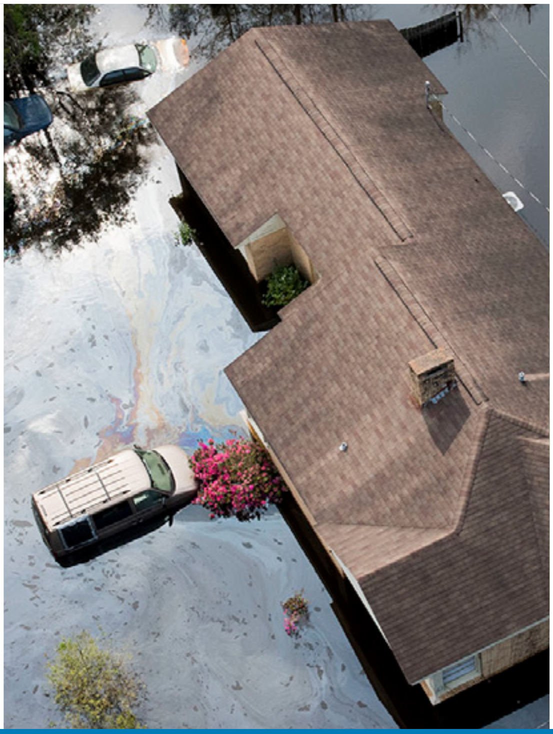
2024 State Flood Plan

TEXAS WATER DEVELOPMENT BOARD



2024 State Flood Plan

Texas Water Development Board Members

Brooke T. Paup, *Chairwoman*

L'Oreal Stepney, *Member*

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Dear Fellow Texans:

On behalf of my fellow Board member, L'Oreal Stepney, I am honored to deliver to you the 2024 State Flood Plan—Texas' first-ever effort to perform comprehensive planning to reduce flood risk and take a broad look at flood hazard across the state. As mandated by Senate Bill 8 adopted by the 86th Texas Legislature in 2019, this watershed-based, bottom-up approach required an incredible, accelerated effort by many and marks a major milestone on the path to reduce the risk and impact of flooding and protect against the loss of life and property due to flood events in Texas.

The state flood plan is based on the collective knowledge generated by Texas' first-ever regional flood planning process. This process was made possible through countless hours dedicated by more than 360 regional flood planning group chairs, officers, and members—all volunteers with an unwavering commitment to reducing the loss of life and property from flooding in Texas. These volunteers held over 550 public meetings throughout the planning process. In addition to the planning groups, I would be remiss not to praise the tremendous support from planning group sponsors and staff, sister agencies, technical consultants, and all the other stakeholders and professionals representing a wide variety of relevant interest groups who also provided valuable input to improve our regional and state flood plans. My deepest gratitude extends to every individual that played a role in these efforts.

Texas' unique flood planning approach is founded on available data and science and guided by a robust framework that requires all 15 regional planning groups to identify the flood risks in their region and recommend solutions to address those risks. The resulting regional and state flood plans set forth thousands of specific, actionable flood management evaluations, flood mitigation projects, and flood management strategies with identified costs and sponsors. Further, the floodplain management recommendations in this plan were made with an eye toward avoiding the creation of additional flood risk in the future.

We recognize that those flood evaluations, projects, and strategies must be funded and implemented to effectively protect against the loss of life and property. Our agency is committed to continually improving data collection, flood science, and other tools in support of better planning that results in projects with tangible benefits that can be implemented.

Since implementing the Flood Infrastructure Fund in 2019, the Texas Water Development Board has committed funding to more than 140 drainage, flood mitigation, and flood control studies and projects during the program's inaugural cycle. These financial commitments represent over $643 million in dedicated funding—a compelling testament to the state's commitment to protecting Texans from flooding. The Flood Infrastructure Fund will continue to serve as a dedicated funding source for evaluations, projects, and strategies recommended in this and future state flood plans.

Lastly, I would like to acknowledge the strong statutory planning framework and substantial support we've received from the Texas Legislature to support development of this initial state flood plan. The TWDB and Texas as a whole are fortunate to be guided by legislators who recognize the significance and tremendous need for statewide flood planning.

Brooke T. Paup, Chairwoman

2024 State Flood Plan

Prepared by the Texas Water Development Board

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Texas Water Development Board

Acknowledgments

The 2024 State Flood Plan would not have been possible without the time, dedication, guidance, and expertise of numerous volunteers and organizations throughout Texas. The Texas Water Development Board (TWDB) would like to extend sincere gratitude and appreciation to everyone who participated in developing the 15 regional flood plans and this state flood plan, including

- more than 300 regional flood planning group voting members, consultants, and administrative sponsors;
- staff of the TWDB, Texas Parks and Wildlife Department, Texas Department of Agriculture, Texas Commission on Environmental Quality, Texas State Soil and Water Conservation Board, Texas General Land Office, and other state and federal agencies; and
- the individuals and organizations who provided public input throughout the planning process.

The TWDB would also like to thank the State of Texas leadership and the Texas Legislature for their continued support of Texas' flood planning process.

Primary authors and contributors

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Numerous TWDB staff members contributed to the development of this state flood plan. The TWDB sincerely appreciates them.

Regional flood planning group voting members

Planning group members displayed in alphabetical order by region and name. (designates planning group chair at the time the 2023 amended regional plans were adopted)*

1 - Bowers, Chandler
1 - Chapman, Layne
1 - Corado, Carolann
1 - Davis, Don
1 - Gordon, Ronnie
1 - Green, Glen
1 - Hartman, Floyd
1 - Howell, Nathan
1 - Ketcham, Jane
1 - Mesler, Tracy
*1 - Schniederjan, Kyle**
1 - Schreiber, Russell
1 - Shehan, Joseph
1 - Watts, Jeff
1 - Whiteman, Randy
2 - Basinger, David
2 - Carter, Greg
2 - Crandall, Clark
2 - Endsley, Andy
*2 - Hayter, Reeves**
2 - Henslee, Dusty
2 - Hollingsworth, Kirby
2 - Hudson, Troy
2 - Ingram, Preston
2 - Johnson, Casey
2 - Mitchell, Kelly
2 - Overdyke, Laura-Ashley
2 - Thomas, Brad
2 - Weidman, David
2 - Weir, Joseph
2 - Whitfield, Susan
3 - Ballard, Chad
3 - Blocker, Sano
3 - Bookhout, Melissa
*3 - Clingenpeel, Glenn**
3 - Harris, Scott
3 - Ickert, Rachel
3 - Isbell, Andrew
3 - Macha, Jordan
3 - Rickman, Mike
3 - Roberts, Galen
3 - Robinson, Matt
3 - Shepard, Lissa
3 - Standifer, Sarah
3 - Ocanas, Gerard
4 - Bradley, Alton
4 - Bruce, James (Bill)
4 - Carona, Don
4 - Davis, Nikki
4 - Falgout, Michelle
4 - Gordon, Ross
4 - Griffin, Roman
4 - Huges, Williams
4 - Manning, Doug
4 - McKee III, Clyde
4 - Rogers, Jeff
4 - Shannon, Francis X.

4 - Trahan, Johnny
*4 - Williams, Travis**
5 - Beard Jr. , John
5 - Branick, Jeff
5 - Buchanan, Ellen
5 - Canant, Doug
5 - Hall, Scott
5 - Haselbach, Liv
5 - Heironimus, Brent
5 - Kelleg, Phil
5 - Kingma, Kyle
5 - Majdalani, Joseph
5 - Mathews, Stan
5 - McDougal, Brian
*5 - Moon, Steve**
5 - Sims, Allen
5 - Starr, Robb
5 - Young, Amanda
6 - Armstrong, Jenna
6 - Barrett, Matthew
6 - Bernhardt, Sarah
6 - Burden, Erwin
6 - Burrer, Todd
*6 - Buscha, Timothy**
6 - Campbell, Augustus
6 - Costello, Stephen
6 - Donovan, Elisa
6 - Fisseler, Gene
6 - Gaynor, Neil
6 - Lock, Paul
6 - Max, Alisa
6 - Maxwell, Brian
6 - Petersen, Tina
6 - Poppe, Russ
6 - Pothier, Connie
6 - Power, Rachel
6 - Quintero, Christina
6 - Rifai, Hanadi
6 - Stuckett, Marcus
6 - Vinson, Alia
7 - Davidson, Jennifer
7 - Jacobson, Kyle
*7 - Keenum, Michael**
7 - McClendon, Michael
7 - Moore, Richard
7 - Oller, Rich
7 - Rainwater, Ken
7 - Spear, Aubrey
7 - Spurgin, Dale
7 - Stiggins, Erin
7 - Wingert, Chris
8 - Alford, Susan
8 - Beach, Anthony
8 - Burch, Carl
8 - Draksharam, Sujeeth
8 - Earles, Andrew
8 - Finley, Tim
8 - Gilpin, Charlotte
*8 - Girard, Alysha**
8 - Lilly, David
8 - Lord, Glenn
8 - Phillips, Matt
8 - Spicer, Gary
8 - Vogler, Mark
8 - Wade, Brandon
8 - Wright, Claudia
9 - Bacon, Rick
9 - Brown, Chuck
9 - Dierschke, Kenneth
9 - Haynes, Morse
9 - Loyd, David
9 - McMillan, Shannon
9 - McWilliams, Scott
9 - Olstowski, Henryk
*9 - Strube, Allison**
9 - Walker, Cole
10 - Acuna, Frances
10 - Been, Terry
10 - Brown, Kirby
10 - Brzozowski, Patrick
10 - Heroy, Ken
10 - Hollon, Matt
10 - Klenzendorf, Brandon
10 - Ludwig, Jason
10 - Paul, Kacey
10 - Payne, Kelly
10 - Smith, Hank
*10 - Spenrath, Phillip**
10 - Textor, G. Nicholas
10 - Yakimovicz, Ann
11 - Bushnoe, Tara
11 - Christmas, Bobby
11 - Fieseler, Ronald
11 - Fonville, Steven
11- Gill, Kenneth
11 - Johnston, John A.
11 - Koone, Matt
11 - Meitzen, Kimberly
*11 - Miller, Doug**
11 - Pantalion, Joe
11 - Peace, Annalisa
11 - Perkins, Brian
11 - Sethness, Doug
11 - Shell, Lon
11 - Stone, Kevin
11 - Villarreal, Gian
12 - Beasley, John
*12 - Boese, Derek**
12 – Burton, Donovan
12 - Carroll, Jeffrey
12 - Cooksey, Doris
12 - Clause, Steve
12 - Garza, Nefi
12 - Gonzales, Steve
12 - Mauk, David
12 - Reid, Deborah
12 - Reyes, Jose
12 - Reyna, Robert
12 - Scott, Suzanne
12 - Tackett, Cara
12 - Wegmann, David
12 - Yanta, Brian
13 - Baker, David
13 - Barrett, Debra
13 - Belaira, Amy
*13 - Canales, Barbara**
13 - Dovalina, Larry
13 - Dugat, Raymond
13 – Francis, LJ
13 - Hutch Williams, Lauren
13 - Lewey, Julie
13 - Lewey, Sky
13 - Owens, Shanna K.
13 - Pollack, Jeffrey
13 - Rajib, Adnan
13 - Ramirez, Javier
13 - Ramirez, JR
13 - Rooke, Andrew
13 - Thomas, Larry
13 - Van Curran, Britni
13 - Wilkerson, Lilly
13 - Williams, Robert
13 - Williams, Sara
13 - Wright, David

14 - Acosta, Javier
14 - Bennett, Jeff
14 - Bryand, Levi
14 - Dagnino, Gisela
14 - Ferdandez, Carlos
14 - Hall, David "Dave"
*14 - Martinez, Omar**
14 - Masoud, Sal
14 - Ornelas, Oscar "Jay"
14 - Rodriguez, Rene
14 - Saldana Jr., Gilberto
14 - Sheng, Zhuping
14 - Tate, Rick
14 - Velarde, Carlos
15 - Califa, Joe
15 - Caso, Jose
15 - DeYoe, Hudson
15 - Estrada, Rene
15 - Fuentes, David L.
15 - Garcia, Ernesto
*15 - Garza, David A.**
15 - Gonzalez, Eduardo
15 - Haley, Laura
15 - Hinojosa, Jose
15 - Lambert, Sonia
15 - Lucio, Daniel
15 - Moore, Alan
15 - Pena Jr., Raul
15 - Rosales, Ernesto
15 - Sanchez, Agusto
15 - Trevino, Joey

Regional flood planning group sponsors

1 – Panhandle Regional Planning Commission
2 – Ark-Tex Council of Governments
3 – Trinity River Authority
4 – Sabine River Authority
5 – Lower Neches Valley Authority
6 – Harris County
7 – South Plains Association of Governments
8 – Brazos River Authority
9 – City of San Angelo
10 – Lower Colorado River Authority
11 – Guadalupe-Blanco River Authority
12 – San Antonio River Authority
13 – Nueces River Authority
14 – Rio Grande Council of Governments
15 – Hidalgo County Drainage District No. 1

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This is Texas' first state flood plan resulting from the inaugural regional and state flood planning process that was created by Senate Bill 8 (2019), during the 86th Texas Legislature modeled partly after Texas' water supply planning process.

This state flood plan presents information from the15 regional flood plans that were developed through the efforts of more than 350 regional flood planning group members, their sponsors, and technical consultants who held over 550 public meetings during the inaugural cycle of regional flood planning.

This regional and state flood planning process identified existing risk to lives and property from flooding and potential actions to mitigate those flood risks; the plan also looks ahead and provides floodplain management recommendations for preventing an increase to flood risks.

The state flood plan provides a comprehensive first look at the flood risk across the entire state of Texas, comprising three components of flood risk: the flood *hazard* (the magnitude and extent of flooding), the potential *exposure* of people and property to that hazard (who and what might flood), and the *vulnerability* (degree to which communities or critical facilities may be affected) of the people and property exposed to that flood hazard.

This plan confirms that the flood risk across Texas is significant and widespread. Almost one fourth of Texas' land area (66,831 square miles) is in either the 1 percent (100-year) or 0.2 percent (500-year) annual chance flood hazard areas, with approximately 21 percent of the land area (56,053 square miles) within the 1 percent annual chance flood hazard areas.

There is significant risk of flooding within all 15 planning regions although the extent and types of flood hazard vary by region due to differences in population, land development, topography, rainfall patterns, and proximity to rivers and the coast.

Approximately one in every six people in Texas lives or works in known flood hazard areas, including in the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains. Approximately 2.4 million people live or work in the 1 percent annual chance floodplain, and an additional 2.8 million people are in the 0.2 percent annual chance floodplain.

Planning groups identified approximately 878,100 buildings within the 1 percent (100-year) annual chance floodplain, and an additional 786,100 buildings within the 0.2 percent (500-year) annual chance floodplain.

More than 6,258 hospitals, emergency medical services, fire stations, police stations, and schools were identified within the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.

Regional flood planning groups identified 9,322 low water crossings within flood hazard areas.

The projected future condition 1 percent (100-year) annual chance floodplain is estimated to increase by 11 percent over the existing flood hazard area to a total of 62,245 square miles.

The regional flood planning groups project an increase of approximately 2.6 million people and 740,000 buildings in the 1 percent annual chance floodplain under projected future condition flood hazard.

A total of 1,239 Texas communities and counties with flood-related authority participate in the National Flood Insurance Program.

More than 500 Texas entities have floodplain management standards that exceed National Flood Insurance Program minimum standards.

The regional flood planning groups recommended 4,609 flood risk reduction solutions: 3,097 flood management evaluations, 615 flood mitigation projects, and 897 flood management strategies in the regional flood plans with an estimated total implementation cost of more than $54.5 billion.

The total cost of recommended flood management evaluations exceeds $2.6 billion.

The total cost of recommended flood mitigation projects totals over $49.1 billion; nearly half of this cost is associated with the Galveston Bay Surge Protection Coastal Storm Risk Management project.

The total cost of recommended flood management strategies is more than $2.8 billion.

Planning groups reported sponsors requiring financial assistance with 80-90 percent of the costs to implement recommended flood risk reduction solutions.

Planning groups reported an estimated 843,339 people and 214,292 buildings would be removed from the 1 percent annual chance floodplain if the state flood plan was implemented.

Three regions identified potential water supply benefits for 37 recommended flood mitigation projects and one region recommended a flood management strategy with a potential water supply benefit.

The flood planning groups included legislative, administrative, and policy recommendations in the regional flood plans, and their policy recommendations informed the development of many of the legislative and floodplain management recommendations in this plan.

Texas has a long history of flooding and flood-related loss that has taken an enormous toll on people and property. In 2017, the Texas coast was hit by Hurricane Harvey, the second most expensive natural disaster to impact the U.S. The losses associated with Hurricane Harvey are estimated to be more than $125 billion (in 2017 U.S. dollars). In the aftermath of Hurricane Harvey, and many previous devastating flood events across the state, the Texas Legislature passed Senate Bill 8 in 2019 that created Texas' first statewide regional flood planning program based on river basins. The Texas Water Development Board (TWDB) was charged with administering the regional and state flood planning and the state flood planning program.

The 15 newly designated regional flood planning groups first convened in fall 2020, during the global pandemic. Over the following 2.5 years, the planning groups managed to meet more than 550 times, and successfully delivered Texas' first 15 regional flood plans[1] to the TWDB in January 2023.

The administrative process of the river basin-based, bottom-up regional flood planning program was modeled after Texas' successful and longstanding water planning process that has been in place since 1997. Although the technical aspects of the flood planning process are vastly different from water supply planning, the overall process of building a state plan using a set of regional plans developed under a state framework is very similar.

This first cycle of the statewide flood planning process is Texas' first attempt to perform comprehensive planning to reduce flood risk and take a broad look at flood hazard across the state. A tremendous amount of information was generated by the planning groups during the historic first cycle of regional flood planning, which aimed to identify who and what might be exposed to flooding; identify the state's major flood risk reduction infrastructure; consider existing floodplain management practices or lack thereof; and identify and recommend flood risk reduction solutions across the state. The recommended flood risk reduction solutions include flood management evaluation, flood mitigation projects, and flood management strategies. The 2024 State Flood Plan is supported by the Interactive State Flood Plan Viewer[2]. The viewer allows stakeholders to view and disseminate the extensive dataset generated by the flood planning process.

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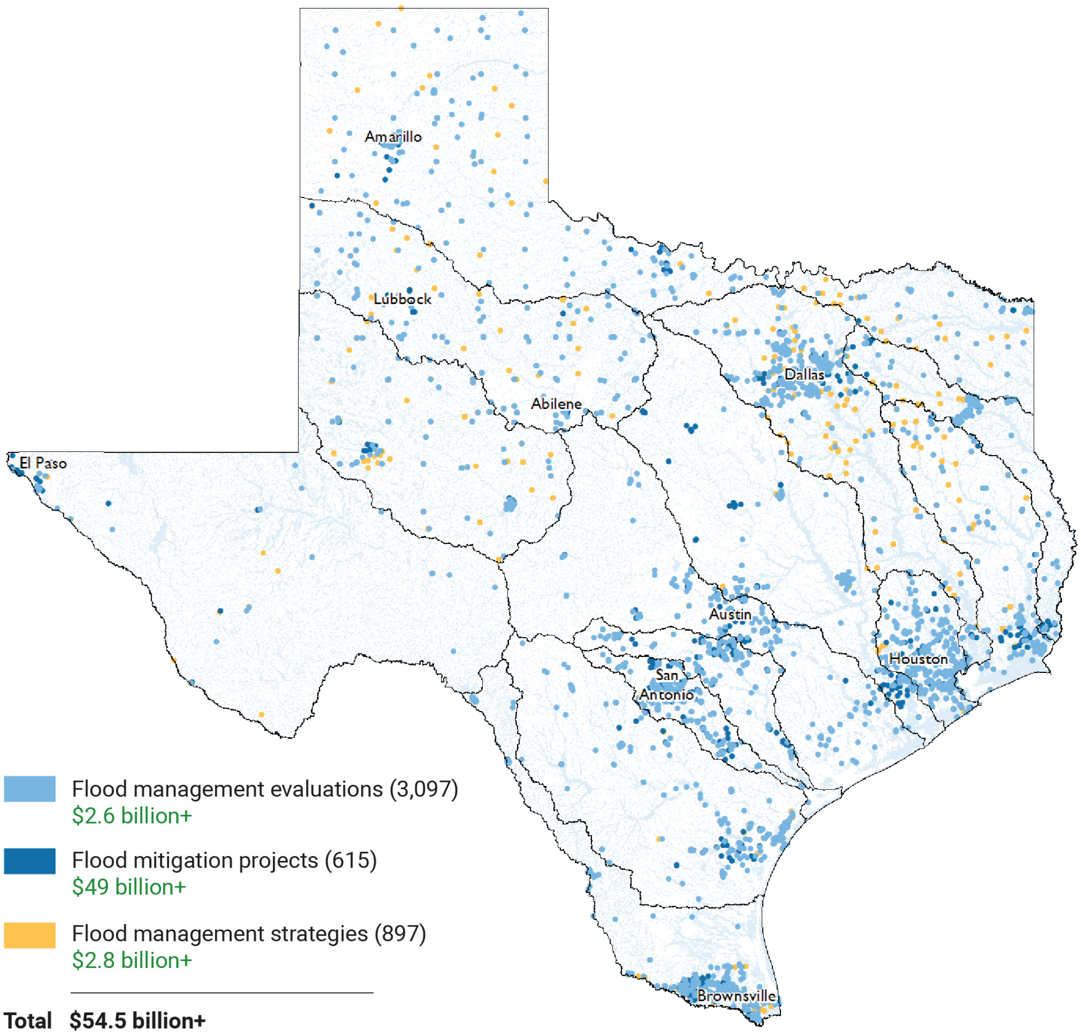
[1] www.twdb.texas.gov/flood/planning/plans/index.asp

[2] Texasstatefloodplan.org

This state flood plan brings together the findings of the 15 regional flood plans and makes legislative and floodplain management recommendations to guide state, regional, and local flood control policy (Figure ES-1).

Figure ES-1. An overview of findings from the first cycle of regional and state flood planning



Existing flood risk

(in 1 percent [100-year] and 0.2 percent [500-year] annual chance flood hazard areas)

5,219,900
Population

1,664,200
Buildings

12,654,000
Agricultural area (acres)

63,900
Roadway miles

1,295,700
Residential buildings

6,258
Hospitals, emergency medical services, fire stations, police stations, and schools

Why do we plan?

The adage that "prevention is better than cure" is highly relevant to flood planning. Resources applied, up front, to reduce the risk and impact of flooding extend much further than the cost of disaster recovery efforts. In addition to reducing human suffering and economic damage caused by a storm event, flood planning and preparedness are wise financial investments for our future.

In Texas, the recurrent and devasting impacts of floods have underscored the necessity of comprehensive flood planning across the state. Understanding that floods do not adhere to political boundaries, Texas has embarked on a coordinated, innovative approach that transcends local jurisdictions. This approach aims to anticipate and reduce existing and future flood risks. The proactive approach of regional and state flood planning in Texas was designed to protect lives, property, Texas' economy, and the well-being of communities across the state. Prior to establishing the regional and state flood planning efforts in 2019, Texas' approach to managing flood risks was largely decentralized, and primarily reliant on local initiatives. While this approach is valuable, it is unable to adequately address the complex, cross-jurisdictional nature of flood management, which requires broader thinking as well as careful consideration of those downstream of potential flood risk reduction solutions.

Historically, Texas has endured catastrophic floods, leaving long-lasting marks on its landscape and population. From the 1921 Williamson County event that set a national record with more than 36 inches of rain in 18 hours, to the extensive flooding across rivers like the Pecos and Sabine in 1957, and the more recent devastation of Hurricane Harvey in 2017, Texas has witnessed the full spectrum of flood-related disasters. Flood events claim lives, damage properties and economies, and strain or even threaten emergency services and critical public facilities. Identifying and mitigating flood risk is widely recognized as a wise investment compared to the enormous costs required to recover from disasters.

An equally important part of the planning process is engaging and educating Texas communities in assessing their flood risk and mitigating flood hazards in their communities. By fostering a culture of awareness, involvement, and preparedness, communities become active participants in reducing their own flood risks.

The TWDB estimates that there are over 1,450 communities in Texas across 254 counties, including more than 1,200 cities and municipalities. The 15 regional flood plans include flood risk reduction solutions from more than 1,050 unique entities and communities. While the need for public outreach persists, the number of participating communities during the first regional flood planning cycle is encouraging.

How do we plan?

Texas is a large state with over 268,000 square miles of diverse geography and rainfall patterns. The river basin-based regional flood planning process enabled each planning group to address its region's unique flood risk and flood risk reduction needs.

Texas' approach to flood planning is comprehensive and rooted in a bottom-up regional process that becomes the basis for the state flood plan, emphasizing local involvement and collaboration. The state is divided into 15 regional flood planning areas based on river basin boundaries (Figure ES-2). Each of these regions is represented by a regional flood planning group composed of voting members from at least 12 required interest categories that include the public, counties, municipalities, agricultural interests, industry, river authorities, small business, water districts, environmental interests, electric generating utilities, flood districts, and water utilities.

The current population of Texas is approximately 30 million and expected to increase to 51.5 million by 2070. While it is essential to understand our *existing* flood risk and work to reduce the risk and impact of flooding for those currently in harm's way, it is equally important to prevent an increase in *future* flood risk. Floodplain management practices play a key role in this. The regional flood planning process also focuses on reducing existing flood risk and avoiding the creation of future flood risks.

The planning groups operate and develop their regional plans on a five-year cycle, setting goals, evaluating flood risks, and recommending potential flood risk reduction solutions. Upon their adoption, each group's goals guide the development of their regional flood plan. The planning groups identify and recommend flood risk reduction solutions, ensuring each is aligned with the associated goals for mitigating flood impacts, and considering local specificities and potential impacts on the region's resources and communities. Each plan is a comprehensive regional flood planning document that reflects the diverse aspects of flood management within its region.

The 2019 Texas Legislature appropriated funds to enable the flood planning program. Each flood planning group selected a political subdivision sponsor that entered into a contract with the TWDB to support regional plan development with the assistance of technical consultants. During the first cycle of statewide regional flood planning, a total of $29.5 million was provided to the 15 planning groups which was primarily used to hire technical consultants.

The regional flood planning groups are required to adhere to all statutory, administrative, and contractual requirements in accordance with the regional and state flood planning framework and guidance principles. This includes maintaining group membership, designating a state political subdivision for administrative support, applying for grant funding, selecting and directing technical consultants, ensuring public participation and transparency, and adopting their regional flood plans.

This state flood plan synthesizes the information from the 15 regional flood plans to create a cohesive summary of statewide flood risk and mitigation opportunities. All numbers in the State Flood Plan are compilations of estimates based on the best available data that the planning groups could identify within the regional planning schedule. The consolidated local knowledge and strategies ensure that the state flood plan is both inclusive and effective, addressing the unique challenges faced by each region while aligning them with overarching state-level flood management objectives. This approach allows for a nuanced, data-driven, and regionally sensitive response to flood risks across the state.

It is important to note that this document is a high-level planning guide offering, for the first time, statewide flood risk information and reduction recommendations, but nothing within the process or results of this process is regulatory. This plan recognizes the importance of well-orchestrated emergency response and disaster recovery, but it does not address or propose changes to the existing regime for disaster response and recovery beyond what already exists. Rather, it focuses on proactively, systematically, and collaboratively identifying, assessing, and reducing the risk of impact and flooding across the state to greatly reduce the need for costly and time-consuming response and recovery efforts.

Figure ES-2. Regional flood planning areas

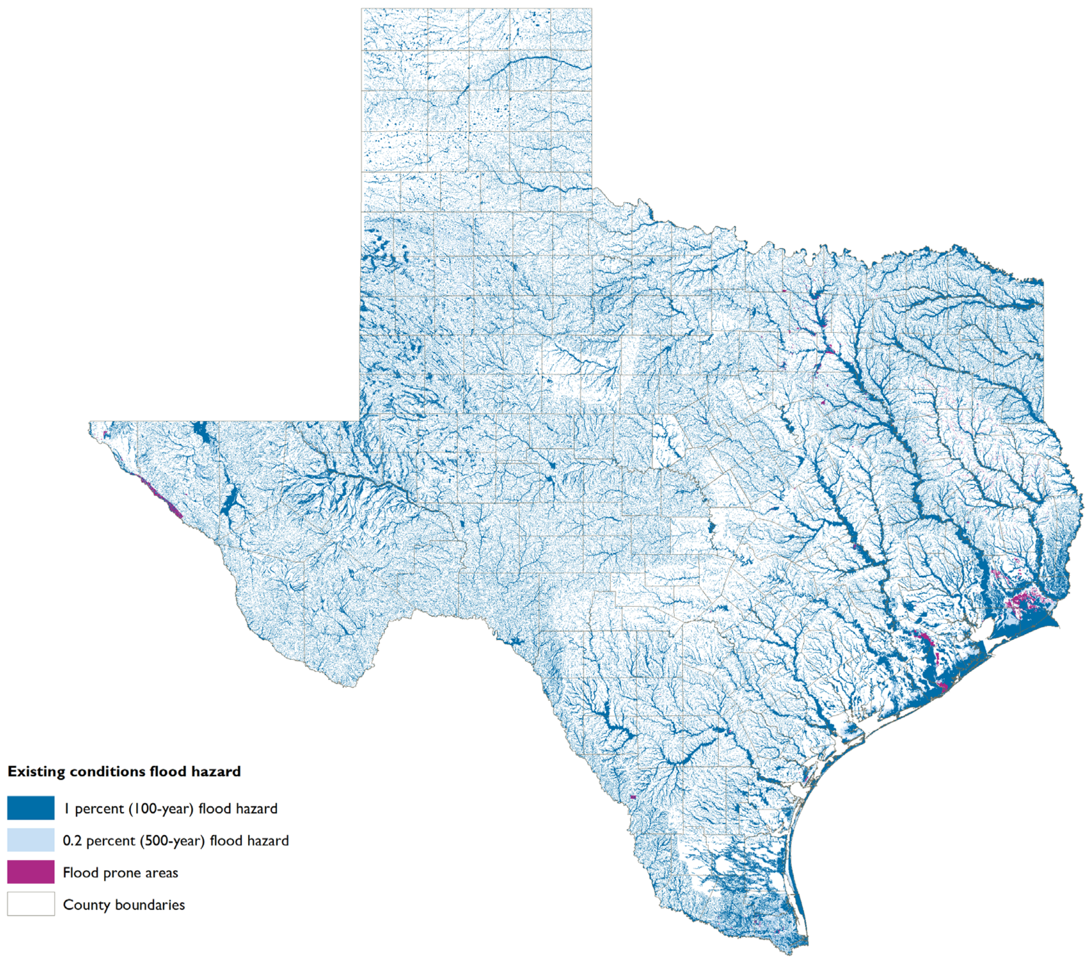
Where are our flood hazards?

The first round of regional flood planning identified and compiled existing condition flood hazards, including riverine flooding, urban flooding, coastal flooding, playa flooding, and possible flood prone areas for the entire state of Texas. While some flood planning regions were already data-rich with flood risk information (e.g., some coastal areas and within Flash Flood Alley of Dallas, Waco, Temple, Austin, and San Antonio), there are several regions in the Texas Panhandle area and West Texas where much of the flood risk was either unmapped or based on outdated maps. As a result, most of the flood risk across these regions was not well quantified, meaning lives and property were unknowingly in harm's way.

The first step of addressing flood risk is to identify the existing flood hazard. Flood hazard is the first of three components to flood risk and represents the location, magnitude, and frequency of flooding events. The regional flood planning groups identified the 1 percent annual chance floodplain, the 0.2 percent annual chance floodplain and flood prone areas based on local knowledge and stakeholder feedback where the flood frequency was unknown. The 1 percent floodplain—often referred to as the 100-year floodplain—is the land predicted to flood during a 100-year storm event and has a 1 percent chance of occurring in any given year. The 0.2 percent floodplain—or 500-year floodplain—is the land predicted to flood during a 500-year storm and has a 0.2 percent chance of occurring in any given year. Areas that are not located in known floodplains or flood hazard areas but are identified as 'flood prone areas' via stakeholder input have an unknown probability of flood occurrence and are classified as having an unknown frequency of flood hazard.

