Because the new mapping, based on gridded engineering, retains the blocky shape of a raster, a simplification process was applied using GIS to smooth the boundaries using a 10-foot smoothing threshold. These processes remove unnecessary points, bends, and angles while preserving the natural shape of the polygon. Furthermore, small voids, or "holes" inside of the floodplain were aggregated with the larger surrounding polygons to merge them and make the floodplain complete. In alignment with the TWDB's 2D BLE Guidelines (May 2022) floodplain polygons were cleaned against the criteria provided below in Table 3.1 which provides thresholds for mapping removal based on depth and area of flood risk.

Table 3.1: 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

For example, if flooding polygons were disconnected from a flooding source and less than two acres in area and 0.1 feet of depth, the polygon was removed from the SFHA. These edits align to the mapping standards adopted by the TWDB and those required by FEMA.

In addition to the SFHA, all other flooding associated with the 1- and 0.2-percent raw results were retained as "on the shelf" data that may be leveraged for future needs and analysis. This information is available in the included Supplemental Data associated with this study .

3.1.3 Flood Hazard Area Layer

Special Flood Hazard Areas (SFHA), as noted above, were developed to at least the extent of the CNMS features and up to 0.1 square mile drainage area and effective zone A study locations. The Regional CNMS database, National Flood Hazard Layer, and paper inventory were used as reference data to ensure extent of the BLE results represents appropriate current flooding extent coverage, at a minimum.

The 0.2-percent flood areas were produced using the same methods as the 1-percent SFHA. After both layers were developed, a union of the two products was performed to develop the deliverable format EBFE_FLD_HAZ_AR.

3.1.4 Mapping Considerations

3.1.4.1 Ponds

Numerous ponds exist throughout the San Ambrosia – Santa Isabel Watershed. Due to the nature of 2D BLE and the large mesh cells used for modeling, the entire extent of smaller, isolated ponding areas is not always fully mapped in the raw model output. To identify flood risk in these areas, the pond footprints were merged in by automated processes using the best available National Hydrography Dataset. This dataset has its own limitations in that it is not current to current topography or LiDAR and may not align completely to the present-day pond footprints. However, it was used as the best available at the time of the study. A nominal depth of 0.1-foot was used for any areas merged into the floodplain that were not in the raw model results and the water surface elevation was interpolated. The water surface elevations in these areas should not be considered correct and would require further study to refine the correct water surface elevation based on detailed modeling.

3.1.4.2 Mapping Tie-Ins

Watershed tie-ins required manual review and coordination between HUCs to ensure tie-ins could be met within the required 0.5-feet FEMA requirement. For the San Ambrosia – Santa Isabel Watershed, significant tie-ins occur at the upstream boundary with Elm – Sycamore, between the half HUCs of San Ambrosia – Santa Isabel, and downstream with International Falcon Reservoir.

At all of these tie-ins, a raster difference was created in ArcGIS based on the raw depth and WSE grids to manually establish the tie-in location for the 10-, 1-, and 0.2-percent ACE floodplain extents. Each difference grid was reviewed to determine a tie-in location with WSE difference no greater than plus/minus 0.5-feet.

Minor fringe watershed tie-ins to adjacent HUCs were checked to ensure they met the 0.5-foot tie-in requirement. These areas were modeled using overlapping meshes between adjacent HUCs and then clipped to the USGS HUC boundaries. These HUC boundaries resulted in minor discrepancies in the mapping extent and water surface elevations, however, no differences exceeded the 0.5-foot mapping tolerance.

3.1.4.3 Centerline Alignment

After completion of the FLD_HAZ_AR, the S_WTR_LNs (centerlines) were reviewed for containment within the 1-percent ACE floodplain. Any centerlines that were 50 feet or greater in length outside of the 1-percent floodplain extent were realigned for containment.

3.2 Validation of Effective Zone A SFHA

The following summarizes the results of the CNMS validation assessments for the effective Zone A studies in the San Ambrosia – Santa Isabel Watershed.

3.2.1 Initial Assessment A1 – Significant Topography Update Check

The significant topography update check determines whether a topographic data source is available that is significantly better than what was used for the effective Zone A modeling and mapping. For this study of the San Ambrosia – Santa Isabel Watershed the topographic data source for the BLE analysis was derived from the best available LiDAR data, as discussed in Section 2.1. This elevation data provides quality LiDAR data coverage for the entire study area, therefore, this check is set to PASS.

