Nueces County

Tri-County Regional Drainage Master Plan Study

Flood Infrastructure Fund Category 1 Project 40032

Halff Associates, Inc.

November 2023

Acknowledgments / Services Provided

halff

Services provided by Halff:

- Hydrologic Modeling (entire project area)
- Existing Hydraulic Modeling for areas outside NCDD2 boundary
- Proposed Hydraulic Modeling of Risk Areas 1, 3, 4, 5, 6, 7, 11, 19, 20, 26, 27, and 28.
- Opinion of Probable Construction Costs for Risk Areas 1, 3, 4, and 5.

ARDURRA
COLLABORATE. INNOVATE. CREATE.

Services provided by Ardurra:

- Detailed Survey (outside of the NCDD2 boundary)
- Opinion of Probable Construction Costs for Risk Areas 6, 7, 11, 19, 20, 26, 27, and 28.

ICE
INTERNATIONAL CONSULTING ENGINEERS
CORPUS CHRISTI · SAN ANTONIO · EDINBURG · HOUSTON

Services provided by ICE:

- Detailed Survey (within the NCDD2 boundary)
- NCDD2 Project Development
- NCDD2 Stakeholder Outreach

Civil Systems Engineering, Inc.

Services provided by CSE:

- Existing Hydraulic Modeling of area within NCDD2 boundary
- Proposed Alternative Modeling for Risk Areas 8, 10, and 12 (Robstown).
- Opinion of Probable Construction Costs for Risk Areas 8, 10, and 12 (Robstown).

SUSAN ROTH water and wastewater consulting

Services provided by Susan Roth:

- Program Management
- TWDB Public Meetings
- Stakeholder Outreach

Table of contents

List of figures

List of tables

List of appendices

ES Executive summary

Several rural communities along the Texas South Coastal Region continue to experience frequent flooding and drainage challenges. These challenges can be attributed to flatter slopes, low permeable soils of the region, and undersized drainage infrastructure that may have been originally designed prior to much of the area's development. More information and statistical data (historical peak rainfall) have provided insight into the overstressed existing infrastructure. As the communities continue to grow, Nueces County and its area partners are interested in pursuing resilient growth and improving existing conditions for these rural communities.

The Baffin Bay and South Corpus Christi watersheds run through Nueces County, with upstream contributions from Jim Wells County and outfalls downstream in Kleberg County. To pursue a study at a regional level, Nueces County partnered with Jim Wells and Kleberg counties, along with Nueces County Drainage District #2 (NCDD2) and several small towns in the watersheds. Study goals and benefits include detailed hydrologic and hydraulic modeling, validated 1% mapping, which influences the identified areas of risk and can be used as a tool for development regulation, as well as model-backed mitigation alternatives to reduce risk for prioritized flood risk areas within Nueces County. Halff, ICE, and their respective subconsultants make up the Study Team, who together completed this analysis, report and supporting data.

During initial modeling efforts to analyze the flat topography, the Study Team identified the need to implement a more complex modeling approach than typical riverine flood risk analyses. Switching to a 2-Dimensional model approach with an integrated hydrologic application provides a comprehensive view of the flooding sources and patterns for the study area. Further refinement of these detailed models includes incorporating 99 surveyed structures and 49 field-verified structures, as well as several cross-section surveys to validate the terrain used. HEC-RAS (Version 6.3) was used to create 29 models. These models are primarily located within Nueces County, with boundaries extending into Jim Wells and Kleberg counties. A detailed hydrology model was developed for upstream areas within Jim Wells County to capture the contributing drainage area into Nueces County. **Table ES.1** below summarizes the total drainage areas contributing to this study.

Table ES.1 Project HUC10 Watershed Drainage Areas

HUC8	HUC10	Project Drainage Area (square miles)
South Corpus Christi	Oso Creek	273.90
Baffin Bay	Agua Dulce Creek	254.64
	Petronila Creek	322.04
	Alazan Bay-Baffin Bay	31.12*
San Fernando	Rosita Creek-San Diego Creek	310.22
	Chiltipin Creek-San Fernando Creek	244.69*
Total Drainage Area		**1,436.61**

**Area is a portion of the total HUC10 area and represents the portion that is accounted for in project limits*

With existing conditions modeling established, inundation mapping was produced. This mapping provides a holistic snapshot of flood risk throughout the watersheds, which community officials can use to plan and prioritize infrastructure improvements while using the models and data to inform, aid, and regulate future development. Based on the criteria listed below, flood risk areas within the study area were identified.

1. High-population areas
2. Existing structures at risk from substantial flooding
3. Critical infrastructure (fire stations, hospitals, schools, etc.)
4. Likelihood of potential future funding
5. Localized improvement projects (inlets, small-scale design/construction of infrastructure)
6. Future urbanization and growth

Thirty-one (31) areas were submitted on behalf of the Study partners to be included within the Texas Water Development Board's (TWDB's) Regional Flood Plan for Region 13. After producing the necessary information needed to get all 31 areas into the Regional Flood Plan, these areas are now primed to have further detailed analyses performed and mitigative measures developed as Flood Mitigation Evaluations (FMEs). The areas are listed below in **Table ES.2.**

Table ES.2 Flood Mitigation Evaluations (FMEs)

Identified Risk Area Number	Identified Flood Risk Area	Identified Risk Area Number (cont.)	Identified Flood Risk Area
1	Ranch Road & Cindy Lane	17	Lost Creek & Nye & Peterson Farm
2	Westwood Estates	18	FM 892
3	Indian Trails	19	City of Driscoll
4	Rancho Banquete	20	Fiesta Ranch
5	Banquete	21	FM 665 & CR 69
6	City of Agua Dulce	22	Petronila Acres
7	La Paloma Ranch	23	Tierra Grande & Crossroads Estates
8	North Robstown	24	San Petronila Estates
9	IH 69E Crossing	25	Corpus Christi International Airport
10	Robstown Drains	26	Balchuck Lane & Digger Lane
11	Callicoatte Farm	27	Nottingham Acres
12	FM 1694 & TX 44 North	28	South Prairie Estates
13	FM 1694 & TX 44 South	29	US Naval Base
14	County Road 61 & TX 44	30	Petronila Creek Environmental Study
15	Spring Gardens & Primavera Estates	31	Santa Maria
16	Tierra Verde		

Of the 31 FMEs, per this Flood Infrastructure Fund (FIF) project, 15 areas were further developed with detailed flood risk reduction alternatives, opinion of probable construction costs (OPCC), and proposed benefits such that these proposed Flood Mitigation Projects (FMPs) were included in the next tier of the Regional Flood Plan and set up for possible future state funding. These projects are centered around several rural communities within Nueces County, including Agua Dulce, Banquete, Petronila, and Robstown. As these communities have limited resources available to tackle large-scale, regional issues, having FMPs primed for additional funding through TWDB greatly benefits this study. **Table ES.3** summarizes the studied flood risk areas and the high-level flood impact descriptions.

Table ES.3 Flood Mitigation Projects (FMPs)

Selected Risk Area Number	Selected Risk Area Name	Project Type Description	Cost	BCA
8, 10, 12	North Robstown, Robstown Drains, FM 1694 & TX 44 North	Detention, Channel, Culvert, and Roadway Improvements	$62,344,000	>1
1*	Ranch Road and Cindy Lane	Channel and Culvert Improvements	$2,100,000	0.5
19	Driscoll	Detention, Channel, Culvert, and Roadway Improvements	$85,018,000	0.3
5	Banquete	Detention, Channel, Culvert, and Roadway Improvements	$87,897,000	0.1
20	Fiesta Ranch	Detention, Channel, Culvert, and Roadway Improvements	$40,688,000	0.1
26	Balchuck Lane & Digger Lane	Detention, Channel, and Culvert Improvements	$22,023,000	0.05
6	City of Agua Dulce	Detention, Channel, and Culvert Improvements	$107,448,000	0.04
27	Nottingham Acres	Detention, Channel, and Culvert Improvements	$56,477,000	0.03
3	Indian Trails	Detention, Channel, and Culvert Improvements	$10,293,000	0.1
4	Rancho Banquete	Detention, Channel, and Culvert Improvements	$68,570,000	0.02
11	Callicoatte Farm	Channel and Culvert Improvements	$6,692,000	0.02
28	South Prairie Estates	Detention, Channel, and Culvert Improvements	$39,673,000	0.01
7	La Paloma Ranch	Detention, Channel, Culvert, and Roadway Improvements	$26,473,000	0.002

** BCA based on alternative for 10% annual chance storm event*

The FMPs' components include hydrologic and hydraulic modeling of existing and proposed conditions, quantifying flood benefits, no adverse impact analyses, Opinion of Probable Construction Costs (OPCCs), and benefit cost analysis (BCAs). The Study conducted a no adverse impact based on multiple factors that amount to a comparison of flood risk between existing and proposed conditions. Proposed alternatives included culvert improvements, regional detention, roadway improvements, and increased channel capacity and conveyance. This Study did not consider structure property acquisition (home buyouts). The majority of the benefits produced by the alternatives are in the form of decreased flood depths, flood water receding more quickly, and fewer structures located within flood inundation mapping. As discussed previously, the mapping produced from the existing conditions modeling is a useful planning tool for the communities, and it is recommended that Nueces County implement the mapping as a regulatory product and provide the models to developers to assess the adverse impact of development.

1 Introduction and project background

The Coastal Bend of South Texas consists of relatively flat terrain comprised of mostly alluvial soils as creeks and river systems make their way to the Gulf of Mexico. While normal annual rainfall averages vary across the region, warm temperatures and the proximity to the gulf leave the area susceptible to severe thunderstorms, tropical storms, and hurricanes.

Nueces County experiences significant drainage and flooding challenges related to low permeability of the soils and flat topography. This is further complicated by drainage systems intended for and optimized for more frequently occurring, lower-intensity storm events. Additionally, Nueces County has experienced growth over the past several years, in part due to the evolution of the Port of Corpus Christi as an international gateway and commercial center. Rapid and unanticipated changes to development patterns resulted in increased impervious cover and additional transportation needs, which have caused an increase in stormwater runoff quantity and decreased stormwater runoff quality.

Throughout the study area, drainage channels quickly reach capacity and backwater from mainstems, including Petronila Creek and Oso Creek, limiting the stormwater runoff each drainage system can accept. **Figure 1.1** below depicts typical flooding experienced by the City of Agua Dulce, located in Nueces County.

Figure 1.1 City of Agua Dulce Flooding May 13, 2015

As a result, Nueces County engaged Susan Roth Consulting in December 2019 to develop the overall master plan study, including identifying key project stakeholders and regional partnerships, securing in-kind service contributions and preparing the TWDB grant application. Nueces County submitted an abridged application in June 2020, followed by a full application in October 2020 to the Texas Water Development Board (TWDB) to obtain grant funding available through the Flood Infrastructure Fund (FIF) Program to conduct a regional drainage study as a result of Senate Bills 7 and 8 adopted during the 2019 Texas Legislative Session. Numerous letters of support from various stakeholders were included with the TWDB application, including those received from Senator Juan “Chuy” Hinojosa (District 20), State Representative Abel Herrero (District 34), and State Representative Todd Hunter (District 32). The Baffin Bay and South Corpus Christi watersheds, encompassed by Jim Wells, Nueces and Kleberg Counties, were selected as the planning boundary for the regional study to address critical flood planning needs.

The regional drainage study led by Nueces County as the lead applicant, along with Jim Wells and Kleberg Counties. Nueces County was successfully awarded $2,137,500 in FIF grant funds by TWDB on May 20, 2021, and closed on the funding on December 3, 2021. Susan Roth Consulting served as the Program Manager for the Tri-County Drainage Master Plan Study on behalf of the three counties. Nueces County contracted with the engineering consultant team for the regional study, which includes Halff Associates, Inc. (Halff) as the prime engineer and International Consultant Engineers (ICE) to represent the interests of Nueces County Drainage District No. 2 (NCDD2). Both Halff and ICE had subconsultants on their respective teams, which include Ardurra, Inc. as a subconsultant to Halff and Civil Systems Engineering, Inc., DEC, Southpoint and ROCK as subconsultants to ICE. In-kind service contributions (graduate students performed drainage structure field verification) were provided by the Environmental Engineering Department at Texas A&M University at Kingsville.

The regional drainage master plan study, referred to as the ‘Tri-County Drainage Master Plan Study’ (Study), is the first of its kind for the area, providing several regional mitigation alternatives analyzed for potential drainage improvements throughout the study area. This report serves as a ‘road map’ for future flood mitigation projects in the region and can be used as a comprehensive planning tool for minimizing the future flood risk to human lives and reducing property loss based on past flooding events.

1.1 Key stakeholders

The Tri-County study area is located within a growing region of the state. Although Jim Wells and Kleberg Counties are considered more rural due to each county having a population of less than 50,000, Nueces County’s current population of approximately 374,000 has doubled in the past 30 years and could increase over the next 20 years. The City of Corpus Christi, the county seat for Nueces County, has experienced approximately 100,000 new residents in the past 20 years, with a higher concentration of growth along the city’s southern side due to more recent residential and commercial development. A substantial portion of the study area remains as open space for viable future growth; however, without conducting proactive flood planning, this future growth could potentially intensify the existing drainage problems within Nueces County and the two participating counties.

The project area for the Tri-County Drainage Master Plan Study is defined by the limits of the hydrologic unit codes (HUC) for the eastern portion of the Baffin Bay HUC8 watershed and the mainland portion of the South Corpus Christi HUC8 watershed. The Baffin Bay watershed (HUC-8) originates in Jim Wells County and continues downstream through Nueces and Kleberg Counties, ultimately discharging into Baffin Bay. The project area is comprised of the following three smaller HUC-10 watersheds: Agua Dulce Creek (1211020505), Petronila Creek (1211020506), and Oso Creek (1211020201), as well as a portion of the Alazan Bay-Baffin Bay (1211020508) watershed. **Figure 1.2** outlines the project boundary for modeling purposes as it relates to the HUC8 boundaries.

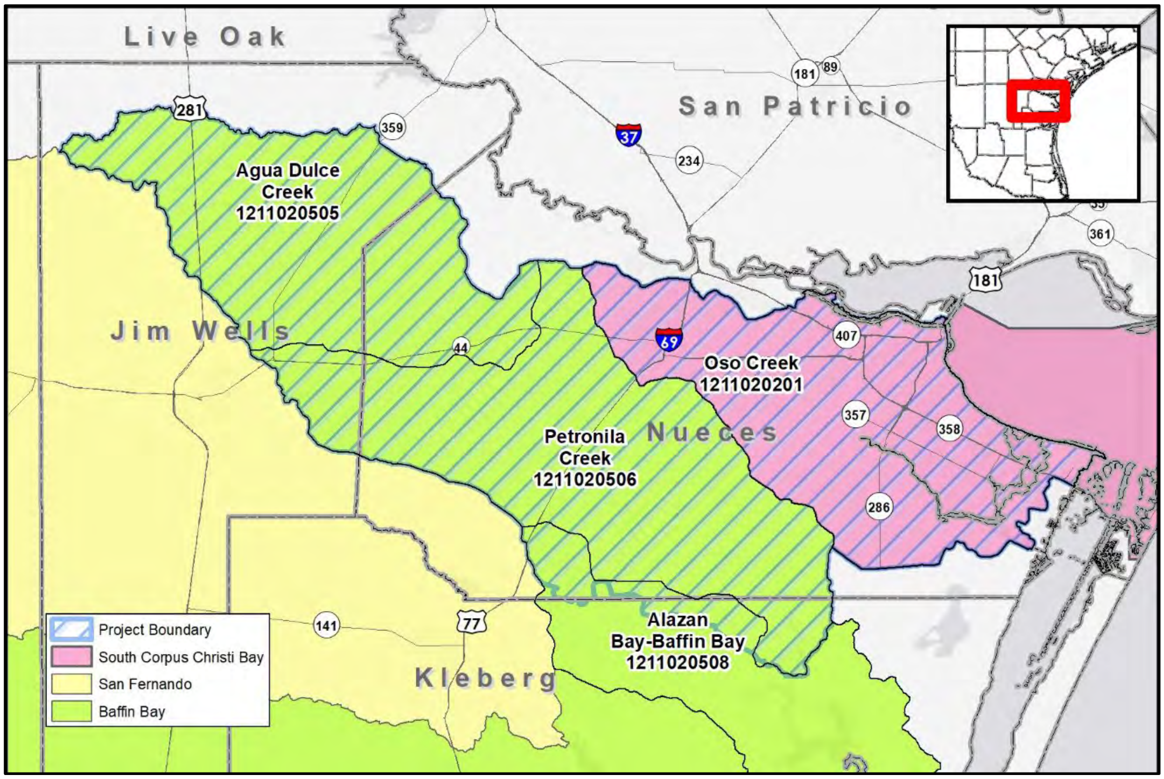

Figure 1.2 Tri-County Drainage Master Plan Study Project Boundary

Many of the unique geographic characteristics that helped shape the growth of the Coastal Bend Region also present some complex challenges for drainage improvements and flood mitigation. Due to the flat topography (often agricultural), runoff generally moves slowly across the area, moving from one pool to another collecting in small ditches and swales. These drainage channels are often constricted by roadways or irrigation canals, which further impede the flow of runoff to Corpus Christi Bay or Baffin Bay. During larger storm events, flow exceeds the relatively flat watershed basin divides and spills into adjacent watersheds. This is shown in the effective FEMA floodplain mapping in Figure 3.

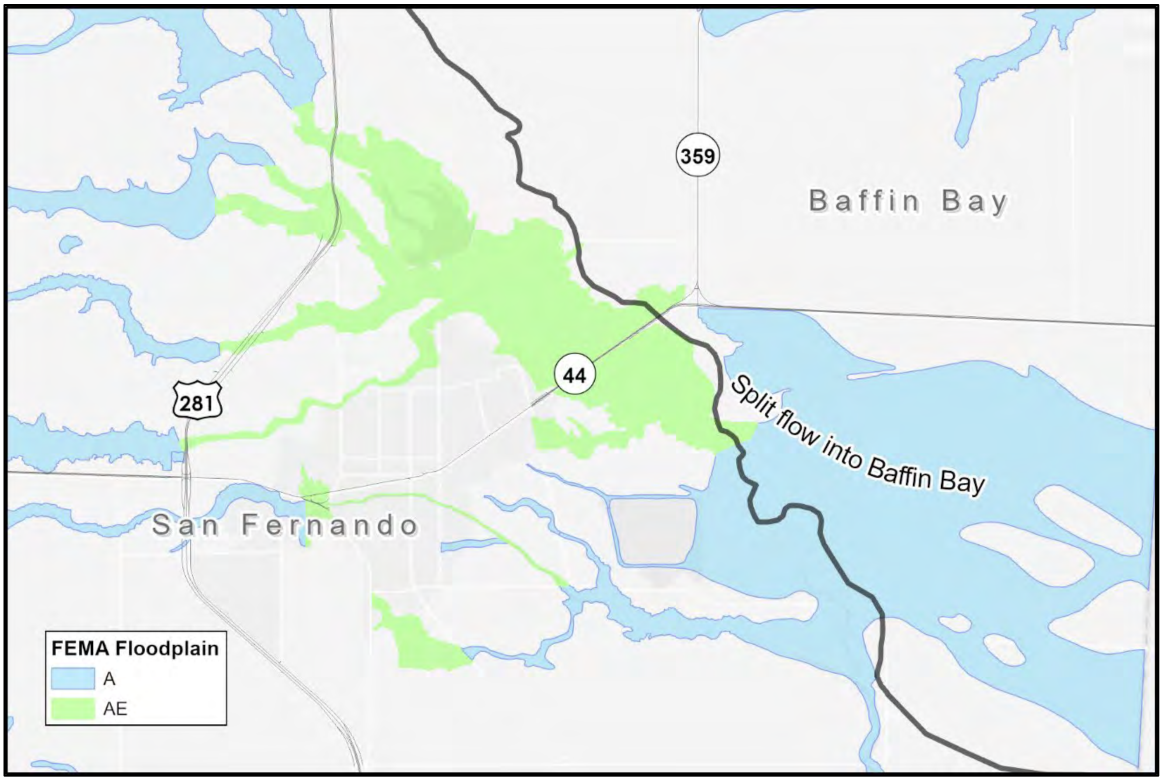

Figure 1.3 Split Flow Between San Fernando HUC8 and Baffin Bay HUC8 Watersheds

This inter-basin transfer of flows contributes to increased runoff, overwhelming drainage systems initially designed for less runoff, as the excess flows were not known to be part of the contributing drainage area. Cross-basin interactions are further complicated by existing drainage networks and man-made channels that cut across these basin divides (Figure 1.4).

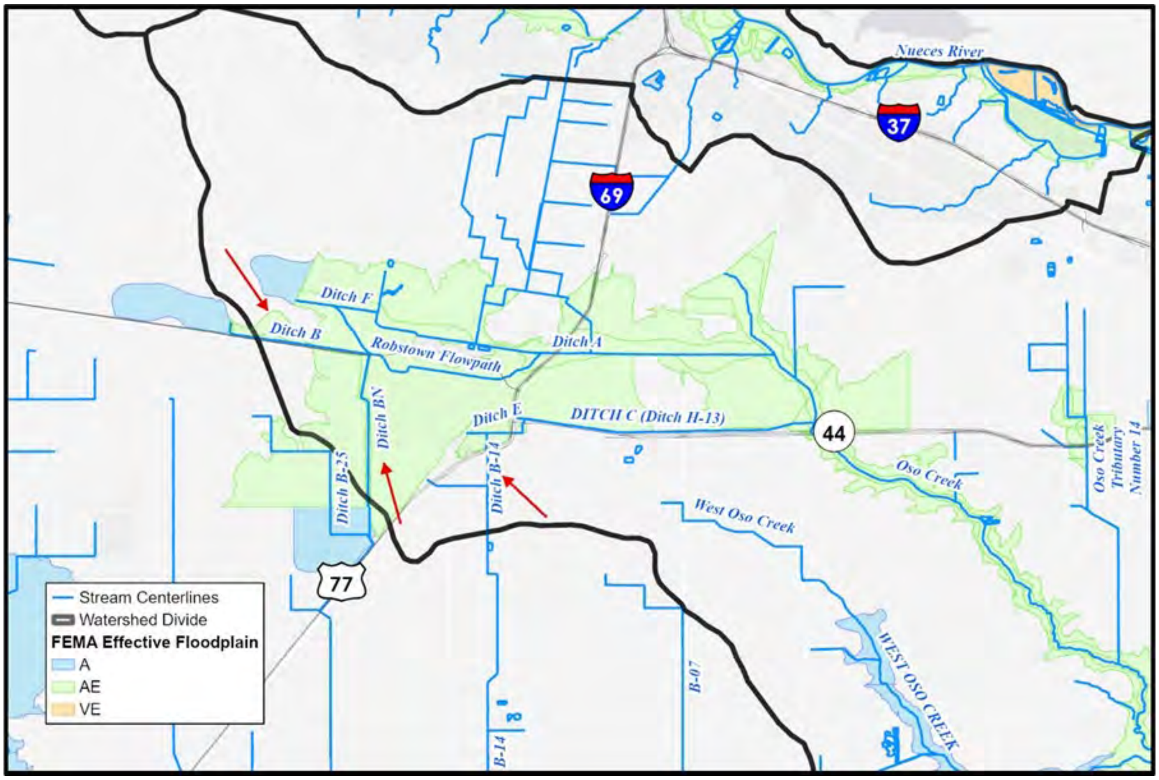

Figure 1.4 Drainage Channels and Streams Crossing HUC8 Watershed Divides

Often, an area can become quickly inundated due to rainfall, and without topographic relief to allow runoff to occur, fields, roads, yards, ponds, and channels cannot recover quickly from storm events. Without recuperating storage between storm events, which is common during peak rainy seasons, ponds and other facilities remain full, resulting in the subsequent storm event having an even more damaging impact. **Figure 1.5** shows this common issue, referred to as time to drain, which refers to the length of time it takes for flood waters to recede.

Figure 1.5 Nottingham Acres Subdivision Pond with Water Above the Headwall

1.2 Past flood events

These characteristics of the study area provide insight into understanding some of the causes of historical flooding within Nueces County. To further support the historical data, previous studies were gathered and reviewed. This included the 2022 Flood Insurance Study (FIS) that was made effective October 13, 2022. A copy of this report is provided in Appendix F. The report states that “Nueces County is subject to both coastal and riverine flooding.” The historical data provided in the FIS references numerous hurricanes from September 1919 to July 2010. The riverine flooding history does not provide dates but instead lists common issues reported by several of the communities. “Principal causative factors of localized flooding in Driscoll are poor natural drainage compounded by inadequate structural systems, not overbank flooding from Petronila Creek” (2022 FIS).

Numerous historical flooding events in the region, including the May 2015 Flood (Federal Disaster 4223), May 2016 Flood (Federal Disaster 4272), 2017 Hurricane Harvey (Federal Disaster 4332) and June 2018 floods, have occurred and illustrate the need for flood protection planning and significant drainage improvements in the urban development corridors. Hurricane Harvey in August 2017 caused tremendous damage to both residential and commercial properties in Nueces County, resulting in $66.15 million paid claims by the National Flood Insurance Program (NFIP) during the recovery efforts. The May 2015 Flood had a significant adverse impact on both Nueces and Jim Wells Counties due to the number of residential, commercial and retail businesses destroyed. The May 2016 Flood resulted in substantial damage to Nueces and

Kleberg Counties with both residential and commercial properties, as well as critical infrastructure impacts within Kleberg County.

Leading up to and throughout the development of this project, field inspections were performed after significant rainfall to capture drainage patterns and flood issues. Several communities and citizens also attended outreach meetings and provided flood photos and input into areas that experienced frequent flooding. Images provided below were taken July 8, 2021, in the London community, just west of Corpus Christi, after they experienced nearly 7 inches of rainfall in 24 hours, nearly equivalent to a 10-year storm event. Figure 1.6 and Figure 1.7 are pictures taken during the field inspection.

The study team conducted additional public engagement through multiple workshops in communities throughout Nueces County and the surrounding area. These workshops were used to gather historical data from the community members so the study team could understand the typical drainage issues experienced or concerns with ongoing projects or new developments. Public engagement is further discussed in **2 Data collection.**

Figure 1.6 Ponding Outside London High School, Corpus Christi

Figure 1.7 Flooding in London Subdivision Near Lion Heart Court

1.3 Study benefits

The Study will provide a comprehensive planning tool for minimizing the risk to human lives and reducing property loss based on past flooding events. Based on the intensity and repetitive nature of flooding issues experienced in this region, area leaders have identified a need to better understand the flood risks and develop mitigation alternatives, resulting in flood risk reduction. FEMA effective data does not capture all of the flooding issues experienced locally and available BLE models only approximate flooding issues. The region recognizes the need to develop more detailed modeling, utilizing a modeling approach that can capture the interaction of riverine and overland flooding previously discussed. A more refined modeling approach provides a greater level of confidence in planning for mitigation implementation.

Nueces County conducted a Drainage Master Plan back in 2009; however, it evaluated only a portion of the county and focused on localized drainage improvements. The focus of the 2009 study was on four priority areas identified by the county at that time: (1) Upper Oso Creek; (2) Chapman Ranch Area; (3) Community of Petronila; and (4) Petronila Creek Area. The study herein provides a holistic assessment of the hydrologic and hydraulic complexities that can be utilized to further analyze potential flood mitigation alternatives that may regionally benefit the area.

New hydrologic analyses were developed throughout the portions of the 4 HUC-10s studied and supported the detailed 2D hydraulic models developed for the Petronila Creek and Oso Creek watersheds within Nueces and Kleberg Counties. These models, in combination with the flood risk mapping, may be used to inform local leaders, emergency management personnel, and stakeholders of flood risk. The models can also be provided to developers to understand their flood risk and so that proposed projects or developments will not adversely impact adjacent properties. Local regulatory entities can also reference these models while reviewing proposed development projects.

Furthermore, the analysis of flood risk reduction and drainage improvement projects identified in this study can be prioritized and advanced for detailed engineering design and construction through future capital improvement programs and other grant funding measures available from local, state, and federal sources.

1.4 Study goals

The primary goal of this regional planning study was to develop an actionable plan to minimize the flood risk to lives and property in the entire study area. Additional study goals of the tri-county effort include:

- Fulfilling the legislative intent of Senate Bills 7 and 8 by studying the Baffin Bay and South Corpus Christi Bay watersheds utilizing a regional approach;
- Providing consistent engineering and final work product for the entire study area;
- Complementing ongoing water quality research, planning and restoration efforts underway in the Baffin Bay watershed;
- Conducting the regional study in an inclusive manner to allow public involvement and to gain buy-in;
- Building upon available information and data from previous planning activities for and by the three counties; and,
- Developing a planning roadmap for the three counties that aligns with the TWDB Region 13-Nueces Regional Flood Plan and well-positions the Tri-County partnership for various grant funding opportunities.

The primary emphasis of the hydrologic and hydraulic modeling activities focused on Nueces County due to the county's existing population and future growth projections, as well as several local, more rural communities that frequently experience flooding and who wished to participate in the FIF study. The portion of the scope pertaining to Jim Wells County included a hydrology analysis to determine the quantity of stormwater discharge contributing to the Eastern portion of the Baffin Bay watershed. The primary reasons for watershed-scale analysis is to understand where runoff is coming from, how much is coming, and to track the impacts of proposed improvements within the watershed. Due to stakeholder concerns regarding water quality and sedimentation of Baffin Bay, this study also includes a hydrologic and hydraulic sedimentation analysis focused on Petronila Creek and its flow into Kleburg County and Baffin Bay. The scope of the project is outlined below.

- Collection of Data & Baseline Information
- Identify Chronic Flooding/Problematic Drainage Areas
- Conduct Field Survey & Site Visits
- Develop Hydrologic/Hydraulic Models
    - Detailed and Limited Detailed Hydraulics
- Consider Water Quality Issues and Environmental Concerns
- Develop Flood Mitigation Improvements for flood-risk areas
    - 15 Locations Selected
    - Structural / Non-Structural Alternatives

- Prepare Benefit/Cost Analysis
- Develop Implementation and Phasing Plans
- Conduct Public Engagement and Stakeholder Outreach Activities

2 Data collection

This study required collection and inventory of available technical resources, including the 1986 Drainage Criteria and Design Manual for Nueces County, infrastructure plans, and historical flooding information. Data collected included historical and previous studies, information needed to support the development of hydrologic and hydraulic model parameters, and as-built structure data to supplement field measurements and survey discussed in later sections.

Data collection was initiated with a public meeting on February 23, 2022, where community members were introduced to the project goals, scope and key participants. These public meetings continued through the finalization of the existing conditions models. This allowed the study team time to identify data gaps, process received data, and set up additional coordination with regulatory entities including TxDOT, City of Corpus Christi, RFPG, GLO, FEMA, Nueces County Water Control and Improvement District 3, Nueces County Public Works, Nueces County Appraisal District, Nueces County Drainage District 2, and surrounding communities, including the cities of Agua Dulce, Banquete, Driscoll, and Robstown.

2.1 Stakeholder information

Numerous communities in the Coastal Bend area have faced challenging drainage issues due to significant historical flooding events in the region. To work collaboratively and to strengthen the tri-county grant application, letters of support were received from key stakeholders wanting to participate in the regional master planning effort. A complete list of the project participants is provided below:

- Nueces County (Primary Applicant)
- Jim Wells County
- Kleberg County
- City of Driscoll
- Nueces County Drainage District No. 2
- City of Corpus Christi
- City of Petronila
- City of Robstown
- Harte Research Institute
- Port of Corpus Christi
- South Texas Water Center/TAMU Kingsville
- Coastal Bend Bays & Estuaries Program
- Coastal Bend Council of Governments
- Baffin Bay Stakeholders Group
- Wildlife Forever
- Texas Water Resources Institute – Texas A&M AgriLife Extension

2.2 Drainage workshops

As part of the Public Engagement efforts for the regional master plan study, multiple individual workshops were hosted in communities throughout Nueces County and the surrounding area. These workshops were used to gather data from the community to better inform the Study Team's understanding of local drainage issues, experienced flooding and flooding concerns with ongoing projects or new development planned for or actively occurring in their area.

The individual workshops were designed to have an Open House format, allowing the public to 'come and go' depending on their schedule. Each meeting included a presentation discussing the project's scope, goals and timeline for completion of the Study. Afterward, an informal session was held with the meeting attendees to view and mark up draft maps of their community to highlight drainage issues/concerns. The meeting attendees also had an opportunity to visit with the study team to discuss any questions and provide additional feedback. A summary of the individual workshops conducted for the regional study is provided below:

- Banquete (December 1, 2021): Over 42 attendees from adjacent communities
- Driscoll (February 22, 2022): City of Agua Dulce and TxDOT also represented
- Petronila (April 27, 2022): Approximately 18 community members attended
- Robstown (August 10, 2022): Approximately 25 community members attended
- London (August 11, 2022): Over 20 community members attended

In addition to Drainage Workshops held at individual communities, multiple Public Meetings were held to provide overall Study updates. Public Engagement and Stakeholder Outreach is further detailed in Chapter 12.

2.3 Existing studies

Existing regulatory studies include the FIS study dated October 13, 2022. Additionally, FEMA funded the development of the Baffin Bay Watershed, Texas 2D Base Level Engineering Methods and Results (December 2021) and the South Corpus Christi Bay Watershed, Texas 2D Base Level Engineering Methods and Results (November 2021). These studies are provided in **Appendix F**. These existing studies provide insight into drainage patterns, technical challenges, historic flooding events experienced in the region, and anticipated flood risks for various reoccurrence events. These studies served as benchmarks to confirm general consistency with the flow patterns and floodplain extents.

2.4 Model parameters

To create the initial hydrologic basin development, further discussed in 5.0 Existing Conditions - Hydrologic Model Development, the parameters from the sources provided in **Table 2.1** were used. Parameters, including rainfall and imagery, were also used to support all the hydraulic models developed.

Table 2.1 Data Collection: Parameters and Sources

Parameter	Source	Year
Soils	NRCS Websoil Survey	2021
Land Cover	USGS National Land Cover Database	2019
Curve Number	USDA Urban Hydrology for Small Watershed, TR-55	1986
Rainfall	NOAA Atlas 14 Precipitation-Frequency Atlas of the United States, Volume 11, Version 2: Texas (Atlas 14)	2018
Imagery	Esri, Google Earth	2021-2023

3 Terrain

Terrain and Digital Elevation Model (DEM) acquisition was completed through the Texas Natural Resources Information System (TNRIS) for the BLE studies covering the Study area. This terrain data, included in the final BLE deliverables, was leveraged for the study herein. All terrain sources are based on the South Texas LiDAR and the South-Central Texas LiDAR from 2018. Below are the specifics of each dataset:

2018 USGS South Texas LiDAR - The 2018 USGS South Texas LiDAR was collected with a nominal pulse spacing of 0.7 meters. The data was tested to meet 19.6 cm vertical accuracy at a 95% confidence level (RMSE * 1.96).

2018 USGS South-Central Texas LiDAR - The 2018 USGS South Central Texas LiDAR was collected with a nominal pulse spacing of 0.7 meters. The data was compiled to meet 11.6 cm vertical accuracy at a 95% confidence level (RMSE * 1.96).

The DEMs used in the BLE models have a 10-foot by 10-foot resolution, which was used to process the Study hydrology. A more refined terrain dataset was developed using the original cell size of 1 meter and converting it to feet for a 3.2808-foot cell size. This more refined DEM is referred to as the "existing-hydraulic terrain" and was used as the base terrain for all hydraulic modeling discussed in **6 Existing conditions - hydraulic model development** and **7 Flood mitigation and alternative analysis**.

The existing hydraulic terrain was validated to survey cross-section data by comparing elevations between the two datasets. Surveyed cross-section elevations agreed with the existing hydraulic terrain and provided confidence in using this terrain for detailed 2D modeling.

The terrain files are available in **Appendix F**.

4 Hydraulic structure survey and field verification

Identification of hydraulic structures for survey and field verification locations began with overlaying the FEMA detailed and limited detailed study streams with major roadways. Structure locations were further identified using aerial imagery, information collected during community meetings, and site visits performed by the project team. Crossings smaller than and up to 36 inches were not included for survey/field verification locations but were noted for model consideration and validation. Based on watershed characteristics, culverts 36 inches or smaller tend to convey small storm flows and are often inundated during major design storms. In addition to being inundated, these culverts often become maintenance challenges as the shallow slopes and slow flow of water increase sedimentation and often result in culvert blockages. As one of the primary goals of this study was the development of models and flood risk reduction alternatives for more severe storm events, these smaller culverts were generally considered to have negligible conveyance benefits and were not included in the hydraulic models. All other identified crossings, 191 in total, were classified as Survey Needed, As-Built Requested, or Field Measurement Needed. Two structures were either located on private property or deemed too dangerous to access. Additional field verification was performed during the alternative analysis phase of the project. During this phase, the Study Team identified additional hydraulic structures not located on FEMA detailed or limited detailed study streams. These structures were captured with limited detailed field verification. See **Table 4.1** below on the division of classifications. **Figure 4.1** shows the locations of the surveyed locations. Exhibits related to survey and field verification can be found in **Appendix A**.

Table 4.1 Structure Survey Classification

Process	**Total Structure Count**
Surveyed	99
Field Verified	49
As-Built	14
Inaccessible	2
Risk Area Structures	27

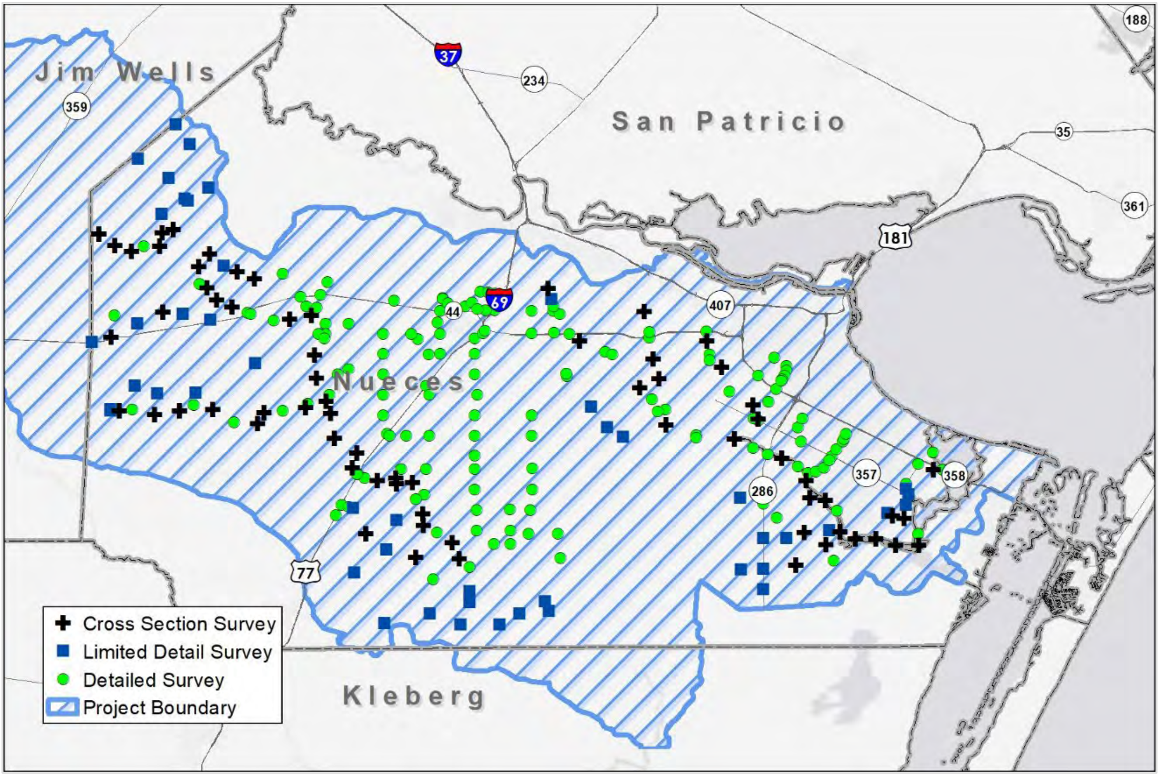

Figure 4.1 Survey Locations

4.1 Structure survey

Survey efforts were scoped based on traditional One-Dimensional (1D) modeling criteria and current FEMA hydraulic modeling data capture standards. To meet these standards, the survey is completed at structures located on detailed study stream limits and surveyed ground cross sections are taken to validate terrain where the stream mile difference between surveyed structures is more than 1 mile. The project team held a pre-survey kick-off meeting to review survey locations, data capture limits, survey codes, and other pertinent information required by FEMA for hydraulic modeling and mapping for flood risk determination. The use of surveyed cross-sections to validate terrain was discussed previously in **3 Terrain**. Appendix A includes survey cross-section data and can also be used for more traditional 1D modeling applications as necessary.

A survey completed by the ICE team was collected utilizing the Lecia Global Positioning System (GPS) GS18 and Lecia TS16 Robotic Total Station. The data referenced the NAD83 Texas State Planes South Central Zone and measurements were obtained in U.S. Feet. The field survey was collected along bridges and culvert crossings and included flowlines, cross sections, pipe materials and sizes, culvert sizes, pier materials and sizes, outfall conditions and locations, utility crossings, sketches, field notes, and photographs. **Appendix A** contains the survey data submittal.

4.2 Field verification

Limited detail survey (LDS) structures were selected along modeled streams within the Oso and Petronila basins in areas of low-impact flooding. The LDS structures include a total of 36 culverts and 17 bridges throughout the study area. Through the partnership with Texas A&M Kingsville (TAMUK), 15 students (primarily Graduate, Senior, and Junior level) in the Environmental Engineering Department participated in the field verification activity and collected LDS data for TAMUK's in-kind service contribution to the Study. Under the guidance and instruction of Halff, Ardurra, and TAMUK staff, the students performed field reconnaissance to obtain measurements, photographs, and observations of channel topography and structure shape, size, material, and condition in accordance with FEMA data capture standards. Halff held a training session with the students and Professor Jennifer Ren, Ph.D. and Department Chair David Ramirez, Ph.D., at the TAMUK campus in early March 2022 before the field verification activity. Halff and Ardurra conducted various site visits to provide field surveys for additional LDS structures inaccessible to the students. **Figure 4.2** shows an example of field verification notes. **Appendix A** contains the field measurement data collected for this study.

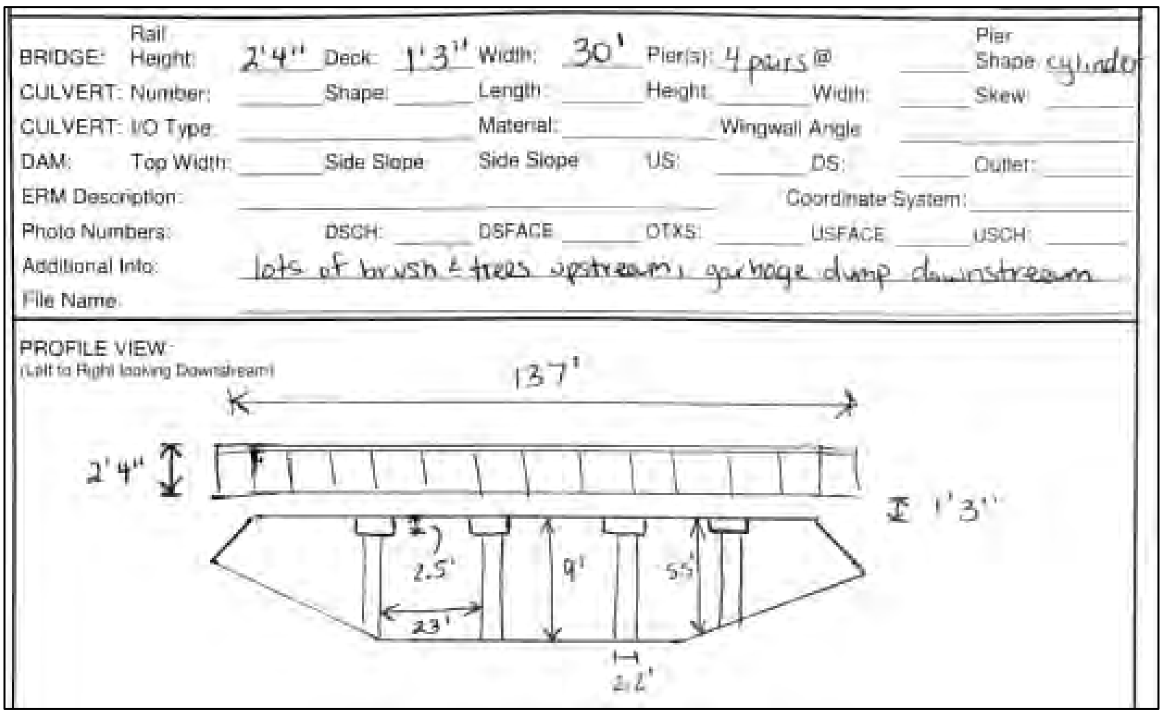
BRIDGE: Rail Height: 2'4" Deck: 1'3" Width: 30' Pier(s): 4 pairs @ Pier Shape: cylinder
CULVERT: Number: Shape: Length: Height: Width: Skew:
CULVERT: I/O Type: Material: Wingwall Angle
DAM: Top Width: Side Slope Side Slope US: DS: Outlet:
ERM Description: Coordinate System:
Photo Numbers: DSCH: DSFACE OTXS: USFACE USCH:
Additional Info: lots of brush & trees upstream, garbage dump downstream
File Name:
PROFILE VIEW:
(Left to Right looking Downstream)

Figure 4.2 Example of Field Verification Sketches

5 Existing conditions - hydrologic model development

HEC-HMS, Version 4.9, was used to create hydrologic runoff parameters incorporated into the 2D HEC-RAS models. These parameters, discussed in greater detail in the proceeding sections, included subbasins and rainfall hyetographs. The inclusion of these parameters in the hydraulic modeling and how they influenced the hydraulic results is discussed in **6 Existing conditions - hydraulic model development** and **7 Flood mitigation and alternative analysis.**

While hydrologic losses (SCS Curve Number method) were calculated within HEC-RAS, a full HEC-HMS model was created with routing, as means of comparison and verification to results produced within the hydraulic models. In addition to parameter creation, a more detailed portion of the HEC-HMS model was created for the project area within Jim Wells County that is not hydraulically studied in detail. A brief description of the methodology and key findings of this more detailed hydrologic analysis is discussed herein. A detailed hydrology memorandum is included in **Appendix B**.

