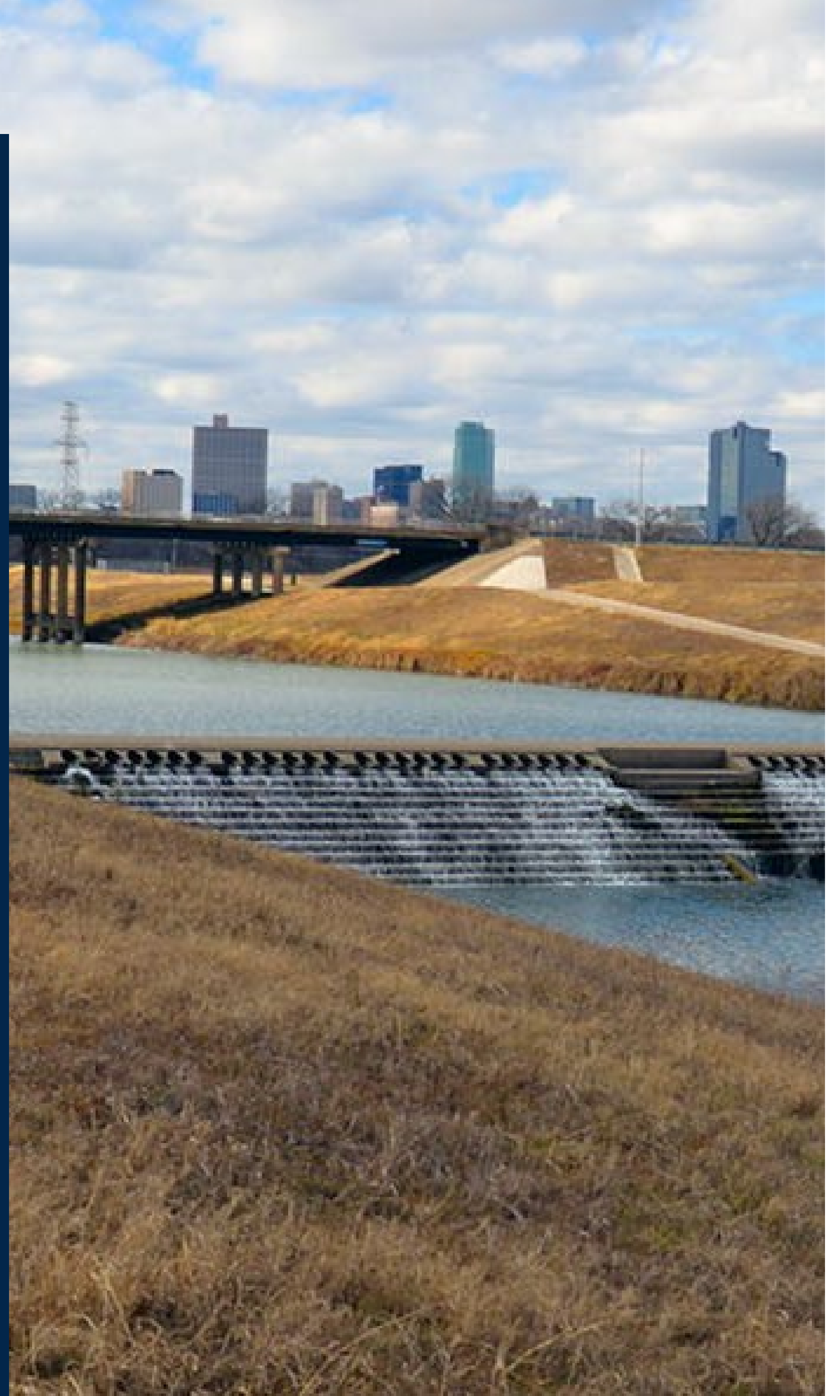

2023

AMENDED

REGION 3 TRINITY REGIONAL FLOOD PLAN

Prepared for the Region 3 Trinity Regional Flood Planning Group

VOLUME I

July 2023

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REGION 3 TRINITY
REGIONAL FLOOD PLANNING GROUP

2023 Amended Region 3 Trinity Regional Flood Plan

July 2023

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07/06/2023

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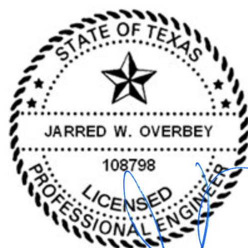

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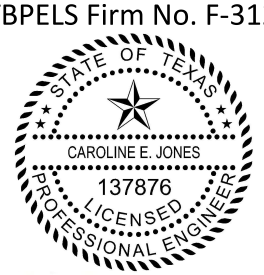

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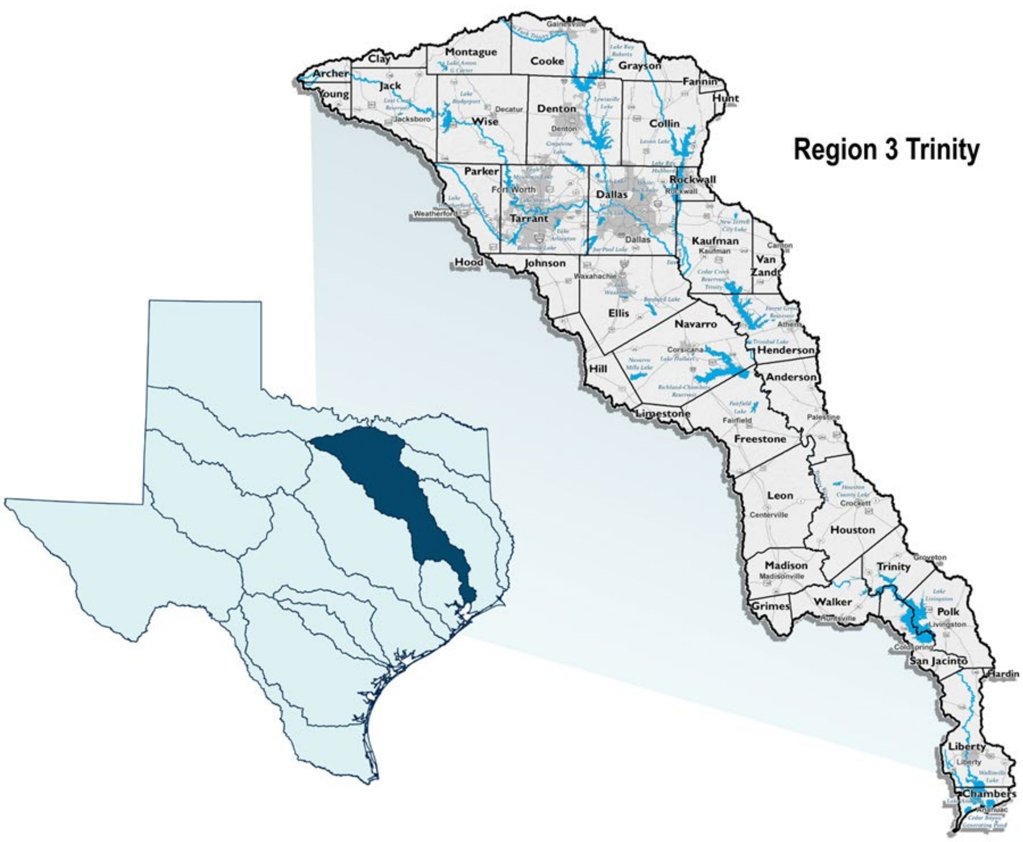
Executive Summary

In 2019, the 86th Texas Legislature passed Senate Bill 8 that authorized and established the regional and state flood planning processes. The legislature assigned the responsibility of the regional and state flood planning process to the Texas Water Development Board (TWDB). Under the direction of TWDB, 15 Regional Flood Planning Groups (RFPGs) across the State of Texas, were tasked with developing a regional flood plan for their respective region. This report represents the first-ever Region 3 (Trinity Region) Regional Flood Plan. Through this effort, over $1 billion in flood risk reduction actions were identified in the Trinity Region.

The Trinity Region encompasses all or part of 38 counties. The region spans a 17,800 square mile area, encompassing 15,855 stream miles. The area stretches from Gainesville, Cooke County in far North Texas all the way to Anahuac, Chambers County at the Gulf of Mexico. ***Figure ES.1*** represents the Trinity Region.

Figure ES.1: Trinity Regional Flood Planning Area



The Trinity RFPG is comprised of 28 volunteers who oversaw and directed the development of this plan. A draft of the Trinity Regional Flood Plan was made available to the public through the RFPG's website in July 2022. The RFPG held a public meeting on July 21, 2022, at which time, they approved the submittal of the Draft Trinity Regional Flood Plan to the TWDB with non-substantive changes. Following the meeting, the Trinity RFPG team addressed comments received, made necessary revisions, and posted a revised Draft Trinity Regional Flood Plan to RFPG's website by the August 1, 2022, deadline. The revised draft was submitted to TWDB and paper copies of the plan were available at three locations within the region:

- Dallas Public Library, 1515 Young St, Dallas, TX 75201 (Dallas County)
- Fairfield Library, 350 W Main St, Fairfield, TX 75840 (Freestone County)
- Sam Houston Regional Library and Research Center, 650 FM 1011, Liberty TX 77575 (Liberty County)

The Trinity RFPG held a public meeting on November 17, 2022, to review the comments received on the draft flood plan. The RFPG finalized and approved the responses to the public and TWDB comments. The RFPG adopted the final flood plan to be amended if all changes were non-substantive and according to the approved responses to comments from the TWDB during the meeting. The Trinity RFPG team made the approved and necessary revisions and submitted the Final Trinity Regional Flood Plan to the TWDB and the public. The final plan was posted to the RFPG's website at www.trinityrfpg.org.

In response to concerns regarding the expedited schedule to prepare the flood plans, the TWDB secured additional funding and provided the planning groups an additional six months to prepare and adopt amended plans to incorporate additional flood mitigation actions. The Trinity RFPG held a public meeting on June 29, 2023, at which it approved the adoption and submittal of this Amended Plan with non-substantive changes. The amended plan was submitted to the TWDB and made available to the public on the RFPG website at www.trinityrfpg.org by the July 14, 2023, deadline.

Chapters Included in the Plan

The TWDB developed the scope of work as well as technical guidelines that adhere to the legislation for each RFPG to develop its regional flood plan. The plan includes 10 required chapters, plus TWDB-required tables. The TWDB-required tables are included in ***Appendix A***.

- **Chapter 1 (Task 1) Planning Area Description**
  An overview of the region, including location, economics, agricultural information, social vulnerability, flood-prone areas, historical floods and associated damages, jurisdictions with flood-related authorities or responsibilities, existing infrastructure, and ongoing flood mitigation projects is presented in ***Chapter 1***.

- **Chapter 2 (Tasks 2A and 2B) Flood Risk Analyses**
  The 1% and the 0.2% annual chance storm event for existing and future conditions is provided in ***Chapter 2***. Future conditions are defined as 30 years from the flood planning kickoff, which is approximately the year 2050.
  - **Task 2A Existing Condition Flood Risk Analyses:** This task estimated existing condition flood risk based on information provided by local entities and the public, as well as regional, state, and federal data sources. The best available existing condition flood risk data was stitched together to create a floodplain quilt. Data gaps are identified, as is the region's vulnerability.
    Task 2B Future Condition Flood Risk Analyses: ***Task 2B*** assessed potential future flood risk considering two scenarios: (1) a "no action" scenario in which development and population growth continues according to current trends, and (2) an "action" scenario where floodplain regulations are incorporated across the region while development and population growth continues. The future flood risk condition considered multiple potential impacts on flood risk, such as land use, population growth, sea level change, land subsidence, and sedimentation. The RFPG developed an approach to estimate a range of potential future flood risk conditions using a TWDB-approved hierarchy of available data sources.
- **Chapter 3 (Tasks 3A and 3B) Floodplain Management Practices and Flood Protection Goals**
  Survey questions related to floodplain management practices within the region were included in the data collection effort in Summer 2021, which the RFPG considered in making its recommendations in this plan. The Trinity RFPG established a Goals Subcommittee that discussed and ultimately recommended the goals presented in ***Chapter 3*** to the full RFPG.
  - **Task 3A Evaluation and Recommendations on Floodplain Management Practices:** The Trinity RFPG recommended six region-wide floodplain management standards be included in this plan. Entities were encouraged to adopt and implement these standards, however, are not required to do so for their Flood Management Evaluations (FMEs), Flood Mitigation Projects (FMPs), and/or Flood Management Strategies (FMSs) to be included in this plan.
  - **Task 3B Flood Mitigation and Floodplain Management Goals:** The Trinity RFPG established seven overarching goals for this plan. Each goal included at least one specific goal statement with short-term (year 2023) and long-term (year 2053) measurements. Every recommended action to understand or mitigate flood risk must meet at least one of these goals.
- **Chapter 4 (Tasks 4A and 4B) Assessment and Identification of Flood Mitigation Needs**
  The RFPG adopted a process to analyze flood mitigation needs and develop potentially feasible actions (FMEs, FMPs, and FMSs) to address these needs.

Task 4A Flood Mitigation Needs Analysis: The scoring criteria to identify the areas of greatest known flood risk and knowledge gaps considered flood-prone areas that threaten life and property, current floodplain regulations, lack of inundation maps, lack of Hydrologic and Hydraulic (H&H) models, emergency needs, existing models, previously identified projects, historical floods, previously implemented projects, and additional factors identified by the Trinity RFPG. The analyses results concluded that approximately two-thirds of the region was inadequately mapped, and that 30 percent of the region contains areas of greatest known flood risk.

Task 4B Classification of Potential FMEs and Potentially Feasible FMSs and FMPs: ***Task 4B*** identified potentially feasible actions (FMEs, FMPs, and FMSs) that might reduce or mitigate flood risk within the region. FMEs included watershed studies, floodplain mapping, modeling, and preliminary engineering reports. FMPs are flood mitigation projects that could include structural or non-structural solutions, such as detention ponds, bridge improvements, costal protection, easement acquisition and floodproofing. FMS is the "catch-all" category for actions that do not easily fit into the evaluation or project category, such as floodplain ordinance development/update and large buyout programs. Potential actions included those identified by the Trinity RFPG in previous tasks, as well as those provided by local entities. Planning level costs and estimated benefits were also developed for each potential action.

- **Chapter 5 (Task 5) Recommendation of FMEs, FMSs, and Associated FMPs**
  The Trinity RFPG established a Technical Subcommittee to review each of the potentially feasible actions and develop lists of FMEs, FMPs, and FMSs for the full RFPG to consider including in this plan. The RFPG applied screening processes to determine the actions for inclusion in the plan, as well as a tiering system to prioritize requested actions according to those that provided the most complete data required for inclusion in the plan. A total of 507 FMEs, 56 FMPs, and 138 FMSs were recommended in this regional flood plan.
- **Chapter 6 (Tasks 6A and 6B) Impact and Contribution of the Region Flood Plan**
  The Trinity RFPG considered potential impacts of the recommended FMEs, FMPs, and FMSs to upstream and downstream neighbors and adjacent regions, as well as potential impacts to the State Water Plan. Each of the recommended FMPs and FMSs demonstrated no negative impacts on its neighboring communities and was included as a recommended action.

  Task 6A Impacts of Regional Flood Plan: The recommended actions were assessed to determine anticipated flood risk reduction and socioeconomic and recreational impacts, as well as environmental, agricultural, water quality, erosion, navigation, and other impacts.

Task 6B Contributions to and Impacts on Water Supply Development and the State Water Plan: The recommended FMPs and FMSs were assessed to determine the potential contribution to or impact on the State Water Plan. The assessment concluded that these recommended actions will not have any anticipated impacts on water supply, water availability, or projects in the State Water Plan.

- **Chapter 7 (Task 7) Flood Response Information and Activities**
  Flood response preparation in the region is summarized in ***Chapter 7***. The four phases of emergency management were discussed at the local, regional, state, and federal levels. Survey responses regarding emergency management are also summarized.
- **Chapter 8 (Task 8) Legislative, Administrative, and Regulatory Recommendations**
  The Trinity RFPG recommended eight legislative ideas to implement the recommended flood mitigation actions. Nine regulatory or administrative regional flood planning process ideas were recommended to provide clarification or updates to statewide concerns. The Trinity RFPG recommended 17 flood planning ideas to improve future cycles of regional flood planning.
- **Chapter 9 (Task 9) Flood Infrastructure Financing Analysis**
  Potential local, state, and federal funding opportunities that local sponsors could pursue for the implementation of the recommended FMEs, FMPs, and FMSs are summarized in ***Chapter 9***. Results of the surveys soliciting sponsor feedback on recommended actions and potential funding sources are presented.
- **Chapter 10 (Task 10) Public Participation and Plan Adoption**
  Throughout the regional flood planning process, the Trinity RFPG incorporated a robust public outreach plan to encourage and solicit local entity and public input, while adhering to the Texas Open Meetings Act and Freedom of Information Act. The development of this plan and its adoption is included in ***Chapter 10***.
- **Related Appendices**
  The TWDB-required tables and maps, as well as additional details that support information presented in many of the chapters, are included in the appendices.

Please note that ***Task 4C*** included the preparation of the Technical Memorandum and Technical Memorandum Addendum. Both were approved by the Trinity RFPG and submitted to the TWDB in January and March 2022, respectively, and indicated significant progress in the development of this plan. These two memos served as significant milestones in plan development but now include information that has become outdated. To reduce confusion, these two memos were not included in the regional flood plan although much of the content has been incorporated.

The TWDB guidance required a series of tables that each RFPG is required to include in the regional flood plan. The TWDB will merge these tables to develop the State Flood Plan and corresponding database. TWDB also required specific Geographical Information System (GIS) schema to be submitted electronically as part of this plan. In addition to providing these files to the TWDB, these files were also provided to the General Land Office (GLO), per TWDB's request, to share regional flood data with this state agency which is preparing its own flood mitigation plan along the Texas coast.

Key Findings and Recommendations

Existing and Future Flood Risks

The regional flood plan considered the 1% annual chance storm event and the 0.2% annual chance storm event. The 100-year floodplain represents the area that has a one percent chance of being inundated (or flooded) in any given year. The 0.2 percent floodplain (500-year) floodplain is the area that has a 0.2 percent chance of being flooded in any given year. Both storm events were considered in the existing conditions and future conditions flood risk analyses. The future conditions scenario uses a 30-year time horizon, which is approximately the year 2050.

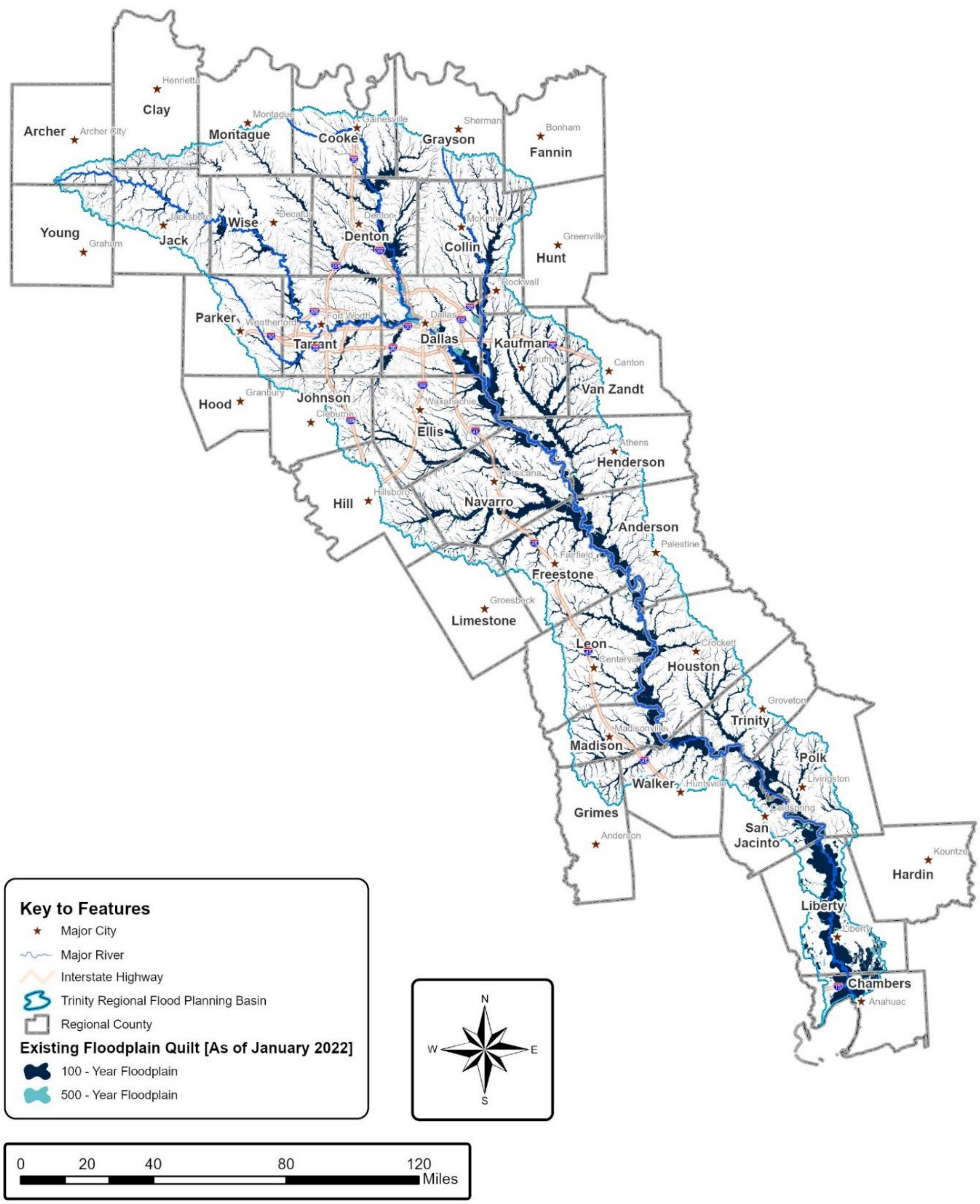
The Trinity RFPG was tasked with determining and using the best available data within the region. In some areas, the RFPG was able to obtain local flood studies with models and maps. In other areas, localized studies were not available leaving significant data gaps. TWDB provided multiple GIS layers for the region to use as a starting point to fill these gaps and assist with the development of the floodplain quilt. A hierarchy for determining what constitutes "best available data" was developed and is presented in ***Table ES.1***. The RFPG applied this hierarchy across the region with local studies typically considered to be the "best available data" depending on quality and moving left to right across the table to the next best option of Federal Emergency Management Agency's (FEMA's) National Flood Hazard Layer data. The RFPG used the TWDB's Fathom data as the most appropriate data when no other suitable data was found. Details about each of these data sources are included in ***Chapter 2***. ***Table ES.1*** was used for existing and future conditions. The RFPG established a range of potential future conditions that are specified in the table.

Following the Trinity RFPG's data collection efforts in Summer and Fall 2021, the floodplain quilt was enhanced with local data. The resulting stitching of floodplain layers produced ***Figure ES.2*** shows the resulting existing flood risks for the 100-year and 500-year floodplains. This information was applied across the region and was used to identify flood data gaps.

Table ES.1: Existing and Future Condition Flood Hazard Analysis Approach

	Best Available	→		→		→			Most Approximate	
	Local Floodplain (if determined current)		NFHL AE		BLE		NFHL A / FAFDS		No FEMA or Better than Quilt	
	100YR	500YR	100YR	500YR	100YR	500YR	100YR	500YR	100YR	500YR
Existing	Local Study (if provided)	Local Study (if provided)	Floodplain quilt 100YR	Floodplain quilt 500YR	BLE 100YR	BLE 500YR	Replaced with Fathom 100YR	Replaced with Fathom 500YR	Fathom 100YR	Fathom 500YR
Future	Local Study (if provided)	Local Study (if provided)	Range between Existing 100-year and 500-year	40-foot buffer of the existing 500YR	Range between BLE Existing 100-year and 500-year	40-foot buffer of the existing 500YR	Range between Fathom Existing 100-year and 500-year	40-foot buffer of the existing 500YR	Range between Fathom Existing 100-year and 500-year	40-foot buffer of the existing 500YR

Figure ES.2: Trinity Region Existing Conditions Floodplain Quilt



Existing Condition Flood Risk

As of 2022, all communities within the Trinity region have modernized FEMA digital county-wide effective Flood Insurance Rate Maps (FIRMs), with the exception of Clay, Freestone, and Trinity counties and their respective communities. Counties along or near the Texas coast within the Trinity Region have incorporated recent rainfall data (Atlas 14) developed by the National Oceanic and Atmospheric Administration (NOAA) in their flood risk maps and models.

Existing flood control infrastructure was identified and assessed according to local and statewide data sources. This plan considered a variety of flood control infrastructure, such as dams (reservoirs), levees, detention/retention ponds, bridges, culverts, storm drain systems and other infrastructure designed to impound flood water. When a storm exceeds the design capacity of these types of systems, the result is increased flood risk to life and property within the region.

Potential Flood Impacts Based on Existing Condition Flood Risk

Severe flooding can impact people, property, critical facilities, infrastructure, agricultural production, and more. Critical facilities provide essential services that are vital to a community during and following a disaster.

The Hazus model was used to estimate anticipated flood exposure and damages for existing conditions. The model predicted that 1.32 million people within the Trinity Region would be displaced during a 1% annual chance storm event and the total exposure value of buildings to be $636.38 billion. The loss of transportation infrastructure was estimated along with water and wastewater treatment facilities. The impacts of flooding on socially vulnerable populations and a community's ability to recover were also assessed in ***Chapter 2***. The Hazus model estimated damages and impacts by assuming that the 1% annual chance storm event occurred across the region at the same time.

Future Flood Risk

The Trinity RFPG considered a variety of factors that could exacerbate future condition flood risk, including:

- Future land use/land cover
- Population growth
- Sea level change
- Land subsidence
- Changes in the floodplain
- Major geomorphic changes
- Sedimentation

The RFPG requested local maps and models from communities within the region. Some communities provided this information, but only a few of the communities included future conditions in their mapping and modeling. Since assumptions may vary from one entity to another when determining future conditions, the RFPG was unable to draw a region-wide conclusion regarding future flood risk based on these few examples.

With so many uncertainties, the Trinity RFPG recommended that the potential future 100-year floodplain be presented as a range between the existing 100-year extents and the existing 500-year extents.

A common method used by cities and regulatory bodies to account for uncertainty of future flood risk is to apply a horizontal buffer area around the stream system or floodplain. The Trinity RFPG performed a case study using nine large-scale studies to determine an appropriate buffer of 40 feet for the region. The range for the potential future 500-year flood risk is a minimum of the existing 500-year floodplain and a maximum of the existing 500-year floodplain plus the 40-foot buffer.

Future flood risk area for the Trinity Region is presented in ***Figure ES.3***. The resulting future conditions 100-year and 500-year flood risk areas shown in the future floodplain quilt generally have larger inundated areas than the existing conditions floodplain quilt. The potential future flood exposure and vulnerability analysis consisted of two scenarios:

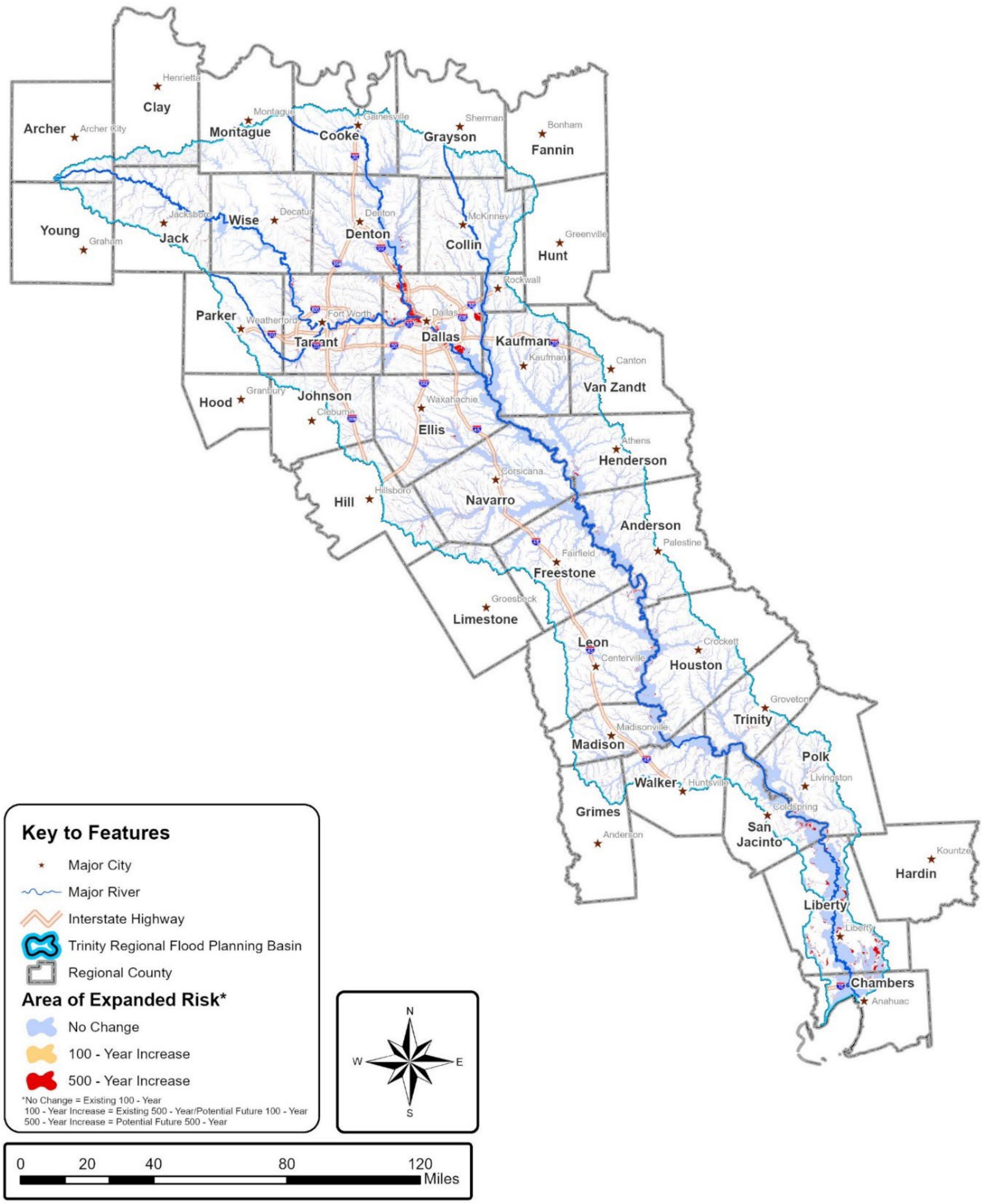
1. Estimating the number of buildings, critical facilities, infrastructure systems, population, and agriculture potentially exposed to flooding by overlaying the future conditions floodplain quilt developed for the Trinity Basin.
2. Estimating additional exposure and vulnerability by identifying areas of existing and known flood hazard and future flood hazard areas where development might occur within the next 30 years if the current land development practices in the Trinity Region continue.

Overall, it is anticipated that 29 percent more structures and 25 percent more people may potentially be impacted by potential future flood risk conditions than existing flood risk conditions.

Identification and Selection of Recommended Floodplain Management and Flood Mitigation Actions

To address the identified flood risks, the Trinity RFPG team developed potential actions to reduce flood risk. Those actions included FMEs, FMPs, and FMSs. FME actions are those that are typically classified as "studies", such as watershed mapping, modeling and watershed studies that provide potential alternatives to mitigate flood concerns. FMEs also include preliminary engineering reports that more clearly define the proposed action and to determine its viability. FMPs are structural or non-structural projects to mitigate flood risk. The FMS category is intended to capture other types of solutions, such as ordinances, flood early warning systems, buyouts, and more.

Figure ES.3: Trinity Region Potential Expanded Risk between Existing and Future Conditions Flood Hazard



The Trinity RFPG established a Technical Subcommittee to review the lists of potentially feasible floodplain management or flood mitigation actions and recommend actions that should be considered for inclusion in the regional flood plan to the full Trinity RFPG. The subcommittee met multiple times over several months and evaluated each potential action.

The screening process removed any potential FMEs, FMPs, and or FMSs that did not support a Trinity RFPG goal. If a potential action had already been completed or was no longer a priority for the affected entity/entities, then the potential action was removed from further consideration. Each potential action required a sponsor with an interest in implementing the action. A sponsor could be a city, county, political jurisdiction with flood-related authority or responsibility, or anyone else with an interest in pursuing a specific floodplain management or flood mitigation action.

For this amended plan, the RFPG solicited new FMPs, FMEs, and FMSs for consideration between November 2022 and January 2023. Potential actions assigned to the appropriate category were based on the information received. To allow interested sponsors the opportunity to include additional FMPs in the plan, the RFPG utilized the data received to establish a tiering system for FMPs. The requests for inclusion were summarized in a work order process that the RFPG approved at its February 2023 meeting.

Selection of Floodplain Management Evaluations

The RFPG analyzed each potential FME following a clearly defined process that included sponsor outreach (when appropriate), likelihood of study/analysis resulting in FMPs in future planning cycles, and development of cost estimates. The RFPG considered potential FMEs submitted by local jurisdictions and others, as well as those prepared by the RFPG team to address areas of greatest need. The RFPG team populated the ***TWDB-Required Table 12*** and considered these details before making its recommendation to include the FME in this plan.

Selection of Flood Mitigation Projects and Floodplain Management Strategies

Ideally, recommended FMPs and FMSs would address the 1% annual chance storm event. However, some actions cannot attain that level of service for a variety of reasons, such as site constraints, environmental impacts, or cost. The RFPG allowed FMPs and FMSs to be considered for recommendation if the level of service was improved but the 1% annual chance storm event threshold could not be achieved.

FMP and FMS evaluations required a “No Negative Impact” determination for the action to be recommended in the plan. No negative impact means that the project or strategy will not increase flood risk of surrounding properties. In short, the recommended action cannot increase the water surface elevation or flood level above the current elevation on neighboring properties. In situations where an increase appears to be unavoidable, mitigation measures may be incorporated to alleviate such impacts.

Benefits and cost estimates were prepared for each potential FMP or FMS, when appropriate. That information was used to develop Benefit-Cost Ratios (BCRs) to determine if the benefits of the proposed action exceeded the cost of the action. Because the BCRs were developed using regional data, the Trinity Region decided to recommend FMPs and FMSs despite the results of the benefit-cost analysis. The sponsor for a particular FMP or FMS will be responsible for developing a more detailed BCR using local data according to the requirements established for a particular funding source.

The RFPG team populated the ***TWDB-Required Table 13*** for potentially feasible FMPs and ***TWDB-Required Table 14*** for potentially feasible FMSs and considered these details before making a recommendation to include the FMP or FMS in this plan. In situations where TWDB-required information was lacking for a potential project or strategy to be considered for recommendation, then the potential FMP or FMS was reclassified as a recommended FMEs, pending receipt of additional information from the sponsor.

The Technical Subcommittee recommended 507 FMEs, 56 FMPs, and 138 FMSs to the Trinity RFPG that were ultimately adopted for inclusion in this plan.

Table ES.2 provides a summary of the types and counts of potential and recommended FMEs. ***Table ES.4*** summarizes the types and counts of potential and recommended FMSs.

Ultimately, the Trinity RFPG agreed with the subcommittee's recommendations and approved the recommended actions at the April and June 2022 Trinity RFPG meetings. The additional flood mitigation actions included in the Trinity Amended Regional Flood Plan were approved during the June 2023 Trinity RFPG meeting.

Cost of the Recommended Plan

Following the selection of recommended actions to mitigate flood risk, the Trinity RFPG team initiated an email survey to potential sponsors regarding the recommended actions for the entity in the final plan. A one-page summary was developed for each recommended action and sent to the potential sponsor. The Trinity RFPG inquired whether the sponsor agreed with the information presented and confirmed the potential sponsor's continued interest in the action. For those actions that were of interest to the sponsors, the Trinity RFPG inquired how the entity might fund the action - such as with grants, loans, stormwater utility fees, general budget, or some other means.

This amended plan includes a simplified version of the Financing Survey whereby the RFPG sent an individualized email to each sponsor with the list of actions and an inquiry as to how the sponsor might pay for each action. In the event a potential sponsor did not respond, the RFPG assumed that there was a continued need for action and would require funding assistance for 90 percent of the action's cost. Overall, the estimated cost to implement the recommended FMEs, FMPs, and FMSs in this plan is $1.6 billion.

Table ES.2: Summary of Flood Mitigation Evaluations

FME Type	FME Description	# of Potential FMEs Identified	# of FMEs Recommended	Total Cost of Recommended FMEs
Watershed Planning	Flood Mapping Updates, Drainage Master Plans, H&H Modeling, Dam and Levee Failure Analysis	160	156	$89,981.000
Project Planning	Feasibility Assessments and Preliminary Engineering Studies (alternative analysis and up to 30% design)	334	324	$118,171,000
Preparedness	Studies on Flood Preparedness	5	5	$3,150,000
Other	Dam Studies	22	22	$9,260,000
	Total	**521**	**507**	**$220,562,000**

Table ES.3: Summary of Recommended Flood Mitigation Projects

FMP Type	FMP Description	# of Potential FMPs Identified	# of FMPs Recommended	Total Cost of Recommended FMPs
Infrastructure	Improvements to stormwater infrastructure including channels, ditches, ponds, stormwater pipes, etc.	46	33	$468,864,000
Storm Drain Improvements	Improvements exclusively to underground urban stormwater infrastructure	14	11	$38,631,000
Regional Detention Facilities	Runoff control and management via detention facilities	5	4	$138,099,000
Property or Easement Acquisition	Acquisition of properties located in the floodplain	3	3	$48,279,000
Dam Improvements, Maintenance and Repair	Dam upgrades to meet TCEQ dam safety requirements	2	2	$5,565,000
Flood Early Warning Systems	Installation of safety improvements at hazardous stream crossings	2	2	$640,000
Low Water Crossing or Bridge Improvement	Low water crossing replaced by a bridge crossing	1	1	$3,319,000
	Total	**73**	**56**	**$703,397,000**

Table ES.4: Summary of Flood Mitigation Strategies

FMS Type	FMS Description	# of Potential FMSs Identified	# of FMSs Recommended	Total Cost of Recommended FMSs
Education and Outreach	Turn Around, Don't Drown Campaigns; NFIP Education; Flood Education; Dam Safety Education; Floodplain Regulatory Awareness	22	19	$975,000
Flood Measurement and Warning	Flood Warning Systems; Rain/Stream Gauges and Weather Stations; Low Water Crossings (LWCs)	20	20	$5,300,000
Property Acquisition and Structural Elevation	Acquire High Risk and Repetitive Loss Properties; Acquire and Preserve Open Spaces	20	20	$181,545,000
Regulatory and Guidance	City Floodplain Ordinance Creation/Updates; Zoning Regulations; Land Use Programs; Open Space Regulations	62	59	$86,600,000
Infrastructure Projects	Hazardous Roadway Overtopping Mitigation Program; Citywide Drainage Improvements; Flood-Proofing facilities	5	5	$430,000,00
Floodproofing	Floodproofing Critical Facilities; Elevating Electrical and Mechanical Equipment; Roof Straps; Storm Shutters; Impact Resistant Windows/Doors; Surge Protection	2	2	$30,500,000
Other	Debris Clearing Maintenance; Channel Maintenance and Erosion Control; Dam Inspections; Levee Inspections; City Parks; Green Infrastructure; Open Space Programs; Nature-Based Solution Planning Studies	14	13	$10,489,000
	Total	**145**	**138**	**$745,409,000**

Public Participation and Outreach

In its inaugural regional flood planning effort, the Trinity RFPG developed a website and an extensive public outreach plan. The website was used to provide information on the planning effort, such as meeting notices, meeting materials, and the posting of draft chapters. Multiple data collection efforts and surveys were accessible through the website. In addition, MailChimp and Twitter were used to notify interested parties about upcoming meetings, surveys, and other Trinity RFPG-related activities.

Most of the Trinity RFPG meetings were held in a hybrid fashion, allowing planning group members and the public to participate virtually. The physical meeting location moved around the region to encourage local, in-person participation.

The series of open houses hosted by the Trinity RFPG team was held in late August 2022 to present the Draft Trinity Flood Plan and to answer basic questions about the flood planning effort. The official public hearing in September 2022 provided entities and the public with the opportunity to submit oral and/or written comments on the Draft Trinity Regional Flood Plan. Written comments were also accepted 30 days prior to and 30 days following the public hearing. These comments were addressed and included as an appendix in the Final Trinity Regional Flood Plan submitted to the TWDB in January 2023.

Immediately after the Trinity RFPG voted to approve the 2023 Region 3 Trinity Regional Flood Plan, the RFPG began soliciting potential FMEs, FMPs, and FMSs for consideration in this amended plan through emails and the website. Follow-up phone calls and meetings were scheduled upon request by multiple sponsors. The RFPG continued to meet every other month. The draft amended plan was posted to the RFPG website for public review and comment 14 days in advance and following the June 29, 2023, RFPG meeting at which time the Trinity RFPG approved this amended plan for submittal to the TWDB and the public. ***Appendix L*** provides an index listing the revisions to this amended plan.

Texas Administrative Code Guiding Principles and Required Statements

In accordance with Title 31 Texas Administrative Code (TAC) §361.20, the draft and final Trinity Regional Flood Plans conformed with the guidance principles established in Title 31 TAC §362.3. A table of the 39 regional flood planning principles and where they are addressed in this plan is provided in ***Chapter 10***. In addition, TAC §361.20 requires the regional flood plan to not negatively affect a neighboring area. The Trinity RFPG performed a No Negative Impact assessment for each potentially feasible FMP and FMS. Those that had or appeared to have a potential negative impact were either reclassified as FMEs for further evaluation or were removed from further consideration and not included as recommended FMPs or FMSs in the Draft or Final Trinity Regional Flood Plan.

The draft, final, and amended Trinity Regional Flood Plans were developed in accordance with the TWDB's scope of work and Technical Guidance documents. Specific requirements are discussed in ***Chapters 1*** through ***10***, the appendices, and/or included in the TWDB-required tables or GIS schema.

Statements Regarding Texas Open Meetings Act and Public Information Act Requirements

The Trinity RFPG posted meeting notices and meeting materials in accordance with the Texas Open Meetings Act. Meeting notices were posted on the Trinity RFPG website at www.trinityrfpg.org and with the Secretary of State. Prior to the Trinity RFPG website development, the meetings were posted on the TWDB's website and with the Secretary of State.

The Trinity RFPG is subject to the Public Information Act and is required to fulfill requests for information that are not protected by another law. As such, the Trinity RFPG team encouraged entities to only provide information to the planning process that the entity deemed as publicly available information. In 2022, the Trinity RFPG received one public request for information through the TWDB. The RFPG team responded that the requested GIS data associated with the draft regional plan was being revised and was not readily available. Per TWDB's instructions, the RFPG team provided the draft GIS files with the following disclaimer, "The attached information, including data and models, are planning-level information submitted by the RFPGs. This data has not been reviewed or approved by the TWDB. The recipient is responsible for confirming the accuracy of the data provided."

The team received and responded to all general comments and questions regarding the regional flood planning process and meetings. includes A summary of the questions and comments received as of June 2022, prior to posting of the draft plan for public review and comment is provided in ***Appendix I***. The transcript of the September 2022 Public Hearing where members of the public had an opportunity to provide in-person oral or written comments on the draft plan is provided in ***Appendix J***. No comments were received at that Public Hearing. Detailed public and TWDB comments received outside of the Public Hearing and RFPG's responses to each specifically regarding the draft plan are provided in ***Appendix K***. ***Appendix I*** also includes general comments and questions received between June 2022 and June 2023.

Chapter 1: Planning Area Description

Figure 1.1: Image of Flooded Gas Station in Grand Prairie, TX in 1976

Source: United States Army Corps of Engineers (USACE)

Origins of the State Flood Planning Process

In Texas, the billion-dollar flood disaster is becoming a regular occurrence (see ***Figure 1.1***). Between 2015 and 2017, flooding alone caused nearly $5 billion in damages to Texas communities. When considered in conjunction with the impact of Hurricane Harvey, the total cost in 2017 approached $200 billion in financial losses (NOAA, 2021) and nearly 100 deaths. As the state grappled with how to better manage flood risk and reduce loss of life and property from future disasters, the Texas Water Development Board (TWDB) prepared the first ever statewide flood assessment which described Texas' flood risks, provided an overview of roles and responsibilities, included an estimate of potential flood mitigation costs, and summarized entities' views on the future of flood planning. This plan was prepared because:

- Flood risks, impacts, and mitigation costs had never been assessed at a statewide level
- Flood risks pose a serious threat to lives and livelihoods
- Much of Texas is unmapped or uses out-of-date maps (Peter M. Lake, 2019)

The TWDB presented its findings to the 86th Texas legislative session in 2019. Later that year, the Legislature adopted changes to Texas Water Code §16.061 which established a regional and state flood planning process led by the TWDB. The legislation provided funding to improve the state's floodplain mapping efforts and to develop regional plans to mitigate the impact of future flooding. Regional flood plans for each of the state's 15 flood planning regions were submitted to the TWDB by January 10, 2023. In response to concerns regarding the expedited schedule to prepare the flood plans, the TWDB secured additional funding and provided the planning groups an additional six months to prepare and adopt amended plans to incorporate additional flood mitigation actions. The amended plans were submitted to the TWDB by July 14, 2023. An updated version of the regional flood plans will be due every five years thereafter. (TWDB Flood Planning Frequently Asked Questions, 2021)

Overview of the Planning Process

Given the diverse geography, culture, and population of the state, the planning effort is being carried out at a regional level in each of the state's major river basins. The Region 3 (Trinity Region) is one of 15 flood planning regions where a regional flood plan will be developed. When complete, the TWDB will compile these regional plans into a single statewide flood plan and will present it to the Legislature in 2024. Regional flood plans are required to be based on the best available science, data, models, and flood risk mapping. The Legislature allocated funding to be distributed by the TWDB for the procurement of technical assistance to develop the flood plans.

Who's Preparing the Plan?

The TWDB has appointed Regional Flood Planning Groups (RFPGs) for each region and has provided them with funding to hire technical consultants to help prepare their plans. Because it is not a political subdivision, the RFPG cannot enter into a contract with the TWDB to receive the funding to develop the plan. Therefore, each RFPG selects a political subdivision to handle contract administration. Trinity RFPG chose the Trinity River Authority (TRA) to serve as its sponsor. The sponsor's role is to provide support for meetings and communications and to manage the technical consultant contract.

The RFPG's responsibilities include directing the work of their technical consultant; soliciting and considering public input; identifying specific flood risks; and identifying and recommending Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs) to reduce risk in their regions.

To ensure a diversity of perspectives are included, members represent a wide variety of entities potentially affected by flooding, including:

- Agriculture
- Counties
- Electric Generation Utilities
- Environmental Interests
- Flood Districts
- Industry
- Municipalities
- Public
- River Authorities
- Small Businesses
- Water Districts
- Water Utilities

The TWDB provided detailed specifications to guide the preparation of the flood plans for each region. When complete, the 15 regional flood plans will be rolled up into the State Flood Plan that will provide a path forward to reduce existing risk to life and property and improve floodplain management data and practices. They will also identify potential FMEs, FMSs, and FMPs which may be appropriate for future studies and funding.

Data Sources

To ensure that flood plans are based upon consistent and reliable information in every region, the TWDB compiled Geographic Information System (GIS) data resources in the Texas Flood Planning Hub GIS layers are provided for:

- Critical infrastructure
- Flood infrastructure
- Flood risk
- Hydrology
- Jurisdiction boundaries
- Parks
- Population
- Property
- Terrain
- Transportation

The RFPG's dedicated GIS experts organized and analyzed this data for the Trinity Region, identified additional data sources needed to meet the TWDB's objectives, and used the data to prepare the illustrative maps included in this report.

To supplement the data provided by the TWDB, the RFPG also developed a data collection tool (survey) for entities with flood-related responsibilities. At least three recipients in flood-related roles from each community received this detailed survey to increase community response rates. Respondents provided contact information and their flood-related responsibilities, verified flood information that had already been collected, responded to questions to support the development of the regional flood plan, and verified and provided geospatial data through data uploads. An interactive web map allowed survey respondents to draw in problem areas and proposed projects that were not included in other information about the region.

Public Outreach

Almost 800 individuals representing the regional entities received the survey in July 2021. Postcards and emails were distributed to introduce the flood planning process and to provide the survey link. ***Figure 1.2*** illustrates the types of entities that were included in the data collection effort. ***Figure 1.3*** illustrates the various methods used to contact entities and the number of entities reached by each effort.

Figure 1.2: Outreach Efforts and Contacts Made

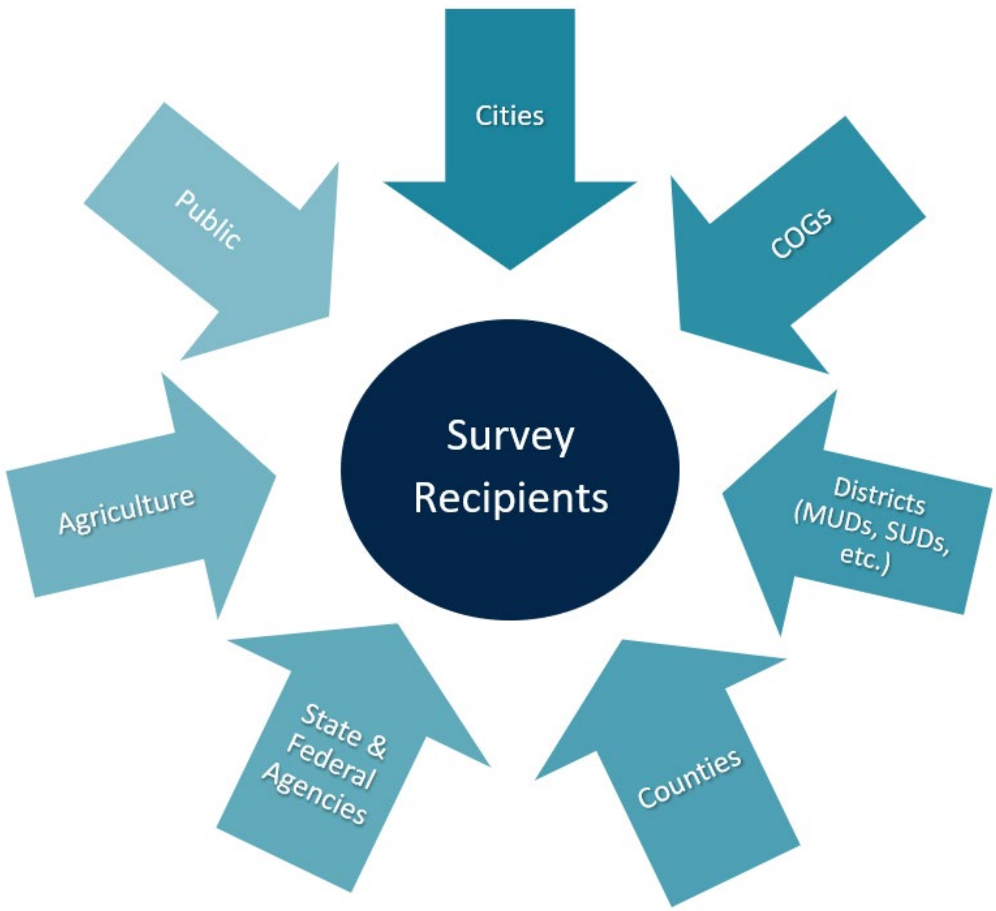
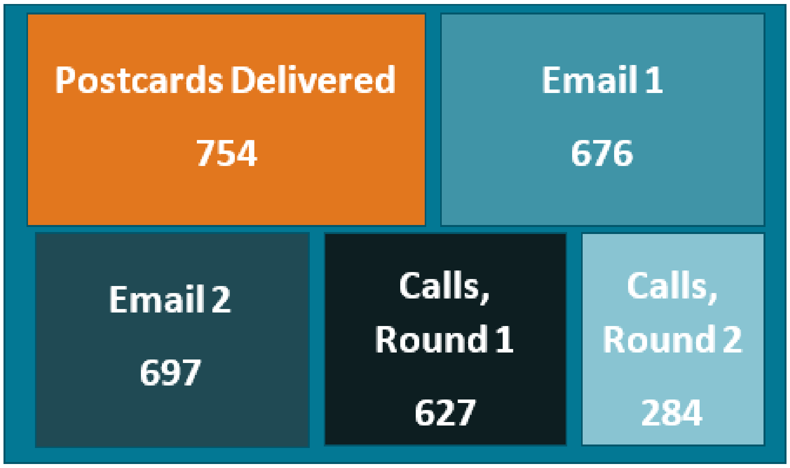


Figure 1.3: Outreach Efforts to Trinity Region Entities



To encourage participation, the RFPG followed up via email a week later. Calls went out to 627 recipients who had not yet responded, and a second round of calls was made to 284 recipients. The result of this effort was a response rate of approximately 30 percent. Survey results are included throughout ***Chapter 1*,** and the chapters to follow.

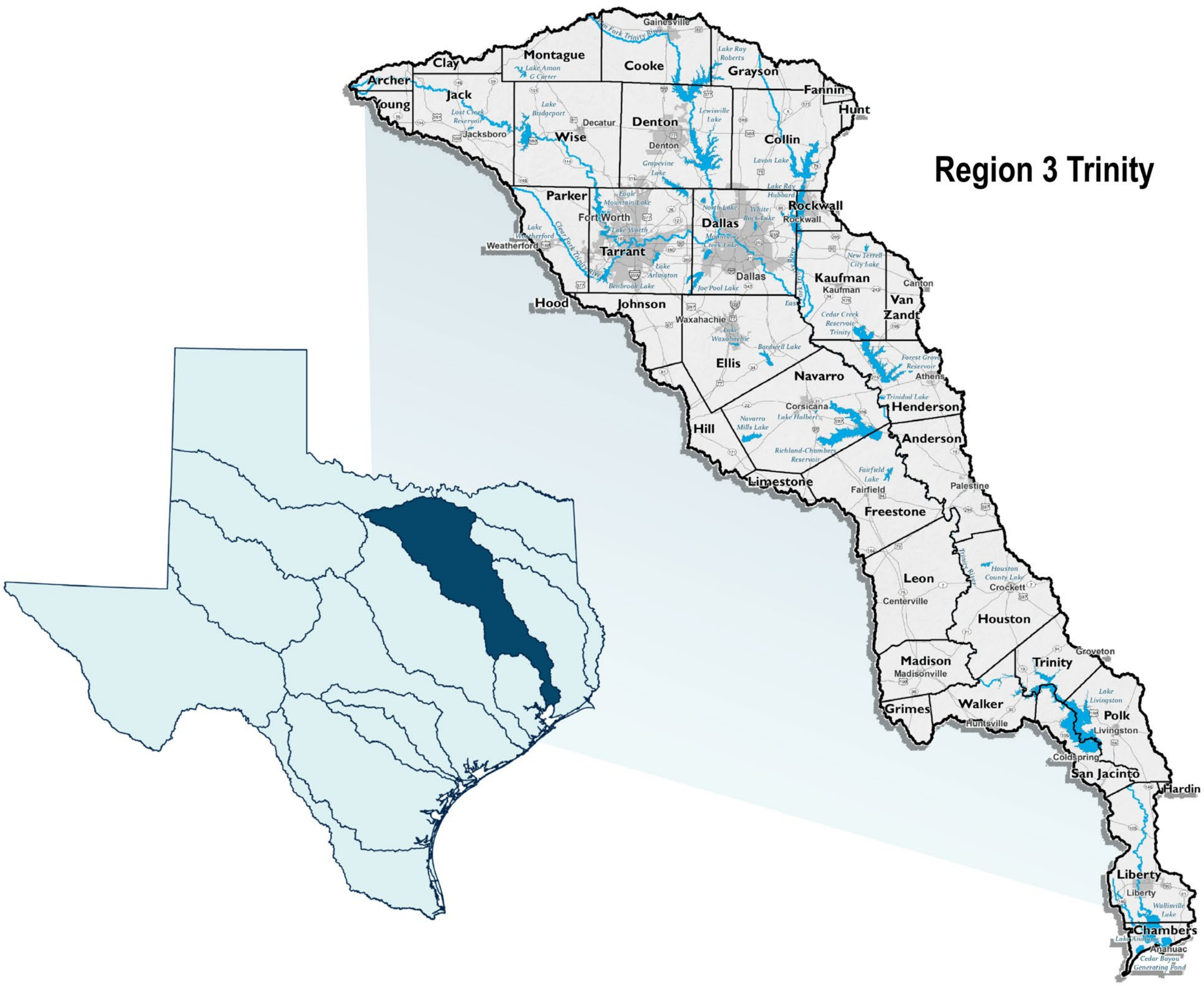
Funding Sources

To fund projects identified by these plans, the legislature created a new flood financial assistance fund and charged the TWDB with administering the fund. The Texas Infrastructure Resiliency Fund, approved by Texas voters in November 2019, is being used to finance the preparation of these plans and will also be used to finance the recommended flood-related studies and projects. Communities who identify future projects aimed at flood mitigation will be eligible for financial assistance in the form of grants and loans from the TWDB. Additional discussion of funding sources available for flood mitigation activities, including federal and state funding, will be discussed in ***Chapter 4, Task 4B*** of this plan.

Characterizing the Trinity Region

Stretching from Gainesville, near the Oklahoma border, to Anahuac which meets the Trinity Bay at the Gulf of Mexico, the Trinity Region encompasses a wide variety of landscapes and communities and includes approximately 15,855 stream miles with a total drainage area of approximately 17,800 square miles. The total context of the Trinity Region with respect to the State of Texas is illustrated in ***Figure 1.4***. It is bounded to the north by the Red River Basin; to the east by the Sabine and Neches River Basins; and to the west and south by the Brazos and San Jacinto River Basins. From arid to subtropical, agricultural to urban, the flood risks faced by communities and landowners vary widely as well.

Figure 1.4: Trinity Region Flood Planning Area



To better understand the nature of that flood risk, this section will discuss people, types, and locations of development; economic activity; and sectors at greatest risk of flood impacts. ***Table 1.1*** summarizes key elements of the primary streams and tributaries of the Trinity River system. ***Figure 1.5*** provides a map of those streams and tributaries described in ***Table 1.1***.

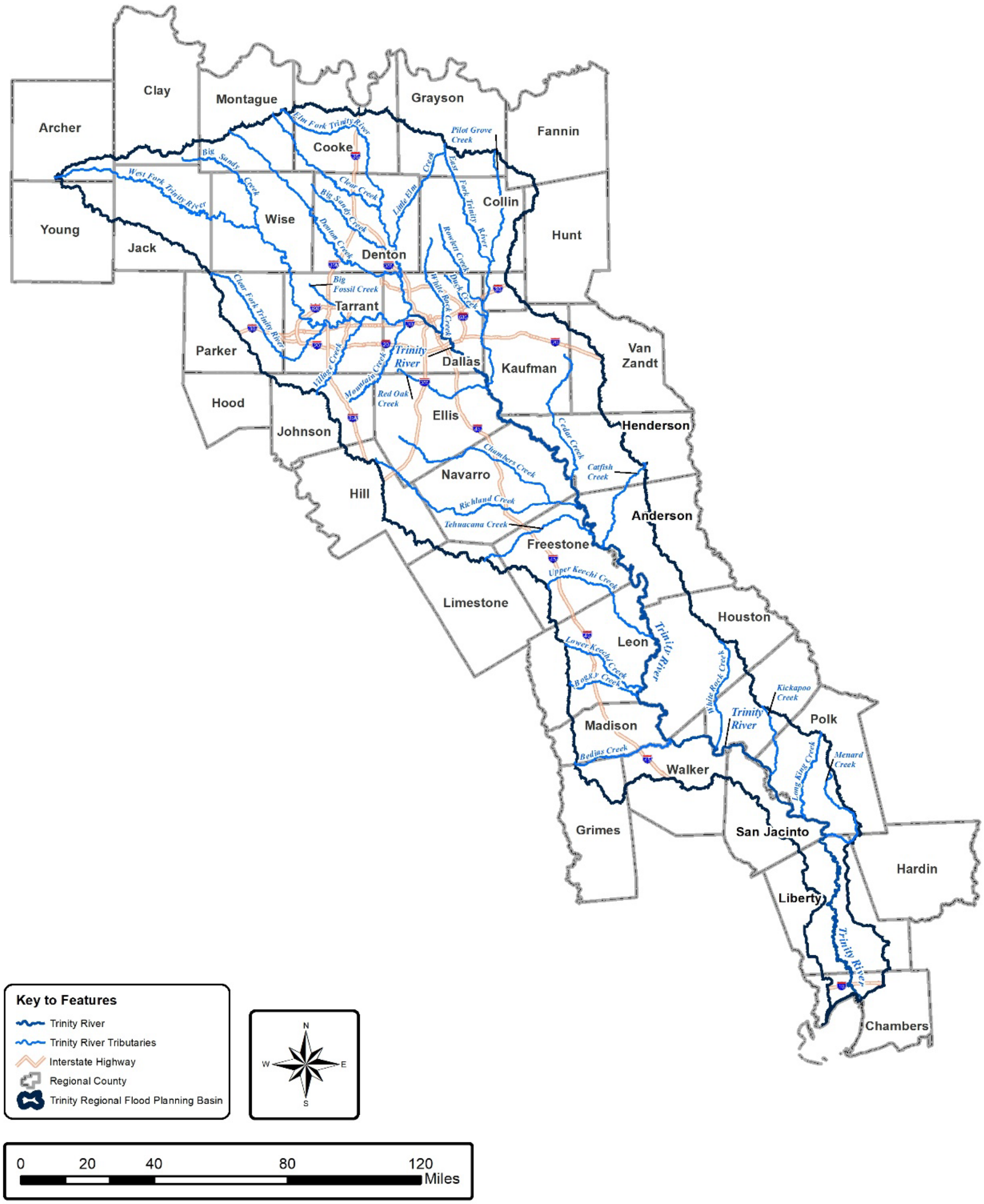
Social and Economic Character

As the Trinity Region grows in population, many communities are expanding outward to accommodate this growth. Texas as a whole grew approximately 15 percent in the last decade, and research by the Texas Land Trends by Texas A&M Natural Resources Institute project found that in the Trinity Region alone, population grew by almost three million residents between 1997 and 2017.

Table 1.1: Primary Streams and Tributaries of the Trinity River System

Stream Name	Length (River Miles)	Drainage Area (Square Miles)
West Fork of Trinity River	326	3,470
Clear Fork of Trinity River	66	524
Big Sandy Creek	53	353
Mountain Creek	40	295
Village Creek	36	191
Big Fossil Creek	20	56
Elm Fork of Trinity River	123	2,611
Denton Creek	107	719
Clear Creek	70	351
Little Elm Creek	39	261
Hickory Creek	46	179
White Rock Creek (Collin and Dallas counties)	38	135
East Fork of Trinity River	105	1,303
Pilot Grove Creek	49	443
Rowlett Creek	39	219
Duck Creek	23	43
Richland Creek	94	1,960
Chambers Creek	69	1,109
Cedar Creek	27	1,065
Tehuacana Creek	59	433
Catfish Creek	44	293
Red Oak Creek	40	232
Menard Creek	58	166
Boggy Creek	40	150
Kickapoo Creek	30	147
Upper Keechi Creek	67	511
Lower Keechi Creek	57	187
Bedias Creek	57	604
White Rock Creek (Houston and Trinity counties)	57	509
Long King Creek	39	225

Figure 1.5: Primary Streams and Tributaries of the Trinity River



Although growth has largely occurred in the Dallas-Fort Worth (DFW) metroplex, its effects can be felt downstream, as land that was once reserved for cropland or grazing declined during this period, with over 350,000 acres (about twice the area of Austin, Texas) of cropland and 120,000 acres of rangeland being converted to other uses. (Texas A&M Natural Resources Institute, 2021) As shopping centers occupy former pastures and row crops are replaced by subdivisions, the increase in paved surfaces reduces the absorption of rainwater. Urban drainage networks may also tax the capacity of the Trinity River's creeks and tributaries. Population growth and the outward expansion of metropolitan areas into what was formerly open space has increased the pressure on the region's flood control network and is exposing a growing number of residents to flood risk.

Population and Future Growth

Current Conditions

The Trinity Region is one of the state's most populated flood planning areas, with an estimated 7,854,000 residents living within a 17,800-square-mile area. The vast majority live in the counties that make up the DFW metroplex in the northern area of the region, with multiple smaller population centers interspersed with farms, ranches, forests, and other "working lands" as the river moves southward. In the central region of the basin, the communities of Corsicana, Trinidad, and Athens are located along an east-west axis that borders both Cedar Creek and Richland-Chambers Reservoirs, with Crockett and Palestine to the south and southeast. As the river moves southward toward Lake Livingston, it approaches the communities of Livingston and Liberty. The southern tip of the region borders the Trinity Bay and the Anahuac National Wildlife Refuge. Although not densely populated, the southernmost portion of the region attracts tourists engaged in birdwatching and fishing activities year-round.

Urbanized Areas

The 2019 Five-Year American Community Survey (United States Census Bureau, 2020) estimates, 27 percent of Texas residents currently reside in the Trinity Region. Within the region, there are 38 counties and 286 local communities, 52 of which have an estimated population of 25,000 or greater. Most of these communities are located within Dallas, Tarrant, Denton, and Collin counties.

Cities in the Trinity Region with an estimated population of 25,000 or greater include:

- Allen
- Arlington
- Balch Springs
- Baytown
- Bedford
- Benbrook
- Burleson
- Carrollton
- Cedar Hill
- Colleyville
- Coppell
- Corsicana
- Dallas
- Denton
- DeSoto
- Duncanville
- Euless
- Farmers Branch

- Flower Mound
- Forney
- Fort Worth
- Frisco
- Garland
- Grand Prairie
- Grapevine
- Haltom City
- Huntsville
- Hurst
- Irving
- Keller
- Lancaster
- Lewisville
- Little Elm
- Mansfield
- McKinney
- Mesquite
- Midlothian
- North Richland Hills
- Plano
- Prosper
- Richardson
- Rockwall
- Rowlett
- Sachse
- Saginaw
- Southlake
- The Colony
- University Park
- Watauga
- Waxahachie
- Weatherford
- Wylie

Only two larger communities are located outside the metroplex. The population of Huntsville in Walker County (which is only partially located within the planning area) was estimated at approximately 43,000 in 2019. Another larger community in the region includes Corsicana, (Navarro County) in the central Trinity Region.

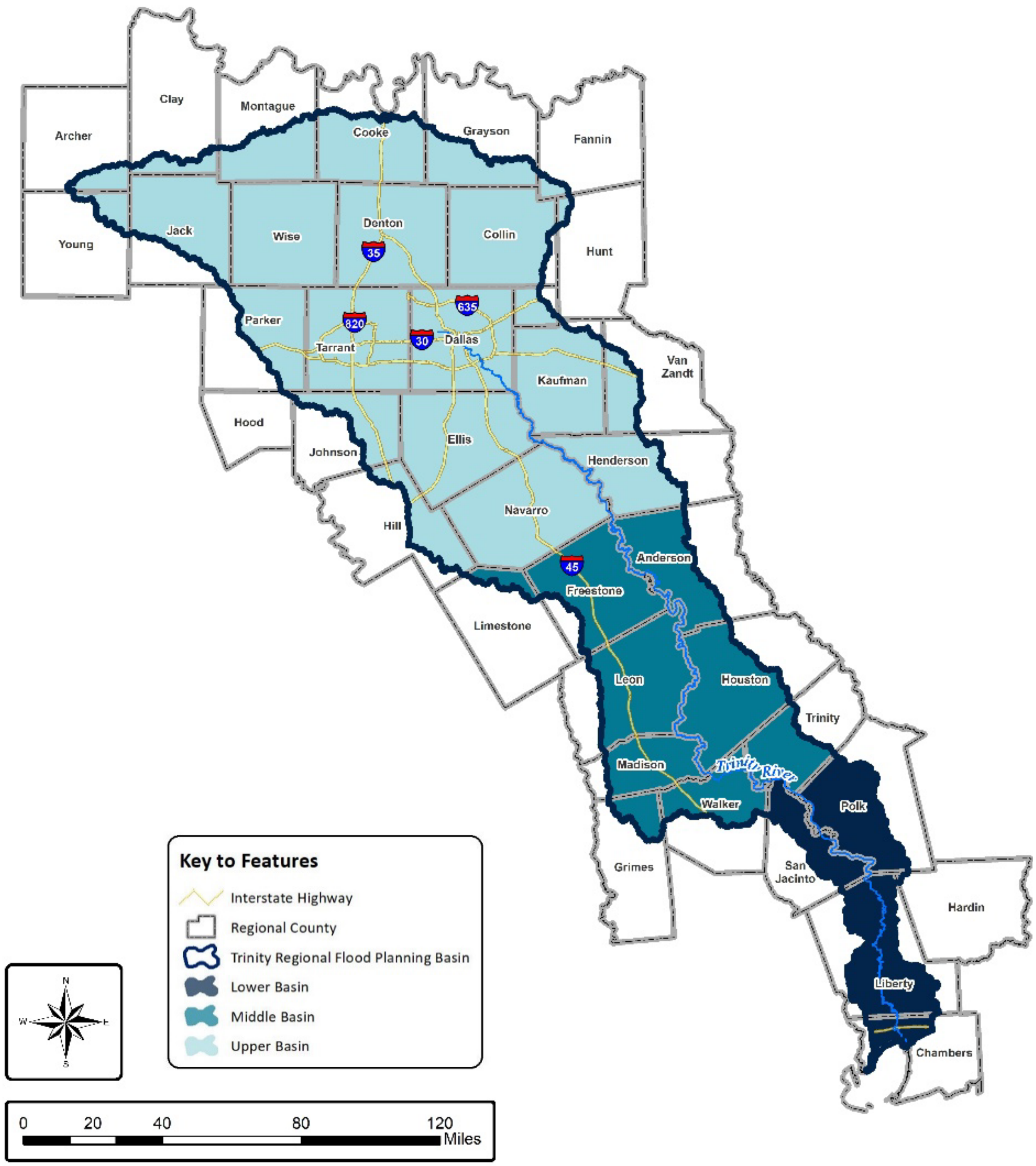
The Trinity Region also encompasses approximately 120 Municipal Utility Districts (MUDs) and Special Utility Districts (SUDs), 37 Water Control and Improvement Districts (WCIDs), and 10 Levee Improvement Districts (LIDs), many of which also have a role in flood protection.

Projected Growth within the Region

The current growth patterns in the Trinity Region are generally projected to continue over the next 30 years, with greater concentration in urban areas and even declining population in some rural counites. The analysis for this section was completed using the Water User Group and Hydrologic Unit Code (HUC)-8 population projections provided by the TWDB from the 2022 State Water Plan. From 2020 to 2050, the number of communities with populations over 25,000 is likely to increase to 64. The majority of these communities are within the DFW metroplex.

Due to the large area covered by the Trinity Region, the population projection analysis will be divided into three subregions (upper, middle, lower) that are generally divided by growth patterns, as illustrated in ***Figure 1.6***. These thresholds separate the communities into categories of similar size. The upper subregion contains those counties north of Navarro and Henderson, the middle subregion contains those counties north of Walker and Trinity counties and south of the upper subregion, the lower subregion contains the rest of the counties south of the middle subregion. ***Figure 1.6*** illustrates the dividing line between these subregions.

Figure 1.6: Trinity River Basin Sub-Regions



To determine growth patterns and population throughout the region, the team prepared ***Figure 1.7*** in which shading on the map indicates the population per community divided into five categories: 0-15,000; 15,001-50,000; 50,001-150,000; 150,001-350,000; 350,001+.

Upper Trinity

The upper portion of the Trinity Region encompasses the DFW metroplex and surrounding counties. A distinctive pattern within this subregion is an intense urban aggregation driven by the rapid acceleration of population growth. In fact, according to the TWDB's Water User Group projections, the top 10 fastest growing communities from 2020 to 2050 in the Trinity Region are within the upper subregion, all of which display over 250 percent increases in their population as shown in ***Table 1.2***. While Dallas, Fort Worth, and Arlington do experience large growth nominally, the higher extreme percentages happen in suburban communities in areas that are currently agricultural or ranching areas, as displayed in ***Table 1.2***. Generally, the fastest pace growth is in the northern portions of the DFW metroplex, specifically north and northeast of the City of Dallas.

Table 1.2: Top 10 Fastest Growing Communities in the Upper Trinity Subregion

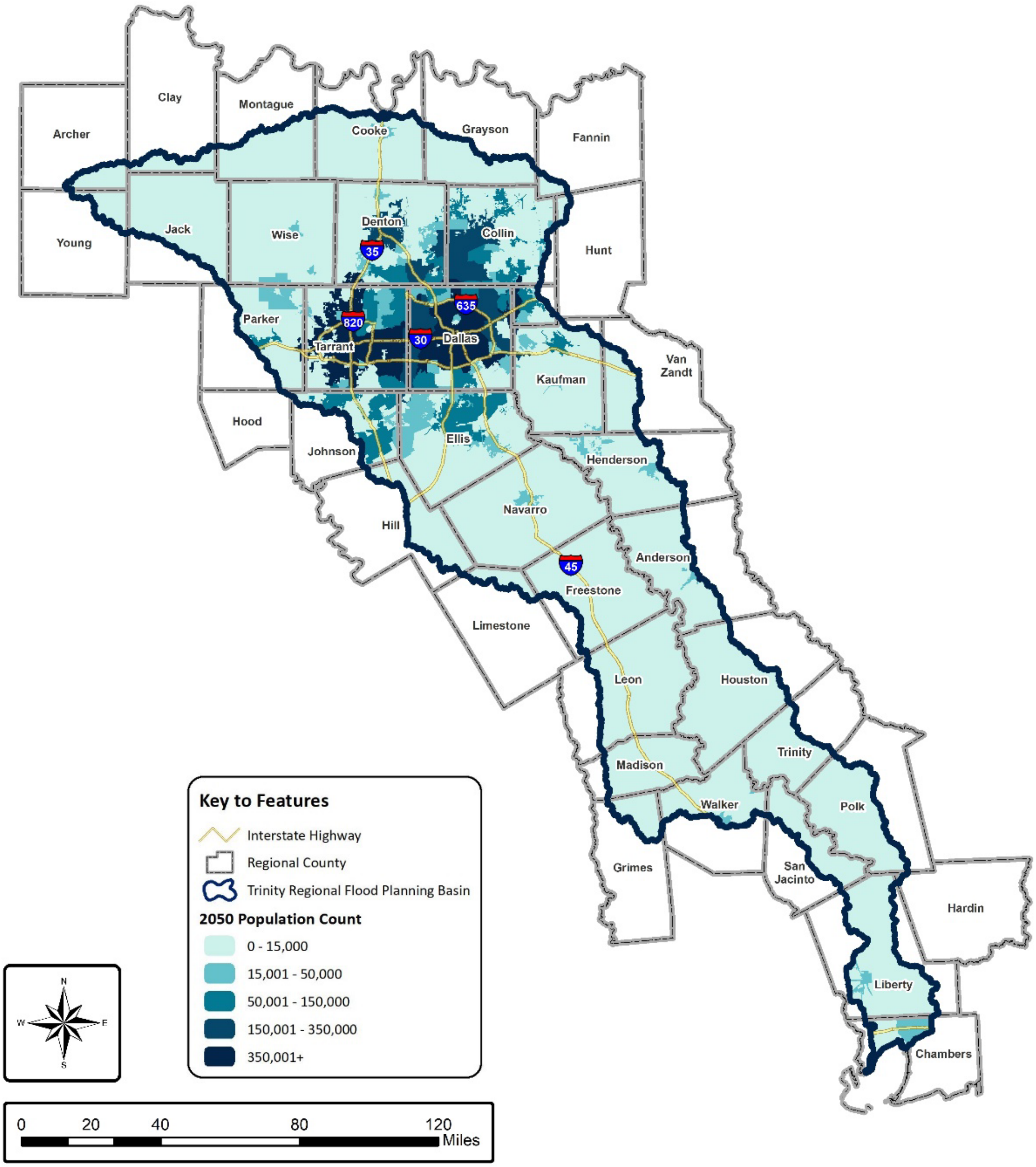
Community	Population 2020	Population 2050	Percent Change
Blue Ridge	2,425	81,703	3269%
Farmersville	8,660	75,393	771%
Princeton	11,047	91,943	732%
Haslet	1,750	14,000	700%
Celina	22,000	143,425	552%
Trenton	736	4,203	471%
Melissa	17,938	100,000	457%
Westlake	1,541	7,750	403%
Northlake	9,500	43,005	353%
Anna	15,037	53,553	256%

Source: TWDB Regional Water Plan, Water User Group Projections 2020-2070 (TWDB, 2020)

Middle Trinity

In the middle subregion, Navarro, Henderson, and Anderson counties feature communities with populations in the 15,000-50,000 range. However, none of these communities is anticipated to experience enough growth to move up to the next population category. Growth will continue to occur in and around larger urban areas. Of the larger communities in the middle subregion, Athens is projected to grow 34.05 percent, Corsicana increases in population by 32.94 percent, and Palestine will see a 4.48 percent increase in population.

Figure 1.7: Community Population Projections (2050)



Lower Trinity

The lower subregion of the Trinity Region's southernmost counties is within the Houston-Galveston Area Council region. Growth from the Houston area is expected to expand into these two counties and increase populations. While Huntsville remains within the 15,000-50,000 range, two communities within Liberty and Chambers counties are anticipated to rise into this range from the smaller category. According to the Water User Group projections of the largest communities, Huntsville will remain at the top with a projected growth rate of 11.5 percent, Dayton will surpass the City of Liberty with a growth percentage of 86.76 percent, and the City of Liberty will have a growth rate of 23.15 percent but will remain within the 0-15,000 category.

Economic Activity

Commercial Activity

To understand the economic risk that the region faces from flood events, this study identified the most significant industries within the region by three measures:

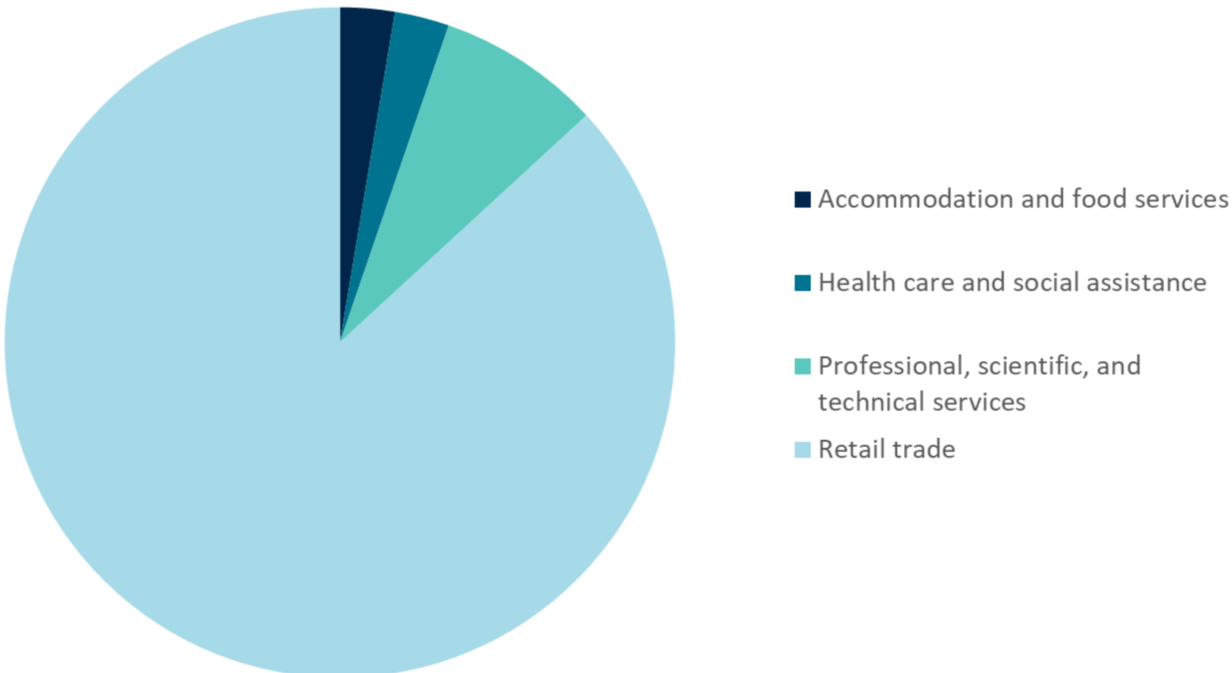
1. Number of establishments
2. Annual payroll
3. Total annual revenue

Data from the United States Census Bureau's Economic Census was used to identify the most predominant industries within the region. Industries were divided in accordance with the North American Industry Classification System (NAICS), which classifies all types of business sectors to facilitate the publication of statistical data related to the United States economy.

Number of Business Establishments

The total number of business establishments as of 2017 for every industry within the Trinity Region is approximately 196,600. As shown in ***Figure 1.8*,** retail trade proved to be the predominant industry throughout the region. Retail trade was followed by professional, scientific, and technical services as the second most predominant industry within the region. Each business contributes to the tax base of their community, and most employ workers who depend on them as a sole source of income. If damaged or forced to close for an extended period of time, these businesses may each need financial and technical support to recover. The Federal Emergency Management Agency (FEMA) reports that roughly 40 percent to 60 percent of small businesses never reopen their doors following a disaster. The impact of business interruption on each individual business is significant. However, it is important to note the possibility that many of these retail establishments are smaller businesses and this measure may not fully capture the impact of a particular economic sector on the overall regional economy.

Figure 1.8: Major Industry by Number of Business Establishments



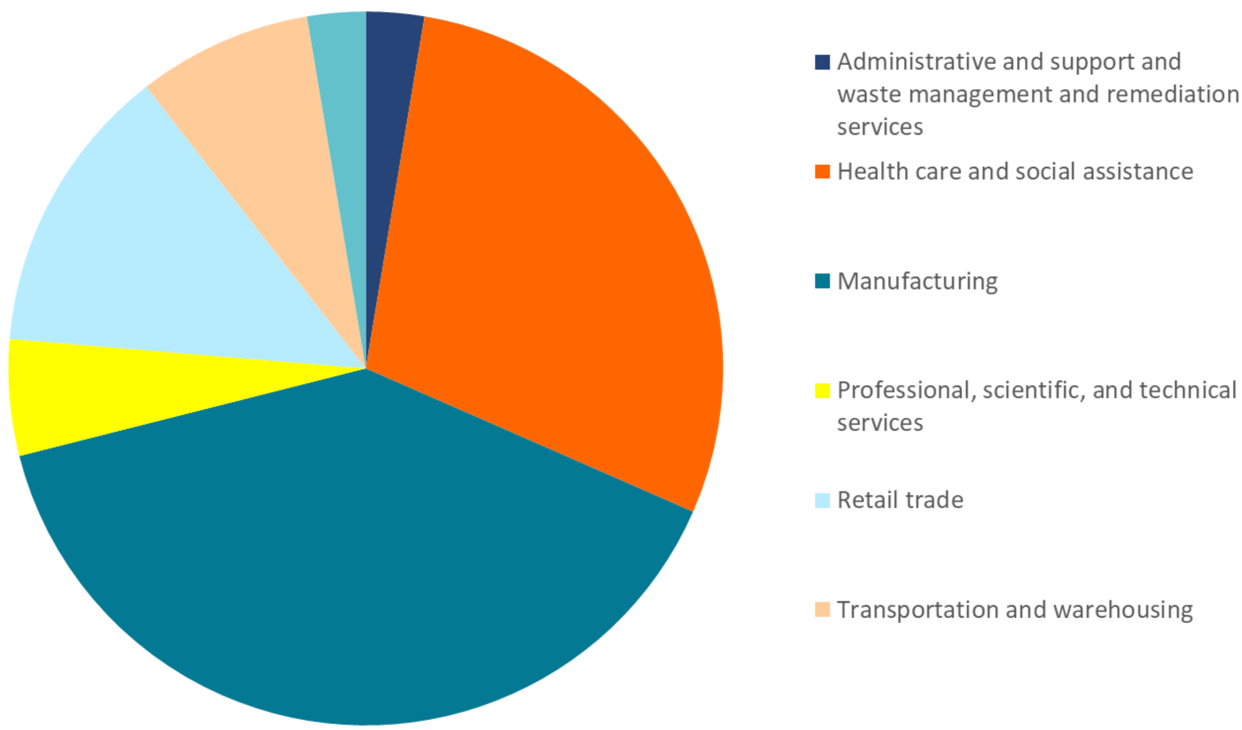
Source: United States Economic Census Table (United States Census Bureau, 2017)

Annual Payroll

The total annual payroll in the region as of 2017 is $178,500,918,000. The share of payroll by industry sector is showcased in ***Figure 1.9.*** Manufacturing and health care and social assistance represent the largest share of all industries by payroll. This is not surprising as both manufacturing and health care are among the highest-paying industries nationwide.

By mitigating the impact of flooding on businesses, communities can become more economically resilient. One factor that is considered in this plan is social vulnerability, as measured by the Social Vulnerability Index (SVI), which accounts for loss of income as one of the greatest predictors of future vulnerability for individuals and communities. The Index (SVI) uses 15 different census variables to help identify communities that may need support before, during, and after a disaster. A severe flood event, which could affect income in these sectors, would heavily impact those vulnerable populations.

Figure 1.9: Major Industry by Payroll

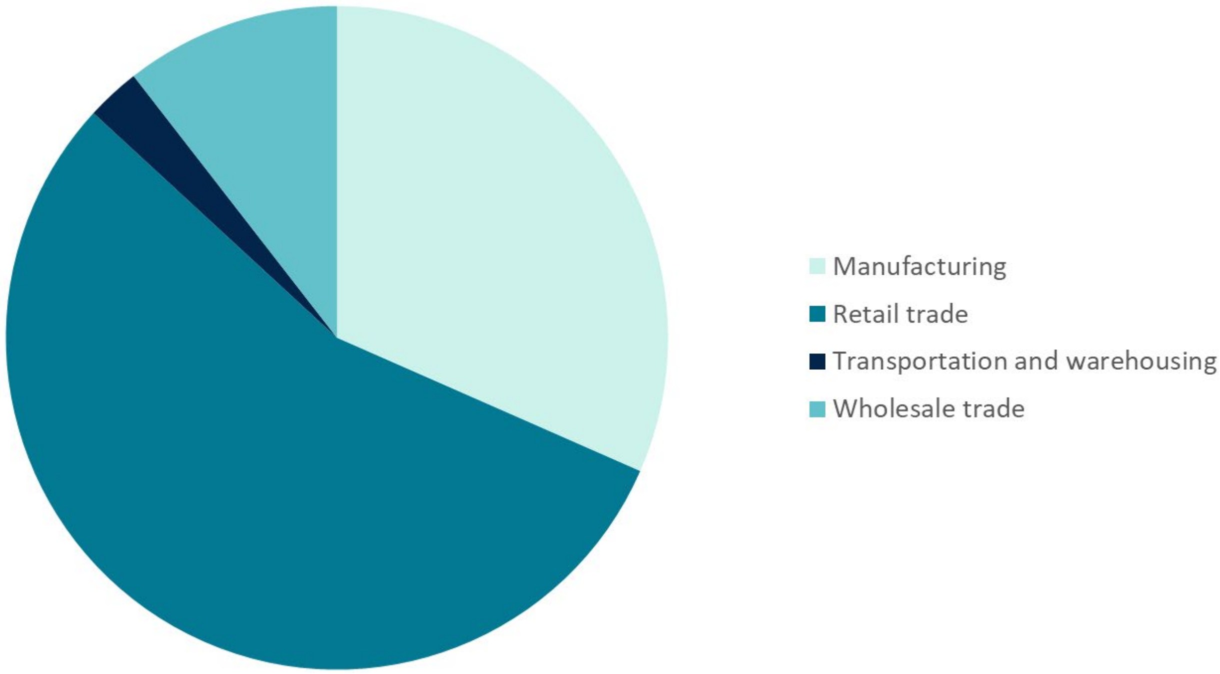


Source: United States Economic Census Table (United States Census Bureau, 2017)

Total Annual Revenue

The analysis for total revenue by industry may provide the most useful insight into potential economic disruption of a major flood event by indicating the sectors most likely to be exposed to this risk. Total revenue indicates which industries have the greatest economic impact. While agriculture is an essential industry throughout the region, it provides a smaller amount of revenue in the region than some of the other categories. ***Figure 1.10*** demonstrates that retail trade remains the dominant industry in this area, followed by manufacturing, and wholesale trade. To extend this assessment to the county level, ***Figure 1.11*** identifies which industry sector makes up the largest share of annual revenue in each Trinity Region county, in order to provide some perspective on the benefit of developing FMSs that reduce future economic impact.

Figure 1.10: Major Industry by Revenue

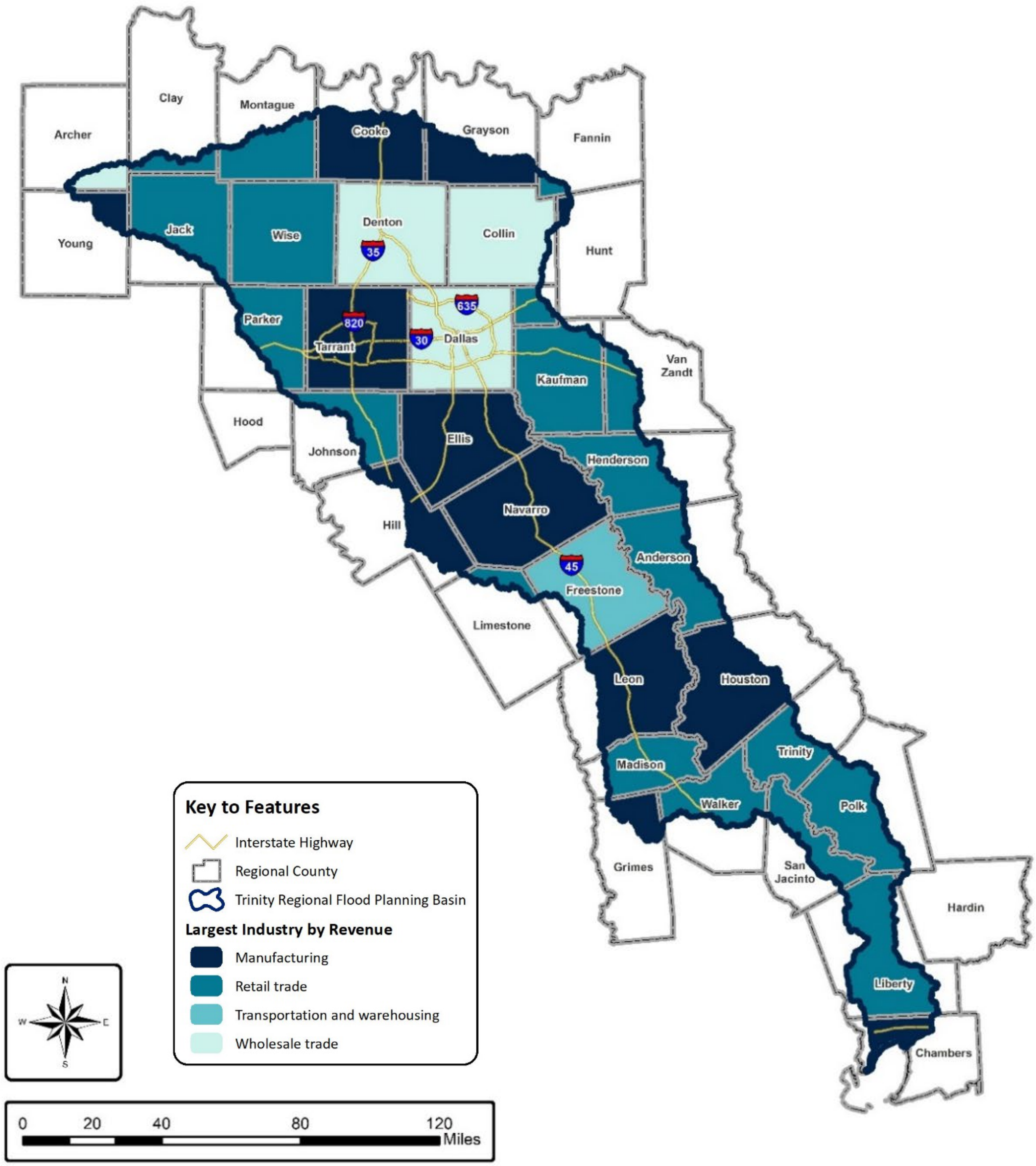


Source: United States Economic Census Table (United States Census Bureau, 2017)

Agricultural and Ranching Activity

While the upper regions of the Trinity Region may draw attention due to the DFW metroplex, the waters of the Trinity River also traverse an extremely productive agricultural region with a rich farming and ranching heritage. Although the census did not record agriculture as being one of the top economic drivers in the region, it is still an integral component of the regional economy. Even though fewer people are exposed to flood hazards in these areas, the impact of flooding on agriculture, ranching, and forestry can be severe. Floods can delay the planting season, as they soak the fields and make them impassable for heavy equipment. This can lead to reduced crop size, lower yields, and reduced profits. When floods occur as crops mature in the fields, they may destroy a whole season's work and investment. Floods at harvest time can make it impossible for farmers to harvest mature crops and get them to market. Livestock may drown in floodwaters if there is no high ground for them to escape. Even if the animals are safe, damage may occur to barns and other structures, and cleanup of muck and debris can affect their feeding grounds. Forestry or orchard operations can lose trees to long periods of inundation, fast moving waters, and erosion, wiping out years of growth.

Figure 1.11: Major Industry by County



Source: United States Economic Census Table (United States Census Bureau, 2017)

To characterize the economic activity and character of Texas' rural spaces, this document employs the term "working lands", used by the Texas A&M Natural Resources Institute to describe rural economic activity. Working lands are privately owned farms or cropland, ranches, and forests and associated uses that make up the majority of economic activity in Texas' rural areas.

The distribution of these land uses across Texas is illustrated in ***Figure 1.12,*** which uses data from the United States Geological Survey (USGS) to help visualize how land is used across the region. The area dedicated to each use identified in ***Figure 1.12*** is as follows:

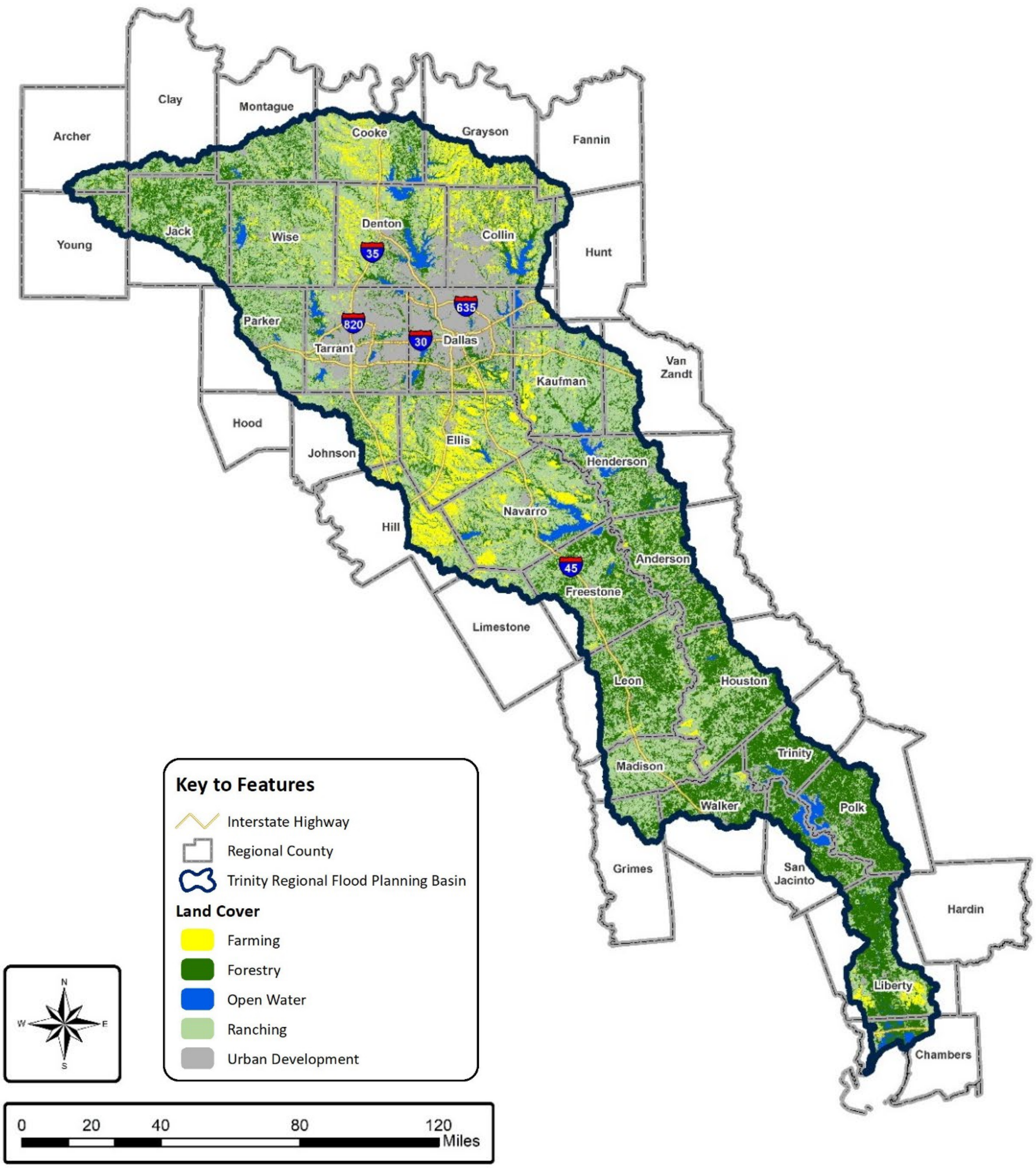
- **Ranching:** 4,882,000 acres
- **Forestry:** 3,415,000 acres
- **Farming:** 1,175,000 acres
- **Urban development:** 1,660,000 acres

Across Texas, the average acreage of farm and ranch operations is decreasing, and smaller parcel size may reduce the profitability of these enterprises. When combined with losses due to flooding, this could increase the likelihood of economic failure of a farming, ranching, or forestry operation.

Ranching and rangeland land uses predominate to the northwest of the Trinity Region in Wise, Parker, and the western half of Tarrant counties. Large landholdings in these counties may also be reflected in socioeconomic data, where census tracts far outside of urbanized areas have a very high median income. In the central portion of the flood planning area, Kauffman, Navarro, Henderson, and Madison counties are home to some of the largest concentrations of rangeland.

Farmland, symbolized in yellow, is the predominant use of working lands in the upper region. The Blackland Prairie Ecoregion in Grayson and Collin counties north of the metroplex, and Ellis, Johnson, Hill, and Navarro counties to the south are home to some of the state's most fertile croplands. Cooke and Denton counties also retain significant farmland in the Cross Timbers Ecoregion, although Denton County cropland continues to experience encroachment from urban areas. As the Trinity Region descends south toward the Gulf, farming activity resumes. According to the United States Department of Agriculture (USDA), major crops between 2015 and 2019 included sorghum, corn, and winter wheat, with rice in Liberty County and a small share of the state's cotton production. (USDA, 2021).

Figure 1.12: Working Lands in the Trinity Region by Land Cover



Source: USGS National Land Cover Database 2016 (USGS, 2016)

Economic Status of Population

Median Household Income (MHI) divides the data from the 2021 Environmental Systems Research Institute (ESRI) Census Tract data levels across the region in two equal halves to provide a good comparison for income levels across the region. The MHI can be affected by many factors, including education levels, opportunity of employment, and location. It is important to note that within any given area, there are residents that are outliers in both directions. The state MHI according to this measure is $63,500. Many communities near the downtown areas of Dallas and Fort Worth, as well as the inner ring suburbs of DFW are living on incomes below the state MHI. The lowest income tier is illustrated on ***Figure 1.13***. Suburban communities outside of these central areas in the northern suburbs have the region's highest median incomes. Another location with higher-than-average incomes is the southernmost portion of the region near the Trinity Bay. As the region moves south, the majority of census tracts have MHIs that are comparable with the state as a whole, however in many rural areas' household incomes are significantly lower than the state median.

Income Levels by Subregion

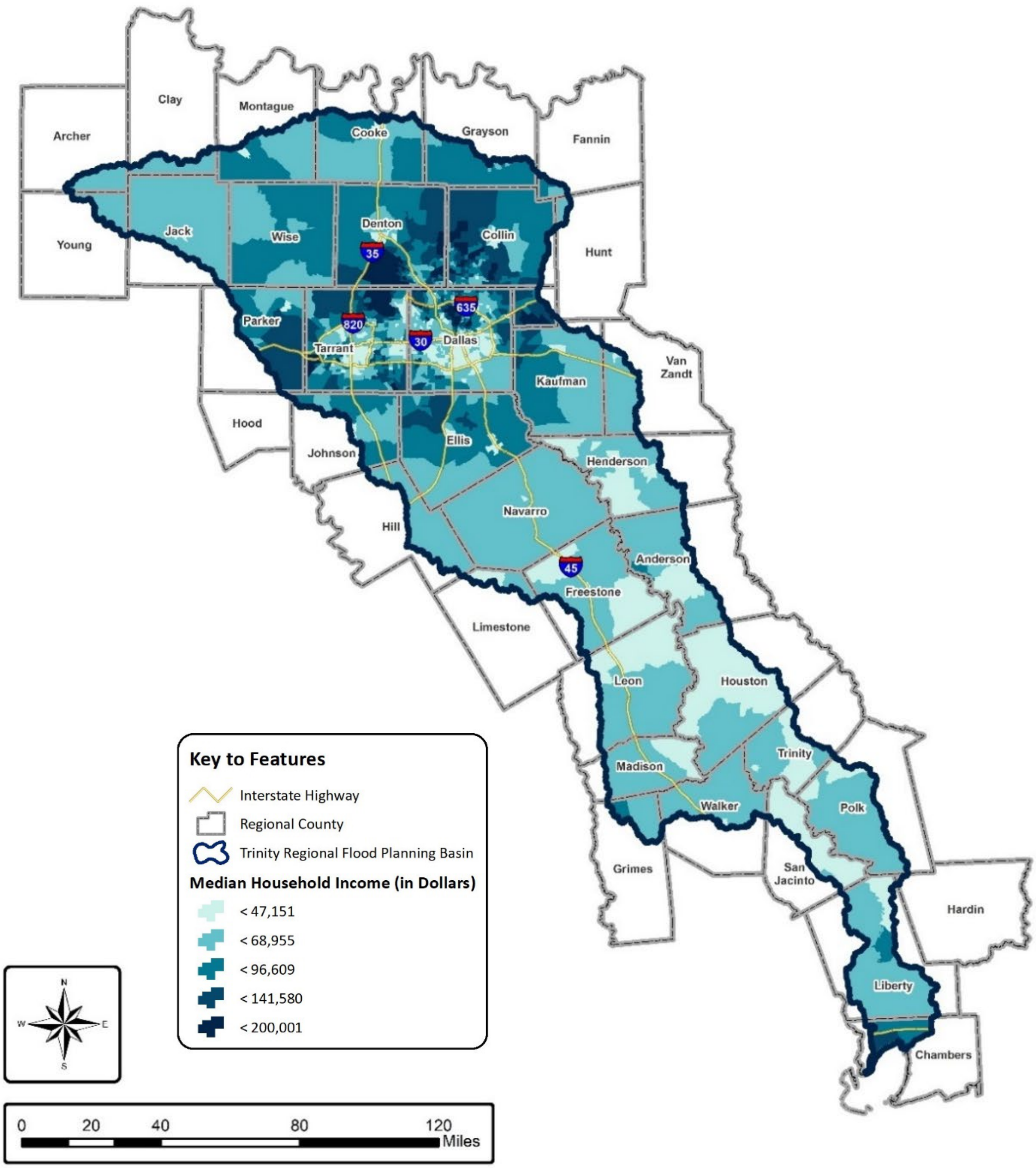
The upper subregion of the Trinity Region features the highest levels of household income, but still shows a wide diversity of incomes, with census tracts in every household income category. All of the region's highest annual income census tracts in the greater than $141,580 category lie within this subregion. The highest median income areas are within North Dallas, Southlake-Flower Mound area, near the Denton County – Collin County border, and to a lesser extent within Rockwall and Tarrant counties. All but one of the census tracts in the $96,609-$141,579 range are within the upper subregion.

As stated previously, many of these tracts lie on the outskirts and suburbs of Dallas and Fort Worth, predominantly in the northern suburbs of Dallas. The $68,955-$96,608 category comprises most of Ellis, Kaufman, and Wise counties and half of Denton County. The final two household income categories are mostly concentrated in the Dallas and Fort Worth area, with some tracts being in the more rural areas of the upper subregion. See ***Figure 1.13*** for more details on the distribution of income across the region.

The majority of the census tracts within the middle subregion have household incomes roughly equivalent to the state median income of $63,500. There is one census tract in the western portion of Anderson County that is within the $68,955-$96,608 category.

The lower subregion increases in household income as it nears the Trinity Bay and the influence of Houston. While there are many tracts in the lower two categories, there are a few tracts within Liberty, Chambers, and Grimes counties that are in the $68,955-$96,608 category. The tract bordering the Trinity Bay within Chambers County is within the $96,609-$141,579 category.

Figure 1.13: Median Income by Census Tract



Source: ESRI Business Analyst Census Tract Data (United States Census Bureau, 2021)

Social Vulnerability Analysis

When anticipating the likely extent of damages to a community from catastrophic floods, this assessment first considers “exposure” based on geographic location of people and property. Another important dimension to increasing the resilience of the communities in the Trinity Flood Planning Region is their relative “vulnerability” to floods when they do occur. Disasters affect different people or groups in different ways, which range from their ability to evacuate an area in harm’s way, to the likelihood of damage to their homes and properties, to their capacity to marshal the financial resources needed to recover and rebuild after a storm. These factors are known as Social Vulnerability, or a person’s or group’s “capacity to anticipate, cope with, resist, and recover from the impacts of a natural hazard” based on their relative vulnerability. ***Figure 1.14*** is based upon an analysis of this region using the SVI – from the United States Department of Health and Human Services (HHS) Centers for Disease Control and Prevention (CDC). The Index is measured on a scale of 0-1, with 1 being the highest level of vulnerability and is used here to map social vulnerability in the region. The index focuses on a series of 15 demographic indicators:

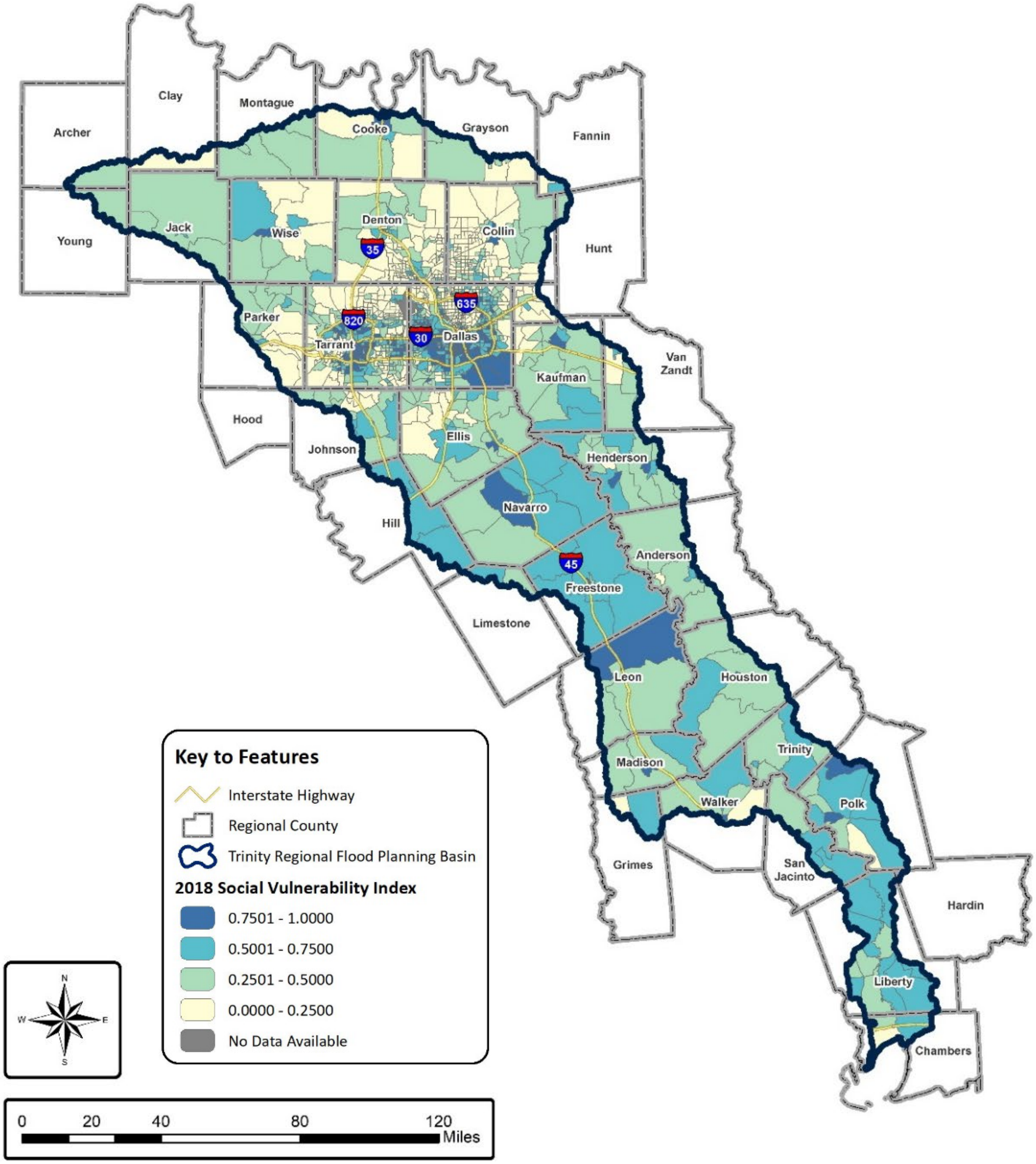
- Below poverty
- Unemployed
- Low Income
- No vehicle
- No high school diploma
- Aged 65 or older
- Aged 17 or younger
- Civilian with a disability
- Single-parent households
- Minority status
- Multi-unit structures
- Mobile homes
- Crowding
- Group quarters
- Language barriers

(Jaimie Hicks Masterson, 2014)

The presence of multiple factors above in a population, or even an individual household, have proven to be a reliable indicator of the long-term impact of a disaster. In ***Chapter 2***, this regional plan engages in a more detailed discussion about the location of high social vulnerability populations, the location of flood protection infrastructure and how future FMPs might reduce their vulnerability to injury and economic losses.

The level of social vulnerability varies widely even within a single county, which may contain both the most and least vulnerable populations. In the Trinity Region, the highest concentrations of social vulnerability, as shown in dark blue, are in the census tracts to the southeast of Dallas in Dallas County, Tarrant County south of Fort Worth, and small but densely populated census tracts in Wise, Collin, and Kaufman counties.

Figure 1.14: Social Vulnerability Index by Census Tract



Source: Social Vulnerability Index by Census Tract
(United States Center for Disease Control, 2018)

Navarro County to the west of I-45 and two census tracts in Henderson County show evidence of high social vulnerability. In the middle subregion, the northernmost census tract of Leon County indicates high social vulnerability. Two census tracts in Polk County are the only areas to show the highest level of social vulnerability in the lower subregion, but as the Trinity River winds southward, there is an increasing likelihood that Counties and census tracts will show a modest to high level of social vulnerability, with a score of 0.5 to 0.75.

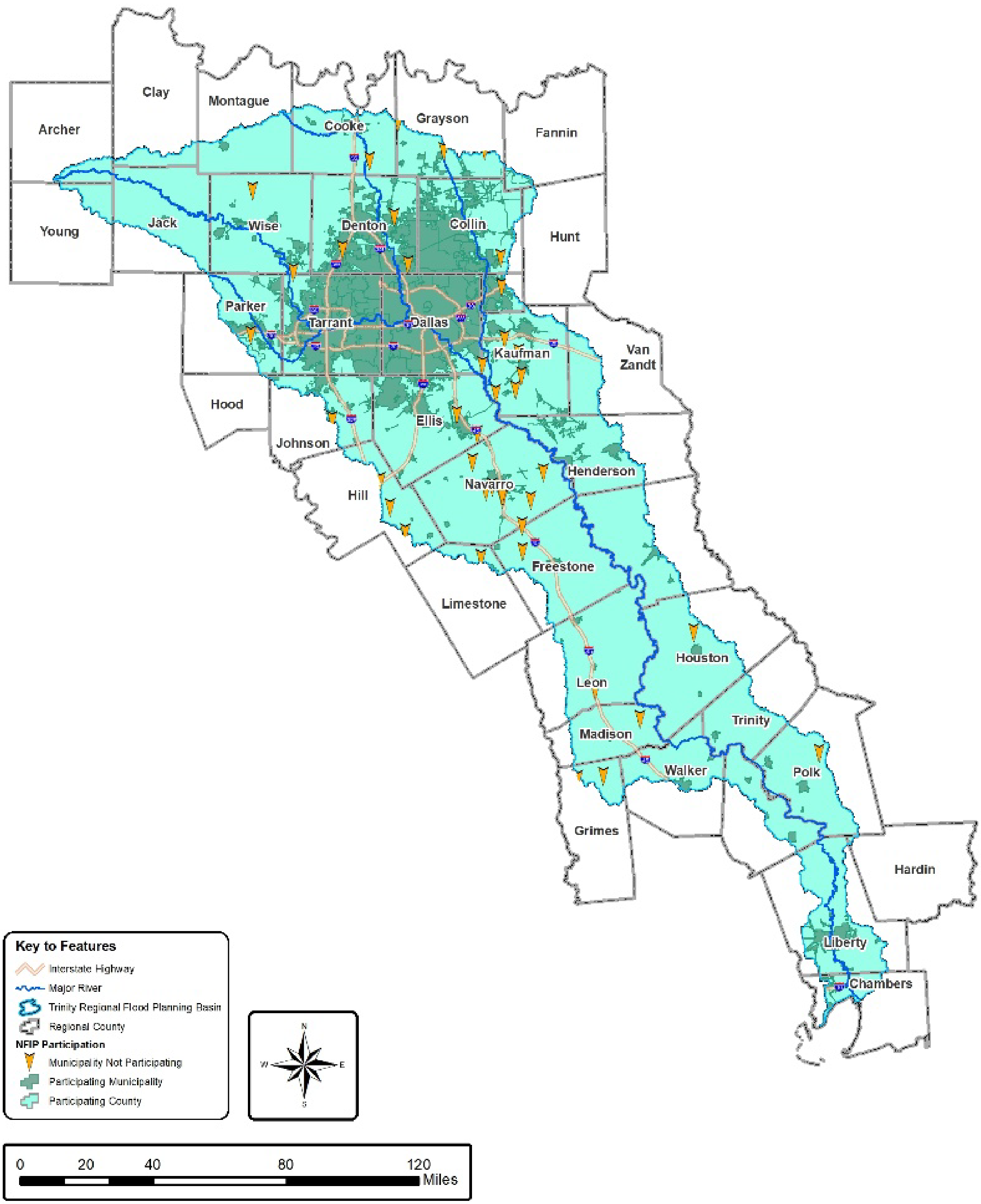
Flood-Prone Areas and Flood Risks to Life and Property

As Texas seeks to better manage flood risk to mitigate loss of life and property from flooding, this section establishes a baseline of what is known with respect to the area's exposure to flood hazards, as well as the vulnerability of the communities within the Trinity Region. This is a critical step in reducing the vulnerability of the Trinity Region's people and places to future flooding.

Today, a patchwork quilt of plans, regulations, and infrastructure provides Texans with limited protection from flooding. This planning largely takes place at a local level, with an inconsistent set of standards from community to community that makes it very difficult to quantify risk across the region. Fortunately, majority of the communities in the Trinity Region (87 percent) participate in the National Flood Insurance Program (NFIP). This is good news, as it improves their prospects for economic recovery in the event of a major flood and provides a system to reduce flood risk to new development. However, many communities are using maps that are decades old and may only tell part of the story. These maps may not reflect changing patterns of development and often fail to identify flood risks associated with changes in the topography and environment. Additionally, Flood Insurance Rate Maps are intended to identify and communicate risks in the watershed less than one square mile but do not always include all watersheds and may be greater than one square mile in many communities. ***Figure 1.15*** shows the participating communities within the Trinity region. While all the counties within the region participate in the NFIP, the same is not true of all the cities.

In the absence of a cohesive flood map that applies across the region, the following chapters of this assessment will piece together an intricate flood quilt, combining several data layers from FEMA, including effective detailed maps, effective approximate maps, Base Level Engineering (BLE) with data from other federal agencies, local and regional studies, and the commercially available data prepared by Fathom that was provided by the TWDB. (Additional information on the floodplain quilt is included in ***Chapter 2***.)

Figure 1.15: Participation in National Flood Insurance Protection Program



Identification of Flood-prone Areas

According to current FEMA mapping, approximately 20 percent of the total area in the region is within the 1% annual chance storm event. In the Trinity Region, more than 50 communities have over 20 percent of their land located in the floodplain. This only tells part of the story, because not all the floodplains within the Trinity Region have been mapped and modeled. While developing a comprehensive flood risk model of the region is beyond the scope of this planning effort, the TWDB provided a floodplain quilt for use in this plan. The quilt is a combination of various sources of data, providing comprehensive coverage of all known existing statewide flood hazard information.

Figure 1.16 shows the initial flood quilt information provided by the TWDB that served as the Trinity Region's starting point, providing an approximation of region-wide flood risk using currently available data. In subsequent chapters, this "quilt" is confirmed, updated, and otherwise enhanced as appropriate to prepare a larger flood risk assessment (TWDB, 2021). When complete, this regional flood quilt identifies gaps in information and more accurately estimates the distribution of flood risk across the region. A more comprehensive description of the identification of flood-prone areas is provided in ***Chapter 2***.

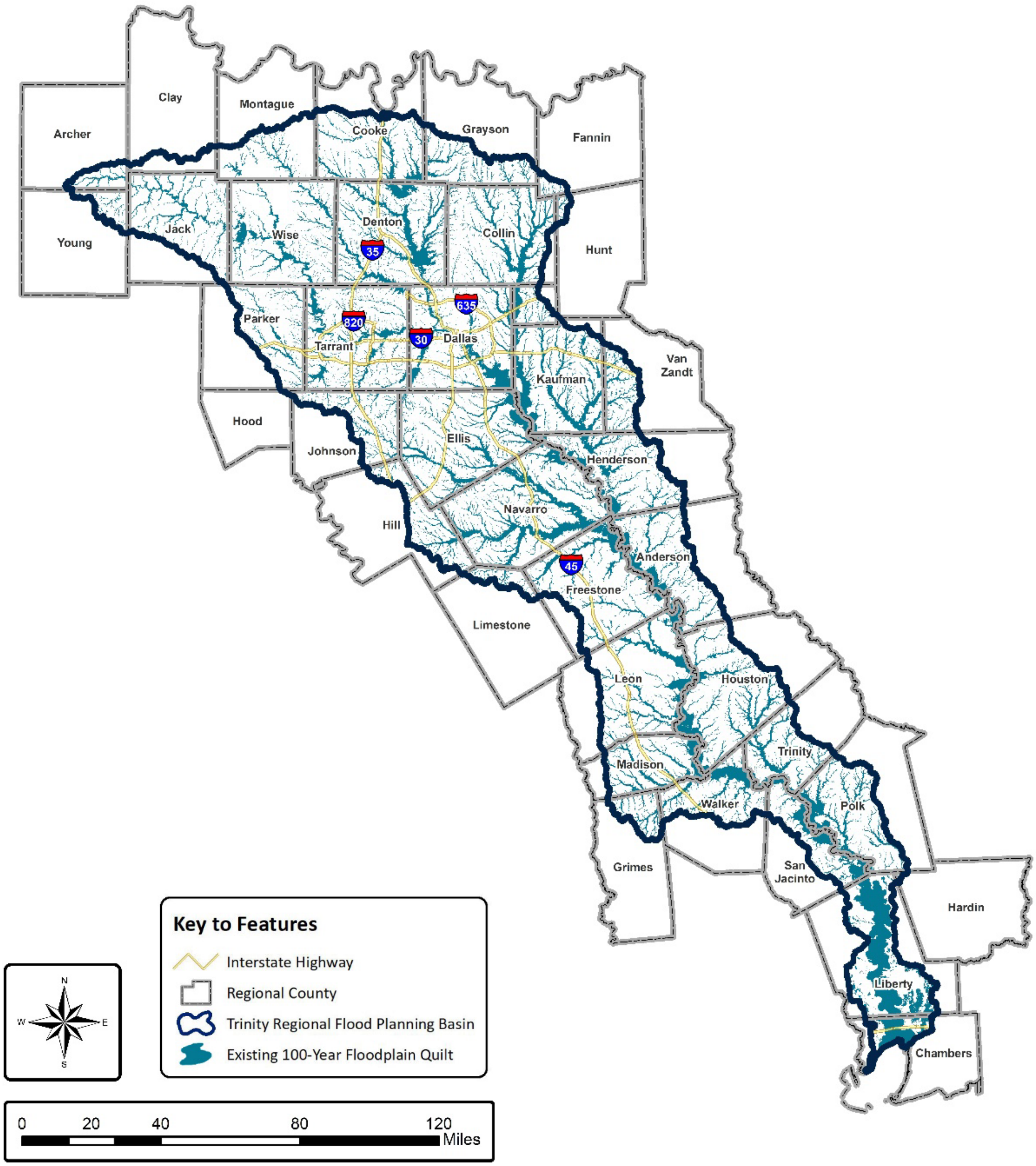
Key Historical Flood Events

The cycle of catastrophic disasters in the Trinity Region ebbs and flows year by year, but a long history of flooding has irrevocably shaped its communities, with flood control measures like dams and levees expanding the lands available for new development. Early historical Trinity River floods affected population centers located along the river and its major tributaries. The 1908 and 1942 floods in Dallas and Fort Worth resulted in the creation of the USACE Fort Worth District in 1950 (USACE, USACE Fort Worth District History, 2021) and spurred the construction of multiple dams for flood control purposes within the Trinity Region (Cotter & Rael, 2015). In the years since, these flooding concerns have been addressed by state and local efforts in addition to the USACE. ***Chapter 4*** includes more detailed information on historical flood events.

For example, one of the most significant storms was the May 1949 flood in the DFW Metroplex. The levee for the Clear Fork of Trinity River in Fort Worth failed, inundating hundreds of homes and businesses. ***Figure 1.17*** illustrates the impacts of this flooding in what are now some of the busiest commercial and residential areas of the City of Fort Worth.

Even though there are many years with no recorded disaster that reaches either the level of a Major Disaster Declaration (DR) or an Emergency Declaration (EM) the cumulative impact is great. Frequently, however, when one disaster occurs, it is followed by one or more catastrophic events during the same year, and perhaps even the same month.

Figure 1.16: Flood-Prone Areas



Source: TWDB Flood Quilt Data

Figure 1.17: Image of Flooded Wards Building and Rooftops, Fort Worth

Source: USACE (USACE, 1949)

Since 2000, there have been 125 EMs and 112 DRs within the Trinity Region (FEMA, 2021). A Presidential DR puts into motion long term federal recovery programs, some of which are matched by state programs, and designed to help disaster victims, businesses, and public entities. An EM is more limited in scope and without the long-term federal recovery programs of a DR.

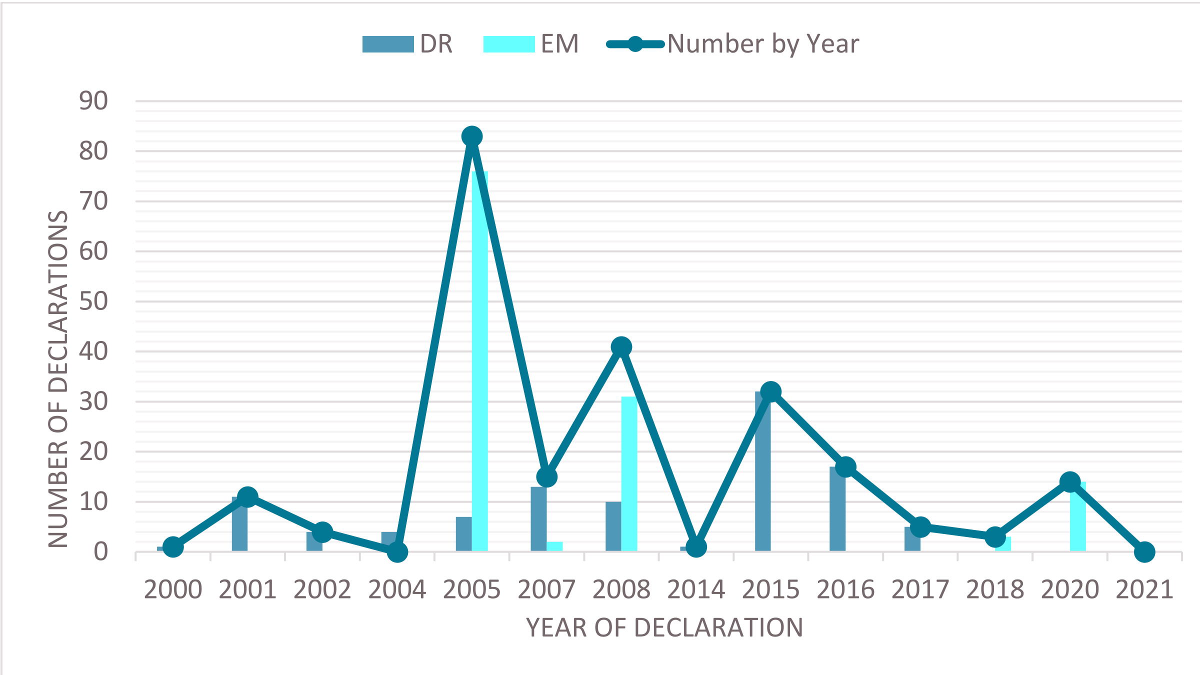
Generally, federal assistance and funding are provided to meet a specific emergency need or to help prevent a major disaster from occurring. Public Assistance (PA) is FEMA's largest grant program providing funds to assist communities responding to and recovering from major disasters or emergencies declared by the president. The program provides funding for emergency assistance to save lives and protect property and assists with funding for permanently restoring community infrastructure affected by a federally declared incident. Supplementally, PAs can be categorized for emergency work such as PA-A which is for debris removal and PA-B which is for emergency protective measures. Individual Assistance (IA) programs are made available under EMs and are limited to supplemental emergency assistance to the affected state, territory, or tribal government to provide immediate and short-term assistance essential to save lives, protect public property, health, and safety, or to lessen or avert the threat of a catastrophe. All IA programs may be authorized once a major disaster has been declared by the president. The approval of IA under a DR may also activate assistance programs provided by other federal agencies based on specific disaster needs.

Figure 1.18 charts the frequency of these declarations across the Trinity Region for the last 21 years. Some of the most significant events in that time period follow. To search for more information on EM of DR, FEMA provides a search tool found here: https://www.fema.gov/disaster/declarations.

EM-3216-TX, August 2005 (Hurricane Katrina)

Hurricane Katrina was a category five Atlantic hurricane that caused over 1,800 deaths and $125 billion in damage in late August 2005, particularly in the City of New Orleans and the surrounding areas. At the time, it was the costliest tropical cyclone on record and is now tied with 2017's Hurricane Harvey. The storm was the twelfth tropical cyclone, the fifth hurricane, and the third major hurricane of the 2005 Atlantic hurricane season, as well as the fourth-most intense Atlantic hurricane on record to make landfall in the contiguous United States. The State of Texas had an EM declared on September 2, 2005, for PA for 254 counties, including all the Trinity Region counties for emergency protective measures. Texas took in over 250,000 evacuees from Louisiana and other affected states.

Figure 1.18: Disaster Declarations within Trinity Region, 2000-2021



Source: Flood Events by County
(National Centers for Environmental Information, 2022)

EM-3261-TX, September 2005 (Hurricane Rita)

Hurricane Rita was the most intense tropical cyclone on record in the Gulf of Mexico. It moved westward through the Florida Straits, where it entered an environment of abnormally warm waters. Moving west-northwest, it rapidly intensified, achieving category five status on September 21. However, it weakened to a category three hurricane before making landfall in Johnson's Bayou, Louisiana, between Sabine Pass, Texas and Holly Beach, Louisiana. The timing of Hurricane Rita following on the heels of Hurricane Katrina compounded the disaster as Texas was still sheltering evacuees across the Trinity Region when Rita made landfall.

The impact of Rita on Southeast and East Texas included both wind and storm-surge damage. Due to the extensive damage, an EM for PA for 254 counties, including all the Trinity Region counties was made.

DR-1791-TX, September 2008 (Hurricane Ike)

On September 12, 2008, a DR was declared due to Hurricane Ike. This event had sustained winds of 110 mph upon landfall in Galveston Island making it a category two hurricane. Ike was of a severity and magnitude that the need for supplemental federal assistance was determined to be necessary. For 34 counties, 11 of which are in the Trinity Region, this declaration made IA funding available to affected individuals and households. This declaration also made the PA program available to state and eligible local governments and certain private nonprofit organizations on a cost-sharing basis. A total of 50 counties qualified for PA with 13 of those counties being within the Trinity Region.

DR-4223-TX, May 2015

In the spring of 2015, the Trinity Region experienced several rounds of severe weather which culminated in supercell thunderstorms, dubbed the Memorial Day floods of 2015. Heavy rainfall leading up to the Memorial Day event saturated the soil, intensifying flooding. The National Weather Service recorded over 16 inches of rainfall at DFW International Airport signaling the wettest single month in the DFW Metroplex since 1982. While the flash flooding event was short lived, the cumulative impacts of the event, coupled with Tropical Storm Bill, taxed the basin's rivers and lakes. Several reservoir levels came within inches of breaking all time crest records recorded from a period of record spanning over 110 years. (NCTCOG, 2015) Another round of severe rainfall and subsequent flooding came in the fall of the 2015. This event particularly impacted the lower portion of the region within Liberty and Chambers County where the Trinity River rose above the flood stage.

On May 29, 2015, the State of Texas requested a DR due to severe storms, tornadoes, straight-line winds, and flooding which began on May 4, 2015, and continued through June 22, 2015. The requested declaration included IA for 22 counties including 17 Trinity Region counties, PA for 110 counties including 31 Trinity Region counties, and hazard mitigation for the entire State of Texas. Preliminary damage assessments were conducted in the requested counties to estimate damages immediately after the event and determine the need for additional assistance. On May 29, 2015, the president declared a Presidential Disaster Declaration in the State of Texas.

DR-4332-TX, August 2017 (Hurricane Harvey)

On August 23, 2017, Harvey was upgraded to a tropical depression. Over the next 48 hours Harvey would undergo a period of rapid intensification from a tropical depression to a category four hurricane. Harvey made landfall along the Texas coast near Port Aransas on August 25, 2017, as a category four hurricane and brought devastating impacts. As Harvey moved inland, its forward motion slowed and then meandered back offshore. Harvey continued to skirt the coastline as it made landfall a second time in the Harris County area on August 26th and then a third time just west of Cameron, Louisiana on August 30th.

Rain bands on the eastern side of the circulation of Harvey produced rapid flash flooding and devastating, widespread flooding as the storm moved into southeast Texas. All of this rainfall caused catastrophic flooding and drainage issues and caused rivers to rise and spill out of their banks. Approximately 46 percent of the river forecast points reached new record levels. Harvey maintained tropical storm intensity the entire time while inland over the Texas coastal bend and southeast Texas.

The southern region of the Trinity Basin was once again severely impacted by flooding during Hurricane Harvey. From late August through early September, approximately 2.8-million acre-feet of water was released to the Galveston Bay from Harvey rainfall in the proximity of Liberty County. The City of Liberty, located in Liberty County, recorded 55 inches of rain during Harvey with damages over $11 million. (TRA of Texas, 2021) Overall, Harvey caused $125 billion in damages.

On August 25, 2017, the State of Texas requested an expedited DR due Hurricane Harvey. The DR request covered 60 counties with 10 Trinity Region counties included. The requested declaration included IA and direct federal assistance under the PA program for 41 counties, including seven Trinity Region counties and hazard mitigation statewide. On August 25, 2017, the president declared a major disaster for the State of Texas.

Past Casualties and Property Damage

In a major flood event, there are often losses incurred. In the Trinity Region, while there were no losses of life or injuries reported as being direct results of a storm event, there were multiple reported losses to property. From 1996 to present, property damage losses throughout the region amounted to $2,754,947,138 (see ***Table 1.3***) in 2021 dollars with the largest losses found in densely populated metropolitan areas that are prone to flash flooding, and in coastal areas that are subject to tropical storms and hurricanes.

Past losses for Farming

The Trinity Region accounts for much of the agricultural production in the State of Texas with much of the corn and cotton being produced in this area. According to the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information, the cumulative reported losses to crops due to flooding in the Trinity Region since 2000 amounted to $642,568,000 in 2021 dollars. As not every county fully reports the extent of agricultural damage, it is likely that even this multimillion-dollar tally of crop damage does not represent the full impact of flooding on agriculture in each county, nor does it include the losses of livestock. ***Table 1.4*** summarizes the crop damages by county within the Trinity Region from 2000 through 2021.

Table 1.3: Total Casualties and Property Damages Reported to National Oceanic and Atmospheric Administration

County	Total Events	Deaths Direct	Injuries Direct	2000-2021 Value Property Damage
Anderson	46	7	0	$3,991,491
Archer	28	0	0	$20,421
Chambers	45	0	0	$87,156,201
Clay	19	0	0	$0
Collin	86	0	0	$483,734
Cooke	68	4	4	$42,348,469
Dallas	215	8	1	$75,615,711
Denton	134	2	0	$15,960,546
Ellis	84	2	0	$9,315,832
Fannin	60	0	0	$876,374
Freestone	38	1	0	$2,432,522
Grayson	86	3	1	$31,441,079
Grimes	38	0	0	$3,274,253
Hardin	34	0	0	$689,456,762
Henderson	56	0	0	$2,015,682
Hill	53	0	0	$2,147,557
Hood	58	0	0	$91,273,610
Houston	41	0	0	$770,755
Hunt	89	0	0	$1,775,035
Jack	38	0	0	$2,417,143
Johnson	104	3	0	$4,021,570
Kaufman	65	0	0	$2,112,810
Leon	30	0	0	$703,321
Liberty	43	0	0	$121,849,147
Limestone	77	0	0	$2,027,384
Madison	25	0	0	$563,389
Montague	34	0	0	$8,430,685
Navarro	79	0	0	$31,014,730
Parker	64	0	0	$12,689,119
Polk	36	0	0	$340,687,942
Rockwall	23	0	0	$52,829
San Jacinto	39	0	0	$395,437,556
Tarrant	247	1	0	$90,479,567
Trinity	28	0	0	$410,671
Van Zandt	44	1	0	$1,082,444
Walker	37	1	0	$678,543,015
Wise	76	0	0	$1,707,134
Young	38	0	0	$360,648
TOTAL	**2182**	**33**	**6**	**$2,754,947,138**

Source: Flood Events by County (National Centers for Environmental Information, 2022)

Note: Some counties included in the table only have a small portion of the county within the Trinity Region.