3.2.2 Initial Assessment A2 – Check for Significant Hydrology Changes

The significant hydrology changes check determines whether new regression equations have become available from the USGS since the date of the effective Zone A study. If newer regression equations exist for the area of interest, then an engineer must determine whether these regression equations would significantly affect the 1-percent-annual-chance flow. It is unknown if regression methods were used in the effective studies, therefore, this element was set to FAIL for newly added streams and left PASS if already attributed as such in previous CNMS.

3.2.3 Initial Assessment A3 – Check for Significant Development

The significant development check, using the National Urban Change Indicator (NUCI) dataset, assesses increased urbanization in the study watershed. If the percentage of urban area within a HUC-12 watershed containing the effective Zone A study is 15 percent or more and has increased by 50 percent or more since the effective analysis, the study would fail this check. The check for significant development in the San Ambrosia – Santa Isabel Watershed was completed by evaluating percentage of urban change at the HUC-12 level. The entire watershed is classified as rural and all reaches were set to PASS for this assessment.

Table 3.2 presents the summarized results of checks A1 through A3.

Table 3.2: A1-A3 Validation Results

Assessment Checks	Pass / Fail	Notes
A1 – Topography	Pass	LiDAR significantly better than effective USGS topo source/Effective mapping leveraged LiDAR data.
A2 – Hydrology	Pass/Fail	Effective hydrology methods are unknown
A3- Development	Pass	Less than 15% of study area is under urban cover/>50% increase in urban area in an urban HUC-12

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

Zone A studies that pass all initial assessment checks described above may be categorized as “Valid” in the CNMS Inventory only if the effective Zone A study is supported by modeling or sound engineering judgment and all regulatory products are in agreement. If the effective Zone A study passes all initial assessment checks, but is not supported by modeling, or if the original engineering method used is unsupported or undocumented, a comparison of the BLE results and effective Zone A’s is performed. Due to lack of documentation of the original engineering methods in the San Ambrosia – Santa Isabel Watershed, check A4 has been marked as FAIL for most parts of this study and left as PASS if it was already identified as such in previous CNMS.

3.2.5 Validation Check A5 – Comparison of BLE and Effective Zone A

The effective Zone A comparison was performed at the full extent of the San Ambrosia – Santa Isabel Watershed. The validation of the effective Zone A boundaries using 2D flood hazard products differ from the standard 1D methods due to the lack of cross sections and their use with standard FBS methodology. For this 2D study, the effective A zone boundaries were compiled using the National Flood Hazard Layer and Core Logic effective digital uplift product. These data were dissolved to one continuous A-zone layer, which then had test points placed along its perimeter every 200 feet.

For each test point, a 75-foot buffer was created. Using this buffer, the minimum and maximum values of the DEM were extracted, as a proxy for the effective base flood elevation. The minimum value of the 1-percent minus raster, and the maximum value of the 1-percent plus raster are also extracted. These 1-percent plus maximum and 1-percent minus minimum values are products of the new 2D BLE study and act as the vertical tolerance. The test point passes if the DEM maximum value is less than or equal to the 1-percent plus maximum value and the DEM minimum value is greater than or equal to the 1-percent minus minimum value. This can be visualized as a short 75-foot radius cylinder, with a height of 1-percent plus maximum – 1-percent minus minimum. This test verifies that at least one point from the ground surface (i.e. proxy BFE) falls both vertically and horizontally within this range.

3.2.6 Validation Results

All 1,807.3 total miles of available CNMS features representing the effective Zone A studies were categorized as shown in Table 3.3 and illustrated in Figure 3.1 below.

summarizes the validation results based on the individual HUC 12 watersheds within the San Ambrosia – Santa Isabel Watershed.

Table 3.3: Aggregated Zone A Validation Results

Validation Status	Status Type	Total Miles
VALID	BEING STUDIED	3.5
UNVERIFIED	BEING STUDIED	1,803.8