Approximately 21 percent (56,053 square miles) of Texas' land area (268,597 square miles) is estimated to be within the 1 percent (100-year) annual chance floodplain (Figure ES-3). Most of the 1 percent (100-year) annual chance floodplain in the state is concentrated along rivers and streams, indicating that riverine flooding, referred to as "fluvial," is the predominant type of flooding in these areas. Other instances of flooding include urban flooding—also referred to as "local" or "pluvial" flooding—in which rainfall overwhelms the drainage capacity of engineered drainage systems leading to localized flooding. Pluvial flooding is also an issue in the flat Panhandle region where both engineered drainage systems and natural playa lakes are overwhelmed by acute intense rainfall, leading to urban flooding. Coastal flooding is prevalent along the Gulf Coast and ranges from nuisance flooding during high tide events to deadly hurricane-driven storm surges. Land subsidence in certain areas contributes to and magnifies the impact of coastal flooding by increasing the rate of relative sea level rise.

Figure ES-3. Existing condition flood hazard areas



Who and what are at risk of flooding?

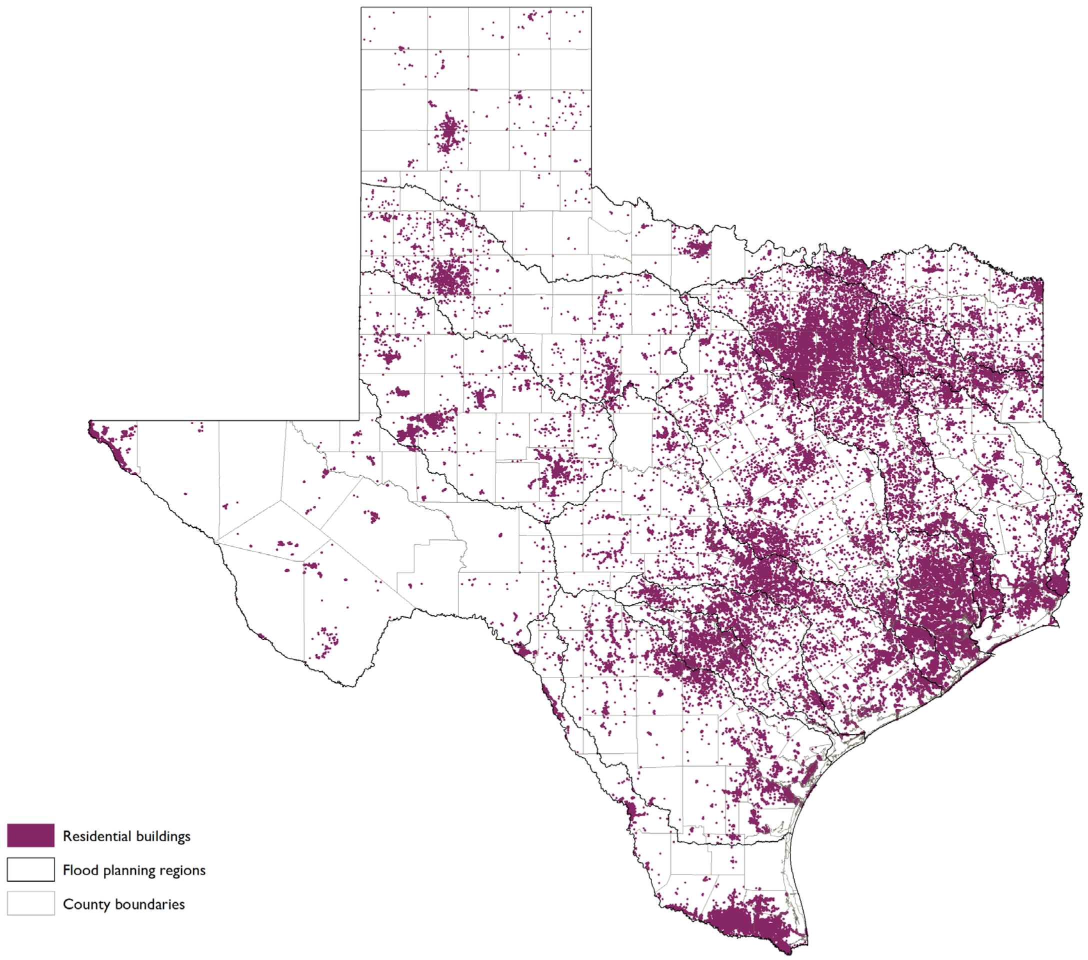
Understanding who and what may be exposed to flooding is a critical aspect of flood risk management and reduction and is the second of three components required to assess flood risk. By identifying the populations, buildings, and infrastructure within the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains, as well as other flood prone areas, decision-makers can develop targeted strategies to mitigate risk. The flood exposure analyses performed by the regional flood planning groups informed the development of robust regional and state flood plans and play a vital role in ensuring the safety and resilience of communities against the devasting impacts of floods.

Of the approximately 30 million Texas residents, the regional flood planning groups estimated that more than 5.8 million live or work in flood hazard areas, with approximately 2.4 million in the 1 percent (100-year) annual chance floodplain, an additional 2.8 million within the 0.2 percent (500-year) annual chance flood floodplain, and approximately 666,000 located within flood prone areas of undetermined flood risk. Regional flood planning groups identified approximately 878,100 buildings within the 1 percent (100-year) annual chance floodplain, and an additional 786,100 buildings within the 0.2 percent (500-year) annual chance floodplain. (Figure ES-4).

Planning groups also evaluated Texas' transportation infrastructure, citing more than 69,000 roadway crossings, and over 43,000 miles of roadways identified within the 1 percent (100-year) annual chance floodplain. The groups identified 9,322 low water crossings within flood hazard areas and approximately 10.2 million acres of farmland in the 1 percent annual chance floodplain.

Vulnerability, the third component of flood risk analysis identifies the degree to which communities and critical facilities may be affected by flooding. Planning groups identified more than 6,258 hospitals, emergency medical services, fire stations, police stations, and schools within the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains. The results of these analyses highlight the need for comprehensive flood risk reduction solutions in Texas, recognizing both the scale of risk and the potential impact that flooding of critical facilities can have on community resilience.

Figure ES-4. Existing residential buildings in the 1 percent (100-year) annual chance floodplain



What has already been done?

Texas has long recognized the importance of mitigating flood risks to safeguard lives and property. Prior to establishing the regional and state flood planning program in 2019, there were various measures implemented at the local, regional, state, and federal levels to manage and mitigate flood risks. These efforts ranged from constructing and maintaining flood-related infrastructure like dams and levees to developing comprehensive watershed management programs. Such initiatives helped lay the groundwork for the flood risk management solutions outlined in this plan.

Existing flood infrastructure in Texas forms the backbone of the state's current flood mitigation strategy. The statewide regional planning process is Texas' first attempt to generate a statewide inventory and assessment of major flood infrastructure. Collecting information regarding the condition of existing infrastructure is effort-intensive and time-consuming. This exercise is only truly feasible at the regional level to the extent that the asset owners already possess the sought-after information, which they often do not. While the information collected during the first cycle of regional flood planning is not a complete assessment of all major infrastructure in the state, it is invaluable to the ongoing planning process. The expectation is that the inventory and assessment of existing major infrastructure will improve during each successive iteration of the state flood plan. Planning groups identified more than 1.3

million existing flood infrastructure features, both natural and constructed. However, the functionality and condition for most of the identified flood infrastructure was not available and therefore reported as unknown.

The planning groups were tasked with cataloging existing and prospective flood mitigation projects with dedicated construction funding. This involved a variety of data collection methods, ranging from community surveys to analyzing disaster mitigation plans. Planning groups identified 2,798 proposed and ongoing flood mitigation projects currently under construction, being implemented, or with dedicated construction funding. Together, the projects have an overall cost of $8 billion dollars. However, the complexity of these projects, coupled with varying levels of community engagement presented challenges in acquiring detailed information, such as project costs and completion timelines.

One of the most efficient and cost-effective ways to mitigate existing and future flood risks is implementing and enforcing sensible floodplain management practices. The planning groups assessed the various existing floodplain management practices across each of their regions, noting how many entities with flood-related authority have minimum standards, participate in the National Flood Insurance Program, and enforce their standards (among other practices). While many communities do not have minimum floodplain regulations, remarkably more than 98 percent of Texas' population resides within communities that participate in the National Flood Insurance Program. Of Texas' 1,473 counties and municipalities, 1,239 participate in the program. More than 500 of those 1,239 entities have floodplain management standards that exceed National Flood Insurance Program minimums. Participation in the National Flood Insurance Program can go a long way to reducing future flood risk and providing financial assistance for post-disaster recovery. However, the program does not assess flood risk to lives or property nor does it mitigate existing flood risks. There is much work to be done through the regional flood planning program to identify flood risk and implement flood mitigation projects.

There are a variety of other, ongoing flood efforts that further demonstrate Texas' commitment to flood risk management. In addition to implementing the regional and state flood planning programs, the TWDB is working to generate base level engineering flood hazard data for the entire state, cooperating as a partner to the Federal Emergency Management Agency (FEMA), managing the Flood Infrastructure Fund, and providing community assistance for entities interested in participating in the National Flood Insurance Program. Other significant ongoing flood efforts are provided by the Texas Commission on Environmental Quality, the Texas Division of Emergency Management, the Texas General Land Office, and the U.S. Army Corps of Engineers, amongst other state and federal agencies.

The Flood Infrastructure Fund, administered by the TWDB, is the result of a 2019 voter-approved state constitutional amendment to assist in financing drainage, flood mitigation, and flood control projects. Since its inception, the Flood Infrastructure Fund has committed over $643 million dollars to more than 140 active and completed projects. Upon adoption of this state flood plan, only projects recommended in the regional and state flood plans will be eligible for grants under the Flood Infrastructure Fund.

What are we doing to make Texas more flood resilient?

The regional flood planning groups recommended a wide range of potential flood risk reduction solutions that are organized into three categories: flood management evaluations, flood mitigation projects, and flood management strategies.

A **flood management evaluation** is a proposed study to identify, assess, and quantify flood risk or identify, evaluate, and recommend flood risk reduction solutions.

A **flood mitigation project** is a proposed structural or non-structural flood project that has a non-zero capital cost or other non-recurring cost and that, when implemented, will reduce flood risk or mitigate flood hazards to life or property.

A **flood management strategy** is a proposed plan to reduce flood risk or mitigate flood hazards to life or property that does not fit within the former two categories. Examples may include regulatory enhancements, development of buyout programs, and public outreach and education. Each regional flood planning group had flexibility on how it chose to utilize flood management strategies in the regional flood planning process.

A total of 4,609 flood risk reduction solutions were recommended across all 15 regional flood planning groups: 3,097 flood management evaluations, 615 flood mitigation projects, and 897 flood management strategies. If each recommended project is implemented, an estimated 843,300 people, 214,300 structures, and 577 low water crossings would be removed from the 1 percent (100-year) annual chance floodplain. The planning groups were required to determine "no negative impacts" for each recommended flood mitigation project and flood management strategy, meaning that implemented projects will not increase the flood risk upstream or downstream of the proposed project.

The recommended flood management evaluations include engineering project planning, watershed planning, flood preparedness studies, and others. Examples of recommended structural flood mitigation projects include low water crossing improvements, constructing or upgrading storm sewers and roadside ditch systems, constructing detention basins, bridge elevation, channel grading, dam improvements, and nature-based solutions (including playa improvements and conservation easement acquisition). Examples of non-structural flood mitigation projects include preparedness studies, property acquisition and structural elevation.

Structural flood mitigation projects are most often noticed by the public because they can take the physical form of low water crossing or bridge improvements, detention ponds, flood walls and levees, and stream channel improvements. The regional and state flood planning rules and guidance principles (31 § TAC 362.3) also required that flood planning groups consider a balance of structural and non-structural flood mitigation measures, including projects that use nature-based solutions that lead to long-term mitigation of flood risk.

Several recommended flood mitigation projects and flood management strategies may also beneficially impact water supply, including projects and strategies that contribute to natural aquifer recharge and additional surface water inflows directed to reservoirs. Three regions (Region 11 Guadalupe, Region 12 San Antonio, and Region 15 Lower Rio Grande) identified potential water supply benefits for 37 recommended flood mitigation projects with an estimated water supply amount of 2,001 acre-feet per year. One region (Upper Rio Grande) recommended a flood management strategy with a potential water supply benefit estimated at 70 acre-feet per year.

Other important flood risk reduction solutions include implementing or expanding flood measurement and warning systems, providing flood-related education, and performing public outreach. There are many solutions identified by the regional flood planning groups that, when implemented, will make Texas more flood resilient.

How much will it cost?

The estimated total implementation cost of all flood risk reduction solutions recommended by the planning groups in the first planning cycle is estimated to exceed $54.5 billion dollars, without accounting for future inflation. Approximately $24 billion of this amount is associated with the various Galveston Bay Surge Protection Coastal Storm Risk Management projects. Project sponsors would typically borrow funds for capital costs and repay them through annual debt service payments. It is important to note that even after this first cycle of regional flood planning, not all flood risk or flood risk reduction solutions could be identified and incorporated into the regional and state flood plans. This is because there will be additional flood mitigation projects identified as the flood management evaluations are funded and performed. Those studies will, in turn, identify specific projects that can be implemented to reduce identified flood risk, and the resulting cost to reduce flood risk will likely be larger than the amount identified in this inaugural state flood plan.

How will flood risk reduction solutions be funded?

The regional flood planning groups were required to indicate how individual local governments, regional authorities, and other political subdivisions in their region that will sponsor flood risk mitigation efforts propose to finance the region's recommended evaluations, projects, and strategies. This effort was intended to identify the overall funding availability and unmet need to implement flood risk reduction solutions. The planning groups administered funding surveys toward the end of the planning cycle to estimate the amount of state financial assistance that communities might require to implement the recommended solutions. They received limited responses to these surveys. However, results indicated that, overall, many local sponsors may require financial assistance with up to 80 to 90 percent of the project implementation costs. This result is generally in line with what the TWDB learned when developing its 2019 State Flood Assessment.

The nature of flood infrastructure can make it difficult to fund and may be under-funded in many cases at least partly because, unlike water supply projects, flood mitigation projects do not generate revenue. In some cases, those entities incurring the cost of flood mitigation measures are not the same entities that realize the benefits. For example, the costs of dam maintenance are incurred by the dam's owner, but downstream residents are among those that benefit from the maintenance. Local and regional governments will need public support to implement and finance expensive flood mitigation projects and other flood mitigation efforts such as floodplain management strategies. Current sources of local funds to pay for flood activities and make debt payments vary by entity and may include a variety of taxes, permitting or utility fees, and bond programs. State financial assistance programs include the Flood Infrastructure Fund, and the Texas Water Development Fund. Federally funded financial assistance programs include state revolving fund programs and FEMA's Flood Mitigation Assistance grant program.

What if we do nothing?

Inaction in the face of existing and growing flood hazards will continue to leave life and property vulnerable to floods in Texas. Texas' vulnerability to flood risk will likely increase into the future, especially in the absence of better floodplain management or failure to implement flood risk reduction solutions. Regional flood planning groups projected flood hazards across the state will increase over the 30-year (long-term) planning horizon, due to changes in precipitation regimes and expanding or shifting land use as Texas' population grows.

Many of the groups projected the future 1 percent (100-year) annual chance floodplain within their region to become equal to the existing 0.2 percent (500-year) annual chance floodplain, with the future 0.2 percent annual chance floodplain extending out from that. Using current or projected population and development information, the planning groups estimated that statewide future 1 percent annual chance floodplain may grow to 62,245 square miles, representing an approximately 11 percent increase over the existing expanse of flood risk. Coupled with this increase in flood hazard, the associated flood exposure would increase significantly. Based on planning group estimates, an additional 2.6 million people may be exposed to 1 percent annual chance flood events—an increase of 110 percent. Critical facilities in that floodplain would increase by an estimated 137 percent. Roadway stream crossings, including low water crossings—where we most commonly see flood-related deaths—in the 1 percent annual chance floodplain would increase by an estimated 12 percent. By recognizing this potential increase in flood risk, Texas has the opportunity now to protect against loss of life and property.

What more can we do?

A tremendous amount of resources are currently spent on reducing existing risk and the impacts of flood risk, and more are needed. The flood planning effort focused on not only reducing the existing flood risk, but also taking steps to prevent increasing the risk of flooding in the future, including not placing additional lives and property at risk. The planning groups offered a variety of administrative, legislative, and regulatory recommendations they deem necessary to better reduce the risk and impact of flooding in Texas. Having considered their recommendations and other potential policy and floodplain management considerations, the TWDB includes three categories of key recommendations in Chapter 2. The Texas Water Development Board makes 5 legislative recommendations, shares 4 regional flood planning group recommendations, and includes 6 floodplain management recommendations as listed below:

1) TWDB legislative recommendations regarding
    a. Flood funding and financial mechanisms
    b. Community financial and technical assistance
    c. Low water crossing safety
    d. Flood early warning systems
    e. Enhanced dam and new levee safety programs
2) Select regional flood planning group legislative recommendations regarding
    a. Authority of counties, including regarding drainage fees
    b. Statewide floodplain management standards for infrastructure and buildings for flood risk reduction
    c. Statewide building codes regarding flood risk
    d. Transportation infrastructure considerations
3) TWDB general recommendations for floodplain management include
    a. Existing minimum FEMA floodplain standards required for cities and counties under Texas Water Code § 16.3145 and recommendations for higher standards
    b. Enhance current floodplain management activities
    c. Nature-based solutions
    d. Asset management
    e. Education and outreach
    f. State flood planning

1 Introduction

Quick facts

One-fourth of Texas' land area (66,831 square miles) is in either the 1 percent (100-year) annual chance or 0.2 percent (500-year) annual chance flood hazard areas.

Approximately 17 percent (5,219,908) or 1 in six Texans live or work in either the (1 percent (100-year) annual chance or 0.2 percent (500-year) annual chance flood hazard areas.

Each of the state's 254 counties has experienced at least one federally declared flood disaster.

Floods are expensive. Resources invested in reducing the risk and impact of flooding, including to avoid creating additional flood risk, and preparing for floods is cost effective.

More than 190 regional flood planning group voting members participated in developing the 2023 regional flood plans, meeting hundreds of times between 2020 and 2023.

This first cycle of the statewide flood planning process is Texas' first attempt to perform comprehensive planning to reduce flood risk and take a broad look at flood hazard across the state.

Texas has a long history of flooding and flood-related loss across the state, which has taken an enormous toll on people and property. In recent years, the 2015 Memorial Day flood took the lives of 14 people in Central Texas and set new river stage records near Wimberley, Texas. In 2017, Hurricane Harvey brought more than 19 trillion gallons of rainwater that caused significant flooding and damage to homes, hospitals, communities, vehicles, and roads with estimated total damage over $125 billion. In the wake of Hurricane Harvey, the 2019 Texas Legislature passed Senate Bill 8, directing the Texas Water Development Board (TWDB) to develop a state flood plan that must provide for orderly preparation for and response to flood conditions to protect against the loss of life and property; be a guide to state flood control policy; and contribute to water development where possible.

Under 31 Texas Administrative Code § 362.3,[3] the TWDB created 15 flood planning regions based on river basins and administered a regional flood planning process (Figure 1-1). The bottom-up, regional approach intentionally mirrors TWDB's successful regional water supply planning process that has been administered for more than 25 years.

Texas is a large state with over 268,000 square miles of diverse geographic coverage and rainfall patterns. The river basin-based regional flood planning process enabled each planning group to address its own region's unique flood risk and flood risk reduction needs.

The current population of Texas is approximately 30 million and expected to increase to 51.5 million by 2070 (TWDB, 2022). While it is essential to understand our current flood risk and reduce the risk and impact of flooding for those who are already in harm's way, equally important is the effort to prevent an increase in future flood risk; floodplain management practices play a key role in this. The flood planning process focuses on reducing existing flood risk and avoiding the creation of future flood risks.

We can prepare for and reduce the risk from certain flooding events; however, flood risk can never be fully mitigated. There will always remain some residual risk, whether from a more severe flood event or associated with the possible deficiency of a flood mitigation measure (e.g., levee failure). For instance, the state may never be fully prepared for an event at the scale or severity of Hurricane Harvey. Understanding this and educating the public are crucial to managing flood risk and protecting lives and

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[3] https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=4&ti=31&pt=10&ch=362

property. The **regional flood planning groups** facilitated broad public involvement and education throughout the planning process. Between the program's inception in October 2020 and completion of this state flood plan, the 15 planning groups conducted more than 550 public flood planning meetings across the state.

This first cycle of the statewide flood planning process is Texas' first attempt to perform comprehensive planning to reduce flood risk and take a broad look at flood hazard across the state. A tremendous amount of information was generated by the planning groups during the historic first cycle of regional flood planning, which aimed to identify who and what might be exposed to flooding; identify the state's major flood risk reduction infrastructure; consider existing floodplain management practices or lack thereof; and identify and recommend flood risk reduction solutions across the state.

This state flood plan brings together the findings of the 15 regional flood plans[4] and makes legislative and floodplain management recommendations to guide state, regional, and local flood control policy.

Figure 1-1. The 15 flood planning regions designated by the TWDB on April 9, 2020.

[4] www.twdb.texas.gov/flood/planning/plans/index.asp

1.1 Why plan for floods?

Due to expanding development within **floodplains** and our improved capability to measure and record weather events, the documented severity and impacts of flooding has escalated over the last century, with notable events like the 1921 rainstorm in Williamson County that set a national record with more than 36 inches of rain in 18 hours. Statewide rainfall in 1957 ended a prolonged **drought** but also brought extensive flooding from the Pecos to the Sabine River. More recently, historic flooding in 1998 along the San Marcos, Guadalupe, and San Antonio rivers and the catastrophic effects of Hurricane Harvey in 2017 exemplified the heightened flood risks in Texas.

Although flooding has certain benefits, like recharging groundwater and providing vital nutrients to ecosystems and agricultural lands, it remains a significant threat to the health and safety of Texans. Each of the state's 254 counties has experienced flooding, tropical storms, severe storm events, or all three, proof that floods can affect all areas of Texas (FEMA, 2024). As of the writing of this plan there have been a total of nine multi-billion-dollar flood events to affect Texas from 1980 to 2024. These range in cost from $10 billion to $20 billion (Consumer Price Index-adjusted) (NOAA, 2024). Managing the risks associated with flooding is crucial, given its recurring nature and potential for destruction. By initiating the statewide regional flood planning process, Texas is taking a major step toward addressing these ongoing challenges to safeguard its communities from the impacts of flooding and ensure future resilience in the face of natural disasters (TWDB, 2019). Prior to the statewide regional flood planning process, Texas did not have any state level, comprehensive effort to identify, address, or plan for flood risk. Since water does not adhere to jurisdictional boundaries, therefore watershed-based flood risk reduction planning with collaboration and cooperation between neighboring stakeholders is essential for appropriate management of flood risk.

In the realm of flood planning, the truth of the adage that "prevention is better than cure" can't be overstated; resources spent to reduce the risk and impact of flooding goes much further than the cost of recovery efforts. Planning for floods is a proactive approach that prioritizes preparedness and mitigation over the costly, time-consuming, and potentially repetitive process of recovery. The cost of recovery from a large flood or storm event is often much greater than the upfront cost of reducing the potential risk and impact of flooding. Once flooding occurs, there may be widespread damage to infrastructure, properties, and ecosystems that are expensive to repair or replace. Floods can also disrupt business operations, leading to revenue losses and job interruptions, and cause long-term and costly impacts to a population's health through waterborne diseases or injuries.

In addition to reducing human suffering and economic damage caused by a storm event, flood planning and preparedness is a good financial investment for our future. The aftermath of flood events often entails significant and ongoing economic and social burdens. For example, Hurricane Harvey in 2017 brought unprecedented devastation to Texas, with nearly 4.5 feet of rain, 130-mile-per-hour winds, and widespread riverine and urban flooding. More than 19 trillion gallons of rainwater caused significant flooding to 80,000 homes and left numerous hospitals, communities, and roads severely impacted. The response efforts involved the deployment of thousands of personnel; provision of such resources as food, water, and medical care; and the allocation of billions in federal funds to assist impacted Texans with recovery.

In areas prone to flooding, the flood recovery process can often take several years, and sometimes communities struggle to fully recover before being impacted by another flood event, perpetuating a cycle of vulnerability and prolonged hardships. Planning for flooding before it occurs allows communities to proactively implement measures to mitigate the impact of floods, reduce potential damage, and safeguard lives and property. By taking pre-emptive action, communities can enhance their resilience, minimize recovery time, and avoid the costly consequences of unpreparedness in the face of future flood events (FEMA, 2023).

Texas faces the dual challenge of high population density in flood prone areas and the increasing risks associated with flooding due to ongoing development and population growth across the state. To effectively address these challenges, we must identify vulnerable areas and implement suitable land-use policies, incorporating flood mitigation strategies into development plans. Furthermore, the uncertainties of climate variability and its impact on precipitation patterns emphasize the need for comprehensive flood planning. Coordinated statewide flood planning is critical to the implementation of cohesive strategies, leveraging collective expertise and resources to help reduce the negative impacts of floods on Texas communities (TWDB, 2019). As such, there are several local, state, and national agencies and programs intended to advance flood mitigation in the state, many of which are listed in Chapter 10 of this plan.

1.2 Flood fundamentals

It is important that everyone reading this flood plan shares at least a basic understanding of a few of the fundamental, and often misunderstood, terms associated with flooding and flood risk. The intricacies of these concepts not only shape our preparedness and mitigation strategies but also influence the way we respond to and recover from flood events.

1.2.1 Key terminology

Flooding

An overflow of water onto normally dry land. The inundation of a normally dry area caused by rising water in an existing waterway, such as a river, stream, or drainage ditch. Ponding of water at or near the point where the rain fell. Flooding is a longer-term event than flash flooding; it may last days or weeks (NWS, n.d.). While it can threaten people and infrastructure and cause economic damage, flooding is also a naturally occurring phenomenon providing beneficial ecosystem services and helps to maintain the natural hydrology of rivers and streams.

Flash flooding

A flood caused by heavy or excessive rainfall in a short period of time, generally less than six hours. Flash floods are usually characterized by raging torrents after heavy rains that rip through riverbeds, urban streets, or mountain canyons. They can occur within minutes or a few hours of excessive rainfall. They can also occur even if no rain has fallen, for instance after a levee or dam has failed or after a sudden release of water by a debris jam (NWS, n.d.). A portion of Central Texas following the curve of the Balcones Escarpment from Dallas to Austin and extending just southwest of San Antonio has earned the moniker **Flash Flood Alley** because of the steep terrain, shallow soil and intense rainfall rates. Areas with large amounts of impervious surfaces, exposed bedrock, or other solid surfaces that reduce infiltration and increase runoff are especially susceptible to flash flooding. Near El Paso, runoff from steep slopes flows rapidly over dry, impenetrable soils, transporting and depositing eroded materials across the landscape.

Flood risk

Flood risk is a combination of the probability (likelihood or chance) of a flood event happening and the impact if it occurred. It is determined by the intersection of three components: hazard, which represents the potential flooding event; exposure, indicating the people and assets in the flood's path; and vulnerability, denoting the susceptibility of those people and to harm. The greater each component, the higher the overall flood risk for an area.

1.2.2 Flood frequency

Frequency of flooding is defined as the probability, expressed as a percentage, that a flood of a given size will be equaled or exceeded in any given year. Flood frequency helps us understand the likelihood of different flood events that may occur in a particular area. A 2-year rainfall or storm event has a 50 percent chance of occurring during any given year; a 2-year rain event can occur multiple times a year. Similarly, a 100-year annual chance flood has a 1 percent chance, and a 500-year annual chance flood has a 0.2 percent chance of occurring within any given year. However, each of these storm events can occur more than once during a year.

To determine flood frequency, scientists analyze historical rainfall data identifying significant rain events over extended periods. This helps estimate the probability of different flood events. Communities can then use that information to plan for floods and design infrastructure to withstand certain annual chance flood events like the 1 percent annual chance storm event or build outside the boundaries of 1 percent annual chance floodplain.

The term "1 percent annual chance flood event" versus "100-year flood" provides a clearer understanding of the probability of occurrence, indicating a 1 percent chance of that specific flood event happening in any given year. Using terminology that's easier to understand helps avoid the misconception that such a flood will only occur once every 100 years. Notably there is a 26 percent or greater likelihood that a building located within a 100-year floodplain will experience at least one flood during a 30-year mortgage (USGS, 2018). For the purposes of this plan, we will use the term "1 percent annual chance flood event."

1.2.3 Types of flooding

Riverine flooding (also known as fluvial flooding)

Abundant rainfall can result in more runoff entering a river channel than can be contained within its banks. When water levels exceed the capacity of a channel, the river overflows onto adjacent lands, called the floodplain. On steep, narrow floodplains, sometimes lesser volume of runoff is needed in the streams to create excess overflows. In areas where the land is flat and floodplains are more expansive, greater volumes of runoff are required to cause flooding, and the impacts of which may take hours or days to reach locations downstream (TWDB, 2019).

Urban, local or stormwater flooding (also known as pluvial flooding)

This type of localized flooding occurs when rainfall overwhelms the capacity of engineered drainage systems to carry away rapidly accumulating volumes of water. It typically dissipates quickly, except in situations when pumping equipment fails due to loss of power, inflows exceed pumping or conveyance capacity, or debris blocks the passage of water. The solid surfaces of buildings and streets (also called impervious cover) prevent rainfall from soaking into the ground, resulting in runoff. Because this type of flooding is most common in urban environments, it is also called urban flooding (TWDB, 2019).

Coastal flooding

Low-pressure systems may gain strength as they travel across the warm waters of the Gulf of Mexico, sometimes developing into tropical storms or hurricanes. As these systems approach the Texas Coast, stronger winds combined with changes in water surface elevation can produce a storm surge that drives ocean water inland across the flat coastal plain. High-tide events also may cause frequent, localized flooding of low-lying coastal lands (TWDB, 2019).

Structural failure flooding

Gradual or sudden catastrophic failure of man-made infrastructure, such as dams or levees, can occur when intense or extensive rainfall results in the uncontrolled release of floodwater. Failures may arise if a rain event exceeds the design capacity of a structure, such as when the Callaway and McGuire dams failed in Robertson County in May 2004 (TWDB, 2019).

Other regional flooding

Texas is defined by a diverse range of landscapes, each characterized by a variety of geological formations and climatic conditions, affecting regional flooding in distinct ways. Storms in the Texas Panhandle cause flooding in and around playa lakes; shallow, circular wetlands primarily fed by rainfall. West Texas' dry climate experiences extended periods of drought conditions. When it rains, alluvial fans, or fan-shaped deposits of water-transported material common to the region, can rapidly redirect water flow across wide areas, creating complex and sudden flooding scenarios (FEMA, 2020). In the Lower Rio Grande Valley, where rainfall can be highly variable, arroyos, dry creeks or stream beds that temporarily fill and flow after heavy rain, can rapidly channel large volumes of water, leading to sudden and severe storm events (Love, 2023).