Table 1.4: Total Crop Damage Value (2000-2021)

County	Total Events	2000-2021 Value Crop Damage
Anderson	46	$23,740
Archer	28	Not reported
Chambers	45	Not reported
Clay	19	Not reported
Collin	86	Not reported
Cooke	68	$644,500
Dallas	215	Not reported
Denton	134	$583,500
Ellis	84	Not reported
Fannin	60	Not reported
Freestone	38	$2,578
Grayson	86	$322,250
Grimes	38	$89,030
Hardin	34	Not reported
Henderson	56	Not reported
Hill	53	$1,697,000
Hood	58	$86,150
Houston	41	$169,700
Hunt	89	Not reported
Jack	38	Not reported
Johnson	104	Not reported
Kaufman	65	Not reported
Leon	30	Not reported
Liberty	43	$66,085
Limestone	77	Not reported
Madison	25	Not reported
Montague	34	$644,500
Navarro	79	Not reported
Parker	64	Not reported
Polk	36	$60,250
Rockwall	23	Not reported
San Jacinto	39	$96,130
Tarrant	247	$21,640
Trinity	28	Not reported
Van Zandt	44	Not reported
Walker	37	$23,330
Wise	76	Not reported
Young	38	Not reported
TOTAL	**2182**	**$4,507,053**

Source: Flood Events by County
(National Centers for Environmental Information, 2022)

Other Losses on Working Lands

When a major rain event occurs causing flooding, it can also cause heavy losses for livestock. The USDA National Agricultural Statistics Service estimates that Texas has 13 million head of cattle and calves as of January 1, 2020, (USDA National Agricultural Statistics Service , 2020). Much of the state's cattle is raised in the Trinity Region, with the largest cattle production in Fannin, Wise, Houston, and Van Zandt counties. If these operations are disrupted due to flooding, particularly if cattle are lost in the flood, it can trigger an impact on milk and beef production statewide.

Political Subdivisions with Flood-Related Authority

The RFPGs are tasked with identifying political subdivisions with flood control authority within their region. The TWDB provided a list of over 550 separate political subdivisions within the Trinity Region who were thought to potentially have some degree of flood-related authority. To collect the highest quality of information, the data collection survey conducted for this effort reached out to each entity, contacting multiple officials in each identified political subdivision.

State guidelines for "Flood Protection Planning for Watersheds" define political subdivisions with flood-related authority as cities, counties, districts, or authorities created under Article III, Section 52, or Article XVI, Section 59, of the Texas Constitution, any other political subdivision of the state, any interstate compact commission to which the state is a party, and any nonprofit water supply corporation created and operating under Chapter 67. Of the political subdivisions referred to above, the majority are municipal or county governments, both of which enjoy broad authority to set policy to mitigate flood risk.

State law also provides for limited purpose utility districts. These are known as MUDs, Municipal Water Districts (MWDs), Fresh Water Supply Districts (FWSDs), or SUDs. These districts may be located in or adjacent to cities or in the county and in some cases, may be involved in the reclamation and drainage of its overflowed land and other land needing drainage (Texas Legislature). During the data collection efforts, entities who responded that they did not have flood responsibilities or authorities were removed from the contact list.

Together, the entities outlined in ***Table 1.5*** constitute the primary flood mitigation entities in the Trinity Region by the numbers. Each of these entities received an invitation to participate in the data collection through the data collection tool and interactive web map located on the Trinity RFPG website.

Two additional types of districts bear more discussion, as they have a more direct relationship to flood management, as outlined in the State Water Code. The differing roles of WCIDs and LIDs are described in ***Table 1.6.***

Table 1.5: Political Subdivisions with Potential Flood-Related Authority

Entity	Number of Jurisdictions	NFIP Participants
Municipality	287	246
County	40	40
COGs	9	Not Applicable
River authority	7	Not Applicable
Water districts	3	Not Applicable
WSUDs (MUDs, FWSDs, MWDs, SUDs)	164	Not Applicable
Flood control entities (WCIDs, LIDs)	39	Not Applicable
Other	5	Not Applicable

Source: TWDB Data Hub (TWDB, 2021)

Table 1.6: Role of Water Control and Improvement Districts and Levee Improvement Districts

Entity	Statutory Authority	Flood Control Responsibilities
Water Control and Improvement Districts	State Water Code, Title 4, CHAPTER 51	(1) the improvement of rivers, creeks, and streams to prevent overflows and to permit navigation or irrigation
		(2) the construction and maintenance of pools, lakes, reservoirs, dams, canals, and waterways for irrigation, drainage, or navigation
		(3) the construction and maintenance control, storage, preservation, and distribution of water for flood control, irrigation, and power
Levee Improvement Districts	State Water Code, Title 4, CHAPTER 5	(1) to construct and maintain levees and other improvements on, along, and contiguous to rivers, creeks, and streams
		(2) to reclaim lands from overflow from these streams
		(3) to control and distribute the waters of rivers and streams by straightening and otherwise improving them
		(4) to provide for the proper drainage and other improvement of the reclaimed land

For political entities that participate in the NFIP program, Texas Water Code § 16.315 requires them to adopt a floodplain management ordinance and to designate a floodplain administrator who will be responsible for understanding and interpreting local floodplain management regulations and reviewing them for compliance with NFIP standards. Some of the rights and responsibilities granted under this authority of the Texas Water Code include:

- Applying for grants and financing to support mitigation activities
- Guiding the development of future construction away from locations threatened by flood hazards
- Setting land use standards to constrict the development of land which is exposed to flood damage and minimize damage caused by flood losses
- Collecting reasonable fees from citizens to cover the cost of administering floodplain management activities
- Using regional or watershed approaches to improve floodplain management
- Cooperating with the state to assess the adequacy of local structural and non-structural mitigation activities

Summary of Existing Flood Plans and Regulations

Approximately 30 percent of the entities who received an invitation to participate in the flood planning process via the Trinity RFPG data collection survey tool and interactive web map provided at least some measure of response at varying levels of detail. The tables that follow summarize the entities' responses to questions about their existing regulatory environment, as well as measures they may have in place to increase resilience. The information in these tables is strictly based on responses to the data collection survey.

Table 1.7 summarizes the number of survey participants who answered that they have a particular regulatory or planning measure in place. These plans and regulations were divided into four categories: drainage criteria manual/design manual, land use regulations, ordinances (floodplain, drainage, stormwater, etc.), Unified Development Code (UDC), and/or zoning ordinance with map. From the four types of regulations and plans, the largest number of respondents indicated that they had an active floodplain, drainage, and/or stormwater ordinance.

Table 1.7: Summary of Flood Plan and Regulations Provided via Survey

Type of Regulation	Count
Drainage Criteria Manual/Design Manual	37
Land Use Regulations	46
Ordinances (Floodplain, Drainage, Stormwater, etc.)	61
UDC and/or Zoning Ordinance with Map	32

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Table 1.8 provides a perspective on the relative complexity of each community's floodplain management approach by tallying the number of regulatory and planning measures for each responding community. This is self-reported data and reflects the knowledge and experience of the respondent. Many communities responded that they do not have any regulating documents that aid with flood management, or that just one is in place. The RFPG researched the flood planning measures taken by each community and determined that a higher level of preparedness than the survey results show. However, 24 respondents indicated they have all four of the measures described in ***Table 1.7*** and may even be taking additional measures to increase their authority to manage development and other activity that would impact flooding within their jurisdictions. A higher number of these measures indicates a greater degree of preparedness for flood management and appropriate regulation of development patterns.

Table 1.8: Number of Flood Plans and Land Use Regulations per Community

Regulations per Community	Count
0	43
1	24
2	6
3	12
4+	24

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Like the last two tables, ***Table 1.9*** includes data that was extracted from the data collection tool survey. In this instance communities identified the types of flood warning measures they were employing within their communities to mitigate the effects of flooding. These measures include regulations, information, education, and warning systems. The types of flood warning measures that are most widely used amongst survey respondents fall into the regulatory and flood warning categories. It is important to note that these results derive from the respondents to the survey and are not an exhaustive count of all flood warning measures being undertaken throughout the region. Resilient communities adapt to changing conditions, allowing people and places to recover quickly from disasters and thrive in the face of adversity.

Using plans and policies to reduce the exposure of people and properties to flood risk is a form of non-structural flood control. By encouraging or requiring communities and developers to avoid developing in flood-prone areas altogether, or to take precautions such as increasing building elevation, preserving overflow areas through buffering and avoiding sensitive natural areas such as wetlands, communities can prevent new development from being located in harm's way.

Table 1.9: Types of Flood Warning Measures based on Survey

Flood Warning Measure	Count
Acquisition of flood-prone properties	12
Automatic low water crossing gates	1
Coordination with TxDOT message boards	2
Crew(s) set up barricades or close gates	5
Flood gauges	2
Flood readiness education and training	17
Flood response planning	23
Flood warning signs	2
Flood warning signs with flashing lights	1
Flood warning system	9
Higher Standards for floodplain management	32
Land use regulations that limit future flood risk	32
Outdoor siren/message speaker system	1
Participation in the Community Rating System	6
Participation in the NFIP	45
Portable/temporary traffic message boards	3
Public facing website	4
Reverse 911 system	2
Social media	7

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Floodplain Ordinances, Court Orders, and Local and Regional Flood Plans

Floodplain ordinances and court orders dictate how development is to interact with or avoid a city's or county's floodplain. FEMA provides communities with flood hazard information upon which floodplain management regulations can be based. Floodplain ordinances and court orders are subject to the NFIP and ensure communities are taking flood hazards into account when making land use and land management decisions. Ordinances may include references to maps with Base Flood Elevations (BFEs), freeboard requirements, valley storage requirements, as well as criteria for land management and use. In addition, communities can regulate floodplains with higher or more restrictive standards.

Local and regional flood plans may go a step beyond the regulations laid out in an ordinance, enhancing a region's understanding of its flood risk, and establishing how that entity will manage or control floods in the future. They also outline the procedures for more sustainable flood risk management in the communities they serve. (Niki L. Pace, 2013)

Land Use Regulations and Policies: Zoning, Subdivision

Zoning ordinances regulate how property owners and developers are allowed to use their property. It is one of the most important tools that communities use to regulate the form and function of current and future development. Within the zoning ordinance, communities may incorporate a variety of tools, which may include, among others:

- Floodplain zones
- Stream buffers
- Setbacks from wetlands and other natural areas
- Conservation easements

Subdivision regulations get into a more focused regulation of the design and form of the building blocks of a city. They regulate platting processes, standards for design and layouts of streets and other types of infrastructure, the design and configuration of parcel boundaries, as well as standards for protecting natural resources and open space. While both cities and counties have subdivision ordinances, counties do not have zoning authority.

Comprehensive Plans and Future Land Use Plans

Comprehensive plans and their associated future land use plans provide legal authority for zoning regulations in the State of Texas and consider capital improvements necessary to support current and future populations and often consider social and environmental concerns the community wishes to address. To produce a comprehensive plan, communities undertake an extensive planning process that encourages discussion about topics such as risk from natural hazards, and may include recommendations regarding the location of development with respect to floodplains the need for future drainage improvements, etc.

In the Trinity Region, the Trinity RFPG has identified 124 future land use plans for municipalities, which are the only entities with the authority to develop and use such plans. The content of these plans varies widely in specificity but is frequently prepared in concert with a comprehensive plan, which establishes policies and program of action for long term growth and development of a community. These plans provide a guide for future areas of growth and development, as well as areas that are to be conserved in their natural state. According to the Texas Local Government Code, the comprehensive plan sets the groundwork that is necessary for a municipality to regulate the location and character of development through local zoning and land use ordinances. (Texas State Legislature)

Drainage Design Criteria

Drainage design criteria is required and developed to set the minimum standards for planners, architects, and engineers to follow when preparing plans for construction within the jurisdictions in which they serve. These could be for regional entities, such as the NCTCOG, for municipalities, or counties within the region. These criteria mitigate flood risk by promulgating a consistent set of standards for location and design criteria that mitigate future flood risk. Criteria may pertain to development and permit applications, right of way/easements, and hydrologic, and hydraulic standards.

Assessment of Existing Flood Infrastructure

This section provides an overview of natural and structural flood infrastructure in the Trinity Region that contribute to lowering flood risk. Because the Trinity River watershed connects communities from Archer County to Chambers County on the Trinity Bay, flood infrastructure in this region benefits the community where it is located but may also have substantial benefits for people and property downstream.

When assessing flood risk management infrastructure, the TWDB guidance directed the RFPG to consider the following types of natural and manmade features that contribute to risk reduction, not all of which are present in the Trinity Region:

Natural Features:

- Rivers, tributaries, functioning floodplains
- Wetlands and marshes
- Parks, preserves, natural areas
- *Playa lakes*
- *Sinkholes*
- *Alluvial fans*
- *Vegetated dunes*

Structural Features:

- Levees
- Dams that provide flood protection
- Local stormwater systems, including tunnels and canals
- Detention and retention ponds
- *Sea barriers, walls, and revetments*
- *Tidal barriers and gates*

Note: Features shown above in *italics* have not been identified as major components of the flood control system in the Trinity Region.

Flood infrastructure in the region is formed by a complex web of natural areas and built features which are owned and managed by entities ranging from the National Parks Service to individual landowners. Flood infrastructure may include non-structural measures, such as natural area preservation, buyout of repetitive flood loss properties, and flood warning systems, but also includes all major public infrastructure, such as regional detention. The TWDB provided several data sources to assist with the identification of flood management infrastructure in the Flood Data Hub. There were also a number of questions posed in the data collection survey that were used to complement the information provided by existing data sources to create a more complete picture of how communities in the region protect themselves from flood risk.

Information in the Inventory of Existing Flood Infrastructure summarized in this section refers to the ***TWDB-Required Table 1***, included in ***Appendix A*** of this plan and serves as the basis for several tables and charts.

Natural Features

When left in their natural state, many soils can be efficient at handling rainfall. As drops fall from the sky, they are intercepted by trees, shrubs or grasses which allow rain time to soak into the soil and slow the passage of runoff to the region's waterways. Wetlands and woodlands are most efficient at recycling rainfall, as the branches and undergrowth intercept water before it even reaches the ground, thus minimizing overland flow to tributaries and the river. Pastureland performs this function effectively as well, whereas croplands may shed a greater degree of water so as not to inundate the fields. Similarly, parklands in urban areas that are designed for dual functions can achieve nearly the same rate of capture of stormwater as lands in undeveloped areas (Marsh, 2010). For natural features to achieve maximum effectiveness at flood mitigation, they should form part of an interconnected network of open space consisting of natural areas and other green features that also protect ecosystem functions and contribute to clean air. This is sometimes known as green infrastructure, the practice of replicating natural processes to capture stormwater runoff (Low Impact Development Center, 2017). Even small changes in developed area can have significant impact on downstream flooding.

Natural areas can be managed to be even more efficient at these functions in a variety of settings:

- **Watershed or Landscape Scale**: Where natural areas are interconnected to provide opportunities for water to slow down and soak in, and to overtop the banks of creeks and channels when needed. These solutions often include multiple jurisdictions and restoration of natural habitat to achieve maximum effectiveness.
- **Neighborhood Scale**: Solutions built into corridors or neighborhoods that better manage rain where it falls. Communities establish regulatory standards for development that guide the use of neighborhood-scale strategies.
- **Coastal Solutions:** To protect against erosion, and mitigate storm surge and tidally influenced flooding, nature-based solutions can be used to stabilize shorelines and restore wetlands. (FEMA, 2021)

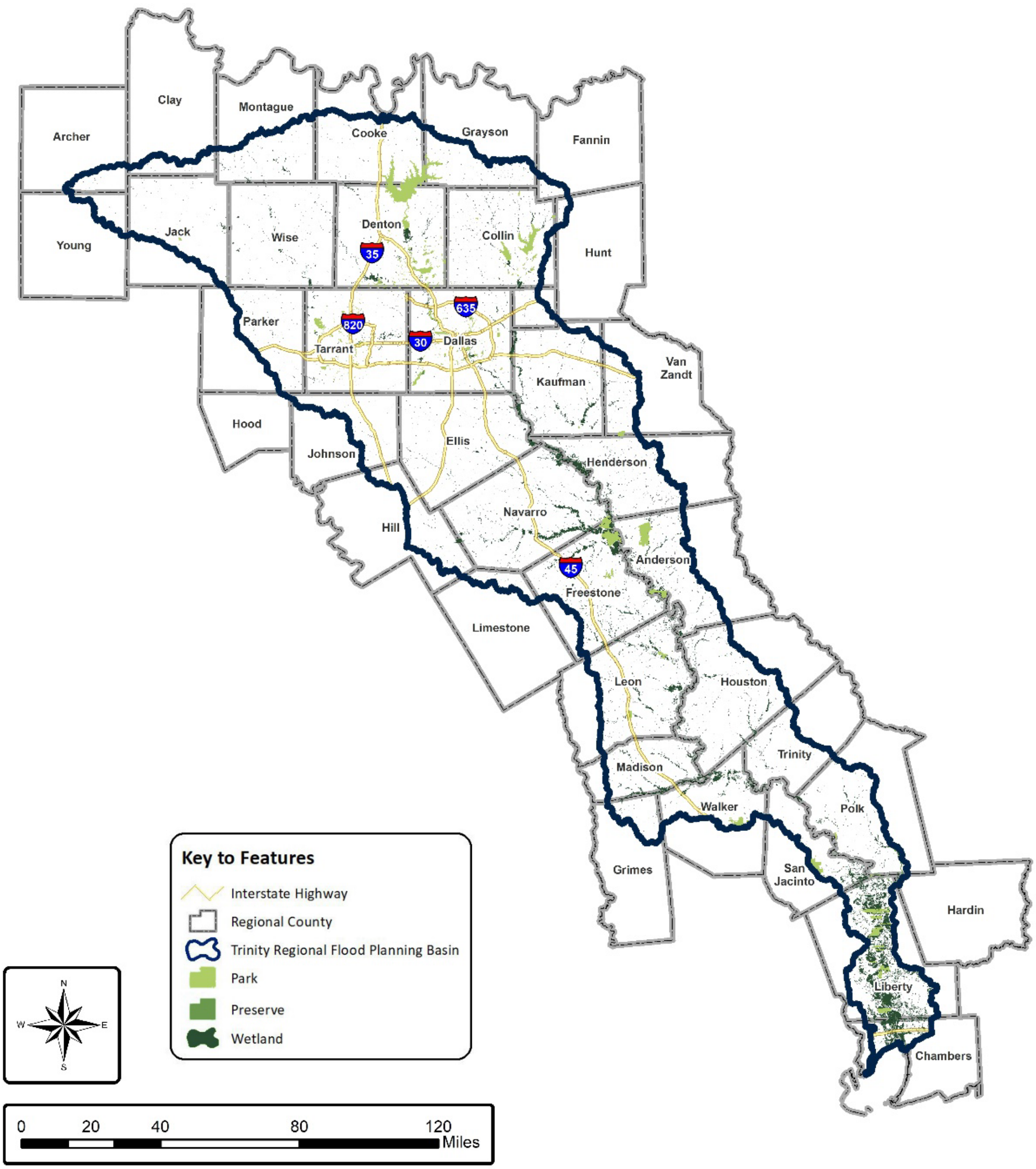
As forests and fields give way to urban development, the permeability of soil decreases. This makes land less efficient at the tasks of maintaining natural runoff velocities and allowing rainfall to soak into the ground and recharge the groundwater. In the 20 years between 1997 and 2017, the Texas Land Trends project found that the Trinity Region lost over 360,000 acres (about twice the area of Austin, Texas) of working land (crops, grazing lands, timber, and wildlife management) to urban and suburban development. While the population increased by more than 50 percent during that time, only 4 percent of the total acreage of natural areas were replaced with structures, roads, and parking lots. These types of hard surfaces can increase the potential for increased runoff unless flood mitigation is incorporated in the development. The acreage that remained as open space grew increasingly fragmented. In 1997, 1,044,255 landholdings consisted of parcels of more than 1,000 acres, whereas by 2017, the number of these larger parcels had declined dramatically. This trend was even more pronounced for landowners who held from 100-499 acres during the same time period. (Texas A&M Natural Resources Institute, 2021)

As the trend toward urbanization and fragmentation continues, the region should consider taking a more deliberate approach to managing its natural infrastructure in order to continue to receive the benefits of open spaces, something which the USACE addresses in its engineering with nature initiatives (USACE, 2022), which align natural and engineering processes to deliver economic, environmental, and social benefits efficiently and sustainably through collaborative projects. The TWDB also identified local, state, and national parks and wildlife management areas that form part of the region's natural infrastructure, all of which are illustrated in ***Figure 1.19.***

Rivers, Tributaries, and Functioning Floodplains

The natural flood storage capacity of all streams and rivers and the adjacent floodplains contribute greatly to overall flood control and management. The floodplain is a generally flat area of land next to a river or stream that stretches from the banks of the river to the outer edges of the valley. The first part of the floodplain is the main channel of the river itself, called the floodway, which may be dry for part of the year. Surface water, floodplains, wetlands, and other features of the landscape function as a single integrated natural system. Disrupting one of these elements can lead to effects throughout the watershed, which increase the risk of flooding to adjacent communities and working lands. Maintaining the floodplain in an undeveloped state provides rivers and streams with room to spread out and store floodwaters to reduces flood peaks and velocities. Even in urban areas, preservation of this integrated system of waterways and floodplains serves a valuable function, as even small floods resulting from a 20% or 10% annual chance storm event can cause severe flood damage.

Figure 1.19: Natural Flood Infrastructure



Source: TWDB Flood Planning Data Hub, (TWDB, 2021), State Wildlife Management Areas and Parks (Texas Parks and Wildlife Department, 2022), National Park Service Lands (USDOI, 2022), National Wetlands Inventory (USGS, 1998)

Depending on soil type and permeability, a single acre of floodplain land can significantly reduce risk to properties downstream. With over 20 percent of its land area located in the floodplain, the Trinity River and its tributaries cross through both rural and highly urbanized areas of Texas. In rural areas where more of the floodplain is preserved in an undeveloped state, the more natural form of the river and its many tributaries and floodplains contribute to flood risk reduction downstream as they meander southeast on their way south to the Gulf of Mexico. (FEMA, 2021)

In the upper basin of the Trinity Region, multiple entities participate in the Trinity Common Vision Corridor Development Certificate program for the purpose of stabilizing flood risk associated with floodplain development along the Trinity River within the DFW metroplex (NCTCOG, 2021). The program is a coordinated effort among NCTCOG, USACE, cities, counties, and others with flood control responsibilities along the corridor. USACE estimates that the Corridor Development Certificate program provides more than 1/3 of the flood protection capacity along the Trinity River in the North Texas area, which is more than any one of its flood-control dams (USACE, Trinity Common Vision Steering Committee Presentation, 2021). Additional information on this program is included in ***Chapter 2***.

Wetlands and Marshes

Wetlands are some of the most effective natural features at recycling water, by minimizing the overland flow and reducing the need for other types of flooding infrastructure. The USGS defines wetlands as transitional areas, sandwiched between permanently flooded deep water environments and well-drained uplands, where the water table is usually at or near the surface or the land is covered by shallow water. They can include mangroves, marshes, swamps, forested wetlands, coastal prairies, among other habitats and their soil or substrate is at least periodically saturated by fresh or salt water. There is a robust concentration of wetlands directly surrounding the Trinity River and as the Trinity River heads southward towards the coast, the concentration of wetlands increases. When left undisturbed by development, wetlands not only mitigate flooding from upstream, but also blunt the force of storm surges from the coast in the form of hurricanes and other tropical storms. According to the USGS National Wetlands Inventory, wetlands comprise 450,300 acres within the Trinity Region. This accounts for one of the largest types of natural infrastructure for the region.

Parks, Preserves, and Other Natural Areas

Parks and preserves serve as essential components of the ecosystem as they house a wide variety of local flora and fauna, as well as physical features that are necessary for the continued ecological health of the region. Parks include municipal, county, state, and national parks within the region, while preserves include the Texas Parks and Wildlife Department's (TPWD's) state wildlife management areas. These areas provide a sanctuary for the natural aspects impacted by human activity. Additionally, these are essential components for water retention in the event of flooding and severe rainfall.

- Parks account for 127,000 acres
- Preserves make up 101,000 acres within the region

This acreage includes state and local parks, wetlands identified on the national wetlands inventory, as well as USACE properties. These types of natural flood infrastructure are generally located in or close to floodplain areas throughout the basin with higher concentrations of them being located along or close to the major rivers. The largest concentration of this infrastructure type is around Lake Ray Roberts between Denton and Cooke counties.

Coastal Areas

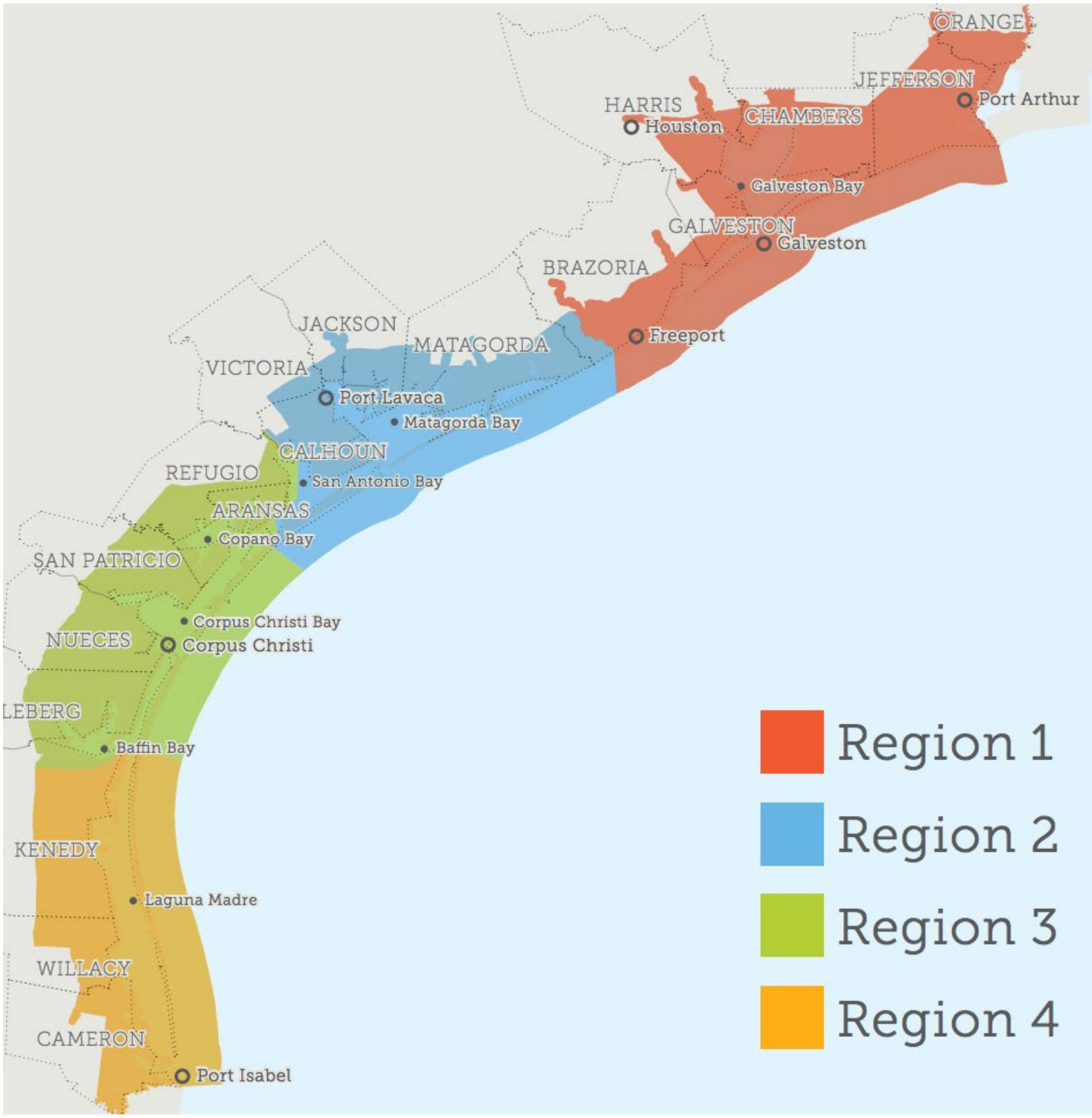
The National Coastal Zone Management Program is a voluntary partnership between NOAA and coastal states that was formed following the passage of the Coastal Zone Management Act of 1972.

In Texas, this program is managed by the Texas General Land Office (GLO) and implemented through the 2019 Coastal Resiliency Master Plan (CRMP). The geographic extent of the state's coastal zone is illustrated in ***Figure 1.20.*** The state divides the Texas coast into four regions for planning purposes based on approximate size, population centers, habitats, and environmental conditions. In the Trinity Region, only the southernmost area of Chambers County that touches Trinity Bay is in the Texas coastal zone, located in Region 1. The dynamics of flooding in coastal areas differ from riverine flooding, in that they are influenced by issues such as sea level rise, land subsidence, tidal flooding and storm surge as well as rainfall events. Mitigating coastal flooding is one of the primary objectives of the CRMP, and proposed solutions include:

- Elevating structures
- Incorporating green infrastructure into development
- Creating flood resilient parks and recreational spaces
- Retaining and restoring open space
- Maintaining/creating freshwater wetlands and coastal prairies

The state is in the process of updating the 2019 CRMP and anticipates the release of a new plan in 2023 that will include a list of Tier 1 projects in each region which will be priority projects for funding in the future years. (Texas GLO, 2019)

Figure 1.20: Texas Coastal Zone



Source: 2019 Texas CRMP

Constructed Flood Infrastructure/Structural Protections

A wide variety of structural measures are used by state and federal agencies, communities, and private landowners to protect development and agricultural areas from flooding. These may include flood control reservoirs, dams, levees, and local drainage infrastructure such as channels and detention areas. Dams and levees are some of the most frequently used defenses to achieve structural mitigation of future flood risk in this region and serve an established role of protecting people and property from flood impacts and will therefore be a primary focus of this section of this plan. ***Figure 1.21*** identifies the location of all known dams and levees in the Trinity Region. ***Figure 1.22*** is a photo of the flooding at the Trinity Levees.

Dams and Reservoirs

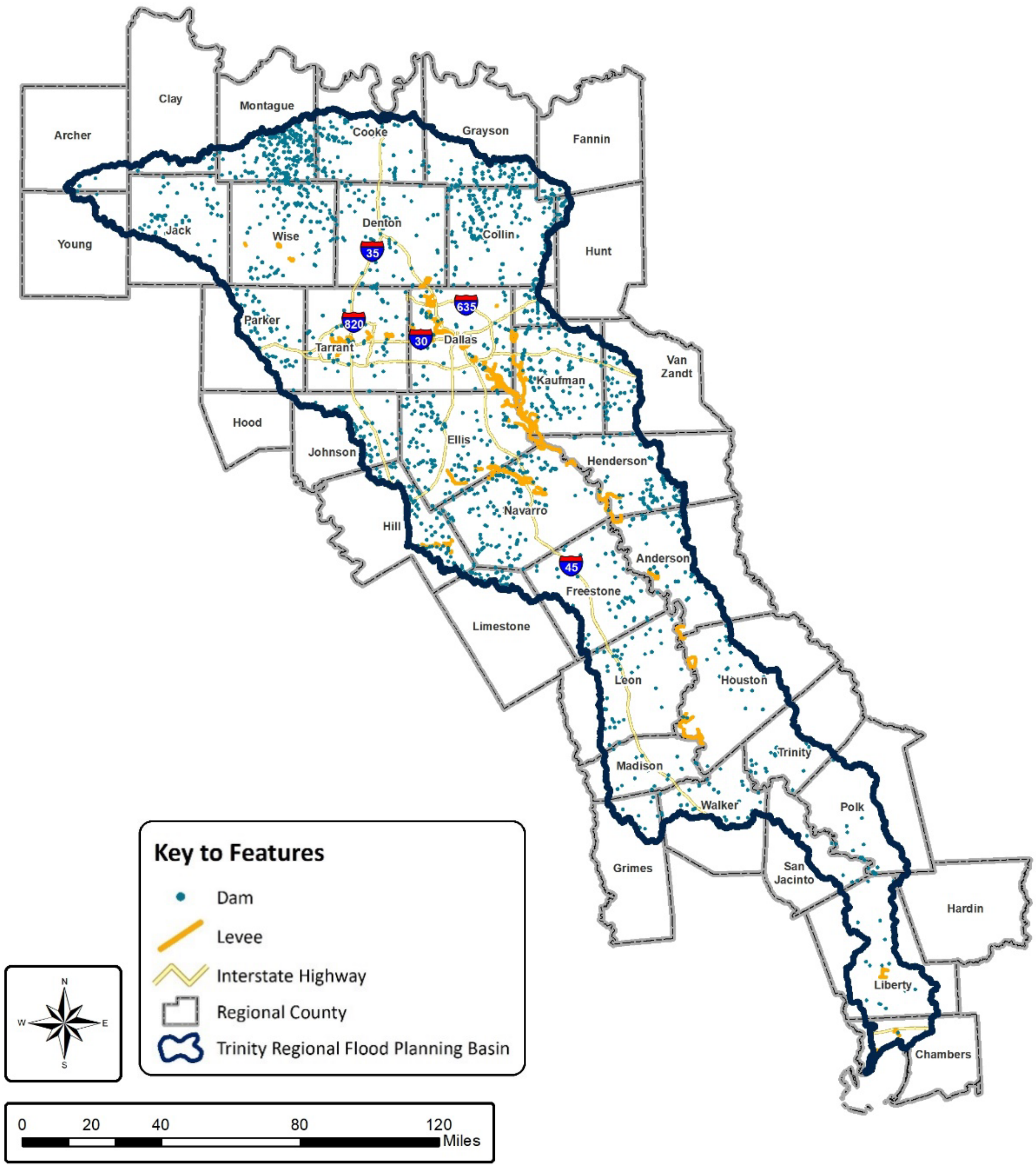
The TCEQ Dams Inventory, provided in September 2021 by the Texas Commission on Environmental Quality (TCEQ), contains a total of 2,037 dams in the Trinity Region. Dams in Texas serve a variety of purposes beyond flood control, including water storage for human consumption, agricultural use, power generation, industrial use, and recreation. Of the dams identified in the region, 1,409 are identified as having flood control as one of its purposes. The focus of this plan is flood control dams, which are associated with reservoirs (lakes) permitted for flood control purposes.

The USACE is responsible for the management of the region's largest dams and flood control reservoirs. Although residents may know them for their recreational, water supply, and power generation functions, these facilities are particularly important in mitigating the effects of flooding because of their scale and ability to store vast amounts of water. Their size allows them to serve as a repository for flood waters and hold, store, and slowly release these waters over time to manage downstream flooding. (TCEQ Dam Safety Program, Field Operations Support Division, 2009).

Reservoirs in the Trinity Region owned and operated by USACE with flood control as a purpose include:

- Bardwell Lake
- Benbrook Lake
- Grapevine Lake
- Joe Pool Lake
- Lake Lavon
- Lake Lewisville
- Navarro Mills Lake
- Ray Roberts Lake (USACE, 2021)

Figure 1.21: Constructed Flood Infrastructure/Structural Flood Protection



Sources: National Inventory of Dams (USACE, 2020), National Levee Database (USACE, 2022)

Figure 1.22: Flooding, Trinity River Levees

For all dams that have a flood control purpose but are not maintained by the USACE, ***Table 1.10*** provides the total number of registered flood control dams in each county. Many of these dams were designed and constructed by the Natural Resources Conservation Service (USDA-NRCS), with the private property owner providing the land, the federal government providing the technical design expertise and the funding, and local government responsible for maintaining them into the future. (Texas State Soil and Water Conservation Board, 2021)

These dams are owned and operated by a wide range of organizations and people, including state and local governments, public and private agencies, and private citizens. The TCEQ Dam Safety Program is involved with the permitting and inspections of these facilities, as well as maintaining hydrological data to establish standards for dam construction. However, the law provides for broad exemptions, which include private ownership, maximum capacity of less than 500 acre-feet, hazard classification, and location in a county with a population of less than 350,000 and/or outside City limits. Because of the diverse nature of ownership and capacity of dams, the frequency of inspection may vary widely as well. While high-hazard and large low-hazard dams are scheduled to be inspected every five years, small and intermediate size and low-hazard dams are only inspected at the request of an owner; as a result of a complaint; following an emergency such as a flooding event; or for determining the hazard classification. (Texas Commission on Environmental Quality, 2021). Even for dams that are not for flood control, however, breaches and overtopping could have significant downstream impacts.

Table 1.10: Number of Flood Control Dams by County

County	No. of Dams
Anderson	3
Clay	4
Collin	185
Cooke	77
Dallas	22
Denton	36
Ellis	141
Fannin	13
Freestone	1
Grayson	77
Henderson	7
Hill	81
Hunt	18
Jack	32
Johnson	39
Kaufman	127
Leon	2
Limestone	23
Madison	4
Montague	154
Navarro	119
Parker	41
Rockwall	50
Tarrant	8
Van Zandt	43
Wise	122
Young	1
Total	**1,430**

Within the Trinity Region, the TCEQ maintains hazard classifications of high, low, and significant for these 1,409 flood control dams, as illustrated in ***Table 1.11***. High-hazard potential dams may be associated with expected loss of seven or more lives or three or more habitable structures in the breach inundation area; excessive economic loss in or near urban areas where failure would be expected to cause extensive damage to:

- Public facilities
- Agricultural, industrial, or commercial facilities
- Public utilities
- Major highways and/or railroads

Table 1.11: Summary of Hazard Classification of Dams in the Trinity Region

	High	Significant	Low	Grand Total
Total	430	78	901	1,409

Source: TCEQ Total of dams in region by classification, provided September 2021

Dams categorized as having significant hazard potential may result in the loss one to six human lives or one or two habitable structures in the breach inundation area downstream of the dam; appreciable economic loss, located primarily in rural areas where failure may cause:

- Damage to isolated homes
- Damage to secondary highways or minor railroads
- Interruption of service or use of public utilities, including the design purpose of the utility

For low hazard dams, no loss of human life or damage to permanent habitable structures and minimal economic loss are anticipated in the breach inundation area (located primarily in rural areas where failure may damage occasional farm buildings, limited agricultural improvements, and minor highways. (Texas Administrative Code, 2009).

Levees

Levees are man-made structures that provide flood protection. More than one million Texans and $127 billion dollars' worth of property are protected by levees. The Texas 2018 Levee Inventory Report lists 51 USACE levee systems in the state (ASCE, 2021). These USACE levees are maintained and inspected to federal standards and provide a high standard of flood protection. Although not all are used for flood control purposes, failure of a single dam or levee could have multiple consequences for property and human safety downstream.

According to the National Levee Database, published in August 2020, there are 101 levees in the Trinity Region with 51 managed by the USACE. The Texas Water Code §16.236 requires that the design be based on the 1% annual chance storm event plus three feet of freeboard in urbanized areas. The water code also outlines a review and approval process for the construction and improvement of levees following the filing of an application and a set of preliminary plans for the levee that includes sufficient engineering detail for evaluation. Applications must include the location and extent of the structure, location of surrounding levees, reservoirs, dams, or other flood control structures which may be affected and the location and ownership of all properties lying within any proposed protected area or others which may be affected by the project's alteration of the flood flows. The preliminary plans must demonstrate the effects the proposed project will impose on existing flood conditions. (Texas Commission on Environmental Quality, 2005).

Table 1.12 provides the number of levees by county throughout the region. Dallas County has the largest number of levees in the region while Tarrant, Hill, and Ellis counties each have between 10 and 20 levees. In 2004, FEMA initiated remapping for both Tarrant and Dallas counties that included the Trinity River and the DFW levee system. Most USACE levees in Texas were designed to withstand a flood that exceeds the 0.2% annual chance storm event, plus an additional three to four feet of freeboard. (Melinda Luna, 2007)

Smaller, concrete-lined channels can be found in many communities across the Trinity Region. Hardened, structural alternatives are being systematically reduced in application due to impacts to the environment and the potential for increasing flooding downstream and loss of open space. Recent channel improvements tend to incorporate more natural features.

Stormwater Management System

Stormwater management systems serve to manage both the quantity and quality of the water that drains into the Trinity River and its tributaries. Although survey respondents provided limited information as to their own stormwater management systems, participants in the Texas Pollutant Discharge Elimination System (TPDES) which is managed by the TCEQ, are likely to have storm drainage infrastructure. Five cities in the region: Dallas, Fort Worth, Arlington, Irving, and Plano have a sophisticated drainage systems and are classified as Phase I Municipal Separate Storm Sewer Systems (MS4s). Small MS4s are communities located in urbanized areas as determined by the 2010 census.

Table 1.12: Number of Levees by County

County	Number of Levees
Anderson	1
Anderson, Henderson, Navarro	1
Anderson, Houston	1
Chambers	2
Cooke	1
Dallas	22
Dallas, Denton	1
Dallas, Ellis	1
Dallas, Kaufman	4
Denton	1
Ellis	10
Ellis, Navarro	3
Henderson	1
Henderson, Kaufman	1
Hill	12
Houston	5
Kaufman	6
Liberty	1
Navarro	6
Tarrant	16
Wise	5
Total	**101**

Source: (USACE, 2022)

Bridges and Culverts

Bridges and culverts are used to provide vehicular and pedestrian transportation across low points, including rivers, streams, and floodplains. Design criteria for these structures varies depending on the governing entity. The structure is required to convey the flow of surface and stream water through the embankment. Culverts and bridges can be overtopped by floodwaters if the design capacity of the structure is exceeded. This type of flooding can occur during or following prolonged periods of rainfall or during an intense rainfall that overwhelms the culvert or bridge, such as a flash flood event. Additional information on bridges and culverts in relation to low water crossings is included in ***Chapter 2*** of this plan.

Coastal Areas

As detailed above, there is a very small portion of the Trinity Region in the Texas coastal zone Region 1. The state's CRMP does not contain any projects within the Trinity Region, and a review of data provided by FEMA and the Texas Coastal Management Program did not include any sea barriers, walls, revetments, tidal barriers, or gates within the Trinity watershed.

Non-Functional/Deficient Flood Mitigation Features/Condition and Functionality of Infrastructure and Other Flood Mitigation Features

As the Trinity Region undertakes its first flood plan, information on the condition of the region's flood mitigation features is in short supply. Neither the State Flood Data Hub nor the participants in the Trinity Region data collection effort provided a great deal of information on this subject. However, throughout Texas, flood infrastructure is rapidly aging and in need of repair. In 2019, the Association of State Dam Safety Officials (ASDSO) estimated the cost to rehabilitate all non-federal dams in Texas at around $5 billion. The Texas State Soil and Water Conservation Board (TSSWCB) estimates about $2.1 billion is needed to repair or rehabilitate dams included in the Small Watershed Programs. (TSSWCB, 2021).

The USACE establishes a rigorous maintenance standard for its eight reservoirs to ensure that they perform to expectations. However, for the 1,409 flood control dams in the region that are not subject to USACE regulations, the consequences of dam failure downstream can be severe, with losses of life, agricultural resources and property.

According to the TCEQ's dam safety program, the primary reasons for dam failure include:

- Overtopping by floods
- Foundation defects
- Piping and seepage

(TCEQ, 2006)

Many Texas dams are exempt from dam safety requirements by state legislation which makes tracking their maintenance status extremely challenging. Condition-related data and associated risk for the region's levees is largely unknown because most of the levees in the state are built, inspected and/or maintained by local governing agencies who may not have the resources for routine assessment and performance tracking. According to the National Levee Database, the levee condition for all 122 levees within the Trinity region is "Unknown".

Recent increases in frequency and intensity of storms continue to test the capacity of the state's levees. Without a clearer picture of the state's levee infrastructure and concerted funding to assist private owners, the majority of the state's levees that are not managed and maintained by the USACE will remain in the presumed deficient status. (ASCE, 2021)

Functionality of Flood Infrastructure

The TCEQ Dam Inventory provides some insight into the functionality and condition of the region's infrastructure. For the majority of dams in the Trinity region, the condition is *Unknown*. However, of those dams that have been assessed, ***Table 1.13*** illustrates that the majority of those dams are in fair or good condition and are considered to be functional.

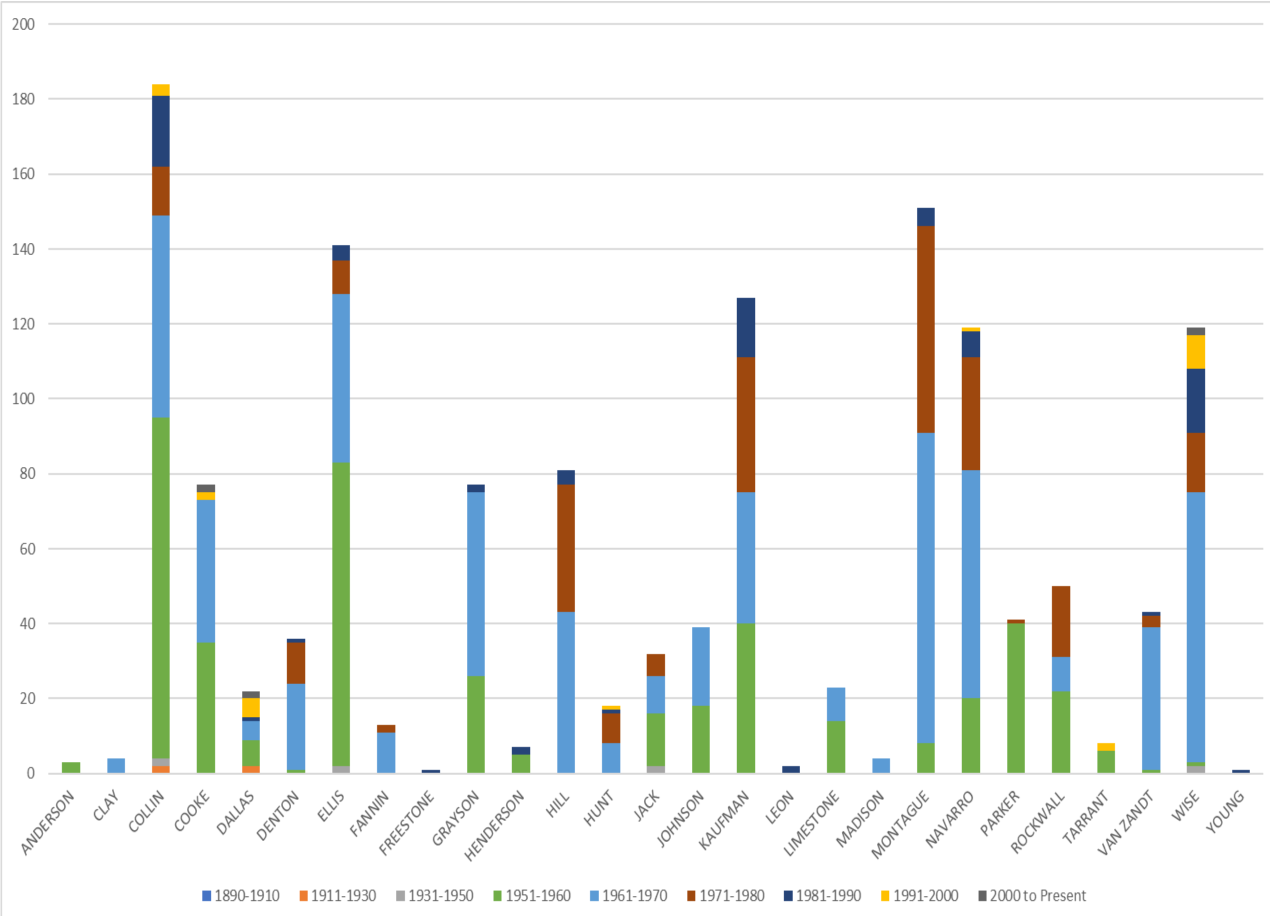
Table 1.13: Condition of Dams

	Functional	Non-Functional	Unknown	Total
Good	398			
Fair	258			
Poor		48		
Unknown			705	
Grand Totals:	**656**	**48**	**705**	**1,409**

Source: TCEQ Dam Inventory, provided September 2021

Although entity participants in the data collection effort provided little information about the nature of their dam infrastructure, TCEQ data on year of construction indicates that many may be due for maintenance, rehabilitation or even retirement. ***Figure 1.23*** provides cumulative totals of dams by county. The stacked colors represent the number of dams by decade of construction. According to the data provided by TCEQ, the majority of the region's dams were built between 1950 and 1980. This is because of federal funding, which provided funds for 50-year infrastructure, most of which has already surpassed this timeframe, creating age and funding challenges. Absent a full picture of the condition of the region's dams, this assessment considers year of construction, which is available for the majority of the dams. In the Trinity Region, over 90 percent of dams were built between 1951-1980. The 1960s were the most prolific period of dam building in the region, when over 43 percent were constructed. The percentage of dams built between 1951-1960 and 1971-1980 are the next largest, at about 30 percent and 17 percent, respectively.

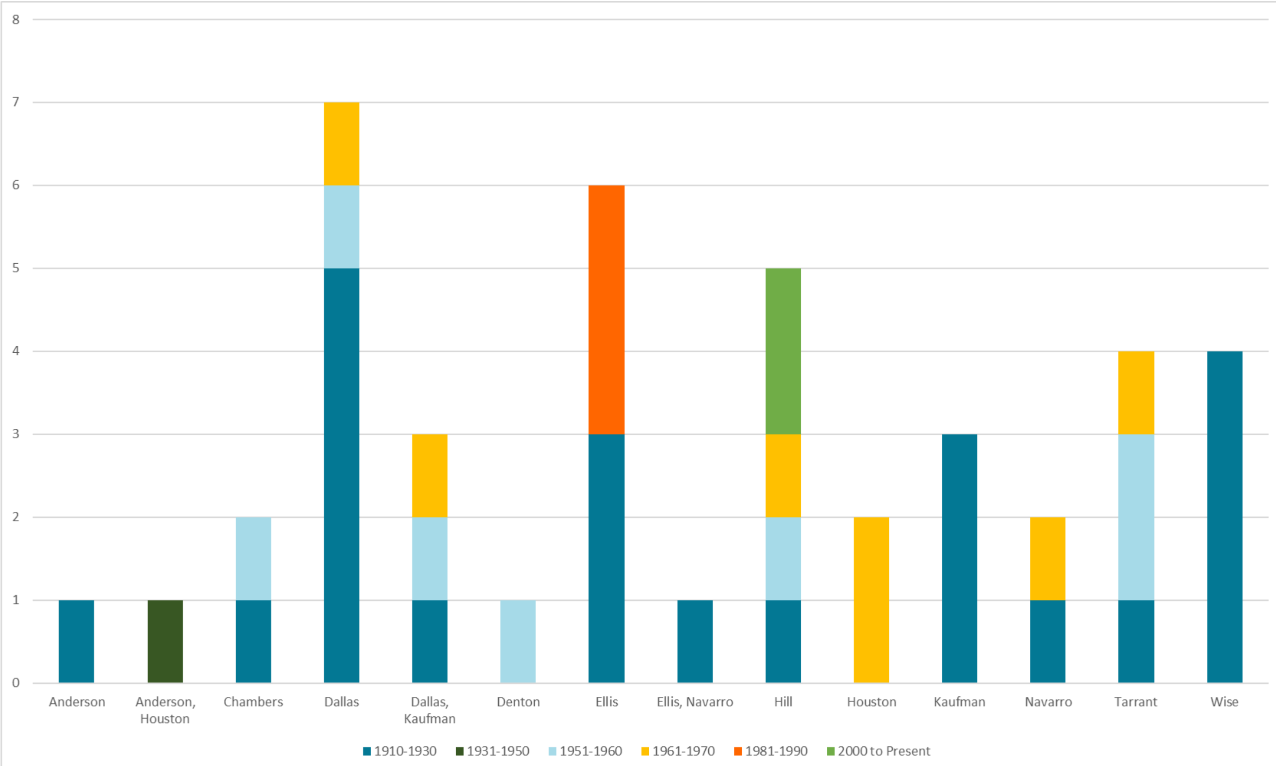
Figure 1.23: Dam by County by Year of Construction



Source: National Inventory of Dams: Local Dams (USACE, 2020)

With respect to levees, a 2021 assessment of the state's levee system by the ASCE continues to give the state's levees a grade of D and emphasizes that the lack of a state Levee Safety program means that few levees may be conducting regular safety inspections and preparing public evacuation plans for affected communities. (ASCE, 2021). There is much less information with respect to year of construction for levees than for dams, however, what is available indicates a substantial proportion of levees were built nearly a century ago, before 1930. Many of these older levees are agricultural in nature, and their primary purpose may be to provide a water supply and/or protect crops and rangeland from flooding. The National Levee Database did not provide a year of construction for all levees, but ***Figure 1.24*** charts the year of construction by county where provided.

Figure 1.24: Levees by County by Year of Construction



Sources: National Levee Database (USACE, 2022)

Deficient and Reasons for Deficiency

Inadequate data is available to assess the condition and functionality of the Trinity Region's infrastructure and other flood mitigation features. One of the reasons that infrastructure may not be maintained or repaired is a lack of funding, particularly for private landowners. The data collection survey requested this information from entities, however, no one self-reported having deficient structures. No further information from survey respondents or the TWDB is available to prepare an assessment of flood infrastructure deficiencies or the reasons for these deficiencies at this time.

Potential for Restoration

No information is currently available to assess the potential for flood infrastructure restoration. None of the survey participants provided any information regarding specific restoration needs for existing infrastructure. However, maintenance and restoration of existing infrastructure are important to maintain functionality.

Proposed or Ongoing Flood Mitigation Projects

The data for this section is derived from two primary sources. The first source of this data is the region's data collection survey, which was supplemented by direct outreach and interviews with entities. More detailed results are available in ***TWDB-Required Table 2*** in ***Appendix A***. The second source is existing Hazard Mitigation Plans (HMPs) in the region. There are also seven recently awarded Flood Infrastructure Fund (FIF) studies in the region.

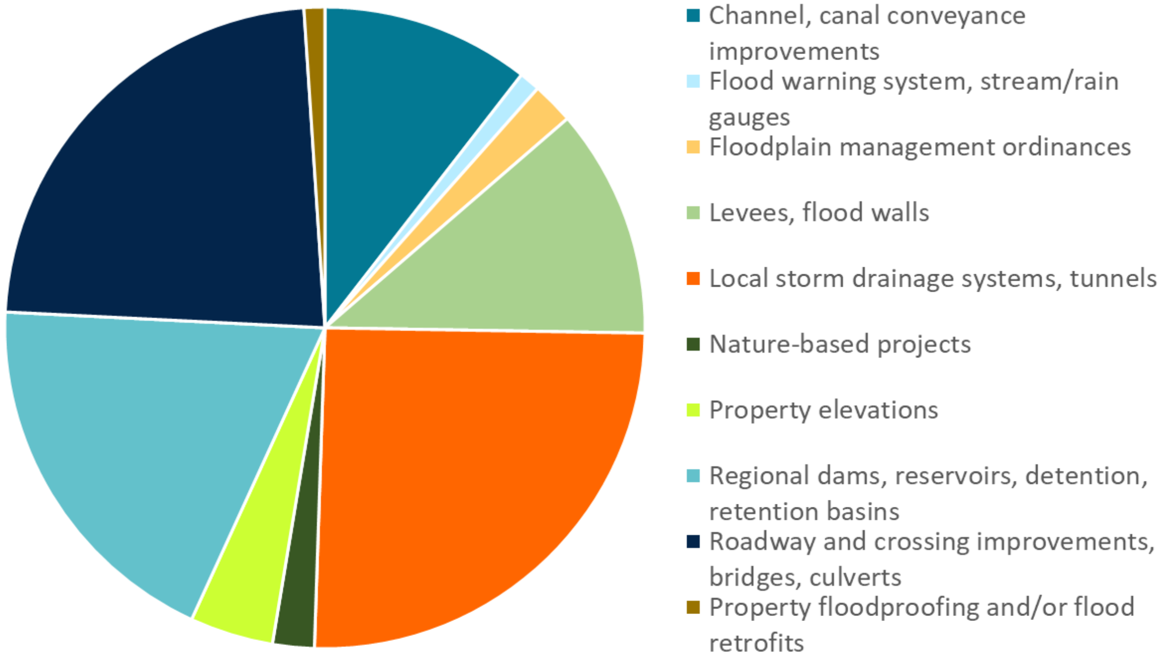
Ongoing or Proposed Projects Identified in Trinity Region Data Collection Tool and Web Map

Over 60 communities indicated in the survey that they planned to undertake FMPs in the coming years. However, there are a number of gaps in this dataset as little data was provided on individual projects. Only two respondents spoke about specific projects. Others indicated that they anticipated pursuing a variety of FMPs in the coming years. Respondents were allowed to select multiple alternatives.

Most respondents to this question indicated they intended to pursue more than one type of FMP. ***Figure 1.25*** represents all potential types of projects identified in the survey. Local storm drainage systems, roadway improvements and regional dams, reservoirs and detention, channel conveyance and levee improvements are among the most frequently cited FMPs for all responding jurisdictions. The topic of FMPs will be covered in greater detail in ***Chapter 4*** of this plan.

To accompany this chart***, Table 1.14*** details the frequency with which communities plan on implementing a particular type of FMP. While several project types, like local storm drainage systems and roadway improvements may be local in nature, many other solutions are more regional in nature, such as regional dams and retention and even highway improvements that may involve state agencies.

Figure 1.25: Proposed or Ongoing Flood Mitigation Projects



Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

Table 1.14: Proposed Mitigation Projects by Type

Type of Projects	Count
Channel, canal conveyance improvements	10
Flood warning system, stream/rain gauges	1
Floodplain management ordinances	2
Levees, flood walls	11
Local storm drainage systems, tunnels	24
Nature-based projects	2
Property elevations	4
Regional dams, reservoirs, detention, retention basins	18
Roadway and crossing improvements, bridges, culverts	22
Property floodproofing and/or flood retrofits	1

Source: Trinity Region data collection tool and interactive web map as of August 9, 2021

These proposed or ongoing FMPs are derived from the community survey responses throughout the basin. They are being completed by cities, counties, and additional entities throughout the basin. According to the self-assessment of survey respondents, about 25 percent of these projects are claimed to be over the 30 percent design mark, with only two projects being labeled as “nature based.” The predominant types of projects being pursued are:

- Local storm drainage systems, tunnels
- Roadway and crossing improvements, bridges, culverts
- Regional dams, reservoirs, detention, retention basins

Of the projects with the lowest interest were those related to flood warning systems, ordinances, and flood retrofits. It is important to notice that there may be a larger number of projects than displayed, since entities submitted the categories of projects they were pursuing, but not the number of projects within each category. Potential funding sources for these projects that were identified by these entities include FEMA, GLO, CDBG-MIT, TWDB, TDEM, as well as local funding sources coming from the general fund, taxes, stormwater utility fees and other fees.

Structural Projects Under Construction

In the survey, 16 respondents noted that some of their proposed infrastructure or FMPs were at or above a 30 percent level of design. However, responses regarding projects under construction were insufficient to provide a complete answer to this question. ***Chapter 2*** includes more detailed assessment of projects under construction.

Nonstructural Flood Mitigation Projects Being Implemented

Information provided in response entity outreach is insufficient to provide a complete answer to this question. ***Chapter 2*** includes more information regarding nonstructural FMPs being implemented.

Structural and Non-Structural Flood Mitigation Projects with Dedicated Funding and Year Complete Funding Sources

Information provided in response entity outreach is insufficient to provide a complete answer to this question. However, several respondents to the survey who indicated that they did have projects at 30 percent level of design also indicated that Stormwater Utility Fees, Bond Programs, Ad Valorem Tax, and the General Fund were anticipated to be their primary source of revenue to complete these improvements. One respondent indicated that the entity would draw down funds from Special Tax Districts.

Non-local funding sources the entities intend to pursue to complete these projects include:

- Hazard Mitigation Grant Program (HMGP- FEMA/TDEM)
- Pre-Disaster Mitigation (FEMA)
- Cooperating Technical Partners (CTP) funds (FEMA)
- Flood Protection Planning Grants (TWDB)
- USDA NRCS
- Flood Mitigation Assistance (FEMA)

Plans Identified in Hazard Mitigation Projects

In addition to the plans identified via the survey conducted for this project, HMPs for the communities of the Trinity Region also served as an important source of information about future actions to promote flood mitigation. ***Table 1.15*** lists the types of FMPs and numbers of each subcategory type identified in the current HMPs in the Trinity Region. ***Chapter 4*** includes more information on specific projects identified in the HMPs.

Table 1.15: Flood Mitigation Projects by Hazard Mitigation Plan

Subcategory	Total Count
Infrastructure Improvement	220
Urban Planning and Maintenance	211
Education & Awareness for Citizens	145
Drainage Control & Maintenance	143
Equipment Procurement for Response	125
Flood Study/Assessment	121
Outreach and Community Engagement	81
Installation/Procurement of Generators	53
Buyout/Acquisition	52
Technology Improvement	35
Flood Insurance Education	34
Natural Planning Improvement	28
Erosion Control Measure	25

Flood Infrastructure Fund Projects

Of the applications to the FIF in 2021, seven projects in the Trinity Region received funding. These projects, awarded to the Trinity River Authority, Jackson County, Chambers County, Dallas County, Kaufman County, and Parker County Soil and Water Conservation District #558 are primarily for flood and drainage studies. The exceptions are Parker County, which received funding to assist with the preparation of an emergency action plan for dam breach and inundation.

These plans are prepared on a five-year cycle, so ***Table 1.15*** is best suited to provide evidence of the types of projects that will need funding in the future. Not every community provides a dollar value for future projects, so it is difficult to tally the total cost of need for mitigation. However, it is likely that a large need for structural improvement remains, given the projects referencing:

- Infrastructure improvement
- Drainage control

Given the 2021 winter storm, additional sources of funding may be available for the purchase of:

- Equipment for emergency response
- Generators

Many of the following non-structural initiatives can be accomplished with lower investment, while an ongoing program of buyouts and acquisitions may be a longer-term initiative:

- Education and citizen awareness
- Outreach and community engagements
- Urban planning and maintenance

Many of the FMPs identified by communities may have already been completed in the time since the HMP was adopted.

Potential Benefits of Planned Mitigation Projects

Although most communities did not provide detailed information about their intended projects, there does appear to be substantial awareness of the value of preparing for future flood events. Both survey responses and a review of HMPs indicate that substantial investments are being made in local drainage, roadway, and flood control infrastructure. An examination of HMPs indicated that 17 percent intended to adopt and/or update their non-structural measures, such as land use regulations that would help future development avoid being in conflict with areas of flood risk. Without greater detail as to the scale, complexity, and location of these projects, it is difficult to quantify the benefit received, but it is anticipated that the inventory of this information will continue to grow in future planning cycles.

Bibliography

USDA National Agricultural Statistics Service . (2020, January 1). *USDA*. Retrieved from National Agricultural Statistics Service: https://quickstats.nass.usda.gov/results/A2951D70-03B0-3686-ABAA-9260FE77FC2D

ASCE. (2021). *2021 Texas Infrastructure Report Card*. Retrieved from ASCE's 2021 Infrastructure Report Card: https://www.texasce.org/wp-content/uploads/2021/02/2021-Texas-Infrastructure-Report-Card.pdf

Cotter, J. L., & Rael, J. S. (2015). History of Federal Dam Construction in Texas (USACE Fort Worth District). *Floods, Droughts, and Ecosystems* (pp. 79-80). World Environmental and Water Resources Congress, ASCE 2015.

FEMA. (2021). *Building Community Resilience with Nature Based Solutions.* Washington DC: Federal Emergency Management Association.

FEMA. (2021, September 3). *Federal Emergency Management Agency*. Retrieved from How a Disaster Gets Declared: https://www.fema.gov/disaster/how-declared

FEMA. (2021, September 1). *Floodplain Natural Resources and Functions, Chapter 8 .* Retrieved from FEMA Emergency Management Institute: https://training.fema.gov/hiedu/docs/fmc/chapter%208%20-%20floodplain%20natural%20resources%20and%20functions.pdf

Jaimie Hicks Masterson, W. G. (2014). *PLANNING FOR COMMUNITY RESILIENCE: A Handbook for Reducing Vulnerability to Disasters.* Island Press.

Low Impact Development Center. (2017). *RESOURCE GUIDE FOR PLANNING, DESIGNING AND IMPLEMENTING GREEN INFRASTRUCTURE IN PARKS.* Ashburn, VA: National Recreation and Park Association (NRPA) and the American Planning Association (APA).

Marsh, W. M. (2010). *Landscape Planning Environmental Applications, 5th Edition.* John Wiley & Sons.

Melinda Luna, P. T. (2007). *Levees in Texas – A Historical Perspective.* https://www.halff.com/downloads/info_bank/levees_in_texas-historical.pdf#:~:text=After%20August%202005%20because%20Hurricane%20Katrina%20and%20its,the%20area%20from%20breaching%20to%20avoid%20further%20flooding.

National Centers for Environmental Information. (2022, March 1). Storm Events Database. Washington, D.C., District of Columbia, United States of America.

NCTCOG. (2015). *North Central Texas Floods May-June,2015*. Retrieved from https://www.nctcog.org/getmedia/8b03d92a-4467-43db-8f21-57a57ca8b20e/FloodReportFinal.pdf

NCTCOG, N. C. (2021, September 30). *Trinity River Corridor Development Certificate Program*. Retrieved from http://trinityrivercdc.com/

Niki L. Pace, J. L. (2013). *Resilient Coastal Development through Land Use Planning: Tools and Management Techniques in the Gulf of Mexico.* Oxford, MS: Mississippi-Alabama Sea Grant Legal Program • University of Mississippi School of Law.

NOAA. (2021, July 20). *Billion-Dollar Weather and Climate Disasters: Time Series*. Retrieved from NOAA National Centers for Environmental Information: https://www.ncdc.noaa.gov/billions/time-series/TX

Peter M. Lake, K. J. (2019). *State Flood Assessment: Report to the 86th Texas Legislature.* Austin: Texas Water Development Board.

TCEQ. (2005). *Texas Commission on Environmental Quality Chapter 301 - Levee Improvement Districts, District Plans.* Retrieved from SUBCHAPTER C: APPROVAL OF LEVEES AND OTHER IMPROVEMENTS, §§301.31 - 301.46: https://www.tceq.texas.gov/assets/public/legal/rules/rules/pdflib/301c.pdf

TCEQ. (2006, November). *Guidelines for Operation and Maintenance of Dams in Texas.* Retrieved from Texas Commission on Environmental Quality: https://www.tceq.texas.gov/assets/public/comm_exec/pubs/gi/gi357/gi-357.pdf

TCEQ. (2021, September 20). *Texas Commission on Environmental Quality Website.* Retrieved from TCEQ Dam Safety Guidance: https://www.tceq.texas.gov/downloads/compliance/enforcement/dam-safety/dam-safety-guidance.pdf#:~:text=The%20Texas%20Commission%20on%20Environmental%20Quality%20%28TCEQ%29%20currently,flooding%20event%3B%20or%20for%20determining%20the%20hazard%20classific

TCEQ Dam Safety Program, Field Operations Support Division. (2009). *Design and Construction Guidelines for Dams in Texas.* Austin: Texas Commission on Environmental Quality .

TCEQ Dam Safety Program, Field Operations Support Division. (2009). *Design and Construction Guidelines for Dams in Texas.* Austin: Texas Commission on Environmental Quality (TCEQ).

Texas A&M Natural Resources Institute. (2021, August 2). *2020. Texas Land Trends: A database of compiled and analyzed values for working lands in Texas.* Retrieved from Texas Land Trends: https://data.txlandtrends.org/trends/riverbasin/Trinity

Texas Administrative Code. (2009, January 1). *Texas Administrative Code: Title 30, Part 1, Subchapter 299, Subchapter B, Rule §299.14 Hazard Classification Criteria.* Retrieved from Texas Administrative Code: https://texreg.sos.state.tx.us/public/readtac%24ext.TacPage?sl=R&app=9&p_dir=&p_rloc=&p_tloc=&p_ploc=&pg=1&p_tac=&ti=30&pt=1&ch=299&rl=14

Texas Commission on Environmental Quality. (2021, September 20). *TCEQ Website.* Retrieved from TCEQ Dam Safety Guidance: https://www.tceq.texas.gov/downloads/compliance/enforcement/dam-safety/dam-safety-guidance.pdf#:~:text=The%20Texas%20Commission%20on%20Environmental%20Quality%20%28TCEQ%29%20currently,flooding%20event%3B%20or%20for%20determining%20the%20hazard%20classific

Texas GLO. (2019). *2019 Texas Coastal Resiliency Master Plan.* Austin: Texas General Land Office.

Texas Legislature. (n.d.). WATER CODE, TITLE 4. GENERAL LAW DISTRICTS, CHAPTER 54. MUNICIPAL UTILITY DISTRICTS, SUBCHAPTER A. GENERAL PROVISIONS. Austin, Texas, USA.

Texas Parks and Wildlife Department. (2022). Wildlife Management Areas of Texas. Austin, Texas, United States of America.

Texas State Legislature. (n.d.). Texas Local Government Code. *75th Leg. R.S., Ch 211, §4, 1997, Tex. Gen. Laws*. Texas General Laws.

Texas State Soil and Water Conservation Board. (2021, September 19). *Flood Control Program*. Retrieved from Texas State Soil and Water Conservation Board: https://www.tsswcb.texas.gov/programs/flood-control-program

TRA of Texas. (2021). *Trinity River Basin Master Plan.* Arlington: Trinty River Authority of Texas.

TSSWCB, T. S. (2021, September 1). *Flood Control Program*. Retrieved from https://www.tsswcb.texas.gov/programs/flood-control-program

TWDB. (2020, September 1). *Water Demand Projections for 2020-2070.* Retrieved from Population and Water Demand Projections: https://www.twdb.texas.gov/waterplanning/data/projections/index.asp

TWDB. (2021, July 27). *Flood Planning Data*. Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/data.asp

TWDB Flood Planning Frequently Asked Questions. (2021, July 22). Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/faq.asp

United States Census Bureau. (2017). *EC1700BASIC.*

United States Census Bureau. (2020, December 10). American Community Survey 2015-2019 5-Year Data Release. Washington, D.C., Washington, D.C., United States of America. Retrieved from https://www.census.gov/newsroom/press-kits/2020/acs-5-year.html

United States Census Bureau. (2021, November 21). *Income Data Tables.* Retrieved from United States Census Bureau: https://www.census.gov/topics/income-poverty/income/data/tables.html

United States Center for Disease Control. (2018). CDC/ATSDR Social Vulnerability Index. Washington, D.C., District of Columbia, United States of America.

USACE. (1949, May). Aerial Photo of 1949 Flood in Fort Worth. *Aerial Photo of 1949 Flood in Fort Worth*. Fort Worth, Texas, United States of America: United States Army Corps of Engineers, Fort Worth District Website.

USACE. (2020). *Dams of Texas*. Retrieved from National Inventory of Dams: https://nid.usace.army.mil/#/

USACE. (2021, 09 29). Retrieved from USACE Fort Worth District History: https://www.swf.usace.army.mil/About/History/

USACE. (2021, September 21). *Trinity Common Vision Steering Committee Presentation*. Retrieved from https://www.nctcog.org/nctcg/media/Environment-and-Development/Committee%20Documents/Trinity%20CV/FY2021/NCTCOG-Presentation-TCV-2021_2.pdf?ext=.pdf

USACE. (2021, September 15). *US Army Corps of Engineers/ Fort Worth District Website*. Retrieved from About / Lakes and Recreation Information: https://www.swf.usace.army.mil/About/Lakes-and-Recreation-Information/

USACE. (2022, June). *Engineering with Nature*. Retrieved from USACE Engineering with Nature: https://ewn.erdc.dren.mil/

USACE. (2022). Levees of Texas. Washington, D.C., District of Columbia, United States of America.

USDA. (2021, August 3). *United States Department of Agriculture National Agricultural Statistics Service*. Retrieved from National Agricultural Statistics Service: https://www.nass.usda.gov/Charts_and_Maps/Crops_County/index.php#ww

USDOI. (2022, May 16). National Park System. Washington, D.C., Washington, D.C., United States of America.

USGS. (1998). *National Wetlands Inventory.* Washington, D.C.: United States Geological Survey. doi:10.3133/fs19195

USGS. (2016). *National Land Cover Database 2016*. Retrieved from https://data.tnris.org/collection/89b4016e-d091-46f6-bd45-8d3bc154f1fc

Chapter 2: Flood Risk Analyses

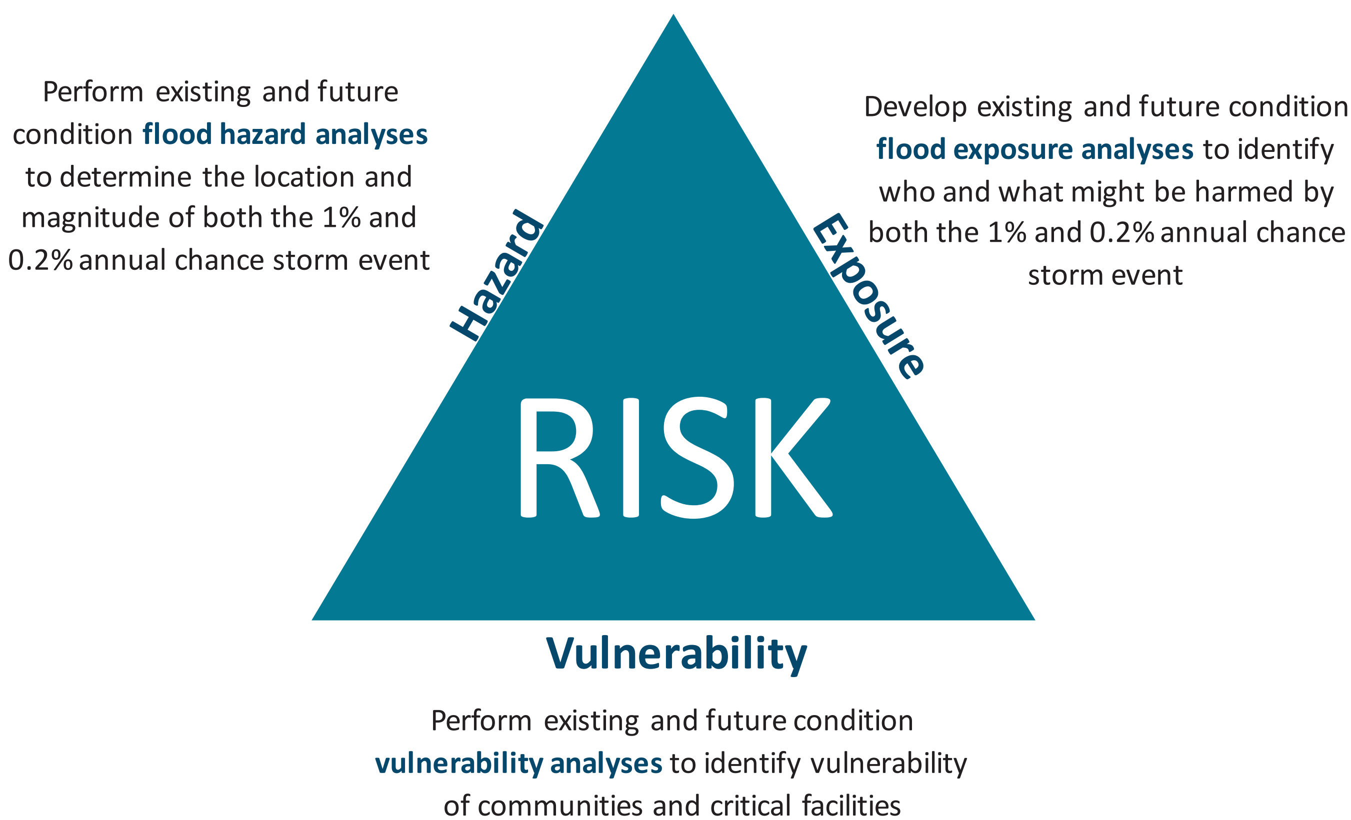
An important aspect of developing a regional flood plan involves providing an accurate assessment of flood risk. This includes a description of flooding, identification of what is at risk, and estimation of the associated impacts. In terms of understanding the environment, the Trinity Regional Flood Plan assessed flood risk for existing and future conditions.

In this Trinity Regional Flood Plan, the existing and future conditions flood risk assessment focused on the following three components:

1. Flood hazard analyses to determine the location, magnitude, and frequency of flooding
2. Flood exposure analyses to identify who and what might be harmed within the Trinity Region
3. Vulnerability analyses to identify the degree to which communities and critical facilities may be affected by flooding

Figure 2.1 below shows the risk triangle framework applied to the Trinity Regional Flood Plan flood risk analyses.

Figure 2.1: Flood Risk Analyses Triangle Framework



Source: TWDB

Task 2A – Existing Condition Flood Risk Analyses

Existing Condition Flood Hazard Analysis

Sufficiency of Existing Conditions for Planning Purposes

In terms of potential flood hazard analysis, existing conditions refers to the hydrologic and hydraulic conditions that were present at the time the analysis was performed. These conditions include current land use, estimated precipitation data, and constructed drainage related infrastructure. Existing conditions in relation to the Trinity Region do not consider projected changes in rainfall patterns, future land use/population growth, or planned new/improved infrastructure. Federal Emergency Management Agency (FEMA) Flood Insurance Rate Maps (FIRMs) Special Flood Hazard Areas (SFHAs) are generally based on existing conditions. The FEMA regulatory SFHA boundaries from these maps form the foundation of the Trinity Region existing conditions flood hazard analysis.

Land Use

Land use is an important factor in determining existing conditions flooding limits. It affects the hydrological processes such as evapotranspiration, interception, and infiltration. As urban development (impervious area) is added to a watershed, the hydrologic response is changed, and surface runoff often increases. As demonstrated in ***Chapter 1***, most of the urban development occurs in the Upper Basin of the Trinity Region watershed located in Collin, Dallas, Denton, and Tarrant Counties. These four counties are surrounded by heavy agricultural use which extends from the headwaters to the mid basin area. From the mid basin area, extending to the coast, the existing land use is predominantly forested, interspersed with agriculture. Localized urban development is largely confined within city boundaries and the Extraterritorial Jurisdictions (ETJs). While not as prolific as urban development, cultivated agricultural and grazed land use still quicken the watershed's response time in comparison to natural forested ground cover, which in turn increases flood risk. The rate of development and changes in land use since the initial determination of the flooding limits affects the validity of the analysis for planning purposes. For example, FEMA's SFHA within the Trinity Region is based on hydrologic and hydraulic analyses that were performed between the mid-1970s and today. While the 1970s studies are nearly 50-years old, the flood limits may still be valid due to little change in land use and basin size.

Precipitation

When planning for existing conditions flood risk, assessing potential anomalous flood-causing precipitation is crucial. Precipitation as it relates to flood risk is commonly analyzed in terms of inches of rainfall that occur within a 24-hour duration. In 1973, the FEMA National Flood Insurance Program (NFIP) set the standard for flood hazard areas based on the 1% annual chance storm event, more commonly referred to as the 100-year flood. For the purposes of the State Flood Plan, all risk assessments will be based on this recurrence interval in addition to the 0.2% annual chance storm event (or 500-year flood). A majority of FEMA's SFHA boundaries within the Trinity Region were developed using hypothetical rainfall data from the National Weather Service (NWS) Technical Paper No. 40/NWS Hydro-35 (Hershfield, 1961) or the United States Geological Survey (USGS) Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas (Asquith & Roussel, 2004). Rainfall data was broken down in terms of duration and recurrence interval. In 2019, National Oceanic and Atmospheric Administration (NOAA) developed updated hypothetical rainfall in Texas based on historic rainfall data in its Atlas 14 study. The NOAA Atlas 14 study anticipates significant differences between hypothetical rainfall in the lower portion of the Trinity Region watershed when compared to the 1961/1977 and 2004 rainfall data. ***Table 2.1*** below shows the range of rainfall for each data source.

Table 2.1: Precipitation Data Comparison

Trinity Region Watershed	TP40/Hydro 35 100-year, 24-hour Rainfall (inches)	USGS 2004 100-year, 24-hour Rainfall (inches)	NOAA Atlas 14 100-year, 24-hour Rainfall (inches)
Upper Basin	8.8-10.5	8.5-11.0	8.5-11.0
Middle Basin	10.5-12.0	11.0-12.0	11.0-14.0
Lower Basin	12.0-13.5	12.0-14.0	14.0-18.5

Infrastructure

Drainage related infrastructure is a key element in determining existing conditions flood risk. Drainage related infrastructure includes but is not limited to, dams, levees, detention/retention ponds, bridges, culverts, Low Water Crossings (LWCs), tunnels, urban storm drain networks, breakwaters, bulkheads, and revetments. The Trinity Region has eight major flood control reservoirs owned and operated by the United States Army Corps of Engineers (USACE). These include Benbrook Lake, Joe Pool Lake, Grapevine Lake, Ray Roberts Lake, Lewisville Lake, Lavon Lake, Navarro Mills Lake, and Bardwell Lake. In addition to the major reservoirs, the region contains nearly 1,000 Soil Conservation Service (SCS) minor reservoirs, which control flood waters along the major and minor tributaries. There are 22 levee districts located within the Trinity Region, which accounts for over 134,000 acres of flood protection.

While flood control infrastructure mitigates existing flood risk, some older drainage-related infrastructure contributes to flooding. Bridges, culverts, and storm drain systems that were designed and constructed before major land use changes and higher standards were implemented, impound flood water, and overtop during major storm events. The result is increased flood risk to both property and life which is expanded upon in the existing conditions exposure analysis.

Existing Hydrologic and Hydraulic Model Availability

Hydrology and Hydraulic (H&H) modeling is a necessary component in determining how water flows over land. It is a crucial element in developing effective flood planning strategies.

Hydrology is the scientific study of earth's natural water movement with a focus on how rainfall and evaporation affect the amount of flow of water in streams and storm drains. Hydraulics represents the engineering analysis of the flow of water in streams and infrastructure, such as channels, pipes, and other man-made structures.

Applied since the 1970s, H&H uses computer software applications that simulate the flow of rainfall runoff over the land to predict the rise of creek and river water levels and potential flooding, as well as test ways to reduce flooding without constructing projects. H&H modeling simulates flow, frequency, depth, and extent of flooding over land. These models assist with making informed decisions about selecting and implementing flood reduction and restoration projects. H&H modeling also satisfies regulatory requirements and confirms that natural, agricultural, and social resources are not damaged by flooding induced by modifications to creeks, rivers, and channels.

Within the Trinity Region's 13 eight-digit Hydrologic Unit Code (HUC-8) watersheds, there are hundreds of H&H models, each calibrated for the specific region, and spanning from the late 1970s to present. All the data output from the various modeling efforts is ultimately incorporated through Geographic Information System (GIS) mapping into the Trinity Region floodplain quilt. ***Figure 2.2*** shows stream model locations in the Trinity Region.

Best Available Existing Flood Hazard Data

Flooding within the Trinity Region is mostly riverine (based on the Region's location, availability of flood mapping data, and historical data) with some coastal influence in Chambers and Liberty counties in the south, where they are directly (and frequently) affected by hurricane storms from the Gulf of Mexico. Hurricanes typically fade and downgrade to tropical storms or tropical depressions as they move inland away from the coast. Riverine flooding often occurs from general rainfall and thunderstorm floods. Flash floods are common from these rainfall events, which can occur within a few minutes or hours of excessive rainfall, exposing valuable public and private properties to flood risk. A portion of the region lies in the flash flood alley of Texas. ***Figure 2.3*** shows reported and documented flood events by county, as well as location band of the flash flood alley.

Figure 2.2: Existing Conditions Model Availability

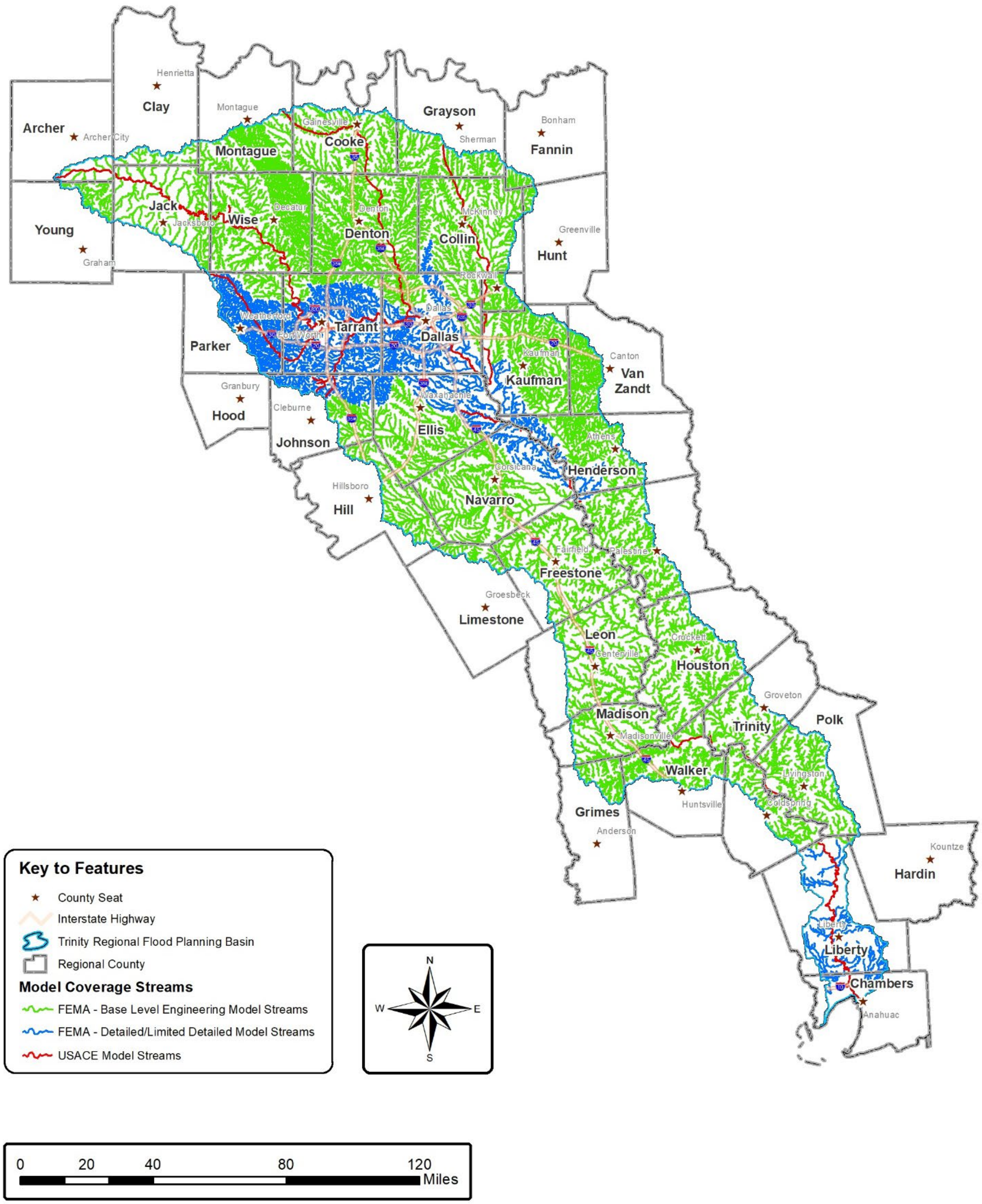
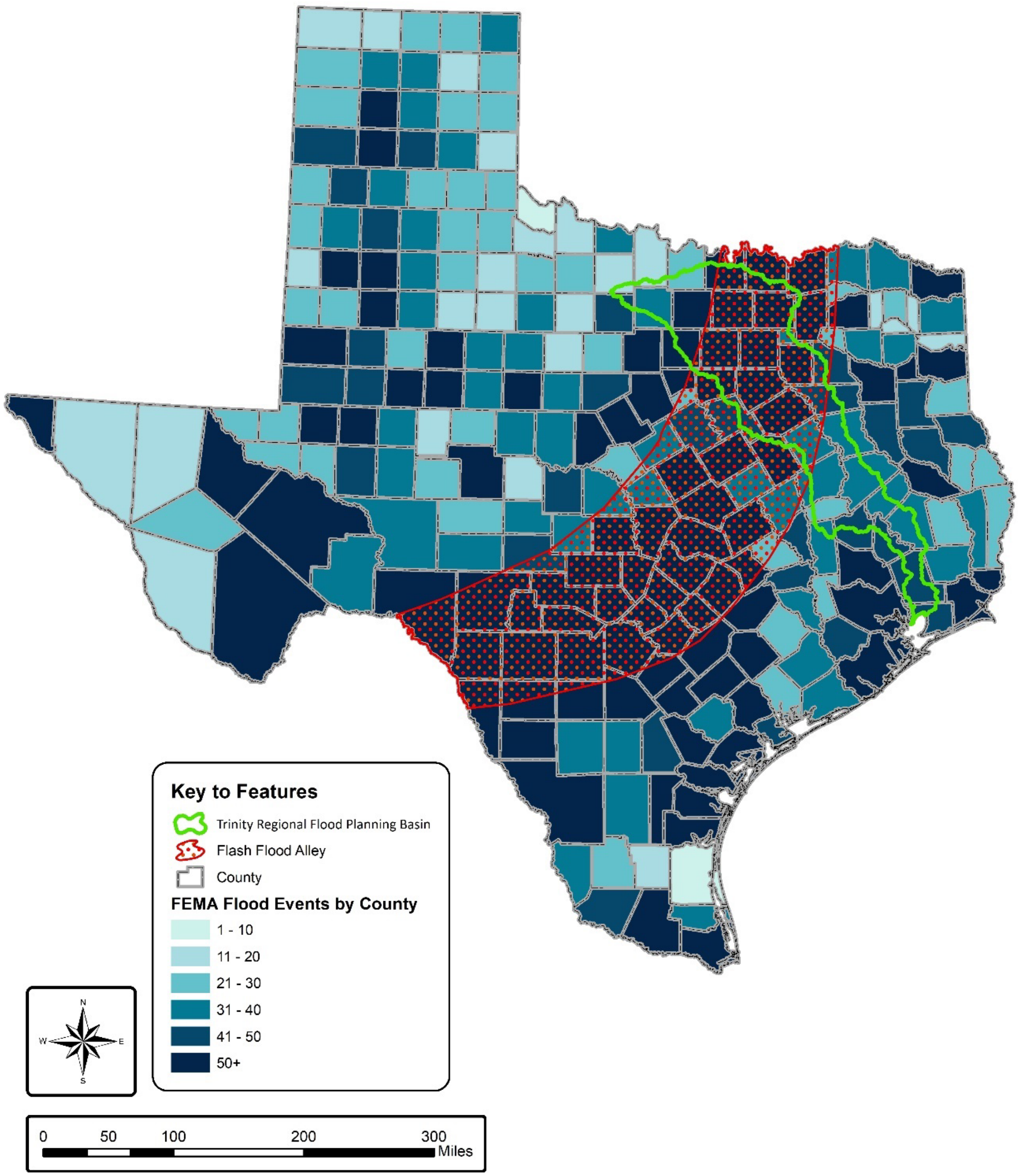


Figure 2.3: Major Documented Storm Events and Flash Flood Alley (1996 through 2019)



Source: FEMA/NOAA Storm Data (1996 – 2019)

Even though riverine and coastal-based flooding are the dominant types of flooding in the Trinity Region, urban flooding data was evaluated for inclusion in the existing floodplain quilt where available. Urban flooding (off-floodplain, pluvial, or surface flooding) is caused by intense local precipitation running-off impermeable surfaces such as paved streets, sidewalks, and structures, and overwhelms local drainage systems and overflows small waterways. This flooding may enter buildings and properties, which often occurs in locations such as historic downtown areas and residential neighborhoods which predate floodplain maps. Communities have done a great job in generally mitigating upland flooding, but this will continue to be much more significant regarding flood infrastructure and on-going operations and mitigation activities. Flood Mitigation Projects (FMPs) are discussed in ***Chapter 4***.

Existing flood hazard mapping estimation is based on the use of current land use and precipitation data to estimate hydrologic condition parameters and discharges. Data is then used to simulate Water Surface Elevations (WSEs) to create existing floodplain mapping extents.

The most current existing flood hazard mapping data from multiple sources was compiled by the Texas Water Development Board (TWDB) to create a comprehensive, single, coherent, continuous set of best available existing floodplain data for the Trinity Region. Mapping data was compiled and included 100-year and 500-year floodplain data. The existing floodplain quilt data was then updated with data obtained from FEMA, USACE, USGS, and local communities where available. The main data sources comprising the existing floodplain data for the Trinity Region are described below.

Regulatory Federal Emergency Management Agency Floodplain Data

FEMA maps flood zones on their FIRMs, which forms the basis of regulatory floodplain management for communities and mandatory flood insurance requirements for structures in the mapped SFHA floodplains. The regulatory FEMA floodplain data used in the Trinity Regional Flood Plan ranged from digital FEMA floodplain datasets from those that were already effective and have become available for NFIP regulatory use, to those that are at the Letter of Final Determination stage and are pending, with six months to become effective. FEMA's preliminary datasets issued for public review, and in due process, were also utilized, including Letter of Map Revision (LOMR) data that has become effective as of March 2022.

1% Annual Chance Storm Event Floodplains

On FIRMs, FEMA maps both the 1% and 0.2% annual chance storm event floodplains. Floodplain data developed for the Trinity Region included only the 100-year and 500-year mapping to describe the flood hazards and perform the exposure and vulnerability analyses.

The 1% annual chance storm event has a one percent chance of being equaled or exceeded in any given year, and it has an average recurrence interval of 100 years. Also referred to as the SFHA, or 100-year flood, this boundary is mapped as a high-risk flood area subject to a one percent or greater annual chance of shallow flooding in any given year, where shallow flooding is usually in the form of ponding or sheet flow with average depths between one and three feet. Along the coast, these high-risk areas are associated with velocity wave action. In the Trinity Region, coastal wave action only affects Chambers County. The areas may also be susceptible to erosion, deposition, and mudflow. It is sometimes referred to as the "Base Flood" and is the national standard used by the NFIP and other federal agencies for the purposes of regulating development and requiring the purchase of flood insurance.

0.2% Annual Chance Storm Event Floodplains

The 0.2% annual chance storm event has a 0.2 percent (or 1-in-500 chance) of occurring in any given year and is also referred to as the 500-year flood or Non-Special Flood Hazard Areas (NSFHAs). The 500-year flood refers to areas of moderate flood risk that are not considered to be in immediate danger from flooding caused by overflowing rivers; areas in the 100-year flood with average depths less than one foot or drainage areas less than one square mile; or areas protected by levees from the 100-year flood.

Other Floodplain Data

Where only paper-based FEMA data was available, digitally converted FIRMs from First American Flood Data Services (FAFDS) was utilized. FEMA and TWDB's Base Level Engineering (BLE) study data, including model-backed HUC-8 wide level studies, was leveraged to revise the existing floodplain quilt.

TWDB provided modeled flood data from the 2021 Cursory Fathom Data to be used where applicable. Fathom was developed by a research group at the University of Bristol in England. The Fathom model has been peer reviewed and compares reasonably well to FEMA flood data. The Fathom model is a two-dimensional (2D) hydraulic framework developed at a national scale using 30-meter Digital Elevation Models (DEMs). The results have been mapped on 10-foot LiDAR for Texas to create statewide flood depth rasters for fluvial, pluvial, and coastal mapping for the 100-year and 500-year and other frequencies. The fluvial, pluvial, and coastal flood depth rasters from the Cursory Fathom Data for the Trinity Region were mosaicked together with maximum depths taken where datasets overlap each other. The combined rasters were processed into flood polygon boundaries using guidance provided by the TWDB. The Cursory Fathom Data served as a supplemental dataset for inclusion in the existing flood boundaries where data was not available or the approximate study extents was abruptly truncated as a limit of study.

Regional Data Collection and Possible Flood-Prone Areas

A regional online data collection website was created as an outreach tool to work closely with regional entities (counties, municipalities, state and federal agencies, or political subdivisions with flood related authorities) to gather local flood-risk information. The website included a web mapping application that enabled entities to document other possible flood-prone areas not previously identified as mapped flood hazard areas. These included areas of historic flooding events, roads that frequently overtopped, and past flood claim hot spots.

The Trinity Regional Flood Planning Group (RFPG) team also collected data related to areas subject to inundation from reservoirs and levee inundation areas. Dam breach inundation areas were included where data was publicly available. Data submitted to the Trinity RFPG through the online GIS-based data collection tool was also added. Cities, counties, entities with flood control responsibilities, and the general public had the opportunity to submit data to the Trinity RFPG.

The Trinity RFPG team weaved the existing conditions flood quilt together. The existing conditions flood quilt was presented at the Trinity RFPG meeting on February 17, 2022 and posted to the Trinity RFPG website for public review and comment on February 21, 2022. The deadline for community, county, entity, and public review and comment period for the existing conditions flood quilt was March 25, 2022. The various data sources received were compiled according to TWDB's ranking hierarchy as shown in ***Table 2.2***. The data ranking was based on a quality and coverage extent relative to other datasets.

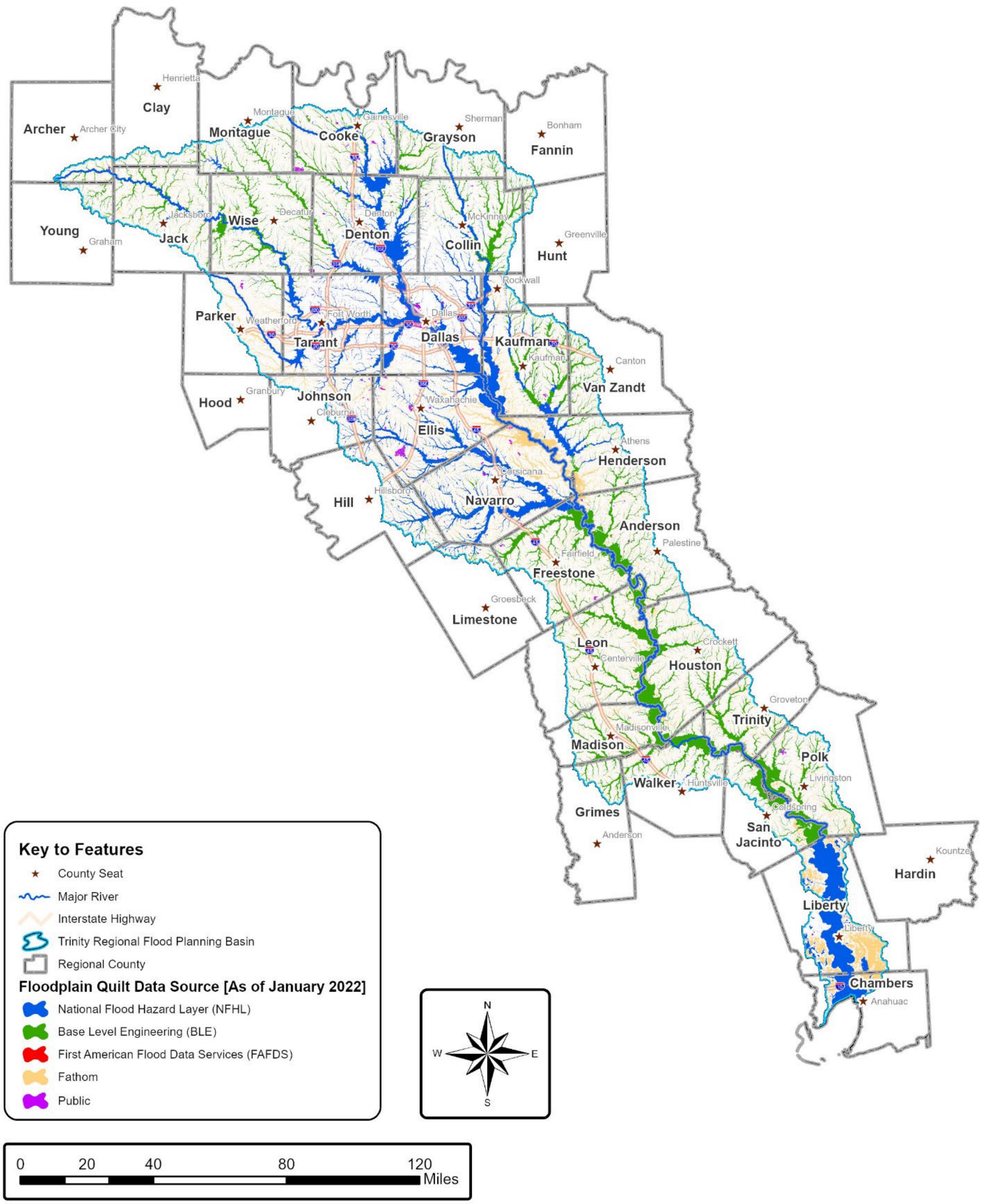
Figure 2.4 shows the floodplain data sources by location developed for the Trinity Region. A larger version of this map is included in ***Appendix B***

Table 2.2: Floodplain Quilt Data Hierarchy and Sources

Ranking	Data Category	Source
1	NFHL Pending (Detailed and Approximate Studies)	FEMA
2	NFHL Preliminary (Detailed and Approximate Studies)	FEMA
3	NFHL Effective (Detailed Study Only)	FEMA
4	BLE	FEMA
4.5	Cursory Fathom Data	FEMA
5	NFHL Effective (Approximate Study Only)	FEMA
6	Digitized Effective FIRMs	CoreLogic FAFDS
	Other Potential Data Sources	USACE or Other Federal Data (0.5 to 4.5 Ranking)
		Regional or Local Community Data (0.5 to 6.5 Ranking)

Source: TWDB Technical Guidelines for Regional Flood Planning

Figure 2.4: Floodplain Quilt Data Sources



The compiled existing condition floodplain quilt data for the Trinity Region is included in the submittal GIS database layer named "ExFldHazard". ***Figure 2.5*** shows a GIS coverage map of the comprehensive existing floodplain data compiled for the Trinity Region showing the 100-year and 500-year floods. Larger detailed maps are included in ***Appendix B***.

The total floodplain area for each county is also shown in ***Figure 2.6*** and ***Table 2.3***.

When this compiled existing floodplain quilt was shown to the public either through an online web map or in-person meeting, the following disclaimer note was used:

"The floodplain quilt is a compilation of data from multiple sources and is intended to approximate the extent of existing flood risk in the Trinity Region. This data layer is for planning purposes only and is not to be used for any regulatory activities. For regulatory floodplain maps, contact your local floodplain administrator or visit the FEMA Map Service Center."

Overall, the Trinity Region covers a total land area of approximately 18,000 square miles with about 22 percent (4,000 square miles) in the existing conditions floodplain. Of note, Chambers County has a high percentage of floodplain area, due to its Gulf Coast location along the Trinity Bay and East Bay along with relatively flat terrain. The County experiences both inundated coastal flooding, as well as riverine flooding from the Trinity River. Hardin and Hood counties exhibit small floodplain area percentages, as they have less than one percent of their land area located in the Trinity Region.

Flood Data Gaps

Once the best available comprehensive existing flood data was complied, data gaps were assessed to identify any remaining areas where flood inundation boundary mapping was missing, lacked modelling and/or mapping, used outdated modeling and/or mapping, or recently had more accurate topographic data produced since the last map update. Other contributing engineering factors considered to identify data gaps included modeling technology, significant land use and/or impervious area change, change in flood control structures, channel configuration (including erosion and sedimentation) changes, as well as rainfall pattern changes, which altered peak discharges.

Figure 2.5: Existing Condition Floodplain Quilt

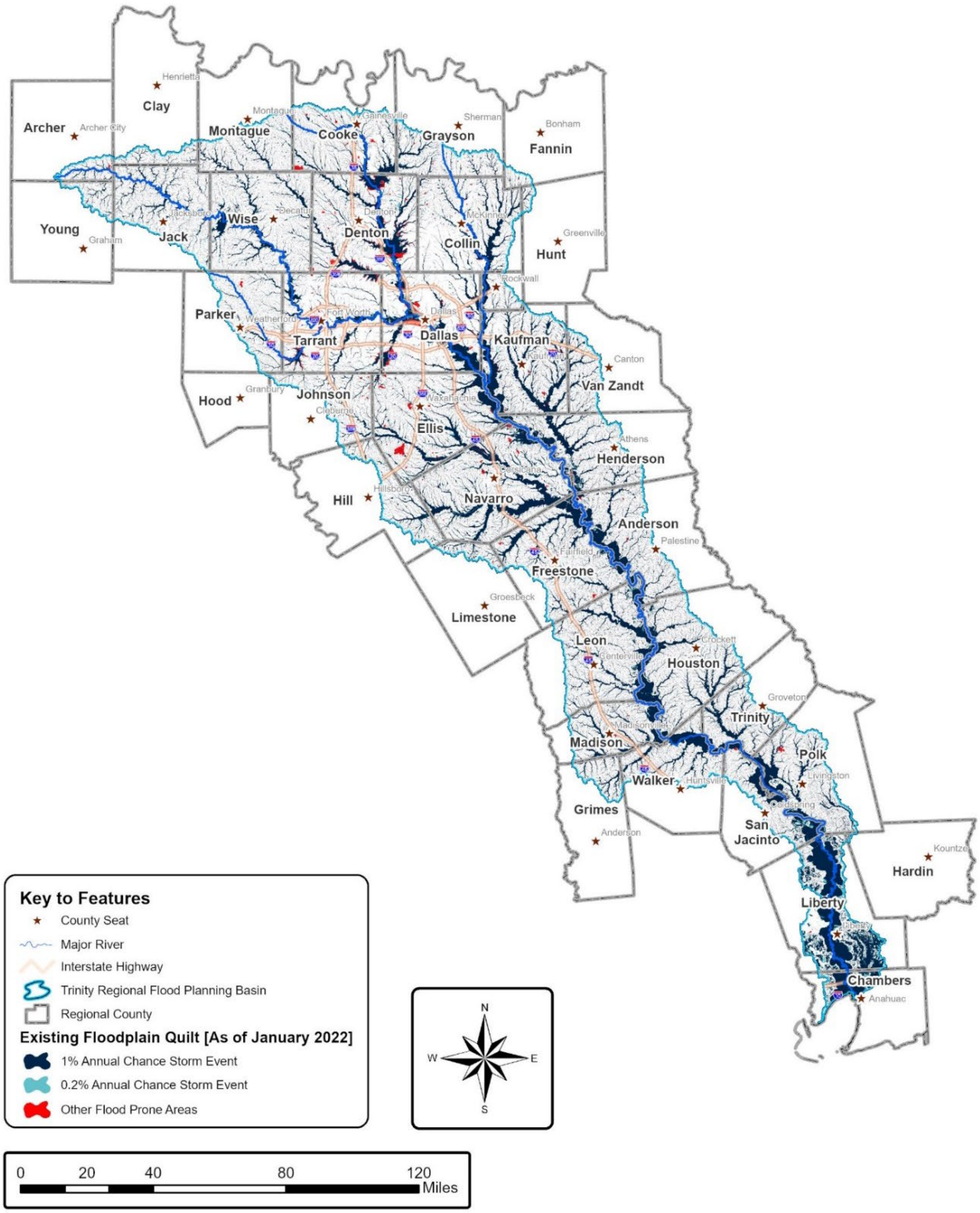


Figure 2.6: Existing Condition Flood Hazard Areas (in Square Miles) by County

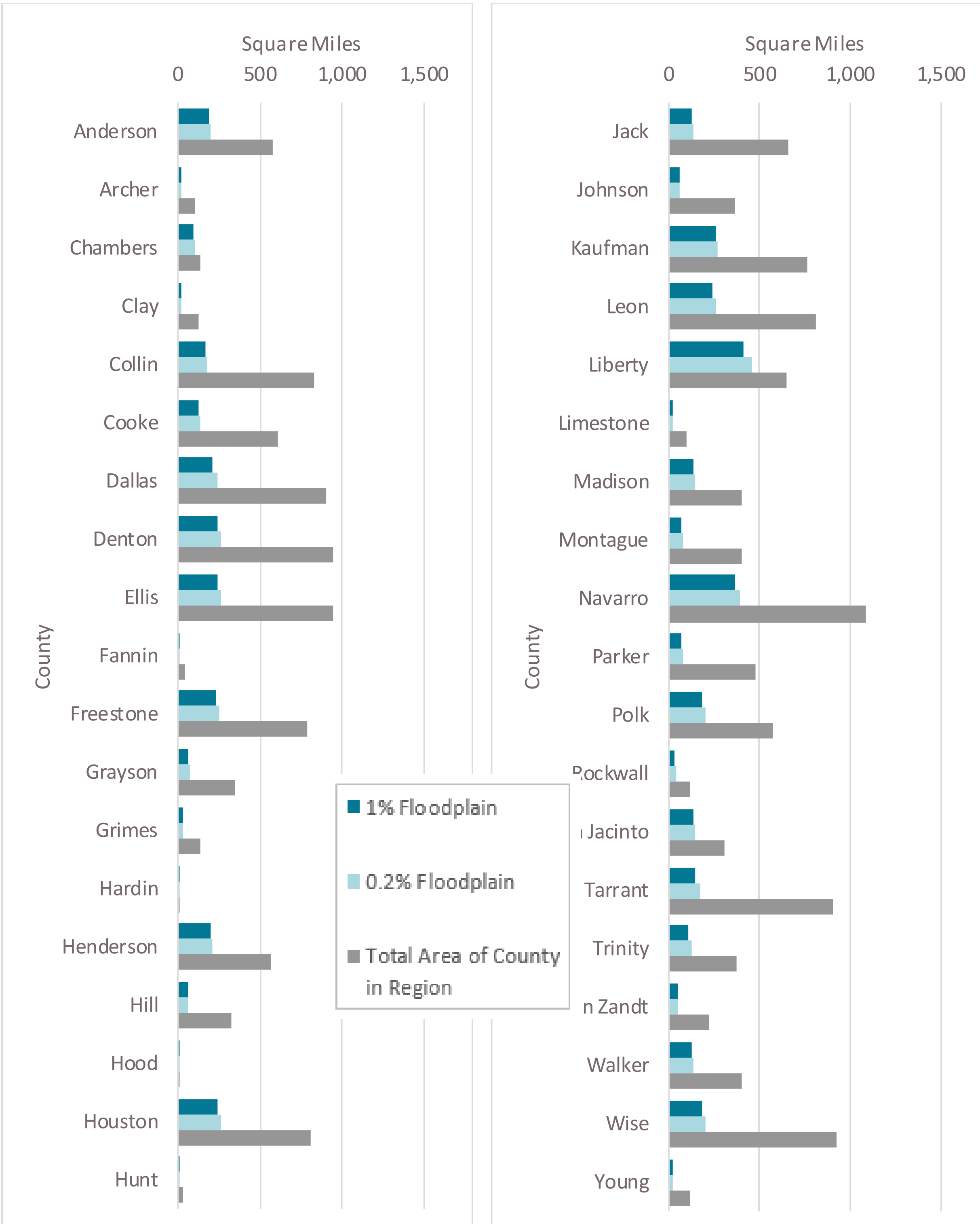


Table 2.3: Existing Condition Flood Hazard Areas (in Square Miles) Flood Type by County

County	1% Annual Chance Flood Risk - Area in Riverine Flood Type (square miles)	1% Annual Chance Flood Risk - Area in Coastal Flood Type (square miles)	0.2% Annual Chance Flood Risk - Area in Riverine Flood Type (square miles)	0.2% Annual Chance Flood Risk - Area in Coastal Flood Type (square miles)
Anderson	184.2	-	11.6	-
Archer	23.7	-	2.3	-
Chambers	54.9	39.3	11.9	0.9
Clay	19.1	-	1.9	-
Collin	170.9	-	11.5	-
Cooke	122.3	-	11.4	-
Dallas	211.7	-	24.8	-
Denton	241.8	-	23.5	-
Ellis	238.8	-	23.2	-
Fannin	5.7	-	0.5	-
Freestone	233.2	-	15.3	-
Grayson	68.0	-	7.2	-
Grimes	33.3	-	2.9	-
Hardin	2.7	-	0.7	-
Henderson	196.9	-	14.0	-
Hill	59.0	-	8.4	-
Hood	0.2	-	0.0	-
Houston	245.8	-	18.1	-
Hunt	6.2	-	0.2	-
Jack	125.3	-	13.9	-
Johnson	55.6	-	7.7	-
Kaufman	254.6	-	17.1	-
Leon	239.1	-	18.9	-
Liberty	408.8	-	50.1	-
Limestone	23.2	-	2.4	-
Madison	130.7	-	9.8	-
Montague	69.0	-	7.8	-
Navarro	359.9	-	30.7	-
Parker	71.4	-	8.8	-
Polk	187.0	-	14.4	-
Rockwall	34.5	-	1.6	-
San Jacinto	135.0	-	9.6	-
Tarrant	146.0	-	23.1	-
Trinity	111.4	-	10.4	-
Van Zandt	49.2	-	4.7	-
Walker	128.8	-	8.9	-
Wise	184.8	-	21.5	-
Young	19.4	-	2.2	-

**The 0.2% flood hazard does not incorporate the 1% flood hazard to avoid overlapping polygons*

Within the Trinity Region, the average age of the effective FIRMs of the study watersheds is nine years. Among the counties with no new Digital FIRM, Clay County had the oldest FEMA effective map, dated 1991. Within the modernized counties, the FIRM effective dates range from 2008 to 2021, with Archer and Jack counties being recently modernized in 2021. As of 2022, all communities in the Trinity Region have modernized FEMA digital county-wide effective FIRMs except for Clay, Freestone, and Trinity counties and their respective incorporated communities. With recently completed BLE flood data, the non-modernized counties have the potential to be eligible for FEMA's Paper Reduction projects and become modernized.

The Trinity RFPG team attempted to determine the validation status (whether a stream model was new or updated) of the associated H&H models supporting the mapped floodplains using the contributing engineering factors listed earlier. For example, Chambers, Liberty, Polk, San Jacinto, and Walker counties, located in the southern portion of the Trinity Region, were greatly affected by NOAA Atlas 14 precipitation updates which showed higher rainfall events, invalidating their effective floodplain information contained within the floodplain quilt. Because of this, these counties are reported as data gaps. Model-backed (H&H) detailed stream study flood data varied in age and conformance to current technologies, even for modernized county-wide FIRMs. In the urban areas, a large percentage of the H&H model data is outdated (HEC-2 or not in digital format), with only a few models revised recently (HEC-RAS, XPSWMM, etc.) and in digital format.

The gap areas data is included in the "Fld_Map_Gaps" GIS database layer. ***Figure 2.7*** shows the locations of identified existing flood data gaps. Additional detailed data gap maps are provided in ***Appendix B***. While areas were identified within the floodplain quilt as data gaps with outdated information, the compiled existing floodplain quilt still comprised the best available floodplain datasets for the Trinity Region and was used for the flood risk analysis in the Trinity Regional Flood Plan. It is the goal of this plan to further evaluate these data gaps for inclusion as Flood Management Evaluations (FMEs). See ***Chapter 4***.

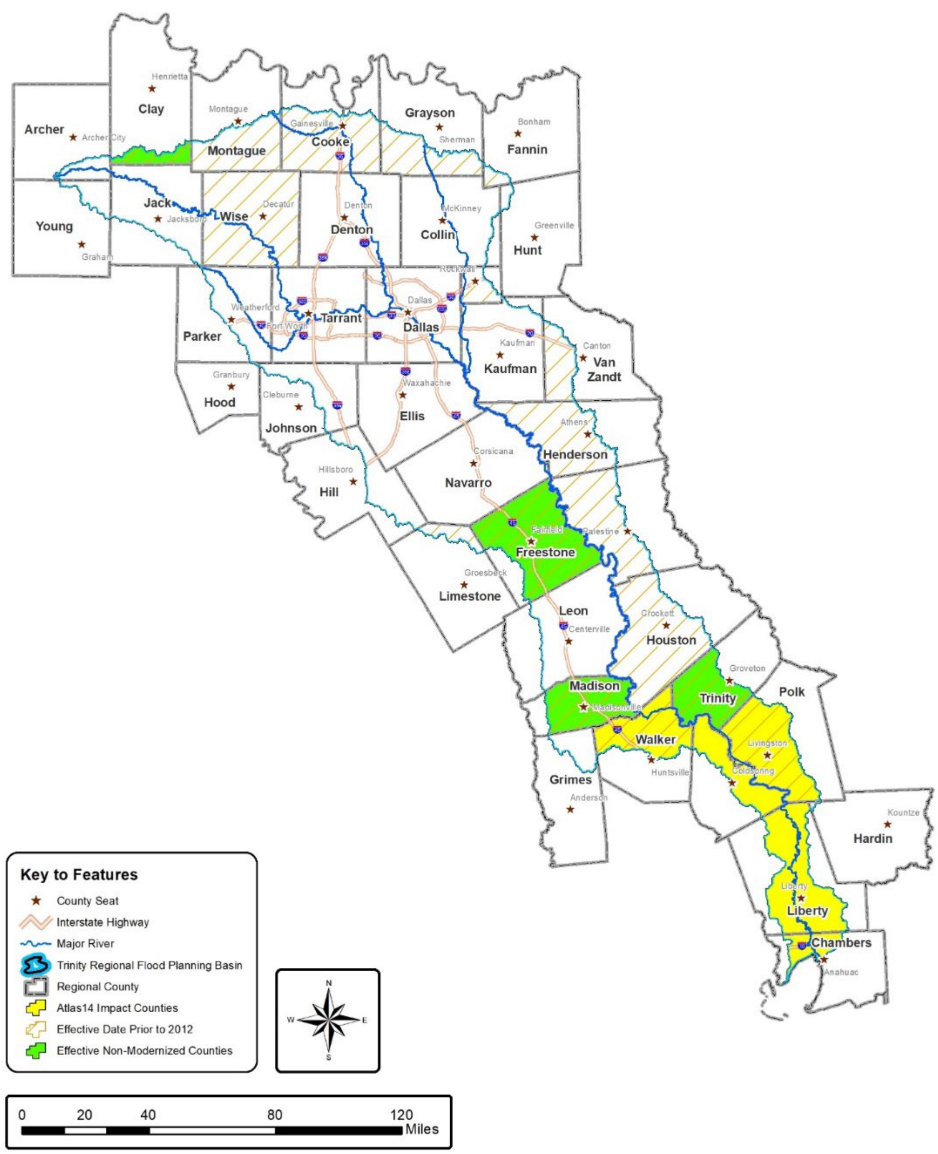
Existing Condition Flood Exposure Analysis

Flooding is a common occurrence within the Trinity Region (See ***Figure 2.3***). Flooding can become a significant hazard when it inundates the built environment and causes direct damage to buildings, critical facilities, crops, or significant injuries and sometimes death to people. Flooding frequency and intensity have been increasing in recent years, often necessitating state and federal relief, which has risen to record levels. The existing condition flood risk exposure analysis leveraged the compiled existing conditions 100-year and 500-year floods in the Trinity Region to determine existing flooding exposure to buildings, critical facilities, and agriculture. Results from the flood exposure analysis were utilized to estimate the impact to socially vulnerable populations or communities discussed in later in this chapter.

Existing Development within the Floodplain

A regionwide inventory of buildings, population, critical facilities, utilities, and agriculture was conducted to assess who and what was at-risk within the Trinity Regional Flood Plan. Existing development data leveraged for the Trinity Regional Flood Plan came from several data sources. The Homeland Infrastructure Foundation Level Data (HIFLD) and data from TWDB were the source of critical facilities data. The Texas Department of Transportation (TxDOT) bridge inventory and roadway data was also used. The TWDB provided building data in August 2021 with associated population and Social Vulnerability Index (SVI) estimates, which were confirmed and updated where additional information was available.

Figure 2.7: Existing Condition Floodplain Quilt Data Gaps



The 2021 TWDB building dataset was built on available Light Detection and Ranging (LiDAR) information (2010 to 2021), Microsoft Artificial Intelligence Version 2 data, and 2021 Open Street Map (OSM) buildings. The 2019 LandScan USA dataset from Oak Ridge National Laboratory (ORNL) was utilized to estimate population per building, for both day and night. The 2018 Center for Disease Control (CDC) SVI dataset was applied at the census tract level.

2020 Texas Cropland Data layer developed by the United States Department of Agriculture (USDA) National Agricultural Statistics Service (NASS) and the bridge and roadway asset inventory data came from the 2020 TxDOT dataset. Communities and invested entities within the Trinity Region also provided data via the online GIS-based data collection tool developed for the Trinity Region.

Results of the detailed analyses of exposure to development within the existing floodplain are presented later in this chapter.

Current Mitigation Projects

Throughout the flood planning region, multiple projects are in various stages of a project lifecycle. As weather and development patterns change, it is crucial that such projects address the changing risks of future disasters. Communities that invest forward-looking projects will see fewer impacts and are more likely to recover quickly after severe events. Projects completed with the consideration of future conditions will minimize structures from being in the floodplain and reduce losses to life and property over time.

When asked what Flood Management Strategies (FMSs) or Flood Mitigation Projects (FMPs) are currently in progress or proposed, survey respondents indicated significant interest in participating in the NFIP, establishing and maintaining floodplain management ordinances, and making improvements to existing roadways and water crossings. ***Figure 2.8*** summarizes the responses received regarding the types and counts of in-progress flood projects.

Per the survey responses, two projects were identified as in-progress with dedicated funding in place: (Each project is summarized in ***Table 2.4***.)

1. The College Street Drainage Improvements in the City of Waxahachie within Ellis County focuses on the building of local storm drainage systems and a tunnel. Due to holes that appeared in the parking lots of businesses on College Street in 2019, the decade-old infrastructure was deemed outdated and no longer serving its intended purpose.
2. Lynchburg Creek Flood Mitigation Grant in the City of Corinth in Denton County is improving and/or building regional dams, reservoirs, detention, and retention basins. The Lynchburg sub-basin is in the central and eastern portion of the city and contains most of the drainage problems in the city. The area is about 2.2 square miles and has mixed development with quite a bit of undeveloped land. The westernmost reach is in the Amity Village. Flooding in this basin has gotten progressively worse over time.

Figure 2.8: Types of Flood Mitigation Strategies or Projects Currently in Progress or Proposed

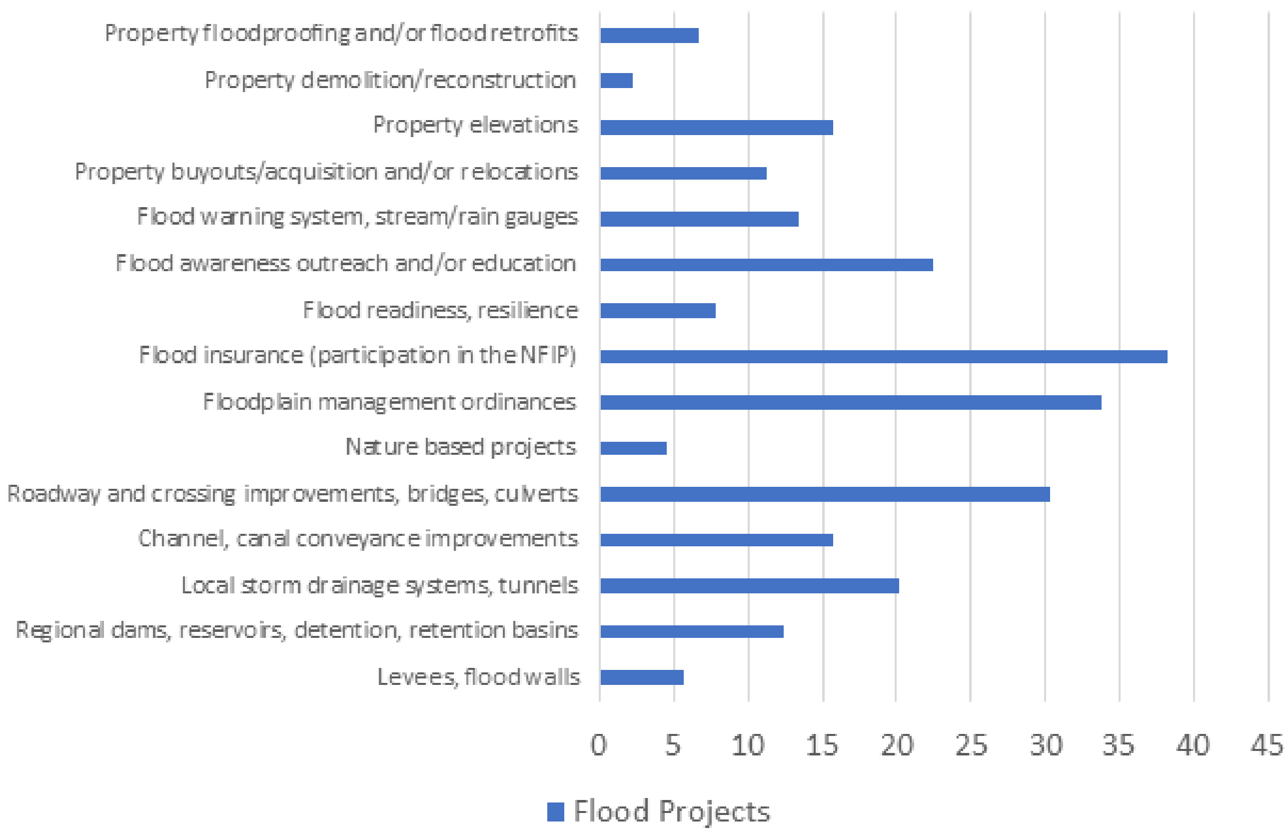


Table 2.4: Projects In-Progress with Dedicated Funding

Project Name	College Street Drainage Improvements	Lynchburg Creek Flood Mitigation Grant
Description	Local storm drainage systems, tunnels	Regional dams, reservoirs, detention, retention basins
Communities	City of Waxahachie, Ellis County	City of Corinth, Denton County
Project Status	In progress	In progress
Project Cost	$2,600,000	$3,000,000
Dedicated Funding for Construction (Yes/No)	YES	YES
Source of Funding	Not Identified	FEMA Grant
Expected Year of Completion	6/1/2022	6/30/2023

Flood Exposure Due to Existing Levees or Dams

Flood exposure is the identification of what is at risk due to extreme flooding. This refers to the people, buildings, businesses, infrastructure systems, and associated functions that could be lost to a flood hazard. Exposure also refers to the economic value of assets subjected to the flood hazard. This section discusses flood exposure due to levees and dams in the Trinity Region.

Levees in the Trinity Region

The USACE National Levee Database (NLD) identifies an estimated 101 levees within the Trinity Region. Approximately 76 percent of the levees are maintained and owned by local entities. The remainder are overseen by USACE or another federal or state agency. These levees are built parallel to rivers, streams, creeks, lakes, and their tributaries. They are also built along the coast to provide protection from certain levels of flooding. Over 26 percent of levees in the Trinity Region are located along the Trinity River mainstem and 24 percent are located along the West Fork Trinity River. The remaining are scattered throughout the Trinity Region.

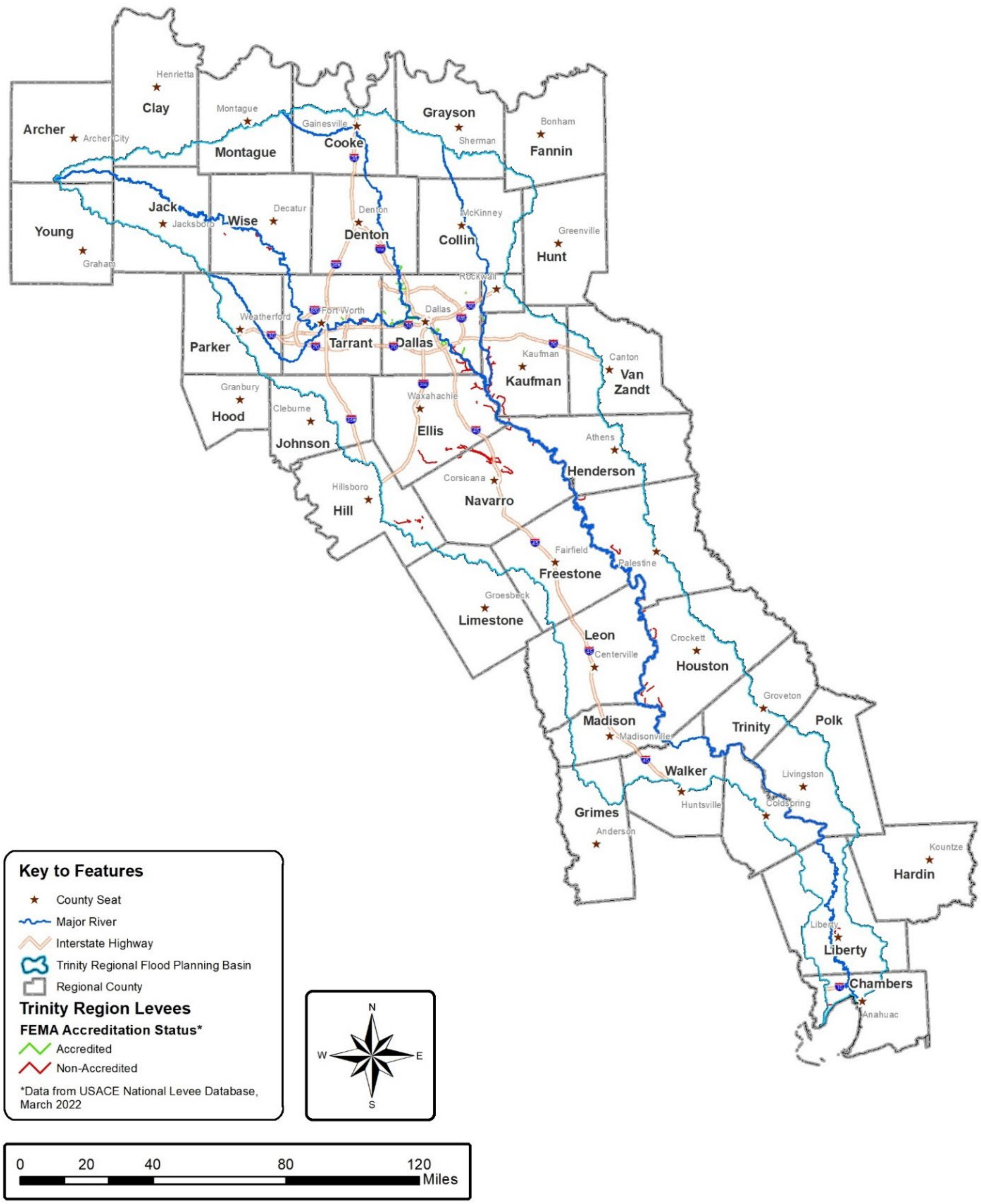
Levees can be breached during flood events due to overtopping, toe scour, seepage/piping, and foundation instability. The resulting torrent can quickly inundate a large area behind the failed levee with little or no warning, thereby exposing them to extreme flooding effects and consequences.

Levee accreditation is FEMA's recognition that a levee is reasonably certain to contain the base (1% annual chance storm event) regulatory flood. To help communities understand the flood risk behind levee structures, FEMA applies levee accreditation information on FIRMs to show the locations with reduced risks from the regulatory flood event. Approximately 34 percent of the levees in the Trinity Region are accredited. See ***Figure 2.9*** for location of the levees and their FEMA accreditation status in the Trinity Region.

On FIRMs, FEMA shows areas mapped behind accredited levees as "Areas with Reduced Risk Due to Levee". These accredited levees protect several thousands of structures and people as well as several billion dollars of property from flood damage. When the levee is not accredited, the embankments are categorized as hydraulically significant structures and the area behind the landward side of the levee is not considered to be protected from any flood event, and consequently, exposed to flooding.

USACE leveed-area floodplain data and FEMA's "Areas with Reduced Risk Due to Levee" datasets were incorporated into the existing floodplain quilt dataset for the Trinity Region as "Other Floodprone Areas".

Figure 2.9: Levees and Federal Emergency Management Agency Accreditation Status



Levee Exposure Assessment

There are more than 13,000 people who live and work behind the non-accredited levees in the Trinity Region. See ***Table 2.5*** for levee exposure by county. The exposure summary was estimated by overlaying the leveed areas within the Trinity Region's existing floodplain quilt with building and population data. The exposure assessments include structure and population counts behind the non-accredited levees.

As shown in ***Table 2.5***, Chambers, Dallas, Kaufman, Liberty, and Tarrant counties have the most exposure with respect to levees.

Dams in the Trinity Region

In the Trinity Region, dams and their associated reservoirs are used for water supply, recreation, navigation, electric generation, irrigation, and flood control. According to the USACE National Inventory of Dams and Texas Commission on Environmental Quality (TCEQ), there are over 1,800 dams in the Trinity Region and most of these dams are used for flood control, water supply, recreation, or agriculture. Most dams are owned by local and private entities.

Dam-controlled reservoirs with flood storage capacities keep floodwaters impounded and either release floodwaters in controlled amounts downstream to the river below or store or divert water for other uses. As such, areas lying adjacent or downstream of dams are exposed to severe flooding and its associated consequences when a dam breaks or fails.

Dams suffer the same failure modes as levees. A dam failure causes an uncontrolled release of impounded water to adjacent or downstream areas. The recent dam failure of Lake Dunlap along the Guadalupe River, downstream of New Braunfels, is a good example; on May 14, 2019, the spillway unexpectedly collapsed due to structural defects. Homeowners experienced flooding with the resultant fear of decline in their property values. Because the area was an attraction for fishing, boating, and other recreational activities, the area experienced significant economic losses after the dam failure.

On average, the dams located in the Trinity Region are 66 years old and over, with 83 percent built before 1975. Typically, the dams that are owned and operated by large entities are well-maintained. However, dams owned and operated by smaller entities or private landowners are more likely to need inspections and/or rehabilitation as funding for such activities is often more costly than the property owners can afford.

Table 2.5: Levee Exposure by County

County	Number of Levees	Buildings Affected	Population Affected	Economic Value
Anderson	3	4	1	$750,708
Archer	0	0	0	$0
Chambers	2	836	2196	$173,038,800
Clay	0	0	0	$0
Collin	0	0	0	$0
Cooke	1	17	3	$2,731,340
Dallas	29	666	1472	$424,888,628
Denton	2	0	0	$0
Ellis	14	49	54	$4,567,667
Fannin	0	0	0	$0
Freestone	0	0	0	$0
Grayson	0	0	0	$0
Grimes	0	0	0	$0
Hardin	0	0	0	$0
Henderson	3	11	2	$1,228,710
Hill	12	2	3	$227,748
Hood	0	0	0	$0
Houston	6	52	102	$36,974,591
Hunt	0	0	0	$0
Jack	0	0	0	$0
Johnson	0	0	0	$0
Kaufman	11	125	185	$52,277,607
Leon	0	0	0	$0
Liberty	1	1651	8671	$516,187,086
Limestone	0	0	0	$0
Madison	0	0	0	$0
Montague	0	0	0	$0
Navarro	10	16	15	$2,610,125
Parker	0	0	0	$0
Polk	0	0	0	$0
Rockwall	0	0	0	$0
San Jacinto	0	0	0	$0
Tarrant	16	81	576	$404,067,033
Trinity	0	0	0	$0
Van Zandt	0	0	0	$0
Walker	0	0	0	$0
Wise	5	5	5	$1,876,655
Young	0	0	0	$0

While FEMA does not show downstream dam inundation extents on maps, such data may be available as non-regulatory products in some of its flood risk studies. TCEQ requires dam inundation mapping for certain dams. Recently, USACE developed dam inundation mapping for six high-hazard dams in the Trinity Region. The dam inundation areas from the National Hydrography Dataset (NHD) were incorporated into the existing floodplain quilt for the Trinity Region as "Other Floodprone Areas". These “Other Floodprone Areas” do not have the same probability of occurrence as the 100-year and 500-year floods.