Table 3.4: HUC 12 Zone A Validation Results

HUC-12 Watershed		Total FBS Points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)
Watershed Name	Watershed Number					
Hediondo Creek-Elm Creek	130800011805	1	0	1	100.0	PASS
Seco Creek-Rio Grande	130800020702	345	180	165	47.8	FAIL
Carr Lake-Rio Grande	130800020703	1,241	651	590	47.5	FAIL
Rosita Creek	130800020704	1,907	513	1,394	73.1	FAIL
Headwaters Saus Creek	130800020707	2,305	437	1,868	81.0	FAIL
Cuevas Creek	130800020708	1,096	257	839	76.6	FAIL
Saus Creek	130800020709	603	152	451	74.8	FAIL
El Indio Farms Lake-Rio Grande	130800020710	820	432	388	47.3	FAIL
Headwaters San Ambrosia Creek	130800021401	1,198	383	815	68.0	FAIL
Coyote Tank-San Ambrosia Creek	130800021402	1,647	413	1,234	74.9	FAIL
Upper Rosita San Juan Creek	130800021403	1,262	651	611	48.4	FAIL
Lower Rosita San Juan Creek	130800021404	1,134	499	635	56.0	FAIL
San Pedro Creek-San Ambrosia Creek	130800021405	2,395	716	1,679	70.1	FAIL

HUC-12 Watershed		Total FBS Points	Fail	Pass	%Pass	BLE Comparison Pass? (>85%)
Watershed Name	Watershed Number					
130800021501-Rio Grande	130800021501	643	349	294	45.7	FAIL
Indio Creek	130800021502	1,238	258	980	79.2	FAIL
Cuervo Creek-Rio Grande	130800021503	1,363	459	904	66.3	FAIL
Tovar Creek-Rio Grande	130800021504	739	428	311	42.1	FAIL
Arroyo Los Puertos-Rio Grande	130800021505	1,121	419	702	62.6	FAIL
Borrego Creek-Rio Grande	130800021506	2,147	687	1,460	68.0	FAIL
Headwaters San Lorenzo Creek	130800021901	714	280	434	60.8	FAIL
Palo Blanco Tank-San Lorenzo Creek	130800021902	2,051	571	1,480	72.2	FAIL
Ojita Tank	130800021903	933	155	778	83.4	FAIL
Guyler Tank-San Lorenzo Creek	130800021904	1,570	346	1,224	78.0	FAIL
Jardin Creek-Rio Grande	130800021905	2,062	756	1,306	63.3	FAIL
Tordillo Tank-Tordillo Creek	130800021907	1,797	583	1,214	67.6	FAIL
San Cirilo Creek-Rio Grande	130800021909	2,276	990	1,286	56.5	FAIL
Cuchara Creek	130800022301	1,355	594	761	56.2	FAIL
Headwaters Santa Isabel Creek	130800022302	1,987	1,050	937	47.2	FAIL
Sardo Tank-Santa Isabel Creek	130800022303	1,008	520	488	48.4	FAIL
Headwaters Cochio Creek	130800022304	1,321	695	626	47.4	FAIL
Cochio Creek-Santa Isabel Creek	130800022305	2,392	1,283	1,109	46.4	FAIL
Paltio Blanco Arroyo-Santa Isabel Creek	130800022401	2,632	1,133	1,499	57.0	FAIL
Tejones Creek	130800022402	1,772	448	1,324	74.7	FAIL
Hondo Tank-Santa Isabel Creek	130800022403	1,853	885	968	52.2	FAIL
Tordillo Creek	130800022404	1,244	255	989	79.5	FAIL
Casa Blanca Tank-Santa Isabel Creek	130800022405	1,132	501	631	55.7	FAIL
Espita Creek-Espada Creek	130800022601	2,081	673	1,408	67.7	FAIL
Pinto Creek	130800022602	722	282	440	60.9	FAIL
Chapote Tank-Espada Creek	130800022603	713	305	408	57.2	FAIL
San Pedro Hill-Rio Grande	130800022604	648	333	315	48.6	FAIL
El Tubo-Rio Grande	130800022606	451	370	81	18.0	FAIL
Carricitos Creek	130800022607	1,734	594	1,140	65.7	FAIL
Wagon Wheel Tank-Rio Grande	130800022609	1,105	434	671	60.7	FAIL
Santo Tomas Creek	130800022610	1,540	593	947	61.5	FAIL
Los Indios Creek-Rio Grande	130800022611	1,488	549	939	63.1	FAIL
Las Presa Azul-Rio Grande	130800022612	643	471	172	26.7	FAIL
Sombrerito Creek	130800022801	3,998	901	3,097	77.5	FAIL
Zacata Creek-Rio Grande	130800022802	988	218	770	77.9	FAIL
San Ygnacio Creek	130800022803	5,896	1,217	4,679	79.4	FAIL
Lake Casa Blanca-Chacon Creek	130800022804	4,310	912	3,398	78.8	FAIL
City of Laredo-Chacon Creek	130800022805	1,842	272	1,570	85.2	PASS
San Idelfonso Creek-Rio Grande	130800022806	649	243	406	62.6	FAIL
Becerra Creek	130800022808	1,449	288	1,161	80.1	FAIL
Arroyo Las Animas-Rio Grande	130800022809	823	547	276	33.5	FAIL
Mendez Hills-Rio Grande	130800030601	2	2	0	0.0	FAIL