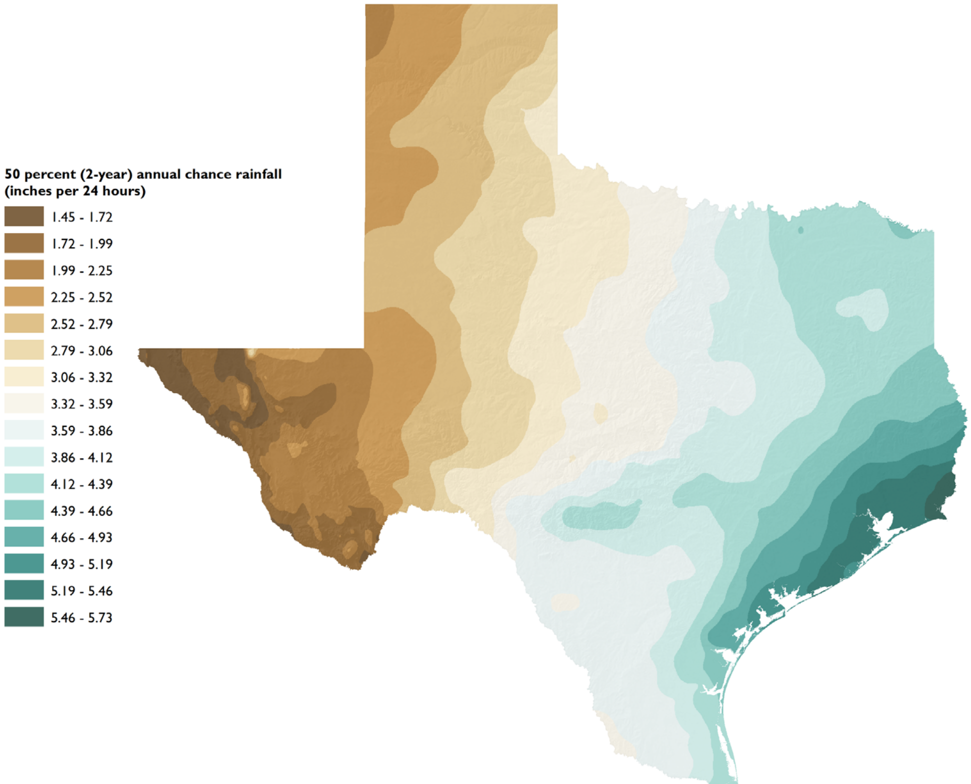
1.2.4 Variability of storm events

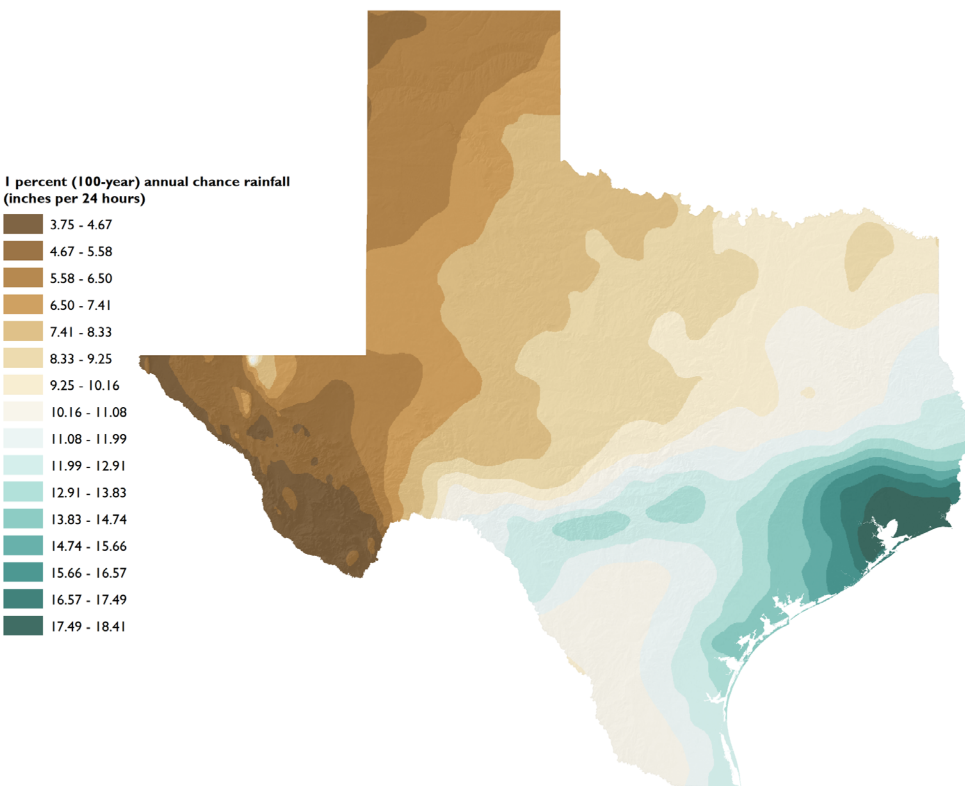
The probabilities of certain rain events change over time as more data is collected when new rain events occur. Large storm events can increase the probabilistic flood depth of a particular region. Much of Texas' rainfall amount for various storm events increased because Atlas 14[5] incorporated more recent rainfall data in the rainfall frequency analysis. Publication of the next iteration, Atlas 15, is expected in 2027. This trend points to the need for updating both flood risk estimates and continued flood planning efforts to address these shifting risks.

The amount of rainfall defining storm events varies across Texas. For comparison, a 1 percent annual chance or a100-year storm event for 24-hour duration ranges from 4 to 5 inches of rainfall in El Paso, 6 to 7 inches in Amarillo, 12 to 13 inches in Austin, and 17 to 18 inches in Houston (NOAA, 2018). Figure 1-2 presents the 1 percent (100-year) and 50 percent (2-year) annual chance rainfall depths across Texas, which reflect the regional variability of rainfall amounts across the state.

[5] Atlas 14 is a rainfall study conducted by the National Oceanic and Atmospheric Administration (NOAA). It offers up-to-date rainfall information, like a weather map for rain. It helps us prepare for floods, plan drainage systems, and manage water resources (OWP, n.d.).

Figure 1-2. Regional variability of rainfall in Texas





Map summary: These maps illustrate the varying intensity of 24-hour rainfall across Texas that corresponds to a 1 percent (100-year) annual chance storm event and 50 percent annual chance storm event (2-year), respectively. These metrics represent the amount of rainfall in inches with a 1 percent chance and 50 percent chance of being exceeded in any given year. The maps were generated utilizing Atlas 14 rainfall dataset.

Regional variations: Rainfall depth for storm events vary significantly across Texas. For example, the Gulf Coast regions receive a much higher rainfall amount during storm events compared to arid areas like West Texas. These variations highlight the differing thresholds for severe weather events across the state.

Significance: Understanding regional differences is important for flood planning and emergency preparedness. Even areas with lower 1 percent (100-year) annual chance storm event values can face significant flood risks, requiring appropriate mitigation efforts statewide.

1.3 Regional flood planning

In the wake of historic flooding in Texas, in 2019 the TWDB presented the Texas State Flood Assessment[6] to the 86th Texas Legislature. The document aimed to assess flood risks across Texas and provide recommendations for better flood management. The report's main findings highlighted the significant flood risks faced by the state, with more than 5 million Texans living in areas at high risk of flooding. It emphasized the need for improved floodplain mapping, infrastructure resilience, and coordination among agencies to enhance preparedness, response, and recovery efforts in the face of future floods. The report's primary recommendations included updating floodplain maps, enhancing infrastructure standards, implementing watershed-based flood management approaches, and investing in flood risk communication and public education to mitigate the impact of floods in Texas (TWDB, 2019).

As a result of the Texas State Flood Assessment, and similar efforts such as the Eye of the Storm Report,[7] the Texas Legislature created Texas' first-ever regional and state flood planning process and provided funding for investments in flood science and mapping efforts to support flood plan development. The legislature created the regional and state flood planning framework and charged the TWDB with designating flood planning regions based on river basins; selecting and convening the initial regional planning group memberships; and administering the funding and flood planning through grant contracts. Additionally, the legislature created a new flood financial assistance fund and directed the TWDB with its administration to help fund flood mitigation projects.

1.3.1 Regional flood planning groups

Each of the 15 regional flood planning areas has an associated planning group composed of local stakeholders who volunteer for this time-consuming process. Under Texas Water Code § 16.061,[8] the regional flood planning groups are responsible for developing regional flood plans every five years that are funded primarily through legislative appropriations, administered by the TWDB, and guided by statute, rules, contracts, and input from planning group members and the public. In accordance with the Texas Open Meetings Act, all planning groups and their committees conduct their business in meetings that are open to the public and that give the public advance notice of the time, date, location, and subject matter of the meetings.

Statute requires that each planning group maintain at least one representative of each of the following 12 interest categories:

1) The public
2) Counties
3) Municipalities
4) Industry
5) Agriculture
6) Environment
7) Small business
8) Electric-generating utilities

[6] https://texasfloodassessment.org/

[7] https://www.rebuildtexas.today/eyeofthestorm

[8] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.16.htm

9) River authorities
10) Flood districts
11) Water districts
12) Water utilities

Planning groups must have at least one voting representative from each required interest. To ensure adequate representation, planning groups may designate representatives for additional interests that are important to the planning area. Planning groups may also add additional voting and non-voting members to each group following their own bylaws. Currently, each planning group has at least 12 voting members. More than 190 voting members participated in developing the 2023 regional flood plans, meeting hundreds of times between 2020 and 2023 (see Acknowledgments). Non-voting members include representatives from the TWDB, Texas Commission on Environmental Quality, Texas General Land Office, Texas Parks and Wildlife Department, Texas Department of Agriculture, Texas State Soil and Water Conservation Board, and Texas Division of Emergency Management.

Similar to the regional water supply planning process, the success of Texas' regional flood planning process depends on the service of planning group members who dedicated many hours to this effort. Strong leadership from planning group chairs and other members, as well as the ability to attract new members who bring fresh ideas to the table, will ensure the dynamic continuity of the planning process.

1.3.2 Program requirements

A regional flood plan must meet all statutory, administrative rule, and contract requirements. During each five-year planning cycle, each planning group must

- maintain its membership and governing bylaws;
- designate a political subdivision of the state, such as a municipality, river authority, or council of governments, to serve as its administrator for the purpose of arranging meetings, managing grant-funded contracts, and providing public notices (the political subdivision provides staff resources, at its region's expense, to perform these administrative services);
- apply to the TWDB for regional flood planning grant funding through its political subdivision;
- select a technical consultant(s) to serve at the direction of the planning group and collect information, perform analyses, and prepare the regional flood plan document;
- direct the development of its flood plan, including making decisions about which flood management strategies, projects, or evaluations to consider and recommend;
- solicit and consider public input, conduct open meetings, and—together with its political subdivision—provide required public notices, including for public hearings on the draft regional flood plan;
- submit its technical memorandum and draft regional flood plan and standardized data to the TWDB for review; and
- adopt a final regional flood plan and submit it to the TWDB for approval.

To facilitate developing the regional flood plans, each planning group is supported by a dedicated TWDB regional flood planner who serves as a project manager and non-voting planning group member that attends every planning group meeting and manages the associated grant contract. The planners also provide technical and administrative assistance during meetings and throughout development of the regional flood plans to help ensure the planning groups meet their deadlines and all planning requirements.

1.3.3 Development of the regional flood plans

Each of the 15 planning groups is tasked with producing long-range regional flood plans that aim to address current and future flood risk across the state. These plans generally follow a standard format across the regions based upon statute, administrative rules, and an established scope of work for each planning cycle. Regional flood planning is based on 39 guiding principles, the most important of which is to provide for the orderly preparation for the identification and reduction of flood conditions to protect against the loss of life and property and reduce injuries and other flood-related human suffering.

Planning groups identify both current and future flood risks, including hazard, exposure, vulnerability, and residual risks; select achievable flood mitigation goals; and recommend evaluations, projects, and strategies to identify or reduce flood risk. Planning groups report the associated data that considers a 30-year planning horizon (in this cycle from 2023 to 2053) by county, river basin, and regional flood planning area. The regional plans also include an assessment of current floodplain management, land use regulations, economic development practices, and policy recommendations.

While each successive iteration of regional flood planning will take place over five-year periods, the first cycle of regional flood planning was completed in a little over two years, an expedited schedule made even more complicated with the global COVID-19 pandemic. Further, during the first cycle of regional flood planning, the groups were given additional funding and time to perform flood management evaluations to be able to recommend additional flood mitigation projects for inclusion in the regional flood plans. This tripled the number of projects recommended in the state flood plan.

It is estimated that there are more than 1,450 communities in Texas including 254 counties and over 1,200 cities and municipalities. The statewide regional flood planning program had a positive impact in promoting awareness about flood risk and flood risk reduction. The 15 regional flood plans include flood risk reduction solutions from more than 1,050 unique entities and communities as sponsors. While there is a need for growth in public outreach in the future planning cycles, this number reflects an encouraging participation by communities in the regional flood planning program, considering this being the first cycle.

Overall, the 15 regional flood plans are the product of hundreds of meetings; the effort and many hours of hard work by the planning group members, consultants, and stakeholders; and a large amount of information that the planning groups developed along the way. Each regional plan presents information in 10 chapters.

1.4 State flood plan

After planning groups adopt their regional flood plans, they submit them to the TWDB for approval. As required by statute, the TWDB develops the state flood plan based on the adopted regional plans. The state flood plan compiles key information from the regional flood plans and serves as a guide to state flood policy. The state plan explains planning methodology, presents data for the entire state, including the statewide flood risk, and provides policy recommendations to the Texas Legislature. Statute requires that the state flood plan rank the flood risk reduction solutions recommended by the regional planning groups based on flood risk and flood risk reduction provided by each solution. Prior to adopting the final flood plan, the TWDB releases a draft state flood plan for public comment, solicits and considers the public comments, holds a minimum of one public hearing, and publishes its intent to adopt the final state flood plan in the Texas Register.

The regional and state flood plans are developed based on adopted guidance principles that were created by the TWDB in coordination with the Texas Commission on Environmental Quality, Texas Department of Agriculture, Texas General Land Office, Texas Parks and Wildlife Department, Texas Division of Emergency Management, and Texas State Soil and Water Conservation Board. Every five years, the TWDB must review and revise the guidance principles with input from these state entities.

1.4.1 The Interactive State Flood Plan Viewer

The 2024 State Flood Plan is supported by an interactive website[9] that is an integral part of the TWDB's adopted state flood plan. The **Interactive State Flood Plan Viewer** allows stakeholders to take an up-close look at data thematically and at discrete levels not found in the electronic or bound versions of this written plan. The enormous amount of flood planning data is presented in geographical and tabular forms with clickable links to help users navigate and download data. The viewer is largely driven by the 15 regional datasets and serves as a user-friendly interface that the public, legislators, and other agencies can explore and utilize. The viewer is publicly available on the TWDB website.

This approach to delivering flood planning data to the public provides more comprehensive and customizable views at a variety of scales, from a single area snapshot to the statewide big picture. The viewer is intended to be suitable for displaying visual information and delivering raw data in a manner that will best serve a wide range of stakeholders, including members of the public, flood planners, local officials, and technical consultants.

The viewer displays, summarizes, and disseminates at varying geographic scales all data generated by the TWDB state flood planning process, including, but not limited to, existing infrastructure, flood hazard areas and exposure, critical and other infrastructure at risk, recommended flood risk evaluations, and flood mitigation project recommendations.

The viewer allows query and download of flood models provided by the regional flood planning groups. Users can find models by location or association with flood management evaluations, flood mitigation projects, and flood management strategies.

1.4.2 Organization of the state flood plan

Chapter 2 of this plan summarizes the TWDB's policy recommendations to the Texas Legislature, and Chapter 3 summarizes existing major flood infrastructure and key ongoing flood projects as identified by the regional flood planning groups. Chapter 4 illustrates existing and future flood risk across the state. Chapter 5 summarizes current floodplain management practices and recommendations from the regional flood planning groups and the TWDB. Chapter 6 describes the goals adopted by the flood planning groups to help guide plan development, and Chapter 7 outlines the flood risk solutions as recommended by the regional flood planning groups. Chapters 8 and 9 examine the outcomes of plan implementation, including potential risk reduction and financial cost. Finally, Chapter 10 includes discussions of ongoing flood efforts in Texas as well as some key challenges and critical factors identified by the regional flood planning groups.

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2 Policy recommendations

Quick facts

The regional flood planning groups included more than 300 legislative, administrative, and policy recommendations in their 15 regional flood plans. Their policy recommendations were considered and helped inform the development of the legislative and other recommendations in this chapter.

The Texas Water Development Board makes 5 legislative recommendations, shares 4 regional flood planning group recommendations, and includes 6 floodplain management recommendations.

The 2019 Texas Legislature passed Senate Bill 8, which directs the Texas Water Development Board (TWDB) to develop a state flood plan that must provide for orderly preparation for and response to flood conditions to protect against the loss of life and property; be a guide to state flood control policy; and should contribute to water development where possible. The state flood plan must include "legislative recommendations the Board considers necessary to facilitate flood control planning and project construction."[10]

This chapter serves as a guide to state flood policy and includes legislative and floodplain management recommendations related to flood risk reduction, minimizing impact of flood risk, preventing increase of future flood risk, and aimed at protecting life and property. The TWDB based the recommendations in this plan largely on recommendations contained in the 2023 regional flood plans.

The regional flood planning groups were required under 31 Texas Administrative Code § 361.43 to develop and include in their plans

1) legislative recommendations that they consider necessary to facilitate floodplain management and flood mitigation planning and implementation;
2) other regulatory or administrative recommendations that they consider necessary to facilitate floodplain management and flood mitigation planning and implementation;
3) any other recommendations that the regional flood planning group believes are needed and desirable to achieve its regional flood mitigation and floodplain management goals; and
4) recommendations regarding potential new revenue-raising opportunities, including potential 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.

The planning groups included more than 300 administrative, legislative, and regulatory recommendations in the 15 regional flood plans. These recommendations were developed to address items that benefit and/or can be implemented at the local, regional, or state level. They were generally aimed at supporting flood risk reduction and supporting implementation of the regional flood plans, including exploring innovative ways of funding flood risk reduction activities.

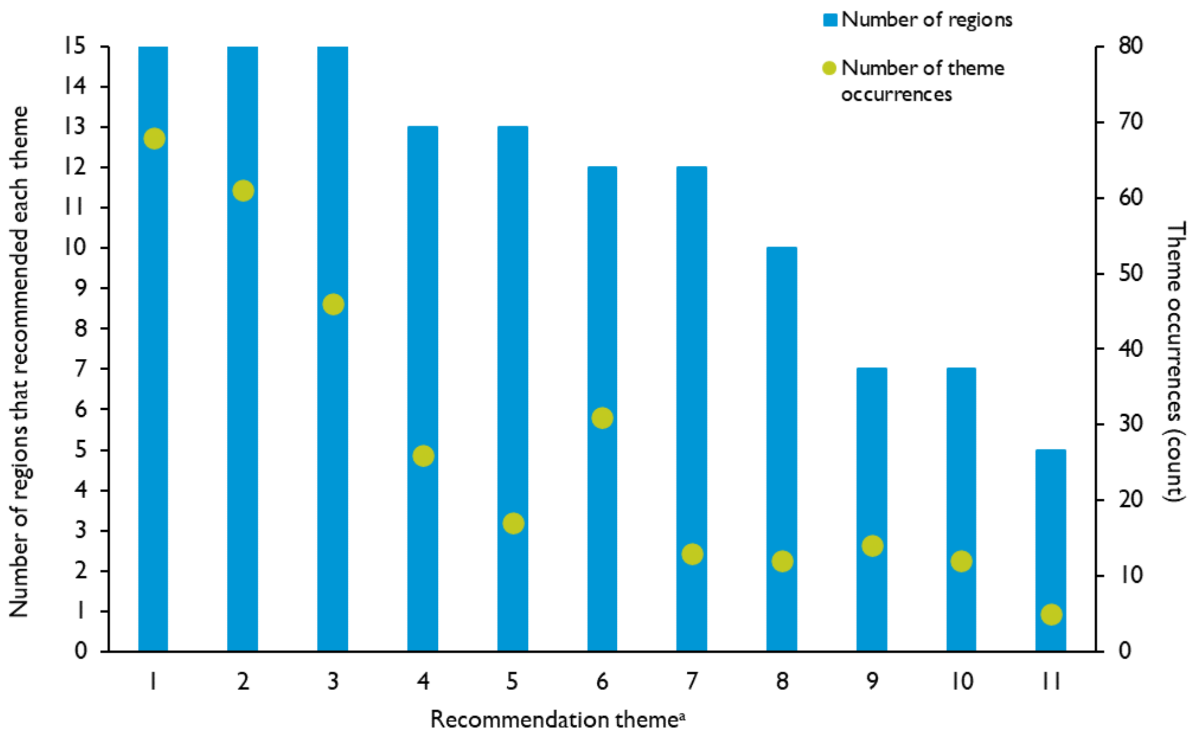
The TWDB carefully reviewed all policy recommendations made by the planning groups for consideration by the Texas legislature, organized and categorized them into major themes, and summarized them (Figure 2-1). An individual region may have made multiple recommendations that fall within a single theme. Because each regional flood planning group independently developed its own sets of recommendations, the grouped recommendations in this chapter are based on similar, but not identical, recommended language and are not meant to imply identical language was used by all the groups.

If one region did not make a particular recommendation, it should not be construed as opposition to the recommendation. Each region put forth its own unique set of recommendations and did not select from

[10] TWC 16.061(b)(5)

a pre-defined list of recommendations. The planning group recommendations strongly informed the TWDB legislative recommendations.

Figure 2-1. Summary of administrative, legislative, and regulatory recommendations made by the regional flood planning groups



[a] Themes:

1. *Infrastructure/stormwater/project design standards and infrastructure programs (dams, levees, roadways, channels, low water crossings)*
2. *Funding and financial mechanisms*
3. *Public education, outreach, interjurisdictional collaboration, and admin training*
4. *Data, mapping, and modeling updates*
5. *Small/rural jurisdiction assistance*
6. *Floodplain ordinances and regulatory authority*
7. *Drainage utility fee authority*
8. *Improving benefit-cost analyses*
9. *Nature-based solutions, green infrastructure, conservation easements, open space preservation*
10. *Federal program participation and collaboration*
11. *Statewide building code*

2.1 TWDB legislative recommendations

The TWDB generally based its legislative recommendations on those included in the 2023 regional flood plans. An early working draft of potential policy recommendations was provided to the public for feedback as part of a public Board work session on April 4, 2024. All written and verbal comments were considered before formulating the following TWDB recommendations for consideration by the Texas Legislature.

2.1.1 Legislative recommendation 1: Flood funding and financial mechanisms

The legislature should consider allocating dedicated funding for ongoing flood mitigation efforts through the Texas Water Development Board, including flood risk reduction solutions through the Flood Infrastructure Fund, and *continued funding for regional flood planning groups, flood risk modeling, and mapping.* [Supported *by Regions 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 11, 12, 13, 14, 15].*

2.1.2 Legislative recommendation 2: Community financial and technical assistance

The legislature should consider establishing and funding a targeted technical assistance program specifically aimed at small, remote, rural, or otherwise socioeconomically disadvantaged communities to develop and/or perform floodplain management activities to protect Texas' most vulnerable communities against loss of life and property. [Supported by Regions 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 12, 13, 14, 15]

- Targeted assistance for historically disadvantaged communities
- Technical assistance for small, remote, and rural communities

2.1.3 Legislative recommendation 3: Low water crossing safety

The legislature should consider expanding funding to enhance safety at low water crossings, prioritizing improvements based on traffic counts, roadway type, and existing risk levels through structural enhancements and flood warning systems. [Supported by Regions 9, 10, 11, 12]

Low water crossings are prone to frequent flooding and swift water flow conditions, posing a high risk to public safety and loss of life. Funding should be prioritized for low water crossing improvements based on traffic volume, roadway characteristics, existing risk levels, and the potential use of signage and flood gates.

2.1.4 Legislative recommendation 4: Flood early warning systems

The legislature should consider prioritizing and expanding funding for implementing flood early warning systems on a regional scale, with emphasis on rural areas, to enhance public safety and reduce flood risk to communities. [Supported by Regions 11 and 12]

Flood early warning systems are vital tools for alerting residents and business owners to imminent flooding events, through various communication channels including social media, radio, and reverse 911 calls, prompting timely evacuations and temporary floodproofing efforts.

2.1.5 Legislative recommendation 5: Enhanced dam and new levee safety programs

The legislature should consider developing a levee safety program and enhancing the existing Dam Safety Program to further identify and assess risks to dams and levees. [Supported by Regions 1, 2, 3, 6, 7, 8, 10, 11]

- Creation of a levee safety program *[Supported by Regions 1, 2, 3, 6, 8, 10]*
- Assistance for local units of government ("Sponsors") owning high-hazard dams built by the Natural Resources Conservation Service in partnership with the Texas State Soil and Water Conservation Board with the costs associated with evaluation, repair, maintenance, and upgrade of dams. [Supported by Regions 1, 2, 3, 6, 7, 8, 11]
- Assistance for private dam owners and other governmental dam owners with the costs associated with evaluation, repair, maintenance, and upgrade of dams. [Supported by Regions 1, 2, 3, 7, 8, 11]
- Resources for high and significant hazard dam emergency action plans

Nationwide, approximately 25,000 miles of levees reduce risk to more than 17 million people that live and work behind them. They also reduce risk to almost $2 trillion in property value and much of our nation's critical infrastructure (USACE and FEMA, n.d.). Texas does not have a state levee safety program, nor a state agency that is specifically tasked with inventorying, inspecting, and identifying risks associated with levees. Consequently, the number of people and amount of property value at risk in Texas are unknown.

2.2 Regional flood planning group legislative recommendations

The following recommendations are not TWDB recommendations. The agency is providing the following Regional Flood Planning Group recommendations in this state flood plan for consideration by the Texas Legislature. Texas Water Code (TWC) § 16.062(h)(1) requires the regional flood planning groups to identify legislative recommendations they consider necessary to facilitate floodplain management and flood mitigation planning and mitigation. The TWDB considered all regional legislative recommendations when forming its five legislative recommendations. Regional Flood Planning Groups that support each recommendation are listed with the respective recommendation.

2.2.1 Regional flood planning group recommendation 1: Authority of counties, including regarding drainage fees

Consider providing counties with authority to establish and collect drainage fees, at their own discretion, in unincorporated areas. [Recommended by Regions 1, 2, 3, 4, 5, 6, 7, 8, 9, 10, 13, 15]

Clarify regulatory authority of counties regarding floodplain management. [Recommended by Regions 1, 3, 7, 8, 9, 11, 13]

Note that Chapter 232 of Local Government Code contains authority related to ensuring adequate drainage regarding subdivision platting.

Under Local Government Code, Title 13, Subtitle A, Chapter 552,[11] municipalities in Texas have statutory authority to establish public utilities to provide various services to their residents, including drainage. Municipal public utilities can assess and collect user fees to fund operations and maintenance for land acquisition and implement drainage improvement and flood risk reduction problems. These funds create a direct and reliable source of revenue to assist in the implementation and long-term maintenance and repair of drainage and flood risk reduction projects. This same authority is not currently granted to unincorporated areas of counties. This limits counties' abilities to self-finance flood mitigation and drainage projects and provide adequate ongoing maintenance of drainage and flood mitigation infrastructure. Regional flood planning groups recommend that the Texas Legislature should provide counties with authority to establish drainage utilities and assess drainage fees.

The TWDB provides a summary of key relevant authorities here. Despite the existing authorities, described below, many of the regional flood planning groups identified the need to establish authority for drainage fees and utilities in unincorporated areas. The Attorney General has made it clear that the county authority requested by the regional flood planning groups does not currently exist.[12] Currently, counties may establish a "flood control fund" and impose ad valorem taxes according to Transportation Code 256.006 and 256.054.[13]

Of approximately 1,450 cities and counties in Texas, fewer than 150 communities have a dedicated drainage fee according to the 2023 Nationwide Stormwater Utility Survey performed by Western Kentucky University.

[11] statutes.capitol.texas.gov/Docs/LG/htm/LG.552.htm

[12] www.texasattorneygeneral.gov/sites/default/files/opinion-files/opinion/2005/ga0366.pdf

[13] https://statutes.capitol.texas.gov/docs/TN/htm/TN.256.htm#:~:text=Sept.%201%2C%201995.-,Sec.%20256.006.,-USE%20OF%20FLOOD

As the state National Flood Insurance Program coordinator, the TWDB is working with the Federal Emergency Management Agency (FEMA) and several Texas counties to resolve concerns regarding implementation of National Flood Insurance Program requirements for floodplain management.

2.2.2 Regional flood planning group recommendation 2: Statewide floodplain management standards for infrastructure and buildings for flood risk reduction

The legislature should consider developing and adopting statewide, minimum design standards for infrastructure and building to reduce loss of life and property from flooding. All statewide design standards must be simple and flexible enough to accommodate the broad range of development needs and flood risk conditions across Texas. [Recommended by Regions 1, 6, 7, 11]

Texas does not have statewide drainage design standards. Though some state agencies, like the Texas Department of Transportation, have drainage design standards that are specific for infrastructure they own and operate. Texas Water Code § 16.3145 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 National Flood Insurance Program".[14] The TWDB provides templates for communities to adopt floodplain management ordinances but does not have detailed drainage design standards. Also, the Texas Water Code requirement does not have an enforcement mechanism.

2.2.3 Regional flood planning group recommendation 3: Statewide building codes regarding flood risk

The legislature should consider updating consistent, statewide building codes in a manner to make Texas eligible for maximum federal Building Resilient Infrastructure & Communities funding regarding flood risk. [Recommended by Regions 6, 7, 10, 11, 13]

Statewide, minimum building codes are needed for improving Texas' eligibility for federal funding programs like the Building Resilient Infrastructure and Communities program (FEMA, 2023). Statewide codes should take into consideration existing, widely used building codes, including the International Building Code and International Residential Code.

2.2.4 Regional flood planning group recommendation 4: Transportation infrastructure considerations

Studies suggest that more than 70 percent of all flood fatalities occur to motorists that became victims of roadway flooding. Texas consistently leads the nation in flood deaths and the majority of those deaths are in vehicles. Many accidents, rescues, and deaths occur at low water crossings, and most occur at night (TxDOT, 2021). Several regional flood planning groups made recommendations relevant to transportation.

The legislature should consider the following:

- *Local regulation integration for Texas Department of Transportation [Recommended by Regions 2, 3, 4, 8, 9, 12]:* In areas where local regulations exceed state minimum criteria, state entities should prioritize compliance with local standards to enhance flood resilience at the community level.
- *Critical infrastructure (roadways and bridges) protection: [Recommended by Regions 2, 3, 5, 6, 7, 8, 9, 12, 13]:* It is essential, particularly for critical infrastructure like evacuation routes and

[14] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.16.htm#:~:text=September%201%2C%202007.-,Sec.%2016.3145.,-NATIONAL%20FLOOD%20INSURANCE

emergency roads, for state entities to meet the National Flood Insurance Program minimum standard for flood protection equivalent to or greater than the 1 percent (100-year) annual chance storm event

- *Minimum elevation standards for roadways [Recommended by Regions 6, 10, 12]:* Public infrastructure, including roadways that serve as evacuation route, to the extent practical, should follow design criteria that requires new and reconstructed infrastructure to be designed and constructed at elevations at or above the 1 percent (100-year) annual chance storm event, with consideration of future flood risk including as a result of increased urbanization.