Dam Flowage Easement

Flowage easements are perpetual rights typical of a government agency such as the USACE. The dam flowage easements grant them the rights to essentially flood privately owned land to properly operate a reservoir. Flowage easements also grant entities the rights to prohibit construction of, or maintenance to, any improvement(s) for human habitation, and the right to approve any other structures constructed on such property. The purpose of establishing these lines is to protect personal property in the event of a flood exposure since they are flood prone. These boundaries, therefore, assist in estimating buildings and population affected in areas subject to dam inundation within the Trinity Region. FEMA identifies these flowage easements lying along reservoirs on its FIRMs. ***Figure 2.10*** shows a typical dam and associated flowage easement on a FEMA FIRM.

Dam Exposure Assessment

For the purposes of the Trinity Region dam exposure analysis, areas subject to flooding from dams were overlaid on buildings, critical facilities, and population to estimate the associated hazard potential. ***Figure 2.11*** shows location of dams in the Trinity Region. There are over 300,000 people living in these exposure areas. These areas are mostly located around dams with no Emergency Action Plans. In populated areas, residents may not be aware of this risk, especially when flooding occurs. According to ***Table 2.6***, high dam exposures are prevalent in Collin, Denton, Ellis, and Tarrant counties, with a few scattered exposures throughout the region.

It must be emphasized that the State of Texas does not regulate development in high hazard areas immediately adjacent to or downstream of dams. While flooding from high precipitation or dam failure impacts dams, human activity must also be considered when analyzing the risks posed by dams. In Texas, the hazard classification of dams is based on the potential for loss of life and economic loss in the area downstream of the dam, not on its structural safety. Thus, dams that may be of very sound construction are labeled “high hazard” if failure could result in catastrophic loss of life. In other words, the term “high hazard” applies if people have settled in the potential inundation zone. The “high hazard” designation does not imply structural weakness or an unsafe dam (TCEQ, 2006).

Figure 2.10: Flowage Easement Area on Federal Emergency Management Agency Flood Insurance Rate Maps

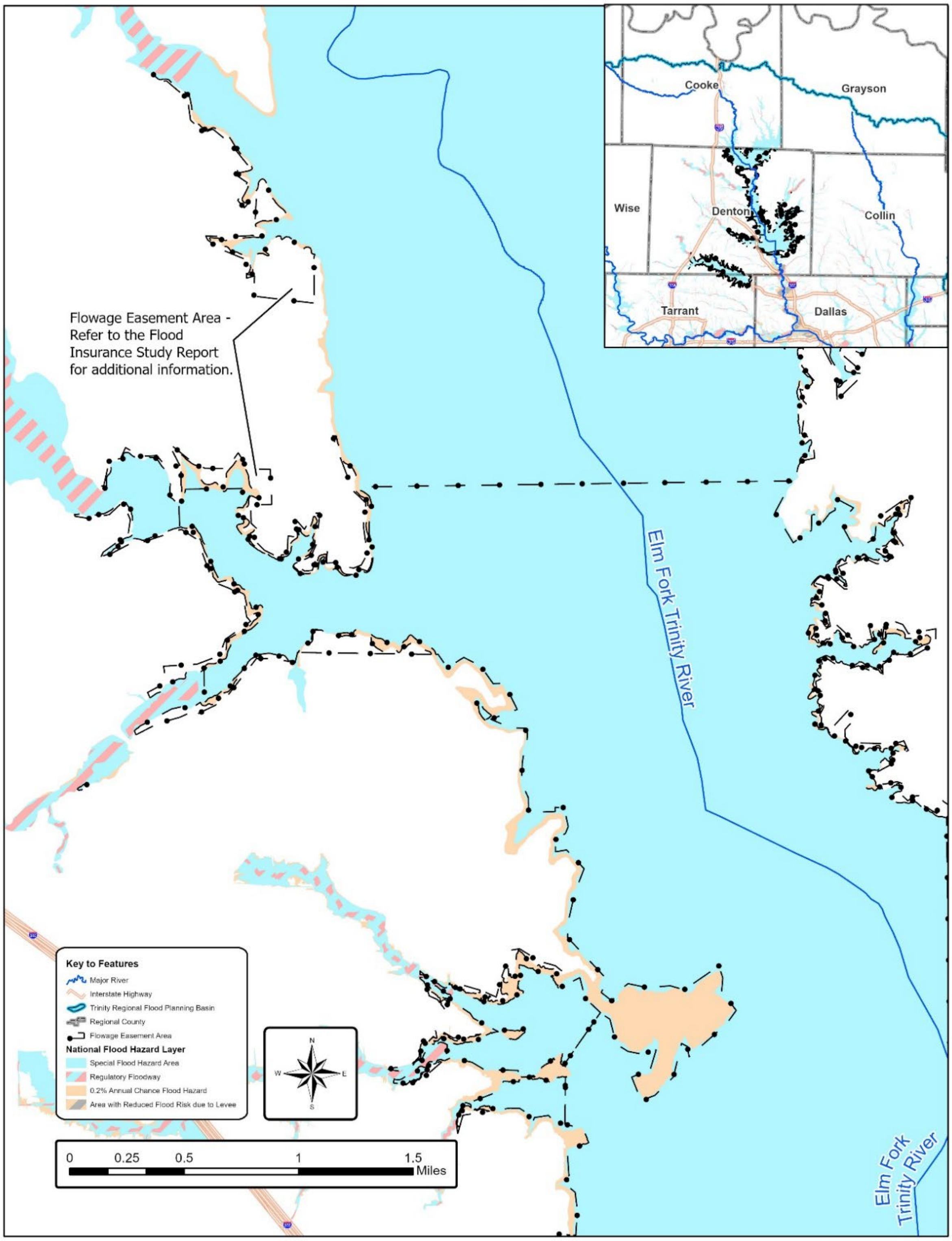


Figure 2.11: Dams in the Trinity Region

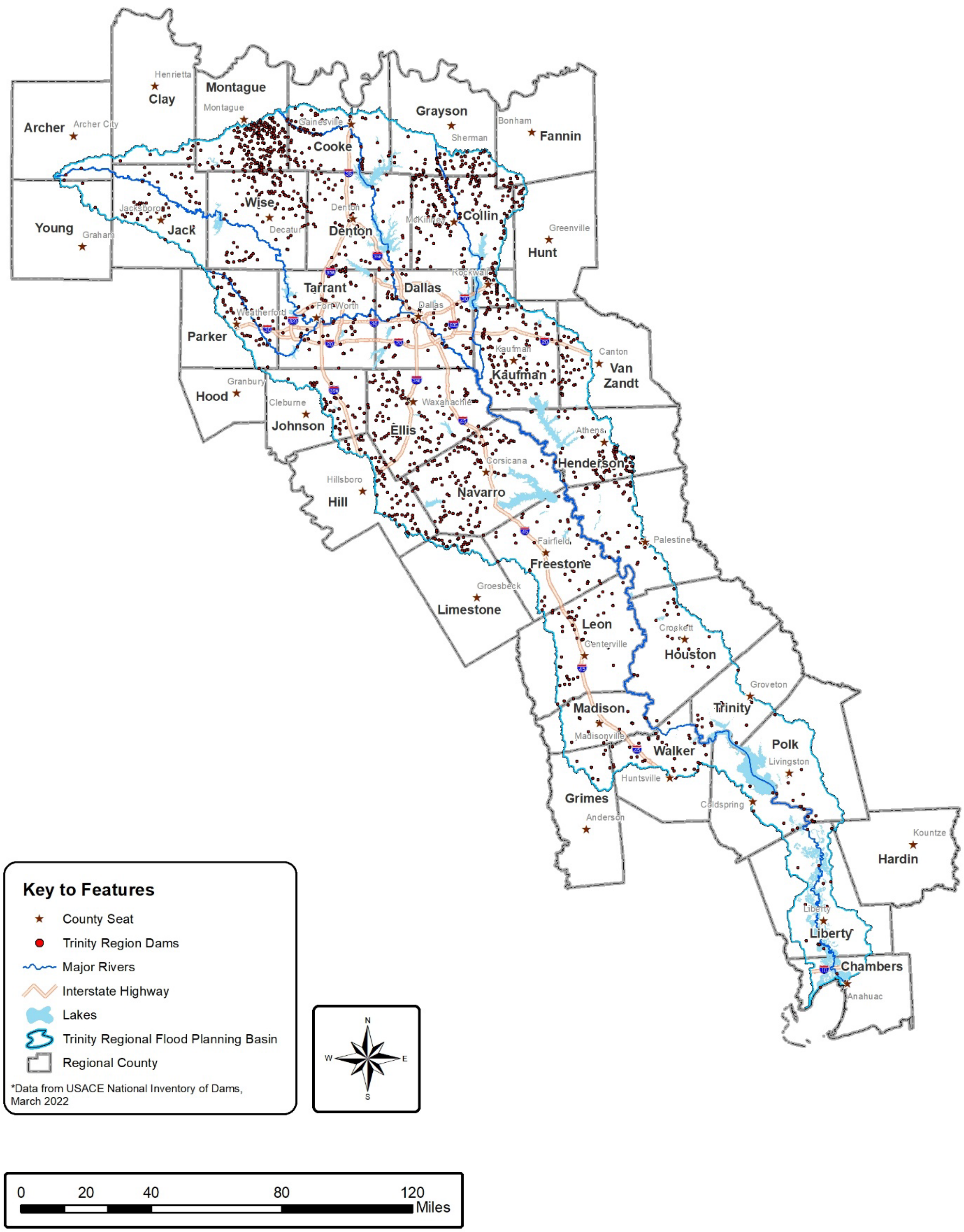


Table 2.6: Dam Exposure by County

County	Dams	Buildings Affected	Population Affected	Economic Value
Anderson	40	2	-	$749,379
Archer	3	-	-	$0
Chambers	4	-	-	$0
Clay	7	-	-	$0
Collin*	162	153	661	$142,688,363
Cooke	68	40	23	$2,116,653
Dallas	74	28	66	$11,247,803
Denton*	71	236	280,538	$29,698,167,896
Ellis*	123	39	10,648	$413,563,584
Fannin	10	-	-	$0
Freestone	46	-	-	$0
Grayson	64	4	2	$460,154
Grimes	7	-	-	$0
Hardin	-	-	-	$0
Henderson	79	1	-	$40,674
Hill	72	11	13	$2,105,550
Hood	-	-	-	$0
Houston	26	2	-	$61,950
Hunt	11	-	-	$0
Jack	51	2	1	$150,137
Johnson	38	19	41	$5,400,036
Kaufman	108	54	122	$6,949,515
Leon	44	-	-	$0
Liberty	16	-	-	$0
Limestone	24	3	2	$64,500
Madison	21	2	2	$20,820
Montague	189	99	81	$9,939,365
Navarro*	117	17	19	$2,091,873
Parker	54	265	338	$19,730,381
Polk	18	91	137	$11,728,800
Rockwall	33	69	298	$17,046,170
San Jacinto	7	88	89	$10,181,303
Tarrant*	70	609	20,368	$661,530,080
Trinity	22	150	233	$21,168,894
Van Zandt	32	-	-	$0
Walker	33	53	63	$35,645,933
Wise	99	647	996	$139,327,119
Young	2	-	-	$0

**Includes data from the 2017 USACE Dam Risk Assessment*

Many developers are purchasing property with small livestock dams and developing property around lakes and downstream of the dams, creating additional risk. Continued growth in rural areas will result in changes to hazard classifications of dams that current residents may not be aware of.

Existing Conditions Flood Exposure

This section of the Trinity Regional Flood Plan discusses and summarizes the results of the existing condition flood exposure to existing development. The existing conditions flood exposure analysis considered buildings, population, public infrastructure, critical facilities, roadway crossings, and agricultural areas exposed to the compiled existing conditions floodplain quilt. This section excludes flood exposure for levees and dams and only applies the existing conditions 100-year and 500-year mapping extents in the Trinity Region floodplain quilt.

Buildings, Critical Facilities, Infrastructure, and Agriculture Exposure Totals by County

For this planning cycle, flood exposure analysis estimated the structure count of buildings, critical facilities, LWCs, roadway segments, and agriculture areas potentially exposed to existing flooding by overlaying these items with the existing conditions floodplain quilt developed for the Trinity Region. ***Figure 2.12*** shows the total number of buildings, critical facilities, LWCs, and agriculture areas exposed to the existing condition floodplain quilt. The highest counts are in the populated areas of Dallas and Tarrant counties, in the Upper Subregion. Collin County, as well as coastal Chambers County, show significant counts. Most of the Trinity Region shows moderate exposure counts with a few overall county totals interspersed between.

Population Totals by County

Population data (day and night) attributed to the buildings and critical facilities data was used to summarize countywide population exposed to the existing conditions floodplain quilt. The higher of the day or night population attributes was used for the exposure population estimates according to guidance received from the TWDB. ***Figure 2.13*** shows the percent population exposure to the existing condition floodplain quilt by county. As shown in ***Figure 2.13***, high population exposures occur in the Dallas-Fort Worth-Arlington area, Collin, Dallas, Denton, and Tarrant counties in the Upper Subregion, as well as coastal Liberty County in the Lower Subregion. It must be noted that because the population count is the higher of the day or night numbers, this assumes the worst possible scenario where the maximum number of people present are exposed to the existing condition floodplain quilt.

Figure 2.12: Existing Condition Flood Exposure Total Numbers by County

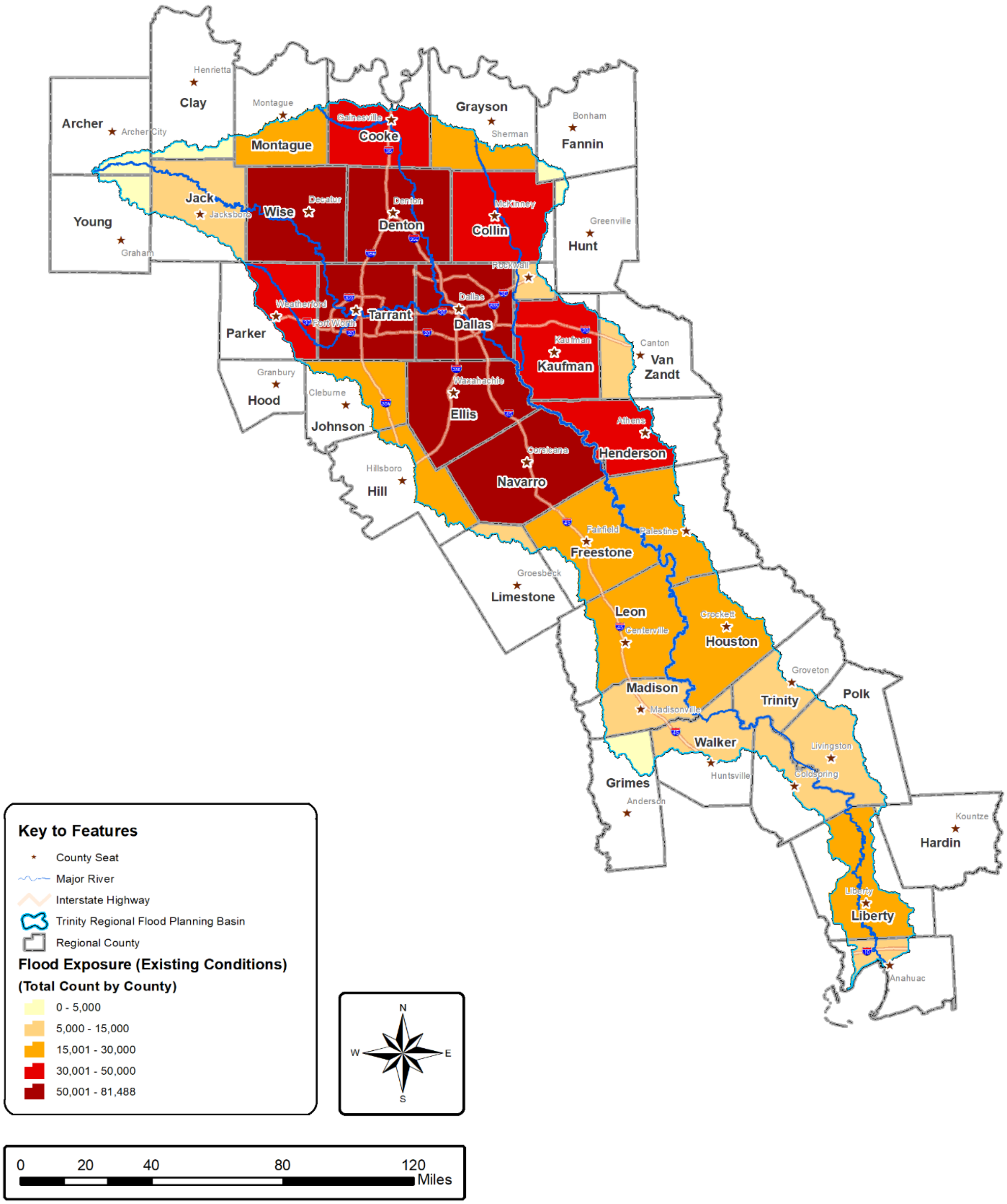
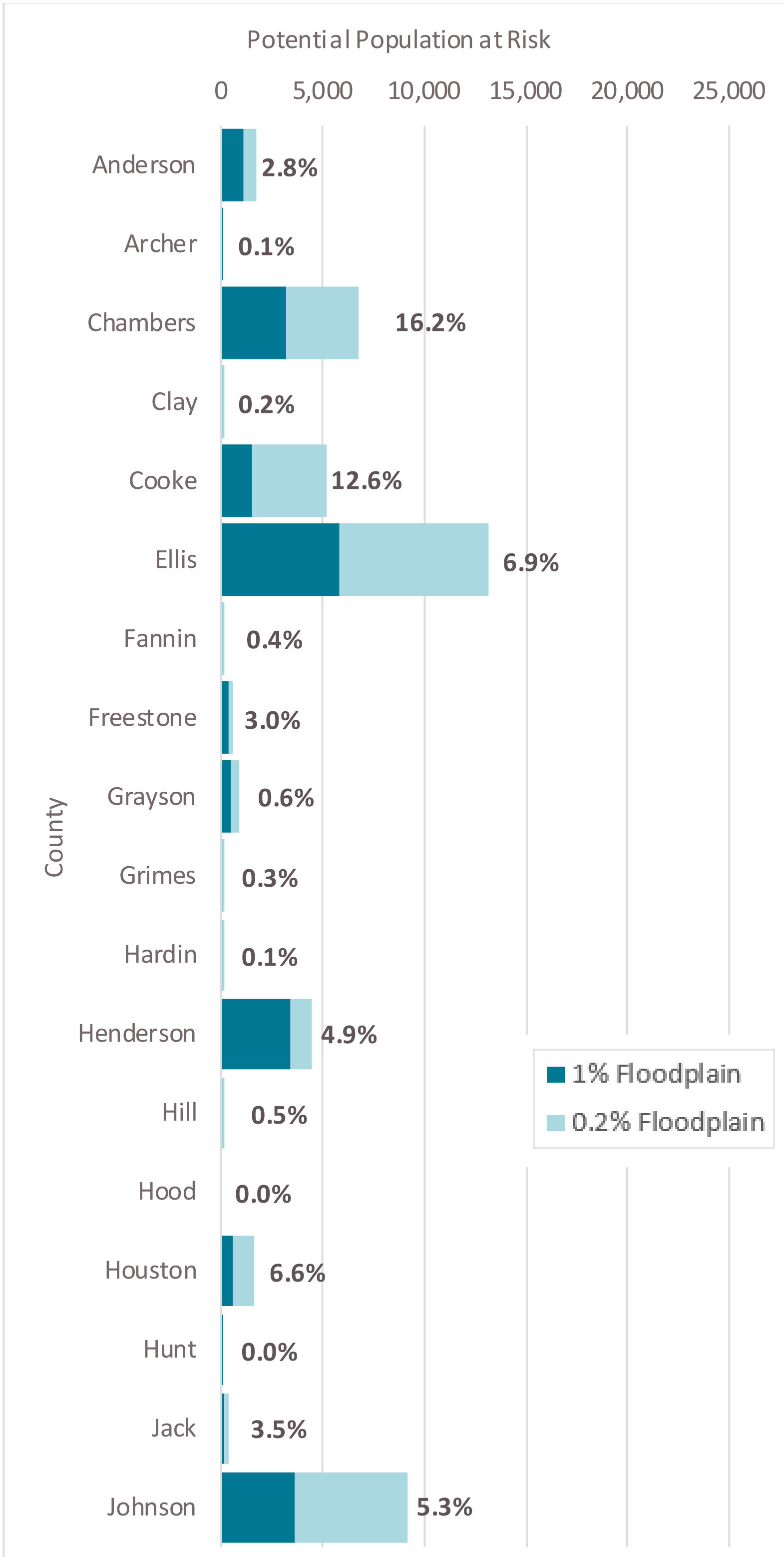
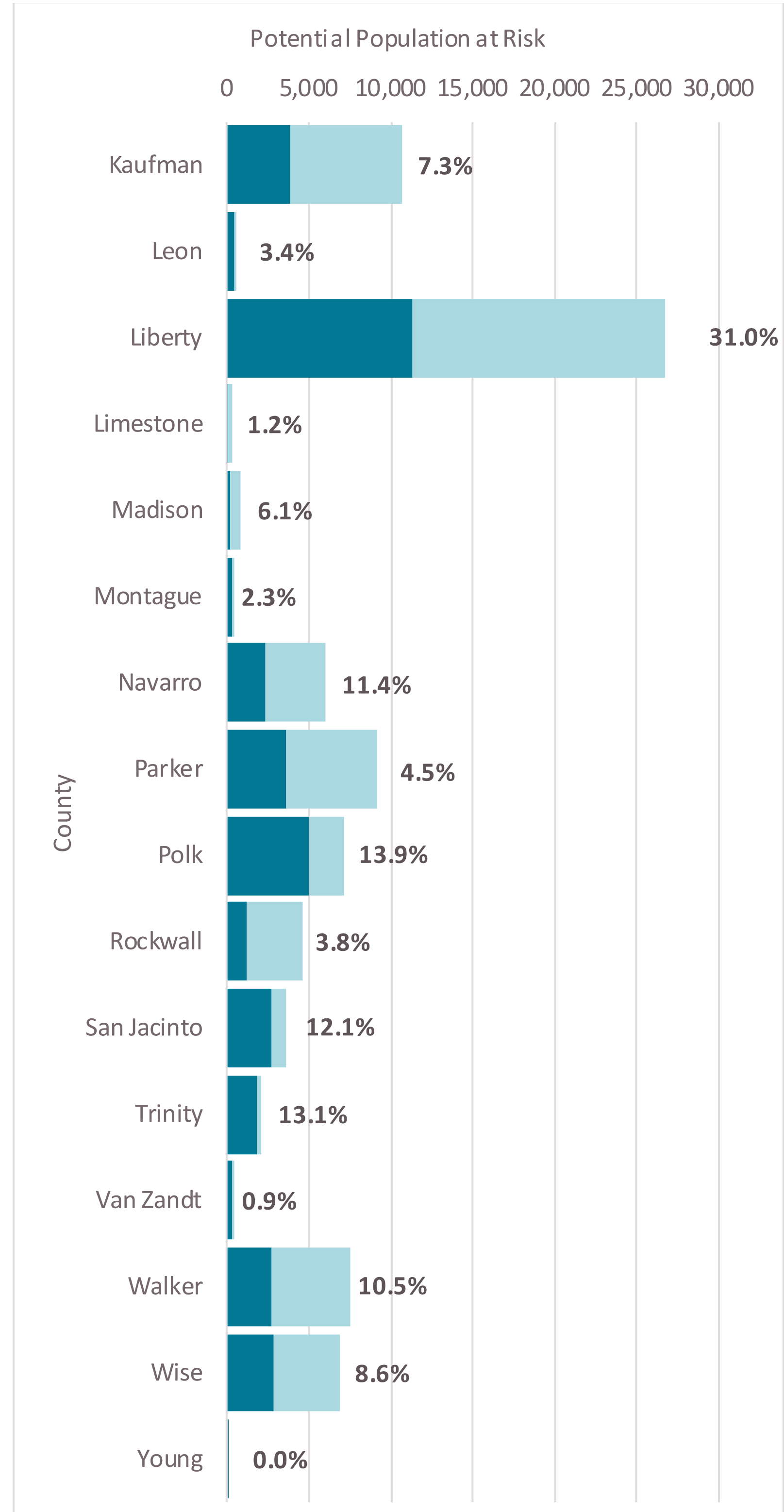
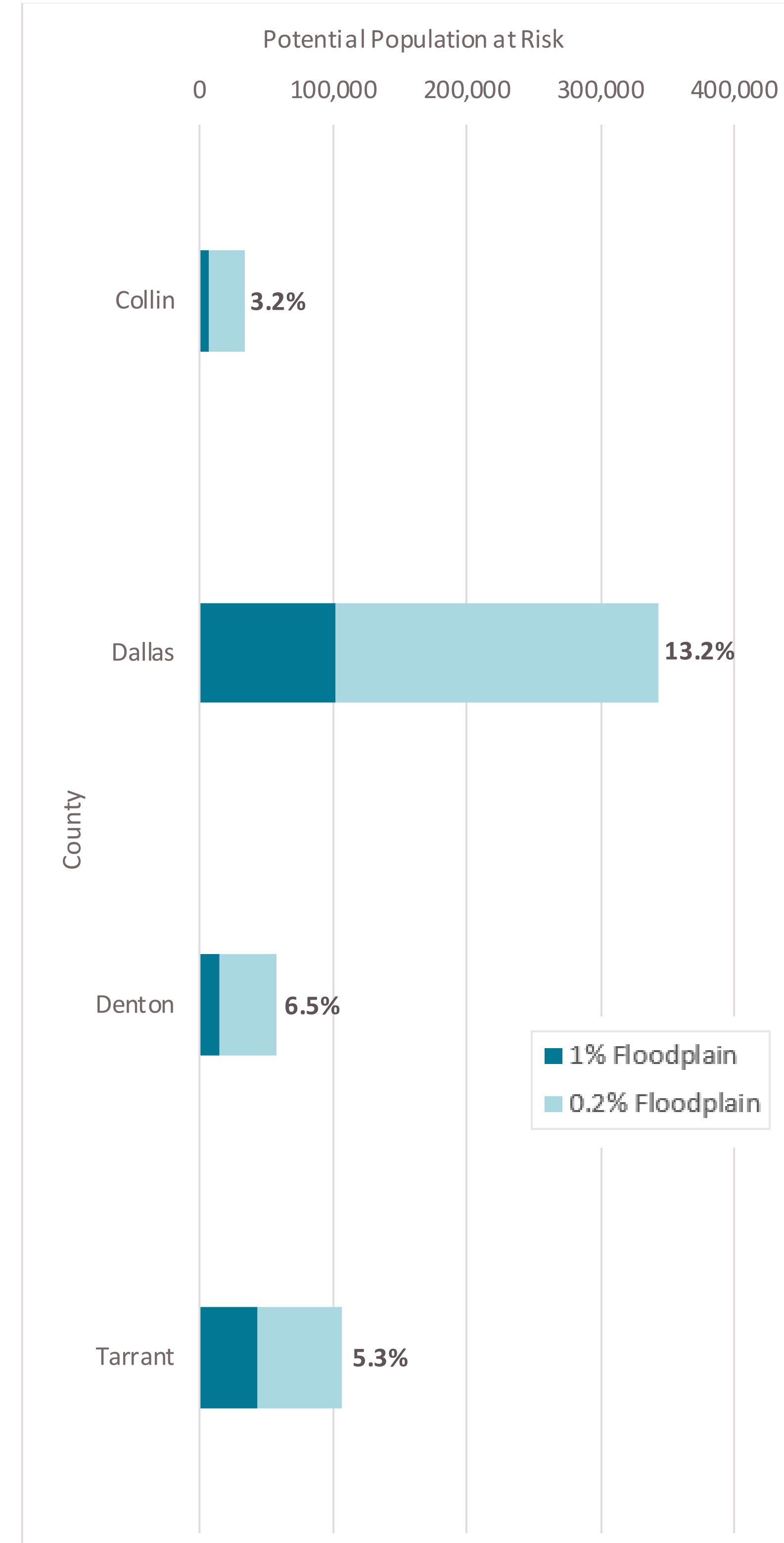


Figure 2.13: Population at Risk in Existing Condition Flood Hazard by County

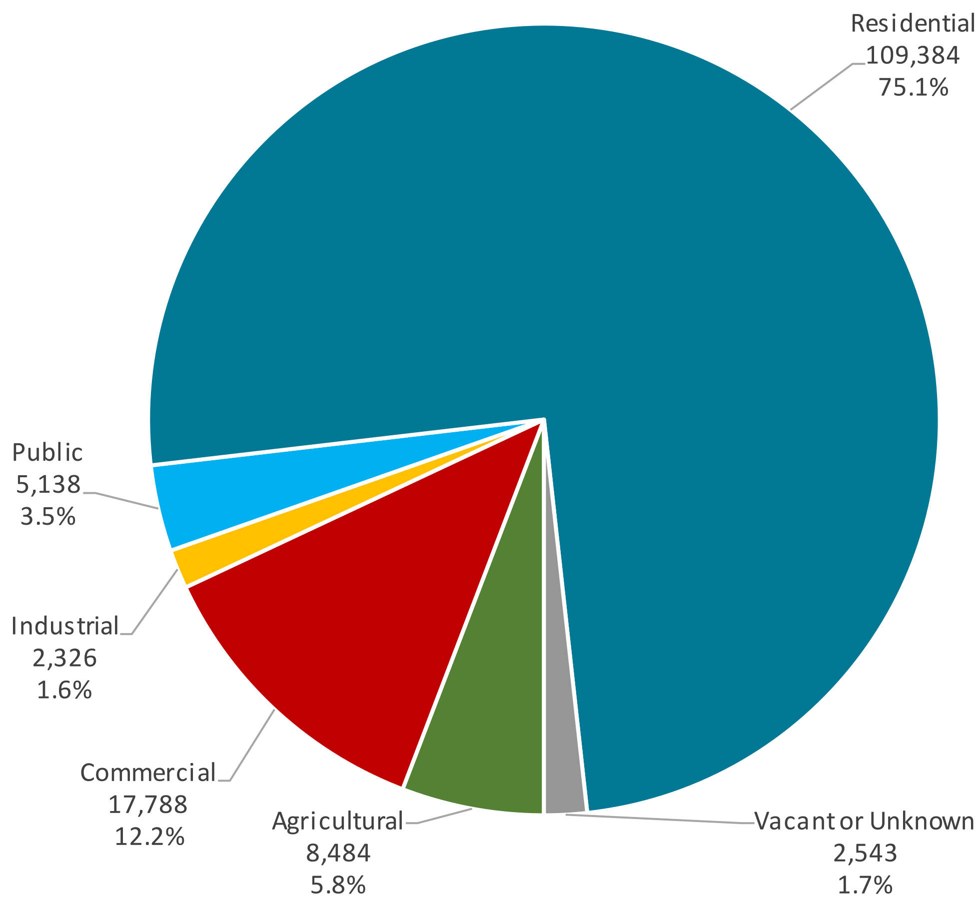






Regional building data collected for the Trinity Region were classified into two main categories: residential and non-residential. Approximately seven percent of buildings within the Trinity Region are within the existing floodplain, as shown in ***Figure 2.14.*** Of those, an estimated 75 percent are residential and 12 percent are commercial. Buildings classified as vacant are structures for which the building type and/or use could not be determined.

Figure 2.14: Building Type Distribution in the Existing Condition Floodplain Quilt



Residential Properties

Residential structure data used in the Trinity Regional Flood Plan included single-family homes, town homes, mobile homes, as well as multi-family residences like apartments and condominiums. Over two million residential building footprints were gathered for the Trinity Region and an estimated seven percent of these buildings were found to be exposed to flooding. An associated population of over 661,000 is estimated of being at risk to flooding.

Figure 2.15 shows the total estimated number of residential structures by county exposed to the existing floodplain quilt. Dallas, Denton, and Tarrant counties (all in the Upper Subregion) and the coastal Liberty County (in the Lower Subregion) have the highest number of residential buildings in the existing floodplain. Archer, Clay, Hardin, Hill, Hood, Hunt, Leon, Limestone, and Young counties show very little residential building exposure because only a very small portion of these counties are in the Trinity Region, most of which are their respective unincorporated areas.

Non-Residential Properties

Non-Residential inventory data also included agricultural, commercial, industrial, and public buildings. Over 406,000 non-residential building footprints were gathered for the Trinity Region and an estimated 25 percent of these buildings are exposed to flooding. An associated population of over 52,000 is estimated of being at risk to flooding. ***Figure 2.16*** shows the total estimated number of non-residential structures by county exposed to the existing condition floodplain quilt.

Ellis County (in the Upper Subregion) and coastal Chambers County (in the Lower Subregion) have the highest number of agricultural buildings in the existing floodplain. Collin, Dallas, Denton, and Tarrant counties (in the Upper Subregion) showed the highest number of commercial buildings in the existing condition floodplain. Archer, Clay, Hardin, Hill, Hood, Hunt, Limestone, and Young counties show very little residential building exposure because only a very small portion of these counties are in the Trinity Region, most of which are their respective unincorporated areas.

Critical Facilities and Public Infrastructure

A critical facility provides services and functions essential to a community, especially during and after a disaster. Critical infrastructure includes all public or private assets, systems, and functions vital to the security, governance, public health and safety, economy, or morale of the state or the nation (TWDB Flood Planning Frequently Asked Questions, 2021). Critical facilities data gathered for the Trinity Region included fire stations, hospitals, nursing homes, police stations, emergency shelters, schools (kindergarten through 12th grade), water and wastewater treatment facilities, TCEQ wastewater outfalls, water supply systems (well sites), and Superfund sites. Lifeline utility systems data, such as petrol storage tanks, power generating plants, as well as natural gas and electric transmission lines, were collected for exposure analysis. Critical facilities data was from TWDB, TCEQ, Railroad Commission (RRC) of Texas, HIFLD, as well as data from Trinity Region area communities.

The existing floodplain quilt was overlaid on the data gathered for critical facilities to estimate the flood exposures. ***Figure 2.17*** shows the total counts of exposed critical facilities to the existing floodplain quilt in the Trinity Region.

Figure 2.15: Residential Structure Counts in Existing Condition Floodplain Quilt

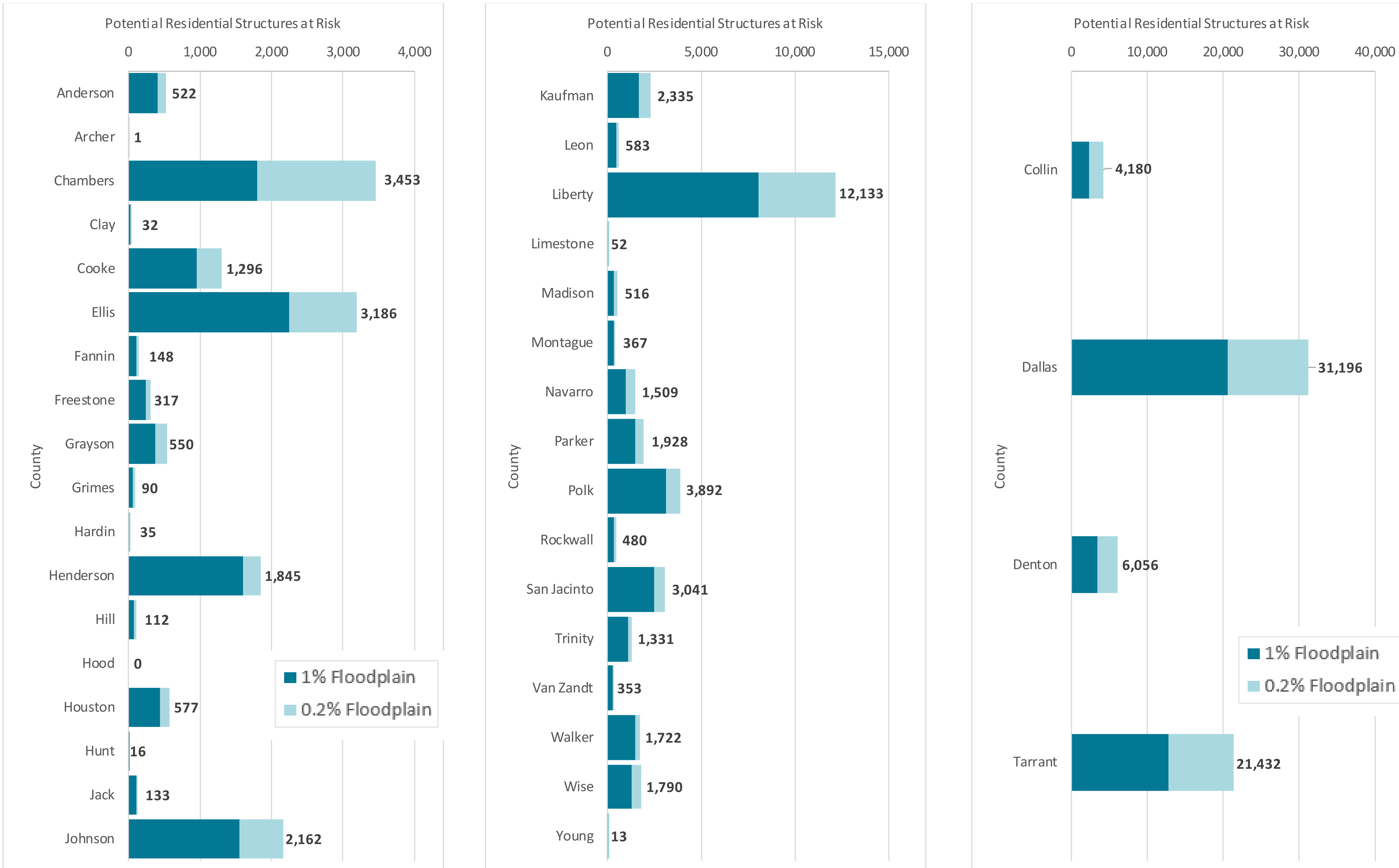


Figure 2.16: Non-Residential Structure Counts in Existing Condition Floodplain Quilt

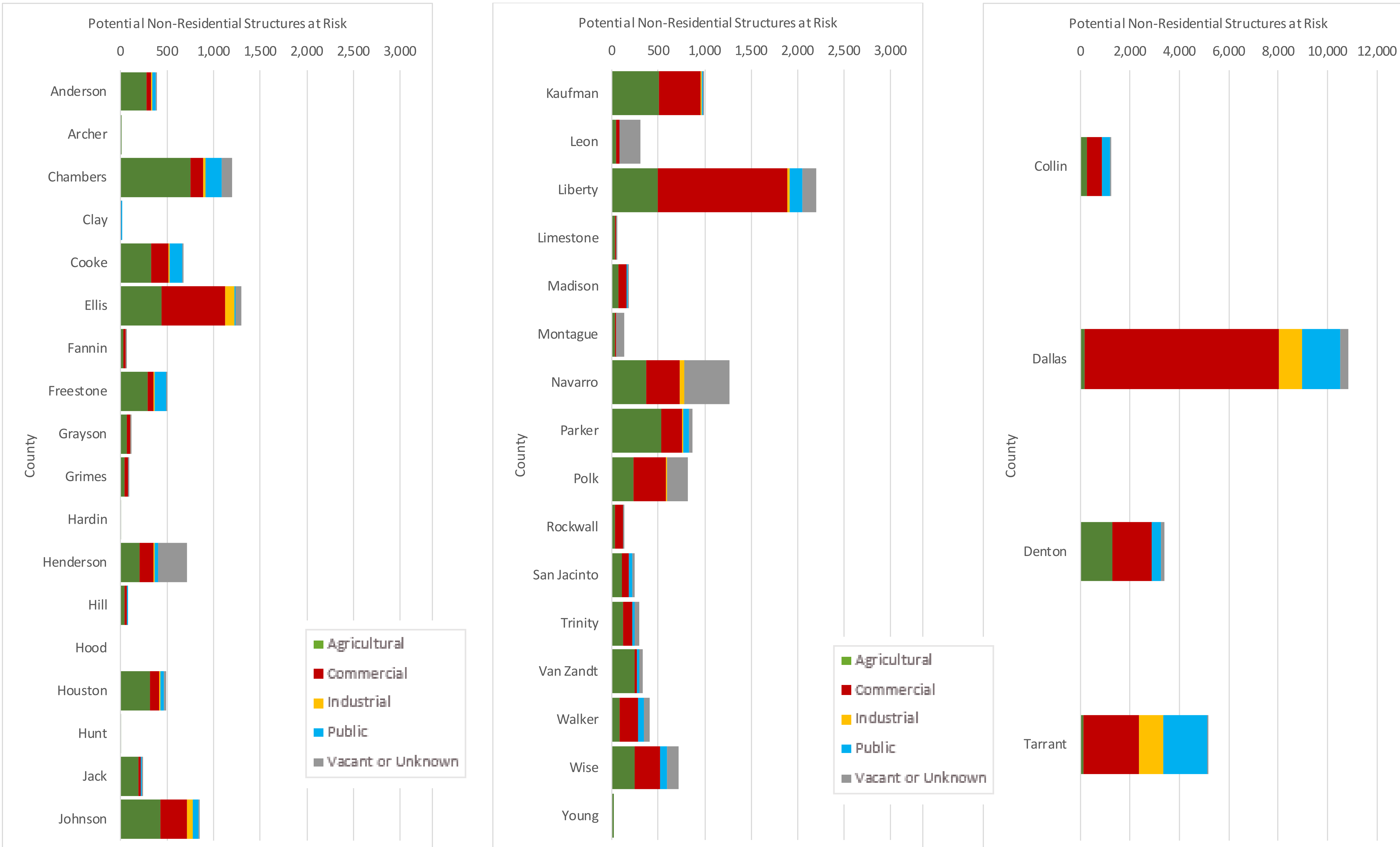
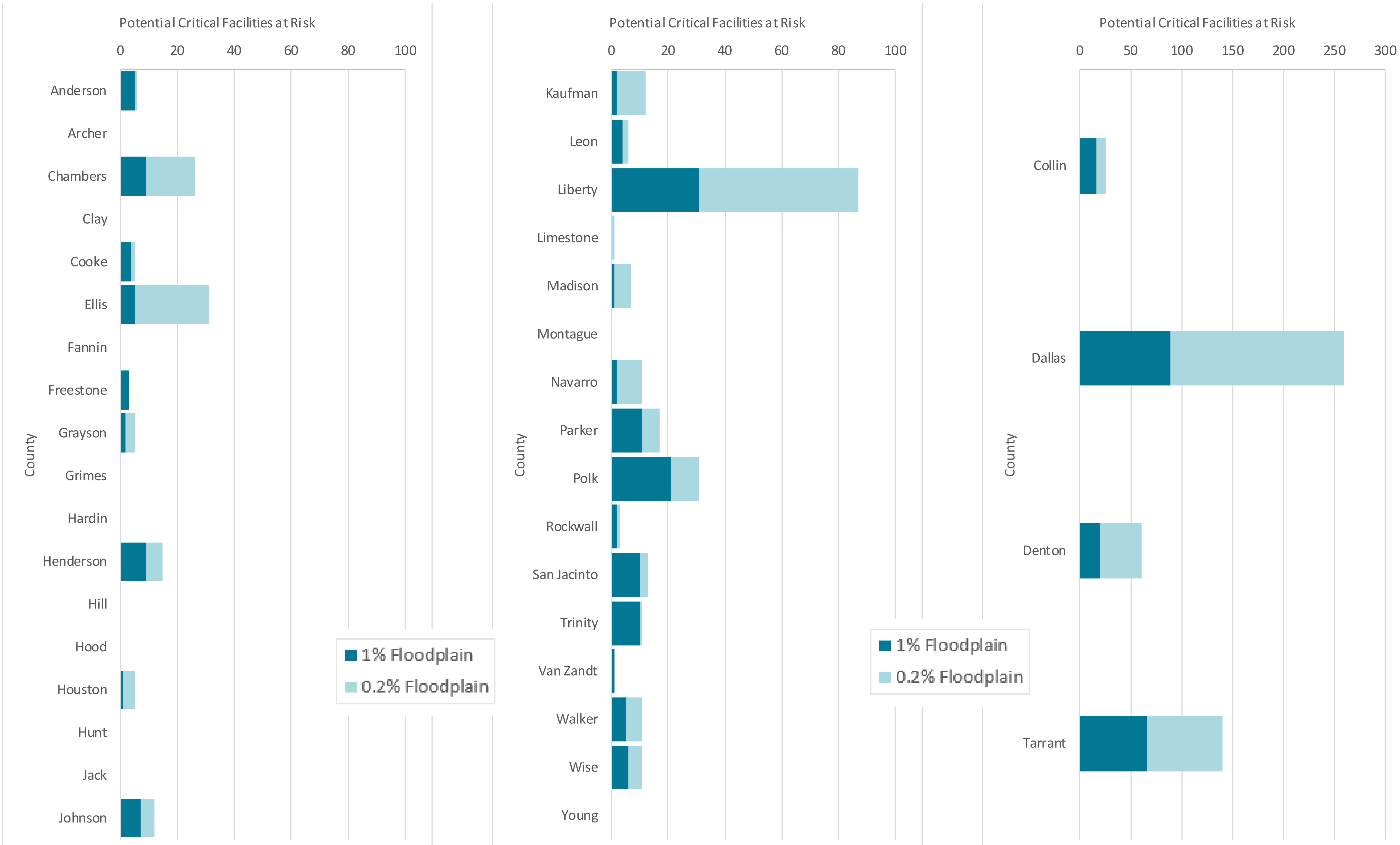


Figure 2.17: Critical Facilities in Existing Condition Floodplain Quilt by County



Over 10,000 critical facilities were identified for the Trinity Region and an estimated 10 percent of these facilities are exposed to flooding.

The Trinity Region's Upper Subregion counties have the most critical exposure counts to the existing floodplain quilt, with the Dallas/Fort Worth (DFW) area counties having the highest exposures of people and structures. Archer, Clay, Hardin, Hood, and Hunt counties showed very little to no exposure of critical facilities to the existing floodplain quilt.

Roadway Crossings and Roadway Segments

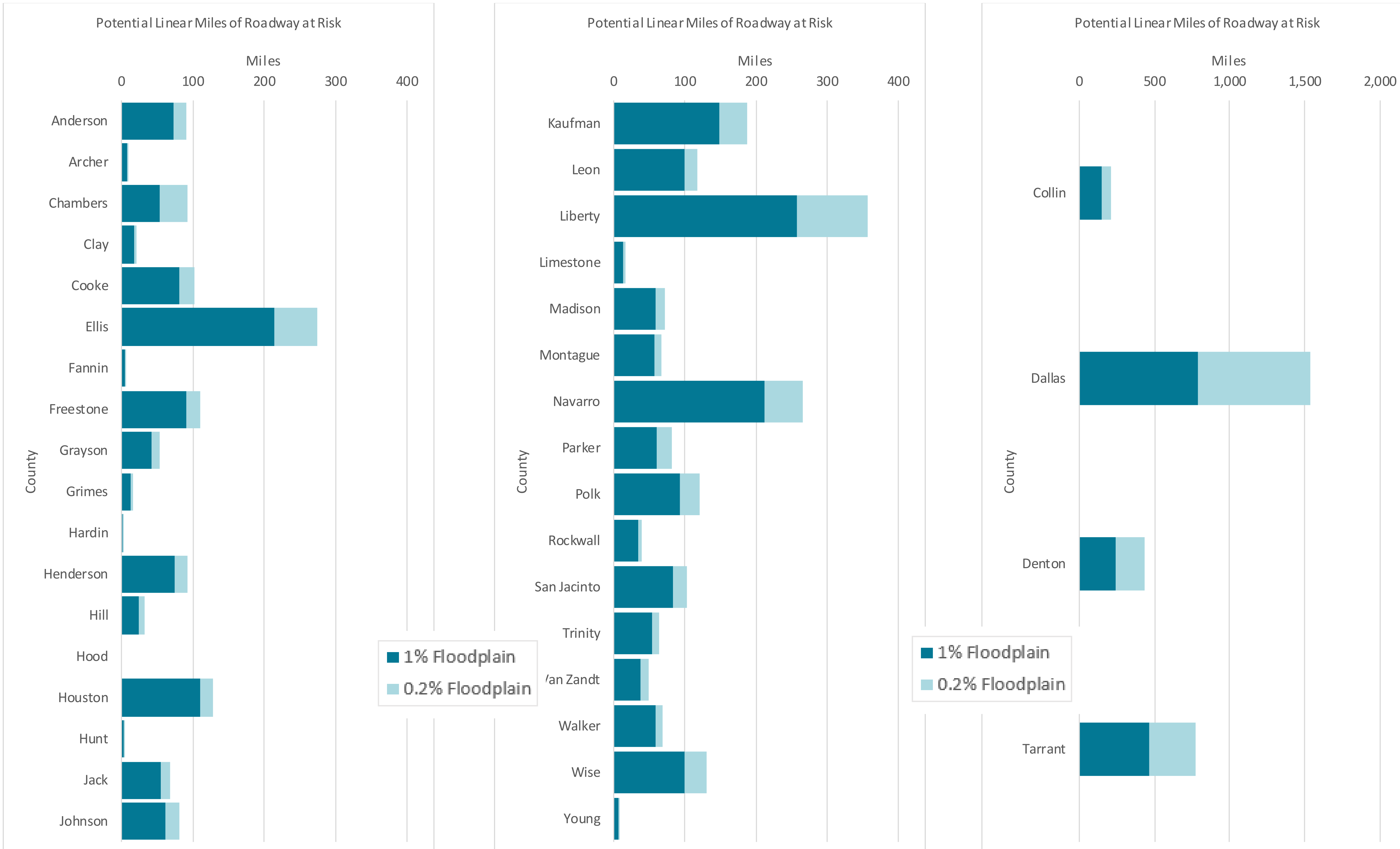
Transportation line data (roadways and railroads) from TxDOT was used to estimate road and railway stream crossings at-risk to flooding. A combination of available flood depth information from BLE and Fathom data, as well as bridge deck elevation from LiDAR data was used to estimate flood exposure of road and railroad bridges at stream crossings. LWC data, provided by Trinity Region area communities and the TWDB, was also used to identify exposed road and railway crossings. The Tarrant Regional Water District (TRWD) also provided information on bridges that are inundated during flood events.

There are approximately 1,700 LWCs in the Trinity Region and several bridges inundated by flooding in the Trinity Region. ***Table 2.7*** shows the LWC exposure totals per county. ***Figure 2.18*** shows the miles of road segment exposed to the existing floodplains. The highest mileage exposures are seen in Dallas and Tarrant counties in the Upper Subregion and in the coastal Chambers County in the Lower Subregion.

Table 2.7: Exposed Bridge and Low Water Crossings in Existing Condition Floodplain Quilt

County	Number of LWCs	County	Number of LWCs	County	Number of LWCs
Anderson	6	Hill	1	Navarro	64
Collin	55	Houston	18	Parker	22
Cooke	32	Jack	6	Polk	3
Dallas	387	Johnson	372	Rockwall	15
Denton	96	Kaufman	16	Tarrant	531
Ellis	57	Leon	5	Trinity	1
Freestone	2	Liberty	6	Van Zandt	2
Grayson	1	Limestone	3	Walker	5
Henderson	11	Madison	1	Wise	16

Figure 2.18: Linear Miles of Roadway at Risk in Existing Condition Floodplain Quilt



Agricultural Area

Crop and livestock data used in the Trinity Region was obtained from the 2020 Texas Cropland Data layer developed by the USDA NASS. In the Trinity Region, increasing population continues to have a significant influence on the continued loss of working lands, changing ownership sizes, and land values. This is occurring particularly within or in surrounding urban centers like DFW in of the Upper Subregion. Large sections of the Lower Subregion are facing similar challenges because of development from the neighboring Houston-Galveston area. (Texas A&M Natural Resources Institute, 2020). ***Figure 2.19*** shows the distribution of Farming (crops) and Ranching (livestock) areas in the Trinity Region.

Crops and livestock exposed to flooding (dollar exposure from production) are documented in ***Table 2.8***, which summarizes estimated exposure values in dollars to the existing floodplain quilt by county. The 2020 FEMA National Risk Index (NRI) data was leveraged to show the value of crops and livestock exposed to flooding. The FEMA NRI uses data from the 2017 USDA CropScape and the Census of Agriculture to document value of exposed crops and livestock. The CropScape data in dollars was used to calculate crop and livestock production value density per county. The county value is divided by the total crop and livestock land area of the county to find its dollar value density as shown below.

$$AgValueDen_{Co} = \frac{AgValue_{Co}}{AgArea_{Co}}$$

$AgValueDen_{co}$ is the crop and livestock value density calculated at the county level (in dollars per square mile; $AgValue_{co}$ is the is the total crop and livestock production value of the county, as reported in the 2017 Census of Agriculture (in dollars); and $AgArea_{co}$ is the total crop and livestock production area of the county (in square miles).

Each county's crop and livestock value losses were then calculated as the product of the crop and livestock production value density per county and the associated crop and livestock areas exposed to flooding from the existing conditions floodplain. ***Table 2.8*** shows the value of crop and livestock (production) areas in dollars and potential agricultural losses to the existing floodplain quilt in the Trinity Region. Denton, Ellis, Hill, Houston, Kaufman, Leon, Limestone, Navarro, and Van Zandt counties have high agricultural exposure values. Even though Madison County showed large agriculture areas (a little more than Anderson County) per ***Figure 2.19***. There was no data available from the 2017 USDA crop and livestock production summaries. ***Figure 2.20*** shows the exposed agricultural areas in square miles.

Figure 2.19: Agricultural Land Distribution in the Trinity Region

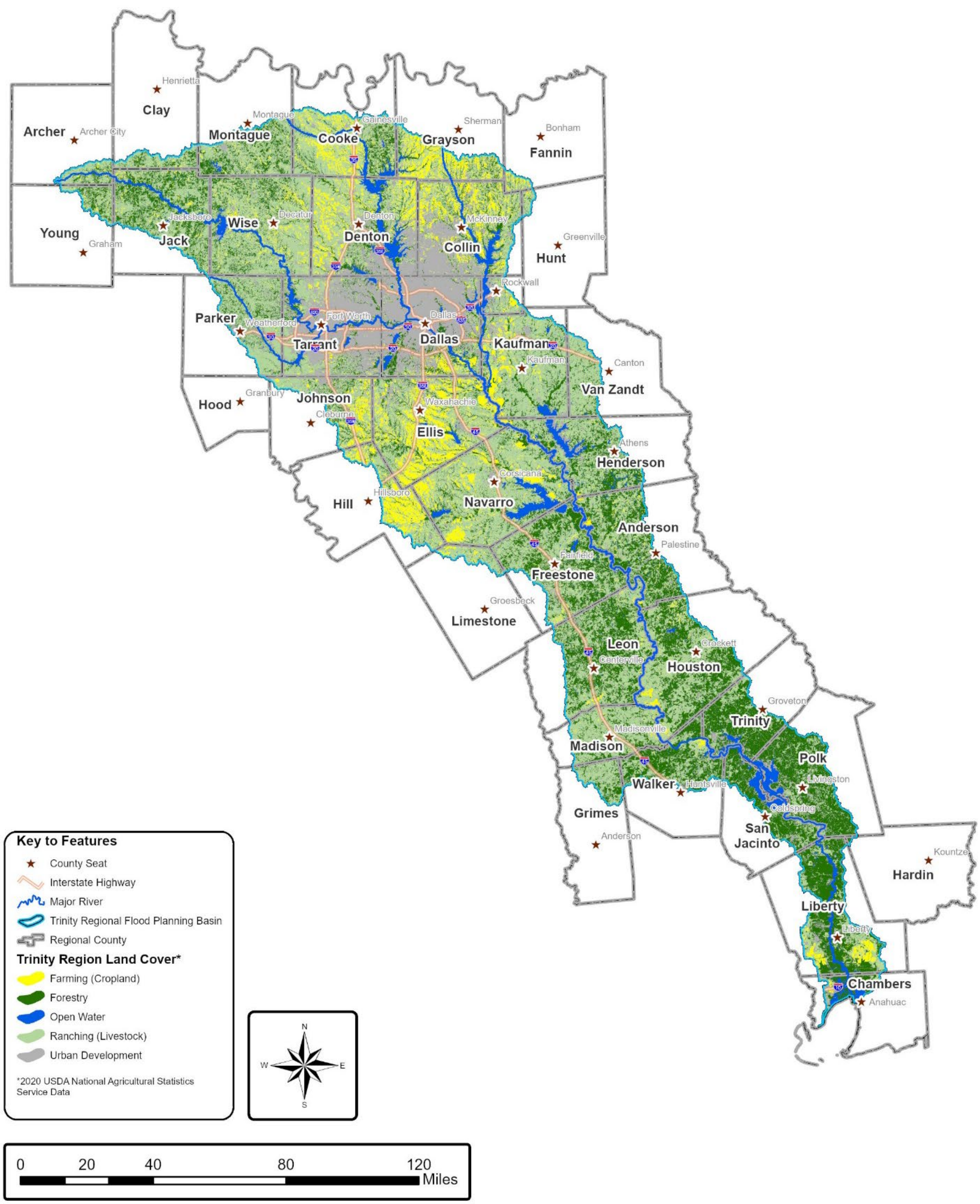


Table 2.8: Exposed Crop and Livestock Production Dollar Losses in Existing Condition Floodplain Quilt

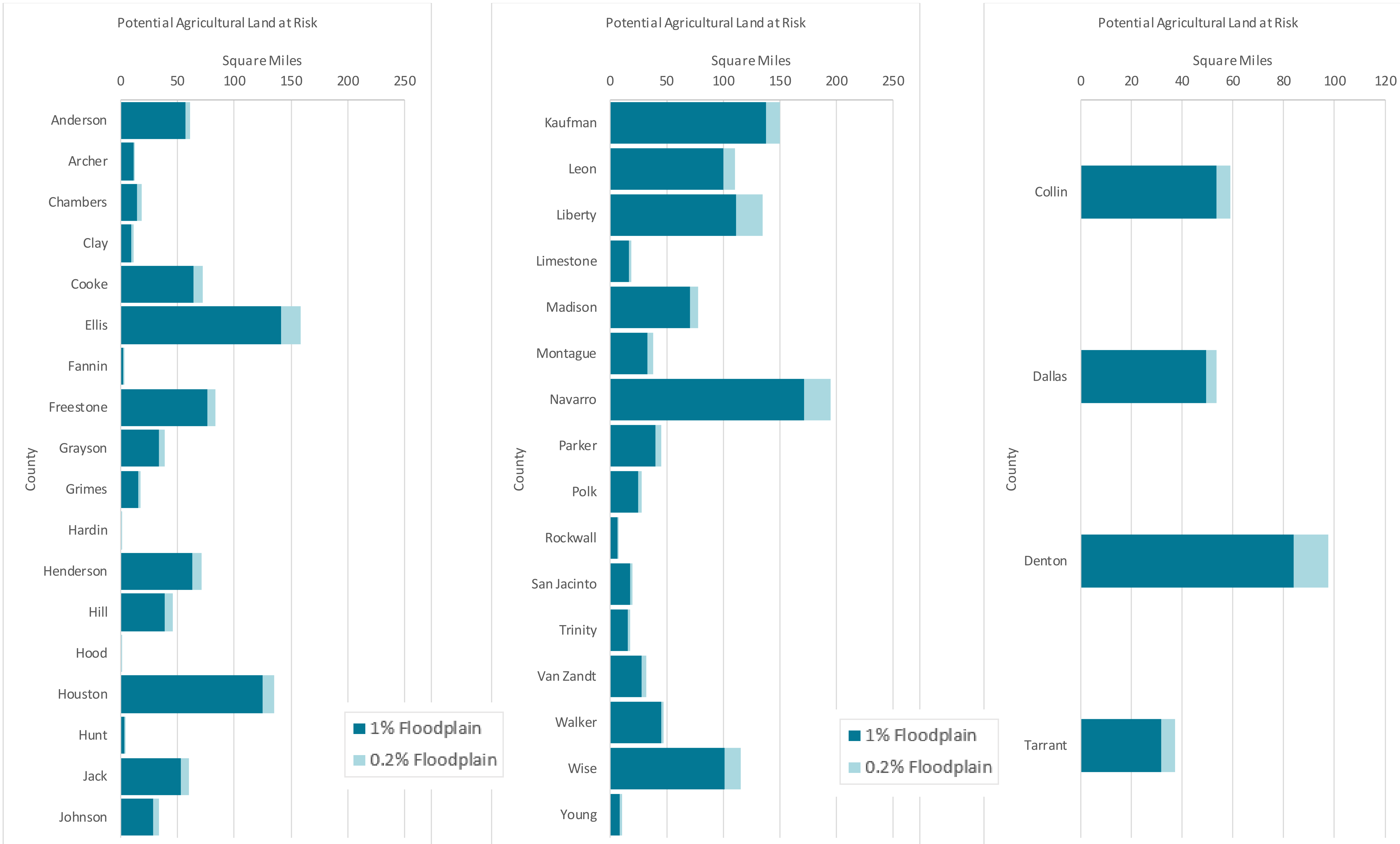
County	Total $ Value of Entire County*	$ Losses in Existing 100-Year**	$ Losses in Existing 500-Year**
Anderson	$92,943,000.00	$21,715,918.00	$1,708,203.00
Archer	$72,439,000.00	$9,723,166.00	$1,239,511.00
Chambers	$19,252,000.00	$8,968,237.00	$2,309,843.00
Clay	$55,650,000.00	$5,829,534.00	$744,411.00
Collin	$66,829,000.00	$8,716,699.00	$854,911.00
Cooke	$53,830,000.00	$7,548,538.00	$939,725.00
Dallas	$29,781,000.00	$9,664,843.00	$755,049.00
Denton	$123,209,000.00	$19,612,554.00	$3,169,336.00
Ellis	$73,146,000.00	$14,616,443.00	$1,728,803.00
Fannin	$86,292,000.00	$6,525,073.00	$805,763.00
Freestone	$68,131,000.00	$13,268,569.00	$1,305,637.00
Grayson	$66,171,000.00	$7,984,512.00	$1,299,493.00
Grimes	$47,509,000.00	$7,888,957.00	$904,180.00
Hardin	$4,694,000.00	$1,115,170.00	$398,147.00
Henderson	$40,183,000.00	$9,107,200.00	$1,089,875.00
Hill	$114,001,000.00	$15,709,210.00	$2,640,526.00
Hood	$18,944,000.00	$1,457,466.00	$155,968.00
Houston	$64,518,000.00	$19,569,365.00	$1,501,746.00
Hunt	$55,313,000.00	$7,140,549.00	$270,679.00
Jack	$23,176,000.00	$3,236,213.00	$461,858.00
Johnson	$57,850,000.00	$6,566,961.00	$1,120,218.00
Kaufman	$57,063,000.00	$14,615,439.00	$1,284,912.00
Leon	$169,404,000.00	$44,322,526.00	$4,490,668.00
Liberty	$29,950,000.00	$15,875,533.00	$3,282,102.00
Limestone	$66,257,000.00	$12,979,920.00	$1,587,206.00
Madison***	$ -	$ -	$ -
Montague	$33,416,000.00	$4,379,931.00	$675,888.00
Navarro	$73,306,000.00	$16,383,199.00	$2,174,067.00
Parker	$65,043,000.00	$7,861,259.00	$1,115,468.00
Polk	$6,831,000.00	$1,863,633.00	$240,164.00
Rockwall	$7,830,000.00	$956,340.00	$121,352.00
San Jacinto	$7,190,000.00	$2,720,949.00	$387,666.00
Tarrant	$29,393,000.00	$4,146,954.00	$762,661.00
Trinity	$8,228,000.00	$1,809,874.00	$242,850.00
Van Zandt	$104,603,000.00	$17,175,275.00	$2,055,396.00
Walker	$33,795,000.00	$11,255,260.00	$649,242.00
Wise	$46,269,000.00	$7,301,649.00	$1,039,654.00
Young	$21,694,000.00	$2,541,545.00	$385,563.00

**Total Agricultural Value of county, including land area outside of Trinity Region*

***Total Agricultural Losses only within Trinity Region*

****USDA/NASS Crop and Livestock Values were unavailable for Madison County*

Figure 2.20: Agricultural Land Exposure (in Square Miles) to Existing Condition Floodplain Quilt



Expected Loss of Function

Severe flooding can cause a loss of function for a community's residential and critical infrastructure, which has an impact on the socio-economic systems supported by them. These impacts include disruptions to life, business, and public services. Some public services are essential to a community during and after a flood event. Flood inundation depth and duration are typically considered the best flood characteristics in predicting expected functionality losses. Inundated structures and critical facilities are often not functional during the flood event and through the recovery process. Closure length is dependent on the severity of damage to the structure, interrupted access, and lingering health hazards.

Inundated Structures

FEMA's HAZUS Program was used to generate quantitative estimates of expected loss of functions for counties in the Trinity Region. Note that the HAZUS analysis assumes that a flood event covers the entire county or river basin. The HAZUS analysis is also based on the default inventory data and future similar assessments will benefit from updated inventory data. The total exposure value of buildings in the Trinity Region is $636.83 billion. HAZUS estimates the total direct and indirect losses for the 100-year flood to be $13.12 billion and $12.33 billion, respectively. Direct losses account for building, content, and inventory losses, while indirect losses include relocation, capital, wages, and rental income losses. The total loss is estimated at $24.45 billion or four percent of the total exposure value of buildings in the Trinity Region. ***Table 2.9*** summarizes direct, indirect, and total building losses by county in the Trinity Region. Liberty County is anticipated to have the highest loss ratio, while no losses are predicted for Chambers County.

The HAZUS analysis predicts that approximately 1,021 million tons of debris will be generated from finishes (drywall, flooring, insulation, etc.), structures (framing, walls, exterior cladding), and foundation weight (concrete slab, concrete block, or other foundation) from a 100-year flood. ***Table 2.10*** summarizes HAZUS' estimated debris generation by county in the Trinity Region. Dallas County is estimated to generate the highest amounts of debris and would account for approximately 35 percent of the total debris generated in the Trinity Region.

HAZUS predicts that 1.32 million people would be displaced during a 100-year flood and approximately 170,000 people would require short-term shelter. ***Table 2.11*** summarizes HAZUS' estimated displacement and shelter requirements by county in the Trinity Region. Dallas and Denton counties are estimated to account for 79 percent of the displaced population, and 65 percent of the people requiring short-term shelter.

Table 2.9: Direct, Indirect, and Total Building Losses by County

County	Direct Loss ($ million)	Indirect Loss ($ million)	Total Loss ($ million)	Total Loss Ratio (%)
Anderson	57.92	34.24	92.16	4.0%
Archer	21.89	9.73	31.62	4.5%
Chambers	0.00	0.00	0.00	0.0%
Clay	0.77	0.16	0.93	2.2%
Collin	1,073.89	754.75	1,828.64	2.3%
Cooke	115.37	78.11	193.49	2.0%
Dallas	5,207.52	6,822.67	12,030.19	3.5%
Denton	1,040.23	599.10	1,639.33	1.4%
Ellis	227.22	151.28	378.50	2.4%
Fannin	4.57	1.27	5.84	1.4%
Freestone	38.06	20.93	58.99	3.5%
Grayson	23.93	8.86	32.79	1.3%
Grimes	4.92	7.01	11.93	3.6%
Hardin	0.76	0.23	0.99	2.7%
Henderson	54.24	47.21	101.44	1.7%
Hill	4.67	1.79	6.46	1.7%
Hood	0.00	0.00	0.00	0.0%
Houston	35.66	13.52	49.17	3.3%
Hunt	1.49	0.27	1.76	2.4%
Jack	9.21	5.05	14.26	2.5%
Johnson	28.42	14.47	42.89	2.6%
Kaufman	172.61	101.70	274.31	2.8%
Leon	48.97	27.75	76.72	4.8%
Liberty	39.07	18.71	57.78	29.3%
Limestone	1.65	0.87	2.52	1.8%
Madison	28.06	26.72	54.78	6.1%
Montague	41.03	19.04	60.07	5.7%
Navarro	92.05	83.82	175.87	4.2%
Parker	40.78	27.91	68.69	3.5%
Polk	190.26	91.15	281.40	8.3%
Rockwall	146.05	56.74	202.79	3.5%
San Jacinto	161.48	82.87	244.35	14.2%
Tarrant	237.29	129.79	367.08	3.7%
Trinity	88.59	36.21	124.79	11.4%
Van Zandt	16.77	14.75	31.52	2.4%
Walker	146.41	59.24	205.66	10.7%
Wise	168.50	85.95	254.45	5.0%
Young	0.26	0.08	0.34	0.9%

Table 2.10: Debris Generation by County

County	Finishes (tons)	Structures (tons)	Foundations (tons)	Total (tons)
Anderson	1,953	1,856	2,914	6,722
Archer	1,366	717	1,048	3,131
Chambers	0	0	0	0
Clay	72	19	35	126
Collin	40,205	11,218	14,144	65,566
Cooke	5,794	1,432	2,274	9,499
Dallas	192,258	62,640	70,061	324,959
Denton	32,371	13,635	18,077	64,083
Ellis	8,450	3,280	5,318	17,049
Fannin	232	57	103	392
Freestone	2,041	1,020	1,764	4,824
Grayson	1,180	454	809	2,442
Grimes	440	104	225	769
Hardin	61	25	53	139
Henderson	3,885	1,598	3,494	8,975
Hill	368	136	255	760
Hood	0	0	0	0
Houston	2,870	1,847	2,898	7,615
Hunt	92	35	70	197
Jack	733	233	424	1,390
Johnson	1,449	729	1,364	3,542
Kaufman	6,732	2,060	4,058	12,849
Leon	2,956	1,996	3,094	8,044
Liberty	2,009	3,083	4,325	9,417
Limestone	100	35	73	209
Madison	2,013	1,131	2,039	5,183
Montague	2,093	2,107	3,367	7,565
Navarro	4,855	1,433	2,691	8,981
Parker	2,385	1,094	2,100	5,579
Polk	13,349	9,510	14,392	37,252
Rockwall	3,984	651	722	5,358
San Jacinto	9,973	8,110	13,111	31,193
Tarrant	7,110	5,839	6,057	19,007
Trinity	6,387	6,630	10,746	23,763
Van Zandt	1,236	523	1,074	2,832
Walker	8,975	9,268	13,817	32,061
Wise	7,751	5,340	8,713	21,804
Young	35	7	14	56

Table 2.11: Displacement and Shelter Requirements by County

County	Number of Displaced People	Number of People Needing Short-Term Shelter
Anderson	2,778	535
Archer	478	105
Chambers	0	0
Clay	36	3
Collin	91,846	16,267
Cooke	36,706	2,190
Dallas	430,161	88,251
Denton	601,551	44,812
Ellis	5,772	2,657
Fannin	150	63
Freestone	800	346
Grayson	9,364	435
Grimes	198	108
Hardin	39	8
Henderson	2,211	1,328
Hill	180	50
Hood	0	0
Houston	842	319
Hunt	57	9
Jack	262	48
Johnson	796	414
Kaufman	5,156	2,116
Leon	831	319
Liberty	331	60
Limestone	47	16
Madison	783	343
Montague	2,633	188
Navarro	2,780	870
Parker	1,432	543
Polk	3,692	1,334
Rockwall	2,776	1,142
San Jacinto	2,460	583
Tarrant	3,655	1,640
Trinity	1,376	421
Van Zandt	827	394
Walker	4,067	806
Wise	4,117	1,038
Young	15	3

Transportation

HAZUS estimates the total highway bridge damage to be $3.49 million in the Trinity Region for a 100-year flood. An average damage of 2.6 percent for a 100-year flood is estimated for the 599 highway bridges in the Trinity Region. Other than the nine bridges identified by TRWD, none of the highway bridges are estimated to be non-functional. ***Table 2.12*** summarizes HAZUS' estimated highway bridge damage by county in the Trinity Region. The highest damages are estimated for Collin and Dallas counties. HAZUS estimates total daytime and nighttime vehicle losses at $1.97 billion and $2.14 billion, respectively for a 100-year flood. ***Table 2.13*** summarizes HAZUS' estimated vehicles losses by county in the Trinity Region. The highest loss is estimated for Dallas County (approximately $900 million) and accounts for more than 45 percent of the total vehicle losses predicted for the Trinity Region.

Health and Human Services

The HAZUS analysis does not predict any losses to small, medium, and large hospitals in the Trinity Region for the 100-year flood. There are no predicted losses to the number of available beds, no building or content losses are predicted, and none of the hospitals are expected to be non-functional based on the results of the HAZUS analysis.

Water Supply

Floods can contaminate water supply sources such as wells, springs, and lakes/ponds through polluted runoff laden with sediment, bacteria, animal waste, pesticides, and industrial waste and chemicals. Drinking water wells have the potential to become contaminated during major flooding events, requiring disinfection and cleanup. Based on TCEQ's Public Water Supply dataset, there are 2,391 public water supply wells in the Trinity Region with 127 in the 100-year floodplain. Therefore, five percent of the public water supply wells in the Trinity Region are potentially exposed to flood risk. The HAZUS analysis predicts damage to one potable water facility in the Trinity Region (as discussed shortly), however, does not estimate any damages to potable water pipelines.

Water Treatment

Failure of water treatment systems due to flooding may consist of direct losses, such as equipment damage and contamination of pipes, as well as indirect impacts, such as disruption of clean water supply (Arrighi, Tarani, Vicario, & Castelli, 2017). Floods have the potential to impact operations at water treatment facilities resulting in poorer potable water quality. HAZUS predicts that one potable water system in Kaufman County will be non-functional due to damages from a 100-year flood. The potable water facility is estimated to sustain an average damage of 40 percent and a total loss of $11.86 million.

Table 2.12: Highway Bridge Damages by County

County	Number of Highway Bridges	Average Damage (%)	Total Loss ($)
Anderson	15	3.8%	61,000
Archer	1	0.3%	2,000
Chambers	0	0.0%	0
Clay	0	0.0%	0
Collin	56	3.3%	576,000
Cooke	0	0.0%	0
Dallas	30	0.6%	534,000
Denton	21	3.4%	180,000
Ellis	82	3.2%	352,000
Fannin	3	3.8%	12,000
Freestone	32	3.3%	143,000
Grayson	32	3.5%	165,000
Grimes	15	4.0%	66,000
Hardin	0	0.0%	0
Henderson	5	2.0%	17,000
Hill	2	0.3%	25,000
Hood	0	0.0%	0
Houston	57	2.9%	173,000
Hunt	3	3.4%	17,000
Jack	1	0.5%	1,000
Johnson	17	4.1%	178,000
Kaufman	31	2.2%	172,000
Leon	25	3.1%	95,000
Liberty	2	1.3%	6,000
Limestone	7	2.9%	28,000
Madison	19	2.2%	59,000
Montague	1	5.0%	4,000
Navarro	21	2.5%	110,000
Parker	0	0.0%	0
Polk	32	1.0%	52,000
Rockwall	3	1.3%	5,000
San Jacinto	6	1.5%	15,000
Tarrant	5	0.9%	15,000
Trinity	3	1.3%	14,000
Van Zandt	29	2.1%	56,000
Walker	8	4.1%	75,000
Wise	6	2.1%	37,000
Young	0	0.0%	0

Table 2.13: Vehicle Losses by County

County	Daytime Loss ($ million)	Nighttime Loss ($ million)
Anderson	10.51	10.99
Archer	2.06	4.08
Chambers	0.00	0.00
Clay	0.07	0.15
Collin	137.28	151.65
Cooke	17.41	19.27
Dallas	838.47	888.81
Denton	114.03	127.59
Ellis	54.47	32.37
Fannin	0.48	0.65
Freestone	8.10	7.10
Grayson	2.63	4.02
Grimes	0.93	1.42
Hardin	0.04	0.07
Henderson	9.87	15.34
Hill	0.53	1.08
Hood	0.00	0.00
Houston	7.84	11.79
Hunt	0.12	0.26
Jack	1.06	1.73
Johnson	4.34	6.15
Kaufman	24.53	29.81
Leon	7.28	11.08
Liberty	4.50	6.61
Limestone	0.30	0.31
Madison	8.81	9.82
Montague	4.26	7.85
Navarro	15.75	18.79
Parker	6.68	8.47
Polk	30.06	49.51
Rockwall	12.70	14.17
San Jacinto	18.91	35.01
Tarrant	27.46	25.94
Trinity	11.43	21.58
Van Zandt	2.24	3.98
Walker	21.54	28.22
Wise	23.12	29.26
Young	0.04	0.08

The HAZUS analysis estimates a total loss of $1.33 billion to wastewater treatment facilities in the Trinity Region. The average predicted damage is approximately 18 percent. Thirty-five of the 38 facilities are predicted to be non-operational due to damages from a 100-year flood. ***Table 2.14*** summarizes HAZUS' predicted wastewater facility losses by county in the Trinity Region. The highest loss is predicted for Wise County with 10 out of 12 facilities estimated to be non-functional.

Utilities

The HAZUS analysis estimates damages to potable water and wastewater facilities amounting to $11.86 million and $1.46 billion, respectively. The analysis estimates no losses to communication systems in the Trinity Region for a 100-year flood. Predicted utility losses at the county level for the Trinity Region are summarized in ***Table 2.15***.

Energy Generation

The HAZUS analysis estimates no losses to oil systems, natural gas, and electric power systems in the Trinity Region.

Emergency Services

Flooding has the potential to cause disruption to emergency services by causing delays in response times. The HAZUS analysis for the Trinity Region quantifies damages and expected loss of use associated with essential facilities including emergency operation centers, fire stations, and police stations. For a 1% annual chance storm event, the HAZUS analysis estimates total building and content damages amounting to $3.75 million and $10.52 million, respectively. One emergency operation center each in Dallas County and one emergency operation center in Liberty County are estimated to be non-functional. A total of 14 fire stations are estimated to be non-functional in the event of a 100-year flood.

Total building and content damages to fire stations are predicted at $2.83 million and $8.76 million, respectively. Total building and content damages to police stations are estimated at $588,000 and $1.14 million, respectively. ***Table 2.16*** summarizes HAZUS estimated losses to emergency services by county in the Trinity Region for a 100-year flood.

Table 2.14: Wastewater Facility Losses by County

County	Number of Wastewater Facilities	Average Damage (%)	Total Loss ($)	Number of Non-Functional Facilities
Anderson	2	7.1%	8,406	0
Archer	0	0.0%	0	0
Chambers	0	0.0%	0	0
Clay	0	0.0%	0	0
Collin	1	40.0%	23,710	1
Cooke	0	0.0%	0	0
Dallas	0	0.0%	0	0
Denton	1	30.0%	17,782	1
Ellis	5	33.6%	146,666	4
Fannin	1	7.9%	4,696	0
Freestone	3	9.4%	16,803	0
Grayson	0	0.0%	0	0
Grimes	0	0.0%	0	0
Hardin	0	0.0%	0	0
Henderson	0	0.0%	0	0
Hill	4	6.2%	29,432	0
Hood	0	0.0%	0	0
Houston	2	4.9%	5,808	0
Hunt	0	0.0%	0	0
Jack	0	0.0%	0	0
Johnson	2	20.6%	24,378	1
Kaufman	4	14.2%	33,609	1
Leon	0	0.0%	0	0
Liberty	0	0.0%	0	0
Limestone	0	0.0%	0	0
Madison	1	30.0%	17,782	1
Montague	0	0.0%	0	0
Navarro	10	18.7%	202,365	7
Parker	0	0.0%	0	0
Polk	2	19.0%	22,524	1
Rockwall	4	20.6%	48,861	3
San Jacinto	2	19.6%	23,235	1
Tarrant	1	40.0%	23,710	1
Trinity	4	22.1%	52,457	3
Van Zandt	0	0.0%	0	0
Walker	0	0.0%	0	0
Wise	12	25.8%	364,869	10
Young	0	0.0%	0	0

Table 2.15: Utility Losses by County

County	Potable Water ($ million)	Wastewater ($ million)	Oil Systems ($ million)	Natural Gas ($ million)	Electric Power ($ million)	Communication ($ million)	Total ($ million)
Anderson	0.00	8.41	0.00	0.00	0.00	0.00	8.41
Archer	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Chambers	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Clay	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Collin	0.00	23.71	0.00	0.00	0.00	0.00	23.71
Cooke	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Dallas	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Denton	0.00	17.78	0.00	0.00	0.00	0.00	17.78
Ellis	0.00	146.67	0.00	0.00	0.00	0.00	146.67
Fannin	0.00	4.70	0.00	0.00	0.00	0.00	4.70
Freestone	0.00	16.80	0.00	0.00	0.00	0.00	16.80
Grayson	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Grimes	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hardin	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Henderson	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Hill	0.00	29.43	0.00	0.00	0.00	0.00	29.43
Hood	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Houston	0.00	5.81	0.00	0.00	0.00	0.00	5.81
Hunt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Jack	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Johnson	0.00	24.38	0.00	0.00	0.00	0.00	24.38
Kaufman	11.85	33.61	0.00	0.00	0.00	0.00	45.46
Leon	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Liberty	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Limestone	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Madison	0.00	17.78	0.00	0.00	0.00	0.00	17.78
Montague	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Navarro	0.00	334.83	0.00	0.00	0.00	0.00	334.83
Parker	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Polk	0.00	22.52	0.00	0.00	0.00	0.00	22.52
Rockwall	0.00	48.86	0.00	0.00	0.00	0.00	48.86
San Jacinto	0.00	23.24	0.00	0.00	0.00	0.00	23.24
Tarrant	0.00	23.71	0.00	0.00	0.00	0.00	23.71
Trinity	0.00	52.46	0.00	0.00	0.00	0.00	52.46
Van Zandt	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Walker	0.00	0.00	0.00	0.00	0.00	0.00	0.00
Wise	0.00	364.87	0.00	0.00	0.00	0.00	364.87
Young	0.00	0.00	0.00	0.00	0.00	0.00	0.00

Table 2.16: Emergency Services Losses by County

		Anderson County	Dallas County	Liberty County	Tarrant County	Wise County
Emergency Operation Centers	Building Damage ($ thousand)	0	147	180	0	0
	Content Damage ($ thousand)	0	253	372	0	0
	Non-Functional	0	1	1	0	0
Fire Stations	Building Damage ($ thousand)	190	867	1038	207	533
	Content Damage ($ thousand)	452	3364	2834	546	1559
	Non-Functional	1	4	5	1	3
Police Stations	Building Damage ($ thousand)	0	229	359	0	0
	Content Damage ($ thousand)	0	393	745	0	0
	Non-Functional	0	2	2	0	0

Note: Only counties for which the HAZUS analysis reported losses are summarized.

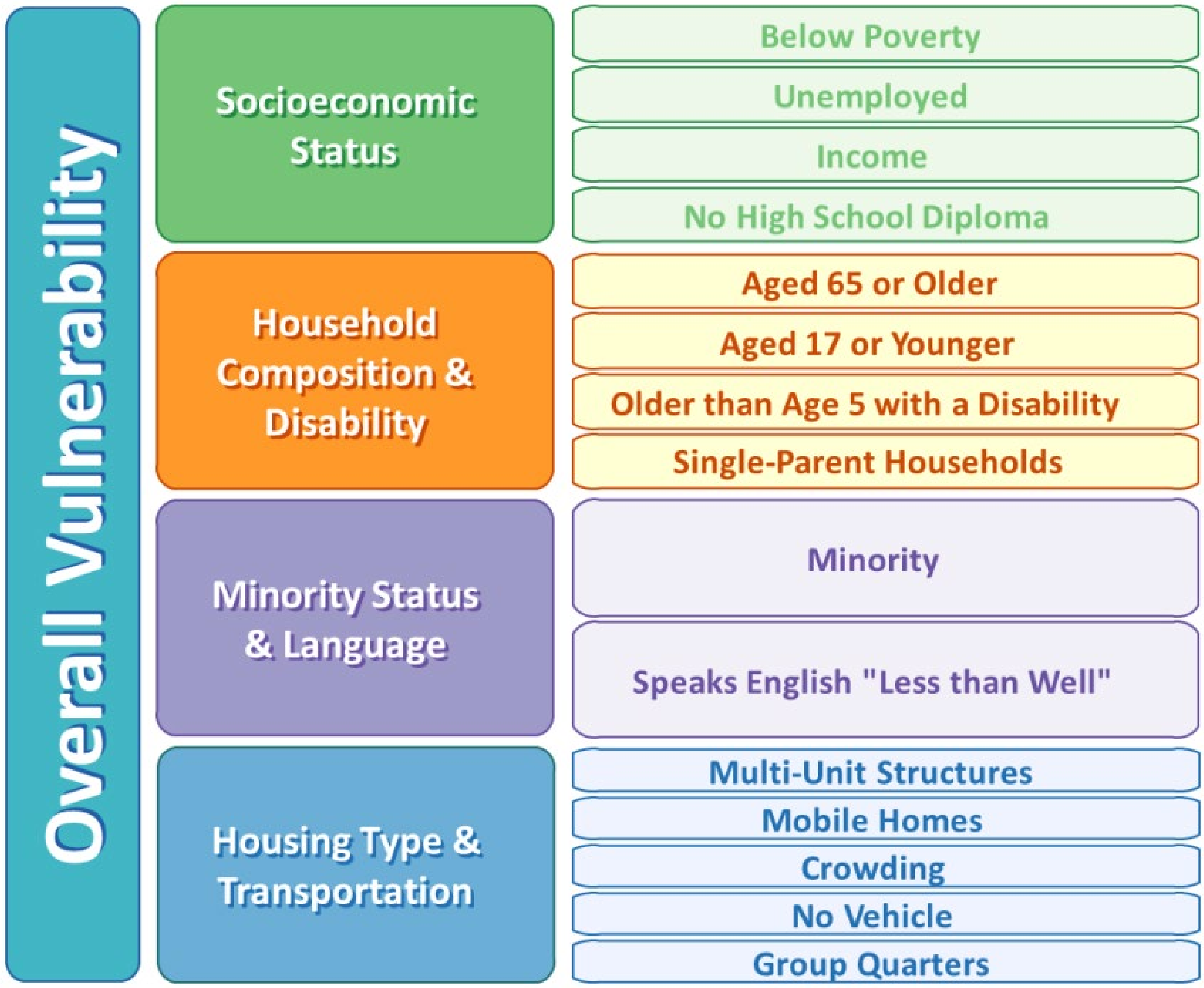
Existing Condition Vulnerability Analysis

Vulnerability is an assessment of the potential negative impact of the flood hazard to communities and a description of the impacts. The existing condition vulnerability analysis uses the 2018 SVI data developed by the CDC. The CDC calculates the SVI at the census tract level within a specified county using 15 sociable factors including poverty, housing, ethnicity, and vehicle access. It then groups them into four related themes: Socioeconomic Status, Household Composition, Race/Ethnicity/Language, and Housing/Transportation. ***Figure 2.21*** shows the CDC themes used for SVI calculation. Each census tract receives a separate ranking for each of the four themes, as well as an overall ranking.

Vulnerabilities of Structures, Agricultural Areas, Bridges, Low Water Crossings, and Critical Facilities

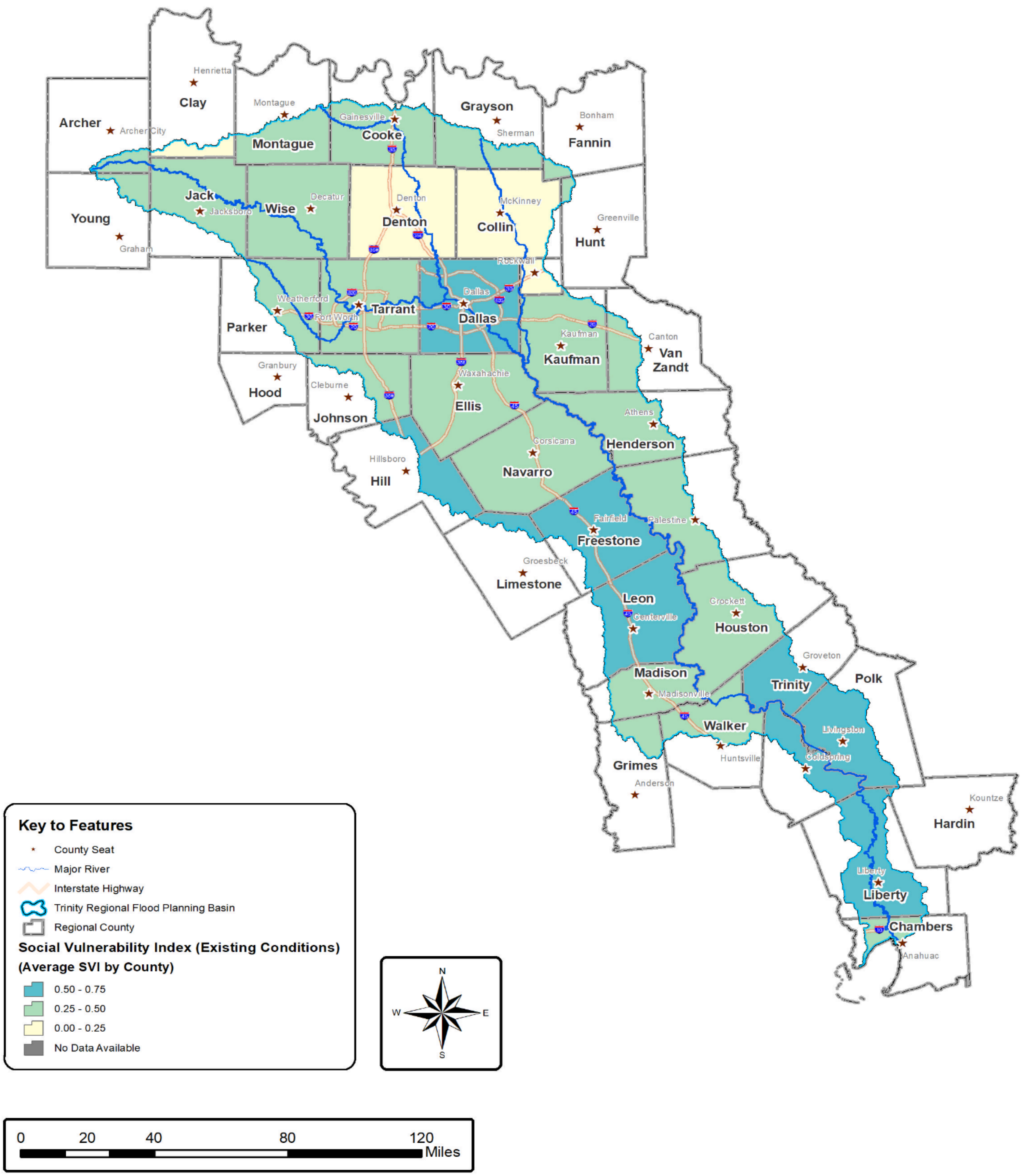
The 2018 CDC SVI data was overlaid with the Trinity Region's buildings, critical facilities, bridges, roadway and railway stream crossings, LWCs, and agricultural areas. The SVI values for all the buildings, critical facilities, agricultural areas, bridges, and LWCs exposed to the existing conditions floodplain quilt are summarized by county averages and shown in ***Figure 2.22***.

Figure 2.21: Center for Disease Control Themes



Source: United States CDC (United States CDC, 2018)

Figure 2.22: Existing Condition Exposure and Social Vulnerability Index by County



A community's social vulnerability score is proportional to a community's risk. Social vulnerability is a consequence-enhancing risk component and community risk factor that represents the susceptibility of social groups to the adverse effects of natural hazards like floods, including disproportionate death, injury, loss, or disruption of livelihood (United States CDC, 2018). An SVI score and rating represent the relative level of a community's social vulnerability compared to all other communities, with a higher SVI score resulting in a higher risk index score (United States CDC, 2018).

Figure 2.22 shows Clay, Collin, and Parker counties as being the least vulnerable with respect to the existing exposure of buildings, critical facilities, agricultural areas, bridges, and LWCs. TWDB considers a threshold of 0.75 as an indicator for highly vulnerable areas. At the county level, none of the counties reached this threshold. ***Figure 2.23*** shows the countywide average distribution of SVI with regards to the exposed buildings, critical facilities, agricultural areas, bridges, and LWCs in the Trinity Region. Leon, Liberty, and Navarro counties had the largest SVI countywide values. Large, detailed maps for the vulnerability assessment are shown in ***Appendix B***.

Resiliency of Communities

Community resilience is a measure of the sustained ability of a community to prepare for anticipated natural hazards, adapt to changing conditions, and withstand and recover rapidly from disruptions. It refers to the ability of a community to survive and thrive when confronted by external stresses, such as natural or human-caused disasters like floods. A community resilience score is inversely proportional to a community's risk.

FEMA's 2021 Resilience Analysis and Planning Tool (RAPT) was leveraged to assess the resilience readiness of communities in the Trinity Region. RAPT uses 20 commonly used community resilience indicators from peer-reviewed published methodologies, infrastructure, and hazard data that informs strategies for preparedness, response, and recovery. Example indicators include median household income, disability (percent of population with disabilities), hospital capacity (number of hospitals per 10,000 people), and NFIP policy penetration rates. ***Table 2.17*** illustrates a summary community resilience indicator used by RAPT. The data is aggregated at the census tract and county levels and then aggregated into bins for visualization using all the indicators combined. ***Figure 2.24*** shows the resiliency ratings of the counties in the Trinity Region. Community resilience is a consequence reduction risk component, and a community resilience score is inversely proportional to a community's risk. A higher community resilience score results in a lower risk index score.

Figure 2.23: Social Vulnerability Index Averages by County

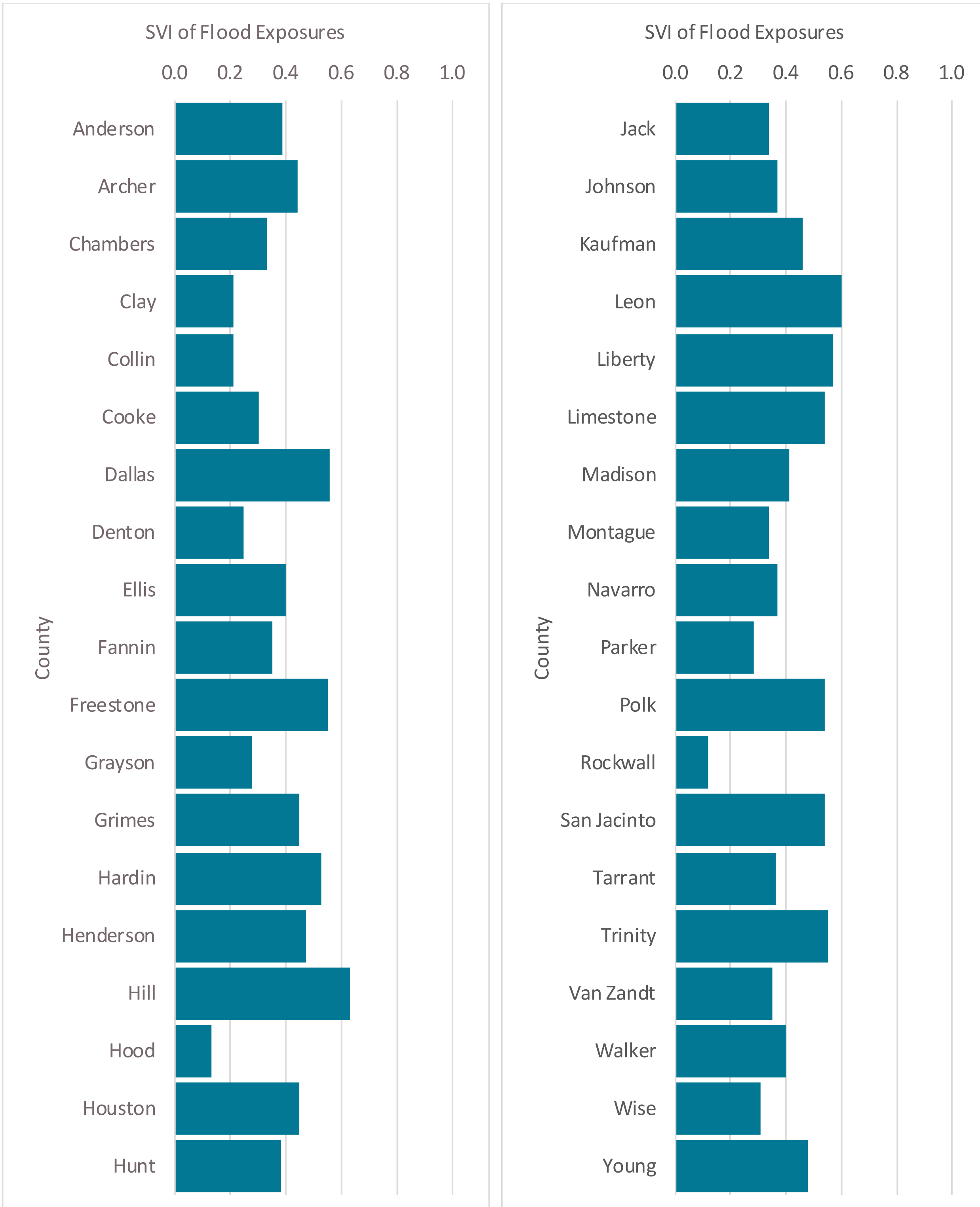
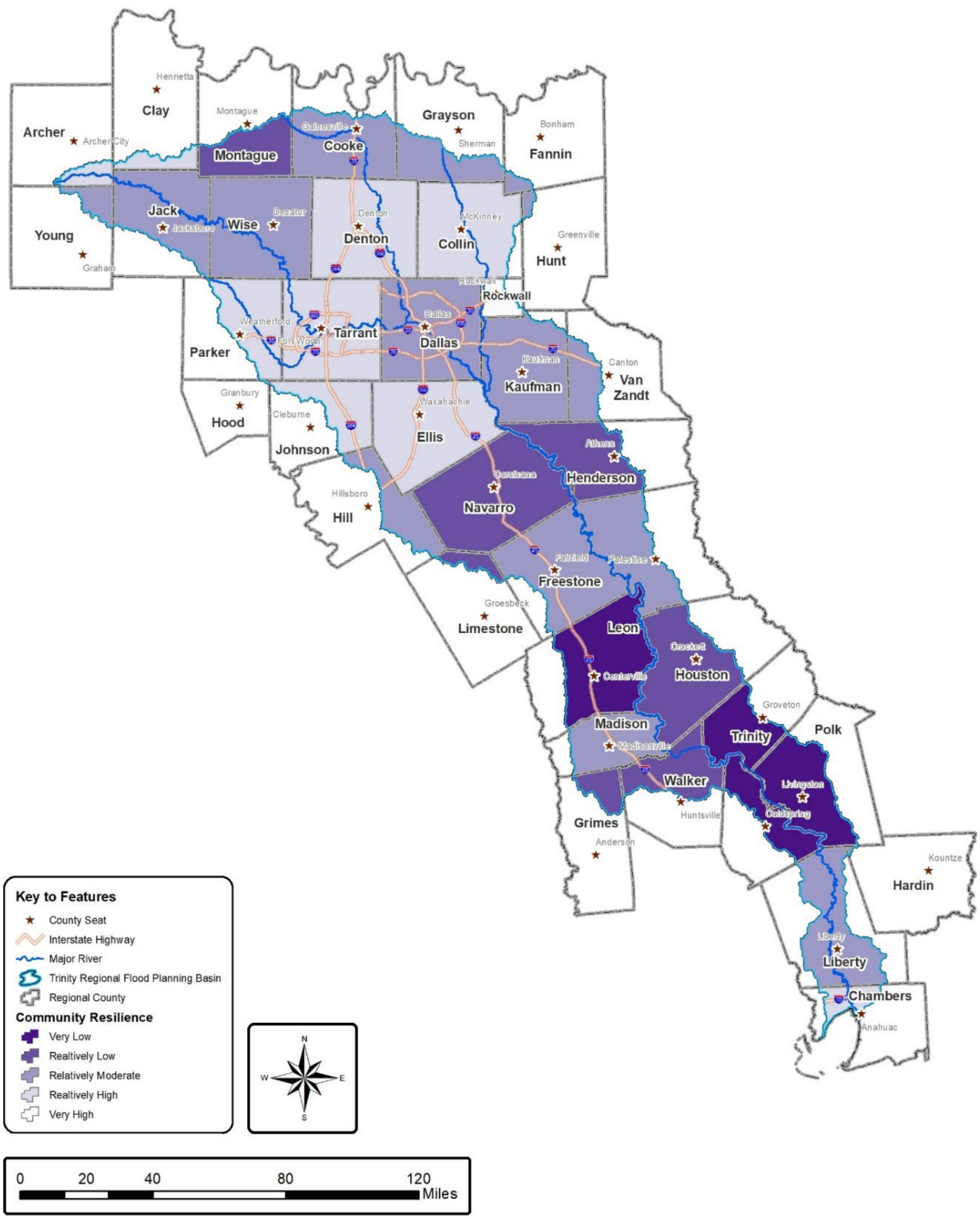


Table 2.17: Commonly Used Resilience Analysis and Planning Tool Indicators and Datasets

Population-Focused Indicators	Community-Focused Indicators	Infrastructure Data	Hazard Data
• % Population without Health Insurance • % Population Unemployed • % Population without a High School Education • % Population with a Disability • % Population without Access to a Vehicle • % Population with Home Ownership • % Population over 65 • % Population Single-Parent Households • % Population with Limited English Proficiency • Median Household Income • Gini Index: Income Inequality • At-risk electricity-dependent Medicare beneficiaries • Tribal Populations • Households without Internet Subscriptions • Power-dependent Devices for Medicare beneficiaries	• Connection to Civic/Social Organizations • Hospital Capacity • Medical Professional Capacity • Affiliation with a Religion • Presence of Mobile Homes • Public School Capacity • Population Change • Hotel/Motel Capacity • Rental Property Capacity • NFIP policy penetration rates (residential) • National Flood Insurance Program policy penetration rates (residential)	• Nursing Homes • Hospitals • Urgent Care Facilities • Public Health Depts. • Fire Stations • Emergency Medical Services (EMS) stations • Local Law Enforcement locations • 911 Service Area Boundaries • Mobile Home Parks • Places of Worship • Public Schools • Private Schools • Colleges and Universities • Prison Boundaries • Transmission Lines • Electric Power Plants • Solid Waste Landfills • Wastewater Treatment Plants • Pharmacies (Rx Open) • Dialysis Centers • High Hazard Dams	• Flood Hazard Zones • Tornado Paths • Tropical Storms • Seismic Hazards • Wildfire • Current Watches/Warnings • Hurricane Outlook: Atlantic • Severe Weather Outlook • Excessive Rainfall Outlook • River Flood Outlook

Figure 2.24 shows that Rockwall County has the highest resiliency rating in the Trinity Region. Leon, Polk, and Trinity counties show the lowest overall resiliency readings. In general, the Trinity Region Upper Subregion shows relatively higher resiliency ratings than the Middle and Lower Subregions.

Figure 2.24: Resiliency Rating by County



Summary of Existing Conditions Flood Exposure and Vulnerability Analyses

Based on exceedance probability for a period of years, and not just one year, there is a 26 percent chance that a 100-year flood will occur over the next 30 years. There are over 140,000 buildings in the Trinity Region that have greater than a 26 percent chance of being severely affected by flooding over the next 30 years. This represents 2.2 percent of all buildings in the region.

While population estimates are valuable for defining the general severity of flood exposure, as documented in the upcoming Existing Conditions Flood Exposure section, such aggregated measures inform only how many people are exposed, but not who. Disaggregating the exposed populations according to SVI helps inform who lives in the floodplain and where. Questions about flood risk, exposure, vulnerability, and resilience are fundamentally questions of where. Hence for the Trinity Region, spatial autocorrelation techniques using the values from the existing flood exposure and social vulnerability were used to map to map and identify hotspots (most vulnerable areas).

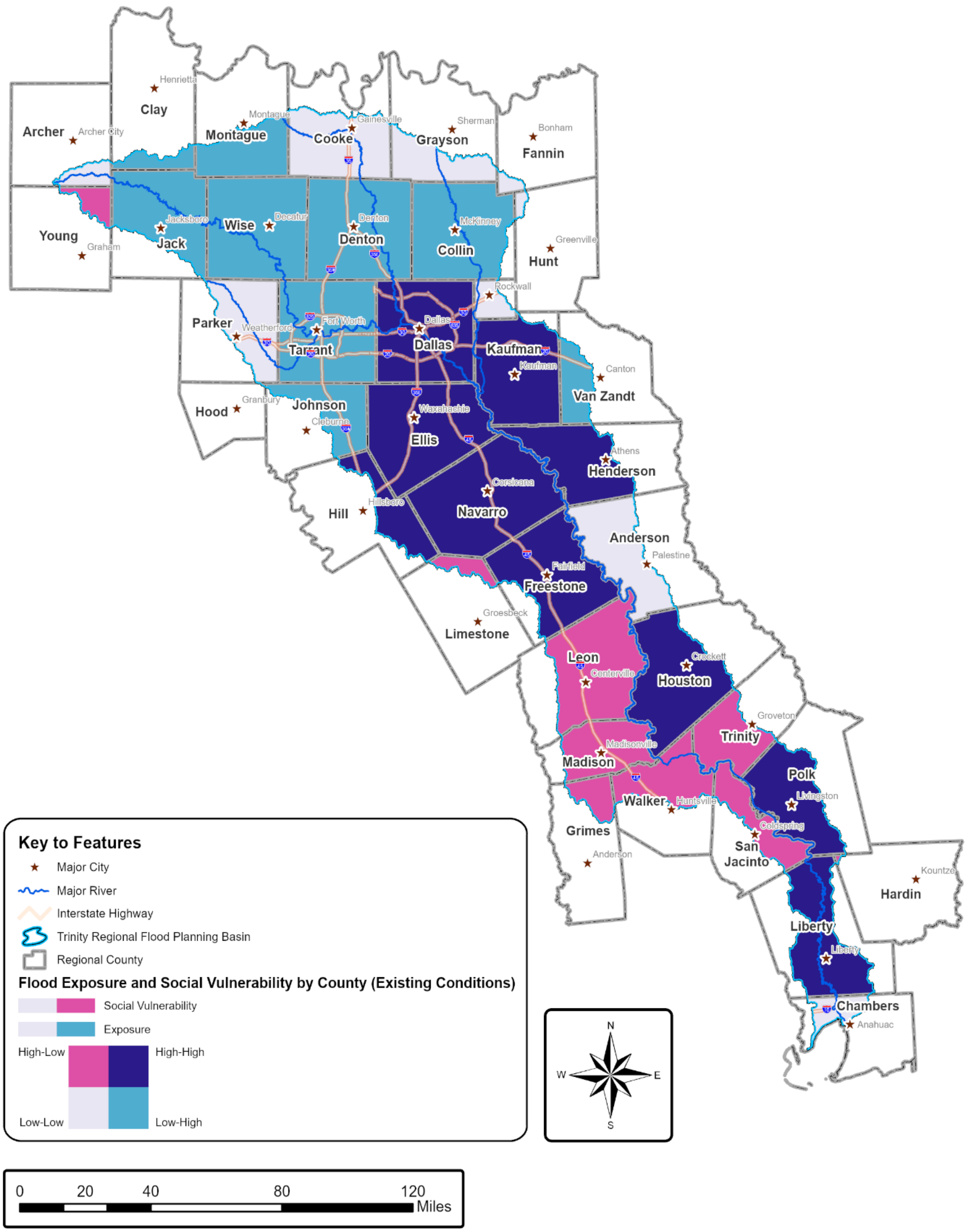
As shown in ***Figure 2.25***, the High-High (HH) hotspots (purple) are counties with higher-than-average flood exposure and are surrounded by areas with higher-than-average social vulnerability. The majority occur in the upper region (Dallas, Henderson, Hill, Kaufman, and Navarro counties). There are also three hotspots in the middle region (Freestone, Houston, and Leon counties) and one in the lower region (Liberty County). These HH counties are home to approximately 3,060,000 people.

The High-Low (HL) counties are in pink, representing counties with high social vulnerability with neighboring low flood exposure. These areas are mostly in the middle region (Grimes, Limestone, Madison, Trinity, and Walker counties), and then two in the lower region (Hardin and San Jacinto counties), and two clusters in the upper region (Archer and Young counties). In total the HL clusters are populated by approximately 275,000 people. Extreme flood events have the probability of high adverse impacts due to the high population susceptibility.

The Low-High (LH) counties in blue, represent counties with low social vulnerability and high flood exposure, and are home to approximately 4,650,000 people. The areas are all in urbanized upper region.

The Low-Low (LL) counties are the least in the Trinity Region and are interspersed throughout the region. These LL counties are Anderson, Chambers, Clay, Fannin, Grayson, Hood, Hunt, Jack, Rockwall, and Van Zandt counties. These counties have the lowest levels of flood exposure and social vulnerability and require less attention from the perspective of flood vulnerability.

Figure 2.25: Flood Exposure and Social Vulnerability Index by County to Existing Condition Floodplain Quilt



A larger version of ***Figure 2.25,*** as well as a more detailed exposure and vulnerability relationship at the census tract level, is shown in ***Appendix B***.

The hotspot area can be used to help identify and justify priority locations for interventions like FMPs that can mitigate both physical and social aspects of flood vulnerability (Tate, Asif, Emrich, & Sampson, 2021). FMPs are discussed in ***Chapter 4***. For example, LH areas (Low vulnerability and High exposure) can become areas where exposure reduction projects like levees, detention basins, and other natural based solutions can be prioritized. If an FMP goal is to optimize both reduction in physical risk and address socially vulnerable populations, then areas can be prioritized.

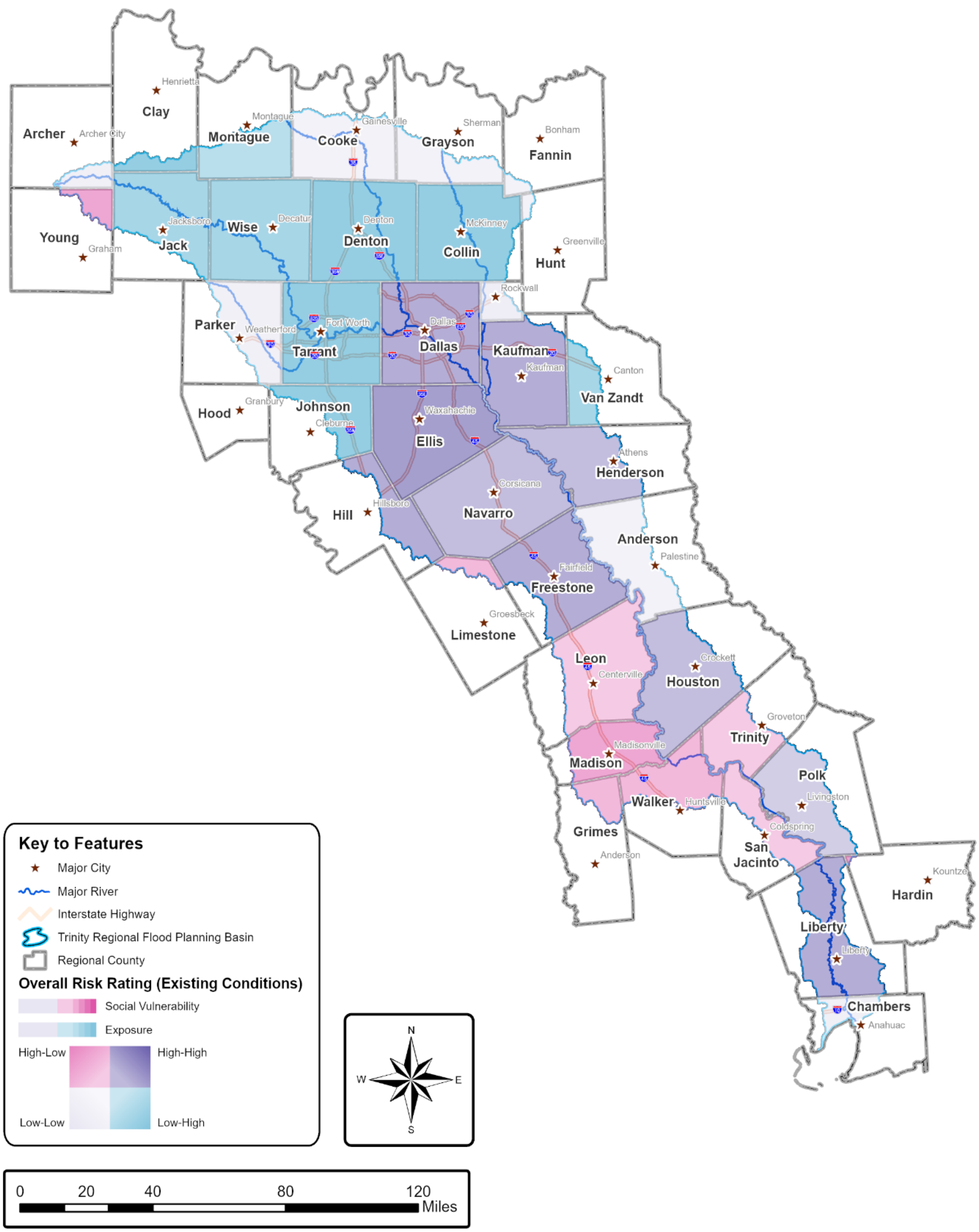
While the product of exposure and vulnerability paints a picture of risk in an area, weighing this against resilience helps to map an overall risk rating for a community. The bivariate map in ***Figure 2.26*** that shows exposure and vulnerability is weighted against the resiliency factors discussed previously in the Resiliency of Communities section. This results in trivariate choropleth map with varying color intensities to maps and display the overall ratings by county.

As shown in ***Figure 2.26***, with the addition of the third variable (resiliency), counties like Henderson, Houston, Leon, and Navarro counties are now in a slightly lower risk rating than Dallas, Freestone, Hill, Kaufman, and Liberty counties. In the previous ***Figure 2.25***, the counties all used to be in the same High Exposure and High vulnerability category (HH). A more detailed-level, larger map of the overall risk rating based on census tract levels for the Trinity Region is shown in ***Appendix B***. Higher intensity colors show higher risk levels within the same category. For example, Limestone, Polk, San Jacinto, and Trinity counties now show a lower risk rating than Archer, Hardin, Madison, and Young counties, even though they all fit in the High-Low category.

The existing flood risk, exposure, and vulnerability for the Trinity Basin are summarized in ***TWDB-Required Table 3***. The TWDB ***Table 3*** provides the results per county of the existing flood exposure and vulnerability analysis as outlined in the Technical Guidelines for Regional Flood Planning. This table is included in ***Appendix A***.

A geodatabase with applicable layers, as well as associated ***TWDB-Required Maps 1*** through ***22*** are provided in ***Appendix B*** as digital data. ***Table 2.1***, included in ***Appendix B***, outlines the geodatabase deliverables included in this Technical Memorandum, as well as spatial files and tables. These deliverables align with the TWDB's Exhibit D: Data Submittal Guidelines for Regional Flood Planning located on the web at www.twdb.texas.gov/flood/planning/planningdocu/2023/index.asp.

Figure 2.26: Overall Risk Rating by County to Existing Condition Floodplain Quilt



Task 2B – Future Condition Flood Risk Analyses

Future Condition Flood Hazard Analysis

The future flood risk assessment begins by estimating the increased extent of the future flood hazard. The future flood risk mapping extent is commonly determined under fully developed watershed conditions, which is the anticipated condition of the watershed after the watershed has undergone ultimate land use development. The determination of the general magnitude of potential increases in the Trinity Region's future 1% and 0.2% annual chance storm events are based on a "do-nothing" or "no-action" scenario of approximately 30 years of continued development and population growth under current development trends and patterns, and existing flood regulations and policies.

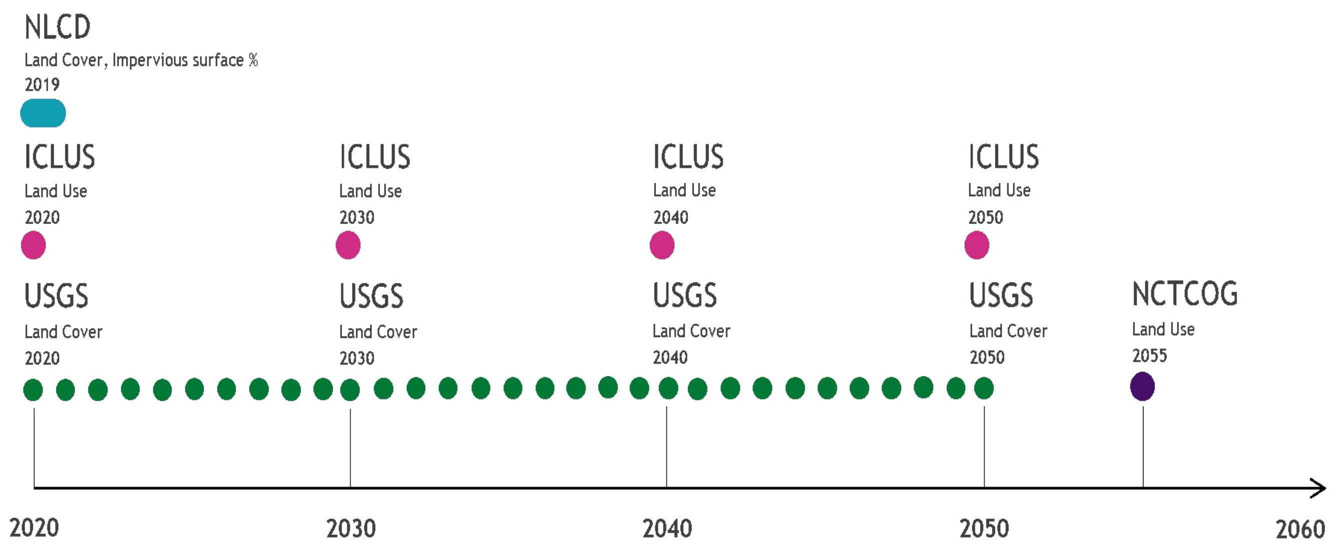
Future Conditions Based on "No Action" Scenario

Land Use and Development Trends

Land use and land cover (LULC) data provides a valuable method for determining the current and future extents of various land types in a floodplain. The LULC datasets are typically derived from the results of classifying satellite images. For the Trinity Region, the open-sourced datasets of current LULC conditions and future projections can be retrieved from the National Land Cover Dataset (NLCD), Environmental Protection Agency (EPA) Integrated Climate and Land Use Scenarios (ICLUS) land use projections, USGS conterminous United States land cover projections, and North Central Texas Council of Governments (NCTCOG) land use projection as shown in the ***Figure 2.27***.

The NLCD provides the latest LULC dataset (2019) for the Trinity Region, which is considered a credible data source with a 30-meter spatial resolution. The current LULC condition can also be estimated based on the projections from the ICLUS and USGS datasets for 2020, which can be consistently compared with the respective projections for 2050. The ICLUS dataset provides decadal land use projections (years 2020, 2030, 2040, and 2050) at a 90-meter spatial resolution, while USGS provides annual land cover projections (every year from 2020 to 2050) at a 250-meter spatial resolution. The NCTCOG also provides a localized land use projection for North Central Texas for the year of 2055. The following sections will include detailed descriptions for each dataset and show how the datasets can be used to investigate future LULC changes in the Trinity Region.

Figure 2.27: Summary of the Current and Future Land Use and Land Cover Datasets



Future Land Use and Land Cover Conditions

Future land use conditions are available from three LULC datasets:

- EPA ICLUS land use projections
- USGS conterminous United States land cover projections
- NCTCOG land use projection

The ICLUS is based on the EPA demographic and spatial allocation models to produce land use changes according to different scenarios. The dataset includes land use classifications of the contiguous United States at a spatial resolution of 90 meters. A demographic model generates population estimates that are distributed by a spatial allocation model (SERGoM v3) (Bierwagen, Theobald, Pyke, & Morefield, 2010) into housing density (HD) across the landscape. In the initial version (1), land-use outputs were developed for the four main Intergovernmental Panel on Climate Change (IPCC) Special Report on Emissions Scenarios (SRES) (A1, A2, B1, and B2) and a baseline. The land use outputs are available for each scenario by decade from 2010 to 2100.

Two of the new Shared Socioeconomic Pathways (SSPs) (SSP2 and SSP5) and two Representative Concentration Pathways (RCPs) (RCP 4.5 and RCP 8.5) were added in the recent version 2. (United States EPA, 2016). The details of the selected pathways are shown below:

- SSP2 is a "middle-of-the-road" projection, where social, economic, and technological trends do not shift markedly from historical patterns, resulting in a United States population of 455 million people by 2100. Domestic migration trends remain largely consistent with the recent past.
- SSP5 describes a rapidly growing and flourishing global economy that remains heavily dependent on fossil fuels, and a United States population that exceeds 730 million by 2100. ICLUS v2.1 land use projections under SSP5 result in a considerably larger expansion of developed lands relative to SSP2.
- RCP4.5 assumes that global greenhouse gas emissions increase into the latter part of the century, before leveling off and eventually stabilizing by 2100 because of various climate change policies.
- RCP8.5 assumes that global greenhouse gas emissions increase through the year 2100.

Figure 2.28 and ***Figure 2.29*** illustrate the land use conditions of the Trinity Region based on the ICLUS dataset of the years of 2020 and 2050.

Another LULC projection dataset for the contiguous United States is produced by USGS. The year 1992 was used by USGS as the baseline for the landscape modeling while other datasets such as NLCD, USGS Land Cover Trends, and USDA's Census of Agriculture were used to guide the recreation of historical land cover information for the 1992 to 2005 period. The forecasting scenarios of land use (FORE-SCE) model were used to produce landscape projections for the 2006 to 2100 period as future projection. The FORE-SCE model also considers four IPCC SRES scenarios (A1/A1B, A2, B1, and B2) corresponding to the four storylines (Shukla, et al., 2019). The details of each storyline are shown below:

- The A1 storyline and scenario family describes a future world of very rapid economic growth, global population that peaks in mid-century and declines thereafter, and the rapid introduction of new and more efficient technologies. As one of A1 scenario family, A1B is selected in the USGS land cover model to represent balanced use across fossil and non-fossil energy sources.
- The A2 storyline and scenario family describes a very heterogeneous world. The underlying theme is self-reliance and preservation of local identities. Fertility patterns across regions converge very slowly, which results in continuously increasing global population. Economic development is primarily regionally oriented and per capita economic growth and technological change are more fragmented and slower than in other storylines.

Figure 2.28: Integrated Climate and Land Use Scenarios Land Use Projections of 2020

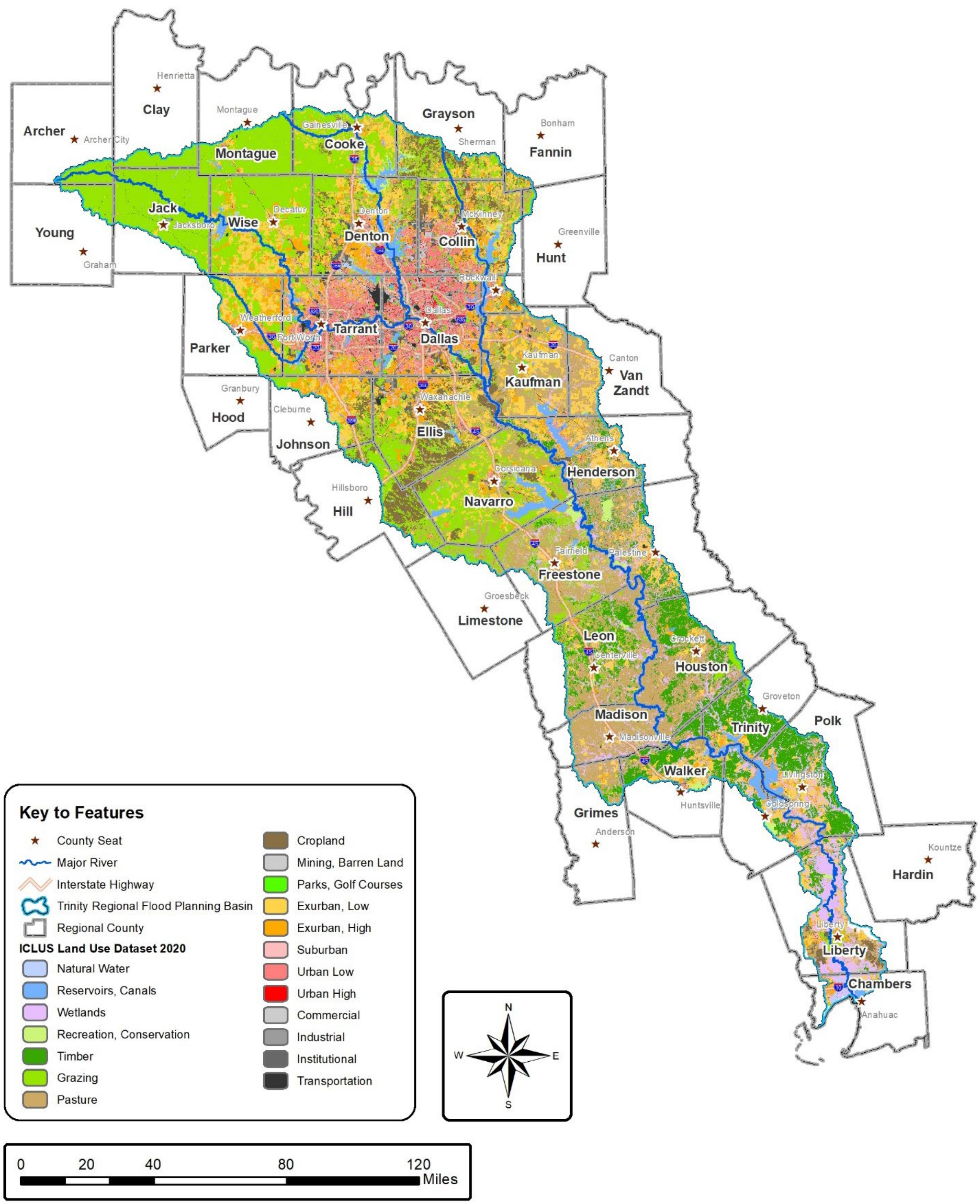
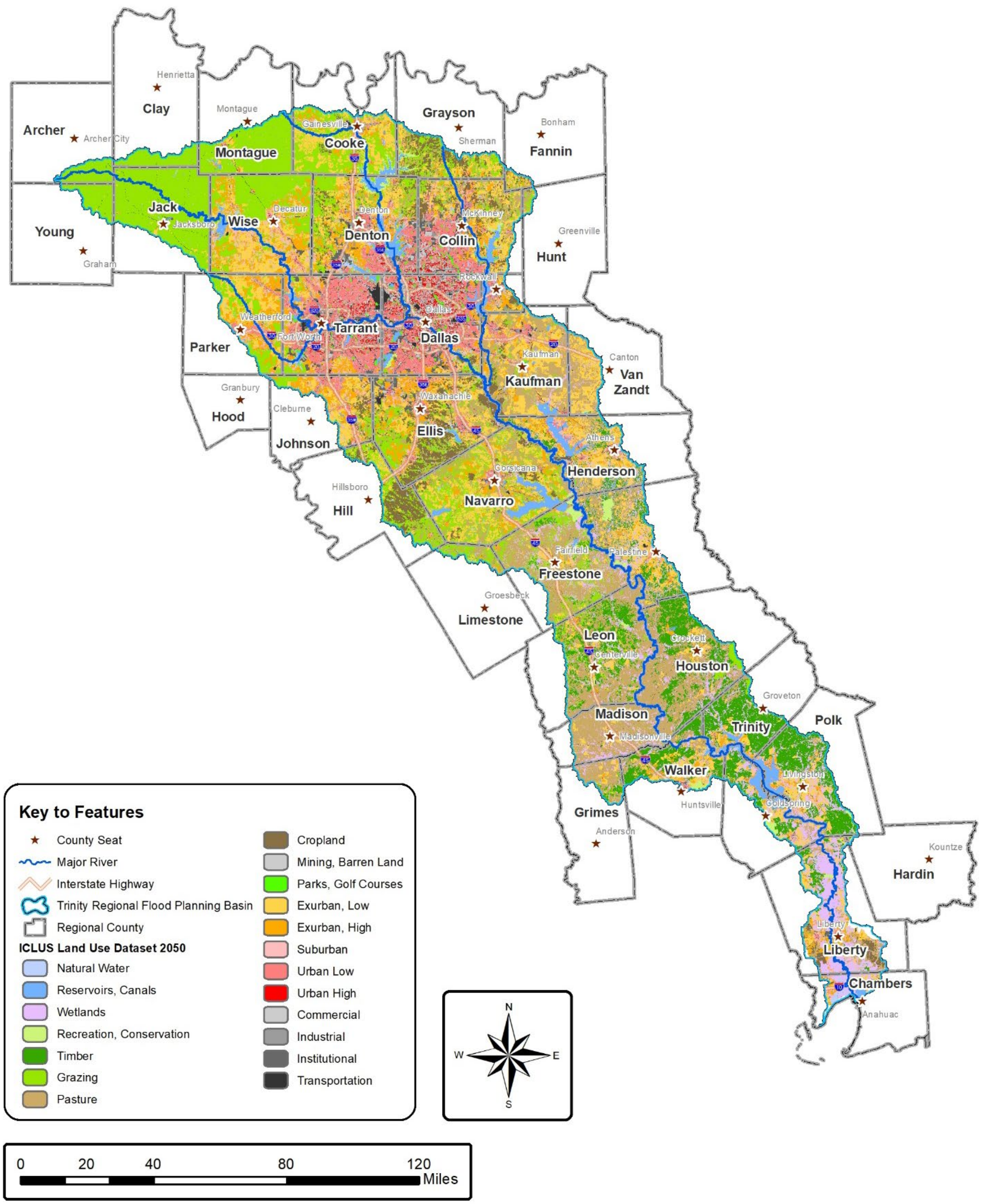


Figure 2.29: Integrated Climate and Land Use Scenarios Land Use Projections of 2050



- The B1 storyline and scenario family describes a convergent world with the same global population that peaks in midcentury and declines thereafter, as in the A1 storyline, but with rapid changes in economic structures toward a service and information economy, with reductions in material intensity, and the introduction of clean and resource-efficient technologies. The emphasis is on global solutions to economic, social, and environmental sustainability, including improved equity, but without additional climate initiatives.
- The B2 storyline and scenario family describes a world in which the emphasis is on local solutions to economic, social, and environmental sustainability. It is a world with continuously increasing global population at a rate lower than A2, intermediate levels of economic development, and less rapid and more diverse technological change than in the B1 and A1 storylines. While the scenario is also oriented toward environmental protection and social equity, it focuses on local and regional levels.

This USGS LULC projection dataset has been used for a wide variety of studies, including topics of regional weather and climate, landscape change on biodiversity, and water quality (Sohl, 2018). ***Figure 2.30*** and ***Figure 2.31*** illustrate the land cover conditions of Trinity Region from the USGS dataset of the years of 2020 and 2050.

From both the LULC projections from ICLUS and USGS datasets, rapid land development is found to occur in the Upper Subregion from 2020 to 2050, indicated by increased coverage of the "Suburban", "Urban Low" and "Urban High" (***Figure 2.30***) and "Developed" (***Figure 2.31***) areas in the DFW metroplex and its suburbs. Rapid land use changes will increase the flood risks for the communities in this region if no proactive flood planning and mitigation measures are taken. On the contrary, areas in the Trinity Region do not show significant changes in the future land use. The comparative analysis between the LULC data suggests that further studies (e.g., hydrologic/hydraulic analyses) should be conducted to provide more detailed information related to impacts from changes of LULC.

For the Upper Subregion, the NCTCOG collects the future land use planning data from individual cities (e.g., Plano, Dallas, Arlington, etc.) and integrates it into a regional future land use planning dataset (as shown by the land use conditions of 2055 in ***Figure 2.32***). This dataset provides a future land use condition scenario for the Upper Subregion and will be compared with the datasets from ICLUS and USGS for future flood risk analyses. In summary, the current and future projection of land cover and land use datasets suggest that the upper basin will experience rapid urban development with significant land use changes. It is highly recommended for communities to consider land use planning and projections in the future flood mitigation and planning to help communities mitigate their current and future vulnerability to floods.