The Baffin Bay and South Corpus Christi HUC8 limits within Nueces County are the primary focus of this study. The hydrologic study was extended through Jim Wells County to capture the upstream contributing area from Baffin Bay to key inflow locations within Nueces County. A portion of Kleberg County was incorporated into the study to follow flow down into the bay, track any potential adverse impacts, identify environmental concerns, and conduct sediment transport modeling. During the data collection activities, it was determined that substantial flow was contributing from the neighboring San Fernando HUC8 watershed into Baffin Bay within Nueces County. These flows were incorporated into the modeling efforts as inflows from the December 2021 San Fernando Watershed, Texas, 2D Base Level Engineering Methods and Results (**Appendix F**). As depicted in **Figure 5.1**, the four HUC10s located within the Baffin Bay and South Corpus Christi HUC8 watersheds, as well as the two HUC10s in the San Fernando HUC8 watershed, are listed below in **Table 5.1,** along with their respective drainage area.

Table 5.1 Project HUC10 Watershed Drainage Areas

HUC8	HUC10	Project Drainage Area (square miles)
South Corpus Christi	Oso Creek	273.90
Baffin Bay	Agua Dulce Creek	254.64
	Petronila Creek	322.04
	Alazan Bay-Baffin Bay	31.12*
San Fernando	Rosita Creek-San Diego Creek	310.22
	Chiltipin Creek-San Fernando Creek	244.69*
Total Drainage Area		**1,436.61**

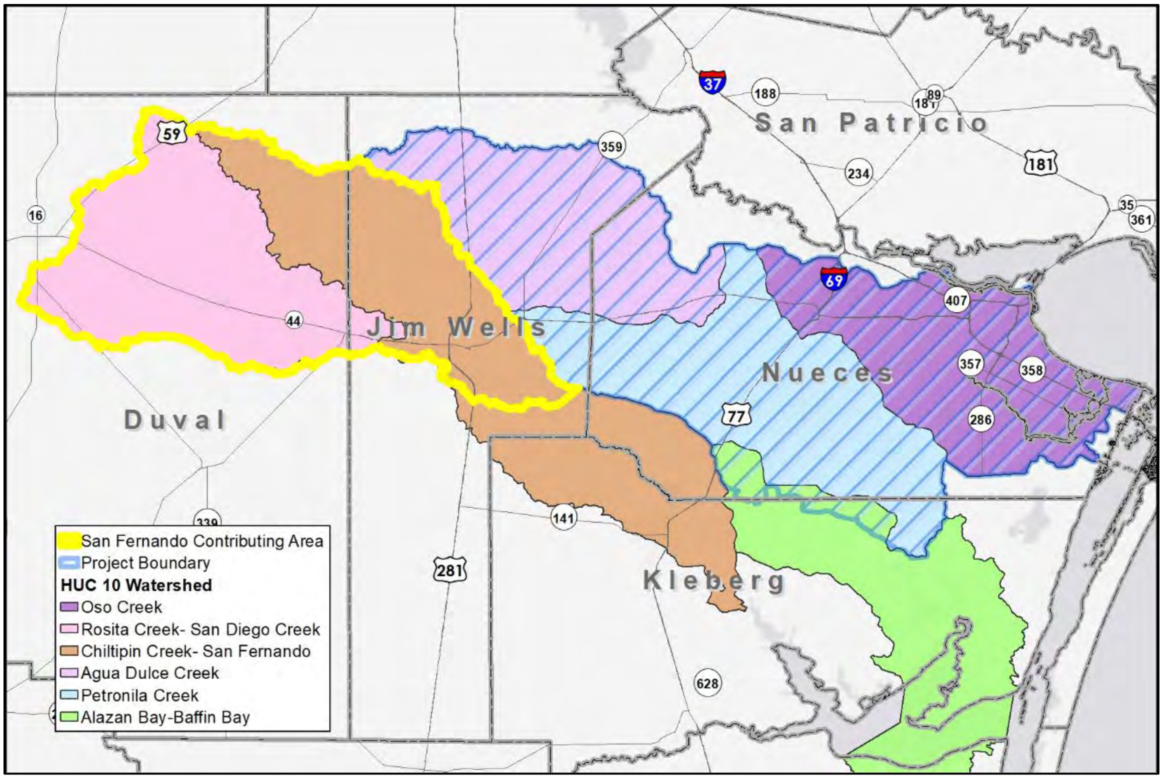

Figure 5.1 Contributing HUC10 Watershed Areas

Based on the hydrologic analysis, along with the review of the previous studies collected, the study team (along with coordination with the TWDB) determined that 2D modeling with more detailed refinement, including surveyed and field-verified structures, would provide the most accurate representation of the project area's flood risk. To keep model file sizes relatively small (and usability more efficient), the project was divided into 29 individual 2D models. HEC-RAS 6.3 modeling software was selected to produce 2D models showcasing the split flow complications while allowing future user refinement. The HEC-RAS modeling platform is the primary software used by FEMA, TWDB, and Nueces County Public Works. These agencies will have greater ease with future model refinement and project integration. Project integration is discussed in **6 Existing conditions - hydraulic model development.**

5.1 Watershed processing

The development of model boundaries is dependent on the creation of basin boundaries. The basins are used for developing representative aggregated flows and rainfall hyetographs for the designated areas. The following subsections discuss the creation and refinement of the subbasins.

5.1.1 Basin delineations

Initial basin delineations were created in HEC-HMS. The program uses the terrain elevation files and, by automated processes, delineates drainage basin boundaries for areas one square mile and greater, depending on the user-defined settings. One square mile drainage areas produced smaller basins that could later be merged together to target specific locations (or hydrologic basin junctions) like stream confluences, roadway crossings, or developed areas.

After the key confluences and junction locations were completed, the smaller basins were combined into larger basins to condense the hydrologic modeling effort for this study's approximated (limited detail) portions. The program was run once for the Petronila Creek watershed (3 HUC-10s) and once on the Oso Creek watershed (1 HUC-10). Although these watersheds share some interconnections, particularly during larger storm events, the official HUC10 boundaries influenced separate watershed boundaries.

Smaller subbasins were merged based on confluences and other key points (community/city boundaries, road crossings, or other critical infrastructure) to keep drainage areas between 2 and 8 square miles. Drainage areas gradually increase from the study headwaters in Jim Wells County towards the Nueces County limits. **Figure 5.2** provides a closer look at the basin delineations in Jim Wells County. Since a primary study goal was to identify risk and mitigation projects within Nueces County, the team used an integrated hydrologic and hydraulic modeling approach for watersheds within Nueces County. With subbasins not having natural boundaries at the county limits, portions of the subbasins spanning across Nueces and Jim Wells Counties were modeled with this detailed hydraulic model approach. Larger basins downstream, within Nueces County, are discussed later in this section. Further discussion on the level of detailed hydraulic modeling in these areas is included in **6 Existing conditions - hydraulic model development.**

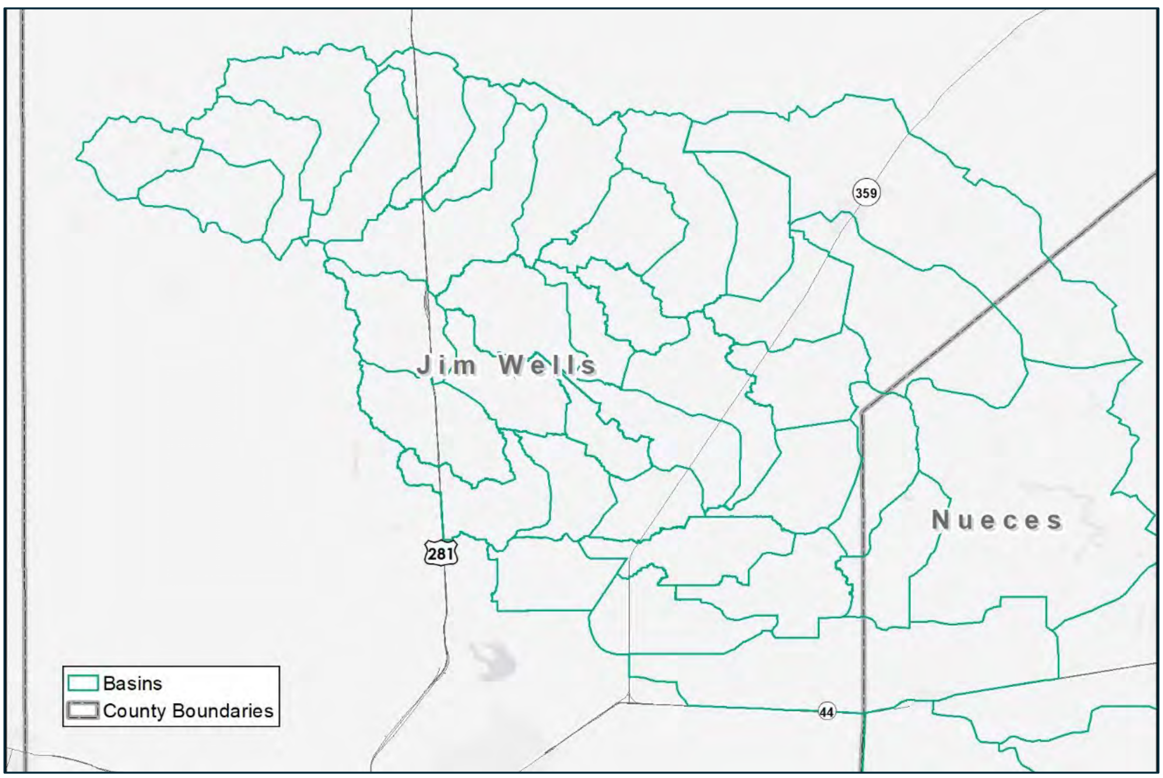

Figure 5.2 Refined Basins highlight for Jim Wells Hydrology.

For model areas that are hydraulically modeled in detail, subbasins are used as hydraulic model boundaries in both existing and proposed alternative analyses. Further discussion is provided in **6 Existing conditions - hydraulic model development** and **7 Flood mitigation and alternative analysis**.

To establish model boundaries, the 2D BLE floodplains discussed in **2 Data collection** were overlayed with the initial basin delineations. Smaller basins were merged together to minimize cross-basin interactions, simplify inflow locations, and refine model sizes. Further refinement of the model and basin boundaries were performed in ArcGIS. Cross-basin interactions create flow exchange locations between models, which become highly complex to model in shallow sloped areas such as the Study area. To account for any cross-basin interaction requires multiple model iterations and model connections linking the individual models together for both existing and proposed scenarios. This can result in model instability and model tie-in issues that would have to be later addressed. In addition, inflow locations need to be applied at locations where flow is all traveling perpendicularly across the full width of the floodplain. **Figure 5.3** shows an example of a model boundary compared to a basin boundary.

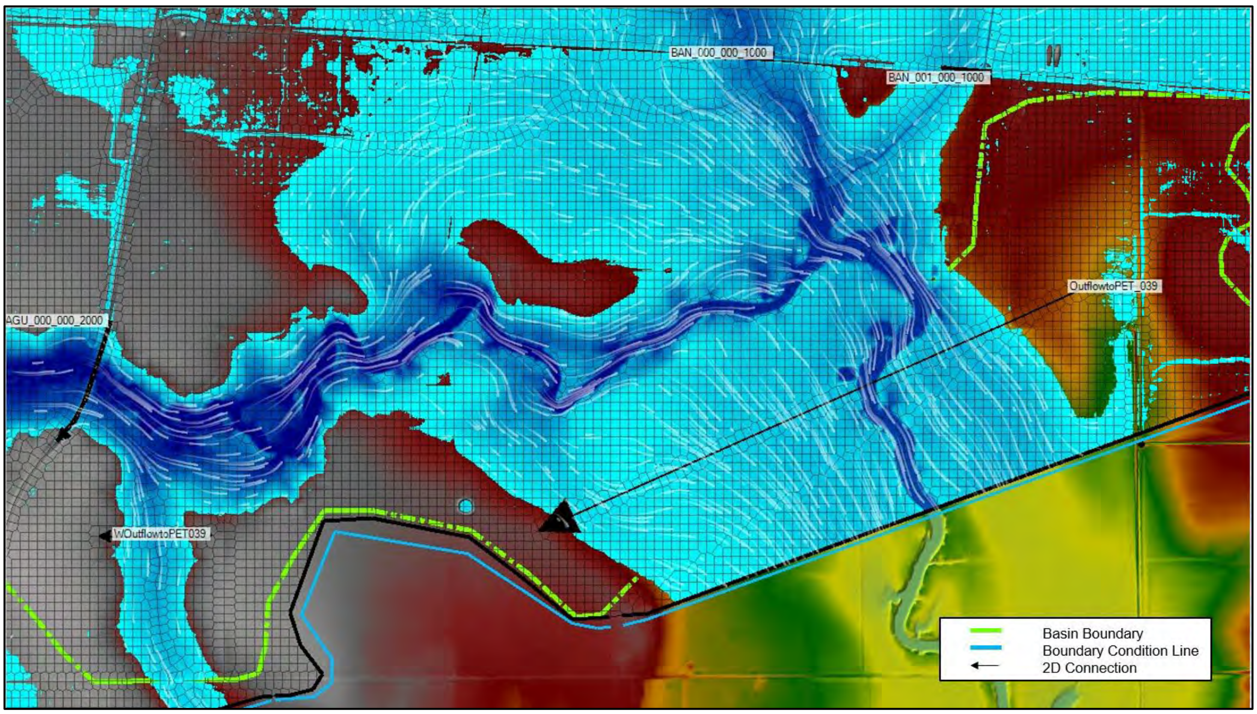

Figure 5.3 Flow across 2D Connection along Petronila Creek south of Banquete.

Figure 5.4 shows markups made to create model boundaries by merging initial basins to minimize cross-basin interactions. Basin merging and model refinement were considered based on parameters that would decrease model instabilities and runtimes, including survey integration, overall model size, cross-basin interactions, and other model refinements further discussed in **6 Existing conditions - hydraulic model development.**

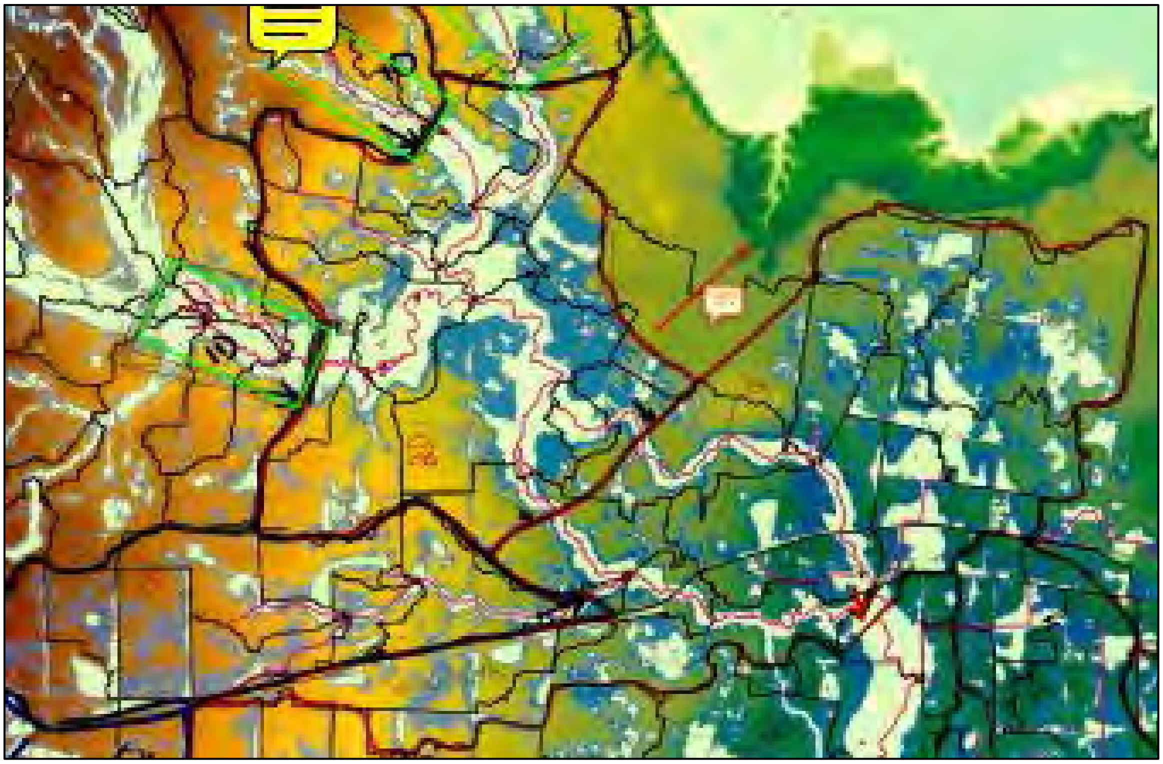

Figure 5.4 Basin revisions for 2D modeling

Basins were merged to create initial model boundaries ranging in size from four square miles to 45 square miles. For NCDD2 modeling, initial model boundaries were merged to create one comprehensive model. This area does not include the Petronila Creek mainstem as the Petronila Creek floodplain extends significantly outside the NCDD2 boundary, which warranted a model for Petronila Creek's mainstem itself. **Figure 5.5** compares the NCDD2 boundary to the model boundary representing most of the NCDD2 area.

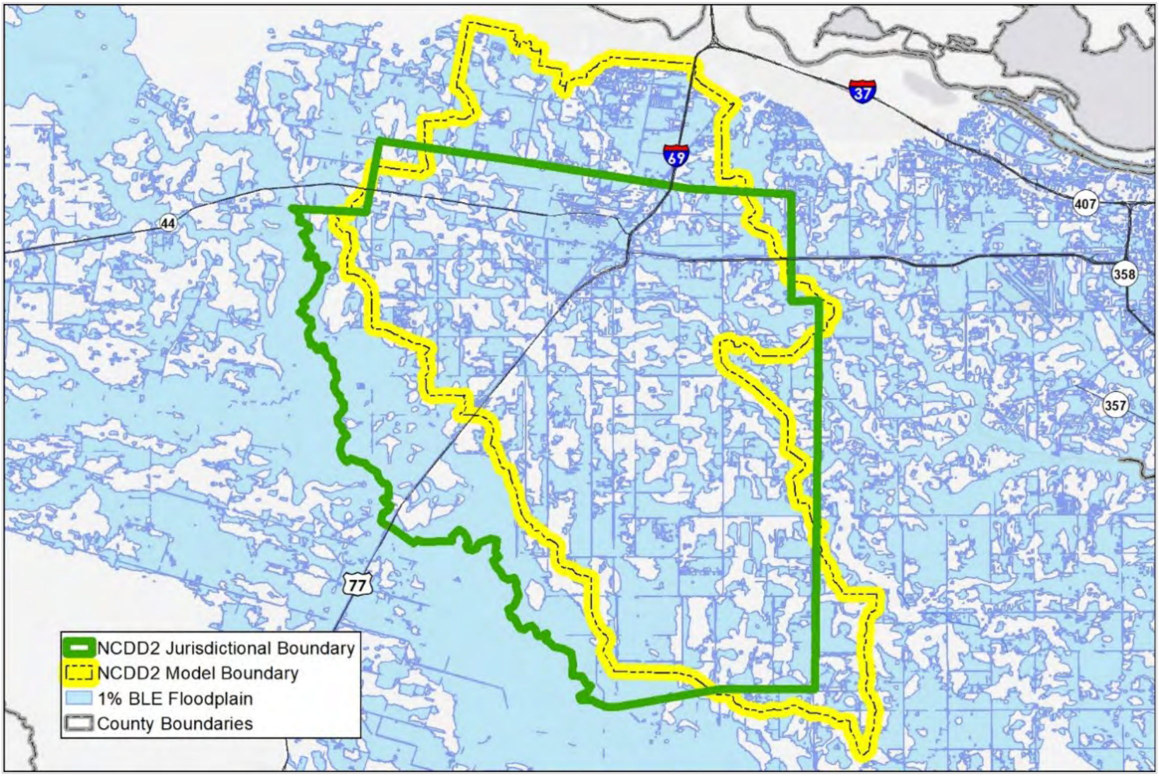

Figure 5.5 NCDD2 Model Boundary completed by ICE and CSE per the grant agreement.

5.1.2 Flowpath refinement

With basins delineated considering confluences, key points, and model needs, further ArcGIS edits were made to the basin boundaries based on flowpath refinements. The flowpaths representing the hydraulically most distant path in the watershed a drop of water would travel to get to the inlet were created for all hydrologically modeled basins. During flowpath creation, additional culverts or cross-conveyance structures were identified in aerial imagery that may not have been seen in the terrain. These resulted in small drainage area refinements between basins.

5.2 Hydrologic losses

A hydrologic analysis was performed to model potential rainfall (storm) events. A rain-on-mesh methodology was used in hydraulic modeling (HEC-RAS) to identify flow patterns, accumulation points, and potential off-site areas that contributed to the defined project areas. The following sections outline the assumptions and methodology used for the hydrologic losses portion of this Study.

5.2.1 Curve number development

All rainfall-runoff was computed using the SCS Curve Number method, developed by the Natural Resources Conservation Service (NRCS). This method predicts an area's direct runoff and infiltration based on the area’s land use, soil type, and hydrologic condition (good, fair, or poor condition).

Land use data provides an estimate of runoff potential. Typically, areas with more impervious coverage (parking lots, buildings, roads) have greater runoff potential. Land use datasets were initially created based on the 2019 National Land Cover Database and then refined using 2022 aerial imagery (Google Earth and NearMap) to capture ongoing and new developments seen in the aerial imagery. The predominant land use type within the Study area is agricultural land mixed with low-density development, typically including limited single-family dwellings, schools, public parks, farms, and churches.

Soil properties influence the relationship between rainfall and runoff, dependent on their physical characteristics. The soils are grouped into four hydrologic soil groups (A, B, C and D). Soil group A represents sandy soils with greater infiltration, whereas D represents clay soils with greater runoff potential. A, B, C, and D each have increasing runoff potential. Soil data was acquired from the web soil survey provided by the NRCS Soil Survey Geographic Database (SSURGO).

The initial land use boundaries and soil information were overlayed to create curve numbers for each drainage area. Curve numbers were computed based on a composite percentage of soil type and land use within each subbasin. The curve numbers used in this study were obtained from the 1986 NRCS Urban Hydrology for Small Watersheds Technical Report-55 (TR-55). Higher curve numbers represent greater runoff potential. **Table 5.2** shows a curve number classification table used in this analysis.

Table 5.2 Curve numbers

NLCD Land Use	Hydrologic Soil Group A	Hydrologic Soil Group B	Hydrologic Soil Group C	Hydrologic Soil Group D
Barren Land	49	69	79	84
Cultivated Crops	61	73	81	84
Deciduous Forest	36	60	73	79
Developed High Intensity	77	85	90	92
Developed, Low Intensity	57	72	81	86
Developed, Medium Intensity	61	75	83	87
Developed, Open Space	49	69	79	84
Emergent Herbaceous Wetlands	55	71	81	89
Evergreen Forest	36	60	73	79
Grassland-Herbaceous	55	71	81	89
Mixed Forest	36	60	73	79
Open Water	99	99	99	99
Pasture-Hay	49	69	79	84
Shrub-Scrub	35	56	70	77
Woody Wetlands	55	71	81	89

5.2.2 Routing

Hydrologic and hydraulic routing is used to quantify the effects of storage volume along river reaches as well as the impact on basin response time. For the Jim Wells County hydrologic model, since a detailed 2D hydraulic model was not developed for this area, a Muskingum-Cunge routing methodology was used with a representative 8-point cross-section to represent the river reach sections. The remainder of the study area used 2D hydraulic modeling, which naturally accounts for the storage volume as flow is conveyed across the topographic surface.

5.3 Precipitation

The rainfall data used for the Study was developed for both the 2D models (HEC-RAS) and the HEC-HMS hydrologic model developed to capture flows for the Jim Wells County (hydrology only) portion of the study. Rainfall hyetographs used in the hydraulic models were developed using an HEC-HMS model. Further discussion of source data, parameters used and resulting hyetographs is provided below.

5.3.1 Rainfall data source

NOAA Atlas 14 Point Precipitation Frequency Estimates was collected as a blanket layer of georeferenced peak rainfall data. For each studied storm event (10%, 4%, 2%, 1%, and 0.2%), the 24-hour peak rainfall data was aggregated based on a weighted zonal statistic for each subbasin. The resulting representative rainfall total was used in the simplified precipitation and Jim Wells hydrologic models.

5.3.2 Precipitation model

The precipitation model is a simplified HEC-HMS model used to convert the peak rainfall data into 24-hr rainfall hyetographs. These hyetographs are applied directly to the HEC-RAS 2D model surface as a rain-on-mesh precipitation boundary condition. With hydrologic losses incorporated into the HEC-RAS 2D model, no loss methods or parameters are required for the HEC-HMS model.

The parameters used to develop the hyetographs for each basin are:

- Drainage area of 1 square mile
- Default Parameters for Loss Methods
- Meteorological Model Parameters:
    - Frequency Storm
    - No Areal Reduction
    - 1-Day Storm Duration
    - 5 Minute Intensity Duration
    - 50 Percent Intensity Position
    - Variable by Subbasin

An example resulting in a hyetograph is provided in **Figure 5.6.** Rainfall hyetographs for all basins are provided in **Appendix B**.

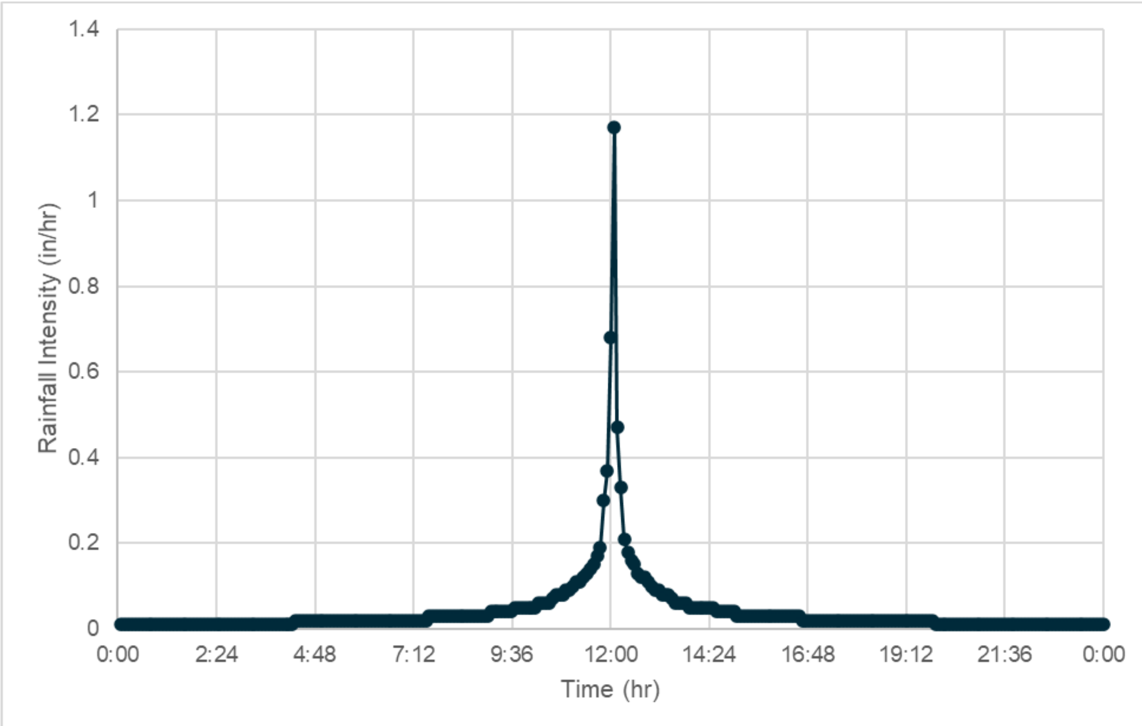

Figure 5.6 Agua Dulce Hyetograph

5.3.3 Jim Wells mapping exercise model precipitation

For the mapping exercise to produce updated 1% floodplain extents for Jim Wells County, an aggregated rainfall hyetograph was used for the hydraulic modeling discussed further in **6 Existing conditions - hydraulic model development**. This hyetograph was created by averaging the resultant hyetographs from the basins in Jim Wells County, provided in **Figure 5.7.**

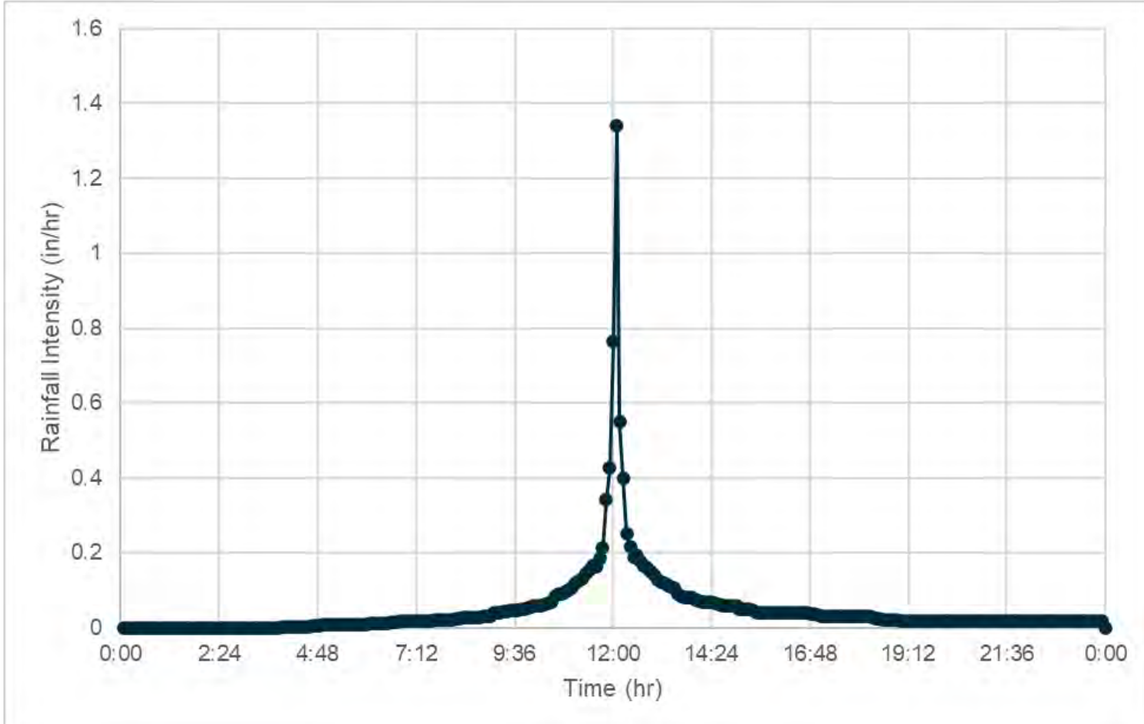

Figure 5.7 Jim Wells Model Hyetograph

5.4 Jim Wells County outflow hydrologic model

The Jim Wells County Hydrologic Model combines the basins, hydrologic losses Muskingum-Cunge routing, and precipitation to develop resulting runoff hydrographs that are applied as inflow hydrographs for the detailed HEC-RAS 2D modeled areas located downstream of Jim Wells County. The application of these inflows into the hydraulic models is discussed in **6 Existing conditions - hydraulic model development**.

5.5 Results validation

The Oso Creek USGS gauge (08211520) is the only existing gauge within the project limits with consistent and recorded historical data. Other gauges were identified within the Study area, as well as others that are planned for installation within the next two years; these gauges are newer and do not have a long enough period of record to be used for calibration or validation with the larger (less frequent) storm events in this study area.

The South Corpus Christi BLE study performed a gauge analysis with respect to the Oso Creek USGS gauge. Hydrologic model validation was achieved by comparing modeled flow values from the HEC-RAS 2D model to the South Corpus Christi BLE study and, by extension, the Oso Creek USGS gauge. Further model validation was achieved during public meetings when existing conditions mapping was presented to the public for review and feedback. Community members, elected leaders, county and NCDD2 staff generally concurred with the mapped results during these meetings. Model results and validation are further discussed in **6.1.6 Results and model validation.**

6 Existing conditions - hydraulic model development

The existing conditions hydraulic models were developed in HEC-RAS, Version 6.3.0. A review of available BLE floodplains in the area identified significant flow interaction between study streams, which is more complex flow modeling than can be completed in a traditional 1D-hydraulic model. These inter-basin and stream flow interactions are most appropriately modeled using 2D hydraulic modeling approaches, which were used for the Study. This modeling approach is typically used for detailed mapping results over a large, generally flat area (this study area), where flooding can primarily be overland sheet flow and less channelized. This procedure is outlined below with more detailed modeling notebooks in **Appendix C - Hydraulic Analysis and Floodplain Mapping Technical Memorandums**.

6.1 2D-model development

This section describes the generation of the parameters for the 2D model development. Key considerations and other modeling approach decisions are also addressed.

6.1.1 Petronila & Oso creeks

The hydraulic models extend from the northeastern edge of Jim Wells County, southeast through Nueces and Kleberg Counties along the Petronila Creek watershed, and from central to eastern Nueces County along the Oso Creek watershed. A total of 29 detailed 2D Hydraulic models were produced along both watersheds, 28 single basin models and one merged basin model covering the NCDD2 area. **Figure 6.1** shows the hydraulic model extents.

Figure 6.1 Hydraulic Model Extents

6.1.1.1 Baffin Bay inflows

At two locations along the western edge of basin models PET-040 and PET-043, inflows were incorporated from the Baffin Bay BLE study. Hydrographs were taken from profile lines in the BLE HEC-RAS models and applied at the same location in this study using boundary condition inflow hydrographs. **Figure 6.2** shows the locations of the inflows applied to the hydraulic modeling.

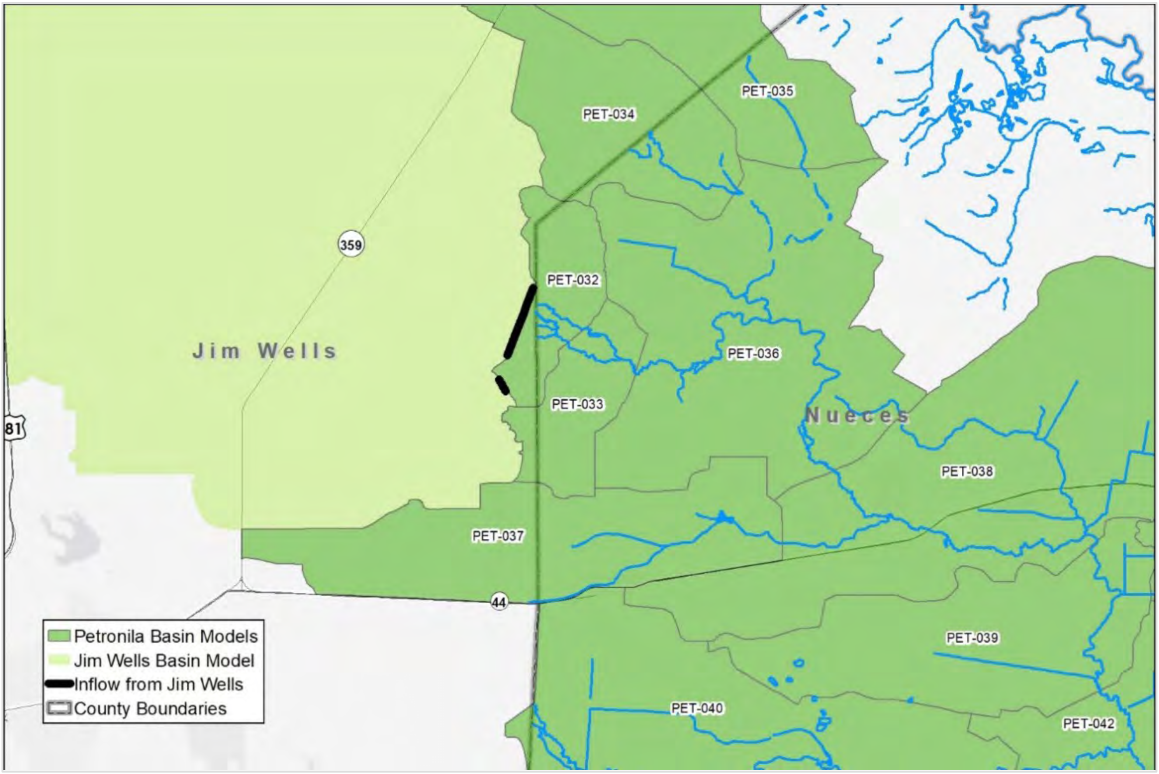

Figure 6.2 Jim Wells Hydraulic Model Inflow Locations

6.1.1.2 Jim Wells County model area

For the 1% flood inundation mapping exercise for Jim Wells, one approximate 2D hydraulic model was produced. The delineated basins in the headwaters of the Petronila Creek watershed (PET-001 to PET-031) that cover the Jim Wells County area were merged into a single model boundary. The hydraulic modeling for this area incorporated no breaklines or structures to produce approximate floodplains for Jim Wells County. The model incorporates the procedures outlined in Sections 6.1.2 Model 2D Mesh and 6.1.3 Boundary Conditions, but no further model refinement was included.

6.1.2 Model 2D mesh

Delineated basin areas were buffered 2,500 feet in ArcGIS to provide significant overlap between basin models. This modeling overlap is necessary to provide appropriate basin-to-basin boundary conditions and facilitate clean mapping tie-ins of the floodplains between basin models by comparing the overlayed floodplains. All model mesh areas were set to an initial cell size of 100 ft x 100 ft. Since these are detailed models, the mesh cell size is more refined than the BLE standard of 200 ft x 200 ft. Basin models OSO-011 and OSO-015 were set with a base cell size of 50 ft x 50 ft due to the higher level of urbanization in those areas located within/surrounding Corpus Christi area).

6.1.1.3 Jim Wells County model area

Breaklines were added and enforced in the 2D mesh to provide alignments for the cell faces. They were placed along high points in terrain that could obstruct flow (i.e., roads, berms), effectively blocking flow between cells by aligning 2D mesh cell faces with the high point in the terrain. Breaklines are also used in stream centerlines to establish flow direction. For this study, breaklines were imported into HEC-RAS from previous BLE Studies (South Corpus Christi and Baffin Bay East), which included most major roads, as well as study stream centerlines. These imported breaklines were then modified to better reflect the refined, smaller-resolution terrain. New breaklines were added to better model visible terrain divides and aid in model stability.

Using terrain and aerial imagery, breaklines were further analyzed to identify areas where V-notch edits could be added to allow leakage between cells. Cell leakage allows runoff to be conveyed from one cell to the next, where high points in terrain may inaccurately block flow (such as non-surveyed/modeled structures). In **Figure 6.3**, a V-notch allows flow through identified culverts, which were not fully surveyed.

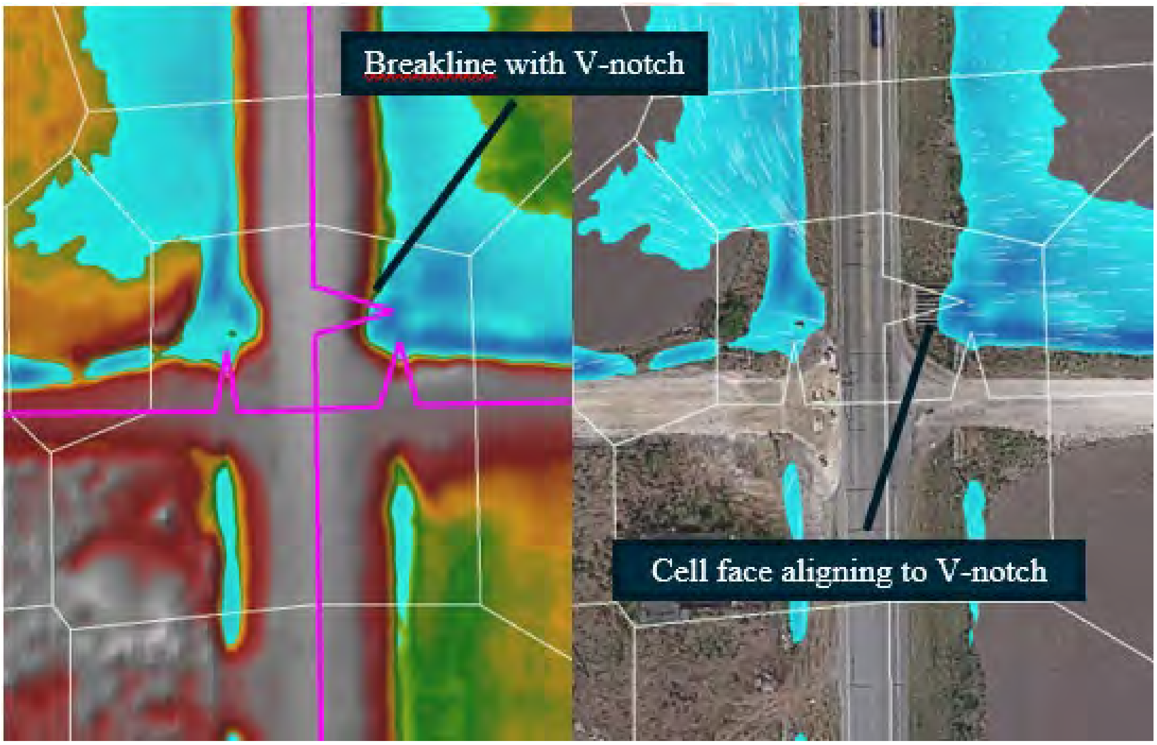

Figure 6.3 Breakline V-notch allowing leakage through non-surveyed structure

6.1.3.2 Manning's "N" values

A Manning's "N" value layer was set for the mesh based on NLCD land use. The roughness values used in this study were based on those previously validated in the Baffin Bay and South Corpus Christi BLE studies. Buffers were established along major stream centerlines and roadways to add calibration regions to the model Manning's "N" layer. Buffer extents varied based on aerial imagery and channel width. Calibration regions define a specific channel Manning's "N" value, which was applied to the detailed stream centerlines. Manning's "N" values for channels were classified based on aerial imagery to be either 0.02 for concrete, 0.045 for shrubby/grassy areas, and 0.07 for densely forested channels.

Table 6.1 Overland Manning's "N" Values

NLCD Land Use	Manning's "N" Value Used
Barren Land	0.03
Cultivated Crops	0.04
Deciduous Forest	0.12
Developed High Intensity	0.12
Developed, Low Intensity	0.06
Developed, Medium Intensity	0.08
Developed, Open Space	0.04
Emergent Herbaceous Wetlands	0.08
Evergreen Forest	0.12
Grassland-Herbaceous	0.045
Mixed Forest	0.12
Open Water	0.03
Pasture-Hay	0.04
Shrub-Scrub	0.06
Woody Wetlands	0.1

6.1.3 Boundary conditions

Three types of boundary conditions were established around the mesh perimeter:

- Inflow Hydrograph: Linked flow hydrographs from upstream models
- Normal Depth: Set normal depth slopes around the model perimeter to allow outflows from the model domain
- Stage Hydrographs: Set to Mean Higher High-Water elevations at coastal boundary locations.