2.3 TWDB general recommendations for floodplain management

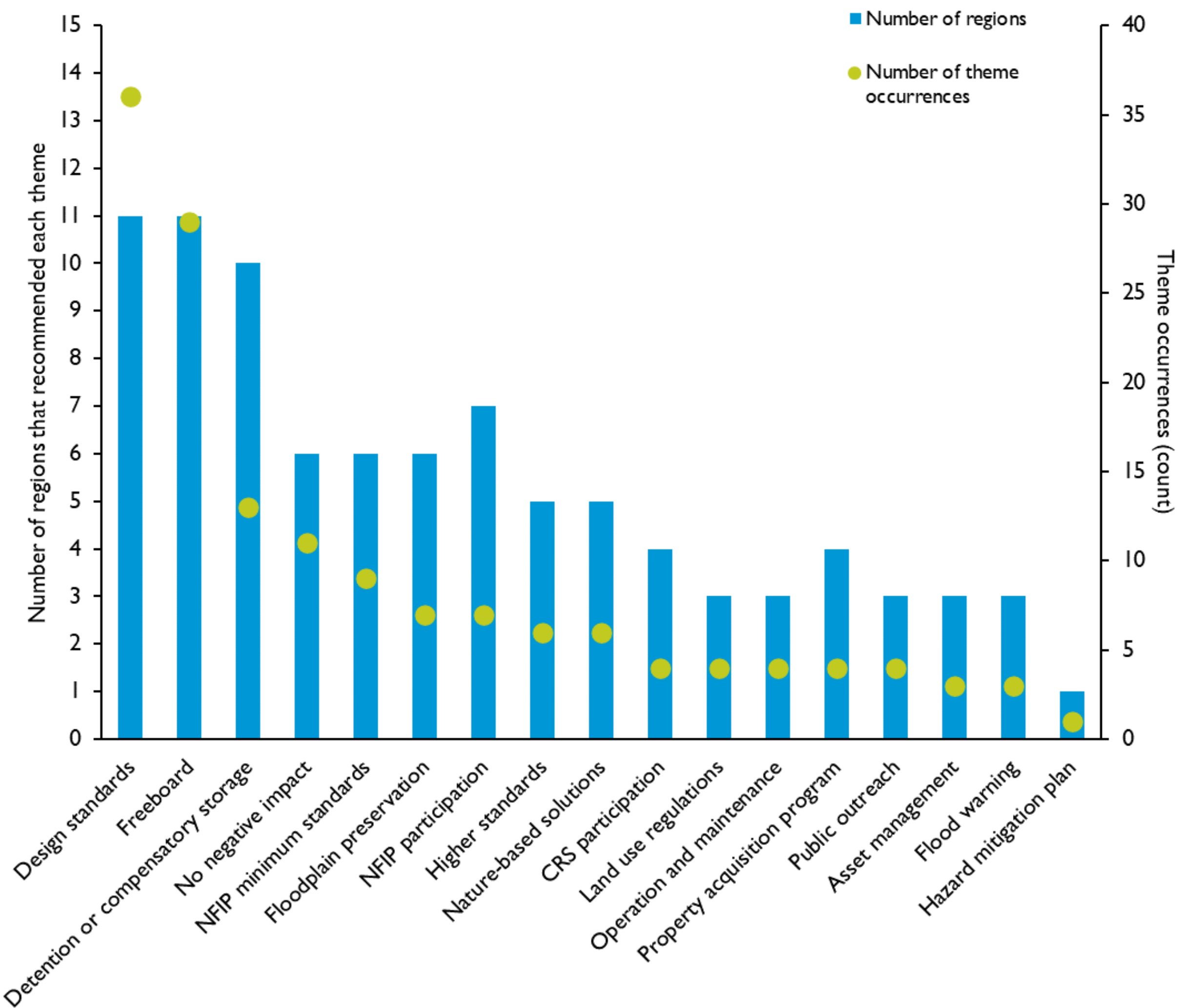
Per Texas Water Code § 16.061(a)(2), the state flood plan must "be a guide to state and local flood control policy." As such, this plan includes several broad recommendations regarding floodplain management that can reduce the risk to life and property from flooding. The following recommendations are aimed at protecting lives and property and are based on recommendations from regional flood planning groups as well as the TWDB's experience working closely with Texas communities. These general recommendations may be implemented locally, ideally at the watershed level, and are provided for consideration by anyone in Texas looking to reduce flooding threats to life and property in their local or regional community by better managing the floodplain.

Floodplain management, land use, infrastructure design, and other practices play a key role in reducing existing risk and impact to life and property and, importantly, avoiding increase or the creation of new flood risk by addressing future development within the areas known to have existing or future flood risk.

The planning groups developed recommendations regarding forward-looking land use and floodplain management practices and economic development strategies that should be implemented by entities within each flood planning region. When doing so, they recognized the extent to which past development decisions may have increased flood risks—including residual risks—and considered broad floodplain management and land use approaches that will avoid increasing flood risks and negatively affecting neighboring areas.

There are a wide variety of means by which states and local communities may implement floodplain management practices to reduce flood risk. The regional flood planning groups made over 150 floodplain management recommendations in their 2023 regional flood plans. Figure 2-2 provides a summary of the broad range of recommendations the TWDB considered when developing the general floodplain management recommendations. Additional detailed recommendations regarding floodplain management best practices are in Chapter 5.

Figure 2-2. Summary of floodplain management recommendations made by the regional flood planning groups



CRS = Community Rating System
NFIP = National Flood Insurance Program

The following are floodplain management recommendations for consideration by communities, and/or state agencies, as applicable.

2.3.1 Floodplain management recommendation A: Existing minimum FEMA floodplain standards required for cities and counties under Texas Water Code § 16.3145 and recommendations for higher standards

Table 2-1 summarizes existing requirements under FEMA's National Flood Insurance Program standards and recommendations to consider for associated higher standards. TWDB recommends considering the

Federal Flood Risk Management Standard developed by FEMA, where appropriate, while developing the design guidelines or flood management standards.[15]

Table 2-1. TWDB recommendations for higher floodplain management standards

	Description of select minimum FEMA NFIP standards[a]	Recommendations to consider for higher standard[b]
1	Managing flood risks to at least the 1 percent (100-year) storm event, in accordance with NFIP minimum standards.	Consider developing standards for a range of flood event frequencies starting with 50 percent (2-year) events up to 0.2 percent (500-year) events.
2	Restricting development and use of fill within SFHA to prevent increasing the risk of flooding.	Consider setting a baseline of criteria ensuring safe development in flood prone areas, including limiting construction within certain high-hazard areas, such as within 10 percent (10-year) annual chance floodplain, and considering flood mitigation approaches, such as detention requirements for new developments, as appropriate.
3	Requiring elevation of the lowest floor of all new residential buildings and substantial improvements to buildings in the SFHA to or above the BFE or the 1 percent (100-year) annual chance water surface elevation.	Consider requiring a minimum freeboard for finished first floor elevation of buildings, (e.g., 1 foot to 2 feet above the BFE and/or an elevation equivalent to a 0.2 percent (500-year) flood event, especially for critical infrastructure) for all new development and substantial improvements within the 1 percent annual chance floodplain, as applicable.
4	Requiring that development in floodplains not increase the base flood elevation by more than 1 foot to ensure no negative impacts on other properties from proposed projects.	Consider adopting smaller allowance for increases to the base flood elevation (less than 1 foot) to limit negative impacts and the potential cumulative impacts of new developments, including those outside of floodplain.
5	Requiring certain construction materials and methods that minimize future flood damage, in accordance with NFIP minimum standard.	Consider meeting flood protection aspects of the 2018 or 2021 versions of International Building Code for all new development and substantial improvements within the 1 percent (100-year) annual chance floodplain, as applicable.

FEMA = Federal Emergency Management Agency
NFIP = National Flood Insurance Program
SFHA = Special flood hazard area, which is the area within the 1 percent (100-year) annual chance floodplain
BFE = Base flood elevation, which is an estimate of the 1 percent flood level

Note: When modifications to a building are made that exceed 50 percent of the replacement value, these modifications are considered by FEMA to be substantial improvements.

[a] Currently required for all counties and cities under Texas Water Code § 16.3145
[b] Exceeding the minimum NFIP standards may lead to lower NFIP insurance costs, both at the individual property level and community-wide, if the community participates in the Community Rating System

Implementing higher standards in floodplain management can result in savings in avoided damages from flood events. Prevention has been found to be a good investment. According to the National Institute of Building Sciences, U.S. disaster losses from wind, floods, earthquakes, and fires now average $100 billion per year and in 2017 exceeded $300 billion. The benefits and costs associated with mitigation measures including adopting and strengthening building codes, upgrading existing buildings, and improving utilities and transportation systems have also been reported to save up to $13 per $1 invested (NIBS, 2020).

[15] www.fema.gov/floodplain-management/intergovernmental/federal-flood-risk-management-standard

2.3.2 Floodplain management recommendation B: Enhance current floodplain management activities

- Encourage National Flood Insurance Program participation and adoption of minimum floodplain management practices for all Texas communities, including ensuring development is in line with current flood risk assessments.
- Enhance coordination among state agencies for floodplain management. Improve education for state agencies that perform a variety of permitting functions, such as
  - Texas Parks and Wildlife Department for park properties,
  - Texas Department of Licensing and Regulation for mobile home installations, and
  - The Railroad Commission of Texas for propane tank installations. *[Supported by Regions 13, 14]*

2.3.3 Floodplain management recommendation C: Nature-based solutions

- Seek ways to provide funding and incentives for incorporating nature-based solutions, such as open space and floodplain preservation for development or drainage projects.
- Water needs space to flow. Consider leaving adequate space for water to flow today so it can prevent increasing or creating new flood risk to life and property in the future. *[Supported by Regions 1, 4, 5, 6, 10, 11, 13]*

2.3.4 Floodplain management recommendation D: Asset management

- Generate and maintain a statewide inventory and assessment of major flood infrastructure. This is a large effort that will require dedicated resources and funding at the local level.
- Provide statewide guidance on how to best manage drainage and floodplain assets.

2.3.5 Floodplain management recommendation E: Education and outreach

- Seek to improve awareness and ways to mitigate risk at low water crossings. Examples include improved mapping of locations, improved flood warning, and increased or prioritized grant funding.
- Improve public flood education and outreach. Improve coordinated messaging between all agencies (federal, state, regional, local). Increase targeted marketing campaigns through avenues like social media, print media, TV, and billboards.
- Increase regional and statewide activities related to flood warning. Support National Weather Service release of new Flood Inundation Mapping products in late 2023. Improve guidance and outreach related to developing flood warning systems and flood sensors.

2.3.6 Floodplain management recommendation F: State flood planning

- Maintain coordination between the Texas Division of Emergency Management's state hazard mitigation planning and the TWDB's state flood planning processes.
- Seek to incorporate state flood planning into other statewide planning processes, such as Texas Department of Transportation planning, Texas Parks and Wildlife Department planning, and Texas Facilities Commission planning.

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3 Existing infrastructure and key ongoing projects

Quick facts

The statewide regional flood planning process is Texas's first attempt to generate a statewide inventory and assessment of major flood infrastructure. The information that planning groups collected during the first cycle of regional flood planning is invaluable; however, it is not a complete assessment of all major flood infrastructure in Texas.

The expectation is that the inventory and assessment of existing major flood infrastructure will improve during each cyclical iteration of the regional and state flood planning process.

More than 1.3 million existing flood infrastructure features, including natural and man-made, were identified by the regional flood planning groups. About 3.5 percent of these were identified as functional and less than 1 percent as non-functional. The functionality and condition information on most of the flood infrastructure identified was not available and reported as unknown.

The regional flood planning groups identified 11,395 low water crossings. Approximately 2 percent (259) of these were identified as functional, and the functionality of the remaining 98 percent (11,116) was identified as unknown. The condition of almost 99 percent (11,234) was identified as unknown.

The regional flood planning groups identified 6,731 flood control dams. Of these, 21 percent (1,411) were reported as functional and 4 percent (294) as non-functional. The functionality of the remaining 75 percent (5,026) was identified as unknown. Ten percent (651) of dams were identified as non-deficient and 1 percent (98) as deficient. The condition of the remaining 89 percent (5,982) was identified as unknown.

Approximately 1,884 linear miles of 515 levees were identified. Of these, approximately 10 percent (188 miles) were identified as functional, 8 percent (147 miles) as non-functional, and almost 82 percent (1,548 miles) as unknown. Approximately 3 percent (60 miles) were identified as deficient, 4 percent (66 miles) as non-deficient, and 93 percent (1,758 miles) as unknown.

Regional flood planning groups identified 2,798 proposed and ongoing flood mitigation projects currently under construction, being implemented, or with dedicated funding to construct them. Together, the projects have an overall cost of $8 billion dollars.

Texas is one of the fastest growing states in the nation, with a projected population of over 30.1 million people in 2024 (Texas Demographic Center, 2022). Such tremendous growth and development necessitate reliable and functional flood infrastructure to protect residents and property from extreme weather and flooding.

The 2019 Texas Legislature passed Senate Bill 8, which requires that "the state flood plan must include: an evaluation of the condition and adequacy of flood control infrastructure on a regional basis." As part of the planning process, each regional flood planning group was required to inventory the existing natural features and major constructed infrastructure including but not limited to:

- Rivers and tributaries
- Wetlands
- Playa lakes
- Levees
- Sea barriers, walls, and revetments
- Dams that provide flood protection
- Storm drain systems

This requirement helped the planning groups make informed decisions on where investment may be needed to address existing deficiencies, enhance functionality, and ensure that Texas' prior investments in infrastructure perform as designed to protect against the risk and impact of flooding.

The Texas Water Development Board (TWDB) provided the following definitions for the planning groups to categorize the functionality and condition of major flood infrastructure in each region:

Functionality:

- **Functional**: The infrastructure is serving its intended design level of service.
- **Non-functional**: The infrastructure is not providing its intended or design level of service.

Condition:

- **Deficient**: The infrastructure or natural feature is in poor structural or non-structural condition and needs replacement, restoration, or rehabilitation.
- **Non-deficient**: The infrastructure or natural feature is in good structural or non-structural condition.

Compiling this information for the first time was a challenging task for the flood planning groups. To assist them, the TWDB provided several datasets via the Flood Planning Data Hub,[16] which included low water crossings, **major reservoirs**, state regulated dams, and the National Levee Database. Because the regional flood planning groups were unable to physically assess existing infrastructure themselves, they requested, collected, and compiled information on the condition and functionality of existing flood infrastructure from communities within their respective regions. The information that planning groups collected during the first cycle of regional flood planning is invaluable; however, it is not a complete inventory or assessment of all major flood infrastructure in Texas. Indeed, much of the condition and functionality of existing infrastructure is currently unknown.

The expectation is that the inventory and assessment of existing major flood infrastructure will improve during each cyclical iteration of the regional and state flood planning process. To that end, the TWDB funded a study that will produce an infrastructure assessment tool to assist the planning groups and communities with improving future assessments of major flood infrastructure. This study is currently scheduled for completion in 2024.

As part of the regional flood planning process, the 15 planning groups were also required to compile a list of proposed or ongoing flood mitigation projects that are currently under construction, being implemented, or with dedicated funding for construction. This information, combined with the data they collected regarding previously constructed major flood infrastructure, helped inform and guide the planning groups in their subsequent effort to identify and recommend flood risk solutions for their regions.

3.1 Inventory and assessment of existing statewide major flood infrastructure

The regional flood planning groups were required to include an assessment of existing infrastructure in their plans, which included a general description of the location, condition, and functionality of natural features and constructed major infrastructure within the flood planning region. The planning groups were required to identify and assess existing major flood infrastructure, and in doing so were given discretion in determining the scale of what constitutes “major” infrastructure.

The flood planning groups identified 1,361,643 major flood infrastructure features across all 15 flood planning regions. Across all flood infrastructure types identified, about 96 percent (1,313,651) of these have an unknown functionality, less than 1 percent (433) were identified as non-functional, and about 3.5 percent (47,559) were found to be functional. Similarly, the condition of about 98 percent (1,339,999)

[16] twdb-flood-planning-resources-twdb.hub.arcgis.com/

was reported by the planning groups as unknown. Less than 1 percent (6,943) were categorized as deficient, while the remaining 1 percent (14,701) were identified as non-deficient. Flood infrastructure refers to natural or constructed systems and structures that manage flooding. Natural flood infrastructure refers to the ecological features and functions that naturally exist and mitigate flood risks. Constructed major flood infrastructure refers to human-built mechanisms that manage flooding, including such structural elements as dams, levees, and drainage systems.

Constructed and natural infrastructure give a river basin its hydraulic and hydrologic characteristics, which are the primary functions and indicators of how floodwater moves and behaves as it travels. The types of existing flood infrastructure vary across the state depending on regional geographic features. For example, Texas coastal regions require coastal barriers and levees to manage flood risk, while areas in West Texas rely on natural playa lakes supplemented with constructed storm drain systems.

The regional flood planning groups reported on existing infrastructure in their regions using a two-step process: first inventorying both natural and constructed major flood infrastructure and, secondly, assessing the condition and functionality of that infrastructure.

The following summarizes the natural features and major constructed infrastructure identified by the regional flood planning groups that contribute to flood risk reduction:

Natural features:

- Rivers, tributaries, and functioning floodplains
- Wetlands and marshes
- Playa lakes
- Ponds
- Sinkholes
- Coastal features
- Parks and preserves
- Other natural features

Constructed:

- Reservoirs, dams, and weirs
- Levees and revetments
- Low water crossings, roadway stream crossings, and bridges
- Detention and retention ponds
- Stormwater management systems and components
- Constructed coastal infrastructure
- Other constructed infrastructure

The regional flood planning groups were also required to assess the functionality and effectiveness of major flood infrastructure.

Since this was the first attempt to create a statewide inventory, there was very limited information available regarding the condition of existing major flood infrastructure, which required the planning groups to obtain this information from communities through outreach. Outreach efforts varied by region, resulting in a range of both volume and quality of information, including an absence of information for some infrastructure. In these cases, regional flood planning groups used other available data, such as age, to estimate the expected condition and functionality of the natural flood features and major flood infrastructure. The majority of information concerning the condition and functionality of major flood infrastructure in Texas currently does not exist. All data reported by the regional flood planning groups, including location, description, level of service, functionality, ownership, and operating details for major flood infrastructure, is accessible via the Interactive State Flood Plan Viewer.[17]

3.1.1 Natural features

Of the 1,361,643 statewide flood infrastructure features identified by the flood planning groups, 54 percent (741,773) were natural features (Table 3-1). The functionality was unknown for almost 95 percent (701,960) of the natural features identified, and the condition for approximately 97 percent (721,191) was unknown.

Table 3-1 Natural features identified by the regional flood planning groups*

Region	Rivers/ tributaries (mile)	Wetland (acre)	Playa (acre)	Playa (count)	Sinkhole	Open space (acre)[a]	Coastal[b]	Other[c]
1	13,152	193,012	204,563	9,302				
2	7,233	432,919				180,055		
3	0.3	447,706			16	317,932		
4	6,267	333,034						
5	8,872	237,147						
6	2,505	188,756						
7	6,854	36,896	147,260	10,109				
8		246,462			3	106,861	63	
9	19,898	132	38	3				26
10	6	275,570			7	131,981	42	
11	4,214	46,405						
12	8,246	58,081			78			
13	29,050	182,377			29			
14	83,579	346,202						
15		355,455			5	44,208	27	
Total	**189,875**	**3,380,155**	**351,861**	**19,414**	**138**	**781,037**	**132**	**26**

Note: Blank cells in this table do not always signify the absence of natural flood features; they indicate that such assets were not identified or reported by the regional flood planning groups.

* *All figures are presented as counts unless otherwise labeled*

[a] *Open space includes features categorized as parks and preserves*
[b] *Ten of the 15 flood planning regions include coastal areas with varying geographical features such as beaches, estuaries, bays, and barrier islands*
[c] *These features were reported as "Other" with no additional description or identification*

Natural features refer to the ecological characteristics and functions of the physical landscape that mitigate flood risk. A lake or wetland, whether man-made or naturally occurring, can mitigate the effects of flooding through water **storage;** the conveyance of stormwater runoff to creeks, streams, and rivers; or through natural infiltration of water into the ground. The efficiency of natural systems varies by soil type, bedrock type, and the amount of vegetation. When allowed to effectively infiltrate the ground, water from rain events is less likely to overwhelm tributaries and stormwater systems. Rivers, streams,

[17] texasstatefloodplan.org

and floodplains are important parts of our natural features and systems. Flooding, to an extent, is a normal part of the hydrology of a river system and is necessary to maintain healthy **fluvial geomorphology** and for the lifecycle of some fish and other aquatic organisms

As the Texas population grows, cities and towns expand and natural areas are developed, altering how floodwater interacts with the land surface. Road construction and housing developments generally create more impervious cover, which does not allow water to easily soak into the ground, resulting in increased stormwater runoff that can overwhelm tributaries and drainage systems. Figures 3-1 and 3-2 show the geographic locations of the major natural flood mitigation infrastructure identified by the 15 flood planning regions.

Figure 3-1. Major natural flood mitigation infrastructure in Texas

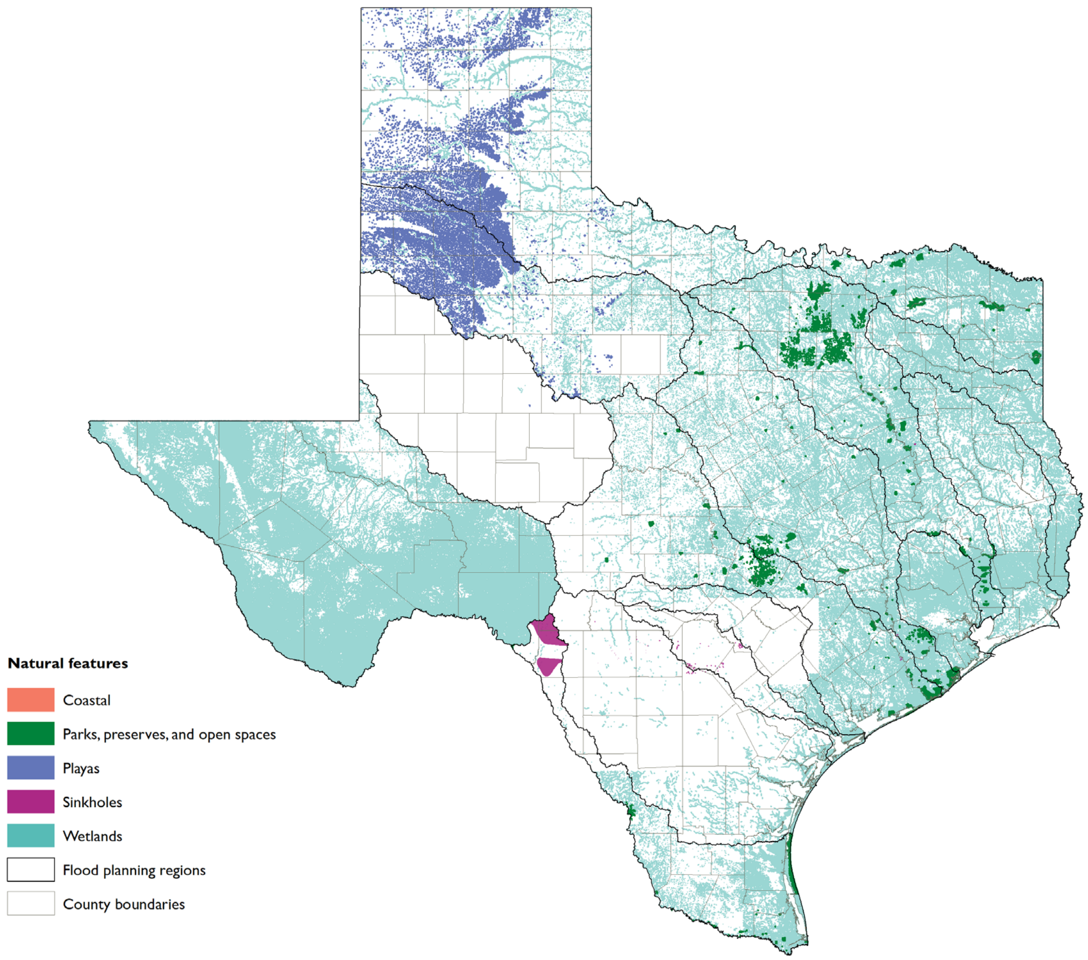
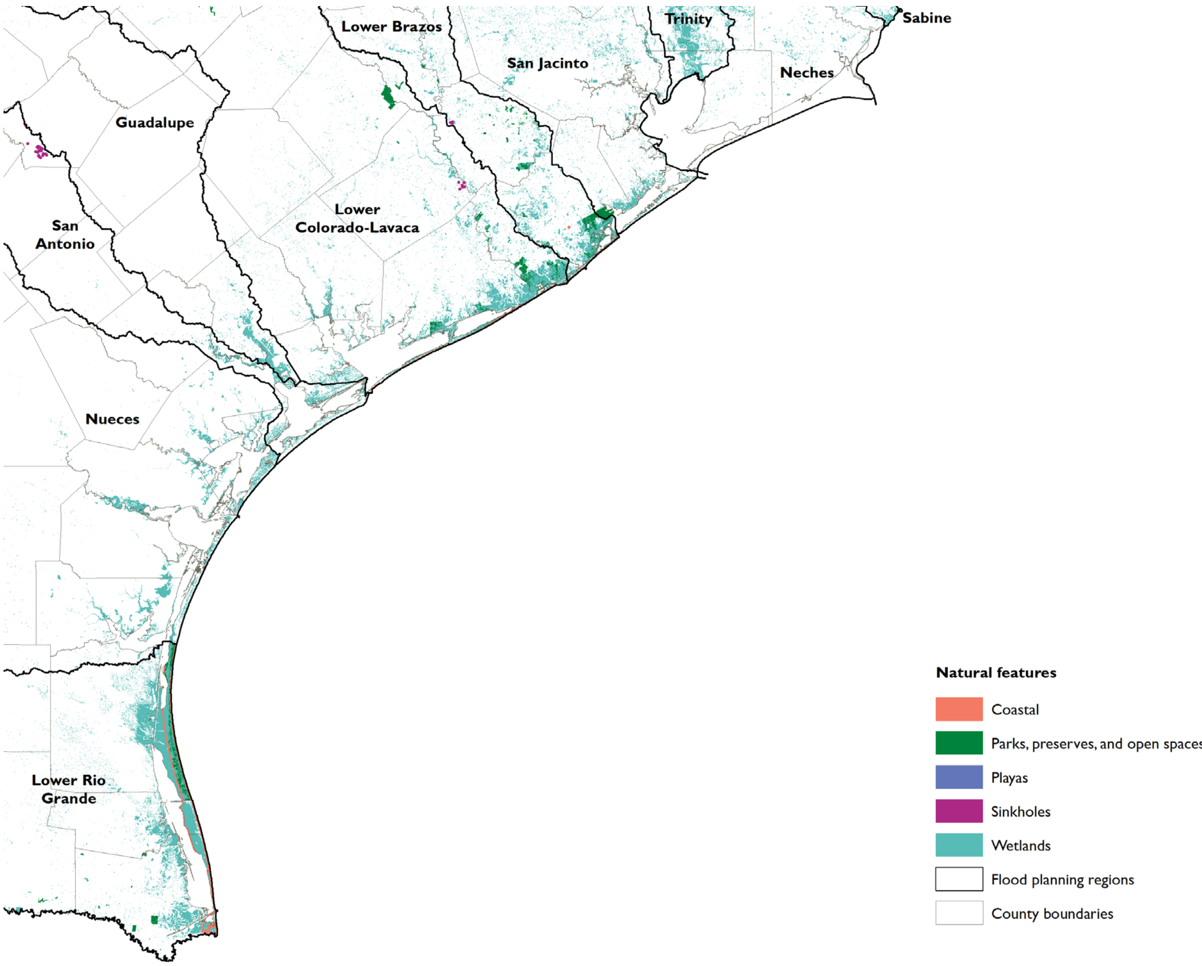


Figure 3-2. Coastal inset of major natural flood infrastructure in Texas



Rivers, tributaries, and floodplains

The regional flood planning groups identified approximately 189,875 miles of combined rivers and tributaries, however there were several regional flood planning groups that did not report any rivers or tributaries or reported very few (Table 3-1). Of the rivers and tributaries identified, about 4 percent (7,233 miles) were identified as functional, while the functionality of almost 94 percent (182,642) miles) was unknown. Similarly, about 4 percent (7,233 miles) were identified as non-deficient, while the condition of almost 94 percent (182,642 miles) was identified as unknown.

Each river, including its major and minor tributaries, comprises a complex network of functioning floodplains. A floodplain refers to the flat areas adjacent to rivers and streams that can absorb, store, and convey floodwater during periods of high flow. Floodplains are also subject to inundation during a flood. The size and shape of a floodplain influences the characteristics and severity of a flood event. The boundaries of a **natural floodplain** can change with each flood event as sediments are scoured and deposited within the river channel and upon adjacent lands. Similarly, the coastal shoreline changes frequently (FEMA, 2022a). A **regulatory floodplain** is determined by FEMA through modeling a specific storm event and depicting the boundaries of inundation resulting from that storm on a map. As a result, a regulatory floodplain only changes when a new study or mapping effort is conducted (TWDB, 2019).

Tributaries and their floodplains are vital components of an integrated system contributing to flood control and management. Land preservation and leaving space for floodwater to flow allow floodplains to carry out their natural flood management role, reducing the intensity of floodwater and lowering the risk of flooding. A discussion of the importance of floodplain management and recommendations is included in Chapter 5.

In addition to flood management, functioning floodplains provide other important benefits, such as erosion control, groundwater **recharge,** and recreational opportunity (FEMA, 2022b).

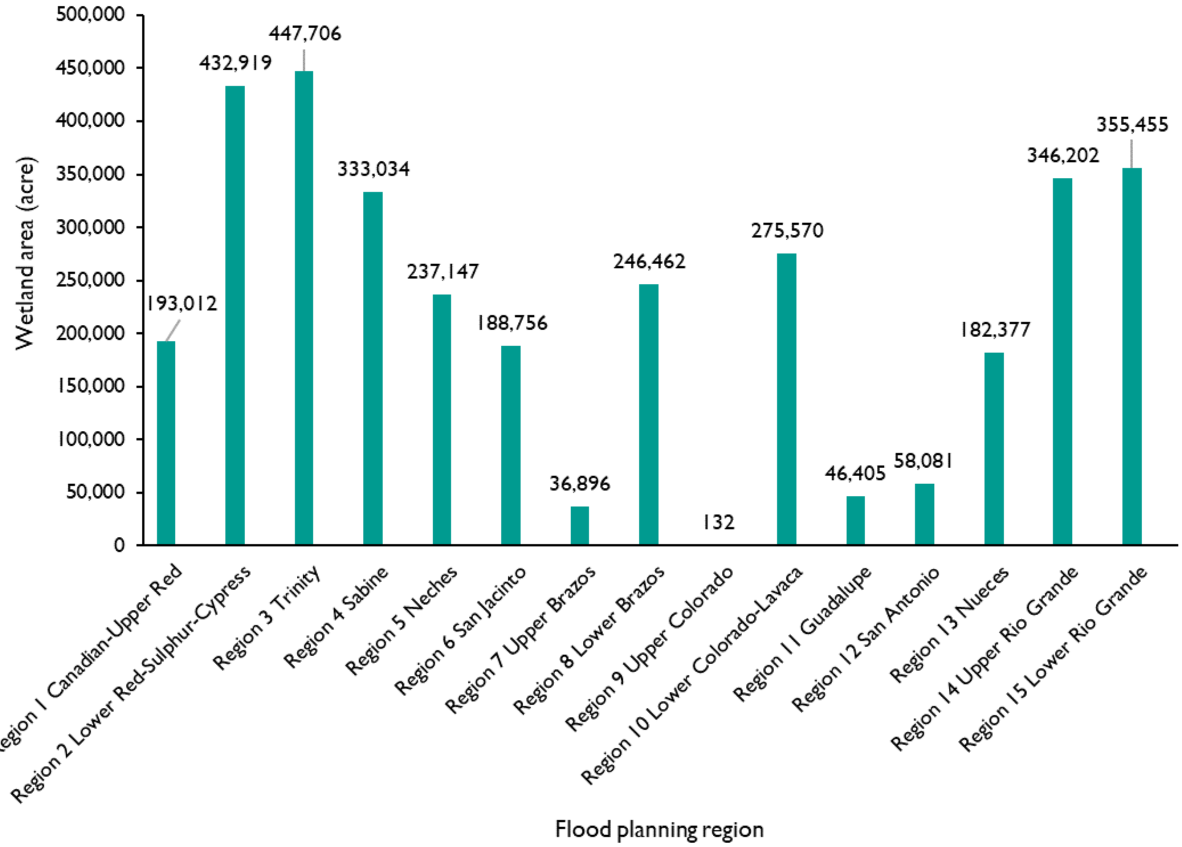
Wetlands and marshes

Wetlands and marshes are natural systems found near lakes, rivers, and oceans that are often inundated by water, either permanently or seasonally during rainy seasons. The natural hydraulics of wetlands and marshes provide significant flood control benefits through temporary water storage during extreme weather events.