Figure 2.30: United States Geological Survey 2020 Land Cover Projection

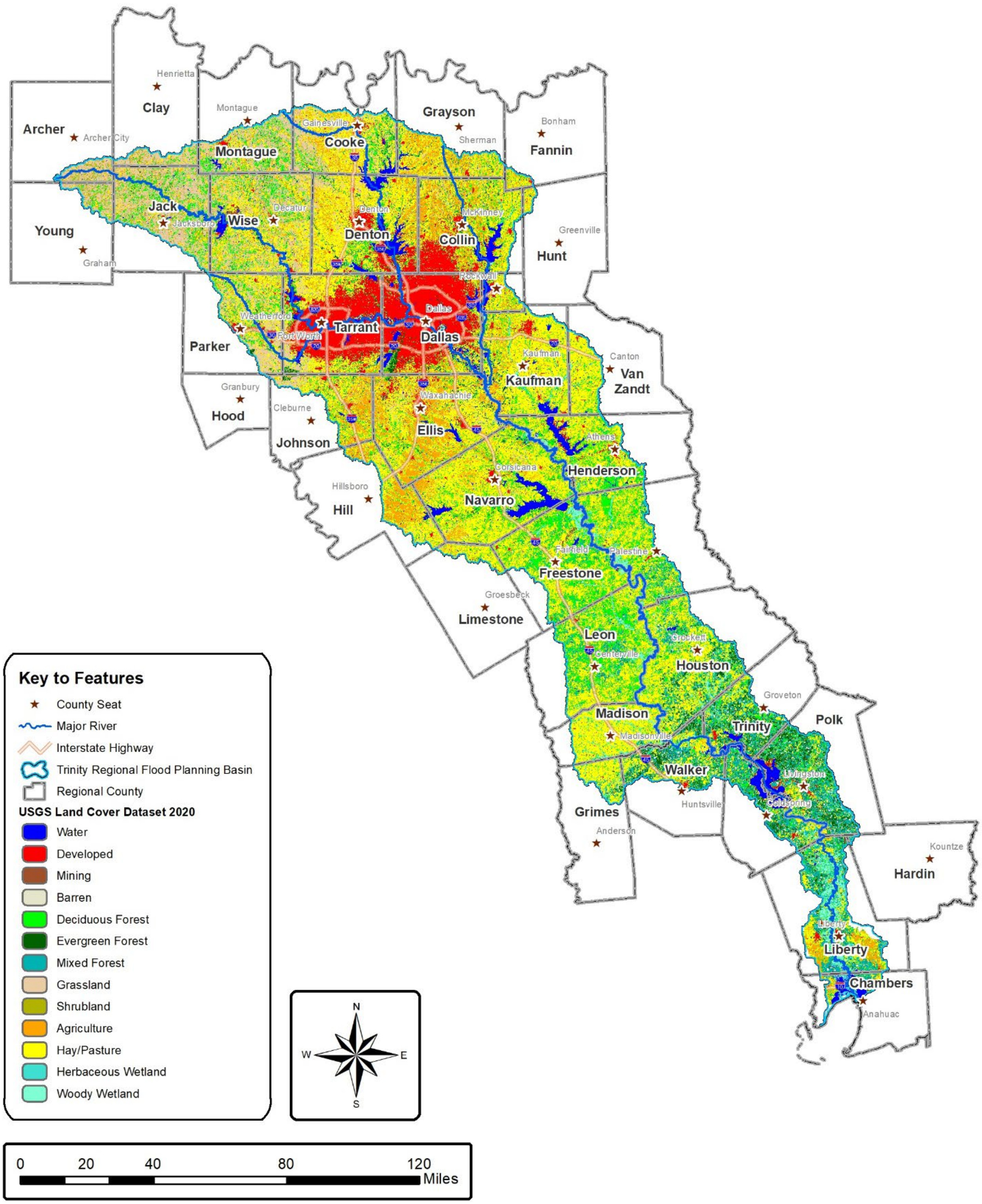


Figure 2.31: United States Geological Survey 2050 Land Cover Projection

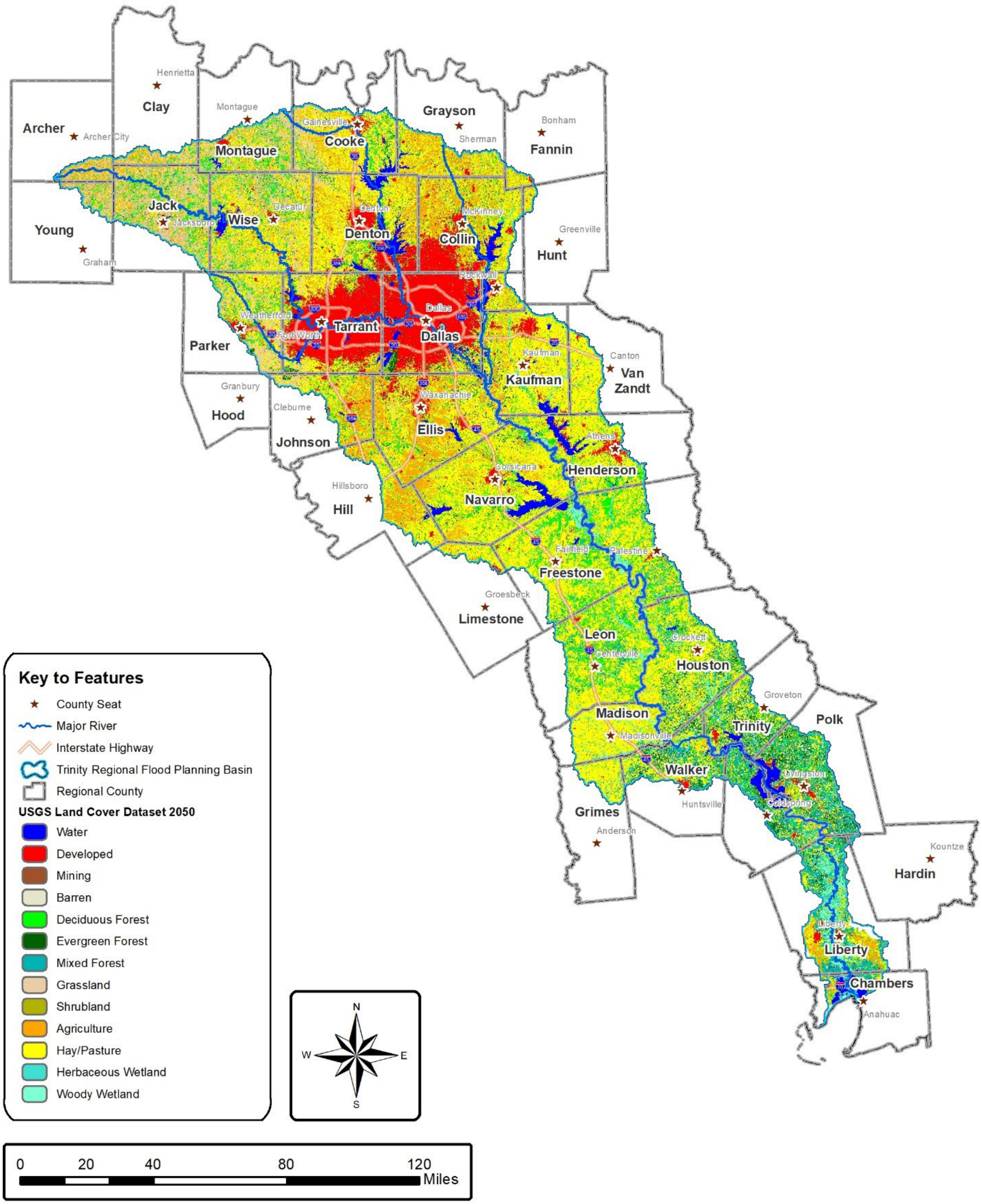
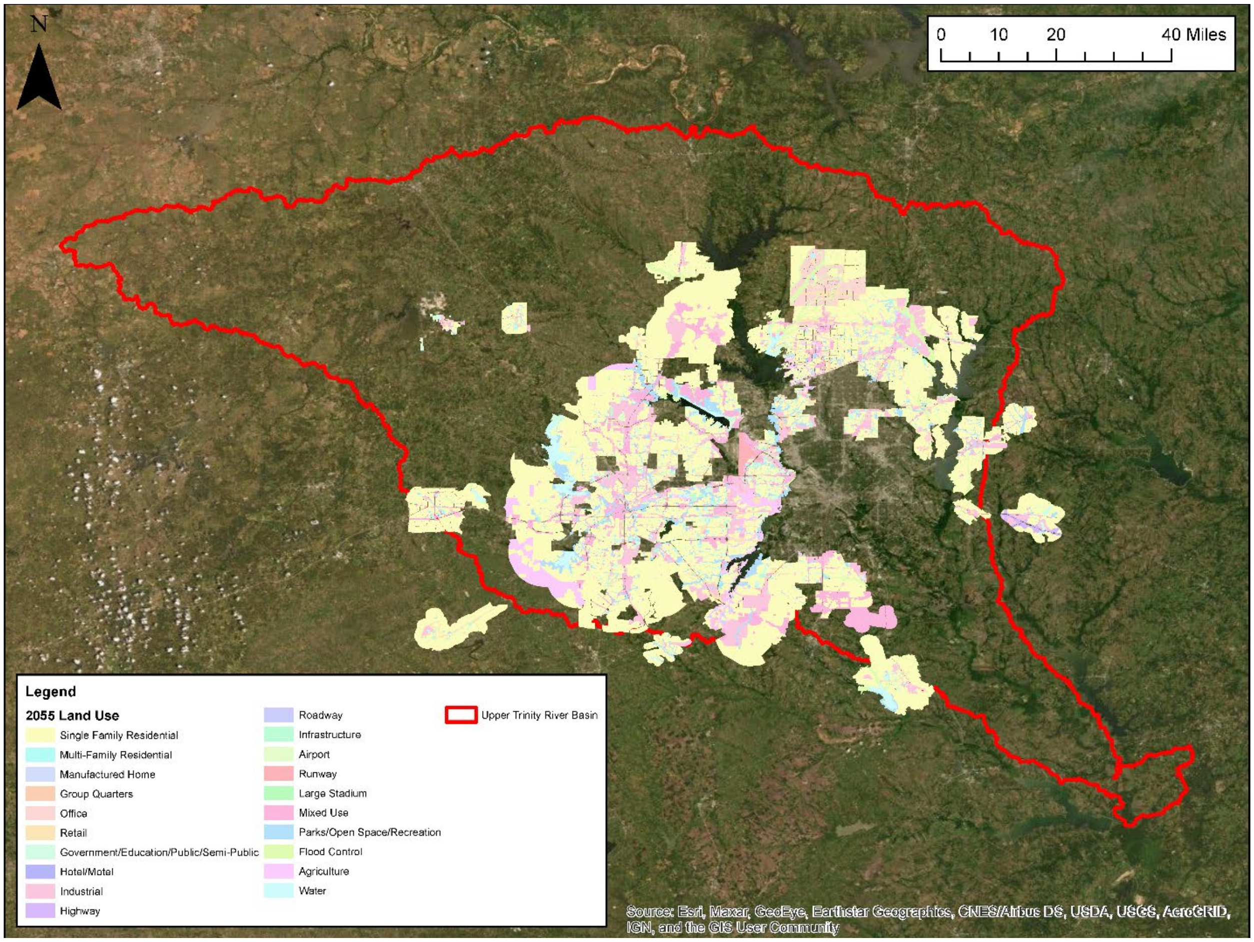


Figure 2.32: North Central Texas Council of Governments Land Use Projection in 2055



It is noted that the future land use and development trends discussed in the section were not used in determining future flood risk for this first regional flood plan due to uncertainties in the model projections and lack of local information. Further investigation is needed to evaluate the impact of LULC change in great details during future cycles of planning.

Population Growth

According to World Bank, 2.2 billion people, or around 29 percent of the world population, live in areas that experience various levels of inundation during 100-year floods (Rentschler & Salhab, 2020). FEMA estimates that 13 million Americans live within a 100-year flood zone. Recent research argues that the real number is about 41 million (Wing, et al., 2018). On one hand, the future flood conditions will significantly affect the people exposed to flood risks, leading to higher flood vulnerability over the areas with rapid population growth in the United States (Swain, et al., 2020).

On the other hand, the population dynamics, which show how and why populations change in structure and size over time, also has important interrelationships with the changes of land cover and land use, as well as water demands for all uses (National Academies of Science, Engineering, and Medicine, 1994). Rapid population growth results in expansion of urban and industrial lands, and depletion of wetlands, floodplains, and waterbodies, which can potentially impact the flood dynamics (Rahman, Tharzhiansyah, Rizky, & Vita, 2021). Identifying future growth, composition, and distribution of a population is crucial for flood planning.

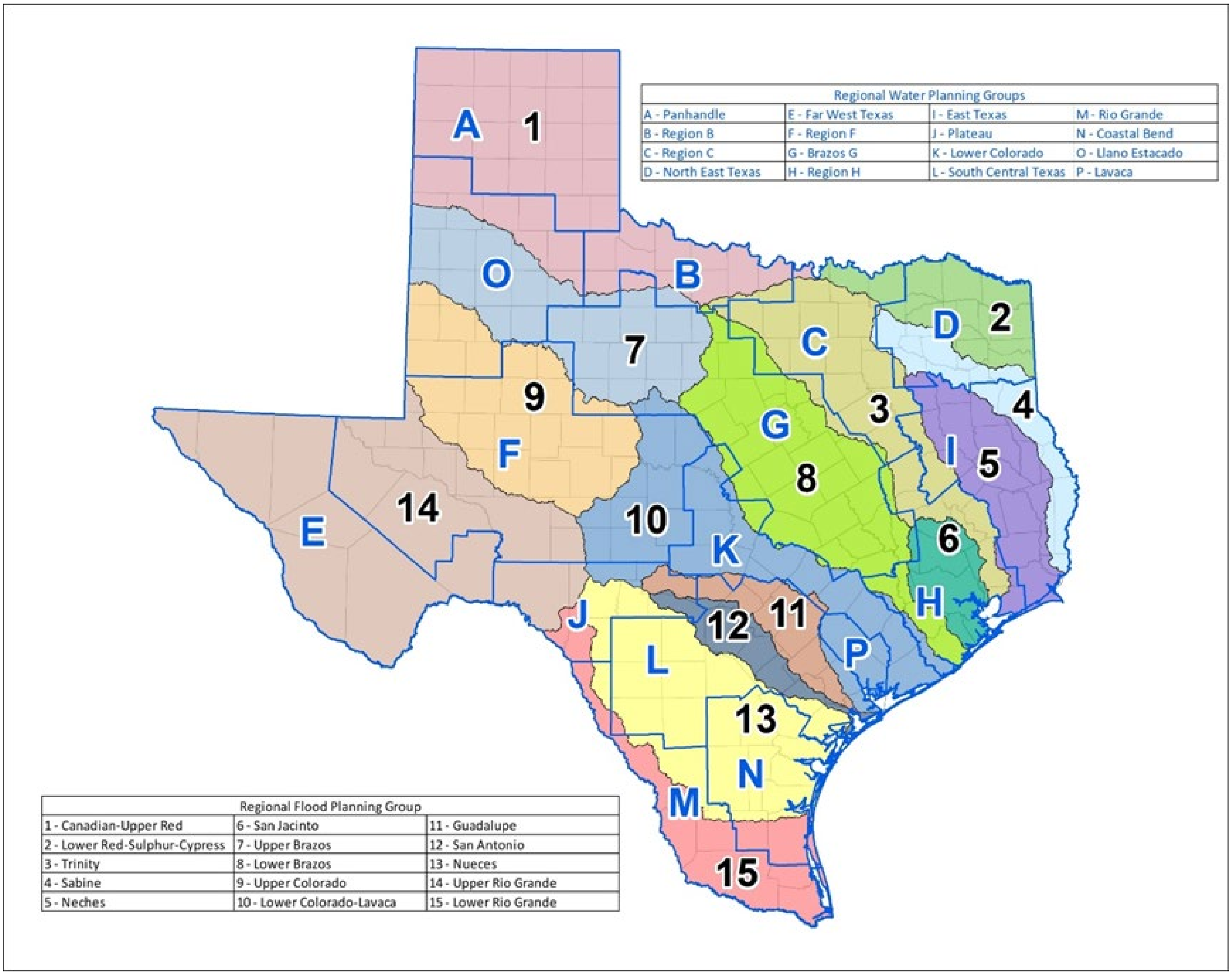
The population in Texas is expected to increase 42 percent between 2020 and 2050, from 29.7 million to 42.3 million people (TWDB, 2021). The projection was made based on a standard demographic methodology known as a cohort-component model, which uses different cohorts (combinations of age, gender, and racial-ethnic groups) and components of cohort change (birth, survival, and migration rates) to estimate future population at a county level. The Texas State Data Center provided the TWDB with the initial 30-year population projections for each county. The TWDB then extended these 30-year projections to the State Water Plan's 50-year planning horizon. In the State Water Plan, the state is divided into 16 RFPGs (***Figure 2.33***). Rapid population growth (over 35 percent) between 2020 and 2050 is expected to occur within Regions C (which includes the Dallas-Fort Worth metropolitan area) and H (which includes the Houston metropolitan area) as shown in ***Table 2.18***. It is noted that the majority of Region C and portions of Region H are contained in the Trinity Region (***Figure 2.33***).

Table 2.18: Decadal Population Growth for Regions C and H Water Planning Areas from 2020 to 2050

Region	2020	2030	2040	2050	Percent Growth from 2020 to 2050
C	7,504,000	8,649,000	9,909,000	11,260,000	50%
H	7,325,000	8,208,000	9,025,000	9,868,000	35%

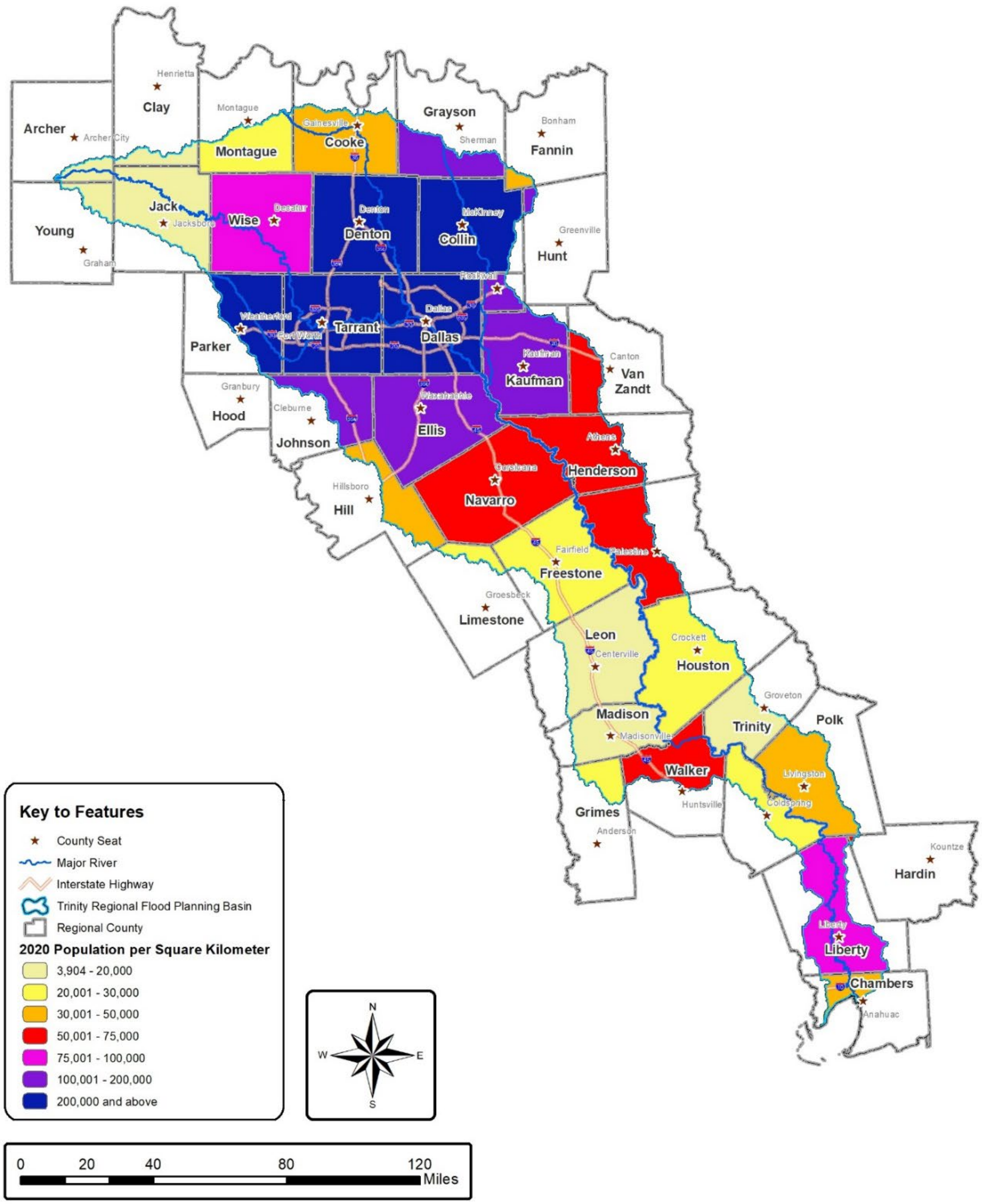
The population of the Trinity Region was estimated to be 7,853,969 in 2019 (TWDB, 2021), where higher population density is present in the Trinity Region's upper reaches (***Figure 2.34***). As an example, the projected population for each county in Region C and Region H in the Trinity Region is listed in ***Table 2.18***. Kaufman County and Rockwall County are projected to more than double their current population by 2050 as shown in ***Table 2.19***. The counties with over one million population, such as Collin, Dallas, and Tarrant counties, will also have rapid growth (over 30 percent) by 2050. Not only will the population growth demand for significantly increased water supply, but also will change regional land cover and land use conditions that could alter the floodplain and increase flood risks in these areas.

Figure 2.33: Texas Water Development Board Regional Water Planning Areas and the Trinity Region



Source: TWDB, 2016

Figure 2.34: Population Density of the Trinity River in 2020



Source: TWDB County Population Projections in Texas: 2020-2070 population projections by county (TWDB, 2021)

Table 2.19: Decadal Population Growth for all the Counties in the Region C and Region H Water Planning Areas from 2020 to 2050

Region	County	2020	2030	2040	2050	Percent Growth (from 2020 to 2050)
C	Collin	1,050,506	1,239,303	1,497,921	1,807,279	72%
C	Cooke	40,903	44,035	46,984	52,427	28%
C	Dallas	2,587,960	2,871,662	3,180,529	3,429,783	33%
C	Denton	891,063	1,115,119	1,329,551	1,584,015	78%
C	Ellis	191,638	241,778	280,745	360,584	88%
C	Fannin	38,330	43,084	52,891	69,328	81%
C	Freestone	20,437	21,077	22,947	31,142	52%
C	Grayson	135,311	149,527	159,610	178,907	32%
C	Henderson	67,579	72,592	78,504	85,901	27%
C	Jack	9,751	10,409	10,817	11,033	13%
C	Kaufman	146,389	195,107	242,354	306,833	110%
C	Navarro	52,505	59,556	65,958	74,213	41%
C	Parker	201,491	260,194	276,979	360,125	79%
C	Rockwall	119,410	160,315	213,619	246,938	107%
C	Tarrant	2,004,609	2,279,113	2,580,325	2,799,127	40%
C	Wise	79,882	95,086	110,343	135,797	70%
H	Chambers	42,162	50,543	59,210	68,541	63%
H	Leon	18,211	19,536	20,603	22,071	21%
H	Liberty	86,303	97,227	107,618	118,048	37%
H	Madison	14,753	15,817	16,786	17,872	21%
H	Polk	42,911	47,935	51,888	55,259	29%
H	San Jacinto	29,610	32,627	34,996	37,614	27%
H	Trinity	12,754	13,793	13,897	13,504	6%
H	Walker	71,800	75,243	77,724	80,050	11%

Note: Regions C and H cover most area in the Trinity Region; and they are the most populated water planning regions in Texas

Consequently, an integrated assessment of linkage between population dynamics and future flood planning is highly recommended for the Trinity Region.

Sea Level Change

Global Mean Sea Level (MSL) has risen by about 0.2 meters (or eight inches) at a rate of 1.7 millimeters per year since reliable record keeping began in 1880 (Church & White, A 20th Century Acceleration in Global Sea-Level Rise, 2006). Research shows that rising sea levels can affect coastal regions in many ways including shoreline erosion, loss of land, tidal flooding, and saltwater intrusion into groundwater (Anthoff, Nicholls, Tol, & Vafeidis, 2006), (Nicholls & Tol, Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century, 2006), (Nicholls & Cazenave, Sea-Level Rise and Its Impact on Coastal Zones, 2010), (Church & White, Sea-Level Rise from the Late 19th to the Early 21st Century, 2011). The contributions to sea level rise come primarily from two factors related to global warming — increases in water mass from melting ice and glaciers, and thermal expansion of seawater (Church & White, A 20th Century Acceleration in Global Sea-Level Rise, 2006) (Nicholls & Cazenave, Sea-Level Rise and Its Impact on Coastal Zones, 2010) (Church & White, Sea-Level Rise from the Late 19th to the Early 21st Century, 2011).

The rapid changes observed in polar regions suggest that the ice sheets melt faster than previously anticipated due to global warming (Masson-Delmotte, et al., 2021) , and many studies show that the sea level is projected to rise another 0.3 to 1.8 meters (one to four feet) by 2100 as global warming continues (Rahmstorf, 2007), (Vermeer & Rahmstorf, 2009), (Jevrejeva, Moore, & Grinsted, 2010), (Nicholls & Cazenave, Sea-Level Rise and Its Impact on Coastal Zones, 2010), (Walsh, et al., 2014). Climate-induced sea level rise will affect a large fraction of the cities located along the coastline by the end of the 21st century (Church, et al., 2013). Meanwhile, high-tide flooding is increasingly common due to years of sea level increases. High tide flooding occurs when tides reach anywhere from 0.53 to 0.61 meters (1.75 to two feet) above the daily average high tide and inundate low-lying streets (NOAA, 2021). Being one of the largest coastal communities in the world, the Houston-Galveston region is highly susceptible to coastal and inland flooding from hurricanes (storm surge and rainfall), high tides, and other extreme storms. Because the Trinity River drains into Galveston Bay, the change of sea level inevitably affects the riverine hydraulics and ecology of the watershed. Thus, the sea level rise near the outlet of the Trinity River must be evaluated by analyzing the MSL measured at tide gauges to help us understand sea level trends and potential hydrodynamic changes to the Trinity River.

Because sea level rise varies around the globe, relative sea level measured locally provides more insights to engineering practices in coastal resilience and flood mitigation for the study area. Five NOAA tide gauges located along the Gulf Coast and near the Trinity River outlet were identified to provide water elevation records: Sabine Pass (8770570), Galveston Pier 21 (8771450), Galveston Pleasure Pier (8771510), Freeport (8772440), and Freeport (8772447) (***Figure 2.35***). All five gauges have monthly data and have more than 50 years of records available from NOAA (2013a); in particular, the Galveston Pier 21 gauge has the longest time series, data ranging from January of 1904 to April of 2021. ***Table 2.20*** summarizes location and period of record for each gauge. Available tidal records are referenced to MSL vertical datum.

Figure 2.35: Locations of the Five Selected National Oceanic and Atmospheric Administration Tide Gauges

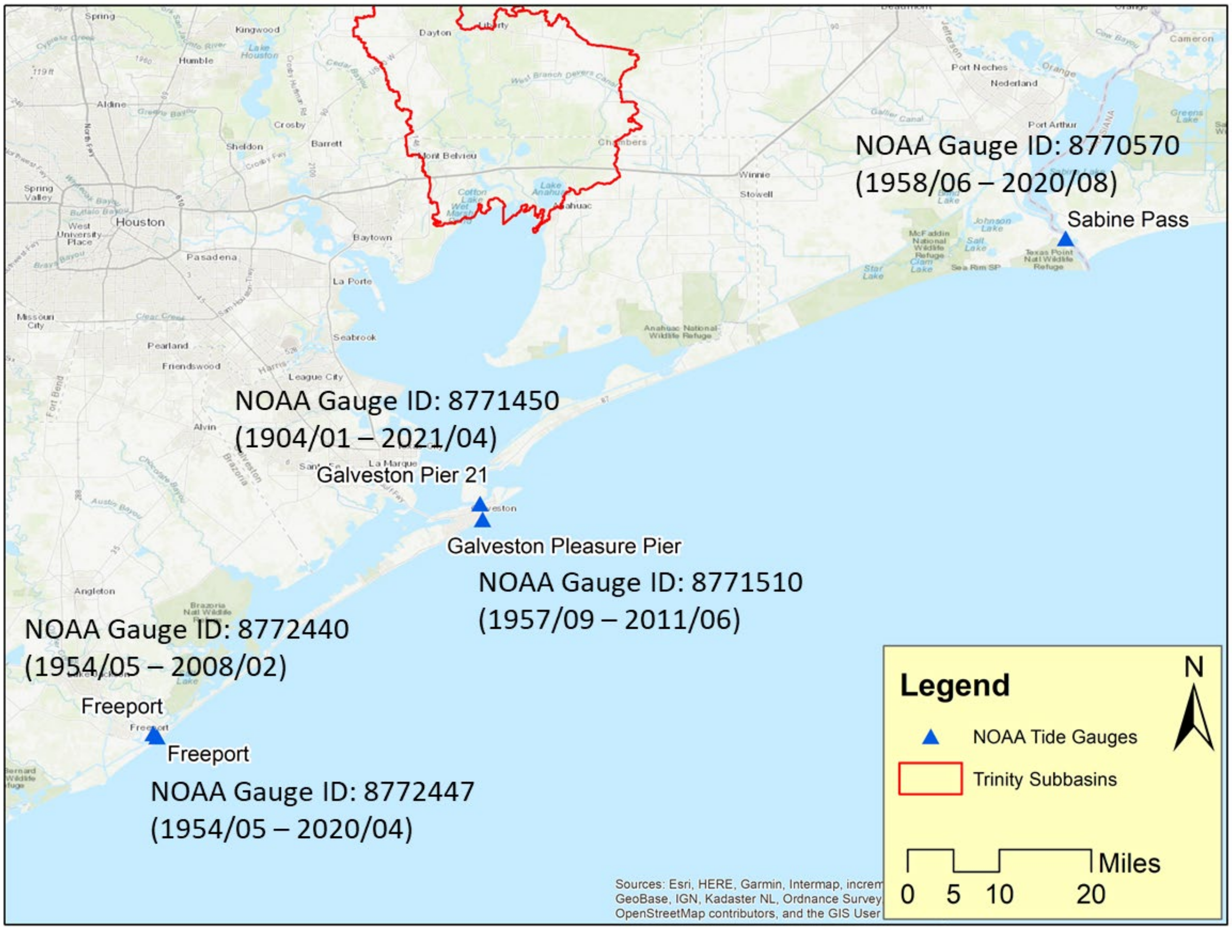


Table 2.20: Tide Gauges Along the Gulf Coast

Gauge ID	Gauge Name	Latitude & Longitude Coordinates	Data Availability Period
8770570	Sabine Pass	29.7284, -93.8701	1958/06 – 2020/08
8771450	Galveston Pier 21	29.3100, -94.7933	1904/01 – 2021/04
8771510	Galveston Pleasure Pier	29.2853, -94.7894	1957/09 – 2011/06
8772440	Freeport	28.9483, -95.3083	1954/05 – 2008/02
8772447	Freeport	28.9433, -95.3025	1954/05 – 2020/04

To examine the trend of MSL along the Galveston Gulf Coast, historical data from the five selected tide gauges is plotted together with a fitted regression line as shown in ***Figure 2.36***. All five gauges show a similar rise in MSL trend between 1980 and 2021. The slope (0.0068) of the regression equation implies the rate (6.8 millimeter per year) of the relative sea level rise for these five locations. As previously noted, the Galveston Pier 21 gauge has the longest time series data and is located closest to the outlet of the Trinity River Estuary. Linear regression is used to simply demonstrate an average change rate of the sea level to date based on available data. The linear trendline of the Galveston Pier 21 gauge is similar to the other four nearby tide gauges, as shown in ***Figure 2.37***.

The trend analysis shows that the MSL at the Galveston Pier 21 gauge has risen 0.167 meter (0.547 feet) between 1904 and 2021. If the trend continues at the current rate (6.6 millimeters per year), the MSL at the Galveston Pier 21 gauge in 2050 will result in an additional MSL increase of 0.19 meter (0.627 feet), or a total increase of 0.358 meter (1.175 feet) since 1904.

Figure 2.36: Plot of the Mean Sea Level at the Five Tide Gauges

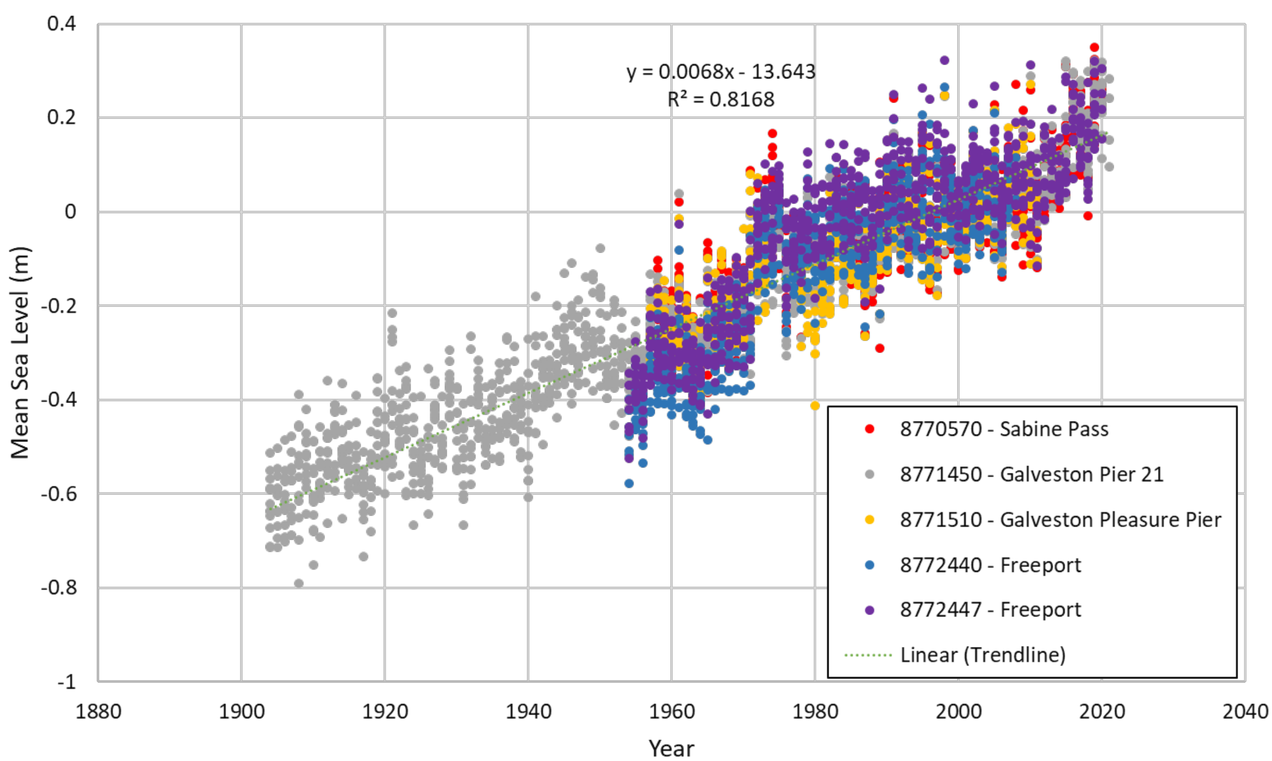
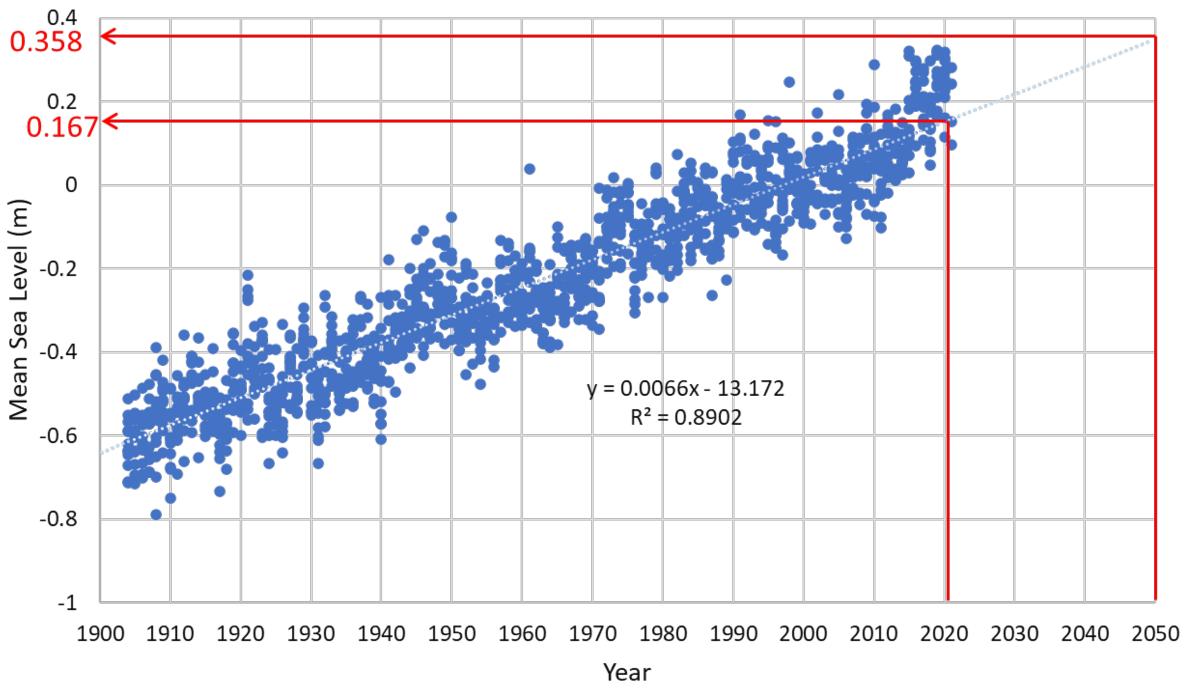


Figure 2.37: Plot of the Mean Sea Level at Gauge: 8771450, Galveston Pier 21, TX



To account for the uncertainty from the expected ice melting volume and ocean temperatures, researchers and engineers from the NOAA and USACE have made predictions based on ranges from low to high (Huber & White, 2017). The governing equations for calculating the sea level change are shown below:

Global Sea Level Change: $E(t) = 0.0017t + bt^2$

In the above equation, t refers to the number of years starting in 1992 (NOAA considers 1992 as the center year of the NOAA National Tidal Datum Epoch (NTDE) ranging from 1983–2001), 0.0017 is the global sea level rise rate (1.7 millimeters per year) and b is a constant parameter.

Relative (Regional) Sea Level Change: $E(t) = Mt + bt^2$

In the above equation, M is the combination of the global sea level rise rate (1.7 millimeters per year) plus the local Vertical Land Movement (VLM). M can be obtained from NOAA's Sea Level trends website (NOAA, 2022) and NOAA Technical Report NOS CO-OPS 65 (Zervas, Gill, & Sweet, 2013).

To visualize different sea level scenarios for any NOAA tide gauge, the data from an online Sea Level Change Curve Calculator (USACE, 2022) can be used. This online tool was developed under the USACE Comprehensive Evaluation of Projects with respect to Sea Level Change in support of vulnerability assessments for USACE coastal projects. The USACE Sea Level Change

Curve Calculator includes the datasets from four studies, namely: the NOAA Technical Report OAR CPO-1 titled Global Sea Level Rise Scenarios for the United States National Climate Assessment (Parris, et al., 2012), the USACE Incorporating Sea Level Changes in Civil Works Programs (Department of the Army, 2013), the Region Sea Level Scenarios for Coastal Risk Management Report by the Coastal Assessment Regional Scenario Working (Hall, et al., 2016), and the United States Global Change Research Program 2017 (Wuebbles, et al., 2017). Different parameters of *b* were utilized to represent different sea level scenarios among the four studies.

Figure 2.38 through ***Figure 2.41*** show the ranges of estimated relative sea level change at the Galveston Pier 21 gauge from (Parris, et al., 2012), (Huber & White, 2017), (Department of the Army, 2013), and (Hall, et al., 2016) for the period of 1992–2050 (Note: (Huber & White, 2017) only shows a ranger from 2000 to 2050). As summarized in ***Table 2.21***, three studies unanimously show the lowest projected sea level is approximately 0.37 meter (1.214 feet) by 2050 (Parris, et al., 2012), (Department of the Army, 2013), (Hall, et al., 2016), and their results are consistent with the historical records by assuming that the sea level rises at the current rate of 6.6 millimeters per year. In other words, the lowest sea level rise scenarios conducted by (Parris, et al., 2012), (Department of the Army, 2013), (Hall, et al., 2016), all produce a rate (6.3 millimeters per year) similar to the average rise rate (6.6 millimeters per year) from 1904 to 2021 at Galveston Pier 21.

Figure 2.38: Estimated Relative Sea Level Change Projections – Gauge: 8771450, Galveston Pier 21, TX (Parris, et al., 2012)

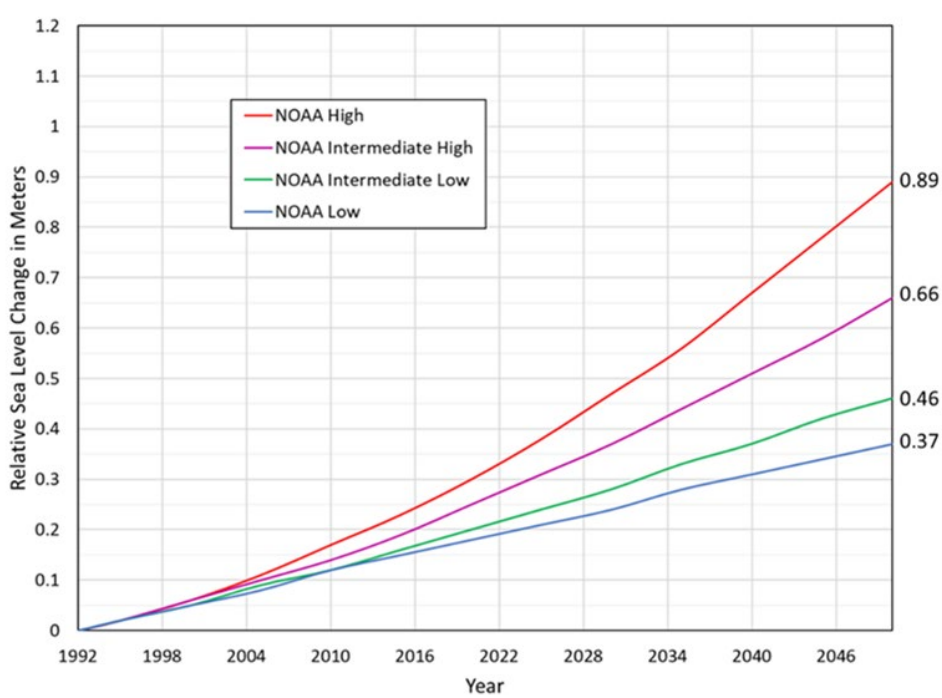


Figure 2.39: Estimated Relative Sea Level Change Projections – Gauge: 8771450, Galveston Pier 21, TX (Department of the Army, 2013)

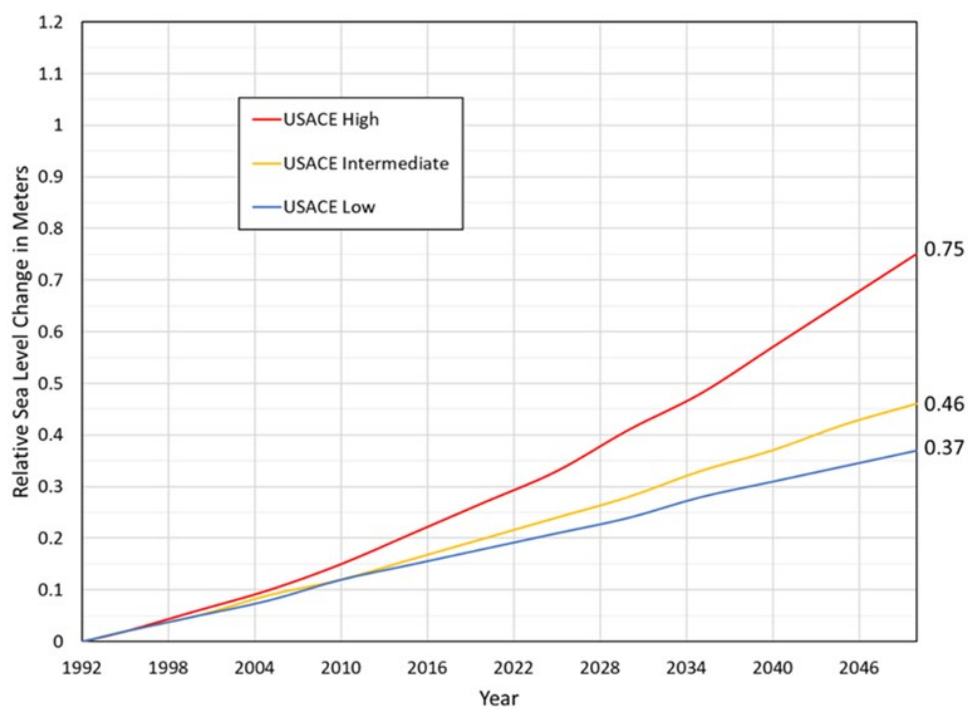


Figure 2.40: Estimated Relative Sea Level Change Projections – Gauge: 8771450, Galveston Pier 21, TX (Hall, et al., 2016)

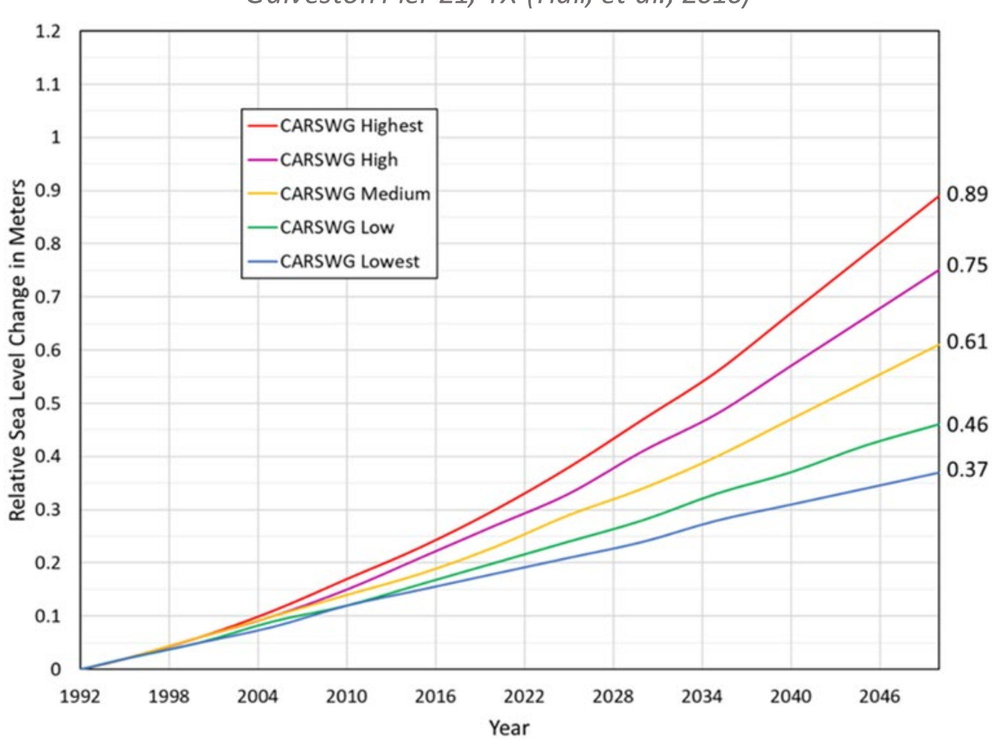


Figure 2.41: Estimated Relative Sea Level Change Projections - Gauge: 8771450, Galveston Pier 21, TX (Huber & White, 2017)

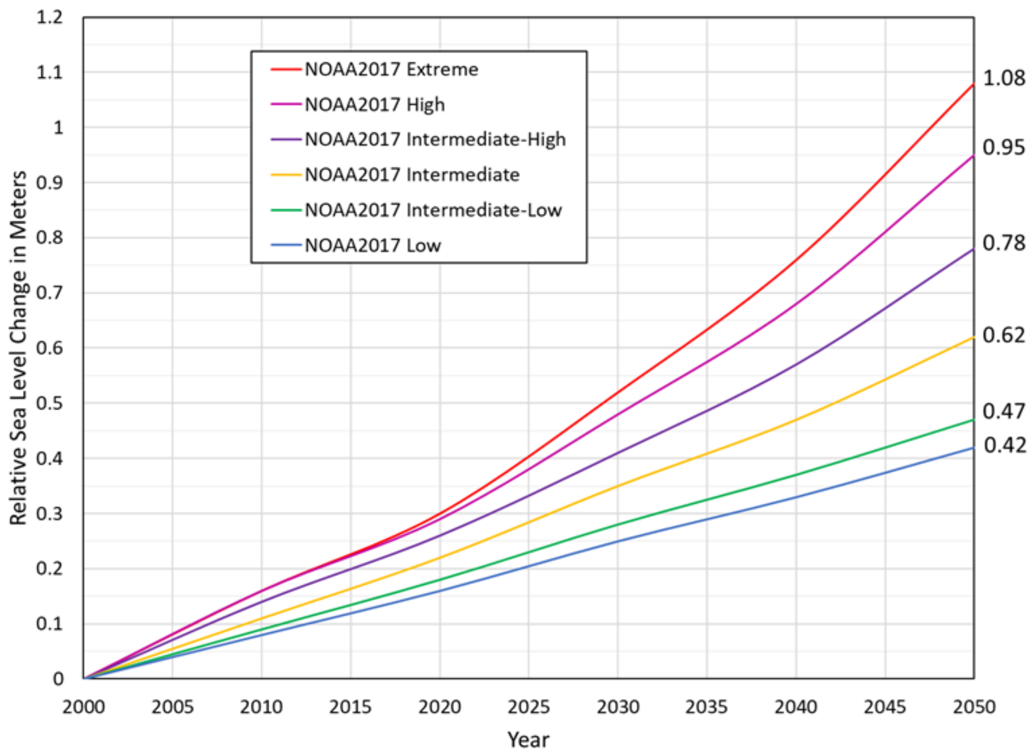


Table 2.21: Estimated Relative Sea Level in Meters for 2020 and 2050 from Various Studies

Study	2020		2050		Delta (Δ) 2020 and	Between 2050
	Lowest (m)	Highest (m)	Lowest (m)	Highest (m)	Lowest (Δ)	Highest (Δ)
NOAA 2012	0.18	0.3	0.37	0.89	0.19	0.59
USACE 2013	0.18	0.27	0.37	0.75	0.19	0.48
CARSWG 2016	0.18	0.3	0.37	0.89	0.19	0.59
NOAA 2017*	0.16	0.3	0.42	1.08	0.26	0.78

**Note:* (Huber & White, 2017) *projects relative sea level changes from 2000 and other three studies* (Parris, et al., 2012)*;* (Department of the Army, 2013)*; and* (Hall, et al., 2016) *project relative sea level changes from 1992.*

The NOAA 2017's extreme scenario forecasts a sea level rise of 1.11 meters (3.642 feet) in 2050. Under the extreme scenario, an increase of 0.78 meters (2.560 feet) sea level would be expected to occur from 2020 to 2050. The delta values of the estimated sea levels between 2020 to 2050 (***Table 2.21***) from various scenarios indicate that the estimated sea level in 2050 range from 0.19 meters to 0.78 meters.

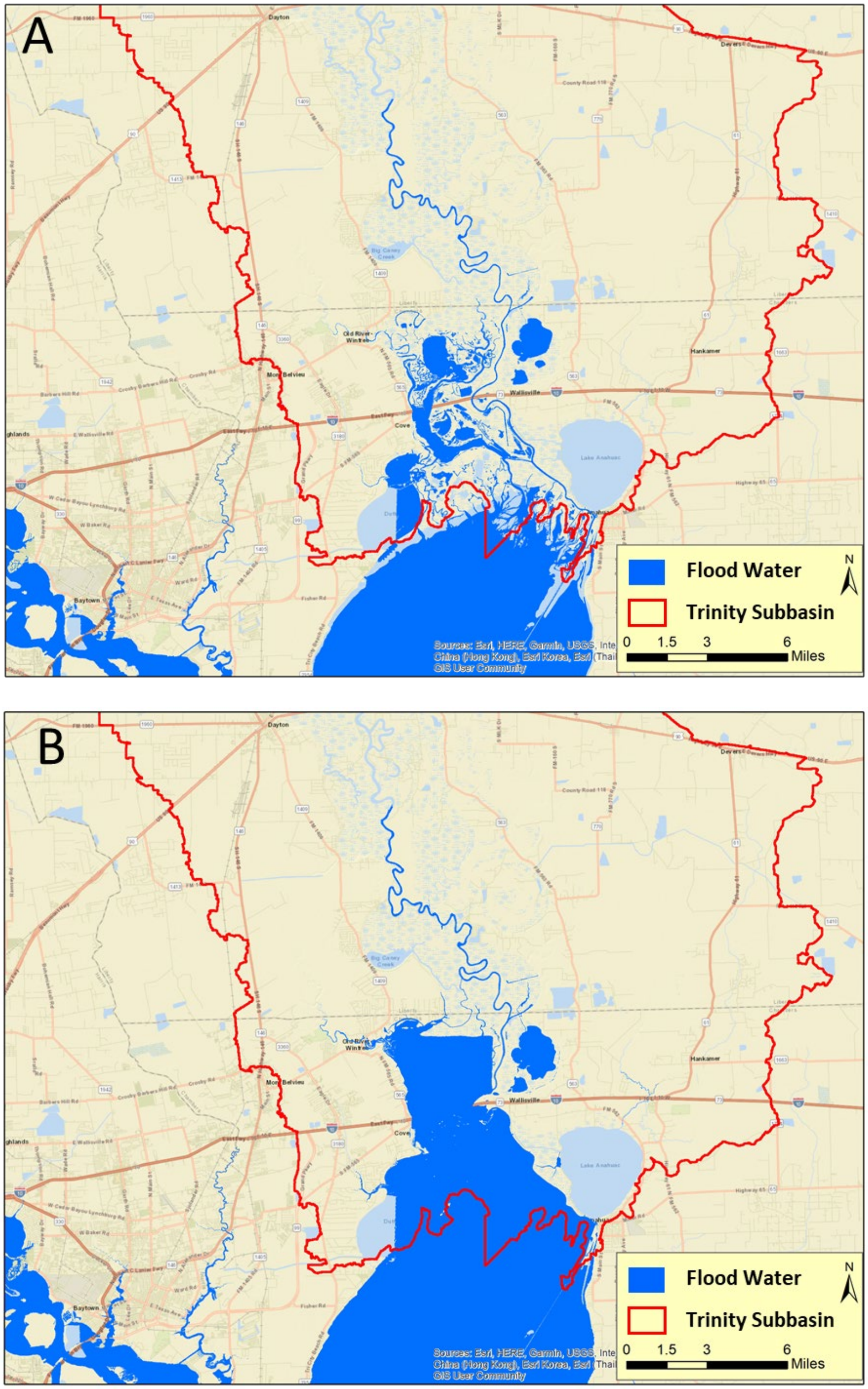
Dr. Nick Fang at the University of Texas at Arlington performed a GIS exercise applying increase of sea level from both low and high scenarios to the study area, as a demonstration of the potential land that would be inundated. ***Figure 2.42*** shows the flooded area (blue) in the Trinity Region caused by a rise of 0.19 meters (Lowest Scenarios from (Parris, et al., 2012), (Department of the Army, 2013), and (Hall, et al., 2016) studies) and 0.78 meters (Highest Scenario from (Huber & White, 2017)) respectively by 2050. While the additional area inundated by sea level rise is limited to the outlet of the Trinity River, the impacts from sea level rise on the Trinity Region cannot be neglected. For more information, Sea Level Rise Viewer from NOAA (https://coast.noaa.gov/slr/) can be utilized to visualize the sea level rise along with potential coastal flooding impact areas and relative depths. Meanwhile, Dr. Fang highly recommends continued monitoring of the local sea level through the tide gauges and/or buoys along the coastline for future flood mitigation and planning.

Land Subsidence

Land subsidence, as a sudden sinking or a gradual settling of the Earth's surface on account of the subsurface movement of earth materials, is regarded as a worldwide problem leading to numerous adverse impacts on infrastructure and the environment (Galloway, Jones, & Ingebritsen, Land Subsidence in the United States, 1999). The natural and human-induced causes of land subsidence include tectonic motion; aquifer-system compaction associated with groundwater, soil, and gas withdrawals; underground mining; etc. ((Galloway, Jones, & Ingebritsen, Land Subsidence in the United States, 1999); (Xue, Zhang, Ye, Wu, & Li, 2005); (Braun & Ramage, 2020); (Herrera-García, et al., 2021)). During the past century, land subsidence caused by the groundwater depletion occurred at approximately 200 locations in 34 countries (Herrera-García, et al., 2021).

In the United States, more than 17,000 square miles in 45 states have been directly affected by land subsidence (Galloway, Jones, & Ingebritsen, Land Subsidence in the United States, 1999). Land subsidence is of particular concern, especially in flat coastal areas such as the Houston-Galveston Region, since land subsidence in conjunction with the sea level rise would exacerbate the severity of flooding in the neighboring watersheds (Galloway & Coplin, Managing Coastal Subsidence, 1999).

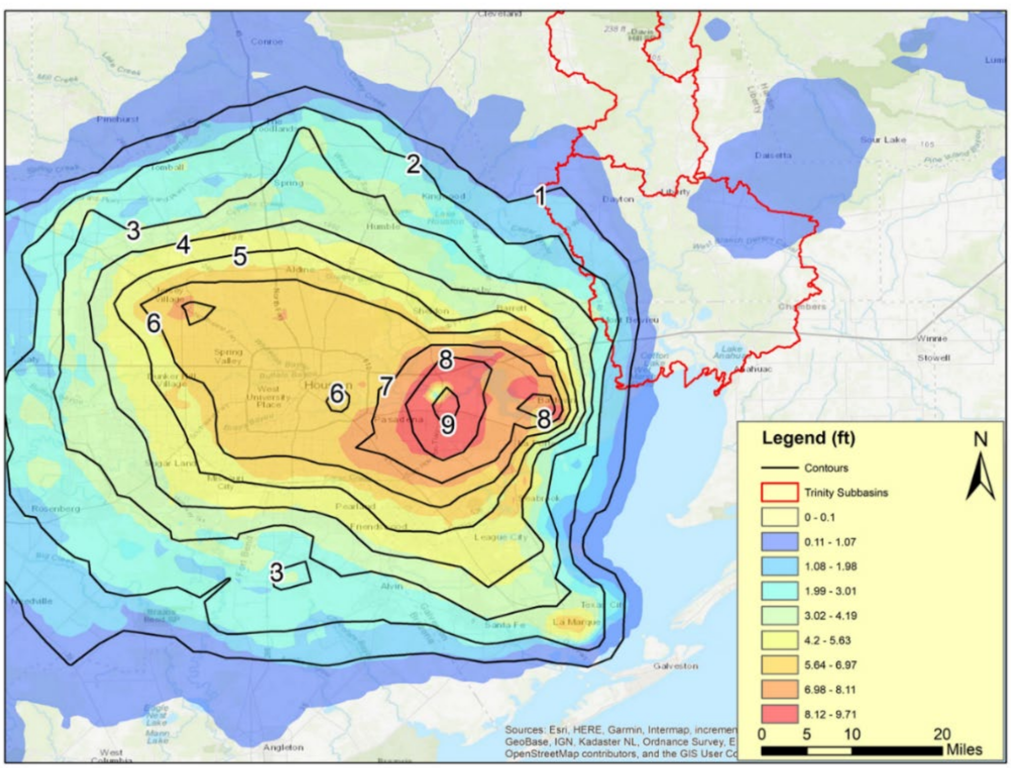
Figure 2.42: Potentially Impacted Area in the Trinity Region Caused by the Increase of (A) 0.19 Meter Sea Level Rise, (B) 0.78 Meter Sea Level Rise by 2050



According to a report produced by the USGS, land subsidence in the Houston-Galveston region continues to occur throughout the 20th century (Stork & Sneed, 2002). Two additional studies by (Kasmarek & Johnson, 2013) and (Liu, Li, Fasullo, & Galloway, 2020) have been completed for investigating the land subsidence in the Houston-Galveston region. Given that the downstream portion of the Trinity River is close to the Houston region, the expansion of land subsidence impacts the H&H of the watershed. Thus, potential impact needs to be understood for the area subject to land subsidence in the Trinity Region.

(Kasmarek & Johnson, 2013) simulated and measured land subsidence between 1900s to 2000 for the Houston-Galveston region. To better illustrate the land subsidence conditions in the Trinity Region, the boundary of the Trinity River is overlaid with the simulated land subsidence data as shown in ***Figure 2.43***. The highest land subsidence (9.7 feet) areas can be found in southeastern Harris County.

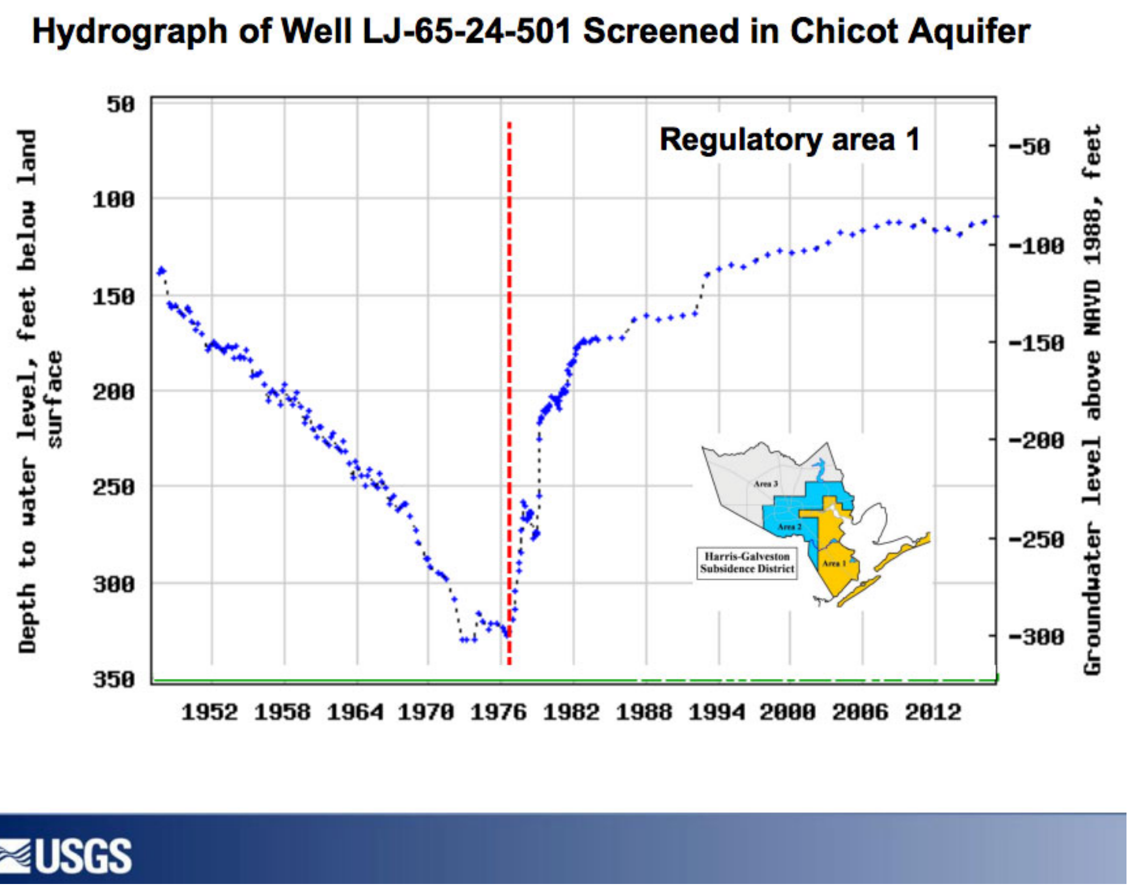
Figure 2.43: Land Subsidence Simulated by the Houston Area Groundwater Model (Liu, Li, Fasullo, & Galloway, 2020)



Since the 1970s, several subsidence regulatory entities (Harris-Galveston Coastal Subsidence District, Fort Bend Subsidence District, Lone Star Groundwater Conservation District, and Brazoria County Groundwater Conservation District) have established various policies to manage groundwater pumping activities and enforce groundwater regulations. The well monitoring data from USGS shows that groundwater levels in the region rose significantly once subsidence districts were established, thereby mitigating subsidence issues in the region (Texas Living Water Project, 2017).

Figure 2.43 shows that when the Harris-Galveston Coastal Subsidence District was created around 1976 (red line), groundwater levels in the Chicot Aquifer rose substantially and have remained relatively constant since 2006, suggesting that the rate of land subsidence should not change significantly compared to the current condition. In other words, the future impact of land subsidence to the Trinity Region in 2050 will not increase, but rather remain the same as 2020 (***Figure 2.44***). The current regional flood plan did not consider land subsidence in determining future flood risk due to its insignificant changes as observed and projected. While the impacted area by land subsidence is considered minimal for the Trinity Region, the Trinity RFPG supports long-term monitoring and management of the groundwater resources for future planning cycles.

Figure 2.44: Chicot Aquifer Hydrograph



Source: USGS Presentation: Connecting Groundwater level altitudes, Compaction and Growth

Changes in Floodplain

Future rainfall patterns are also considered regarding potential impacts to the floodplains in this plan. To aid the regional planning groups, the Office of the Texas State Climatologist provided TWDB with guidance on how to incorporate future rainfall in its April 16, 2021 report, titled “Climate Change Recommendations for Regional Flood Planning.” (Nielsen-Gammon & Jorgensen, 2021) The report states that 24-hour, 100-year rainfall amounts increased by approximately 15 percent between 1960 and 2020. The climatologist coupled historic rainfall data with results from climate models to develop a relationship between extreme rainfall amounts and future increases in global temperature. Percent increase in future precipitation was developed for both urbanized and rural watershed conditions. Due to the uncertainty of predicting weather patterns for extreme rainfall events, the climatologist provided a minimum and maximum range for estimating future rainfall increases. The climatologist found even more uncertainty when analyzing rural and large river catchments due to future decreases in soil moisture. This uncertainty resulted in the climatologist developing a range of future rainfall increases as shown in ***Table 2.22***.

Table 2.22: Trinity Region Range of Potential Future Rainfall Increase 2050-2060

Location	Range - Minimum	Range - Maximum
Urban Areas	12%	20%
Rural Areas/River	-5%	10%

Sedimentation and Major Geomorphic Changes

Anticipated Impacts of Sedimentation in Flood Control Structures

Flood control structures prevent floodwaters, either stormwater or coastal water, from inundating vast amounts of land and property. Hydraulic works (levees, flood walls, dams, river diversions, etc.) represent the single, most important form of human adaptation to the flood hazard. In the Trinity Region, the most prominent flood control structures at a regional scale are levees, dams, and their associated reservoirs. In general, reservoirs are the flood control facilities that are most susceptible to the impacts of sediment deposition over time within this watershed. While sedimentation in reservoirs is a directly measurable impact and is typically accounted for in the design, the plan needs to recognize the reduction in conveyance capacities due to sedimentation in channels, and floodplain fringes, and ultimately bays and estuaries.

Historically, reservoirs have been designed with relatively large storage capacities to offset sediment deposition and achieve the desired reservoir life. In general, reservoir design includes a sedimentation pool, commonly known as “dead storage”, which is a portion of its storage capacity that is essentially set aside for sediment deposition during the design life of the structure. It could be argued that the operation of the reservoir for authorized purposes, such as municipal water supply, flood control, hydropower generation, and recreation, is not significantly impacted if sediment accumulation does not exceed the dead storage capacity. However, large flood events can carry relatively large loads of sediment that can be deposited in portions of the reservoir that are outside of the designated dead storage areas. Thus, provisions need to be taken for sediment management in order to achieve a sustainable long-term use of the facility.

Within the framework of this regional flood plan for the Trinity Region, the loss of flood storage is considered the primary impact of sedimentation in terms of increasing future flood risk. Reservoir flood operations can be severely impacted by the time 50 percent of the sedimentation volume has been filled with sediment, but operational issues may arise even when smaller percentages of flood storage are lost. The intent of this section is to provide a high-level assessment of the expected loss of flood storage capacity due to sedimentation in the region's flood control facilities and determine if these losses would result in a significant increase to flooding risks. Data for this assessment was obtained from Natural Resources Conservation Service (NRCS) historical documents, TWDB volumetric and sedimentation surveys, and recent NRCS basis of design reports. The assessment was subdivided into two main groups: major reservoirs and NRCS floodwater retarding structures.

It is recognized, however, that sediment transport within a river system is a complex phenomenon with substantial geographic and temporal variability. The assessment and information provided in this section is based on a series of simplifying assumptions and are only intended to serve as a general indicator of the potential impacts of sedimentation in future flood risk at a regional scale within a 30-year planning horizon.

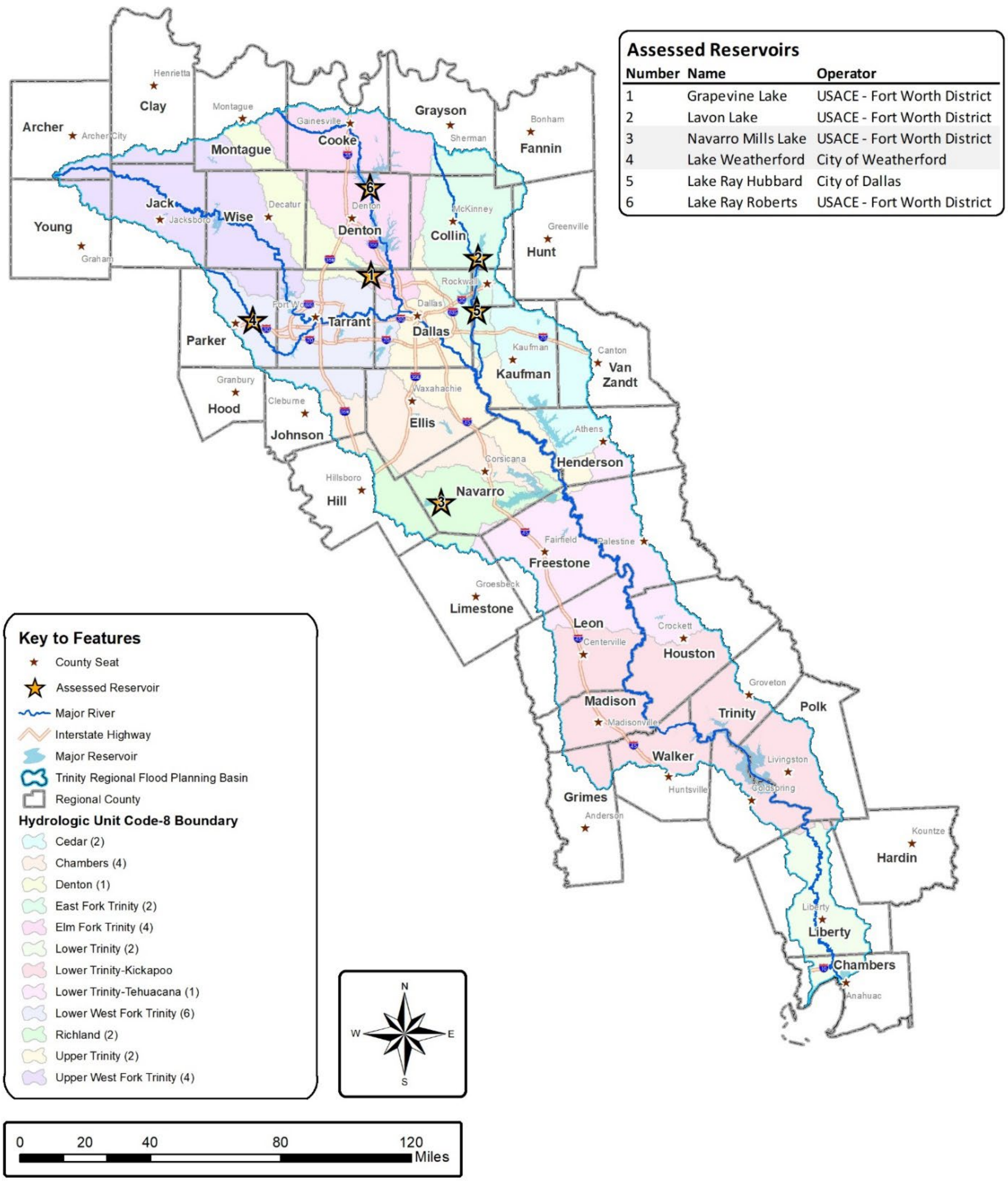
Major Reservoirs Assessment

The TWDB recognizes 34 major lakes and reservoirs within the Trinity Region. A body of water that contains at least 5,000 acre-feet of storage capacity at its normal operating level is considered a major reservoir, according to the TWDB. Some of the operators of these reservoirs include the USACE, TRWD, Trinity River Authority (TRA), and local municipalities. These facilities may serve multiple purposes including municipal water supply, irrigation, flood control, and/or recreation. Not all reservoirs are designed with flood control capacity. Six of these reservoirs were selected for this high-level assessment as a representative sample for the watershed (see ***Figure 2.45***).

Design and Operation of Multipurpose Reservoirs

The design and operation of reservoirs includes allocating volumes of reservoir storage (typically referred to as "pools") for each purpose. There are three broad categories of pools (***Figure 2.46***): flood control, conservation (also referred to as multi-purpose), and sediment (also referred to as inactive or dead storage). In ***Figure 2.46***, these water storage areas are depicted. Each reservoir is designed with specific capacity limits for each pool.

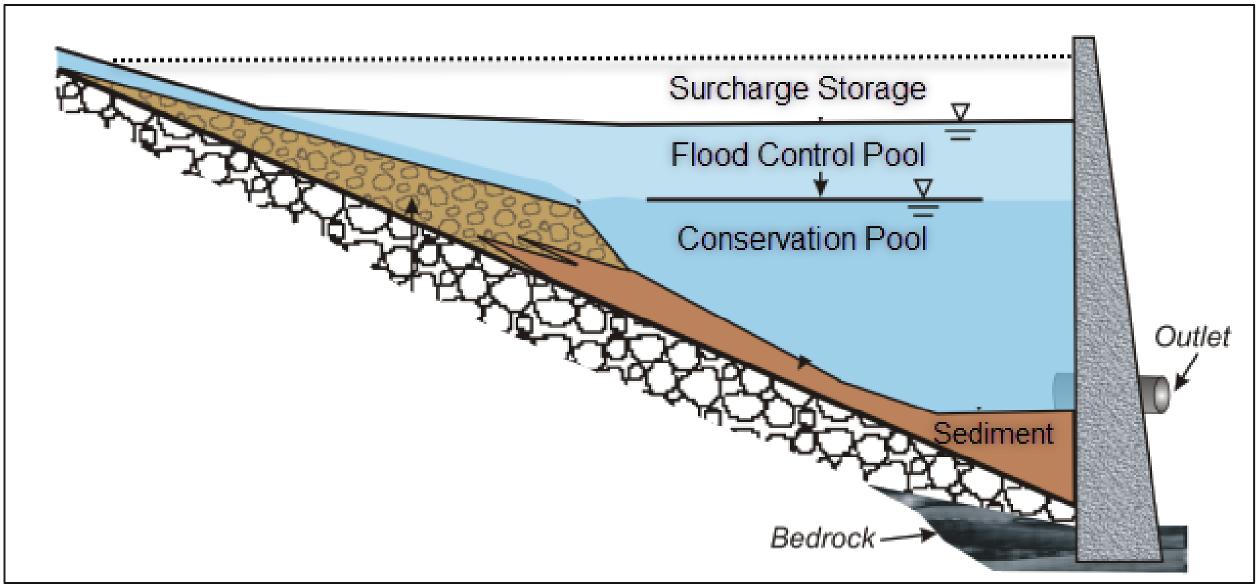
Figure 2.45: Locations of Major Reservoirs Analyzed



Assessed Reservoirs

Number	Name	Operator
1	Grapevine Lake	USACE - Fort Worth District
2	Lavon Lake	USACE - Fort Worth District
3	Navarro Mills Lake	USACE - Fort Worth District
4	Lake Weatherford	City of Weatherford
5	Lake Ray Hubbard	City of Dallas
6	Lake Ray Roberts	USACE - Fort Worth District

Figure 2.46: Typical Multipurpose Reservoir Design



Source: Modified from https://acwi.gov/sos/faqs_2017-05-30.pdf

The conservation pool is generally the largest layer, with the greatest capacity. The top of the conservation pool is typically varied based on seasonal patterns. Reservoir operators attempt to maintain this pool at the highest possible level. On top of the conservation pool is the zone reserved for flood control, which is also influenced by seasonal variations. Major reservoirs that provide flood control benefits are designed to capture upstream runoff, store it, and then release it at a controlled rate to minimize the flooding downstream.

Sediment Deposition

The amount of sediment accumulation in a reservoir depends on the sediment yield to the reservoir and the trap efficiency. Trap efficiency is the amount (percentage) of the sediment delivered to a reservoir that remains in it. How the accumulated sediment is distributed within the reservoir pools depends on the character of the inflowing sediment, the operation of the reservoir, detention time, and other factors. The incoming sediment that is deposited under water is called “submerged sediment”. The sediment deposited above the conservation pool elevation is referred to as “aerated sediment” (United States Soil Conservation Service, 1983).

The distinction between submerged and aerated sediment is important in determining the capacity that each will displace within a reservoir. The high-level assessment presented in the following sections assumes that 80 percent of the incoming sediment will be submerged and 20 percent aerated. This assumption is based on guidelines established on the SCS National Engineering Handbook, Section 3 (United States Soil Conservation Service, 1983) and a study performed by (Strand & Pemberton, 1987) for 11 reservoirs in the US Great Plains region. In this study, the reported percent of aerated sediment deposited in the flood control pool for Lavon Lake was approximately 20 percent, and this same value was adopted for all other reservoirs included in this assessment. Due to the complexity in determining the trap efficiency for each reservoir, a conservative assumption of 100 percent trap efficiency was adopted for the purposes of this assessment. A 100 percent trap efficiency indicates that all sediment delivered to a given reservoir remains in it and there are no sedimentation management practices being implemented.

Flood Control Capacity Loss Assessment

The TWDB in conjunction with the USACE-Fort Worth District, TRWD, and TRA, developed Volumetric and Sedimentation Surveys for several major reservoirs within the Trinity Region (Texas Water Development Board, 1993-2020). Six reservoirs were identified as a representative sample of all the major reservoirs in the watershed for this high-level assessment (see ***Figure 2.45***).

In the sedimentation surveys, a range of values is provided for the annual sedimentation rates of each reservoir. The reported high and low annual sedimentation rate estimates are reflected in ***Table 2.23***. These sedimentation rates are generally determined based on a comparison of storage capacity from volumetric surveys over time. In addition to the TWDB Volumetric and Sedimentation Surveys, the TWDB's Water Data for Texas website, and the USACE – Fort Worth District website were used to collect pertinent reservoir data. The flood control storage volume was not provided as part of the TWDB surveys; however, those volumes were collected from multiple sources including data sheets from the USACE – Fort Worth District website (USACE, 2021), interpolation of rating curves from TRWD, and original reservoir/dam design documents from Freese and Nichols, Inc. (FNI).

The objective of this assessment is to estimate the potential loss of flood control storage capacity for the selected reservoirs over a 30-year planning horizon. Sediment accumulation was calculated from the year of the latest volumetric survey for each reservoir until year 2053. The percent of reservoir capacity lost from the conservation and flood pools by year 2053 was determined using both the high and low annual sedimentation rates. This calculation assumes that the annual sedimentation rate will be constant over time and that, as stated in the previous section, 80 percent of the annual sediment load will deposit in the conservation pool and 20 percent in the flood control pool. A conservative 100 percent trap efficiency assumption was adopted for this assessment. It was also assumed that the conservation storage included any additional volume designated as dead pool storage.

Table 2.23: Estimate of Flood Control Storage Capacity Remaining by 2053 – Representative Reservoirs

Reservoir Name	Reservoir Operator	Drainage Area (square miles)	Conservation Storage (acre-feet)	Flood Control Storage (acre-feet)	Annual Sedimentation Rate (acre-feet/year)		Remaining Flood Control Capacity (%) by 2053	
					Low	High	Low	High
Lavon Lake	USACE – Fort Worth District	770	409,360	338,840	1,212	1,310	97.1%	96.9%
Lake Ray Roberts	USACE – Fort Worth District	692	788,490	276,110	180	483	99.4%	98.5%
Navarro Mills Lake	USACE – Fort Worth District	320	49,827	149,403	124	124	99.3%	99.3%
Lake Weatherford	City of Weatherford	109	17,812	11,188	37	37	97.1%	97.1%
Grapevine Lake	USACE – Fort Worth District	695	163,064	235,136	392	426	98.6%	98.5%
Lake Ray Hubbard	City of Dallas	1,074	439,559	44,224	719	1,097	88.0%	81.6%

A summary of analysis results is presented in ***Table 2.23*** and ***Figure 2.47***. Detailed calculations are provided in ***Table 2.24***. Analysis results suggest that, overall, sedimentation will have a minor impact in the flood control function of the major reservoirs in the Trinity Region, as nearly all reservoirs resulted in over 90 percent of their flood control storage capacity still available by the end of the 30-year planning horizon.

Natural Resources Conservation Service Floodwater Retarding Structures

The NRCS, formerly known as the SCS, has a long history of designing and building dams and reservoirs with the primary purpose of serving rural/agricultural areas. Based on a combination of data from the (USACE, 2020) and the Texas State Soil and Water Conservation Board's (TSSWCB) Local Dams Inventory (Texas State Soil and Water Conservation Board, 2021), there are 1,128 NRCS dams within the Trinity Region (see ***Figure 2.48***), most of which were designed and built during the early 1950s and 1960s. These dams are one of the elements that comprise what is known as a Watershed Work Plan (WWP), developed by the NRCS. The typical goals of a WWP are to improve agricultural practices, apply land treatment practices that will reduce upland erosion, and implement structural measures to reduce flood damages and provide for sediment control.

The WWPs refer to their dams and reservoirs as “Floodwater Retarding Structures”. Their intent is to reduce flood-related damages to both private property and agricultural crops. Reduction of floodplain scour and capturing excess sediment is also a typical goal for these facilities. A section of a typical floodwater retarding structure is shown in ***Figure 2.49***. It is important to note that the design of these structures includes a sediment pool and a sediment reserve. Thus, sedimentation may be considered to have an adverse impact to the structure’s flood control performance only when the sediment pool capacity has been depleted and sediment starts to accumulate in the detention pool. However, as stated earlier, large flood events may carry relatively large loads of sediment that can be deposited in portions of the reservoir that are outside of the designated sediment pool, which results in some loss of detention storage prior to filling the entire sediment pool.

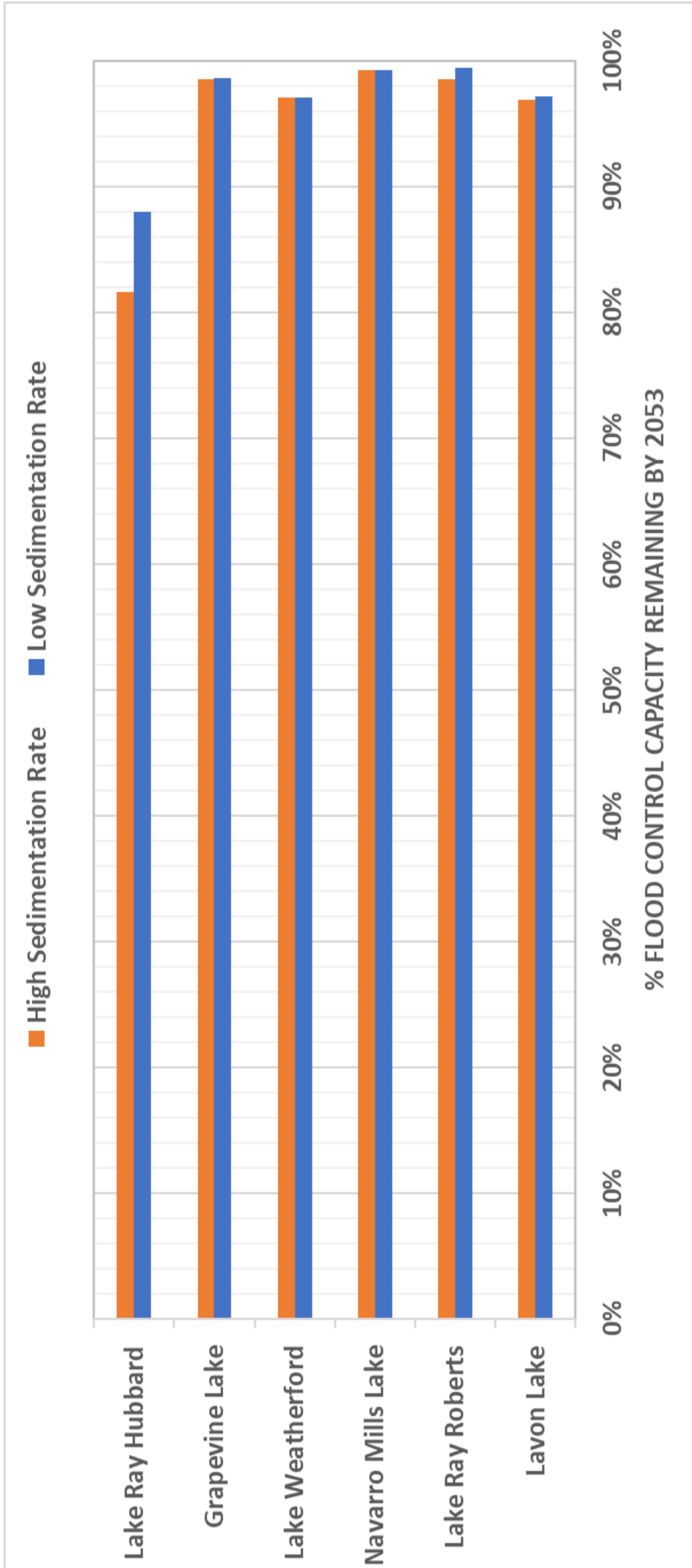
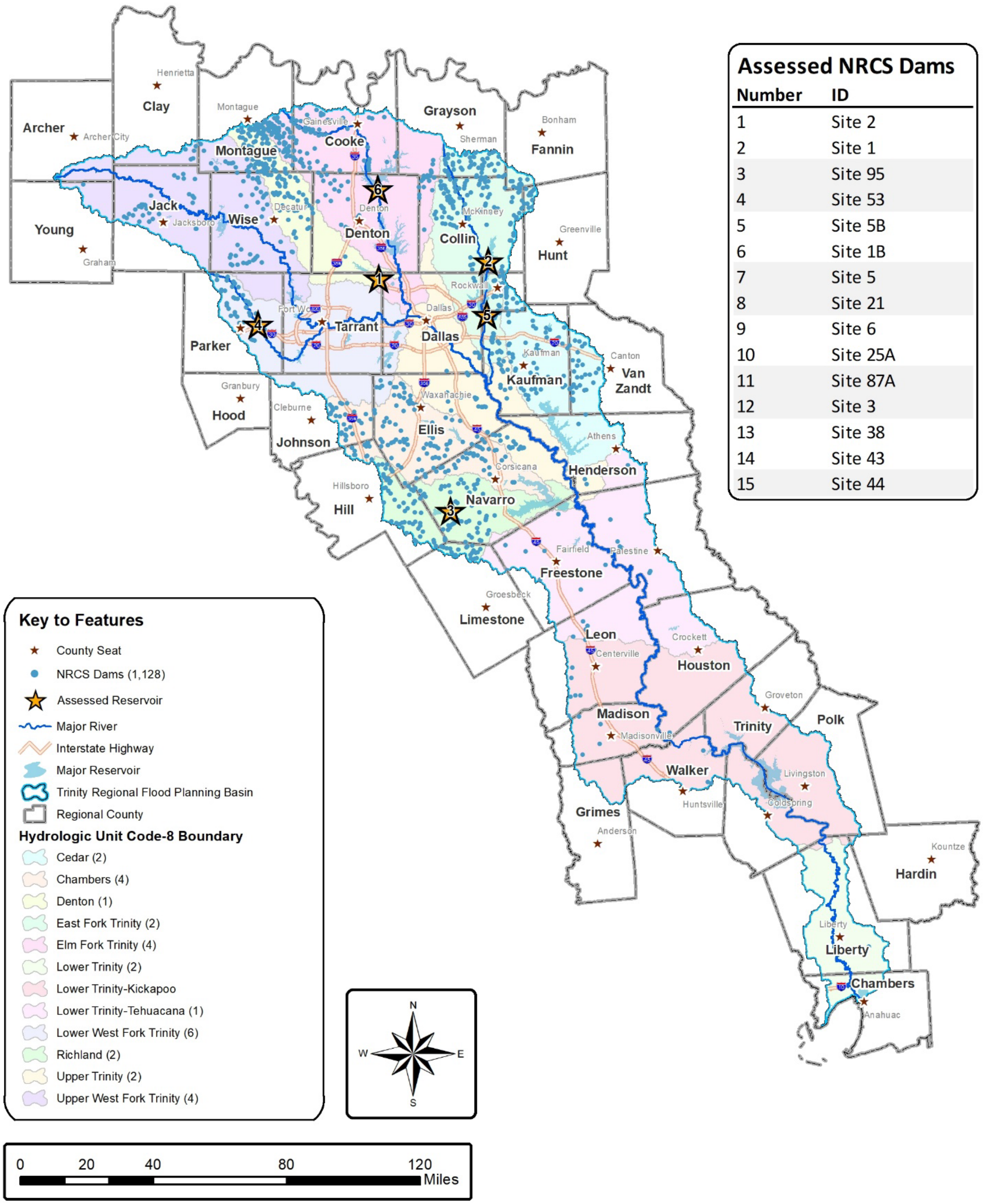


Figure 2.47: Estimate of Flood Control Storage Capacity Remaining by 2053 – Representative Reservoirs

Table 2.24: Estimated Loss of Conservation Pool and Flood Control Pool Capacity due to Sedimentation – Detailed Calculations

Reservoir Name	Reservoir Operator	Drainage Area (square miles)	Survey Year	Years to 2053	Conservation Storage (acre-feet)	Flood Control Storage (acre-feet)	Annual Sedimentation Rate (acre-feet/year)		Average Annual Sedimentation Rate (acre-feet/year)	% Capacity Lost from Conservation Pool by 2053		% Capacity Lost from Flood Control Pool by 2053		Average % Capacity Lost from Flood Control Pool by 2053	Remaining Flood Control Capacity (%) by 2053	
							Low	High		Low	High	Low	High		Low	High
Lavon Lake	USACE – Fort Worth District	770	2013	40	409,360	338,840	1,212	1,310	1,261	9.5%	10.2%	2.9%	3.1%	3.0%	97.1%	96.9%
Lake Ray Roberts	USACE – Fort Worth District	692	2010	43	788,490	276,110	180	483	332	0.8%	2.1%	0.6%	1.5%	1.0%	99.4%	98.5%
Navarro Mills Lake	USACE – Fort Worth District	320	2009	44	49,827	149,403	124	124	124	8.8%	8.8%	0.7%	0.7%	0.7%	99.3%	99.3%
Lake Weatherford	City of Weatherford	109	2009	44	17,812	11,188	37	37	37	7.3%	7.3%	2.9%	2.9%	2.9%	97.1%	97.1%
Grapevine Lake	USACE – Fort Worth District	695	2012	41	163,064	235,136	392	426	409	7.9%	8.6%	1.4%	1.5%	1.4%	98.6%	98.5%
Lake Ray Hubbard	City of Dallas	1,074	2016	37	439,559	44,224	719	1,097	908	4.8%	7.4%	12.0%	18.4%	15.2%	88.0%	81.6%

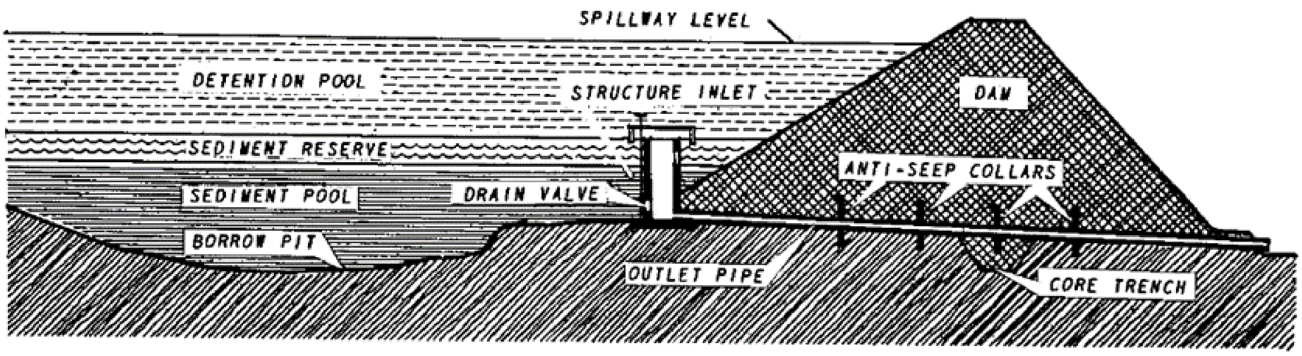
Figure 2.48: Locations of Natural Resources Conservation Service Dams



Assessed NRCS Dams

Number	ID
1	Site 2
2	Site 1
3	Site 95
4	Site 53
5	Site 5B
6	Site 1B
7	Site 5
8	Site 21
9	Site 6
10	Site 25A
11	Site 87A
12	Site 3
13	Site 38
14	Site 43
15	Site 44

Figure 2.49: Section of a Typical Natural Resources Conservation Service Floodwater Retarding Structure



Source: Big Sandy Creek WWP, SCS, 1955 (USDOA, 1955)

Flood Storage Loss Assessment

A high-level assessment of the loss of flood storage capacity due to sedimentation in the region's NRCS facilities was conducted as part of this regional flood plan. A total of 30 WWPs were reviewed for this plan. The watershed areas included in these WWPs are scattered throughout the Trinity Region and represent areas that are within 10 of its 12 sub-basins. No WWPs were available for floodwater retarding structures located within the Lower Trinity-Kickapoo and Lower Trinity sub-basins. WWPs can be downloaded from the following NRCS website: www.nrcs.usda.gov/wps/portal/nrcs/detail/tx/programs/planning/wpfp/?cid=stelprdb1186445.

The WWPs include relevant data about each of the floodwater retarding structures, including sedimentation pool storage, detention storage, drainage area, and the year the facility was built. Most WWPs include a "Sedimentation Investigation" section or similar that provides an average annual rate per area of sediment deposition into the floodwater retarding structures. This data was used to perform approximate calculations of the time it would take to fill the sedimentation pool and the time it would take to fill a given percentage of the detention or flood control storage. For the purposes of this high-level assessment, it is assumed that the performance of the structure in terms of reducing flooding risk begins to be significantly affected once 15 percent of the flood control pool is lost due to sedimentation.

Given the large number of NRCS floodwater retarding structures in the region and other limitations, the assessment was limited to 15 representative structures. At least one structure was included in each Trinity Region sub-basin (see ***Figure 2.48***). Structures that were analyzed by FNI in 2021 (four sites) were also included to supplement the assessment (Freese and Nichols, Inc., 2021).

Based on the sedimentation rates reported in the above-mentioned references, an average rate was calculated for each structure except for those that were analyzed by FNI in 2021. In these four cases, the sedimentation rate that was calculated as part of those investigations was adopted for the analysis. To calculate how long it would take to fill 100 percent of the sediment pool and 15 percent of the flood control pool, it was assumed that 80 percent of the annual sediment deposition would occur within the sediment pool and 20 percent within the flood pool. Once the sediment pool was filled, the entire sediment accumulation would occur within the flood pool. A conservative 100 percent trap efficiency assumption was adopted for this assessment. The results of these calculations are presented graphically in ***Figure 2.50*** and summarized in ***Table 2.25***. Further details on the data used and calculations are presented in ***Table 2.26***.

Figure 2.50 shows a series of bar graphs representing each site. The first point on the bar represents the year the structure was built. The segment between the first and second points represents the time it would take to fill the sedimentation pool. At that point, the facility would no longer perform its sediment control purpose as designed. The segment between the second and third points represents the additional time it would take to fill 15 percent of the flood control pool. This point represents a conservative assumption of when flood control benefits could start to be significantly reduced due to loss of storage capacity. The red dashed line that marks year 2053 depicts the long-term planning horizon for this first regional flood plan. Based on these calculations, flood control operations would not be significantly affected for most of the selected sites within the next 30 years. Ten sites would still have residual capacity in their sedimentation pool to continue accumulating sediment beyond 2053. In some instances, the bars extend beyond the limits of the time axis, indicating extensive time frames to reach the set storage losses.

Figure 2.50: Estimate of Time to Lose Sediment Pool and Flood Control Pool Capacity due to Sedimentation – Representative National Resources Conservation Services Structures

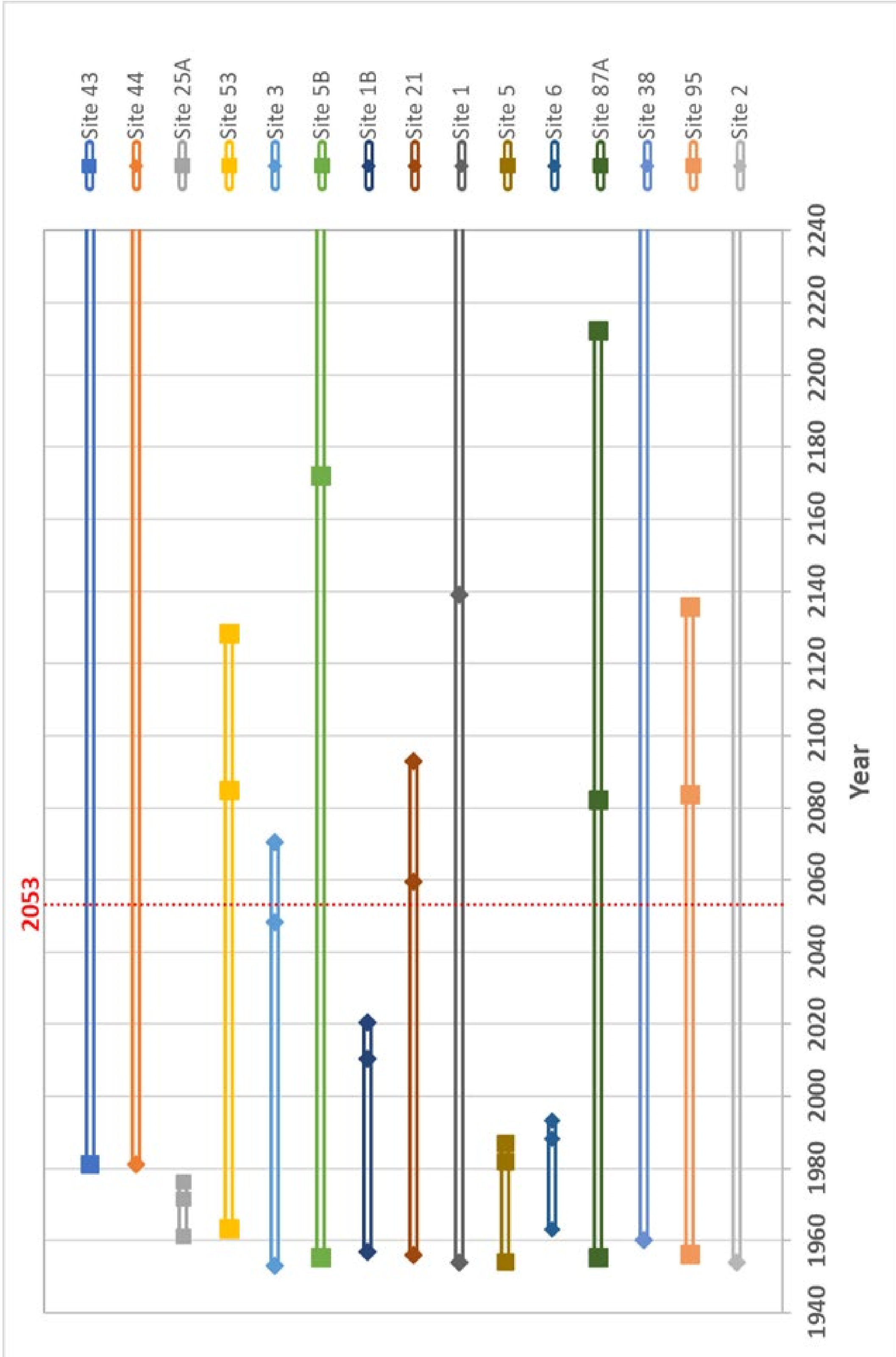


Table 2.25: Estimate of Time to Lose Sediment Pool and Flood Control Pool Capacity due to Sedimentation – Representative Natural Resources Conservation Service Structures

Trinity Region Sub-basin	Creek	NRCS Dam ID	Average or *FNI 2021 Sedimentation Rate (ac-ft/yr)	Year Built	Estimated Year Sediment Pool is Filled	Estimated Year Flood Pool is Filled 15%
Upper West Fork Trinity	Blue Creek	Site 43	0.07*	1981	3963	5242
Upper West Fork Trinity	Blue Creek	Site 44	0.09*	1981	3050	3660
Denton Creek	Denton Creek	Site 25A	12.42	1961	1971	1976
Elm Fork Trinity	Clear Creek	Site 53	2.50	1963	2085	2128
East Fork Trinity	Buffalo Creek	Site 3	2.26*	1953	2048	2070
East Fork Trinity	Buffalo Creek	Site 5B	1.77*	1955	2172	2245
East Fork Trinity	Rutherford Branch	Site 1B	4.10	1957	2010	2020
Lower West Fork Trinity	Clear Fork	Site 21	1.79	1956	2059	2093
Upper Trinity	Turkey Creek	Site 1	0.80	1954	2139	2291
Upper Trinity	Grays Creek	Site 5	13.92	1954	1982	1987
Upper Trinity	Village Walker Creek	Site 6	1.59	1963	1988	1993
Cedar Creek	Muddy Cedar Creek	Site 87A	4.80	1955	2082	2212
Chambers	Boss Branch	Site 38	0.55	1960	2407	2702
Richland	Post Oak Creek	Site 95	1.81	1956	2083	2135
Lower Trinity Tehuacana	Lake Creek	Site 2	1.36	1954	2354	2384

*Note: * Sedimentation Rates from FNI 2021 Basis of Design Reports for NRCS*

Table 2.26: Estimated Loss of Sediment Pool and Flood Control Pool Capacity due to Sedimentation – Detailed Calculations

Trinity Region Sub-basin	Creek	NRCS Dam ID	Year Built	Drainage Area (square miles)	Sediment Pool Storage (acre-feet)	Flood Pool Storage (acre-feet)	Total Capacity (acre-feet)	Sediment Rate Estimate (acre-feet/square miles/year)		Sediment Rate Estimate (acre-feet/year)		FNI 2021 Sedimentation Rate Estimate (acre-feet/year)	Average or FNI 2021 Sedimentation Rate (acre-feet/year)	Estimated Years to Fill Sediment Pool	Estimated Year when Sediment Pool is Filled	Additional Years to fill 15% of Flood Pool	Estimated Year when 15% of Flood Pool is Lost
								High	Low	Low	High						
Upper West Fork Trinity	Blue Creek	Big Sandy Creek Site 43	1981	3.2	111	782	893	--	--	--	--	0.07	0.07	1982	3963	1,279	5242
Upper West Fork Trinity	Blue Creek	Big Sandy Creek Site 44	1981	2.0	77	494	571	--	--	--	--	0.09	0.09	1069	3050	609	3660
Denton Creek	Denton Creek	Site 25A	1961	2.2	103	575	678	10	1.5	21.6	3.2	--	12.42	10	1971	5	1976
Elm Fork Trinity	Clear Creek	Site 53	1963	4.4	243	1,129	1,372	0.76	0.37	3.4	1.6	--	2.50	122	2085	43	2128
East Fork Trinity	Buffalo Creek	LEF Site No. 3	1953	2.0	172	623	795	4	2	7.9	4.0	2.26	2.26	95	2048	22	2070
East Fork Trinity	Buffalo Creek	UEFL Site No. 5B	1955	4.8	307	1,376	1,683	--	--	--	--	1.77	1.77	217	2172	73	2245
East Fork Trinity	Rutherford Branch	Site 1B	1957	2.1	175	568	743	3	1	6.2	2.1	--	4.10	53	2010	10	2020
Lower West Fork Trinity	Clear Fork	Site 21	1956	2.8	148	645	793	1	0.3	2.8	0.8	--	1.79	103	2059	33	2093
Upper Trinity	Turkey Creek	Site 1	1954	3.2	118	1,006	1,124	0.4	0.1	1.3	0.3	--	0.80	185	2139	152	2291
Upper Trinity	Grays Creek	Site 5	1954	3.2	308	983	1,291	6	2.7	19.2	8.6	--	13.92	28	1982	5	1987
Upper Trinity	Village Walker Creek	Site 6	1963	0.4	32	105	137	7.68	1.13	2.8	0.4	--	1.59	25	1988	5	1993
Cedar Creek	Muddy Cedar Creek	87A (New Terrell City Lake)	1955	14.3	488	4,968	5,456	0.45	0.22	6.4	3.2	--	4.80	127	2082	130	2212
Chambers	Boss Branch	Site 38	1960	3.4	197	1,411	1,608	0.22	0.11	0.7	0.4	--	0.55	447	2407	295	2702
Richland	Post Oak Creek	Site 95	1956	4.3	184	934	1,118	0.43	0.40	1.9	1.7	--	1.81	127	2083	52	2135
Lower Trinity Tehuacana	Lake Creek	Site 2	1954	3.4	435	1,000	1,435	0.5	0.3	1.7	1.0	--	1.36	400	2354	30	2384

Results also show that there are four sites that should theoretically be experiencing a significant reduction in their flood control effectiveness. However, sedimentation rates do change significantly over time, and more recent sedimentation rate estimates are typically much lower due to significant improvements in agricultural practices and the implementation of erosion control policies among other factors. FNI's long-term experience with NRCS ponds and results from recent FNI detailed assessments suggest that sedimentation rates reported in these early documents can be quite conservative and not representative of current rates. For example, the sedimentation rates estimated in the early documents for Site 3 in the East Fork Trinity sub-basin range from four to 7.9 acre-feet per year, while the most recent estimates calculated by FNI (2021) resulted in a rate of 2.26 acre-feet. This is a 44 percent reduction from the low estimate indicated in the early documentation.

The results of this high-level assessment suggest that at a regional scale, sedimentation will not pose a significant limitation to achieving flood control benefits from these structures within the 30-year planning horizon. However, it is recognized that 15 structures is a relatively small sample size, and that further analysis is required to comprehensively assess the impacts of sedimentation on these structures, especially at the local scale. Sedimentation was not used in determining future flood risk for the this first regional flood plan due to the minimal effect at the regional scale. Reduction in reservoir capacity may be looked at in greater detail by local entities and in future planning cycles.

Anticipated Impacts of Major Geomorphic Changes in Flood Risk

Geomorphic changes in fluvial systems have a clear relationship with flood hazard protection. Fluvial systems are a series complex feedback loops where many interrelated variables influence both flood hazards and changes in a river condition. In short, the geometry of river systems changes when the influencing variables, such as hydrology (caused by things such as climate change, land use changes, stormwater infrastructure, etc.) and sediment dynamics such as erosion, sediment deposition, and sediment transport change. This ultimately relates back to flood hazards because of increases or decreases in flood conveyance inherent to changes in river geometry.

Most flood hazard assessments assume the capacity of river channels to convey flood flows is stationary, with the thought that changes in flood frequency are primarily driven by hydrology. However, several studies have shown that while hydrology has a greater influence on flood hazards and flood variability, identifying potential geomorphic changes is important because flood hazards and flood variability is not driven by hydrology alone.

Predicting Geomorphic Changes

Quantitatively predicting geomorphic channel changes requires intense data collection and modeling. These requirements are further magnified at larger scales because the factors that control the geomorphology of a system are variable throughout a watershed. At the regional scale, there is significant heterogeneity within a river system. As such, geomorphic channel changes and sediment dynamics are difficult to quantify at the regional scale because of the lack of available data, number of interrelated influential variables, and differences in the local conditions within a watershed.

Including predicted geomorphic changes into flood assessment is often not appropriate or feasible at the regional scale. This is because the uncertainty of predictions become exceedingly high with the introduction of additional variables/complexity, which can lead to erroneous flood predictions (Stanzel & Natchnebel, 2009). However, this does not mean that general effects of geomorphic channel changes on flood risks should not be considered.

Effects of Geomorphic Changes on Flood Risks

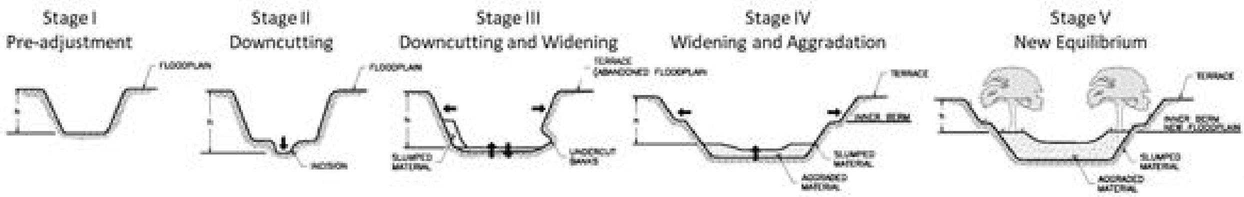
While major geomorphic changes can occur at the regional scale, their effect on flood risks are most apparent at the local level. This is because of the variability of geomorphic conditions within a river. Local changes in the channel geometry and sediment dynamics of the system can have profound effects on flood inundation extents at smaller scales. This section provides high-level descriptions of how geomorphic changes can affect flood risks.

Hydrology and Channel Changes

River geometry changes to accommodate the amount of flow it receives. Both increases and decreases in flow regime can initiate these changes. Common causes of hydrologic changes include urbanization/land-use changes, implementation of stormwater infrastructure (such as detention/retention ponds), climate change, and reservoir release schedules.

Increased flow often occurs when a watershed urbanizes or has land-use changes. Flow in streams become flashier because surface runoff reaches streams more quickly and in greater magnitude due to increased smooth impermeable surfaces that prevent infiltration of water into the ground. While this gets floodwaters downstream more quickly, stream geometries will enlarge via erosion to accommodate the additional flow. This is manifested by channel downcutting until the stream slope can accommodate the discharge without scouring the channel bed; and by channel widening caused by overly steepened stream banks following downcutting. ***Figure 2.51*** shows the processes involved in the channel evolution model.

Figure 2.51: Diagram of Channel Downcutting and Channel Widening (Adapted from Schumm et al, 1984)



Channel enlargement is a gradual process that migrates from downstream to upstream between local baselevels or hardpoints. Local baselevels are features that prevent the channel from downcutting. Examples may include tributary confluences, bedrock outcrops, concrete-lined channels, and culvert crossings. Geometric changes to the channel (i.e., channel enlargement) typically affect flood levels within these bounded local baselevels.

Locally, channel enlargement may increase the flow capacity and reduce flood risks. This effect scales with river size/drainage area. Flood capacity is less impacted by erosion in larger streams than in smaller streams because the amount of material removed relative to the channel size is less in larger streams. In smaller streams it is common for erosion to create enough capacity to completely remove overbank flows during flood events. Likewise, significant amounts of erosion in larger streams may only have a marginal effect on flood inundation levels.

This does not mean that erosion is solely beneficial to flood risks. There are adverse impacts of erosion brought about by increased hydrology including:

- Direct erosion impacts to homes, infrastructure (e.g., stormwater outfalls, waterlines, sewer lines, roads, bridges, culverts, etc.), and private property adjacent to the stream
- Channel geometry used in flood assessment analyses becoming outdated
- Excess sediment yields sourced from channel erosion and subsequent downstream effects

Decreased flow in the stream can also occur due to the presence of detention/retention ponds, lakes/reservoirs, and other factors. This can cause channels to aggrade because flows no longer have enough stream power to carry the sediment in the system. As a result, channel capacity will decrease as sediment aggrades in the channel and flood levels can rise for a given storm event. In addition to aggradation, erosion can also occur on stream banks caused by deposition patters/sediment bars directing flow into stream banks.

Changes to Sediment Dynamics and Culvert Sedimentation

Sediment transport is a fundamental function of stream systems. However, changes in sediment dynamics can affect flood risk. These changes are often interrelated with hydrologic changes, the presence of man-made structures, or local disturbances to channel geomorphology. Upstream channel change/erosion can account for as much as 90 percent of sediment yield volumes. When sediment yields increase, the resulting excess sediment typically has one of three fates:

1. Sediment can be redeposited downstream within the channel or floodplain. This reduces flood capacity in locations where the stream no longer has the sediment transport capacity to move the sediment through the system. This can happen in locations where the channel has become overly wide as a result of historic channel downcutting and widening.
2. Sediment can be transported and stored within reservoirs or retention/detention ponds. This can reduce flood storage if not properly addressed by maintenance (as discussed in previous sections). This then becomes a maintenance responsibility for the owner of the reservoir.
3. Sediment is effectively transported out of the watershed over time.

Sedimentation within culverts or stormwater infrastructure is also a common source of increased local flood risk. Culvert designs are typically based on maximum expected flood events. However, culvert designs have traditionally not considered lower-level flood events or sediment transport. As such, many culverts are oversized for more frequent storm events. Flows entering culverts spread out laterally, increasing the channel width and decreasing the channel depth. This reduces the stream power through the culvert. The result is a loss in sediment transport capacity and deposition within the culvert. As deposition continues, culverts lose capacity. This can cause increased flood risks as water stacks up behind filled in culverts and road crossings. This phenomenon is often not accounted for in flood risk analysis.

There are two primary solutions to local sedimentation at culverts and road crossings: ongoing monitoring and maintenance by the owner of the culvert to make certain that sedimentation is not reducing culvert capacities that could lead to local increases in flood risks and considering sediment transport and stream geomorphology during culvert design.

One example of culverts that accounts for sediment transport is tiered culverts or staged culverts. These have shown to be considerably more effective at reducing sedimentation, while still maintaining flood capacity, than the traditional practice of oversizing culverts. A tiered culvert set-up has a primary culvert that accommodates more frequent flow events and maintains the stream channels width-depth ratio and sediment transport capacity. Adjacent culverts are placed at higher flow elevations and become activated during larger flood events. This allows flood capacity to be maintained while reducing sedimentation within culverts. An example of a staged culvert is shown in ***Figure 2.52***.

Figure 2.52: Staged or Tiered Culvert Design Used in North Texas with Multiple Culvert Sizes and Flow Elevations

Other Considerations

It is often not feasible to evaluate region scale geomorphic changes and their potential effects on flood hazards because of the significant uncertainties introduced into flood hazard assessment without accounting for the intensive data requirements, extensive analysis of interrelated variables, and system heterogeneity. Major geomorphic changes and their effects on flood hazards are most prominently experienced at the local level and can be accounted for at this scale.

The above sections provide high-level examples of the connection between geomorphic changes and flood hazards at specific locations due to local sediment dynamics or bank erosion. As such, mitigation of flood hazards is often a maintenance concern located at specific areas or pieces of infrastructure (such as easements, culverts, retention/detention ponds, reservoirs, etc.). The maintenance responsibilities of these areas, and therefore much of flood hazard mitigation practices, falls onto the owners of these assets.

One method used by numerous cities and regulatory bodies to account for uncertainty in geomorphic changes at a high level includes erosion hazard setbacks (also known as erosion clear zone, stream buffer area, etc.). This consists of a buffer area around the stream system that is not allowed to be disturbed without prior investigation. Multiple methods of creating this setback distance have been developed in design criteria manuals and local flood plans as a means of accounting for the uncertainty in future geomorphic changes without intense data requirements. Maintaining a buffer around streams provides numerous benefits including:

- Allowing for geomorphic channel adjustments to occur within an allotted lateral extent without significantly affecting flood inundation extents;
- Reducing hydrologic changes in the stream by slowing overland flow via riparian vegetation;
- Improving water quality via riparian vegetation filtering surface runoff;
- Reduction of bank erosion and subsequent excess sediment due to streambanks increased resistance to bank erosion from the roots of established riparian vegetation (i.e., bank vegetation reduces stream bank erosion); and
- Prevention of erosion impacts to homes, infrastructure, and property adjacent to the stream.

For larger streams with more thorough flood inundation mapping, setbacks may not be as effective at reducing flood risk due to their relatively small buffer distances from streams compared to mapped floodplains. However, in smaller watersheds with limited flood analysis, setbacks can be an effective means of providing an extra layer of protection with relatively low effort.

Future Conditions H&H Model Availability

Table 2.27 shows a list of projects that include H&H models with future conditions. Details for two of the projects follows:

- **The Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity Region:** A watershed model was built for the Trinity Region with input parameters that represented the physical characteristics of the watershed. The rainfall-runoff model for the basin was completed using the basin-wide Hydrologic Engineering Center – Hydrologic Modeling System (HEC HMS) model developed for the 2015 Trinity Basin Corps Water Management System (CWMS) implementation as a starting point. This model was further refined by adding additional detailed data, updating the land use, and calibrating the model to multiple recent flood events. Through calibration, the updated HEC-HMS model was verified to accurately reproduce the response of the watershed to multiple, recently observed storm events, including those similar in magnitude to a 100-year flood. Finally, frequency storms were built using the depth area analysis in HEC-HMS and the latest published frequency rainfall depths from NOAA Atlas 14 (NOAA, 2018). These frequency storms were run through the verified model, yielding consistent estimates of the 100-year and other frequency peak flows at various locations throughout the basin.

Table 2.27: Hydrology and Hydraulic Models by Project

Project	Model Name	Date Created	Stream Section	HEC RAS version	Steady or Unsteady state	Model Developer
Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity River Basin	AP_Freq_002yr AP_Freq_005yr_NOAA AP_Freq_025yr AP_Freq_050yr AP_Freq_250yr	09/17/2018	Trinity Bay, Lewisville Lake, Lavon Lake, Grapevine Lake, Ray Roberts Lake, Benbrook Lake, Joe Pool Lake	HEC-HMS 4.3	Steady Flow	USACE
Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity River Basin	AP_Freq_002yr_NOAA AP_Freq_200yr_NOAA_WF	01/18/2021	Trinity Bay, Lewisville Lake, Lavon Lake, Grapevine Lake, Ray Roberts Lake, Benbrook Lake, Joe Pool Lake	HEC-HMS 4.3	Steady Flow	USACE
Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity River Basin	AP_Freq_002yr_NOAA_WF AP_Freq_005yr AP_Freq_005yr_NOAA_WF AP_Freq_010yr AP_Freq_010yr_NOAA_WF AP_Freq_025yr_NOAA_WF AP_Freq_050yr_NOAA AP_Freq_050yr_NOAA_WF AP_Freq_100yr_NOAA AP_Freq_100yr_NOAA_WF AP_Freq_200yr AP_Freq_500yr_NOAA_WF	05/7/2021	Trinity Bay, Lewisville Lake, Lavon Lake, Grapevine Lake, Ray Roberts Lake, Benbrook Lake, Joe Pool Lake	HEC-HMS 4.3	Steady Flow	USACE
Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity River Basin	AP_Freq_010yr_NOAA	01/11/2019	Trinity Bay, Lewisville Lake, Lavon Lake, Grapevine Lake, Ray Roberts Lake, Benbrook Lake, Joe Pool Lake	HEC-HMS 4.3	Steady Flow	USACE
Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity River Basin	AP_Freq_100yr AP_Freq_500yr	12/10/2018	Trinity Bay, Lewisville Lake, Lavon Lake, Grapevine Lake, Ray Roberts Lake, Benbrook Lake, Joe Pool Lake	HEC-HMS 4.3	Steady Flow	USACE
Interagency Flood Risk Management (InFRM) Watershed Hydrology Assessment for the Trinity River Basin	AP_Freq_500yr_NOAA	01/14/2019	Trinity Bay, Lewisville Lake, Lavon Lake, Grapevine Lake, Ray Roberts Lake, Benbrook Lake, Joe Pool Lake	HEC-HMS 4.3	Steady Flow	USACE
Marine and Cement Creek Frequency and Probability Maximum Flood Study	002_Year_AMC_II 005_Year_AMC_II 010_Year_AMC_II 025_Year_AMC_II 050_Year_AMC_II 100_Year_AMC_II 500_Year_AMC_II	04/9/2020	Marine and Cement Creeks	HEC-HMS 3.5	Steady Flow	USACE
Marine and Cement Creek Frequency and Probability Maximum Flood Study	AMC_II_002_Freq AMC_II_005_Freq AMC_II_100_Freq AMC_II_500_Freq	04/9/2020	Marine and Cement Creeks	HEC-HMS 3.5	Steady Flow	USACE
Marine and Cement Creek Frequency and Probability Maximum Flood Study	Marine_CementCreek	03/1/2008	Marine and Cement Creeks	HEC-HMS 4.0	Steady Flow	USACE

- **Marine and Cement Creek Frequency and Probability Maximum Flood Study:** Marine Creek is in the northwest portion of Tarrant County. The headwater of Marine Creek is approximately 3.5 miles northwest of Saginaw, Texas, and the flow is in a general southeasterly direction. The Marine Creek confluence with the West Fork of the Trinity River is just downstream of the Fort Worth Stockyards near Samuel Avenue, north of downtown Fort Worth. Total drainage area of the Marine Creek watershed is approximately 22.2 square miles, including portions of the City of Saginaw, Fort Worth, Lake Worth, Sansom Park, and unincorporated Tarrant County. H&H models for the study were developed using HEC-HMS version 3.4 and HEC-RAS version 4.0, as well as GIS applications.

Best Available Data

Even though there were some models with future conditions in the Trinity Region as identified previously, these models did not have corresponding mapping data available; therefore, the methodology described in the next section was developed to delineate consistent seamless future conditions floodplain extents for the Trinity Region.

Hydrology and Hydraulic Models Without Future Conditions

The methodology to leverage existing conditions modeling and mapping to produce the future conditions floodplain extents for the Trinity Region was approved by the TWDB on January 21, 2022 and described in the following narrative.

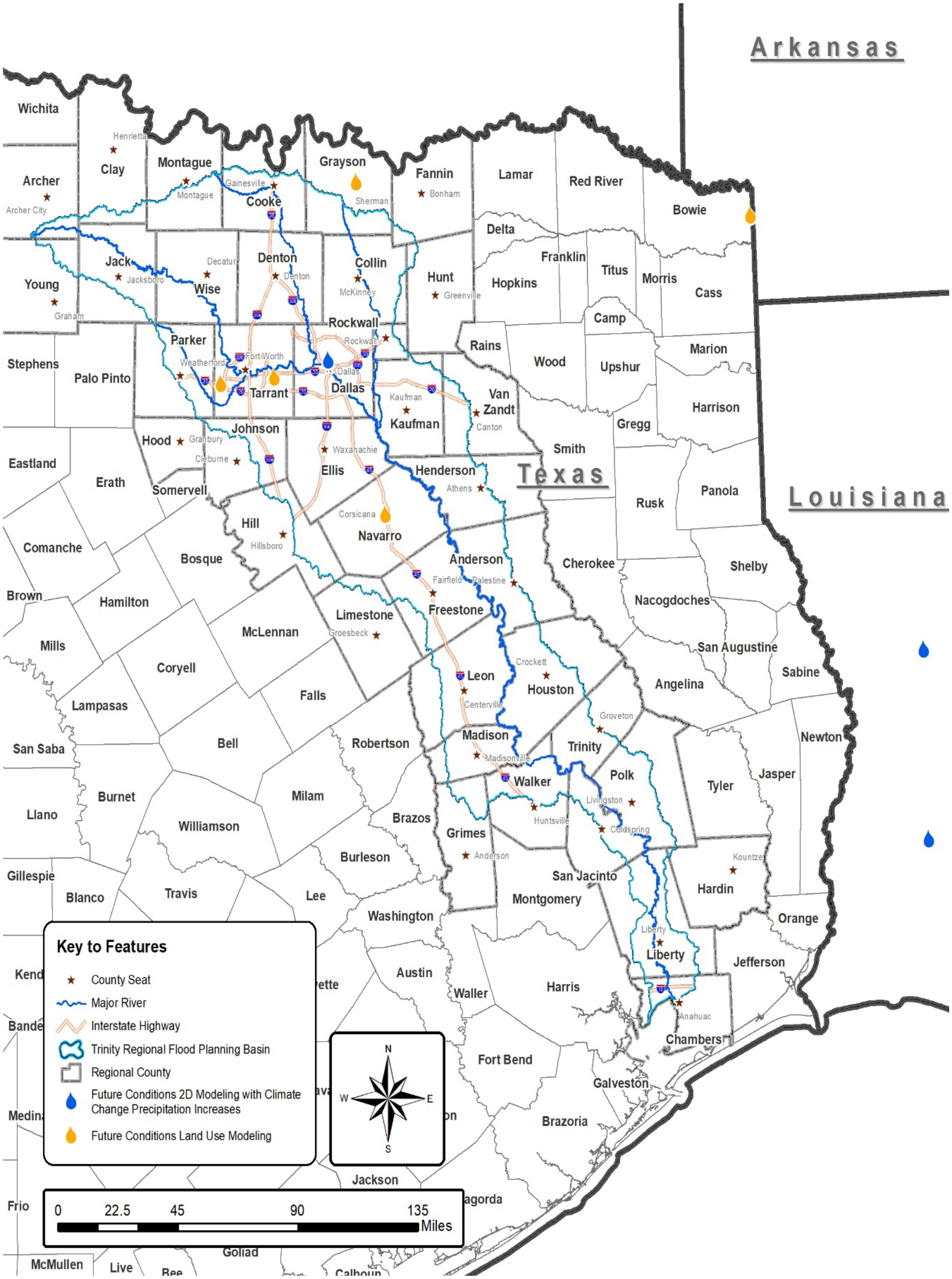
1% and 0.2% Annual Chance Storm Event Exceedance Floodplains

When developing a predictive assessment for future conditions flood risk, two major factors were considered: unmitigated population increase and projected future rainfall.

Case Studies – Future Conditions Flood Risk

To obtain a better understanding of how future conditions affect extreme rainfall flood risk within the Trinity Region, existing H&H models containing future flood risk data were analyzed. Results from these studies served as an estimation of how future land use and climate change impact floodplain elevations and widths when compared to existing conditions. Comparable studies were chosen based on availability, location, and similar H&H parameters. ***Figure 2.53*** provides a location for the existing studies collected for this assessment.

Figure 2.53: Case Study Locations



Future Conditions – Land Use Studies

Five drainage/floodplain master plans were utilized to assess potential flood risk increases due to future fully-developed land use conditions. The future conditions analysis for these studies did not consider potential increases to rainfall data and are, therefore, based on land use changes only. A comparison was made between the existing and future conditions 100-year flood elevations. In addition to the future 100-year comparison, a flood elevation comparison was made between the existing 100-year and 500-year storm events to analyze the viability of utilizing the existing 500-year floodplain to represent future 100-year flood hazard data for this planning cycle. Results of the comparisons are provided in ***Table 2.29***.

Table 2.28: Future Condition Land Use Water Surface Elevation Comparison

Location	Flooding Source	Average WSE Change Existing vs. Future 100-year (feet)	Average WSE Change Existing 100-year vs. 500-year (feet)
Parker County	Marys Creek	0.1	0.8
Grand Prairie	Fish, Kirby, Rush, Prairie Creek	0.2	1.4
Sherman	Post Oak, EF Post Oak, Sand Creek	0.7	1.0
Texarkana	Wagner, Swampoodle, Corral Creek	0.6	1.8
Corsicana	Post Oak, SF Post Oak, Mesquite Creek	0.2	1.0
	Average	**0.4**	**1.2**

Future Conditions – Projected Future Rainfall

During the data collection phase, the Trinity RFPG team was unable to obtain studies that analyzed future flood risk based on potential future rainfall predictions. As a substitute, two large scale rain on grid studies were obtained: Dallas City-Wide Watershed Masterplan and the FEMA Louisiana Upper Calcasieu BLE Analysis. The modeling methodology of these studies allowed for rainfall data to be quickly modified in accordance with the recommendations from the state climatologists. The 100-year storm event rainfall was increased by 15 percent for both studies and the flood elevation results were compared to the present-day conditions. The increase of 15 percent was chosen because it fell into the high range of rainfall increases and matched the historic period of record increase. The existing 100-year and 500-year flood elevations were also compared. Results of the comparisons are provided in ***Table 2.30***.

Table 2.29: Trinity Region Future Rainfall Increase Water Surface Elevation Comparison

Location	Average WSE Change Existing vs. Future 100-year (feet)	Average WSE Change Existing 100-year vs. 500-year (feet)
Dallas	0.2	Unavailable*
Upper Calcasieu	0.4	1.7
Average	**0.3**	**N/A**

** Dallas Watershed Master Plan only considered the 100-year storm event*

Future Conditions Flood Hazard Approach

Potential Future 100-year Flood Hazard Methodology

Due to the relatively large coverage of adequate existing 500-year floodplain data within the region, utilizing the existing 500-year floodplain quilt to represent potential future 100-year flood hazard was considered the most reasonable approach. Results from the comparison showed that using this methodology would be considered a more conservative approach.

From the future conditions land use case study results, the average change in potential future 100-year WSE compared to existing conditions was only 0.4 feet, while the comparison between the existing 100-year and existing 500-year WSE yielded an average 1.2 feet change. By increasing the average change in WSE between existing and potential future conditions from ***Table 2.29***. by the average taken from ***Table 2.30*** to account for future rainfall projections, the results generally yielded a comparison less than that of the differences between the existing 100-year and existing 500-year WSE. This evaluation, taken from detailed future conditions hydraulic studies, demonstrated that the future 100-year floodplain is generally located between the existing 100-year and 500-year floodplain limits, with its location lying closer to the existing 100-year boundary.

Entities mistakenly using this data for regulatory purposes was evaluated as a potential concern. As a solution to this concern, the potential future 100-year floodplain was presented in this planning cycle as a range between the existing 100-year and the existing 500-year (zone of potential expanded risk). The methodology covers the uncertainty and variability resulting from the case study analysis. The exposure and vulnerability assessment data would be extracted from the maximum potential future 100-year floodplain limit.

Potential Future 500-year Flood Hazard Methodology

Under Method 2 in the TWDB Technical Guidelines, an excerpt regarding the determination of the future 500-year flood hazard states:

"RFPGs will have to utilize an alternate approach to develop a proxy for the 0.2 percent annual chance future condition floodplain, such as adding freeboard (vertical) or buffer (horizontal) estimates. The decision on what specific approach or values to use, which may vary within the region (e.g., for urban vs. rural areas), for these estimates will be up to the RFPGs, but technical justification should be provided to explain how the estimates were developed. This method cannot be applied to flood risk areas that do not already have a delineated existing condition 0.2 percent annual chance floodplain, (i.e., flood-prone areas)."

Based on this statement, reasonable buffer limits were researched based on the difference in existing top widths between the 100-year and 500-year floodplain quilt within the Trinity Region. It is reasonable to assume that the difference between top widths for the existing conditions, will be similar for potential future conditions. To establish a reasonable buffer zone to represent potential future 500-year flood risk, BLE data previously collected for the plan was analyzed. Nine large-scale studies were selected to form the basis for the buffering analysis. ***Figure 2.54*** shows the general location and coverage of the nine studies selected.

The nine studies collected represent over 25,000 miles of floodplain, with over 300,000 cross-sections. Using automated means, 600,000 individual distance measurements were collected along these cross-sections between the existing 100-year and 500-year floodplains. ***Figure 2.55*** shows an example of measurement locations. The measurements were then averaged for each of the nine study locations. The average distance measurement along the right or left overbank of the floodplain ranged from 30 feet to 50 feet. The total average overbank measurement of all nine studies was determined to be approximately 40 feet, representing an 80-foot total change in top width. Similar to the future 100-year flood risk boundary, the future 500-year will be presented as a range between the existing 500-year flood risk boundary and the 40-foot buffer. ***Table 2.31*** provides the average measurement results of the analysis.

Summarization of Potential Flood Hazard Methodology

A procedure for generating potential future 100-year and 500-year flood risk data that generally follows the TWDB's Technical Guidance was developed for the Trinity Region. The existing 500-year floodplain was selected to serve as a proxy for the potential maximum 100-year flood hazard. A 40-foot buffering of the existing 500-year flood hazard boundary was selected to serve as the potential maximum future 500-year flood hazard. Using the previously described buffering methodology for potential future 500-year conditions allows for rapid development of estimated expanded risk within the constraints of the flood plan timeline and lack of future 500-year detailed data throughout the planning area.

Figure 2.54: Future Condition 500-year Case Study Locations

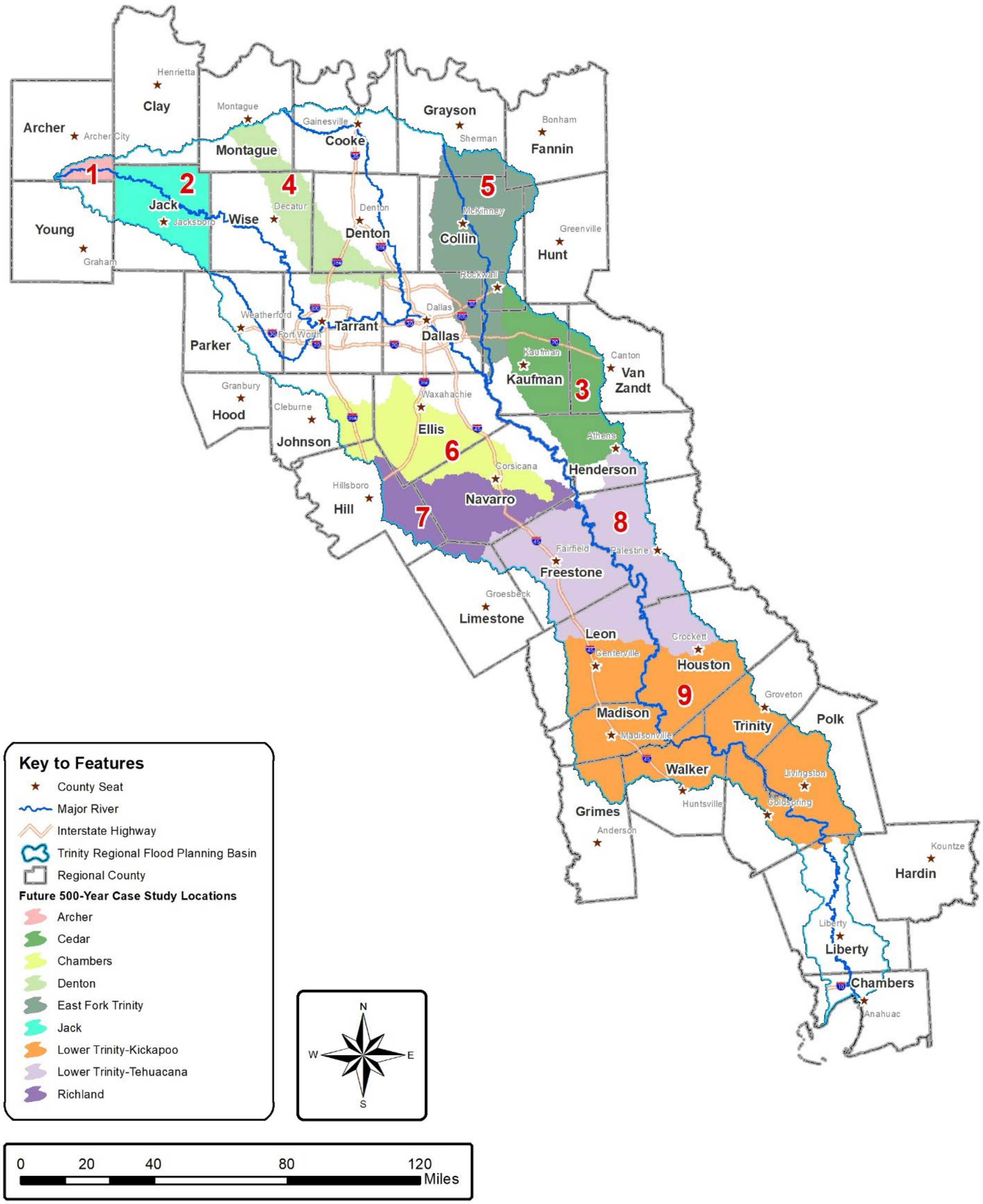


Figure 2.55: Measurement Locations to Develop Potential Future Condition 500-year Flood Risk Buffer

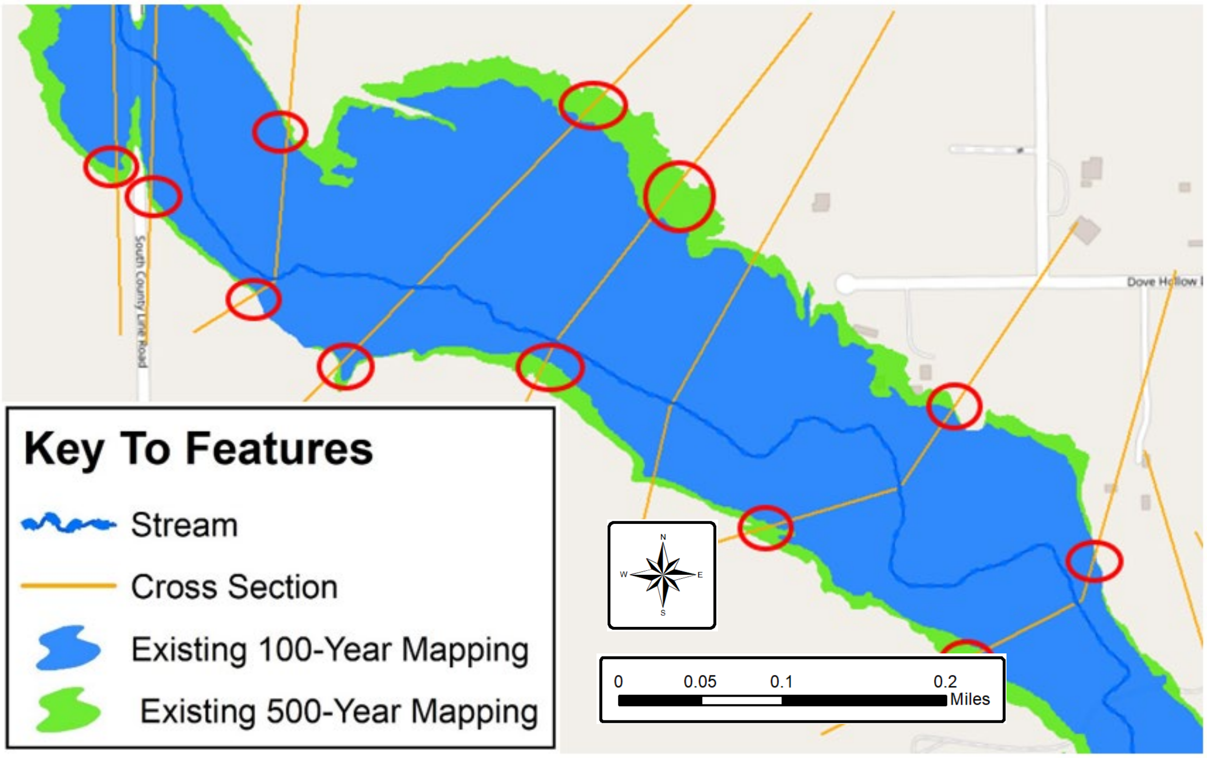


Table 2.30: Average Change in Horizontal Distance

Location	Average Width Change (Left or Right Overbank) Existing 100yr vs 500yr (ft)
1. Archer	30.8
2. Jack	32.2
3. Denton	32.6
4. Cedar	30.8
5. East Fork Trinity	42.6
6. Chambers	37.2
7. Richland	44.5
8. Lower Trinity Tehuacana	36.3
9. Lower Trinity Kickapoo	47.6
Rounded Average	**40**

A disadvantage of this approach is that average buffering is performed independent of topographic or WSE changes. For areas with relatively flat terrain, the potential 500-year flood risk limit based on buffering may underestimate the expanded urban exposure risk. This disadvantage may be less impactful on rural floodplains whose exposure risks are large tracts of agricultural land. ***Table 2.31*** shows the existing and range of potential future conditions flood risk approach summary. ***Figure 2.56*** presents an example of the range of potential future flood risk.