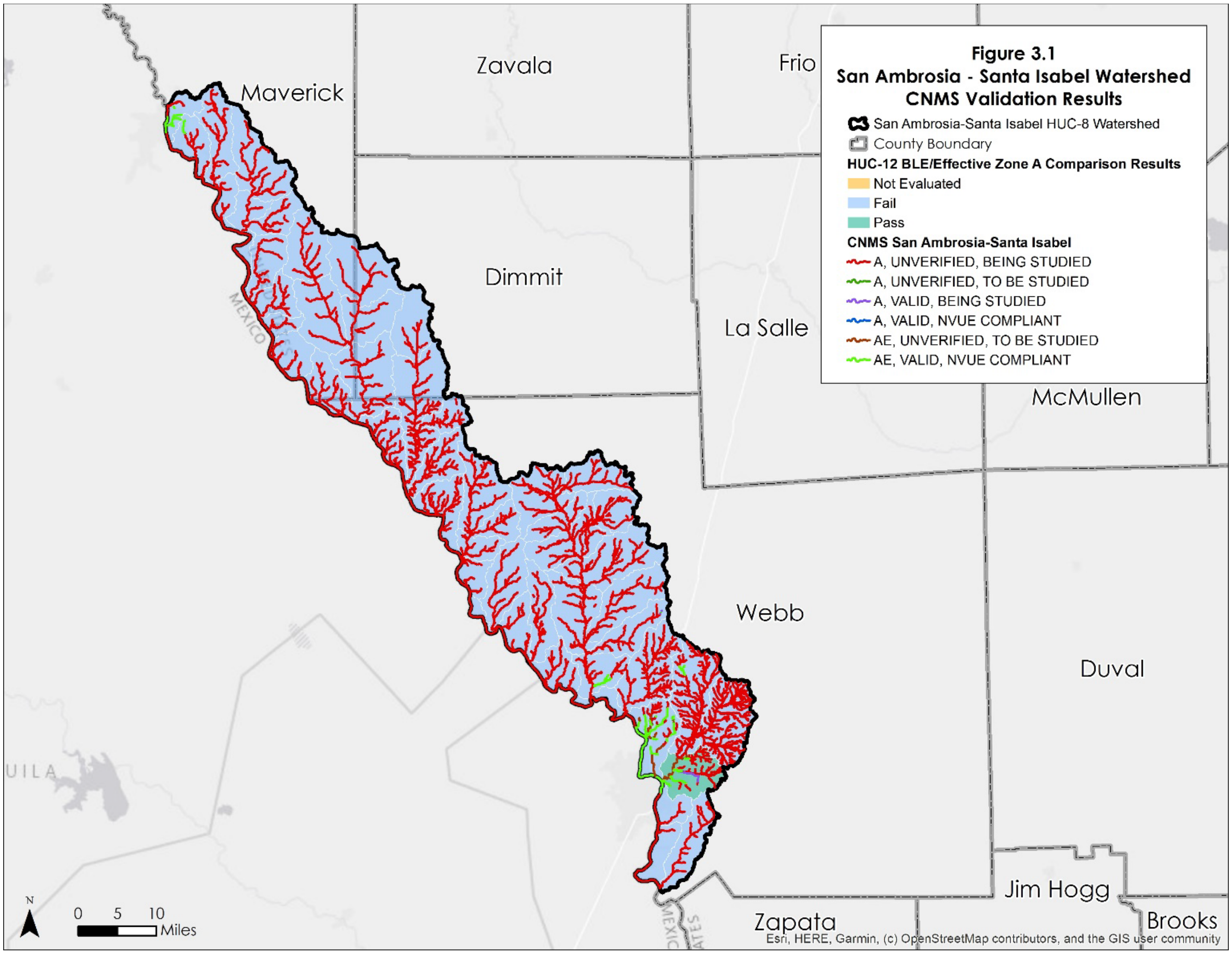

Figure 3.1: San Ambrosia – Santa Isabel Watershed CNMS Validation Results

3.3 Flood Risk Analysis

A flood risk analysis was performed for this project. The updated 1-percent 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 are reported in whole dollar values.