For most model boundary condition outflows, normal depth slopes were set to basin slopes averaged across the modeling region, with slopes generally decreasing closer to the coastal region (reference **Figure 6.4**). At major connected outflow/inflow locations that linked flow between models, slopes were adjusted as necessary to aid in floodplain tie-ins between basin models to meet the FEMA-required mapping tolerance of difference of less than 0.5 feet.

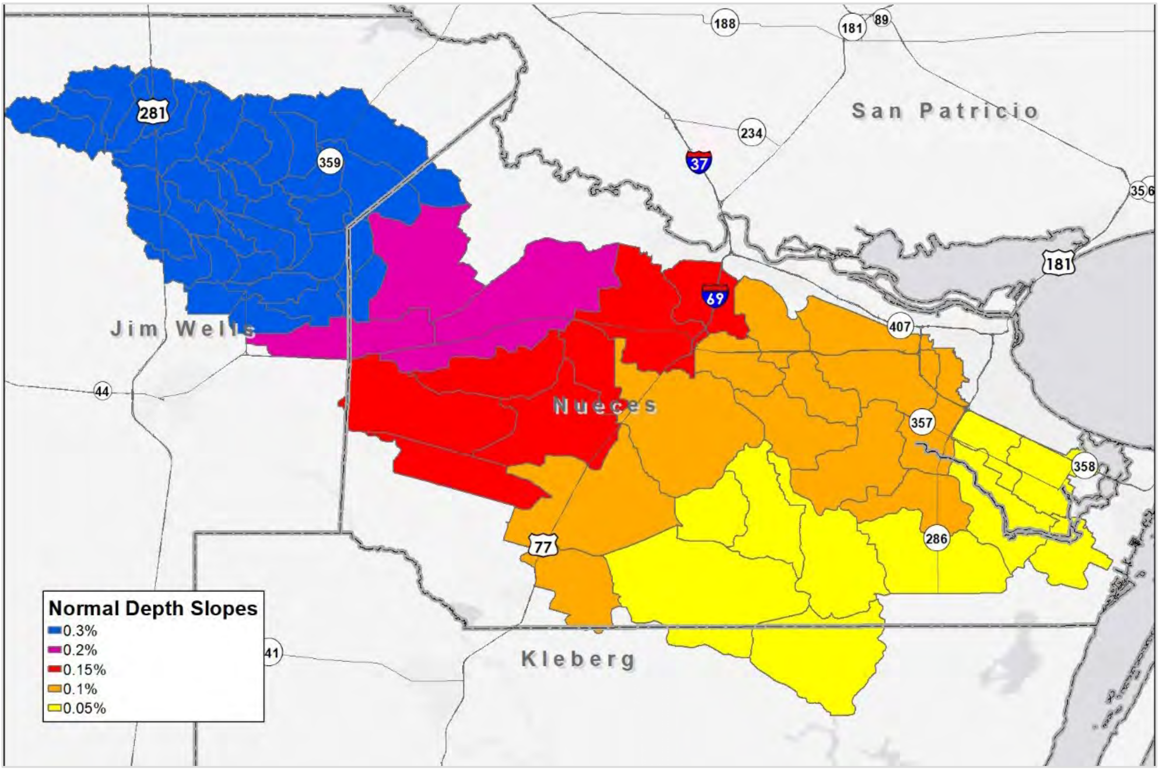

Figure 6.4 Average Basin Slopes

6.1.4 2D connections

There are two main types of 2D connections used in these models, structures (culverts and bridges) and outflow connections (links between model domains).

6.1.4.1 Surveyed structures

2D Connections were added to the geometry meshes to model the effects of the structures surveyed throughout the study area. Bridges and culverts were added based on detailed and limited detail survey data, with adjustments made to model parameters to aid in stabilizing results. Terrain edits were made to match the survey where necessary if terrain values near culvert inverts were inconsistent with surveyed elevations.

6.1.4.2 Model outflow connections

2D Connections were also used to link outflow hydrographs from upstream models to inflow boundary conditions in downstream models at locations of significant flow transfer. Initial model run floodplains were reviewed to optimize locations to pull flow hydrographs for connection to downstream models.

6.1.5 Computational settings

The 2D unsteady flow analysis was run for all model areas. Since the models were directly linked and modeled the delay in peak flooding as water moves downstream through the watersheds, a simulation time window of three days was used to capture the full peak of flooding through the most downstream basins.

Fixed computational time steps of either 15 or 30 seconds were used; the 30-second time step was used for models with fewer structure-related instabilities. All output intervals were set to 15 minutes.

6.1.6 Results and model validation

Only USGS gauges with more than 20 years of flow data available and located within the Study area were used for model validation. These criteria are designed so that PeakFQ analysis would have sufficient data to produce frequency storm flow data. Of the two gauges in the study area (USGS Gauge 08212820 – Petronila Creek at FM 665 near Driscoll, USGS Gauge 08211520 – Oso Creek at Corpus Christi, TX), only the Oso Creek gauge met the recorded timespan criteria.

This same validation method was used within the previously referenced South Corpus Christi BLE study for the Oso Creek gauge. Peak flows within the model were compared with a Bulletin 17B Analysis of the gauge data using PeakFQ. Results of the flow comparisons and water surface elevation are presented in **Table 6.2.**

Table 6.2 1% Annual Chance Reasonability Comparisons

Flooding Source	USGS Gauge Used for Verification	HEC-RAS 5.0.7 (South Corpus Christi BLE Study) WSEL (ft)	HEC-RAS 5.0.7 (South Corpus Christi BLE Study) Discharge (cfs)	HEC-RAS 6.3.0 (Basin Model OSO-008) WSEL (ft)	HEC-RAS 6.3.0 (Basin Model OSO-008) Discharge (cfs)	Gauge Analysis Results WSEL (ft) [1]	Gauge Analysis Results Discharge (cfs) [2]
Oso Creek	08211520	28.79	10,672	29.31	11,287	28.55	10,890

[1] Water surface elevation is approximate based on Power Function TWRI – A10 input data and adjusted to NAVD 88 Datum.

[2]Discharge value is the result of Bulletin 17B Analysis of gauge data using PeakFQ

Due to the lack of observed flows over 6,000 cubic feet per second and inconsistent water surface elevations compared to peak flows, the Power function method was used to determine Water Surface Elevations at the gauge. This method is based on the Texas Water Resource Institute's *Techniques of Water-Resources Investigations of the United States Geological Survey Chapter A10: Discharge Rating at Gaging Stations*. The 50-year PeakFQ Discharge and WSEL value were also calculated and used as another verification method for further confidence; results are shown in **Table 6.3**.

Table 6.3 2% Annual Chance Reasonability Comparisons

Flooding Source	USGS Gauge Used for Verification	HEC-RAS 5.0.7 (South Corpus Christi BLE Study) WSEL (ft)	HEC-RAS 5.0.7 (South Corpus Christi BLE Study) Discharge (cfs)	HEC-RAS 6.3.0 (Basin Model OSO-008) WSEL (ft)	HEC-RAS 6.3.0 (Basin Model OSO-008) Discharge (cfs)	Gauge Analysis Results WSEL (ft) [1]	Gauge Analysis Results Discharge (cfs) [2]
Oso Creek	08211520	28.10	9,444	28.39	9,400	27.8	9,364

[1] Water surface elevation and Discharge is approximate based on PeakFQ input data and adjusted to NAVD 88 Datum.

7 Flood mitigation and alternative analysis

7.1 Selection and prioritization

Upon completion of the existing conditions modeling and mapping, a full-scale mapping review of the study area was performed to identify flood risk areas. The following criteria was established for the identification of significant risk areas:

1. High-population areas
2. Existing structures at risk from substantial flooding
3. Critical infrastructure (fire stations, hospitals, schools, etc.)
4. Likelihood of potential future funding
5. Localized improvement projects (inlets, small-scale design/construction of infrastructure)
6. Future urbanization and growth

Using these criteria to review the 1% and 4% existing conditions flood extents, 31 flood risk areas were identified, as shown in **Table 7.1** below:

Table 7.1 Preliminary Identified Areas of Flood Risk

Identified Risk Area Number	Identified Flood Risk Area
1	Ranch Road & Cindy Lane
2	Westwood Estates
3	Indian Trails
4	Rancho Banquete
5	Banquete
6	City of Agua Dulce
7	La Paloma Ranch
8	North Robstown
9	IH 69E Crossing
10	Robstown Drains
11	Callicoatte Farm
12	FM 1694 & TX 44 North
13	FM 1694 & TX 44 South
14	County Road 61 & TX 44
15	Spring Gardens & Primavera Estates
16	Tierra Verde
17	Lost Creek & Nye & Peterson Farm
18	FM 892
19	City of Driscoll
20	Fiesta Ranch
21	FM 665 & CR 69
22	Petronila Acres
23	Tierra Grande & Crossroads Estates
24	San Petronila Estates
25	Corpus Christi International Airport
26	Balchuck Lane & Digger Lane
27	Nottingham Acres
28	South Prairie Estates
29	US Naval Base
30	Petronila Creek Environmental Study
31	Santa Maria

7.1.1 County and public input

Preliminary identified risk areas, provided in **Table 7.1** above, were presented during TWDB Public Meeting No.3 on September 29, 2022. During this meeting, the public was given the opportunity to provide feedback on the FRAs, as well as identify their top 10 to help prioritize areas for further analysis. **Figure 7.1** is an example of the physical voting platform the participants used to choose their highest areas of concern. Participants were asked to place stickers next to project area names in the upper portion of the maps.

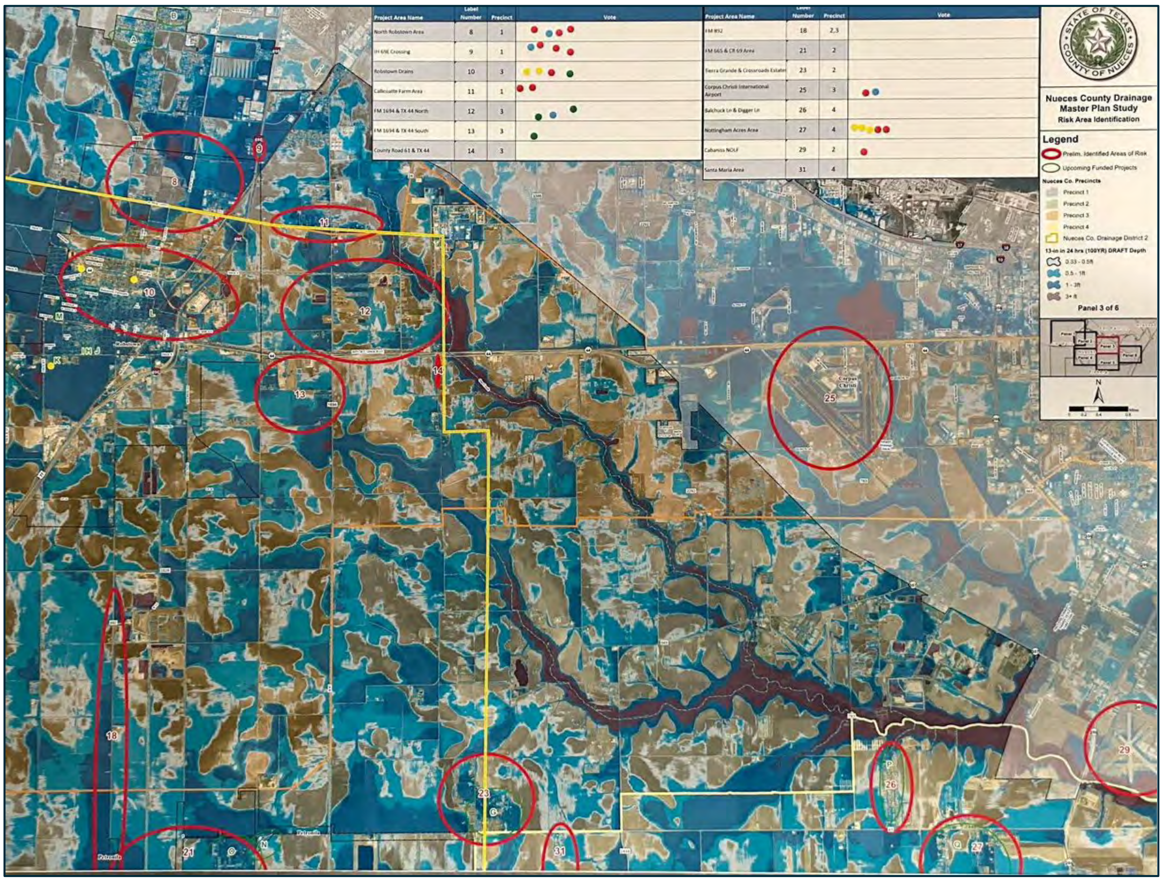

Figure 7.1 Public Input for Risk Area Selection

7.1.2 Final selection of flood risk areas

As scoped for this Study, a total of 15 flood risk areas were selected from the preliminary list of 31 to be further analyzed for potential mitigation alternatives that would reduce flood risk adverse impacts. The selection of these project areas was partly based on public input but also considered flood risk areas previously studied or those that had anticipated or planned funding for flood mitigation projects. The areas with planned funding were given lower priority than those project areas without anticipated or planned funding. The selected flood risk areas to be further analyzed are provided in **Table 7.2** and were approved by the Nueces County Commissioners on November 2, 2022. The selected risk area number associated with each selected risk area correlates to the original numbers assigned during flood risk area identification.

Table 7.2 Selected Flood Risk Areas

Selected Risk Area Number	Selected Risk Area Name	Flood Impact Description
1	Ranch Road & Cindy Lane	Localized flooding begins in the neighborhood and worsens as Quinta Creek flows through the low-lying area.
3	Indian Trails	The first peak of flooding was primarily due to ponding and local drainage within the Indian Trails subdivision—the second peak of flooding was primarily due to stream flooding and flow constrictions at FM 1833 and FM 666.
4	Rancho Banquete	Backwater from the stream into the neighborhood and downstream bridge constriction.
5	Banquete	Flow constriction along several roadways causes significant flooding in the area and overflow into Banquete Creek.
6	City of Agua Dulce	Excessive runoff over CO Rd 105 further inundates the town of Agua Dulce.
7	La Paloma Ranch	There is significant ponding at the intersection of La Paloma and CR 18 and a buried culvert at the intersection of La Paloma and CR 93. Flow overtopping CR 93, cutting off the main route that connects La Paloma with FM 665.
8	North Robstown	Low terrain and roads create excess ponding from the flow conveyed into the North Robstown area and cannot properly drain out.
10	Robstown Drains	Excess runoff from the surrounding stream flows west to east through the area. Local ponding and flooding occur in most of the residential area.
11	Callicoatte Farm	Runoff collects and passes through the area near the CO Rd 44 and FM 1694 intersection and surrounding structures before going to Oso Creek and Ditch A to Oso Creek.
12	FM 1694 & TX 44 North	Flooding causes mobility issues at the intersection of TX44 and FM 1964. TX44 North impedes conveyance, resulting in additional flooding to the west.
19	City of Driscoll	Conveyance of flows across the City into Petronila Creek, which flows through the City, with split flows causing widespread flooding.
20	Fiesta Ranch	The area is initially flooded through local runoff. Backwater from Petronila Creek further inundates the area.
26	Balchuck Lane & Digger Lane	Many drainage issues from recent development and runoff from nearby streams cause flooding in the residential areas.
27	Nottingham Acres	Flooding at Loxley Drive causes neighborhood inundation due to limited existing drainage infrastructure. Ponding occurs due to limited topographic relief.
28	South Prairie Estates	S. Prairie Rd and Rabbit Run are overtopped by runoff from surrounding areas.

7.2 Flood risk reduction and mitigation project alternatives

For the selected risk areas, proposed improvements were optimized for the 4% annual chance flood event unless otherwise noted.

All models were run for a 48-hour simulation. For some risk area models, two major flooding peaks were observed during the model simulation. The first peak was due to the localized storm event established by the rain on grid modeling methodology. The second peak was due to riverine flooding accumulating from upstream to downstream, causing significant backwater in areas adjacent to the mainstems. In these areas, proposed improvements were analyzed to a shortened 18-hour simulation, isolating the localized peak and optimizing to mitigate the localized first peak. The second riverine-based peak represents a worst-case scenario (coincidental peak), which is a very conservative modeling approach, as it is less likely for a large, uniform storm event to occur across the entire contributing area. Mitigation for this peak was analyzed in several instances by removing the upstream contributing drainage area, similar to a regional detention analysis; however, the local flooding experienced due to the second peak was not significantly reduced. The conveyance capacity of the mainstem channel in these areas was exceeded by the immediate contributing drainage area in the vicinity of the proposed mitigation alternatives, resulting in widespread flooding from the channel into the adjacent areas. Thus, mitigation for the second riverine-based peak was not feasible. The risk areas that experienced two peaks and were analyzed using this approach are identified below:

- FRA 3: Indian Trails
- FRA 4: Rancho Banquete
- FRA 5: Banquete
- FRA 19: Driscoll
- FRA 20: Fiesta Ranch

All proposed improvements were checked for adverse impact for the 1% and 4% annual chance storms following TWDB guidance document “Exhibit C: Technical Guidelines for Regional Flood Planning.”

7.2.1 North Robstown

Robstown is a small city in Nueces County located along US 77/ I-69 at SH 44. Risk Area 8 represents the area of northern Robstown and the unincorporated area north of Robstown, located generally west of US 77/ I-69. The city of Corpus Christi limits is in the northern portions of the risk area. Additional major roads within the area include BS 77, CR 44 (E. Congressman Solomon P. Ortiz Blvd), CR 48, CR 52, CR 69, FM 1889, Northwest Blvd, and UPRR (Union Pacific Railroad). The area is bound by UPRR (east of US 77/ I-69) to the east, CR 44 to the south, Northwest Blvd to the north, and FM 1889 to the west.

7.2.1.1 Existing Conditions/Flooding Issues

The area consists of agricultural undeveloped land, residential development (small and large lots), and commercial development concentrated along US 77/ I-69 and Northwest Blvd. Recent commercial and industrial developments have occurred within the eastern portions of the area along US 77/ I-69. Additionally, some residential growth is anticipated in the eastern portions of the area along the county and FM roadways.

The area generally flows from west to east across open fields and along roadside ditches to existing box culvert crossings under US 77/ I-69. The runoff is then conveyed via existing drainage ditches that run east to the drainage ditch along UPRR north to its outfall to Nueces River. The UPRR ditch serves as the main outfall for this study area. Additionally, portions of the overland flow in the area’s southern reaches overflow south towards Robstown via the upper portions of Ditch ‘A-01’. Also, areas south of CR 44 are shown to overflow north into Risk Area 8. The overall area of existing flooding and inundation is presented in **Figure 7.2**.

Due to the lack of existing drainage infrastructure within the area and the limited capacity of the roadside ditches, ponding occurs behind roadways and existing irrigation canals, which causes flooding within the area. In general, a majority of the risk area is inundated during the 4% annual chance storm event by over 0.5 feet. Additionally, the US 77/ I-69 frontage roads are shown inundated during the 4% annual chance storm event.

The area's outfall for the UPRR ditch is located upstream of Hearn Road. At this location, the topography and existing ditch configuration change dramatically, providing sufficient capacity and slope to convey all the flow from the contributing drainage area to Nueces River without impacting adjacent areas. At this location, the computed peak flows for the UPRR ditch are 1570 cfs and 2310 cfs during the 4% and 1% annual chance storm events, respectively.

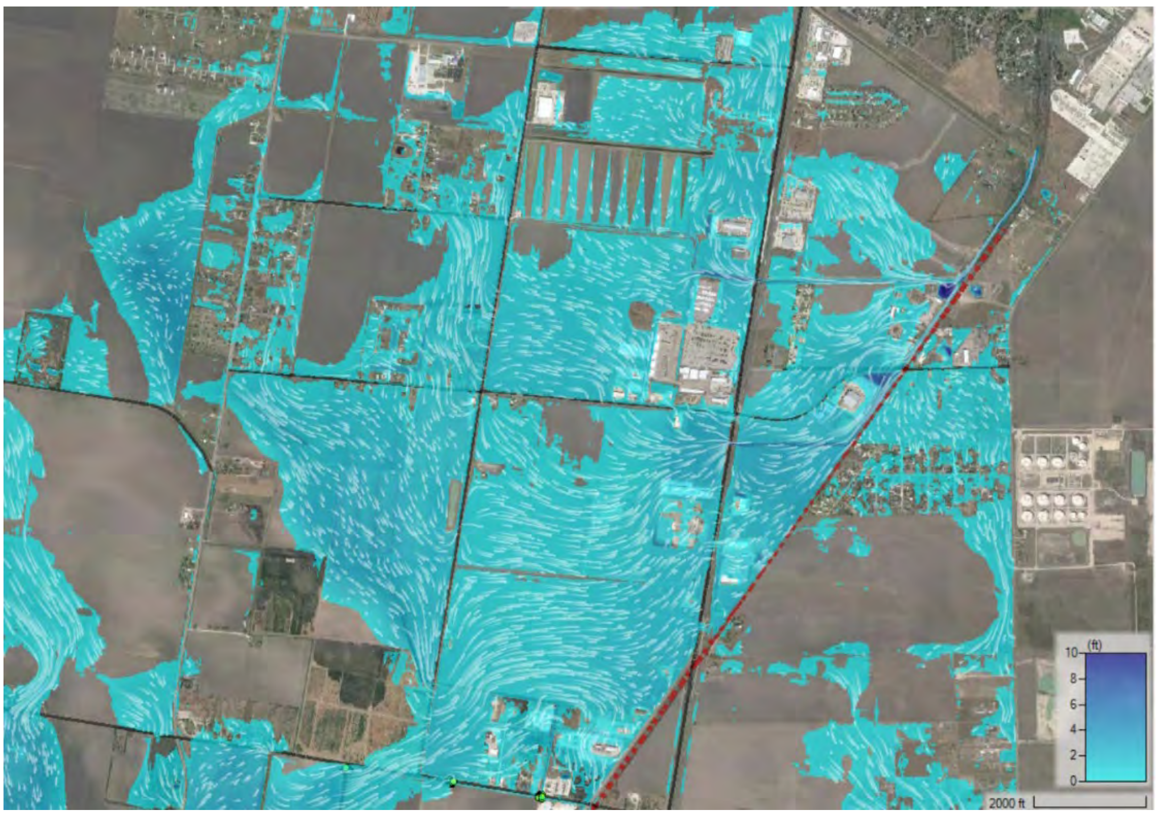

Figure 7.2 Existing Conditions 4% Annual Storm Depth – Robstown North

7.2.1.2 Proposed alternative

Proposed improvements were investigated to mitigate existing flooding and provide drainage infrastructure within the area. These proposed improvements consist of channel improvements, new channel alignments, associated culvert installation/ replacements, and a detention facility to relieve existing flooding issues within Risk Area 8. These improvements are presented in Figure 7.3**.** The drainage channels were proposed to collect the existing overland sheetflow and convey it through and away from the area, across US 77/ I-69, to the area's outfall within the UPRR ditch. A regional detention facility is proposed along the UPRR ditch, downstream of US 77/ I-69, to provide runoff mitigation for the proposed improvements.

The channel improvements consist of widening existing drainage ditches and constructing new drainage ditches for conveyance, as well as providing depth for additional improvements proposed by others to relieve localized flooding issues. The proposed channel improvements include trapezoidal earthen sections with bottom widths ranging from 10' to 60' and 3:1 (H: V) side slopes. Culverts are proposed to convey the ditches across existing roadways. The existing bridge-class culverts under US 77/ I-69 are to remain since they are shown to have sufficient capacity to convey the proposed project flows. The proposed improvements are presented in **Figure 7.3**.

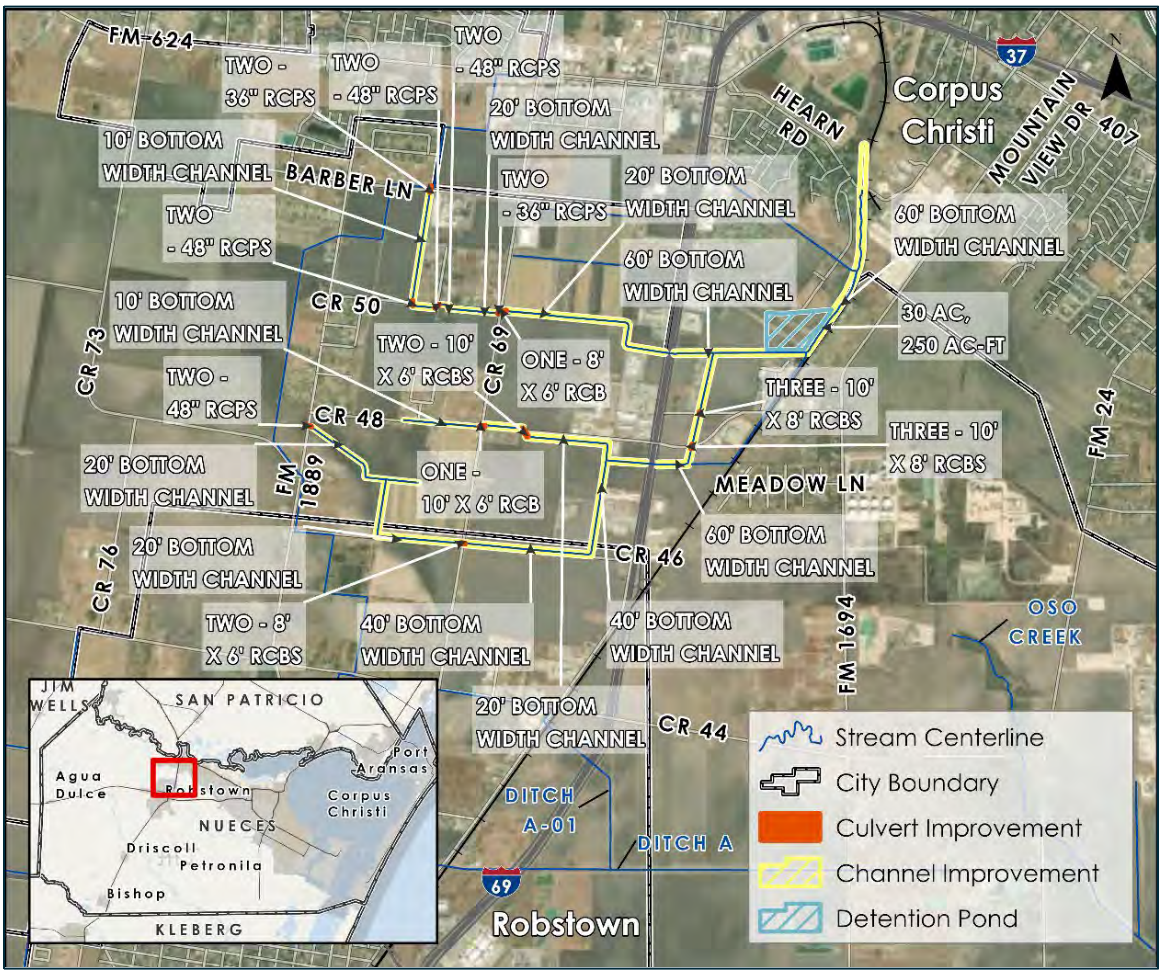

Figure 7.3 Proposed Improvements – North Robstown

The proposed improvements reduce the water elevations by 0.3 – 1.5 feet across the risk area for the 4% annual chance storm event. The proposed improvements for Risk Area 8 work in conjunction with Risk Area 10 and Risk Area 12. The proposed improvements benefit the adjacent areas by eliminating sheetflow overflows into Ditch 'A-01' and Robstown's central development area. Additionally, Risk Area 8 benefits from Risk Area

10 improvements by reducing and/or eliminating the overflow sheetflow from south of CR 44.

The improvements increase the drainage conveyance within the risk area, provide drainage infrastructure within the area to collect the runoff, increase the drainage conveyance downstream of US 77/ I-69 to receive the runoff, and provide a detention facility in conjunction with the inline channel storage to offset improvement impacts. Based on the analysis, the proposed improvements show no notable adverse impacts on the water surface elevations and flooding areas upstream and downstream of the risk area. **Figure 7.4** below shows the risk area's flood depth reduction.

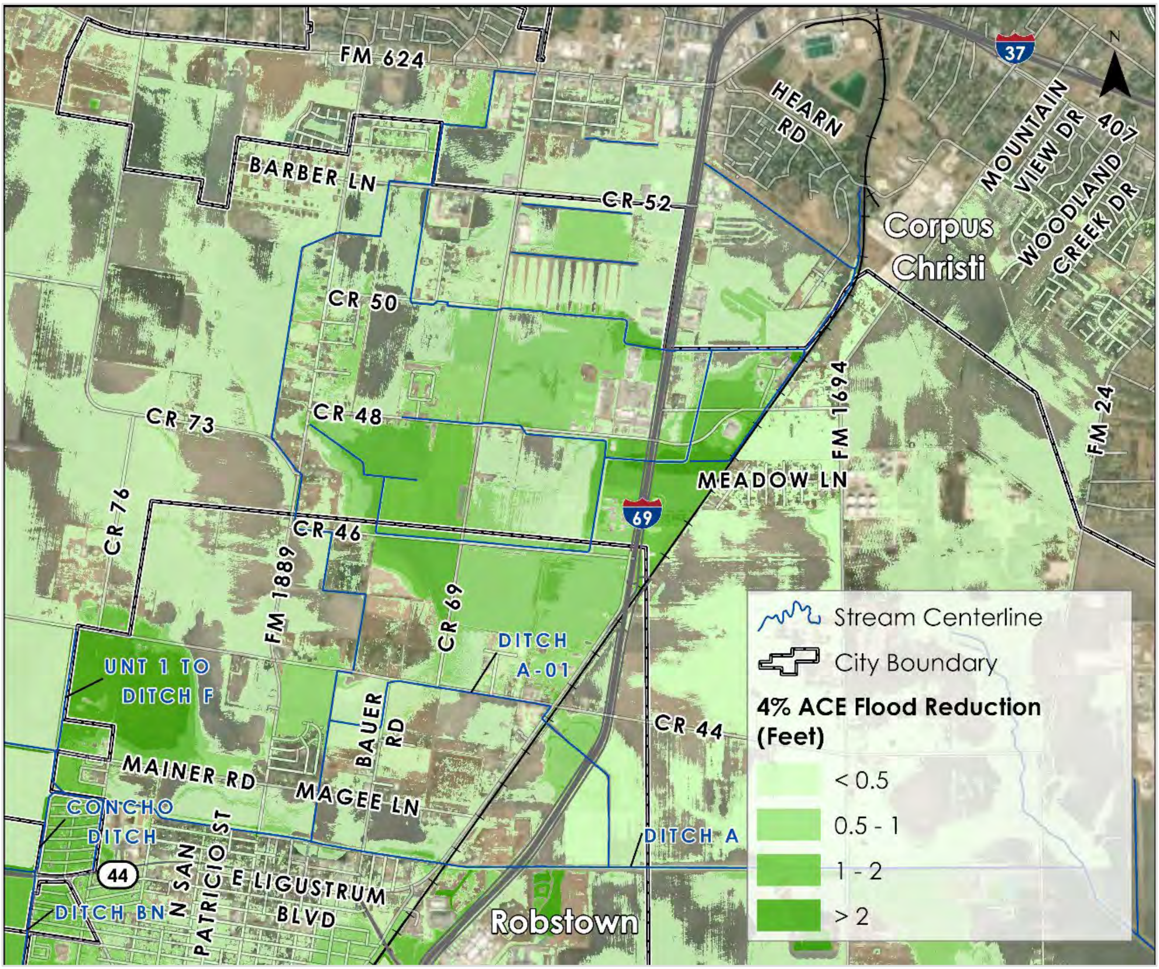

Figure 7.4 Proposed Conditions 4% Annual Storm Depth Reduction – North Robstown

7.2.2 South Robstown

Robstown is a small city in Nueces County located along US 77/ I-69 at SH 44. Risk Area 10 represents the area of Robstown west of US 77/ I-69. Additional major roads within the area include BS 77, Avenue J (SH 44), Avenue A (BS 44), N. 1st (FM 1889), and E. Main Avenue, as well as the UPRR. The development within this area is generally bound by US 77 to the east, Ditch 'A' to the north, Ruben Chavez Road to the south, and Concho Ditch (Concho St.) to the west.

7.2.2.1 Existing conditions/flooding issues

This area in the city's center is heavily developed, consisting of residential, industrial, commercial, and public facilities development. The area adjacent to Robstown's central area is mostly agricultural or undeveloped pastureland with some sparse residential areas.

The area generally flows from northwest/west to east into NCDD2 Ditch 'A'. Ditch 'A' runs west to east along the northern reach of the city's developed area. It conveys runoff from the city, across US 77/ I-69, and ultimately to Oso Creek. East of US 77/ I-69, this study identifies the area as Risk Area 12. Other conveyance systems within Risk Area 10 that provide drainage outfall for Robstown include the internal storm sewer systems, Concho Ditch, Ruben Chavez Road Ditch, Ditch 'E', and Ditch 'C'.

The internal storm sewer systems collect and convey the city's central area and outfalls into the headwaters of Ditch 'C' near BS 77, which ultimately outfalls into Oso Creek. Concho Ditch collects contributing overland sheetflow from the west of the city as well as overflow from Ditch 'A' and conveys the flow to the south towards a Petronila Creek tributary. During large events south of Ruben Chavez Road, the ditch overflows east and is collected by Ruben Chavez Rd Ditch and Ditch 'E' to be conveyed to Oso Creek via Ditch 'C'. Ruben Chavez Rd Ditch runs along the roadway east, mainly serving as an outfall for the Casa Blanca Subdivision and collecting the overflow from Concho Ditch. East of Liberty Ave (BS 77), it is collected by Ditch 'E' and conveyed across US 77/ I-69 before out-falling into Ditch 'C'.

The area's runoff and flooding are mostly controlled by the large contributing area (~2200 acres) west of Ditch 'A' headwaters, which overwhelms the existing drainage ditch and surpasses its conveyance capacity (the 10% annual chance storm event). This results in large sheetflow volumes through the city, inundating streets and structures. This overflow is also collected by and overwhelms Concho Ditch. Overflow within the city also overwhelms the city's storm sewer systems and its receiving drainage ditches: Ditch 'C' and Ditch 'E'. The overall area's existing flooding and inundation condition is shown in **Figure 7.5** & **Figure 7.6**.

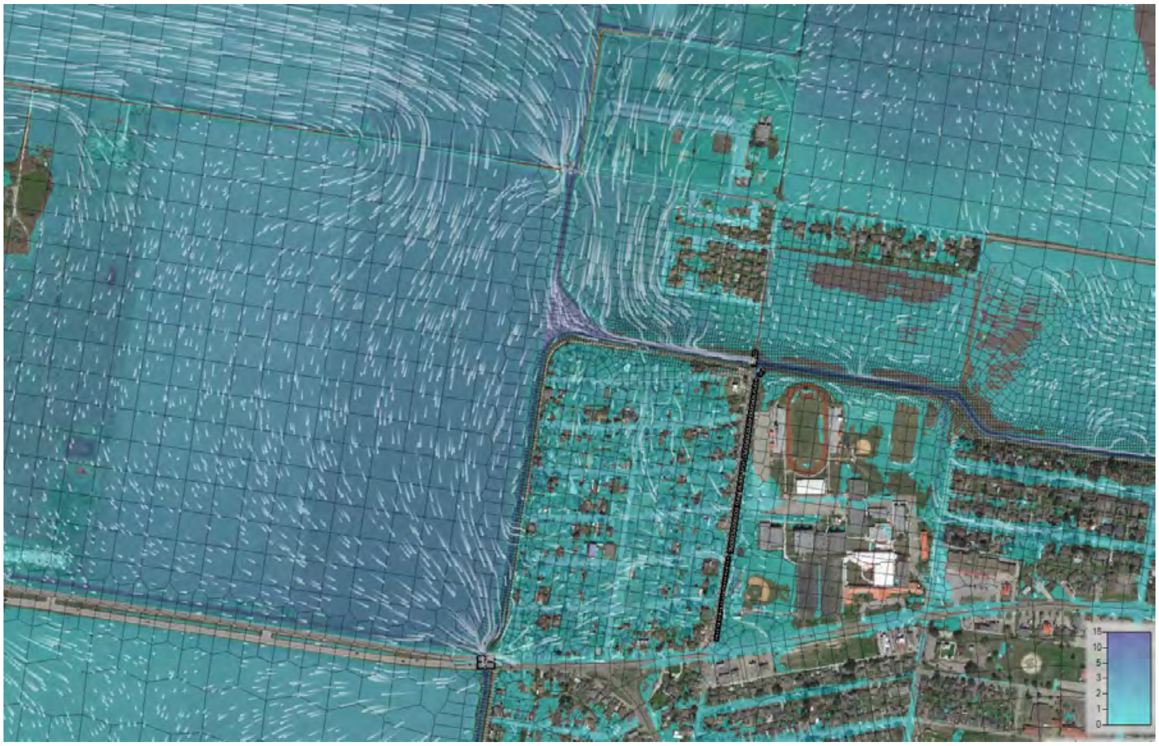

Figure 7.5 Existing Conditions – South Robstown (north of SH 44)

Figure 7.6 Existing Conditions – South Robstown (south of SH 44)

The western offsite area results in a peak overflow rate of 2780 cfs and 3140 cfs during the 4% & 1% annual chance storm events, respectively. This overflow crosses into the city along Concho St and SH 44. The peak flows within the upper reach of Ditch 'A' are 520 cfs and 720 cfs for the 4% & 1% annual chance storm events, respectively. These differences in flows show the limited capacity of Ditch 'A' respective to the total contributing runoff.

7.2.2.2 Proposed alternative

Proposed improvements were investigated to mitigate existing flooding within the area. These proposed improvements consist of channel improvements with associated bridge/ culvert replacements and regional detention facilities to relieve existing flooding issues. The risk area's proposed improvements are shown in **Figure 7.** and **Figure 7.8.**

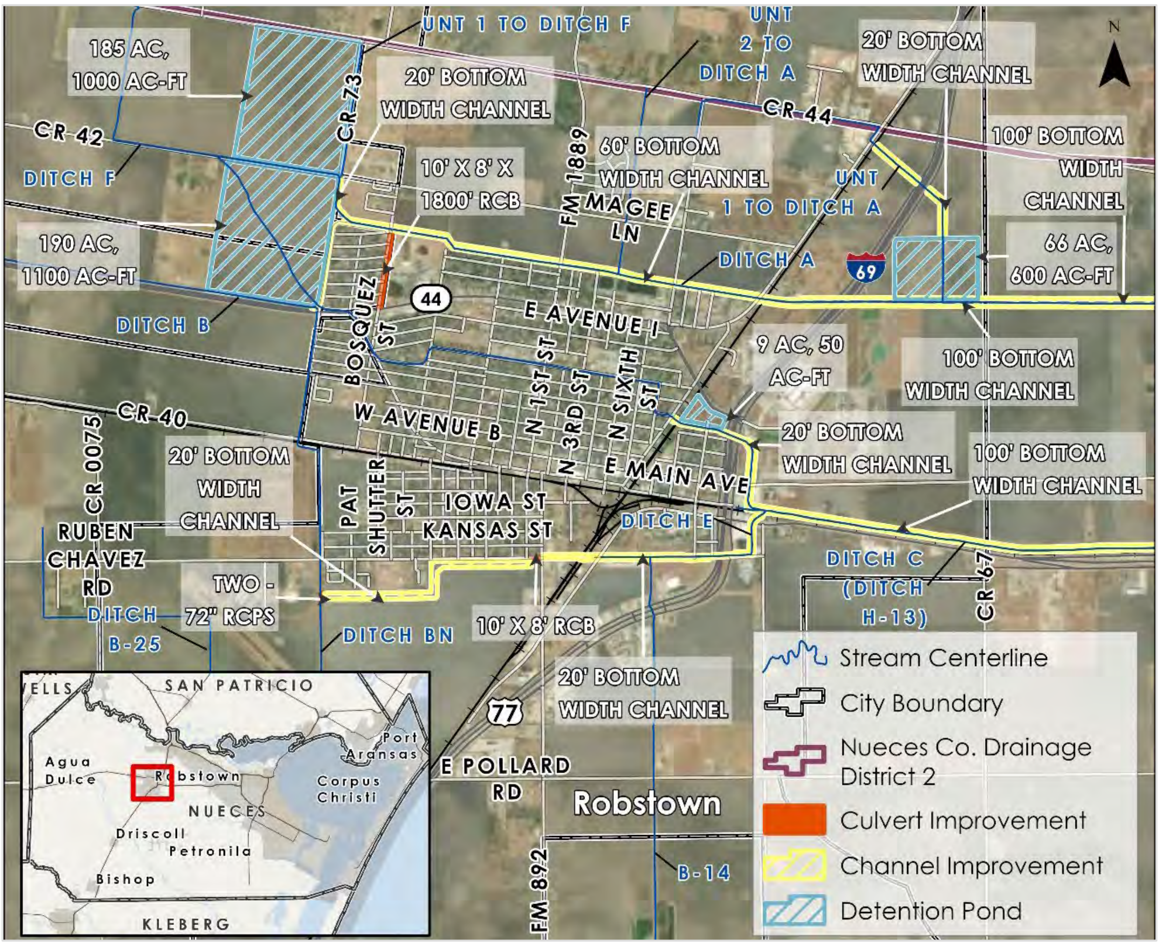

Figure 7.7 Proposed Improvements – South Robstown (West)

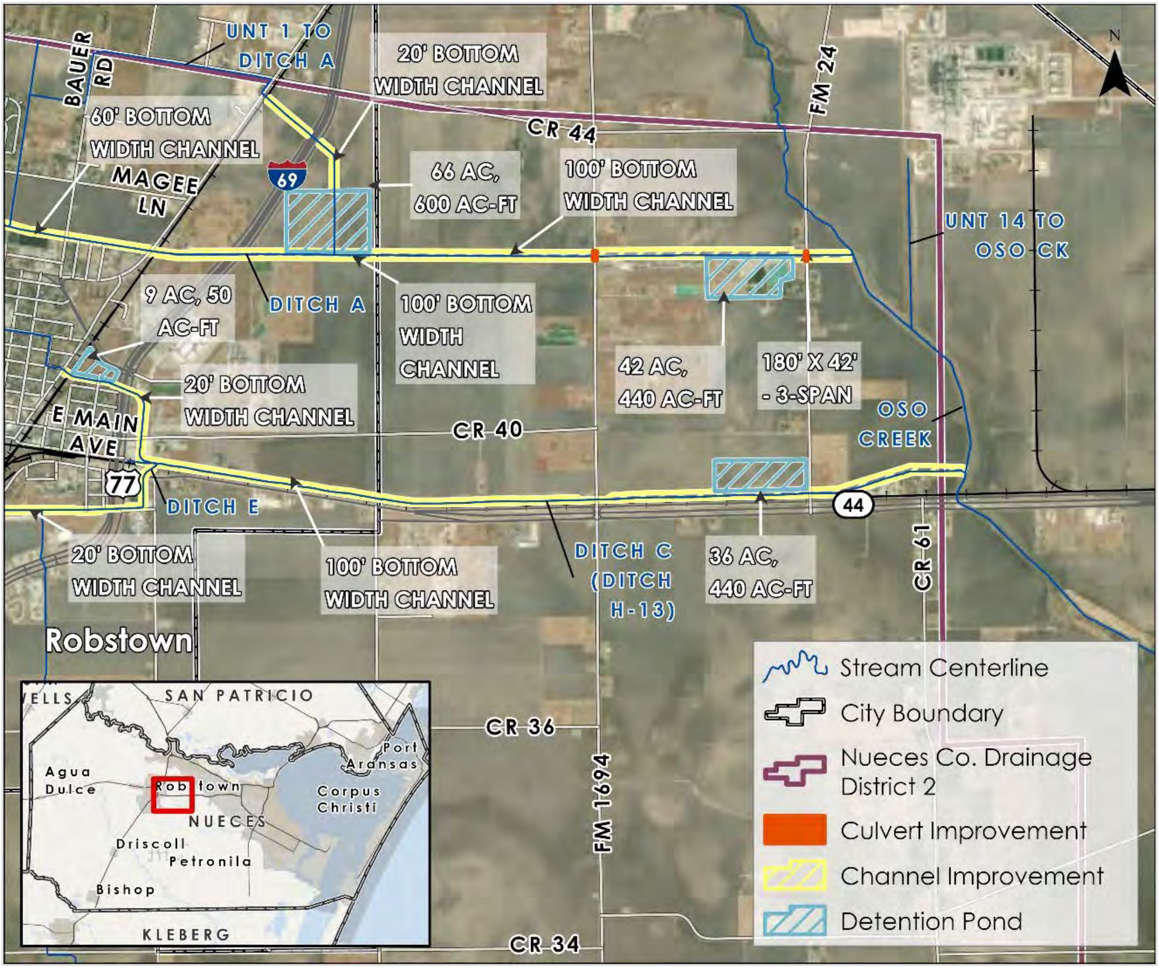

Figure 7.8 Proposed Improvements-South Robstown (East)

The regional detention facilities are placed upstream of the upper end of Ditch A to intercept large contributing drainage area sheet flow; the total proposed volume represents approximately 2100 ac-ft of storage. These facilities serve as collections and distributors of the overland sheet flow runoff into Ditch A, providing multiple benefits to the area. These benefits include storage volume to reduce the flows contributing to Ditch 'A' and the city area, funneling the flow to Ditch 'A' without overwhelming the receiving system, and mitigating the receiving Oso Creek for the improvements along Ditch 'A'.