Large maps showing the future conditions floodplain extents developed for the Trinity Region are included in ***Appendix B***.

Data Gaps

Future conditions mapping data gaps include the existing conditions data gaps in addition to the unavailability of extensive future flood models and associated mapping data in the Trinity Region.

Future Condition Flood Exposure Analysis

Existing Development within the Existing Conditions Floodplains

To assist with flood risk analysis, TWDB was provided statewide coverage of building footprints along with improvement value, land use, population estimate, and SVI values at the census tract level. This dataset formed the basis for determination of existing development within the existing conditions floodplains in the Trinity Region. According to this database, there are approximately three million buildings in the counties intersected by the Trinity Region. Approximately 65,000 buildings in the Trinity Region are partially or completely within the 100-year floodplain. ***Table 2.32*** summarizes existing development in existing conditions floodplains. Note that these estimates are based on a GIS analysis that accounts for the area of impact without necessarily considering the finished floor elevations of structures.

Existing and Future Developments within the Future Conditions Floodplains

Assuming that the 100-year future conditions floodplains are limited to the existing conditions 500-year floodplain, approximately 275,000 buildings in the TWDB database are partially or completely within the future conditions floodplains.

Table 2.31: Existing and Future Condition Flood Hazard Analysis Approach

	Best Available		→		→		→		Most Approximate	
	Local Floodplain (if determined current)		NFHL AE		BLE		NFHL A / FAFDS		No FEMA or Better than Quilt	
	100YR	500YR	100YR	500YR	100YR	500YR	100YR	500YR	100YR	500YR
Existing	Local Study (if provided)	Local Study (if provided)	Floodplain quilt 100YR	Floodplain quilt 500YR	BLE 100YR	BLE 500YR	Replaced with Fathom 100YR	Replaced with Fathom 500YR	Fathom 100YR	Fathom 500YR
Future	Local Study (if provided)	Local Study (if provided)	Range between Existing 100-year and 500-year	40-foot buffer of the existing 500YR	Range between BLE Existing 100-year and 500-year	40-foot buffer of the existing 500YR	Range between Fathom Existing 100-year and 500-year	40-foot buffer of the existing 500YR	Range between Fathom Existing 100-year and 500-year	40-foot buffer of the existing 500YR

Figure 2.56: Example of 2020-2023 Planning Cycle Range of Potential Future Condition Flood Risk Data

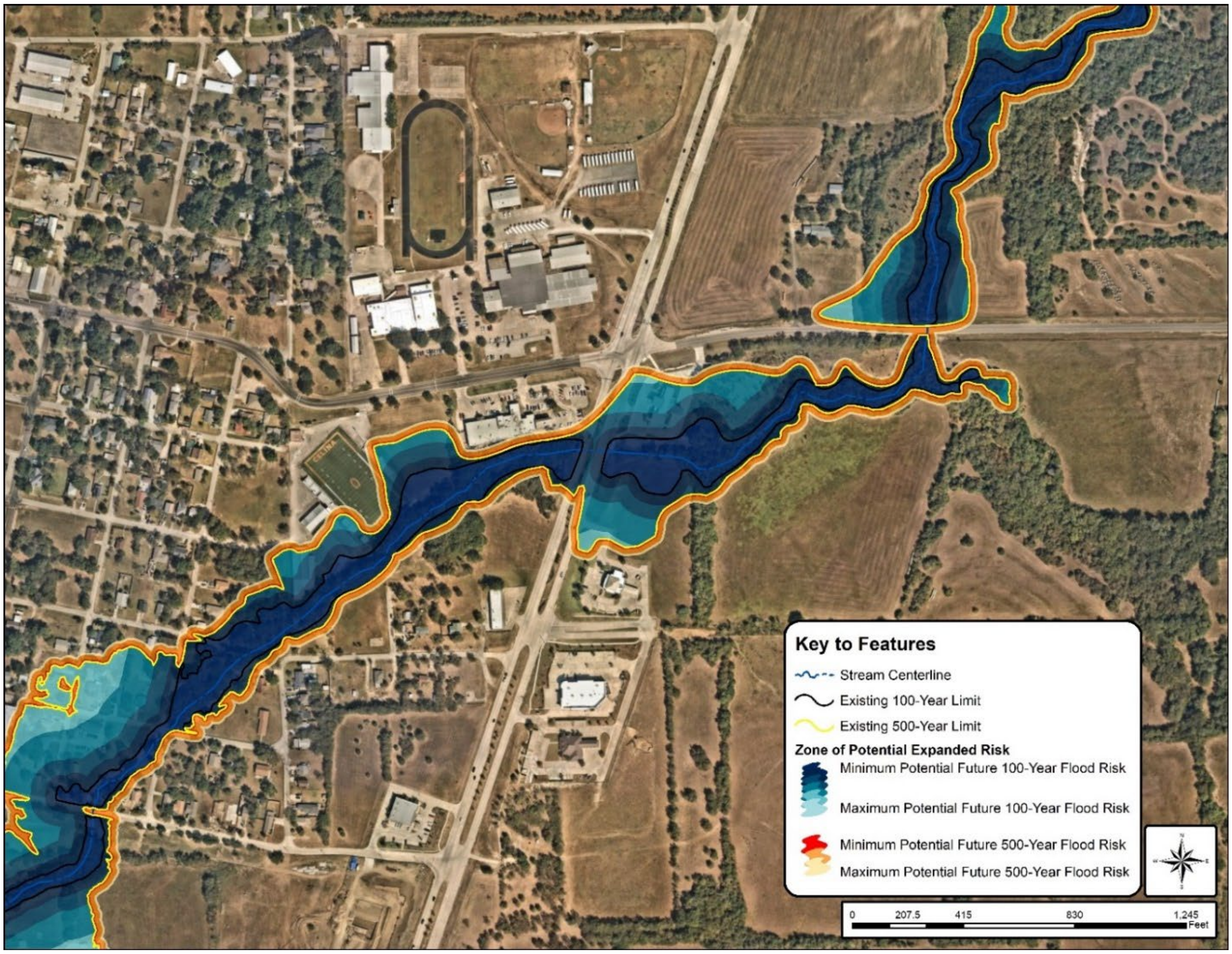


Table 2.32: Existing Development in Existing Condition Floodplain Quilt

County	Number of Structures within Existing Conditions Floodplains
Anderson	164
Archer	1
Chambers	551
Clay	32
Collin	2,283
Cooke	1,382
Dallas	13,532
Denton	4,292
Ellis	1,637
Fannin	129
Freestone	370
Grayson	312
Grimes	100
Hardin	0
Henderson	2,481
Hill	42
Hood	0
Houston	435
Hunt	15
Jack	156
Johnson	1,465
Kaufman	1,214
Leon	408
Liberty	4,740
Limestone	32
Madison	329
Montague	348
Navarro	1,373
Parker	1,164
Polk	4,142
Rockwall	485
San Jacinto	2,701
Tarrant	13,984
Trinity	1,302
Van Zandt	256
Walker	1,398
Wise	1,370
Young	11

Current development trends, combined with future population projections were used to estimate future developments within future condition floodplains. The United States Census Bureau's county level annual building permits survey data from 1991 to 2019 (30 years) along with TWDB's population projections were used to determine the average number of new building permits per unit change in population for each county in the Trinity Region. The number of new permits were divided by the change in population for each year from 1991 to 2019. The average over the 30-year period is reported as the average number of permits per unit population change.

The county specific number of permits per unit change in population were multiplied by the respective county level change in population between existing and future conditions to estimate the potential number of new buildings in the future. The TWDB's county level population data for 2020 and 2050 was used to determine the county change in population between existing and future conditions.

Table 2.33 summarizes the county level number of permits per unit change in population (as determined from United States Census data), existing and future populations, and existing and future estimated buildings in the Trinity Region.

Future Flood Mitigation Project with Dedicated Funding

Future FMPs with dedicated construction funding scheduled for completion within the next 30 years are included in the Current Mitigation Projects section of this plan. Typically, funding committed for FMPs is within a shorter timeframe than the 30-year TWDB planning period. Once the funding is committed, the project moves forward as the funding usually must be spent within a specified timeframe, which is often less than two years.

Future Conditions Flood Exposure

The potential future conditions mapping methodology (also discussed in the previous Best Available Data section) for the Trinity Region was accepted by the TWDB on January 21, 2022. This methodology was used to develop the 30-year potential future conditions floodplain quilt for the Trinity Region. For this planning cycle, the potential future flood exposure and vulnerability analysis consisted of two scenarios:

1. Estimated the structure count of buildings, critical facilities, infrastructure systems, population, and agriculture potentially exposed to flooding by overlaying the future conditions floodplain quilt developed for the Trinity Region
2. Estimated additional exposure and vulnerability by identifying of areas of existing and known flood hazard and future flood hazard areas where development might occur within the next 30 years if the current land development practices in the Trinity Region continues

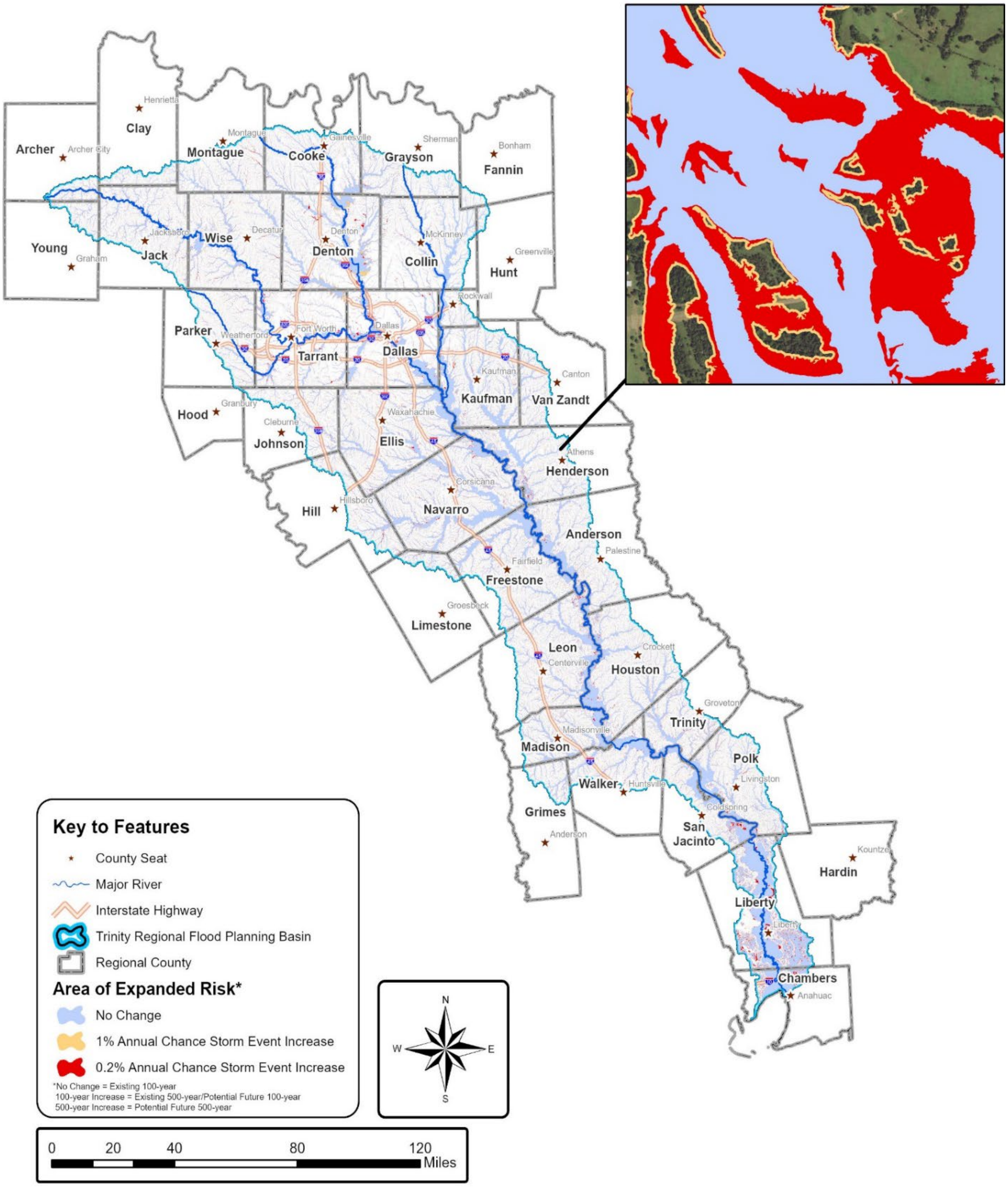
Potential Future Floodplain Changes

The potential 30-year future conditions floodplain quilt generally resulted in larger mapping extents when compared to the existing conditions floodplain quilt. ***Figure 2.57*** (See ***Appendix B*** for a larger version map) shows the areas of expanded risk between the existing and future conditions mapping.

Table 2.33: Estimated Future Development per County

County	Average # Permits per Unit Population Change	Existing Buildings (TWDB 2021)	Existing County Population (TWDB 2020)	Future County Population (TWDB 2050)	Future Additional Buildings (Estimated 2050)	Future Total Buildings (Estimated 2050)
Anderson	0.089	26,693	61,016	63,746	244	26,937
Archer	0.551	8,030	9,409	9,960	304	8,334
Chambers	0.432	26,162	42,162	68,541	11,395	37,557
Clay	0.771	10,078	11,154	11,503	269	10,347
Collin	0.281	269,530	1,050,506	1,807,279	212,791	482,321
Cooke	0.238	28,628	40,903	52,427	2,742	31,370
Dallas	0.629	674,024	2,587,960	3,429,783	529,228	1,203,252
Denton	0.185	231,182	891,063	1,584,015	128,532	359,714
Ellis	0.248	69,578	191,638	360,584	41,838	111,416
Fannin	0.120	23,852	38,330	69,328	3,718	27,570
Freestone	0.131	15,685	20,437	31,142	1,408	17,093
Grayson	0.228	67,409	135,311	178,907	9,957	77,366
Grimes	0.118	23,976	29,441	36,454	829	24,805
Hardin	0.260	30,186	59,477	69,560	2,626	32,812
Henderson	0.182	54,344	92,383	116,100	4,318	58,662
Hill	0.125	24,540	37,828	43,643	728	25,268
Hood	0.095	32,259	61,316	84,147	2,169	34,428
Hunt	0.229	58,373	104,894	207,929	23,554	81,927
Jack	0.069	7,867	9,751	11,033	89	7,956
Johnson	0.275	76,028	173,835	258,414	23,258	99,286
Kaufman	0.123	57,781	146,389	306,833	19,680	77,461
Leon	0.017	20,298	18,211	22,071	65	20,363
Liberty	0.961	53,494	86,303	118,048	30,513	84,007
Limestone	0.272	16,635	25,136	29,134	1,088	17,723
Madison	0.106	10,574	14,753	17,872	330	10,904
Montague	0.048	17,326	20,507	21,979	71	17,397
Navarro	0.191	31,296	52,505	74,213	4,154	35,450
Parker	0.144	67,342	201,491	360,125	22,812	90,154
Polk	2.458	29,354	51,870	66,796	36,692	66,046
Rockwall	0.292	30,887	119,410	246,938	37,239	68,126
San Jacinto	0.252	22,719	29,610	37,614	2,017	24,736
Tarrant	0.258	606,697	2,004,609	2,799,127	205,307	812,004
Trinity	0.069	10,819	16,502	17,473	67	10,886
Van Zandt	0.049	52,369	58,455	72,817	699	53,068
Walker	0.184	34,518	71,800	80,050	1,516	36,034
Wise	0.075	39,611	79,882	135,797	4,197	43,808
Young	0.183	13,485	19,336	21,972	484	13,969

Figure 2.57: Potential Expanded Risk between Existing and Future Conditions Floodplain Quilt



The largest increases in the potential future 100-year floodplain are seen in Collin, Dallas, Denton, Ellis, Navarro, and Tarrant counties. While Chambers County shows minimal increase from existing to future conditions, it must be noted that Chambers County has a high percent of the land areas in the Trinity Region within the potential future floodplain (63 percent). This is because Chambers is a coastal county located along the Trinity Bay and East Bay with relatively flat terrain and inundated with coastal flooding coupled with riverine flooding from the Trinity River. Hardin and Hood counties have less than 20 percent of their land area in the Trinity Region and, therefore, exhibit small floodplain area percentages. ***Table 2.34*** shows the floodplain area increases between the existing and future conditions mapping, in addition to the percent county area in the potential future mapping.

Per the future conditions mapping methodology and ***Figure 2.58,*** the horizontal increases in potential future mapping extents are shown as a range of potential minimum and maximum extents.

Scenario 1

The 30-year potential future conditions floodplain quilt was overlaid with all the same GIS exposure layers (buildings, critical facilities, agricultural areas, bridges, and LWCs) as in ***Task 2A*** to get an estimation of exposure to the future mapping based on existing development. For population estimates, the higher of the day or night population attributes was used for the exposure population estimates per guidance received from the TWDB.

Buildings, Critical Facilities, Infrastructure and Agriculture Exposure Totals by County

Figure 2.59 shows the total exposure counts of buildings, critical facilities, infrastructure, and agriculture by county of existing development to the future floodplains. The highest counts are in the populated areas of Collins, Dallas, Denton, and Tarrant counties in the Upper Subregion. Chambers, Henderson, and Liberty counties also show significant counts.

Population Totals by County

Figure 2.60 shows the population exposure to the existing floodplain quilt by county. As shown in ***Figure 2.13***, high populations exposures occur in the Collin, Dallas, Denton, and Tarrant counties in the Upper Subregion, as well as the coastal Liberty County in the Lower Subregion. Because the population count is the higher of the day or night numbers, the worst possible scenario was assumed where the maximum number of people present are exposed to the future condition floodplain quilt.

Figure 2.58: Future Condition Flood Hazard Areas (in Square Miles) by County

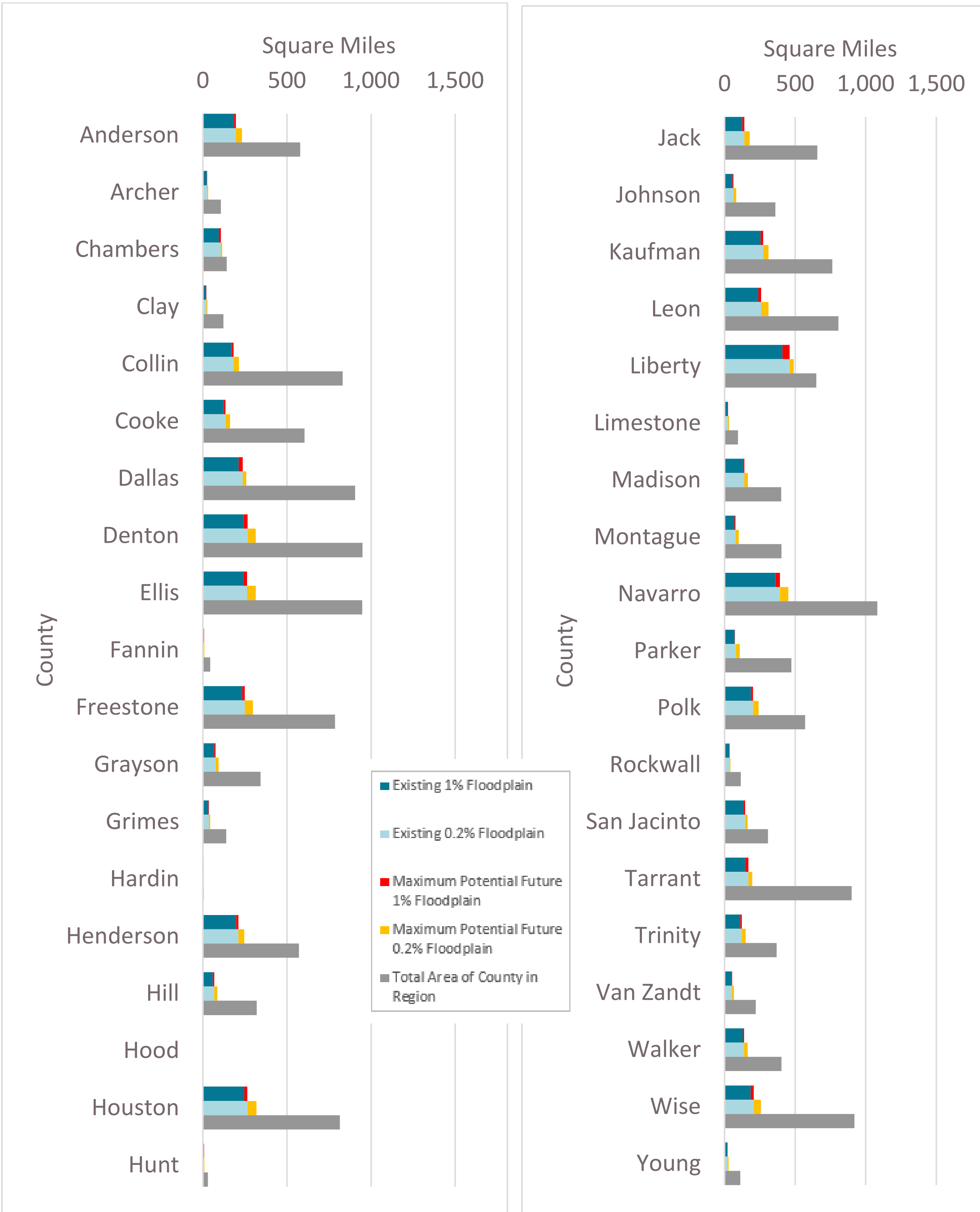


Table 2.34: Future Condition Flood Hazard Areas (in Square Miles) Flood Type by County

County	1% Annual Chance Flood Risk - Area in Riverine Flood Type (sq.mi.)	1% Annual Chance Flood Risk - Area in Coastal Flood Type (sq.mi.)	0.2% Annual Chance Flood Risk - Area in Riverine Flood Type (sq.mi.)	0.2% Annual Chance Flood Risk - Area in Coastal Flood Type (sq.mi.)
Anderson	196.7	-	35.9	-
Archer	26.1	-	5.9	-
Chambers	67.2	40.2	6.4	0.1
Clay	21.0	-	6.5	-
Collin	182.9	-	32.0	-
Cooke	134.1	-	27.9	-
Dallas	237.4	-	20.8	-
Denton	266.1	-	48.1	-
Ellis	263.0	-	50.7	-
Fannin	6.3	-	1.9	-
Freestone	249.5	-	47.8	-
Grayson	75.5	-	18.5	-
Grimes	36.4	-	7.8	-
Hardin	3.5	-	0.6	-
Henderson	211.8	-	34.5	-
Hill	67.6	-	18.1	-
Hood	0.3	-	0.1	-
Houston	265.0	-	53.1	-
Hunt	6.4	-	1.9	-
Jack	139.6	-	38.2	-
Johnson	63.6	-	19.0	-
Kaufman	272.7	-	38.3	-
Leon	259.1	-	51.4	-
Liberty	460.7	-	29.0	-
Limestone	25.7	-	5.9	-
Madison	141.1	-	24.9	-
Montague	77.0	-	24.0	-
Navarro	392.1	-	59.5	-
Parker	80.5	-	26.7	-
Polk	202.2	-	38.0	-
Rockwall	36.2	-	4.9	-
San Jacinto	145.2	-	17.9	-
Tarrant	169.7	-	26.9	-
Trinity	122.4	-	26.4	-
Van Zandt	54.1	-	13.2	-
Walker	138.3	-	24.5	-
Wise	206.9	-	50.6	-
Young	21.7	-	6.0	-

Figure 2.59: Potential Future Condition Flood Exposure by County

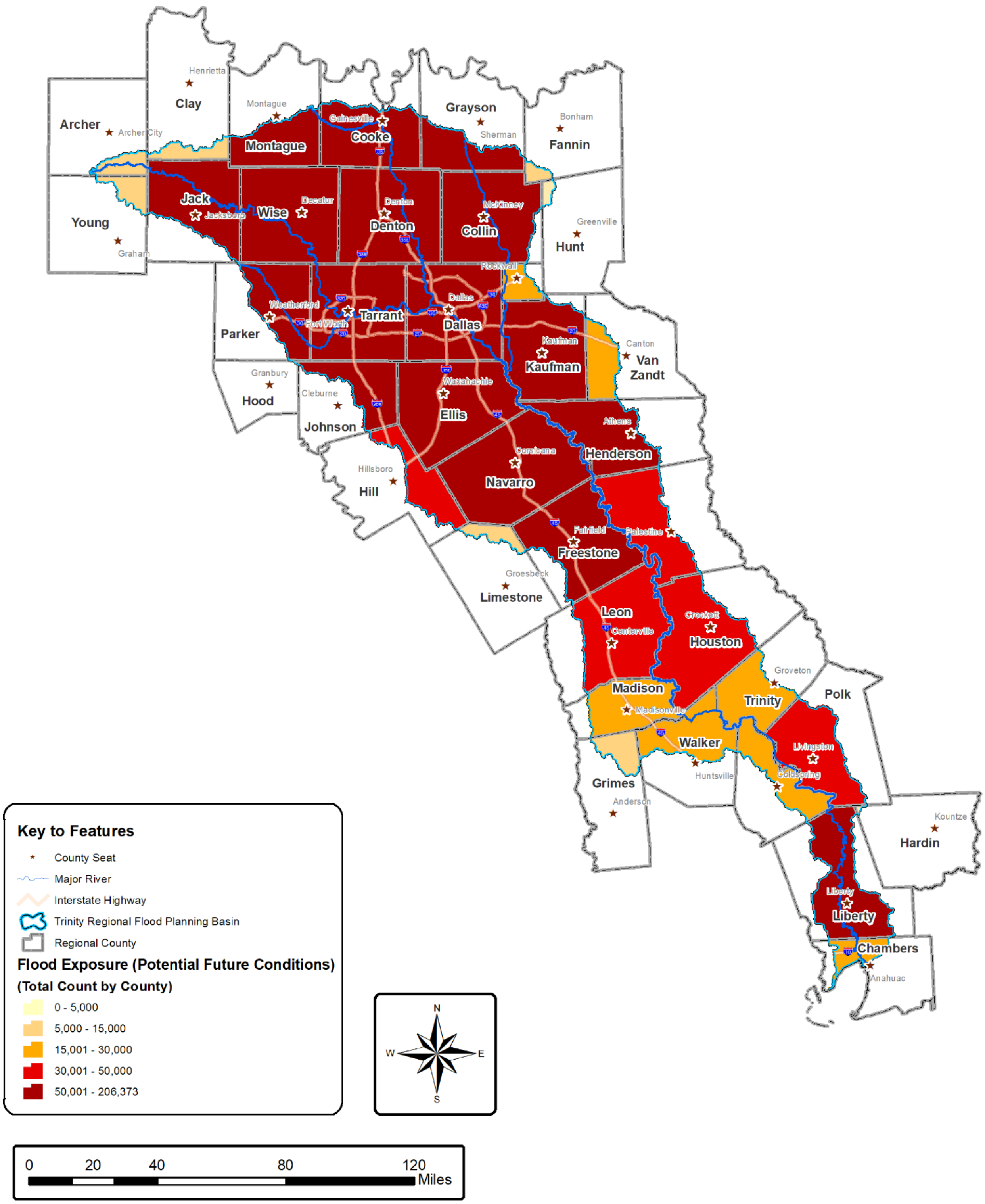


Figure 2.60: Potential Population at Risk in Future Condition Floodplain Quilt

Building Exposure Totals by County

Figure 2.61 shows the existing building type exposure distribution in the Trinity Region with the future condition's floodplain quilt.

Residential Properties

Figure 2.62 was made to show the maximum exposure additions to the existing conditions floodplain quilt exposure estimates, that results in the exposure counts for the potential future conditions 100-year and 500-year mapping. The largest increases occur in Collin, Dallas, Denton, and Tarrant counties. Ellis, Henderson, Johnson, Kaufman, Polk, and San Jacinto counties also showed significant increases in exposure to the future floodplain.

Non-Residential Properties

Figure 2.63 shows the total exposure counts by county of existing non-residential buildings to the future floodplains. In addition, ***Figure 2.64*** included a comparison exposure to existing conditions. The upper chart in ***Figure 2.64*** refers to existing conditions exposure while the lower chart applies to future conditions exposure. Overall, there were increases in exposure to the future floodplains for all non-residential buildings, with the largest increases in Collin, Dallas, Denton, and Tarrant counties. Tarrant County has very little agricultural exposure to floodplains. Dallas, Ellis, and Tarrant counties show industrial buildings in the floodplain with increases in exposures from existing to the future floodplains. The comparison chart also reveals that agriculture sector is a very small percentage of the non-residentials structures, flood exposure can be extensive across several counties and significant.

Critical Facilities Exposure Totals by County

The Trinity Region's existing critical facilities exposure to the potential future conditions mapping is shown in ***Figure 2.65***. The largest increases occur in Collin, Dallas, Denton, and Tarrant counties. Ellis, Kaufman, and Navarro counties also showed significant increases.

Roadway Crossings and Roadway Segments

Road and railroad crossing in the Trinity Region at risk of flooding to future conditions mapping are shown in ***Figure 2.66***.

Agricultural Area

Crop and livestock production dollar losses due to the 30-year future conditions mapping are summarized in ***Table 2.35*** and ***Figure 2.67***. Denton, Ellis, Hill, Houston, Kaufman, Leon, Limestone, Navarro, and Van Zandt counties have high agriculture exposure values to the future conditions mapping. The largest increases from existing conditions to future conditions were seen in Clay, Denton, Ellis, Fannin, Hill, Hunt, Leon, Limestone, and Van Zandt counties.

Figure 2.61: Building Type Distribution in the Future Condition Floodplain Quilt

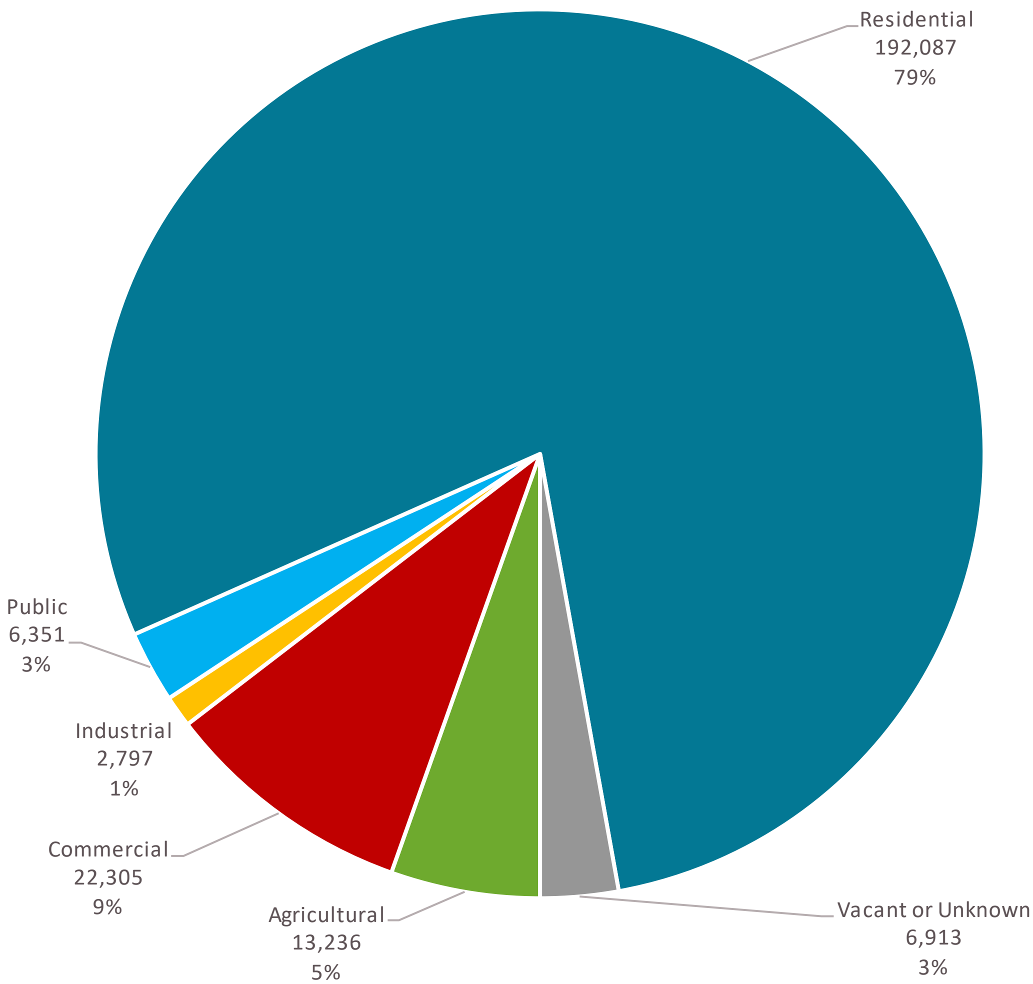


Figure 2.62: Potential Residential Structures at Risk in Future Condition Floodplain Quilt

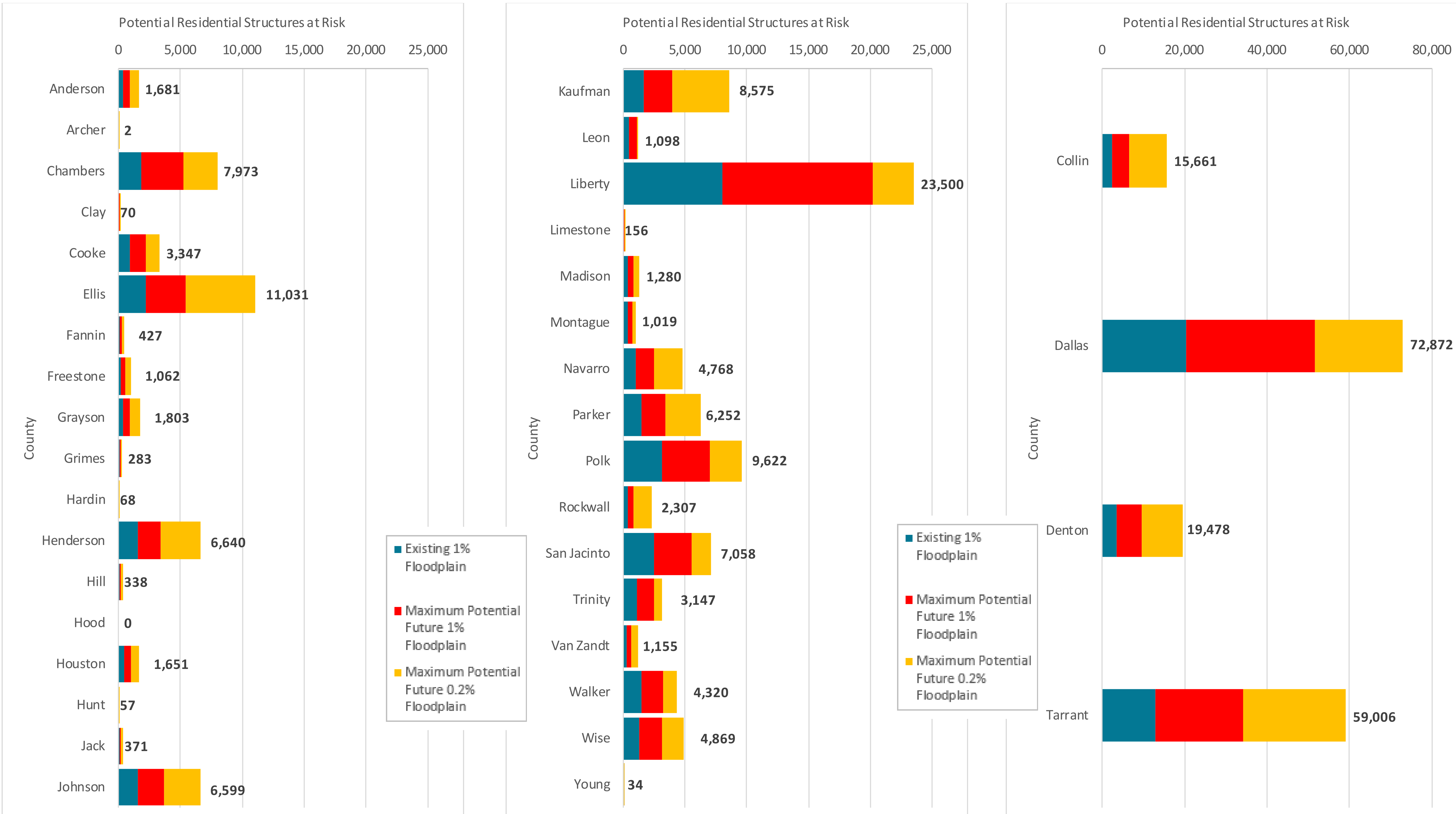
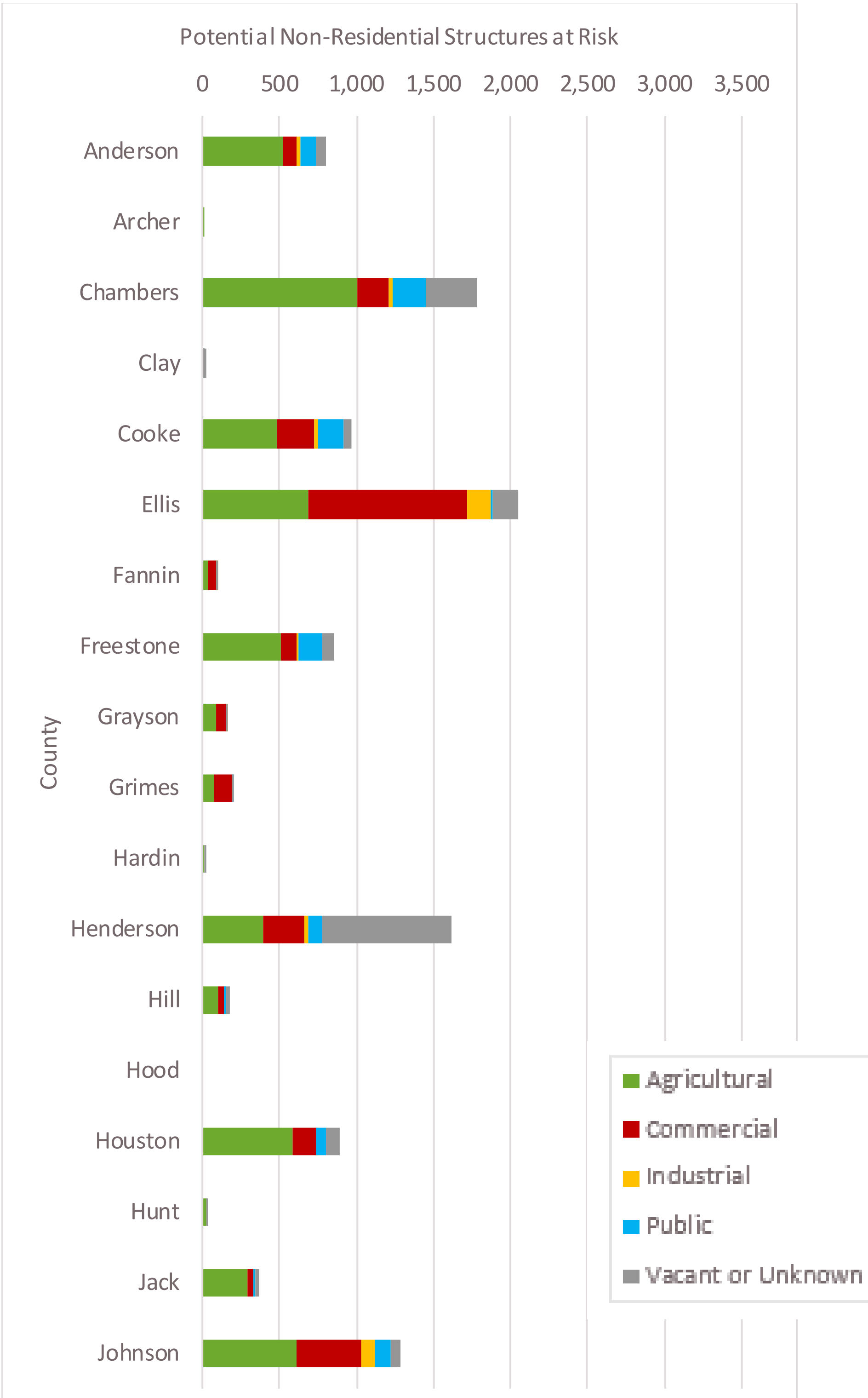
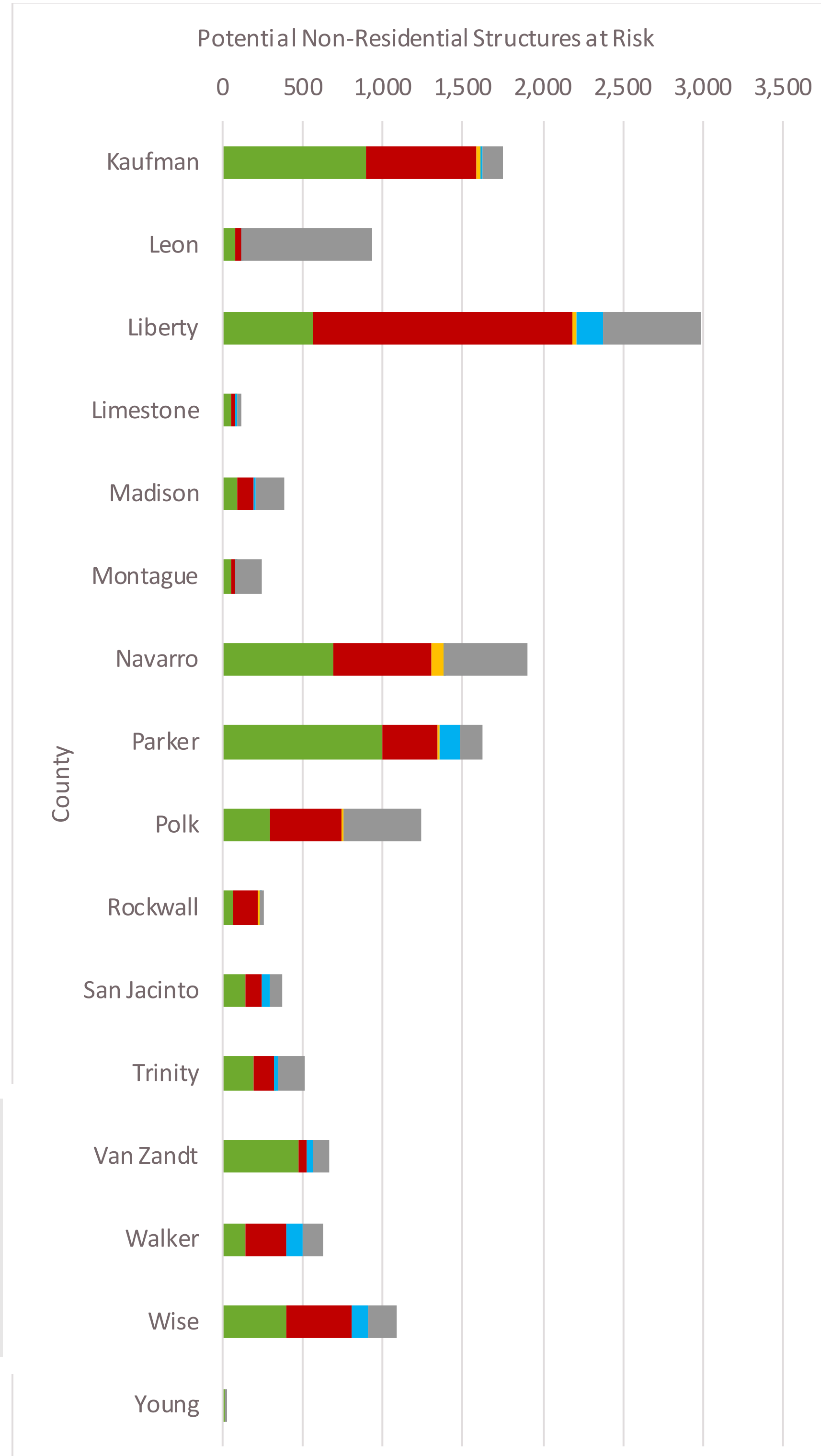


Figure 2.63: Potential Non-Residential Structures at Risk in Future Condition Floodplain Quilt





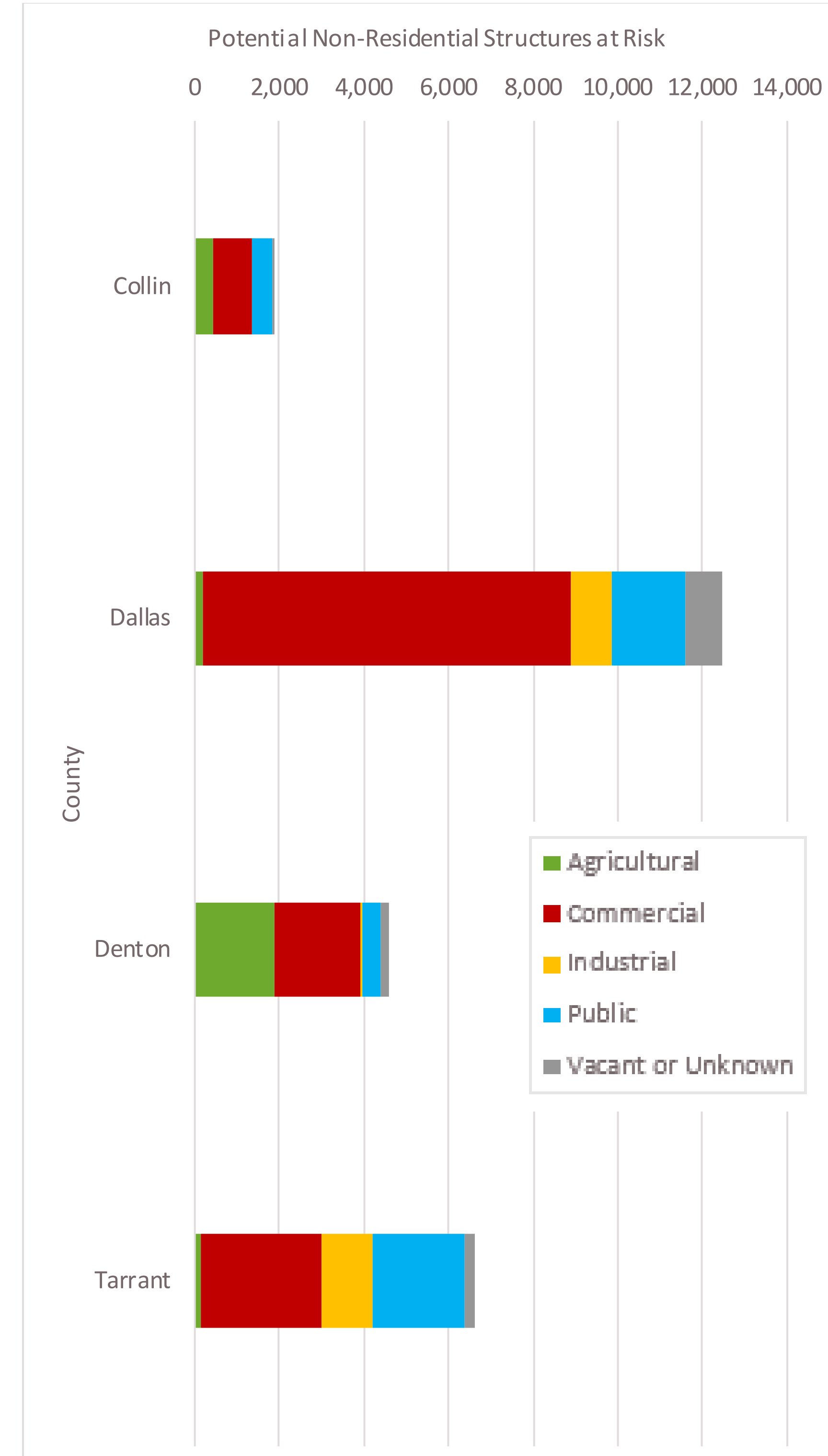


Figure 2.64: Comparison of Existing Non-Residential Structures at Risk to Potential Non-Residential Structures in Future Condition Floodplain Quilt

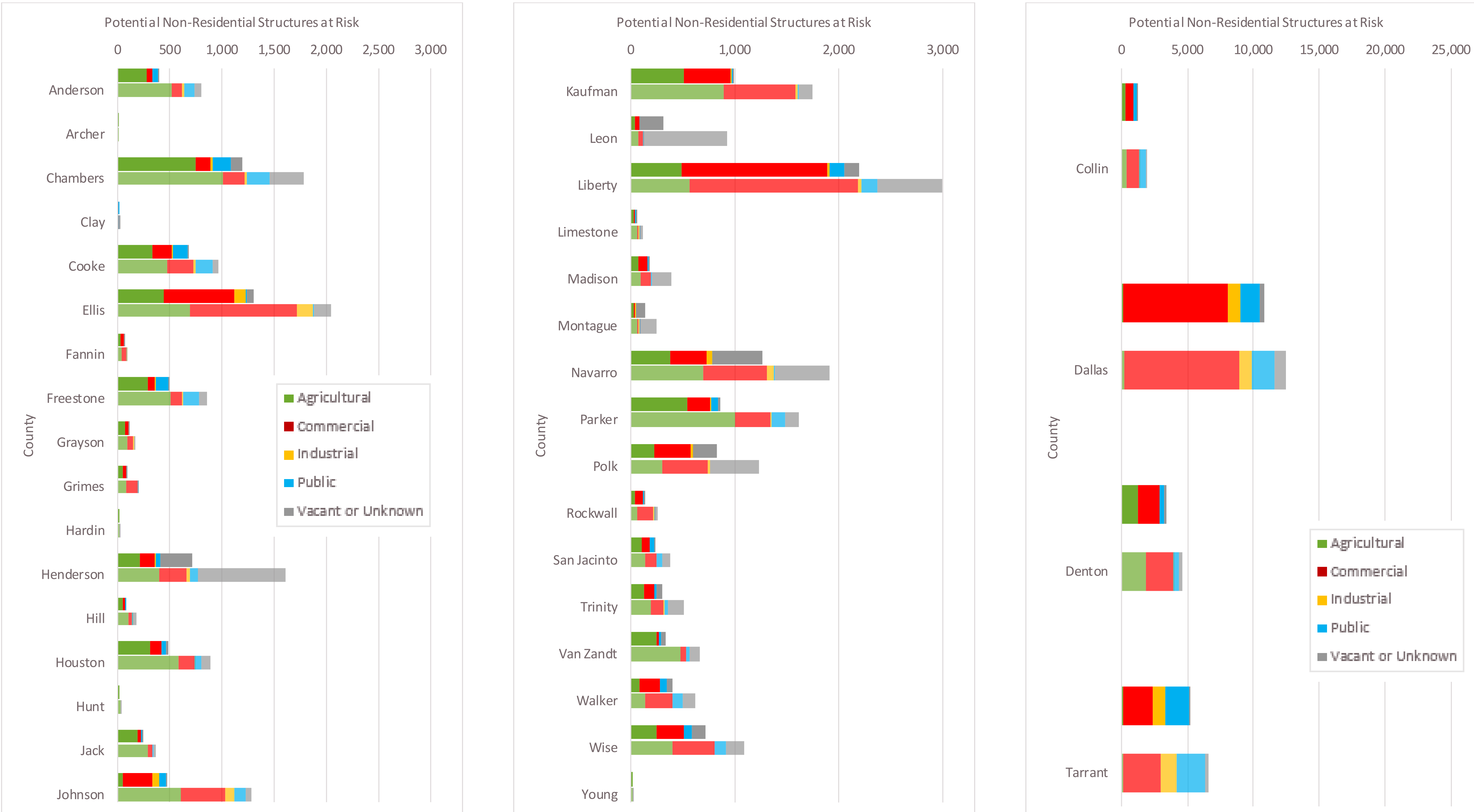


Figure 2.65: Potential Critical Facilities at Risk in Future Conditions Floodplain Quilt

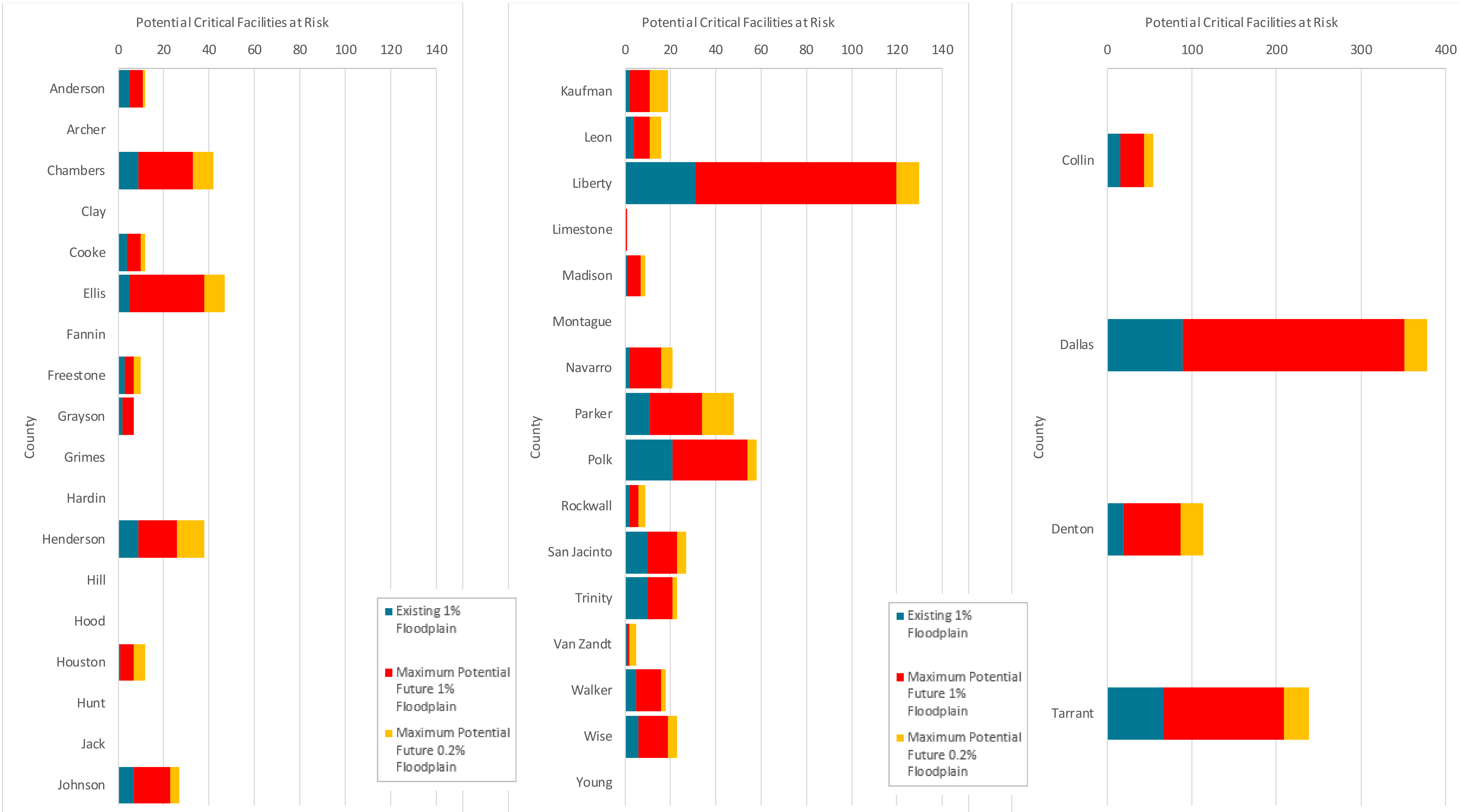


Figure 2.66: Linear Miles of Roadway at Risk in Future Condition Floodplain Quilt

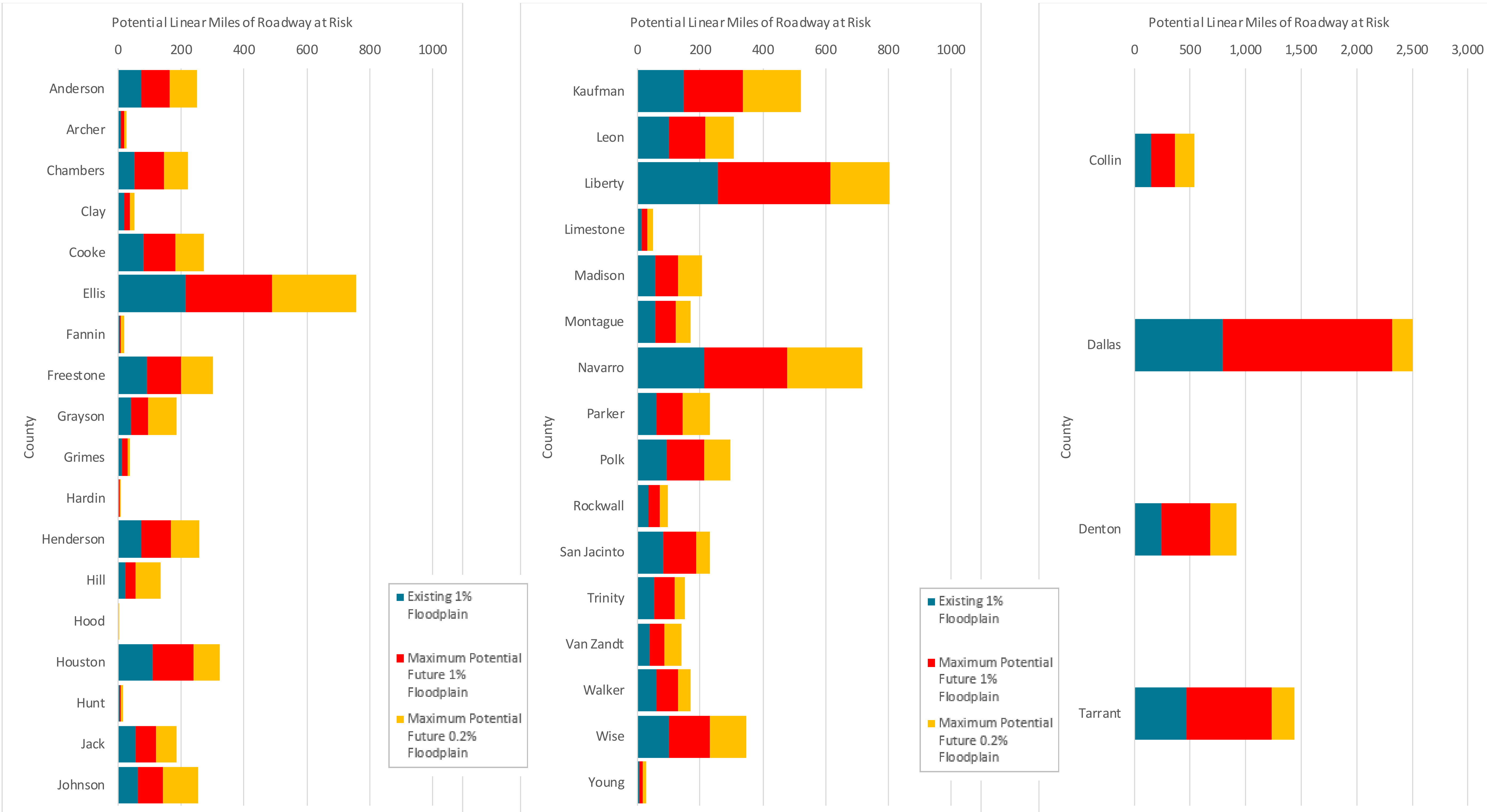


Figure 2.67: Agricultural Land at Risk in Future Condition Floodplain Quilt

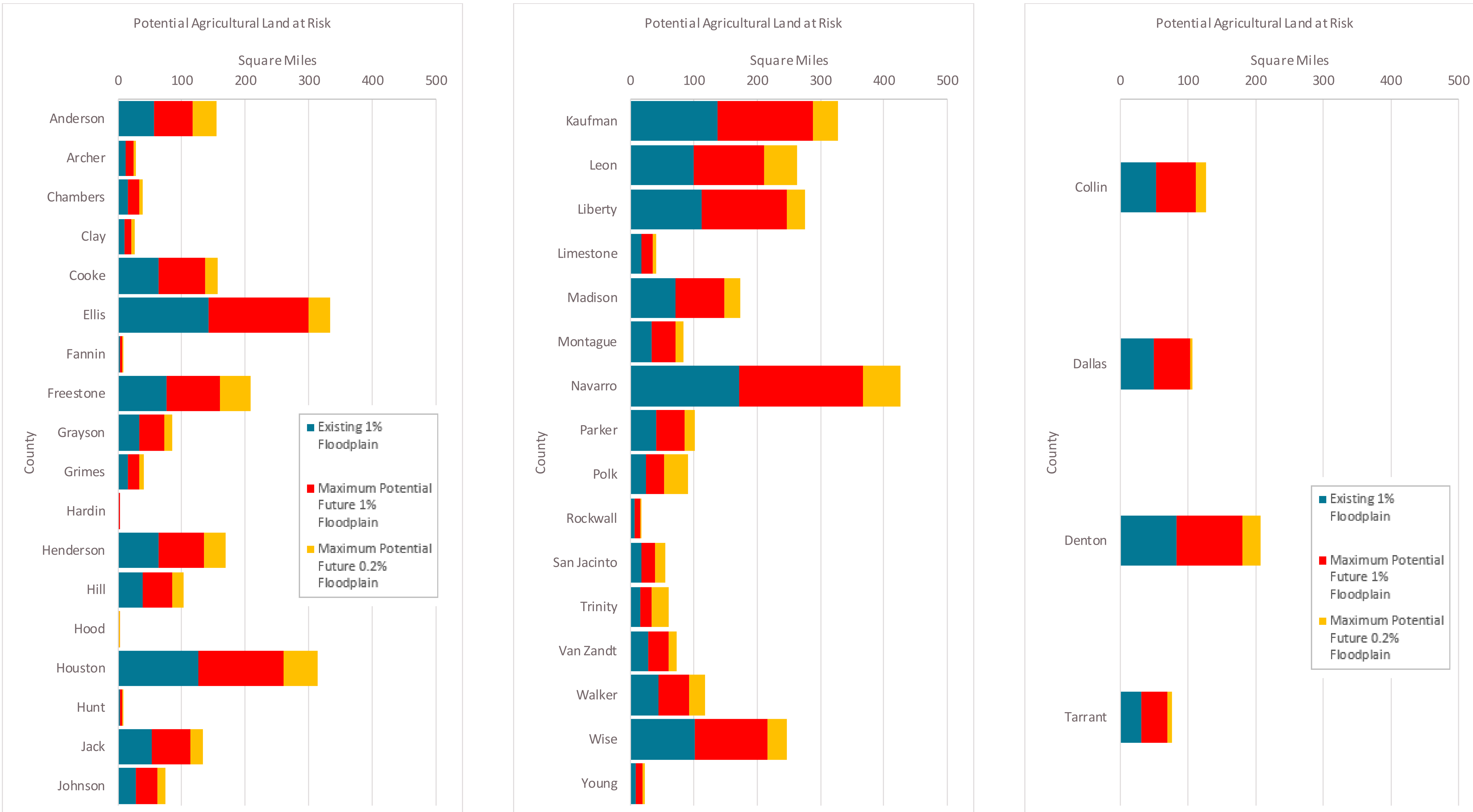


Table 2.35: Exposed Crop and Livestock Production Dollar Losses in Future Condition Floodplain Quilt

County	Total $ Value of Entire County*	$ Losses in Existing 100-Year**	$ Losses in Existing 500-Year**
Anderson	$92,943,000.00	$23,424,121.00	$13,806,549.00
Archer	$72,439,000.00	$10,962,677.00	$3,580,853.00
Chambers	$19,252,000.00	$11,278,080.00	$4,034,961.00
Clay	$55,650,000.00	$6,573,944.00	$2,592,881.00
Collin	$66,829,000.00	$9,571,610.00	$2,422,392.00
Cooke	$53,830,000.00	$8,488,262.00	$2,357,510.00
Dallas	$29,781,000.00	$10,419,892.00	$719,657.00
Denton	$123,209,000.00	$22,781,889.00	$6,230,762.00
Ellis	$73,146,000.00	$16,345,246.00	$3,463,058.00
Fannin	$86,292,000.00	$7,330,836.00	$3,025,653.00
Freestone	$68,131,000.00	$14,574,206.00	$8,376,853.00
Grayson	$66,171,000.00	$9,284,005.00	$3,108,307.00
Grimes	$47,509,000.00	$8,793,137.00	$4,031,577.00
Hardin	$4,694,000.00	$1,513,317.00	$0
Henderson	$40,183,000.00	$10,197,075.00	$4,985,599.00
Hill	$114,001,000.00	$18,349,735.00	$7,316,132.00
Hood	$18,944,000.00	$1,613,435.00	$823,939.00
Houston	$64,518,000.00	$21,071,110.00	$8,332,324.00
Hunt	$55,313,000.00	$7,411,228.00	$2,899,387.00
Jack	$23,176,000.00	$3,698,071.00	$1,184,036.00
Johnson	$57,850,000.00	$7,687,178.00	$2,685,601.00
Kaufman	$57,063,000.00	$15,900,351.00	$4,062,636.00
Leon	$169,404,000.00	$48,813,193.00	$22,727,493.00
Liberty	$29,950,000.00	$19,157,635.00	$4,150,038.00
Limestone	$66,257,000.00	$14,567,126.00	$4,582,737.00
Madison***	$ -	$0	$0
Montague	$33,416,000.00	$5,055,819.00	$1,608,111.00
Navarro	$73,306,000.00	$18,557,266.00	$5,693,506.00
Parker	$65,043,000.00	$8,976,727.00	$3,068,840.00
Polk	$6,831,000.00	$2,103,797.00	$2,833,191.00
Rockwall	$7,830,000.00	$1,077,692.00	$359,566.00
San Jacinto	$7,190,000.00	$3,108,614.00	$2,757,655.00
Tarrant	$29,393,000.00	$4,909,615.00	$1,066,072.00
Trinity	$8,228,000.00	$2,052,724.00	$3,070,382.00
Van Zandt	$104,603,000.00	$19,230,671.00	$8,065,974.00
Walker	$33,795,000.00	$11,904,502.00	$6,156,123.00
Wise	$46,269,000.00	$8,341,303.00	$2,226,117.00
Young	$21,694,000.00	$2,927,108.00	$1,015,784.00

**Total Agricultural Value of county, including land area outside of Trinity Region*

***Total Agricultural Losses only within Trinity Region*

****USDA/NASS Crop and Livestock Values were unavailable for Madison County*

Hardin County had no agricultural exposure in the Trinity Region. (Less than one percent of the land area of Hardin County is in the Trinity Region.) Even though Madison County showed a large agriculture area exposure to the future conditions mapping (a little more than Anderson County), there was no data available from the 2017 USDA crop and livestock production summaries.

Scenario 2

The Existing and Future Developments within Future Conditions Floodplains section discussed existing and future developments in the floodplain and estimated number of potential buildings per county in 2050 using the number of permits per unit change in population. However, the number of permits per unit change in population in the future condition floodplains are not expected to be the same as the county level values since development in future condition floodplains are likely to be regulated by floodplain regulations (assuming existing floodplain management practices will not change). Therefore, four criteria were used to determine weighting factors for development in the future condition floodplains:

- FEMA's Community Rating System (CRS)
- Participation in the NFIP
- Adoption of higher standards
- Presence or absence of a Hazard Mitigation Plan (HMP)

Figures showing spatial distribution of these factors in the Trinity Region are included in ***Appendix B***. CRS applicable discounts ranging from 0 to 45 percent were converted to normalized scores ranging from 0 to 1. For example, a community with a CRS rating of 5 (or 25 percent discount) received a score of 0.56. Each community was given a score of 1 or 0 depending on participation or non-participation in NFIP. Similarly, a score of 1 was assigned to communities adopting higher standards and 0 for others. Communities with a HMP were assigned a score of 1 and 0 for others. The community level scores for each criterion were averaged at the county level. Each county level criterion was assigned an equal weight of 0.25 and summed to generate one weighted score for each county. A higher score implies more rigorous regulations associated with floodplain development. Therefore, a county with a weighted score of 1 implies that the likelihood of floodplain development is close to 0. The floodplain number of permits per unit change in population for such instance is 0 or county level number of permits per unit change in population multiplied 1 minus the weighted score. The weighting factors were determined as 1 minus the weighted scores and were subsequently multiplied by the county level number of permits per unit change in population to determine floodplain number of permits per unit change in population. ***Table 2.37*** summarizes the scores for each criterion, weighting factor, and floodplain number of permits per unit change in population by county in the Trinity Region.

Table 2.36: Development Factor Per Unit Change in Population

County	Average # Permits per Unit Population Change	NFIP Score	CRS Score	HMP Score	Higher Standards Score	Weighting Factor	Floodplain # Permits per Unit Population Change
Anderson	0.089	1.00	0.00	0.00	0.67	0.58	0.052
Archer	0.551	1.00	0.00	0.00	0.00	0.75	0.413
Chambers	0.432	1.00	0.03	0.00	0.86	0.53	0.228
Clay	0.771	1.00	0.00	0.00	1.00	0.50	0.386
Collin	0.281	0.96	0.00	0.88	0.79	0.34	0.096
Cooke	0.238	0.88	0.00	0.00	0.63	0.62	0.148
Dallas	0.629	1.00	0.04	0.08	0.96	0.48	0.302
Denton	0.185	0.91	0.01	0.67	0.85	0.39	0.072
Ellis	0.248	0.88	0.00	0.94	0.75	0.36	0.089
Fannin	0.120	1.00	0.00	1.00	0.67	0.33	0.040
Freestone	0.131	0.67	0.00	0.00	0.00	0.83	0.109
Grayson	0.228	0.70	0.00	1.00	0.80	0.38	0.086
Grimes	0.118	0.33	0.00	1.00	0.00	0.67	0.079
Hardin	0.260	1.00	0.00	0.00	1.00	0.50	0.130
Henderson	0.182	1.00	0.00	0.00	0.92	0.52	0.095
Hill	0.125	0.63	0.00	0.00	0.63	0.69	0.086
Hood	0.095	1.00	0.00	0.00	0.50	0.63	0.059
Houston	0.075	0.80	0.00	1.00	0.40	0.45	0.034
Hunt	0.229	1.00	0.00	1.00	1.00	0.25	0.057
Jack	0.069	1.00	0.00	0.00	0.00	0.75	0.052
Johnson	0.275	0.90	0.00	0.10	0.50	0.63	0.172
Kaufman	0.123	0.63	0.00	0.38	0.63	0.59	0.072
Leon	0.017	0.86	0.00	0.00	0.57	0.64	0.011
Liberty	0.961	1.00	0.00	0.00	0.50	0.63	0.601
Limestone	0.272	0.75	0.00	0.25	0.00	0.75	0.204
Madison	0.106	0.67	0.00	0.33	0.67	0.58	0.062
Montague	0.048	1.00	0.00	0.00	0.67	0.58	0.028
Navarro	0.191	0.63	0.00	0.16	0.47	0.69	0.131
Parker	0.144	0.91	0.00	0.09	0.64	0.59	0.085
Polk	2.458	0.80	0.00	0.00	0.60	0.65	1.598
Rockwall	0.292	0.83	0.00	0.00	0.67	0.63	0.183
San Jacinto	0.252	1.00	0.00	0.00	0.75	0.56	0.142
Tarrant	0.258	1.00	0.03	0.00	0.94	0.51	0.131
Trinity	0.069	1.00	0.00	0.00	0.33	0.67	0.046
Van Zandt	0.049	1.00	0.00	0.00	1.00	0.50	0.024
Walker	0.184	1.00	0.00	0.00	0.33	0.67	0.123
Wise	0.075	0.85	0.00	0.38	0.62	0.54	0.040
Young	0.183	1.00	0.00	0.00	1.00	0.50	0.092

The 2021 TWDB buildings dataset was used to determine the existing structure and exposed population in the existing and future 100-year and 500-year floodplains. The exposed population in the floodplains at the county level divided by the existing population provides an estimate of the percent of the county population exposed to flood risk. Assuming that the percent of exposed population at the county level in the future conditions floodplains remains unchanged from existing conditions, the existing percent exposed population multiplied by the future county population provides the future exposed population in the future condition floodplains. The additional future population in the future condition floodplains multiplied by the floodplain number of permits per unit population change provides an estimate of additional future buildings in future conditions floodplains. ***Table 2.38*** and ***Table 2.39*** summarize the existing buildings and population in the existing conditions floodplains, and future estimated buildings and population in future condition floodplains.

Future Condition Vulnerability Analysis

Resiliency of Communities

The resiliency ratings of communities in the Trinity Region, previously discussed in the Resiliency of Communities section, helps predict a community's ability and readiness to recover quickly from disruptions such as flood-related disasters. This means that the current resiliency rating in the Trinity Region is a measure of the communities' abilities within the region to prepare for future threats, absorb impacts, and to recover and adapt after disruptive event such as a flood.

Recent developments in flood data science and data development such as FEMA's planned shift from binary in/out floodplain mapping to graduated risk analysis and Risk Rating 2.0 will help create better risk-informed communities. Local communities, regional entities, state and federal authorities, as well as floodplain-related organizations continue to encourage and advocate for higher standards and No Adverse Impacts (NAI).

These and many other floodplain management practices will create plans and systems that future-proof communities in the Trinity Region.

Vulnerabilities of Structures, Low Water Crossings, and Critical Facilities

The 2018 CDC SVI data was used to estimate community vulnerability in the context of the potential future conditions flood quilt. The SVI values for all the structures, critical facilities, and LWCs exposed to the future condition floodplain quilt are summarized by county average and shown in ***Figure 2.68***.

Table 2.37: Estimated Building and Population in Existing and Future Floodplain (100-Year)

County	Existing Buildings in Existing Floodplain	Existing Population in Existing Floodplain	Existing Buildings in Future Floodplain	Future Buildings in Future Floodplain	Future Population in Future Floodplain
Anderson	164	74	192	192	77
Archer	1	5	2	2	5
Chambers	551	547	1,317	1,395	889
Clay	32	13	35	35	13
Collin	2,283	16,526	4,011	5,158	28,431
Cooke	1,382	1,764	1,697	1,771	2,261
Dallas	13,532	114,007	38,910	50,101	151,092
Denton	4,292	11,530	8,384	9,033	20,497
Ellis	1,637	3,369	2,197	2,460	6,339
Fannin	129	75	168	170	136
Freestone	370	212	458	470	323
Grayson	312	393	339	350	520
Grimes	100	55	132	133	68
Hardin	0	0	0	0	0
Henderson	2,481	2,601	2,540	2,603	3,269
Hill	42	86	67	68	99
Hood	0	0	0	0	0
Houston	435	334	562	562	336
Hunt	15	6	15	15	12
Jack	156	85	210	211	96
Johnson	1,465	2,821	1,788	2,024	4,194
Kaufman	1,214	1,893	1,525	1,675	3,968
Leon	408	229	484	485	278
Liberty	4,740	4,841	8,152	9,222	6,622
Limestone	32	29	50	51	34
Madison	329	367	412	417	445
Montague	348	229	355	355	245
Navarro	1,373	2,318	1,702	1,828	3,276
Parker	1,164	2,300	1,253	1,407	4,111
Polk	4,142	5,028	4,832	7,144	6,475
Rockwall	485	1,047	508	712	2,165
San Jacinto	2,701	2,507	3,234	3,330	3,185
Tarrant	13,984	61,398	24,511	27,702	85,733
Trinity	1,302	1,669	1,489	1,494	1,767
Van Zandt	256	195	340	341	243
Walker	1,398	3,654	1,650	1,702	4,074
Wise	1,370	1,521	1,429	1,472	2,586
Young	11	0	11	11	0

Table 2.38: Estimated Building and Population in Existing and Future Floodplain (500-Year)

County	Existing Buildings in Existing Floodplain	Existing Population in Existing Floodplain	Exiting Buildings in Future Floodplain	Future Buildings in Future Floodplain	Future Population in Future Floodplain
Anderson	28	38	90	90	40
Archer	1	0	2	2	0
Chambers	766	1,142	503	666	1,857
Clay	3	1	32	32	1
Collin	1,728	12,331	4,805	5,660	21,214
Cooke	315	2,526	347	452	3,238
Dallas	25,378	232,851	12,083	34,939	308,594
Denton	4,092	33,060	3,744	5,604	58,770
Ellis	560	1,190	904	997	2,239
Fannin	39	45	83	84	81
Freestone	88	60	209	212	91
Grayson	27	62	144	146	82
Grimes	32	17	34	34	21
Hardin	0	0	0	0	0
Henderson	59	43	1,562	1,563	54
Hill	25	22	50	50	25
Hood	0	0	0	0	0
Houston	127	184	156	156	185
Hunt	0	0	12	12	0
Jack	54	27	85	85	31
Johnson	323	1,778	723	872	2,643
Kaufman	311	404	656	688	847
Leon	76	50	176	176	61
Liberty	3,412	8,324	538	2,377	11,386
Limestone	18	26	25	26	30
Madison	83	53	100	101	64
Montague	7	3	65	65	3
Navarro	329	384	588	609	543
Parker	89	711	478	526	1,271
Polk	690	1,092	847	1,349	1,406
Rockwall	23	52	477	487	108
San Jacinto	533	618	561	585	785
Tarrant	10,527	43,205	14,471	16,717	60,329
Trinity	187	196	188	189	208
Van Zandt	84	63	213	213	78
Walker	252	1,382	267	287	1,541
Wise	59	86	550	552	146
Young	0	0	3	3	0

Figure 2.68: Future Condition Exposures Averaged by County

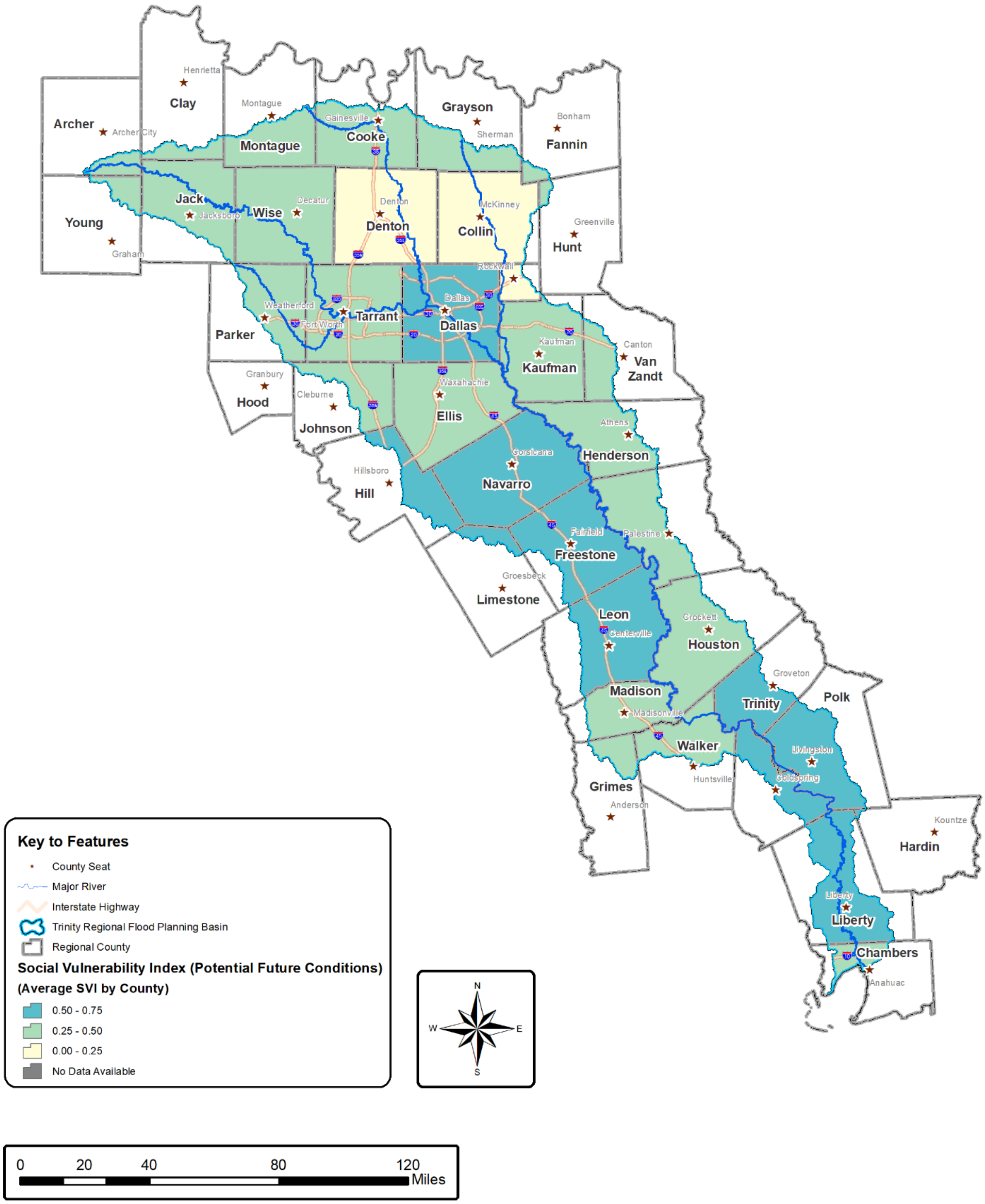


Figure 2.69 shows the countywide average distribution of SVI with regards to the exposed structures, critical facilities, and LWCs in the Trinity Region. ***Figure 2.68*** shows Clay, Collin, Denton, Parker, and Rockwall counties as being the least vulnerable with respect to the future condition exposure of structures, critical facilities, and LWCs. TWDB has a threshold of 0.75 as an indicator for highly vulnerable areas. At the county level, none of the counties reached this threshold. Large, detailed maps for the vulnerability assessment are shown in ***Appendix B***.

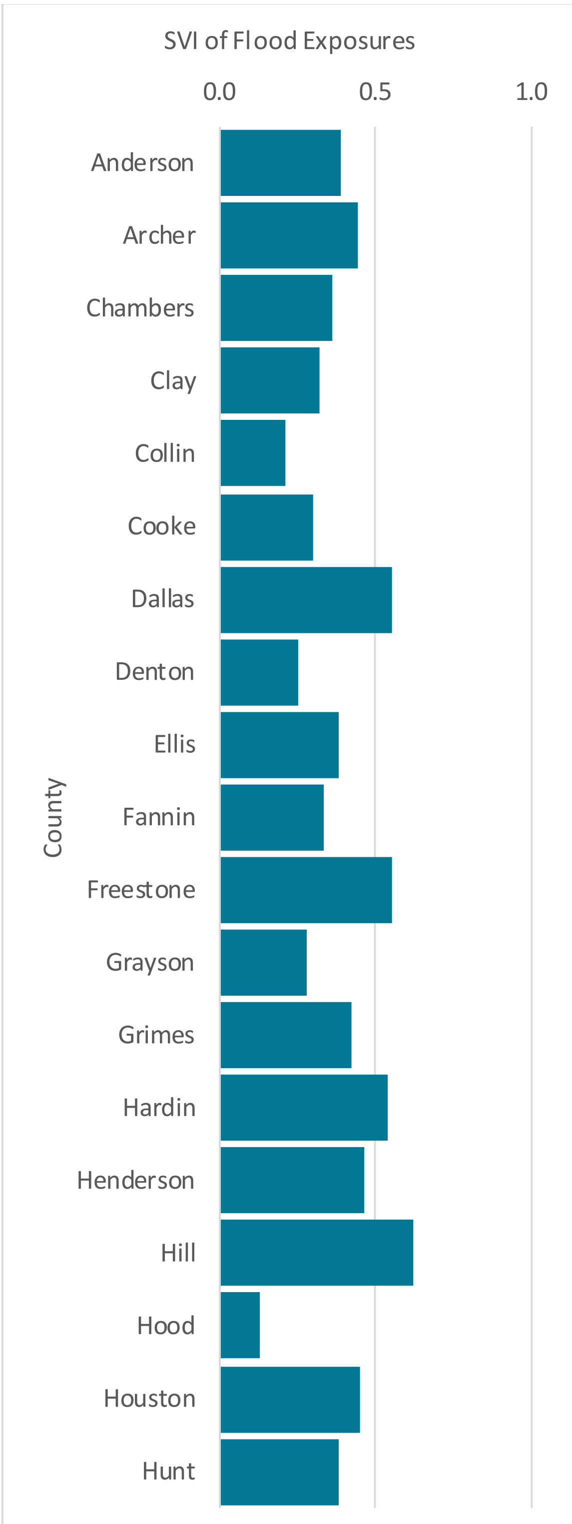
Summary of Future Conditions Flood Exposure and Vulnerability Analyses

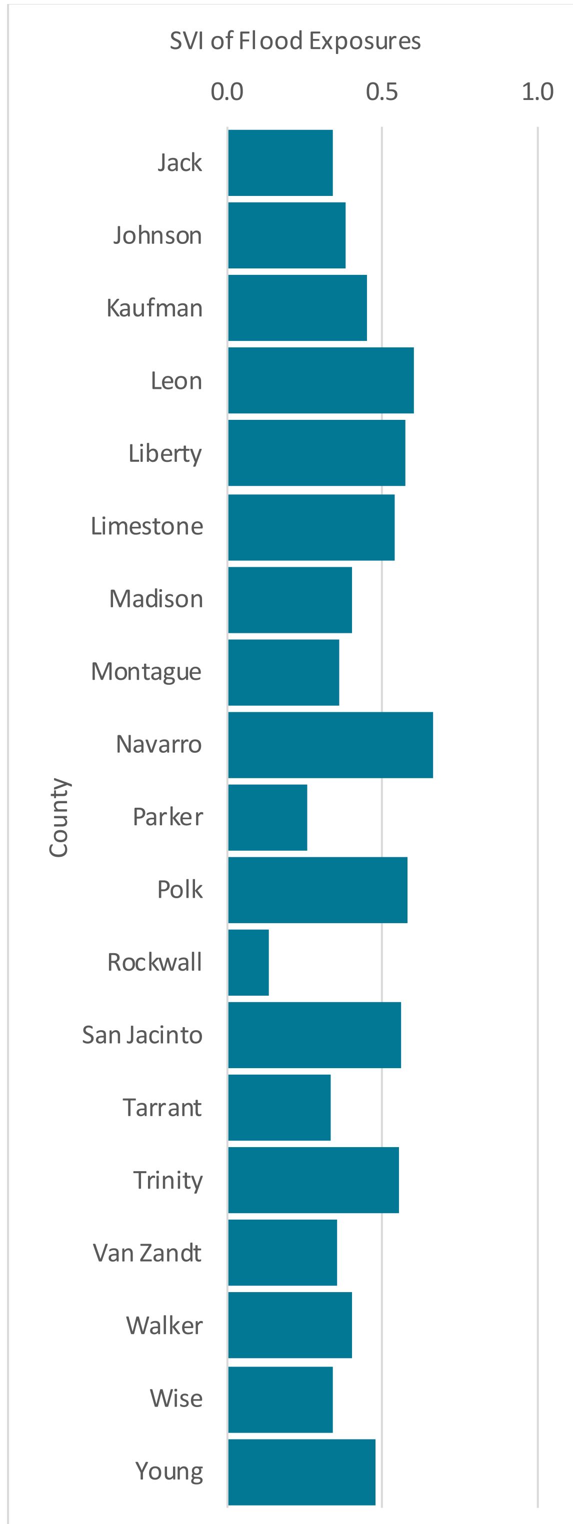
The future condition floodplain anticipates that there will be 51 percent more structures and 52 percent more people potentially impacted than under current conditions.

The future flood risk, exposure, and vulnerability assessment for the Trinity Region are summarized in ***TWDB-Required Table 5*** located in ***Appendix A***. The ***TWDB-Required Table 5*** provides the results per county of the future flood exposure and vulnerability analysis as outlined in the Technical Guidelines for Regional Flood Planning.

A geodatabase with applicable layers as well as associated ***TWDB-Required Maps 1*** through ***22*** are provided in ***Appendix B*** as digital data. ***TWDB-Required Table 2.2***, included in ***Appendix A***, outlines the geodatabase deliverables included in this Technical Memorandum as well as spatial files and tables.

Figure 2.69: Future Condition Flood Exposures by County





Bibliography

Anthoff, D., Nicholls, R. J., Tol, R. S., & Vafeidis, A. T. (2006). *Global and regional exposure to large rises in sea-level: a sensitivity analysis.*

Arrighi, C., Tarani, F., Vicario, E., & Castelli, F. (2017). Flood Impacts on a Water Distribution Network. *Natural Hazards and Earth System Sciences*.

Asquith, W. H., & Roussel, M. C. (2004). *Atlas of Depth-Duration Frequency of Precipitation Annual Maxima for Texas.* U.S. Geological Survey, Water Resources Division. Austin, TX: U.S. Department of the Interior. Retrieved from https://pubs.usgs.gov/sir/2004/5041/pdf/sir2004-5041.pdf

Bierwagen, B. G., Theobald, D. M., Pyke, C. R., & Morefield, P. (2010). National Housing and Impervious Surface Scenarios for Integrated Climate Impact Assessments. *Proceedings of the National Academy of Sciences*, 107.

Braun, C. L., & Ramage, J. K. (2020). *Status of Groundwater-Level Altitudes and Long-Term Groundwater-Level Changes in the Chicot, Evangeline, and Jasper Aquifers, Houston-Galveston Region, Texas, 2020.* Houston: U.S. Geological Survey.

Church, J. A., & White, N. J. (2006). A 20th Century Acceleration in Global Sea-Level Rise. *Geophysical Research Letter*, 4.

Church, J. A., & White, N. J. (2011, March 30). Sea-Level Rise from the Late 19th to the Early 21st Century. *Surveys in Geophysics*, pp. 585-602.

Church, J. A., Clark, P. U., Cazenave, A., Gregory, J. M., Jevrejeva, A., Levermann, A., . . . Unnikrishnan, A. A. (2013). *Sea Level Change.* Cambridge: Cambridge University Press.

Department of the Army. (2013). *Incorporating Sea Level Change in Civil Works Programs.* Washington, D.C.: United States Army Corps of Engineers.

Freese and Nichols, Inc. (2021). *Lower East Fork Laterals of the Trinity River Watershed.* Freese and Nichols, Inc.

Galloway, D. L., & Coplin, L. S. (1999). Managing Coastal Subsidence. *Land Subsidence in the United States*, 35-48.

Galloway, D. L., Jones, D. R., & Ingebritsen, S. E. (1999). *Land Subsidence in the United States.* Washington, D.C.: U.S. Geological Survey.

Hall, J. A., Gill, S., Obeysekera, J., Sweet, W., Knuuti, K., & Marburger, J. (2016). *Regional Sea Level Scenarios for Coastal Risk Management.* Alexandria: SERDP.

Herrera-García, G., Ezquerro, P., Tomás, R., Béjar-Pizarro, M., López-Vinielles, J., Rossi, M., . . . Ye, S. (2021). *Mapping the Global Threat of Land Subsidence.* Science.

Hershfield, D. M. (1961). *Rainfall Frequency Atlas of the United States.* Washington, D.C.: U.S. Department of Agriculture.

Huber, M., & White, K. (2017). *Sea level change curve calculator.* USACE Responses to Climate Change Program.

Jevrejeva, S., Moore, J. C., & Grinsted, A. (2010, April 3). How will sea level respond to changes in natural and anthropogenic forcings by 2100? *Geophysical Research Letters*, p. 5.

Kasmarek, M. C., & Johnson, M. R. (2013). *Groundwater Withdrawals 1976, 1990, and 2000–10 and Land-Surface-Elevation Changes 2000–10 in Harris, Galveston, Fort Bend, Montgomery, and Brazoria Counties, Texas.* U.S. Geological Survey.

Liu, Y., Li, J., Fasullo, J., & Galloway, D. L. (2020). Land subsidence contributions to relative sea level rise at tide gauge Galveston Pier 21, Texas. *Scientific Reports*.

Masson-Delmotte, V., Zhai, P., Pirani, A., Connors, S. L., Pean, C., Berger, S., . . . Zhou, B. (2021). *Climate Change 2021: The Physical Science Basis.* New York City: IPCC.

National Academies of Science, Engineering, and Medicine. (1994). *Science Priorities for the Human Dimensions of Global Change.* Washington, D.C.: National Academies Press. doi:https://doi.org/10.17226/9175

Nicholls, R. J., & Cazenave, A. (2010, June 18). Sea-Level Rise and Its Impact on Coastal Zones. *Science, 328*(5985), pp. 1517-1520.

Nicholls, R. J., & Tol, R. S. (2006). *Impacts and responses to sea-level rise: a global analysis of the SRES scenarios over the twenty-first century.* The Royal Society Publishing.

Nielsen-Gammon, J., & Jorgensen, S. (2021). *Climate Change Recommendations for Regional Flood Planning.* College Station: Office of the Texas State Climatologist.

NOAA. (2018). National Oceanic and Atmospheric Administration Atlas 14 Point Precipitation Frequency Estimates. Silver Spring, Maryland, United States of America.

NOAA. (2021, July 20). *Billion-Dollar Weather and Climate Disasters: Time Series*. Retrieved from National Oceanic and Atmospheric Administration National Centers for Environmental Information: https://www.ncdc.noaa.gov/billions/time-series/TX

NOAA. (2022). *Tides & Currents*. Retrieved from National Oceanic and Atmospheric Administration: https://tidesandcurrents.noaa.gov/sltrends/

Parris, A. S., Bromirski, P., Burkett, V., Cayan, D. R., Culver, M., Hall, J., . . . Weiss, J. (2012). *Global sea level rise scenarios for the United States National Climate Assessment.* National Oceanic and Atmospheric Administration.

Rahman, A., Tharzhiansyah, M., Rizky, M., & Vita, H. (2021). Problems and Urban Sustainable Development in Wetlands Based on the Thermal Conditions. *IOP Conference Series: Earth and Environmental Science* (p. 780). IOP.

Rahmstorf, S. (2007). *A Semi-Empirical Approach to Projecting Future Sea-Level Rise.* American Association for the Advancement of Science.

Rentschler, J., & Salhab, M. (2020). *People in Harm's Way: Flood Exposure and Poverty in 189 Counties.* Washington, D.C.: World Back.

Shukla, P. R., Skea, J., Buendia, E. C., Masson-Delmotte, V., Portner, H. O., Roberts, D. C., . . . Malley, J. (2019). *Climate Change and Land: an IPCC special report on climate change, desertification, land degradation, sustainable land management, food security, and greenhouse gas fluxes in terrestrial ecosystems.* IPCC.

Sohl, T. L. (2018, September 27). Conterminous United States Land Cover Projections - 1992 to 2100. United States of America.

Stanzel, N. C., & Natchnebel, H. P. (2009). Incorporating River Morphological Changes to Flood Risk Assessment Uncertainties, Methodology, and Application. *Natural Hazards and Earth System Science*, 789-799.

Stork, S. V., & Sneed, M. (2002). *Houston-Galveston Bay Area, Texas, from Space: A New Tool for Mapping Land Subsidence.* Houston: U.S. Geological Survey.

Strand, R. I., & Pemberton, E. L. (1987). *Reservoir Sedimentation in Design of Small Dams.* Denver: U.S. Bureau of Reclamation.

Swain, D. L., Wing, O. E., Bates, P. D., Done, J. M., Johnson, K. A., & Cameron, D. R. (2020). Increased Flood Exposure Due to Climate Change and Population Growth in the United States. *Earth's Future*, 17.

Tate, E., Asif, R., Emrich, C., & Sampson, C. (2021). Flood Exposure and Social Vulnerability in the United States. *Natural Hazards*, 106.

TCEQ. (2006, November). *Guidelines for Operation and Maintenance of Dams in Texas.* Retrieved from Texas Commission on Environmental Quality: https://www.tceq.texas.gov/assets/public/comm_exec/pubs/gi/gi357/gi-357.pdf

Texas A&M Natural Resources Institute. (2020, August 2). *Texas Land Trends Data.* Retrieved from Texas Land Trends: https://data.txlandtrends.org/trends/riverbasin/Trinity

Texas Living Water Project. (2017). *Understanding Subsidence in the Houston-Galveston Region.* Austin: Texas Living Water Project.

Texas State Soil and Water Conservation Board. (2021, September 19). *Flood Control Program*. Retrieved from Texas State Soil and Water Conservation Board: https://www.tsswcb.texas.gov/programs/flood-control-program

Texas Water Development Board. (1993-2020). Volumetric and Sedimentation Survey Results. Austin, Texas, United States of America.

TWDB. (2021, July 27). *Flood Planning Data*. Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/data.asp

TWDB Flood Planning Frequently Asked Questions. (2021, July 22). Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/faq.asp

United States CDC. (2018). CDC/ATSDR Social Vulnerability Index. Washington, D.C., District of Columbia, United States of America.

United States EPA. (2016). Updates to the Demographic and Spatial Allocation Models to Produce Integrated Climate and Land Use Scenarios (ICLUS) (Version 2) (External Review Draft). *United States Environmental Protection Agency*, 600.

United States Soil Conservation Service. (1983). Sedimentation. In U. S. Service, *SCS National Engineering Handbook.* Soil Conservation Service, United States Department of Agriculture.

USACE. (2020). *Dams of Texas*. Retrieved from National Inventory of Dams: https://nid.usace.army.mil/#/

USACE. (2021). Fort Worth District Pertinent Data. Fort Worth, Texas, United States of America.

USACE. (2022, May 01). Sea-Level Change Curve Calculator (Version (2022.34)). United States Army Corps of Engineers.

USDOA. (1955). *Big Sandy Creek Watershed.* United States Department of Agriculture.

Vermeer, M., & Rahmstorf, S. (2009). Global sea level linked to global temperature. *Proceedings of the National Academy of Sciences*, 106.

Walsh, K. J., Camargo, S. J., Vecchi, G. A., Daloz, A. S., Elsner, J., Emanuel, K., & Henderson, N. (2014). Hurricanes and climate: The U.S. CLIVAR working group on hurricanes. *Bulletin of the American Meteorological Society*, pp. 997-1017.

Wing, O., Bates, P., Smith, A., Sampson, C., Johnson, K., Fargione, J., & Morefield, P. (2018). Estimates of Present and Future Flood Risk in the Conterminous United States. *Environmental Research Letters*, 13.

Wuebbles, D. J., Fahey, D. W., Hibbard, K. A., Dokken, D. J., Stewart, B. C., & Maycock, T. K. (2017). *Climate Science Special Report.* Washington, D.C.: U.S. Global Change Research Program.

Xue, Y.-Q., Zhang, Y., Ye, S.-J., Wu, J.-C., & Li, Q.-F. (2005). *Land Subsidence in China.* Environmental Geology.

Zervas, C., Gill, S., & Sweet, W. (2013). *Estimating Vertical Land Motion from Long-Term Tide Gauge Records.* Silver Spring: National Oceanic and Atmospheric Administration.

Chapter 3: Floodplain Management Practices and Flood Protection Goals

Task 3A – Evaluation and Recommendations on Floodplain Management Practices (361.35)

The Region 3 (Trinity) Regional Flood Planning Group (RFPG) solicited local entity and public input in the development of floodplain management practices and flood protection goals for the Trinity Region. During the Trinity RFPG's data collection effort in summer 2021, 90 communities and counties provided feedback on these specific topics, which represents 28 percent of the region. Public input included written and oral comments at planning group meetings in June, August, and September 2021, as well as interactive polling. In addition, the recommended floodplain management practices were posted to www.trinityrfpg.org and an email was sent to the distribution list encouraging interested parties to provide input and feedback by October 27, 2021. The North Central Texas Council of Governments (NCTCOG) spans a 16-county area that overlaps much of the Trinity Region in the Upper Basin from Parker County on the west side to Hunt County on the east side and from Wise County on the north side to Navarro County on the south side. NCTCOG also sent a similar email to its distribution list encouraging participation.

The region's data collection effort included requests for local floodplain ordinances and court orders. The following section of this report focuses on cities and counties as these are the entities with the ability to adopt and enforce floodplain ordinances and court orders. As of September 16, 2021, the Trinity RFPG received 48 floodplain management documents from the data collection effort. Additional research resulted in the identification and collection of five additional ordinances on entity websites. The Texas Water Development Board (TWDB) provided floodplain ordinances, as well as a summary of the Texas Floodplain Management Association's (TFMA's) 2018-19 Higher Standards Survey results by those entities who participated.

Extent to which Current Floodplain Management and Land Use Practices Impact Flood Risks

Floodplain management and land use practices were examined by looking at regulations, policies, and trends in the region. The purpose of these management practices is to help with protection of life and property. Floodplain management and land use practices vary from one entity to another. Most communities in the region follow rules and policies of the Federal Emergency Management Agency (FEMA), who manages the National Flood Insurance Program

(NFIP) where the minimum standards for development in and around the floodplain can be found.

In 1968, Congress established the NFIP through the National Flood Insurance Act of 1968 to provide federally subsidized flood insurance protection (FEMA, 1968). The program has been updated multiple times since then to strengthen the program, provide fiscal soundness, and better inform the public of flood risk by the publication of insurance rate maps. Title 44 of the Code of Federal Regulations (44 CFR) includes the rules and regulations of the program. Title 44 CFR, Part 60 establishes the minimum criteria that FEMA requires for NFIP participation, which includes identifying Special Flood Hazard Areas (SFHAs) within the community (CFR, 2011).

The Biggert-Waters Flood Insurance Reform Act of 2012 authorized and funded the national mapping program, as well as rate increases to transition the NFIP into a fiscally sound program (PL 112-141, 2012). The increases in flood insurance rates were intended to move the program to full actuarial rates that reflect the flood risk, as opposed to subsidized rates. In 2019, five federal regulatory agencies issued a joint final rule regarding Biggert-Waters that required regulated lending agencies to accept private flood insurance that meets specific criteria defined in the act (OCC, 2019). Private flood insurance providers offer more coverage options compared to the FNIP, including higher dollar amounts for maximum building coverage, a shorter waiting period for policies to become effective, and competitive rates (National Flood Insurance, 2020). However, private flood insurance is not backed by the federal government, which means the money needed for flood repairs may be at risk when a policy holder files a claim. The private flood insurance option provides competition in the market where consumers can shop around and compare rates. Whereas the NFIP option rate for a particular property remains the same no matter the provider, which eliminates the need to shop around for a better rate.

Cities and counties work with FEMA to create and update Flood Insurance Rate Maps (FIRMs) and the flood water surface elevations to define SFHA along rivers, streams, lakes, and coastal areas. Communities that participate in the NFIP are required to use the FIRMs and flood water surface elevations provided in their floodplain permitting processes. Insurance agents use FIRMs to determine flood risk, which determines the flood insurance policy rate for individual properties.

Cities and counties have the authority to establish their own policies, standards, and practices to manage land use in and around areas of flood risk. NFIP participating communities have the responsibility and authority to restrict development in SFHAs to help protect areas from potential flooding. They can also adopt and enforce higher standards than the FEMA NFIP minimum standards to further reduce flood risk to people and property. FEMA supports and encourages entities to establish higher standards to reduce flood risk to life and property.

Residents and businesses in cities and counties who participate in the NFIP program can purchase NFIP flood insurance to reduce the economic impacts of floods (FEMA Flood

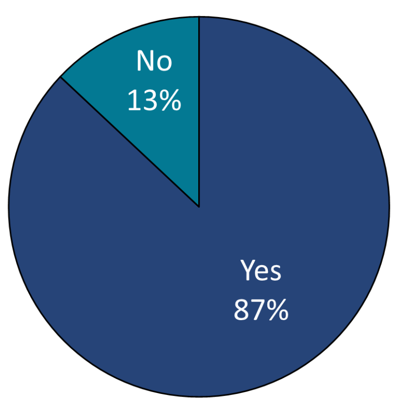
Insurance, 2021). Renters may also purchase NFIP "contents only" flood insurance policies to cover the cost of their belongings in the event of flood damage. NFIP participation also makes the community eligible for disaster assistance following a flood event (FEMA Floodplain Management, 2021).

Existing Population and Property

Multiple resources were considered in determining the extent to which current floodplain management and land use practices impact flood risk to existing population and property. Cities and counties can establish floodplain regulation and permitting by ordinance or court order, respectively. Not all entities with flood responsibilities are eligible to participate in the NFIP program. Only cities and counties are eligible to participate in the NFIP program. Therefore, the tables and figures included in this section of the report are limited to cities and counties. ***Appendix A*** includes a list of all cities and counties within the Trinity Region with information regarding their floodplain management programs.

Communities that participate in the NFIP are required to have a floodplain ordinance or court order that meets or exceeds the NFIP minimum standards (FEMA Flood Insurance Rules & Regs, 2021). As of October 2020, 288 cities and counties in the Trinity Region participate in the NFIP and have floodplain ordinances that meet or exceed the NFIP minimum standards (FEMA, 2021). Approximately 87 percent of the communities in the Trinity Region have floodplain ordinances that meet the criteria. All counties within the Trinity Region participate in the NFIP; however, 40 cities within the region do not participate in the NFIP. Of those 40 cities, the Trinity RFPG found five entities who have adopted minimum regulations pursuant to Texas Water Code Section 16.3145 that appear to meet or exceed the NFIP minimum standards. Thus, the Trinity Region has a total of 293 entities (89 percent) with floodplain regulations that meet or exceed the NFIP minimum standards. ***Figure 3.1*** shows the percentage of entities within the region that participate in the NFIP.

Figure 3.1: Percentage of National Flood Insurance Program Participating Entities in Trinity Region



In support of the NFIP, the 77th Texas Legislature amended Subchapter 1, Chapter 16 of the Texas Water Code with the addition of Section 16.3145 that states, "the governing body of each city and county shall adopt ordinances or orders, as appropriate, necessary for the city or county to be eligible to participate in the NFIP, not later than January 1, 2001." (TWDB, 2001) TWDB's Flood Infrastructure Fund (FIF) requires that the area served by the proposed study or project must have and enforce floodplain regulations that meet or exceed the NFIP minimum standards (TWDB FIF, 2021). ***TWDB-Required Map 13*** is located in ***Appendix B***.

Higher Standards

The NFIP establishes minimum standards that a city or county must meet to be eligible to participate in the NFIP. The minimum standards require buildings to be constructed at or above the Base Flood Elevation (BFE), provide for floodproofing as an option for nonresidential buildings, and mandate provisions specific to the elevation and anchoring of manufactured houses (CFR, 1976). The BFE is the anticipated water surface level that has a one percent chance of being equaled or exceeded in any given year (FEMA Glossary, 2021); that is, the 1% annual chance storm event water surface elevation. In many cases, minimum standards may be based on maps that were developed with outdated topography, rainfall, and runoff data. Therefore, adopting minimum standards based on these sources may result in protection from flood damages that is less than the NFIP intends.

According to the TWDB Exhibit C guidance document, the term "higher" standard is defined as freeboard, detention requirements, or fill restrictions. FEMA defines freeboard as additional height above the BFE that provides a factor of safety when determining the minimum elevation of the lowest floor (FEMA Glossary, 2021). The TFMA performs a Higher Standards Survey every year of cities and counties to document which entities have adopted higher development standards. According to the TFMA Higher Standards Survey results for 2019-2020, 104 entities within the Trinity Region self-reported as having freeboard one or more feet above the BFE for current and/or fully developed conditions (TFMA, 2020).

The Trinity RFPG performed a data collection effort in summer 2021. A question was included regarding the description of the higher standards required by the entity. The BFE is typically shown on FEMA FIRMs and in associated Flood Insurance Studies, and/or models. However, the BFE can be based on localized data developed by the community that may not be incorporated into a FEMA mapping product. The survey response options included in the data collection question were:

- At or above current BFE
- BFE plus one foot (current 1% annual chance storm event conditions)
- BFE plus one foot (future 1% annual chance storm event conditions)
- BFE plus two feet (current 1% annual chance storm event conditions)

- BFE plus two feet (future 1% annual chance storm event conditions)
- BFE plus three feet (current 1% annual chance storm event conditions)
- Blank/unknown

In a few instances, the number provided in the survey response differed from the number provided in the TFMA response. In these situations, the Trinity RFPG reviewed the floodplain ordinances to determine the appropriate response. The Trinity RFPG also searched and reviewed online ordinances for missing communities. Otherwise, the information provided in ***Table 3.1*** relies heavily on self-reported information to provide a summary of the entities with higher standards associated with freeboard at or above the BFE. ***Figure 3.2*** demonstrates the freeboard requirements for the cities within the region. ***Figure 3.3*** shows the freeboard requirements for each of the counties in the Trinity Region. The county freeboard requirements are effective in areas outside city boundaries. In some cases, Extra Territorial Jurisdictions (ETJs) may be required to follow the city freeboard requirements depending on the specifics included in the city's ordinance.

Table 3.1: Summary of Freeboard Requirements for Communities in Trinity Region

Freeboard	Current 1% Annual Chance Storm Event Conditions	Future 1% Annual Chance Storm Event Conditions
At or above current BFE	72	4
BFE + 1 foot	25	9
BFE + 1.5 feet	1	1
BFE + 2 feet	164	42
BFE + 3 feet	9	3
Total	**271**	**59**

Source: Trinity Region data collection survey results as of September 16, 2021

Of the entities that require freeboard, the majority use the BFE plus two feet for current conditions. Fewer entities have future 1% annual chance storm event condition information; however, many of those entities. require two feet of freeboard above the current BFE.

In addition, the NCTCOG developed and continues to oversee the integrated Stormwater Management (iSWM) program that recognizes cities and counties who achieve water quality protection, streambank protection, and flood mitigation, while meeting construction and post-construction requirements for Texas Commission on Environmental Quality (TCEQ) stormwater permits (NCTCOG iSWM, 2021). Based on the level to which a city or county participates in the program, the entity can apply for and obtain regional recognition for its effort with a bronze, silver, or gold certification.

Figure 3.2: City Freeboard Requirements

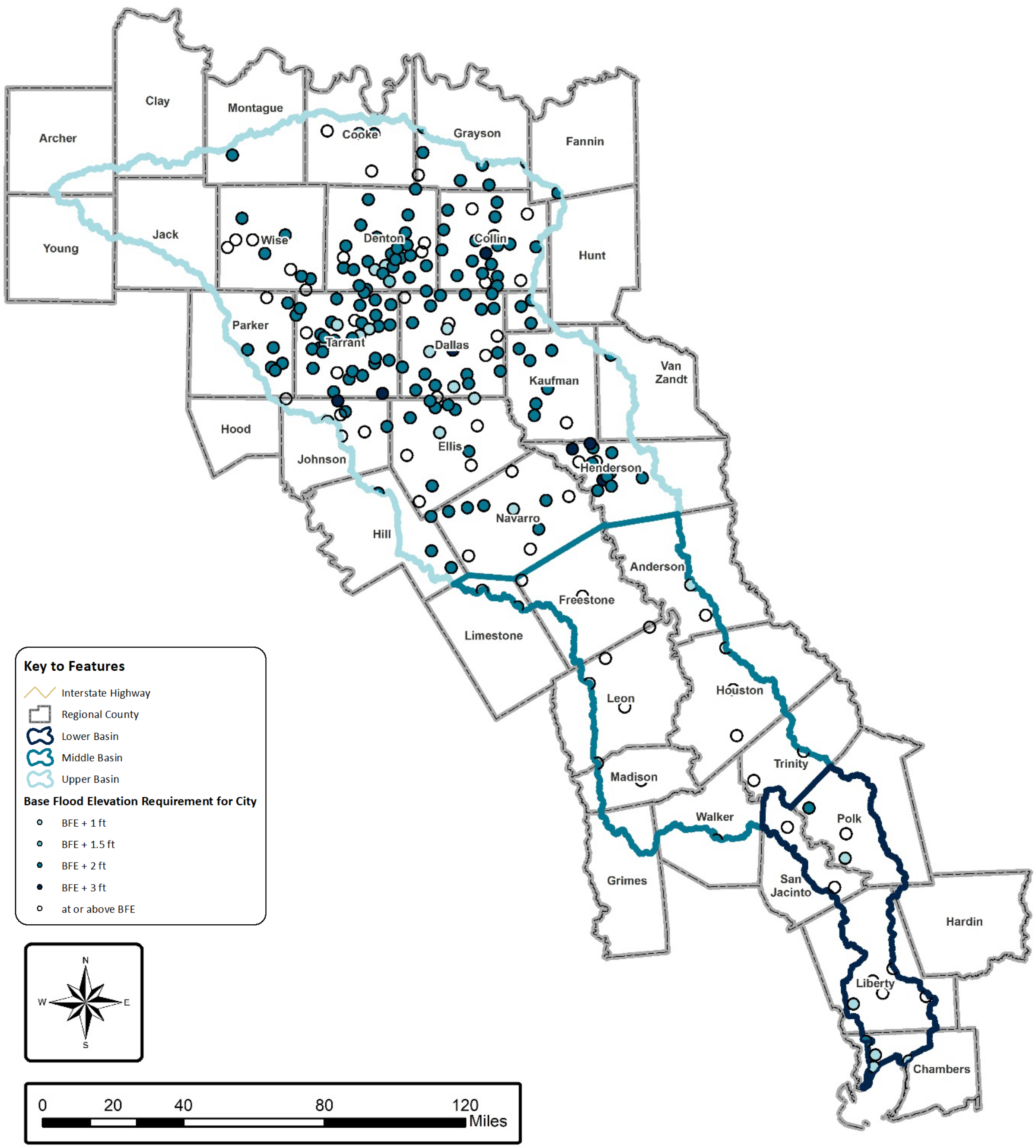
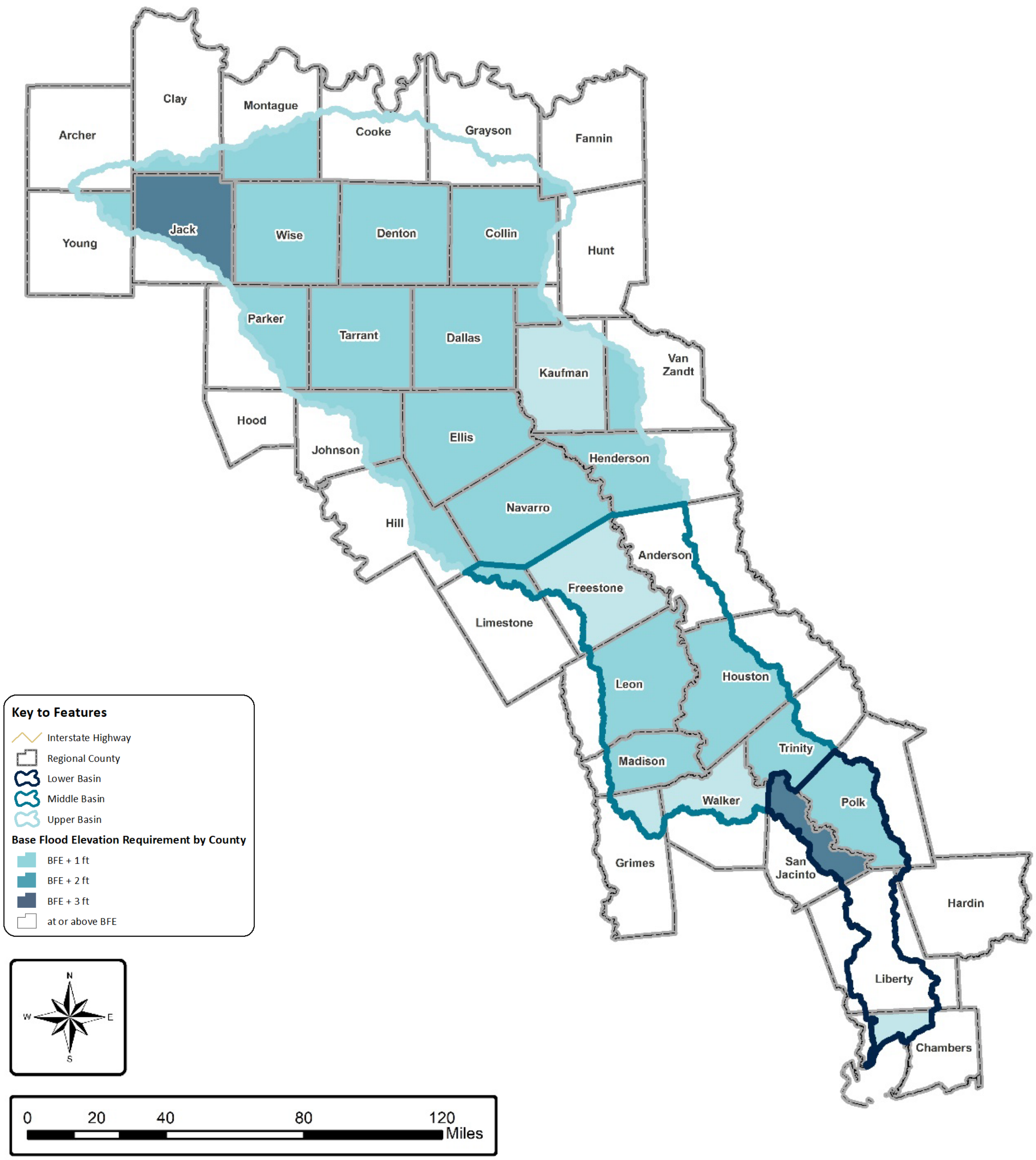


Figure 3.3: Trinity Region Freeboard Requirements by County

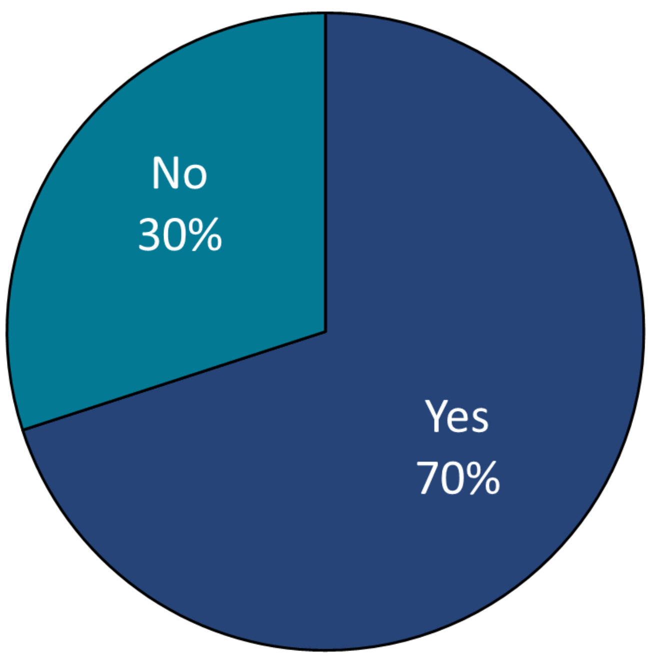


NCTCOG maintains an inventory of the iSWM participants and the elements of the iSWM program that each entity includes. The iSWM program includes detention structure discharge criteria, flood mitigation/downstream assessments, and/or finished floor elevations that are relevant to the TWDB's definition of higher standards for this regional flood plan. The NCTCOG information was considered in determining the number of entities within the region with higher standards as defined by the TWDB.

In 2017, NCTCOG hosted two Countywide Watershed Management roundtable discussions and presentations (NCTCOG Countywide Watershed Standards, 2017). NCTCOG also performed a survey of the 16 counties within their area. The discussion and input resulted in the development of a document that specifies 13 regionally recommended standards for new development within county-regulated areas. The document includes a sample resolution that counties can use to enact their authority to regulate development within the floodplains. Some higher standards include requiring freeboard for fully developed conditions, maintaining valley storage, protecting against erosive velocities, and matching pre-development site runoff.

In all, 231 of the 328 cities and counties require some form of higher standards. ***Figure 3.4*** demonstrates that more than two-thirds of the region's entities require some form of higher standards, whether it be elevation requirements, detention requirements, and/or fill restrictions.

Figure 3.4: Percentage of Entities that Require Higher Standards



Source: Trinity Region data collection survey results as of September 16, 2021 and additional Trinity RFPG research

Within the NFIP, FEMA manages the Community Rating System (CRS) program. The CRS program is a voluntary program in which cities and counties can participate (FEMA CRS, 2021), (FEMA CRS Manual, 2021). The more flood risk reduction activities in which an entity participates, the more points it earns. The points translate to a CRS score that ultimately provides residents and businesses within the jurisdiction the opportunity to receive a discount on flood insurance premiums. The flood insurance savings encourages residents and businesses to purchase flood insurance to protect buildings and contents.

Twenty entities within the region participate in the CRS program (FEMA, 2021). These communities have a CRS class ranging between five and 10 and represent a 25 percent to 0 percent savings on flood insurance premiums, respectively. Per TWDB Technical Guidance, these communities qualify as having "Strong" floodplain management standards. The list of CRS participating entities is provided in ***Table 3.2***.

Table 3.2: Trinity Region Cities and Counties Participating in Community Rating System Program

Entity	CRS Class	% Discount for Structures within SFHA	% Discount for Structures Located Outside the SFHA
Arlington, City of	6	20	10
Benbrook, City of	7	15	5
Burleson, City of	9	5	5
Carrollton, City of	6	20	10
Coppell, City of	8	10	5
Dallas, City of	5	25	10
Denton, City of	8	10	5
Denton County	10	0	0
Duncanville, City of	8	10	5
Flower Mound, City of	8	10	5
Fort Worth, City of	8	10	5
Garland, City of	7	15	5
Grand Prairie, City of	5	25	10
Haltom City, City of	8	10	5
Hurst, City of	8	10	5
Lewisville, City of	9	5	5
North Richland Hills, City of	7	15	5
Plano, City of	8	10	5
Richardson, City of	8	10	5
Richland Hills, City of	8	10	5

Source: FEMA CIS Report as of October 1, 2020

Part of the summer 2021 data collection effort included a question that asked survey participants to select the description that best represented their impression of their enforcement of their floodplain regulations.

TWDB Exhibit C Guidance document described enforcement activities as the following:

- High – actively enforces the entire ordinance, performs many inspections throughout construction process, issues fines, violations, and Section 1316s where appropriate, and enforces substantial damage and substantial improvement
- Moderate – enforces much of the ordinance, performs limited inspections, and is limited in issuance of fines and violations
- Low – provides permitting of development in the floodplain, may not perform inspections, and may not issue fines or violations
- None – does not enforce floodplain management regulations

Approximately 56 percent of the participants who responded to this question described their level of enforcement as being moderate or high activity. The remaining participants have a low, none, or unknown activity with regards to enforcing the floodplain regulations. These entities have a significant opportunity to improve the effectiveness of their ordinance or court order by increasing the enforcement of their existing floodplain ordinances. ***Table 3.3*** summarizes the survey participant responses.

Table 3.3: Survey Participant Level of Enforcement of Floodplain Regulations

Level of Enforcement	Number of Responses	Percent
High Activity	24	26%
Moderate Activity	28	30%
Low Activity	14	15%
None	11	13%
I do not know	15	16%
Total	**92**	**100%**

Source: Trinity Region data collection survey results as of September 16, 2021

The TWDB guidance defines the existing floodplain management practices as

- **Strong:** significant regulation that exceed NFIP standards with enforcement, or community belongs to the CRS
- **Moderate:** some higher standards, such as freeboard, detention requirements or fill restrictions
- **Low:** regulations meet the minimum NFIP standards
- **None:** no floodplain management practices in place

The Trinity Region rated each community and county using these definitions. Entities participating in the CRS program received a “Strong” classification for floodplain management practices. Entities that have higher standards but responded to the survey as having low levels of enforcement were typically categorized as having “Moderate” floodplain management practices unless the entity participated in the CRS program which automatically results in a “Strong” classification. For those entities who reported that they require construction to be at or above BFE, the floodplain management practice was typically classified as “Low”. If an entity had some form of higher standards as determined from other resources but did not respond to the survey or responded with “I do not know” with regards to enforcement, the floodplain management practices were categorized as “Low” unless the level of enforcement or elevation above base flood warranted a different classification. In some instances, an entity responded that its level of enforcement was “None” even though it has adopted some form of higher standards. In these situations, the floodplain management practices were ranked as “None”. ***Table 3.4*** summarizes the results of the floodplain management practices. ***TWDB-Required Table 6*** is included in ***Appendix A*** and provides details considered for each community and county in determining the appropriate description of overall floodplain management practices.

Table 3.4: Floodplain Management Practices for All Communities and Counties in the Trinity Region

Description	Number of Communities and Counties	Percent
Strong	35	11%
Moderate	23	7%
Low	228	69%
None	42	13%
Total	**328**	**100%**

Source: Trinity Region data collection survey results as of September 16, 2021

Local Government Code, Title 13, Subtitle A, Chapter 552 authorizes cities to establish stormwater utilities and assess stormwater utility fees, also referred to as drainage utility fees. Only cities have the authority to establish and assess stormwater utility fees. Western Kentucky 2020 data was used as the primary source for identifying cities with stormwater utilities (Western Kentucky, 2020). The summer 2021 data collection effort included two questions regarding stormwater utilities. The responses to these questions were considered more accurate and were confirmed when the Western Kentucky data differed from the survey responses. In all, only 62 (or 22 percent) of the 288 cities within the region have established stormwater utilities.

One of the questions in the Trinity Region data collection effort in summer 2021 asked about sources of revenue and specific stormwater utility rates, if applicable. Seventeen cities responded that they have stormwater utilities and provided their rates as of July 2021. The provided rates ranged from $1.66 to $13.59 per Equivalent Residential Unit (ERU). One community responded that it has established a stormwater utility but was in the process of developing the rate.

Future Population and Property

Existing floodplain ordinances and court orders with higher standards may continue to protect future population and property as long as they are enforced. Future floodplain maps and models are anticipated to be updated with higher resolution data, best available data, and advanced modeling techniques in the years to come. The combination of applying higher standards and best available data should translate into life and property savings in the future.

Areas without flood maps and models or with outdated maps and models are at greater danger of increased flood risk in terms of future population and property development within the floodplain. Entities need comprehensive and updated maps to direct development away from flood-prone areas. Local floodplain regulations with higher standards need to be adopted and enforced to better reduce the flood risk to future population and property.

The Trinity Region encourages those cities and counties without floodplain ordinances or court orders to develop, adopt, implement, and enforce floodplain regulations that at least meet the NFIP minimum standard.

Some cities and counties have already developed watershed studies that include existing and future flood conditions. Sometimes the future flood conditions represent a future time period, often 30 years. In other cases, the future flood conditions are based on fully developed land conditions. Entities who currently apply future flood conditions as part of their design criteria essentially apply a factor of safety to better protect today's developments from future flood risks.

In the Upper Basin area of the Trinity Region, communities along the West Fork and Elm Fork of the Trinity River participate in the NCTCOG's Corridor Development Certificate program (NCTCOG CDC, 2021). The Corridor Development Certificate program is a regional approach to maintain flood capacity within the Trinity River. The Corridor Development Certificate flood model includes current conditions and future (year 2055) conditions flood discharges that must be considered for evaluating proposed projects within the Trinity River corridor.

The three primary criteria (NCTCOG Corridor Development Certificate Criteria Manual, 2021) of the Corridor Development Certificate program that proposed new development in the corridor must meet are:

- Water surface elevations do not increase for the 1% annual chance storm event flood elevation and no significant increase for the standard project flood elevation
- Valley storage must be maintained in the 1% annual chance storm event floodplain with a maximum loss of 5 percent in the standard project floodplain
- Channel and floodplain velocities cannot be increased

According to the United States Army Corps of Engineers (USACE), the Standard Project Flood (SPF) is the flood that may be anticipated from the most severe combination of meteorological and hydrologic conditions that are reasonably characteristic of the region (USACE Engineering Manual, 1965). The SPF flood discharges are typically 40 to 60 percent of the probable maximum flood for the basin. USACE defines the probable maximum flood as the flood resulting from the most extreme combination of meteorological and hydrological conditions that are reasonably possible for the area (USACE, 1970). The SPF represents the “standard” degree of flood control project should be designed to protect life and property.

When a project is proposed within the Corridor Development Certificate area, the applicant submits a Corridor Development Certificate Permit to the appropriate county or city. Once the floodplain administrator determines that the proposed project generally meets the Corridor Development Certificate requirements, as well as its local requirements, the floodplain administrator forwards the application to the Corridor Development Certificate reviewers, including state and federal agencies. The USACE performs detailed model analyses to confirm the proposed project meets the Corridor Development Certificate requirements. Other Corridor Development Certificate participants can review the application and supporting documentation and ask questions or raise any concerns they might have. Once the model is deemed acceptable and all concerns have been addressed to the city or county’s satisfaction, the county or city may issue the Corridor Development Certificate permit.

NCTCOG is actively working with additional jurisdictions to expand the Corridor Development Certificate program to other branches of the Trinity River, as well as the main stem of the Trinity River located downstream of where the flood model currently ends (just south of I-20 and east of Hutchins, TX). The future conditions considered in the model and the expansion of the program to other areas will provide valuable flood risk information for existing and future property, people, and infrastructure.

Future Flood Hazard Exposure

Future flood hazard exposure is assessed in ***Chapter 2*** of this report. This section of the report focuses on the potential impact that floodplain management and land use practices may have in the future. Cities and counties that have and enforce floodplain regulations reduce the future flood hazard impact. As of September 16, 2021, the Trinity RFPG data collection effort revealed 34 entities have these regulations, but have a low, no, or unknown activity with regards to enforcement. The Trinity RFPG supports and encourages entities' abilities to enforce their regulations. The TWDB developed a sample Flood Damage Prevention Ordinance that communities can use as a starting point in developing their own floodplain ordinances. (TWDB NFIP, 2021)

Cities and counties that implement future land use plans consider areas of anticipated population growth and development within their communities. However, the existing and future floodplains are not necessarily a component in developing the future land use plan. (Land use planning is addressed is ***Chapter 1*** of this report in more detail.) Incorporating the existing and future floodplains will provide cities and counties with additional direction as to where population and development should be directed to avoid flood risk to people and property.

It is challenging to define future floodplains with complete certainty. However, one should anticipate that the future floodplains will be different from existing floodplains in some areas within the region. Maps and models are regularly being updated with new topography, survey, precipitation, runoff, and other data as development occurs in and around floodplains and the watershed. One should anticipate that the BFEs will increase in the future due to a number of conditions that are presented in ***Chapter 2***. Cities and counties that require future conditions in the evaluation and modeling of proposed projects and seek to minimize the allowable increases in water surface elevations, will reduce future flood hazard to new and existing developments.

One factor of safety that can be implemented today to reduce future flood hazard exposure is freeboard. Freeboard is the term used for the additional height provided above the BFE as discussed previously. Even if the BFE changes in the future, freeboard can result in allowing the structure to remain above the future flood water surface if higher as is often the case.

The Trinity RFPG supports the use of freeboard in local floodplain ordinances and court orders. Ideally, the Trinity RFPG recommends cities and counties to adopt and enforce a minimum freeboard requirement of one foot above the BFE based on future 1% annual chance storm event conditions, where possible.

Another higher standard that can be implemented today that will limit future flood hazard exposure is maintaining valley storage, which is also referred to as prohibiting fill without equivalent, compensatory excavation. Maintaining valley storage aids in maintaining "no rise" in water surface elevations. Reducing a river or streams valley storage tends to increase downstream flooding. Currently, a property within the floodplain holds a certain volume of water during a flood event. After the proposed project is completed, the property must still hold the same volume of floodwater. The shape may be different, but the volume remains the same. Maintaining valley storage allows a property owner to move dirt around on the property, while still containing the volume of floodwaters prior to the earthwork activity. If the existing soil is not suitable for construction, then soil can be replaced with appropriate soils. Typically, this is a one-to-one match meaning that for every amount of dirt brought into the floodplain, an equal amount of dirt is removed. Some communities, however, may have differing requirements on the amount of material removed and replaced.

Detention and retention ponds are often required to mitigate the impacts that impervious surfaces and more efficient drainage infrastructure have on the runoff from a developed property. The standard engineering design requirement in the Upper Basin area, within the NCTCOG area (NCTCOG iSWM Site Development Manual, 2006), is to manage runoff so that it discharges from the developed property at the existing rate that it leaves the property in its natural state. Incorporating this requirement mitigates increased runoff in the future, which in turn, can reduce future flood hazard exposure for adjacent properties. However, detention does not mitigate the increases in runoff volume associated with development activity that cumulatively can increase flood risk for properties downstream. This design criteria could be applied in other areas of the Trinity Region.

Consideration of Recommendation or Adoption of Minimum Floodplain Management and Land Use Practices

The Trinity RFPG is required to consider the possibility of recommending or adopting consistent minimum floodplain management standards and land use practices for the entire region. Recommended practices encourage entities with flood control responsibilities to establish minimum floodplain management standards over the next several years, whereas the adoption of minimum standards requires entities to have adopted the minimum standards before their Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs) could be considered for potential inclusion in the regional flood plan.