Wetlands and marshes also provide important ecosystem benefits for people in coastal communities and the environment through water filtration and purification, biodiversity, climate regulation, and carbon sequestration. As flood waters withdraw, the water retained by wetlands is slowly released from the soil, reducing the amount of flooding downstream (VDEC, n.d.). When left undisturbed, wetlands and marshes act as natural barriers that shield the coast from the force of wave action and storm surges.

The planning groups identified 3,380,155 acres of freshwater and coastal wetlands, making wetlands one of the most prominent natural features in the state (Figure 3-3). Of these wetlands, almost 13 percent (432,919 acres) were identified as functional, with the functionality of the remaining 87 percent (2,947,236 acres) identified as unknown. The condition of all 3,380,155 acres was identified as unknown.

Figure 3-3. Area of identified wetlands by flood planning region



Playa lakes

Despite only covering approximately 2 percent of the state's landscape, playa lakes are notably one of the most significant natural features of the High Plains region in the northwestern and central-western portions of the state, which are characterized by little variation in elevation. Playa lakes are shallow, clay-lined depressions in the otherwise flat landscape that act as natural water detention areas of rainfall and irrigation runoff. Unlike many wetlands, playas are ephemeral, going through unpredictable periods of wet and dry cycles depending on the region's precipitation patterns (TPWD, n.d.).

Playa lakes are categorized as overflow or non-overflow playas depending on their hydrologic characteristics. Non-overflow playas have enough storage capacity to completely contain all the combined runoff in the area during a 1 percent (100-year) annual chance storm event, also known as the 100-year storm event. Overflow playas typically lack the storage capacity to completely contain the area's combined runoff water from a 1 percent annual chance storm event, which ultimately contributes, as the name states, to overflow. When one playa is filled with water, excess water flows to the next playa lake, creating an efficient method for controlling runoff. Playa lakes may become deficient if they are mismanaged. For example, when playas are "pitted" or dug out to create ponds for livestock, they drain too quickly and aquifers are not recharged (PLJV, 2012).

The flood planning groups identified approximately 351,861 acres of playa lakes, all located in the Texas High Plains and all with unknown functionality (Table 3-1). About 14 percent (47,889 acres) were identified as non-deficient, while almost 28 percent (99,370 acres) were identified as deficient. The condition of approximately 58 percent (204,601 acres) was identified as unknown.

Ponds

While there are few naturally occurring ponds and only one naturally occurring lake in Texas (Caddo Lake), man-made ponds and lakes are often thought of as natural flood infrastructure because they mimic the flood mitigation qualities of natural features, like water storage and natural infiltration of water into the ground. Ponds can be a useful tool for mitigating localized flood risk, particularly in urban or suburban areas where space is limited. Ponds capture and store excess water during periods of heavy precipitation. Once full, they release water in a controlled manner to mitigate the effects of downstream flooding. While ponds are important components of local flood infrastructure, they are unlikely to provide benefits at the regional or statewide scale. For the purposes of this plan, combined reported data on both ponds and reservoirs is included in Section 3.1.2.

Sinkholes

Sinkholes are geological formations characterized by the collapse or subsidence of the Earth's surface, often caused by the dissolution of soluble rocks, such as limestone. In some circumstances, sinkholes can have limited benefits for flood protection, including temporary storage capacity for water, providing natural drainage points allowing water to infiltrate the ground, and groundwater recharge. However, sinkholes in Texas pose unique challenges for flood infrastructure due to their potential to impact the stability and functionality of flood control systems. In Texas, where limestone formations are prevalent, sinkholes present risks to flood infrastructure, including levees, canals, and drainage systems by compromising their structural integrity (USGS, 2018). The regional flood planning groups identified 138 sinkholes throughout the state, the functionality and condition of which are all unknown.

Coastal areas

Texas has 367 miles of coastline between Orange County to the north and Cameron County to the south. Of the 15 flood planning regions, 10 include coastal areas with varying geographical features such as beaches, estuaries, bays, and barrier islands. The planning groups identified 132 natural coastal features, of which all were identified as unknown functionality. Natural coastal features like alluvial fans, beaches, and coastal dunes help protect the coast against waves and tidal action that can cause erosion and worsen inland flooding. They provide flood protection by acting as a natural buffer against storm surges and tidal action, reducing the potential impact on coastal communities.

Many of the coastal regional flood planning groups' plans referenced the beneficial role of estuaries in flood protection. Estuaries are characterized by shallow, sheltered waterways that are home to a unique range of plant and animal species. During storm events, estuaries act as natural buffers, sequestering excess water and slowing its flow into coastal land areas. **Estuary** vegetation also helps to trap sediments, which stabilizes the shoreline and reduces erosion, further protecting the coastline from storm surges and wave action. There are 10 major river basins that terminate at the Texas coast, creating seven major and five minor estuaries by mixing freshwater runoff with the saltwater of the Gulf of Mexico (Figure 3-4).

A variety of studies and projects are underway to protect and revitalize the Texas coast, such as wetland restoration, beach nourishment, and the construction of new seawalls. These initiatives include the Texas Water Development Board's Coastal Science Program,[18] the National Coastal Zone Management Program[19] managed by the National Oceanic and Atmospheric Administration, and the 2019 Coastal Resiliency Master Plan[20] managed by the Texas General Land Office. Also notable is the

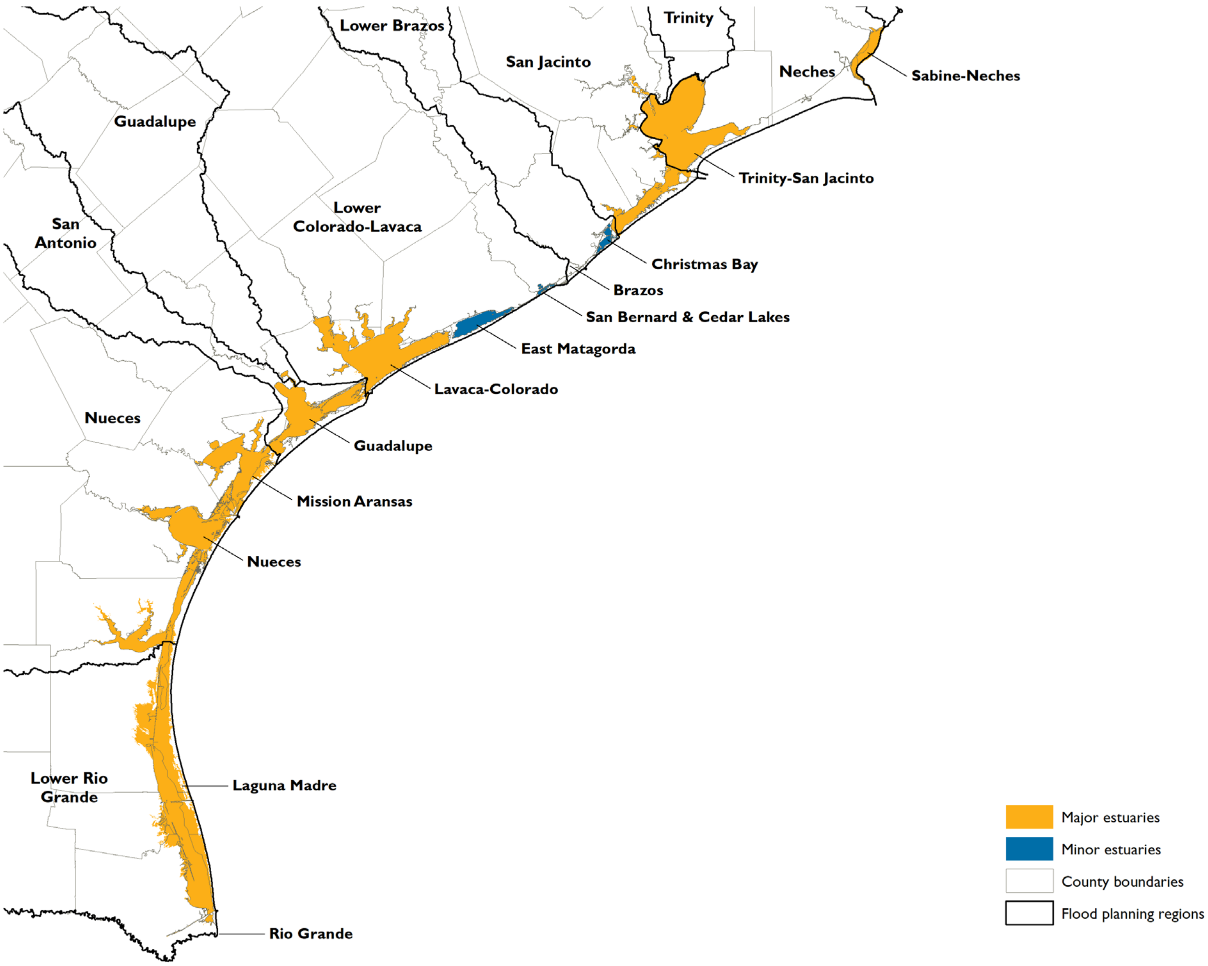
[18] http://www.twdb.texas.gov/surfacewater/bays/index.asp

[19] www.coast.noaa.gov/czm/

[20] http://www.glo.texas.gov/coast/coastal-management/coastal-resiliency/index.html

National Estuaries Program,[21] which includes the Galveston Bay Estuary Program and Coastal Bend and Bays Estuary Program, managed in Texas by the Texas Commission on Environmental Quality.

Figure 3-4. Major and minor estuaries along the Texas coast



Parks, preserves, and open spaces

While over 96 percent of Texas land is privately owned, its public lands are some of the most diverse in the country with 88 state parks, 14 national park units, and numerous other city, county, and community green spaces across the state (ASCE, 2021). Parks and preserves are broadly recognized for their recreational and aesthetic benefits, but they also serve crucial components of any major flood infrastructure assessment. They are often located within floodplains, near rivers and creeks, and help retain excess water runoff that may otherwise overwhelm channels and drainage systems during rainfall. Parks, preserves, and open spaces may become deficient when they are developed or interfered with, making their floodplains less effective at handling flood waters.

The types of areas identified range from wildlife management areas and national and state parks to golf courses and school sports fields. The regional flood planning groups identified approximately 781,037 acres of parks, preserves, and open spaces (Table 3-1). Nearly 6 percent (46,177 acres) of parks,

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[21] www.epa.gov/nep

preserves, and open spaces were identified as functional and non-deficient, while the functionality and condition of the remaining 94 percent were identified as unknown.

Other natural features

The regional flood planning groups identified 26 natural features that did not fall into any of the categories discussed in preceding sections. All 26 were identified by the Region 9 Upper Colorado Regional Flood Planning Group and called "unnamed other." The functionality and condition of all 26 were identified as unknown.

3.1.2 Constructed major flood infrastructure

The planning groups were required to identify and assess existing major flood infrastructure, and in doing so were given discretion in determining the scale of what constitutes "major" infrastructure. Of the 1,361,643 statewide flood infrastructure features identified by the flood planning groups, about 46 percent (619,870) were constructed major flood infrastructure (Table 3-2).

Table 3-2. Summary of major constructed flood infrastructure types by flood planning region*

Region	Reservoirs	Dams	Levees (mile)	Low water crossings	Ponds	Storm drain system (mile)[a]	Coastal	Gauges[b]	Other[c]
1	22	624	14	1,249	25,132	329			5
2	29	487	100	133	115			35	1
3		1,845	402	2,298	531	3,599		1,545	115,443
4	15	341	64	132	58,591	235			0
5	1,159	338	205	186	57,780	79	160		20
6	17	180	152	239	22,738	178	59	312	0
7	12	240	0	300	37,617	184			0
8	67	485	255	1,168	281		40	1,942	53
9	76	120	5	538	27,968				0
10	2	700	110	1,354	2,030		454	157	4
11	6	221	28	815	30,502	517			0
12	28	162	13	496	424	806		49	2,714
13	10	501	25	576	1,483	1,102	6	65	2,707
14		218	249	1,782	674	774			4,197
15		269	261	129	199	128	217		5
Total	**1,443**	**6,731**	**1,884**	**11,395**	**266,065**	**7,931**	**936**	**4,105**	**5,876**

Note: Blank cells in this table do not necessarily signify the absence of flood infrastructure; they indicate that such assets were not identified or reported by the regional flood planning groups

** All figures are presented as counts unless otherwise labeled*

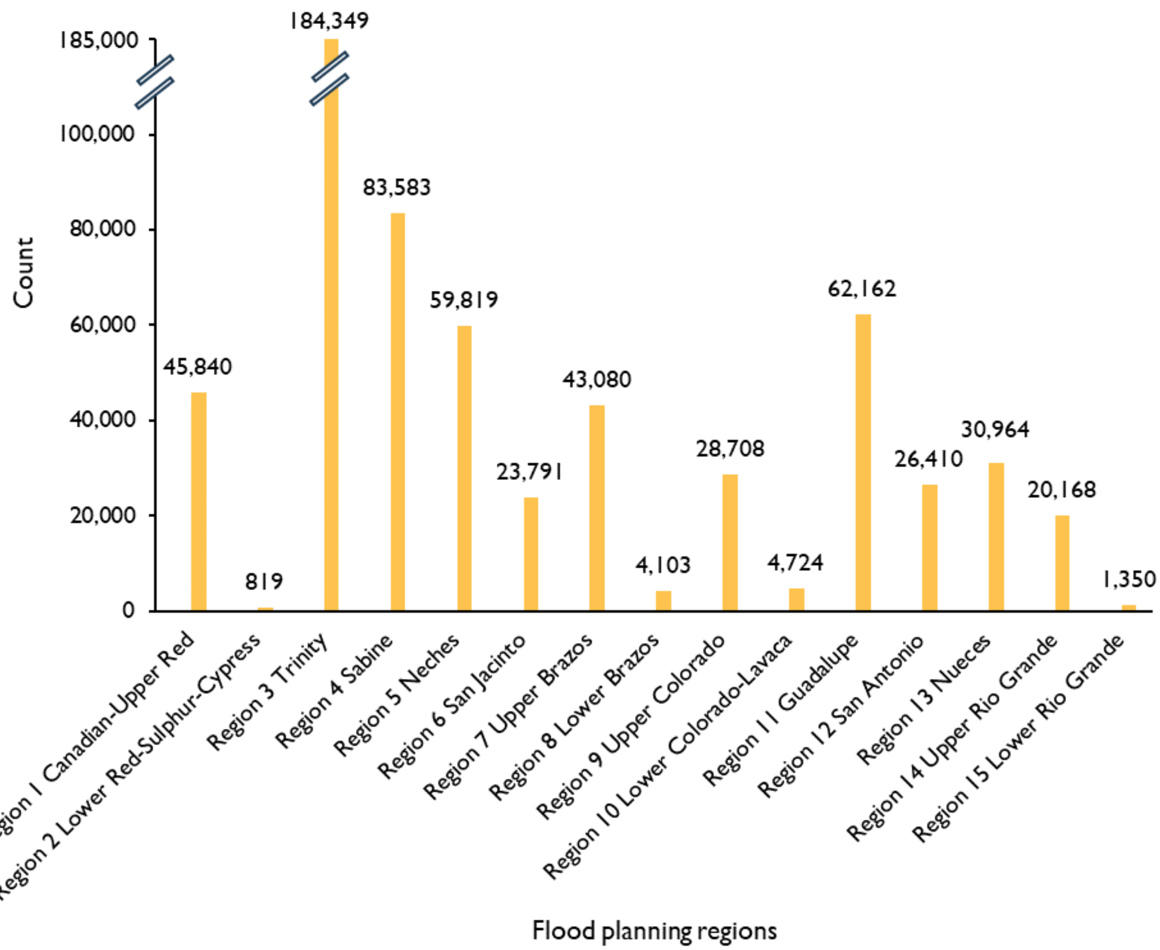
[a] Storm drain systems include features classified as canals

[b] Gauges includes features classified as high-water marks

[c] Other category includes storm drain system components, revetments, bridges, and weirs

The number of identified major constructed flood infrastructure varied by flood planning region (Figure 3-5). Texas communities deploy a variety of constructed or non-natural measures to protect themselves from flood risk. Across the state, dams and levees are considered constructed major flood infrastructure for mitigating future flood risk. More localized features are also common, including man-made channels and ditches, stormwater management systems, and detention and retention ponds. All these constructed elements are crucial for protecting Texas communities from flood risk. Figures 3-6 and 3-7 provide a map of the major constructed flood infrastructure identified by the planning groups.

Figure 3-5. Number of identified major constructed flood infrastructure by flood planning region



It is important to understand that much of the minor, localized municipal stormwater drainage infrastructure throughout cities consists of smaller drains and culverts and is, for practical and cost purposes, generally designed to handle smaller, more frequent rainfall events (e.g., 10-year event). It is therefore expected for the stormwater municipal drainage infrastructure to be overwhelmed by larger, more severe, infrequent storm events. In contrast, the major flood infrastructure addressed in the regional and state flood planning process, such as major drainage channels within urban areas, is generally designed to mitigate flood risk associated with larger storm events.

Although not included as major flood infrastructure in the regional flood plans, many roadways are designed to handle stormwater and often serve as part of the drainage system to carry stormwater during a larger storm event.

Figure 3-6. Locations of constructed major flood mitigation infrastructure

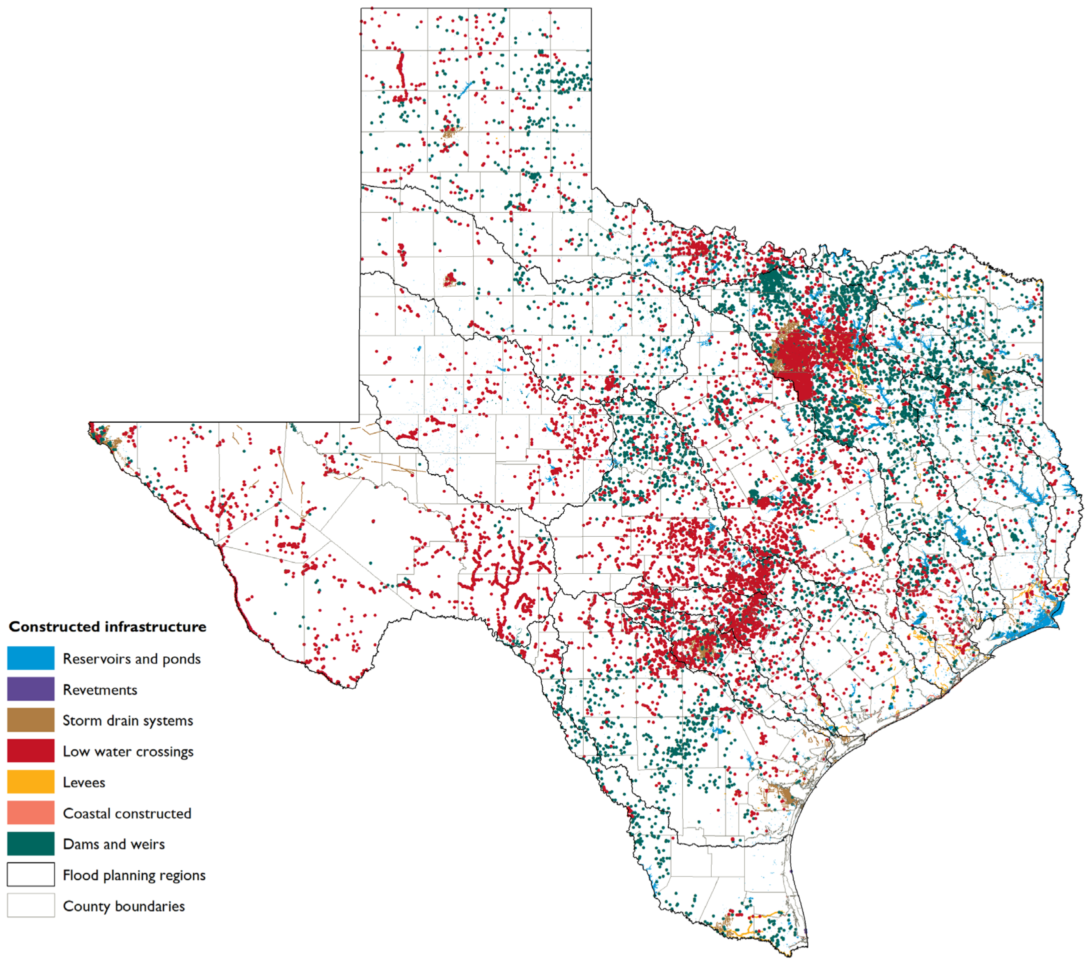
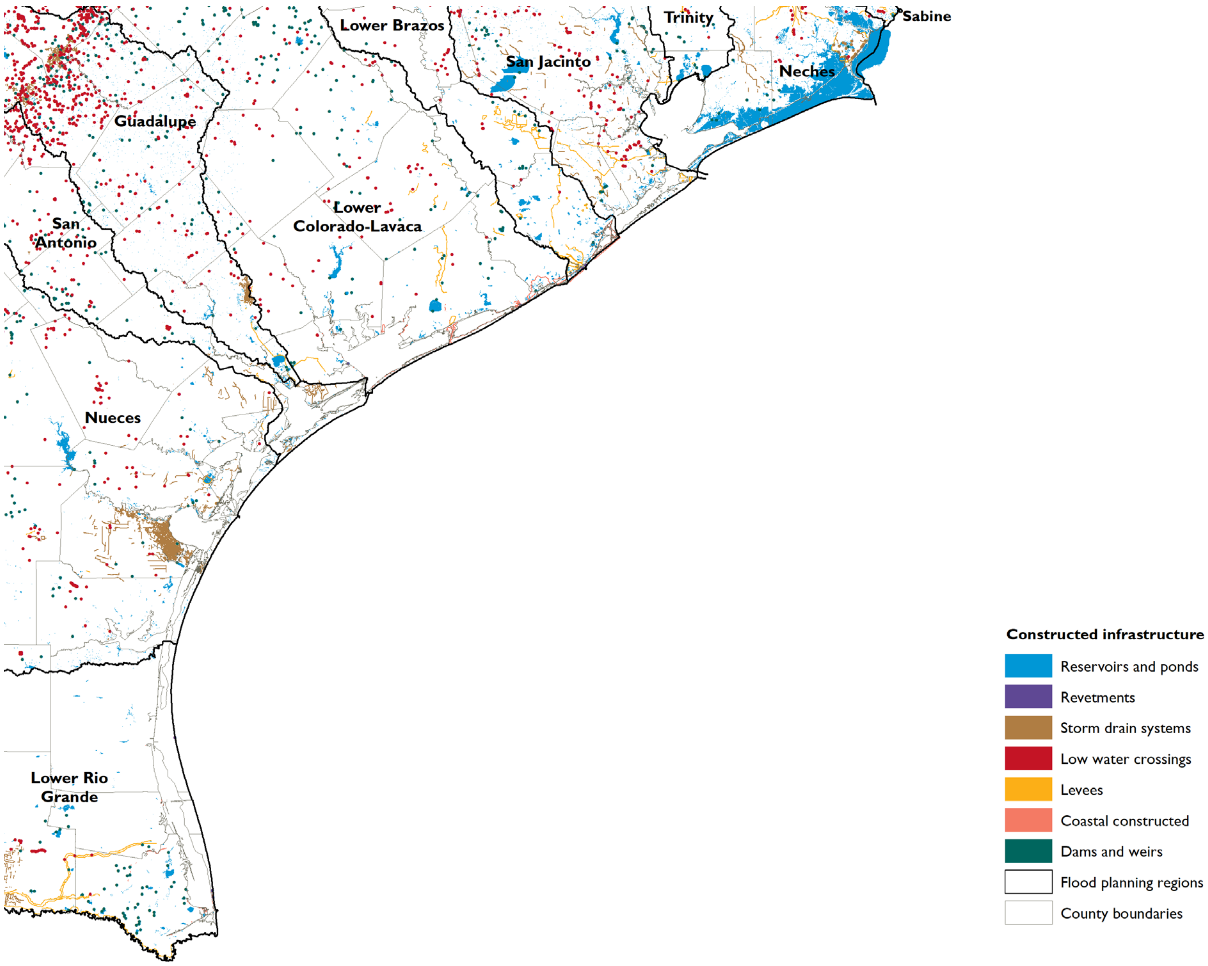


Figure 3-7. Coastal inset of major constructed infrastructure in Texas



The condition and functionality of much of the constructed major flood infrastructure were largely unknown to the flood planning groups. The functionality of two types of constructed major flood infrastructure, dams and levees, is described in greater detail in later sections of this chapter.

The key types of constructed major flood infrastructure identified by the regional flood planning groups are:

- reservoirs, dams, and weirs;
- levees and revetments;
- low water crossings, roadway stream crossings, and bridges;
- detention and retention ponds;
- stormwater management systems and components;
- constructed coastal infrastructure; and
- other constructed infrastructure.

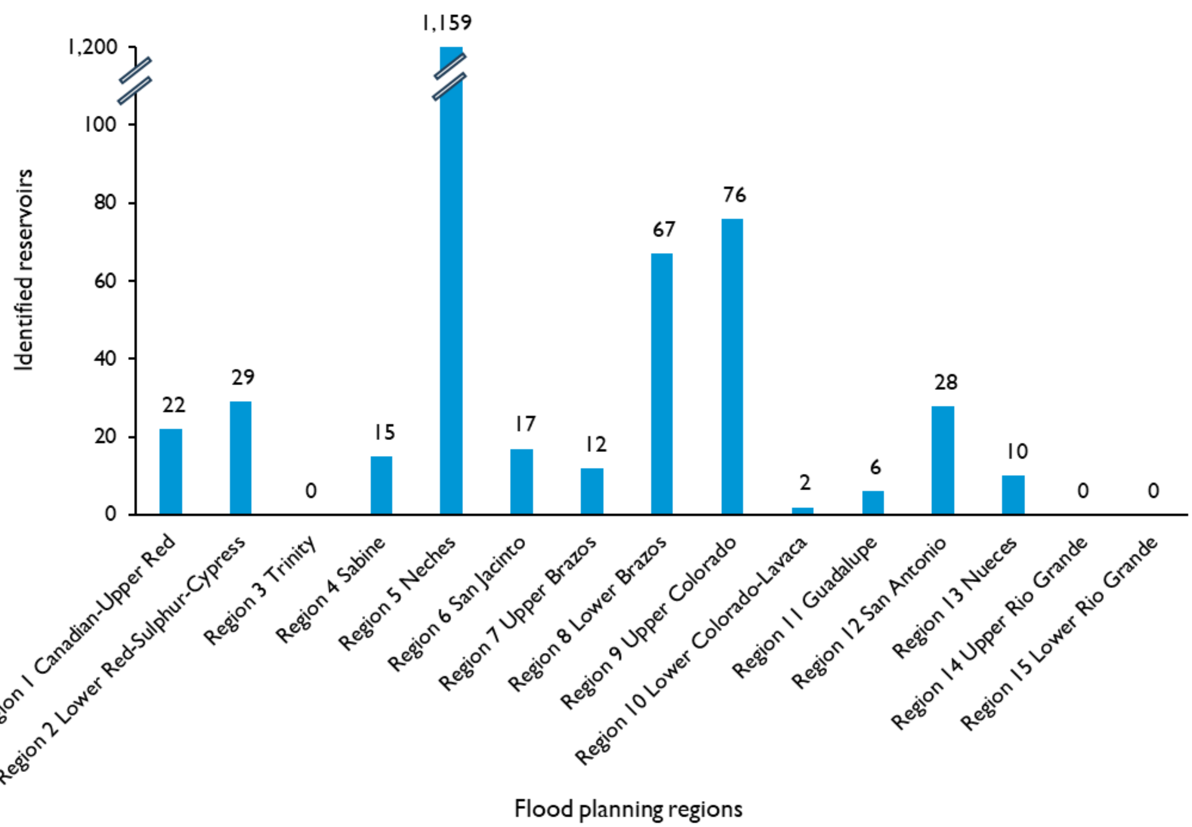
Reservoirs, dams, and weirs

Reservoirs

Man-made lakes, also called reservoirs, are often created by installing dams across rivers or tributaries to capture and store water for a variety of purposes, including water supply. Flood control reservoirs mitigate risk by impounding excess water that would otherwise overwhelm downstream areas during extreme weather events. The planning groups identified a total of 1,443 reservoirs across the state that have some measure of flood control (Figures 3-8 and 3-9). Of the 1,443, Region 5 Neches accounted for almost 80 percent (1,159). Of all reservoirs identified as having some measure of flood control, the functionality of more than 98 percent (1,414) is unknown and the condition of all 1,443 is unknown.

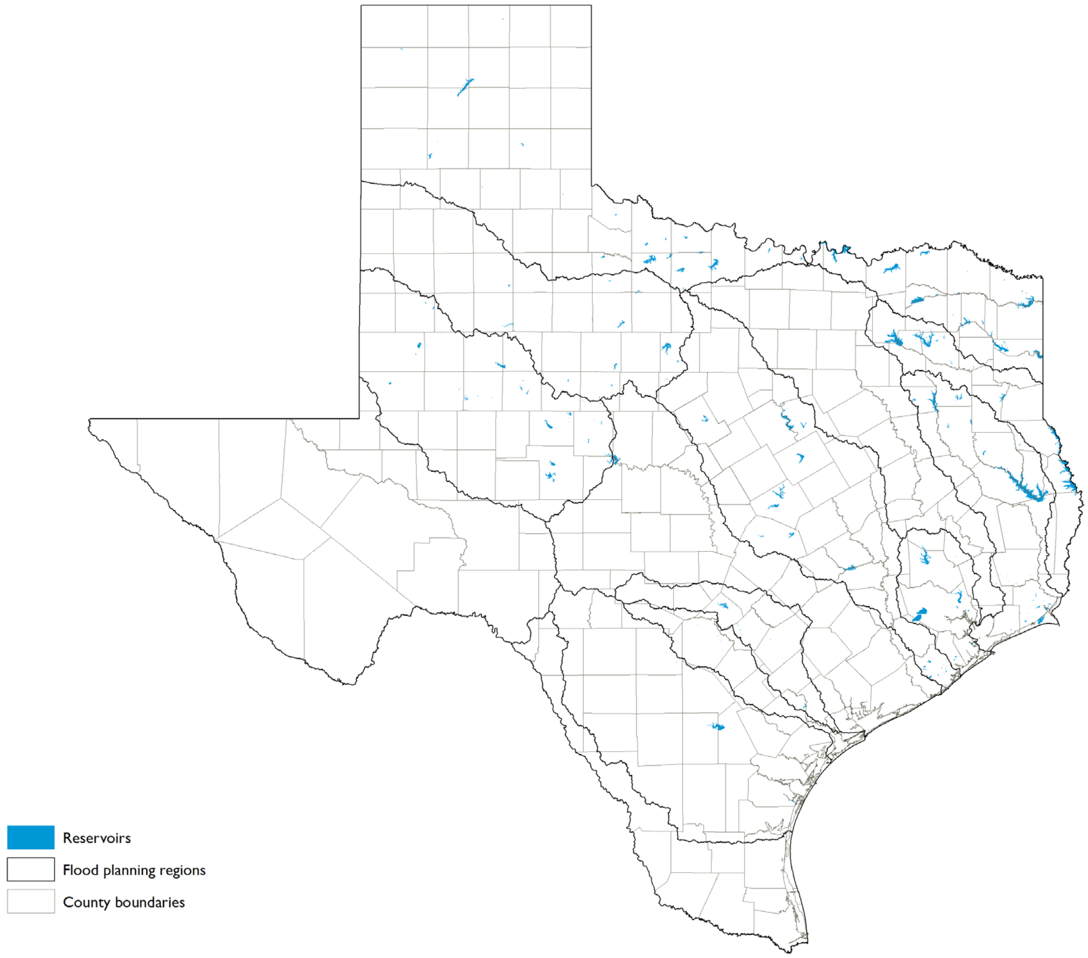
Most reservoirs in Texas generally serve one of two primary functions: water supply, which is used for irrigation and human consumption, or flood control. Some reservoirs serve both purposes either through separate, designated storage volumes or by carefully managing a common storage volume using sophisticated techniques (e.g., Forecast Informed Reservoir Operations). Major water supply reservoirs are defined as those having at least 5,000 acre-feet of storage capacity and often serve additional purposes beyond water supply, including recreation and fire protection. Of the 1,443 reservoirs identified by the regional flood planning groups as providing some measure of flood control, at least 177 of those are also considered major water supply reservoirs.