The channel improvements consist of the widening of existing drainage ditches for conveyance. Additionally, an extension of the Chavez Ditch (Ditch E) is proposed to extend to the existing Concho Ditch. This extension provides interception of overland overflow from the Concho Ditch and flow balancing between the two drainage systems. The overall drainage within the Robstown area west of I-69 (US 77) is to be conveyed east of US 77 within NCDD2 Ditch 'A' and Ditch 'C' to their ultimate outfalls into Oso Creek. These improvements work in conjunction with the downstream channel improvements shown in Risk Area 12 - FM 1694 & TX 44 North (See Section 7.2.10).

The proposed channel improvements along Ditch ‘A’ include a trapezoidal earthen section that consists of a 60’ bottom width and 3:1 & 2:1 (H: V) side slopes. The 2:1 side-slopes along the south bank represent the existing channel side-slope, which could not be expanded due to adjacent development restrictions. The total top width of the channel was restricted by the AEP utility ROW north of the channel. The crossings upstream of BS 77 have sufficient capacity to convey the proposed flows; therefore, the channel sections will be transitioned through these crossings without modifications.

Proposed improvements along Chavez Ditch and Ditch ‘E’ include an earthen, trapezoidal section with a 20’ bottom width and 3:1 side slopes. The Chavez Ditch will be extended upstream to the Concho Ditch to provide a conveyance facility for the overflow from the Concho Ditch, which will contain and direct the overflow. A structure is proposed at Concho Ditch to connect the two ditches. Also, the Liberty Road crossing of Chavez Ditch is proposed for replacement. Crossings along Ditch ‘E’, including US 77/ I-69 box culverts and at UPRR, will remain with the channel improvements to transition to the existing structures.

The upper portion of Ditch ‘C’ is to be improved to provide a conveyance increase for the city’s major storm sewer system outfall at Upshaw Blvd (BS 77) and Ave E. A small detention facility is proposed just downstream of the system outfall located between the UPRR, SH 44, and US 77/ I-69 along the north side of the ditch. The detention facility is approximately 9 acres and provides approximately 50 acre-feet of storage.

The proposed improvements for Risk Area 10 work in conjunction with Risk Area 12, which receives the runoff from Risk Area 10. Additionally, Risk Area 8 improvements provide benefits to Risk Area 10 by reducing and/or eliminating overflow sheet flow and contributing runoff to Ditch ‘A’.

The proposed improvements reduce the water elevations by 0.5 to 1.0 feet in the western portions and 0.3 – 0.5 feet within a substantial portion of the city’s developed area for the 4% annual chance storm event. The improvements also significantly increased safe street passage during events and reduced street inundation time during extreme events. The improvements also show no notable adverse impacts to the water surface elevations and flooding areas upstream and downstream of the risk area. **Figure 7.9** below shows the risk area’s flood depth reduction.

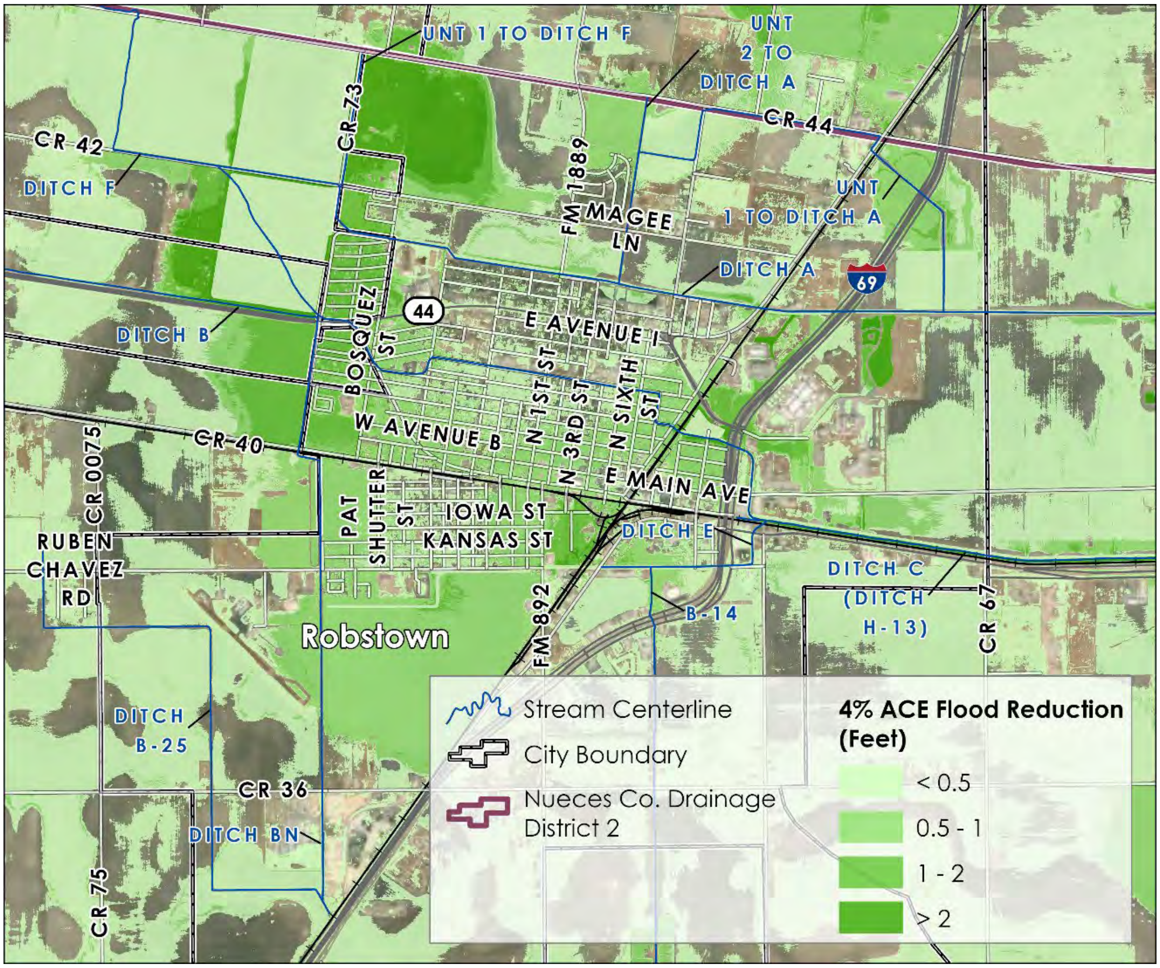

Figure 7.9 Proposed Conditions 4% Annual Storm Depth Reduction – South Robstown

7.2.3 FM 1694 and TX 44 north

Robstown is a small city in Nueces County located along US 77/ I-69 at SH 44. Risk Area 12 represents the area of Robstown west of US 77/ I-69. Additional major roads within the area include BS 77, FM 1694, CR 44 and FM 24. The development within this area is generally commercial development concentrated along US 77/ I-69. Some large-lot residential areas are found scattered within the eastern portions of the area. The remaining area is agricultural and/or undeveloped land. The area is bound by US 77/ I-69 to the west, SH 44 to the south, CR 44 to the north, and Oso Creek to the west. Recent developments, including commercial, industrial, and public facilities, have occurred within the western portions of the area along US 77/ I-69. Additionally, some residential growth is anticipated in the eastern portions of the area along the county and FM roadways.

7.2.3.1 Existing conditions/flooding issue

The area generally flows from west to east along Ditch ‘A’ and Ditch ‘C’ to Oso Creek. Ditch ‘A’ receives additional runoff from Ditch ‘A-01’, which conveys flow from north of Robstown, east across US 77/ I-69 to Ditch ‘A’. Some notable flooding occurs along Ditch ‘C’, which results from the Ditch ‘A’ overflow west of Robstown that flows along Concho Ditch and overflows into Ditch ‘E’ and ultimately conveyed into Ditch ‘C’.

Additionally, flooding within the area consists of the sheet flow towards the receiving drainage ditches. The area's overall existing flooding and inundation condition is shown in **Figure 7.10**.

Ditch 'A' peak outflow into Oso Creek is computed as 2970 cfs and 3600 cfs during the 4% & 1% annual chance storm events, respectively. Downstream of US 77/ I-69 and its confluence with Ditch 'A-01', Ditch 'A' peak flows are computed as 805 cfs and 1000 cfs for the 4% & 1% annual chance storm events, respectively. From the runoff hydrographs, the peak inundation time at this location is 15 – 18 hours.

Ditch 'C' peak outflow into Oso Creek is computed as 2350 cfs and 2420 cfs during the 4% & 1% annual chance storm events, respectively. Additionally, due to the Ditch 'A' overflow into the Ditch 'C' subarea, a secondary peak within 5 percent of the initial peak is observed 12 hours later. This results in an inundation time of 18 – 24 hours at the channel outfall. Downstream of US 77/ I-69 and its confluence with Ditch 'E', and Ditch 'C' peak flows are computed as 1990 cfs and 2070 cfs for the 4% & 1% annual chance storm events, respectively. These flows are directly related to the Ditch 'A' overflow, being 250 cfs and 420 cfs, respectively, larger than the ditch's contributing area peak flows.

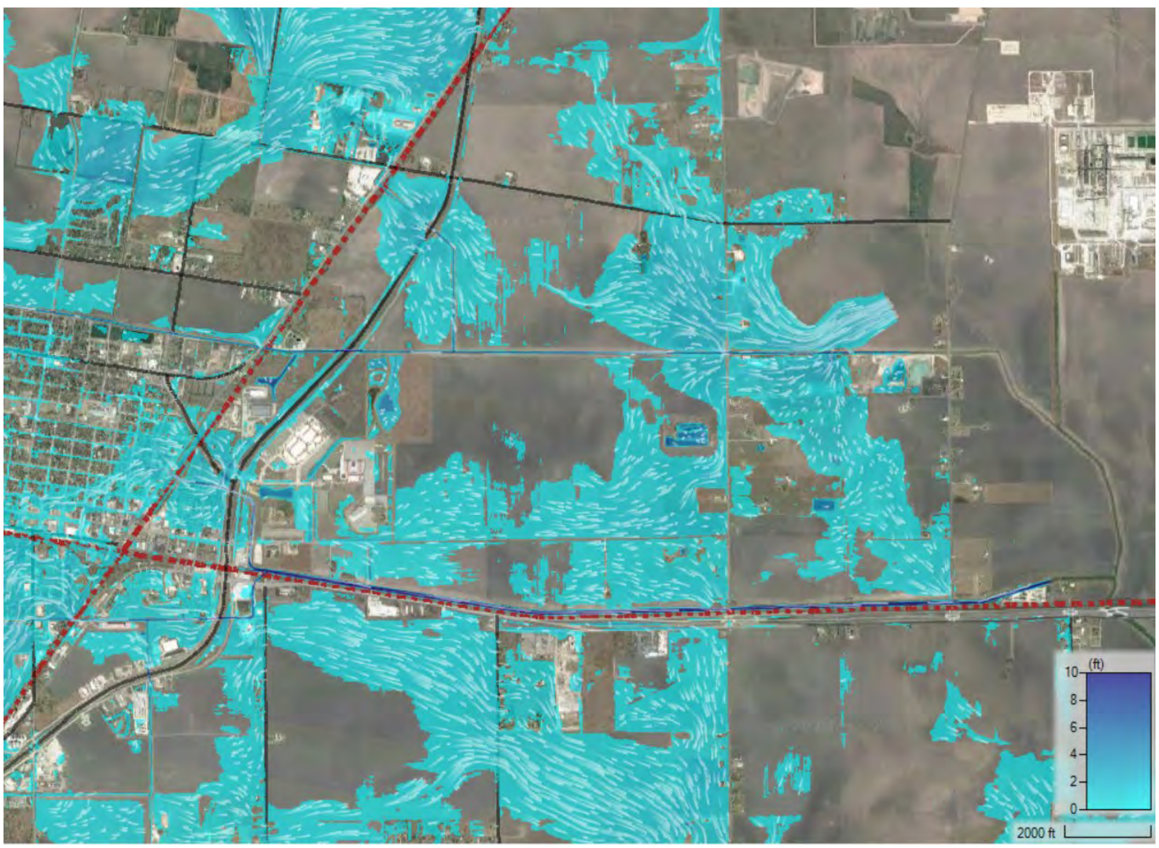

Figure 7.10 Existing Conditions 4% Annual Storm Depth – FM 1694 & TX 44 North

7.2.3.2 Proposed alternative

Proposed improvements were investigated to mitigate existing flooding within the area. These proposed improvements consist of channel improvements with associated bridge/ culvert replacements and regional detention facilities to relieve existing flooding issues within Risk Area 12 as well as provide the necessary receiving conveyance and mitigation storage for Risk Area 10 – South Robstown improvements (See Section 7.2.8). The proposed improvements are shown in **Figure 7.11**. The regional detention facilities are placed at the downstream reaches of Ditch ‘A’ and Ditch ‘C’ to provide mitigation to offset flow increases to Oso Creek. Ditch ’A’ detention consists of two options, including a 66-acre (600 ac-ft) facility at the confluence of Ditch ‘A-01’ and Ditch ‘A’, just downstream of US 77/ I-69 and a 42-acre (440 ac-ft) facility located along FM 24 immediately upstream of Ditch ‘A’ confluence with Oso Creek. The latter option is considered more favorable since it is currently being excavated as a limestone pit, thereby not incurring excavation construction cost, and its location away from future commercial development areas. Ditch ‘C’ detention facility is located along FM 24 immediately upstream of the ditch’s confluence with Oso Creek.

The channel improvements consist of the widening of existing drainage ditches for conveyance. The proposed channel improvements along Ditch ‘A’ include a trapezoidal earthen section that consists of a 100’ bottom width and 3:1 (H: V) side slopes. The proposed channel improvements along Ditch ‘C’ include a trapezoidal earthen section that consists of a 100’ bottom width and 3:1 (H: V) side slopes.

The proposed improvements for Risk Area 12 work in conjunction with Risk Area 10, which conveys the runoff to Risk Area 12. Additionally, Risk Area 8 improvements provide benefits to Risk Area 10 by reducing and/or eliminating overflow sheetflow and contributing runoff to Ditch ‘A’ and Ditch ‘A-01’.

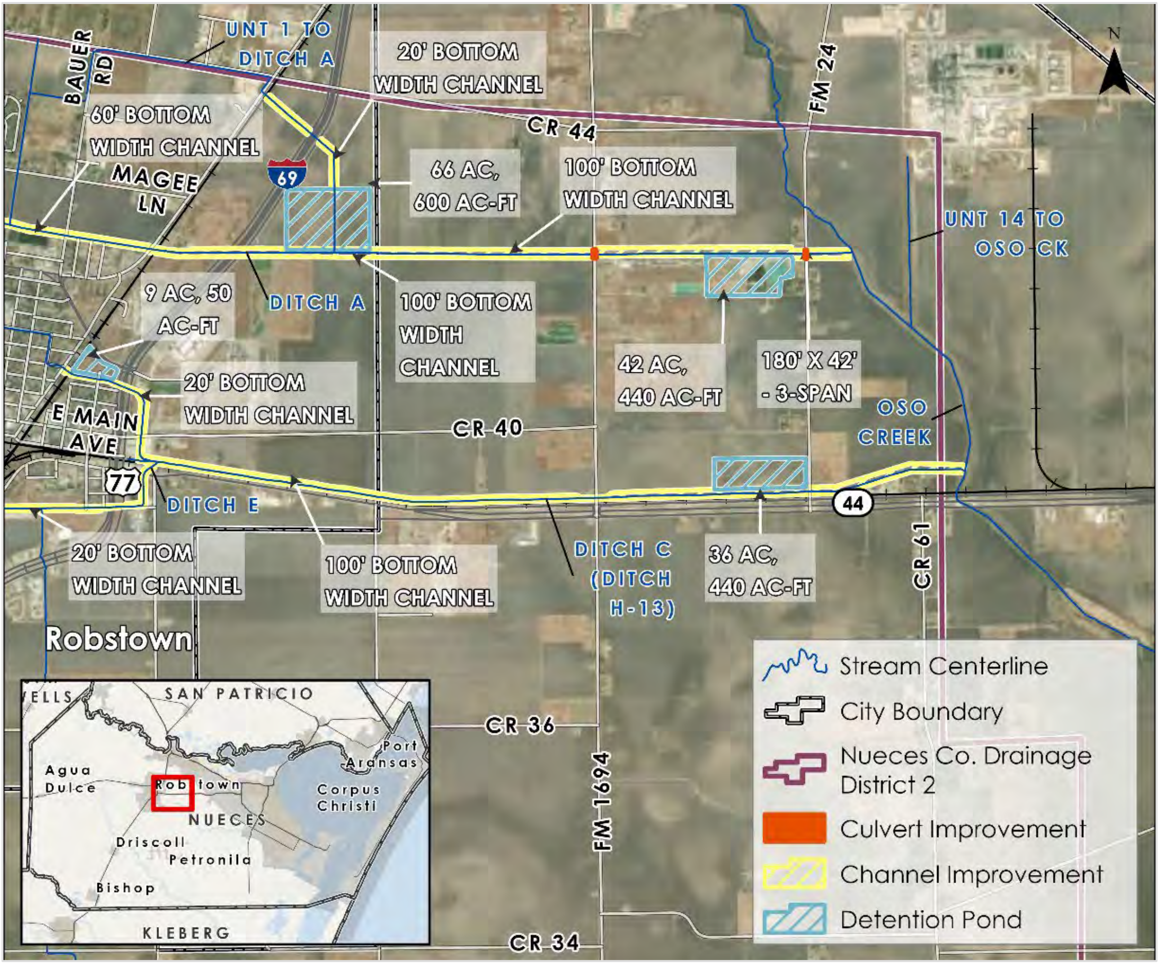

Figure 7.11 Proposed Improvements – FM 1694 & TX 44 North

The proposed improvements reduce the water elevations by 0.3 – 0.5 feet for the 4% annual chance storm event within the area, with some localized greater depths adjacent to the channels. These improvements provide the necessary downstream conveyance for implementing the improvements within Risk Area 10. The proposed detention facilities within Risk Area 12 provide additional storage to offset the runoff impacts of the improvements to Oso Creek. The improvements also show no notable adverse impacts to the water surface elevations and flooding areas upstream and downstream of the risk area. Below shows the risk area's flood depth reduction.

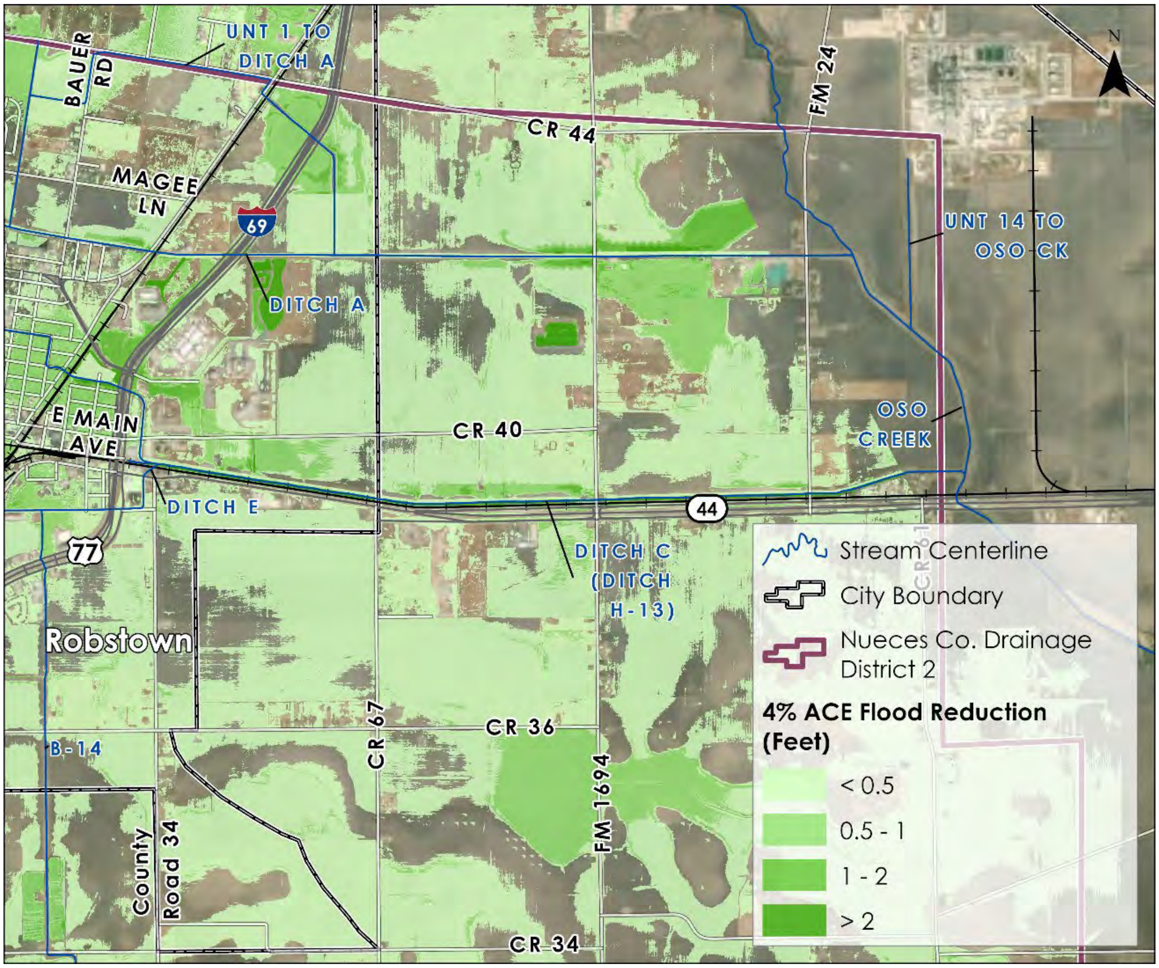

Figure 7.12 Proposed Conditions 4% Annual Storm Depth Reduction – FM 1694 & TX 44 North

7.2.4 City of Driscoll

Driscoll is a small city located along Highway 77 and is bordered by West Avenue A to the north and East Avenue G to the south, with Petronila Creek just 0.5 miles north of the area. Driscoll sits 2.5 miles northwest of Risk Area 20 – Fiesta Ranch.

7.2.4.1 Existing conditions/flooding issues

There are two major sources of flooding for Driscoll: one stemming directly from *Petronila Creek*, running south through the city over West Avenue A, and the other from the overflow of *Ditch B-17*, which runs north alongside Highway 77 and over West Avenue G. *Petronila Creek* contributes approximately 3,400 and 7,800 CFS for the 4% and 1% annual chance storm event, respectively. Flooding from south to north totals 1,700 CFS and 3,800 CFS for the 4% and 1% annual chance storm event, respectively. The area's overall existing flooding and inundation condition is shown in **Figure 7.13**.

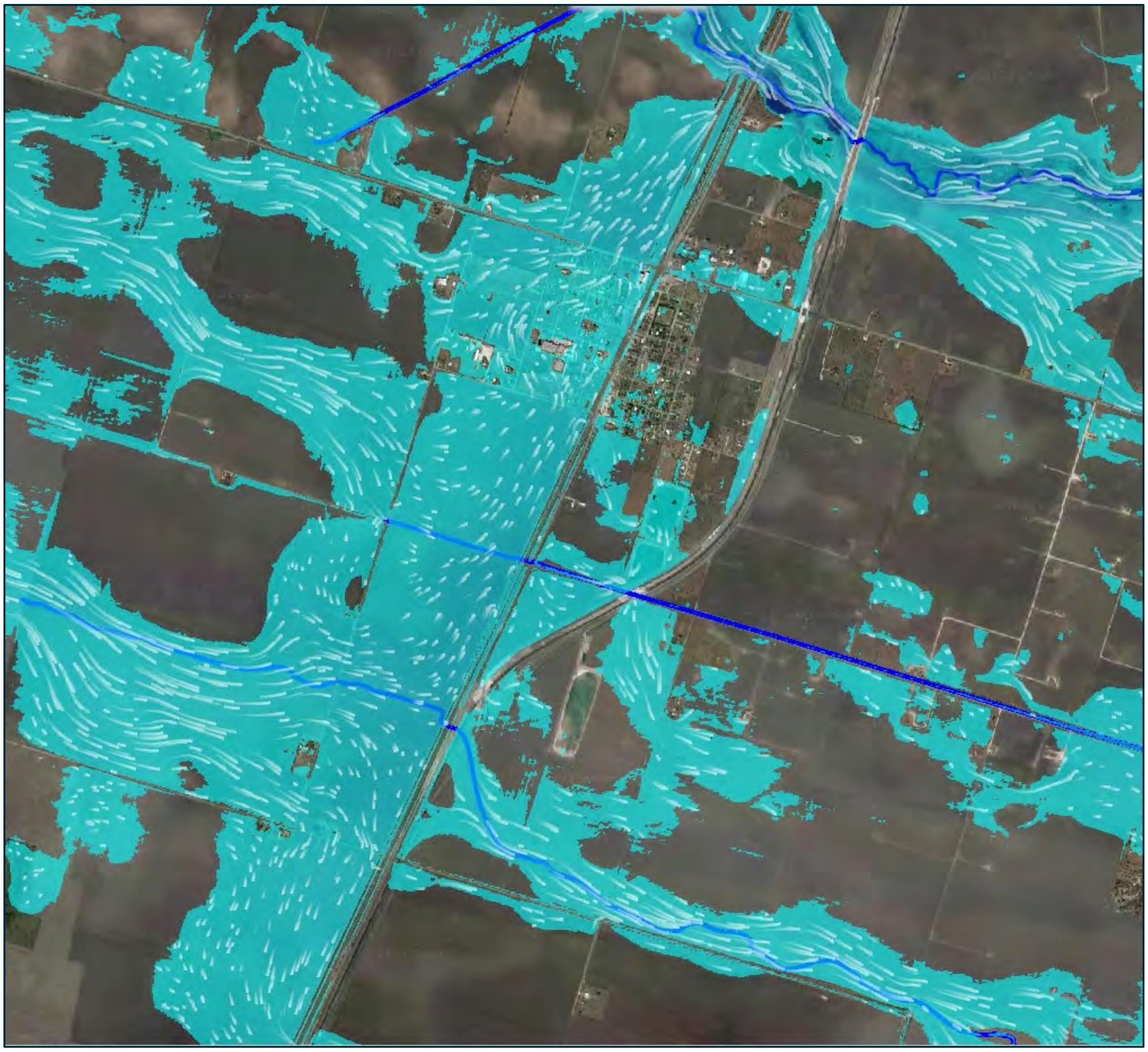

Figure 7.13 Existing Conditions 4% Annual Storm Depth – City of Driscoll

Additional complexity is added to solving the flooding issues for the City of Driscoll due to the two observed flooding peaks. Initial flooding in Driscoll comes directly from the west and south along Highway 77. Towards the second day of the storm event, flooding reverses direction going north to south and directly results from *Petronila Creek* backwater.

7.2.4.2 Proposed alternative

Due to the severity of flooding from the second peak of the storm event and the difficulty in realistically containing floodwater from *Petronila Creek*, the proposed alternative is designed to address more localized flooding from the first flood peak for the 4% annual chance storm event.

The railroad along Highway 77 acts as a major barrier for floodwater coming from the south and, as a result, forces water to travel north through Driscoll. Four large culvert improvements are proposed within the Highway 77/Railroad system to allow water to pass through. A wooden railroad bridge is being replaced by a 110-foot bridge with the adjacent 5 – 6’x4’ RCBs system being replaced by a 100-foot bridge just before the point where Highway 77 diverges into two separate roads, approximately 5,500 feet south of Driscoll. Another 2,500 feet south, at the intersection of Highway 77 and County Road 16, a wooden rail bridge and 4 – 5’x3’ RBCs are proposed to be replaced by a 140-foot bridge.

To further control excess flooding running from south to north along Highway 77, a proposed 103-acre-foot detention pond was designed just south of West Avenue G. Floodwater is detained before reaching the roadway, directed through the pond into 3-8’x4’ RCBs, and then into a proposed channel (30-foot bottom width, 3:1 side-slopes) running north through Driscoll alongside the railroad and eventually out-falling into *Petronila Creek*.

Additionally, two large channel improvements are being proposed alongside the culvert improvements on Highway 77. A smaller channel (30 ft bottom width, 3:1 side slopes) begins at the proposed 110 ft bridge improvement. Eventually, it connects to a larger channel (90 ft bottom width, 3:1 side slopes) that outfalls into *Petronila Creek*. The risk area’s proposed improvements are shown in **Figure 7.14**.

The proposed alternative has an OPCC of $85,018,000.

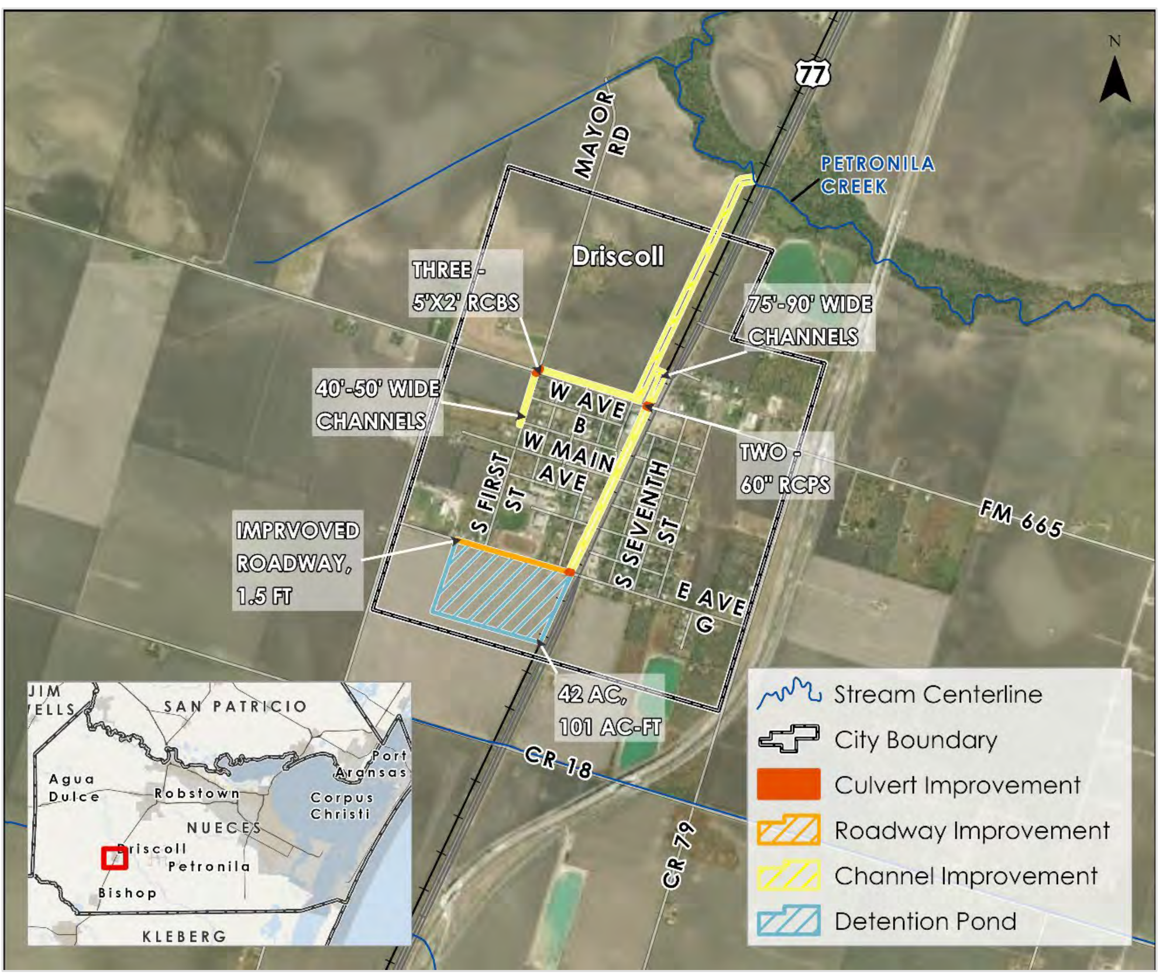

Figure 7.14 Proposed Improvements – City of Driscoll

7.2.4.3 Project benefit

The proposed alternative for the 4% annual chance storm event removes 14 structures from the floodplain. The risk area's flood depth reduction is shown in **Figure 7.15** and removes two Driscoll School District structures from the 4% annual chance storm event. Proposed improvements decrease the duration of standing water along FM 665. Additionally, residential and commercial structures not removed from the floodplain benefit from flood depth reduction. The improvements also show no notable adverse impacts to the water surface elevation in the areas upstream and downstream of the risk area. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 19 are available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

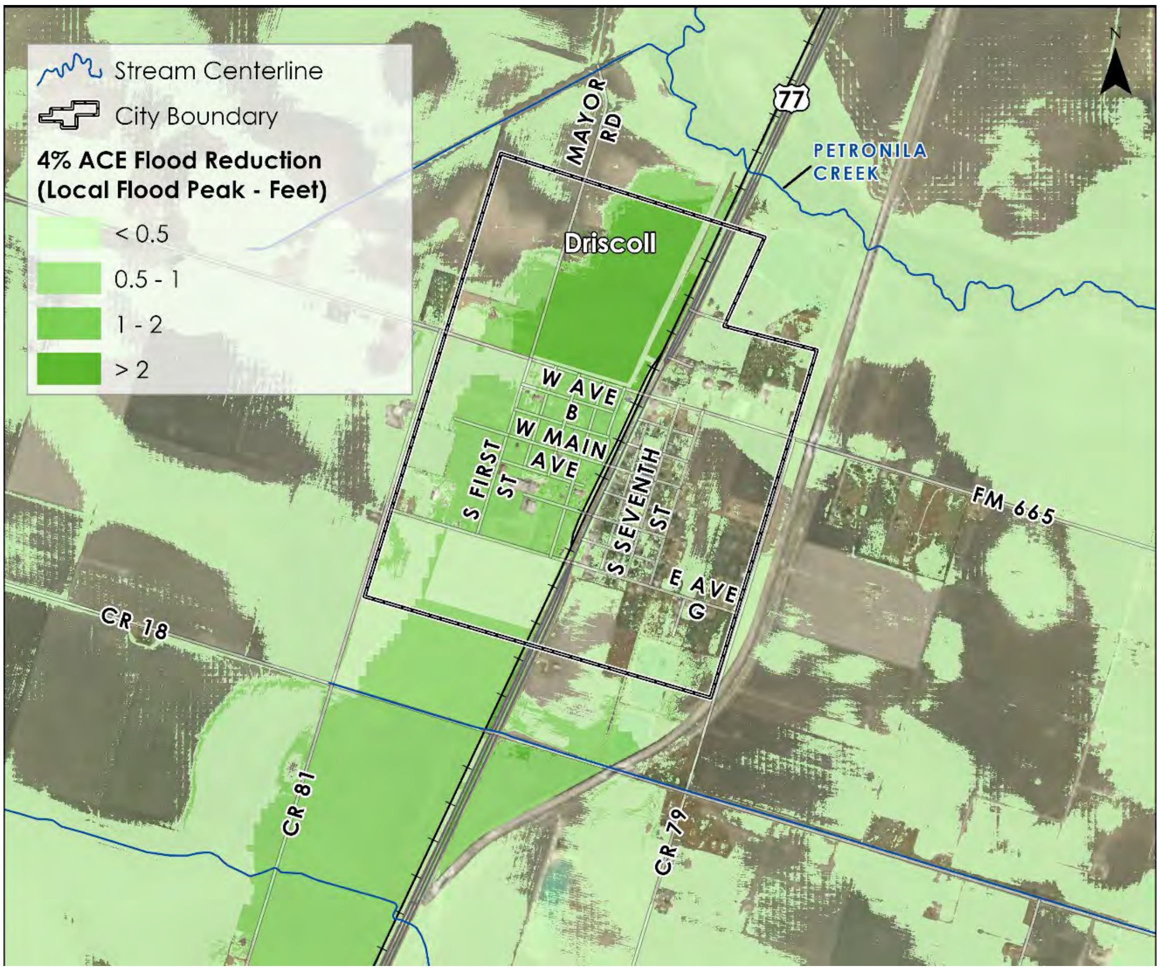

Figure 7.15 Proposed Conditions 4% Annual Storm Depth Reduction – City of Driscoll

7.2.5 Banquete

Banquete is a small residential area located at the intersection of State Highway 44 and FM 666, approximately 8 miles west of Robstown in Nueces County (Risk Area 5).

7.2.5.1 Existing conditions/flooding issues

Two streams, *Banquete Creek* from the north and *Agua Dulce Creek* from the west, converge on the southeast side of the area, contributing approximately 15,500 CFS and 22,000 CFS respectively, for the 4% annual chance storm event. The main contributors to the flooding of this area stem from large flows entering the area without adequate conveyance at roadway crossings. State Highway 44, Robstown Road, and the railway crossing along *Banquete Creek* create high backwater conditions, pushing flood waters into the north and central areas of Banquete. The confluence of *Agua Dulce Creek* and *Banquete Creek* downstream of Banquete creates a lack of drainage capacity for local rainfall to run off out of the residential area. The area's overall existing flooding and inundation condition is shown in **Figure 7.16**.

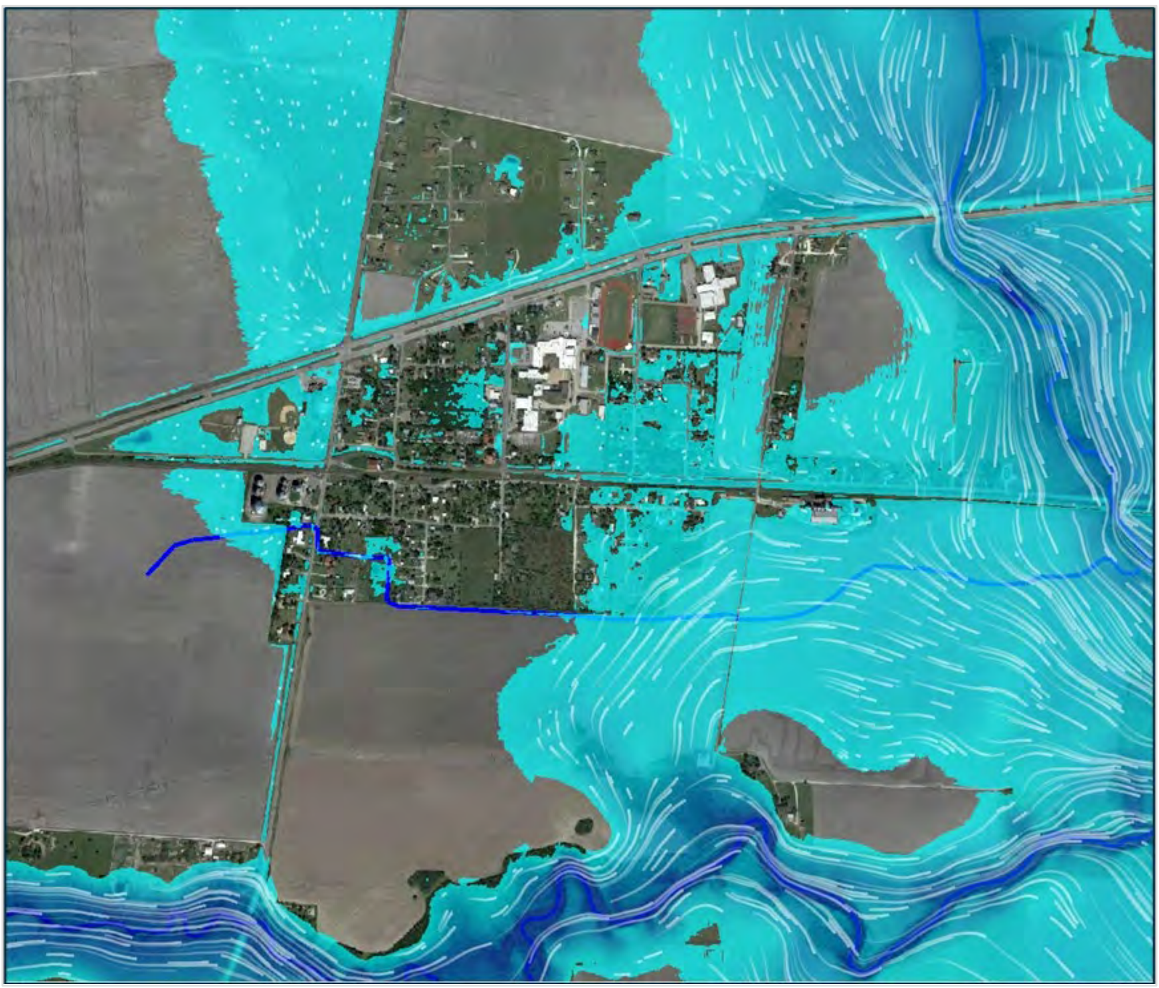

Figure 7.16 Existing Conditions 4% Annual Storm Depth – Banquete

7.2.5.2 Proposed alternative

The proposed alternative consists of two detention facilities, multiple culvert and bridge crossing improvements, and various proposed channel improvements. The risk area's proposed improvements are shown in **Figure 7.17**.

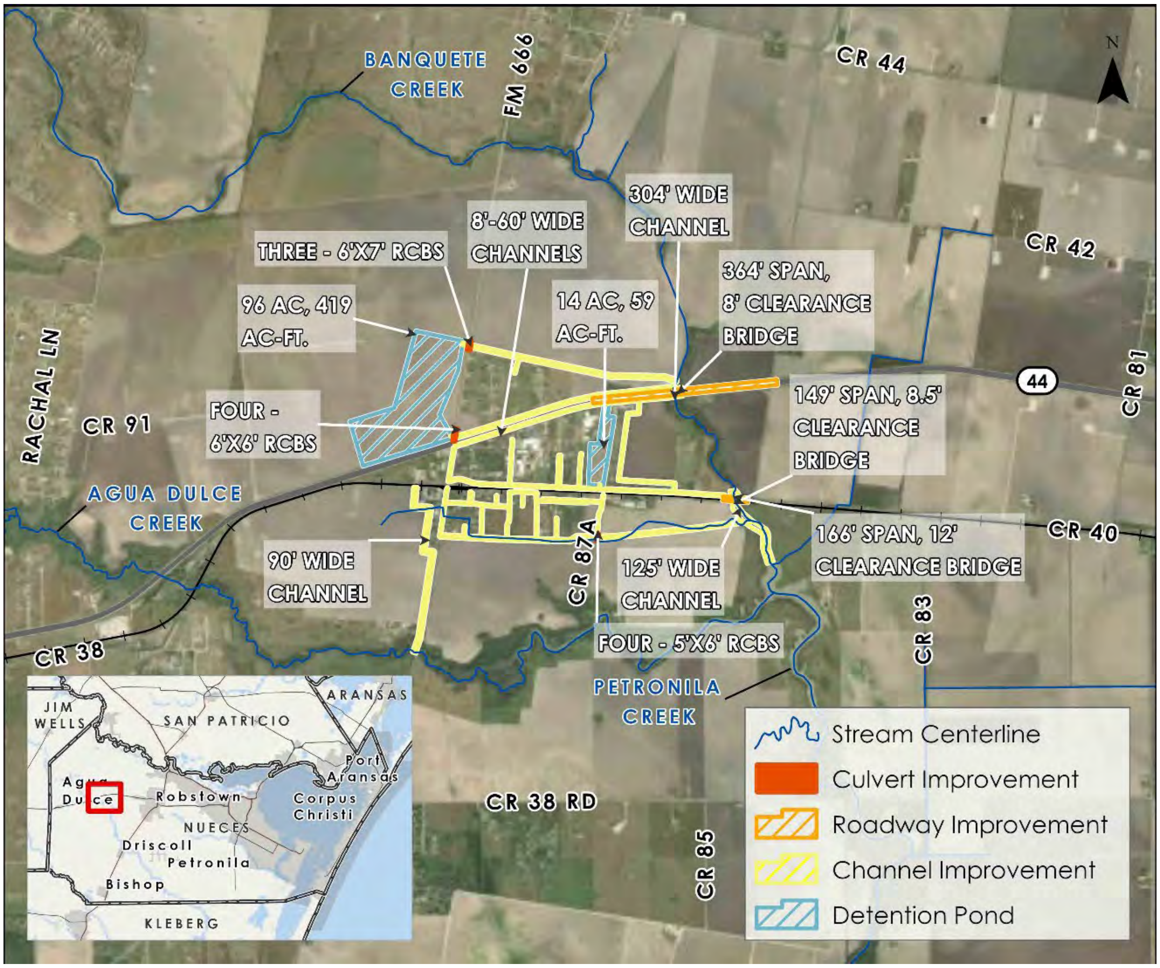

Figure 7.17 Proposed Improvements – Banquete

Existing drainage in Banquete is characterized by having three areas that drain somewhat independently of each other. State Highway 44 and Old Robstown Road (County Road 40) serve to break the town into a northern, central, and southern areas. Drainage issues in these areas were addressed with a series of detention and local drainage improvements, along with increased conveyance between the three areas.