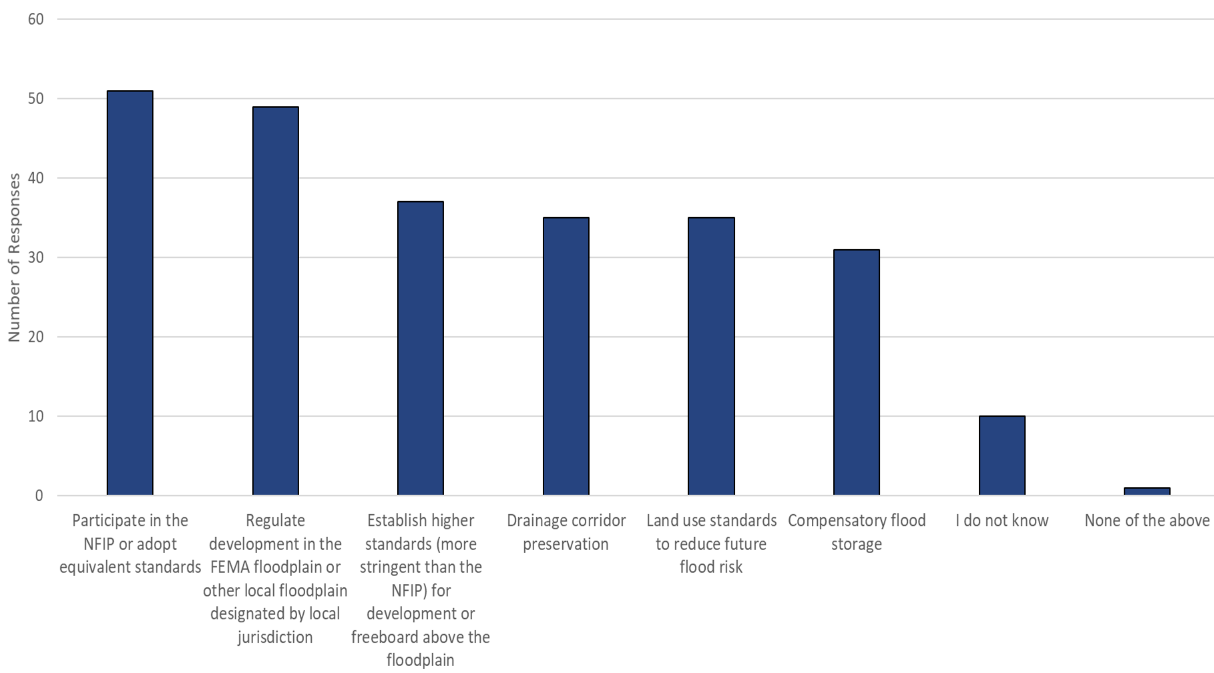
Several questions were included in the data collection effort in Summer 2021 regarding region-wide minimum floodplain management standards. Survey participants were asked if they thought the Trinity RFPG should recommend consistent minimum standards across the region. As of September 16, 2021, 95 entities responded to this question. ***Table 3.5*** summarizes participant responses regarding the question of recommending region-wide minimum floodplain management practices. ***Figure 3.5*** shows the survey responses in support of specific management practices for potential consideration by the Trinity RFPG. (Participants were able to select multiple responses.)

Table 3.5: Survey Responses for Potentially Recommending Consistent Minimum Floodplain Management Standards

Description	Number of Responses	Percent
Yes	58	61%
No	12	13%
I don't know	25	26%
Total	**95**	**100%**

Source: Trinity Region data collection survey results as of September 16, 2021

Figure 3.5: Survey Responses in Support of Potential Recommended Minimum Floodplain Management Standards

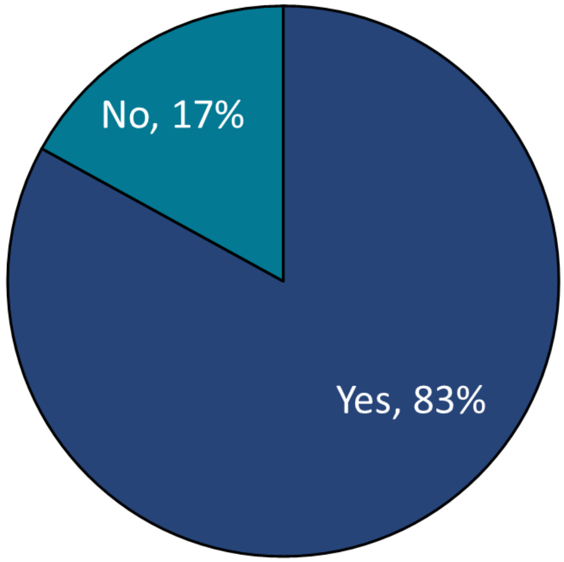


Source: Trinity Region data collection survey results as of September 16, 2021

The idea of recommending consistent minimum floodplain management standards for the Trinity Region is supported by 61 percent of the survey participants. The survey participants showed significant support for entities to participate in the NFIP or adopt equivalent standards. Survey participants also expressed significant interest in local entities regulating development in the FEMA floodplain or other local floodplain designated by the local jurisdiction.

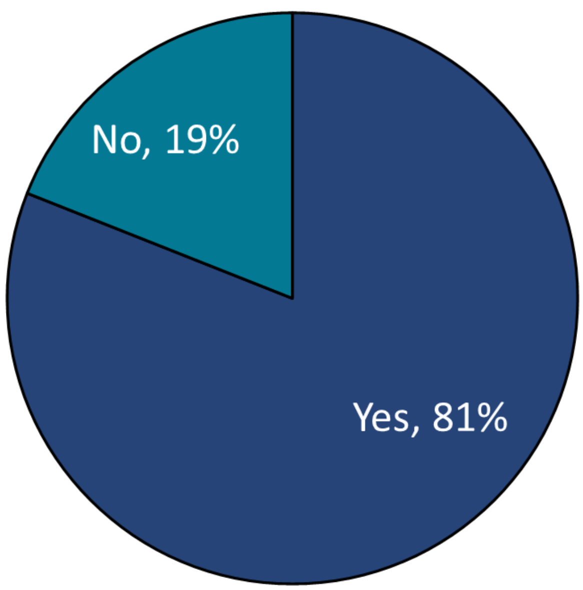
Figure 3.6 and ***Figure 3.7*** show the percent support of these two potential recommended minimum standards as of September 16, 2021.

Figure 3.6: Survey Participants in Support of Recommending All Entities Participate in the National Flood Insurance Program or Adopting Equivalent Standards



Source: Trinity Region data collection survey results as of September 16, 2021

Figure 3.7: Survey Participants in Support of Recommending the Regulation of Development in the Federal Emergency Management Agency Floodplain or Other Local Floodplain



Source: Trinity Region data collection survey results as of September 16, 2021

The Summer 2021 data collection also asked survey participants their opinion on whether the Trinity RFPG should adopt consistent minimum standards across the entire region. The survey question went on to clarify that such a requirement would only allow the Trinity RFPG to consider including flood mitigation solutions for those entities who currently meet the adopted/required minimum standards. Ninety-five entities responded to the question but most respondents were less committed to the idea of requiring consistent minimum standards for a flood mitigation solution to be included in the regional flood plan. ***Table 3.6*** summarizes the participant responses, and ***Figure 3.8*** shows the number of survey participants supporting specific standards.

Table 3.6: Survey Responses for Potentially Adopting (Requiring) Consistent Minimum Floodplain Management Standards

Description	Number of Responses	Percent
Yes	47	49%
No	13	14%
I don't know	35	37%
Total	**95**	**100%**

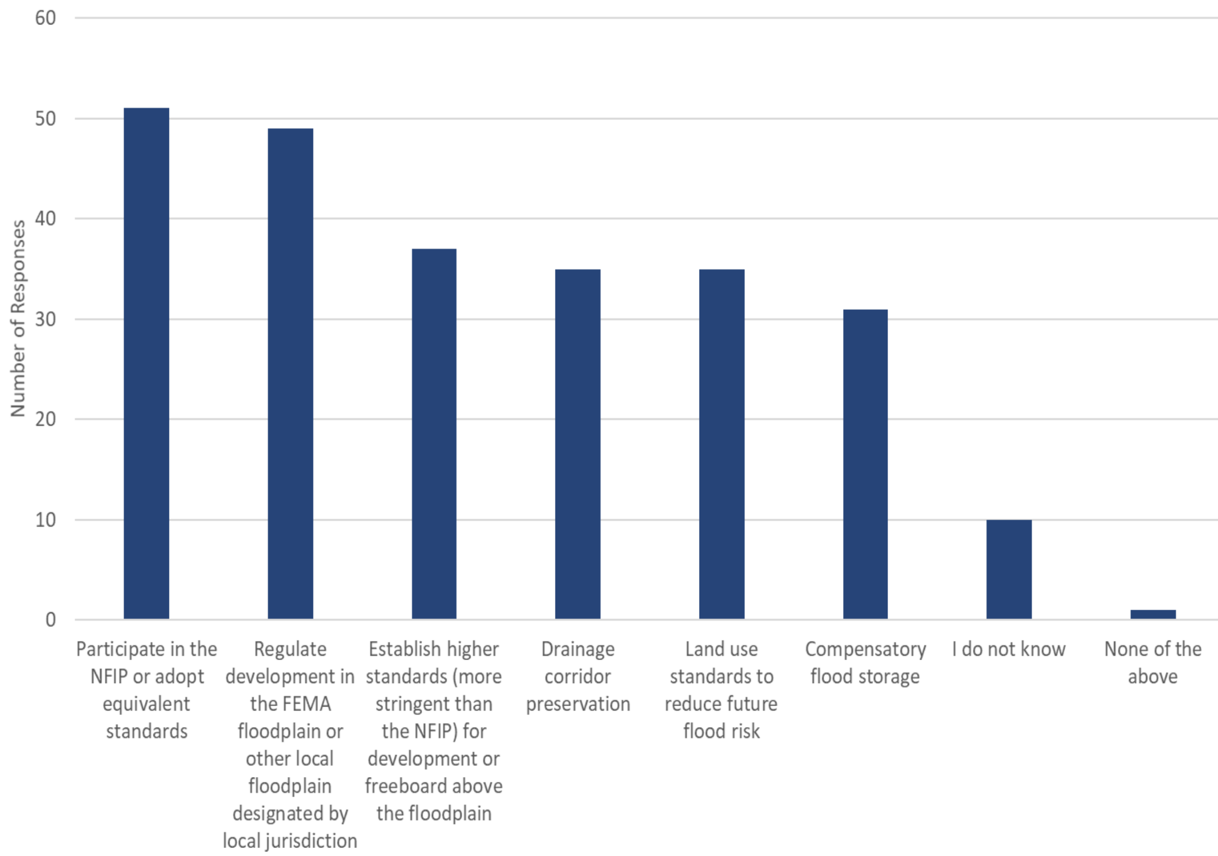
Source: Trinity Region data collection survey results as of September 16, 2021

In contrast, less than half of the survey participants supported the concept of requiring consistent minimum floodplain management standards. Those potential required region-wide minimum standards that received the most support included the same top two potential standards in the consideration for recommended standards. However, more participants responded with "I do not know" or did not respond.

The Trinity RFPG considered all the information gathered and analyzed in this chapter. The Trinity RFPG held a public meeting on September 23, 2021 to consider the question of recommending or adopting (requiring) minimum standards for this plan. The Trinity RFPG approved the following recommended region-wide floodplain management standards for this plan:

- Participate in the NFIP or adopt equivalent standards
- Regulate development in the FEMA floodplain or other local floodplain designated by local jurisdiction
- Establish higher standards (more stringent than the NFIP) for development or freeboard above the floodplain
- Support drainage corridor preservation
- Utilize land use standards to reduce future flood risk
- Consider compensatory flood storage

Figure 3.8: Survey Responses for Potential Adopted (Required) Minimum Floodplain Management Standards



Source: Trinity Region data collection survey results as of September 16, 2021

The recommended standards were summarized in a memorandum, posted to the Trinity RFPG website, and distributed by email to the list of interested parties informing them of the decision and soliciting feedback by October 27, 2021. A copy of the memo and the email notification are included in ***Appendix C***.

As in other chapters of this report, the TWDB requires a detailed table of existing floodplain management practices with the region. The ***TWDB-Required Table 6*** has been populated for all cities and counties within the Trinity Region and is included in ***Appendix A***.

Task 3B – Flood Mitigation and Floodplain Management Goals (361.36)

A critical component of the inaugural State Flood Plan process is the development of flood mitigation and floodplain management goals. As such, the Trinity RFPG spent a significant amount of time and resources exploring values and measurable goals that the region should aspire to reach.

As set out in the Guidance Principles in 31 TAC §362.3, the overarching intent of the region's goals must be "to protect against the loss of life and property." This is further defined to:

1. Identify and reduce the risk and impact to life and property that already exists
2. Avoid increasing or creating new flood risk by addressing future development within the areas known to have existing or future flood risk

The goals, when implemented, must demonstrate progress towards the fundamental goal set forth by the state. This section summarizes the results of the Trinity RFPG efforts and the initial flood mitigation and floodplain management goals for the Trinity Region.

Flood Mitigation and Floodplain Management Goal Categories

The Trinity RFPG selected seven overarching goal categories. These categories are further defined to clarify the general focus and resulting benefits of each specific, measurable goal and to create a one-to-one connection with the FMS types as outlined in TWDB Data Submittal Guidelines. The selected specific goals guide the development of the FMSs, FMEs, and FMPs for the Trinity Region. They build upon TWDB regional flood planning guidance and provide a comprehensive framework for future strategy development focused on reducing flood risk to people and property, while not negatively affecting neighboring areas. The seven overarching goal categories include:

1. Improving flood warning and public safety
2. Improving flood analyses
3. Reducing property damage and loss
4. Preserving the floodplain
5. Improving flood infrastructure
6. Expanding flood education and outreach
7. Expanding funding

The seven categories are further discussed in detail later in this chapter.

To determine the overarching goals and the specific and attainable goals, the Trinity RFPG provided multiple opportunities for discussion and public input:

- **June 24, 2021 Trinity RFPG Meeting**: Discussed legislative and TWDB Guidance and conducted interactive goal setting exercise to determine the Trinity RFPG's overarching goals and values.
- **August 19, 2021 Trinity RFPG Meeting:** Presented a refined list of potential specific goals for discussion based upon feedback received during the June meeting using interactive polling. Established the Goals Subcommittee to narrow the list of potential goals for consideration in this plan.
- **August 31, 2021 Trinity RFPG Subcommittee Meeting**: Refined the overarching and specific goals and set measurable indicators.
- **September 23, 2021 Trinity RFPG Meeting:** Considered and approved the draft goals as refined by the Goals Subcommittee and added a seventh overarching goal with specific goals. Requested the consultants distribute the draft goals to the list of interested parties and request input for an additional 30 days. The goals were distributed on September 27 with a request for comments to be submitted by October 27.
- **November 18, 2021 Trinity RFPG Meeting:** Reported results of outreach activity related to goals. Feedback from those who responded was that the goals were appropriate for the region.
- **December 12, 2021 Trinity RFPG Meeting:** Discussed and revised the language of several specific goal statements, added a few new specific goal statements with measurable indicators appropriate to the region, and moved one goal statement related to funding eligibility to Chapter 8. The RFPG approved the goals.

Appendix D includes documents showing the Trinity RFPG's progression of refining the goals for the Trinity Region.

Goals

The seven overarching goal categories are detailed below and include specific goal statements that are achievable, measurable, and time specific. Per TWDB requirements and guidelines, the goals selected by the Trinity RFPG must be specific and achievable and include the information listed below:

- Description of the goal
- Term of the goal set at 10 years (short-term) and 30 years (long-term)
- Extent or geographic area to which the goal applies
- Residual risk that remains after the goal is met
- Measurement method that will be used to quantify goal attainment
- Association with the overarching goal categories

The following specific goals associated with each overarching goal were reviewed and approved by the Trinity RFPG on September 23, 2021, during the Trinity RFPG meeting.

Goal Category 1. Improving Flood Warning and Public Safety

Goal Category 1 intends to improve the dissemination of information regarding early flood recognition and danger, emergency response procedures, and post-flood recovery actions to protect the public. ***Table 3.7*** includes two detailed goals within this category that also align with the TWDB's fundamental goal of protecting against the loss of life by keeping the public informed, prepared, and aware of flood risk.

Table 3.7: Goal Category 1. Improving Flood Warning and Public Safety Specific Goal Statements

Goals	Specific Goal Statements	Baseline	Short Term (2033)	Long Term (2053)
A	Increase the number of entities with flood warning programs that can detect flood threats and provide timely warning of impending flood danger.	Number of entities with flood warning programs	Establish a baseline measurement	Increase by 10 from 2033
B	Improve safety at Low Water Crossings (LWCs) by adding warning systems/signage or improving LWCs in high-risk areas	Number of warning systems/ signs installed at LWCs	100 total	300 total

Communicating flood risk and appropriate flood response to the public often involves multiple entities and departments within those entities. Flood warnings may be issued via television, radio, websites, electronic message boards, roadway signage, and other measures. Flood warning programs could include a variety of measures, such as rain gauges, stream gauges, stage gauges, emergency action plans, and others. Potential LWC safety measures might include Turn Around Don't Drown signs, barricades, flashing lights, and automated gates to name a few. Advanced technology can be used to report readings from rain and stream gauge equipment to the entity's website to inform the public of real-time flood risks during and following storm events.

Goal Category 2. Improving Flood Analyses

Goal Category 2 intends to increase the number and extent of regional flood planning studies (FMEs) and analyses. By accomplishing this, the studies will be used to identify flood risk and better prepare communities for implementing FMPs. ***Table 3.8*** provides details on the three specific goal statements that support this category, as well as the TWDB's fundamental goal of protecting against the loss of life and property by utilizing the best available data when performing flood analyses.

Table 3.8: Goal Category 2. Improving Flood Analyses Specific Goal Statements

Goals	Specific Goal Statements	Baseline	Short Term (2033)	Long Term (2053)
A	Increase the availability of flood hazard data that uses the best available land use and precipitation data to reduce gaps in floodplain mapping.	Flood hazard data gaps identified in regional flood plan	25% gap reduction	95% gap reduction
B	Increase the number of entities that conduct detailed studies of localized/urban flooding impacts within the flood planning region.	Number of entities that conduct detailed, local studies	Establish a baseline measurement	30%
C	Increase the number of entities that utilize latest and most appropriate precipitation and land use data as a basis for design criteria and flood prevention regulations.	Number of entities that are utilizing latest, most appropriate data	Establish a baseline measurement	30%

Goal Category 3. Reducing Property Damage and Loss

Increase the number and extent of protective regulatory measures and programs to limit future risk andreduce flood damage in the flood planning region. ***Table 3.9*** includes five specific goal statements that aim to protect property and people and align with the TWDB's fundamental goal of protecting against the loss of life and property by reducing current flood risk and providing more flood risk awareness to the public.

Table 3.9: Goal Category 3. Reducing Property Damage and Loss Specific Goal Statements

Goals	Specific Goal Statements	Baseline	Short Term (2033)	Long Term (2053)
A	Increase the number of entities that have floodplain standards that meet or exceed the NFIP-minimum standards.	Number of entities with NFIP minimum standards	5 new cities/ towns	25 additional cities/ towns
B	Reduce the number of structures within the 1% floodplain (i.e. through structural projects, property buyouts, acquisitions, elevations, and/or relocations).	96,575 structures identified within 1% floodplain in regional flood plan	5%	10%
C	Reduce the vulnerability of agriculture, ranching and forestry to flood-related losses.	Number of projects reducing flood risk to agricultural, ranching, and forestry lands within 1% floodplain.	2	8
D	Reduce the number of critical facilities within the 1% floodplain	929 critical facilities identified in 1% floodplain in regional flood plan.	5%	10%
E	When relocation and/or elevation adjustment is not possible, increase the number of non-residential facilities that implement floodproofing	Non-residential facilities with floodproofing in 1% floodplain	5	25

Goal Category 4. Floodplain Preservation

Maintain the natural and beneficial functions of floodplains by preservation and conservation programs. In other words, allow floodplains to reduce flood risk by slowing runoff and storing floodwaters as intended (FEMA Benefits of Natural Floodplains, 2021). ***Table 3.10*** provides information on three goal statements that directly supports the TWDB's fundamental goal of protecting against the loss of life and property by reducing current and future flood risk in low-lying areas.

Table 3.10: Goal Category 4. Floodplain Preservation Specific Goal Statements

Goals	Specific Goal Statements	Baseline	Short Term (2033)	Long Term (2053)
A	Increase the acreage of publicly protected natural areas for flood and ecosystem purposes to reduce future impacts of flooding.	Number of projects that protect natural areas	2	8
B	Increase the number of entities that include the 1% floodplain on Future Land Use plans and other planning documents	Number of entities with future land use zoning regulations that incorporates floodplain	Increase by 20	Increase by 50
C	Avoid new exposure to flood hazards by adopting comprehensive plans or subdivision regulations that direct development away from the floodplain.	Entities with plans/ regulations including floodplain preservation tactics	Establish a baseline measure ment	10%

Publicly protected natural areas may include dedicated or deed-restricted parks, wetlands, preservations, forests, and other similar areas.

Future land use plans or comprehensive plans provide a guide for communities in determining where and what types of future development will occur in accordance with the community's long-range goals (Gary D. Taylor, 2019). These plans consider existing physical factors, such as topography, infrastructure, and development. Topography should include rivers and creeks and their associated floodplains.

Cities and counties have the authority to establish subdivision regulations that govern the platting process of property, including the identification and designation of floodplains (LGC, 2017) and (LGC, 2021). Subdivision rules can apply to Extraterritorial Jurisdictions (ETJs) if designated in the city ordinance.

Goal Category 5. Flood Infrastructure Improvement

Reduce flood risk and mitigate flood hazards to life and property through the maintenance and rehabilitation of existing infrastructure and implementation of new flood infrastructure projects. Four specific goal statements are included in ***Table 3.11***, all of which directly support the TWDB's fundamental goal of protecting against the loss of life and property by reducing current flood risk.

Table 3.11: Goal Category 5. Flood Infrastructure Improvement Specific Goal Statements

Goals	Specific Goal Statements	Baseline	Short Term (2033)	Long Term (2053)
A	Increase the number of nature-based practices as part of flood risk reduction projects.	Stormwater or drainage projects that incorporate nature-based solutions	Establish a baseline measurement	30%
B	Improve flood infrastructure and maintain streams and drainage channels to reduce flood risk to agricultural lands.	Stormwater or drainage projects that reduce risk to agricultural lands	Establish a baseline measurement	10%
C	Improve urban drainage infrastructure to minimize flood risk.	Mileage of drainage infrastructure	50 miles	500 miles
D	Perform regular inspections and maintain existing dams, levees, and other flood mitigation structures.	Number of regular inspections	Establish a baseline measurement	10%

Nature-based practices often involve geomorphic assessments to understand the specific site conditions and to select the most appropriate flood infrastructure improvement, including stream restoration or erosion solution. Geomorphologic studies also aide in identifying the locations for needed improvements. ***Chapter 2*** includes a discussion of geomorphology. Nature-based solutions may include strategically placed plantings, wood/logs, stakes, geotextile fabric, boulders, or other materials (USDA, 2021). In some cases, a combination of traditional engineered solutions can be used with certain nature-based components.

Goal Category 6. Expanding Flood Education and Outreach

Increase the amount of flood education and outreach opportunities to improve awareness of floodhazards and promote future participation throughout the flood planning region. Flood education and outreach is critical to protecting people and property. The goal category aligns with TWDB's fundamental goal of reducing loss of life and property by helping people understand and avoid flood risk. ***Table 3.12*** includes three specific goal statements within the category.

Table 3.12: Goal Category 6. Expanding Flood Education and Outreach Specific Goal Statements

Goals	Specific Goal Statements	Baseline	Short Term (2033)	Long Term (2053)
A	Increase the number of participating entities in the regional flood planning process.	Entities participating in the regional flood plan	35% [1]	90% [1]
B	Increase the number of local entities that host annual public outreach and education activities to improve awareness of flood hazards, benefits of flood planning, and procedures associated with emergency response associated with flooding.	Number of entities that host public, flood-related outreach	Establish a baseline measurement	50 total
C	Increase the number of entities that work cooperatively as part of an overall floodplain management program.	Number of entities participating in overall floodplain management programs	5 total	25 total

[1] *Percentage shown is the percent of total entity participation.*

Public education and outreach may incorporate a variety of methods from publishing newsletter articles to hosting booths at in-person events. Communities that participate in FEMA's CRS program typically have significant public outreach elements in their stormwater programs as they receive credit for doing so. The CRS program is described in ***Task 3A*** of this plan. Topics that might be covered in public education programs could include the following:

- Risks associated with driving through floodwaters
- Understanding/reading floodplain maps
- Being aware of the risks associated with living near rivers, creeks, and dams
- Being aware that the flood risks can be located in low-lying areas and away from streams
- Offering amenities with flood risk projects
- Understanding need and advantages of having dedicated funding

One of the key messages that is often misunderstood by the public is that anyone who lives in a community or county that participates in the NFIP can purchase FEMA flood insurance. Flood insurance is available to residential owners and renters, as well as commercial buildings. Flood insurance is required by mortgage companies if a house is located within the 1% annual chance storm event floodplain. Houses outside the floodplain are also eligible for flood insurance and at a lower rate because the risk of flooding is lower.

Goal Category 7. Expand Funding

Funding, or lack thereof, is a constant struggle for communities. Most communities have more stormwater needs and flood-related issues to address than they have funding to do so. Goal 7 directly supports the fundamental goal of reducing loss of life and property by expanding funding options for implementing FMEs, FMSs, and FMPs. ***Table 3.13*** provides a detailed goal statement aimed at expanding funding for stormwater and flood-related needs.

Table 3.13: Goal Category 7. Expand Funding Specific Goal Statements

Goals	Specific Goal Statements	Baseline	Short Term (2033)	Long Term (2053)
A	Increase the number of entities with dedicated stormwater funding mechanisms.	Number of entities with stormwater funding mechanisms	10%	30%

In addition to traditional state and federal funding opportunities that could potentially be expanded, local communities have the authority to establish and collect stormwater utility fees (also known as drainage utility fees) to support stormwater-related needs within the community (LGC, 2009). Stormwater utilities generate dependable revenue that can be used as local matching funds for state and federal grants to broaden the reach of such programs.

Benefits and Residual Risk after Goals are Met

The selected goal statements were developed in a manner to set the stage for specific actions that can be quantified and measured in future regional and state flood planning cycles. Future data collection efforts or implementation of FMEs, FMSs, and/or FMPs may be used to establish baseline data. The established baselines will be used for future measurements to determine progress towards achieving the goals. Implementation efforts will also demonstrate progress towards the overall purpose and intent of the regional flood planning process and will result in various benefits to individuals, communities, and the region as a whole.

Beyond protecting against the loss of life and property, the goals offer several benefits, including protecting infrastructure, water supply, the environment, and sustainability. The types of benefits to be realized with implementation of the Trinity Regional Flood Plan were explained previously and presented in ***Table 3.14.***

If the goals are fully achieved, then the residual risk should be minimal. However, residual risks should be anticipated for each of the overarching goal categories. Overall, the goal categories fall into one or more of the following residual risks:

- Storm events exceeding the design capacity of the infrastructure
- Time and budget limitations
- Human behavior
- Funding limitations for maintenance
- Policy and regulation changes

Goal Category 1: Flood warning and public safety residual risk depends on public response to flood warnings. Drivers may choose to ignore flood warning signs or barricaded roads for a variety of reasons. Despite an entity's best effort, risk will remain at LWCs.

Goal Category 2: Reducing residual risk associated with improving flood analyses involves technology that is always changing and improving. Due to the change and updates to terrain, land use, precipitation, and other data, the risk associated with the floodplains may change over time. While a new development may be constructed outside the 1% annual chance storm event floodplain, future improvements in technology and other data may change the floodplain boundary resulting in some structures being located within the floodplain.

Goal Category 3: Reducing the residual risk to property damage and loss depends on the local community's floodplain management policies and political leaders. Getting every community within the Trinity Region to adopt and enforce NFIP minimum standards, let alone higher standards, may prove to be challenging. The lack of local enforcement of floodplain regulations also creates risk.

Table 3.14: Flood Planning Goals and Benefits

Types of Benefits	Overarching Goal Categories						
	Goal 1: Flood Warning and Public Safety	Goal 2: Improving Flood Analyses	Goal 3: Reducing Property Damage and Loss	Goal 4: Floodplain Preservation	Goal 5: Flood Infrastructure Improvement	Goal 6: Flood Education and Outreach	Goal 7: Funding
Protect against the loss of life	●	●	◑	◑	●	◑	●
Protect against the loss of property	◑	●	●	◑	●	◑	●
Protect infrastructure	●	●	●		●		●
Protect the environment	◑	◑	●	●			●
Protect water supply			◑	●	◑		●
Sustain the economy	●	◑	●		◑		●
Design for co-benefits*			◑	●	●		●
Increase public awareness	●	●				●	●
Build community support	●	●				●	◑

● Benefit
◑ Potential Benefit

** Single project with multiple benefits, i.e. improves floodplain protection and water supply, increases recreation opportunities, habitat preservation, etc.*

Goal Category 4: Floodplain preservation allows floodplains to serve their natural and intended purpose to mitigate floods. Residual risk depends on people stepping back and allowing space for flooding to remain in natural areas.

Goal Category 5: Flood infrastructure improvements can only be expected to perform based on the design capacity. In other words, if any storm that exceeds the design capacity was to occur, the infrastructure will still be at risk. Most community stormwater collection systems are not designed to collect the 1% annual chance storm event due to cost constraints. Even if the system was designed for that storm, a larger storm would still overwhelm the system. Likewise, storm intensities can overwhelm stormwater collection systems resulting in flooded roadways, bridges, culverts, and other damages. Also, routine maintenance of infrastructure is required to maintain the design capacity. Maintenance is sometimes overlooked due to budget, staff, and time constraints.

Goal Category 6: Flood education and outreach primarily provide benefits when implemented. The primary risks associated with public education and outreach are misunderstandings and lack of attention. Misunderstandings happen when the public becomes confused about the message, possibly due to its length or complex nature.

Goal Category 7: Funding residual risk includes lack of funding for design and construction of FMPs that result in delayed or shelved projects leaving the area(s) at risk. Lack of funding for maintenance may result in unanticipated infrastructure failure that costs much more to repair than to maintain. Local entities have more stormwater and flood-related needs than they have the funding to resolve.

Consideration of Minimum Recommended Flood Protection Goal

The Trinity RFPG is tasked with identifying specific and achievable flood protection goals that address risks to life and property. ***Table 3.14*** includes the Trinity RFPG's selected overarching goals and the goals' relation to the TWDB's fundamental goal with a benefit or co-benefit to protect life and property. The selected goals are more fully described in earlier in this section.

Goals Applicable to HUC-8 Watersheds

The Trinity RFPG discussed whether to apply goals differentially across the Upper, Middle, and Lower regions of the Trinity River Watershed, given their differences in flood risk. The group also considered if any of the goals should be applied to specific HUC-8 areas. The Trinity RFPG determined that the goals are universal in nature and each selected goal applies to each entity within the entire flood planning region. Therefore, no regional or HUC-8 watershed distinctions are recommended.

Short-Term Goals (10 years) and Long-Term Goals (30-years)

The selected goals guide the preparation of recommendations for FMSs, FMEs, and FMPs in this plan. They build upon TWDB's regional flood planning guidance and provide a comprehensive framework for future strategy development focused on reducing flood risk to people and property, while not negatively affecting neighboring areas.

Table 3.7 through ***Table 3.13*** include the short-term and long-term measurements towards accomplishing the specific goal statements. As this is the first regional flood plan prepared for the Trinity Region, the short-term goal for several of these statements will be to establish a baseline from which to measure future successes. The measurements of other goals are stated in these tables. The ***TWDB-Required Table 11*** is included in ***Appendix A*** and contains similar details as the above referenced tables.

Bibliography

CFR. (1976). Retrieved from CFR Title 44 Chapter I Subchapter B Part 60 Subpart A Section 60.3: https://www.ecfr.gov/current/title-44/chapter-I/subchapter-B/part-60/subpart-A/section-60.3

CFR. (2011). Retrieved from Code of Federal Regulations, Title 44 (begins on page 200 of the PDF): https://www.govinfo.gov/content/pkg/CFR-2011-title44-vol1/pdf/CFR-2011-title44-vol1.pdf

FEMA. (1968). Retrieved from FEMA Flood Insurance Rules and Legislation: https://www.fema.gov/flood-insurance/rules-legislation

FEMA. (2021, June). *CIS Community Status Book.*

FEMA Benefits of Natural Floodplains. (2021). Retrieved from FEMA Benefits of Natural Floodplains: https://www.fema.gov/floodplain-management/wildlife-conservation/benefits-natural?web=1&wdLOR=cD8A47D5F-4D26-4C5D-A738-A0A8A48CB36A

FEMA CRS. (2021). Retrieved from FEMA Floodplain Management Community Rating System: https://www.fema.gov/floodplain-management/community-rating-system

FEMA CRS Manual. (2021). Retrieved from FEMA CRS Resources website: https://crsresources.org/manual/

FEMA Flood Insurance. (2021). Retrieved from FEMA Flood Insurance: https://www.fema.gov/flood-insurance

FEMA Flood Insurance Rules & Regs. (2021). Retrieved from FEMA Flood Insurance Rules and Regulations: https://www.fema.gov/flood-insurance/rules-legislation

FEMA Floodplain Management. (2021). Retrieved from FEMA Floodplain Management / Management Risk / Local: https://www.fema.gov/floodplain-management/manage-risk/local

FEMA Glossary. (2021). Retrieved from FEMA Glossary: https://www.fema.gov/glossary/freeboard#:~:text=Freeboard-,a.,or%20community%20floodplain%20management%20regulations

Gary D. Taylor, I. S. (2019, July 25). *Community Planning Extension.* Retrieved from Community Planning and Zoning "The Purpose of the Comprehensive Land Use Plan": https://community-planning.extension.org/the-purpose-of-the-comprehensive-land-use-plan/

LGC. (2009, April 1). Retrieved from Local Government Code Title 13, Subtitle A, Chapter 552, Subchapter C: https://statutes.capitol.texas.gov/Docs/LG/htm/LG.552.htm#552.046

LGC. (2017, December 1). Retrieved from Local Government Code Title 7, Subtitle A, Chapter 212, Subchapter A: https://statutes.capitol.texas.gov/Docs/LG/htm/LG.212.htm

LGC. (2021, September 1). Retrieved from Local Government Code, Title 7, Subtitle B, Chapter 232, Subchapter A: https://statutes.capitol.texas.gov/Docs/LG/htm/LG.232.htm

National Flood Insurance. (2020, May). Retrieved from Flood Insurance Options: The NFIP VS. Private Flood: https://nationalfloodinsurance.org/blog/NFIP-VS-Private

NCTCOG CDC. (2021). Retrieved from NCTCOG Corridor Development Certificate: https://www.nctcog.org/envir/watershed-management/corridor-development-certificate-program

NCTCOG Corridor Development Certificate Criteria Manual. (2021). Retrieved from NCTCOG Corridor Development Certificate Criteria Manual: http://trinityrivercdc.com/index.php#faq

NCTCOG Countywide Watershed Standards. (2017). Retrieved from NCTCOG Countywide Watershed Management Roundtable: https://www.nctcog.org/envir/watershed-management/floodplain-management

NCTCOG iSWM. (2021). Retrieved from NCTCOG iSWM: iswm.nctcog.org

NCTCOG iSWM Site Development Manual. (2006). Retrieved from NCTCOG iSWM Site Design Manual Chapter 4: http://iswm.nctcog.org/Documents/archives/site_development_manual/Chapter4.pdf

OCC. (2019, February 12). Retrieved from Office of the Comptroller of Currency (OCC) New Rule Covers Private Flood Insurance: https://www.occ.gov/news-issuances/news-releases/2019/nr-ia-2019-15.html

PL 112-141. (2012, July 6). Retrieved from United States Government Publishing Office (GPO) Public Law 112-141 (begins on page 212): https://www.govinfo.gov/content/pkg/PLAW-112publ141/pdf/PLAW-112publ141.pdf

TFMA. (2020). TFMA Higher Standards Survey Results 2019-2020.

TWDB. (2001). Retrieved from Texas Water Development Board Flood Insurance Participation: https://www.twdb.texas.gov/flood/insurance/participation.asp?web=1&wdLOR=c9E70E758-CE06-44A5-B251-3E8A2D23ED56

TWDB FIF. (2021). Retrieved from TWDB Flood Infrastructure Fund (FIF) FAQ #4, Item 5: http://www.twdb.texas.gov/financial/programs/fif/index.asp

TWDB NFIP. (2021, October). Retrieved from TWDB Participation in the NFIP Sample City Resolution: file:///C:/Users/ah3829/Downloads/city.pdf

USACE. (1970, May). *USACE PMP.* Retrieved from United States Army, Corps of Engineers, Hydrometeorologcal Report No. 46: https://www.weather.gov/media/owp/oh/hdsc/docs/TP46.pdf#:~:text=Probable%20maximum%20flood%20is%20defined%20as%20the%20flood,conditions%20that%20are%20reasonably%20possible%20in%20the%20region.

USACE Engineering Manual. (1965, March). Retrieved from USACE Engineering Manual EM-1110-2-1411: https://www.publications.usace.army.mil/Portals/76/Publications/EngineerManuals/EM_1110-2-1411.pdf

USDA. (2021). Retrieved from USDA NRCS Natural Channel and Floodplain Restoration, Applied Fluvial Geomorphology: https://www.nrcs.usda.gov/wps/portal/nrcs/detail/tx/home/?cid=stelprdb1247762

Western Kentucky. (2020). *Western Kentucky 2020 data.*

Chapter 4: Assessment and Identification of Flood Mitigation Needs

Task 4A: Flood Mitigation Needs Analysis

This chapter describes the process adopted by the Trinity Regional Flood Planning Group (RFPG) to conduct a Flood Mitigation Needs Analysis (***Task 4A***) to identify the areas of greatest known flood risk and areas where the greatest flood risk knowledge gaps exist. The ***Task 4A*** process is a big picture assessment that helps guide the subsequent ***Task 4B*** effort of identifying Flood Management Evaluations (FMEs), Flood Mitigation Projects (FMPs), and Flood Management Strategies (FMSs). ***Table 4.1*** provides a summary of the Texas Water Development Board (TWDB) guidance and factors that were considered in the Flood Mitigation Needs Analysis.

Process and Scoring Criteria

The ***Task 4A*** analysis is based on a geospatial process that combines information from multiple datasets representing several of the factors listed in ***Table 4.1*** and provides a basis for achieving the ***Task 4A*** objectives. The geospatial process was developed in a geographic information system (GIS) and was based on the data collected in ***Tasks 1*** through ***3***. A variety of data sources were used in this assessment, including GIS data collected directly from communities during outreach efforts. During the data collection phase, individuals participated in an online survey where they were able to respond geographically on a map. The entity responses, as of September 16, 2021, were directly applied to this assessment.

A Hydrologic Unit Code (HUC) is a unique code assigned to watersheds in the United States. As the watersheds get smaller, the number of units used to identify them get longer. Therefore, the smallest unit of division used to identify a watershed is 12 digits, or a HUC-12. The geospatial assessment was prepared at a HUC-12 watershed level of detail, which is consistent with the minimum watershed size for ***Task 4B*** specified in the Technical Guidelines (at least one square mile). The Trinity Region has a total of 471 HUC-12 watersheds, with an average size of 40 square miles.

A total of 13 data categories (see ***Table 4.2***) were used in the geospatial assessment. A scoring range was determined for each data category based on the statistical distribution of the data. The scoring ranges vary for each category based on the HUC-12s with the smallest and largest quantity. A uniform scoring scale of zero to five was adopted and each HUC-12 was assigned an appropriate score for each category.

Table 4.1: Texas Water Development Board Guidance and Factors to Consider

Guidance	Factors to Consider
1. Most prone to flooding that threatens life and property	• Buildings and critical facilities within 100-year floodplain • Low water crossings (LWCs) • Agricultural and ranching areas in 100-year floodplain
2. Locations, extent, and performance of current floodplain management and land use policies and infrastructure	• Communities not participating in National Flood Insurance Program (NFIP) • Disadvantaged/underserved communities • City/county design manuals • Land use policies • Floodplain ordinance(s)
3. Inadequate inundation mapping	• No mapping • Presence of Fathom/base level engineering (BLE)/Federal Emergency Management Agency (FEMA) Zone A flood risk data • Detailed FEMA models older than 10 years
4. Lack of hydrologic and hydraulic (H&H) models	• Communities with zero or limited models
5. Emergency need	• Damaged or failing infrastructure • Other emergency conditions
6. Existing modeling analyses and flood risk mitigation plans	• Exclude FMPs already in implementation • Leverage existing models, analyses, and flood risk mitigation plans
7. Previously identified and evaluated flood mitigation projects	• Exclude FMPs already in implementation • Leverage existing FMPs
8. Historic flooding events	• Disaster declarations • Flood insurance claim information • Areas with a history of flooding according to survey responses • Other significant local events
9. Previously implemented FMPs	• Exclude areas where FMPs have already been implemented unless significant residual risk remains
10. Additional other factors deemed relevant by the Trinity RFPG	• Alignment with Trinity RFPG goals • Alignment with TWDB guidance principles • Social Vulnerability Index (SVI)

Table 4.2: Task 4A Scoring Ranges: Areas Most Prone to Flooding that Threatens Life and Property

Score (points)	0	1	2	3	4	5
Number of Buildings	0	1-50	51-250	251-500	501-750	751+
Number of LWCs	0	1-5	6-10	11-15	16-20	21+
Total Agricultural Area (square miles)	0	0.01-0.35	0.36-2.00	2.01-3.00	3.01-5.50	5.51+
Number of Critical Facilities	0	1-5	5-10	11-25	26-50	51+
Number of Locations where Roads Flood	0	1	2	3	4	5+

The scores for each HUC-12 under each category were then added to obtain a total score that was used to reveal the areas of greatest known flood risk. The Inadequate Inundation Mapping category (which is discussed further later in this chapter) was selected as the basis for determining the areas where the greatest flood risk knowledge gaps exist.

The following sections provide a brief description of the data categories included and how each HUC-12 watershed was scored. Note that the objective of the ***Task 4A*** process is to determine the factors that are present within a given HUC-12, and to what degree; not necessarily to determine the relative importance of each factor in determining flood risk. Therefore, no weight has been applied to emphasize one factor over another at this time.

Areas Most Prone to Flooding that Threatens Life and Property

Buildings in the 100-year Floodplain

The building footprints dataset was provided by the TWDB on the Data Hub. This dataset was divided into point values based on the total number of buildings in the 100-year floodplain within each HUC-12. The count ranged widely throughout the region, with rural HUC-12s only having one to two buildings in the floodplain, while major urban centers may have over 1,000 buildings in the floodplain. The points breakdown for this metric is shown in ***Table 4.2***.

Low Water Crossings

LWCs were identified in ***Tasks 1*** (***Chapter 1***) and ***2*** (***Chapter 2***) and were downloaded from the TWDB Data Hub. LWC data was also provided by communities through the data collection portal developed for the Trinity Region. ***Task 2*** also identified a few more based on bridge deck elevation from LiDAR data and flood depths. This category is scored based on the quantity of LWCs occurring in a HUC-12. The points breakdown for this metric is shown in ***Table 4.2***.

Agricultural Areas at Risk of Flooding

Agricultural areas have been defined for this task as a land use of either farming or ranching. Impacted agricultural areas are those intersecting the 100-year floodplain as determined in the flood exposure analysis (See ***Chapter 2***). This layer will emphasize rural HUC-12s where agricultural impacts due to flooding are most prominent. The total impacted agricultural area in each HUC-12 was the criteria considered to assign points. The points breakdown for this metric is shown in ***Table 4.2***.

Existing Critical Facilities

Critical facilities for this assessment include hospitals, schools, fire stations, shelters, as well as electric and gas lines. Critical facilities within the 100-year floodplain were identified as part of the flood exposure analysis (See ***Chapter 2***). The community representatives were able to update the existing critical facilities by adding or removing facilities in the web GIS survey from ***Task 2***. A total of 159 critical facilities were added by survey participants, and 26 were removed or corrected. This category is scored based on the total number of critical facilities identified within the 100-year floodplain. The points breakdown for this metric is shown in ***Table 4.2***.

Locations Where the Road Floods

This dataset is based on survey responses from ***Task 2***. Survey participants identified roads that are prone to flooding by drawing lines on the interactive map. A total of 49 locations were added by survey participants. Although this factor primarily addresses water over roadways, it also represents potential urban flooding scenarios. Each line entered was given one point. If the line was drawn across multiple HUC-12s, then both HUCs received a point. The point breakdown for this metric is shown in ***Table 4.2***.

Current Floodplain Management and Land Use Policies and Infrastructure

Communities Not Participating in the National Flood Insurance Program

Participation in the NFIP was considered as a proxy for having adequate floodplain management regulations in each community. The NFIP participation status for each community is presented in ***Chapter 3***. Non-participating communities are not eligible for flood insurance under the NFIP. Furthermore, if a presidentially-declared disaster occurs because of flooding, no federal financial assistance can be provided to non-participating communities for repairing or reconstructing insurable buildings in Special Flood Hazard Areas (SFHAs). Therefore, this analysis considered non-NFIP communities as being more vulnerable to flooding risks. If most of the HUC-12 (greater than 50 percent) intersected a non-NFIP community, it was assigned five points. Otherwise, no points were allocated. Non-NFIP communities are mostly clustered in the mid-basin area, with others dispersed throughout the region. The point breakdown for this metric is shown in ***Table 4.3.***

Table 4.3: Task 4A Scoring Range: Current Floodplain Management and Land Use Policies and Infrastructure

Score (points)	0	1	2	3	4	5
Community	NFIP Participant					Non-NFIP Participant

Areas Without Adequate Inundation Maps

Inadequate Inundation Mapping

This analysis was completed using the ExFldHazard layer. This layer contains existing seamless floodplain quilt inundation boundaries gathered for the Trinity Region in ***Task 2***. The floodplain quilt attributes include the source of the floodplain data. Based on the definitions of the source data from TWDB (TWDB, 2021), the Trinity RFPG assumed that the sources that represented adequate inundation mapping data include:

- National Flood Hazard Layer (NFHL) Preliminary Data (Zones AE, AH, AO, VE, and X)
- NFHL Effective Data (Zones AE, AH, AO, VE, and X)

The following data sources were considered inadequate inundation mapping data in this assessment as they are not considered appropriate for regulatory purposes:

- BLE
- NFHL Zone A
- First American Flood Data Services (FAFDS)
- Fathom

The total floodplain area (from all sources in the floodplain quilt) and the amount of inadequate floodplain data in each HUC-12 were calculated. The computation produced a percentage of the HUC-12 floodplain data that is considered inadequate for the purposes of this assessment. The HUC-12s with the highest percentages of inadequate data appear in the very far north region area and in the middle of the region. The points breakdown for this metric is shown in ***Table 4.4***.

Table 4.4: Task 4A Scoring Range: Areas Without Adequate Inundation Maps

Score (points)	0	1	2	3	4	5
% Inadequate	0	0.01-20%	21-50%	51-75%	76-90%	90%+

Areas Without Hydrologic and Hydraulic Models

The existing H&H models that were identified for the Trinity Region are presented in ***Chapter 2***. Separate scoring criteria was not developed for this category since the risk associated with lack of technical data is already being considered by the "Inadequate Inundation Mapping" category. Any areas with detailed mapping are presumed to have H&H modeling.

Areas with Emergency Needs

The Trinity RFPG has developed a definition for emergency needs based on regional needs and input from the planning committee. Areas with severe repetitive loss (SRL), critical facilities within the 1% annual chance storm event area, and locations associated with a high number of fatalities are the three metrics the Trinity Region has decided to use to attribute as emergency need. For a more detailed description, please see the ***Task 4B*** discussion later in this chapter.

Existing Modeling Analyses and Flood Risk Mitigation Plans

Hazard Mitigation Action Plans were identified for all 38 counties within the Trinity Region. Therefore, this category was not included in the assessment since it does not provide any differentiation regarding flood risk within the region.

Flood Mitigation Projects Previously Identified

Per the public survey responses, only two ongoing projects were identified with dedicated funding in place (see ***Chapter 2***). Due to the limited data available, this category was not included in this assessment.

Historic Flooding Events

Report Flood Concerns

This category was generated by the community responses to the survey in ***Task 2***. A total of 110 data point locations were provided by survey participants. This dataset primarily included flood concerns related to undersized storm drain systems and localized street flooding. The score for this factor was based on the number of flood concern locations identified by survey participants within each HUC-12. The points breakdown for this metric is shown in ***Table 4.5***.

Table 4.5: Task 4A Scoring Ranges: Historic Flood Events

Score (points)	0	1	2	3	4	5
Number of Flood Concerns	0	1	2	3	4	5+
Number of FEMA Claims	0	1-5	6-10	11-30	31-50	51+
Number of Historic Storms Events	0	1-2	3-4	5-6	7-8	9+
Property Damages ($)*	0	1-10,000	10,001-30,000	30,001-100,000	100,001-500,000	500,000+
Number of Areas with History of Flooding or need Mitigation	0	1	2	3	4	5+

** One additional point was added if injuries were reported, and two additional points if deaths were reported.*

Federal Emergency Management Agency Claims

This dataset compiles all the FEMA flood claims within the Trinity Region as of July 31, 2021. The geospatial data assigned to the claims was highly redacted. Therefore, the Trinity RFPG opted for using the cities to which the flood claims were assigned. Each city was divided into the HUC-12s that intersected the city limits. The number of flood claims for each city was divided proportionately amongst the HUC-12s composing each city. Most of the claims recorded in this dataset occurred in the Dallas-Fort Worth (DFW) metropolitan area. The points breakdown for this metric is shown in ***Table 4.5***.

Historic Storm Events

The occurrence of historic storm events was evaluated using the National Oceanic and Atmospheric Administration (NOAA) National Centers for Environmental Information Storm Events Database (NCEI, 2022). This database compiles historic storm events from 1950 to 2021. This dataset is an official NOAA publication which documents the following:

- The occurrence of storms and other significant weather phenomena having sufficient intensity to cause loss of life, injuries, significant property damage, and/or disruption to commerce
- Rare, unusual, weather phenomena that generate media attention
- Other significant meteorological events, such as record maximum or minimum temperatures or precipitation that occurs in connection with another event

Storm events are included in this database following the procedures established in the National Weather Service (NWS) Directive Number 10-1605 – Storm Data Preparation (NWS, 2021). Storm events are subdivided into 48 categories, which include flood related events as well as other natural hazards. Three primary event categories were selected for this assessment: floods, flash floods, and heavy rain. A total of 837 storm events were reported for the Trinity Region between 1996 and 2020, consisting of 158 floods, 660 flash floods, and 19 heavy rain events. Each event includes the source of data and a narrative describing the details of the event.

The number of historic storm events occurring within each HUC-12 was tabulated and scores were assigned according to the point breakdown shown in ***Table 4.5***.

Damages from Historic Storms

In addition to the frequency of historic storm events, the severity of these events was also considered in the assessment. Event severity was represented by reported damages, injuries, and deaths associated with each event as recorded in the Historic Storm Events database. A score of zero to five points was first assigned based on reported property damages. (See scoring scale in ***Table 4.5.***) One additional point was added if injuries were reported, and two additional points were added if deaths were reported.

Areas with a History of Flooding/Areas that need Mitigation

The data collection survey performed in ***Task 2*** also provided an opportunity for participants to identify areas in their communities that repetitively flood or may require mitigation. A total of 87 data points were provided by survey participants. Within each HUC-12 boundary, the number of areas marked were scored according to the scale shown in ***Table 4.5***. This dataset is limited to locations identified by individuals in the ***Task 2*** survey.

Previously Implemented Flood Mitigation Projects

Per the data collection survey responses, no FMPs were identified as previously implemented (see ***Chapter 2***); therefore, this category was not included in this assessment.

Other Factors

Social Vulnerability Index

As discussed in ***Chapter 2***, SVI refers to the potential negative effects on communities caused by external stresses on human health. Such stresses include natural or human-caused disasters, or disease outbreaks. SVI values for the State of Texas were downloaded from the Centers for Disease Control and Prevention's (CDC) Agency for Toxic Substances and Disease Registry (ATSDR) website (United States CDC, 2018). The most recent SVI values published on the website (2018) were used in this assessment. SVI values are assigned per census tract, which needed to be converted to SVI per HUC-12. SVI values were assigned to each HUC-12 based on an area-weighted average. The percent of a census tract that intersects a HUC-12 was multiplied by the SVI. This procedure was followed for all census tracts intersecting a HUC-12 boundary, and those weighted SVI values were added together to produce one SVI value for each HUC-12. The SVI ratings vary between zero and one and were scored according to ***Table 4.6***. The higher the SVI, the higher the vulnerability of a community; the lower the SVI, the higher the resilience. Overall, the HUC-12s in the middle and lower portions of the region resulted in the highest SVI values.

Table 4.6: Task 4A Scoring Ranges: Social Vulnerability Index Ratings

Score (points)	1	2	3	4	5
SVI rating	0.01-0.16	0.17-0.33	0.34-0.50	0.51-0.67	0.67+

Scoring Example

Five HUC-12 basins were selected to demonstrate, in detail, the scoring process described earlier in this chapter. The selected basins are located in the Lower Trinity-Kickapoo and Lower Trinity Sub-Basins, south of Lake Livingston (see ***Figure 4.1***). These five basins, labeled A through E for simplicity, had a wide variety of scores for each category and resulted in total scores that represent the entire range of known flood risk levels as defined in this assessment.

Figure 4.1: Example Task 4A Hydrologic Unit Code-12 Scoring

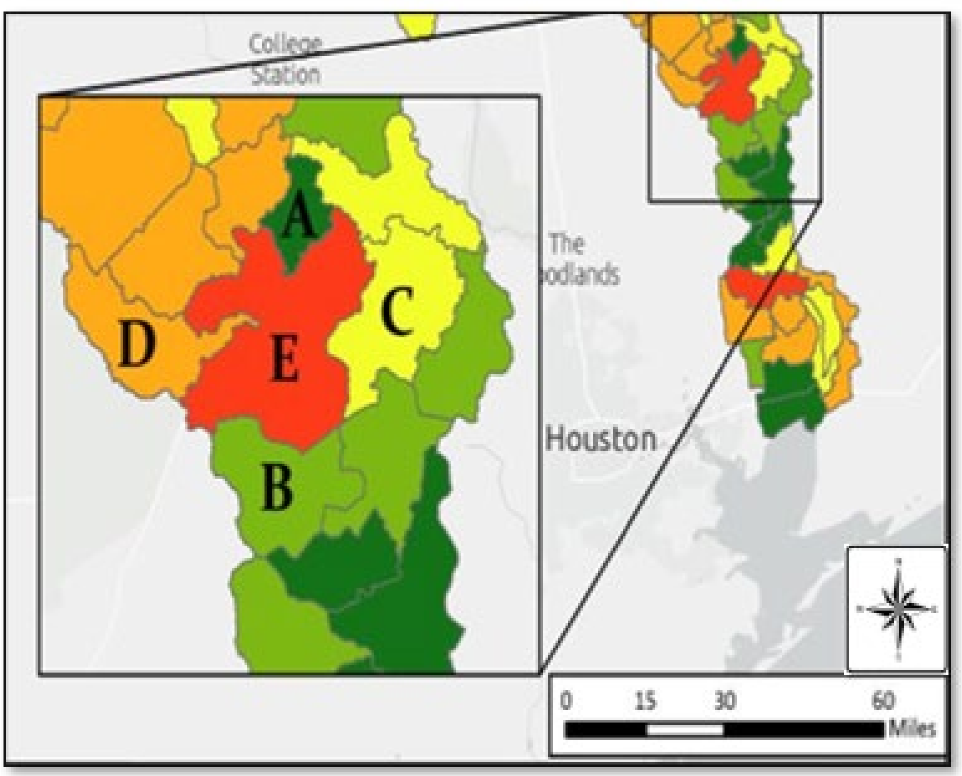


Table 4.7shows the detailed scores for the selected HUC-12 basins. These results are presented graphically in ***Figure 4.2***. This data demonstrates how the combination of different factors can help determine if a given HUC-12 has a high level of known flood risk relative to others. In this example, Basin E scored high in several categories, which resulted in the highest total score. Conversely, Basin A only scored high in the SVI category, indicating a much lower level of known flood risk. However, the fact that a HUC-12 results in a low score does not necessarily mean that there is no flood risk in this area. The results for Basin B show a relatively low total score, but it scored high in the SVI and inadequate inundation mapping categories. In addition, some buildings, critical facilities, and LWCs would still be impacted by the 1% annual chance storm event. This clearly indicates that there is still a level of flood risk associated to this area, but not as significant as in Basin E.

The inadequate inundation mapping category was selected as the basis for determining the areas where the greatest flood risk knowledge gaps exist. In this example, four of the selected HUC-12s scored high for this category, indicating that inundation maps in these areas are considered inadequate. This result indicates that there is significant uncertainty regarding floodplain boundaries in these areas and that studies (FMEs) would be needed to reduce uncertainty, and in turn, minimize flood risk.

Analysis Results

The process and scoring methodology described above was implemented across the entire Trinity Region. As previously discussed, this assessment was performed to address the two goals of ***Task 4A***. The first goal was to identify the areas where the greatest flood risk knowledge gaps exist. The inadequate inundation mapping category was selected as the basis for identifying these areas. Based on the data utilized in this preliminary assessment, approximately two-thirds of the Trinity Region is considered inadequately mapped (as indicated by the red HUC-12s in ***Figure 4.3***). Note that the red HUC-12s may contain studies that have been completed but are not yet regulatory products.

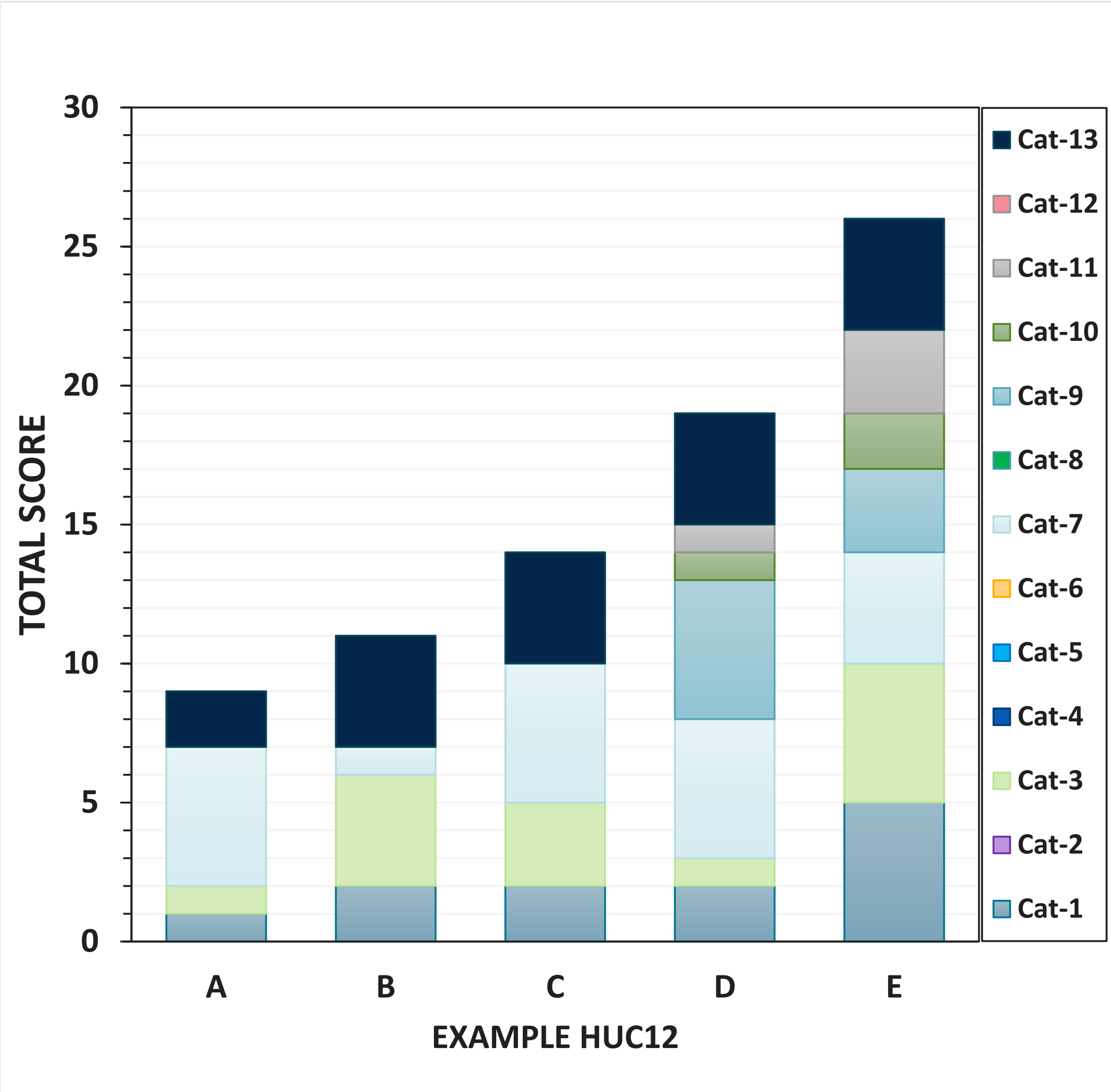
The second goal was to determine the areas of greatest known flood risk and flood mitigation needs. For each HUC-12 in the Trinity Region, the scores from the 13 categories were added to obtain a total score. All categories have an equal representation in the total score. This analysis also included the inadequate inundation mapping category because uncertainty itself is a risk. Based on the distribution of the final scores in this preliminary assessment, the top 10 percent were colored red, and the top 30 percent were colored either red or orange to highlight the areas with the greatest known flood risks (***Figure 4.4***). It is important to note that a HUC-12 with a low score does not necessarily mean that there is no flood risk in this area, only that this risk is relatively low compared to the others.

Table 4.7: Example Task 4A Hydrologic Unit Code-12 Scoring

Category / Score	HUC-12				
	A	B	C	D	E
Category 1 – # of Buildings	2	191	203	56	1018
Category 1 – Score	1	2	2	2	5
Category 2 – # of Crossings	0	0	0	0	0
Category 2 – Score	0	0	0	0	0
Category 3 – Agricultural Area Impacted (mi^2)	0.09	4.64	2.27	0.34	16.67
Category 3 – Score	1	4	3	1	5
Category 4 – # of Critical Facilities	0	0	0	0	0
Category 4 – Score	0	0	0	0	0
Category 5 – # of Locations where Road Floods	0	0	0	0	0
Category 5 – Score	0	0	0	0	0
Category 6 – NFIP Community	0	0	0	0	0
Category 6 – Score	0	0	0	0	0
Category 7 – Inadequate Inundation Mapping	100%	5%	96%	100%	84%
Category 7 – Score	5	1	5	5	4
Category 8 – # of Flood Concerns	0	0	0	0	0
Category 8 – Score	0	0	0	0	0
Category 9 – # of FEMA Claims	0	0	0	76	12
Category 9 – Score	0	0	0	5	3
Category 10 - # of Historic Storm Events	0	0	0	1	3
Category 10 – Score	0	0	0	1	2
Category 11 – Damages ($)	0	0	0	$10,000	$35,000
Category 11 – Score*	0	0	0	1	3
Category 12 – # of Areas with History of Flooding	0	0	0	0	0
Category 12 – Score	0	0	0	0	0
Category 13 – SVI Rating	0.23	0.57	0.59	0.60	0.61
Category 13 – Score	2	4	4	4	4
Total Score	**9**	**11**	**14**	**19**	**26**

**HUC-12 did not have any injuries or deaths associated with the historic storms; therefore, no additional points were given for this category.*

Figure 4.2: Distribution of Points and Total Score for Hydrologic Unit Code-12 Examples



The maps resulting from the ***Task 4A*** assessment served as a guide to the Trinity RFPG's subsequent efforts in ***Task 4B***. The red and orange HUC-12s in ***Figure 4.3*** highlight the areas in the Trinity Region where potentially feasible flood risk studies (FMEs) should be considered as part of ***Task 4B***. The red and orange HUC-12s in ***Figure 4.4*** emphasize watersheds where the Trinity RFPG should strive to identify and implement FMSs and FMPs as part of ***Task 4B*** to reduce the known flood risks within those areas.

Figure 4.3: Flood Risk Knowledge Gaps

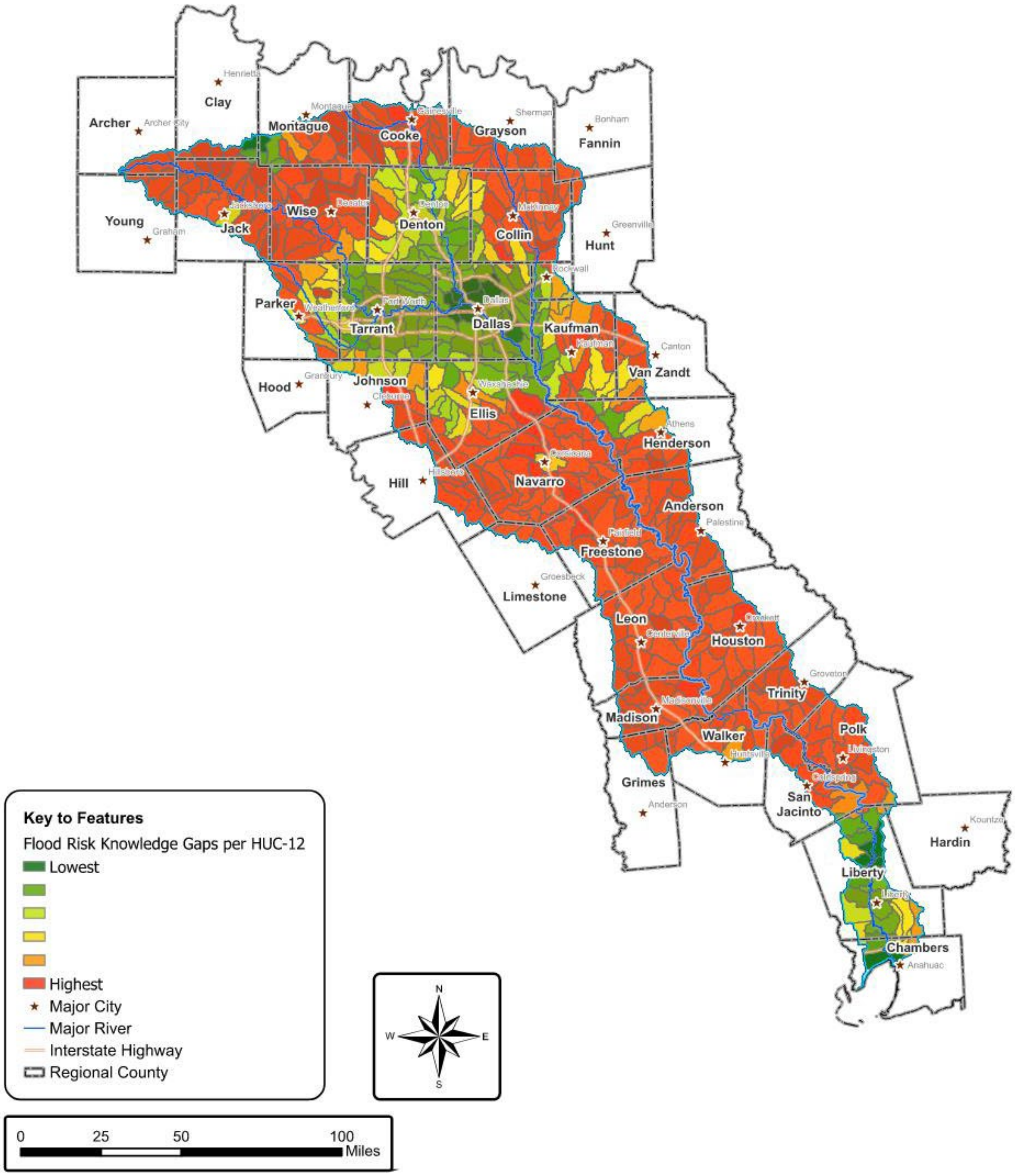
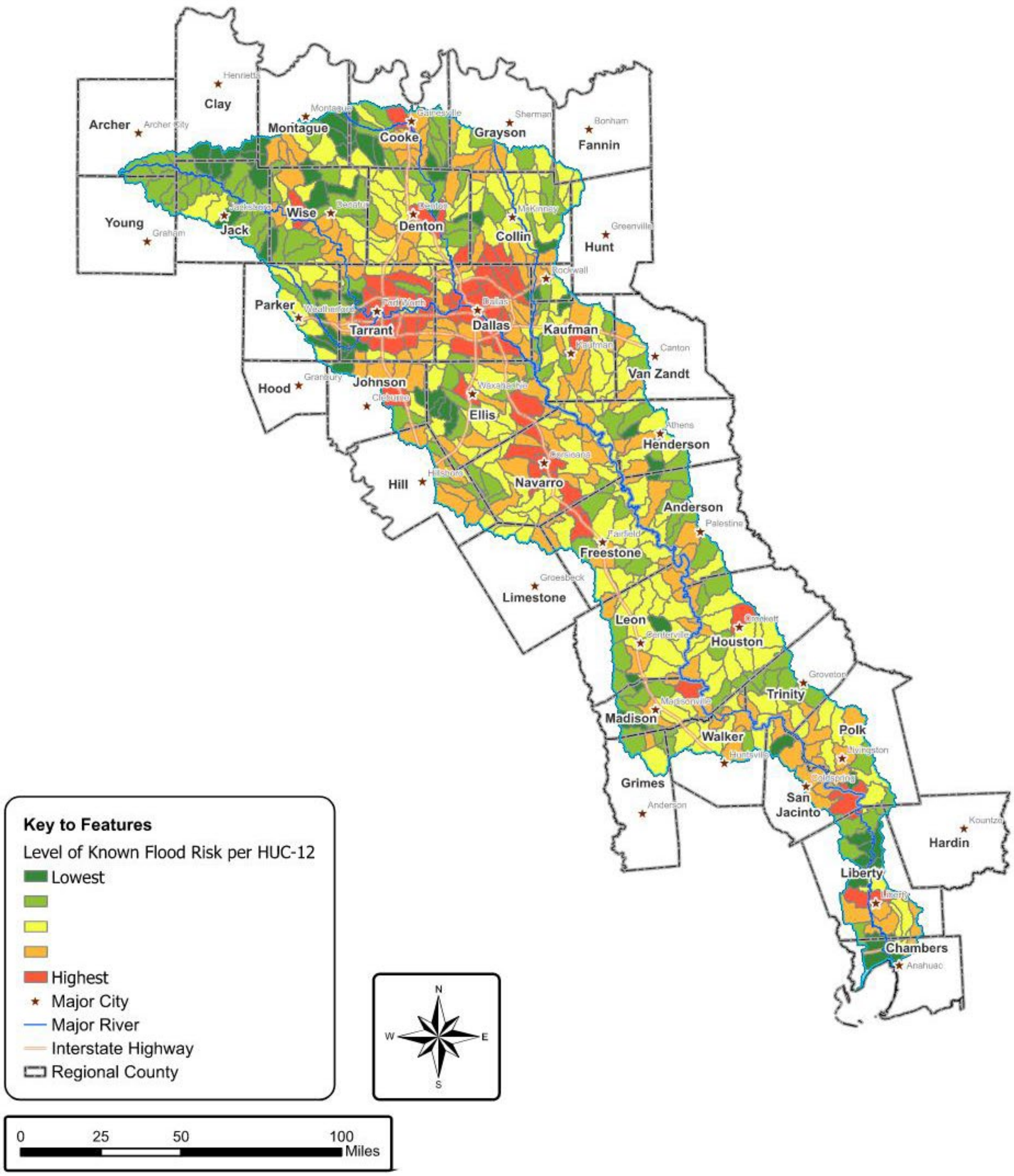


Figure 4.4: Areas of Greatest Known Flood Risk



Task 4B: Identification and Evaluation of Potential Flood Management Evaluations, Potentially Feasible Flood Management Strategies, and Flood Mitigation Projects

Process to Identify Flood Management Evaluations, Strategies, and Flood Mitigation Projects

The goal of ***Task 4B*** was to identify and evaluate a wide range of potential actions to define and mitigate flood risk across the basin. These actions were broadly categorized into three distinct types, as defined below:

- **FME**: a proposed flood study of a specific, flood prone area that is needed to assess flood risk and/or determine whether there are potentially feasible FMSs or FMPs
- **FMP**: a proposed project, either structural or non-structural, that has non-zero capital costs or other non-recurring cost, and when implemented will reduce flood risk or mitigate flood hazards to life or property
- **FMS**: a proposed plan to reduce flood risk or mitigate flood hazards to life or property

Identification of potential FMEs and potentially feasible FMPs and FMSs began with the execution of the Flood Mitigation Needs Analysis to identify the areas with the greatest gaps in flood risk knowledge and the areas of greatest known flood risk. This process and its outputs have been described previously in ***Task 4A***. Based on the results of this analysis, several sources of data were used to develop a list of potential flood risk reduction actions for addressing the basin's needs. The data includes information compiled under previous tasks, such as:

- Existing flood infrastructure, flood projects currently in progress, and known flood mitigation needs (***Task 1***)
- Existing and future flood risk exposure and vulnerability (***Tasks 2A*** and ***2B***)
- Floodplain management and flood protection goals and strategies developed by the Trinity RFPG (***Task 3A*** and ***3B***)
- Community input

Once these datasets were identified and evaluated through initial screening and data gathering under this task, the FMEs, FMSs, and FMPs were further evaluated to compile the necessary technical data for the Trinity RFPG to decide whether to recommend these actions, or a subset of these actions, as part of ***Task 5***.

This flood plan relies primarily on compiling readily available information to determine appropriate flood mitigation actions to recommend for inclusion in the regional flood plan, rather than performing technical analyses to identify new actions.

The lists of potential FMEs and potentially feasible FMSs and FMPs were compiled based on contributions from the Trinity RFPG and other regional communities, using sources such as previous flood studies, drainage master plans, flood protection studies, and capital improvement studies. In addition, plans that were considered in the flood planning process include local and countywide Hazard Mitigation Plans (HMPs); various ordinances, planning, and zoning documents; and FEMA NFHL data. Each of these documents and datasets provides insight into the jurisdiction's capabilities, the guidelines of each location, and the potential challenges of implementing FMEs, FMSs, and FMPs within the flood planning area. A list of data sources relevant to the regional flood plan development for the Trinity RFPG are provided in ***Table 4.8*** through ***Table 4.10***.

In all, 38 counties and seven cities within the Trinity Region had HMPs ranging from 2013 to 2021. Several communities provided their zoning and land use documents. Drainage studies, flood prevention ordinances, regulations for floodplain managements, and flood control ordinances were also included in the planning process. All participating counties have data in the NFHL; however, Trinity County does not have countywide data available. Additionally, five counties have preliminary flood studies in progress that will go effective in the near future.

Classification of Potential Flood Management Evaluations and Potentially Feasible Flood Management Strategies and Flood Mitigation Projects

Several different general action types provided by the TWDB considered are listed in ***Table 4.11.*** Once potential flood risk reduction actions were preliminarily identified using this list, a high-level screening process was used to confirm that potential actions had been sorted into their appropriate categorization. The screening process is shown in ***Figure 4.5***.

Generally, an action was considered an FME if it was meant to study and quantify flood risk in an area, as well as define potential FMPs and FMSs to address the risk. Potential actions that could be considered FMPs were screened to determine if they were developed in enough detail and included sufficient data to meet the technical requirements for these action types. Actions that were initially considered for FMPs that did not meet these requirements were adapted and repurposed as FMEs. Potential solutions that did not easily meet the criteria of FMEs or FMPs could be included as FMSs. The specific requirements for each action type are described in subsequent sections.

Table 4.8: Local Plans, Manuals, and Ordinances Submitted to the Trinity Regional Flood Planning Group through the Survey

Document	Year
Anderson County Floodplain Resolution	2010
Chambers County Drainage Criteria Manual	2020
Chambers County Floodplain Regulations	2015
City of Addison Code of Ordinances	2021
City of Aledo Subdivision Ordinance	2007
City of Allen Land Development Code	2020
City of Alma Planning and Zoning	n/a
City of Alvarado Code of Ordinances	2018
City of Ames Subdivisions	2021
City of Anahuac Code Compliance	2021
City of Anna Code of Ordinances	2021
City of Burleson Design Standards Manual	2008
City of Burleson Future Land Use Map	n/a
City of Burleson Subdivision Regulations	2021
City of Combine Code of Ordinances	2018
City of Crockett Zoning Map	2006
City of Dallas Floodplain and Escarpment Zone Regulations	n/a
City of Decatur Executed Flood Control Ordinance	2011
City of Decatur Future Land Use Map	n/a
City of Decatur Zoning	n/a
City of Keene Flood Hazard Reduction	2012
City of Mansfield Flood Damage Prevention Ordinance	2013
City of Mansfield Storm Water Management Design Manual	2010
City of McKinney Engineering Design Manual	2021
City of McKinney Stormwater Management	2018
City of Mesquite Engineering Design Manual	2020
City of Mesquite Stormwater and Flood Prevention Ordinance	2012
City of Mont Belvieu City Limits and ETJ Map	2021
City of Newark Floodplain Ordinance	2001
City of Retreat Code of Ordinances	1986
City of Sanger Comprehensive Land Use Plan	2007
City of Sanger Future Land Use Map	2007
City of Talty Flood Damage Prevention Ordinance	2009
City of Tioga Flood Damage Prevention Ordinance	1989
City of Tom Bean Comprehensive Zoning Ordinance and Zoning Manual	2008
City of Whitesboro Floodplain Ordinance	2005
Denton County Floodplain Regulations	2019
Denton County Subdivision Rules and Regulations	2009
Fannin County Flood Damage Prevention Ordinance	2011
Fannin County Lake Zoning Regulations	2018
Kaufman County Floodplain Management Court Order	2019
Kaufman County Subdivision and Land Development Regulations	2019
Madison County Flood Damage Prevention Order	2011
Polk County Flood Damage Prevention Order	2019
Polk County Subdivision Regulations	2021
Town of Annetta North Floodplain Ordinance	2018
Town of Dish Comprehensive Plan Zoning Map	n/a
Town of Dish Zoning Map	2018
Town of St Paul Flood Damage Prevention	2009
Walker County Regulations for Flood Plain Management	1987

Table 4.9: Federal Emergency Management Agency Flood Insurance Studies

Entity Name	Flood Insurance Study Name	Effective Date
Anderson	Anderson County, Texas and Incorporated Areas	2010
Archer	Archer County, Texas and Incorporated Areas	2021
Chambers	Chambers County, Texas and Incorporated Areas	2018
Clay	Clay County, Texas and Incorporated Areas	1991
Collin	Collin County, Texas and Incorporated Areas	2017
Cooke	Cooke County, Texas and Incorporated Areas	2008
Dallas	Dallas County, Texas and Incorporated Areas	2019
Denton	Denton County, Texas and Incorporated Areas	2020
Ellis	Ellis County, Texas and Incorporated Areas	2013
Fannin	Fannin County, Texas and Incorporated Areas	2011
Freestone	-	N/A
Grayson	Grayson County, Texas and Incorporated Areas	2010
Grimes	Grimes County, Texas and Incorporated Areas	2012
Hardin	Hardin County, Texas and Incorporated Areas	2010
Henderson	Henderson County, Texas and Incorporated Areas	2010
Hill	Hill County, Texas and Incorporated Areas	2019
Hood	Hood County, Texas and Incorporated Areas	2019
Houston	Houston County, Texas and Incorporated Areas	2011
Hunt	Hunt County, Texas and Incorporated Areas	2012
Jack	Jack County, Texas and Incorporated Areas	2021
Johnson	Johnson County, Texas and Incorporated Areas	2019
Kaufman	Kaufman County, Texas and Incorporated Areas	2020
Leon	Leon County, Texas and Incorporated Areas	2013
Liberty	Liberty County, Texas and Incorporated Areas	2018
Limestone	Limestone County, Texas and Incorporated Areas	2019
Madison	Madison County, Texas and Incorporated Areas	1991
Montague	Montague County, Texas and Incorporated Areas	2011
Navarro	Navarro County, Texas and Incorporated Areas	2012
Parker	Parker County, Texas and Incorporated Areas	2020
Polk	Polk County, Texas and Incorporated Areas	2010
Rockwall	Rockwall County, Texas and Incorporated Areas	2020
San Jacinto	San Jacinto County, Texas and Incorporated Areas	2018
Tarrant	Tarrant County, Texas and Incorporated Areas	2020
Trinity	-	N/A
Van Zandt	Van Zandt County, Texas and Incorporated Areas	2010
Walker	Walker County, Texas and Incorporated Areas	2011
Wise	Wise County, Texas and Incorporated Areas	2020
Young	Young County, Texas and Incorporated Areas	2019

Note: Data as of March 2022

Table 4.10: Hazard Mitigation Plans

Entity Name	Year of HMP
Anderson County	2018
Archer County	2020
Chambers	2017
City of Dallas	2018
City of Decatur	2016
City of Garland	2017
City of Grand Prairie	2017
City of McKinney	2015
City of Mesquite	2020
City of Plano	2013
Clay County	2020
Collin County	2016
Cooke County	2018
Dallas County	2020
Denton County	2016
Ellis County	2014
Fannin County	2015
Freestone County	2021
Grayson County	2012
Grimes County	2013
Hardin County	2017
Henderson County	2020
Hill County	2020

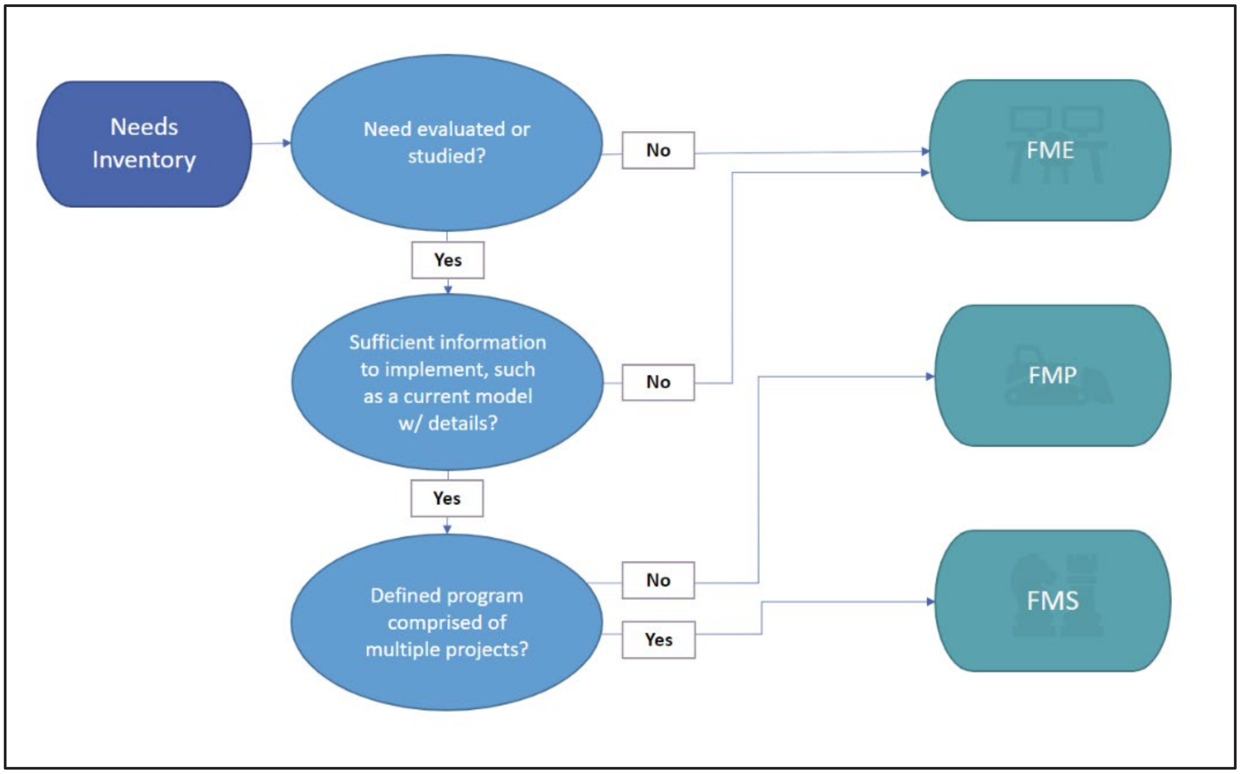
Entity Name	Year of HMP
Hood County	2021
Houston County	2020
Hunt County	2014
Jack County	2020
Johnson County	2019
Kaufman County	2015
Leon County	2019
Liberty County	2018
Limestone County	2019
Madison County	2013
Montague County	2020
Navarro County	2015
Parker County	2021
Polk County	2019
Rockwall County	2017
San Jacinto County	2018
Tarrant County	2020
Trinity County	2019
Van Zandt County	2020
Walker County	2017
Wise County	2014
Young County	2020

Note: Data as of March 2022

Table 4.11: General Flood Risk Reduction Action Types

Flood Risk Reduction Action Category	Action Types
FME	a. Watershed Planning i. H&H Modeling ii. Flood Mapping Updates iii. Regional Watershed Studies b. Engineering Project Planning i. Feasibility Assessments c. Preliminary Engineering (alternative analysis and up to 30% design) d. Studies on Flood Preparedness
FMP	**Structural** a. LWCs or Bridge Improvements b. Infrastructure (channels, ditches, ponds, stormwater pipes, etc.) c. Regional Detention d. Regional Channel Improvements e. Storm Drain Improvements f. Reservoirs g. Dam Improvements, Maintenance, and Repair h. Flood Walls/Levees i. Coastal Protections j. Nature Based Projects – living levees, increasing storage, increasing channel roughness, increasing losses, de-synchronizing peak flows, dune management, river restoration, riparian restoration, run-off pathway management, wetland restoration, low impact development, green infrastructure k. Comprehensive Regional Project
	Non-Structural a. Property or Easement Acquisition b. Elevation of Individual Structures c. Flood Readiness and Resilience d. Flood Early Warning Systems, including stream gauges and monitoring stations e. Floodproofing f. Regulatory Requirements for Reduction of Flood Risk
FMS	None specified; RFPGs were instructed to include at a minimum any proposed action that the group wanted to consider for inclusion in the plan that did not qualify as either an FME or FMP.

Figure 4.5: Potential Flood Risk Reduction Action Screening Process



FMSs were also identified for other strategies the RFPG wished to pursue. One example of a potential FMS was identifying repetitive loss properties and establishing a community-wide program of voluntary acquisitions to be implemented over several years. Another example included a program to enhance public education and awareness about flooding throughout the region, which does not require a construction cost.

Evaluation of Potential Flood Management Evaluations

Several actions were identified as potential FMEs to address gaps in available flood risk data associated with the first planning cycle. The following data sources were used to identify FMEs across the basin:

- Previous flood studies
- Capital Improvement Plans (CIPs)
- Drainage master plans
- FEMA Flood Insurance Studies (FISs)
- Hazard Mitigation Plans (HMPs)
- Flood Infrastructure Fund (FIF) applications
- Direct input from the Trinity RFPG
- Requests submitted by potential sponsors

The evaluation of FMEs relied on the compilation of planning level data to gauge alignment with regional strategies, flood planning guidance, the potential flood risk in the area, and the funding need and availability. This data included:

- Type of study and location
- Availability of existing modeling and mapping data
- Regional flood mitigation and floodplain management goals addressed by the FME, and whether the FME meets an emergency need
- Flood risk information, including flood risk type, number and location of structures, population, roadways, and agricultural areas at risk
- Sponsor entity and other entities with oversight
- Cost information, including study cost and potential funding sources

Flood Mitigation Evaluation Types

The definition of an FME allows for a variety of study types to help assess flood risk and potentially define future FMPs and FMSs. A general list of study types is summarized in ***Table 4.12***. The following section describes these project types in more detail and provides a summary of the different potential FMEs identified in the Trinity Region.

Watershed Planning

FMEs classified as watershed planning typically involved efforts associated with H&H modeling to help define flood risk or identify flood prone areas at a regional scale. The goal of watershed planning was to distribute resources equitably throughout a watershed to implement plans, programs, and projects that maintain watershed function and prevent adverse flood effects. A wide variety of project types fit under the umbrella of watershed planning, and the subcategories defined in the Trinity Region include:

- **Flood Mapping Updates:** Flood mapping data helps communities quantify and manage their flood risk. It also provides communities a pathway to access flood insurance administered through the NFIP. Flood mapping FMEs were identified for all counties within the Trinity Region except for Tarrant and Dallas counties. The FMEs included both the development of regulatory maps where none exist and updating existing maps to account for revised rainfall data, recent development conditions, and advances in floodplain modeling and mapping methodologies. Existing Base Level Engineering (BLE) studies will be leveraged, and the H&H analysis will be expanded as necessary to achieve a higher level of detail that will allow communities to adopt the mapping products as Zone AE. Areas currently classified as FEMA Zone AE based on recent H&H studies (less than 10 years) are considered adequate and will not be updated as part of the recommended flood mapping FMEs.

Table 4.12: Flood Mitigation Evaluation Types and General Description

FME Type	FME Sub-Types	General Description	Number of FMEs Identified
Watershed Planning	Watershed Planning – Drainage Master Plans	Supports the development and analysis of H&H models to evaluate flood risk within a given jurisdiction, evaluate potential alternatives to mitigate flood risk, and develop capital improvement plans.	53
	Watershed Planning – H&H Modeling, Regional Watershed Studies	Supports the development and analysis of H&H models to define flood risk or identify flood prone areas OR large-scale studies that are likely to benefit multiple jurisdictions.	21
	Watershed Planning – Flood Mapping Updates	Promotes the development and/or refinement of detailed flood risk maps to address data gaps and inadequate mapping. Creates FEMA mapping in previously unmapped areas and updates existing FEMA maps as needed.	75
	Watershed Planning – Flood Mapping for Dam and Levee Failure	Conducts studies to develop dam and levee failure inundation maps and models. Hydrologic studies to determine threat, risk, and potential impacts of flooding from dam and levee failure.	11
Project Planning	Engineering Project Planning	Evaluation of a proposed project to determine whether implementation would be feasible OR initial engineering assessment that includes conceptual design, alternative analysis, and up to 30 percent engineering design.	334
Preparedness	Studies on Flood Preparedness	Encourages preemptive evaluations and strategies to better prepare an area in the event of flood.	5
Other	Other – Dam Studies	Other projects not classified above.	22

- **Drainage Master Plans:** Drainage master plans support the development and analysis of H&H models to evaluate flood risk within a given jurisdiction, evaluate potential alternatives to mitigate flood risk, and develop capital improvement plans.
- **H&H Modeling:** The objective of H&H modeling FMEs is to evaluate and define flood risk, identify flood prone areas, and evaluate alternatives for mitigating risk at a local level.
- **Regional Watershed Studies:** Regional watershed studies are large-scale H&H studies that will likely benefit multiple jurisdictions.
- **Flood Mapping for Dam Failure**: Studies are conducted to develop dam failure inundation maps and models. Per the Texas Commission on Environmental Quality (TCEQ) regulations, dams are required to be evaluated for hydrologic capacity for minimum design flood based on the Probable Maximum Flood (PMF) event. In addition to evaluating the design flood capacity, the hydrologic models are used to establish peak water surface elevations (WSEs) and reservoir inflow hydrographs, which are in turn utilized for performing the breach analysis and generating breach inundation mapping.
- **Flood Mapping for Levee Failure:** Studies are conducted to develop levee failure inundation maps and models. These hydrologic studies help to determine threat, risk, and potential impacts of flooding from levee failure.

Engineering Project Planning

FMEs classified as engineering project planning included studies to evaluate potential construction projects. These evaluations included feasibility assessments, preliminary alternatives analysis, and preliminary engineering design. The scope of the flood planning process defined a 30 percent design level as the cut-off between the study phase associated with an FME and the design and implementation phase associated with an FMP. The following engineering project planning subcategories were identified in the Trinity Region:

- Channelization
- Culvert improvements
- Erosion control
- LWC improvements
- Road/bridge improvements
- Storm drain improvements
- Stream stabilization
- Property Acquisition
- Ditch/Gully Improvements
- Other

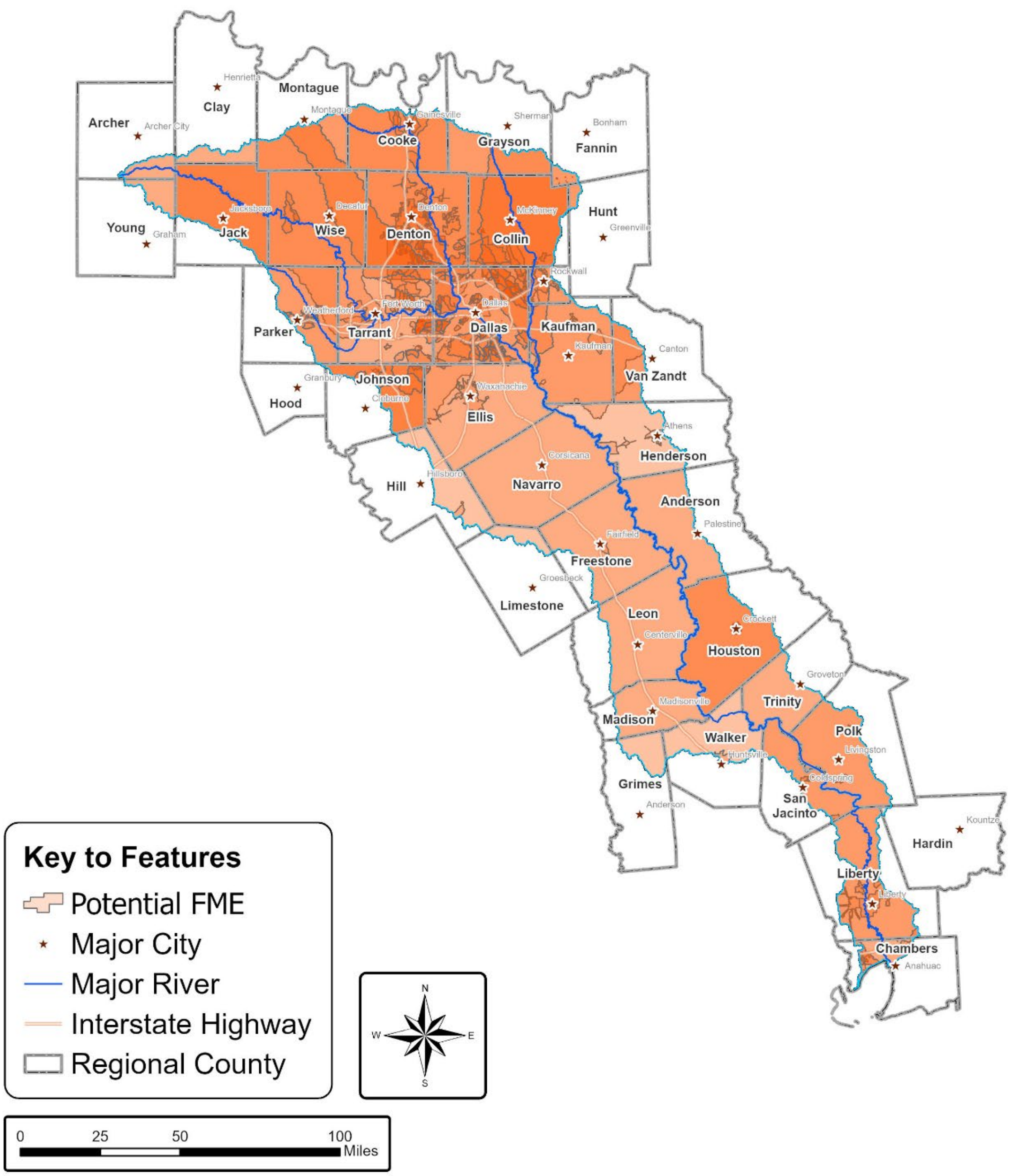
Flood Preparedness Studies

FMEs classified as studies on flood preparedness included proactive evaluations of a community's readiness to respond to a flood event. These types of evaluations considered factors such as early warning systems, public awareness programs about flooding, capabilities of emergency operations personnel, and the development of emergency operations and evacuation plans.

Flood Mitigation Evaluation Classification Summary

An overall summary of the identified FMEs was provided in ***Table 4.12*.** All potential FMEs that were identified are listed with their supporting technical information in ***TWDB-Required Table 12*** (***Appendix A***). In total, 521 potential FMEs were identified and evaluated. The geographical distribution of the identified FMEs is shown in ***Figure 4.6***. Color gradations in ***Figure 4.6*** reflect the number of FMEs that overlap for the same area, the darker the color, the greater the number of FMEs.

Figure 4.6: Geographical Distribution of Potential Flood Mitigation Evaluations



Planning Level Cost Estimates

A planning level cost estimate was developed for each FME in accordance with the *Technical Guidelines*. The process to produce these cost estimates for each FME project type is outlined in the following sections. Cost estimates presented in this section are for planning purposes only and are not supported by detailed scopes of work or workhour estimates. The Trinity RFPG expects that the local sponsor will develop detailed scopes of work and associated cost estimates prior to submitting any future funding application through TWDB or other sources.

Watershed Planning – Flood Mapping Updates

A spreadsheet was generated to produce planning level cost estimates for Flood Insurance Studies (FIS) utilizing relevant line items from the FEMA guidance document, *Estimating the Value of Partner Contributions to Flood Mapping Projects* (FEMA Cooperating Technical Partners, 2017). Costs pertaining to management; discovery, alluvial, hydrologic, hydraulic, coastal, and floodplain mapping data capture; and final deliverables were included as part of the overall cost. The number of FIRM panels contained within each project boundary was also accounted for in the cost estimates.

The FME study area was defined as the portion of the county boundary that is within the Trinity Region. A range of unit costs was developed to generate estimates based on the square mileage of the study areas and the total length of stream miles for which hydraulic modeling would be performed. The Trinity RFPG estimated that the stream miles to be included would be 25 percent of the total stream miles classified as FEMA Zone A, Zone X, or unmapped within a given study area. This estimate was based on the adopted short-term goal of reducing gaps in flood mapping by 25 percent (see ***Chapter 3***).

Experience with previous mapping projects was used to estimate the level of detail associated with the H&H analyses that are required for these studies. The level of detail needed to perform a regulatory study reflects differences in the physical characteristics of the basins and their levels of urban development. In terms of hydrologic analysis, it was estimated that 80 percent of the total project area could be analyzed using low-detail methods, while 20 percent would require more in-depth rainfall-runoff analyses. For the hydraulic analysis, it was estimated that 70 percent of the included streams could be properly modeled with a low-detail hydraulic model, 20 percent with a medium-detail model, and only 10 percent would require highly detailed models. Unit costs were applied to reflect these different levels of detail.

Each cost estimate also included standard budget items based on the total project cost. These included a markup of two percent to account for quality assurance and quality control; 15 percent for project management, survey data capture, and technical reporting; and finally, a 30 percent contingency to account for uncertainties associated with planning level estimates.

Watershed Planning – Drainage Master Plans

Separate planning level cost estimates were developed for drainage master plans depending on whether the sponsor was a county or city. Initially, the cost of each countywide drainage master plan was generated using a cost per square mile methodology, based on the cost of previous countywide drainage master plan studies. This quantity included basic services such as project management, coordination and collaboration work sessions, data collection, screening assessment, targeted H&H modeling and alternatives analysis, a technical report, and public outreach. A 30 percent contingency was applied to account for uncertainties associated with planning level estimates. After a comparative analysis of results, it was noted that a uniform cost estimate of $500,000 would be appropriate to complete each countywide plan. It is anticipated that this placeholder budget will provide sufficient funds for each county to broadly evaluate their jurisdiction and develop potential FMEs and FMPs that could be included in future regional flood plans.

The same scope and basic services were applied for citywide drainage master plans. However, the cost varied based on each city or town's population size, which was taken from 2020 United States Census data (United States Census Bureau, 2020). Three categories were identified for the population sizes and a corresponding cost estimate was assigned based on professional engineering experience (***Table 4.13***).

Table 4.13: Citywide Drainage Master Plan Cost Estimate Ranges

Relative City Size	Population (2020 Census)	Cost Estimate
Small	< 25,000	$250,000
Medium	25,000 - 100,000	$500,000
Large	> 100,000	$1,000,000

Watershed Planning – Hydrologic and Hydraulic Modeling and Regional Watershed Studies

Planning level cost estimates were developed for FMEs assuming a typical scope of work that included project management, data collection, topographic survey, hydrologic analysis, hydraulic analysis, alternatives evaluation, and final deliverables. A range of unit costs was developed to generate estimates based on the square mileage of the study areas and the total length of stream miles for which hydraulic modeling would be performed. Experience from previous studies was used to scale the study effort and estimate the level of detail associated with the H&H analyses that are required for these studies. It was estimated that 20 percent of the total project area could be analyzed with low level of detail, 70 percent with medium level of detail, and 10 percent would require highly detailed H&H models. Unit costs were applied to reflect these different levels of detail, while also considering the differences in the physical characteristics of the basins and their levels of urban development.

Each cost estimate also included standard budget items based on the total project cost. These included a markup of 2 percent to account for quality assurance and quality control; 15 percent for project management, survey data capture, and technical reporting; and finally, a 30 percent contingency was applied for uncertainties associated with planning level estimates.

Watershed Planning – Flood Mapping for Dam and Levee Failure

Cost estimates for FMEs under this category reflect the following basic services: project management, discovery data capture, screening assessment, and detailed dam breach analysis. Each cost estimate also included standard budget items based on the total project cost and a 30 percent contingency to account for uncertainties associated with planning level estimates.

The discovery data capture effort involved dam data collection and a built-in cost to account for quality assurance and quality control. The screening assessment identified all public and private dams in each county by researching and gathering any historical information about the dams. The detailed dam breach analysis was the bulk of this overall evaluation cost since it required a complex H&H analysis. It was assumed that a maximum of 10 dams would be analyzed at this level for cost estimating purposes. In instances where there were less than 10 dams in a county, the value decreased, and the cost estimate was adjusted accordingly.

Engineering Project Planning

Engineering project planning considers two important components: (1) the evaluation of a proposed project to determine whether implementation would be feasible, and (2) an initial engineering assessment including conceptual design, alternative analysis, and up to 30 percent engineering design. Each evaluation area was project-specific and varied greatly due to the wide range of improvements in channels, culvert improvements, LWCs, roads and bridges, storm drain systems, and stream stabilization.

Costs for each evaluation were taken from Capital Improvement Projects (CIP) when available. It was assumed that the total cost represented in the report was the overall construction cost and that the evaluation effort would equate to five percent of the total construction cost or a minimum of $250,000. This methodology was applicable to the City of Grand Prairie and the City of Hurst – both of which, together, comprised 81 out of the 332-engineering project planning FMEs.

The City of Garland had 32 FMEs that fell under this category, 22 of which were updates to previous drainage studies. The year(s) these studies were initially performed range from April 2003 to September 2010. Thus, the project cost was taken for each of these, when available, and scaled accordingly to September 2020 United States dollars.

The HMPs were used, when available, for determining planning level cost estimates. It was assumed that the costs provided for the HMPs were in 2020 United States dollars. In instances where neither HMPs nor CIPs were available, additional research and outreach were conducted to gather supplemental information from potential FME sponsors and previously conducted studies to develop a general scope of work and associated cost estimate.

Studies on Flood Preparedness

Studies on flood preparedness encourage preemptive evaluations and strategies to better prepare an area in the event of a flood. The identified FMEs in this category included studies to perform vulnerability assessments, develop emergency action plans, and perform dam compliance assessments. Placeholder costs were assigned to these FMEs based on professional engineering experience with similar projects.

Other

The 22 FMEs classified as “Other” were dam studies and evaluations for Denton County, City of Dallas, and several Soil and Water Conservation Districts (SWCDs). The scope and scale of these dam studies could vary widely, and there is uncertainty in terms of the number of dams that could potentially be rehabilitated and further studied. Using a dam failure analysis as a basis of comparison, it is likely that this effort would cost $9.26 million.

Process to Determine Flood Risk Indicators

Flood risk indicators were quantified to define the existing flood hazard, flood risk, and flood vulnerability within each FME project area. GIS operations were performed to combine and summarize this information by clipping the flood risk information generated for the basin as part of ***Task 2A*** to the individual project boundaries associated with each FME. The resulting flood risk indicator information was used to populate the associated fields in the FME feature class. These values are summarized in ***TWDB-Required Table 12***.

Comparison and Assessment of Flood Mitigation Evaluations

As previously stated, most of the counties within the Trinity Region have been submitted as a flood mapping update FME due to a lack of current, fully detailed, model-backed H&H floodplain analyses. Clay County contains no regulatory floodplain information. Apart from Dallas and Tarrant counties, the exposure analysis resulted in the highest exposed structure counts within Denton and Liberty counties, demonstrating the need for accurate floodplain information for future mitigation and resiliency planning. Navarro and Hill counties have the Trinity Region’s highest flood exposure SVI, equating to a possible disproportionate amount of potential loss due to inaccurate floodplain information. Current mapping within the lower portion of the Trinity Region did not reflect the increase in rainfall resulting from the NOAA

Atlas 14 release, prompting a significant need for FME flood mapping updates in counties south of Leon County.

Over 50 drainage master plan FME projects were collected for inclusion in ***TWDB-Required Table 12***. Drainage master plan areas were based on either city or county boundaries. Of the counties listed, the Dallas County drainage master plan and vulnerability assessment project area had the highest floodplain exposure and most population at risk. The City of Denton and Haltom City had the highest floodplain exposure out of the cities listed.

A majority of the FMEs collected were categorized as engineering project planning. These were either riverine or urban flood prone specific areas that were identified and collected by a community. These FMEs were identified either by observation and eyewitness flood reports or through a detailed study with conceptual improvement alternatives. The analysis obtained from these proposed projects did not meet the full requirements to be included as an FMP and were relegated to an FME for further refinement. Three FMEs listed are contained within Hill County, which has the second highest flood exposure SVI within the Trinity Region. The total engineering project planning areas contained over 3 million structures at risk, with over 85 percent of the structures being classified as residential.

Every recommended FME would leverage existing studies and H&H models. The FMEs would expand the existing analysis as necessary and perform an accurate No Negative Impact Analysis in support of potential FMP candidates for future state flood plans.

Determination of Emergency Need

The term “emergency need” can be interpreted in multiple ways, and each region was tasked with defining the term for each individual flood planning region. The Trinity RFPG used several criteria to determine areas of emergency need.

Removing SRL properties through FMSs were deemed emergency needs. SRL properties are those that flood repeatedly, causing significant difficulties for property owners. The National Flood Insurance Reform Act of 2004 defined a SRL as “a single family property (consisting of one to four residences) that is covered under flood insurance by the NFIP and has incurred flood-related damage for which four or more separate claims payments have been paid under flood insurance coverage, with the amount of each claim payment exceeding $5,000 and with cumulative amount of such claims payments exceeding $20,000; or for which at least two separate claims payments have been made with the cumulative amount of such claims exceeding the reported value of the property”. (FEMA, 2005) Property acquisition, demolition, or elevation can remove SRL structures from the floodplain through coordinating FMSs.

Other emergency needs that would remove critical facilities from the 1% annual chance storm event risk area through various types of FMEs, FMPS, and FMSs included acquisition, demolition, or elevation; floodproofing or retrofitting; and infrastructure projects. Designating these critical facility structures as emergency need enabled mitigation measures in the form of FMEs, FMPs and FMSs to be enacted to reduce future risk.

Loss of life due to a flood event is used to determine emergency need when corresponding data was available in determining the location of the fatality. Ultimately, emergency needs were designated as areas that would sustain negative impacts within the foreseeable future if no measures were taken.

Evaluation of Potentially Feasible Flood Mitigation Projects and Flood Management Strategies

Potentially feasible FMPs were identified based on responses to the survey, reviews of previous studies, FIF applications within the region, and direct coordination with communities. FMSs and FMPs are required to be developed with a sufficient level of detail to be included in the regional flood plan and recommended for state funding. In most cases, this included having recent H&H modeling data to assess the impacts of the project and an associated project cost to develop the project’s benefit-cost ratio (BCR). The development and use of the technical information to evaluate potentially feasible actions are described in the subsections that follow.

Potentially Feasible Flood Mitigation Projects

The Trinity RFPG identified 73 potentially feasible FMPs for the Trinity Region. The geographical distribution of each identified FMP is shown in ***Figure 4.7*,** with technical information for each FMP summarized in ***TWDB-Required Table 13*** (***Appendix A***). Each project is unique, and the specific FMPs recommended by the Trinity RFPG will be described in detail in ***Chapter 5***. A general description of the potentially feasible FMPs is presented in ***Table 4.14***.

Figure 4.7: Geographical Distribution of Potential Flood Mitigation Projects

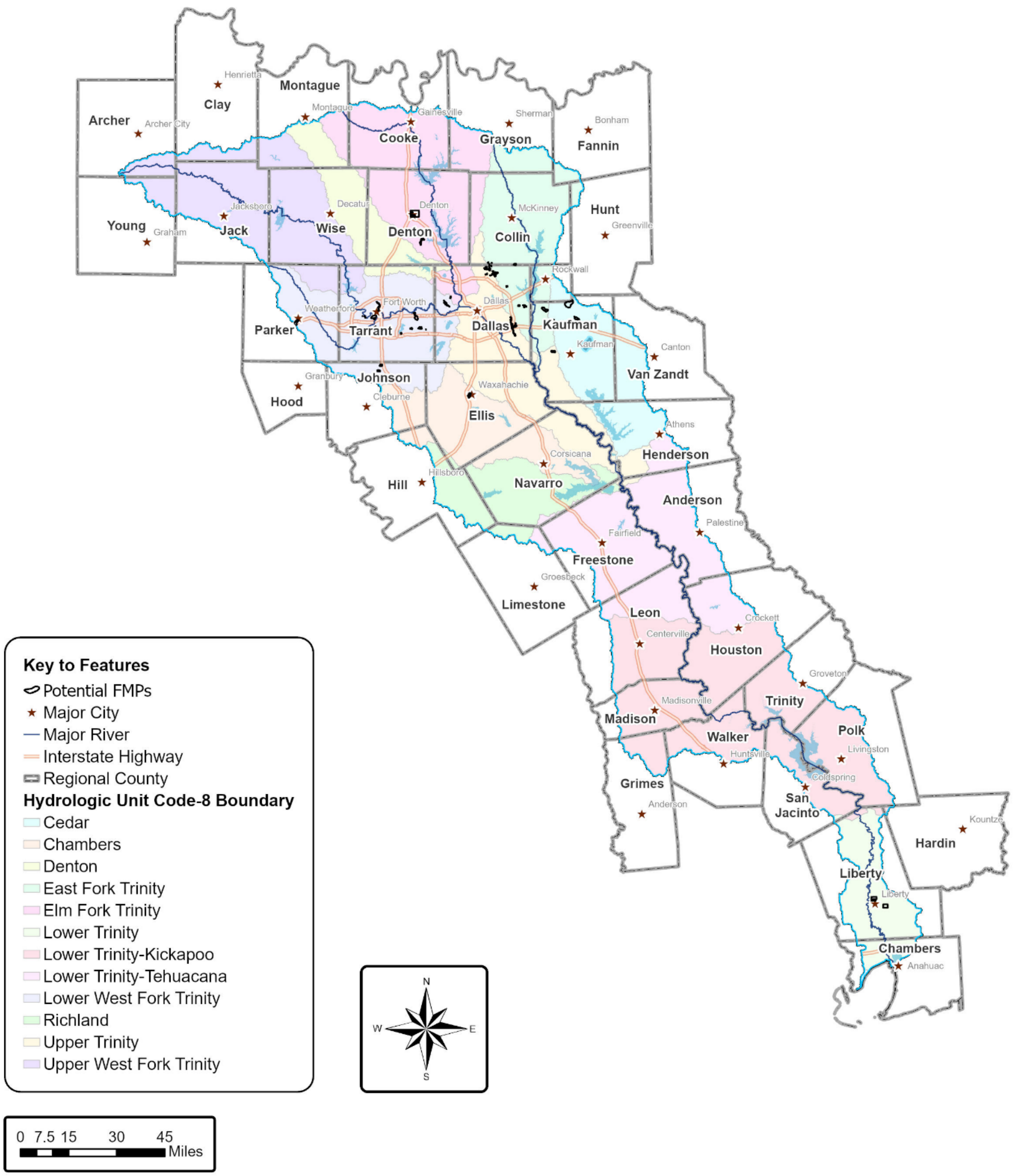


Table 4.14: Summary of Flood Mitigation Project Types

FMP Type	General Description	Number of FMPs Identified
Infrastructure	Improvements to stormwater infrastructure including channels, ditches, ponds, stormwater pipes, etc.	46
Storm Drain Improvements	Improvements exclusively to underground urban stormwater infrastructure.	14
Regional Detention Facilities	Runoff control and management via detention facilities.	5
Property or Easement Acquisition	Acquisition of properties located in the floodplain	3
Dam Improvements, Maintenance and Repair	Dam upgrades to meet TCEQ dam safety requirements	2
Flood Early Warning Systems	Installation of safety improvements at hazardous stream crossings	2
Low Water Crossing or Bridge Improvement	Low water crossing replaced by a bridge crossing	1

The identified potentially feasible FMPs were primarily located within the Upper Basin area. These were the only actions for which a sponsor provided sufficient information to be considered as a potentially feasible FMP, or that an existing FIF application was potentially available. The potential sponsors and their associated number of FMPs are listed below:

- City of Arlington (6)
- City of Fort Worth (4)
- City of Irving (2)
- City of Richardson (29)
- City of Sachse (1)
- Town of Sunnyvale (2)
- City of Burleson (4)
- Liberty County Water Control Improvement District #5 (3)
- City of Waxahachie (2)
- City of Weatherford (2)
- City of Dalworthington Gardens (1)
- City of Terrell (1)
- City of Denton (3)
- Kaufman County (5)
- City of Balch Springs (3)
- City of Westworth Village (3)
- City of Garland (1)
- Town of Copper Canyon (1)

Additional potentially feasible FMPs were identified through continued outreach with regional entities under ***Task 11*** and were approved by the Trinity RFPG to be performed and included under ***Task 12*** of the Amended Flood Plan***.***

Potentially Feasible Flood Management Strategies

The Trinity RFPG identified 145 potentially feasible FMSs for the Trinity Region. The geographical distribution of each identified FMS is shown in ***Figure 4.8*,** with technical information for each FMS summarized in ***TWDB-Required Table 14*** (***Appendix A***). Color gradations in ***Figure 4.8*** reflect the number of FMSs that overlap for the same area, and the darker the color is, the greater the number of FMSs.

A variety of FMS types were identified. Some FMSs proposed to establish and implement public awareness and educational programs to better inform communities of the risks associated with flood waters. Other FMSs proposed to improve preventative maintenance programs to maximize operational efficiency of existing stormwater management infrastructure, develop stormwater management manuals to encourage best management practices, or establish community-wide flood warning systems. A significant number of property acquisition programs were also identified. These programs included a variety of purposes such as acquiring floodplain and environmentally sensitive areas to convert them into open space land and acquisition of repetitive loss structures. A summary listing of FMS types is provided in ***Table 4.15***.

Comparison and Assessment of Flood Management Strategies and Flood Mitigation Projects

Potentially Feasible Flood Mitigation Project Comparison and Assessment

Over 70 FMPs were collected and met the recommendation requirements to be considered for inclusion. Approximately 80 percent of the FMPs recorded are categorized as infrastructure or storm drain improvements. These FMPs represented proposed design and construction projects that would improve a sponsor's storm drainage and channel infrastructure to reduce flooding in high flood risk areas. The City of Fort Worth's Linwood-University Drive project had the potential to protect the highest population count from flooding compared to the other FMPs listed. Drainage improvement projects located in Fort Worth and Irving were proposed to mitigate flood threat to the highest number of residential properties. FMPs located in Arlington, Balch Springs, Fort Worth, Irving, Richardson, and Terrell had the highest SVI, ranging from 0.7 to 0.9.

Figure 4.8: Geographical Distribution of Potential Flood Management Strategies

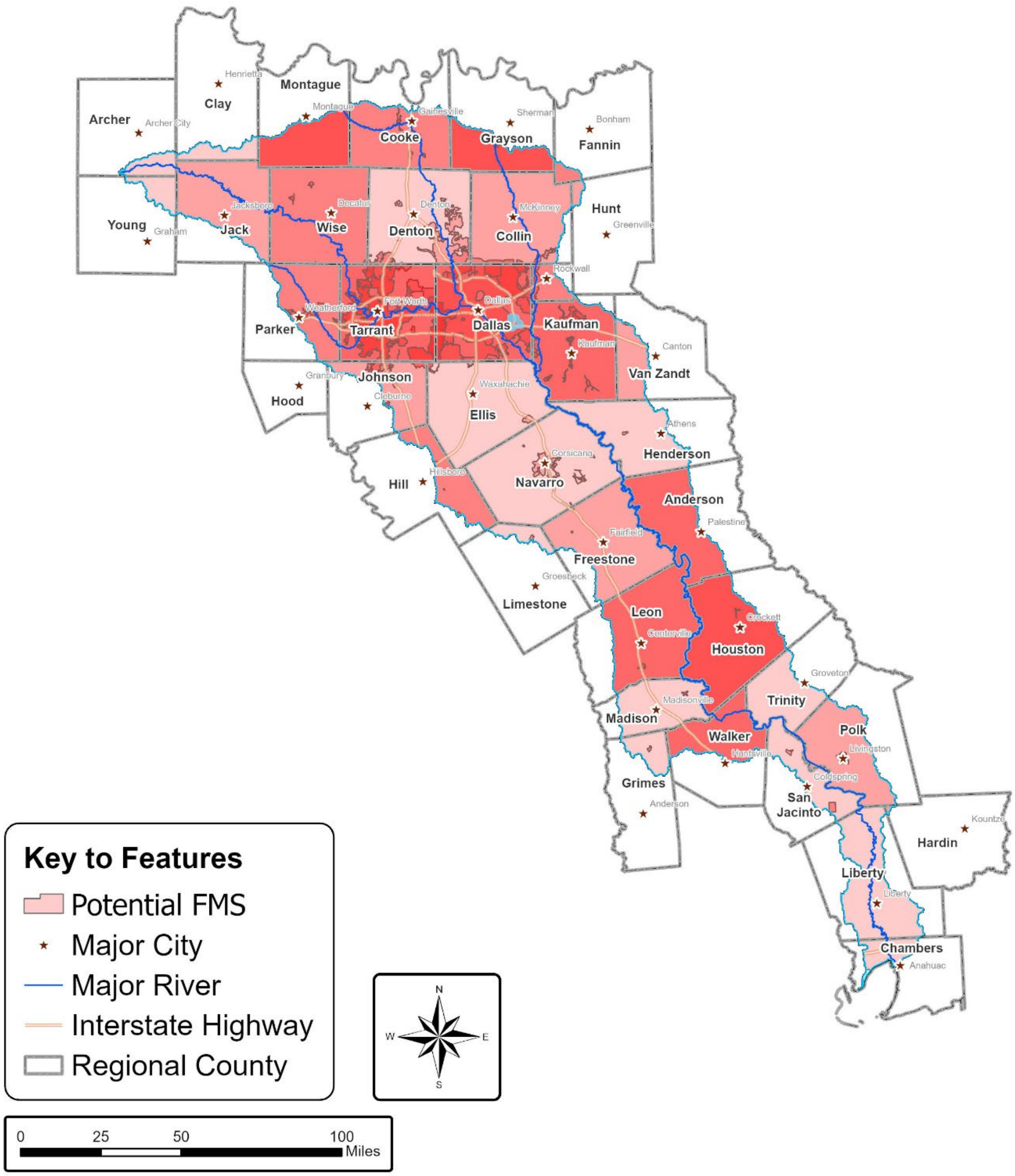


Table 4.15: Summary of Flood Management Strategy Types

FMS Type	General Description	Number of FMSs Identified
Education and Outreach	Develop a coordinated education, outreach, and training program to inform and educate the public about the dangers of flooding and how to prevent flood damages to property.	22
Flood Measurement and Warning	Install gauges, sensors, and precipitation measuring sites to monitor streams and waterways for potential flooding.	20
Infrastructure Projects	City-wide improvement projects.	5
Property Acquisition and Structural Elevation	Acquire, relocate, and/or elevate flood-prone structures.	20
	Acquire floodplain and protect environmentally sensitive areas by converting floodplain encroachments into open space land.	
Regulatory and Guidance	Develop and implement flood damage prevention ordinances.	62
	Catalog, evaluate, and update floodplain regulations to comply with the latest FEMA minimum regulations or to adopt higher standards.	
	Incorporate regulatory standards to protect open space in flood prone areas.	
	Promote the inclusion of low impact development requirements in local and regional development ordinances.	
Floodproofing	Structural and nonstructural measures to reduce a structure's risk of flooding; weather hardening.	2
Other	Other items may include preventive maintenance programs, erosion control programs, funding mechanisms, nature-based solutions - implement the use of green infrastructure.	14

Potentially Feasible Flood Management Strategy Comparison and Assessment

Approximately 25 percent of the FMSs listed are categorized as floodplain management policy/regulatory guidance. Developing minimum NFIP or higher floodplain regulatory standards for new development near a regulatory or community effective floodplain preserves the natural capacity of the flooding source and limits upstream and downstream negative impacts. Minimum FEMA NFIP floodplain regulations can be found in Chapter 44 of the *Code of Federal Regulations* (FEMA, 2022). The Texas Floodplain Management Association (TFMA) has developed a *Guide for Higher Standards for Floodplain Management (2018)* (TFMA Higher Standards Committee, 2018), which can serve as an example for higher floodplain development standards for the referenced FMSs.

Twenty-two sponsors requested flood awareness and safety education support. These FMSs ranged from implementing the NWS's "Turn Around, Don't Drown" campaign to general education regarding the NFIP. Of the sponsors requesting education and outreach support, Houston County demonstrated the highest flood risk to habitable structures, road crossings, and agricultural land.

Nearly 20 sponsors expressed interest in flood measuring, monitoring, and warning systems. These systems may include local warning notifications, monitoring/measuring gages, highwater detection systems, sirens, warning lights, signage, and automated gates. Seven of these types of FMSs were requested in Dallas and Tarrant counties, which had the highest flood exposure in the Trinity Region. The proposed flood warning system in Leon County would service the most socially vulnerable among the list of flood warning FMSs.

Another FMS that sponsors requested related to property and land acquisition programs. These "buyout" program FMSs were provided on either a county or city-wide basis. Four of these programs, which span multiple jurisdictions, were planned to have multiple sponsorship. Of the county-wide buyout FMSs, the Leon County repetitive loss property acquisition had the highest SVI. Of the city-wide buyout FMSs, Chico and Terrell ranked as having the highest SVI, with values ranging from 0.75-0.95.

Effects on Neighboring Areas of Flood Management Strategies or Flood Mitigation Projects

Each potentially feasible FMP and FMS must demonstrate that there would be no negative flood impacts on a neighboring area due to its implementation. No negative impact means that a project will not increase flood risk to surrounding properties. The analysis must be based on best available data and be sufficiently robust to demonstrate that the post-project flood hazard is no greater than the existing flood hazard.

Several communities in the Trinity Region have established no negative flood impact policies for proposed development. However, communities have different thresholds for defining what level of impact is considered adverse and require the analysis to be performed for different flood event scenarios. The *Technical Guidelines and Rules* governing state flood planning require the impacts analysis to be performed for the 1% annual chance storm event. Additionally, the *Technical Guidelines* require the following criteria to be met, as applicable, to establish no negative flood impact:

- Stormwater does not increase inundation in areas beyond the public right of way, project property, or easement.
- Stormwater does not increase inundation of storm drainage networks, channels, and roadways beyond design capacity.
- Maximum increase of one-dimensional (1D) WSE must round to 0.0 feet (< 0.05 foot), measured along the hydraulic cross-section.
- Maximum increase of two-dimensional (2D) WSE must round to 0.3 feet (< 0.35 foot), measured at each computational cell.
- Maximum increase in hydrologic peak discharge must be less than 0.5 percent, measured at computational nodes (sub-basins, junctions, reaches, reservoirs, etc.). This discharge restriction does not apply to a 2D overland analysis.

If negative impacts are identified, mitigation measures may be utilized to alleviate such impacts. Projects with design level mitigation measures already identified may be included in the regional flood plan and could be finalized at a later stage to conform to the "No Negative Impact" requirements prior to funding or execution of a project.

Furthermore, the Trinity RFPG has flexibility to consider and accept additional "negative impact" for the requirements listed based on professional engineering judgment and analysis, given any affected communities are informed and accept the impacts. This should be well-documented and consistent across the entire region. However, flexibility regarding negative impact remains subject to TWDB review.

A comparative assessment of pre-project and post-project conditions for the 1% annual chance storm event (100-year flood) was performed for each potentially feasible FMP based on associated H&H models. The floodplain boundary extents, resulting WSEs, and peak discharge values were compared at pertinent locations to determine if the FMP conformed to the no negative impacts requirements. This comparative assessment was performed for the entire zone of influence of the FMP.

The comparative assessment to determine "no negative flood impact" on upstream or downstream areas or neighboring regions was performed based on currently available regional planning level data. The local sponsor will be ultimately responsible for proving the final project design has no negative flood impact prior to initiating construction.

Estimated Benefits of Flood Mitigation Projects or Flood Management Strategies

To be recommended, each FMP or FMS must align with a regional floodplain management goal established under ***Task 3*** and demonstrate a flood risk reduction benefit. To quantify the flood risk reduction benefit of each FMP or FMS, the anticipated impact after project implementation was evaluated as providing:

- Reduction in habitable, equivalent living units flood risk
- Reduction in residential population flood risk
- Reduction in critical facilities flood risk
- Reduction in road closure occurrences
- Reduction in acres of active farmland and ranchland flood risk
- Estimated reduction in fatalities, when available
- Estimated reduction in injuries, when available
- Reduction in expected annual damages from residential, commercial, and public property
- Other benefits as deemed relevant by the RFPG including environmental benefits and other public benefits

These estimated benefits were produced from geospatial data by analyzing the existing 1% and 0.2% annual chance storm event floodplain boundaries with the proposed post-project floodplain boundaries. The proposed flood risk conditions were compared to the existing conditions flood risk indicators for a given area to quantify the reduction of flood risk achieved by implementation of an FMP or FMS. The results of the analysis are shown for each FMP or FMS in ***TWDB-Required Table 13*** and ***Table 14***, respectively.

Potential Impacts and Benefits from the Flood Management Strategies or Flood Mitigation Projects to Other Resources

Potential impacts and benefits from FMS or FMP were explored for the Trinity Region from the standpoint of environment, agriculture, recreation, navigation, water quality, erosion, and sedimentation. Factors unique to the Trinity Region were reviewed and an assessment of how these factors might interact with a potential FMS or FMP are discussed below.

Environmental

Senate Bill 3 (SB3) was designed to establish environmental flow standards for all major river basins and bay systems in Texas through a scientific, community-driven, and consensus-based process. The key questions addressed by the SB3 process as defined by TWDB include:

1. What is the quantity of water required by the state's rivers/estuaries to sustain a sound ecological environment?
2. How can this water be protected?
3. What is the appropriate balance between water needed to sustain a sound ecological environment and water needed for human or other uses?

FMSs or FMPs in the Trinity Region should consider potential impacts as they relate to the ecological flows established under the directive of SB3. Several studies have been completed for the Trinity Region with the purpose of studying environmental flow needs as part of the objectives of SB3 (Quigg & Steichen, 2015); (Mangham, Osting, & Flores, 2015); (Quigg & Steichen, Defining Bioindicators for Freshwater Inflow Needs Studies Phase 2: Defining a Sound Ecological Environment for Galveston Bay, 2018).

FMSs or FMPs should be able to maintain the established SB3 environmental flows in the Trinity River at the Grand Prairie, Dallas, Oakwood, and Romayor gauge locations. (Li, Passalacqua, & Hodges, 2018) identified anthropogenic factors affecting this study site and the stream segment. The study identified floodplain management as more impactful on riparian areas than high pulse flow management. The study also determined return flows at the base flow level as the main factor to satisfy subsistence and base flows. FMSs or FMPs at or upstream of these locations should focus on floodplain management and maintaining return flows. Similarly, at the Dallas location, FMSs or FMPs should be able to maintain return flows to satisfy SB3 subsistence and base flows. A study conducted under SB 2 by Texas Instream Flow Program (TIFP) suggests that base flows between 75 and 450 cubic feet per second at Oakwood could exhibit temperatures above the TIFP goals in select shallow areas. FMSs or FMPs that increase the base flows could ensure that the TIFP temperature goals are met at this location. Dissolved oxygen (DO) could also improve if FMSs or FMPs increase base flows. FMSs or FMPs should maintain return flows to satisfy SB3 subsistence and base flows. An FMS or FMP, in all likelihood, will increase base flows at Romayor above 575 cubic feet per second, which is required for continuous sand transport.

The high pulse flow SB3 values at the above locations primarily provide sediment, water table, and in-channel habitat functions. FMSs or FMPs are expected to reduce the extreme peak flows yet maintain the periodic high pulse flows required at these locations to sustain ecological and habitat functions.

Agricultural

According to the Texas A&M AgriLife Extension Service economists, Hurricane Harvey caused more than $200 million in crop and livestock losses in Texas. Flood waters have the potential to destroy standing crops, create water-logged conditions that delay planting or harvesting, wash away productive topsoil, and damage farm equipment and infrastructure. FMSs or FMPs potentially reduce extremely high flows in rivers and streams, thereby preventing flood waters from inundating areas outside of the floodway, including agricultural areas. Structural FMSs or FMPs, like small flood control ponds, also have the potential to assist in agricultural production by serving the dual purposes of flood mitigation and water supply. Non-structural FMSs or FMPs can have similar impacts on peak flow and flood reduction including agricultural conservation practices such as conservation tillage, residue management, cover crops, and furrow dikes. These practices not only reduce downstream flooding by reducing surface runoff and increasing infiltration on agricultural lands, but also decrease sediment and nutrient losses, thereby improving downstream water quality.

Recreational Resources

There are 34 major lakes and reservoirs in the Trinity Region. Recreational opportunities associated with these lakes and reservoirs have the potential to be impacted when the water bodies are being operated to mitigate flood risk. Flood control reservoirs hold water in their flood pools during peak runoff periods until the impounded water can be safely released downstream. During these periods, recreational use of adjacent parks and playgrounds may be vastly reduced. Flood risk management through FMSs or FMPs may consist of creating additional flood control reservoirs with the intent of impounding water to mitigate flood risk. The impoundment of water at flood pool elevations (which are considerably higher than the normal pool elevations) can potentially impact recreational functions of parks, campgrounds, boat ramps, etc.

Recreational use in flood control reservoirs may also be impacted by the water quality in the waterbodies. TCEQ assesses waterbodies in Texas every two years for five designated use categories including recreational use. The biennial recreational use assessment by TCEQ consists of evaluating waterbodies for E. coli (fresh water) or Enterococcus (tidal waters) from a standpoint of human health protection from recreational contact in the waterbodies. The 2020 Texas Integrated Report classifies a significant number of segments in the Trinity Region as “Non-Supporting” for recreational use (TCEQ, 2020). FMSs or FMPs that focus on reducing runoff and therefore reducing export of bacteria to waterbodies have the potential to improve the recreational use condition of segments currently assessed as “Non-Supporting”.

Navigation

The Trinity River is not used for commercial navigation. In 1963, the United States Army Corps of Engineers (USACE) approved making the Trinity River navigable by barges. In 1965, Congress and then-President Lyndon B. Johnson approved a package of flood control and navigation projects, including a barge canal connecting the DFW metroplex with the Gulf of Mexico. The barge canal was estimated to cost approximately $1 billion. In 1973, voters rejected to finance the barge canal and USACE subsequently abandoned the project. Navigation on the Trinity River is generally limited to recreational canoeing and kayaking in the rivers and creeks and boating in the lakes and reservoirs. These activities are impacted when flows in the Trinity River and water levels in the reservoirs are being actively managed for flood control. FMSs or FMPs are expected to have similar impacts on recreational navigation in the Trinity Region.

Water Quality

Many of the reservoirs in the Trinity Region are saturated with nutrients, and stormwater runoff is the primary source of nutrient loading. Despite the high levels of nutrients, reservoirs in the Trinity Region are classified as mesotrophic or eutrophic. The Trinity River Authority (TRA) hypothesizes that light penetration in the turbid waters rather than nutrient availability is the limiting factor for algal growth in these reservoirs (TRA, 2020). The TRA 2020 basin summary report explains that zebra mussels increase water clarity thereby allowing light penetration deeper in the water, resulting in increased nuisance plant growth. TRA therefore recommends proactive watershed protection programs and extensive use of best management practices to reduce nutrient loading and risk of harmful algal blooms. Structural FMSs or FMPs such as small flood control ponds are designed to capture stormwater runoff and pollutants thereby improving the water quality reaching the water supply reservoirs. However, the algal blooms might occur in these small reservoirs due to excessive availability of nutrients. Non-structural FMSs or FMPs that reduce stormwater runoff production have the potential to reduce nutrient loading to water supply reservoirs and other structural FMSs or FMPs.

Based on sampling for bacteria throughout the Trinity Region, TCEQ found that 69 of the 162 assessment units have concerns or do not support contact recreational use. Many of these findings are intermittent urban streams in the DFW metroplex. Intermittent streams can have high bacteria levels because they are not washed out frequently or assimilated. A total maximum daily loads (TMDLs) Implementation Plan, covering much of the metroplex, outlines activities to potentially reduce bacteria loading to these streams. Non-structural FMSs or FMPs that focus on runoff reduction from sources are expected to reduce bacteria loads. Depending on their location and operation, structural FMSs or FMPs, such as small flood control ponds, may maintain small levels of flows in downstream intermittent streams to flush out the streams and improve assimilation.

Erosion

The Trinity River Environmental Restoration Initiative 2010, funded by the TWDB, studied the rates and sources of sediment (and nutrient) loading to 12 major water supply reservoirs in 10 watersheds of the Upper Trinity Region (Wang, et al., 2010). The study reported a wide range of annual overland erosion rates, varying from 0.07 tons per acre per year in the Bridgeport Basin to 0.7 tons per acre per year in the Lewisville Basin. The study found that in most watersheds, the total sediment loading to the reservoirs was larger than the overland erosion amounts, suggesting bank and bed erosion as important sources.

The study also concluded that small flood control reservoirs (PL-556 structures) generally had a positive impact on reduction of total sediment load delivered to the flood control reservoirs. The efficiency of these small flood control structures in trapping sediment varied greatly from approximately four percent in the Ray Hubbard watershed to 48 percent in the Lewisville watershed. The effectiveness of these flood control structures in reducing delivery of sediment loads to water supply reservoirs are directly influenced by the percentage of watershed area draining to the ponds, their locations and the watershed's erosion characteristics. Structural FMSs or FMPs are expected to have similar impacts as the small flood control reservoirs identified in the TWDB study. Sediment attenuation will be largely influenced by the location and drainage area of the structural FMSs or FMPs, and watershed characteristics.