Figure 3-8. Number of identified reservoirs with some measure of flood control by flood planning region



Note: Data reflects existing infrastructure as identified and reported by the regional flood planning groups

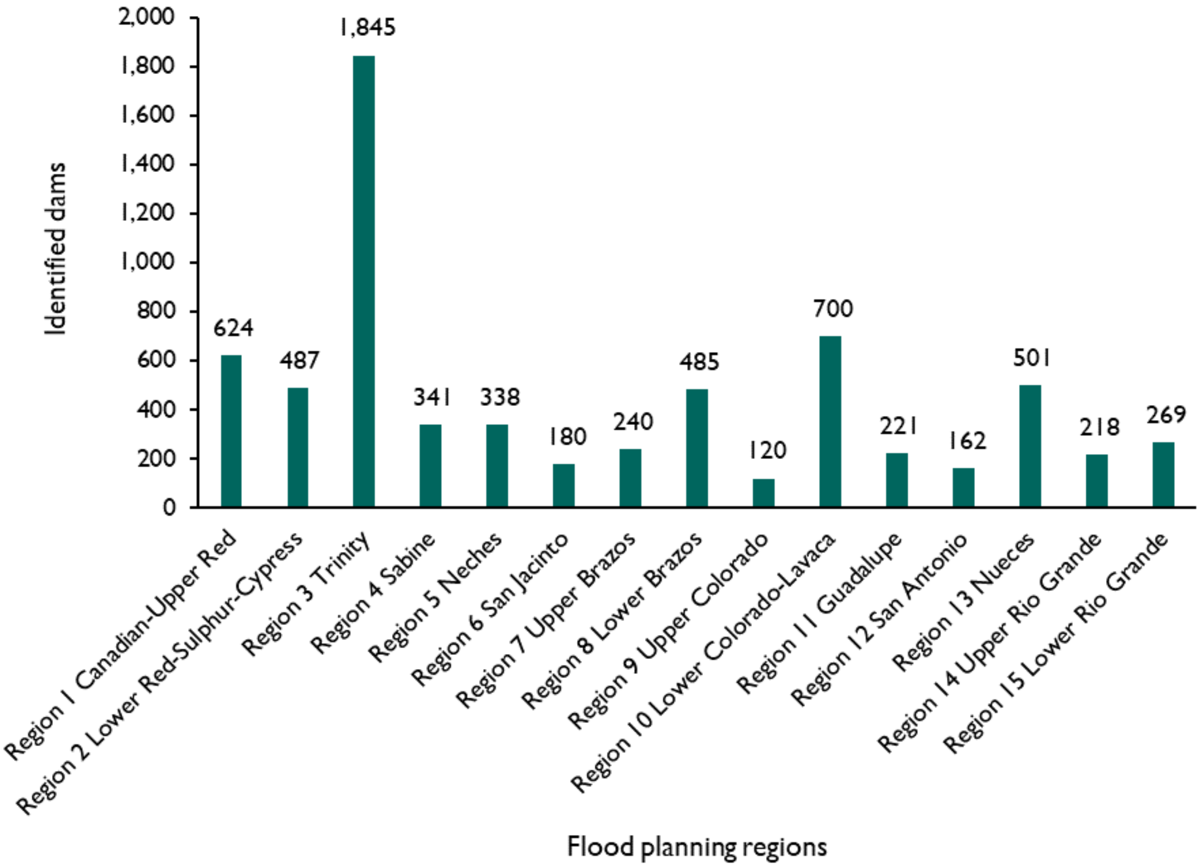
Figure 3-9. Locations of identified reservoirs with some measure of flood control



Dams

The planning groups were given latitude to identify dams that have some flood mitigation functionality to include in the regional flood plans. The dams with only water supply functionality were not included for this exercise. The groups identified a total of 6,731 dams as having some measure of flood risk reduction (Figure 3-10). Of these, 27 percent (1,845) are within Region 3 Trinity and, overall, identified dams are highly concentrated around the Dallas-Fort Worth area. The dam evaluation identified 21 percent (1,411) as functional and 4 percent (294) as non-functional. The functionality of the remaining 75 percent (5,026) was identified as unknown. The condition of 10 percent (651) of dams was identified as non-deficient, 1 percent (98) of dams were identified as deficient, and the remaining 89 percent (5,982) were identified as unknown.

Figure 3-10. Number of identified dams with some measure of flood control by flood planning region



Note: Data reflects infrastructure as identified and reported by the regional flood planning groups

Dams can be owned and operated by state and local governments, public and private agencies, and private citizens, making data collection challenging. As such, much information on dams, including ownership information and the dams' original purpose, is generally unavailable. The 15 regional flood planning groups obtained dam and reservoir information for their regions through various sources, including the Texas State Soil and Water Conservation Board, the Texas Commission on Environmental Quality, and the United States Army Corps of Engineers. Figure 3-11 shows the location of dams with flood control functionality across the state as identified by the planning groups.

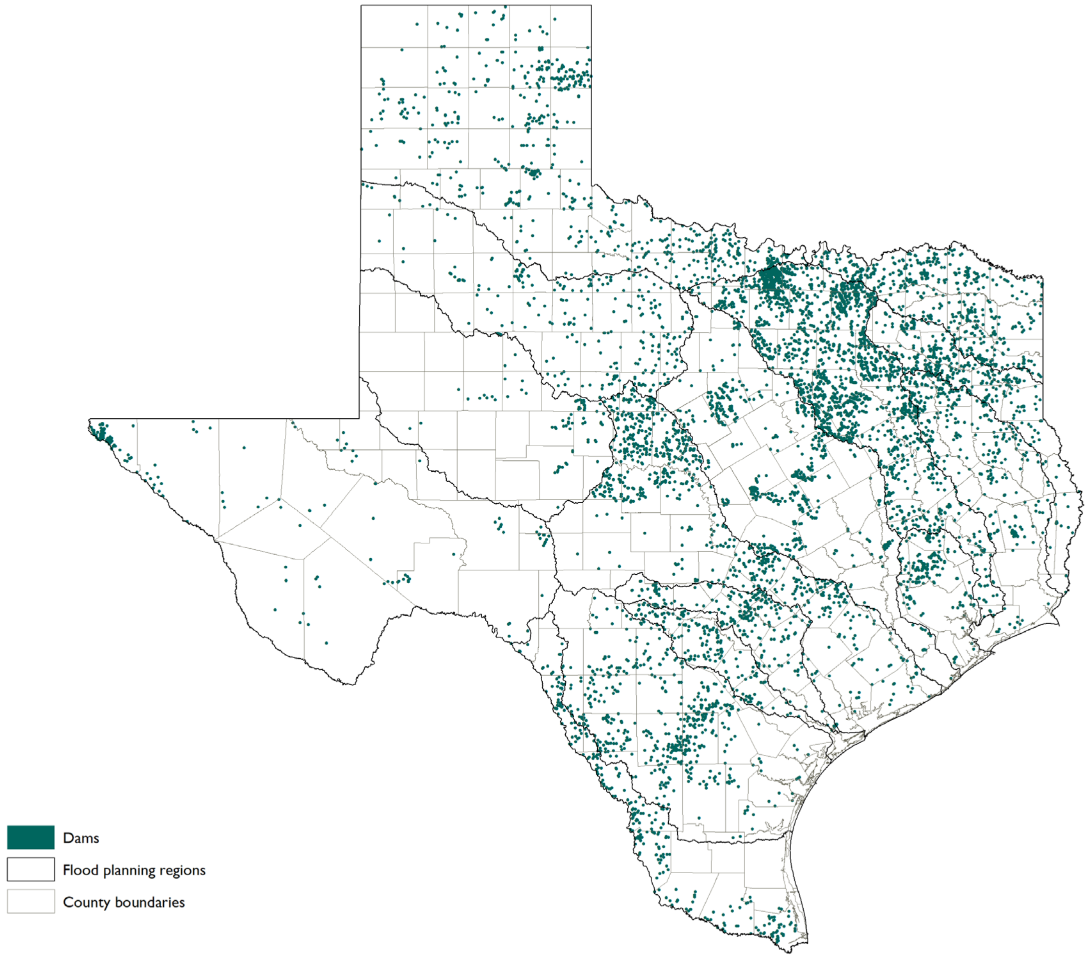
The Texas State Soil and Water Conservation Board is responsible for developing and implementing a *Ten-Year Dam Repair, Rehabilitation, and Maintenance Plan*, in which it identifies and prioritizes high-risk Natural Resource Conservation Service dams that require attention. The agency also coordinates with local sponsors to develop cost-effective solutions to ensure that repairs and upgrades meet regulatory safety standards. A discussion of the *Ten-Year Dam Repair, Rehabilitation, and Maintenance Plan* is provided under Section 3.1.4.

The U.S. Army Corps of Engineers maintains the National Inventory of Dams based on information provided by dam owners, federal agencies, and state dam safety agencies. The inventory is a collaborative effort involving various entities that contribute data and updates on dams throughout the United States.

The Natural Resources Conservation Service within the United States Department of Agriculture plays a role in providing technical assistance and expertise related to the construction and inventorying of dams in Texas. The Natural Resources Conservation Service collaborates with landowners, communities, and other stakeholders to develop and implement conservation practices for various purposes, such as water resource management, erosion control, flood mitigation, and wildlife habitat enhancement. It may collect and maintain data on dams implemented through its programs or projects. However, it's important to note that the primary responsibility for dam inventorying and regulation in Texas lies with the Texas Commission on Environmental Quality. Over the past 70 plus years, the Natural Resources Conservation Service has assisted local sponsors in constructing 2,041 flood control dams in Texas (TSSWCB, 2020).

The Texas Commission on Environmental Quality Dam Safety Program is authorized under Texas Water Code § 12.052 and regulates dams based on 30 Texas Administrative Code § 299. The primary objective of the Dam Safety Program is to ensure that dams are constructed, operated, and maintained in a manner that minimizes risks to public safety and the environment. The Texas Commission on Environmental Quality also maintains a comprehensive database of state-regulated dams in Texas. This inventory includes dams that meet specific criteria, such as size, hazard classification, and location. The agency classifies dams based on size using the maximum capacity and height of the dam to determine if it is a small, intermediate, or large dam. Dams are also classified by their downstream hazards and can be classified as low, significant, or high hazard depending on what or who is located downstream that could potentially be impacted by a dam breach. The Texas Commission on Environmental Quality collects and updates data on these dams, which helps in monitoring their condition, identifying potential risks, and facilitating effective regulatory oversight. It also reviews construction plans and specifications for new dams and for modifications to existing dams, hydrologic and hydraulic studies, breach studies, emergency action plans, water right permit applications, and water district creations for dam safety issues and attends emergency action plan tabletop exercises. The agency does not regulate any federal dams; they are maintained and operated at the federal level (TCEQ, 2023).

Figure 3-11. Locations of identified dams with some measure of flood control



Texas began constructing dams and reservoirs in the 1930s and 1940s to combat the devastating effects of fluvial flooding that damaged livestock supply and property (Brazos River Authority, n.d.). From the 1950s through the 1970s, most of Texas' dams were constructed primarily for water supply purposes during drought conditions. Per the American Society of Civil Engineers – Texas Section (2021), dams have a typical lifespan of about 50 years, which suggests that about 73 percent (4,907) of the state's dams are either reaching or have exceeded their lifespan. However, timely rehabilitation of aging dams could extend their life spans well beyond 50 years.

Of the 6,731 flood protection dams identified by the flood planning groups, construction completion dates were available for approximately 83 percent (5,603). While approximately 58 percent of those with known dates were constructed prior to 1969, the 1960s were the most prolific period of dam construction in the state. Nearly 2,000 of the dams identified by the planning groups were constructed between 1960 and 1969. The average age of all dams as identified and reported by the flood planning groups was 67 years old.

As of May 2023, there are a total of 7,367 dams regulated by the Dam Safety Program, regardless of their primary function. Of these, 1,541 dams are classified as having a high hazard potential, meaning those where failure or mis-operation will likely cause loss of life. 544 dams were classified as having significant hazard potential, and 5,254 were classified as having low hazard potential (TCEQ, 2023; Trina Lancaster, Texas Commission on Environmental Quality, written comm., 2023).

The consequences of dam failure can be severe and depend on several factors, including the volume of water that would be released due to sudden failure and the size and distance of communities located downstream from the dam. Consequences of dam failure include loss of life, extensive damage to private property and critical infrastructure, and the loss of agricultural lands and the disruption to local economies (TCEQ, 2023).

There are several sources of dam failure. For example, poorly constructed dams or those built before the establishment of improved building standards may be particularly prone to failure. Dams require regular maintenance and inspections to ensure they function properly, especially to be able to withstand intense rain events. Dams that go without proper maintenance will deteriorate much more quickly than they would otherwise. All dams have a design lifespan when built and, over time, the materials used to construct the dam can deteriorate, leading to failure if left unchecked. Dams designed for a limited storage capacity, or those that have lost storage capacity over time through **sedimentation**, may become overwhelmed during severe rain events, resulting in what is called overtopping. This can lead to failure (TCEQ, 2023).

Aging dams combined with increasing populations and urbanization results in a growing need for dam maintenance, repair, and rehabilitation in Texas. The 2021 American Society of Civil Engineers Infrastructure Report Card[22] gave Texas a D+ for dams, meaning that the majority of those surveyed were in poor condition or at risk of failure. The Association of State Dam Safety Officials estimated the cost for rehabilitating all nonfederal dams in Texas at around $5 billion in 2019, and the Texas State Soil and Water Conservation Board estimates that approximately $2.1 billion is needed to repair or rehabilitate dams included in the Small Watersheds Program (ASCE, 2021). Several of the planning groups recommended legislative funding initiatives to support the maintenance of private dams in the regional flood plans. These and all other planning group legislative recommendations are discussed in Chapter 2 of this plan. Some of the planning groups also recommended dam-related flood management projects. For example, Region 3 Trinity recommended a project focused on upgrading the Holland Lake Spillway, so it can meet Texas Commission on Environmental Quality dam safety requirements.

Weirs

Weirs are typically small, wall-like dams, built across waterways that allow water to flow over the top and are used to control the water level upstream. Weirs are used at stream gauges and on canals to determine the volume of flow. Occasionally, these may serve as flood management infrastructure by capturing flood waters before overtopping. The regional flood planning groups identified a total of 189 weirs across the state, of which nearly 100 percent were identified as having unknown functionality and condition.

Levees and revetments

Levees

Levees are man-made structures composed of long mounds of earth, concrete, and other materials built up along the banks of rivers to contain flood flows within a restricted floodplain. They prevent overflow from reaching nearby communities and infrastructure and are typically built in low-lying areas that are naturally prone to flooding during heavy rain events. As such, levees are critical for protecting communities from flooding, and safety assessments are vital to ensuring performance at their designed standards.

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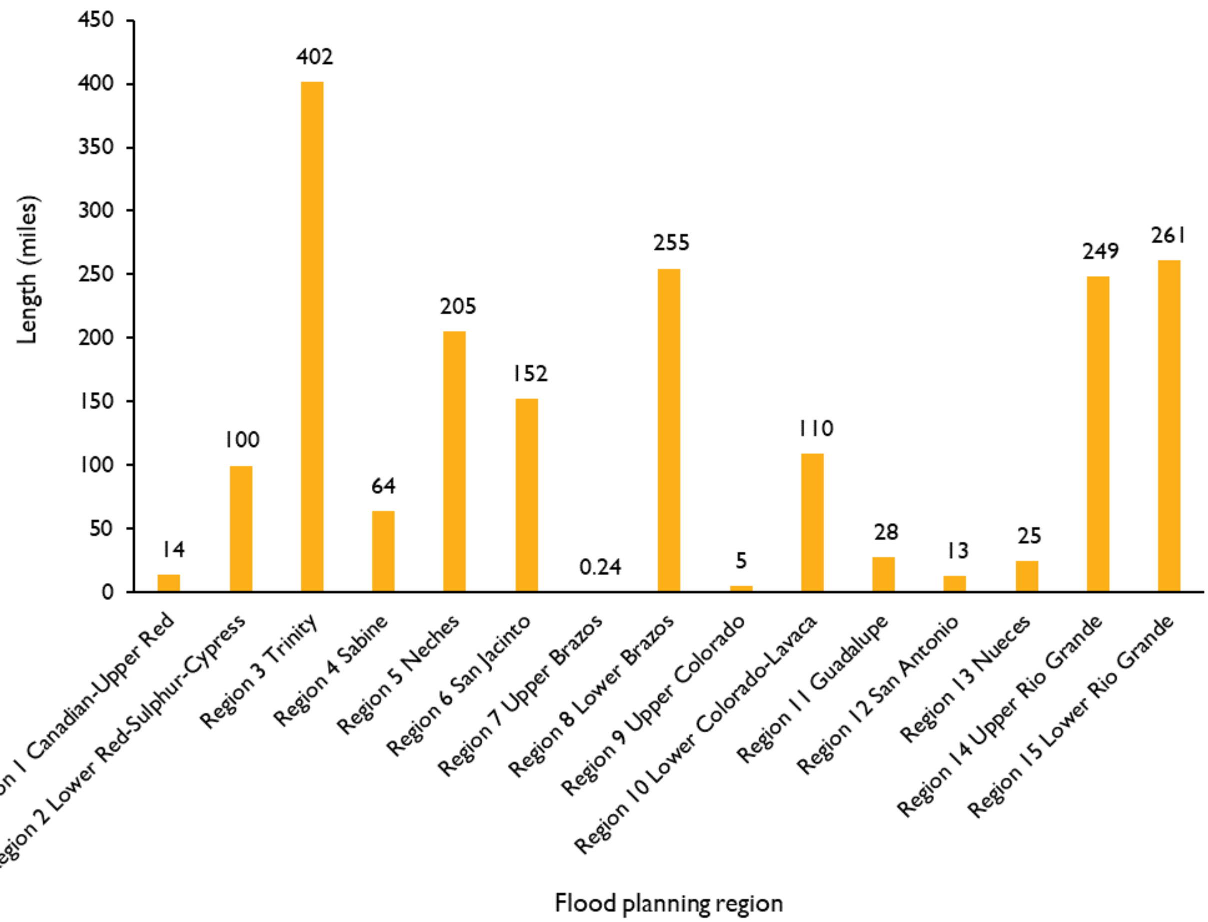
[22] www.infrastructurereportcard.org/wp-content/uploads/2021/07/TxIRC_2021_Brief.pdf

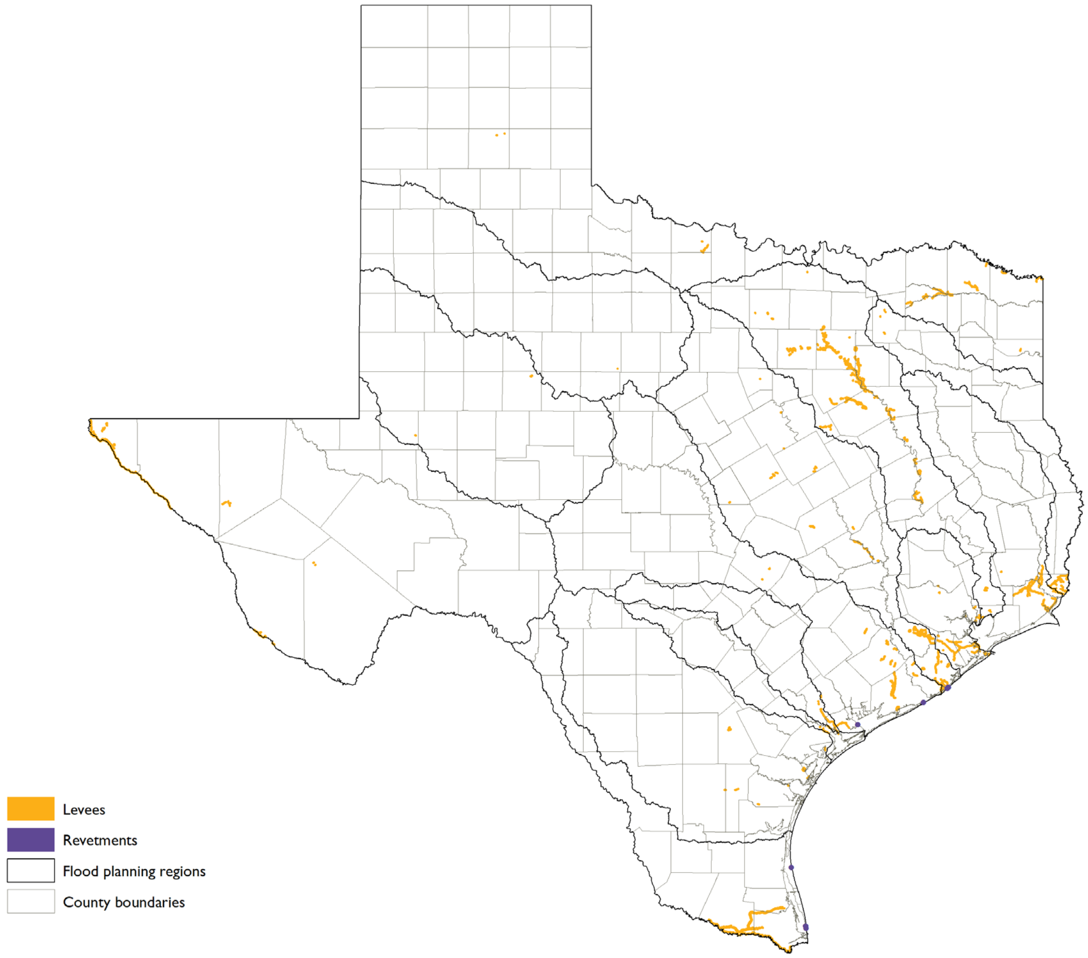
The flood planning regions identified approximately 1,884 miles of levee systems across the state (Figure 3-12). Region 3 Trinity identified the most mileage of levees by length, with a total of approximately 402 miles. Figure 3-13 shows the locations of the identified levees across the state.

Figure 3-12. Length of Texas levees by regional flood planning area



Note: Statewide total length of levees, as reported by the regional flood planning groups, is approximately 1,884 miles

Figure 3-13. Locations of identified levees and revetments in Texas



Of the levees identified, the functionality of 82 percent (1,548 miles) was identified as unknown, while about 10 percent (188 miles) was identified as functional and 8 percent (147 miles) as non-functional. Similarly, the condition of approximately 93 percent (1,758 miles) was identified as unknown, while 3 percent (60 miles) was identified as deficient, and 4 percent (66 miles) were non-deficient. For future planning cycles, coordination with communities, special districts, and the public will likely lead to the collection of more detailed information that can be incorporated into future regional flood plans.

According to the 2021 Texas Infrastructure Report Card, almost 90 percent of Texas levees are constructed, inspected, and maintained by local agencies that often lack the resources necessary for regular evaluations, making functionality and condition-related information more difficult to collect.

Under Texas Water Code § 16.236,[23] the Texas Commission for Environmental Quality is granted the authority to regulate the construction, maintenance, repair, and removal of levees. All new levee construction and improvements are required to undergo a review and approval process with the agency. All applications must include the location and extent of the proposed structure and be accompanied by preliminary engineering plans that demonstrate the effects the project will have on neighboring areas. Additionally, per 30 Texas Administrative Code § 301.34, levees constructed in urbanized areas should

[23]https://statutes.capitol.texas.gov/Docs/WA/htm/WA.16.htm

be designed to manage the 1 percent (100-year) annual chance storm event and 3 to 4 feet of freeboard, or the safety margin built into a levee or flood protection structure. The state's existing levee systems protect more than one million Texans and approximately $127 billion of property (ASCE, 2021).

The U.S. Army Corps of Engineers maintains and publishes a congressionally authorized database of levees in the United States known as the National Levee Database.[24] The database contains information on the condition and risk for approximately 2,000 levee systems nationwide, most of which are affiliated with U.S. Army Corps of Engineers programs. The National Levee Database reports a total of 255 Texas levee systems stretching more than 1,400 miles. Fifteen percent (51) of the U.S. Army Corps of Engineers-affiliated Texas levee systems are owned, inspected, and maintained by the U.S. Army Corps of Engineers, while the remaining 85 percent (276) are constructed and under the purview of local governing bodies, many of which often lack the resources necessary to perform routine inspections and maintenance (ASCE, 2021).

One of the tools commonly used to classify levee systems by their condition and current and future maintenance is the U.S Army Corps of Engineers Levee Safety Action Classification, in which risk categories range from one (very high) to five (very low). Of the 41 Texas levee systems assessed to date, five are classified as high to very high risk. More than 75 percent of Texas levee systems remain unscreened for classification. While levee failures have been rare in Texas, increasingly intense and frequent storm events are testing the capacity of Texas levee systems (ASCE, 2021).

Finally, the U.S. Army Corps of Engineers and Federal Emergency Management Agency (FEMA) established the National Levee Safety Program,[25] authorized by the National Levee Safety Act (2007) to improve public safety by reducing the risk of failure of levee systems in the United States. The program works to promote and standardize levee safety practices, provide technical assistance and resources to levee owners and operators, and develop and maintain a national levee inventory and assessment database. The program also conducts outreach and education to increase public awareness of the potential risks associated with levees and encourage community participation in levee safety efforts (USACE, 2018).

Revetments

Revetments are components of flood protection infrastructure in Texas that are strategically incorporated along riverbanks and coastal areas prone to flooding. These structures are designed to reduce flood risk by preventing erosion and stabilizing the water's edge. Made of durable materials, such as concrete, riprap, or geotextile fabrics, revetments effectively dissipate the energy of flowing water and waves, safeguarding adjacent properties and critical infrastructure from damage. By providing a protective barrier, revetments help maintain the integrity of riverbanks, channels, and shorelines, minimizing erosion and the potential for flood-related devastation. Only three flood planning groups identified revetments within their regions. Of the revetments identified, the functionality and condition of all were identified as unknown.

Roadway stream crossings, low water crossings, and bridges

Roadway stream crossings

In Texas, most flood-related fatalities occur when a vehicle is washed off an inundated roadway during storm events. A roadway stream crossing refers to a location where a road or highway intersects with a stream or watercourse that may be susceptible to floodwater during periods of heavy rain or other flood events. These crossings are designed to accommodate the flow of water over or under the road,

[24] www.levees.sec.usace.army.mil/#/

[25] www.leveesafety.org/pages/about-the-program

allowing for the safe passage of vehicles and minimizing the impact of flooding on the transportation system (RIDOT, 2021). Not all roadway stream crossings are low water crossings; however, all low water crossings are roadway stream crossings.

Low water crossings

Low water crossings are roadway creek crossings that are subject to frequent inundation during storm events during a 50 percent (2-year) annual chance storm event. They are designed to allow vehicles and pedestrians to cross creek beds during periods of low water flow. As such, low water crossings and other at-risk roadways pose significant flood risk during periods of intense rainfall and flash flooding. Loss of life may occur when drivers attempt to cross low water crossings during a flood event. Even a little water flowing through a creek bed may be powerful enough to disrupt a vehicle's contact with the roadway, sweeping the vehicle off the road. Chapter 4 includes additional discussion of the risk associated with low water crossings in the existing conditions of flood hazard areas.

During the first planning cycle, the planning groups were given flexibility to utilize a community's discretion to identify roadway creek crossings as low water crossings in their regions. As such, the planning groups identified 11,395 low water crossings across Texas (Figure 3-14). While low water crossings span the entirety of the state, they are highly concentrated in the north central area of the state (Region 3 Trinity) and in Central Texas (Region 10 Lower Colorado-Lavaca, Region11 Guadalupe, and Region 12 San Antonio). Of the low water crossings identified, the functionality of 98 percent and the condition of 99 percent was reported as unknown. Figure 3-15 shows the locations of identified low water crossings across Texas.