To improve flooding conditions in the northern section of Banquete, the State Highway 44 bridge crossing *Banquete Creek* is proposed to be lengthened. Analysis shows that the existing bridge serves as a constriction of flow, which causes a high-water surface elevation on the upstream side of the bridge, flooding multiple structures in the north section of Banquete. The proposed bridge maintains the existing deck elevation but approximately doubles the span to 364 feet. Bridge pier spacing and deck thickness observed on the existing bridge were replicated in the proposed extension.

To improve the flooding conditions in the central section of Banquete, the County Road 40 bridge that crosses Banquete Creek is proposed to be lengthened from 112 to 166 feet to reduce flow restriction, as it had been accumulating backwater into the central section of Banquete. The proposed structure maintains existing deck elevation and pier spacing but does offer more flow clearance due to channel excavation to deepen and widen the channel beneath both the County Road R 40 *Banquete Creek* bridge and the *Banquete Creek* railway bridge crossing, which parallels County Road 40. With these improvements, fewer structures are impacted by floodwaters in the central area of Banquete Creek.

The proposed alternative has an OPCC of $87,897,000.

7.2.5.3 Project benefit

The proposed alternative for the 4% annual chance storm event removes 80 structures from the floodplain. The risk area's flood depth reduction is shown in **Figure 7.18**. The proposed improvements remove three Banquete Independent School District structures from the 4% annual chance storm event. Proposed improvements decrease the duration of standing water along State Highway 44 and County Road 40, which increases mobility for Banquete. Additionally, residential and commercial structures not removed from the floodplain benefit from flood depth reduction. No notable adverse impacts are observed for the 1% annual chance storm event adverse impact analyses. Appendix D- Flood Mitigation Project Technical Memorandums contains the detailed proposed design, adverse impact analysis, and other tested alternatives.

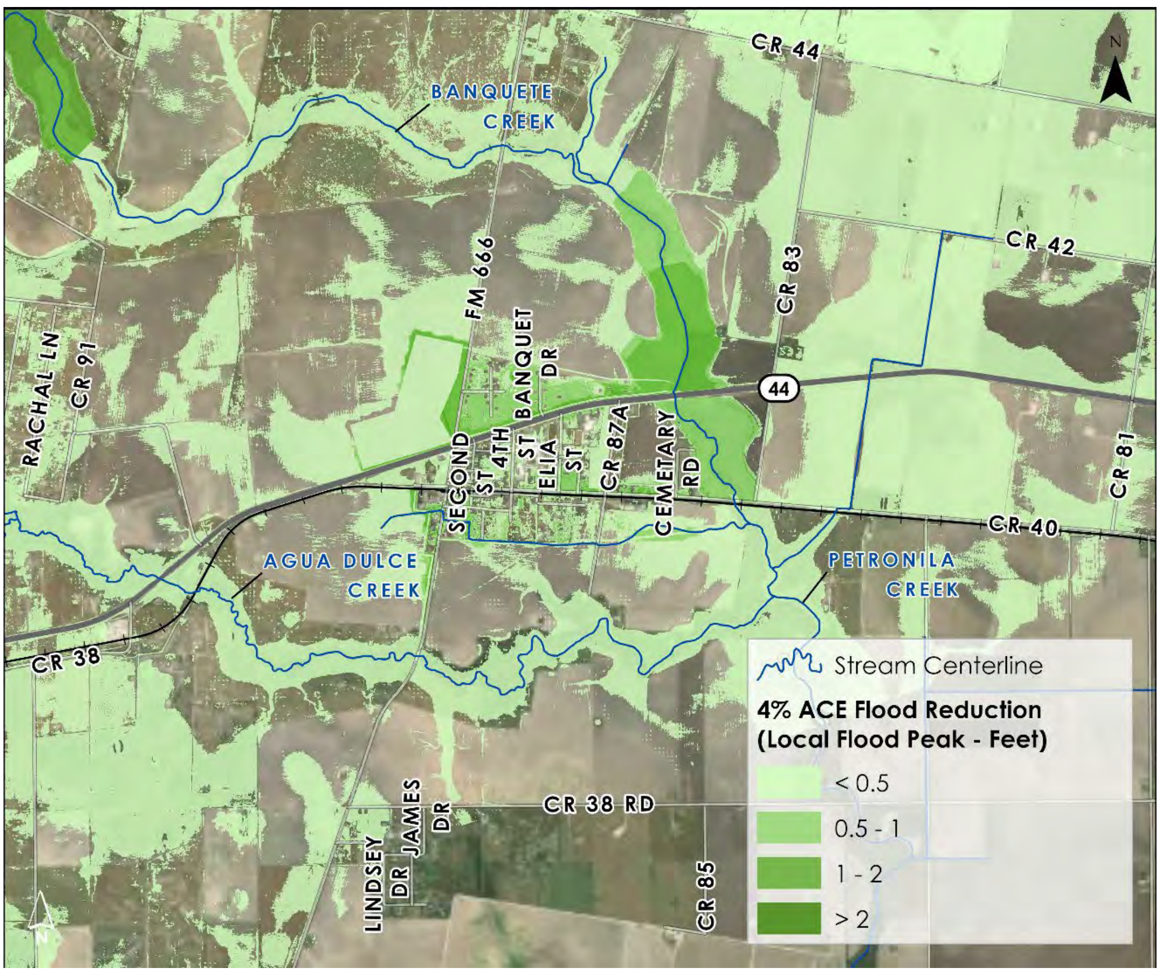

Figure 7.18 Proposed Conditions 4% Annual Storm Depth Reduction – Banquete

7.2.6 Fiesta Ranch

Fiesta Ranch is a small residential area located 2 miles southeast of the City of Driscoll along Country Road 18 and County Road 75 (Risk Area 20).

7.2.6.1 Existing conditions/flooding issues

Petronila Creek runs northwest to southeast, approximately 1 mile north of the development. Flooding stemming from the north results in up to 10,000 CFS and 26,000 CFS for the 4% and 1% annual chance storm events to cross County Road 18 and through Fiesta Ranch, eventually draining back into *Petronila Creek* further south. The area's overall existing flooding and inundation condition is shown in **Figure 7.19**.

The Fiesta Ranch area experiences two flooding peaks: the first resulting more from localized flooding and the second storm peak resulting from backwater directly from *Petronila Creek*. Initial flooding runs southeast through Fiesta Ranch, eventually draining into *Petronila Creek*. During the first peak event, flooding from the north runs both southeast through Fiesta Ranch and directly east over Highway 75 into *Petronila Creek*. As *Petronila Creek* fills, backwater causes the flooding running east to divert into Fiesta Ranch, worsening flood conditions and resulting in a second flood peak for the area.

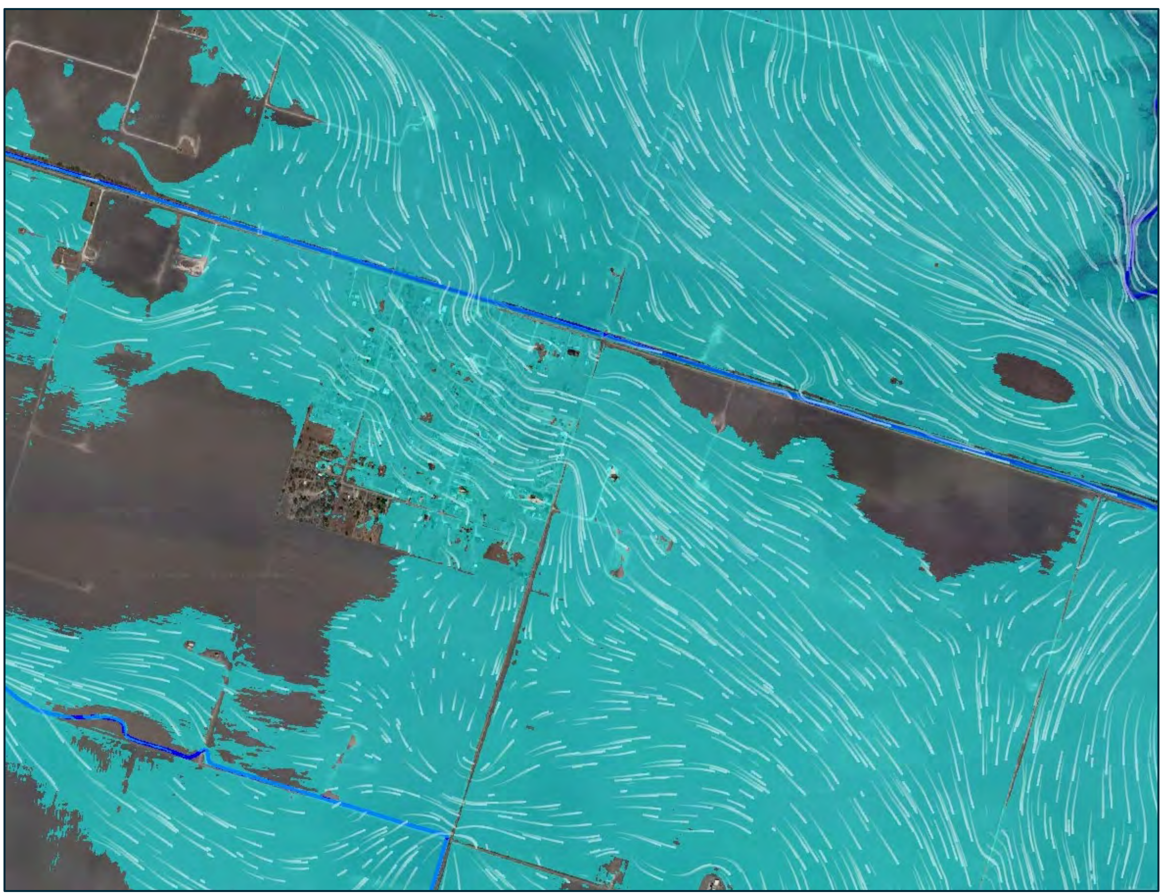

Figure 7.19 Existing Conditions 4% Annual Storm Depth – Fiesta Ranch

7.2.6.2 Proposed alternative

The proposed alternative is comprised of larger existing channel improvements along *Ditch B-17*, new channel improvements along County Road 665, a detention pond on the northwest corner of Fiesta Ranch just south of County Road 18, and smaller channel and culvert improvements directly within Fiesta Ranch.

A proposed channel (70 ft bottom width, 3:1 side-slopes) along County Road 665 acts to intercept floodwater spilling from the northern section of *Petronila Creek* and divert water back into the creek before it can spill over the roadway and travel south to Fiesta Ranch. Channel improvements along County Road 18 (110 ft bottom width, 3:1 side-slopes) act similarly to the channel along County Road 665, diverting flooding from the north into *Petronila Creek*. Local ditch improvements (bottom widths of 15-30 feet, 3:1 side-slopes) connect directly into the optimized ditch along County Road 18. A 74-acre-foot pond on the northwest side of Fiesta Ranch collects floodwater from west to east along County Road 18 and floodwater from south to north on the west side of the development. The pond outfall is connected to the 110-foot bottom width channel via 4 – 72” RCPs. The risk area’s proposed improvements are shown in **Figure 7.20.**

The proposed alternative has an OPCC of $40,688,000.

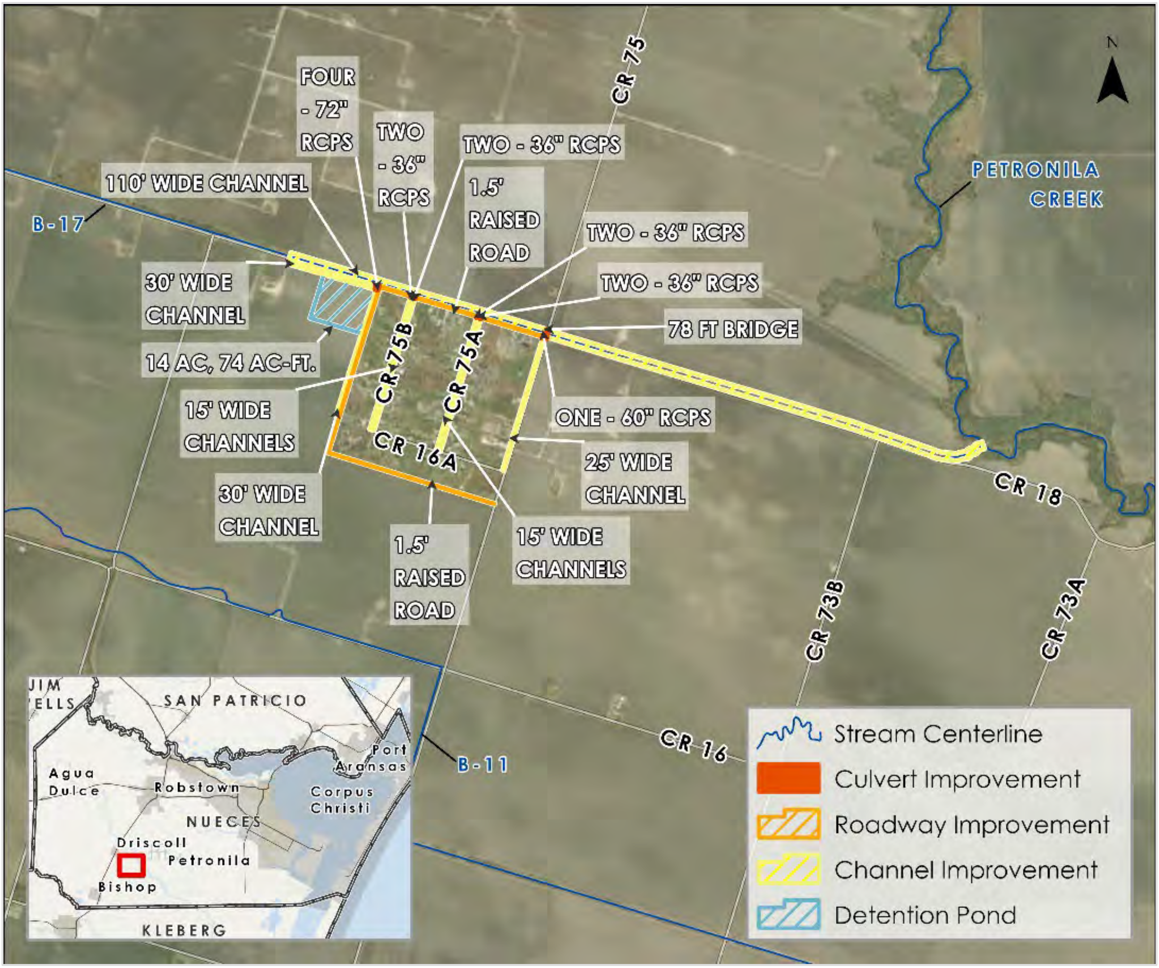

Figure 7.20 Proposed Improvements – Fiesta Ranch

7.2.6.3 Project benefit

The proposed alternative for the 4% annual chance storm event removes 33 structures from the floodplain. The risk area's flood depth reduction is shown in **Figure 7.21.** Proposed improvements decrease the duration and amount of standing water in the Fiesta Ranch residential area, which increases mobility during local flooding (first peak) in the 4% annual chance storm event. No significant adverse impacts were detected within the risk area. Additionally, residential structures not removed from the floodplain benefit from flood depth reduction. Minor areas of adverse impact exist within unpopulated areas and can be refined during detailed design. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 20 are available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

Figure 7.21 Proposed Conditions 4% Annual Storm Depth Reduction – Fiesta Ranch

7.2.7 Balchuck Lane and Digger Lane

The Balchuck Lane & Digger Lane Risk Area 26 is a residential suburban area located on the north side of FM 43, approximately 2.3 miles west of TX-286.

7.2.7.1 Existing conditions/flooding issues

This risk area is bounded by cultivated open space to the west, an ongoing future development to the east, and is approximately 0.5 miles south of *Oso Creek*. Drainage patterns generally run south to north across the risk area and flow drains into *Unnamed Tributary 9 to Oso Creek.*

On the upstream end (south of the residential area) is an existing culvert, approximately 1 – 5' x 2' culvert, crossing under FM 43 to the north. For the 4% annual chance storm event, discharge from the culvert and localized flooding in the bordering cultivated field back up along the neighborhood's west side and flood the homes in the south.

Unnamed Tributary 9 to Oso Creek begins in the northern half of the cultivated field, with approximately 330 cfs flowing northeast across the north end of the residential area. The worst flooding occurs in this area, with flood depths of 1-2 feet for many properties for the 4% annual chance storm event. The area's overall existing flooding and inundation condition is shown in **Figure 7.22.**

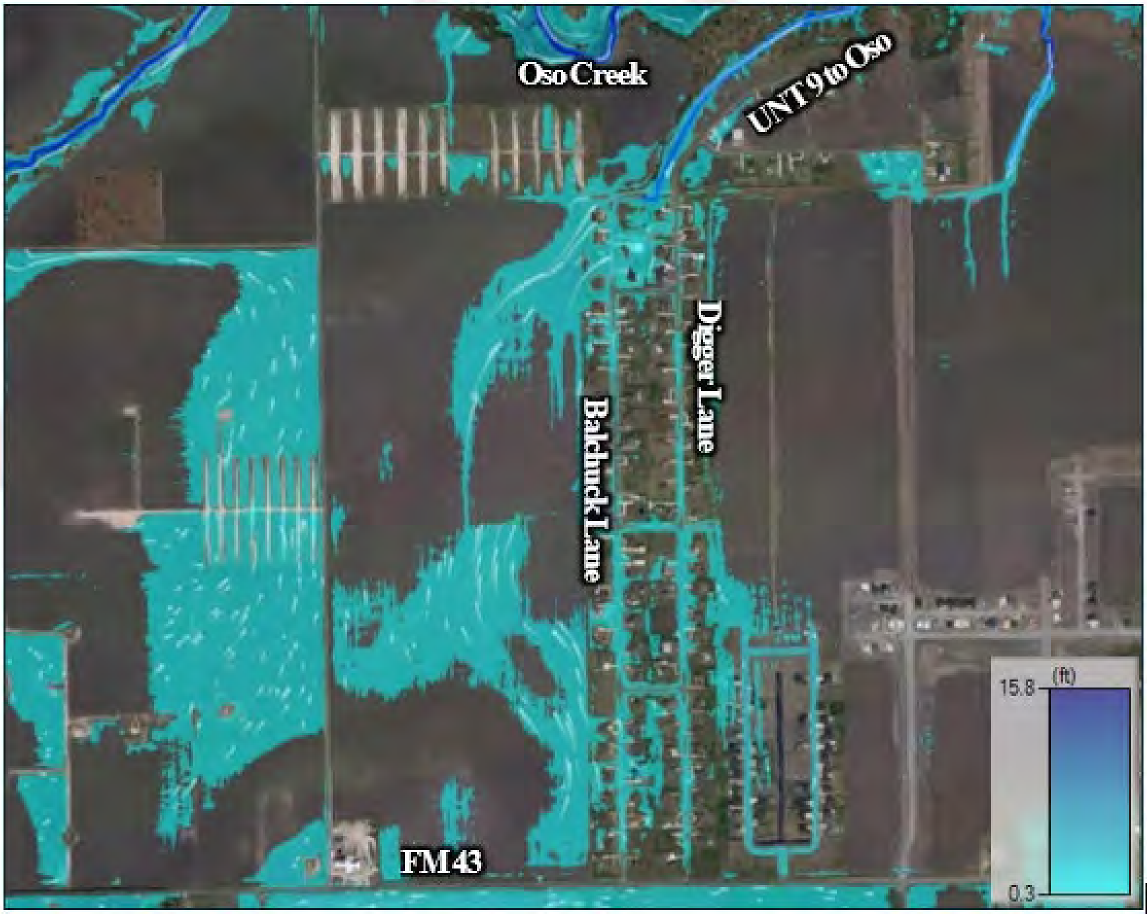

Figure 7.22 Existing Conditions 4% Annual Storm Depth– Balchuck Lane & Digger Lane

7.2.7.2 Proposed alternative

The proposed alternative is comprised of several ditch/channel improvements, culvert improvements and a detention pond.

The main component to the proposed alternative is a drainage channel running from the south, at the FM 43 culvert crossing, to the north along the western border of the residential area, and out-falling into *Unnamed Tributary 9 to Oso Creek*. The proposed ditch has a 20-foot bottom width, a 5:1 side slope, and flowline elevations generally 4–5 feet.

Channel improvements were also made along all residential streets within the neighborhood, increasing their current capacity. These ditches outfall west towards the proposed channel. Each ditch has a proposed bottom width of 3 ft, a 3:1 side slope and varying top width. Two storm drain improvements with grate inlets are proposed along Balchuck Lane, allowing drainage from the residential roadside ditches to the main channel west of the neighborhood.

The proposed detention pond is located at the northeast corner of the adjacent field, with an approximate footprint of 7.5 acres and a max depth of 6 feet, detaining the flooding that backs up along the northwestern side of the neighborhood. The proposed outlet is 3 – 36" RCPs with flap gates that outfall to the downstream end of the main channel.

At the downstream end of the proposed main channel, 3 – 5 x 2 RCBs replace the existing 6 – 24" RCPs to allow greater conveyance to the creek outfall. The risk area's proposed improvements are shown in **Figure 7.23**.

The proposed alternative has an OPCC of $22,023,000.

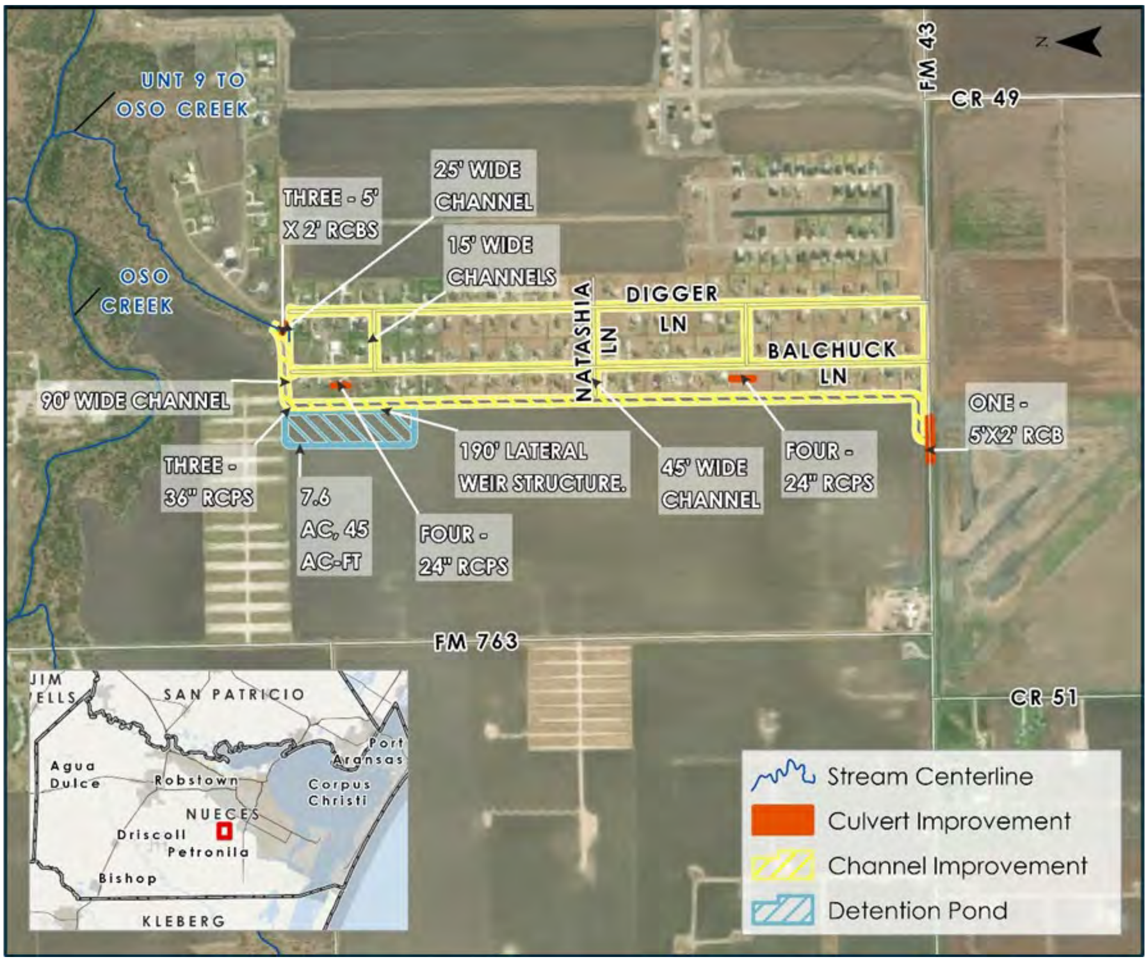

Figure 7.23 Proposed Improvements – Balchuck Lane & Digger Lane

7.2.7.3 Project benefit

The proposed alternative in the 4% annual chance storm event removes seven structures from the floodplain. The risk area's flood depth reduction is shown in **Figure 7.24**. Proposed improvements decrease the duration of standing water, improving drain time for Balchuck Lane and Digger Lane residential areas. Additionally, residential structures not removed from the floodplain benefit from flood depth reduction. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 26 is available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

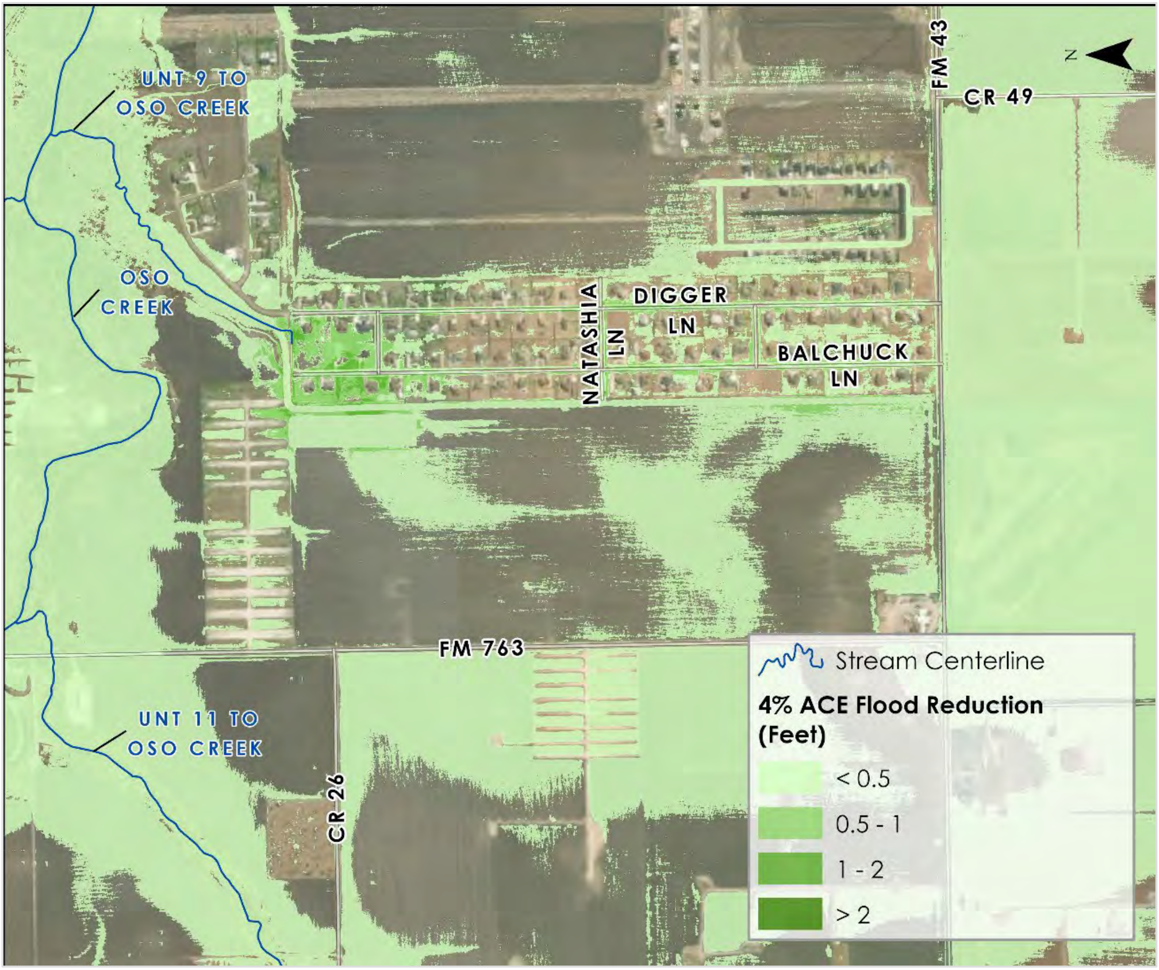

Figure 7.24 Proposed Conditions 4% Annual Storm Depth Reduction – Balchuck Lane & Digger Lane

7.2.8 Agua Dulce

Agua Dulce (Risk Area 6) is a small city in Nueces County located at the intersection of County Road 105 and State Highway 44 and along Yakey Swale Tributary 1.

7.2.8.1 Existing conditions/flooding issues

As the flow moves through the area from the west, it is directed along the north side of State Highway 44 until it dams behind the west side of County Road 105. The lack of drainage infrastructure along County Road 105 allows the flow to quickly overtop the road and inundate the northwest and central areas of Agua Dulce with nearly 2000 cfs of flow overtopping the road for the 4% annual chance storm event. The area's overall existing flooding and inundation condition is shown in **Figure 7.25**.

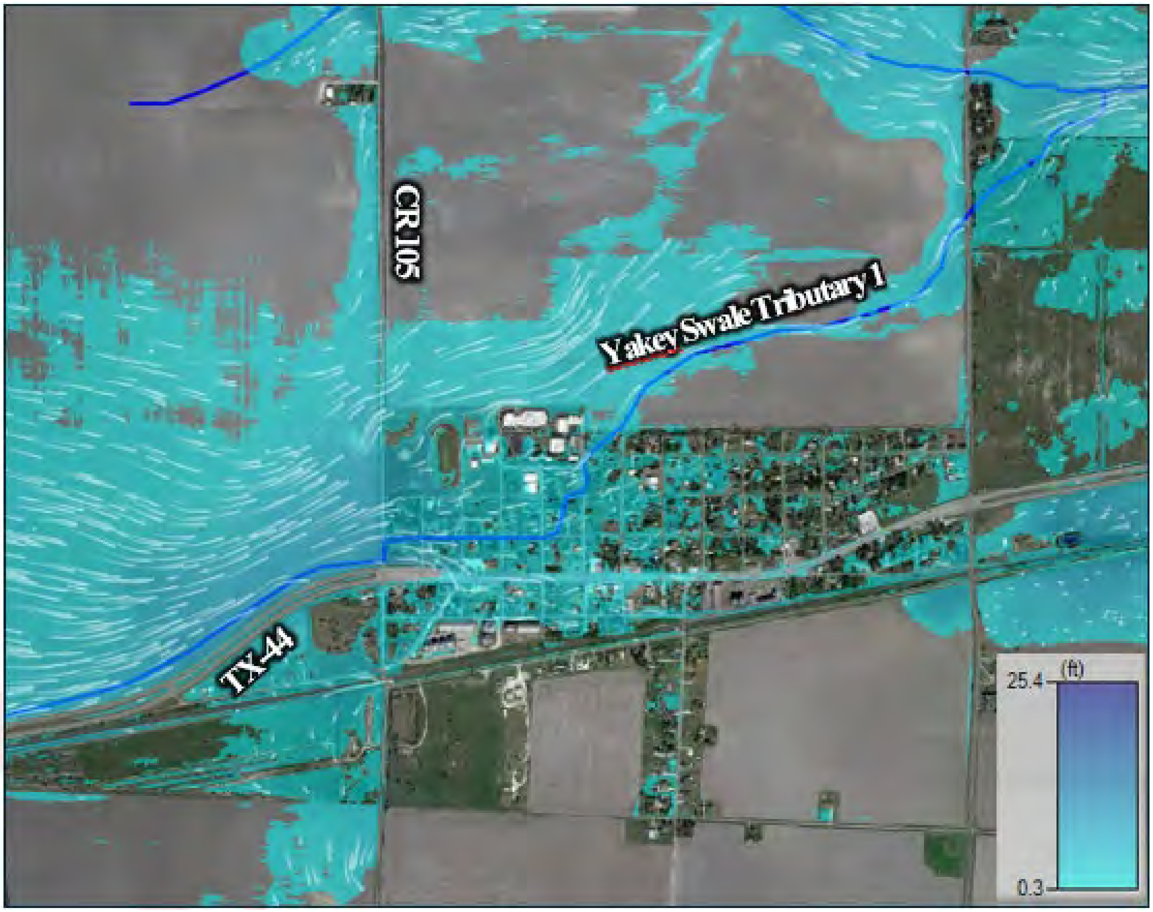

Figure 7.25 Existing Conditions 4% Annual Storm Depth – Agua Dulce

7.2.8.2 Proposed alternative

The proposed design comprises a detention pond and channel improvements.

A large detention was modeled west of County Road 105 to intercept flow and divert it around Agua Dulce. The available land for this design is currently an agricultural field. The proposed pond intercepts flow as it heads towards County Road 105 and exits through an outlet structure underneath County Road 105. The proposed pond has a footprint of approximately 133 acres with an average depth of 5 feet. The outlet structure is comprised of 5 – 5' x 4' RCBs and discharges into a proposed grass-lined channel that directs flow around the north side of the city.

The proposed channel has a 125-foot bottom width, 3:1 side-slopes, and a length of approximately 5,200 feet. The proposed channel then widens to a 300-foot bottom width. It continues 3:1 side-slopes for a 1,474 length before daylighting just downstream of the existing culvert structure where *Yakey Swale Tributary 1* crosses FM 70. The risk area's proposed improvements are shown in **Figure 7.26**.

The proposed alternative has an OPCC of $107,448,000.

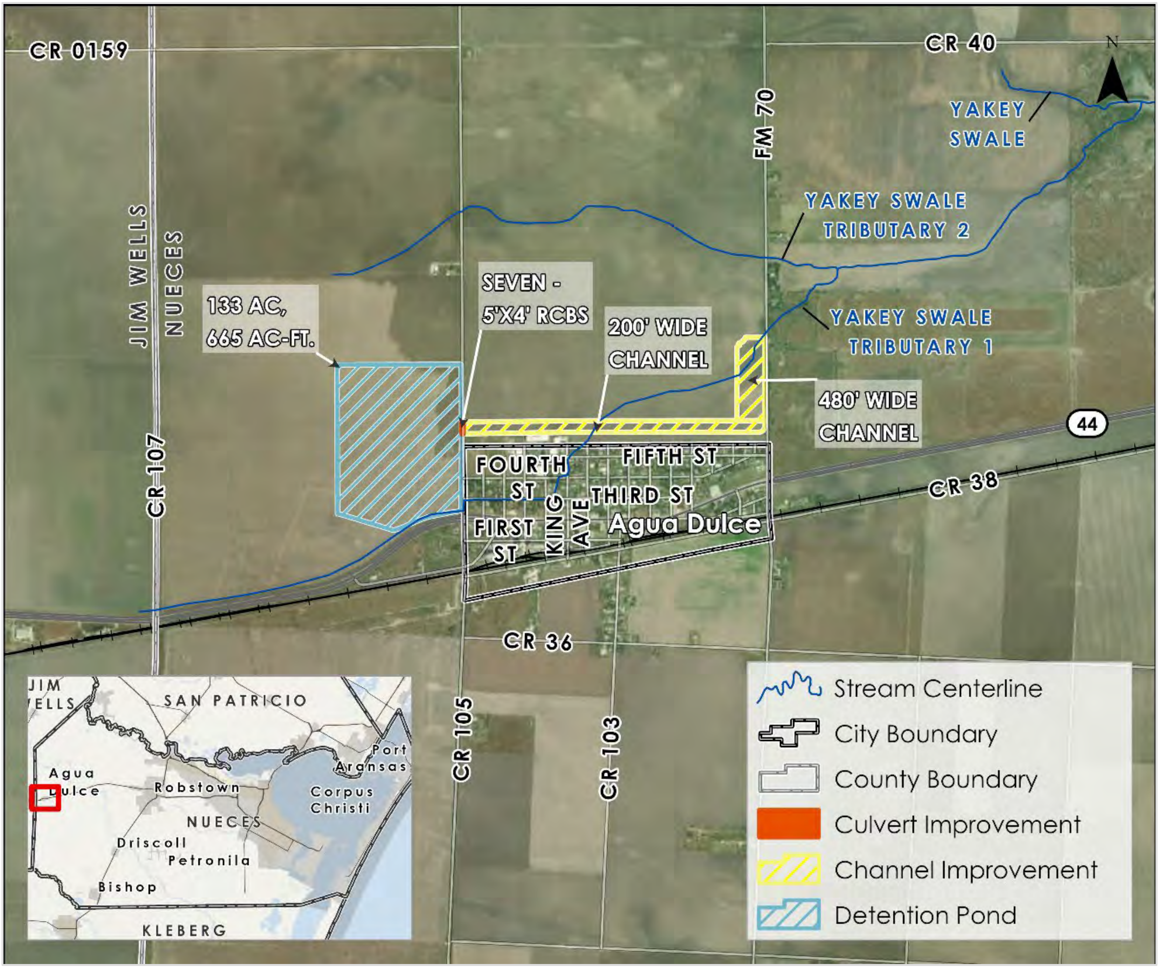

Figure 7.26 Proposed Improvements – Agua Dulce

7.2.8.3 Project benefit

The proposed alternative for the 4% annual chance storm event removes 91 structures from the floodplain. The risk area's flood depth reduction is shown in **Figure 7.27**. Additionally, residential and commercial structures not removed from the floodplain benefit from flood depth reduction. In the 4% annual chance storm event, there are 14 Agua Dulce Independent School District structures with flood depths ranging from half a foot to two feet. The proposed alternative removes eight of the 14 and reduces the flood depth by five to 16 inches in the remaining six structures. The proposed alternative reduces flow overtopping County Road 105, increasing mobility for the city of Agua Dulce. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 6 are available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

Figure 7.27 Proposed Conditions 4% Annual Storm Depth Reduction – Agua Dulce

7.2.9 Nottingham Acres

The Nottingham Acres risk area is two small residential subdivisions located along the south side of FM 43, approximately 1.6 miles west of TX-286, just northwest of Risk Area 28 – South Prairie Estates.

7.2.9.1 Existing conditions/flooding issues

The two developing neighborhoods are located along Loxley Drive and Shaftsbury Drive, with localized flooding that originates in an adjacent field and is impeded by the neighborhoods as it moves eastward. Due to this impedance of flow, localized flooding within the neighborhoods is also unable to drain away quickly enough, causing further flooding. The area's overall existing flooding and inundation condition is shown in **Figure 7.28**.

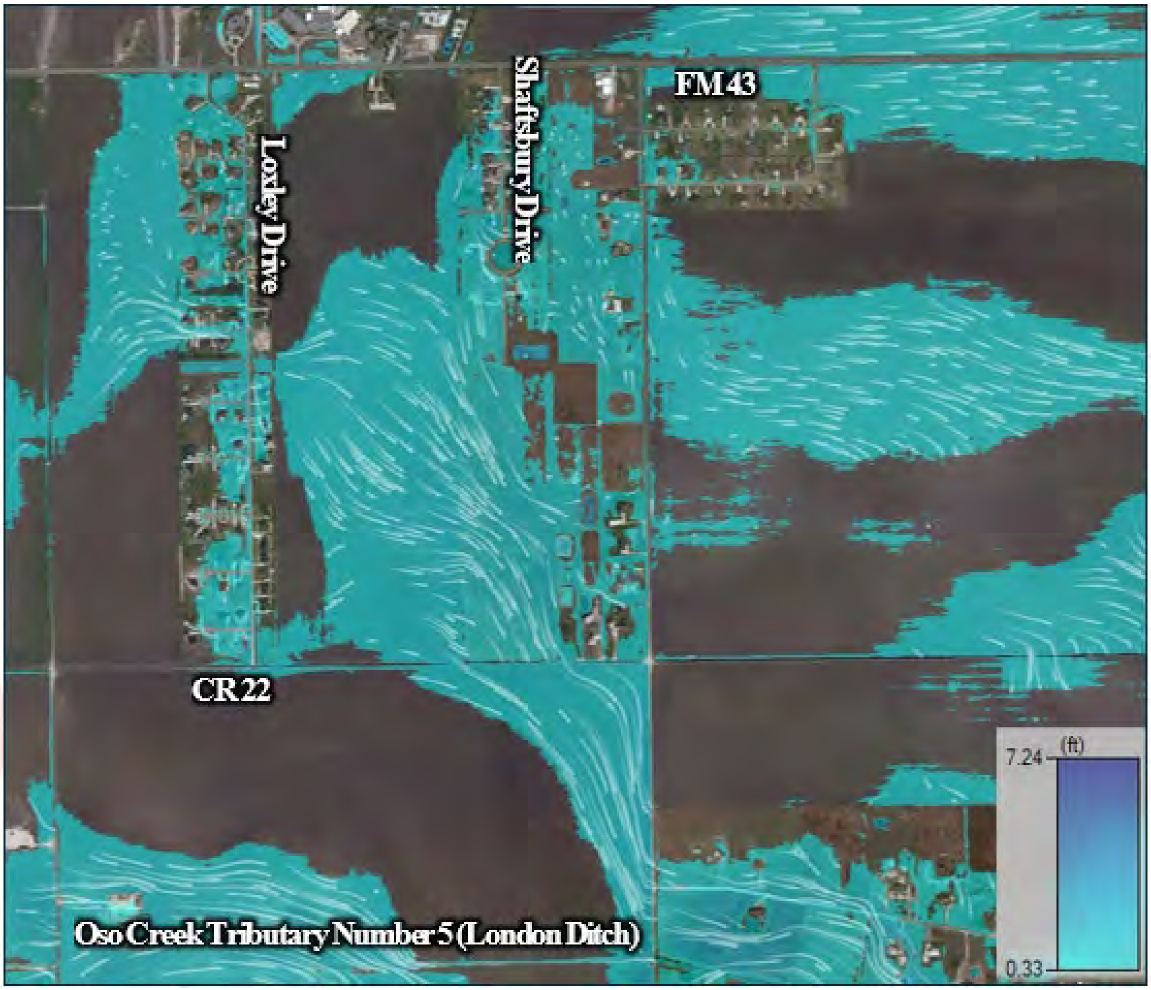

Figure 7.28 Existing Conditions 4% Annual Storm Depth – Nottingham Acres

7.2.9.2 Proposed alternative

The proposed design comprises two detention ponds and channel improvements.

The proposed alternative to mitigate flooding from the west is the construction of a detention pond (Detention Pond 1) to the west of the residences along Loxley Drive. The available land for this design is currently unoccupied. The proposed detention pond intercepts flow accumulation from the field west of the neighborhood. The detention pond footprint is approximately 40 acres with a storage volume of 121 ac-ft. The discharge of the pond is directed through an outlet structure (1- 36" RCP) into a new downstream channel (40 ft bottom width, 3:1 side-slopes), which empties into *Oso Creek Tributary Number 5 (London Ditch)* further to the south.