Non-structural FMSs or FMPs that limit sediment production and transport may be viable options for reducing erosion and transport of sediment in the Trinity Region. The TWDB study found that conservation practices, such as no rangeland grazing, resulted in reduced source sediment loads and delivered loads. Non-structural and structural FMSs or FMPs have the potential to reduce sediment production in the watersheds and delivery to the waterbodies in the Trinity Region.

Sedimentation

Sedimentation is a natural process by which runoff water, often rivers, transport small particles from upstream to downstream. As the water slows down, the particles settle to the bottom of the river or lake. A volumetric and sedimentation survey of Lake Livingston by the TWDB (Leber, et al., 2022) measured 129,149 acre-feet of sedimentation. The survey concluded that the lake had lost capacity at an average of 2,583 acre-feet per year due to sedimentation since impoundment in 1971. Sedimentation has been reported for most major reservoirs in the Trinity Region based on periodic volumetric and sedimentation surveys conducted by the TWDB.

Structural FMSs or FMPs, such as small flood control reservoirs, receive and impound water (and sediment) from the respective drainage areas. Long residence time in a flood control pond results in settling of large proportions of the incoming sediment. Periodic discharges from small flood control projects are generally expected to carry smaller sediment loads than the influent runoff. Therefore, structural FMSs or FMPs are expected to reduce sedimentation in downstream water supply reservoirs by trapping sediment in their pools. While sedimentation in the large downstream reservoirs potentially reduce, sedimentation is expected to occur in the individual flood control projects.

Non-structural FMSs or FMPs, such as conservation practices that potentially reduce sediment production at the source, are expected to reduce sedimentation in structural FMSs or FMPs, as well as large downstream reservoirs.

Estimated Capital Cost of Flood Mitigation Projects and Flood Management Strategies

Cost estimates for each FMP were acquired from the engineering report that was used to generate the FMP. Cost estimates were adjusted as needed to account for inflation and other changes in price of labor and commodities that had taken place since the publication date of the original reports. In addition, cost estimates were adjusted as needed to include any applicable non-recurring and recurring project costs as listed on ***Table 22*** of the *Technical Guidance*. The cost estimates listed in ***TWDB-Required Table 13*** and ***Table 14*** are expressed in September 2020 dollars (see ***Appendix A***).

Cost estimates for each FMS were acquired from the HMPs that were used to generate the FMS, if available. Cost assumptions from ***Table 4.16*** were used if the HMPs did not have associated costs or if the reported costs were lower than the cost assumptions. The cost assumptions are expressed in 2020 dollars and were developed based on engineering experience and other similar projects.

FMS cost estimates presented in this section are for planning purposes only and are not supported by detailed scopes of work or workhour estimates. The Trinity RFPG expects that the local sponsor will develop detailed scopes of work and associated cost estimates prior to submitting any future funding application through TWDB or other sources.

Table 4.16: Flood Mitigation Strategy Cost Estimates Assumptions

FMS Type	Cost Estimate Range	Scope and Assumptions
Education and Outreach	$50K	"Turn Around Don't Drown" Campaign: Assume $50,000 based on other similar educational programs.
		NFIP Public Education: Assume $50,000 based on other similar educational programs.
Flood Measurement and Warning	$250K to $500K	Early/Local Flood Warning System: Assume $250,000 based on similar projects that have received TWDB FIF grants.
		Rain/Stream Gauge and Weather Station Installation: Assume $250,000 based on similar projects that have received TWDB FIF grants.
		LWC Warning Devices: Assume $250,000 based on similar projects that have received TWDB FIF grants.
Infrastructure Projects	$500K to $35M	Hazardous Roadway Crossings: There is one strategy identified within the region that consists of strategically improving hazardous road crossings within a community. This program cost is estimated at $35,000,000 for a single community.
		Capital Improvement Plan (CIP): Community planning tool including a compilation of drainage infrastructure projects. Costs are included in the CIP and aggregated for the assigned FMS.
Other	$50K to $5M	Debris Clearing Maintenance Program: Assume $100,000 based on a similar project in the region.
		Channel Maintenance and Erosion Control: Assume $250,000 based on high level engineering consultant estimate.
		Dam Inspection Program: Assume $100,000 per dam, per year based on high level engineering consultant estimate.
		Levee Inspection Program: Assume $50,000 per levee system, per year based on high level engineering consultant estimate.
		Establish City Parks: Assume $1,000,000 based on high level engineering consultant estimate.
		Implement Green Infrastructure: Assume $500,000 based on high level engineering consultant estimate.
Property Acquisition and Structural Elevation	$5M to $50M	Acquire High Risk and Repetitive Loss Properties: Assume $5,000,000 to acquire as many properties as possible with this cost. This assumption is based on other similar projects in the region.
		Acquire and Preserve Open Space: Assume $5,000,000 based on other similar projects in the region.
Regulatory and Guidance	$100K to $1M	City Floodplain Ordinance Creation/Update: Assume $100,000 to cover engineering consultant fees.
		Zoning Regulations and Land Use Programs: Assume $100,000 to cover engineering consultant fees.
		Stormwater Management Plan: Assume $300,000 to cover engineering consultant fees.
		Levy Stormwater Fee: Assume $200,000 based on another similar project.

Benefit Cost Ratio for Flood Mitigation Projects

Benefit-Cost Analysis (BCA) is the method by which the future benefits of a hazard mitigation project were determined and compared to its costs. The end result is a BCR, which is calculated by dividing the project's total benefits, quantified as a dollar amount, by the total costs. The BCR is a numerical expression of the relative "cost-effectiveness" of a project. A project is generally considered to be cost effective when the BCR is 1.0 or greater, indicating the benefits of a prospective hazard mitigation project are sufficient to justify the costs (URS Group, Inc., 2009). However, a BCR greater than 1.0 is not a requirement for inclusion in the regional flood plan. The Trinity RFPG can recommend a project with a lower BCR with appropriate justification.

When a BCR had been previously calculated in an engineering report or study that was used to create an FMP, the previously calculated BCR value was utilized for the FMP analysis. For any FMP that did not already have a calculated BCR value, the TWDB BCA Input Spreadsheet was utilized, in conjunction with the FEMA BCA Toolkit 6.0, to generate BCR values.

Residual, Post-Project, and Future-Risks of Flood Mitigation Projects

While it is not possible to protect against all potential flood risks, the evaluation of FMPs should consider the associated residual, post-project and future risks, including the risk of potential catastrophic failure and the potential for future increases to these risks due to lack of maintenance. For more details of the approach and TWDB's proposed scoring guidelines, please see TWDB's *Exhibit C: Technical Guidelines for Regional Flood Planning* (TWDB, 2021).

Residual Risk

Residual risk describes the risks after structural or non-structural FMPs have been implemented (United Nations Office for Disaster Risk Reduction, 2020). Even after meeting the FMP goals, residual flood risk will remain (TWDB, 2021). The RFPG must consider and identify residual risk for each goal identified. As an example, if the goal is to protect all life and property from the 1% annual chance storm event (100-year flood), the residual risk to life and property remains for flood events that exceed a one percent likelihood.

Transformed risk is defined by the USACE as the change in nature of flood risk for an area associated with the presence of flood hazard reduction infrastructure. Flood risk is often reduced by the construction of flood mitigation structures but, as a result, may also be 'transformed' into a different type of risk; for example, in the form of risk from structural failure of that mitigation infrastructure (e.g., a dam or levee).

Residual risks by nature have a low probability of occurrence. Keeping residual risks low requires continued maintenance of FMPs and effective emergency services for preparedness, response, and recovery as a holistic approach.

Post-Project Risk

Post-project risk analysis is typically utilized to gather information for evaluating the final risk impacts at the completion of a project. A report of the post-project risk analysis informs individuals and decision-makers with a general idea of what worked well and what did not in the Project Management Plan, so future projects can benefit from the lessons learned. The post-project information can be used to prioritize a list of recommended FMPs with a set of criteria, including:

- Post-project 100-year flood risk reduction
- Post-project 100-year critical facilities damage reduction
- Post-project 100-year flood damage reduction
- Post-project improvement of mobility

Post-Project 100-year Flood Risk Reduction

After a project is constructed, the analysis indicates the reduced flood risk by percentage of structures removed from a 100-year floodplain in the post-project condition, using the data of

- 100-year floodplain shapefiles with elevations in the pre- and post-project conditions
- Structures within the 100-year floodplains in the pre- and post-project conditions
- Land elevations and structure shapefiles
- Other available data

Post-Project 100-year Flood Damage Reduction

After construction, the analysis indicates flood damage reduction (property protection) by a percentage of 100-year damage reduction calculation using:

- Data of average depth of a 100-year flood in the pre-project condition
- Shapefiles, elevations, or average depth/reduction of the 100-year flood in the post-project condition
- Shapefiles, land elevations, and structure shapefiles
- Other available data

Post-Project 100-year Critical Facilities Damage Reduction

Following construction, the analysis indicates reduced flood risk by percentage of critical facilities removed from a 100-year floodplain in the post-project condition using the data of:

- Average depth of the 100-year flood in the pre-project condition
- Floodplain shapefile, elevations, or average depth/reduction of the 100-year flood in the post-project condition

- Critical facilities in the 100-year floodplains in the pre- and post-project conditions

Mobility

This criterion indicates project improvement and protection of mobility during flood events, with particular emphasis on emergency service access and other major access routes, using the data of:

- 100-year floodplain shapefile with elevations in the pre- and post-project conditions
- TxDOT Functional Classification Shapefile
- Project shapefiles and other available data

Future Risks

Future flood risks shall be determined considering three components:

- Flood hazards in future condition
- Additional exposure and vulnerability
- Operations and maintenance (O&M) and design standards

Flood Hazards in Future Condition

Future risk analyses of FMPs should consider the changes in flood risks in future conditions. The factors that may result in altered flood hazards include increase of impervious surface cover, change in sea level and/or land subsidence, anticipated erosion, and sedimentation in flood control structures. In particular, any future flood risk analysis should consider potential effects of climate change on future rainfall patterns, flood frequency, and magnitude, which will possibly lead to substantial increases in future flood risks over areas with greater population.

Information from existing resources like H&H model results and maps should be summarized with details in terms of the source of flood hazard data, associated dates, timeframe of future conditions (fully developed land use conditions, 30-year, 50-year, etc.), and a brief description of each existing dataset compiled for flood hazard analysis.

Additional Exposure and Vulnerability

Exposure and vulnerability analyses identifies the existing and future flood hazard areas if the current development practices continue in the region of FMPs. According to ***Chapter 2*** of this plan, a rapid increase of structures and population is projected in the Trinity Region over the next 30 years. This implies that potential exposure and vulnerabilities of the population, structures, critical facilities, and public infrastructure to the flood hazards may increase. While future condition floodplain maps cannot be used for emergency operation and insurance rating purposes, they can be used to enhance public awareness of future flood risks, exposure, and vulnerability. The detailed information of flood exposure and vulnerability analyses for the future conditions are included in ***Chapter 2*** of this plan.

Operations and Maintenance and Design Standards

O&M, as well as the standards of public infrastructure design can greatly distress future flood risks. FMPs can fail to function as designed due to improper operations and poor maintenance. Examples of the catastrophic dam failures include the Oroville Dam in California in 2017 and Edenville Dam in Michigan in 2020, which both resulted in massive floods from the combination of intense rainfall events and lack of maintenance.

Future risks of structural failures can increase if the FMPs are not properly managed and maintained. Thus, re-evaluation of the design standards and requirements of O&M of FMPs should be considered to reduce future risks. Minimum and most stringent specifications of the design standards of FMPs should be followed to prepare for flood hazard in the future.

Implementation Issues of Flood Mitigation Projects

Project implementation issues include conflicts pertaining to right of way, permitting, acquisitions, utility, or transportation relocations, amongst other issues that might be encountered before an FMP is able to be fully implemented. Such issues are an inherent part of FMPs.

Because a right of way is a public path across private land, it can create issues when securing access to projects for construction and maintenance. The acquisition of right of way or utility relocation located near or on property impacted by a project requires close coordination between the state, cities, counties, and other forms of local government, as well as private entities and landowners. Coordination with the appropriate entities is key to facilitating projects. The Right of Way Division of Texas Department of Transportation (TxDOT) coordinates the acquisition of land to build, widen, or enhance highways, and provides relocation assistance when needed.

Most FMPs will require a variety of permits so that they are following best practices, meeting code requirements, following regulations, and adhering to the laws and regulations. During the implementation of any project, the goal is to obtain and acquire all necessary and required permits and approvals as efficiently as possible. Although acquiring permits can also be a lengthy process, it is an essential step in any FMP.

The terms “buyout**”** and “acquisition” are often utilized interchangeably, but in the context of flood protection, both refer generally to the purchase of private property by the government for public use. After properties are purchased through a buyout program, the land is converted to open space. In the case of flood acquisitions, the process involves the purchase of a property in a floodplain to reduce the damage of future flooding on the site and/or for properties adjacent to the one being acquired.

Voluntary property acquisition is not a simple process and requires agreement by the property owner and local jurisdiction. If state or federal funding is involved, then the property acquisition could also include other governmental officials, the state, and federal agencies. Voluntary buyout programs are a specific subset of property acquisitions in which private lands are purchased, existing structures are demolished, and the land is returned to its natural undeveloped state for public use in perpetuity. Buyouts are voluntary and no one is required to sell their property which provides no guarantee of acquisition. The process can also be financially burdensome and lengthy.

Additional issues can arise with utility relocation. Utilities may include water lines, wastewater lines, storm drain systems, telecommunications, power lines, and other similar infrastructure. Utilities may be buried below the surface, attached to the side of bridges, or suspended aerially. Utilities located in a road or highway right of way may need to be relocated to allow for construction of a mitigation project. The local government is usually responsible for utility relocations; however, TxDOT may assume responsibility, particularly for projects along the state highway system. Developers may also assume responsibility for utility relocations depending on the project. Utility relocation means the adjustment of a utility facility required for the construction of a project. It includes removing and reinstalling the facility, including necessary, temporary facilities; acquiring necessary right of way on new location; moving, rearranging, or changing the type of existing facilities; and taking any necessary safety and protective measures. Such measures can be time consuming as well as costly.

Potential Funding Sources

A wide variety of funding opportunities could be utilized to fund the identified actions. Traditionally, stormwater funding sources have been locally sourced (user fees or general taxes) or state or federal grants. While low-interest loan programs do provide for additional funding, few local entities choose this option due to the lack of a dedicated funding source sufficient to cover debt service. Therefore, many communities adopt a “pay-as-you-go” method of funding stormwater projects or, in the event of a disaster, apply for state and federal disaster recovery grants. Today, communities have a broader range of funding sources and programs that include the mentioned options plus recently created mitigation grant and loan programs, such as the FEMA Building Resilient Infrastructure and Communities (BRIC) and the TWDB FIF. The potential funding sources for the identified FMEs, FMPs, and FMSs are listed in ***TWDB-Required Tables 12**, **13**,* and ***14***, respectively (see ***Appendix A***). Further details on funding opportunities and the anticipated funding sources for the recommended actions are included in ***Chapter 9***.

Bibliography

FEMA. (2005, October). *National Flood Insurance Program: Frequently Asked Questions*. Retrieved from FEMA: https://www.fema.gov/txt/rebuild/repetitive_loss_faqs.txt

FEMA. (2022). Title 44 - Emergency Management and Assistance. In F. E. Agency, *Code of Federal Regulations* (pp. 50-149). Washington, D.C.: National Archives and Records Administration.

FEMA Cooperating Technical Partners. (2017). *Estimating the Value of Partner Contributions to Flood Mapping Projects.* Federal Emergency Management Agency, Cooperating Technical Partners. Atlanta: Federal Emergency Management Agency. Retrieved from https://www.fema.gov/sites/default/files/documents/fema_risk-map_blue-book_2017.pdf

Leber, N., Holmquist, H., Iqbal, K., Duty, J., Pruitt, E., & Crouse, L. (2022). *Volumetric and Sedimentation Survey of Lake Livingston.* Arlington: Trinity River Authority.

Li, Z., Passalacqua, P., & Hodges, B. R. (2018). *Hydrodynamic Model Development for the Trinity River Delta.* Austin : Texas Water Development Board.

Mangham, W., Osting, T., & Flores, D. (2015). *LiDAR Acquisition and Flow Assessment fo rthe Middle Trinity River.* Arlington: Trinity River Authority.

NCEI. (2022). Storm Events Database. Washington, D.C., District of Columbia, United States of America.

NWS. (2021). *Storm Data Preparation.* National Oceanic and Atmospheric Administration.

Quigg, A., & Steichen, J. (2015). *Defining Bioindicators for Freshwater Inflow Needs Studies.* Galveston: Texas Water Development Board.

Quigg, A., & Steichen, J. (2018). *Defining Bioindicators for Freshwater Inflow Needs Studies Phase 2: Defining a Sound Ecological Environment for Galveston Bay.* Galveston: Texas Water Development Board.

TCEQ. (2020). *2020 Texas Integrated Report - Assessment Results for Basin 8 - Trinity River Basin.* Austin: Texas Commission on Environmental Quality.

TFMA Higher Standards Committee. (2018). *A Guide for Higher Standards in Floodplain Management.* Texas Flooplain Management Association.

TRA. (2020). *2020 Basin Summary Report.* Arlington: Texas Commission on Environmental Quality.

TWDB. (2021, July 27). *Flood Planning Data*. Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/data.asp

TWDB. (2021, July 22). *TWDB Flood Planning Frequently Asked Questions*. Retrieved from Texas Water Development Board: https://www.twdb.texas.gov/flood/planning/faq.asp

United Nations Office for Disaster Risk Reduction. (2020). *2020 Annual Report.* Geneva: United Nations.

United States CDC. (2018). CDC/ATSDR Social Vulnerability Index. Washington, D.C., District of Columbia, United States of America.

United States Census Bureau. (2020, March 3). 2020 United States Census Results. Washington, D.C., District of Columbia, United States of America.

URS Group, Inc. (2009). *BCA Reference Guide.* Washington, D.C.: Federal Emergency Management Agency.

Wang, X., White, M., Lee, T., Tuppad, P., Srinivasan, R., Jones, A., & Narasimhan, B. (2010). *Trinity River Basin Environmental Restoration Initiative 2010.* Arlington: Texas Water Development Board.

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Chapter 5: Recommendation of Flood Management Evaluations, Flood Management Strategies, and Associated Flood Mitigation Projects

The objective of ***Task 5*** is for the Trinity Regional Flood Planning Group (RFPG) to use the information developed under ***Task 4*** to recommend flood mitigation actions, including Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs) for inclusion in the Trinity Regional Flood Plan. While ***Chapter 4B*** discussed the technical evaluations of the potential FMEs and potentially feasible FMSs and FMPs identified by the Trinity RFPG, ***Chapter 5*** focuses on how the Trinity RFPG used this data to make a recommendation for a given flood mitigation action. Generally, this chapter summarizes and documents:

- The process undertaken by the Trinity RFPG to make final recommendations on the given flood mitigation action types
- The potential FMEs and potentially feasible FMSs and FMPs identified and evaluated under ***Task 4B***, and whether these actions are recommended by the Trinity RFPG

While there is abundant need across the region and the state for better, recent, and more widely available data on flood risk, it is evident that not every conceivable flood mitigation action can be recommended in the Trinity Regional Flood Plan or included in the State Flood Plan. The Trinity RFPG evaluated the identified potential flood mitigation actions and based on the significant needs in the region, recommended those that met the Texas Water Development Board (TWDB) requirements, with the understanding that not all recommendations may be performed in the same planning cycle as they are identified. Finally, all recommendations considered alignment with Trinity RFPG-adopted flood mitigation and floodplain management goals.

Trinity Regional Flood Planning Group Evaluation and Recommendation Process

The Trinity RFPG considered recommendations on flood mitigation actions through a multi-step process. The Trinity RFPG created a Technical Subcommittee tasked with establishing a selection methodology, implementing the evaluation and selection process, and reporting their findings and recommendations back to the Trinity RFPG for formal approval. ***Figure 5.1*** provides a timeline and key decisions of the Trinity RFPG evaluation and recommendation process.

Figure 5.1 Trinity Regional Flood Planning Group Evaluation and Recommendation Process Timeline

Feb/10/2022 — **Technical Subcommittee Meeting #1**
- Reviewed screening process for evaluating and recommending flood mitigation actions.

Mar/15/2022 — **Technical Subcommittee Meeting #2**
- Vetted screening process.
- Provided additional guidance for recommending flood mitigation actions.

Apr/13/2022 — **Technical Subcommittee Meeting #3**
- Evaluated all flood mitigation actions.
- Recommended FMEs, FMSs, and FMPs.

Apr/21/2022 — **RFPG Meeting**
- RFPG voted to recommend FMEs and FMSs, as advised by the Technical Subcommittee.

Jun/02/2022 — **RFPG Meeting**
- RFPG approved additional FMEs and voted on FMP recommendations based on the outcomes of the no negative impacts analysis and LOS and BCR estimations.

Oct/20/2022 — **Technical Subcommittee Meeting #4**
- Developed proposed Task 12 approach that included a tiering system.
- Established proposed date of Jan 27, 2023 as deadline to receive potential new FMPs.

Nov/17/2022 — **RFPG Meeting**
- Approved Task 12 approach.

Jan/27/2023 — **Deadline**
- Deadline to submit new FMPs for consideration in Amended Plan.

Feb/16/2023 — **RFPG Meeting**
- Approved work order plan.

Jun/29/2023 — **RFPG Meeting**
- Voted on and approved inclusion of FMEs, FMPs and FMSs in the Amended Plan.

The general methodology included a screening of all potential flood mitigation actions considering TWDB requirements for inclusion in the Regional Flood Plan and any other additional considerations established by the Technical Subcommittee. The reasons for not recommending a particular flood mitigation action were clearly documented as part of the evaluation and recommendation process.

The first Technical Subcommittee meeting was held on February 10, 2022. This meeting focused on reviewing the proposed screening process for evaluating and recommending flood mitigation actions. This process is summarized in ***Figure 5.2*** for FMEs and in ***Figure 5.3*** for FMPs and FMSs. The process was primarily developed following the TWDB rules and requirements for inclusion in the plan. However, the TWDB left some evaluation criteria to the discretion of each individual RFPG to implement in the screening process. The main discretionary evaluation criteria included the Level of Service (LOS) to be provided by an FMP and the Benefit-Cost Ratio (BCR) for the project.

The TWDB recommends that, at a minimum, FMPs should mitigate flood events associated with the 1% annual chance storm event (100-year LOS). However, if a 100-year LOS is not feasible, the Trinity RFGP can document the reasons for its infeasibility and still recommend an FMP with a lower LOS. Similarly, the TWDB recommends that proposed actions have a BCR greater than one, but the Trinity RFPG may recommend FMPs with a BCR lower than one with proper justification.

During the second Technical Subcommittee meeting held on March 15, 2022, the participants provided a series of sample evaluations to demonstrate how the screening process would be implemented and requested feedback on the discretionary evaluation criteria. The Technical Subcommittee vetted the process and provided the following additional guidance to determine whether a flood mitigation action may be recommended:

- The Trinity RFPG will not require confirmation from potential sponsors to support a flood mitigation action as a prerequisite for recommendation. (see Sponsor Outreach section)
- All potential actions should be considered for inclusion in the plan unless an entity specifically declines to be listed as a sponsor and no other appropriate potential sponsor is identified.
- If a potential flood mitigation action falls within multiple flood planning regions, the Trinity RFPG will consider recommending that action for the portion that falls within Trinity RFPG's jurisdiction.

Figure 5.2: Flood Management Evaluation Screening Process

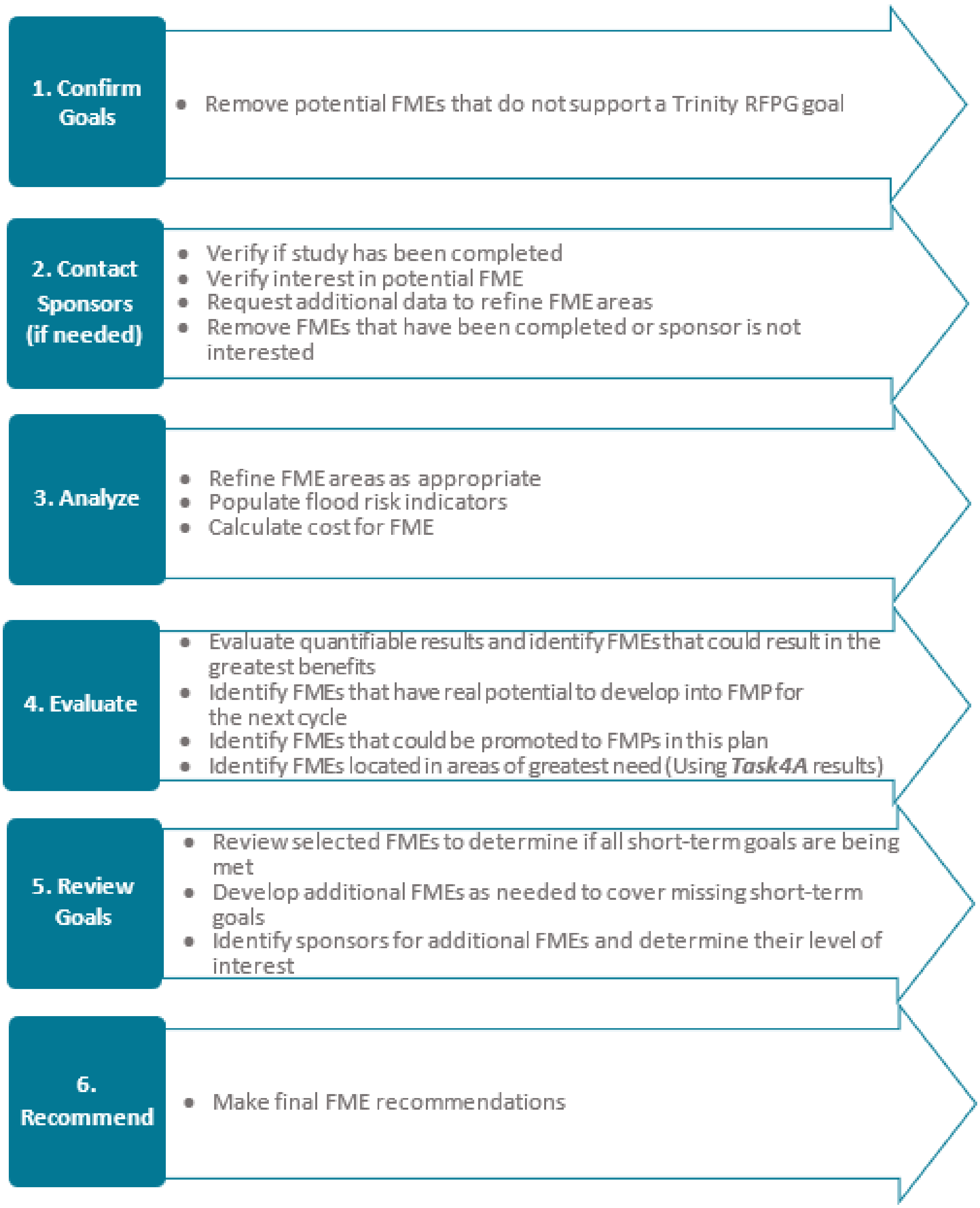


Figure 5.3: Flood Management Project and Flood Management Strategy Screening Process

1. Goals
- Remove FMPs/FMSs that do not support a Trinity RFPG goal

2. Screen 1
- Focus is on addressing response and recovery rather than mitigation
- Does not provide flood mitigation for the 100-year flood event (The Trinity RFPG is willing to accept flood mitigation actions with a LOS that is lower than the 100-year flood event.)

3. Contact Sponsors (as appropriate)
- Verify if the project has been completed/already funded
- Verify interest in potential FMP/FMS and request additional data
- Remove FMPs/FMSs that have been completed or sponsor is not interested in pursuing

4. Initial Analysis
- Populate flood risk indicators
- Calculate Reduction in Flood Risk
- Calculate costs

5. Full Analysis
- Determine no negative Impacts
- Perform estimated benefit-cost analysis

6. Screen2
- Confirm no adverse impacts
- Determine no quantifiable flood reduction benefits
- Duplicates benefits

7. Demote
- Determine if any of the FMPs should be demoted to an FME

8. Evaluate
- Quantify results to ID FMPs/FMSs with the most complete information and/or could result in the greatest benefits
- Identify FMPs/FMSs located in areas of greatest need (Use *Task 4A* results)

9. Recommend
- Make final FMP/FMS recommendations

- The Trinity RFPG is willing to accept flood mitigation actions with a LOS that is lower than the 100-year flood event. The Trinity RFPG team shall determine the estimated LOS for each FMP and the Trinity RFPG will make the final determination for its recommendation.
- The Trinity RFPG is willing to accept an FMP with a BCR less than one. The Trinity RFPG team shall determine the estimated BCR for each FMP based on readily available data and/or generalized assumptions. The Trinity RFPG will make the final determination regarding each FMP recommendation.

The RFPG team applied the screening process based on the technical data developed under ***Task 4B*** and the Technical Subcommittee guidance. An initial recommendation for each flood mitigation action was presented to the Technical Subcommittee on April 13, 2022. This working session allowed for multiple adjustments to the flood mitigation action lists, including additions of new FMEs and FMSs, merging multiple FMEs or FMSs into one action, and enhancing project descriptions. All FMEs and FMSs were reviewed, and those that met all screening criteria were selected for recommendation. All FMPs were recommended contingent upon confirmation of no negative impacts and a completion of estimated LOS and BCR estimations.

On April 21, 2022, the Trinity RFPG voted to recommend FMEs and FMSs, as advised by the Technical Subcommittee. The Trinity RFPG approved these FMEs and FMSs with the understanding that they could revisit them at a future meeting if new information warranted additional discussion and possible action.

Finally, on June 2, 2022, the Trinity RFPG approved additional FMEs received since the last Technical Subcommittee meeting and voted on FMP recommendations based on the outcomes of the no negative impacts analysis and the LOS and BCR estimations. These were included in the Draft and Final Flood Plans.

The regional flood plan was developed on an expedited schedule to meet legislative requirements. The regional flood planning groups expressed concern that the time constraint limited local jurisdiction participation. In response, the TWDB authorized ***Tasks 12 and 13*** to provide additional time and budget to develop an Amended Plan by July 14, 2023.

The Technical Subcommittee reconvened on October 20, 2022, to develop an approach to incorporate as many new FMPs as possible in the Amended Plan. The Technical Subcommittee provided guidance to the proposed approach, including an outreach plan, tiering criteria for FMPs, and a deadline for all potential new FMEs, FMPs, and FMSs. Although the focus was on FMPs, the Technical Subcommittee recognized that the information received may not meet the TWDB's project criteria. Therefore, a single deadline for all new potentially feasible flood mitigation actions was recommended.

On November 17, 2022, the RFPG met and approved the Technical Subcommittee's recommendations for ***Task 12***. The RFPG established January 27, 2023, as the deadline for potential new FMEs, FMPs, and FMSs to be submitted for consideration in the Amended Plan. The RFPG subsequently approved the Work Order of FMPs at its meeting on February 16, 2023. On June 29, 2023, the RFPG held a regularly scheduled meeting at which time it approved the recommended FMEs, FMPs, and FMSs for inclusion in the Amended Plan.

All meetings were held in accordance with the requirements of the Trinity RFPG bylaws, the Texas Open Meetings Act, the general requirements of the Texas Water Code, and the TWDB's flood planning process requirements. Additional details regarding the flood mitigation action evaluation process and final recommendations are provided in subsequent sections.

Sponsor Outreach

A supplemental effort to contact potential sponsors was conducted to obtain clarification on flood mitigation actions where there was significant uncertainty regarding their location and/or scope of work. Feedback from potential sponsors was requested via email. These outreach emails included a one-page summary of the potential flood mitigation action with a map showing its approximate location, allowing the potential sponsors to view the potential actions for their entity. In addition, potential sponsors were encouraged to provide any other flood mitigation action of their interest for the Trinity RFPG to consider for inclusion in the regional flood plan. Several conference call meetings were held following this outreach effort, which resulted in multiple positive outcomes for the flood planning process. Potential sponsors were able to fill in data gaps, identify actions that were already completed or had allocated funding, add new actions for consideration, and confirm interest in including the identified potential actions in the Final Trinity Regional Flood Plan.

Due to schedule limitations, this outreach effort targeted potential flood mitigation actions with the greatest data gaps. Because flood mitigation actions must be included in the regional flood plan to be eligible for future state funding from the TWDB, the Trinity RFPG decided that an affirmative willingness to sponsor a given action would not be a prerequisite for inclusion in the plan. As a result, all potential actions were considered for inclusion unless an entity had specifically declined to be listed as a sponsor and no other appropriate potential sponsor was identified. This approach was adopted because:

- It provides a conservative estimate of the flood mitigation needs in the region.
- It does not obligate an entity to sponsorship; it simply allows an entity to be eligible for funding if interest in and capacity to sponsor an action becomes evident before the next regional flood plan is adopted.

The RFPG implemented an outreach program between November 2022 and January 2023 soliciting new FMPs, FMEs, and FMSs for potential inclusion in the Amended Plan. The outreach program included multiple emails, a website notification posting, and meetings with the consultant team as requested by potential sponsors.

It is important to note that all sponsors associated with recommended actions subsequently received a survey to communicate that they were identified as a sponsor and were asked to provide information for potential funding sources for the actions listed in the plan. This effort is detailed in ***Chapter 9***.

Flood Management Evaluations

Summary of Approach in Recommending Flood Management Evaluations

The Trinity RFPG evaluated the identified potential FMEs and based on the significant needs in the region, recommended all FMEs that met the TWDB requirements, with the understanding that not all FMEs may be performed during the same planning cycle as they are identified. Recommended FMEs were also required to demonstrate alignment with at least one regional floodplain management and flood mitigation goal developed in ***Chapter 3***. Finally, each recommended FME should identify and investigate at least one solution to mitigate the 1% annual chance storm event. It is the intent that all FMEs with a Hydrologic and Hydraulic (H&H) modeling component will evaluate multiple storm events, including the 1% annual chance storm event. The exact solutions identified through performing these FMEs cannot be defined at this time. However, it is anticipated that an impact analysis will be performed for all alternatives and project benefits will be tabulated for the 100-year storm to inform any recommended alternatives and to define potentially feasible FMPs under this planning framework. Based on these TWDB requirements, the Trinity RFPG identified and recommended two main types of FMEs:

1. **FMEs that would result in increased flood risk modeling and mapping coverage across the region as they are implemented –** These types of FMEs have two major implications for the identification of potentially feasible FMSs and FMPs. First, a current and comprehensive understanding of flood risk across the basin is necessary to identify high-risk areas for evaluation and development of flood risk reduction alternatives. Second, FMPs, and in some cases, FMSs, require a demonstrated potential reduction in flood risk to be recommended in the regional flood plan. For this metric to be assessed, H&H modeling must be available to compare existing and post-project floodplain boundaries to determine the flood risk reduction potential of a given project.
2. **FMEs classified as project planning –** These FMEs are generally studies or preliminary designs to address a specific, known flood need. However, these flood mitigation actions currently lack some or all of the detailed technical data necessary for evaluation and

recommendation as an FMP. An example would be an existing study that identifies potential drainage construction projects but does not provide a full impacts analysis. Completing these components as part of an FME will result in a potentially feasible FMP for consideration during future flood planning efforts.

The primary reason for not recommending an FME was based on sponsor input. An FME was not recommended if a sponsor indicated that the proposed study was already in progress, had been completed, or was no longer a priority they intended to pursue. In some cases, multiple FMEs were combined into a single FME for recommendation due to the proximity of the study areas.

Multiple requests for new FMEs were received and were included in the Amended Plan as potentially feasible FMEs. All FME requests required a short description of the desired study and a shapefile or graphic showing the area that would benefit from the study. These two pieces of information allowed the RFPG to populate the TWDB-required tables and maps for FMEs.

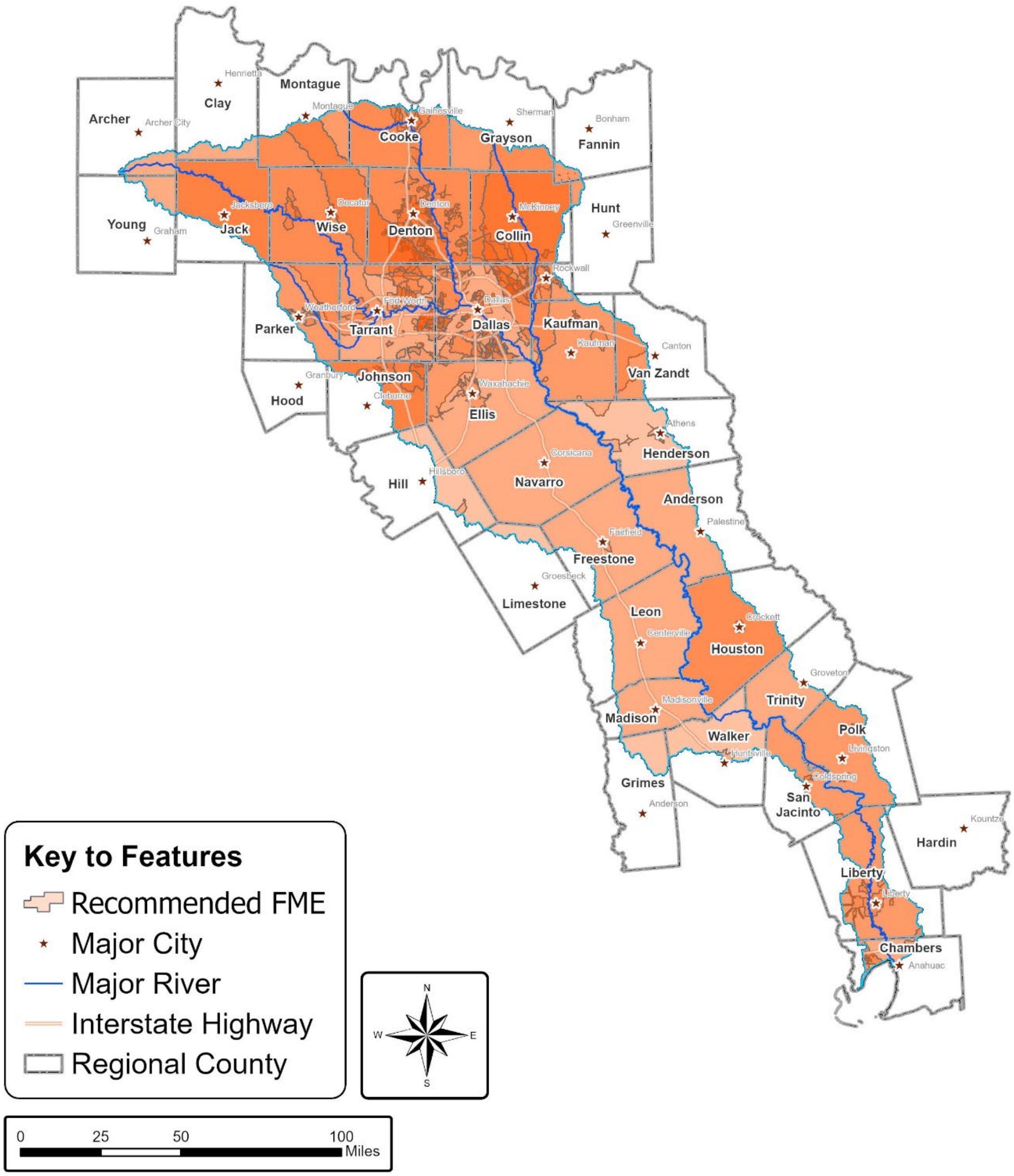
Description and Summary of Recommended Flood Management Evaluations

Between the Final Plan in January 2023 and this Amended Plan, a total of 521 potential FMEs were identified and evaluated by the Trinity RFPG. Of these projects, 507 were recommended, representing a combined total of approximately $221 million dollars of FME needs across the region. The number and types of projects recommended by the Trinity RFPG are summarized in ***Table 5.1***. The full list of FMEs and supporting technical data is included as ***TWDB-Required Table 15*** in ***Appendix A***. A map of recommended FMEs is presented as ***Figure 5.4.*** Color gradations in ***Figure 5.4*** reflect the number of FMEs that overlap for the same area - the darker the color, the greater the number of FMEs. A one-page report summary for each recommended FME is included in ***Appendix E.*** Overall, the recommended FMEs provide extensive coverage of the Trinity Region.

Table 5.1: Summary of Recommended Flood Management Evaluations

FME Type	FME Description	# of Potential FMEs Identified	# of FMEs Recommended	Total Cost of Recommended FMEs
Watershed Planning	Flood Mapping Updates, Drainage Master Plans, H&H Modeling, Dam, and Levee Failure Analysis	160	156	$89,981,000
Project Planning	Feasibility Assessments and Preliminary Engineering Studies (alternative analysis and up to 30% design)	334	324	$118,171,000
Preparedness	Studies on Flood Preparedness	5	5	$3,150,000
Other	Dam Studies	22	22	$9,260,000
	Total	**521**	**507**	**$220,562,000**

Figure 5.4: Map of Recommended Flood Management Evaluations



Flood Management Projects

Summary of Approach in Recommending Flood Management Projects

For consideration as an FMP, a project must be defined in a sufficient level of detail to meet the technical requirements of the regional flood planning scope of work and the associated Technical Guidelines developed by the TWDB. In summary, the Trinity RFPG must be able to demonstrate that each recommended FMP meets the following TWDB requirements:

1. The FMP supports at least one regional floodplain management and flood mitigation goal
2. The primary purpose of the FMP is mitigation (response and recovery projects are not eligible for inclusion in the State Flood Plan)
3. The FMP is a discrete project (not an entire capital program or drainage master plan)
4. Implementation of the FMP results in:
    a. Quantifiable flood risk reduction benefits
    b. No negative impacts to adjacent or downstream properties (a No Negative Impact Certification is required)
    c. No negative impacts to an entity's water supply
    d. No overallocation of a water source based on the water availability allocations in the most recently adopted State Water Plan

In addition, the TWDB recommends that, at a minimum, FMPs should mitigate flood events associated with the 1% annual chance storm event (100-year LOS). However, if a 100-year LOS is not feasible, the Trinity RFPG can document the reasons for its infeasibility and may recommend an FMP with a lower LOS.

Updated construction cost estimates and estimates of project benefits must also be available to define a BCR for each recommended FMP. The TWDB recommends that proposed projects have a BCR greater than one, but the Trinity RFPG may recommend FMPs with a BCR lower than one with proper justification.

All potentially feasible FMPs that had the necessary data and detailed H&H modeling results available to populate these technical requirements were considered for recommendation by the Trinity RFPG. Pertinent details about the FMP evaluation are provided in the following section.

Flood Management Project Evaluation

Initial Evaluation

Each FMP was evaluated to verify that it would support at least one of the regional floodplain management and flood mitigation goals established in ***Chapter 3***. The goal(s) associated with each FMP are included in ***TWDB-Required Table 16*** in ***Appendix A***. Based on a review of the supporting studies and H&H models, the region determined that the primary purpose for each FMP is mitigation (rather than a response or recovery project), is a discrete project, and does not have any anticipated impacts to water supply or water availability allocations as established in the most recently adopted State Water Plan.

No Negative Impacts Determination

Each identified FMP must demonstrate no negative impacts on a neighboring area would result from its implementation. No negative impacts means that a project will not increase flood risk of surrounding properties. Using best available data, the increase in flood risk is measured by the 1% annual chance storm event Water Surface Elevation (WSE) and peak discharge. According to TWDB's Technical Guidelines, it is recommended that no rise in WSE or discharge should be permissible, and that the analysis extent must be sufficient to prove proposed project conditions are equal to or less than the existing conditions. These conditions were evaluated for each potentially feasible FMP based on currently available regional planning level data. However, the local sponsor will be ultimately responsible for proving the final project design has no negative impacts prior to initiating construction.

For the purposes of flood planning effort, no negative impact can be established if stormwater does not increase inundation of infrastructure such as residential and commercial buildings and structures. Additionally, the following requirements, per TWDB Technical Guidelines, should be met to establish no negative impact, as applicable:

1. Stormwater does not increase inundation in areas beyond the public right of way, project property, or easement
2. Stormwater does not increase inundation of storm drainage networks, channels, and roadways beyond design capacity
3. Maximum increase of one-dimensional (1D) WSE must round to 0.0 feet (<0.05 feet) measured along the hydraulic cross-section
4. Maximum increase of two-dimensional (2D) WSE must round to 0.3 feet (<0.35 feet) measured at each computation cell
5. Maximum increase in hydrologic peak discharge must be less than 0.5 percent measured at computation nodes (sub-basins, junctions, reaches, reservoirs, etc.). This discharge restriction does not apply to a 2D overland analysis.

If negative impacts are identified, mitigation measures may be utilized to alleviate such impacts. Projects with design level mitigation measures already identified may be included in the regional flood plan and could be finalized at a later stage to conform to the "No Negative Impact" requirements prior to funding or execution of a project. Furthermore, the Trinity RFPG has flexibility to consider and accept additional "negative impact" for requirements one through five based on the RFPG team's professional judgment and analysis given any affected communities are informed and accept the impacts. This should be well-documented and consistent across the entire region. Flexibility regarding negative impact remains subject to Trinity RFPG review.

A comparative assessment of pre- and post-project conditions for the 1% annual chance storm event (100-year storm) was performed for each potentially feasible FMP based on their associated H&H models. The floodplain boundary extents, resulting WSE, and peak discharge values were compared at pertinent locations to determine if the FMP conforms to the no negative impacts requirements. This comparative assessment was performed for the entire zone of influence of the FMP.

A general description of the scope of work and a summary of the expected benefits and impacts of the proposed improvements for each potentially feasible FMP is provided in ***Appendix F***. This appendix also provides a summary of the comparative assessment of H&H parameters and the final determination of no negative impacts for each FMP. Based on this evaluation, it was determined that 73 potentially feasible FMPs conform to the no negative impact requirements (see ***Appendix F***). However, 16 FMPs that do not strictly comply with these requirements were still considered by the Trinity RFPG as not having adverse impacts due to various justified conditions and based on RFPG team's professional judgment. These particular cases are explained as appropriate in the project descriptions included in ***Appendix F*** and are identified in ***Table F.1***.

Benefit Cost Analysis

Benefit Cost Analysis (BCA) is the method by which the future benefits of a hazard mitigation project are determined and compared to its costs. The end result is a BCR, which is calculated by dividing the project's total benefits, quantified as a dollar amount, by its total costs. The BCR is a numerical expression of the relative "cost-effectiveness" of a project. A project is generally considered to be cost effective when the BCR is one or greater, indicating the benefits of a prospective hazard mitigation project are sufficient to justify the costs (FEMA, 2009). However, a BCR greater than one is not a requirement for inclusion in the Trinity Regional Flood Plan. The Trinity RFPG can recommend a project with a lower BCR with appropriate justification.

When a BCR had been previously calculated in an engineering report or study that was used to create an FMP, the previously calculated BCR value was utilized for the FMP analysis. For any FMP that did not already have a calculated BCR value, the TWDB BCA Input Spreadsheet was utilized in conjunction with the FEMA BCA Toolkit 6.0 to generate BCR values. BCR calculations are included in ***TWDB-Required Table 16*** in ***Appendix A***).

FMP Tiers System

For the Amended Plan, the RFPG approved a tiering system shown in ***Figure 5.5*** that categorized potential FMPs according to the data received.

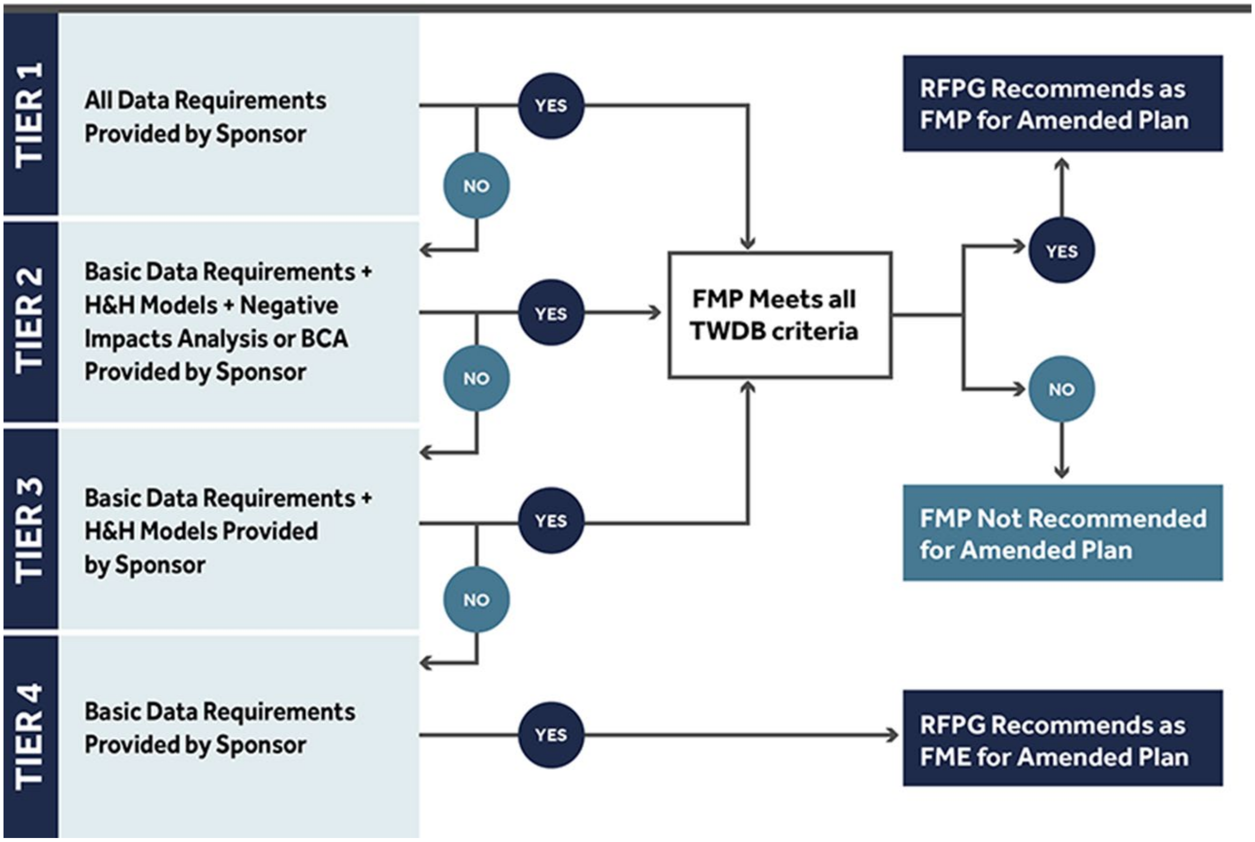
- Tier 1 FMPs included all TWDB-required data and documentation, including the confirmation of no negative impacts (NNI) and benefit cost analyses. Tier 1 required little effort to review and confirm the TWDB criteria had been met. Thus, Tier 1 FMPs would be included in the Amended Plan.
- Tier 2 FMPs were received with the basic data requirements, H&H models, and either a NNI analysis or BCA provided by the sponsor. Tier 2 FMPs required some time for the RFPG to review the documentation and complete the missing TWDB-required documentation.
- Tier 3 FMPs included the basic data requirements and H&H models provided by the sponsor. Tier 3 FMPs required significantly more time for the RFPG to review the documentation received and complete the remaining TWDB-required criteria.
- Tier 4 FMPs were submitted to the RFPG with basic data requirements provided by the sponsor. All Tier 4 FMPs were reclassified as FMEs.

The RFPG wanted to include at least one FMP per sponsor in the Amended Plan as time permitted. Therefore, the RFPG asked each sponsor to prioritize the order of their requested FMPs for inclusion in the Amended Plan. The RFPG reviewed each of the submittals to confirm if the required documentation had been provided for each tier.

If a sponsor submitted multiple projects that fell in a particular tier, then the sponsor's highest priority FMP would be evaluated and completed. Then, another sponsor's highest priority FMP within that tier would be evaluated and completed. The RFPG applied this process until it reached the end of the first projects within the tier before looking at the next requested FMP by the same sponsor.

This process framed the work order plan that the RFPG approved during the February 2023 meeting with the caveat that if information was found to be missing, and the sponsor was slow to respond or unable to provide the missing data, the RFPG would move to the next FMP on the list to minimize delays and to evaluate as many FMPs as possible for potential inclusion in the plan. Some FMPs were reclassified in the event that TWDB-required documentation was unable to be met. The RFPG was unable to evaluate all Tier 3 FMPs, which were then reclassified and considered as FMEs for potential inclusion in the Amended Plan.

Figure 5.5: Trinity Tiers Flow Chart



Description and Summary of Recommended Flood Management Projects

After the evaluation of 73 potentially feasible FMPs, the Trinity RFPG determined that 56 met all the TWDB requirements for inclusion in the Trinity Regional Flood Plan. The Trinity RFPG recommendations also considered the LOS and BCR of each FMP as discretionary evaluation criteria. Some FMPs do not provide a 100-year LOS and/or their BCR is less than one.

- Physical, environmental, or other constraints may impact the ability of a recommended FMP regarding the LOS to which it can provide. The Trinity RFPG considered these results and determined that recommending these FMPs would still be consistent with the overarching goal of the regional flood plan, which is "*to protect against the loss of life and property*" (TWDB, 2021), even if that protection can only be provided against smaller storm events.
- The costs and benefits of the FMPs are developed at a high level or regional scale. A sponsor will need to refine the BCR according to the funding program BCA requirements if and when the sponsor decides to pursue funding to move forward with the implementation of an FMP. Every funding program has its own BCA tool that is required for its specific funding application. Therefore, the Trinity RFPG considered potential non-

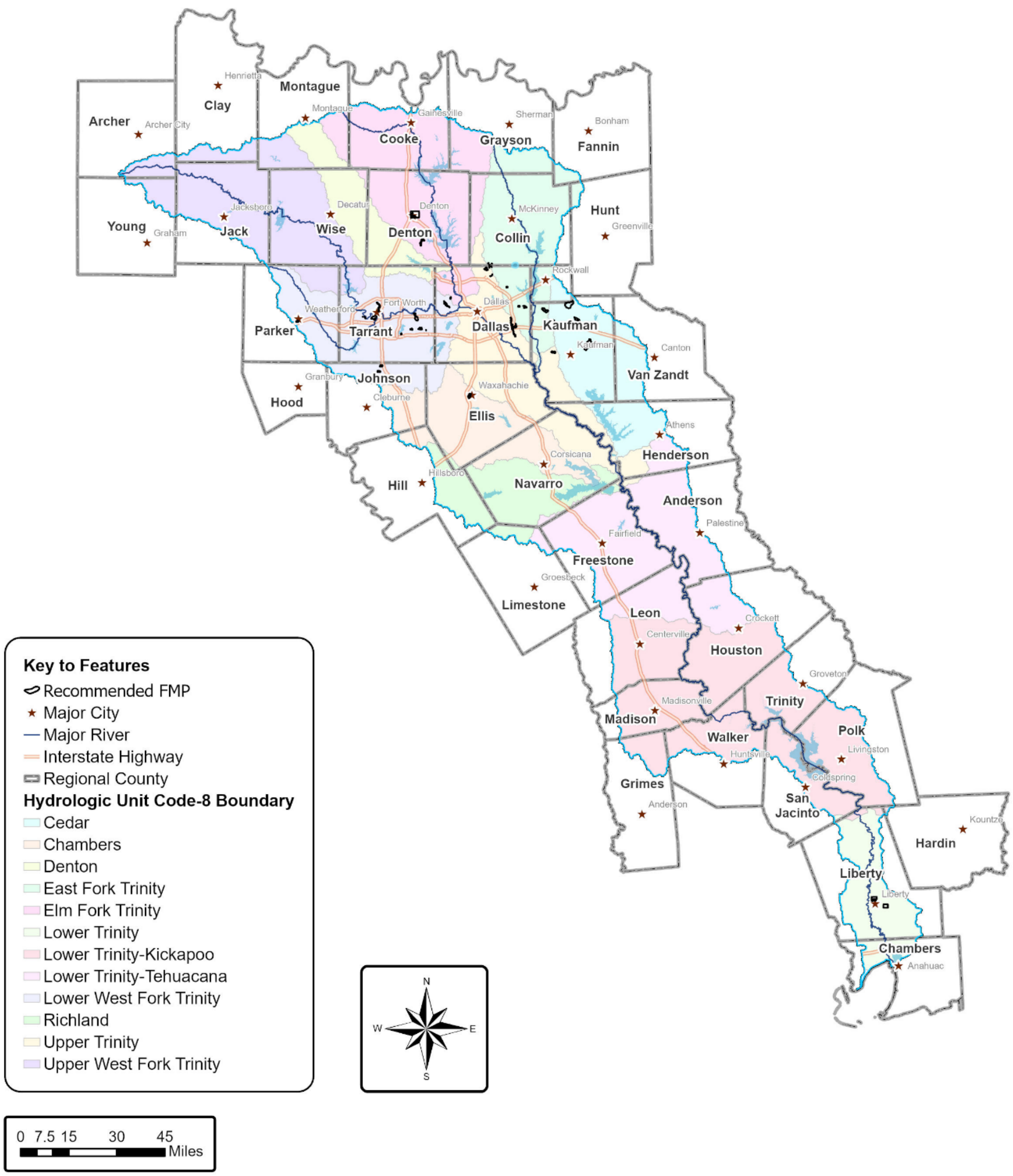
quantifiable secondary benefits, such as improving water quality, expanding recreational opportunities, and improvements in community livability, as a justification for recommending FMPs with BCRs less than one.

A summary of the recommended FMPs for inclusion in the Trinity Regional Flood Plan is presented in ***Table 5.2***. These projects are primarily located within the Upper Subregion, and they represent a combined total construction cost of more than $703 million. Supporting technical data for each FMP, including their flood risk reduction benefits, is included as ***TWDB-Required Table 16*** in ***Appendix A***. A map of project areas for the recommended FMPs is provided as ***Figure 5-6***. A one-page report summary for each recommended FMP is included in ***Appendix F***. Additionally, ***Appendix G*** provides a detailed breakdown of the estimated planning level costs for each FMP following the TWDB Technical Guidelines.

Table 5.2: Summary of Recommended Flood Management Projects

FMP Type	FMP Description	# of Potential FMPs Identified	# of FMPs Recommended	Total Cost of Recommended FMPs
Infrastructure	Improvements to stormwater infrastructure including channels, ditches, ponds, stormwater pipes, etc.	46	33	$468,864,000
Storm Drain Improvements	Improvements exclusively to underground urban stormwater infrastructure	14	11	$38,700,000
Regional Detention Facilities	Runoff control and management via detention facilities	5	4	$138,099,000
Property or Easement Acquisition	Acquisition of properties located in the floodplain	3	3	$48,279,000
Dam Improvements, Maintenance and Repair	Dam upgrades to meet TCEQ dam safety requirements	2	2	$5,565,000
Flood Early Warning Systems	Installation of safety improvements at hazardous stream crossings	2	2	$640,000
Low Water Crossing or Bridge Improvement	Low water crossing replaced by a bridge crossing	1	1	$3,319,000
	Total	**73**	**56**	**$703,466,000**

Figure 5.6: Map of Recommended Flood Management Projects



Flood Management Strategies

Summary of Approach in Recommending Flood Management Strategies

The approach for recommending FMSs adheres to similar requirements as the FMP process. However, due to the flexibility and varying nature of RFPG's potential utilization of FMSs, some of these requirements may not be applicable to certain types of FMSs. In general, the RFPG must be able to demonstrate that each recommended FMS meets the following TWDB requirements as applicable:

1. The FMS supports at least one regional floodplain management and flood mitigation goal
2. The primary purpose is mitigation (response and recovery projects are not eligible for inclusion in the regional flood plan)
3. Implementation of the FMS results in:
    a. Quantifiable flood risk reduction benefits
    b. No negative impacts to adjacent or downstream properties (a No Negative Impact Certification is required)
    c. No negative impacts to an entity's water supply
    d. No overallocation of a water source based on the water availability allocations in the most recently adopted State Water Plan

In addition, the TWDB recommends that, at a minimum, FMSs should mitigate flood events associated with the 1% annual chance storm event (or 100-year LOS). However, if a 100-year LOS is not feasible, the Trinity RFPG may document the reasons for its infeasibility and recommend an FMS with a lower LOS.

Although each potentially feasible FMS must demonstrate that there would be no negative flood impacts on a neighboring area due to its implementation, there were no structural FMSs identified for this region. Therefore, no adverse impacts from flooding or to the water supply are anticipated.

In addition to the above requirements, some FMSs were not recommended if they were redundant with another recommended FMS or if their purpose was primarily related to stormwater quality. In some cases, multiple FMSs were combined into a single FMS for recommendation. These merged FMSs included the development of county-wide educational programs and updates to land use planning and zoning regulations. Only two additional FMSs were submitted for the Amended Plan. Both FMSs were submitted with sufficient information to complete the required analyses.

Description and Summary of Recommended Flood Management Strategies

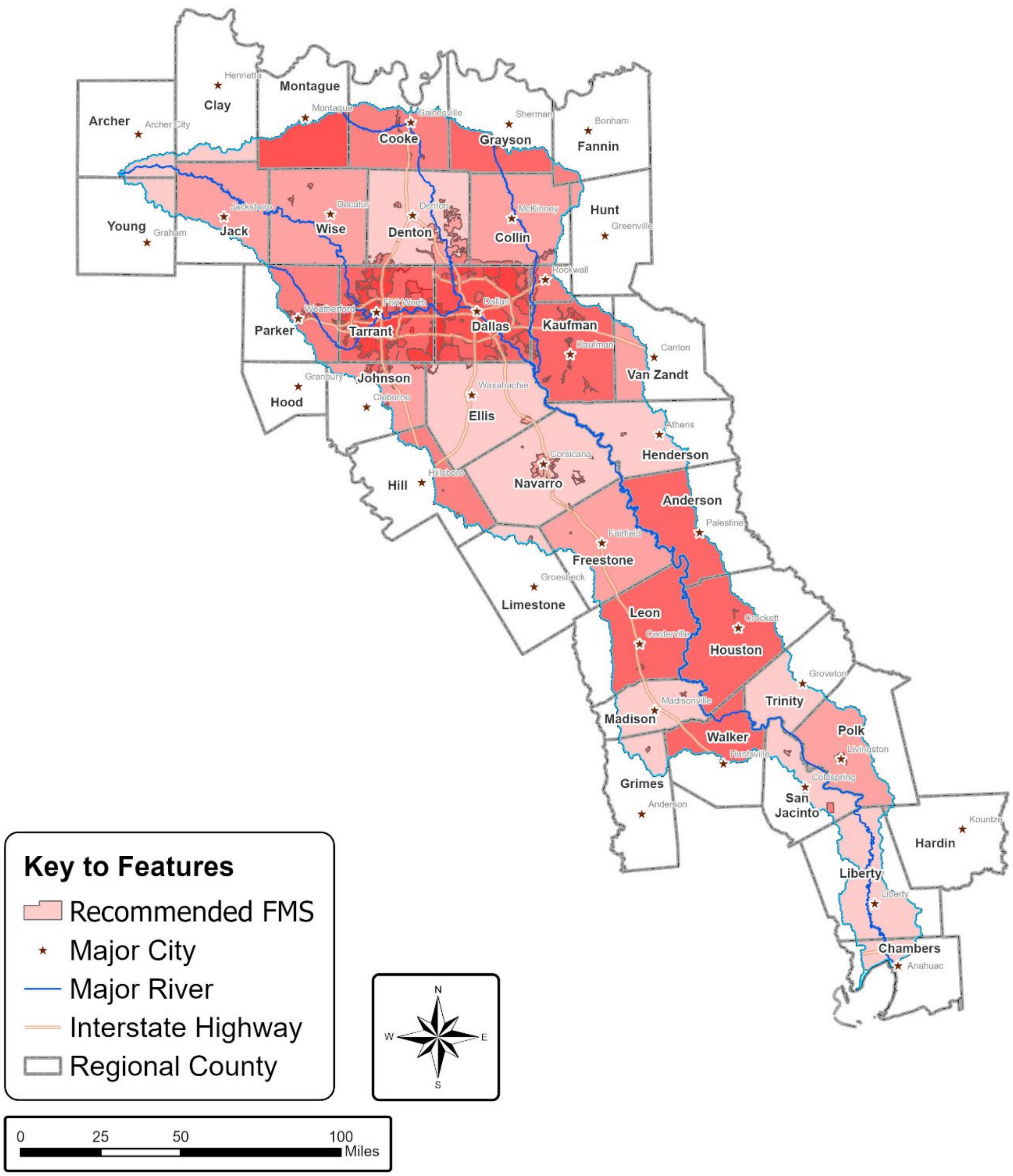
A wide variety of FMS types were identified and evaluated for the Trinity Region. A total of 145 potentially feasible FMSs were considered by the Trinity RFPG and 138 were recommended for inclusion in the Trinity Regional Flood Plan. Generally, these FMSs recommend city-wide, county-wide, and region-wide strategies and initiatives that represent a combined total cost of approximately $745 million. Some projects did not meet FMP requirements and therefore were listed individually as FMEs or collectively as city-wide FMSs to capture the anticipated construction costs. These FMSs support several of the regional floodplain management and flood mitigation goals established in ***Chapter 3***.

The number and types of projects recommended by the Trinity RFPG are summarized in ***Table 5.3.*** The full list of FMSs and supporting technical data, including their flood risk reduction benefits as applicable, is included in ***TWDB-Required Table 17*** in ***Appendix A***. A map of recommended FMSs is presented as ***Figure 5.7.*** Color gradations in ***Figure 5.7.*** reflect the number of FMSs that overlap for the same area; the darker the color is, the greater the number of FMSs. A one-page report summary for each recommended FMS is included in ***Appendix E***.

Table 5.3: Summary of Recommended Flood Management Strategies

FMS Type	FMS Description	# of Potential FMSs Identified	# of FMSs Recommended	Total Cost of Recommended FMSs
Education and Outreach	Turn Around, Don't Drown Campaigns; NFIP Education; Flood Education; Dam Safety Education; Floodplain Regulatory Awareness	22	19	$975,000
Flood Measurement and Warning	Flood Warning Systems; Rain/Stream Gauges and Weather Stations; Low Water Crossings (LWCs)	20	20	$5,300,000
Property Acquisition and Structural Elevation	Acquire High Risk and Repetitive Loss Properties; Acquire and Preserve Open Spaces; Flood-Proofing Facilities	20	20	$181,545,000
Regulatory and Guidance	City Floodplain Ordinance Creation/Updates; Zoning Regulations; Land Use Programs; Open Space Regulations	62	59	$86,600,000
Infrastructure Projects	Hazardous Roadway Overtopping Mitigation Program; Citywide Drainage Improvement	5	5	$430,000,00
Floodproofing	Structural and nonstructural measures to reduce a structure's risk of flooding; weather hardening.	2	2	$30,500,000
Other	Debris Clearing Maintenance; Channel Maintenance and Erosion Control; Dam Inspections; Levee Inspections; City Parks; Green Infrastructure; Open Space Programs; Nature-Based Solution Planning Studies	14	13	$10,489,000
	Total	**145**	**138**	**$745,409,000**

Figure 5.7: Map of Recommended Flood Management Strategies



Bibliography

FEMA. (2009, June). *Final BCA Reference Guide.* Retrieved from https://www.fema.gov/sites/default/files/2020-04/fema_bca_reference-guide.pdf

TWDB. (2021, April). Exhibit C: Technical Guidelines for Regional Flood Planning.

Chapter 6: Impact and Contribution of the Regional Flood Plan

Task 6A – Impacts of the Regional Flood Plan

The goal of ***Task 6A*** is to summarize the overall impacts of the Flood Management Evaluations (FMEs), Flood Mitigation Projects (FMPs), and Flood Management Strategies (FMSs) recommended in the Trinity Regional Flood Plan. This includes potential impacts to:

- Areas at risk of flooding
- Structures and populations in the floodplain
- The number of Low Water Crossings (LWCs) impacted
- Future flood risk
- Water supply (more detail provided in ***Task 6B***)
- Overall impact on the environment, agriculture, recreational resources, water quality, erosion, sedimentation, and navigation within the Trinity Region

The Trinity Regional Flood Plan fosters the preservation of life and property and the development of water supply sources, where applicable. This chapter describes the processes undertaken by the Trinity Regional Flood Planning Group (RFPG) to evaluate these impacts and summarizes the outcomes of this effort.

The impacts will generally be determined based on two, before-and-after comparisons considering implementation of the Trinity Regional Flood Plan. The comparisons are made for the 1% and 0.2% annual chance storm events for the same types of information provided under ***Task 2A*** and ***Task 2B***. These two comparisons may, for example, also indicate a percent change in flood risk faced by various elements, including critical infrastructure. The comparisons illustrate how much the region's existing flood risk will be reduced through implementation of the plan, as well as how much additional, future flood risk (that might otherwise arise if no changes were made to floodplain policies) will be avoided through implementation of the Trinity Regional Flood Plan, including recommended changes/improvements to the region's floodplain management policies. This effort included:

- A region-wide summary of the relative reduction in flood risk that implementation of the Trinity Regional Flood Plan would achieve in regard to life, injuries, and property.
- A statement that the FMPs in the plan, when implemented, will not negatively affect neighboring areas located within or outside of the region.
- A general description of the types of potential positive and negative socioeconomic or recreational impacts of the recommended FMSs and FMPs within the region.

- A general description of the overall impacts of the recommended FMPs and FMSs in the Trinity Regional Flood Plan on the environment, agriculture, recreational resources, water quality, erosion, sedimentation, and navigation.

Summary of Flood Risk Reduction

Flood Mitigation Project Impacts

Fifty-six FMPs were identified and recommended, as discussed in ***Chapters 4*** and ***5***. As proposed, the recommended FMPs within this plan, when implemented, will not negatively affect neighboring areas located within or outside of the Trinity Region. The local sponsor will ultimately be responsible for proving that the final project design has no negative flood impacts prior to construction.

Thirty-three of these recommended projects are infrastructure improvement projects that have the potential to increase flows downstream by adding and expanding channels, culverts, storm drain systems, and/or bridges. Four of the recommended FMPs are local or regional detention projects that provide sufficient storage capacity to mitigate for flood events associated with the 25-year (25% annual chance storm event) or 100-year flood (1% annual chance storm event). Eleven of the recommended projects are infrastructure improvements exclusively related to urban storm drain enhancements. Three of the recommended FMPs are property acquisitions that are located within the 100-year floodplain extents. Two of the recommended projects are dam improvements to meet Texas Commission on Environmental Quality (TCEQ) dam safety requirements. Two of the recommended FMPs involve the installation of safety improvements at hazardous stream crossings. The last recommended project proposes to replace a low water crossing with a bridge crossing.

To make certain that there will be no negative impacts to neighboring areas, conveyance mitigation measures (such as detention and water quality ponds) have been included in the projects and should be analyzed and designed by the sponsor when the projects are funded. The comparative assessment to determine "no negative flood impact" on upstream or downstream areas or neighboring regions was performed based on currently available planning level data.

Table 6.1 provides a summary of the expected reduction in flood risk (100-year flood) that would result from the implementation of the 56 recommended FMPs. These FMPs will provide flood risk reduction benefits to nearly 26,000 people within their zone of influence and help alleviate roadway flooding conditions. It is anticipated that these exposure reduction results will significantly increase as additional FMPs are further developed and added to the plan in the future.

Table 6.1: Summary of Impacts of Recommended Flood Mitigation Projects to Flooding in the Trinity Region for the 1% Annual Chance Storm Event Flood

Flood Exposure*	Existing Conditions	After FMP Implementation	Exposure Reduction from FMPs
Exposed structures	5,084	3,102	1,982
Exposed population	45,691	25,880	19,811
Exposed LWCs	129	91	38
Number of road closure occurrences	950	604	346
Road length (mile)	154	97	57

In general, an analysis of the 0.2% annual chance storm event was not included in the Hydrologic and Hydraulic (H&H) models that supported the recommended FMPs. However, three models submitted by the FMP sponsors included an analysis of the 500-year storm event. The summary of these results for the 500-year storm event, including the exposed area and the number of structures removed from the exposed area, are included in ***TWDB-Required Table 13***. The specific flood exposure parameters called out in ***Table 6.1*** cannot be quantified for the 500-year storm event at this time. In general, these FMPs are designed to mitigate for the impacts caused by the 100-year storm event. Therefore, the benefits for the 500-year storm event are much smaller, but it is anticipated that positive impacts would result from the implementation of the recommended FMPs for the 0.2% annual chance storm event for flood exposures.

If fully implemented, this plan will have profound and lasting impacts on flood reduction in the Trinity Region. It is important to note that ***Table 6.1*** only demonstrates the flood exposure analysis for the 56 recommended FMPs.

Flood Management Strategy Impacts

One hundred thirty-eight FMSs have been recommended by the Trinity RFPG, in seven comprehensive categories. While not readily quantifiable, these strategies and measures will generally:

- Protect the health, safety, and well-being of individuals within the region while simultaneously improving the economic well-being by reducing the flood frequency and severity
- Provide advanced warning of flood risks
- Minimize the number of drivers on flooded roads
- Give community officials the resources they need to prevent construction in flood prone areas
- Alleviate known flooding issues

Development, especially in the floodplain, leads to increases in flood flows that can cause downcutting and erosion of streams – both of which ultimately lead to environmental issues. The FMSs in the Trinity Region will help minimize and prevent future damage, which will help preserve developable land, protect agriculture, reduce erosion, and reduce downstream sedimentation. Most flood mitigation measures have the potential to adversely impact neighboring areas, especially when conveyance is increased. These impacts will be mitigated during design and construction to verify that no adverse impacts occur. Many of the FMSs will require more active floodplain management by communities in the region which will burden community officials who must enforce regulations and will likely meet some resistance from citizens and developers wishing to engage in construction within the floodplain. These issues can be overcome and lead to more resilient communities, and full funding of the recommendations in the Trinity Regional Flood Plan would aid in providing the tools needed to accomplish these goals.

Regulatory and Guidance

There are 59 recommended FMSs that are classified in this category. Actions listed within this category will improve regulation of development to decrease current and future flood risks. Some sample FMSs include National Flood Insurance Program (NFIP) participation, stormwater management criteria development, and stormwater utility fee development. Positive impacts include:

- Reducing the number of structures and roadways built in the floodplain
- Minimizing expansion of future floodplains
- Protecting riparian areas from development – which supports the environment, water quality, erosion, and sedimentation
- Providing more regulatory certainty and consistency across the region

Potential negative impacts include increased regulatory burden on citizens and increased staff workload for communities.

Property Acquisition and Structural Elevation

These actions acquire properties or raise structures to protect against flooding. There are 20 FMSs in the Trinity Region that fall within this category. Example FMSs include flood-proofing or buying flood-prone structures for demolition to remove them from the floodplain. Anticipated positive impacts include reducing the number of structures in the floodplain; increasing protection of citizens, allowing people to remove themselves from the floodplain without losing their investments; and ultimately protecting riparian areas from development, which in turn protects natural environments and water quality while reducing erosion and sedimentation. Potential negative impacts include increasing the regulatory burden on citizens, increasing staff workloads for each community, causing "blight" in certain neighborhoods if not handled appropriately, and creating politically objectionable appearances in some circumstances.

There are four property acquisition FMSs in this category with detailed evaluations regarding the estimated effects of implementing these strategies. As detailed in ***TWDB-Required Table 14 (Appendix A)*** and summarized in ***Table 6.2***, these recommended FMSs would remove 189 structures, 75 of which are residential structures, from the 1% annual chance storm event floodplain. Doing so would help protect over 200 people within the 100-year floodplain. This table quantitatively demonstrates how property acquisition minimizes the number of repetitive flood loss properties, prevents new structures from being built in the floodplain, and removes existing structures from the floodplain. Moreover, these flood risk reductions can be increased as additional FMSs are further developed and added to the plan in the future.

Table 6.2: Flood Exposure Reduction of Flood Management Strategies in the Trinity Region for 1% Annual Chance Storm Event

Flood Exposure*	Existing Conditions	After FMS Implementation	Exposure Reduction from FMSs
Exposed structures	23,846	23,657	189
Exposed population	185,068	184,843	225

**This table only demonstrates reductions for FMSs 032000061, 032000062, 032000074, and 032000147.*

The potential 0.2% annual chance storm event flood exposure reduction for these FMSs is currently unknown and will depend on the property acquisition programs defined by the sponsors. Typically, property acquisition programs focus on properties that are within the regulatory 100-year floodplain, but the sponsors may decide to expand their programs to include properties in the 500-year floodplain. As such, there is potential for these FMSs to have an impact in the number of structures located within the 500-year floodplain, but the exact number cannot be determined at this time.

Education and Outreach

Some strategies considered in this category will increase awareness of flooding issues, risks, and regulation to citizens and other entities. There are 19 recommended Education and Outreach FMSs for the Trinity Region, including:

- Turn Around Don't Drown campaigns
- Public awareness campaigns
- County-wide flood education programs

Anticipated positive impacts include reduced floodplain regulation violations which can decrease flood risks, increased public awareness of flood hazard areas, and increased awareness of imminent flood events. These activities would promote early evacuations and mitigation measures to prevent damages, save lives, and minimize risky behavior during floods. A negative impact of this strategy category is that it could increase staff workloads for communities.

Flood Measurement and Warning

There are 20 of these strategies for the Trinity Region. This type of FMS involves the installation and operation of rainfall and streamflow measurement devices. These devices provide real-time or near real-time measurements that can be sent to entities for further analysis. Such information provides first responders with advanced notification to set out barricades to block streets, check that automated gates operated as expected, confirm flashing lights activated, and issue other warnings, as appropriate. Example FMSs include installing rain and stream gauges and flood warning systems, in addition to general safety improvements. The anticipated benefits of implementing this FMS would be allowing first responders to better advise people at risk of anticipated flooding to better prepare for potential flooding or to evacuate the area based on the conditions at the time. Flashing lights and barricaded roads reduce the number of vehicles driving across flooded roads. All of these measures can help save lives. Potential negative impacts include increasing staff workloads for communities and possible false alarms or failed warnings if the system is not properly maintained and calibrated.

Infrastructure Projects

This category contains five recommended strategies that all relate to infrastructure improvements. The actions listed in this category include the Hazardous Roadway Overtopping Mitigation Program for the City of Fort Worth and multiple entities with citywide drainage improvement programs. These programs generally include storm drain improvements, channel improvements, culvert enhancements, upsizing railroad crossings, and the construction of detention ponds. These actions are listed as strategies since the Sponsors submitted the program in its entirety and the Sponsor has already established the program.

Floodproofing

Two FMSs that fall into this category. Floodproofing includes structural and nonstructural additions, changes, or adjustments to structures which reduce or eliminate flood damage to real estate or improved real property, water and sanitary facilities, structures, and their contents. One of the strategies relates to the Polk County facilities, and the other strategy is for the Montague County Sewage Treatment Plants.

Other

This category is comprised of any other type of FMS that does not fall within the six categories previously outlined. Examples of types of FMSs that fall within this category are dam and levee inspection programs, nature-based solutions (i.e., green infrastructure), site-specific maintenance programs, and county-wide maintenance programs. Thirteen FMSs were identified in this category. Some of the potential benefits include:

- An established, routine-level maintenance plan/program to clear debris from flood-prone areas such as bridges, box culverts, and drainage systems to prevent overtopping and backup during flood events
- developing plans to increase channel and bank stabilization by reducing erosion impacts
- Preparing an inspection program to look for any maintenance problems or levee and dam failure issues

A potential negative impact includes increasing local staff workloads to maintain these areas routinely and properly.

Flood Management Evaluation Impacts

A total of 507 FMEs were recommended by the Trinity RFPG in four broad categories. Descriptions of these categories, examples, and their positive and negative impacts follow.

Preparedness

Preparedness conducts evaluations pertaining to preparing for flood events. Example FMEs in this category are inundation studies, dam compliance assessments, and a hazard/vulnerability assessment. These actions can provide a positive impact by having preemptive evaluations and strategies to better prepare an area or community in the event of flood. A potential negative impact of these types of FMEs is that they could increase staff workloads for communities. There are five FMEs in this category.

Project Planning

Evaluations marked as project planning are those associated with feasibility assessments and preliminary engineering studies to evaluate alternatives and/or perform designs up to 30 percent for specific flood prone areas that were previously identified by sponsors. There are 324 recommended FMEs in the Trinity Region in this category. Typical FMEs in this category include storm sewer upgrades, culvert upsizing, and channel modifications. Expected positive impacts include reducing properties at risk of flooding, reducing existing facilities exposure, and reducing roadway overtopping. One negative impact is that all conveyance improvement projects have the potential to increase flooding downstream. Mitigation measures will need to be considered during the development of these actions.

Watershed Planning

Actions conducting watershed studies to establish accurate floodplain modeling and mapping and evaluation of potential flood mitigation measures are marked as watershed planning. This includes Flood Insurance Studies (FIS), watershed studies, and city-wide and county-wide drainage master plans. Typical positive impacts include:

- More accurate flood maps, which promote risk avoidance and improved regulations and planning
- Understanding the needs for flood reduction in a watershed for better allocation of resources
- Providing design details needed for eventually converting a FME into an FMP that can be funded and implemented
- Reductions in flood exposure

All conveyance improvement projects have the potential to increase flooding downstream; therefore, mitigation measures will need to be considered if any such projects are identified during the FME analysis. In addition, more projects are usually identified than can be funded.

Most of the Trinity Region has floodplain mapping, but approximately 70 percent of mapped areas are considered outdated and/or approximated. A total of approximately 38,000 stream miles were classified as outdated and/or approximated in the Trinity Region. The Trinity RFPG recommended 35 county-wide FMEs to improve mapping coverage, each of which identifies the areas in need of flood risk identification and/or updates. The Trinity RFPG determined that the stream miles to be included in this initial set of FMEs would be 25 percent of the total within a given county. This determination was based on the adopted short-term goal of reducing areas identified as having gaps in flood mapping by 25 percent. Overall, the recommended county-wide FMEs would provide up-to-date mapping for approximately 9,500 stream miles.

Flood mapping data helps communities quantify and manage their flood risk. It also provides communities a pathway to access flood insurance administered through the NFIP. Improved mapping and models would allow the public, developers, planners, and local officials to consider their flood risks, while balancing the desire to develop in such areas. The model availability will help communities evaluate potential FMPs to reduce flood risks and impacts in the area. These models, along with flood gauges and flood early warning systems, will also help bring awareness to flooding and allow for more rapid and accurate road closures.

Other

There are 22 evaluations outside of the categories previously discussed, and they include dam studies and evaluations. These actions focus on increased awareness on the condition of Natural Resources Conservation Service (NRCS) and Soil and Water Conservation District

(SWCD) dams and rehabilitating the dams that are not in compliance. The scope and scale of a dam study can vary widely, and there is uncertainty in terms of the number of dams that could potentially be rehabilitated and further studied. A positive impact of this action is that it can lead to better prioritization of the dams for continued and future maintenance. A negative impact is that this evaluation does not directly address flooding issues. Also, dams generally require both federal and local government participation to maintain data and allocate resources such as budget, staff availability, and time.

Existing Flood Risk Exposure

Table 6.3 demonstrates the existing flood risk exposures for all FMEs in the boundaries of the Trinity Region. The watershed studies and project specific FMEs will provide the information needed to verify that cost-effective flood mitigation measures are implemented in the Trinity Region that do not adversely impact other areas. These projects will reduce flood risks, save lives, and protect valuable infrastructure.

Flood mapping will help communities quantify and manage their flood risk and provide a pathway to access flood insurance administered through NFIP. Watershed planning will help distribute resources equitably throughout the region to implement plans, programs, and projects that maintain watershed function and prevent adverse flood effects. Moreover, the detailed modeling and mapping will also help protect recreational resources and agriculture by identifying flood risk to these areas and allowing evaluation of impacts of future development.

Table 6.3: Summary of Existing Flood Risk Exposure in the Trinity Region

Flood Management FME Exposures	1% Annual Chance Storm Event	0.2% Annual Chance Storm Event
Population	11,032,923	444,808
Agricultural land (square miles)	9,178,538	234
Critical facilities	284,145	474
Road length (miles)	170,778	1,940
Structures	3,129,957	55,581
Residential structures	2,701,686	36,454
LWCs	11,247	110

Until all FMEs are completed, their specific benefits cannot be quantified; however, the initial analysis shows that over 2.5 million residential structures are currently in the 1% annual chance storm event floodplain impacted by the proposed FMEs. These structures house approximately 11 million people. Tens of thousands of additional people are exposed to risk as they travel across flooded roadways and over 11,000 LWCs. These FMEs will help reduce the risks to the Trinity Region and help prevent additional people from being exposed to the 1% annual chance storm event floodplain due to expansion of the floodplain and uncontrolled development. By providing more accurate information on the flood risks, the communities will be empowered to control development within the floodplain.

None of the FMSs, FMEs, or FMPs specifically address water supply issues and are not expected to have an impact on the water supply.

Effects of Regional Flood Plan Implementation

Avoidance of Negative Effects

Potential negative effects were analyzed in detail for each FMP. The Trinity RFPG reviewed the models submitted for adherence to the Texas Water Development Board (TWDB) guidance on determining negative effects. While impacts were discovered for 16 of the 56 FMPs, the Trinity RFPG determined that the impacts were minor based on professional engineering judgement. Some FMPs included high-level mitigation measures in the preliminary design, while other FMPs may still need mitigation measures prior to funding or execution of a project. The Trinity RFPG agreed with the findings and chose to recommend these FMPs. The impacts were reasonable based on the scope of the individual projects, and the overall project benefits exceeded the impacts.

Potential negative effects were also a consideration for the FMEs and FMSs. The planning-level assessment for these actions included a review of the potential impacts, based on the limited data available. The FMEs must consider any potential negative effects of the proposed action. There are no negative effects for completing a study or evaluation to gain a better understanding of the proposed flood mitigation action. Like the FMEs, the FMSs will also identify negative impacts if the proposed action is executed. However, there are no negative effects to implement new FMSs. The sponsors for all actions will be responsible for demonstrating a commitment to no negative effects before they can receive state or federal funding. Ultimately, it will be the responsibility of the local sponsor to demonstrate the final project design has no negative effects prior to construction.

Potential Future Benefits

Many of the proposed actions included in this plan will reap benefits now and long into the future. Evaluations and strategies are the best candidates for actions that include current benefits, future benefits, and no adverse effects. Examples of these actions include flood warning systems, buyouts, higher design standards, education and outreach programs, and flood preparedness. These types of actions will increase the community’s resiliency by providing knowledge in advance of a storm, removing development in the floodplain, and preventing future development in the floodplain. With basic floodplain standards, population growth and economic development would occur in areas outside of the floodplain and further away from the flooding source. Together these actions will remove people and structures from the existing floodplain and reduce the future flood risk.

Regional detention, when sized for future development conditions, is an example of a FMP with current benefits, future benefits, and no adverse effects. This allows for future development to occur upstream, while the increased flows have already been mitigated with a detention pond that has been sized to accommodate the increased flows and increased volume of runoff. No negative effects are anticipated for this type of project, as the downstream discharge and volume can be controlled by the outlet structure on the pond.

The policies, developed in ***Chapter 3,*** are another example of how this plan can provide long lasting benefits. The implementation of these policies will reduce future flood risk throughout the region. Collectively, the recommended policies will protect the riparian areas of the floodplain from encroaching development, providing a buffer between development and the flooding source now and in the future.

The implementation of this plan cannot remove all risk associated with flooding. As discussed in ***Chapter 3***, there will be some residual risks that remain even if all actions were pursued and constructed. However, this residual risk would still be much lower in the future with the implementation of the plan, as compared to a no action scenario.

Socioeconomic and Recreational Impacts of the Regional Flood Plan

Flooding can result in significant damage to the economy, environment, infrastructure, property, and people. Various types of flooding can include flash floods, coastal floods, urban floods, riverine floods, and pluvial floods. Several types of flood strategies and projects have been developed to protect against flooding. However, the management of flood risk and the development and implementation of flood defenses has both advantages and disadvantages recreationally and socioeconomically.

There are several types of proposed FMSs and FMPs that could provide recreational or socioeconomic impacts. As stated in ***Chapter 4***, FMS types include education and outreach, flood measurement and warning, infrastructure projects, property acquisition and structural elevation, regulatory and guidance, as well as other strategies like preventative maintenance, erosion control programs, and nature-based solutions. FMPs can include stormwater infrastructure improvements, roadway drainage improvements, regional detention facilities, property acquisition, and flood warning systems.

Ultimately, flood evaluations and the resulting projects protect homes and people, and decrease the rate of erosion, preventing foundation and structural damage in the long run. They also save money in terms of roadway infrastructure repairs due to the effects of flooding.

Socioeconomic Impacts

According to the American Psychological Association, "socioeconomic status can encompass quality of life attributes as well as the opportunities and privileges afforded to people within society" (APA). Studies of socioeconomic status reveal inequities of resources which could prevent people from accessing the services required to plan, respond, and recover from flood events.

Flooding does not only result in destroyed infrastructure and damaged property, but also has an adverse social impact on residents affected. The short-term and long-term impacts on physical and mental health result in changes to the livelihoods of affected citizens creating greater socioeconomic disparity.

The FMSs and FMPs listed can provide region-wide benefits to the disadvantaged or socially vulnerable population by reducing risk and promoting recovery. Watershed planning can contribute to the region's ability to prepare for, respond to, and recover from flood events. Reducing socioeconomic disparities through the implementation of equitable measures can be initiated through planning.

Considering equity of property in the development and implementation of strategies and projects reduces any perceived disadvantages. Any disadvantages would occur if the socioeconomically disadvantaged population was not served directly or indirectly by the FMSs or FMPs.

Recreational Impacts

Using natural or man-made water bodies for recreation is highly valued in the region and throughout Texas. Many waterfront parks are spaces that are designed to be flooded with minimal damage during storm or flood events. Additionally, urban river restorations focus on restoring aquatic and riparian habitats, increasing flood protection, and enhancing recreational potential. Wetlands also play an important role in water resources as these areas store and filter water pollutants. When floodplains are not full of water, they can be used as grazing areas or for other agricultural purposes. Floodplains and wetlands can support tourism, recreation, and agriculture.

While flood defense or protection projects do protect homes, infrastructure, and people, they also protect natural habitats. Many shorelines are conservation areas, and flood defenses help preserve these areas. Maintaining floodplains in their natural states can create positive impacts through potential recreational, environmental, and biological benefits. Several types of flood projects, mainly those that are classified as natural systems, promote biodiversity. Wetlands that function as floodplains support a wide range of bird species, while ponds support a range of reptiles, amphibians, and fish. Riparian systems also sustain several types of animal life.

There are potential disadvantages to using the floodplain and waterfront parks for recreation. If damages were to occur to recreational waterbodies, they could become dangerous to use. While flood strategies and projects can be effective at protecting people, property, and resources, the initial installation and ongoing maintenance costs could be prohibitive. These costs can overwhelm communities struggling to find funding for long-term flooding solutions.

Summary of Regional Flood Plan Impacts

The Trinity RFPG created a Technical Subcommittee that performed a comprehensive evaluation and selection process to make recommendations on flood mitigation actions and reported their findings to the Trinity RFPG. After a thorough screening, keeping all the TWDB requirements in mind for inclusion in the Trinity Regional Flood Plan and other additional considerations established by the Technical Subcommittee, the Trinity RFPG made final recommendations. Only 56 out of 73 potentially feasible FMPs and 138 out of 145 potentially feasible FMSs were recommended. Each of the recommended FMPs and FMSs demonstrated no negative impacts on its neighboring area, which means the action will not increase the flood risk of surrounding properties and will have no negative impact on an entity's water supply. While evaluating the FMPs, the Trinity RFPG confirmed that each of the recommended FMPs supports at least one of the regional floodplain management and flood mitigation goals established in ***Chapter 3*** and each FMP does not have any anticipated impacts to water supply or water availability allocations as established in the most recently adopted State Water Plan. Only 56 FMPs out of 73 potential ones complied with the TWDB data requirements. For the FMSs, some were not recommended if they were redundant with another recommended FMS or if their purpose was primarily related to stormwater quality. In some cases, multiple FMSs were combined into a single FMS for recommendation. These merged FMSs included the development of county-wide educational programs and updates to land use planning and zoning regulations.

Sixteen of the recommended FMPs did not strictly comply with the no negative impacts requirements. However, they were still considered by the Trinity RFPG as not having adverse impacts due to various justified conditions and based on professional engineering judgment. Since no structural FMSs were identified within the region, no negative impacts are anticipated from them. Overall impacts and benefits from these recommended FMSs or FMPs in the regional flood plan were explored for the Trinity River Region from the standpoint of environment, agriculture, recreational resources, water quality, erosion, sedimentation, and navigation in the following section.

Environmental

According to Senate Bill (SB) 3 (Texas Legislature, 2007), all major river basins and bay systems in Texas should be able to maintain an environmental flow to sustain a good ecological balance.

To maintain flows, the necessary quantity of flow must be defined and protected while maintaining balance with human and other uses. ***Chapter 4*** mentioned multiple studies on the Trinity Region's environmental flow needs. Per those studies, recommended FMSs and FMPs should be able to maintain the environmental flow in the Trinity River at the Grand Prairie, Dallas, Oakwood, and Romayor gauge locations as established in SB 3.

According to a Trinity River Authority (TRA) study (TRA, 2017), floodplain management is more impactful on riparian areas than high pulse flow management and return flows at the base flow level to satisfy subsistence and base flows. Recommended FMSs or FMPs at or upstream of the above-mentioned locations will focus on managing floodplain and maintaining return flows to satisfy SB 3 subsistence and base flows. Furthermore, by ensuring an increase of base flow, FMSs and FMPs can increase Dissolved Oxygen (DO) in the water. Increased base flows can also keep the water temperature within a goal range and to meet the Texas Instream Flow Program (TIFP) temperature goals in select shallow areas in Oakwood. At Romayor, maintaining the required baseflow will provide continuous sand transport. Apart from these, the recommended FMSs or FMPs are expected to reduce the extreme peak flows of the high pulse flow SB 3 values at the above locations and maintain the periodic high pulse flows required to flush sediment and to sustain ecological and habitat functions.

Agricultural

While the occasional seasonal flood can provide benefits to agricultural lands such as depositing nutrient-rich sediment onto the floodplain, flood water can also be harmful to crops and livestock. Some harmful outcomes include destroying millions of dollars' worth of agricultural investment, stranding or even drowning livestock, creating water-logged conditions that delay planting or harvesting, washing away productive topsoil, and damaging farm equipment and infrastructure.

Implementing the recommended FMSs or FMPs will potentially reduce extremely high flows in rivers and streams, thereby preventing flood waters from inundating areas outside of the overbanks including agricultural areas. Structural FMSs or FMPs, such as small flood control ponds, also have the potential to assist in agricultural production by serving the dual purpose of flood mitigation and water supply. Non-structural FMSs or FMPs include agricultural conservation practices such as conservation tillage, residue management, cover crops, and furrow dikes which can contribute to flood peak flow reduction and reduce the overall impact of flooding. These practices not only reduce downstream flooding by containing or delaying surface runoff and increasing infiltration on agricultural lands, but also reduce soil and nutrient losses, thereby improving downstream water quality.

Recreational Resources

When operated to mitigate flood risk, recreational use of the lakes and reservoirs in the Trinity Region can be significantly reduced. Flood control reservoirs hold water at the flood pool level (which is considerably higher than the normal pool) during peak runoff periods until the impounded water can be safely released downstream. During these periods, recreational use of adjacent parks, playgrounds, campgrounds, boat ramps etc. may be vastly reduced. Flood risk management through FMSs or FMPs may consist of creating additional flood control reservoirs with the intent of impounding water to mitigate flood risk.

Water quality in the waterbodies may also impact recreational use in flood control reservoirs. The Texas Commission on Environmental Quality (TCEQ) 2020 Texas Integrated Report classifies 69 of the 159 assessment units as "non-supporting" or do not recommend contact recreational use. Recommended FMSs or FMPs include actions that focus on reducing runoff and therefore reducing export of bacteria to waterbodies. Implementing those actions has the potential to improve the recreational use of segments that are currently identified as non-supporting.

Water Quality

The TRA Clean Rivers Program 2020 Basin Summary Report (TRA, 2020) hypothesizes that light penetration in the turbid waters rather than nutrient availability is the limiting factor for algal growth in many of the reservoirs in the Trinity Region. The report also identified the reasons for this additional light penetration and eventually increased algal growth in the presence of abundant nutrients. Proactive watershed protection programs and extensive use of best management practices can counter this nutrient loading and risk of harmful algal blooms. By capturing stormwater runoff and pollutants, structural FMPs - such as small flood control ponds - are expected to improve the water quality of the water supply reservoirs. However, excessive nutrients in these reservoirs may cause algal blooms. In such cases, non-structural FMEs or FMPs that reduce stormwater runoff production are recommended to reduce the amount of nutrient runoff.

Since intermittent streams are not frequently washed out or assimilated, many can have high bacteria levels. Recommended non-structural FMPs and FMSs will reduce the runoff and subsequently, not provide transport for the bacteria; conversely, structural solutions will help to maintain small levels of flows, flushing out the downstream intermittent streams and improve assimilation.

Erosion

The TWDB funded the Trinity River Basin Environmental Restoration Initiative 2010 (Wang, et al., 2010) which studied the rates and sources of sediment (and nutrient) loading to 12 major water supply reservoirs in 10 watersheds of the Upper Trinity Region. The initiative identified a few basins with a wide range of annual overland, bank, and bed erosion. Some of those basins are within the recommended FMS and FMP areas. One of the other relevant findings of this study was identifying the positive impact of small flood control reservoirs on the reduction of total sediment load delivered to those reservoirs.

Recommended structural FMSs or FMPs are expected to have similar impacts as small flood control reservoirs identified in the TWDB study. Location, drainage area, and watershed characteristics of the structural FMSs or FMPs are some of the factors that will influence the severity of erosion. Conservation practices, which are part of the recommended non-structural FMSs or FMPs, may also contribute to reducing erosion and transport of sediment in the Trinity Region. Practices like 'no rangeland grazing' can reduce source sediment loads to the waterbodies in the Trinity Region.

Sedimentation

Sedimentation is a natural process by which surface water runoff transports small particles of soil from upstream to downstream. As the water slows down, the particles settle to the bottom of the river or lake. Sedimentation has been reported for most major reservoirs in the Trinity Region based on surveys conducted by the TWDB.

Structural FMSs or FMPs, such as a small flood control reservoir, receive and impound water (and sediment) from the respective drainage area. Long residence time in a flood control pond results in settling of large proportions of the incoming sediment. Periodic discharges from small flood control projects are generally expected to carry smaller sediment loads than the influent runoff. Therefore, structural FMSs or FMPs are expected to reduce sedimentation in downstream water supply reservoirs by trapping sediment in their pools. While sedimentation in the large downstream reservoirs potentially reduce, sedimentation is expected to occur in the individual flood control projects.

Non-structural FMSs or FMPs, such as conservation practices that reduce sediment production at the source, are expected to reduce sedimentation in both structural FMSs or FMPs and large downstream reservoirs.

Navigation

In 1963, the United States Army Corps of Engineers (USACE) approved making the Trinity River navigable by barges. In 1965, Congress and former President Lyndon B. Johnson approved the project as a package of flood control and navigation projects including a barge canal connecting the Dallas-Fort Worth (DFW) metroplex with the Gulf of Mexico. The barge canal was estimated to cost approximately $1 billion. In 1973, voters rejected to finance the barge canal and USACE subsequently abandoned the project. Therefore, the Trinity River is not used for commercial navigation. Only recreational navigation - such as canoeing and kayaking in the rivers and creeks and boating in the lakes and reservoirs - was observed in the Trinity Region. These activities are impacted when flows in the Trinity River and water levels in the reservoirs are being actively managed to mitigate flood risk. Recreational activities are restricted when the rivers and reservoirs are at or above flood stage. Structural FMSs or FMPs that recommend building flood control structures or any other measures that capture the additional water are expected to increase recreational navigation in the Trinity Region. None of these structural improvements are located along the main stem of the Trinity River.

Task 6B – Contributions to and Impacts on Water Supply Development and the State Water Plan

The goal of ***Task 6B*** is to evaluate potential impacts of the regional flood plan on water supply development and the State Water Plan. This section describes the processes undertaken by the Trinity RFPG to achieve these tasks and summarizes the outcomes of this effort. This effort included:

- A region-wide summary and description of the contribution that the Trinity Regional Flood Plan would have on water supply development, including a list of specific FMSs and FMPs that would measurably impact water supply
- A description of any anticipated impacts that the recommended FMSs and FMPs may have on water supply, water availability, or projects in the State Water Plan

Contribution of the Regional Flood Plan on Water Supply Development

RFPGs must list recommended FMSs or FMPs that, if implemented, would measurably contribute to water supply, such as:

- A direct increase of water supply volume available during drought of record
- A direct benefit to water availability
- An indirect benefit to water availability
- No anticipated impact on water supply

Examples of FMSs and FMPs that could measurably contribute to water supply include those that:

- Recharge aquifers (directly or indirectly)
- Modify large stormwater detention structures to include a water supply component for irrigation or other needs
- Implement stormwater management ordinances that manage flooding and also include a water supply aspect of beneficial reuse for irrigation purposes
- Implement green infrastructure, natural channel design, stormwater detention, low impact development, and other measures that – while not generating a measurable water supply impact – can help mitigate flood flows and protect water quality

These solutions can help manage downstream water treatment costs and benefit rate payers. Additionally, RFPGs must also list recommended FMSs or FMPs that, if implemented, would negatively impact and/or measurably reduce water availability volumes that are the basis for the most recently adopted State Water Plan or water supply volumes.

An example of an FMS or FMP that could measurably reduce water availability involves reallocating a portion of existing reservoir storage that is currently designated for water supply purposes to be used for flood storage instead. No such actions are recommended for the Trinity Region. Additionally, land use changes over time could potentially reduce groundwater availability due to less naturally occurring aquifer recharge. Alternatively, an FMS that preserves open space or limits additional impervious cover could help maintain aquifer recharge.

As noted in ***TWDB-Required Table 13*** and ***TWDB-Required Table 14*** in (***Appendix A***), the Trinity Region determined that no recommended FMSs or FMPs that would measurably contribute or have a negative impact and/or measurably reduce water supply.

Flood Management Strategies

Several nature-based FMSs that could potentially be applicable to water supply are recommended in this plan, including the implementation of green infrastructure, low impact development, and regional detention ponds. These nature-based FMSs could help mitigate flood risk by slowing and reducing stormwater discharges while improving water quality. Other FMSs that could be applicable include property acquisition and/or preservation of open spaces as these types of FMSs could limit impervious cover and help maintain aquifer recharge. Additionally, erosion control and/or channel maintenance strategies could impact sedimentation and improve water quality. Regulatory and guidance FMSs may affect water supply through floodplain ordinances that manage flooding but could also include reuse or green infrastructure aspects. Ultimately, it was determined that these strategies would not have a measurable impact on water supply.

Other FMS project types, such as education and outreach strategies and flood measurement and warning strategies, do not apply to water supply development.

Flood Mitigation Projects

Additionally, several FMPs could be relevant to water supply. Five FMPs involve the design and construction of detention ponds which will reduce peak flows and improve water quality. Although not currently planned, the design phase of these detention ponds could potentially be modified to include a small-scale water supply component for irrigation or other nearby needs. Infrastructure FMPs, such as channel and drainage improvements, could increase peak discharges downstream, allowing stormwater to flow faster into a state water course and impact water supply. While these FMPs could potentially impact water supply, the region determined that the potential impacts are insignificant.

Anticipated Impacts to the State Water Plan

In response to the 1950's drought, the Texas Legislature established the TWDB in 1957 to prepare a comprehensive long-term plan for the development, conservation, and management of the state's water resources. The TWDB recently produced the 2022 State Water Plan based on the TWDB-approved regional water plans. As stated in SB 1 Section 16.053.a (Texas Legislature, 1997), the purpose of the regional water planning effort is to:

> *"…provide for the orderly development, management, and conservation of water resources and preparation for and response to drought conditions in order that sufficient water will be available at a reasonable cost to ensure public health, safety, and welfare; further economic development; and protect the agricultural and natural resources of that particular region."*

The TWDB established 16 Regional Water Planning Groups (RWPGs) and appointed members who represent 12 key interest categories to each RWPG. This grassroots approach allows planning groups to evaluate region-specific risks, uncertainties, and potential water management strategies from the local water providers. The Trinity Region primarily overlaps the Region C, Region H, and Region I RWPGs as shown in ***Figure 6.1.*** Additionally, a small portion of the Trinity Region (less than 11 percent) falls within the Region B, Region G (Brazos G), and Region D (North East Texas) RWPGs. ***Table 6.4*** shows the RWPGs within the Trinity Region along with associated areas. The Trinity RFPG determined that the recommended FMSs and FMPs are not anticipated to have any measurable impact on water supply, water availability, or projects in the State Water Plan.

Region C

The majority of the Trinity Region is located within Region C. Region C covers all or portions of 16 counties located in North Central Texas. Two major aquifers along with four minor aquifers are located in the region. About 90 percent of the water use in Region C is supplied by surface water. According to the 2021 Region C Plan, there are 34 major reservoirs with conservation storage over 5,000 acre-feet in the region. Major existing reservoirs in Region C that are also located within the Trinity Region flood planning area are listed in ***Table 6.5.*** These reservoirs are permitted for various uses, such as water supply, conservation, irrigation, industrial, navigation, and recreation purposes. Some reservoirs also have additional operational goals that support flood control and/or flood regulation. None of the Trinity Region's recommended FMSs or FMPs impact the operation of these existing reservoirs. A new major reservoir, Bois d'Arc Lake, located in Fannin County is currently impounding water. Bois d'Arc Lake's primary purpose is water supply.

Figure 6.1: Trinity Region Associated Regional Water Planning Groups

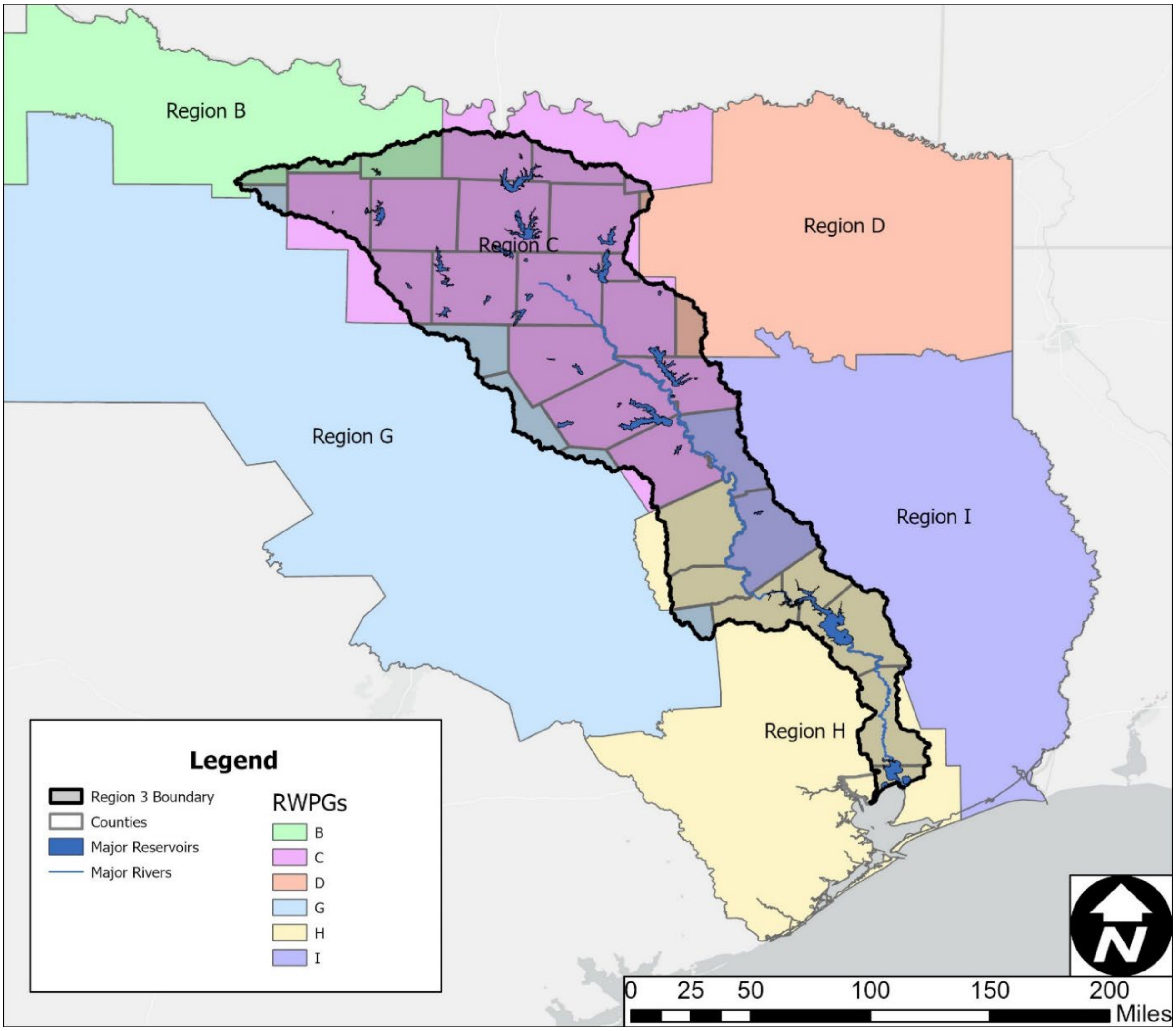


Table 6.4: Regional Water Planning Areas within the Trinity Region

Regional Water Planning Area	Overlapping Area Within Trinity Region (sq. mi.)	Percent of Overlapping Area within Trinity Region (%)
Region C	10,900	61
Region H	3,600	20
Region I	1,400	8
Region G	1,000	6
Region B	600	3
Region D	300	2
Total	**17,800**	

Table 6.5: Major Existing Reservoirs Associated with the Trinity Region

Lake/Reservoir	County	Regional Water Planning Area
Bardwell Lake*	Ellis	Region C
Benbrook Lake*	Tarrant	Region C
Cedar Creek Reservoir	Henderson/Kaufman	Region C
Eagle Mountain Lake	Tarrant	Region C
Fairfield Lake	Freestone	Region C
Forest Grove Reservoir	Henderson	Region C
Grapevine Lake*	Tarrant/Denton	Region C
Joe Pool Lake*	Tarrant/Dallas/Ellis	Region C
Lake Arlington	Tarrant	Region C
Lake Bridgeport	Wise/Jack	Region C
Lake Halbert	Navarro	Region C
Lake Ray Hubbard	Collin/Dallas/Kaufman/Rockwall	Region C
Lake Ray Roberts*	Cooke/Denton/Grayson	Region C
Lake Waxahachie	Ellis	Region C
Lake Weatherford	Parker	Region C
Lake Worth	Tarrant	Region C
Lavon Lake*	Collin	Region C
Lewisville Lake*	Denton	Region C
Lost Creek Reservoir	Jack	Region C
Mountain Creek Lake	Dallas	Region C
Navarro Mills Lake*	Navarro	Region C
New Terrell City Lake	Kaufman	Region C
North Lake	Dallas	Region C
Richland-Chambers Reservoir	Navarro/Freestone	Region C
Trinidad Lake	Henderson	Region C
White Rock Lake	Dallas	Region C
Lake Kiowa	Cooke	Region C
Lake Livingston	Trinity/Walker/San Jacinto/Polk	Region H
Wallisville Lake	Liberty/Chambers	Region H
Lake Anahuac	Chambers	Region H
Cedar Bayou Generating Pond	Chambers	Region H
Alders Reservoir	Liberty	Region H
Houston Country Lake	Houston	Region I
Lake Amon G Carter	Montague	Region B

**Reservoir is permitted to provide flood control and/or flood regulation benefits.*

Region H

The southern portion of the Trinity Region covers the northeastern part of the Region H water planning area. Eight counties from Region H fall fully or partially within the Trinity Region. Region H has two major and four minor aquifers. The major existing reservoirs in Region H that are also within the Trinity Region are listed in ***Table 6.5***. These reservoirs have various uses such as salinity control, water supply, fish and wildlife enhancement, conservation, irrigation, industrial, navigation, recreation, and cooling purposes. None of the Trinity RFPG's recommended FMSs or FMPs impact the operation of these existing reservoirs.

Region I

The Trinity Region flood planning boundary overlays a small part of the Region I water planning area. Only two counties from Region I (Anderson and Houston) fall fully or partially within the Trinity Region. These two counties are on the western side of Region I. Two major and three minor aquifers are located within Region I and the Trinity Region. Only one major reservoir, Houston County Lake (***Table 6.5***) is located in both Region I and the Trinity Region. None of the recommended FMSs or FMPs impact the operation of this existing reservoir.

Region B

The north-western portion of Trinity Region covers part of the southern counties in Region B. Only three counties (Archer, Clay, and Montague) in Region B partially fall within the boundary of the Trinity Region. There are two major aquifers and two minor aquifers within the Region B planning area. One major aquifer (Trinity) and one minor aquifer (Cross Timbers) intersects the Trinity Region. Only one major reservoir, Lake Amon G Carter, is located in this part of Trinity Region (***Table 6.5***). This reservoir is permitted for municipal and industrial mining water supply and recreational purposes. None of the recommended FMSs or FMPs impact the operation of this existing reservoir.

Region D

The north-eastern portion of the Trinity Region covers very small parts of two western counties in Region D. Those two counties are Hunt and Van Zandt. Only two percent of the Trinity Region falls within this Region D boundary. Among the two major and four minor aquifers in the North East Texas Region (Region D), part of both the major aquifers (Trinity and Carrizo-Wilcox) and one minor aquifer (Woodbine) fall within the Trinity Region boundary. None of the reservoirs in the Region D area included in the Trinity Region.

Region G

The western portion of the Trinity Region covers small portions of five counties from the eastern and south-eastern part of Region G. Six percent of Trinity Region falls within the Region

G boundary. Portions of six major and eleven minor aquifers extend into the Brazos G Region and among them two major aquifers (Trinity and Carrizo-Wilcox) and three minor ones are part of the Trinity Region. None of the reservoirs in Region G are included in the Trinity Region.

Bibliography

(n.d.). Retrieved from https://www.apa.org/pi/ses/resources/publications/education

Texas Legislature. (1997). *SB 1*. Retrieved from Texas Legislature Online: https://capitol.texas.gov/BillLookup/Text.aspx?LegSess=75R&Bill=SB1

Texas Legislature. (2007). *SB 3*. Retrieved from Texas Legislature Online: https://capitol.texas.gov/billlookup/Text.aspx?LegSess=80R&Bill=SB3

TRA. (2017, Nov). *Evaluation of Adopted Flow Standards for the Trinity River, Phase 2 (Final Report).* Retrieved from Trinity River Authority of Texas: https://cms9files.revize.com/trinityriverauth/Documents%20Center/Basin%20Planning/Reports/River%20Studies/20171020TRASB3v3phase2.pdf

TRA. (2020). *Trinity River Autoirity Clean Rivers Program 2020 Basin Summary Report.* Retrieved from https://cms9files.revize.com/trinityriverauth/Documents%20Center/Basin%20Planning/Reports/Basin%20Summary%20and%20Highlight%20Reports/2020%20TRA%20Basin%20Summary%20Report%20reduced.pdf

Wang, X., White, M., Lee, T., Tuppad, P., Srinivasan, R., Jones, A., & Narasimhan, B. (2010). *Trinity River Basin Environmental Restoration Initiative 2010.* Retrieved from https://www.twdb.texas.gov/publications/reports/contracted_reports/doc/0704830646_Trinity.pdf

Chapter 7: Flood Response Information and Activities

The following chapter summarizes the flood response preparations in the Trinity Region using demographic, historical, projected, and statistical data from the previous chapters, and by documenting survey responses received from entities through the online data collection website. The Texas Water Development Board (TWDB) stated that the Regional Flood Planning Groups (RFPGs) "shall not perform analyses or other activities related to planning for disaster response or recovery activities." Therefore, this chapter documents the information obtained from entities regarding existing preparations for flood response activities, existing recovery efforts, and potential administrative or policy recommendations (included in more detail in Chapter 8) of this Trinity Regional Flood Plan.

Types of Flooding in the Trinity Region

There are five types of floods that impact the Trinity Region:

- Coastal floods
- Flash floods
- Pluvial floods
- Riverine floods
- Urban floods

Whenever a coastal process such as waves, tide, storm surge, or heavy rainfall from coastal storms creates a flood, it is referred to as coastal flooding. Coastal flooding tends to be the most extreme when the storm surge is high. Storm surge is an abnormal rise of water generated by a storm, over and above the predicted astronomical tides.

Flash floods are floods caused by heavy rainfall over a short period of time. The flood water can be very powerful, making it extremely dangerous. Flash flooding often occurs with little to no advance notice.

Pluvial floods happen when flooding is independent from an overflowing body of water, due to excessive rainfall. The most common example of this is when the drainage system is overwhelmed, and the excess water floods streets and surrounding properties. This may also be known as local flooding.

Riverine floods, or fluvial floods, occur when excess rainfall overtops the riverbank. This overtopping then spills water onto nearby land.

Urban flooding occurs when water flows into an urban region faster than it can be absorbed into the soil or moved to and stored in a lake or reservoir. The two most common types of urban flooding include riverine and flash floods. The Trinity Region is prone to both types of floods.

When such flood events occur, it is imperative that plans are in place to combat the effects of the flooding to protect people and property.

The Four Phases of Emergency Management

As shown in ***Figure 7.1***, emergency management involves four phases (FEMA, 1998):

- **Flood Preparedness:** Actions, aside from mitigation, that are taken before flood events to prepare for flood response activities.
- **Flood Mitigation:** The implementation of both structural and non-structural solutions to reduce flood risk to protect against the loss of life and property.
- **Flood Response:** Actions taken during and in the immediate aftermath of a flood event.
- **Flood Recovery:** Actions taken after a flood event involving repairs or other actions necessary to return to pre-event conditions.

Figure 7.1: Four Phases of Emergency Management

When a severe rain event is projected to occur, steps are taken for preparedness. Disaster preparedness plans are in place, drills and exercises are performed, an essential supply list is created, and potential vulnerabilities are assessed. Examples of preparedness actions include installing disaster warning systems, purchasing radio communication equipment, or conducting emergency response training.

During the response phase, disaster plans are implemented, search and rescue activities may occur, and/or Low Water Crossing (LWC) signs may be erected. Response examples include addressing immediate flood needs through actions such as placing temporary barriers or closing gates at LWCs, installing signage near overtopped roads, or using sandbags to divert water.

In the recovery phase, evaluation of flood damage occurs. Examples of recovery activities can include comprehensive debris management, rebuilding damaged structures, and utilities restoration.

The most important step of the four phases of emergency management is mitigation. Examples of mitigation actions include planning and zoning, floodplain protection, property acquisition and relocation, and public outreach projects. Hazard mitigation is defined by the Federal Emergency Management Agency (FEMA) as any sustained action taken to reduce or eliminate the lasting risk to life and property from hazard events. It is an ongoing process that occurs before, during, and after disasters and seeks to break the cycle of damage and restoration in hazardous areas (FEMA, n.d.). Flood mitigation is the primary focus of the regional flood planning process and plan development efforts regarding identifying and recommending FMEs, FMSs and FMPs by the RFPG. The plan may also include flood preparedness Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs).

Flood Preparedness, Response, and Recovery in the Trinity Region

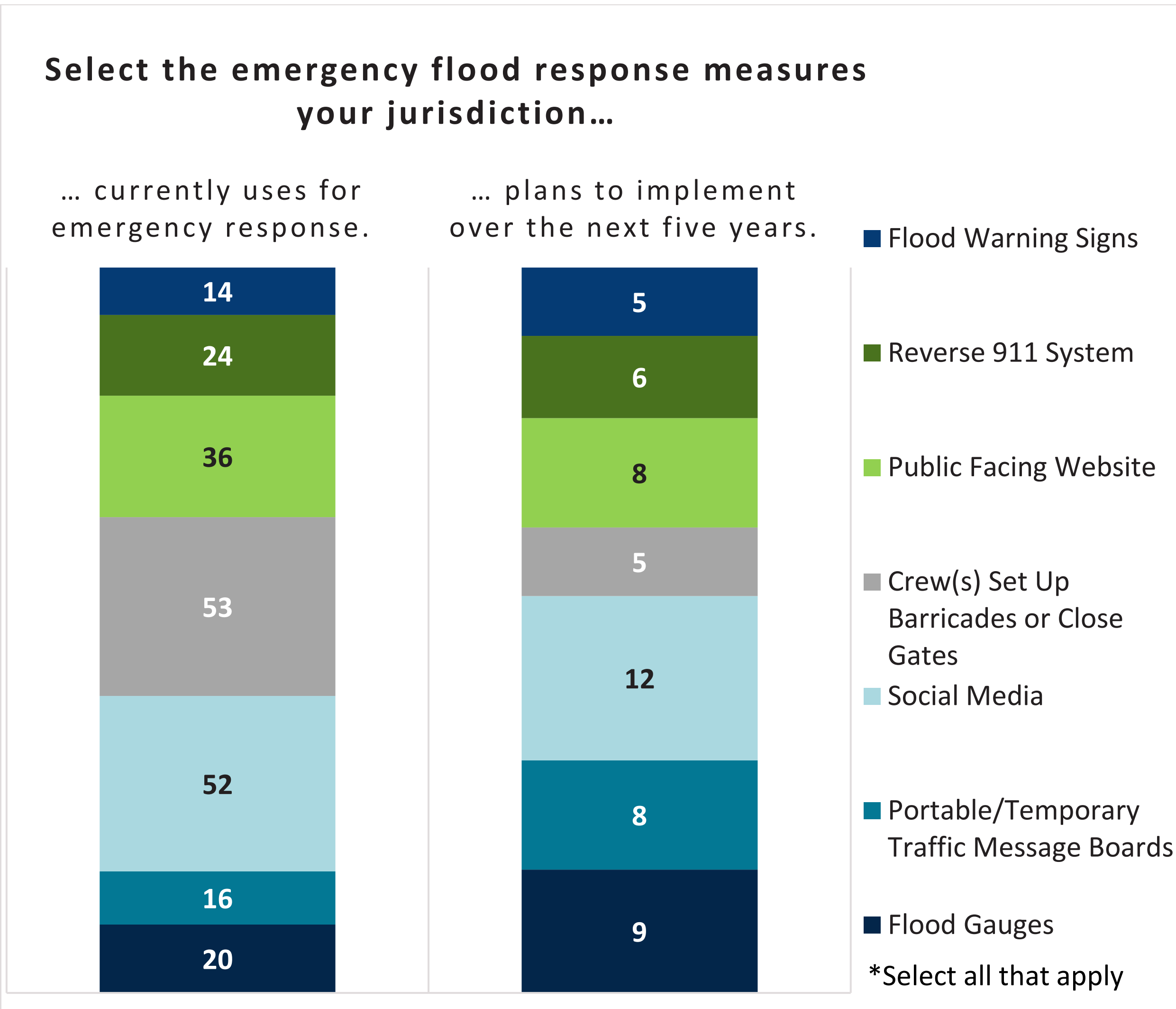
Some cities and counties have Hazard Mitigation Plans (HMPs) that support the preparedness, response, recovery, and mitigation phases. Currently, only 70% of county HMPs in the Trinity Region are approved by FEMA, although some may be in the process of being updated for FEMA approval.

Mitigation actions from HMPs can include the following types of actions:

- Buyout/acquisition/elevation projects
- Drainage control and maintenance
- Education and awareness for citizens
- Equipment procurement for response
- Erosion control measures
- Flood insurance education
- Flood study/assessment
- Infrastructure improvement
- Installation/procurement of generators
- Natural planning improvement
- Outreach and community engagement
- Technology improvement
- Urban planning and maintenance

As discussed in ***Chapter 1***, the Trinity RFPG performed a data collection outreach effort in 2021 that included survey questions applicable to multiple chapters within this plan. The survey responses received from entities in the Trinity Region indicated that several types of actions listed were in place or being implemented in the next five years including flood warning signs, a Reverse 911 system, a public facing website, crews to set up barricades or close gates, social media, portable and/or temporary traffic message boards, and flood gauges. ***Figure 7.2*** summarizes the responses to the survey to which participants were able to select all the options that apply to their entity.

Figure 7.2: Flood Response Measures



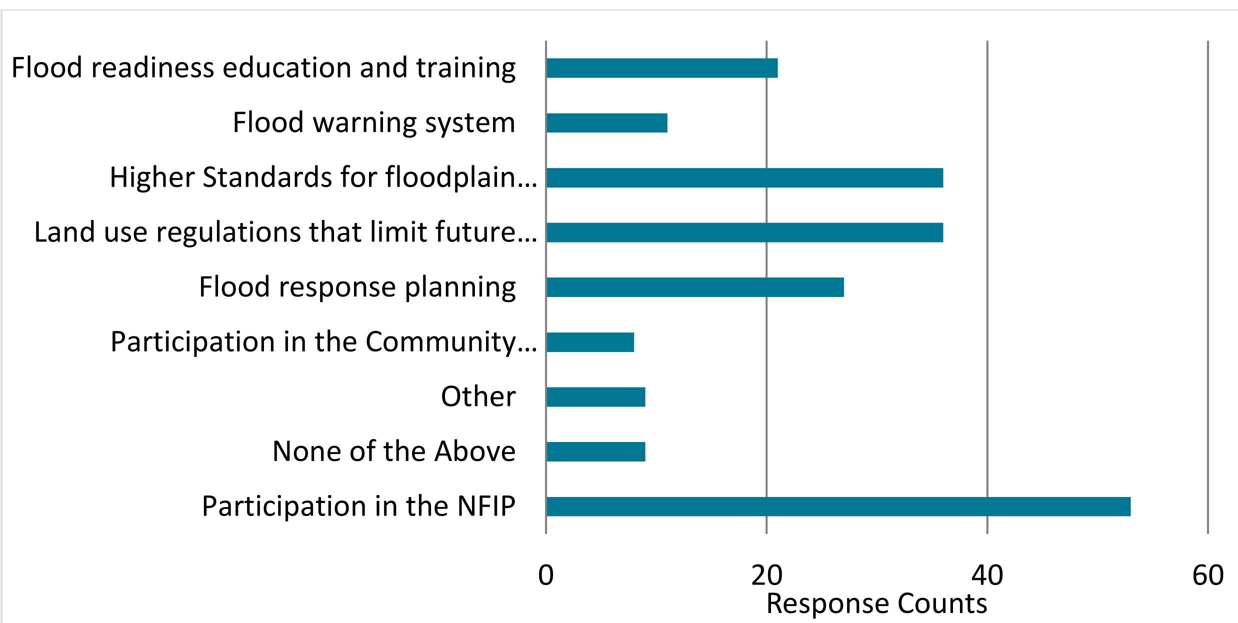
Source: Trinity Region data collection survey results as of September 16, 2021

Once the response measures are in place, recovery can begin. Depending on the duration and extent of the event, various recovery actions may be needed. In the recovery process it is key to have clear communication with relevant entities to communicate needs and with citizens to communicate risks. It is also essential to have trained professionals who can respond to and recover from disasters efficiently and effectively. Debris management and utility maintenance and/or restoration through public works are necessary and time sensitive services. If flooding occurs within a structure, communication with the local floodplain administrator may be required to obtain permits before beginning repairs.

The Texas Flood website, www.texasflood.org, is a collaboration between TWDB, Texas Department of Emergency Management (TDEM), and the General Land Office (GLO) to provide information and resources after a flood event. The website provides helpful information and resources for both communities and individuals seeking post event financial assistance.

Additional measures indicated by the survey responses include measures taken by jurisdictions include promoting the participation in the National Flood Insurance Program (NFIP), focusing on higher standards for floodplain management, and utilizing land use regulations that limit future flood risk. ***Figure 7.3*** summarizes participant responses to these resiliency measures (multiple responses could be selected).

Figure 7.3: Measures to Promote Resilience



Source: Trinity Region data collection survey results as of September 16, 2021

As noted in ***Chapter 1, Table 1.9****,* 45 respondents indicated participation in the NFIP was key to promoting resilience, 32 respondents indicated land use regulations that limit future flood risk were important, and 32 respondents stated taking measures to promote higher standards for floodplain management were key.

Many of the mitigation and preparation actions are done in conjunction with the relevant entities who put these actions into practice.

Relevant Entities in the Trinity Region

The purpose of flood risk management is to help prevent or reduce flood risk by using either structural or non-structural means or a combination of the two. Responsibility for flood risk management is shared between federal, state, and local government agencies; private-sector entities; and the general public. In ***Chapter 1***, the various communities contacted to provide data via the survey included: agricultural agencies, cities, counties, Councils of Government (COGs), districts such as Municipal Utility Districts (MUDs) and Special Utility Districts (SUDs), and state and federal agencies. The various contributing entities and partners are discussed here.

Local Entities

Cities, or municipalities, generally take responsibility for parks and recreation services, police and fire departments, housing services, emergency medical services, municipal courts, public transportation services, and public works (streets, sewers, snow removal, signage, and so forth) services. The Trinity Region includes all or portions of 287 municipalities.

In the aftermath of a flood event, cities and counties coordinate to provide recovery services for residents including but not limited to debris clean up, vital resource distribution, medical care, short-term shelter, buyout programs for flooded properties, and local infrastructure improvements to mitigate future risk in long-term implementation. Cities and counties can provide increased resiliency through the successful implementation of mitigation projects to reduce the impact of floods.

The major responsibilities of the 38 county governments in the Trinity Region include providing public safety and justice; holding elections at every level of government; maintaining Texans' most important records; building and maintaining roads, bridges, and in some cases, county airports; providing emergency management services; providing health and safety services; collecting property taxes for the county and sometimes for other taxing entities; issuing vehicle registrations and transfers; and registering voters.

The preparedness role for a city or county can involve creating an emergency preparedness plan for their entities, educating and training community members on flooding, encouraging people and businesses to purchase flood insurance, and setting up emergency communication lines. In the flood response phase, the entities are to implement the disaster preparedness plan, monitor high water at high-risk locations, alert the community to unsafe conditions, conduct road closures, perform search and rescue missions, update Geographic Information System (GIS) mapping as needed, and contact the federal government for disaster relief. When it is time to implement the recovery phase, each entity should update old or damaged infrastructure, work with the federal government to assess damages, communicate with volunteers and local leaders, and utilize free advisory services that can aid in the recovery process.

Regional Entities

Agricultural extension agents (or "ag extension agents") are employed by land-grant universities and work for the citizens of that particular state by serving as an expert or teacher on the topic of agriculture. Ag extension agents can provide valuable information on preparation and recovery from flood events specific to agricultural entities. The Trinity Region has a significant agricultural footprint that makes working closely with ag extension agents crucial in preparing for disasters, learning about types of disasters, and accessing disaster recovery information.

The nine COGs located within the region are voluntary associations that represent member local governments, mainly cities and counties, and seek to provide cooperative planning, coordination, and technical assistance on issues of mutual concern that cross jurisdictional lines. COGs typically aid in the preparedness phase and can serve as a resource for flood data, flood planning, and flood management. COGs can also be recipients of federal and state grants and have their own response programs. The North Central Texas Council of Governments (NCTCOG) within the Trinity Region includes the Public Works Emergency Response Team (PWERT). This team provides aid during an emergency or disaster when local public works departments are overwhelmed and request assistance.

During recovery from a flood event, COGs serve as a valuable resource by providing information, services, and tools for communities. COGs facilitate recovery through public engagement and community outreach, planning of regional infrastructure studies, and the development of plans to aid in recovery and resilience.

Additionally, NCTCOG provides a Local Disaster and Recovery Framework and Toolkit which includes post-disaster recovery checklists, local plan templates, as well as other documents to aid in the recovery process.

Four Trinity Region COGs (Brazos Valley Council of Governments, Deep East Texas Council of Governments, South East Texas Regional Planning Commission, and Houston-Galveston Area Council) received Community Development Block Grants for Disaster Recovery (CDBG-DR) allocated by the United States Department of Housing and Urban Development (HUD) for

Hurricane Harvey housing recovery assistance. These funds are for housing, infrastructure, and planning through state and local programs.

River authorities or districts in the State of Texas are public agencies established by the state legislature and given authority to develop and manage the waters of the state. The Trinity Region has seven river authorities within its region that have the power to conserve, store, preserve, utilize, and distribute the waters of a designated geographic region for the benefit of the public. The river authorities or districts are essential partners in floodplain management and create their own regulatory and management plans for water use and retention.

Texas Association of Regional Councils assists state and federal partners by coordinating and improving regional homeland security preparedness, planning, and response activities across jurisdictional boundaries. The TDEM works with the regional councils to verify that all regional and local emergency plans are up-to-date and compliant with Texas Government Code. Regional councils also work with TDEM in the event of a disaster within their region to access state resources in a timely manner.

Water districts are local government entities that provide water and sewer service and sometimes roads to its customers and residents, depending on the type of districts. There are three of these types of districts in the Trinity Region. Water districts play a role in the water quality and distribution and can aid in the construction of drainage and infrastructure. In relation to flood preparedness and response, water districts actively monitor water levels of the flood control systems they operate. They are active in flood planning, protection, and outreach efforts within the region.

Water supply and utility districts can include MUDs, Freshwater Supply Districts (FWSDs), Municipal Water Districts (MWDs), and SUDs. A water supply district is a special district given the task of supplying water and sewer needs to a community. Utility districts are political subdivisions that provide infrastructure and services such as water, sewer, and stormwater drainage in areas where city services are not available. Throughout the Trinity Region, there are a total of 164 of these districts. These districts can be useful in the containment and release of flood waters before or during a flood event. During the recovery phase of an event, districts can provide access to services such as water, sewer, and stormwater drainage.

A flood control district is a special purpose district created by the Texas Legislature and governed by County Commissioners Courts. It is a government agency established to reduce the effects of flooding. They utilize flood control infrastructure, such as levees, seawalls, and tide gates to work as physical barriers to prevent areas from flooding. Other measures, such as pump stations and channels, help reduce flooding. There are 39 flood control districts in the region that provide flood control. Flood control districts oversee construction and maintenance of the levees, storm water pump stations, canals, ponds, and other storm drainage management facilities to protect residents, businesses, and their respective assets from the impact of flood-related damage.

Daily river forecasts are issued by the 13 River Forecast Centers (RFCs) using hydrologic models based on rainfall, soil characteristics, precipitation forecasts, and several other variables. Some RFCs, especially those in mountainous regions, also provide seasonal snowpack and peak flow forecasts. These forecasts are used by a wide range of users, including those in agriculture, hydroelectric dam operation, and water supply resources. The forecasts can provide essential information on river levels and conditions for flood preparation and potential evacuations.

Dams and levees are owned and operated by individuals, private and public organizations, and the government. The responsibility for maintaining a safe dam rests with the owner. A dam failure resulting in an uncontrolled release of the reservoir can have a devastating effect on persons and property downstream. It is critical that the owners are part of the flood planning process to promote collaborative and cohesive flood planning.

State Entities

The mission of the TWDB is to lead the state's efforts in providing a secure water future for Texas and its citizens**.** TWDB provides water planning, data collection and dissemination, financial assistance, and technical assistance services to the citizens of Texas. TWDB is statutorily responsible for administering the regional water planning process and preparing and adopting the State Water Plan every five years. Additionally, TWDB offers a variety of cost-effective loan and grant programs that provide for the planning, acquisition, design, and construction of flood related infrastructure, watershed studies, flood warning systems, flood awareness and outreach programs, and water quality improvements. TWDB also works with the Texas Natural Resources Information Systems (TNRIS) to provide real time flooding information through www.texasflood.org.