Figure 3-14. Number of identified low water crossings by flood planning region

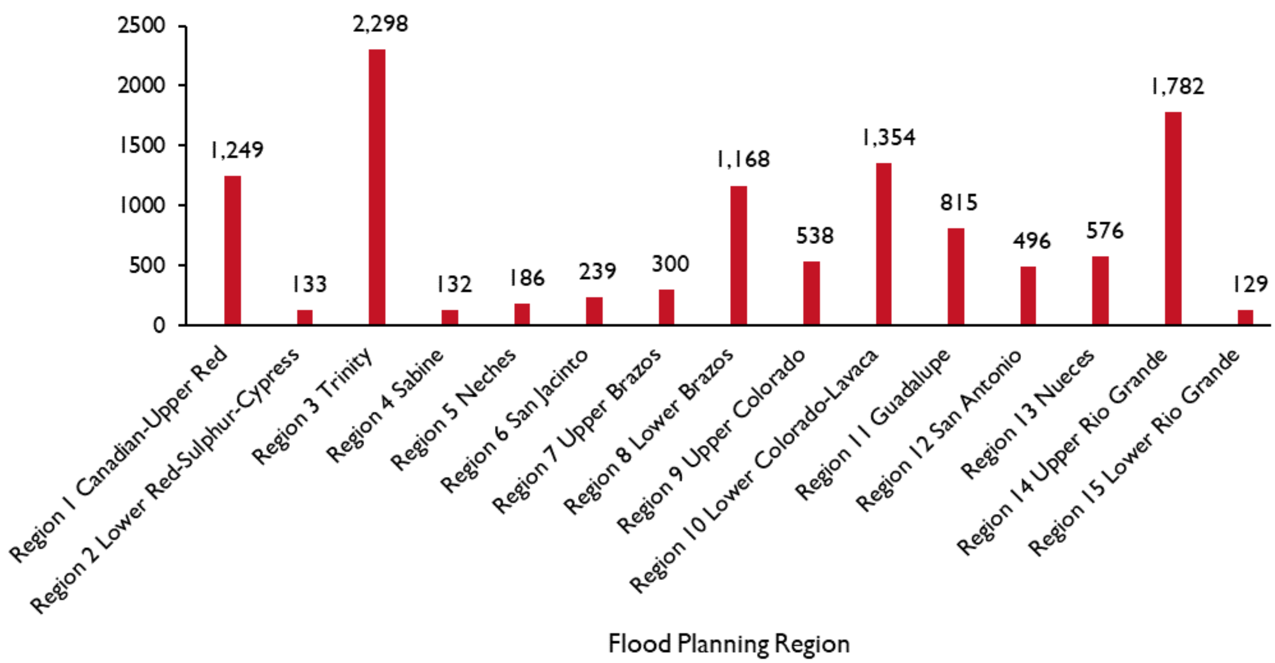
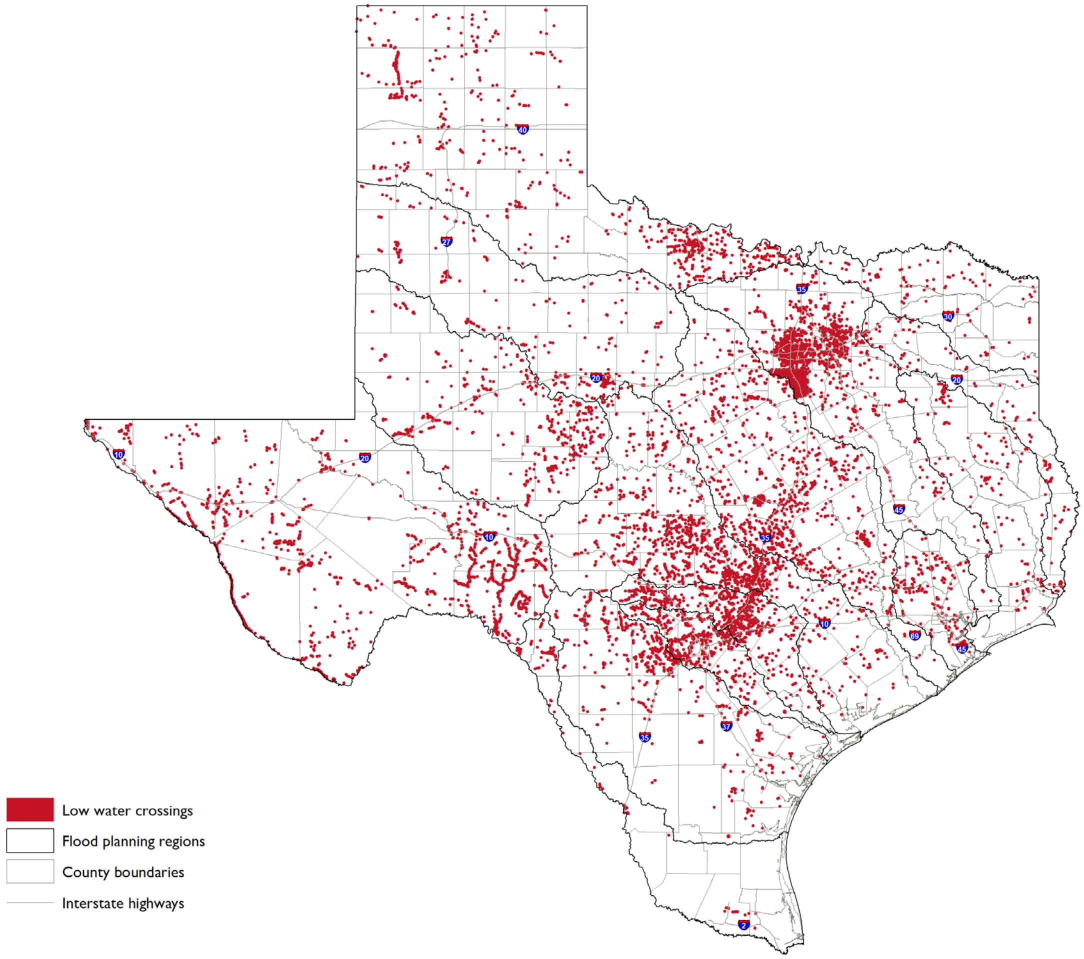


Figure 3-15. Locations of identified low water crossings across Texas



Bridges

Bridges in Texas serve a critical role as major flood infrastructure by providing essential lifelines during severe weather events. These structures are designed to withstand the forces of floodwater, allowing for safe passage of vehicles and pedestrians when other routes may be impassable. Bridges act as vital connections, enabling transportation and emergency services to reach affected areas and ensuring the movement of essential goods and services. During floods, when roads and low-lying areas become submerged, bridges remain elevated, allowing for continued access and evacuation routes ASCE, 2021).

While not a requirement, several planning groups identified a total of 5,478 bridges as constructed major infrastructure (Table 3-2). The functionality and condition of these bridges were identified as unknown by the regional flood planning groups.

Engineers consider such factors as water flow velocity, debris impact, and scour potential when designing bridges in flood prone areas. However, bridges are still vulnerable to floods, and regular maintenance and monitoring are essential to mitigate potential risks. In 2019 the U.S. Department of Transportation published state bridge inventories, finding that out of 55,000 bridges in Texas, only 1.4 percent (787) are identified as being in "poor condition"–much lower than the national average (TxDOT, 2020). To maintain the functionality and safety of these bridges as flood infrastructure, the

Texas Department of Transportation implements a comprehensive maintenance program throughout the state.[26]

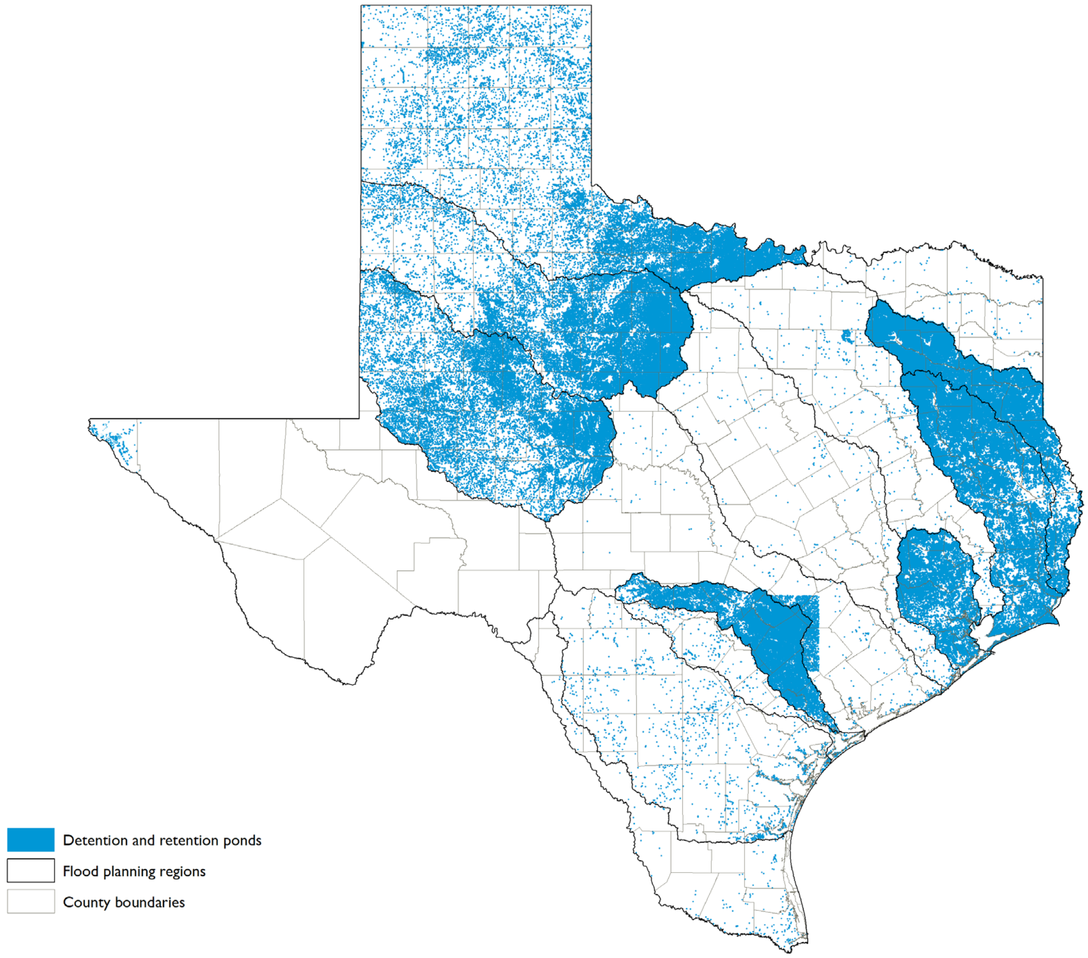
Detention and retention ponds

Detention and retention ponds are large, excavated areas installed on, or adjacent to, tributaries of rivers, streams, lakes, or bays and in urban areas to protect against flooding and, in some cases, downstream erosion by storing water for a limited period. Detention ponds are designed to temporarily store stormwater until it can be released at a controlled rate into local channels, whereas retention basins are designed to hold water permanently, allowing it to be treated over time. Detention/retention ponds are considered stormwater management best practices that provide general flood protection and can also control extreme floods, such as a 1 percent (100-year) annual chance storm event. Detention ponds are typically required for floodplain management by local land development codes during the construction of new land development projects, including residential subdivisions or shopping centers. The ponds help manage the excess urban runoff generated by newly constructed impervious surfaces, such as roads, parking lots, and rooftops.

The regional flood planning groups had discretion in determining the scale of what constitutes "major" infrastructure to be included in the regional flood plans. For example, the inventory is not expected to include every small detention pond in a region—rather, only *major* regional detention ponds. As such, the regional flood planning groups identified 266,065 retention and detention ponds (Table 3-2) covering a combined area of about 1,394,232 acres across Texas (Figure 3-16). Of these,100 percent were identified as having unknown functionality and condition.

[26] www.txdot.gov/business/grants-and-funding/highway-bridge-program-hbp-federal-aid.html

Figure 3-16. Locations of identified detention and retention ponds*



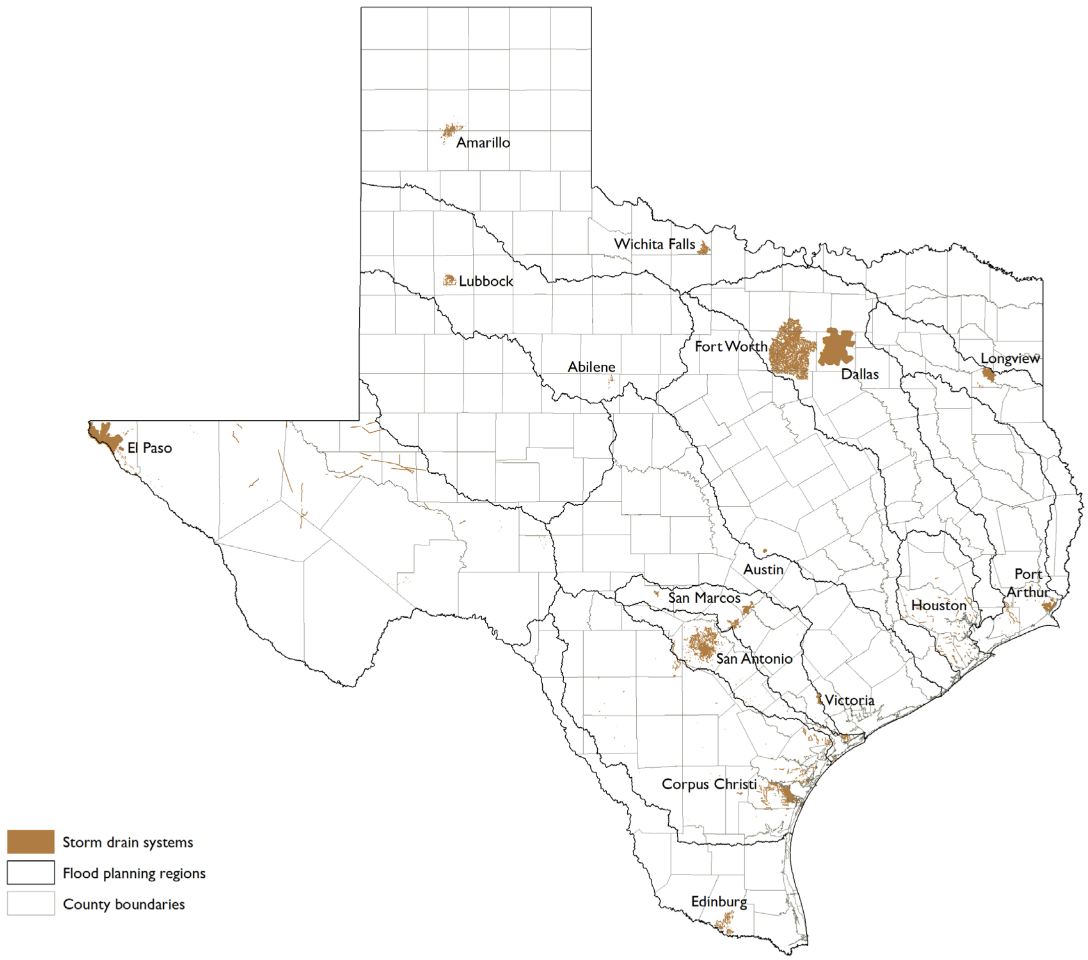
[*] Data density on this map demonstrates the variability of how flood infrastructure was identified by the regional flood planning groups. While some planning groups chose to include small, unnamed ponds others included only large ponds designed for flood control.

Stormwater management systems and components

Stormwater management systems are designed to manage the excess water generated during rainfall events to prevent flooding, erosion, and water pollution. In urban areas, storm drains are a common type of flood infrastructure that collects and conveys stormwater away from populated areas through underground pipes to inlets and outflows.

While the availability of data and information for identified storm drain systems varied from region to region, the regional flood planning groups identified a combined total of approximately 7,931 miles of stormwater management systems, storm drain components—which may include pipes, flumes, bends, culverts, etc.—and stormwater canals. The planning groups identified the highest concentrations of these systems around urban centers, including Dallas-Fort Worth, San Antonio, and El Paso (Figure 3-17). The condition for nearly 100 percent of storm water management systems, components, and canals identified was unknown. Fifty-five were identified as non-functional, with the remaining were identified as functionality unknown.

Figure 3-17. Locations of stormwater management systems as reported by the regional flood planning groups*



* *Map reflects stormwater management systems as reported by the regional flood planning groups. This information is displayed with the acknowledgement that much of the state's stormwater infrastructure may not have been identified by the regional flood planning groups due to constraints in the availability of infrastructure data across the state. The TWDB is currently funding and guiding a research project to develop infrastructure assessment guidance and a toolkit to help local communities identify and determine functionality of their existing stormwater infrastructure.*

These systems are typically managed by the same entity responsible for their construction. Management responsibilities include routine maintenance, like cleaning debris from catchment areas, repairing infrastructure, and generally ensuring that all pieces are functioning properly during rainfall events. In some cases, particularly in larger cities or regions with relatively extensive storm drain systems, specialized stormwater management districts or utilities are created to manage these systems. Examples include the Harris County Flood Control District and the Lower Colorado River Authority. These entities play a critical role in managing stormwater and protecting the environment and public health in their respective communities.

Until now, Texas has not had a statewide inventory of built drainage systems, and the TWDB and regional flood planning groups were not tasked or resourced to create an inventory of all drainage systems. This is a large and complex endeavor that would cost millions of dollars to eventually generate. Instead, local entities are charged with keeping a comprehensive inventory of their own drainage systems. However, Senate Bill 8 (2019) directed the TWDB and regional flood planning groups to include an assessment of existing infrastructure, including a general description of the location, condition, and functionality of natural features and constructed major infrastructure in the regional and state flood plans. To their credit, the groups accomplished a great deal during the compressed first planning cycle as they were able to identify a great number of drainage systems in the state. As the regional and state flood planning program continues, each iteration of the plans will improve upon the inventory of major storm drain infrastructure but will not produce a comprehensive inventory of all drainage systems. That type of inventory effort will continue to be the responsibility of communities to generate and maintain. The current effort to inventory major flood infrastructure does not specifically identify which drainage systems lack topographic relief and slope, or specific challenges with those areas, or potential solutions associated with them.

Constructed coastal infrastructure

Coastal infrastructure plays a vital role in minimizing the potential damage caused by flooding events along the Texas coastline. By providing a first line of defense against the encroaching waters, these structures aim to protect critical assets, infrastructure, and human lives in vulnerable coastal areas. Each infrastructure type exhibits different designs, materials, and capacities tailored to suit specific coastal conditions and local needs. The flood planning groups identified a total of 936 constructed **coastal infrastructure**, including sea walls, tidal barriers, and tidal gates (Table 3-2). The functionality and condition for almost 100 percent of these were unknown.

Other constructed infrastructure

The regional flood planning groups identified 191 discrete constructed infrastructure that did not fit within the above categories. The names and descriptions of these 'other' features varied but included utilities, roadway stream crossings, schools, and water supply. The functionality and condition for these constructed features were identified as unknown.

3.1.3 Summary of functionality and condition of existing flood infrastructure

As previously mentioned, the regional flood planning groups were required to assess the condition and functionality of major flood infrastructure (Tables 3-3 and 3-4).

Functionality

- Functional: The infrastructure is serving its intended design level of service.
- Non-functional: The infrastructure not providing its intended or design level of service

Condition

- Deficient: The infrastructure or natural feature is in poor structural or non-structural condition and needs replacement, restoration, or rehabilitation.
- Non-deficient: The infrastructure or natural feature is in good structural or non-structural condition and does not require replacement, restoration, or rehabilitation.

Table 3-3. Summary of the functionality of identified major flood infrastructure

Region	Total infrastructure	Functional	Non-functional	Functionality unknown
1	66,637			66,637
2	40,656	40,572	20	64
3	237,849	708	76	237,065
4	102,649	32	31	102,586
5	108,066	31	26	108,009
6	73,934			73,934
7	69,365			69,365
8	52,272	100	115	52,057
9	62,434	69	1	62,364
10	54,296			54,296
11	74,446			74,446
12	52,034	2,745	13	49,276
13	98,801	2,867	15	95,919
14	235,891	435	136	235,320
15	32,313			32,313
Total	**1,361,643**	**47,559**	**433**	**1,313,651**

Note: Blank cells signify that the functionality of identified major flood infrastructure is not categorized and should not be interpreted as definitive statements of operational status; they merely reflect that the regional flood planning group(s) did not supply information regarding functionality

Table 3-4. Summary of the condition of identified major flood infrastructure

Region	Total infrastructure	Deficient	Non-deficient	Condition unknown
1	66,637			66,637
2	40,656	20	10,472	30,164
3	237,849		8	237,841
4	102,649	15	81	102,553
5	108,066	16	88	107,962
6	73,934			73,934
7	69,365	6,774	3,394	59,197
8	52,272	24	248	52,000
9	62,434			62,434
10	54,296			54,296
11	74,446			74,446
12	52,034	8	52	51,974
13	98,801	28	166	98,607
14	235,891	58	192	235,641
15	32,313			32,313
Total	**1,361,643**	**6,943**	**14,701**	**1,339,999**

Note: Blank cells signify that the condition of identified major flood infrastructure has not been specified and should not be construed as an assessment of its state; they merely reflect that the regional flood planning group(s) did not supply information regarding condition

When assessing the condition of existing major flood infrastructure, many engineers use the term "intended design level of service." Intended design level of service refers to specific performance and safety requirements that various infrastructure is designed to meet. For dams and levees, level of service is determined by considering such factors as the potential consequences of dam failure, the size of the reservoir that the dam/levee is intended to create, and the expected frequency and magnitude of expected flood events. The intended design level of service is based on a combination of engineering analysis, scientific data, and risk assessments.

Determining the level of service is required to ensure that the dam can safely perform its intended functions, whether that be flood control, water storage, generating hydroelectric power, or creating a recreational reservoir. The intended design level of service is also intended to reduce the risk of dam failure and its potential consequences, including loss of life, property damage, and environmental impacts.

Dams, for example, are typically designed to meet a specific level of service at the time of their construction. However, over time, the performance and safety requirements of dams must evolve due to population growth, changes in climate patterns, or changes in land use. As a result, dams must be periodically re-evaluated and, if necessary, upgraded to ensure that they continue to meet their intended level of service.

3.1.4 Dam repair maintenance plan

In addition to creating the regional and state flood planning process, Senate Bill 8 (2019) amended Subchapter B, Chapter 201, of the Agriculture Code to include Section 201.0227. This requires the

Texas State Soil and Water Conservation Board to develop a 10-year plan for the repair and maintenance of dams identified as requiring rehabilitation. The *Ten-Year Dam Repair, Rehabilitation and Maintenance Plan*[27] (2020) addresses the increasing number of deteriorating dams across the state.

The plan involves identifying and prioritizing high-risk dams for repair, rehabilitation, or maintenance based on their potential hazard to life and property downstream. In the plan, the Texas State Soil and Water Conservation Board reported that only 123 of the 639 dams classified as high hazard currently meet the high hazard criteria, indicating that 516 dams require rehabilitation or upgrade to meet safety standards and adequately protect lives downstream. The agency has begun work to implement projects focused on operation, maintenance, repair, and rehabilitation/upgrading of these dams, with an average annual general revenue appropriation of approximately $6.8 million since 2010. Additionally, a supplemental appropriation of $150 million from the Economic Stabilization Fund was provided in 2019, and annual general revenue appropriations for 2020 and 2021 amount to $8,832,484 (TSSWCB, 2020b).

The Texas State Soil and Water Conservation Board works with dam owners to develop and implement cost-effective solutions that meet regulatory standards and protect the environment. The plan also includes a public education and outreach program to raise awareness of the importance of dam safety and encourage proactive maintenance by dam owners. While the agency aims to complete implementation of the plan by 2030, the current Flood Control Program needs include $14 million for maintenance of 2,041 dams, $136 million for repair of 188 dams, and $2 billion construction cost for rehabilitation and upgrade of 516 high hazard dams (TSSWCB, 2020a).

It also offers an Operation and Maintenance Grant Program to support the ongoing maintenance and upkeep of conservation practices implemented through the agency's programs. The program provides financial assistance to eligible landowners for the operation and maintenance of conservation practices, including terraces, grassed waterways, diversions, and other practices designed to reduce erosion and improve water quality. The Texas State Soil and Water Conservation Board Flood Control Program’s 2020 *Ten-Year Dam Repair, Rehabilitation, and Maintenance Plan* identified 2,041 flood control dams eligible for the Operation and Maintenance Grant Program.

The Texas State Soil and Water Conservation Board must also provide yearly reports to the TWDB on the progress of dam repairs and maintenance from the *Ten-Year Dam Repair, Rehabilitation and Maintenance Plan*.

3.2 Proposed or ongoing flood mitigation projects

Each regional flood planning group was required to include a general description of the location, source of funding, and anticipated benefits of proposed or ongoing flood mitigation projects in the flood planning regions, including:

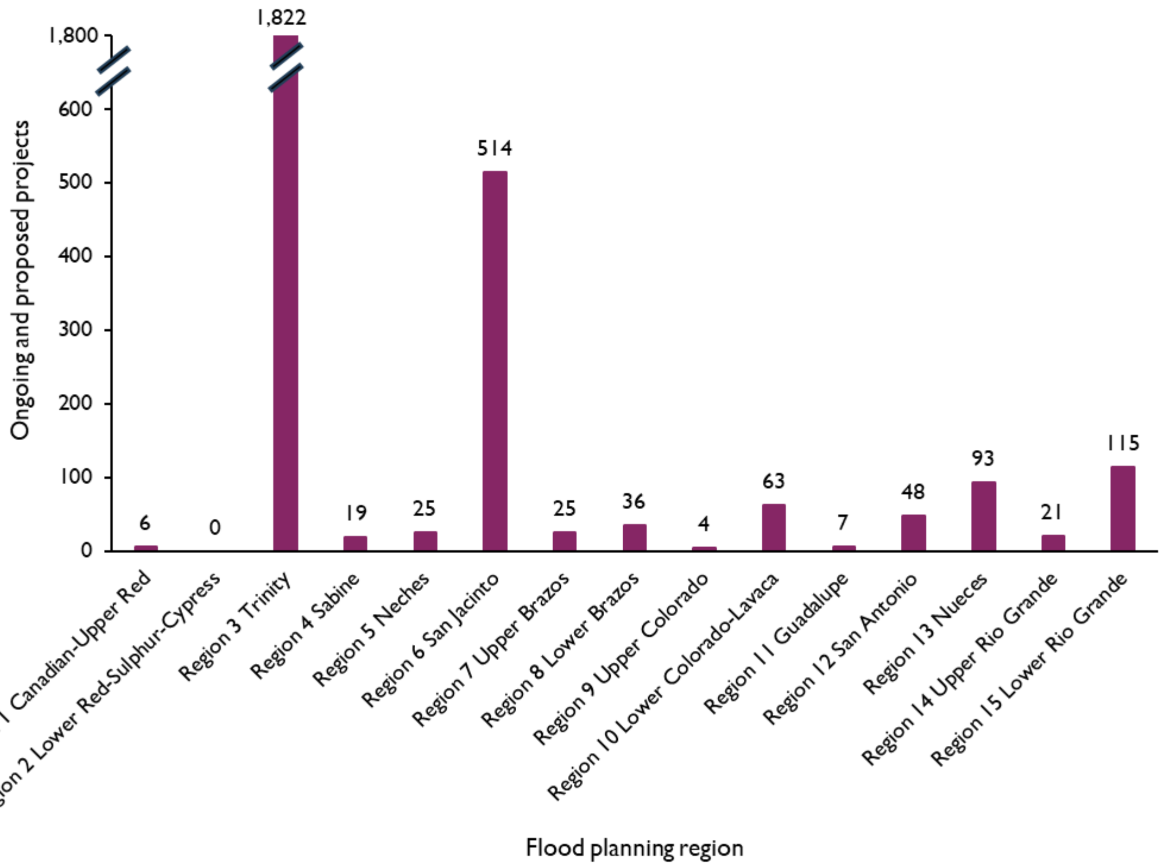
- new structural flood mitigation projects currently under construction;
- non-structural flood mitigation projects currently being implemented; and
- structural and non-structural flood mitigation projects with dedicated funding to construct and the expected year of completion.

Like the inventory of existing major flood infrastructure, this effort was intended to help inform planning groups as part of their overall flood mitigation needs analyses and to inform their recommendations for flood risk solutions and actions to meet their regions' needs. The information helped to avoid duplication of efforts and potential conflicts between ongoing and newly proposed flood projects.

[27] www.twdb.texas.gov/flood/planning/resources/doc/2020_05_TSSWCB%2010-Year%20Dam%20Repair,%20Rehabilitation,%20and%20Maintenance%20Plan.pdf

Data collection methods varied across regional flood planning groups but included outreach to local communities through surveys, one-on-one interviews, and reviewing existing disaster mitigation and comprehensive plans. The planning groups identified and compiled a total of 2,798 ongoing or planned projects and studies across the state (Figure 3-18), which included structural and non-structural measures with dedicated funding sources, like repetitive loss land acquisition and buyouts, coastal protection measures, regional detention and conveyance improvements, and public education campaigns. However, many groups had less success acquiring additional information about each project, including expected completion date and cost. While the cost for only about 20 percent (558) of the proposed and ongoing projects was known, that total cost exceeded $8 billion.

Figure 3-18. Number of identified proposed and ongoing projects per flood planning region*



* *Note: Region 2 Lower Red-Sulphur-Cypress did not identify any proposed ongoing projects in its 2023 amended regional flood plan*

Planning groups also inventoried ongoing flood-related studies in their regions. Flood studies are important tools to identify a community's flood risk by utilizing up-to-date data on rainfall trends, topography, land use, and existing infrastructure. Ongoing flood studies can be used in future flood planning efforts to enhance a community's understanding of existing and future flood risk. The evaluations identified by the regional flood planning groups include base level engineering studies, local and county-wide drainage studies, dam inundation studies, and vulnerability assessments. Many of the identified studies include those funded through programs administered by the TWDB, FEMA, and the Texas General Land Office. These key programs are discussed in Chapter 10 Section 10.2.

The success of outreach measures also varied by region. However, the expectation is that participation by local communities will increase as general awareness of Texas' regional flood planning program spreads, ideally facilitating more robust and extensive data collection. A complete list of proposed and ongoing projects and studies, as acquired by the flood planning groups, is included in the Interactive State Flood Plan Viewer.

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4 Flood risk

Quick facts

Approximately 21 percent (56,053 square miles) of Texas' land area (268,597 square miles) is within the 1 percent (100-year) annual chance floodplain.

Approximately one in every six people in Texas lives or works in known flood hazard areas, including in the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.

Approximately 2.4 million people live or work in the 1 percent (100-year) annual chance floodplain, and an additional 2.8 million people are in the 0.2 percent (500-year) annual chance floodplain.

Regional flood planning groups identified 9,322 low water crossings within flood hazard areas.

Regional flood planning groups identified approximately 878,100 buildings within the 1 percent (100-year) annual chance floodplain, and an additional 786,100 buildings within the 0.2 percent (500-year) annual chance floodplain.

More than 6,258 hospitals, emergency medical services, fire stations, police stations, and schools were identified within the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.

The projected future conditions 1 percent (100-year) annual chance floodplain is estimated to increase by 11 percent over the existing flood hazard area to a total of 62,245 square miles.

The regional flood planning groups project an increase of approximately 2.6 million people and 740,000 buildings in the 1 percent annual chance floodplain under projected future condition flood hazard.

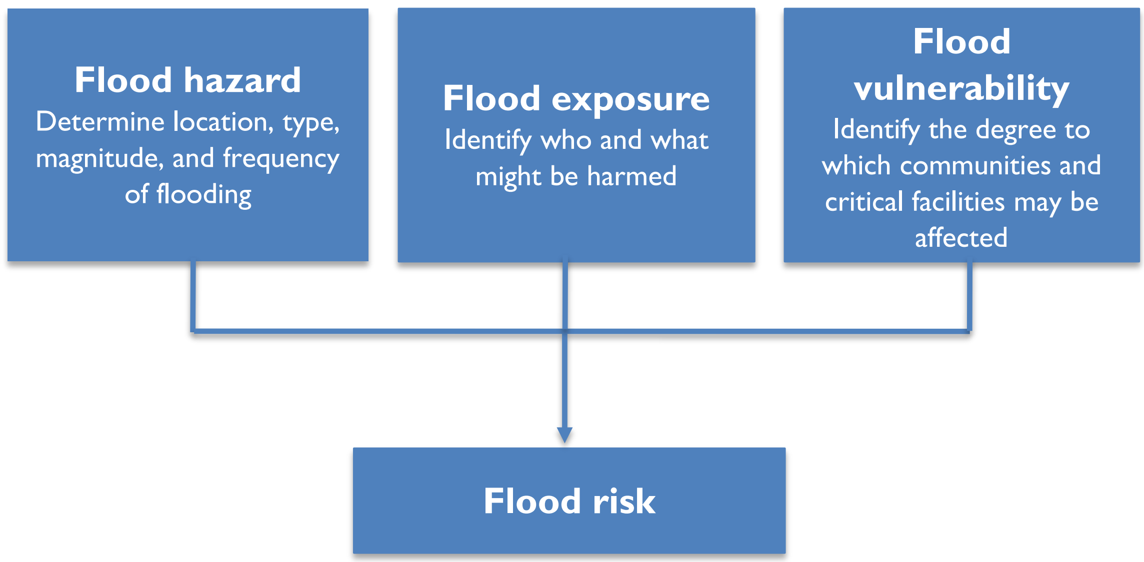
Regional flood planning groups estimate approximately 10,243 low water crossings will be within future condition flood hazard areas.

An estimated 10,007 hospitals, emergency medical services, fire stations, police stations, and schools are projected to be within the future 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.

Texas unfortunately leads the nation in flood-related property damage and fatalities. The cost of Hurricane Harvey alone is estimated at more than $125 billion (2017 U.S. dollars) in damage, primarily from catastrophic rainfall-triggered flooding in the Houston metropolitan area and Southeast Texas (NOAA, 2024). From 1959 to 2019, there have been 1,069 flood-related deaths in Texas, 570 of which are vehicle-related flood fatalities (Han and Sharif, 2020). Planning for future flood hazards by analyzing flood risk is a highly cost-effective way to identify solutions that will reduce current flood risk and avoid increasing future flood risk.

Flood risk is a function of three factors: the specific flood *hazard* (where is it going to flood), the potential *exposure* of people and property to that hazard (who and what might flood), and the *vulnerability* of the people and property exposed to that flood hazard (the degree to which a community and/or critical facilities are affected and how quickly and easily they may recover after a flood event). For the purposes of the regional and state flood planning efforts, flood risk analyses comprised a three-step assessment of flood hazard, flood exposure, and vulnerability analyses (Figure 4-1). The greater each component, the greater the overall flood risk. By understanding and addressing each component, we can better manage and reduce flood risk.