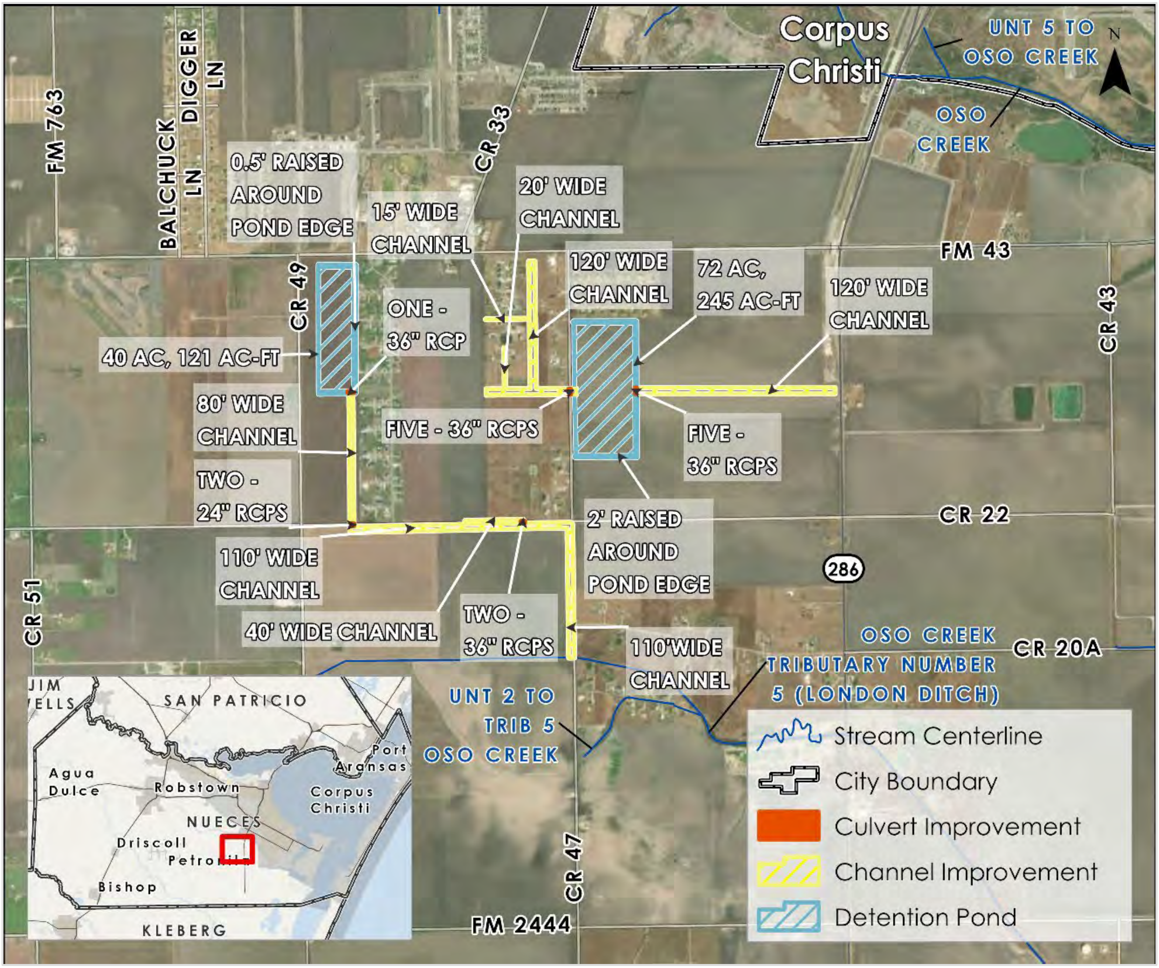

Figure 7.29 Proposed Improvements – Nottingham Acres

Detention Pond 2 is planned to be located on an empty parcel of land along County Road 47 downstream of the Shaftsbury Drive neighborhood. The detention pond footprint is approximately 72 acres with a storage volume of 245 acre-feet. New roadside ditches and larger conveyance channels direct flooding from the neighborhood to the pond inlet (5 – 36" RCPs). The pond outlet consists of 5 – 36" RCPs and empties into a small outlet channel. The risk area's proposed improvements are shown in **Figure 7.29**.

The proposed alternative has an OPCC of $56,477,000.

7.2.9.3 Project benefit

The proposed alternative in the 4% annual storm event removes 16 structures from the floodplain. The risk area's flood depth reduction is shown in **Figure 7.30**. Proposed improvements decrease the duration of standing water, improving the drain time for the Nottingham Acres residential area. Additionally, residential structures not removed from the floodplain benefit from flood depth reduction. The improvements also show no notable adverse impacts to the water surface elevation in the areas upstream and downstream of the risk area. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 27 are available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

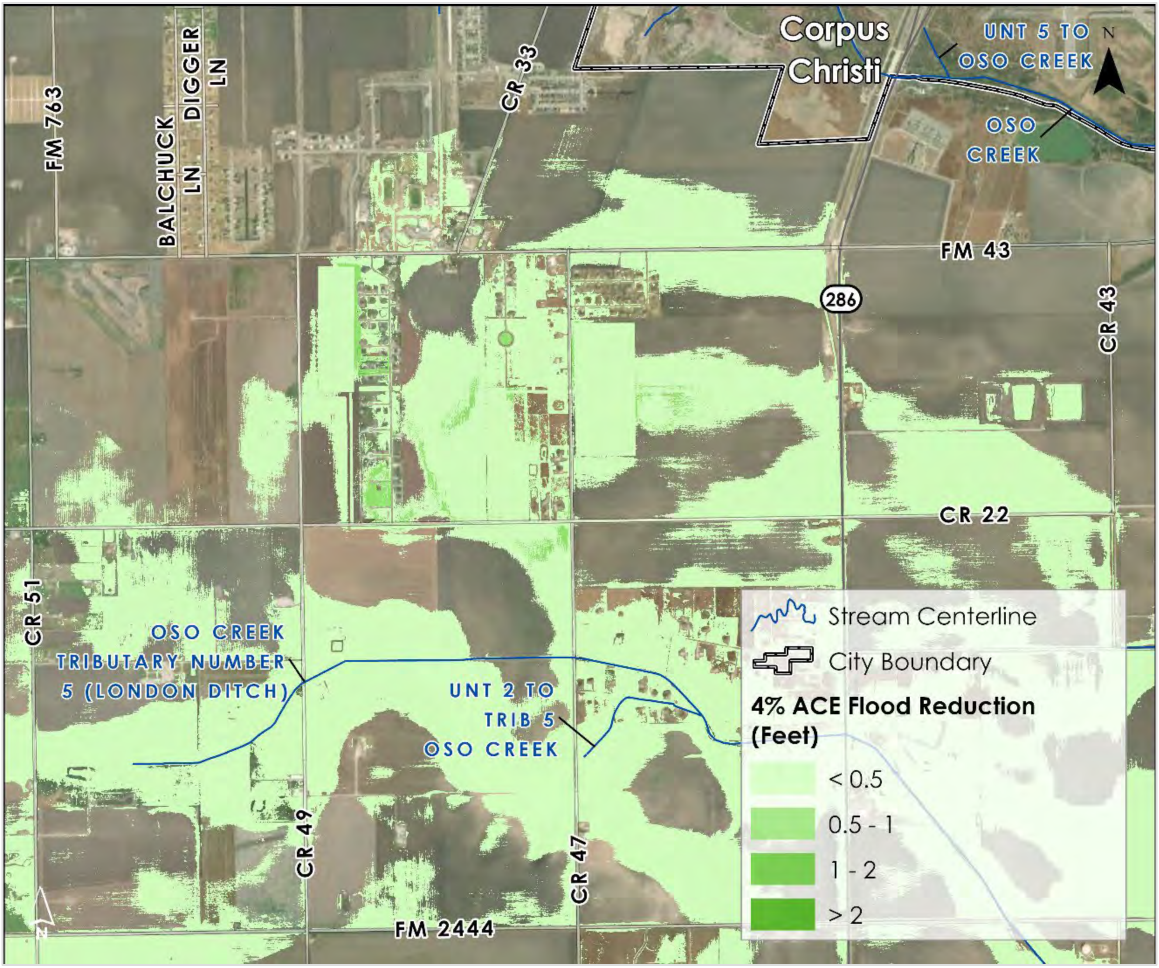

Figure 7.30 Proposed Conditions 4% Annual Storm Depth Reduction – Nottingham Acres

7.2.10 Indian Trails

Located just within the northern boundary of the Petronila watershed, Indian Trails (Risk Area 3) is a residential area bordered by FM 666 to the east, FM 1833 to the north, and cultivated fields to the west and south.

7.2.10.1 Existing conditions/flooding issues

Before the construction of FM 1833 and FM 666, the natural terrain in this region would split the flow from runoff into two directions: to the north into the Nueces River Watershed via two gullies and to the east into the Petronila Watershed, where the natural terrain would eventually direct the runoff into Unnamed Tributary 1 to Banquete Creek. While the flow is still split between the two watersheds, the flow restrictions caused by FM 1833 and FM 666 significantly slows the release of water into the Nueces River Watershed, resulting in accumulation of backwater along FM 1833 and FM 666. Additionally, minimal to no local drainage can be observed along the residential streets or throughout Indian Trails. The area's overall existing flooding and inundation condition is shown in **Figure 7.31**. This area experiences two peaks: the first occurs due to the direct rainfall over Indian Trails and the surrounding area, with resulting flooding primarily caused by insufficient local drainage, while the second peak, with an approximate flow of 2500 CFS, occurs due to upstream flooding, resulting in accumulation of backwater along and at the intersection of FM 1833 and FM 666.

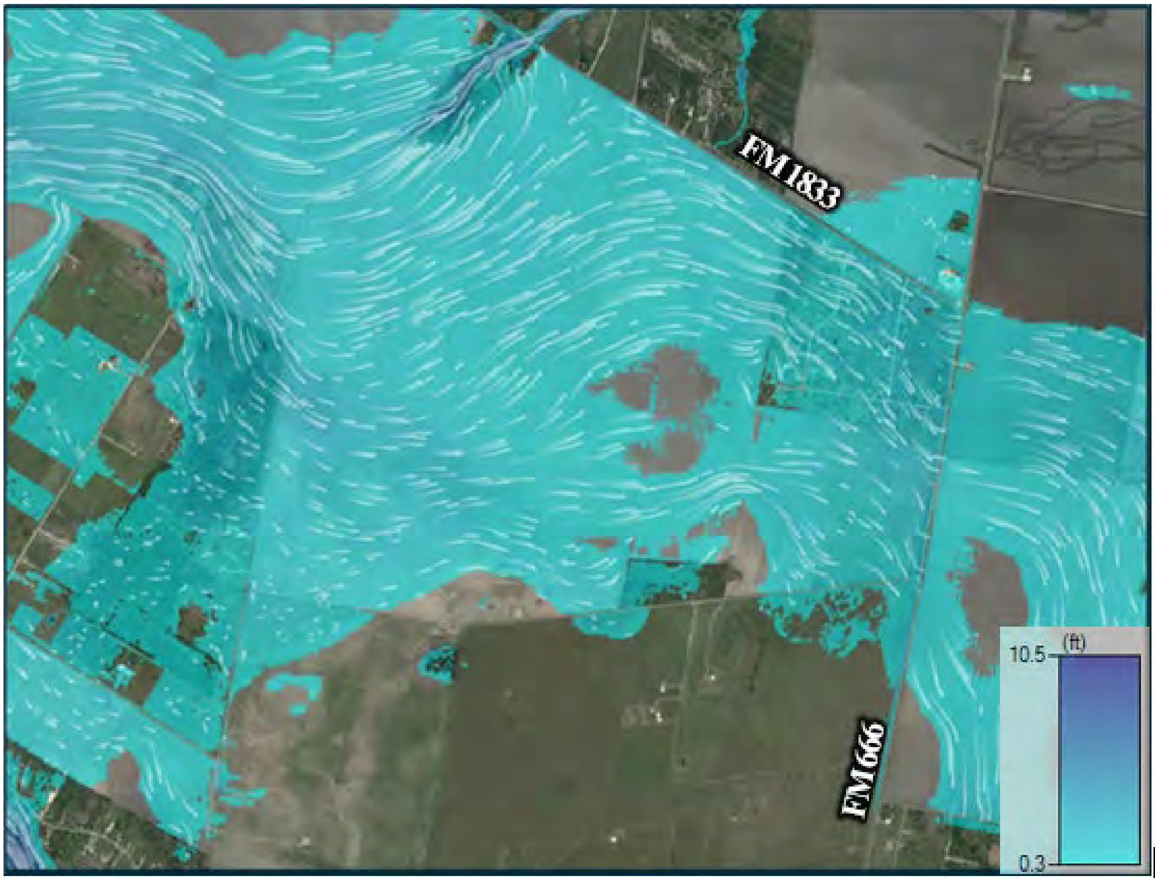

Figure 7.31 Existing Conditions 4% Annual Storm Depth – Indian Trails

7.2.10.2 Proposed alternative

The proposed design consists of a detention pond, a series of culvert improvements, and a network of local drainage ditches and channels to mitigate flooding in the Indian Trails residential area.

A network of local drainage ditches is proposed to mitigate local flooding, particularly during the first peak. These ditches generally have a bottom width ranging from 3 to 8 feet and have 3:1 side-slopes with a flowline ranging from 0.5 to 2.0 feet in depth. To improve water conveyance around Indian Trails, larger channels are proposed. Along FM 1833, proposed channels tie into existing drainage networks and are proposed to have bottom widths ranging from 5 to 8 feet with expected channel depths between 3 and 4 feet and 3:1 side-slopes. Proposed interceptor channels bound the west and south sides of Indian Trails and have bottom widths ranging from 20 to 35 feet with expected depths between 3 and 4 feet and 3:1 side-slopes. Proposed channels along FM 666 tie into the proposed detention pond and downstream drainage networks and range in bottom width from 13 to 60 feet with 3:1 side-slopes and expected depths between 1 and 3 feet.

The detention pond is located southeast of Indian Trails along FM 666 and has a footprint of approximately 87.3 acres. The inflow to the pond is connected to one of the proposed channels along the west side of FM 666 via an inlet structure comprising three 5’x2’ RCBs. The outlet structure consists of four 36” RCPs and outfalls into the same channel as the inflow.

A series of culvert improvements are proposed along FM 1833 and FM 666 to reduce backwater within Indian Trails by increasing flow across these two roads. Two existing culvert structures, one along FM 1833 and one at the intersection of FM 1833 and FM 666, are proposed to be removed and replaced with culverts that will allow increased flow capacity. Additional culvert structures are proposed along both FM 1833 and FM 666. The risk area’s proposed improvements are shown in **Figure 7.32**.

The proposed alternative has a cost of $10,293,000.

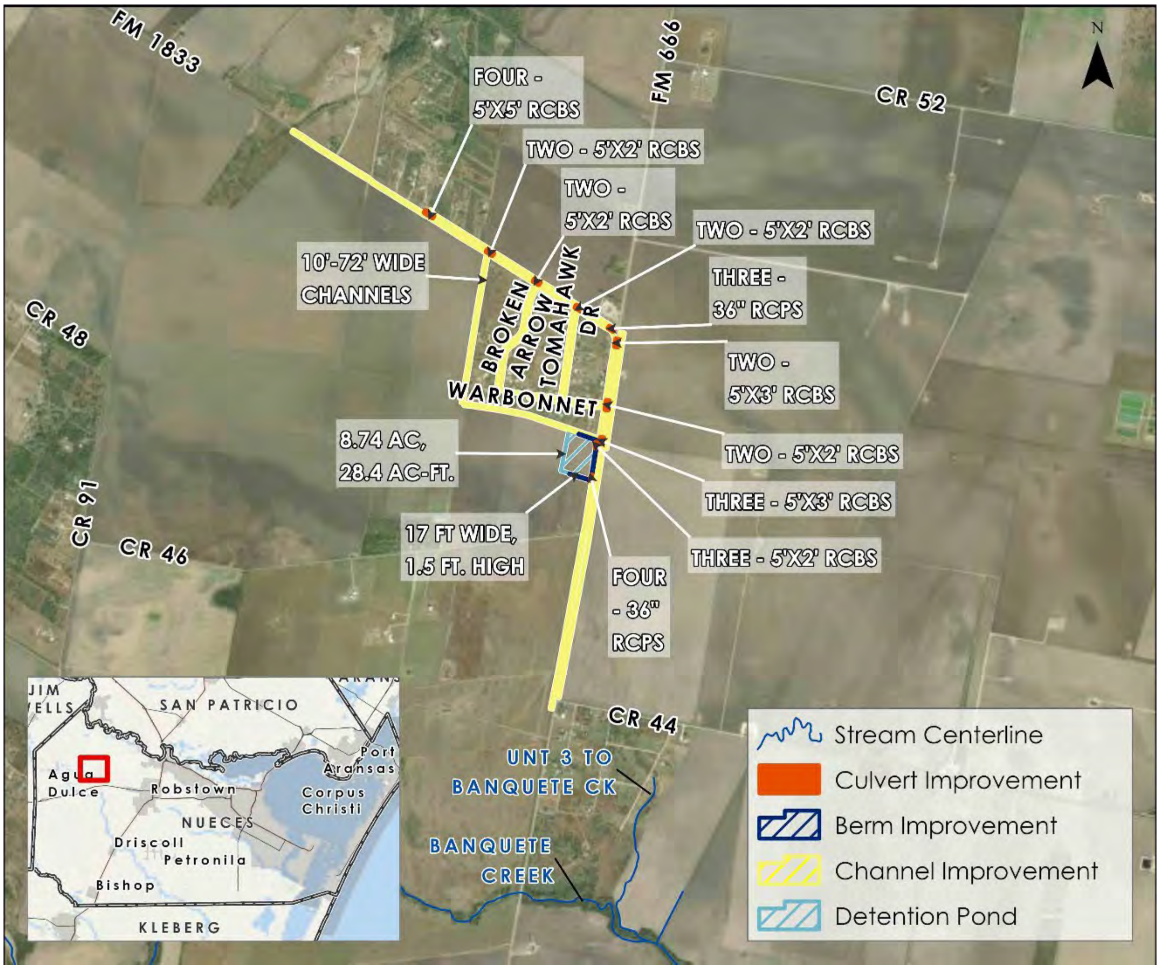

Figure 7.32 Proposed Improvements – Indian Trails

7.2.10.3 Project benefit

For the 4% annual chance storm event, the proposed alternative removes nine structures from the floodplain. The risk area’s flood depth reduction is shown in **Figure 7.33**. Additionally, residential and commercial structures not removed from the floodplain benefit from flood depth reduction. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 3 is available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

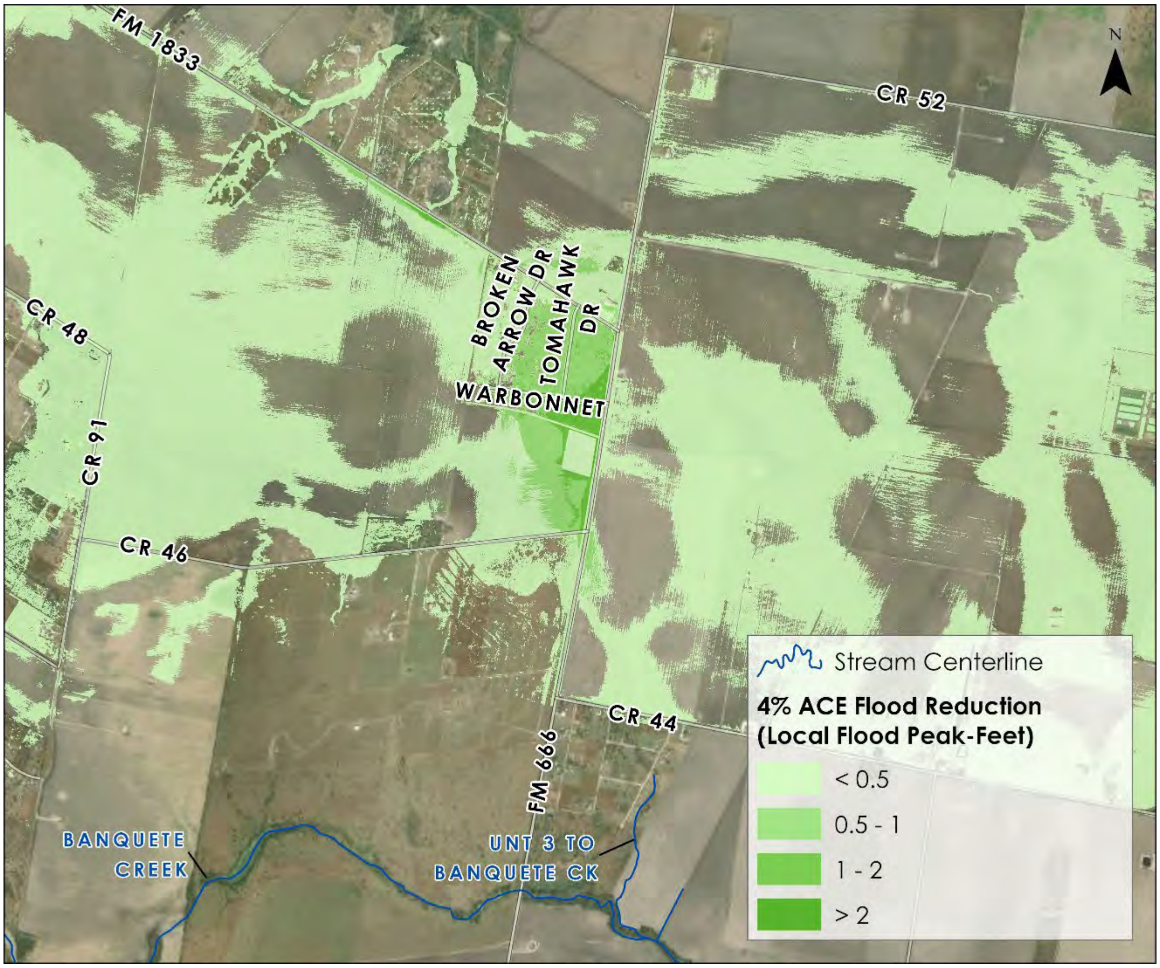

Figure 7.33 Proposed Conditions 4% Annual Storm Depth Reduction – Indian Trails

7.2.11 Rancho Banquete

Rancho Banquete (Risk Area 4) is a small residential area bounded east by County Road 91, north by County Road 42 (Groneveld Dairy Road), south by Agua Dulce Creek, and west by a cultivated field.

7.2.11.1 Existing conditions/flooding issues

During a 4% annual chance storm event, this neighborhood experiences two peak flowrates: the first, which occurs as a direct result of rainfall in the immediate area and the second, which occurs as the creeks in the surrounding area reach their peak flows from the cumulation of upstream and local runoff. Flooding occurs in the northernmost portion of Rancho Banquete, resulting from both local runoff and overflow from *Banquete Creek*, which backs up into the neighborhood through the natural terrain. At peak, the flowrate into the north region of the neighborhood is approximately 100 CFS. The confluence of *Agua Dulce Creek* and *Yakey Swale Tributary*, contributing 22,900

CFS and 5,350 CFS, respectively, occurs due south of Rancho Banquete. As a result of the natural terrain and the stream confluence, low-lying homes within the southern portion of Rancho Banquete are inundated by up to 8 feet of flood water during the second peak. Additionally, minimal to no local drainage improvements exist within Rancho Banquete. The area's overall existing flooding and inundation condition is shown in **Figure 7.34**.

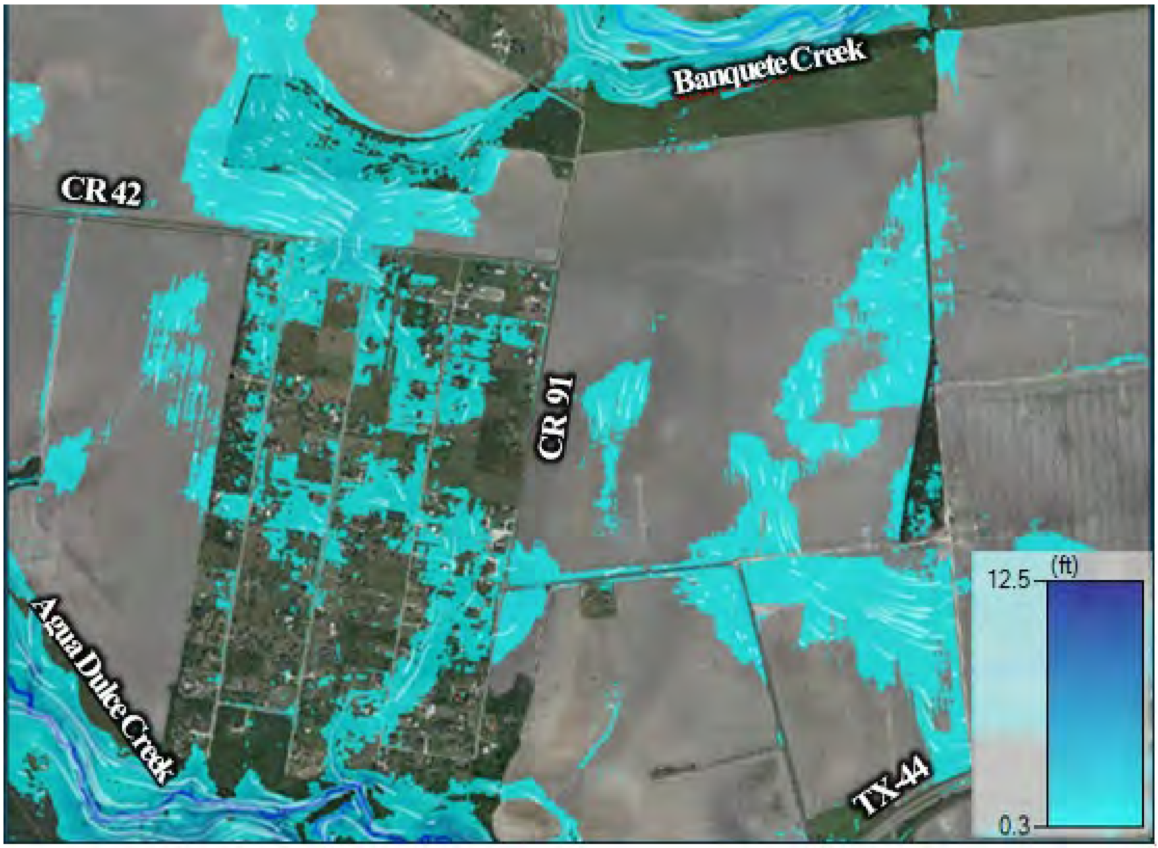

Figure 7.34 Existing Conditions 4% Annual Storm Depth – Rancho Banquete

7.2.11.2 Proposed alternative

The proposed design to mitigate flooding in a 4% annual chance storm event consists of a network of local drainage ditches, an interceptor channel, a detention pond with inlet and outlet structures, and a detention pond outlet channel that outfalls to *Banquete Creek*. The proposed improvements are focused predominantly on mitigating flooding in the northern portion of Rancho Banquete and are optimized for a 4% annual chance storm event.

Seven local drainage ditches are proposed to parallel either side of local streets and the west side of CR 91 within the northern portion of Rancho Banquete. These ditches have bottom widths ranging from 4 to 5 feet with 2:1 side-slopes and are proposed to have average flowline depths ranging from 3 to 5 feet, which drain northward into an interceptor channel. Ditch design may be modified to fit field constraints and/or soil characteristics. The interceptor channel has a bottom width of 50 feet and 3:1 side-slopes and is located within a cultivated field just north of CR 42. This proposed channel intercepts local runoff and overflow from *Banquete Creek* before it can enter Rancho Banquete. The channel conveys floodwaters eastward with an average flowline depth of 9.0 feet and crosses County Road 42 to outfall into the detention pond, located in a cultivated field northeast of Rancho Banquete. The proposed pond has a 118-acre footprint and 3:1 side slopes. Where the interceptor channel crosses County Road 91, a culvert structure with three 4’x6’ barrels is proposed as the detention pond inlet structure. The detention pond outlet structure, which consists of two 4’x8’ barrels, is located on the north side of the detention pond and feeds into an outlet channel with an outfall to *Banquete Creek*. This channel is proposed to have a bottom width of 10 feet with 2:1 side slopes and an average flowline depth of 6.7 feet. Channel design may be modified to fit field constraints and/or soil characteristics.

The proposed improvements reduce water surface elevations throughout Rancho Banquete by up to 0.9 feet in some areas. Two small areas of adverse impact were noted in the 1% annual chance storm event analysis, both of which occur within cultivated fields and have no effect on structures or transportation routes. Minor refinements during detailed design should alleviate these areas. The risk area’s proposed improvements are shown in **Figure 7.35**.

The proposed alternative has an OPCC of $68,570,000.

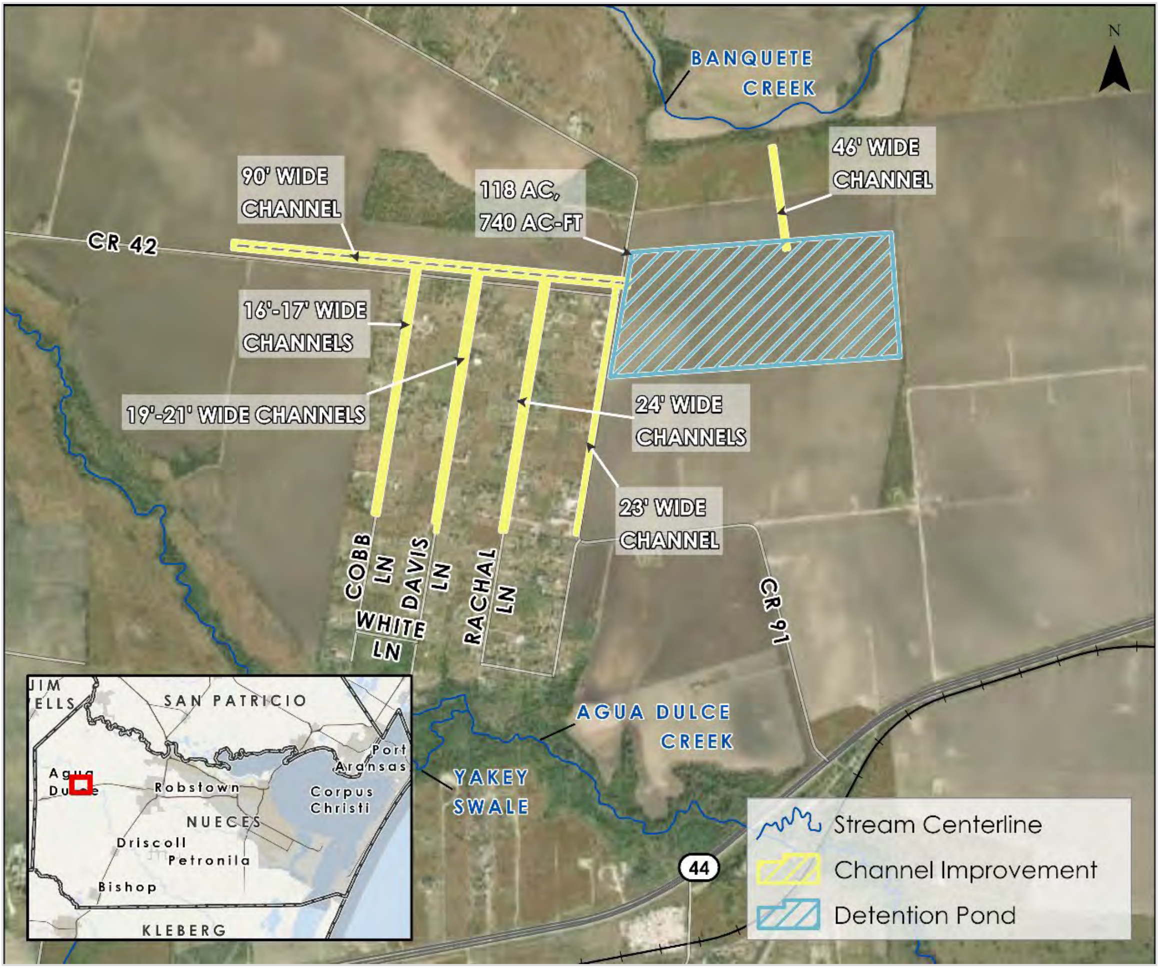

Figure 7.35 Proposed Improvements – Rancho Banquete

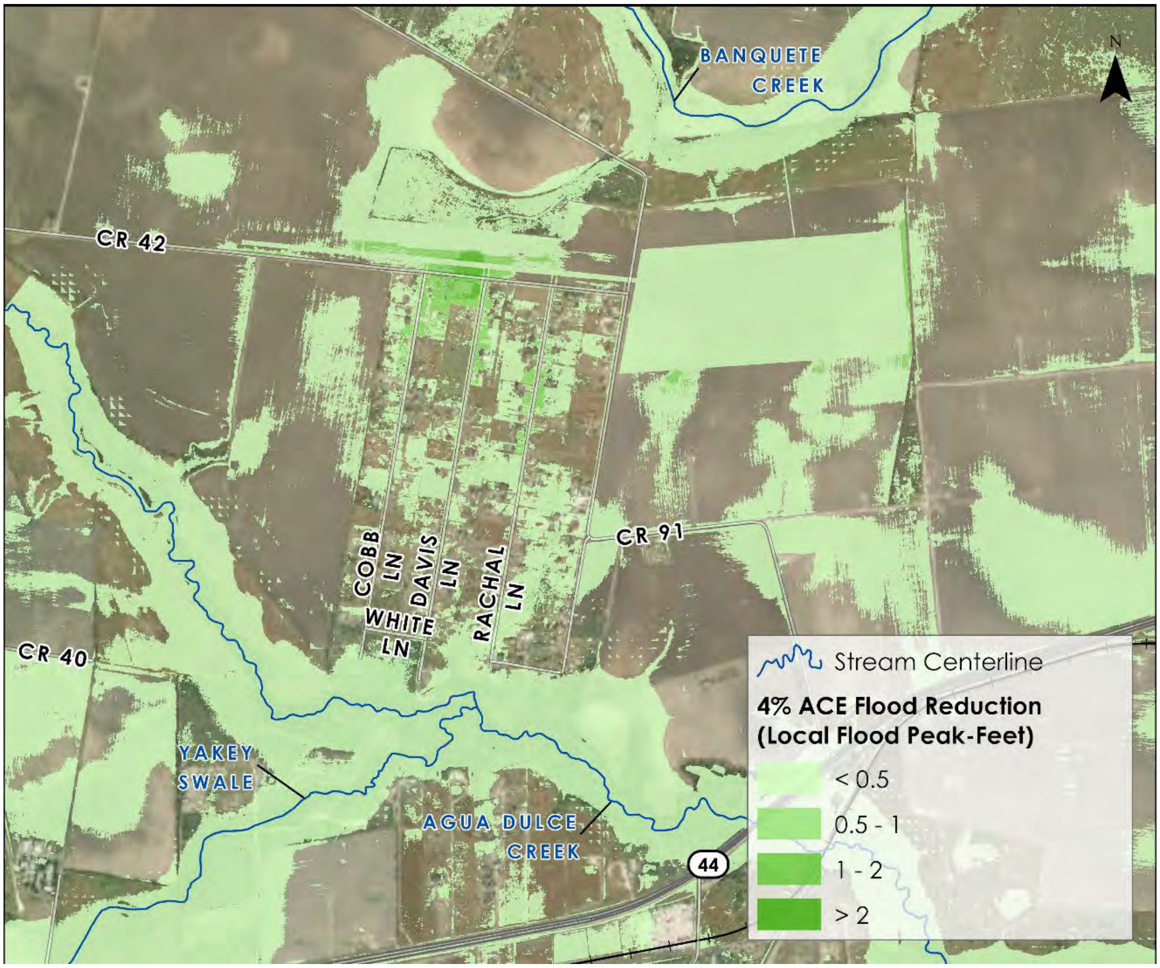

Figure 7.36 Proposed Conditions 4% Annual Storm Depth Reduction – Rancho Banquete

7.2.12 Callicoatte Farms

Callicoatte Farms (Risk Area 11) is a residential/business area surrounding the intersection of FM 1694 and Country Road 44, located in the Oso Creek watershed.

7.2.12.1 Existing conditions/flooding issues

The Callicoatte Farms risk area is mostly inundated by runoff from the surrounding area. There is minimal drainage infrastructure along FM 1694 and County Road 44 and at their intersection, so as the flow moves into the area from the west and northwest, it ponds upstream of both roads and has a difficult time draining to *Oso Creek*. The area's overall existing flooding and inundation condition is shown in **Figure 7.37**.

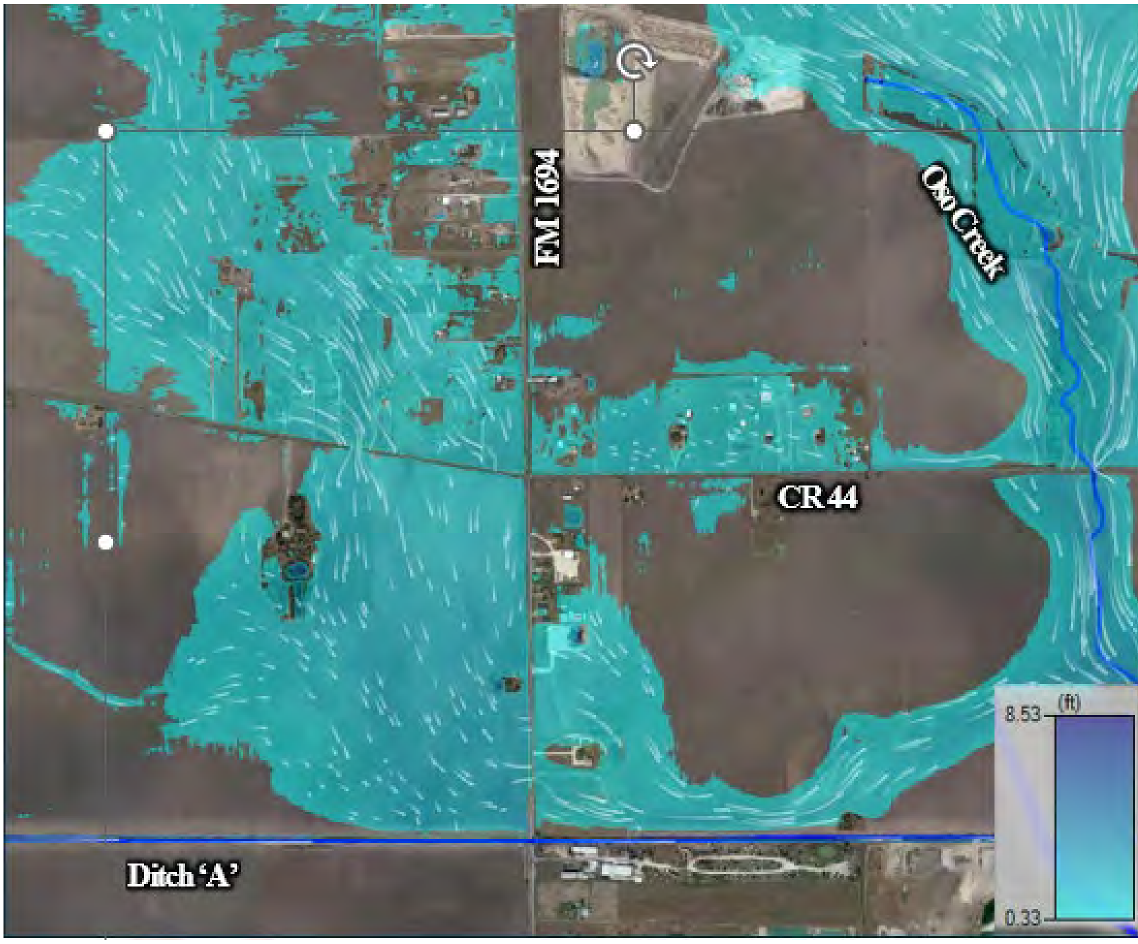

Figure 7.37 Existing Conditions 4% Annual Storm Depth – Callicoatte Farms

7.2.12.2 Proposed alternative

The proposed design consists of a series of culvert improvements and a network of local drainage ditches/channels to allow ease of drainage in the Callicoatte Farms risk area.

A network of three channels has been proposed to allow flow an easier drainage route. A channel with a 15-foot bottom width and 3:1 side-slopes was proposed east of FM 1694, following along the northside of County Road 44 and tying into *Oso Creek*. A second channel with a 25-foot bottom width and 3:1 side-slopes is proposed on the south side of County Road 44 that also ties into *Oso Creek*. A third channel with a 15-foot bottom width and 3:1 side slopes is proposed south of County Road 44, running south alongside FM 1694 and tying into Ditch A.

In addition to the proposed channels, a series of culvert improvements are proposed along County Road 44 and west of FM 1694 to help convey flow into the proposed channels. Two groups consist of 5 – 4'x2' RCBs, and the third is a group of 10 – 4'x2' RCBs. Additionally, culvert improvements are proposed across FM 1694 to convey flow to the first and second proposed channels. They are 2 – 4'x2' RCBs and 3 – 5'x4' respectively.

Figure 7.38 Proposed Improvements – Callicoatte Farm

The proposed alternative for the 4% annual chance storm event has minor impact on flood depths yet removes one structure from the floodplain. The proposed alternative focuses on increasing mobility and decreasing drain time around the County Road 44 and FM 1694 intersection. The risk area's proposed improvements are shown in **Figure 7.38**.

The proposed alternative has an OPCC of $6,962,000.

7.2.12.3 Project benefit

The proposed 4% annual chance storm event alternative removes one structure from the floodplain. The risk area's flood depth reduction is shown in **Figure 7.39**. The proposed alternative increases mobility and decreases drain time around the County Road 44 and FM 1694 intersection. Additionally, several residential structures not removed from the floodplain benefit from some flood depth reduction. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 11 is available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

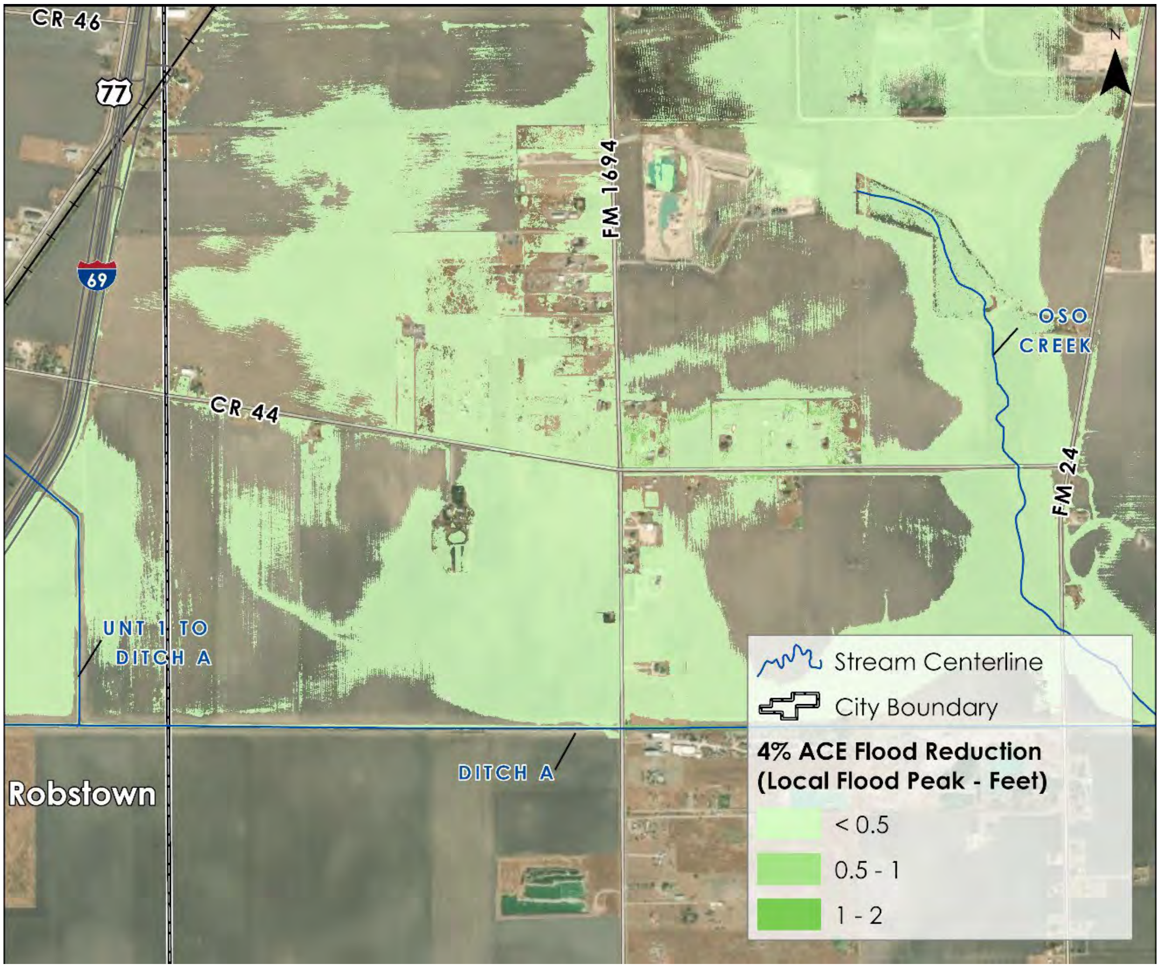

Figure 7.39 Proposed Conditions 4% Annual Storm Depth Reduction – Callicoatte Farms

7.2.13 South Prairie Estates

South Prairie Estates (Risk Area 28) is a small residential area located along South Prairie Road and Rabbit Run, bordered east and west by TX-286 and County Road 47, respectively, just southeast of Risk Area 27 – Nottingham Acres.