The GLO is the oldest state agency in Texas. The GLO manages state lands, operates the Alamo, helps Texans recovering from natural disasters, helps fund Texas public education through the Permanent School Fund, provides benefits to Texas Veterans, and manages the vast Texas coast. GLO, through the community development and revitalization division, aids communities in rebuilding, restoring critical infrastructure, and mitigating future damage through resilient community planning. The GLO administers both CDBG-DR and Mitigation (CDBG-MIT) funds from the HUD on behalf of the State of Texas.

The TDEM, a division of the Texas Department of Public Safety (DPS), is charged with coordinating state and local responses to natural disasters and other emergencies in Texas. TDEM is intended to verify the state and its local governments respond to and recover from emergencies and disasters, as well as implement plans and programs to help prevent or lessen the impact of emergencies and disasters. TDEM's Recovery and Mitigation divisions work closely with local jurisdictions, state agencies, and federal partners to confirm Texans successfully navigate recovery processes and become more resilient for future disasters. The Disaster Recovery Task Force was created to assist jurisdictions that have been impacted by an emergency or disaster, to recover more efficiently by starting the recovery process early in the response phase.

There are six TDEM regions within Texas. In those regions, Assistant Chiefs and District Coordinators serve as the division's field response personnel stationed throughout the state. They have dual roles as they carry out emergency preparedness activities and coordinate emergency response operations. In their preparedness role, they assist local officials in carrying out emergency planning, training, and exercises. They also develop emergency teams and facilities and teach a wide variety of emergency management training courses. In their response role, they deploy to incident sites to assess damages, identify urgent needs, advise local officials regarding state assistance, and coordinate the deployment of state emergency resources to assist local emergency responders. The Trinity Region is primarily in TDEM Regions 1 and 2, with some counties extending into TDEM Regions 5 and 6.

Though the public face of the agency is generally associated with the construction and maintenance of the state highway system, the Texas Department of Transportation (TxDOT) is also responsible for overseeing aviation, rail, and public transportation systems. TxDOT can provide real-time road closure and LWC information in the response and recovery phases of a flood event. Users can access this data through TxDOT's Drive Texas website, www.drivetexas.org.

Federal Entities

FEMA is an agency of the United States Department of Homeland Security (DHS). FEMA's mission is "helping people before, during and after disasters." While on-the-ground support of disaster recovery efforts is a major part of FEMA's charter, the agency provides state and local governments with experts in specialized fields and funding for rebuilding efforts and relief funds for infrastructure by directing individuals to access low-interest loans, in conjunction with the Small Business Administration. In addition to this, FEMA provides funds for training of response personnel, establishes accessible flood hazard limit information, participates in flood outreach and awareness activities, provides floodplain management standard guidance, and works with local, regional, and state floodplain administrators as part of the agency's preparedness efforts.

The National Weather Service (NWS) mission is to provide weather, water and climate data, forecasts, warnings, and impact-based decision support services for the protection of life and property and enhancement of the national economy. NWS provides flash flood indicators through watches, warnings, and emergency notices to inform the public of potential flood risks.

The National Oceanic and Atmospheric Administration (NOAA) is an American scientific and regulatory agency within the United States Department of Commerce that forecasts weather, monitors oceanic and atmospheric conditions, charts the seas, conducts deep sea exploration, and manages fishing and protection of marine mammals and endangered species in the United States exclusive economic zone. NOAA's National Center for Environmental Information (NCEI) provides historical data that can help communities determine their future probability of flood events and is key in the planning and mitigation process. For coastal flood events, NOAA's Office of Coastal Management plays a key role in providing information, technology, and flood management strategies. NOAA weather data enables communities to prepare for flood events by providing weather information.

The United States Army Corps of Engineers (USACE) is essential to the nation's military. The agency is responsible for a wide range of efforts in the United States including addressing safety issues related to waterways, dams, and canals, but also environmental protection, emergency relief, hydroelectric power, and much more. USACE is composed of several divisions, with the Trinity Region being in the Southwest Division and the Galveston and Fort Worth districts.

The USACE Flood Risk Management Program (FRMP) focuses on the policies, programs, and expertise of USACE to help reduce overall flood risk. This includes the appropriate use and resiliency of structures such as levees and floodwalls, as well as promoting alternatives when other approaches (e.g., land acquisition, flood proofing, etc.) reduce the risk of loss of life, reduce long-term economic damages to the public and private sector, and improve the natural environment.

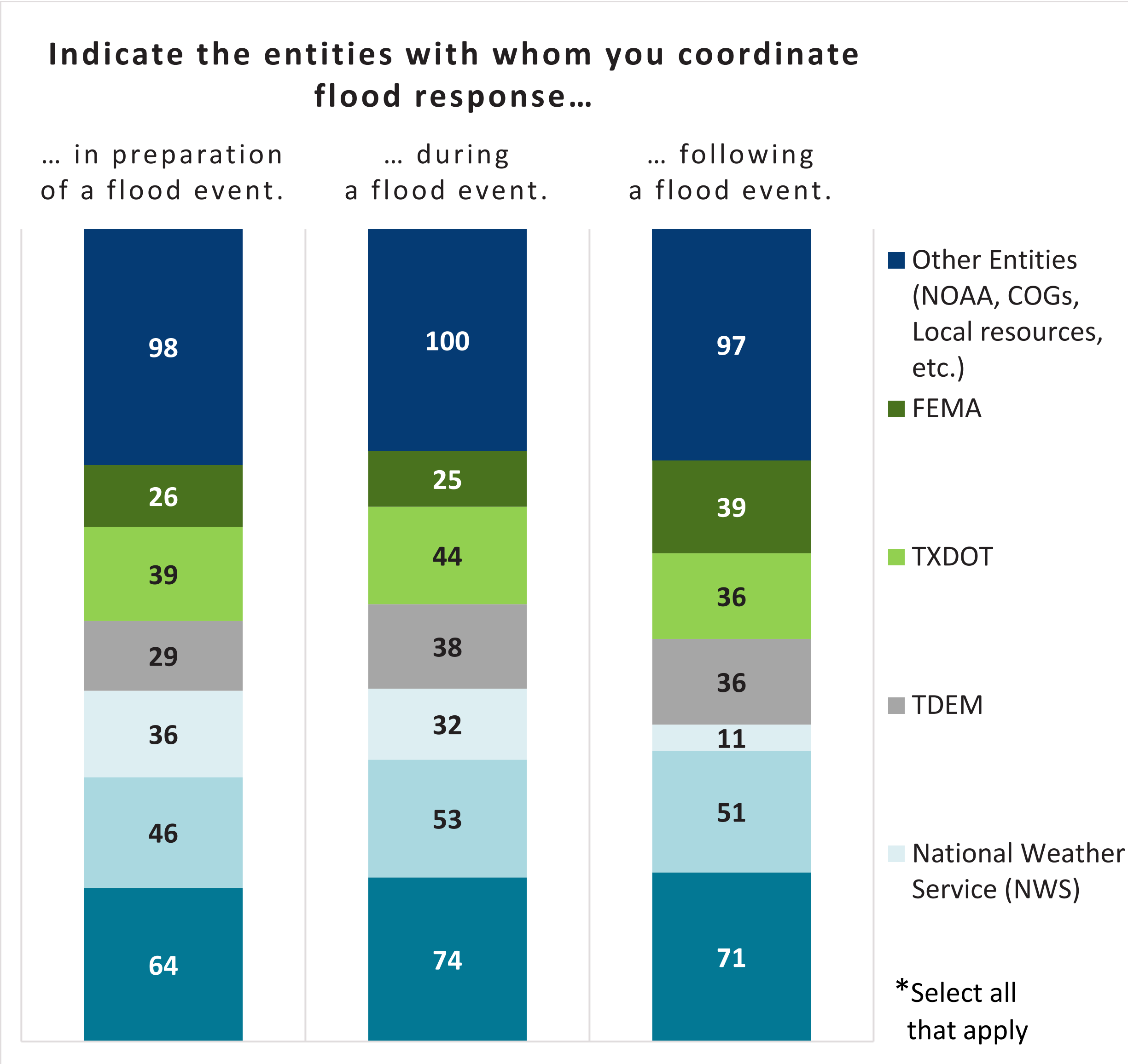
USACE responds to disasters each year by deploying hundreds of trained personnel and providing resources nationwide. USACE works under the direction of FEMA as a member of the federal team to support state and local governments in responding to major disasters.

Entities in Preparation of a Flood Event

In the planning process it is important to consider flood planning in preparation, during, and following a flood event to access the entities that provide the respondents with the most assistance and support. Of the survey responses received, the top six entities in which coordination was indicated as key were county, city, TDEM, TxDOT, NWS, and FEMA with all other entities accounting for much smaller responses.

Figure 7.4 shows the breakdown of survey responses regarding entities that contribute most significantly in the preparation, the response, and the recovery efforts within the Trinity Region's various jurisdictions. Respondents could select all that apply in their responses. For example, all of the survey participants responded that during a flood event, they coordinate with other entities, such as NOAA, COGs, etc.

Figure 7.4: Flood Event Entities



Source: Trinity Region data collection survey results as of September 16, 2021

Emergency Information Dissemination

There are various means by which data can be collected and disseminated before and during a flood event.

Two types of gauges used are rain gauges and stream gauges. A rain gauge is a meteorological instrument to measure the rain in a given amount of time per unit area. It collects water falling on it and records the change over time in the rainfall depth. Stream gauging is a technique used to measure a stream's discharge or the volume of water moving through a channel per unit of time. The height of water in the stream channel, known as a stage or gauge height, can be used to determine the discharge in a stream.

In addition to the NWS, local media such as news or radio stations are vital components in relaying real time information to local residents about inclement weather and flooding. Local media can also alert residents of LWC closings, dam or levee breaches, and other potential dangers. They typically relay NWS messages regarding flood watches, warnings, and emergency notifications. Some media outlets have created their own weather apps that include real-time weather alerts including rain and flood notices. NWS provides data for Emergency Alert Systems (EAS) to alert individuals to imminent or dangerous weather conditions.

In the Trinity Region, the Graphical Severe Weather Warnings project (GWARN) represents a collaborative effort between the NWS Fort Worth office, the NWS Southern Region Headquarters, and the NCTCOG. Using the warning polygon area, a demographic database at NCTCOG is queried to determine characteristics of the population at risk. This has served as a model for numerous other integrations of demographics data into weather impacts. (NCTCOG, n.d.)

An EAS is software that provides alert messages during an emergency. Messages can interrupt radio and television to broadcast emergency alert information. Messages cover a large geographic footprint including the entirety of the Trinity Region. Emergency message audio/text may be repeated twice, but EAS activation interrupts programming only once, then regular programming continues. According to the county websites, 32 counties within the Trinity Region are currently enrolled in some type of EAS program.

A local entity can invest in a reverse 911 system that allows the entity to pull up a map on a computer, define the area of interest, and send a recorded phone message to each business or residence in that area. The reverse 911 program participants can opt to receive text messages or calls through this system. Per the survey and in reviewing data from the HMPs, entities within the Trinity Region have indicated interest in pursuing the reverse 911 system to provide data to residents regarding flood dangers in their area.

School emergency alert systems are tools that allow schools to communicate quickly to staff, students, first responders, and others so that they can take appropriate action in the event of an emergency situation. Various versions of this tool are used in schools throughout the region from daycares to K-12 grade schools and universities.

Plans to be Considered

Local Plans

In the Trinity Region's data collection effort and survey tool in 2021, publicly available local emergency management and emergency response plans were requested. An emergency management plan is a course of action developed to mitigate the damage of potential events that could endanger an organization's ability to function. These plans include measures that provide for the safety of personnel and, if possible, property and facilities. Some emergency plans are protected by law and are not available to the general public. The region obtained emergency management plans, HMPs, and other regional and local flood planning studies from county and local jurisdictions.

The Trinity Region has several region-wide plans and regulations in place that dictate a community's capabilities in implementing mitigation and preparedness actions. While each of the region's counties have a HMP, only 27 of 38 county plans are currently approved by FEMA, as they are to be updated on a five-year cycle. One plan is expired with the county seeking funding or funding pending for an update to their plan. Eight counties have a plan in development or being updated, and two counties have a plan in review, revision, or adoption. Additionally, eight cities have HMPs, with two of them being expired. Having an up-to-date HMP is key to assessing risk and developing mitigation actions.

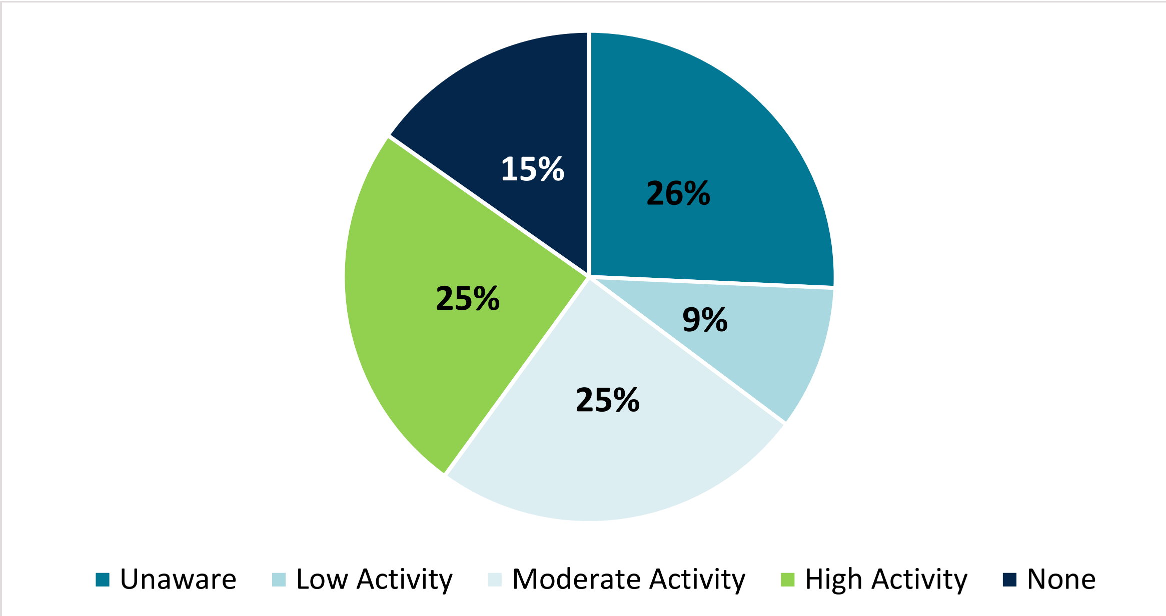
Other plans to consider include Emergency Action Plans (EAPs) and watershed master plans. An EAP provides the basis for the coordinated planning and management of types of emergencies and disaster events. Watershed master plans promote collaboration between all community sectors to create a resilient flood hazard area.

Hazard mitigation planning reduces loss of life and property by minimizing the impact of disasters. It begins with state, tribal, and local governments identifying natural disaster risks and vulnerabilities in their area. After identifying these risks, they develop long-term strategies for protecting people and property from similar events. Mitigation plans are key to breaking the cycle of disaster damage and reconstruction.

In the private sector, an EAP is a document required by the Occupational Safety and Health Administration (OSHA) standards. The purpose of an EAP is to facilitate and organize employer and employee actions during workplace emergencies. EAPS are an essential in emergency management for critical facilities and for dams. EAPs for dams are essential for identifying potential emergency conditions and specifying preplanned actions to be followed to minimize property damage and loss of life.

These plans are critical components in creating and maintaining strong floodplain management practices in the region. When asked which of the following best describes the activity of your jurisdiction in floodplain management practices, only 26% of survey respondents indicated that their jurisdiction maintained strong practices indicating interest in improved floodplain management practices throughout the region. ***Figure 7.5*** summarizes the survey responses regarding the self-reported strength of local floodplain management practices.

Figure 7.5: Floodplain Management Practices



Source: Trinity Region data collection survey results as of September 16, 2021

Aligning common goals and objectives in the region can facilitate the efficiency of plans and actions taken. Having more robust floodplain practices both locally and regionally creates an ideal flood mitigation scenario and promotes good floodplain management practices.

The Trinity Region's ability to prepare, respond, recover, and mitigate disaster events is determined by several factors. With a clear understanding of the plans that determine a community's capabilities, a recognition of the entities with whom coordination is key, and knowledge of the actions sustained to promote resiliency, the region can be better equipped to implement sound measures for flood mitigation and preparedness.

Regional and State Plans

As part of the NCTCOG, the Regional Emergency Preparedness Program (REPP) is brings together urban, suburban, and rural jurisdictions to facilitate information sharing, collaboration, and cooperation among jurisdictions. (NOTCOG, n.d.) Preparedness is defined by the DHS and FEMA as "a continuous cycle of planning, organizing, training, equipping, exercising, evaluating, and taking corrective action in an effort to ensure effective coordination during incident response." (DHS, 2022)The REPP accomplishes this through networking, standardization of policy and procedures, and coordination efforts with entities.

FEMA's Regional Catastrophic Preparedness Grant Program (RCPGP) provides funding to close gaps in housing, logistics, and supply chain management; encourages innovative regional solutions to issues related to catastrophic incidents; and builds on existing regional efforts. (FEMA, 2022)

The State HMP can reduce losses by reducing the impact of disasters on people and property. Mitigation efforts cannot eliminate all potential impacts of disastrous events. (Minnesota Department of Public Safety, 2014) However, the implementation of HMPs can significantly reduce the anticipated impacts of hazardous events.

The plan evaluates, profiles, and ranks natural and human-caused hazards effecting Texas by frequency of event, economic impact, deaths, and injuries. The plan:

- Assesses hazard risk through a risk and vulnerability assessment
- Reviews current state and local hazard mitigation and climate adaption capabilities
- Develops mitigation strategies
- Identifies state agency (and other entities) potential actions to address state and regional needs.

Potential Regulatory Recommendations

In the Trinity Region, improvements could be made to further the effectiveness of emergency actions, especially preparedness. Recommendations made by the Trinity RFPG are included in ***Chapter 8*** and promote the creation and use of floodplain mapping, education of entity officials regarding flooding, and encouragement of local regulations. A couple of recommendations also address emergency mitigation, such as encouraging jurisdictions to work towards common flood mitigation goals and the establishment of a dam safety program. Furthermore, recommendations such as preparing a statewide database of disaster-related fatalities can assist entities with emergency recovery and preparation for future flooding events.

Bibliography

DHS. (2022, June 28). *Plan and Prepare for Disasters*. Retrieved from United States Department of Homeland Security: https://www.dhs.gov/plan-and-prepare-disasters

FEMA. (1998, May). Definitions Adapted from Animals in Disaster, Module A, Awareness and Preparedness. FEMA.

FEMA. (2022, 6 27). *Fiscal Year 2022 Regional Catastrophic Preparedness Grant Program - FAQs*. Retrieved from FEMA: https://www.fema.gov/grants/preparedness/regional-catastrophic/fy-22-faqs

FEMA. (n.d.). *Hazard Mitigation Assistance Grants*. Retrieved from https://www.fema.gov/grants/mitigation

Minnesota Department of Public Safety. (2014). *Minnesota State Hazard Mitigation Plan 2014.* Minnesota: Minnesota Department of Public Safety. Retrieved from https://dps.mn.gov/divisions/hsem/hazard-mitigation/Documents/State%20Plan%20Final%202014.pdf

NCTCOG. (n.d.). *North Texas Graphical Warnings*. Retrieved from North Central Texas Council of Governments: https://www.nctcog.org/regional-data/regional-data-center/north-texas-graphical-warnings

NOTCOG. (n.d.). *NCTCOG Regional Emergency Preparedness Program* . Retrieved from North Cental Texas Council of Governments : https://www.nctcog.org/ep/emergency-preparedness-planning-council-eppc-1/regional-service-award/members

Chapter 8: Legislative, Administrative, and Regulatory Recommendations

Part of the regional flood planning effort includes proposing changes to existing statutes to make floodplain management and flood mitigation planning and implementation throughout the State of Texas more efficient or logical. Recommendations can include alterations to the legislature associated with flood planning throughout the state, as well as regulatory or administrative features associated with flood-related activities. Recommendations may also be proposed to further the flood planning process itself, such as desired support or data from the Texas Water Development Board (TWDB) or from other entities. Lastly, the planning process includes recommendations regarding new funding or revenue-raising opportunities for stormwater and floodplain management

Legislative Recommendations

Being a part of the state flood planning effort has allowed the Regional Flood Planning Groups (RFPGs) and sponsors to communicate and interact with a wide variety of entities. The RFPGs have been able to identify trends and occurrences throughout a large portion of the state. Some of these practices are positive and should be encouraged, while others may be detrimental to the floodplain and stormwater management of the entity, region, and/or state as a whole. Throughout the flood planning process, the RFPG teams, surveyed entities, and members of the public provided input on the functionality and usefulness of existing legislature as it relates to floodplain and stormwater management. ***Table 8.1*** identifies the Trinity RFPG's legislative recommendations for consideration in relation to floodplain and stormwater management.

Regulatory or Administrative Recommendations

Some of the suggestions that the Trinity RFPG's proposed are not directly controlled by the Texas Legislature. Rather, some recommendations are of a regulatory or administrative nature, concerning existing procedures, state entities, or state/regional regulations. Alterations to these procedures could also be proposed to the TWDB for consideration.

Confusion and uncertainty exist regarding current floodplain management regulations and responsibilities that are applicable to counties. Counties would benefit from clarification and guidance on their current flood-related authorities within their jurisdictions. The lack of guidance has hindered several recommendations from being included in this section for the Trinity Region. Recommendation ID 8.2.2 in ***Table 8.2*** addresses this concern. ***Table 8.2*** provides suggested changes to the implementation of existing standards and procedures by state-controlled entities.

Table 8.1: Legislative Recommendations for the Trinity Region

ID	Recommendation Statements	Reason for Recommendation
8.1.1	Increase state funding to help counties maintain drainage and stormwater infrastructure in unincorporated areas.	Counties in the State of Texas have floodplain and drainage related responsibilities without a current way to fund projects.
8.1.2	Develop state strategies to aid in acquiring federal funds.	Entities in Texas do not qualify for some federal funding programs due to minimal or no state participation, such as Federal Emergency Management Agency (FEMA) Building Resilient Infrastructure and Communities (BRIC) grants.
8.1.3	Provide funding and/or technical assistance to develop regulatory floodplain maps.	Several entities who have outdated maps or no mapping at all are not able to fund the projects necessary to update or create regulatory floodplain maps.
8.1.4	Develop and allocate state funding to assist dam owners with the costs associated with repairing, maintaining, and upgrading dam structures, as well as decommissioning studies, where applicable.	A number of dams that were originally constructed in rural areas are now surrounded by developments. Therefore, the potential impact of flood damages resulting from dam failure has increased significantly. Often, the cost of maintenance is far too high for a private entity to take on.
8.1.5	Provide additional grant funding to the RFPGs to enable them to continue to function during the interim timeframe between planning cycles	Between planning cycles, RFPGs could continue adding FMEs, FMPs, and/or FMSs to the regional flood plan, as well as implement RFPG-sponsored flood management activities, perform public outreach, and stay informed on regional flood-related occurrences.
8.1.6	Establish a state levee safety program and/or ensure that state and local interests are represented in any national level levee safety programs. The program should solicit input from a broad range of levee sponsors to leverage the owner's and operator's expertise in the development of the program.	Levees need to be properly maintained to provide their design level of flood protection. A program that includes periodic inspections would promote maintenance of levees in the state. Guidelines for inspection and maintenance should be based on sound engineering principles, and not a direct duplication of federal guidelines, as not all levees are federal. It should be acknowledged that any program without funding will struggle to meet its goals; therefore, a funding source should be established as well.
8.1.7	Extend Local Government Code, Title 13, Subtitle A, Chapter 552 to allow counties the opportunity to establish and collect drainage utility fees in unincorporated areas.	Counties in the State of Texas have floodplain- and drainage-related responsibilities. Currently, counties do not have the ability to establish and collect stormwater utility fees, thus limiting their ability to fund stormwater or drainage projects, despite having the responsibility to do so.
8.1.8	Provide for alternative sources of funding. Expand eligibility for, and use of funding for stormwater and flood mitigation solutions (local, state, federal, public/private partnerships, etc.)	Flood mitigation studies/projects are intended to protect property and the health and safety of the public but are challenging to fund at the local level. Furthermore, flood mitigation activities are not intended to generate revenue. FMPs impact the property tax base.

Table 8.2: Regulatory and Administrative Recommendations for the Trinity Region

ID	Recommendation Statements	Reason for Recommendation
8.2.1	Review and revise, as necessary, all state infrastructure entities' standards and practices for legislative and regulatory compliance with stormwater best practices.	State entities should be cognizant of the drainage and stormwater standards in the areas where they are active. State entities should be held to consistent standards that the local entities uphold.
8.2.2	Provide guidance on the extent of county authority related to the regulation of floodplain management under existing state law, including potential best management practices.	Some county officials are unclear on the responsibilities, restrictions, and regulations current state law allows them to establish and enforce. Continued confusion of this matter prevents the counties from setting beneficial regulations for their jurisdictions and hinders the RFPG from being able to provide recommendations that would be of further use to the counties in the region.
8.2.3	Develop resources for and educate city and county officials regarding the respective entities' ability/authorization to establish and enforce higher development standards.	City and county officials are often unaware of their authority to establish and enforce stormwater regulations. (Texas Local Government Code Title 7, Subtitle B.; Texas Water Code Chapter 16, Section 16.315) City and county officials often have inadequate flooding and drainage training for their level of responsibility.
8.2.4	Provide measures to encourage and allow jurisdictions to work together towards regional flood mitigation solutions.	Flooding does not recognize jurisdictional boundaries. Encouraging entities to work together towards common flood mitigation goals would be beneficial to all involved.
8.2.5	Develop a publicly available, statewide database and tracking system to document flood-related fatalities.	In order to more accurately address the health, safety, and welfare of the public, high flood-risk areas should be tracked and reported. Doing so would increase awareness of the area, both so the public could be cognizant of the risks, and so elected officials and decision-makers could institute solutions to reduce the risk in those areas. Information gathered could include presence/absence of flashers, barricades, and/or signs.
8.2.6	Revise the scoring criteria for funding associated with stormwater and flood-related projects that benefit agricultural activities.	The traditional benefit-cost analysis tools prevent agricultural projects from competing with municipal benefit-cost ratios.
8.2.7	Provide financial or technical assistance to smaller/rural jurisdictions.	The former Office of Rural Affairs/Texas Department of Rural Affairs was intended to assist and work with rural entities; however, the department was disbanded. Actions such as maintaining a department specifically for smaller/rural entities, incentivizing consultants to pursue work for smaller or rural entities or adjusting BCAs to rank small/rural entities equally are all ideas towards this goal.
8.2.8	Simplify all funding application processes.	Current funding applications require significant time and resources to prepare a project for consideration, as well as complete the application itself, especially for jurisdictions with limited resources. Thus, jurisdictions that need the funding the most typically do not apply for current opportunities, despite having needs.
8.2.9	Allow for more frequent inspection of high-hazard dams in poor condition.	TAC Rule 299.42(a)(2)(A) states, "High-hazard dams shall be inspected once every five years." Five years is an adequate inspection frequency for well-maintained high-hazard dams. However, TCEQ should be allowed to inspect high-hazard dams found to be in poor condition more frequently until said condition is improved.

Flood Planning Recommendations

Having been part of the first-ever state flood planning effort, the Trinity Region offers the recommendations in ***Table 8.3*** to improve the regional flood planning process for future planning cycles.

Funding Recommendations

The RFPG is responsible for providing funding recommendations to the TWDB. These ideas could include new, revenue-raising opportunities, as well as "new municipal drainage utilities or regional flood authorities that could fund the development, operation, and maintenance of floodplain management or flood mitigation activities in the region."

In ***Chapter 1,*** responders to the data collection survey indicated the use of stormwater utility fees, bond programs, ad valorem taxes, and the general fund to sponsor projects in their regions. Non-local funding sources included the Hazard Mitigation Grant Program (HMGP) through FEMA and Texas Department of Emergency Management (TDEM), Pre-Disaster Mitigation through FEMA, Cooperating Technical Partner (CTP) funds through FEMA, Flood Protection Planning Grants through TWDB, United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS), and Flood Mitigation Assistance through FEMA.

No additional funding sources were identified in the Trinity Region during this planning cycle.

Table 8.3: State Flood Planning Recommendations for the Trinity Region

ID	Recommendation Statements	Reason for Recommendation
8.3.1	Update the scope of work, guidance documents, rules, checklists, etc. based on the adjustments made to these planning documents during the first cycle of planning.	During the first cycle of the State Flood Plan, multiple amendments and additions to the TWDB documents and the TWDB's interpretation of its documents occurred. Moving forward, the TWDB documents provided at the onset of each new planning cycle should reflect what is ultimately required of the RFPGs.
8.3.2	Develop a fact sheet and/or other publicity measures to encourage entities to participate in the regional flood planning effort.	Many entities were unaware of the regional and state flood planning efforts despite the RFPG's outreach efforts. Some entities are still requesting information regarding the flood planning process and do not understand the benefits of participating.
8.3.3	Host "lessons learned" discussions with RFPG members, sponsors, and technical consultants following the submittal of the final regional flood plans.	Opening dialogue among these participants to discuss proposed improvements to the regional planning process will streamline and improve future regional flood planning cycles.
8.3.4	Develop an amendment process similar to the regional water planning process to efficiently amend RFPG-approved regional flood plans to incorporate additional recommended FMEs, FMPs, and FMSs. Include language to allow the RFPG to advance the recommended FMEs to FMPs based on the results provided at the conclusion of an FME.	Amending the regional flood plan, as seen with the Technical Memorandum Addendum, can be an extensive process. Amendments to move FMEs to FMPs and incorporate new flood management solutions should have a quicker turn-around time to efficiently include them in the regional flood plan. Recommend utilizing the regional water planning amendment process as a go-by.
8.3.5	Implement an invoice review and advancement request process that provides for timely reimbursements.	Several regions experienced extensive delays in their billing cycles which can delay planning efforts.
8.3.6	Include the reimbursement of costs for Audio/Visual (A/V) equipment expenses required to support hybrid and/or virtual meetings for the RFPG grants	Many RFPGs have had to rent or purchase A/V equipment in order to uphold the Texas Open Meetings Act guidelines while supporting hybrid meetings. Given the area spanned by the regions and today's technology, RFPG members prefer to offer hybrid meetings to reduce travel time and to increase the opportunity for public participation in the regional flood planning process. Expenses accrued to maintain Texas Open Meetings Act standards – set in place by the state – should be eligible for reimbursement.
8.3.7	Remove information requirements regarding the condition of Homeland Security protected infrastructure, such as dams, from the TWDB-required tables.	The requested information is purposefully not publicly available. Structural conditions of certain critical infrastructure are protected to minimize the risk of the information being used to cause negative consequences.
8.3.8	Reduce the amount of information required to escalate potentially feasible FMEs to FMPs.	Some data currently requested for FMPs is more detailed than traditional planning level data. TWDB recommended leaving those cells blank in ***TWDB-Required Table 13***, which would likely result in lower scoring for the project, and a lower probability to garner funding. Thus, certain FMPs were submitted as FMEs or FMSs despite having sufficient data to produce a project.
8.3.9	Revise the criteria for the "No Adverse Impact" Certification required for FMPs.	The current criteria provide thresholds for increases in flow, water surface elevation, and inundation extents. The current criteria do not allow for projects that exceed these thresholds, even if the impact is accounted for in the design or by other accommodations.
8.3.10	Provide clarification for the phrase "flood-related authorities or entities", who that includes, and what that entails.	The phrase is used in the TWDB planning documents multiple times and is a central part of multiple tasks. TWDB originally provided the RFPG with a list of entities that were thought to have flood-related responsibilities. During outreach efforts, many of those entities informed the Trinity Region that they did not have flood responsibilities and did not believe they should be part of the flood planning effort. Therefore, the Trinity Region removed these entities from the plan. Clarification is requested regarding the intent of this phrase.
8.3.11	Streamline the data collection requirements, specifically those identified in Task 1. Focus on collecting the data that was most useful to the regional flood plan development.	This first round of planning proved that very few entities have the data requested as part of the flood planning process readily available in a geographical information system (GIS) format. Of those entities who did have GIS data, most were unable to share that information. Furthermore, some of this data was not used or was used minimally to develop potentially feasible and recommended FMEs, FMPs, and FMSs.

ID	Recommendation Statements	Reason for Recommendation
8.3.12	Provide applicable data sources and a methodology to determine infrastructure functionality and deficiencies in the next cycle of the flood planning process. Consider the lack of readily available local data when developing the methodology.	Most entities do not have information regarding the functionality and deficiency of their infrastructure. Some fields required by the TWDB-required tables in the regional flood plans are based on data that is not available to entities without extensive field work.
8.3.13	Review and revise the geodatabase submittal attributes and elements.	Normalizing the geodatabase with relationships would allow for cross-referencing of data elements and attributes. More domains for attributes need to be developed.
8.3.14	Use FEMA's Social Vulnerability Index (SVI) when available instead of the Center for Disease Control's (CDC's) SVI in future planning cycles.	FEMA's SVI is reasoned to be more relevant to flood resiliency and risk than the CDC's SVI. SVI should not be the primary component considered when allocating funding.
8.3.15	Use consistent Hydrologic Unit Code (HUC) reporting requirements throughout the TWDB-required tables.	The RFPG guidance requires HUC-8 in some tables, HUC-10 in other tables, and HUC-12 in yet other tables. Some tables require multiple HUCs to be provided. The Trinity RFPG recommends that the TWDB require HUC-8 in all TWDB-required tables for consistency, and to correspond to FEMA's base level watershed planning granularity.
8.3.16	Develop a statewide bridge inventory with bridge deck elevations.	The availability of statewide LiDAR provides the opportunity to more accurately describe the risk at riverine crossings (i.e. overtopping elevation). The creation of a statewide database would further simplify this data.
8.3.17	Improve upon the flood risk identification and exposure process with regards to building footprints and population at risk.	While the building footprints are helpful, without the first-floor elevations of each structure, it is difficult to determine the actual extent of flood risk per structure. For example, if a structure is sufficiently elevated above the Base Flood Elevation (BFE), the footprint still shows the structure in the floodplain and the corresponding population is considered "at risk" although the structure meets NFIP standards. This overestimates the population at risk quantification.

Chapter 9: Flood Infrastructure Financing Analysis

The Texas Water Development Board (TWDB) requires that each Regional Flood Planning Group (RFPG) assess and report on how sponsors propose to finance recommended Flood Management Evaluations (FMEs), Flood Management Strategies (FMSs), and Flood Mitigation Projects (FMPs). This chapter will focus on understanding the funding needs of the Trinity RFPG's sponsors and recommend what role the state should have in financing the recommended FMEs, FMSs, and FMPs.

This chapter presents an overview of common sources of funding for flood mitigation planning, projects, and other flood management efforts. It then describes the methodology and results of the financing survey.

Sources of Potential Funding for Flood Management Activities

Communities, counties, and entities with flood-related authority or responsibility across the state utilize a variety of funding sources for their flood management efforts, including local, state, and federal sources. This section discusses some of the most common avenues of generating local funding, as well as various state and federal financial assistance programs available to communities. ***Table 9.1*** summarizes the local, state, and federal funding sources presented in this chapter, and characterizes each by the following three key parameters:

- Which state and federal agencies are involved with the funding, if applicable
- Whether the funding offers grants, loans, or both
- Whether the funding is classified as a regularly occurring opportunity or is only available after a disaster

Local Funding

Through the Trinity RFPG's initial stakeholder outreach efforts, the Trinity Region sought to understand the landscape of local funding for flood efforts in the region. Many communities, particularly smaller and more rural communities, reported that they did not have any local funding sources for flood management activities. Those communities who reported having local funding indicated the following primary sources:

- General fund
- Dedicated fees, such as stormwater or drainage utility fees
- Bonds

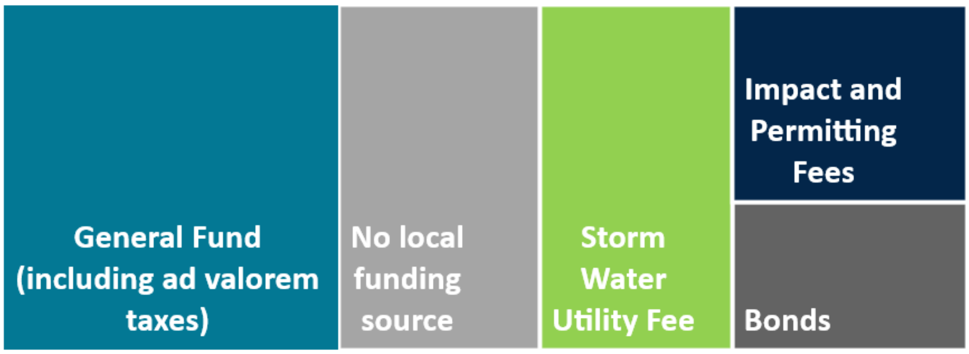
Table 9.1: Common Sources of Flood Funding in Texas

Source	Federal Agency	State Agency	Program Name	Grant (G)	Loan (L)	Post-Disaster (D)
Local			General fund			
			Bonds			
			Stormwater or drainage utility fee			
			Special purpose district taxes and fees			
State		TWDB	Flood Infrastructure Fund (FIF)	G	L	
		TWDB	Texas Water Development Fund (Dfund)		L	
		TSSWCB	Operation and Maintenance (O&M) Grant Program	G		
		TSSWCB	Flood Control Dam Infrastructure Projects - Supplemental Funding	G		
		TSSWCB	Structural Dam Repair Grant Program	G		
Federal	FEMA	TWDB	Flood Mitigation Assistance (FMA)	G		
	FEMA	TDEM	Building Resilient Infrastructure and Communities (BRIC)	G		
	FEMA	TCEQ	Rehabilitation of High Hazard Potential Dam Grant Program (HHDP)	G		
	FEMA	TBD[3]	Safeguarding Tomorrow through Ongoing Risk Mitigation (STORM)		L	
	FEMA	TDEM	Hazard Mitigation Grant Program (HMGP)	G		D
	FEMA	TDEM	Public Assistance (PA)	G		D
	FEMA		Cooperating Technical Partners (CTP)	G		
	HUD	GLO	Community Development Block Grant – Mitigation (CDBG-MIT)	G		D
	HUD	GLO	Community Development Block Grant Disaster Recovery Funds (CDBG-DR)	G		D
	HUD	TDA	Community Development Block Grant (TxCDBG) Program for Rural Texas	G		
	USACE		Partnerships with USACE, funded through Continuing Authorities Program (CAP), Water Resources Development Acts (WRDA), or other legislative vehicles[1]			
	EPA	TWDB	Clean Water State Revolving Fund (CWSRF)	G[2]	L	

[1]Opportunities to partner with USACE are not considered grant or loan opportunities, but shared participation projects where USACE performs planning work and shares in the cost of construction.
[2]The CWSRF program offers principal forgiveness, which is similar to grant funding.
[3]To be determined

Figure 9.1 presents these results visually, indicating how stakeholders responded when asked about their local funding sources for flood management activities. The relative size of the box represents the relative response rate for each local source, with the larger boxes indicating greater utilization of the source. It is important to note that these results are self-reported and do not include a response from every community in the region.

Figure 9.1: Local Funding Sources Utilized by Communities in the Trinity Region



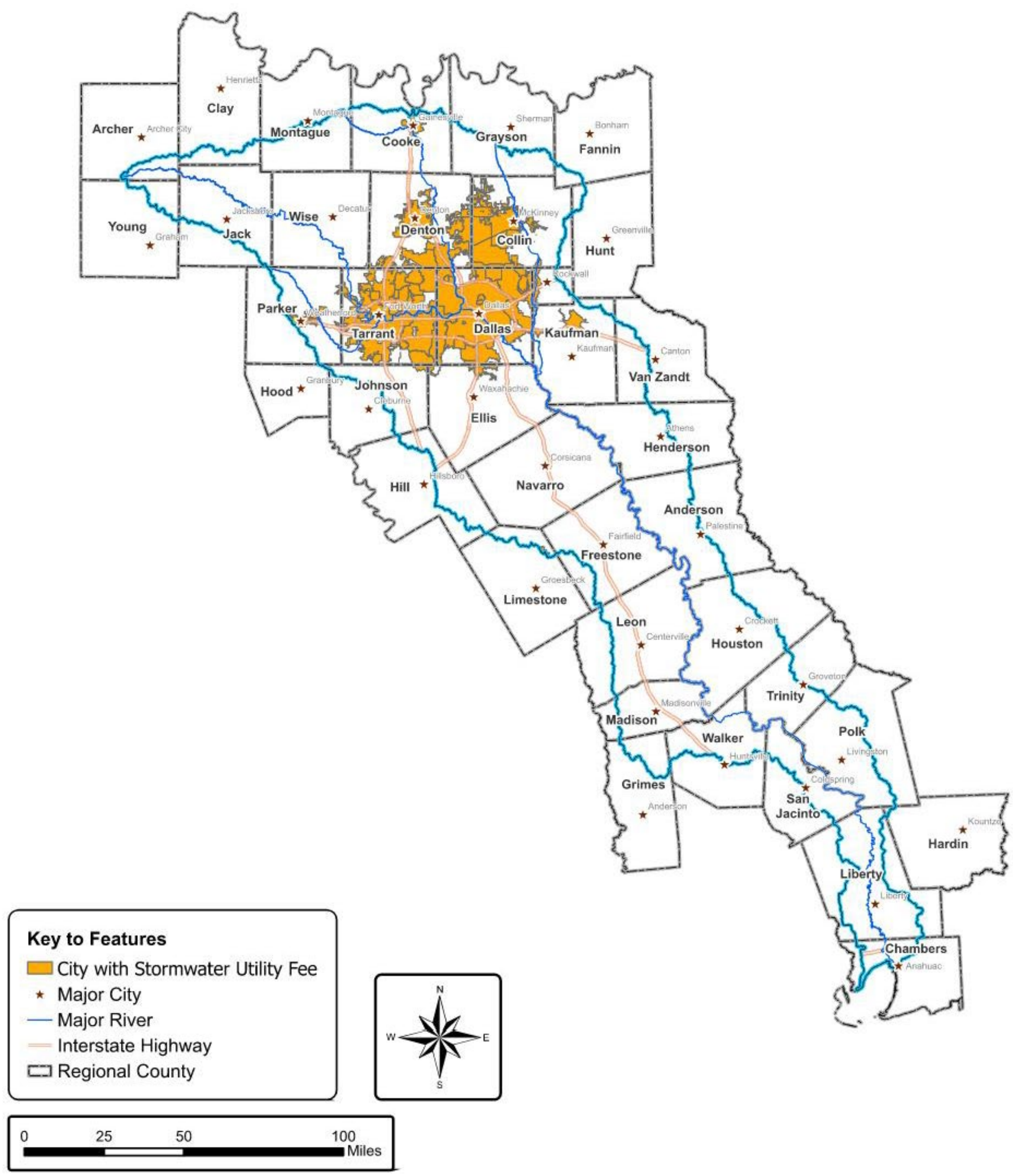
This section primarily focuses on the funding mechanisms available to municipalities and counties, as a large majority of the FME, FMS, and FMP sponsors are these types of entities. Special purpose districts are briefly discussed as there may be opportunities to create more of these types of districts in the region. River authorities typically generate their own revenue from fees charged to users for selling water, electricity, wastewater treatment, and other services.

A community's general (for cities or counties) revenue fund stems from sales, property, and other taxes and is typically the primary fund used by a local governmental entity to support most departments and services such as police, fire, parks, trash collection, and local government administration. Due to the high demands on this fund for many local needs, the general fund often is not often a viable option to provide a significant amount of funding for flood projects. State agencies including TWDB, Texas State Soil and Water Conservation Board (TSSWCB), Texas Department of Emergency Management (TDEM), Texas Commission on Environmental Quality (TCEQ), Texas General Land Office (GLO), and Texas Department of Agricultural (TDA), as well as federal agencies such as the Federal Emergency Management Agency (FEMA), United States Department of Housing and Urban Development (HUD), United States Army Corps of Engineers (USACE), and Environmental Protection Agency (EPA), offer many common sources of flood funding.

Dedicated stormwater or drainage fees are an increasingly popular tool for local flood-related funding. Municipalities can establish a Stormwater Utility (SWU), sometimes called a drainage utility, which is a legal mechanism used to generate revenue to finance a city's cost to provide and manage stormwater services. According to the 2020 Western Kentucky University

Stormwater Utility Survey, 62 entities within the Trinity Region have a SWU fee, while 266 entities do not have a SWU (Campbell, 2020). Entities that have SWU fees are shown in orange in ***Figure 9.2.*** To provide these services, municipalities assess fees to users of the stormwater utility system. Impact fees, which are collected from development to cover a portion of the expense to expand municipal storm water systems necessitated by the new development, can also be used as a source of local funding for flood-related efforts.

Figure 9.2: Entities within the Trinity Region that have a Stormwater Utility



Another source for local funding to support flood management efforts includes special districts. A special district is a political subdivision established to provide a single public service (such as water supply, drainage, or sanitation) within a specific geographic area. Examples of these special districts include Water Control and Improvement Districts (WCID), Municipal Utility Districts (MUD), Drainage Districts (DD), and Flood Control Districts (FCD). Each of these different types of districts are governed by different state laws, which specify the authorities and process for creating a district. Districts can be created by various entities, including the Texas Legislature, the TCEQ, county commissioners' courts, or city councils. Some types of districts may have the ability to raise revenue through taxes, fees, or bonds to fund flood and drainage-related improvements within their jurisdiction.

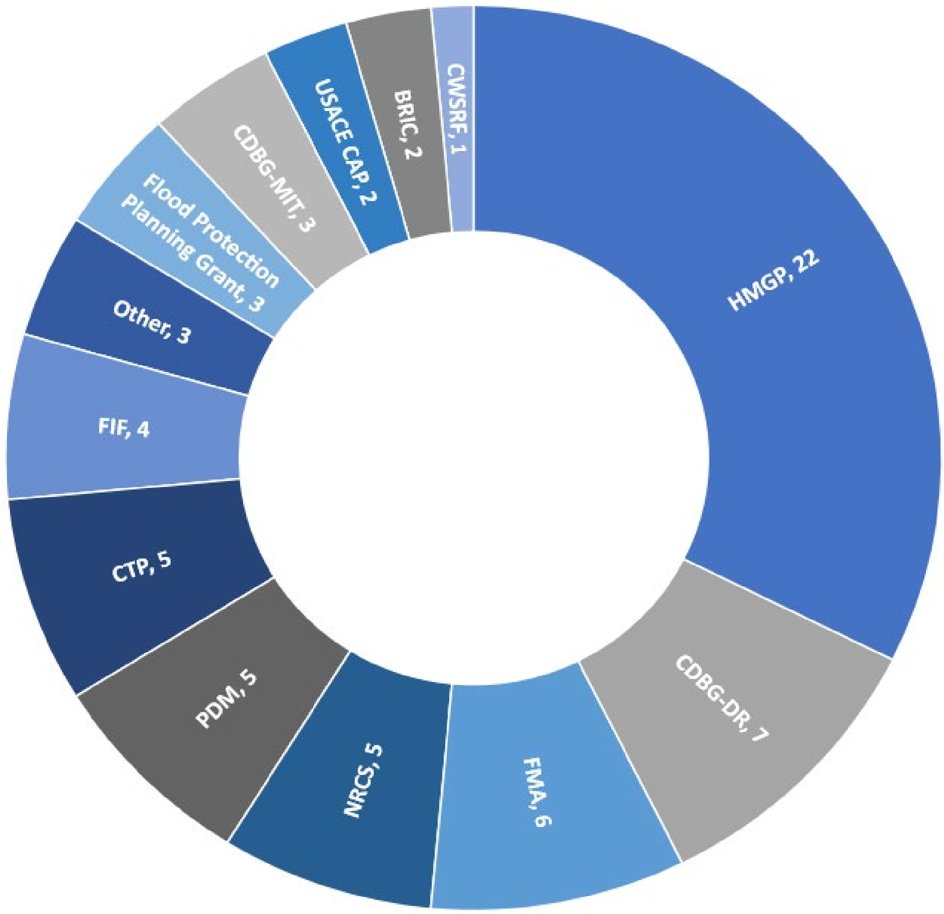
Lastly, municipalities and counties have the option to issue debt through general obligation bonds, revenue bonds, or certificates of obligation, which are typically paid back using any of the previously mentioned local revenue mechanisms.

Overall, local governments have various options for raising revenue to support local flood-related efforts; however, each avenue presents its own unique challenges and considerations. It is important to note that municipalities have more authority to establish various revenue raising options in comparison to counties. Of the communities that have access to local funding, the amount available is generally much lower than the total need, leading local communities to seek out state and federal financial assistance programs.

State Funding

Today, communities have a broader range of state and federal funding sources and programs available thanks to new grant and loan programs that did not exist even five years ago. Currently, two primary state agencies are involved in providing state funding for FMPs: the TWDB and the TSSWCB. ***Figure 9.3*** depicts how many local communities responded when asked what state and federal funding sources they have obtained to implement flood management activities. It is important to note that state and federal financial assistance programs discussed herein are not directly available to homeowners and the general public. Local governments may apply on behalf of their communities to receive and implement funding for FMPs within their jurisdictions.

Figure 9.3: State and Federal Funding Sources Utilized by Local Communities in the Trinity Region



The TWDB's FIF is a new funding program passed by the Texas Legislature and approved by Texas voters through a constitutional amendment in 2019. The program provides financial assistance in the form of low or no interest loans and grants (cost match varies) to eligible political subdivisions for flood control, flood mitigation, and drainage projects. FIF rules allow for a wide range of FMPs, including structural and nonstructural projects, planning studies, and preparedness efforts such as flood early warning systems. After the first State Flood Plan is adopted, only projects included in the most recently adopted state plan will be eligible for funding from the FIF. FMEs, FMSs, and FMPs recommended in this regional flood plan will be included in the overall State Flood Plan, and the sponsor for a particular recommended action will be eligible to apply for this funding source. The Flood Protection Planning Grant referenced in ***Table 9.1*** has been replaced by the FIF Category 1 planning grants.

The TWDB also manages the Dfund program, which is a state-funded, streamlined loan program that provides financing for several types of infrastructure projects to eligible political subdivisions. This program enables the TWDB to fund projects with multiple eligible components (water supply, wastewater, or flood control) in one loan at a low interest rate. Financial assistance for flood control may include structural and nonstructural projects, planning efforts, and flood warning systems.

The TSSWCB has three state-funded programs specifically for flood control dams:

- O&M grant program
- Flood Control Dam Infrastructure Projects - supplemental funding program
- Structural Repair Grant program

The O&M grant program provides grants for local soil and water conservation districts (SWCDs) and certain co-sponsors of flood control dams. This program reimburses SWCDs 90 percent of the cost of an eligible O&M activity as defined by the program rules; the remaining 10 percent must be paid with non-state funding. The Flood Control Dam Infrastructure Projects - Supplemental Funding program was created and funded in 2019 by the Texas Legislature. Grants are provided to local sponsors of flood control dams, including SWCDs, to fund the repair and rehabilitation of the flood control structures, to verify dams meet safety criteria to adequately protect lives downstream. The Structural Repair Grant program provides state grant funds that cover up to 95 percent of the cost of allowable repair activities on dams constructed by the United States Department of Agriculture - Natural Resources Conservation Service (USDA-NRCS), including match funding for federal projects through the Dam Rehabilitation program and the Emergency Watershed Protection (EWP) program of the Texas NRCS.

Federal Funding

Federal funding currently accounts for a large share of total available funding for flood projects throughout the state and region, with federal funding programs having greater access and availability to large funding amounts appropriated by Congress. Commonly utilized funding programs administered by seven different federal agencies are discussed in this section. The funding for these programs originates from the federal government. For many of the programs, a state agency partner plays a key role in the management of the program. Each funding program has its own unique eligible applicants, project types, requirements, and application and award timelines.

Federal Emergency Management Agency

Common FEMA-administered flood-related funding programs include:

- FMA
- BRIC
- HHPD grant program
- STORM
- HMGP
- PA program
- CTP program

FMA is a nationally competitive grant program that provides funding to states, local communities, federally recognized tribes, and territories. FMA is administered in Texas by the TWDB. Funds can be used for projects that reduce or eliminate the risk of repetitive flood damage to buildings insured by the National Flood Insurance Program (NFIP). Funding typically includes a 75 percent federal grant with a 25 percent local match. Projects mitigating repetitive loss and Severe Repetitive Loss (SRL) properties may be funded through a 90 percent federal grant and 100 percent federal grant, respectively. FEMA's FMA program now includes a disaster initiative called Swift Current. The program was released as a pilot initiative in 2022 and explored ways to make flood mitigation assistance more readily available during disaster recovery. Similar to a traditional FMA, the Swift Current program mitigates repetitive losses and substantially damaged buildings insured under the NFIP.

BRIC is a new nationally competitive grant program implemented in 2020. The program supports states, local communities, tribes, and territories as they undertake Hazard Mitigation Projects (HMPs), reducing the risks they face from disasters and natural hazards. BRIC is administered in Texas by the TDEM. Funding is typically a 75 percent federal grant with a 25 percent local match. Small, impoverished communities and United States island territories may seek funds through a 90 percent federal grant and 100 percent federal grant, respectively.

STORM is a new revolving loan program enacted through federal legislation in 2021 to provide needed and sustainable funding for HMPs. The program is designed to provide capitalization grants to states to establish revolving loan funds for projects to reduce risks from disaster, natural hazards, and other related environmental harm. At the time of the publication of this plan, the program does not yet appear to be operational and has not yet been implemented in Texas.

FEMA’s HHPD grant program, administered in Texas by the TCEQ, provides technical, planning, design, and construction assistance in the form of grants for rehabilitation of eligible high hazard potential dams. The cost share requirement is typically no less than 35 percent for either the state or local agency.

Under the HMGP, FEMA provides funding to state, local, tribal, and territorial governments so they can rebuild from a recent disaster in a way that reduces, or mitigates, future disaster losses in their communities. The program is administered in Texas by TDEM. Funding is typically a 75 percent federal grant with a 25 percent local match. While the program is associated with Presidential Disaster Declarations, the HMGP is not a disaster relief program for individual disaster victims or a recovery program that funds repairs to public property damaged during a disaster. The key purpose of HMGP is to make certain that the opportunity to take critical mitigation measures to reduce the risk of loss of life and property from future disasters is not lost during the reconstruction process following a disaster.

FEMA's PA program provides supplemental grants to state, tribal, territorial, and local governments, as well as certain types of private non-profits following a declared disaster so communities can quickly respond to and recover from major disasters or emergencies through actions such as debris removal, life-saving emergency protective measures, and restoring public infrastructure to its pre-disaster condition. Funding cost share levels are determined for each disaster and are typically not less than 75 percent federal grant (25 percent local match) and typically not more than 90 percent federal grant (10 percent local match). In Texas, FEMA PA is administered by TDEM. In some situations, FEMA may fund mitigation measures as part of the repair of damaged infrastructure. Generally, mitigation measures are eligible if they directly reduce future hazard impacts on damaged infrastructure and are cost-effective. Funding is limited to eligible damaged facilities located within PA-declared counties.

The CTP program is an effort launched by FEMA in 1999 to increase local involvement in developing and updating FIRMs, Flood Insurance Study reports, and associated geospatial data in support of FEMA's Risk Mapping, Assessment, and Planning (Risk MAP) program. To participate in the program, interested NFIP-participating communities, (state or regional agencies, universities, territories, tribes, or nonprofits), must complete training and execute a partnership agreement. Working with the FEMA regions, a program participant can develop business plans and apply for grants to perform eligible activities.

United States Department of Housing and Urban Development

HUD administers the following three federal funding programs:

- CDBG-DR
- CDBG-MIT
- TxCDBG for rural Texas

Following a major disaster, Congress may appropriate funds to the HUD under the CDBG-DR program when there are significant unmet needs for long-term recovery. Appropriations for CDBG-DR are frequently very large, and the program provides 100 percent grants in most cases. The CDBG-DR is administered in Texas by the Texas GLO. The special appropriation provides funds to the most impacted and distressed areas for disaster relief, long term-recovery, restoration of infrastructure, housing, and economic revitalization.

CDBG-MIT is administered in Texas by the GLO. Eligible grantees can use CDBG-MIT assistance in areas impacted by recent disasters to carry out strategic and high-impact activities to mitigate disaster risks. The primary feature differentiating CDBG-MIT from CDBG-DR is that, unlike CDBG-DR which funds recovery from a recent disaster to restore damaged services, systems, and infrastructure, CDBG-MIT funds are intended to support mitigation efforts to rebuild in a way which will lessen the impact of future disasters.

The CDBG program provides annual grants on a formula basis to small, rural cities and counties to develop viable communities by providing decent housing and suitable living environments. It also expands economic opportunities principally for persons of low- to moderate-income. Funds can be used for public facilities such as water and wastewater infrastructure, street and drainage improvements, and housing. In Texas, the CDBG program is administered by the TDA.

United States Army Corps of Engineers

The USACE works with non-federal partners (states, tribes, counties, or local governments) throughout the country to investigate water resources and related land problems and opportunities. If warranted, they develop civil works projects that would otherwise be beyond the sole capability of the non-federal partner(s). Partnerships are typically initiated or requested by the local community to their local USACE district office. Before any project or study can begin, USACE determines whether there is an existing authority under which the project could be considered, such as the USACE CAP, or whether Congress must establish study or project authority and appropriate specific funding for the activity. New study or project authorizations are typically provided through periodic WRDA or via another legislative vehicle. Congress will not provide project authority until a completed study results in a recommendation to Congress of a water resources project, conveyed via a Report of the Chief of Engineers (Chief's Report) or a Report of the Director of Civil Works (Director's Report). Opportunities to partner with USACE are not considered grant or loan opportunities, but shared participation projects where USACE performs planning work and shares in the cost of construction. USACE also has technical assistance opportunities, including Floodplain Management Services, Silver Jackets team, and the Planning Assistance to States program, available to local communities.

Environmental Protection Agency

The CWSRF provides financial assistance in the form of loans with subsidized interest rates and opportunities for partial principal forgiveness for planning, acquisition, design, and construction of wastewater, reuse, and stormwater mitigation infrastructure projects. Projects can be structural or non-structural. Low Impact Development (LID) projects are also eligible. The CWSRF is administered in Texas by the TWDB.

United States Department of Agriculture

The USDA's NRCS provides technical and financial assistance to local government agencies through the following programs: EWP program, Watershed Protection and Flood Prevention program, watershed surveys and planning, and watershed rehabilitation. The EWP program, a federal emergency recovery program, helps local communities recover after a natural disaster by offering technical and financial assistance to relieve imminent threats to life and property caused by floods and other natural disasters that impair a watershed. The Watershed

Protection and Flood Prevention program helps units of federal, state, local, and tribal government protect and restore watersheds to prevent erosion, floodwater, and sediment damage; to further the conservation development, use, and disposal of water; and to further the conservation and proper use of land in authorized watersheds. The focus of Watershed Surveys and Planning program is funding the development of watershed plans, river basin surveys and studies, flood hazard analyses, and floodplain management assistance aimed at identifying solutions that use land treatment and nonstructural measures to solve resource problems. Lastly, the Watershed Rehabilitation program helps project sponsors rehabilitate aging dams that are reaching the end of their design lives. This rehabilitation addresses critical public health and safety concerns. The USDA also offers various water and environmental grant and loan funding programs, which can be used for water and waste facilities, including stormwater facilities, in rural communities.

Special Appropriations

On occasion, and when the need is large enough, Congress may appropriate funds for special circumstances, such as natural disasters or pandemics (COVID-19). A few examples of recent special appropriations from the federal government that can be used to fund flood-related activities include:

- American Rescue Plan Act (ARPA)
- Infrastructure Investment and Jobs Act (IIJA)/Bipartisan Infrastructure Law (BIL)

In 2021, the ARPA provided for a substantial infusion of resources to eligible state, local, territorial, and tribal governments to support their response to and recovery from the COVID-19 pandemic. Coronavirus State and Local Fiscal Recovery Funds (SLFRF), a part of ARPA, delivers $350 billion directly to state, local, and tribal governments across the country (Coronavirus State and Local Fiscal Recovery Funds, 2022). Communities have significant flexibility to meet local needs within the eligible use categories, one of which includes improving stormwater facilities and infrastructure as an authorized use. Eligible entities may request their allocation of Coronavirus SLFRP directly from the United States Department of Treasury.

Although not a direct appropriation to local governments like ARPA, the 2021 IIJA, also called the BIL, authorized over $1 trillion for infrastructure spending across the United States and provides for a significant infusion of resources over the next several years into existing federal financial assistance programs, including several of the flood funding programs discussed herein, as well as creating new programs.

Barriers to Funding

Local communities in the Trinity Region identified several barriers to accessing or seeking funding sources for flood management activities, including lack of knowledge of funding sources, lack of expertise to apply for funding, lack of resources to prepare funding applications, lack of expertise to manage funding awards when received, and lack of funds available for local match requirements. Unlike other types of infrastructure projects, flood projects do not typically generate revenue and many communities do not have steady revenue streams to fund flood projects. Consequently, communities struggle to generate funds for local match requirements or loan repayment. Complex or burdensome application or program requirements, as well as prolonged timelines also act as barriers to accessing state and local financial assistance programs. Of those communities that can overcome these barriers, apply for funding, and generate local resources for match requirements, the high demand for state and federal funding, particularly for grant opportunities, means that the need exceeds available funds, leaving many local communities without the resources they need to address flood risks.

Flood Infrastructure Financing Survey

Flood Infrastructure Financing Survey Methodology

The Trinity RFPG performed surveys of the sponsors for the recommended FMEs, FMPs, and FMSs in preparation of the January 2023 Final Plan and the July 2023 Amended Plan. The Trinity RFPG primarily used email to send the surveys to the sponsors. When email addresses were unavailable, additional outreach such as phone calls were used to obtain emails. As a last resort, the Trinity RFPG mailed surveys or used other means of collecting the required information. The primary aim of this survey effort was to understand the funding needs of local sponsors and obtain feedback regarding the role the state should have in financing the recommended FMEs, FMSs, and FMPs.

The Trinity RFPG collected information from sponsors by creating a survey through mail merge and sending it through email. Mail merge allowed the Trinity RFPG to automate a batch of emails that were personalized for each sponsor by linking a main template to a data source. The main template contained the text that was the same for each survey, while the data source was a file containing all the information to be merged into the survey and the sponsor's email address. An example of the survey emailed out to sponsors is shown in ***Figure 9.4***. A similar survey was emailed to sponsors of new FMEs, FMSs, and FMPs for this Amended Plan.

Figure 9.4: Flood Infrastructure Financing Survey Example

Hello Sponsor,

We are reaching out to you because there are one or more actions for your community that will be listed in the Trinity regional flood plan, and we need your help to identify how much state or federal funding you may need to implement these projects.

Please reply to this email and fill out the drop-down menu in the table below for each of your entities' Flood Mitigation Actions by June 28, 2022. Please note the percent funding financed by sponsor and other funding needed must equal 100%. For more information regarding your Flood Mitigation Actions, visit the following link: RFP Region 3 - FMX Summaries by Sponsor . If we do not receive a response, we will assume that 90% of the cost for that action will need other funding (including state, federal and/or other funding).

The Texas Water Development Board (TWDB) designated 15 regional flood planning areas each of which began with a designated regional flood planning group that will develop a regional flood plan for their region by January 2023. TWDB will bring the regional flood plans together to produce the first State Flood Plan by September 1, 2024. Entities must have their project listed in the State Flood Plan to receive state funding for a proposed flood project. As part of the regional flood planning process, RFPGs must indicate how sponsors will propose to finance recommended Flood Mitigation Actions included in the Flood Plan[1]. Flood Mitigation Actions include Flood Management Evaluation (FME), Flood Mitigation Strategy (FMS), and Flood Mitigation Project (FMP)[2].

There is no commitment associated with being a sponsor for an action in the plan, this is just a planning level study.

Flood Mitigation Action ID	Flood Mitigation Action Type[2]	Flood Mitigation Action Name	Flood Mitigation Action Description	Flood Mitigation Action Total Estimated Cost*	Sponsor Funding		Other Funding Needed** (including state, federal and/or other funding)
					Anticipated Source of Sponsor Funding	Percent Funding to be Financed by Sponsor**	
032000095	FMS	Floodplain Regulatory Awareness Public Information Campaign	Rewrite, improve, and implement new local floodplain regulations, to include a public information campaign on regulatory awareness	$50,000	General Revenue	90%	10%
032000058	FMS	Acquisition of Repetitive Loss Properties	Acquire repetitive flood loss properties and properties prone to flooding in the Deep River Plantation Subdivision	$5,000,000	Choose an item.	Choose an item.	Choose an item.
032000070	FMS	Voluntary Buyout Program	The county and partnering jurisdictions will begin a voluntary buyout program for insured severe repetitive loss properties that are in the floodplain	$5,000,000	Choose an item.	Choose an item.	Choose an item.
031000033	FME	FEMA Mapping	Create FEMA mapping in previously unmapped areas and update existing FEMA maps as needed.	$1,276,000	Choose an item.	Choose an item.	Choose an item.

**Costs are based on high level engineering estimates and assumptions.*

***Percent funding financed by sponsor and other funding needed MUST equal 100%.*

During the mail merge process, a personalized table of recommended FMEs, FMSs, and FMPs was generated for each sponsor. The table included the identification number, type, name, description, and total estimated cost for each FME, FMS, and FMP listed. Additionally, a link was provided where sponsors could navigate to their one-page report summaries for more information about their FMEs, FMSs, and FMPs (***Appendices E, F and G***). After receiving the email, sponsors were asked to reply to the survey by selecting from the drop-down menu of possible answers under the financing columns. Sponsors could select a percentage between zero percent to 100 percent (in five percent increments) under the 'Percent Funding to be Financed by Sponsor' and 'Other Funding Needed' columns for each FME, FMS, and/or FMP.

Drop-down menu options for 'Anticipated Source of Sponsor Funding' included:

- Taxes
- General revenue
- Dedicated revenue inclusion fees
- Entity budget/funds
- Donations
- Bonds/other financing
- Other
- To be determined

The Trinity RFPG scheduled phone call survey meetings with sponsors to address any questions or concerns, resulting from the funding survey. Additionally, the Trinity RFPG followed up with sponsors who did not initially respond to the funding survey to improve the response rate.

Following the Draft Plan submittal in the Fall of 2022, the Trinity RFPG performed two additional rounds of phone calls to sponsors. These phone calls aimed to confirm the correct e-mail addresses in which to send the Financing Survey. These phone calls also allowed the Trinity RFPG to answer any sponsor questions and encourage them to respond to the survey.

Amended Plan Methodology

The additional outreach following the Final Plan submittal in January 2023 resulted in many additional actions requested for inclusion in this Amended Plan. These actions were submitted by both existing sponsors and new sponsors. Both sets of sponsors were sent a simplified version of the Financing Survey as shown in ***Figure 9.4***. The simplified version of the Financing Survey did not use the mail merge feature. The list of actions was populated manually and was sent using a traditional email message. The one-page summaries were also excluded from these emails because the sponsors are already familiar with their requested FMEs, FMSs, and FMPs. Due to time constraints, the RFPG assumed that sponsors who did not respond to the survey would need 90 percent of the anticipated project costs to be met with state and/or federal funding sources.

Flood Infrastructure Financing Survey Results

The flood infrastructure funding survey was sent to 194 sponsors of recommended FMEs, FMSs, and FMPs in the development of the Final Plan and this Amended Plan. The primary goal of the survey effort was to understand the funding needs of local sponsors and then propose what role the state should have in financing the recommended FMEs, FMSs, and FMPs. Of the 195 entities surveyed, 43 responded. This represents a response rate of 22 percent. ***Appendix A*** presents the results of the survey for each FME, FMS, and FMP in the ***TWDB-Required Table 19***. The response rate for the survey does not represent a significant percentage of respondents and, therefore, does not accurately represent the total need for state and federal funding in the Trinity Region. With additional time provided in the second cycle of regional flood planning, the Trinity RFPG anticipates that a greater response rate may be obtained through additional outreach efforts such as follow-up emails, phone calls, and meetings.

The Trinity RFPG assumed that those sponsors who did not respond to the survey would need 90 percent of the total project costs to be funded by state and/or federal sources. This represents an average of 10 percent projected local investment in projects. A high percentage of outside need is supported by the initial outreach efforts discussed in earlier in this chapter, which confirmed that many communities, particularly smaller and more rural communities, do not have any local funding available for flood management activities. Those communities that reported having local funding indicated relatively little local funding available in relation to the overall need.

Overall, there is a total cost of $1,595,648,000 needed to implement the recommended FMEs, FMSs, and FMPs in this regional flood plan. From the total cost, it is projected that $1,426,504,000 of state and federal funding is needed. This number does not represent the amount of funding needed to mitigate all risks in the region and solve flooding problems in their entirety. This number simply represents the funding needs for the specific, identified studies, strategies, and projects in this cycle of regional flood planning. Future cycles of regional flood planning will continue to identify more projects and studies needed to further flood mitigation efforts in the Trinity Region.

Bibliography

Campbell, C. W. (2020). *Western Kentucky University Stormwater Utility Survey 2020.* SEAS Faculty Publications.

Coronavirus State and Local Fiscal Recovery Funds. (2022, April 1). Retrieved from United States Department of the Treasury: https://home.treasury.gov/policy-issues/coronavirus/assistance-for-state-local-and-tribal-governments/state-and-local-fiscal-recovery-funds

Chapter 10: Public Participation and Plan Adoption

This chapter describes the plan adoption and approval process for the Trinity Regional Flood Planning Group (RFPG) Regional Flood Plan and its 2023 amendments, as well as the efforts made to inform the public and encourage public participation in the planning process. Special efforts were made during this inaugural regional flood planning cycle to inform the general public and entities with flood-related authority or responsibility throughout the Trinity Region about this important, new planning effort – and to seek their crucial input. All public participation and plan adoption activities were conducted in accordance with the state's flood planning guidance principles, as well as in accordance with the requirements of the Texas Open Meetings Act and Public Information Act.

Regional Flood Planning Group

The 86th Texas Legislature passed Senate Bill 8 in 2019, which authorized the Texas Water Development Board (TWDB) to oversee the regional flood planning and state flood planning processes. The legislation included specific information to be included in the regional flood plans. In addition, the TWDB established planning rules and guidance documents for the flood planning process and the plans themselves. The TWDB established 15 RFPGs across Texas to implement the flood planning process. Each RFPG includes designated representatives of 12 required interest categories:

- Agriculture
- Counties
- Electric-generating utilities
- Environment
- Flood districts
- Industry
- Municipalities
- Public
- River authorities
- Small business
- Water districts
- Water utilities

The initial voting members of the 15 RFPGs were designated by the TWDB during its October 1, 2020, board meeting. Each RFPG, at its discretion, added additional voting or non-voting members for any additional interest category needed to represent the region or added additional members to the required interest categories. Since its inception, the Trinity RFPG has added several members and replaced members to fill vacancies. Each member also had the opportunity to designate an alternate to represent their interest category in the event they were unable to attend a meeting.

The TWDB included multiple agencies as non-voting members to each RFPG, and each of those agencies assigned representatives. In addition, liaisons were selected from adjacent regions to participate as non-voting members to share information on activities occurring within their region that might be of interest or relevant to the Trinity Region.

The process for adding new voting or non-voting members, filling vacancies, or creating new interest categories or organizational representations is outlined in the Trinity RFPG bylaws adopted on October 27, 2020, which can be found on the RFPG website.

Table 10.1 lists the voting members of the Trinity RFPG as of June 2023, and the interests they represent. For the first round of regional flood planning, Glenn Clingenpeel (Trinity River Authority) served as the Trinity RFPG Chair, Sarah Standifer (City of Dallas) served as the Vice Chair, and Scott Harris (Gulf Coast Authority) served as the Secretary.

Table 10.1: Current Trinity Regional Flood Planning Group Voting Members

Interest	Member
River Authorities	Glenn Clingenpeel, Chair
Municipalities	Sarah Standifer, Vice Chair
Water Utilities	Scott Harris, Secretary
Small Business	Chad Ballard
Electric Generating Utilities	Sano Blocker
Agriculture	Melissa Bookhout
Flood Districts	Rachel Ickert
Public	Andrew Isbell
Environmental	Jordan Macha
Water Districts	Galen Roberts
Industry	Matt Robinson
Counties	Lissa Shepard

Table 10.2 lists the non-voting members of the Trinity RFPG as of June 2023 and the interest or organization they represent. Among the non-voting members were liaisons from neighboring regions who helped facilitate interregional cooperation, where necessary. These liaisons also supported efforts to resolve issues, including potential negative impacts on neighboring areas within and between regions.

Table 10.2: Current Trinity Regional Flood Planning Group Non-Voting Members

Interest and/or Organization	Member
TWDB	Richard Bagans
Texas Department of Agriculture (TDA)	Rob Barthen
Texas State Soil and Water Conservation Board (TSSWCB)	Steve Bednarz
*Council of Governments (COG) - Houston-Galveston Area Council	Justin Bower
Neches Flood Planning Group (liaison)	Ellen Buchanan
Region 6 San Jacinto Flood Planning Group (liaison)	Todd Burrer
*United States Army Corps of Engineers (USACE), Fort Worth	Jerry Cotter
Texas Commission on Environmental Quality (TCEQ)	Bert Galvan
*Federal Emergency Management Agency (FEMA)	Diane Howe
*COG - Deep East Texas Council of Governments	Lonnie Hunt
* North Central Texas Council of Governments (NCTCOG)	Kate Zielke
*USACE, Galveston	Lisa McCracken
General Land Office (GLO)	Kris Robles
Texas Division of Emergency Management (TDEM)	Andrea Sanders
*National Weather Service (NWS) - West Gulf River Forecast Center	Greg Waller
Texas Parks and Wildlife Department (TPWD)	Adam Whisenant

**These non-voting seats, not required by TWDB rule or statute, were added by the Trinity RFPG and the respective interests or organizations were invited to appoint representatives or submit nominees to serve as non-voting members.*

Outreach to Cities, Counties, and Other Entities with Flood-Related Authority or Responsibility

The Trinity RFPG made special efforts to contact cities, counties, and various other entities and individuals across the Trinity Region with flood-related authority – including flood planning, floodplain management, and/or flood mitigation responsibilities.

Securing input from these regional entities was a vital priority of the Trinity RFPG so outreach efforts focused on:

- Making certain regional entities were aware of the regional flood planning process
- Encouraging the exchange of necessary data to assist with development of the inaugural regional flood plan
- Providing abundant opportunities to be engaged with the planning process from beginning to end

The Trinity RFPG team began its outreach effort by developing a robust database of entities or individuals with flood planning, floodplain management, and/or flood mitigation responsibilities across the entire 38-county region. This database also included "interested parties" who requested electronic notifications about regional flood planning activities and milestones on the Trinity RFPG website or through team members. As of June 2023, the database included over 900 individual contacts, and the Trinity RFPG continues to update or add to the list as new contact information becomes available, or as individuals indicate their interest in the regional flood planning process. Among the entity types represented in the database were:

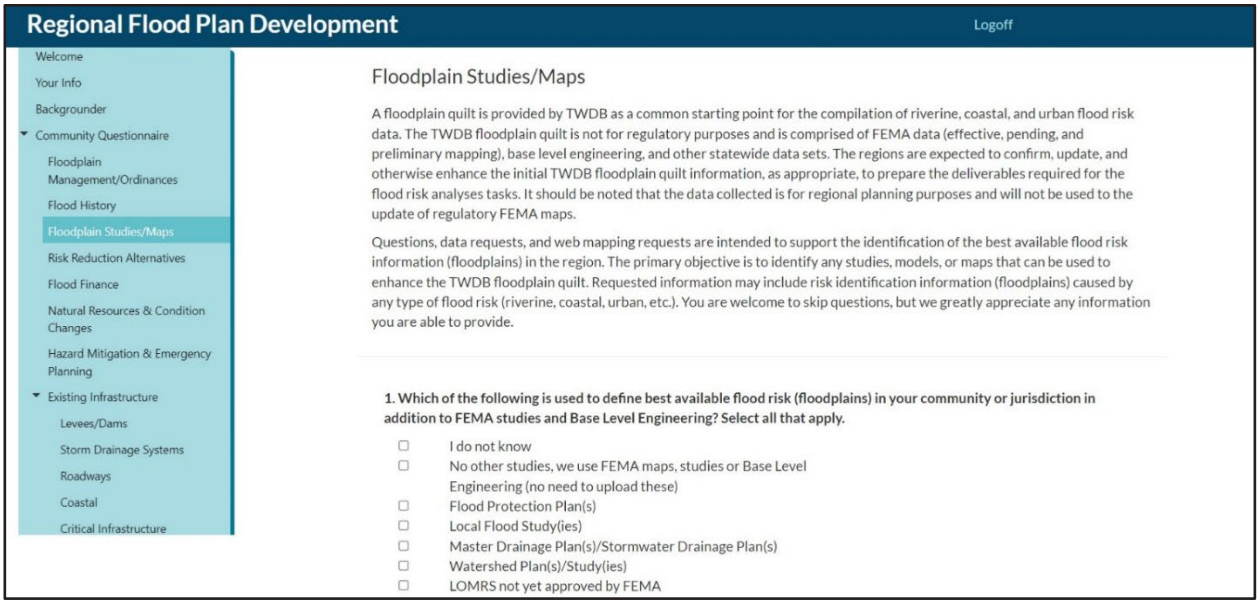
- Agriculture
- Cities and towns
- COGs
- Counties
- Districts of various types, such as:
  - Development Districts
  - Drainage Districts
  - Flood Control Districts (FCD)
  - Municipal Management Districts
  - Municipal Utility Districts (MUD)
  - Special Utility Districts (SUD)
  - Water Control and Improvement Districts (WCID)
  - Water Supply Districts (WSD)
- Electric generating utilities
- Environmental groups
- Federal agencies
- Industries
- Public (including "interested parties" who subscribed to receive electronic communications through the Trinity RFPG website)
- River authorities
- Small businesses
- State agencies or entities
- Water authorities
- Water utilities

In addition, many of these entity types or interest categories were represented among the voting and non-voting membership of the Trinity RFPG.

Data Collection Tools and Surveys

Several data collection surveys or tools were developed by the Trinity RFPG and made available to the regional entities, interested parties, and the general public to facilitate the data collection and mapping process essential for the development of the inaugural regional flood plan. This included an initial electronic data collection tool that was posted to the Trinity RFPG website in June 2021 to gather information on local flood planning resources, as well as existing and future flood-related risks in the Trinity Region. A screenshot of the data collection tool is shown in ***Figure 10.1***.

Figure 10.1: Online Data Collection Tool



This survey included access to an Interactive Floodplain Web Map where participants could identify specific flood-prone areas. Entities and individuals were notified of the data collection tools, and were strongly encouraged to participate in the data collection process, via several methods (shown in ***Figure 10.2***):

- Extensive discussion and demonstration of the data collection tool and Interactive Web Map occurred during a public meeting of the Trinity RFPG
- Emails were sent to the regional entities and interested parties (distributed via MailChimp)
- Postcard were sent via United States postal services to each entity or interested party with a known mailing address
- Two rounds of direct phone calls were made in June and July 2021 to try and contact each entity and identify alternative contacts, where needed
- Press releases were distributed to media across the region, resulting in news article placements

Based on the initial data gathered, an updated, preliminary version of the interactive flood risk web map was generated and made available on the Trinity RFPG website for public comment in February 2022. Entities and individuals were asked to review the map and identify any potential gaps or inaccuracies in the depiction of current flood-prone areas. Entities and individuals could add comments to the map by dropping points to indicate areas where there might be errors or missing areas of flood risk for their community or neighborhood. This preliminary interactive flood risk web map was publicized via:

- Extensive discussion and demonstration of the new, preliminary interactive floodplain web map during the Trinity RFPG public meeting
- Email blast to the regional entities and interested parties email list (distributed via MailChimp)
- Press releases distributed to media across the region, resulting in news article placements

As a result of the above public outreach efforts, the Trinity RFPG's electronic data collection tool received responses from nearly 100 entities across the Trinity Region.

In early June 2022, the consultant Trinity RFPG team developed and distributed a survey to sponsors of recommended flood mitigation actions including Flood Management Evaluations (FMEs), Flood Management Strategies (FMS), and/or Flood Mitigation Projects (FMPs) to identify how much state and/or federal funding might be needed by sponsors to implement their recommended flood mitigation actions. In addition to distributing the survey via email, follow-up phone calls were made during the summer and fall by the Trinity RFPG team to potential project sponsors to maximize participation. Ultimately, 18 percent of those surveyed provided responses. The RFPG assumed that those sponsors that did not respond would be able to provide 10 percent local funding to implement the recommended action. Overall, the total cost of implementing the recommended actions in this plan is $1,076,686,000. The RFPG anticipates that $966,309,000 in state and federal funding is needed for implementation.

Figure 10.2: Methods Used for June – July 2021 Data Collection and Related Public Outreach

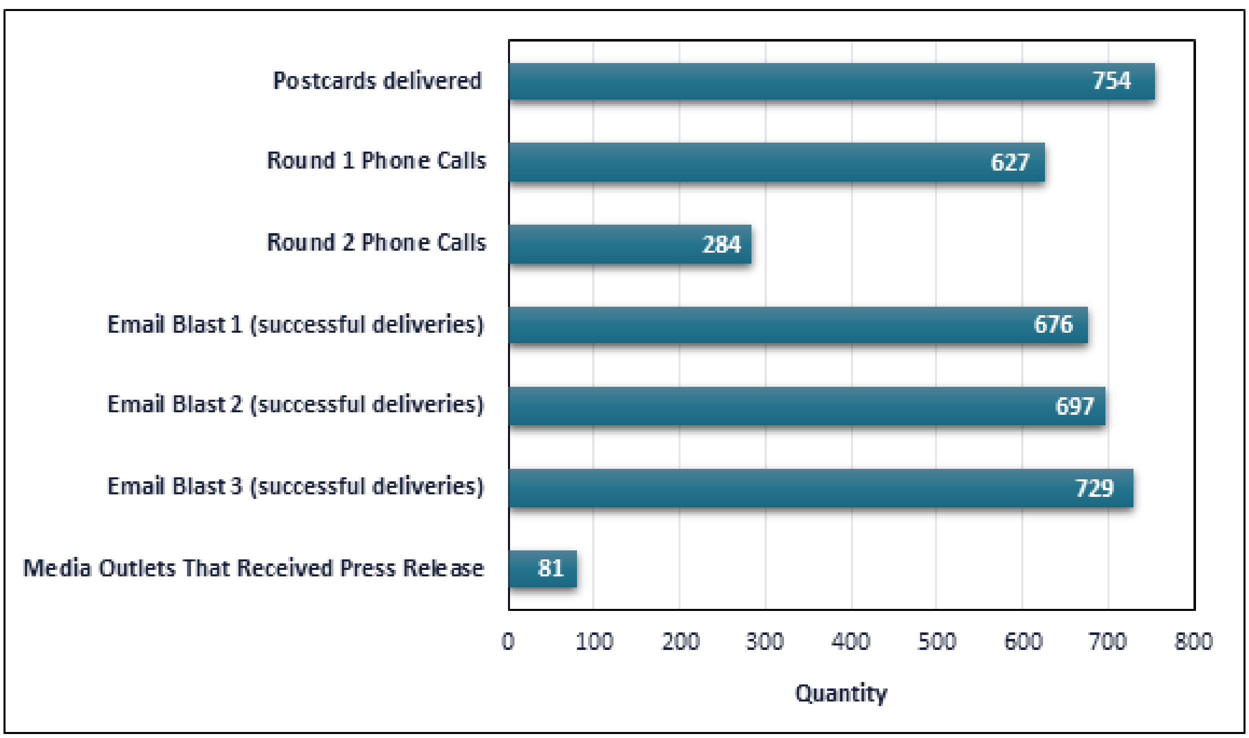


Figure 10.3: Image of the Interactive Web Map Prior to June – July 2021 Public Input

Figure 10.4: Image Showing Public Input Received from Data Collection Process

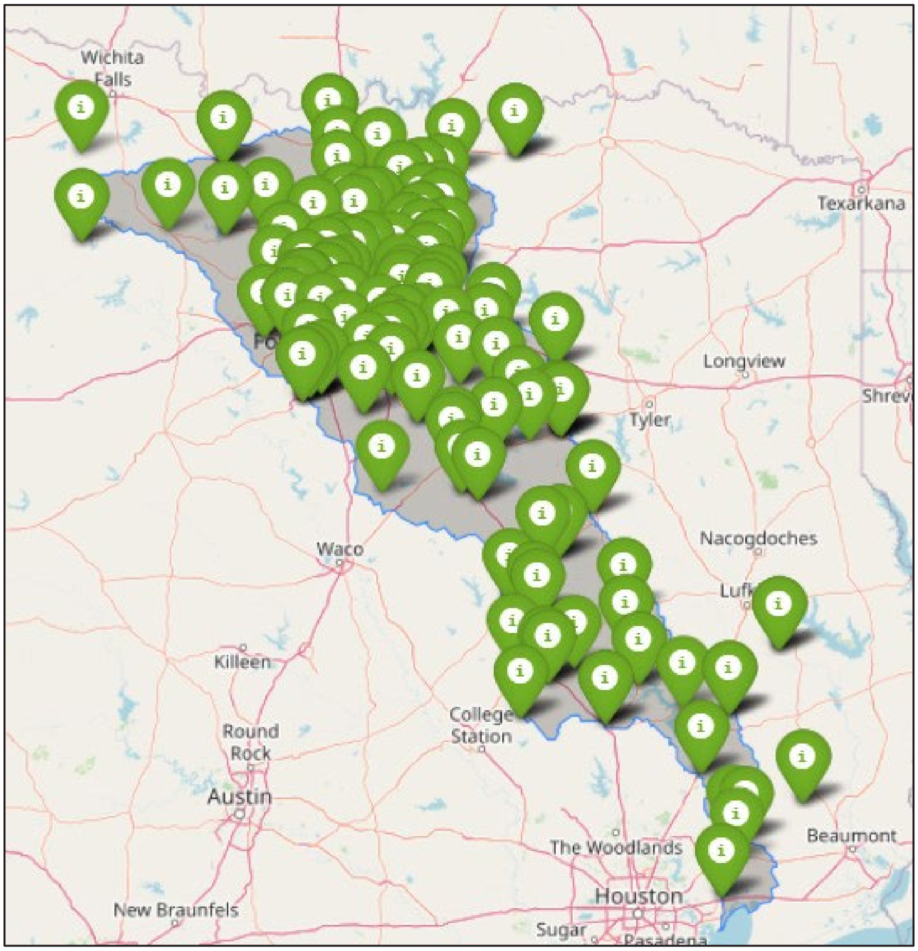


Figure 10.5: Methods Used for February 2022 Interactive Web Map Public Outreach

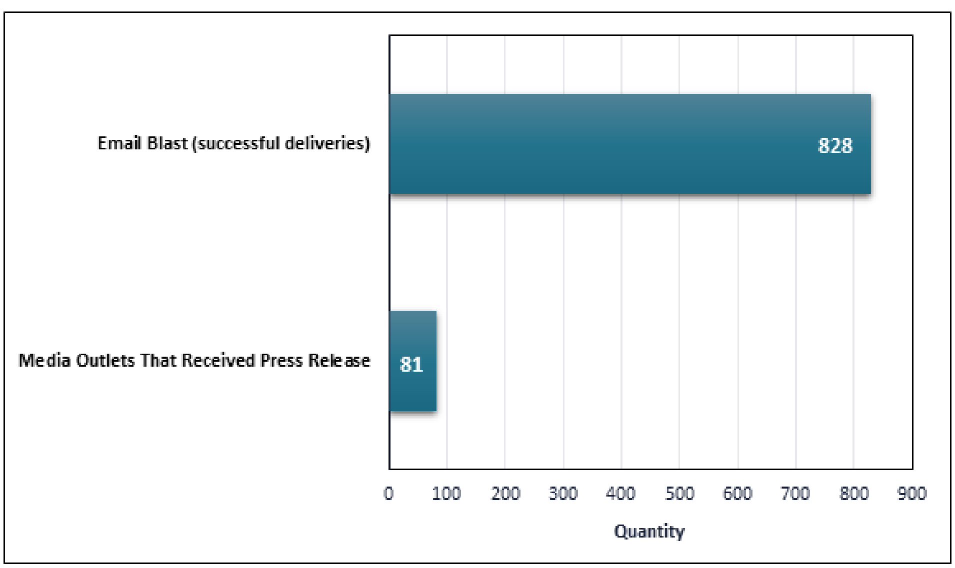


Figure 10.6: Additional Public Input Received on Updated Interactive Web Map, February 2022

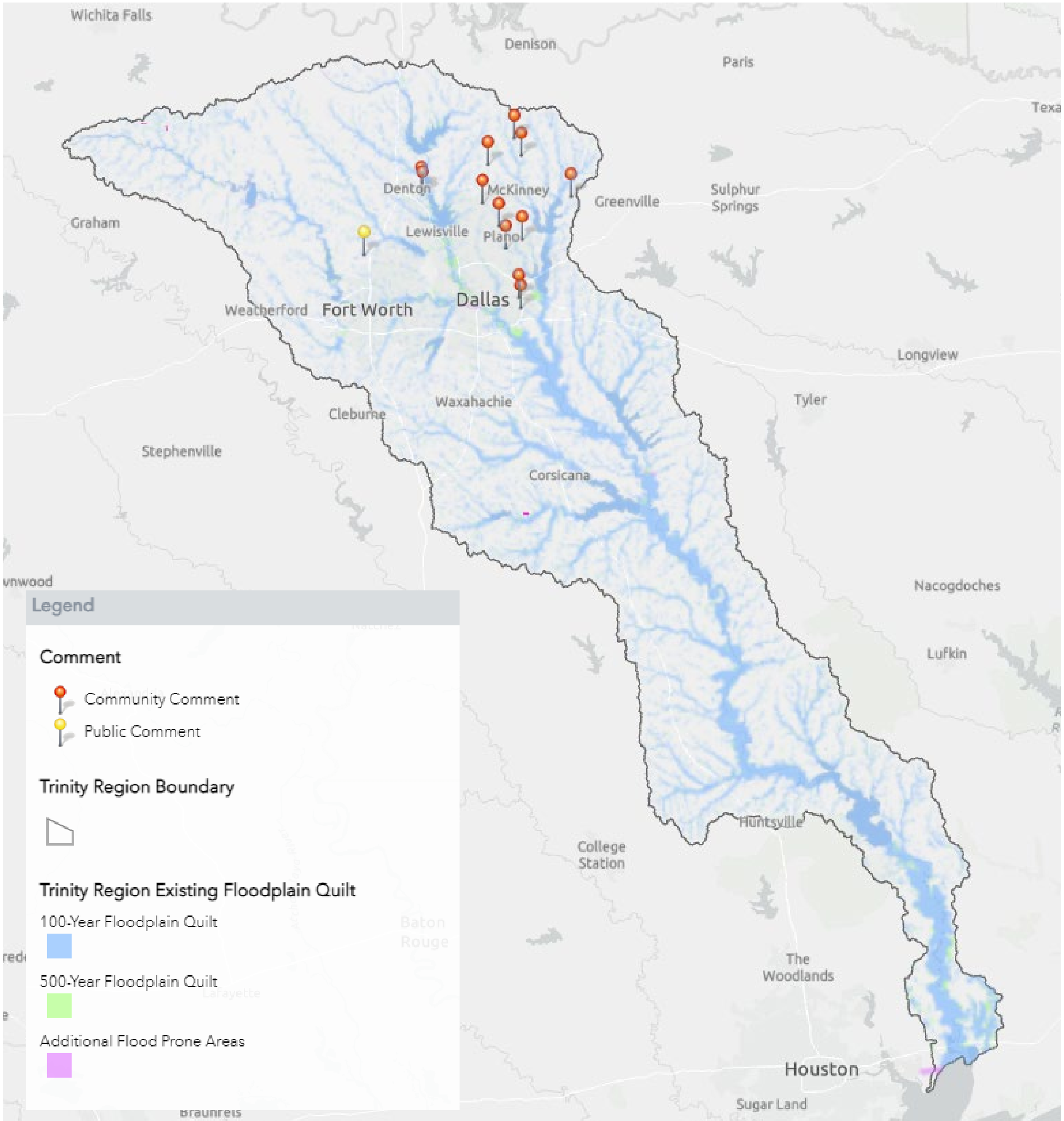


Figure 10.7: Image of the Survey Distributed to Sponsors of Potential Flood Mitigation Actions

Hello Sponsor,

We are reaching out to you because there are one or more actions for your community that will be listed in the Trinity regional flood plan, and we need your help to identify how much state or federal funding you may need to implement these projects.

Please reply to this email and fill out the drop-down menu in the table below for each of your entities' Flood Mitigation Actions by June 28, 2022. Please note the percent funding financed by sponsor and other funding needed must equal 100%. For more information regarding your Flood Mitigation Actions, visit the following link: RFP Region 3 - FMX Summaries by Sponsor . If we do not receive a response, we will assume that 90% of the cost for that action will need other funding (including state, federal and/or other funding).

The Texas Water Development Board (TWDB) designated 15 regional flood planning areas each of which began with a designated regional flood planning group that will develop a regional flood plan for their region by January 2023. TWDB will bring the regional flood plans together to produce the first State Flood Plan by September 1, 2024. Entities must have their project listed in the State Flood Plan to receive state funding for a proposed flood project. As part of the regional flood planning process, RFPGs must indicate how sponsors will propose to finance recommended Flood Mitigation Actions included in the Flood Plan[1]. Flood Mitigation Actions include Flood Management Evaluation (FME), Flood Mitigation Strategy (FMS), and Flood Mitigation Project (FMP)[2].

There is no commitment associated with being a sponsor for an action in the plan, this is just a planning level study.

Flood Mitigation Action ID	Flood Mitigation Action Type[2]	Flood Mitigation Action Name	Flood Mitigation Action Description	Flood Mitigation Action Total Estimated Cost*	Sponsor Funding		Other Funding Needed** (including state, federal and/or other funding)
					Anticipated Source of Sponsor Funding	Percent Funding to be Financed by Sponsor**	
032000095	FMS	Floodplain Regulatory Awareness Public Information Campaign	Rewrite, improve, and implement new local floodplain regulations, to include a public information campaign on regulatory awareness	$50,000	General Revenue	90%	10%
032000058	FMS	Acquisition of Repetitive Loss Properties	Acquire repetitive flood loss properties and properties prone to flooding in the Deep River Plantation Subdivision	$5,000,000	Choose an item.	Choose an item.	Choose an item.
032000070	FMS	Voluntary Buyout Program	The county and partnering jurisdictions will begin a voluntary buyout program for insured severe repetitive loss properties that are in the floodplain	$5,000,000	Choose an item.	Choose an item.	Choose an item.
031000033	FME	FEMA Mapping	Create FEMA mapping in previously unmapped areas and update existing FEMA maps as needed.	$1,276,000	Choose an item.	Choose an item.	Choose an item.

**Costs are based on high level engineering estimates and assumptions.*

***Percent funding financed by sponsor and other funding needed MUST equal 100%.*

Immediately after the Trinity RFPG voted to approve the 2023 Region 3 Trinity Regional Flood Plan in November 2022, its consultant team began the process of soliciting and reviewing further input as part of their preparations to amend the Plan in 2023. Emails sent to regional stakeholders between November 17, 2022, and January 27, 2023 requested sponsors from across the Trinity River Basin to submit data for potential FMEs, FMSs, and FMPs to be considered for inclusion in the Amended Regional Flood Plan. Multiple meetings were held during this period with potential project sponsors to discuss their proposed FMEs, FMSs, and FMPs. The consultant team also developed a methodology for grouping all proposed project submissions into tiers, based on certain RFPG-approved criteria, and presented this methodology to the Trinity RFPG for approval. The goal of this effort was to get more FMEs, FMSs, and FMPs qualified for inclusion in the Amended Plan as recommended solutions. As a result of this purposeful outreach, additional data for 165 new FMEs, two new FMSs, and 69 new FMPs was received and had the potential to be added to the Amended Regional Flood Plan.

Meetings with Local Political Subdivisions with Flood-Related Authority

During this initial planning round, the Trinity RFPG's team met with 16 local political subdivisions with flood-related authority who were identified as potential sponsors of flood mitigation actions. The purpose of these meetings was to specifically identify the locations of potential FMEs, FMSs, and FMPs and to gather other necessary details for planning purposes. These entity meetings were held in a virtual format and included cities, counties, river authorities, and others.

Meetings with Other Entities and Interested Parties

The Trinity RFPG team also met with a variety of other regional entities and interested parties during the initial planning round to gain input on potential flood mitigation actions and to collect any relevant data these entities wished to be considered in the planning process. These entities included eight state and federal agencies, COGs, and environmental advocacy groups. Much like the Trinity RFPG meetings with political subdivisions with flood-related authority throughout the region, these meetings were held in a virtual format.

Outreach to the Public

In addition to the regional entity outreach described above, members of the general public were informed about planning activities through the development and/or distribution of a variety of communications vehicles. More information on public meetings, hearings, and open houses is included in later in this chapter.

Digital Media: Website and Twitter

In May 2021, the Trinity RFPG created a Twitter account and began using it to regularly to update the public about meetings and planning activities, as well as to share flood-related data and stories from other sources.

In accordance with regional flood planning guidelines and public engagement best practices, the Trinity RFPG team developed and launched a website (www.trinityrfpg.org) in June 2021. In accordance with the Texas Open Meetings Act and Senate Bill 8/TWDB guidelines, the website was also used for timely postings of all meeting agendas/notices, meeting materials, meeting minutes, and recordings. The homepage features a form where interested parties can sign up to receive electronic notifications for meeting-related document postings, along with key planning milestones.

The site also includes a dedicated Public Comment page, where members of the public can submit questions or concerns. Other avenues for the public to contact the Trinity RFPG team are also provided, including the identification of a dedicated email address, info@trinityrfpg.org. The site also uses Google Analytics, which allows the Trinity RFPG team to determine how many visits the site receives overall, as well as which pages receive the most traffic.

All key planning documents are uploaded to the site for public review through a searchable/sortable document library page.

In February 2022, the Trinity RFPG website was recognized with a Gold Award in the 2022 AVA Digital Awards, an international marketing communications competition, in the Web-Based Production/Government category. This annual, global awards program, administered and judged by the Association of Marketing and Communication Professionals, honors outstanding work by creative professionals involved in the concept, direction, design, and production of media that are part of the evolution of digital communication. Out of the thousands of entries submitted from creative agencies and organizations worldwide, around 19 percent receive Gold-level recognition.

The Draft Trinity Regional Flood Plan was made available on the website at the same time that it was submitted to the TWDB in late July 2022. Both the Final Trinity Regional Flood Plan and the Trinity RFPG's request for project sponsors across the region to submit additional FME, FMS, and FMP data were posted to the website in January 2023.

Informational Handouts

To support the initial data collection effort and educate regional stakeholders about the new regional flood planning process, the Trinity RFPG developed two informational, one-page flyers in the spring of 2021. One was designed for the general public or landowners of flood-prone areas. The other was designed specifically for political entities with flood-related authority or responsibility. Each flyer described the origins of the regional flood planning process and the basic timeline for development of the first regional flood plan.

The public version of the flyer encouraged members of the public or landowners to use the Interactive Web Map tool to mark known flood-prone areas in their community or neighborhood. It also encouraged them to stay informed and participate throughout the regional flood planning process.

The political entity-focused version of the flyer showcased the electronic data collection tool and Interactive Web Map and described the types of information that should be gathered by the political entity before receiving the Trinity RFPG's June 2021 survey. (see previous Data Collection and Tools section) The flyer also described ways that political entities could upload relevant reports, maps, and models to the Trinity RFPG website's data collection tool, or how those materials could be mailed directly to the Trinity RFPG. Finally, the flyer reinforced that participation in the planning process was important because projects included in the regional and State Flood Plans would be better positioned in the future to potentially receive funding.

The RFPG team developed two additional flyers with the release of the draft plan. A two-page flyer provided a brief overview of the Trinity Regional Flood Plan, identified the RFPG members and representative categories, and highlighted the RFPG's accomplishments through July 2021. The RFPG members shared this flyer with interested parties. A separate one-page flyer encouraged public participation in the open houses scheduled in August 2022 and the Public Hearing in September 2022. This flyer provided information on where the draft plan could be viewed and the available methods for public comments to be submitted to the RFPG. See ***Appendix H*** for copies of these flyers.

PowerPoint Slideshow Presentation

The Trinity RFPG developed an educational PowerPoint presentation for Trinity RFPG members to use when speaking to various organizations about the regional flood plan. The presentation included an overview of the regional flood planning process and its history, as well as a comparison to the regional water planning process that was already well-known to many in the region due to the regional water planning groups' nearly 25-year history of planning activities.

The Trinity RFPG Chair used the created presentation at the 2021 North Texas Infrastructure Summit (organized by the North Texas Commission), a meeting with the NCTCOG Flood Management Task Force, and a meeting of local elected officials convened by NCTCOG, among others. The presentation was also used by the RFPG Chair and several RFPG members for presentations at several 2022 opportunities, including the North Texas Infrastructure Summit, the Texas Floodplain Management Association (TFMA) Region 4/10 Educational Luncheon Forum, and the Society of American Military Engineers (SAME) 22nd Annual Infrastructure Forum.

Press Releases and Media Advisories

Press releases and/or media advisories were developed and issued to regional media prior to every meeting of the Trinity RFPG during this first round of regional flood planning. These notices alerted the media of the opportunity to attend and cover these public meetings (or to observe them online), as well as requested the media to include meeting information in their publications and event calendars to enhance overall public awareness and public participation opportunities.

The Trinity RFPG team also worked directly with numerous editors and reporters to promoted Trinity RFPG meetings and to encourage them to write stories about the importance of the flood planning process. Media outreach avenues included:

- ABC News Radio Network
- Anahuac Progress
- Archer County News
- Athens Daily Review
- Bowie News
- Bluebonnet News
- Cleburne Times-Review
- Collin County Business Press
- Community Impact Newspaper: DFW and other local editions

- Corsicana Daily Sun
- The Community News
- Cross Timbers Gazette
- Dallas Business Journal
- The Dallas Morning News
- Dallas Observer
- Denton Record-Chronicle
- The Fairfield Recorder
- The Ennis News
- Fort Worth Report
- Fort Worth Star-Telegram
- Freestone County Times
- Gainesville Daily Register
- Good Morning Parker County
- The Graham Leader
- Grand Saline Sun
- The Grapeland Messenger
- The Herald-Banner
- The Hometown Press
- Hood County News
- Houston County Courier
- Hubbard City News
- Huntsville Item
- Intown Magazine
- Irving Rambler
- Jacksboro Herald-Gazette
- KAND-AM
- Kaufman Herald
- KBOC-FM
- KDAF-TV
- KDFW-TV
- KGAF-AM
- KGVL-AM
- KIVY-AM
- KLIF-AM
- KMVL-AM
- KPIR-AM
- KPYK-AM
- KRVF-FM
- KTVT-TV
- KWBC-AM
- KWWJ-AM
- KXAS-TV
- KXII-TV
- KXTX-TV
- KZHN-AM
- The Lakelander
- Lone Star Politics (KXAS-TV)
- Madisonville Meteor
- Mansfield Magazine
- The Mexia News
- Messenger News
- Muenster Enterprise
- Nocona News
- Normangee Star
- North Texas e-News
- Ozona Stockman
- Palestine Herald-Press
- Polk County Enterprise
- The Reporter (Hillsboro)
- The Seabreeze Beacon
- Sherman Herald Democrat
- Star Local Media (various publications – Allen, Carrollton, Celina, The Colony, Coppell, Flower Mound, Frisco, Lake Cities, Lewisville, Little Elm, McKinney, Mesquite, Plano, Rowlett)
- The Teague Chronicle
- Terrell Tribune
- Texas Forest Country Living
- Van Zandt News
- Waxahachie Daily Light
- WBAP-AM
- Weatherford Democrat
- WFAA-TV
- Wise County Messenger

Public Hearings, Public Meetings, and Open House Roadshow

Numerous public hearings and public meetings were held as part of the first round of regional flood planning for the Trinity Region to provide ample opportunities for public engagement, feedback, and suggestions for the first Trinity Regional Flood Plan. Additionally, the Trinity RFPG held a series of open house roadshow events at various locations in the late summer of 2022 to provide an overview of the Draft Trinity Regional Flood Plan and take questions prior to collecting formal input on the draft plan. More details about these meetings and events are provided in the following sections.

Public Hearings

As required by TWDB rules, the Trinity RFPG held two pre-planning meetings on April 22, 2021, and August 19, 2021, to receive public input on the development of the regional flood plan. During these meetings, a TWDB representative presented background information on the formation of RFPGs and the regional flood planning process. The Trinity RFPG encouraged the public to provide feedback and general suggestions to issues, provisions, projects, and strategies that should be considered in the development of the regional flood plan. No written or oral comments were provided during either pre-planning meeting. Two written comments of a general nature were submitted through the Trinity RFPG website in between the pre-planning meetings and were shared with the Trinity RFPG for consideration in the planning process.

The Trinity RFPG held a public hearing on September 8, 2022, to present an overview of the Draft Trinity Regional Flood Plan and to receive formal public input on the draft plan. No public comments were received at that hearing.

Public Meetings

The Trinity RFPG has held many regular public meetings during the development of the Draft Trinity Regional Flood Plan. These meetings were open to the public, proper notice was made following Senate Bill (SB) 8 guidelines, and meetings met all requirements of the Texas Open Meetings Act. Additionally, detailed minutes and recordings of all meetings were kept and subsequently posted to the Trinity RFPG website.

Most Trinity RFPG meetings were held in a hybrid (virtual and in-person) format to facilitate greater, more convenient participation opportunities for planning group members, regional entities, and individual members of the public. Additionally, the Trinity RFPG used a variety of locations for the in-person component of its meetings, including meetings in Arlington (NCTCOG), Dallas (Dallas City Hall), Corsicana (Navarro College), Crockett (Houston County Electric Cooperative), Huntsville (Sam Houston Statue Visitor Center and TRA’s Southern Region Office), and Streetman (TRWD Richland Chambers Lake Office).

The Trinity RFPG met regularly, approximately once every one to two months, to verify that flood planning topics were given due consideration and that the draft plan was developed on schedule. ***Table 10.3*** shows the dates of the Trinity RFPG public meetings, including meetings of its committees and subcommittees, held during this round of planning*:*

Table 10.3: Trinity Regional Flood Planning Group Public Meetings

Full Regional Flood Planning Group	Technical Subcommittee	Goals Subcommittee	Nominating Subcommittee
October 27, 2020	February 10, 2022	August 31, 2021	March 12, 2021
December 17, 2020	March 15, 2022		June 23, 2021
March 16, 2021	April 13, 2022		April 21, 2022
April 22, 2021	October 20, 2022		
May 27, 2021			
June 24, 2021			
August 19, 2021			
September 23, 2021			
November 18, 2021			
December 16, 2021			
February 17, 2022			
April 21, 2022			
June 2, 2022			
July 21, 2022			
November 17, 2022			
February 16, 2023			
April 6, 2023			
June 29, 2023			

Open House Roadshow

The Trinity RFPG team planned and conducted a roadshow series of open house meetings in late August 2022 at locations across the Trinity Region – including in the Lower, Middle and Upper portions of the basin – to present an overview of the initial draft plan that was submitted to the TWDB in late July 2022, and to address regional entities' and individuals' questions. Those meeting dates and locations were as follows:

- Lower Basin: Monday, August 29, 2022, 5:00 – 7:00 p.m., Dayton Community Center, Ballroom 300B, 801 S. Cleveland St., Dayton, Texas 77535
- Mid Basin: Tuesday, August 30, 2022, 5:00 – 7:00 p.m., Houston County Electric Cooperative Community Room, 1701 Loop 304, Crockett, Texas 75835
- Upper Basin: Wednesday, August 31, 2022, 6:00 – 8:00 p.m., North Central Texas Council of Governments, William Pitstick Conference Room, Centerpoint II Building, 616 Six Flags Drive, Arlington, Texas 76011

The purpose of these events was to provide entities and individuals in each area of the region – including entities with flood-related authority or responsibility, and any interested members of the public – with a chance to ask questions and gain a solid understanding of the Draft Trinity Regional Flood Plan's recommendations, as well as the process the Trinity RFPG used to develop the recommendations. These open house sessions enabled entities and the public to be more meaningfully engaged and better informed, so they could provide vital input on the draft plan during the 60-day comment period surrounding the Trinity RFPG's September 2022 Public Hearing for the draft plan. These open house sessions were publicized in a variety of ways, including through:

- Prominent posting on the Trinity RFPG website and social media
- Emails sent to the regional entities and interested parties email list (distributed via MailChimp)
- Postcards sent via United States mail to each regional entity with a known mailing address
- Press releases distributed to media across the region, resulting in numerous news article placements in the relevant portion of the Trinity Region where a particular open house session was held
- Encouraging Trinity RFPG members to notify their contacts about the open house session in their local area and encourage entity and individual attendance

Public Input

The Trinity RFPG encouraged the public to participate in the planning process by providing an opportunity for the public to speak to the planning group at each public meeting during the planning cycle. Since the majority of Trinity RFPG meetings were conducted in a hybrid (in-person and via videoconference or teleconference) format, members of the public could provide comment during meetings either in-person, by phone, or by videoconference as they so desired. The public was invited to provide comments of a general nature, or to address the planning group on particular agenda items. Written comments were also accepted on specific agenda topics or materials for 14 days prior to certain public meetings or pre-planning meetings as required by the TWDB and/or statute.

Members of the public also had the opportunity to provide written public comments at any time using the Public Comment form on the Trinity RFPG website, via email to info@trinityrfpg.org, or by contacting any of the Trinity RFPG contacts listed on the website's Contact page (via email or phone).

Prior to submission of the Draft Trinity Regional Flood Plan to the TWDB in late July 2022, written comments by regional entities or members of the public were also provided throughout the development of the draft plan. Those are included in ***Appendix I*** along with a notation indicating any response made or resulting action taken. ***Appendix I*** also includes general comments and questions received between June 2022 and June 2023.

Various questions of an informational or technical nature were also raised by regional entities throughout the planning process, including requests for clarifications about upcoming meeting dates or materials presented at past meetings, requests to update contact information in the regional entity database, requests for assistance locating information on the website, and requests for assistance with login issues pertaining to the password-protected data collection survey. In such cases, the Trinity RFPG team responded directly to the inquiring party and provided direct assistance.

After the submittal of the Draft Trinity Regional Flood Plan to the TWDB, the Trinity RFPG distributed copies of the draft plan to several locations around the region (Dallas Public Library, Fairfield Library and the Sam Houston Regional Library & Research Center) and also posted the full, draft plan to the Trinity RFPG website for review. These postings were made available to the public at least 30 days prior to the September 8, 2022, Public Hearing at which the Trinity RFPG received formal public input on the draft plan and were kept available at these locations for at least 30 days after the Public Hearing. The Trinity RFPG also posted a notice on its website making the public aware of where and how to access the draft plan. Members of the public were given the opportunity to comment on the draft plan at the Public Hearing and/or to submit written comments up to 30 days after the Public Hearing. The RFPG team also created an interactive web map that was posted to the RFPG website and made available to the public throughout the public comment period on the Draft Trinity Flood Plan for the public to provide additional comments on known flood-prone locations. No oral or written comments were received at the Public Hearing, but a transcript of the Public Hearing is included in ***Appendix J*** of this report. Written comments on the draft plan were also accepted by the planning group and are included in ***Appendix K*** along with a notation indicating where changes to the plan were made in response to those written comments, as appropriate. In addition to the written public comments, the Texas Water Development Board provided comments in a letter that is included in **Appendix K** along with a spreadsheet indicating responses and/or resulting actions taken.

Plan Adoption and Approval Process

The initial voting members of the 15 RFPGs were designated by the TWDB during its October 1, 2020, Board meeting. The Trinity RFPG held its first public meeting on October 27, 2020, and as noted previously, the planning group met roughly every 1-2 months since then to continue its work in developing the first Region 3 Trinity Regional Flood Plan.

In early 2021, the Trinity RFPG solicited proposals for a technical consultant to assist the group with its initial planning cycle, and a consultant team led by Halff Associates was formally engaged by the Trinity RFPG in March 2021. The consultant team also includes Freese and

Nichols, Inc., H2O Partners, Cooksey Communications, and Dr. Nick Fang of the University of Texas at Arlington.

Since being engaged by the Trinity RFPG, the team has presented regular progress updates on key elements of the plan development process, giving the planning group, regional entities, and the general public as much time as possible to see the draft plan in development and to shape its final draft form.

A critical milestone for the regional flood planning process occurred with the development and submission to the TWDB of the Technical Memorandum in January 2022, which described the significant progress achieved up to that point on Tasks 1-4 of the TWDB's initial scope of work for all RFPGs. Among its included elements was a list of potential FMEs, potentially feasible FMSs, and potentially feasible FMPs identified to date by the Trinity RFPG. The Technical Memorandum also included the Trinity RFPG's specific and measurable goals for the plan, which the Trinity RFPG spent considerable time defining and refining. A supplement to the Technical Memorandum, called the Technical Memorandum Addendum, was developed and submitted to the TWDB in March 2022, and included more information on Tasks 2 and 4.

Throughout 2021 and the first half of 2022, the Trinity RFPG team completed and presented preliminary draft chapters of the Draft Trinity Regional Flood Plan at public meetings. The team accepted input from the planning group and the public on those preliminary draft chapters in preparation for completion and approval of the complete Draft Trinity Regional Flood Plan in July 2022. As noted above, these meetings have taken place in a hybrid format to allow for convenient participation by planning group members and members of the public. The in-person components of these hybrid meetings have been held in a variety of locations throughout the Trinity Region to help generate local interest in participating in the plan development. The full draft plan was presented to the Trinity RFPG for formal approval at its July 21, 2022, public meeting and approved by the RFPG.

Upon submission of the Draft Trinity Regional Flood Plan to the TWDB, the Trinity RFPG published the draft plan to the planning group's website, posted hard copies of the draft plan in at least three publicly accessible locations around the region – the Dallas Public Library (Dallas), Fairfield Library (Fairfield), and Sam Houston Regional Library and Research Center (Liberty) – and officially opened the minimum 60-day public comment period on the draft plan beginning August 1, 2022. As described above, the RFPG team planned and executed a series of open house events at locations around the region. During these meetings:

- A planning group member provided welcome remarks
- Team members presented an overview of the draft plan
- Team members received and answered general questions from the public
- During breakout sessions and one-on-ones, team members:

- Provided interactive web maps for the public to mark-up and identify flood-prone areas in need of further analysis
- Shared the draft list of recommended flood mitigation actions (FMEs, FMSs, and FMPs) for the local area in the draft plan, and fielded questions regarding recommendations
- Encouraged the public to submit written comments on the draft plan by October 10, 2022, and/or provide written or oral comments at the September 8, 2022, Public Hearing.

Subsequently, the Trinity RFPG consultant team collected and reviewed all comments received from the public and the TWDB during the comment period and developed proposed responses or proposed revisions to the draft plan taking those comments into account, before presenting the proposed responses and revisions to the RFPG at its November 17, 2022, public meeting.

Comments, responses, and all input shared, collected, and considered by the Trinity RFPG were also collected throughout the process of amending the Regional Flood Plan in early 2023.

Public Comments on Draft Flood Plan and RFPG Responses

The Trinity RFPG accepted written comments on the draft plan through multiple formats, including email, postal, public comment web form, interactive web map and at the Public Hearing. Oral comments were also accepted at the Public Hearing, but none were provided. In all, the Trinity RFPG received 17 public comments on the draft plan during the public comment period. ***Table 10.4*** provides a summary of the public comments received. ***Figure 10.8*** shows the locations of the flood-prone areas submitted through the interactive web map. Detailed responses to these comments are included in ***Appendix K.***

TWDB Comments on Draft Flood Plan

TWDB provided comments on the Draft Trinity Regional Flood Plan on October 18, 2022. TWDB's comments included:

- 43 Level 1 comments directly linked to specific statute, rule, or contract requirements that had to be addressed in the Final Trinity Regional Flood Plan
- 38 Level 2 comments that were provided as suggested changes to improve the plan

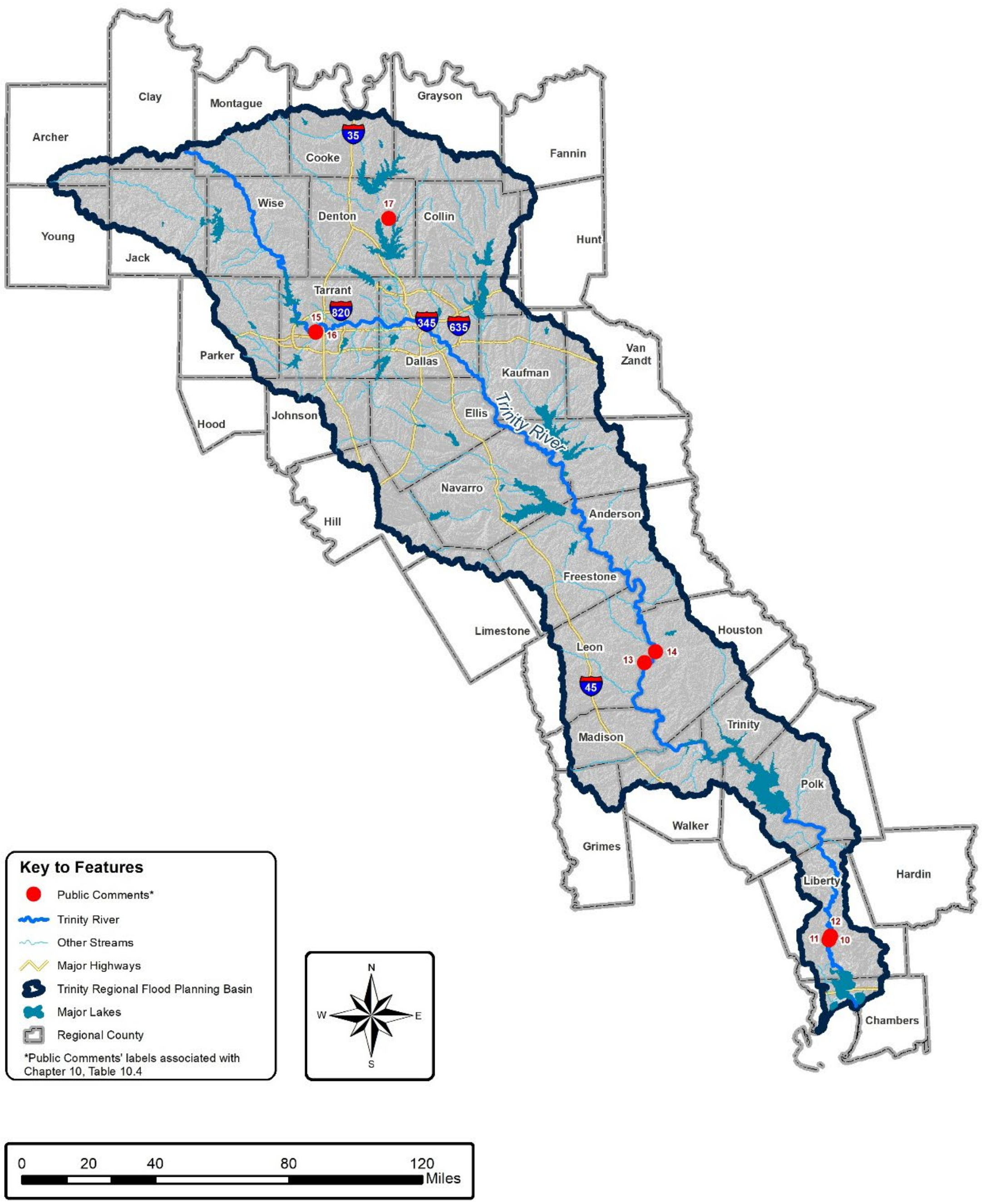
The RFPG team developed preliminary draft responses to TWDB's comments prior to meeting with TWDB staff on November 3. During the conference call, the TWDB provided clarification on its comments and confirmation of acceptable RFPG responses. The TWDB comments focused on Chapters 1 through 5 and confirmed that the comments provided were the agency's complete set of comments for the Draft Trinity Region Flood Plan. TWDB confirmed that the maps initially thought to be missing were actually provided in the electronic "Appendix B" folder.

Table 10.4: List of Public Comments Received

Comment #	Date	Submission Platform	Comment Topic	Response
1	July 18, 2022	email to sAmoako-Atta@halff.com	Editorial and proposed revisions to Chapters 1, 2 and 3	Revisions were made where appropriate
2	August 28, 2022	Public Comment Web Form	Flooding in Fort Worth neighborhood	Forwarded email to city. Recommended FMP in draft plan addressed this area. No changes made.
3	August 28, 2022	Public Comment Web Form	Flooding in Fort Worth neighborhood	Forwarded email to city. Recommended FMP in draft plan addressed this area. No changes made.
4	August 29, 2022 and October 7, 2022 (duplicate comment except the latter included a new sentence referring to the potential Floodwater Detention Basin and an extra description of the affected area as a high-end neighborhood)	Public Comment Web Form and email (same comment)	Flooding in Fort Worth neighborhood	Forwarded email to city. Recommended FMP in draft plan addressed this area. No changes made.
5	September 1, 2022	Email to David.Rivera@freese.com	Request for new FME for retention pond in Liberty County	Requested FMP was located in Region 6 and submitted to Region 6 RFPG. No changes made.
6	September 8, 2022	Email to info@trinityrfpg.org	Recommendations for inclusion in Chapter 8 Legislative, Regulatory & Administrative and State Flood Planning Recommendations	RFPG considered many of these ideas in its meetings. The RFPG did not have adequate time to investigate these ideas and potential unintended consequences or liabilities in this cycle of planning. The RFPG may establish a subcommittee in a future cycle of regional flood planning. No changes made.
7	September 22, 2022	Email to info@trinityrfpg.org	Creek crossing floods and prevents access to residence in City of Cross Roads	RFPG initially recommended resident coordinate with City for potential FME. After receiving interactive web map location (Comment #17), the RFPG determined that the area is located outside the city limits. RFPG submitted information to Grimes County.
8	October 10, 2022	Email to info@trinityrfpg.org	Support for nature-based solutions. Concerns with no negative impact determinations and Alligator Gar. Preferred TPWD design criteria.	RFPG supports nature-based solutions. RFPG used engineering judgement on no negative impact determination and included additional explanation in final report. RFPG welcomes input on Alligator Gar. RFPG recommended TPWD contact specific sponsors regarding preferred design criteria.

Comment #	Date	Submission Platform	Comment Topic	Response
9	October 10, 2022	Email to info@trinityrfpg.org	Suggested additional goals. Concerned about no negative impacts. Requested minimum floodplain standards be required. Questioned future conditions flood risk determination. Supports nature-based solutions. Questioned critical facilities.	RFPG spent considerable time developing goals. RFPG recommended but did not require minimum floodplain standards for this planning cycle. Goals and minimum floodplain standards may be reconsidered in a future cycle of regional flood planning. RFPG included additional information on no negative impacts in final report. RFPG supports nature-based solutions. Other comments should be directed to TWDB.
10	August 29, 2022	Interactive Web Map	Illegal Coffer Dam blocking floodwater flow	RFPG does not have regulatory or enforcement authority. RFPG recommended resident reported this to Liberty County. RFPG submitted information to Liberty County. No changes made.
11	August 29, 2022	Interactive Web Map	Abandoned pipeline. Public safety and navigation hazard.	RFPG does not have regulatory or enforcement authority. RFPG recommended resident reported this to Liberty County. RFPG submitted information to Liberty County. No changes made.
12	August 29, 2022	Interactive Web Map	Second abandoned pipeline since 1940s.	RFPG does not have regulatory or enforcement authority. RFPG recommended resident reported this to Liberty County. RFPG submitted information to Liberty County. No changes made.
13	August 30, 2022	Interactive Web Map	Major Agricultural Flooding in this area when water gets released from reservoirs	RFPG recognizes flooding impacts agricultural activities. Property is located within the 100-year floodplain as shown in the draft plan flood quilt. RFPG forwarded comment to appropriate counties. No changes made.
14	August 30, 2022	Interactive Web Map	Major Flooding in this area. Also flooding from water releases from reservoirs upstream. Costing major damages to crops and ranchland	RFPG recognizes flooding impacts agricultural activities. Property is located within the 100-year floodplain as shown in the draft plan flood quilt. RFPG forwarded comment to appropriate counties. No changes made.
15	September 1, 2022	Interactive Web Map	Major Flooding in this whole area both upstream and downstream. Pluvial and Fluvial flooding. extensive flooding. Potential backflow issues in this whole area (Flooding in Fort Worth neighborhood)	Forwarded email to city. Recommended FMP in draft plan addressed this area. No changes made.
16	September 1, 2022	Interactive Web Map	Massive storm drain Backflow flooding in this area (Flooding in Fort Worth neighborhood)	Forwarded email to city. Recommended FMP in draft plan addressed this area. No changes made.
17	September 23, 2022	Interactive Web Map	At this pin there is a low water crossing over Cantrell Slough. This crossing floods several times annually and poses dire emergency risk to both residents and wildlife. This risk has been amplified by the recent housing subdivision development,	Roadway is located within 100-year floodplain. RFPG added location to low water crossing layer. RFPG recommended resident contact the county. RFPG forwarded to the Grimes County. (Related to Comment #7)

Figure 10.8: Flood-Prone Areas Identified via Interactive Web Map



Other results from the meeting included noted areas of inconsistencies between GIS and summary tables and assumed benefit-cost ratios of 0 for potentially feasible FMPs that were not identified as recommended FMPs.

The RFPG addressed all of the Level 1 comments and most of the Level 2 comments. Time constraints limited the RFPG's ability to respond to some Level 2 comments. A copy of the TWDB's comment letter and the RFPG's responses to each comment is included in Appendix K.

Adoption of Amended Plan

The RFPG held a regularly scheduled public meeting on June 29, 2023. At which time, the RFPG approved the addition of the new recommended FMEs, FMPs, and FMSs for inclusion in this amended plan. The RFPG approved the adoption of this amended plan for submittal to the TWDB. Appendix L includes an index listing the revisions made in this amended plan since the January 2023 final plan.

Conformance with Title 31 TAC §362.3 Guidance Principles

In accordance with Title 31 TAC §361.20, the Draft and Final Trinity Regional Flood Plans conformed with the guidance principles established in Title 31 TAC §362.3. The Trinity RFPG performed a No Negative Impact assessment for each potentially feasible FMP and FMS. Those that had, or appeared to have, a potential negative impact were removed from further consideration and were not included as recommended FMPs or FMSs in the draft or final plans. ***Table 10.5*** includes a list of the 39 regional flood planning principles and where they are addressed in this plan.

Table 10.5: Title 31 TAC §362.3 Guidance Principles and Regional Flood Planning Group Response Satisfying Said Principles

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
1	shall be a guide to state, regional, and local flood risk management policy	Incorporated throughout the regional flood planning process
2	shall be based on the best available science, data, models, and flood risk mapping	Included in ***Chapters 2, 4, 5, 6***, and ***9***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
3	shall focus on identifying both current and future flood risks, including hazard, exposure, vulnerability and residual risks; selecting achievable flood mitigation goals, as determined by each RFPG for their region; and incorporating strategies and projects to reduce the identified risks accordingly	Included in ***Chapters 2, 3, 4,*** and ***5***
4	shall, at a minimum, evaluate flood hazard exposure to life and property associated with 0.2% annual chance storm event (the 500-year flood) and, in these efforts, shall not be limited to consideration of historic flood events	Included in ***Chapter 2***
5	shall, when possible and at a minimum, evaluate flood risk to life and property associated with 1% annual chance storm event (the 100-year flood) and address, through recommended strategies and projects, the flood mitigation goals of the RFPG (per item 2 above) to address flood events associated with a 1% annual chance storm event (the 100-year flood); and, in these efforts, shall not be limited to consideration of historic flood events	Included in ***Chapters 2, 3,*** and ***5***; ***TWDB-Required Tables 15, 16,*** and ***17***
6	shall consider the extent to which current floodplain management, land use regulations, and economic development practices increase future flood risks to life and property and consider recommending adoption of floodplain management, land use regulations, and economic development practices to reduce future flood risk	Included in ***Chapter 3***
7	shall consider future development within the planning region and its potential to impact the benefits of flood management strategies (and associated projects) recommended in the plan	Included in ***Chapters 2, 3, 4,*** and ***5***
8	shall consider various types of flooding risks that pose a threat to life and property, including, but not limited to, riverine flooding, urban flooding, engineered structure failures, slow rise flooding, ponding, flash flooding, and coastal flooding, including relative sea level change and storm surge	Included in ***Chapters 2, 4, 5,*** and ***7***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
9	shall focus primarily on flood management strategies and projects with a contributing drainage area greater than or equal to 1.0 (one) square miles except in instances of flooding of critical facilities or transportation routes or for other reasons, including levels of risk or project size, determined by the RFPG	Included in ***Chapter 5*** and ***TWDB-Required Tables 15, 16,*** and ***17***
10	shall consider the potential upstream and downstream effects, including environmental, of potential flood management strategies (and associated projects) on neighboring areas. In recommending strategies, RFPGs shall ensure that no neighboring area is negatively affected by the regional flood plan	Included in ***Chapters 4, 5,*** and ***6***
11	shall include an assessment of existing, major flood mitigation infrastructure and will recommend both new strategies and projects that will further reduce risk, beyond what existing flood strategies and projects were designed to provide, and make recommendations regarding required expenditures to address deferred maintenance on or repairs to existing flood infrastructure	Included in ***Chapters 2*** and ***5*** and ***TWDB-Required Tables 1, 16,*** and ***17***
12	shall include the estimate of costs and benefits at a level of detail sufficient for RFPGs and sponsors of flood mitigation projects to understand project benefits and, when applicable, compare the relative benefits and costs, including environmental and social benefits and costs, between feasible options	Included in ***Chapters 4*** and ***5*** and ***TWDB-Required Tables 12, 13, 14, 15, 16,*** and ***17***
13	shall provide for the orderly preparation for and response to flood conditions to protect against the loss of life and property and reduce injuries and other flood-related human suffering	Included in ***Chapter 7***
14	shall provide for an achievable reduction in flood risk at a reasonable cost to protect against the loss of life and property from flooding	Included in ***Chapters 5*** and ***9*** and ***TWDB-Required Tables 15, 16, 17,*** and ***19***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
15	shall be supported by state agencies, including the TWDB, General Land Office, Texas Commission on Environmental Quality, Texas State Soil and Water Conservation Board, Texas Parks and Wildlife Department, and the Texas Department of Agriculture, working cooperatively to avoid duplication of effort and to make the best and most efficient use of state and federal resources	Held conference calls as appropriate and shared data and files with these agencies and others upon request.
16	shall include recommended strategies and projects that minimize residual flood risk and provide effective and economical management of flood risk to people, properties, and communities, and associated environmental benefits	Included in ***Chapters 5*** and ***6***
17	shall include strategies and projects that provide for a balance of structural and nonstructural flood mitigation measures, including projects that use nature-based features, that lead to long-term mitigation of flood risk	Included in ***Chapters 4*** and ***5*** and ***TWDB-Required Tables 13, 14, 16,*** and ***17***
18	shall contribute to water supply development where possible	Discussed in ***Chapter 6***
19	shall also follow all regional and state water planning guidance principles (31 TAC 358.3) in instances where recommended flood projects also include a water supply component	Discussed in ***Chapter 6***
20	shall be based on decision-making that is open to, understandable for, and accountable to the public with full dissemination of planning results except for those matters made confidential by law	Included in ***Chapter 10***
21	shall be based on established terms of participation that shall be equitable and shall not unduly hinder participation	Included in ***Chapter 10***; bylaws are available on the RFPG website
22	shall include flood management strategies and projects recommended by the RFPGs that are based upon identification, analysis, and comparison of all flood management strategies the RFPGs determine to be potentially feasible to meet flood mitigation and floodplain management goals	Included in ***Chapter 5*** and ***TWDB-Required Tables 16*** and ***17***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
23	shall consider land-use and floodplain management policies and approaches that support short- and long-term flood mitigation and floodplain management goals	Included in ***Chapter 3*** and ***TWDB-Required Tables 6*** and ***10***
24	shall consider natural systems and beneficial functions of floodplains, including flood peak attenuation and ecosystem services	Included in ***Chapters 1, 3, 4,*** and ***5***
25	shall be consistent with the National Flood Insurance Program (NFIP) and shall not undermine participation in nor the incentives or benefits associated with the NFIP	Included in ***Chapter 3*** and ***TWDB-Required Table 6***
26	shall emphasize the fundamental importance of floodplain management policies that reduce flood risk	Included in ***Chapter 3*** and ***TWDB-Required Table 6***
27	shall encourage flood mitigation design approaches that work with, rather than against, natural patterns and conditions of floodplains	Included in ***Chapter 5*** and ***TWDB-Required Table 16***
28	shall not cause long-term impairment to the designated water quality as shown in the state water quality management plan as a result of a recommended flood management strategy or project	Included in ***Chapter 6***
29	shall be based on identifying common needs, issues, and challenges; achieving efficiencies; fostering cooperative planning with local, state, and federal partners; and resolving conflicts in a fair, equitable, and efficient manner	Included in ***Chapters 3, 8,*** and ***10***
30	shall include recommended strategies and projects that are described in sufficient detail to allow a state agency making a financial or regulatory decision to determine if a proposed action before the state agency is consistent with an approved regional flood plan	Included in ***Chapters 5*** and ***9*** and ***TWDB-Required Tables 15, 16, 17,*** and ***19***
31	shall include ongoing flood projects that are in the planning stage, have been permitted, or are under construction	Included in ***Chapter 1*** and ***TWDB-Required Table 2***

Principle #	Principle Description	Explanation of How Plan Satisfies Principle
32	shall include legislative recommendations that are considered necessary and desirable to facilitate flood management planning and implementation to protect life and property	Included in ***Chapter 8***
33	shall be based on coordination of flood management planning, strategies, and mitigation projects with local, regional, state, and federal agencies projects and goals	Included in ***Chapters 1, 3, 5, 9,*** and ***10*** and ***TWDB-Required Tables 16*** and ***17***
34	shall be in accordance with all existing water rights laws, including but not limited to, Texas statutes and rules, federal statutes and rules, interstate compacts, and international treaties	Included in ***Chapter 6***
35	shall consider protection of vulnerable populations	Included in ***Chapters 1*** and ***5*** and ***TWDB-Required Tables 3, 13,*** and ***16***
36	shall consider benefits of flood management strategies to water quality, fish and wildlife, ecosystem function, and recreation, as appropriate	Included in ***Chapter 6***
37	shall minimize adverse environmental impacts and be in accordance with adopted environmental flow standards	Discussed in ***Chapter 6***
38	shall consider how long-term maintenance and operation of flood strategies will be conducted and funded	Discussed in ***Chapters 4*** and ***6***
39	shall consider multi-use opportunities such as green space, parks, water quality, or recreation, portions of which could be funded, constructed, and or maintained by additional, third-party project participants	Included in ***Chapters 5, 6, 8,*** and ***9***