Hazus Version 5.1 (SP02) was used for the basic and refined loss analysis. The losses are reported via census blocks. It is important to note that Hazus Version 5.1 (SP02) uses dasymetric census blocks. Dasymetric mapping removes undeveloped areas (such as areas covered by bodies of water, wetlands, or forests) from the census blocks, changing their shape and reducing their size in these areas. For more information on dasymetric data visit FEMA's Media Library for the Hazus-MH Data Inventories: Dasymetric vs. Homogenous, or Hazus 3.0 Dasymetric Data Overview.

Hazus analysis was performed by county within the project watershed extents for the 1-percent return period to ensure proper model processing. A summary of results per county for the 1-percent ACE scenario is shown in Table 3.5.

Table 3.5: Hazus 5.1 (SP02) Results for 1-percent-annual-chance (100-year) scenario for San Ambrosia – Santa Isabel Watershed, Texas

County	Full Replacement – Total Loss	Dollar Exposure (Replacement Value) - Buildings	Dollar Exposure (Replacement Value) - Contents
Dimmit	$146,000.00	$15,836,000.00	$10,023,000.00
Maverick	$437,587,000.00	$10,756,732,000.00	$6,437,852,000.00
Webb	$3,168,355,000.00	$142,893,288,000.00	$92,245,595,000.00
Total	**$3,606,088,000.00**	**$153,665,856,000.00**	**$98,693,470,000.00**

04 References

1. Centro Nacional de Prevencíon de Desastres. (http://www.atlasnacionalderiesgos.gob.mx/portal/fenomenos/). Accessed August 2021.
2. Chow, Ven T. "Development of Uniform Flow and It Formulas." *Open Channel Hydraulics*. Caldwell, NJ: Blackburn, 1959. 109-113. Print.
3. FEMA, "Coordinated Needs Management Strategy (CNMS) Technical Reference", November 2021 (https://www.fema.gov/sites/default/files/documents/fema_CNMS-technical-reference_112021.pdf).
4. FEMA, 'Data Capture Technical Reference", November 2021, (https://www.fema.gov/sites/default/files/documents/fema_data-capture-technical-reference_112021.pdf).
5. FEMA, "Flood Risk Database Technical Reference", February 2018 (https://www.fema.gov/sites/default/files/2020-02/Flood_Risk_Database_Technical_Reference_Feb_2018.pdf).
6. FEMA, "Guidance for Flood Risk Analysis and Mapping – Base Level Engineering (BLE) Analyses and Mapping", February 2018. (https://www.fema.gov/media-library-data/1526489690918-2862bece100f28564c4167aaf4b2378b/Base_Level_Engineering_Guidance_Feb_2018.pdf).
7. Instituto Nacional de Estadística, Geografía y Informatica (INEGI), "Hidrología." (https://www.inegi.org.mx/temas/hidrologia/#Mapa). Accessed August 2021.
8. Instituto Nacional de Estadística, Geografía y Informatica (INEGI), "Edafología." (https://www.inegi.org.mx/temas/edafologia/#Descargas). Accessed August 2021.
9. NOAA, "NOAA Atlas 14 Precipitation-Frequency Atlas of the United States", 2013. Volume 9, Version 2.0. (https://www.nws.noaa.gov/oh/hdsc/PF_documents/Atlas14_Volume9.pdf).
10. North American Land Change Monitoring System, Commission for Environmental Cooperation, *Land Cover 30m, 2015 (Landsat and RapidEye)*. (http://www.cec.org/north-american-environmental-atlas/land-cover-30m-2015-landsat-and-rapideye/). Accessed August 2021.
11. U.S. Army Corps of Engineers, Hydrologic Engineering Center. (March 2019). HEC-RAS River Analysis System, Version 6.1 Davis, California.
12. USGS, "Areal-Reduction Factors for the Precipitation of the 1-Day Design Storm in Texas," Water-Resources Investigations Report 99-4267, 1999.
13. USGS, "Estimating Magnitude and Frequency of Floods Using PeakFQ Program: USGS Fact Sheet," 2006.
14. USGS. Multi-Resolution Land Characteristics Consortium. *National Land Cover Database 2016*. (https://www.mrlc.gov/national-land-cover-database-nlcd-2016).