7.2.13.1 Existing conditions/flooding issues

Two streams, *Oso Creek Tributary Number 5 (London Ditch)* from the northwest and *Unnamed Tributary 2 to Oso Creek Tributary Number 5* from the southwest, converge in the area contributing approximately 200 CFS and 1200 CFS, respectively, for the 4% annual chance storm event. The main contributors to the flooding of this area stem from the large flow coming from the south after overtopping County Road 47 and crossing through the homes along Rabbit Run with the inability of the existing channel to convey flow downstream quickly enough. Downstream of the residential area, there is a quarry with a small service road that crosses the stream, obstructing some lower flows. The area's overall existing flooding and inundation condition is shown in **Figure 7.40**.

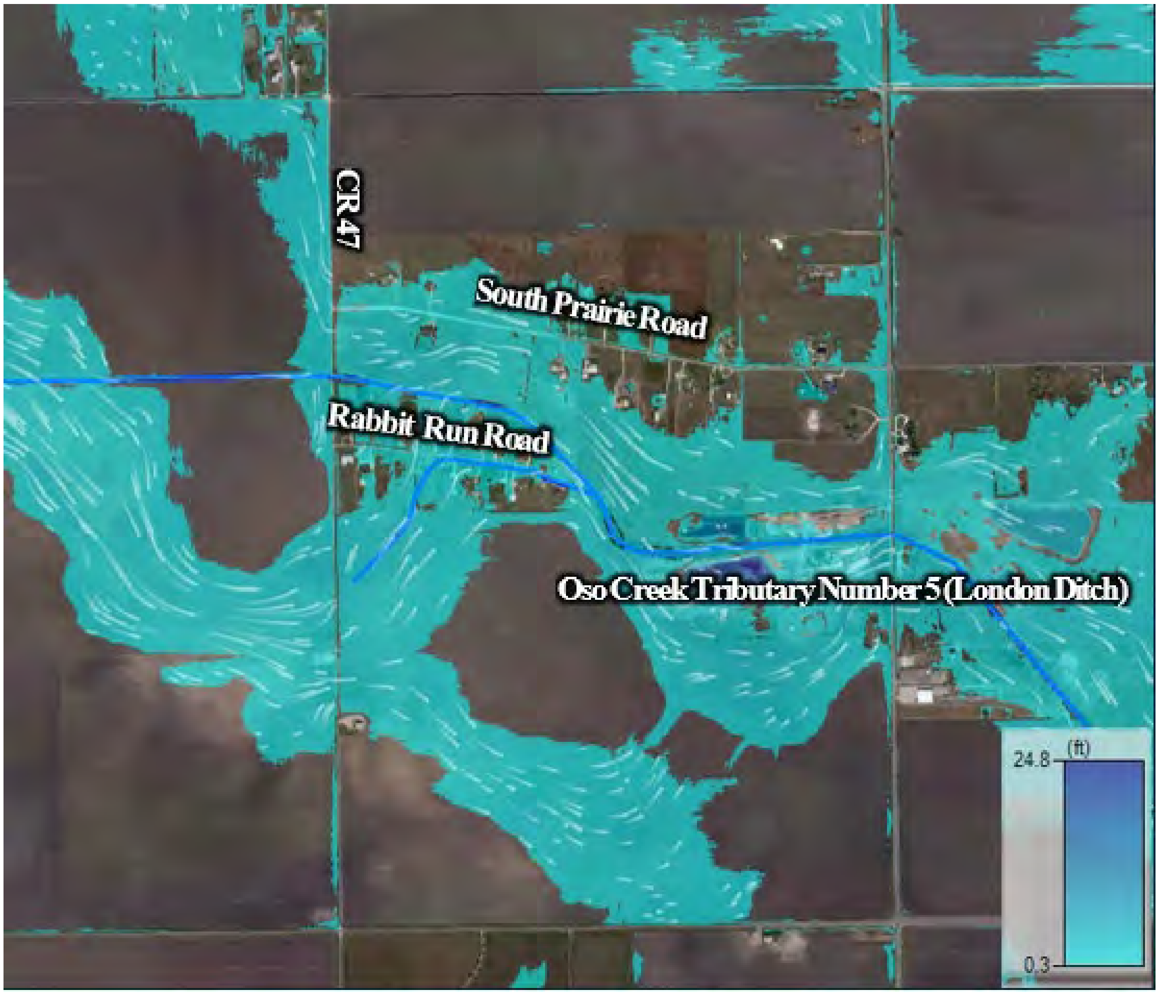

Figure 7.40 Existing Conditions 4%-Annual Storm Depth – South Prairie Estates

7.2.13.2 Proposed alternative

The proposed design comprises two detention ponds and channel improvements.

To accommodate more flow between the residential areas, channel widening improvements (50 ft bottom width, 2:1 side slopes) were modeled along *Oso Creek Tributary Number 5 (London Ditch)* through the risk area from the existing culvert crossing at County Road 47 down through the quarry and to the existing culvert crossing at TX-286. Channel design may be modified to fit field constraints and/or soil characteristics.

A proposed alternative to mitigate flooding from the south (*Unnamed Tributary 2 to Oso Creek Tributary Number 5)* is the construction of a detention pond (Detention Pond 1) to the south of the Rabbit Run residences. The available land for this design is currently unoccupied. The proposed detention pond intercepts flow accumulation from the west side of CR47 through an inlet structure under the road (4 - 10’x5’ RCBs). The detention pond footprint is approximately 31 acres with a depth of 4.5 feet. The discharge of the pond is directed through an outlet structure (6 - 8’x3’ RCBs) into a downstream channel (60 ft bottom width, 3:1 side slopes), which empties into *Oso Creek Tributary Number 5*

(London Ditch). A berm on the north side of the pond and channel further protects the homes on Rabbit Run from flood waters and directs flow towards the outlet.

Figure 7.41 Proposed Improvements – South Prairie Estates

Detention Pond 2 is planned to be located on an empty parcel of land along South Prairie Road north of the widened main channel. The detention pond footprint is approximately 8.9 acres with a depth of 1.5 feet. The detention has been proposed inside the perimeter of the available parcel of land. The pond outlet is 6 – 5'x2' RCB, 16 feet long, and empties directly into *Oso Creek Tributary Number 5 (London Ditch)*. The risk area's proposed improvements are shown in **Figure 7.41**.

The proposed alternative has an OPCC of $39,673,000.

7.2.13.3 Project benefit

The proposed alternative for the 4% annual storm event removes two structures from the floodplain and provides more unflooded access to main roads in the area. The risk area's flood depth reduction is shown in **Figure 7.42**. Proposed improvements decrease the duration of standing water, improving the drain time for South Prairie Road and County Road 47. Additionally, residential structures not removed from the floodplain benefit from flood depth reduction. The improvements also show no notable adverse impacts to the water surface elevation in the areas upstream and downstream of the risk area for the 1% annual chance storm event. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 28 is available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

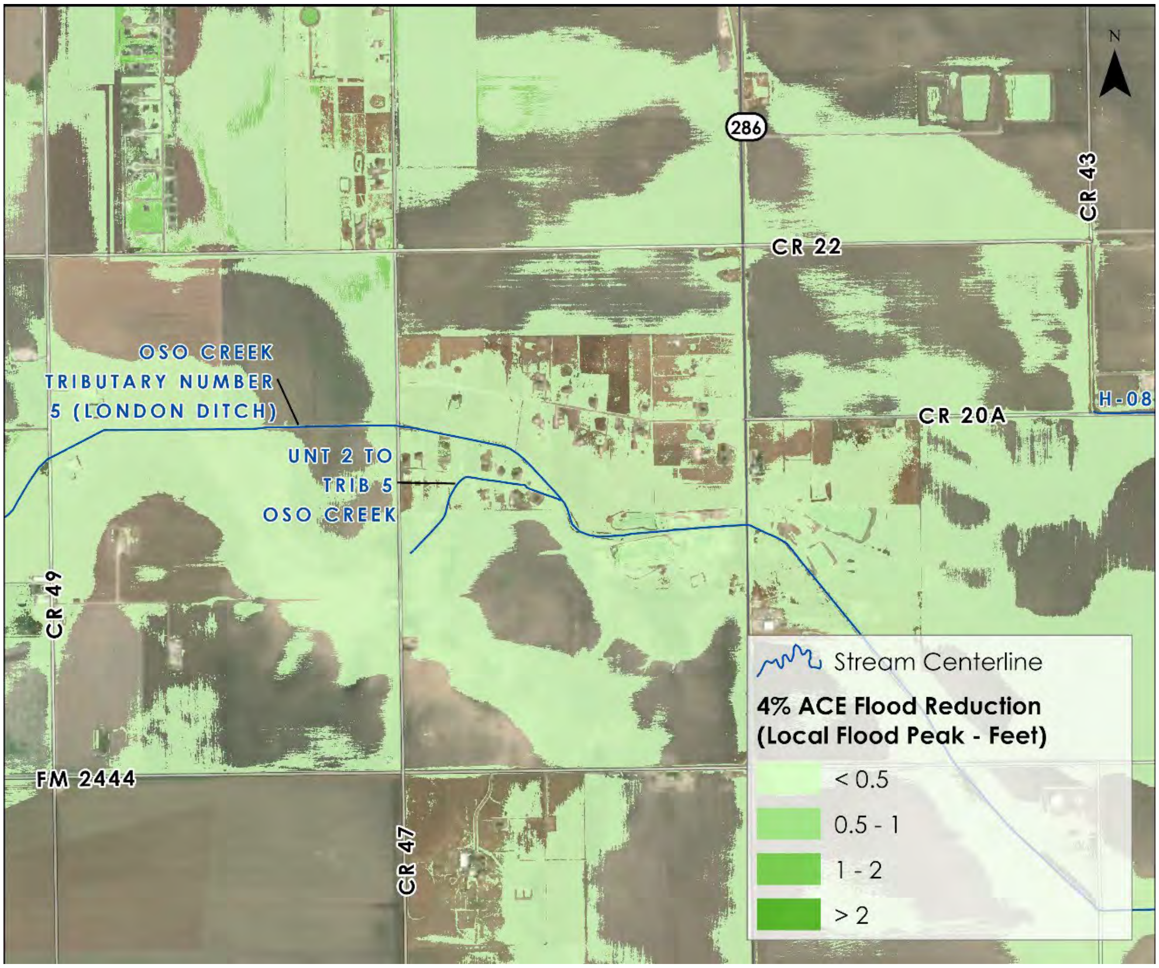

Figure 7.42 Proposed Conditions 4% Annual Storm Depth Reduction – South Prairie Estates

7.2.14 La Paloma Ranch

La Paloma Ranch (Risk Area 7) is a small residential area surrounded by cultivated open space and is located approximately 7 miles west of the City of Driscoll. The area is bounded by County Road 18 to the north and County Road 93 to the east, while La Paloma Road marks the western and southern borders.

7.2.14.1 Existing conditions/flooding issues

There is no major flooding within the residential boundaries; however, study stream B-17, a Petronila Creek tributary, is located north of the project area, crossing County Road 93 and draining towards the east. Flooding occurs on two county roads: County Road 93 to the north and County Road 16 to the south, which provide access to the residential homes from the main roads. *Ditch B-17* conveys a total of 7,000 cfs to County Road 93, which currently floods the roadways for approximately 0.23 miles. The existing culvert structure is unable to convey the flow. Flooding also occurs along the intersection of County Road 16 and 93, located on the south end of the project area. Both flooding scenarios cause mobility difficulties in and out of the residential area during a storm. The area's overall existing flooding and inundation condition is shown in **Figure 7.43**.

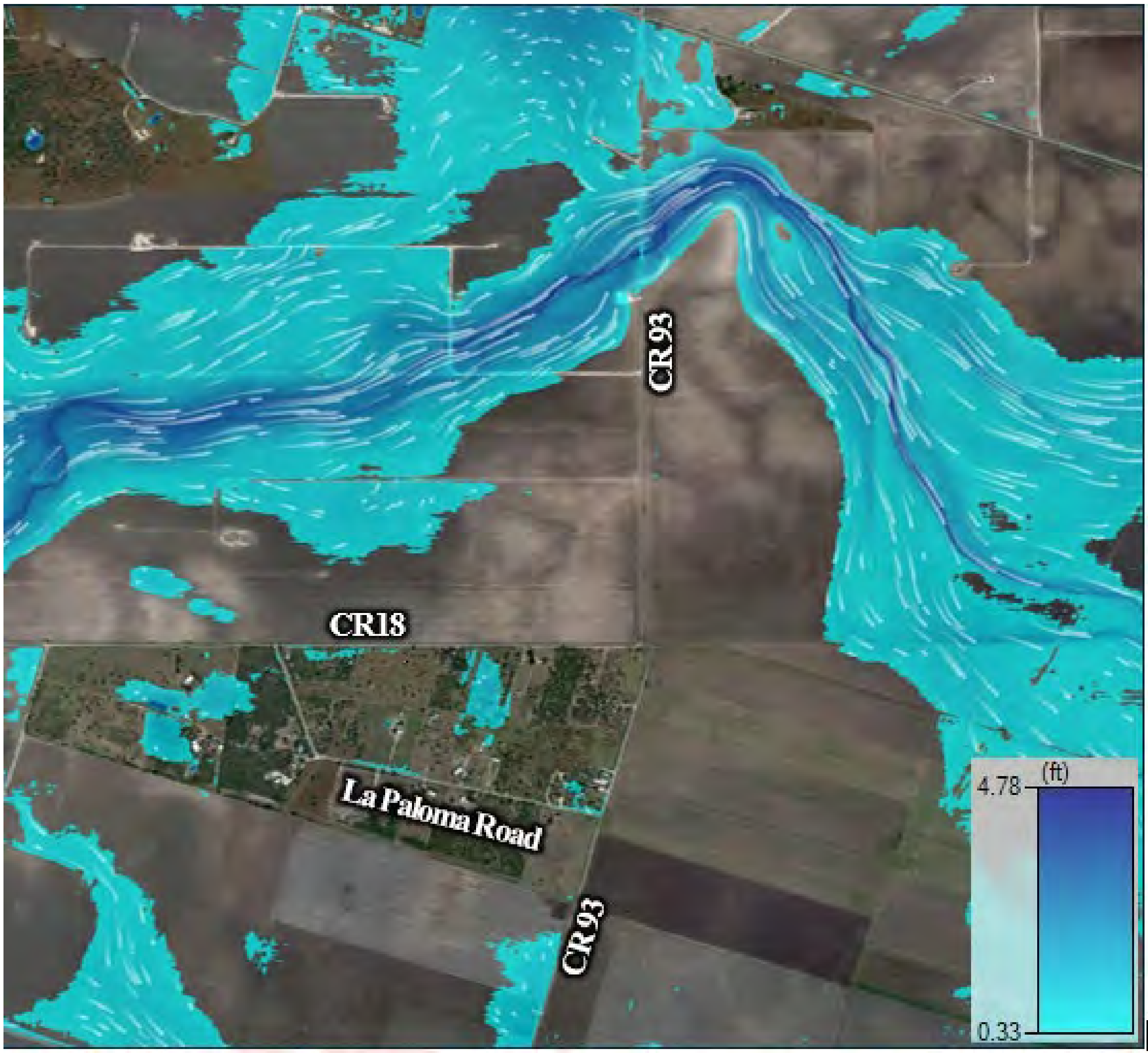

Figure 7.43 Existing Conditions 4% Annual Storm Depth – La Paloma Ranch

7.2.14.2 Proposed alternative

The proposed alternative comprises a bridge, culverts, several ditch/channel improvements and two detention ponds.

Due to the high flow through County Road 93, the proposed alternative requires upgrading the existing 6 - 36" RCPs to a 275-foot-long bridge with a 45-foot width, elevating the road by 2 feet, and some channel improvements upstream and downstream of the structure. The bridge was modeled to reduce roadway flooding without causing any adverse impact upstream and downstream of the crossing. The proposed alternative conveys the flow without overtopping the road for the 4% annual chance storm event.

Channel improvements were made along the boundaries of the residential area; this alternative provides a more defined water flow around the homes. The proposed channels have side slopes of 3:1 and bottom widths ranging from 5-15 feet. Improvements were made along County Road 18 past the intersection with County Road 93, along La Paloma Road and along County Road 93 from the intersection with La Paloma to County Road 18. The channels were placed on both sides of the road and sized as necessary. This system alleviated the minimal flooding/ponding around the residential homes.

Five different culvert structures were placed around the project area to reduce water surface elevation around roadways. Proposed culverts (5 - 5' x 2' RCBs) placed across County Road 18, which connect the two parallel channels to continue downstream through proposed culverts (6 - 5' x 2' RCBs) located at the intersection of County Roads 18 and 93. The last two culverts, both of which are 4 - 5' x 2' RCBs, can be found along La Paloma Road, transporting the flow across the road into the proposed channel improvements.

Two detention ponds are proposed to counter adverse impacts within the project area. This reduces the amount of flow that could overtop the roads. The first detention pond is located at the intersection of County Roads 18 and 93 on the left corner of the road, which is currently unoccupied land. The detention pond footprint is approximately 6.26 acres with a depth of 4 feet. The pond outlet consists of 2 – 30" RCPs, which empties directly into the proposed channel along County Road 18. The second detention pond is located south of La Paloma Road at the intersection with County Road 93. The detention pond footprint is approximately 8.77 acres with a depth of 3 feet. The pond outlet consists of 2 – 30" RCP, which empties directly into the proposed channel along La Paloma Road. The risk area’s proposed improvements are shown in **Figure 7.44**.

The proposed alternative has an OPCC of $26,473,000.

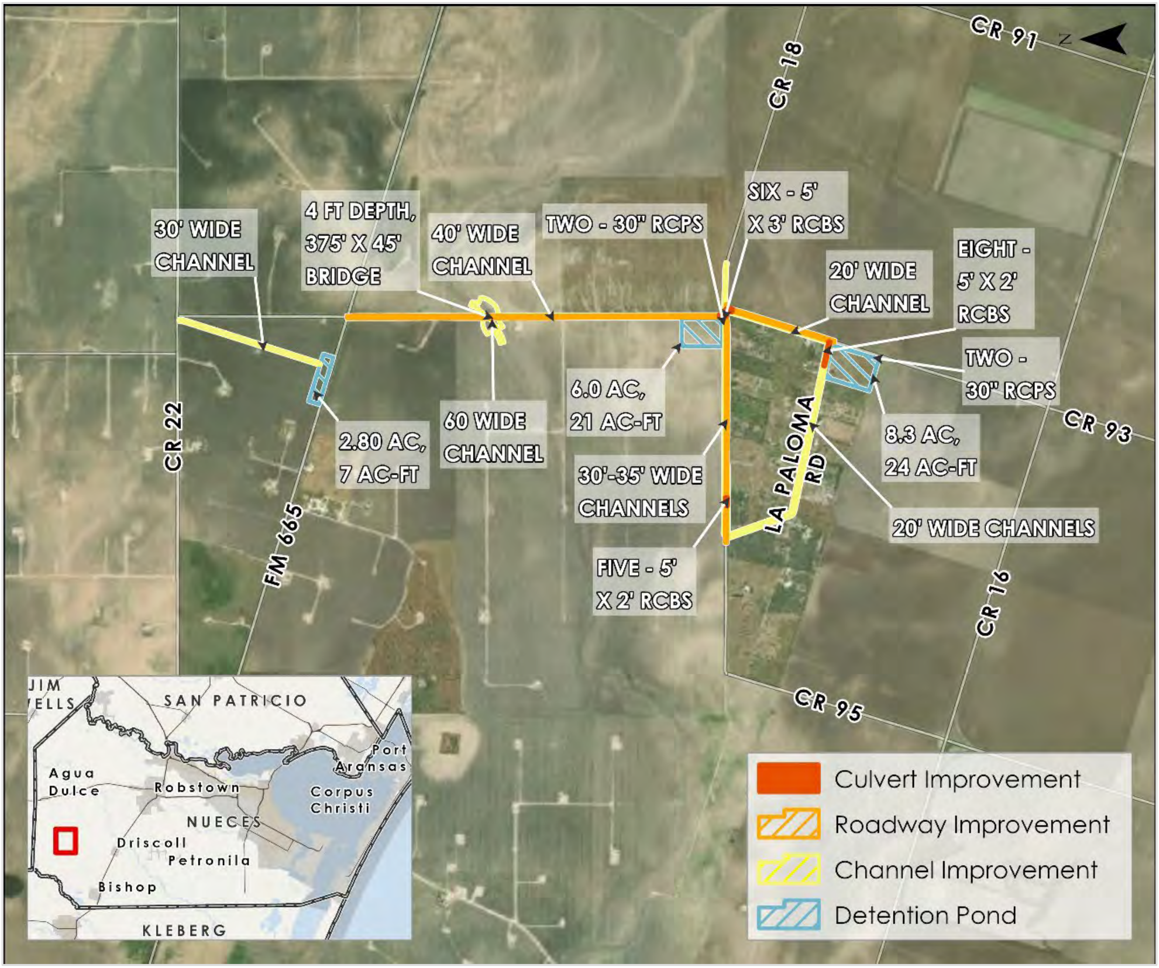

Figure 7.44 Proposed Improvements – La Paloma Ranch

7.2.14.3 Project benefit

The risk area's flood depth reduction for the 4% annual chance storm event is shown in **Figure 7.45**. The proposed alternative increases mobility along County Rd. 18 and County Rd. 93 and decreases the time to drain. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 7 is available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

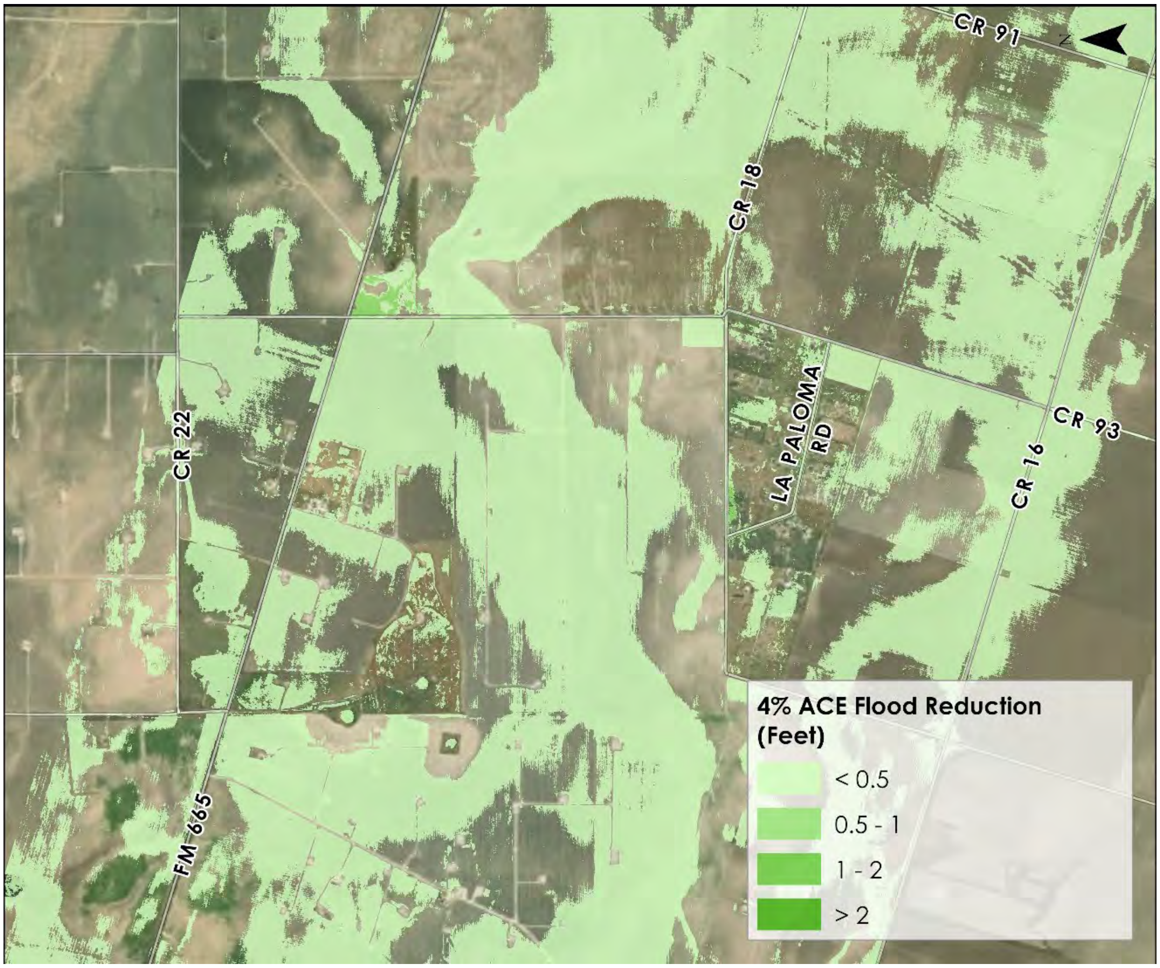

Figure 7.45 Proposed Conditions 4% Annual Storm Depth Reduction – La Paloma Ranch

7.2.15 Ranch Road & Cindy Lane

The Ranch Road & Cindy Lane (Risk Area 1) proposed alternative was initially developed to address riverine flooding issues for the 4% annual chance storm event. The scale of improvements and detention necessary, as well as the general flooding issues of the area, made improving issues for the peak of the 4% annual chance storm event beyond what is economically feasible. Instead, smaller scale ditch and culvert improvements were modeled for the 10% annual chance storm event, focusing on improved drainage time for localized flooding not attributed to riverine overflow across the area.

7.2.15.1 Existing conditions/flooding issues

The primary flooding issue results from riverine flooding overtopping the banks and flowing through the low-lying area where the at-risk neighborhood is situated, just upstream of the confluence of *Leon Creek* and *Quinta Creek*. However, for this alternative design, flooding as a result of localized rainfall was focused on. Due to the under sizing (and poor maintenance) of roadside ditches and culverts to drain localized rainfall to receiving streams, the 10% annual chance storm event causes flooding depths up to 1 foot across some residential lots in the area. The area's overall existing flooding and inundation condition is shown in **Figure 7.46**.

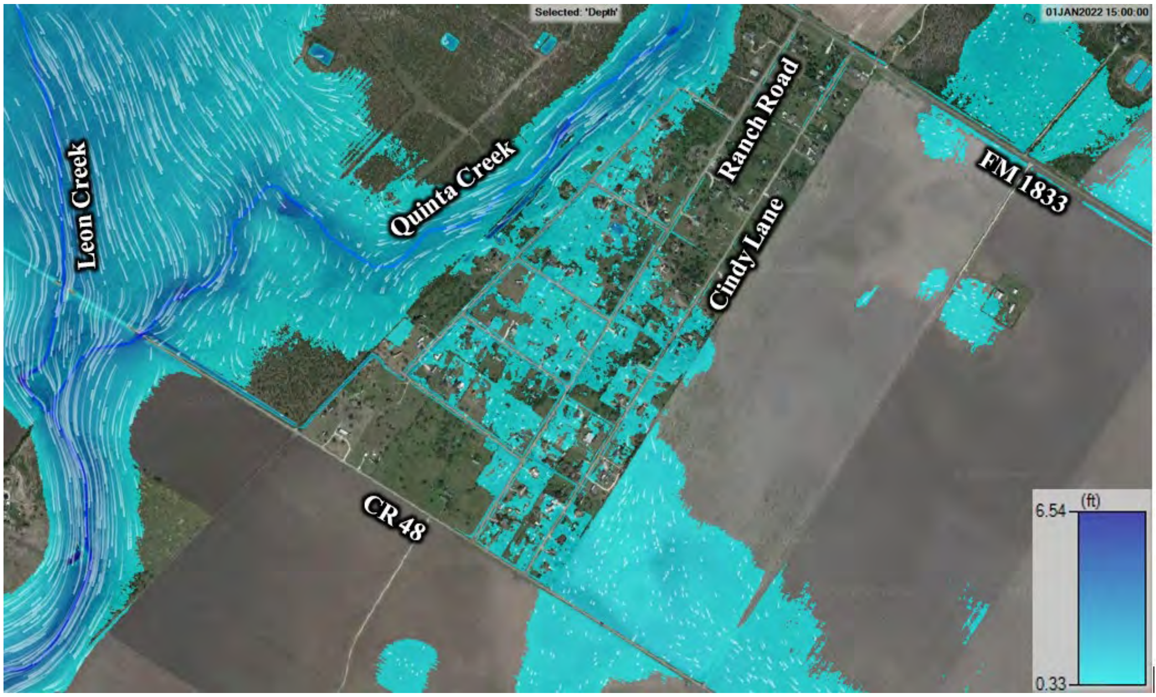

Figure 7.46 Existing Conditions 10% Annual Storm Depth – Ranch Road & Cindy Lane

7.2.15.2 Proposed alternative

The proposed design consists of a series of culvert improvements and a network of local drainage ditches/channels to allow ease of drainage in the Ranch Road & Cindy Lane risk area.

Three distinct channel systems were developed to provide flood depth reductions as well as quicker drainage times for residential lots in the area.

The first of these improves roadside ditches to a 10’ width, draining west from the center of Ranch Road, through a culvert group consisting of 3 5’ x 2’ RCBs, to a 20’ outlet channel draining directly into Quinta Creek.

The second system, like the first, improves existing roadside ditches ranging from 15’ to 20’ widths, draining west through a 20’ wide outlet channel to Quinta Creek at the crossing with CR 48. Culvert improvements for the second system include new installations of a single 36” RCP, 4 – 24” RCPs, and 3 – 12” RCPs.

The third of the channel systems includes a new 30’ wide drainage channel just to the east of the neighborhood which collects ponded water through both new and improved roadside ditches, from both the middle and southern portions of Cindy Lane. The 30’ wide channel outlets through 5 – 5’ x 2’ RCBs draining under CR 48 to what is currently flooded farmland.

The risk area’s proposed improvements are shown in **Figure 7.47**. The proposed alternative has a cost of $2,100,000.

Figure 7.47 Proposed Improvements – Ranch Road & Cindy Lane

7.2.15.3 Project benefit

The risk area's flood depth reduction for the 10% annual chance storm event is shown in **Figure 7.48.** For the 10% annual chance storm event, the proposed alternative reduces flood depth by up to 6 inches and removes seven structures from the floodplain. Proposed improvements decrease the duration and depth of standing water, improving the drain time for the Ranch Road and Cindy Lane residential areas. More detailed information on the proposed improvements and other alternatives modeled for Risk Area 1 is available in **Appendix D – Flood Mitigation Project Technical Memorandums**.

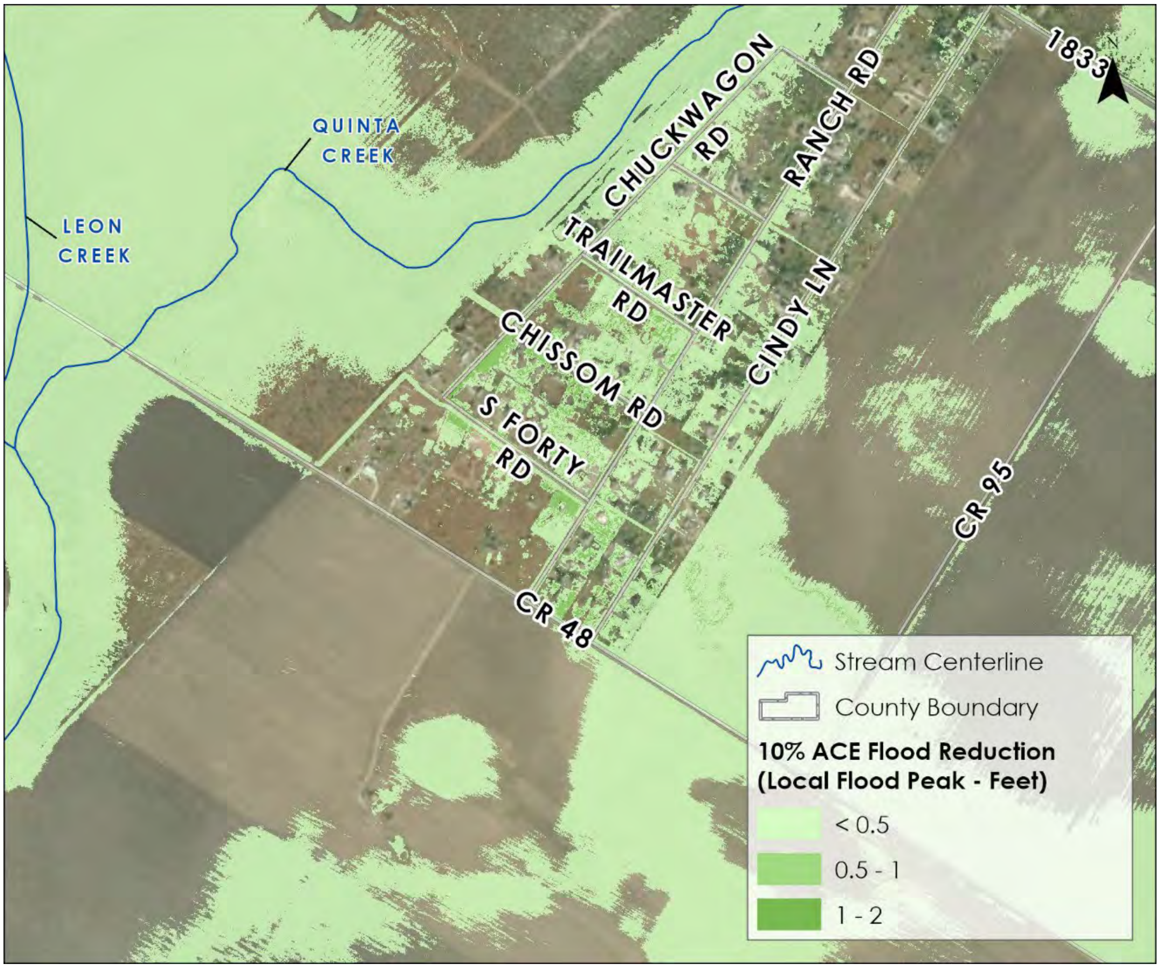

Figure 7.48 Proposed Conditions 10% Annual Storm Depth Reduction – Ranch Road & Cindy Lane

7.3 Project summaries

Below is a list of high-level summaries of the proposed alternatives. These include the types of proposed improvements, OPCC, and a summarized project benefit.

7.3.1 North Robstown

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $62,344,000 (Combined cost for North Robstown, South Robstown, and FM 1694 & TX 44 North)

Project benefit for 4% annual chance storm event

- Approximately 1.5’ of flood depth reduction across the risk area
- Eliminates sheetflow overflows into Ditch ‘A-01’
- Increase drainage conveyance
- Detention structure could be a multi-use park facility

7.3.2 South Robstown

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $62,344,000 (Combined cost for North Robstown, South Robstown, and FM 1694 & TX 44 North)

Project benefit for 4% annual chance storm event

- Approximately 1' of reduction in the western portion of the risk area
- Approximately 0.5' of reduction in developed area
- Increased mobility on multiple roadways
- Detention structure could be a multi-use park facility

7.3.3 FM 1694 & TX 44 North

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $62,344,000 (Combined cost for North Robstown, South Robstown, and FM 1694 & TX 44 North)

Project benefit for 4% annual chance storm event

- Approximately 0.5' of flood depth reduction
- Provide additional conveyance
- Detention structure could be a multi-use park facility

7.3.4 City of Driscoll

Proposed improvements

- Channel Improvement, Culvert Improvement, Roadway Improvement, Detention

Project cost

- $85,018,000

Project benefit for 4% annual chance storm event (local storm)

- 14 structures removed
- Two Driscoll School District structures were removed
- Approximately 1' of flood depth reduction throughout downtown Driscoll (western half of town)
- Mobility improvements along FM 665, now dry for 25-year local storm
- Mobility improvements throughout downtown streets
- Detention structure south of the school could be a multi-use park facility

7.3.5 Banquete

Proposed improvements

- Channel Improvement, Culvert Improvement, Roadway Improvement, Detention

Project cost

- $87,897,000

Project benefit for 4% annual chance storm event (local storm)

- 80 structures removed
- Three Banquete Independent School District structures were removed
- Approximately 1' of flood depth reduction through residential area North of State Highway 44 and in southern portions of Banquete
- Time to drain reduction
- Mobility improvements throughout Banquete and along State Highway 44
- Detention structure northwest of town could be a multi-use park facility

7.3.6 Fiesta Ranch

Proposed improvements

- Channel Improvement, Culvert Improvement, Roadway Improvement, Detention

Project cost

- $40,688,000

Project benefit for 4% annual chance storm event (local storm)

- 33 structures removed
- Approximately 1'-2' of flood depth reduction through the residential area of Fiesta Ranch
- Mobility improvement for residential area
- Detention structure could be a multi-use park facility

7.3.7 Balchuck Lane and Digger Lane

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $22,023,000

Project benefit for 4% annual chance storm event

- Seven structures removed
- Approximately 1' of flood depth reduction on the north end of Balchuck Lane and Digger Lane residential area
- Mobility improvement for Balchuck Lane and Digger Lane residential area
- Time to drain reduction
- Detention structure could be a multi-use park facility

7.3.8 Agua Dulce

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $107,448,000

Project benefit for 4% annual chance storm event

- 91 structures removed
- Eight Agua Dulce Independent School District structures were removed
- Approximately 1'-2' of flood depth reduction through the town of Agua Dulce
- Reduces water surface elevations from overtopping County Rd 105, which significantly reduces flood depths for structures east of County Road 105
- Increased mobility across County Road 105, State Hwy 44 and throughout the city of Agua Dulce
- Detention structure west of County Road 105 could be a multi-use park facility

7.3.8 Nottingham Acres

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $56,477,000

Project benefit for 4% annual chance storm event

- 16 structures removed
- Approximately 0.5' of flood depth reduction through residential area
- Mobility improvement for the Nottingham Acres residential area and County Road 22
- Time to drain reduction
- Detention structure could be a multi-use park facility

7.3.9 Indian Trails

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $10,293,000

Project benefit for 4% annual chance storm event (local storm)

- Nine structures removed
- Approximately 1' of flood depth reduction through residential area
- Mobility improvements through residential area
- Detention structure could be a multi-use park facility

7.3.10 Rancho Banquete

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $68,570,000

Project benefit for 4% annual chance storm event (local storm)

- 18 structures removed
- Approximately 1’ of flood depth reduction through residential area
- Time to drain reduction
- Mobility improvement along County Road 42 and residential area
- Detention structure could be a multi-use park facility

7.3.11 Callicoatte Farms

Proposed improvements

- Channel Improvement, Culvert Improvement

Project cost

- $6,692,000

Project benefit for 4% annual chance storm event

- Approximately 0.5’ of flood depth reduction
- Increased mobility at County Road 44 and FM 1694 intersection
- Time to drain reduction across the entire project area

7.3.12 South Prairie Estates

Proposed improvements

- Channel Improvement, Culvert Improvement, Detention

Project cost

- $39,673,000

Project benefit for 4% annual chance storm event

- 2 structures removed
- Approximately 1’ of flood depth reduction east of County Road 47
- Mobility improvement for South Prairie Road and County Road 47
- Time to drain reduction
- Detention structure could be a multi-use park facility

7.3.13 La Paloma Ranch

Proposed improvements

- Channel Improvement, Culvert Improvement, Roadway Improvement, Detention

Project cost

- $26,473,000

Project benefit for 4% annual chance storm event

- Increased mobility along La Paloma Road
- Time to drain reduction

- Approximately less than 0.5’ of flood depth reduction
- Detention structure could be a multi-use park facility

7.3.14 Ranch Road and Cindy Lane

Proposed improvements

- Channel Improvement, Culvert Improvement

Project cost

- $2,100,000

Project benefit for 10% annual chance storm event

- Seven structures removed
- Approximately 3”- 6”’ of flood depth reduction in residential area
- Decrease in duration and depth of standing water for Ranch Road and Cindy Lane residential structures

8 Benefit/cost analysis

The TWDB funded and guided the development of a benefit cost analysis (BCA) input interface in the form of an Excel spreadsheet that works in conjunction with the FEMA Benefit-Cost Analysis Toolkit. TWDB BCA Input Tool V1.1 and V1.2 were utilized to develop the economic analysis of the flood reduction alternatives. For each alternative, the baseline existing conditions and post-project flood depths were associated with structures in the project area and evaluated for baseline and post-project damages within the TWDB input spreadsheet. Additional benefits were accounted for, such as reduced street flooding, structure damages and associated loss of function, utility loss of function, agricultural damages, and low water crossings replacements, when applicable to proposed project areas.

In conjunction with the TWDB BCA Input tool, the calculated baseline and post-project damage numbers were incorporated into the FEMA BCA Toolkit 6.0. The FEMA Toolkit calculated the project benefit, which was used to calculate the overall project BCA for each flood risk area. These results are presented in **Table 8.1** below.

Table 8.1 Benefit Cost Ratio

Risk Area	BCA
RA 1: Ranch & Cindy Park*	0.5
RA 3: Indian Trails	0.1
RA 4: Rancho Banquete	0.02
RA 5: Banquete	0.1
RA 6: Agua Dulce	0.04
RA 7: La Paloma Ranch	0.002
RA 8, 9, 10: North Robstown, Robstown Drains, FM 1694 & TX 44 North	>1
RA 11: Callicoatte Farms	0.02
RA 19: Driscoll	0.3
RA 20: Fiesta Ranch	0.1
RA 26: Balchuck Lane & Digger Lane	0.05
RA 27: Nottingham Acres	0.03
RA 28: South Prairie Estates	0.01

** BCA based on alternative for 10% annual chance storm event*

9 Sedimentation analysis

This study investigated erosion-related issues in the Petronila Creek watershed to provide an integrated analysis and holistic understanding of flood damage to support future watershed management. A hybrid 1D-2D HEC-HMS (Version 4.10) model was developed to assess the impacts of multiple rainfall frequency events on sediment transport in the Petronila Creek Watershed. An advantage of using HEC-HMS in comparison to HEC-RAS is that HEC-HMS offers the unique capability to model watershed hydrology in a one-dimensional framework. In conjunction with this, it also facilitates the simulation of hydraulic processes and sediment transport in a two-dimensional setting. This multi-dimensional approach optimizes computational efficiency, making it a robust choice for comprehensive watershed studies.

The model simulates the sediment deposition, erosion and sediment load produced within the Petronila Creek Watershed, specifically along the Petronila Creek mainstem. Upstream model extents start within the Petronila Creek subbasin PET-035, with downstream modeling extents ending at Petronila Creek subbasin PET-050.

9.1 HMS modeling

Sediment transport is a complex process that can show a significant spatial variation within the watershed and even within each sub-watershed (Pak et al., 2008). While simulating the sediment transport as a one-dimensional process can provide a general idea of the watershed characteristics, this approach does not provide any details regarding the spatial variation of the sediment transport (erosion, deposition) within the watershed. As such, a hybrid (1D-2D) model was adopted to better simulate the sediment transport in the Petronila watershed, focusing on the Petronila Creek mainstem. As a result, a detailed 2D grid was used to model the hydrodynamics and the sediment transport in the Petronila Creek watershed, while a 1D model was implemented for the rest of the watershed, as shown in **Figure 9.1**. The hybrid approach provided a computationally effective model considering a relatively larger domain while requiring minimal boundary condition setup.

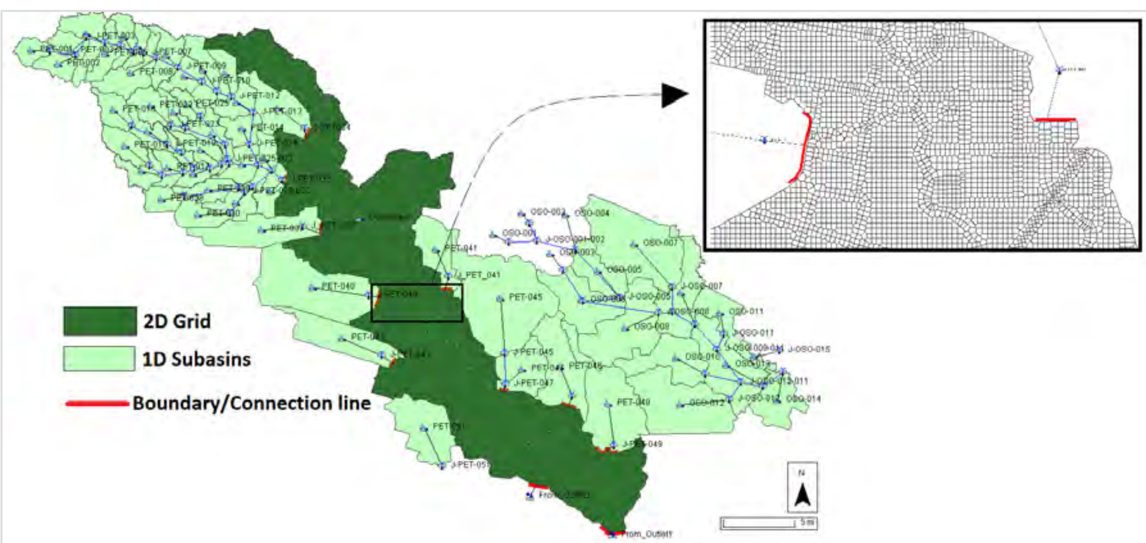

Figure 9.1 Petronila and Oso Watersheds 1D/2D Hybrid HEC-HMS Model

To assure the quality of the grid in representing the stream flows in the reaches, meshes were imported from the 2D HEC-RAS models developed for this study. HEC-HMS retains the mesh parameters imported from HEC-RAS, such as Manning's "N" value and the boundary conditions, allowing a smooth transition from HEC-RAS to HEC-HMS. HEC-HMS requires a terrain model to perform the 2D computations in the watershed. A terrain mesh size of 100 ft x 100 ft was used to be consistent with the rest of the Study. Adjacent basins outside the mesh area were connected using normal depth boundary conditions.

The Modified Universal Soil Loss Equation (MUSLE) was used for sediment transport, accounting for the actual stream flow rather than the rainfall intensity. This method incorporates rainfall patterns, soil type and topography. **Table 9.1** provides MUSLE factors used for sediment modeling in this study.

Table 9.1 MUSLE Method Parameter Values

Parameter	Value
Erodibility Factor	0.6
Topographic Factor	5
Cover Factor	0.1
Practice Factor	0.75
Threshold (CFS)	200
Exponent	0.5

The soil in the area was represented by a gradation curve obtained from the Gridded Soil Survey Geographic Database (gSSURGO) (**Figure 9.2**). The current work assumes a homogenous soil distribution for all the subbasins (i.e., implementing the same soil gradation curve).

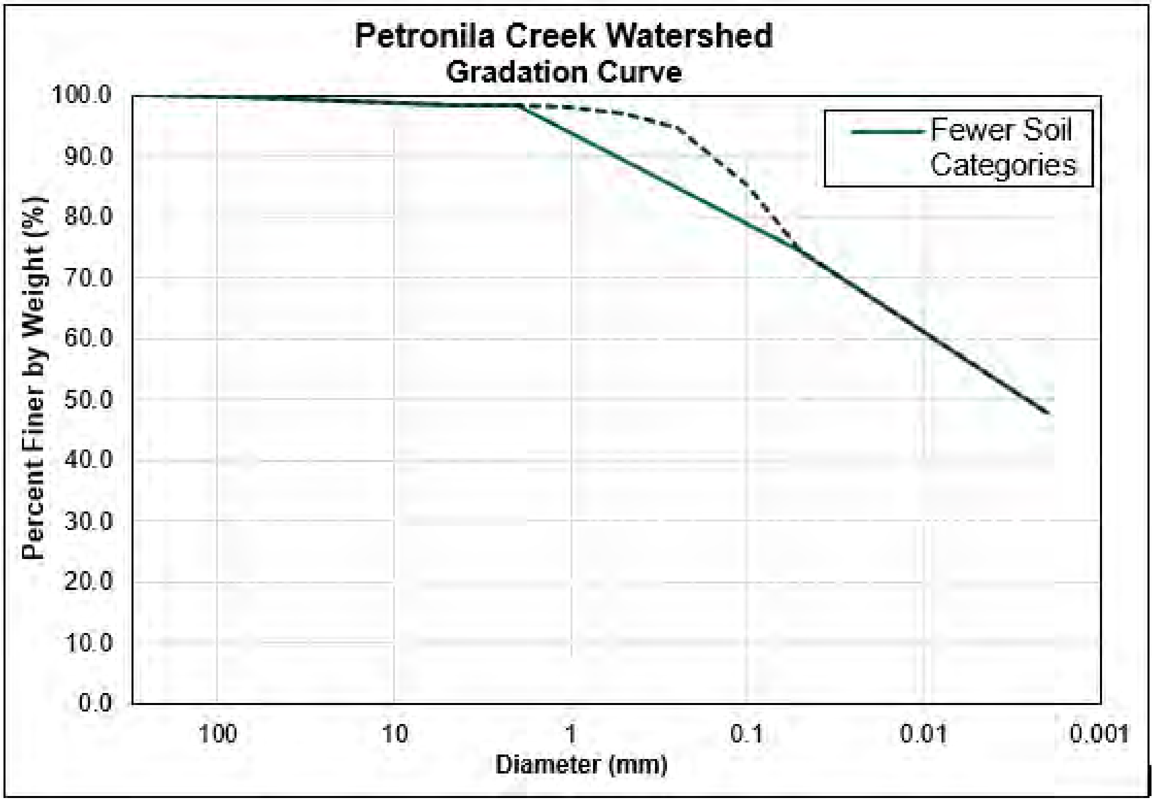

Figure 9.2 Soil Gradation Curve

9.2 Preliminary results

The sediment concentration in the Petronila Creek watershed is depicted in **Figure 9.3** at the peak of the 10% annual chance storm event (maximum depth of 16 inches). The results illustrate the spatial heterogeneity of the sediment concentration across the watershed, highlighting the areas of high concentrations.

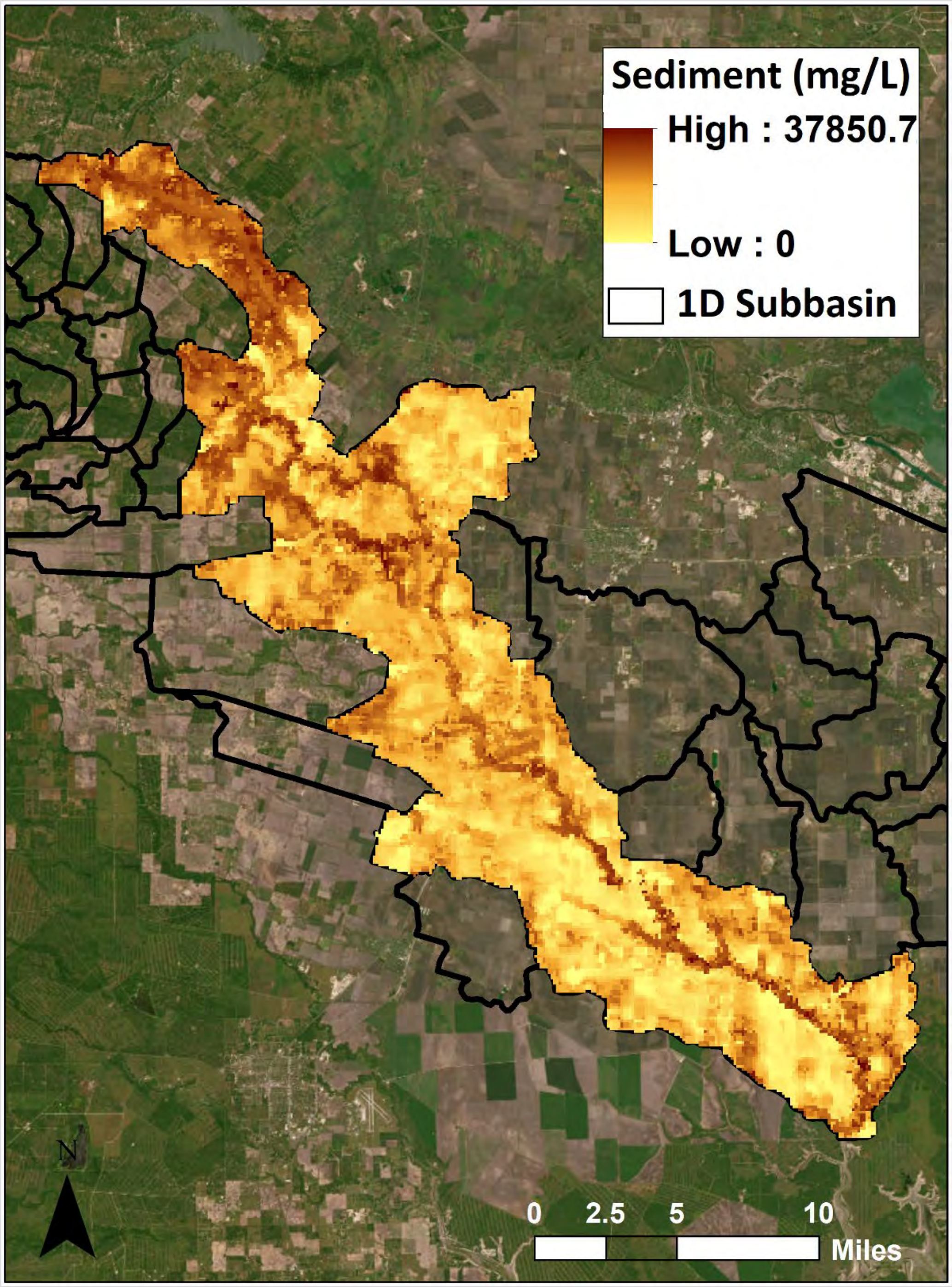

Figure 9.3 Sediment Concentration (mg/l) across Petronila Creek Watershed for 10% annual chance storm event (16 inch depth).

The maximum sediment concentration at the outlet (**Figure 9.4**) shows a value of 1,800 mg/l, which aligns with the values reported by Ockerman and Fernandez (2010) in their study. The model results also show that the maximum load at the outlet can reach up to 30 tons on day 1, consisting of 16 tons of clay, 8 tons of silt and 6 tons of sand, while gravel showed a minimum value (<0.5 ton).

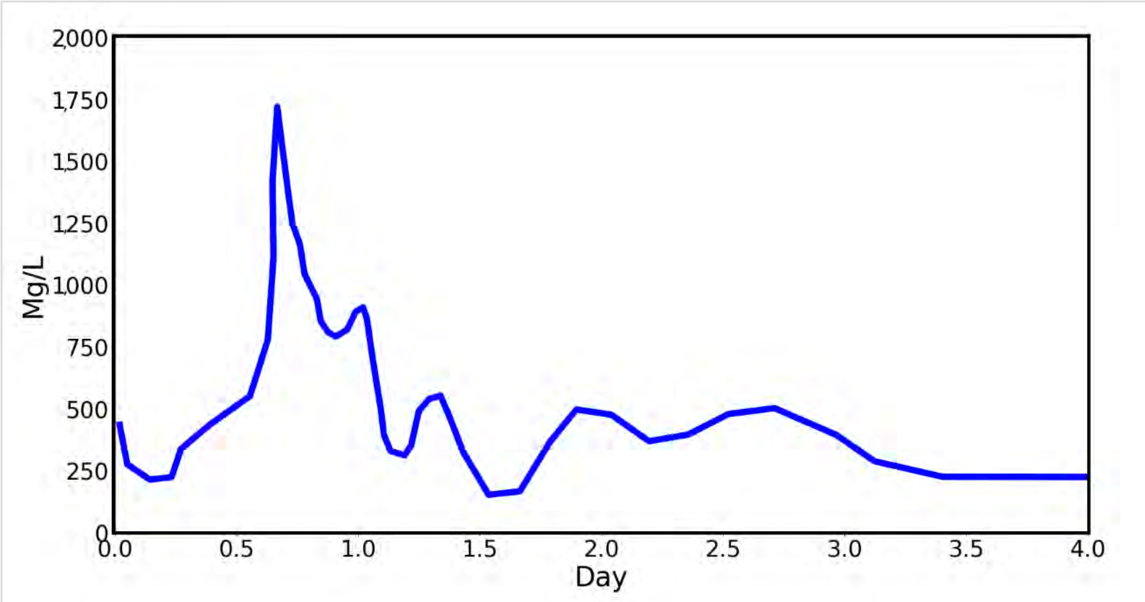

Figure 9.4 Sediment Concentration at the Petronila Creek Outlet for 10% annual chance storm event

10 Environmental constraints

An environmental constraints analysis was conducted for the 15 flood risk areas that included a review of readily available geospatial data sources to identify the following: potential waters of the United States (WOTUS), threatened and endangered species habitat, hazardous materials concerns, cultural resources, and other resources that may require local, state or federal regulatory coordination and/or permitting as part of the design/construction process. Data sources reviewed from other governmental agencies included USGS, U.S. Fish and Wildlife Service (USFWS), Federal Emergency Management Agency (FEMA), Texas Parks and Wildlife Department (TPWD), Natural Resource Conservation Service (NRCS), Railroad Commission of Texas (RCC), Texas Commission on Environmental Quality (TCEQ), U.S. Environmental Protection Agency (USEPA), Texas Department of Transportation (TxDOT), and Texas Archeological Research Laboratory (TARL). A summary of environmental concerns within each of the 15 flood risk areas is presented below in **Table 10.1**, and the complete Environmental Constraints Analysis is included in **Appendix E**.

Table 10.1 Summary of Environmental Concerns within the 15 Flood Risk Areas

Flood Risk Area (FRA)	Name	Water Resources	Biological Resources	Hazardous Material	Cultural Resources
1	Ranch Lane & Cindy Lane	Two stream/river features (e.g., Leon Creek, Quinta Creek) and 20 emergent wetland feature(s) are mapped within the FRA. The FRA is not located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	No concerns were identified.
3	Indian Trails	A stream/river feature and an emergent wetland feature are mapped within the FRA. The FRA is not located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species. One TNXDD element occurrence record for the state-threatened, black-spotted newt is located within 1 mile of the FRA.	No concerns were identified.	No concerns were identified.

Flood Risk Area (FRA)	Name	Water Resources	Biological Resources	Hazardous Material	Cultural Resources
4	Rancho Banquete	No concerns were identified. The FRA is not located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	No concerns were identified.
5	Banquete	A stream/river (e.g., Banquete Creek) is mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	Three sites were identified but are considered low-risk. No additional investigations are warranted.	Two previously documented archeological sites are located within the FRA.
6	Agua Dulce	No concerns were identified. The majority of the FRA is located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	No concerns were identified.
7	La Paloma Ranch	A stream/river and emergent wetland feature(s) are mapped within the FRA. The FRA is not located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	No concerns were identified.
8	North Robstown	A stream/river and canal/ditch are mapped within the FRA. The FRA is not located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	One site was identified but is considered low-risk. No additional investigations are warranted.	No concerns were identified.
10	South Robstown	A canal/ditch and riverine feature are mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	Five sites were identified but are considered low-risk. No additional investigations are warranted.	No concerns were identified.

Flood Risk Area (FRA)	Name	Water Resources	Biological Resources	Hazardous Material	Cultural Resources
11	Callicoatte Farm	No concerns were identified. Portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species. One TNXDD element occurrence record for the state-threatened sheep frog is located within 1 mile of the FRA.	No concerns were identified.	No concerns were identified.
12	FM 1694 & TX 44 North	A canal/ditch, riverine, and emergent wetland feature(s) are mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	One site was identified but is considered low-risk. No additional investigations are warranted.	No concerns were identified.
19	Driscoll	A forested/shrub wetland and riverine feature(s) are mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	Four sites were identified but are considered low-risk. No additional investigations are warranted.	No concerns were identified.
20	Fiesta Ranch	A stream/river (e.g., Petronila Creek) and riverine feature are mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	No concerns were identified.

Flood Risk Area (FRA)	Name	Water Resources	Biological Resources	Hazardous Material	Cultural Resources
26	Balchuck Lane & Digger Lane	A stream/river and riverine feature are mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	No concerns were identified.
27	Nottingham Acres	A canal/ditch is mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	No concerns were identified.
28	South Prairie Estates / Rabbit Run	A canal/ditch and riverine feature is mapped within the FRA and portions of the FRA are located within the 1% floodplain.	The FRA has the potential to contain suitable habitat for species.	No concerns were identified.	One previously documented archeological site is located within the FRA.

Notes:

Cells with blue fill indicate that a potential environmental concern has been identified within the FRA.

For water resources, waterbodies and wetlands within the FRAs may be considered waters of the U.S. and are subject to U.S. Army Corps of Engineers (USACE) regulatory authority. If the project(s) necessitate(s) unavoidable impacts to WOTUS, USACE permits may be required under Section 404 of the Clean Water Act.

For biological resources, best management practices for avoiding impacts to wildlife and potential habitat for wildlife during construction should be implemented.

Coordination with the THC under the Antiquities Code of Texas would be required for cultural resources before any ground-disturbing activity within the FRAs.

Desktop data reviews cannot substitute for on-site evaluations conducted by qualified personnel. On-site evaluations are recommended to determine actual project impacts to environmental constraints.

Additional actions regarding potential environmental impacts may be required based on assessing potential environmental constraints within the FRAs.

As required by the rules of the Texas Water Development Board (TWDB), 31 Texas Administrative Code (TAC) § 363.14 and 363.16, an environmental review should be performed for the FRAs if the County is proposing to use financing from the Flood Infrastructure Fund Program for acquisition and construction of the proposed projects. The environmental review would consist of the preparation and submittal of an Environmental Data Form for the FRAs to the TWDB for an environmental determination.

The U.S. Army Corps of Engineers (USACE) administers and enforces Section 404 of the Clean Water Act (CWA). Under the CWA, a permit is required to discharge dredged or fill material into WOTUS. Waterbodies and wetlands within the FRAs may be considered WOTUS and are subject to the USACE regulatory authority. If the project(s) necessitate(s) unavoidable impacts to WOTUS, USACE permits may be required under the CWA. To facilitate avoidance/minimization of impacts to WOTUS, Halff recommends conducting an on-the-ground delineation of aquatic resources within the FRAs following the USACE “Wetland Delineation Manual, Technical Report Y-87-1” and the “Regional Supplement to the Corps of Engineers Wetland Delineation Manual: Great Plains Region (Version 2.0)” and preparation of a WOTUS delineation report to satisfy the jurisdictional determination requirement for future permits, if necessary.

To demonstrate compliance with the Endangered Species Act (ESA), Halff recommends conducting threatened and endangered species and habitat (T&E) assessments within the FRAs, including evaluating federal and state-listed threatened and endangered species for Nueces County.

Coordination with THC under the Antiquities Code of Texas would be required before any ground-disturbing activity within the FRAs. In addition, if the project includes any federal funding or permitting, compliance with Section 106 of the National Historic Preservation Act would be evoked, requiring an evaluation of indirect (e.g., visual) effects to above-ground historic properties identified within the FRAs and adjacent properties.

11 Capital improvement plan and funding alternatives

Table 11.1 FMP Ranking based on BCAs

Selected Risk Area Number	Selected Risk Area Name	Project Type Description	Cost	BCA
8, 10, 12	North Robstown, Robstown Drains, FM 1694 & TX 44 North	Detention, Channel, Culvert, and Roadway Improvements	$62,344,000	>1
19	Driscoll	Detention, Channel, Culvert, and Roadway Improvements	$85,018,000	0.3
5	Banquete	Detention, Channel, Culvert, and Roadway Improvements	$87,890,000	0.1
20	Fiesta Ranch	Detention, Channel, Culvert, and Roadway Improvements	$40,688,000	0.1
26	Balchuck Lane & Digger Lane	Detention, Channel, and Culvert Improvements	$22,023,000	0.05
6	City of Agua Dulce	Detention, Channel, and Culvert Improvements	$107,448,000	0.04
27	Nottingham Acres	Detention, Channel, and Culvert Improvements	$56,477,000	0.03
3	Indian Trails	Detention, Channel, and Culvert Improvements	$10,293,000	0.1
4	Rancho Banquete	Detention, Channel, and Culvert Improvements	$68,570,000	0.02
11	Callicoatte Farm	Channel and Culvert Improvements	$6,692,000	0.02
28	South Prairie Estates	Detention, Channel, and Culvert Improvements	$39,673,000	0.01
7	La Paloma Ranch	Detention, Channel, Culvert, and Roadway Improvements	$26,473,000	0.002
1*	Ranch Road and Cindy Lane	Channel, and Culvert Improvements	$2,100,000	0.5

** BCA based on alternative for 10% annual chance storm event*

Potential funding mechanisms and opportunities

This section defines some current and traditional funding opportunities that the County, Drainage District, or individual communities may seek to assist in funding drainage projects. Some funding assistance applications require evidence of flood damages occurring due to a nationally declared disaster and/or must be in areas with low to moderate income levels. Some funding assistance comes from full or partial grants, while others are low-interest loans. The sections below define the most common funding assistance opportunities and is not a complete list. Regardless, much of the data and analysis presented within this Study is needed for many of the funding options described below.

11.1.1 Non-disaster funding assistance opportunities

Listed below are funding opportunities that are aimed at helping communities reduce their flood risks. The availability of these funding opportunities is dependent on federal and state budgets allocating funding to these programs. The funding programs listed below are administered by the Federal Emergency Management Agency (FEMA) or the Texas Water Development Board.

11.1.1.1 Building Resilient Infrastructure and Communities (BRIC) program.
BRIC is a new FEMA pre-disaster hazard mitigation program that replaces the existing Pre-Disaster Mitigation (PDM) program. This is a FEMA program for which local communities apply through the Texas Department of Emergency Management (TDEM) as a sub-applicant and are limited by the program's available funding. The major program details are outlined below.

1. Cost Share (typically): 75% federal grant / 25% local share
2. Small, impoverished communities are eligible for increasing cost share up to 90% federal grant / 10% local share
3. Projects must be cost-effective and designed to increase a community's resilience and public safety, reduce injuries and loss of life, and reduce damage and destruction to property, critical services, facilities, and infrastructure.
4. Must prove to be cost-effective (have a BCR > 1.0)
5. Must have a current FEMA-approved hazard mitigation plan at the time of application
6. Must be in conformance with all applicable environmental planning and historic preservation (EHP) laws, regulations, executive orders, and agency policies
7. Under National Competition for Mitigation Projects, project caps are $50 million

More information is available at www.fema.gov/grants/mitigation/building-resilient-infrastructure-communities

11.1.1.2 Flood mitigation assistance (FMA)
This is one of FEMA's Hazard Mitigation Assistance programs that the TWDB administers for the state of Texas. The funding is limited by the available funding of the program.

- Cost Share (typically): 75% federal grant / 25% local share
- For properties that are insured under the National Flood Insurance Program (NFIP) at the time of the application and have suffered repetitive loss, the federal cost share portion can be increased to 90% or 100% federal grant, depending on the severity of the losses

- Projects must reduce overall risk to the population and structures from future hazard events while also reducing reliance on federal funding from future disasters
- Typical projects include the acquisition of insured structures and real property; relocation, elevation or demolition of insured structures; or flood reduction projects
- Must prove to be cost-effective (have a BCR > 1.0)
- Must be identified in FEMA-approved hazard mitigation plan
- Project caps are $30 million per flood mitigation project

More information is available at www.twdb.texas.gov/flood/grant/FMA.asp

11.2.1.3 Clean water state revolving fund (CWSRF)

This program is administered by the Texas Water Development Board (TWDB) and consists of a two-part application process. This program provides project financing through a low-interest loan for local communities and water supply corporations. Areas that meet the program's qualifications for disadvantaged communities are eligible for loan forgiveness, a term given to the part of the loan that the entity is not required to repay.

- Low-interest loan with a repayment period of up to 30 years
- Multi-year commitments are optional
- Entities using these programs achieve substantial savings by receiving below-market interest rates and, in some instances, principal forgiveness (may be available for entities that qualify as disadvantaged communities and/or projects with green components)
- CWSRF loans may be used for the planning, design and construction of flood control mitigation
- Construction projects must be in conformance with National Environmental Policy Act (NEPA)-type environmental and historical review
- Entities receiving assistance over $500,000 must adopt a water conservation and drought contingency plan (to be updated every 5 years)
- Davis-Bacon wage rate requirements for construction projects
- American Iron and Steel requirements for construction projects
- Applications for funding are accepted year-round but must be included in the current CWSRF Intended Use Plan (the deadline to be included is early in the year's first quarter) to receive funding
- No maximum funding limits

More information is available at www.twdb.texas.gov/financial/programs/CWSRF/

11.2.1.4 Flood infrastructure fund (FIF)

This program is also administered by the TWDB and consists of a two-part application process. This program provides project financing through a 0% interest loan and grants for flood control, flood mitigation, and drainage projects for cities, counties, and districts. Texas voters approved a constitutional amendment in November of 2019, which created the Flood Infrastructure Fund (FIF). Applicants were invited to apply for funding assistance for the first time under this program in June 2020.

- Cost Share: % grant / local share: The amount of grant assistance an entity is eligible for varies depending on the category applying for, the income levels of the project beneficiaries relative to the state average, the unemployment rate, population decline, whether a project has green or nature-based elements, and/or population size. Funding assistance opportunities range from 100% grant to 100% loan (at 0% interest)
- Four categories of potential projects: (1) flood protection planning for watersheds, (2) planning, acquisition, design, construction and rehabilitation, (3) federal award matching funds, and (4) measures immediately effective in protecting life and property
- Must prove to be cost-effective, except for watershed studies
- Requires MOUs from affected entities within a watershed
- Applications for funding are accepted year-round but must be included in the current CWSRF Intended Use Plan (the deadline to be included is early in the year's first quarter) to receive funding
- $23 million funding limit per project

More information is available at www.twdb.texas.gov/financial/programs/fif/index.asp

11.2.1.5 Federal Clean Water Act (CWA) section 319(h) grants

Administered by the Texas Commission on Environmental Quality (TCEQ) and the Texas State Soil and Water Conservation Board, this program provides grants to develop and implement watershed plans, restore impaired watersheds, and protect waterbodies. TCEQ solicits project proposals each summer and awards grants the following year for projects lasting up to three years. These grants fund 60% of the cost of the selected projects; applicants provide the other 40% of the cost as a match, which may include in-kind services by volunteers or partner organizations. Priority is given to developing and implementing watershed protection plans; however, implementing low-impact development facilities is also considered an eligible activity.

More information is available at https://www.tceq.texas.gov/waterquality/nonpoint-source/grants

11.1.2 Disaster funding assistance opportunities

Listed below are funding opportunities made available after the president has declared a certain event a national disaster. The applications for funding assistance are usually only available for a limited period and are administered by FEMA or HUD.

11.2.2.1 Community development block grant: mitigation (CDBG-MIT)

Funding for this program comes from the U.S. Department of Housing and Urban Development (HUD) through the Community Development Block Grant Mitigation Program (CDBG-MIT). The Texas General Land Office administers this program and provides project financing through 100% grants for cities, counties, and districts for flood control, flood mitigation, and drainage projects.

- Cost Share: 100 % grant
- Funds allocated using a risk-based, mitigation needs assessment focused on impacts/risks to community lifeline (official action plan released February 2020)

- Eligible activities include local and regional mitigation activities to improve long-term community resilience
- Large emphasis on low-moderate income (LMI) areas
- Entities are limited to two applications per disaster.
- Each proposed project must have a total estimated cost between $3 million to $10 million

More information is available at www.twdb.texas.gov/flood/grant/FMA.asp

11.2.2.2 Community development block grant: disaster recovery (CDBG-DR)

Funding for this program comes from the U.S. Department of Housing and Urban Development (HUD) through the Community Development Block Grant Disaster Recovery (CDBG-DR). CDBG-DR grants provide impacted areas housing, infrastructure, and economic revitalization assistance. The CDBG-Disaster Recovery (CDBG-DR) program provides additional funding to increase resilience to disasters by lessening the impact of future disasters.

- Cost Share: 100 % grant
- In response to presidentially declared disasters, CDBG-DR grants work to rebuild affected areas and provide crucial seed money to start the recovery process
- Funds cover a broad range of recovery activities
- Can help communities and neighborhoods that otherwise might not recover due to limited resources
- Large emphasis on LMI
- Communities must have significant unmet recovery needs and the ability to implement disaster recovery program
- Project caps are $30 million per flood mitigation project

11.2.2.3 Hazard mitigation grant program (HMGP)

This is a FEMA program for which local communities apply through TDEM as sub-applicants and are limited by the program's available funding. The major program details are outlined below.

- Cost Share (typically): 75% federal grant / 25% local share
- Authorized under Presidential major disaster declaration
- Amount of funding available based upon the total Federal assistance from FEMA for disaster recovery
- Must have a FEMA-approved Hazard Mitigation Action Plan
- All projects must prove to be cost-effective to be eligible (BCR > 1.0)
- Limited funding is also available for initiative projects (public awareness, enhanced flood warning systems, etc.) and development of hazard mitigation plans

More information is available at https://www.fema.gov/grants/mitigation/hazard-mitigation

11.3 Texas Water Development Board regional flood planning

In 2020, the TWDB created regional flood planning groups (RFPGs) for each of the major watersheds in Texas. The purpose of these groups is to collect information and quantify the need for flood mitigation projects and best management practices throughout each watershed. As described in Chapter 7, the Study team has been actively coordinating with the Nueces River Basin RFPG (Region 13) so that the proposed mitigation projects, as well as risk areas in need of further study, have been included in this first Regional Flood Plan Report. Projects will be categorized across the basin, and there is the possibility (not yet determined) that projects must be included in the regional plans to be eligible for future state or federal funding opportunities.

More information is available at https://www.nueces-rfpg.org/

11.4 TxDOT funding

Transportation funding is available through various regional, state, and federal funding mechanisms. For Nueces County, the primary regional agency that manages funds for state and federal transportation funding lies with the Corpus Christi Metropolitan Planning Organization (CCMPO). The CCMPO is an independent local (covering Nueces and San Patricio Counties) government transportation agency created by federal law to provide local direction and allocate state and federal funding for a wide range of transportation facilities and services. One of their primary project planning mechanisms, which prioritizes local projects, is through the Transportation Improvement Program (TIP). Several projects identified within the Study are expected to have common infrastructure improvement elements; creating a dual purpose in improving drainage and transportation infrastructure. These shared infrastructure projects have the potential of being included in the TIP and eligible for future funding. Additional cost-sharing opportunities include the Surface Transportation Block Grant Program (STPG), which provides flexible funding for localities to preserve the conditions and performance on any Federal-aid highway, bridge and tunnel projects on any public road, pedestrian and bicycle infrastructure, and transit capital projects.

More information is available at https://www.corpuschristi-mpo.org/.

Throughout the Study process, the project team coordinated with TxDOT Corpus Christi district personnel to update their planning team on the efforts and proposed projects of the study. In particular, the South Prairie Estates project is directly adjacent to an ongoing expressway expansion design for SH 286 between FM 43 (Weber Rd) and FM 2444 (S Staples). Drainage improvements on SH 286 are currently being developed, and the proposed improvements shown on the S. Prairie Estates project could provide some mutual benefit for both projects. In the coming months, more coordination and discussions should be conducted to further explore these mutual benefits. The project team will also provide the Corpus Christi District with locations of drainage improvements within and adjacent to TxDOT right-of-way throughout the study area.

12 TWDB public meetings and stakeholder outreach

Stakeholder outreach and public participation played an important role in the development of the Study, the first of its kind for the basin. Not only was stakeholder and public feedback crucial to identify and confirm flood risk and project needs in the study area, but collecting data from these communities was necessary to better understand the local flooding issues when developing the regional study. TWDB typically requires a minimum of three public meetings for Category 1 FIF Projects; however, additional public meetings for the Tri-County DMP Study were held due to the extensive study area of the four HUC-10s and the partnership between the three counties and NCDD2. The meetings were held at a central location for all three counties at the Richard M. Borchard Fairgrounds in Robstown, Texas.

Nueces County publicized the public meetings via social media and the county's website. For each TWDB public meeting, an informative flyer was developed for the counties and NCDD2 to post on their social media accounts. Nueces County typically sent email blasts and news releases summarizing the event details three to four weeks in advance to their contacts database of citizens who signed up to receive county notifications. These meetings were open to the public and complied with both Senate Bill 8 and the Texas Open Meetings Act.

12.1 TWDB public meetings

Five TWDB public meetings were held during the 18-month project study period to provide updates from the Consultant Team, discuss project tasks, offer the public an opportunity to provide input and feedback and address questions during the interactive sessions at each meeting. In addition to the TWDB public meetings, the Consultant Team hosted individual drainage workshops in Banquete, Driscoll, Petronila, Robstown and London as part of the public engagement efforts for the regional study (reference Chapter 2 for additional information). The public meetings and workshops were conducted to collect flood risk data and allow the public to review and validate the hydrology/hydraulic computer models and mapping of the Baffin Bay and South Corpus Christi Bay watersheds for the study area.

12.1.1 Project kick-off meeting

The Tri-County DMP Study was started with the first meeting held from 6:00 to 8:00 p.m. on February 23, 2022, at the Richard M. Borchard Fairgrounds-Ballroom A in Robstown, Texas. Over 50 people attended the kick-off meeting, representing Jim Wells, Nueces and Kleberg Counties, as well as NCDD2, TxDOT, TAMUK, Harte Research Institute, Port of Corpus Christi Authority, TAMUCC, and the Cities of Corpus Christi, Robstown, Bishop, Driscoll and Petronila. TWDB Director of Flood Planning sent a prerecorded video message that was shared at the beginning of the event. An overview of the regional drainage study was presented, including project stakeholders, scope of work, goals and timeline. Attendees were also provided the opportunity to view the initial mapping of the study area to provide feedback during the interactive session following the opening presentation.

12.1.2 Public meeting number 2

The second public meeting was held in the Exhibits Hall of the Richard M. Borchard Fairgrounds in Robstown on May 18, 2022, from 6:00 to 8:00 p.m. This meeting had over 50 people attend to receive an update on the Tri-County DMP Study. TWDB Director Kathleen

Jackson also attended and provided the welcome remarks. The Tri-County DMP Program Manager and the Consultant Team were also in attendance. The purpose of this meeting was to present the initial assessment of the flood risk data collected to date and to also share the data gaps with the entities in attendance. Attendees were again provided the opportunity to view the initial mapping of the study area to provide feedback during the interactive session following the presentation on the project update.

12.1.3 Public meeting number 3

The third public meeting was held in Ballroom A of the Richard M. Borchard Fairgrounds in Robstown on September 29, 2022, from 6:00 to 8:00 p.m. This meeting had 39 people in attendance, representing Nueces, Jim Wells and Kleberg Counties, as well as Senator Hinojosa's office, NCDD2, TxDOT, USACE, King Ranch Inc., Port of Corpus Christi Authority, Nueces River Authority, and the Cities of Corpus Christi, Driscoll, Agua Dulce and Robstown. TWDB Director of Flood Planning, TWDB Project Manager, Tri-County DMP Program Manager and the Consultant Team also attended the meeting.

Preliminary results of the hydrologic/hydraulic computer models of the Petronila Creek and Oso Creek watersheds were available for the public during the interactive session following the PowerPoint presentation. The public also had the opportunity to provide feedback to validate the flooding issues in the 31 initial flood risk areas identified within the study area, as well as help prioritize these risk areas for developing potential flood reduction projects.

12.1.4 Public meeting number 4

The fourth public meeting was held in Ballroom A of the Richard M. Borchard Fairgrounds in Robstown on February 28, 2023, from 6:00 to 8:00 p.m. This meeting had 47 members of the public in attendance, representing Nueces, Jim Wells and Kleberg Counties, as well as NCDD2, NCDD1, TxDOT, USACE, Nueces River Authority, King Ranch Inc., Port of Corpus Christi Authority, and the Cities of Corpus Christi, Driscoll, Agua Dulce and Robstown. TWDB Director of Flood Planning provided a prerecorded message in advance to share with the meeting attendees. The Tri-County DMP Program Manager and the Consultant Team were also in attendance.

Following the brief PowerPoint presentation with the latest update on the Flood Risk Areas, an interactive session was held to allow the public to view the proposed drainage improvements identified within each of the 15 Flood Risk Areas and provide feedback. Mapping and videos showing the proposed drainage improvements were presented on large monitors at four stations, one for each of the four precincts within Nueces County.

12.1.5 Public meeting number 5

The final public meeting was held at the Richard M. Borchard Fairgrounds-Ballroom A in Robstown on May 23, 2023, from 5:00 to 6:30 p.m. TWDB Project Manager, Tri-County DMP Program Manager, and the Consultant Team also attended the meeting. Highlights of each chapter included in the initial draft report for the Study were presented. Following the PowerPoint presentation, an interactive session was held to provide the public an opportunity to once again view the proposed drainage improvements identified within each of the 15 flood-risk areas. This information was previously presented at Public Meeting No. 4. Mapping and videos showing the proposed drainage improvements were again presented on large monitors at four stations, one for each of the four precincts within Nueces County.

12.2 Coordination with other stakeholder groups

Additional coordination efforts were conducted with other key stakeholder groups, including TxDOT, the City of Corpus Christi, TWDB Region 13 Regional Flood Planning Group (RFPG) and the Texas General Land Office (TxGLO) Combined River Basin Flood Studies Program – Western Region. All four entities had ongoing drainage planning efforts during the same study period as the Tri-County Drainage Master Plan. Based on TWDB's encouragement, in-person and virtual meetings were held with TxDOT, City of Corpus Christi, TWDB Region 13 RFPG and TxGLO-Western Region to provide project updates, sharing of data as applicable and to minimize the duplication of planning efforts that utilized state funding.

12.2.1 TWDB Region 13 regional flood planning group

In 2019, the Texas Legislature passed Senate Bill 8, directing the creation of the first-ever State Flood Plan for Texas. As part of this effort, TWDB designated 15 flood planning regions within the state based on the corresponding river basins, including Region 13 for the Nueces Basin. Similar to Texas' water supply planning process, the State Flood Plan is based on regional flood plans developed by local stakeholders representing diverse interests. More importantly, proposed flood mitigation projects must be included in the Regional and State Flood Plans to be eligible to apply for future State financial assistance.

For the Region 13 Regional Flood Planning Group, the regional flood plan was submitted to TWDB by the initial deadline on January 10, 2023. However, in February 2023, the state authorized an amendment period for regions to submit a revised regional flood plan by July 14, 2023, to TWDB before the information is incorporated into the overall State Flood Plan. Due to the revised timeline for Region 13, the Consultant team was able to submit the 31 Flood Risk Areas and the resulting 15 Flood Mitigation Projects identified from the Tri-County DMP Study in early May 2023 for inclusion in the Region 13 Flood Plan and ultimately the State Flood Plan. As a result, entities in the Tri-County study area will have the flexibility to pursue future state funding to implement these regional drainage projects if interested.

12.3 GLO combined river basin flood studies program – western region

The Texas GLO (TxGLO) Combined River Basin Flood Studies Program is a one-time study for counties that received a presidential disaster declaration due to the impact of Hurricane Harvey. This program is comprised of three regions, including the Western Region, which covers the Tri-County DMP study area and has focused on preparing communities for future flood impacts associated with extreme weather events. This TxGLO program also complements and works in conjunction with TWDB's Regional Flood Planning Groups, including sharing flood data through the Texas Disaster Information System. The target completion date for the TxGLO Combined River Basin Flood Studies is Summer 2024.

For the Western Region, the TxGLO conducted a pilot hydraulic study on Oso Creek in Nueces County while developing the flood risk analysis Standard Operating Procedures (SOPs). The pilot study, performed by AECOM, studied a 9-mile stretch of Oso Creek from Corpus Christi

Bay upstream through the headwaters near Robstown using HEC-RAS 2D, Version 6.1 with HEC-HMS, and Version 4.8 inflows. Halff Associates reviewed the Oso Creek model in May 2022 for possible use and inclusion within the Nueces County/Tri-County DMP Study. The TxGLO model focused primarily on riverine flows and the coastal influence of Oso Creek, whereas the Study project goals are focused on communities and neighborhoods that are in the overbanks and further upstream in contributing areas/tributaries to Oso Creek. As a result, sharing data from both the TxGLO program and the Tri-County DMP Study has been beneficial to both regional planning efforts and helped minimize the duplication of work using State funding.

13 Conclusion

Continued growth in the South Texas Coastal Region combined with repetitive losses during frequent and intense storm events created the need for Nueces County to pursue this Study. This study was aided and supported by upstream (Jim Wells County) and downstream (Kleburg County) partners with the understanding that drainage issues are regional and flood problems are not contained within political boundaries. The Study Team identified and addressed numerous challenges plaguing the more rural areas of Nueces County, including delayed runoff conveyance, insufficient stormwater storage, flood-inundated structures, and stormwater quality concerns. During analyses, typical hydrologic and hydraulic modeling approaches were adjusted to capture complex flow interchanges, leading to the development of validated inundation mapping. This mapping provides a holistic snapshot of Nueces County flood risk, which community officials can use to aid and regulate development.

In addition to developing products and models that can drive sustainable, resilient growth for the future, the Study identified 31 flood-risk areas that have been experiencing repetitive flooding and water quality issues during minor and/or major storm events. These 31 areas were submitted on behalf of the Study partners to be placed in the TWDB’s Regional Flood Plan for Region 13. With the Study producing the necessary information needed to get all 31 areas into the Regional Flood Plan, these areas are now primed to have further detailed analyses performed and mitigative measures developed as Flood Mitigation Evaluations (FMEs). Of the 31 FMEs, 15 areas were further developed with detailed flood risk reduction alternatives, OPCCs, and proposed benefits such that these proposed Flood Mitigation Projects (FMPs) were included in the next tier of the Regional Flood Plan and set up for possible future state funding. These projects are centered around several rural communities within Nueces County, including Agua Dulce, Banquete, Petronila, and Robstown. As these communities have limited resources available to tackle large-scale, regional issues, having FMPs primed for additional funding through TWDB greatly benefits this study.

The FMPs' components include hydrologic and hydraulic modeling of existing and proposed conditions, quantifying flood benefits, no adverse impact analyses, Opinion of Probable Construction Costs (OPCCs), and benefit cost analysis (BCAs). The Study conducted a no adverse impact based on multiple factors that amount to a comparison of flood risk between existing and proposed conditions. Proposed alternatives included culvert improvements, regional detention, roadway improvements, and increased channel capacity and conveyance. This Study did not consider structured property acquisition (home buyouts). The majority of the benefits produced by the alternatives are in the form of decreased flood depths, flood water receding more quickly, and fewer structures located within flood inundation mapping. The OPCCs and BCAs provided with this study are useful information for the Study’s proposed next steps.

Implementation in the finalized Region 13 Flood Plan creates just one of the funding mechanisms available for the projects derived from this study. Important next steps for Nueces County consist of finalizing project prioritization and identifying project phases. Project phasing can identify components of these regional improvement systems that can be developed without adverse impacts for a portion of the overall OPCC. Depending on the availability of the County resources, some project phases could be completed with in-kind work. Being able to self-perform construction could improve project implementation timelines and potentially reduce the overall funding needed to complete the regional projects' full system.

As discussed previously, the mapping produced from the existing conditions modeling is a useful planning tool for the communities, and it is recommended that Nueces County implement the mapping as a regulatory product and provide the models to developers to assess the adverse impact of development.

List of references

Compass PTS JV. (2021). *Baffin Bay Watershed, Texas 2D Base Level Engineering Methods and Results*. DHS/FEMA (Federal Emergency Management Agency).

Compass PTS JV. (2021). *San Fernando Watershed, Texas 2D Base Level Engineering Methods and Results*. DHS/FEMA (Federal Emergency Management Agency).

Compass PTS JV. (2021). *South Corpus Christi Watershed, Texas 2D Base Level Engineering Methods and Results*. DHS/FEMA (Federal Emergency Management Agency).

Federal Emergency Management Agency. (2019). *Flood Insurance Study, Aransas County, Texas and Incorporated Areas* (Report No. 48007CV001B). https://map1.msc.fema.gov/data/48/S/PDF/48007CV001B.pdf?LOC=cc9986f4e9a7b663299a4decc041859f