Figure 4-1. The three components of flood risk: hazard, exposure, and vulnerability



The initial round of regional flood planning was the first comprehensive evaluation of flood risk for Texas. While some flood planning regions (Flash Flood Alley and some coastal areas) already had substantial flood hazard data, there were several regions in the Texas Panhandle and West Texas where much of the flood hazard was either unmapped or based on outdated maps. As a result, most of the flood risk across these regions was not well quantified, meaning lives and property were unknowingly within harm's way.

Each of the 15 planning groups completed a comprehensive assessment of flood risk in their regions. Each region performed flood risk analyses for existing conditions, as well as a future conditions scenario that considered potential changes in flood hazards over a 30-year planning horizon.

As reported in the 15 regional flood plans, approximately 21 percent of the state (56,053 square miles) falls within the extent of the 1 percent (100-year) annual chance floodplain, and an additional estimated 4 percent (10,778 square miles) falls within the 0.2 percent (500-year) annual chance floodplain. Approximately 8 percent of the state's population is located within the 1 percent (100-year) annual chance floodplain, and an additional estimated 9 percent is within the 0.2 percent annual chance floodplain (Table 4-1). The planning groups identified 9,322 low water crossings across the state.

Table 4-1. Estimated existing flood risks identified within Texas*

	1 percent (100-year) annual chance floodplain	0.2 percent (500-year) annual chance floodplain[a]	Total
Population	2,408,600	2,811,300	**5,219,900**
Buildings[b]	878,100	786,100	**1,664,200**
Residential buildings	662,100	633,600	**1,295,700**
Hospitals, emergency medical services, fire stations, police stations, and schools	2,924	3,334	**6,258**
Roadway miles	43,400	20,500	**63,900**
Agricultural area (acres)	10,200,000	2,454,000	**12,654,000**

* *Compilation of data as reported by the regional flood planning groups; statistics are rounded*
a *In addition to flood risk in 1-percent annual chance floodplain*
b *Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown*

4.1 Existing flood risk

Recognizing the degree and extent of existing flood risk faced by communities is a fundamental component of comprehensive flood planning; it is impossible to mitigate a risk without understanding or awareness of the possible danger. Using best available information, the regional flood planning groups were required to identify and compile existing flood hazards in their regions, including riverine flooding, urban flooding, coastal flooding, playa flooding, and possible flood prone areas of risk. This required each planning group to consider existing conditions and perform:

1) flood hazard analyses that determine location, type, magnitude, and frequency of flooding;
2) flood exposure analyses to identify who and what might be harmed within the region; and
3) vulnerability analyses to identify vulnerabilities of communities and critical facilities.

To accomplish this, the planning groups first collected and considered flood hazard information of varying quality and age from a wide variety of sources and, when possible, enhanced the data with additional local stakeholder input. The planning groups then built a comprehensive existing flood hazard dataset based on the collected assortment of information.

Then they used the existing flood hazard dataset to identify who and what may be exposed to those existing flood hazards as well as the vulnerabilities of those communities.

4.1.1 Existing condition flood hazard

The Texas Water Development Board (TWDB) provided a foundational flood hazard dataset for the planning groups using a variety of existing condition flood hazard information, including Federal Emergency Management Agency (FEMA) regulatory effective products, base level engineering floodplains, and cursory (approximate) floodplain information developed for the TWDB. The planning groups identified additional flood prone areas based on local knowledge of previous flood events acquired from public meetings, online surveys, and other outreach efforts.

To support and accelerate the new regional planning process, the TWDB developed a **floodplain "quilt"** and provided this to the planning groups as a common starting point for riverine and coastal flood risk data within their regions. While the TWDB also provided an initial ranking, or hierarchy, of these flood planning datasets within the quilt, each flood planning group was expected to confirm, modify, and/or otherwise enhance the initial floodplain quilt information as appropriate to support its flood risk analyses. The following floodplain quilt datasets were made available to the planning groups and others through the TWDB's Flood Planning Data Hub.[28]

- **FEMA mapping:** The floodplain quilt utilizes FEMA's **National Flood Hazard Layer**, including effective, pending, and preliminary flood hazard data, known as **Flood Insurance Rate Maps**, as the best available dataset, where available. The National Flood Hazard Layer is made from effective flood maps and covers more than 90 percent of the U.S. population (FEMA, 2021). According to FEMA's National Flood Hazard Layer data, out of the 254 counties in Texas, 133 counties have Flood Insurance Rate Maps (FEMA, 2024).
- **Base level engineering:[29]** An automated riverine hydrologic and hydraulic modeling approach that builds on lessons learned to produce a baseline understanding of a communi'y's flood risk. Where available, base level engineering is meant to complement the current effective Flood Insurance Rate Map (FIRM) data but not replace it.
- **Digitized paper Flood Insurance Rate Maps:** Dataset that covers portions of the state where no digital Flood Insurance Rate Map data has been created and is not available on the National Flood Hazard Layer.
- **Cursory floodplain data:** The TWDB acquired statewide cursory floodplain data through a contract with Fathom that filled any remaining data gaps. This flood risk data includes complete, but approximate, flood risk coverage for Texas developed from very large nationwide 2D hydrodynamic modeling data. A publicly available early derivative of this data, called Flood Factor, is published by First Street Foundation.[30]

Planning groups also used the following additional datasets to support flood hazard analysis:

- **Local studies**: Regional or local flood risk data not currently available to the TWDB and therefore not included in the floodplain quilt datasets. There are many parts of Texas where regional or local entities have better-quality flood risk data than any other listed sources.
- **U.S. Army Corps of Engineers or other federal data**
- **Land cover data:** Watershed runoff is greatly impacted by land cover conditions, including development and soil information. Soil properties influence the relationship between rainfall and runoff because different soils have varying rates of infiltration. Land use affects such hydrologic processes as evapotranspiration, interception, and infiltration. As urban development (impervious cover) is added to a watershed, the hydrologic response is changed, and surface runoff often increases. While not as prolific as urban development, cultivated agricultural and grazed land use results in increased levels of runoff in a watershed and, therefore, increased existing flood risk, as compared to natural forested and woodland ground cover. The rate of development and land use change in Texas necessitates updated floodplain modeling to adequately estimate flood risk.
- **Rainfall data**: Accurate rainfall data is crucial to mapping the existing flood risk condition. The TWDB recommended that **Atlas 14** rainfall data be used for flood modeling associated with the state flood planning efforts. When applicable, each planning group utilized the Atlas 14 rainfall dataset to inform its flood hazard areas based on the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood events. Atlas 14 indicates that the 1 percent annual chance 24-hour

[28] www.twdb-flood-planning-resources-twdb.hub.arcgis.com/

[29] https://webapps.usgs.gov/fema/ble_firm/

[30] www.firststreet.org/flood-factor/

rain event may be greater than what we previously considered in many areas. The greatest rainfall changes occur along the Texas coast and in Central Texas.

Using these datasets, the planning groups were required to consider the following for their flood hazard analyses:

1) **Riverine flooding** caused by bank overtopping when the flow capacity of rivers is exceeded locally. The rising water levels generally originate from high-intensity rainfall, creating soil saturation and large volumes of runoff either locally and/or in upstream watershed areas.
2) **Pluvial flooding**, including urban flooding, is caused when the inflow of stormwater in urban areas exceeds the capacity of drainage systems to infiltrate stormwater into the soil or carry it away. The inflow of stormwater results from (a) heavy rainfall, which can collect on the landscape (pluvial flooding) or cause rivers and streams to overflow their banks and inundate surrounding areas; or (b) storm surge or high tides, which push water onto coastal cities. Floodwater inundation and movement are influenced by (a) land development, which disturbs natural drainage patterns and creates hardened, impervious surfaces that inhibit infiltration of stormwater; and (b) stormwater systems that are undersized for current needs and thus increase exposure to drainage hazards.
3) **Coastal flooding**, which occurs when normally dry, low-lying land is flooded by seawater. Coastal flooding can be caused by high-tide events, storm surges, and wind-driven waves. Relative sea level rise exacerbates these drivers, leading to more frequent coastal inundation and more destructive flooding events (Sweet and others, 2014).
4) **Other possible flood prone areas** are areas that have not been previously identified as mapped flood hazard areas but that were captured in the regional flood planning process through other means, including local knowledge of historic flooding. To collect this information from stakeholders, planning groups utilized interactive web maps and information gathered during public meetings to identify flood prone areas. Additional methods for collecting this information included the following:
    - Delineation of low water crossings outside of the known and mapped 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains.
    - The use of historical flood data to identify flood prone areas outside of known and mapped 1 percent and 0.2 percent annual chance floodplains.
    - Identification of areas subject to inundation from reservoirs and levees. Dam breach inundation areas (downstream) were also included where data was publicly available.

The flood hazard analyses revealed the locations and extent of flood hazard areas that are subject to flooding during 1 percent (100-year) and 0.2 percent (500-year) annual chance flood events (Figure 4-2) and known flood prone areas (Figure 4-3). This flood hazard analyses shows that the flood risk across Texas is significant and widespread with almost one fourth of Texas' land area (66,831 square miles) in either the 1 percent or 0.2 percent annual chance flood hazard areas, with approximately 21 percent of the land area (56,053 square miles) within the 1 percent annual chance flood hazard areas. An additional 603 square miles are identified as flood prone areas through stakeholder feedback where the annual chance of flooding is reported as unknown (Table 4-2).

This effort is not regulatory in nature, and the results of this evaluation have no impact on National Flood Insurance Program insurance requirements or premiums. Rather, this exercise is intended to gather a comprehensive set of best available information reflecting actual, statewide flood risk to improve communities' understanding of their current risks and to better prepare for future flood events.

Figure 4-2. Locations of flood hazards under existing conditions

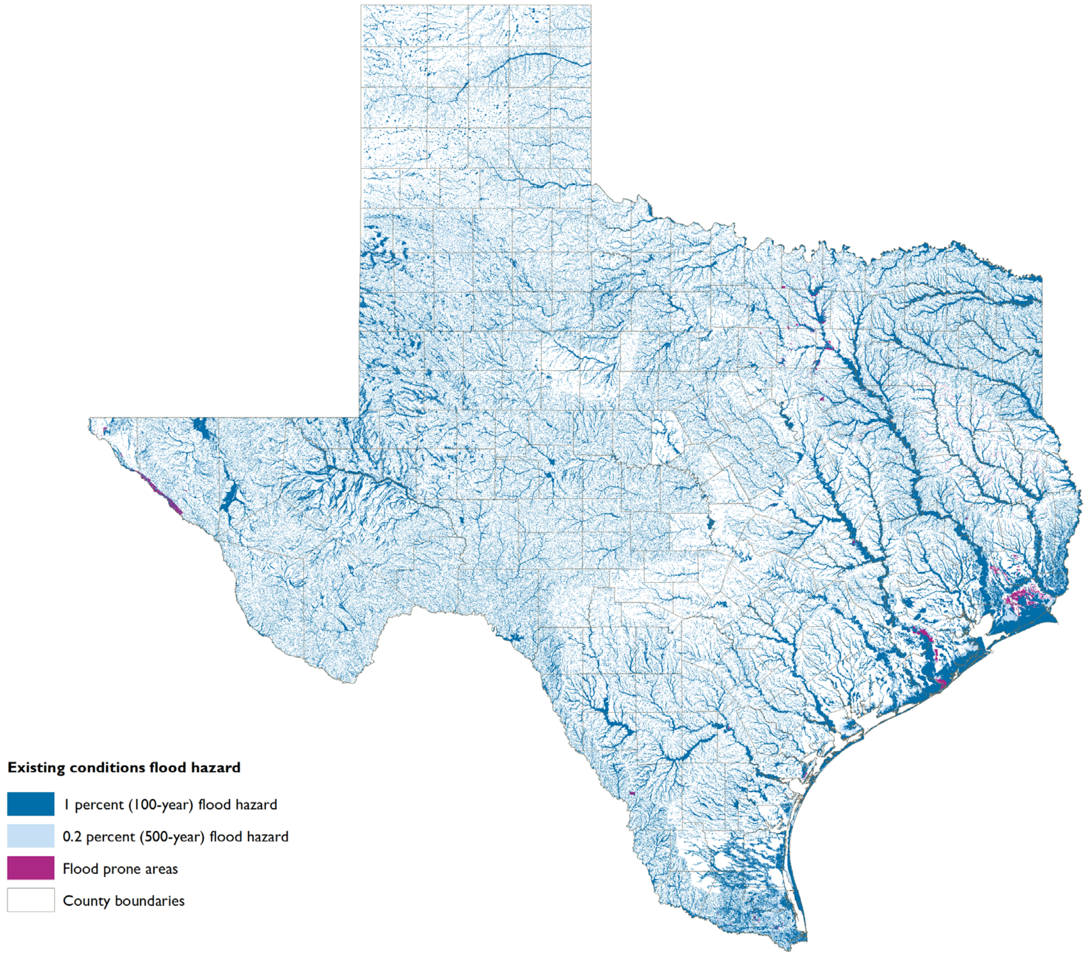


Figure 4-3. Example of known flood prone areas

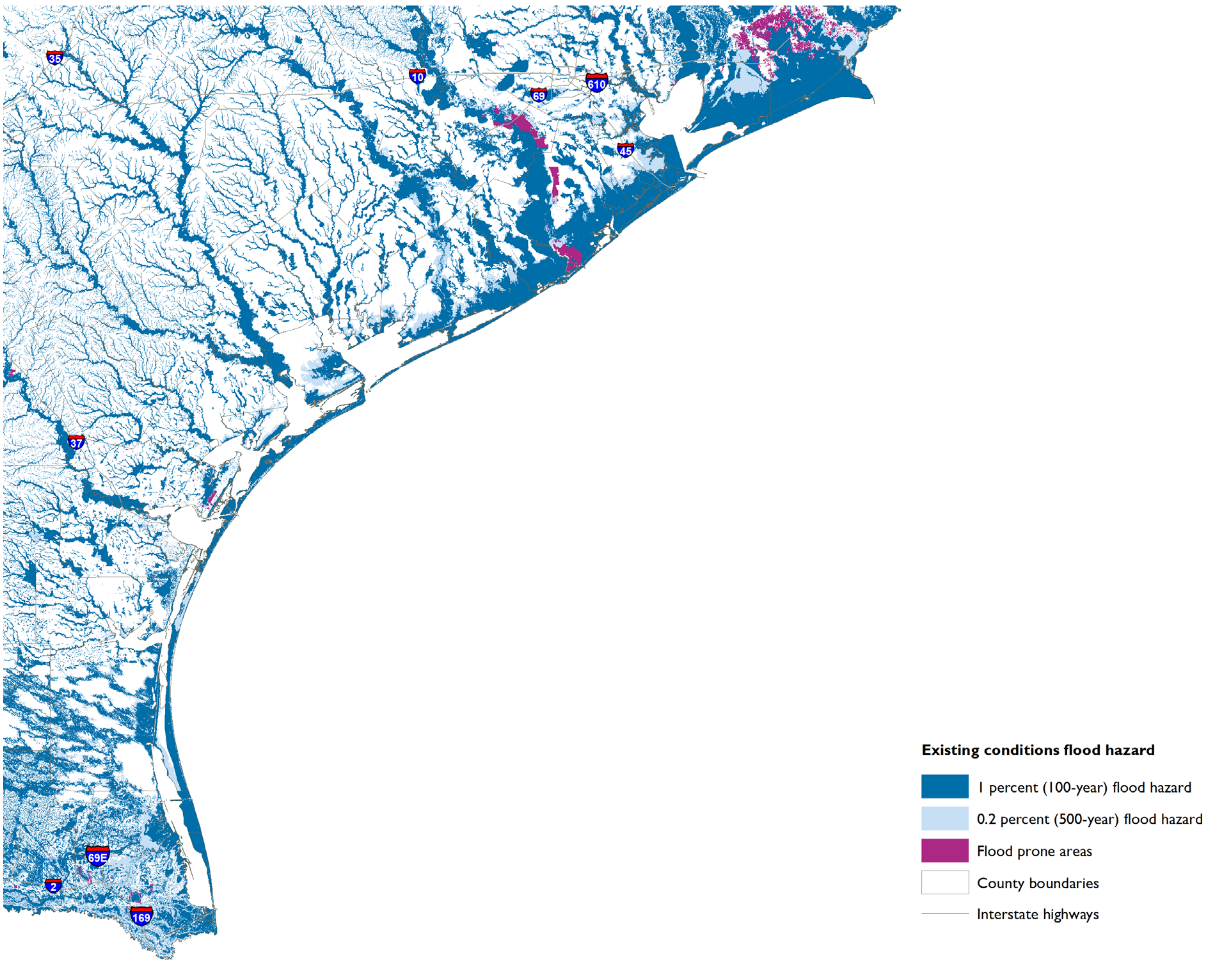


Table 4-2. Identified existing flood hazard areas (square miles) by flood planning region

Region	1 percent (100-year) annual chance floodplain	0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance)	Total
1	4,305.21	929.65	0.24	**5,235.10**
2	2,820.71	115.16		**2,935.87**
3	4,882.12	451.21	103.91	**5,437.24**
4	2,310.67	176.21		**2,486.88**
5	3,078.52	374.32	261.91	**3,714.75**
6	1,485.56	471.48	1.25	**1,958.29**
7	3,634.37	1,393.99		**5,028.36**
8	4,688.02	485.21	106.18	**5,279.41**
9	4,521.09	1,127.23		**5,648.32**
10	4,514.84	723.23		**5,238.07**
11	985.62	182.84	1.27	**1,169.73**
12	800.20	124.34	0.05	**924.60**
13	4,577.86	1,287.41	8.32	**5,873.59**
14	9,284.72	1,755.47	98.58	**11,138.77**
15	4,163.14	1,180.61	21.38	**5,365.12**
Total	**56,052.64**	**10,778.35**	**603.09**	**67,434.09**

4.1.2 Gaps in available flood risk data

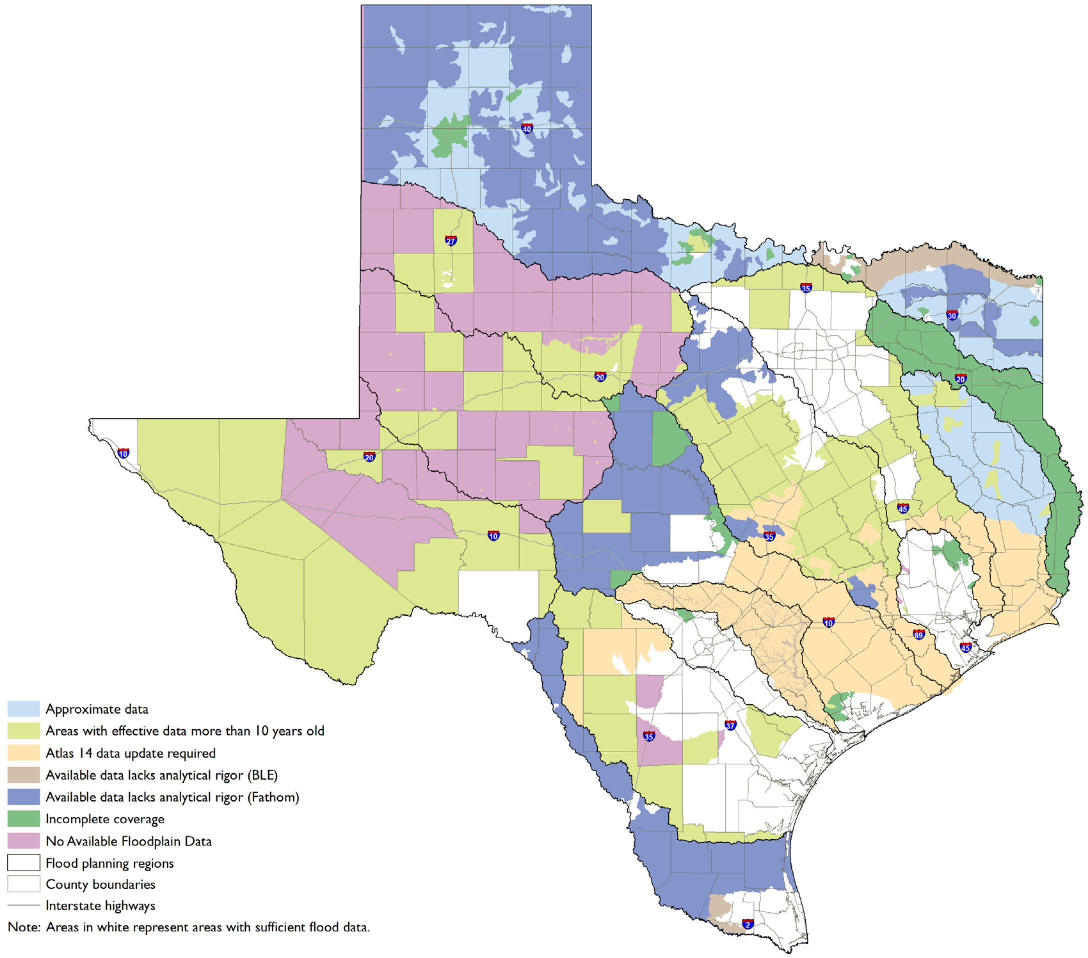
Once planning groups completed flood hazard analysis, including collecting all known flood hazard locations and previously documented flood prone areas, they could determine the geographic areas that represented gaps or need for additional analyses in flood hazard information. They did this primarily through stakeholder input. The gap analyses identified areas that had outdated or non-existent modeling and/or mapping, which the planning groups later utilized to identify potential flood management evaluations, described in Chapter 7 of this plan.

Not surprisingly, gap analyses revealed that some flood planning regions are far more "data rich" than others, meaning up-to-date mapping and modeling are available for most of the key areas in the region. These regions include Region 6 San Jacinto, Region 11 Guadalupe, and Region 12 San Antonio. By contrast, other planning regions, including those in the Texas Panhandle, West Texas, and East Texas, have significantly more data gaps (Figure 4-4).

Floodplain data gaps generally included the absence of detailed hydraulic and hydrologic modeling, modernized data, and broad coverage of digitized flood hazard information from previously published sources. Outdated information included studies over 10 years old, approximate data, outdated modeling software, base level flood elevation data, outdated FEMA maps, and inadequate flood risk mapping. According to FEMA's National Flood Hazard Layer data, of the 133 counties that do have Flood Insurance Rate Maps, four are only partially mapped. There are 121 counties in Texas that do not have any effective Flood Insurance Rate Maps (FEMA, 2024).

Updates were also needed for significant land use changes, new flood control structures, alterations in channel geometry, or changes in rainfall pattern based on Atlas 14 data.

Figure 4-4. Flood map gaps and data quality identified by the planning groups*



* *"Incomplete coverage" is composed of several map coverage deficiencies identified by the regions, including: <50 percent detailed study; additional reach floodplain modeling recommended by the client; detailed FEMA mapping is only associated with the main reach for the watershed; detailed study covers less than half of watershed; incomplete coverage of recent, detailed mapping; lacks effective FEMA mapping near areas of recent development or floodplain road crossings; no 0.2 percent (500-year) exists.*

4.1.3 Existing condition flood exposure

After identifying flood hazard locations based on the best available information, the planning groups developed analyses to identify who and what might be in harm's way and to determine if they are located within any flood risk or flood prone areas.

All structures and populations located within the 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas were determined by intersecting the flood hazard layer with GIS data features, including buildings, roadways, population estimate, agricultural areas, etc.

The exposure analyses performed by the regional flood planning groups identified all buildings located in the flood hazard areas, however they did not take the finished floor elevation of a building and flooding depth into account. Therefore, the number of buildings within flood hazard areas identified by the flood planning groups using two-dimensional analyses may be higher than the number of buildings identified using flood elevation (three-dimensional analyses). Therefore, the number of buildings at risk of flooding during a particular storm event is lower than the number of buildings located in the flood hazard area.

The TWDB is currently working to generate statewide damage estimates from these flood risk assessments as a part of a new broader Flood Analytics initiative seeking to leverage new statewide flood hazard data. These hazard datasets include information such as water surface elevation, flood depths, and flood extents for a variety of annual chance flood events (10-year through 500-year). By combining these datasets with exposure datasets such as building footprints, flood risk can be expressed in monetary terms such as average annualized losses. While the overall initiative is envisioned to be ongoing and longer-term, the TWDB has conducted some initial testing on software tools to assess their capabilities and feasibility of developing statewide flood risk assessments.

This preliminary analysis was performed on the entire state of Texas using the 1 percent (100-year) flood fluvial depth grid from the cursory floodplain dataset. The estimated flood damage statewide is about $32 billion. This effort identified about 410,000 buildings within the 1 percent annual chance floodplain that may experience flood damage. Damage to residential buildings accounts for about 81 percent of the total flood damage amount. These results should be considered as very preliminary and subject to change and are being provided for general informational purposes. Being exposed to a hazard does not automatically mean harm will occur, but identifying flood hazard exposure helps determine the overall flood risk. For example, a building located within a 0.2 percent (500-year) annual chance floodplain may be exposed to but not vulnerable to a flood hazard if it is elevated and fortified specifically against the threat of flooding.

The flood exposure analyses considered available datasets and different types of developments within flood hazard areas to estimate the existing flood hazard exposure (Table 4-3), including:

1) population;
2) buildings, including residential and nonresidential;
3) critical facilities;
4) roadways, including the estimated number of roadway stream crossings, low water crossings, and the total length of roadway; and
5) agricultural areas, including the total area of farms and ranches.

Table 4-3. Summary of statewide existing condition flood exposure

	1 percent (100-year) annual chance floodplain	0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance)	Total
Population	2,408,561	2,811,347	665,911	**5,885,819**
Buildings[a]	878,098	786,132	125,610	**1,789,840**
Residential buildings	662,107	633,563	106,305	**1,401,975**
Roadways stream crossings (including low water crossings)	69,839	7,669	1,012	**78,520**
Roadway miles	43,444	20,468	1,856	**65,768**
Agricultural areas (acre)	10,200,323	2,453,832	51,695	**12,705,850**
Critical facilities[b]	6,153	8,252	693	**15,098**
Hospitals, emergency medical services, fire stations, police stations, and schools	2,924	3,334	401	**6,659**

Note: All values are counts unless otherwise labeled.

[a] Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown
[b] Critical facilities include hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plants

Population

All planning groups were required to include daytime and nighttime population estimates located within 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas. The higher of the day and night estimates per county was utilized in estimating the total population potentially exposed to flood hazards. The regional planning groups calculated that an estimated 5,885,830 people are potentially exposed to existing flood hazards. Of those, 2,408,561 people were identified within the 1 percent, 2,811,347 within the 0.2 percent, and 665,911 within the flood prone areas (Table 4-4). Figure 4-5 and Figure 4-6 illustrate the populations potentially exposed to flood hazard areas by flood planning region and county, respectively.

*Table 4-4. Populations within existing flood hazard areas by flood planning region**

Region	Population within 1 percent (100-year) annual chance floodplain	Population within 0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance) population	Total
1	29,996	38,834	161	**68,991**
2	37,963	4,610		**42,573**
3	241,489	444,808	319,858	**1,006,155**
4	65,006	25,551		**90,557**
5	65,717	92,558	89,118	**247,393**
6	785,857	919,945	2,204	**1,708,006**
7	63,447	54,412		**117,859**
8	129,887	133,705	197,630	**461,222**
9	83,020	40,357		**123,388**
10	155,127	97,279		**252,406**
11	63,857	52,575	696	**117,128**
12	67,738	22,812	26	**90,576**
13	144,054	100,356	9,090	**253,500**
14	115,530	47,985	35,740	**199,255**
15	359,873	735,560	11,388	**1,106,821**
Total	**2,408,561**	**2,811,347**	**665,911**	**5,885,819**

Note: Blank cells do not always signify the absence of populations within flood hazard areas; they may indicate that such populations were not identified or reported by the regional flood planning groups.

** Values represent the maximum daytime or nighttime population provided by the regional flood planning groups*

Figure 4-5. Populations within existing flood hazard areas by flood planning region

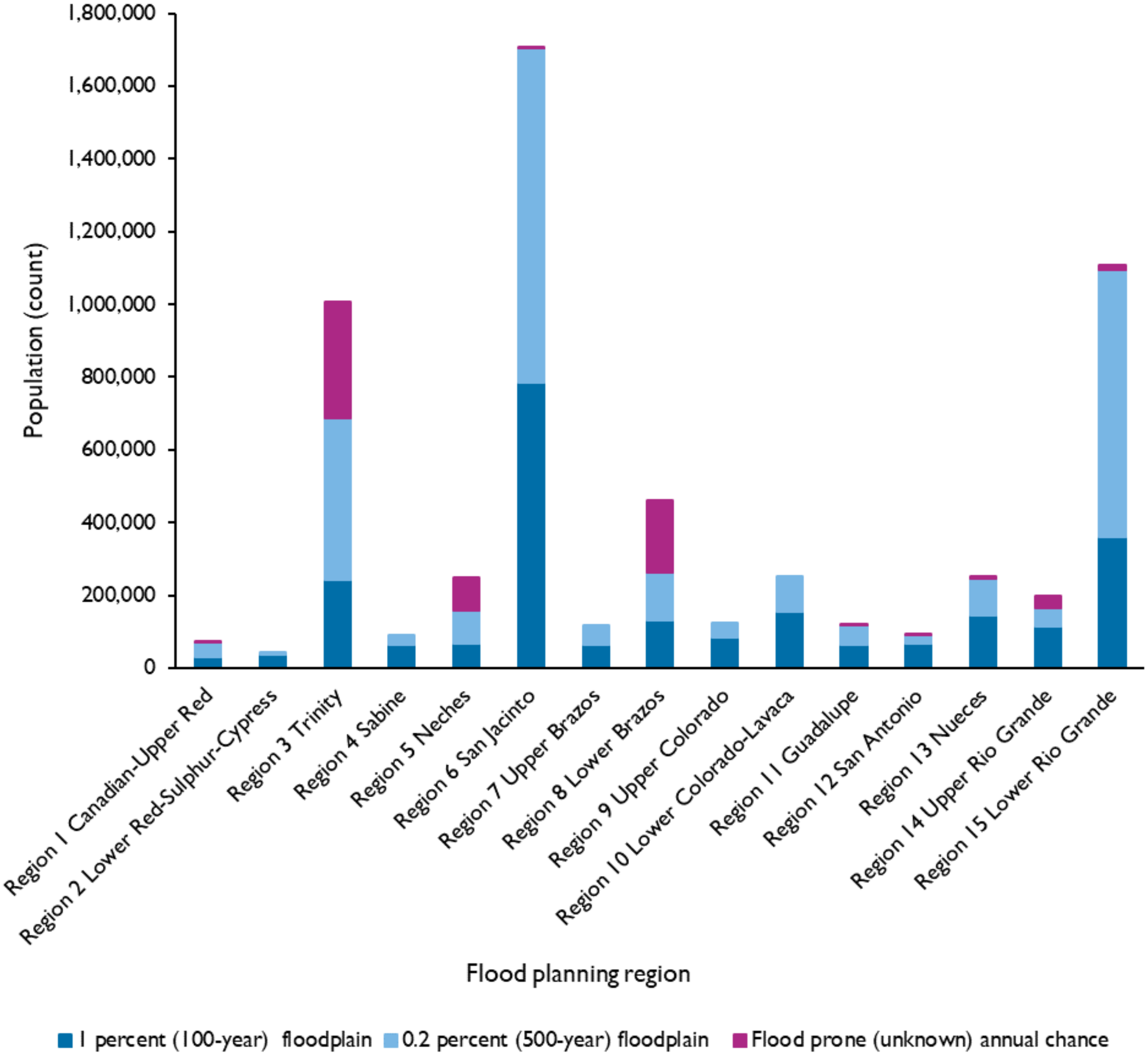
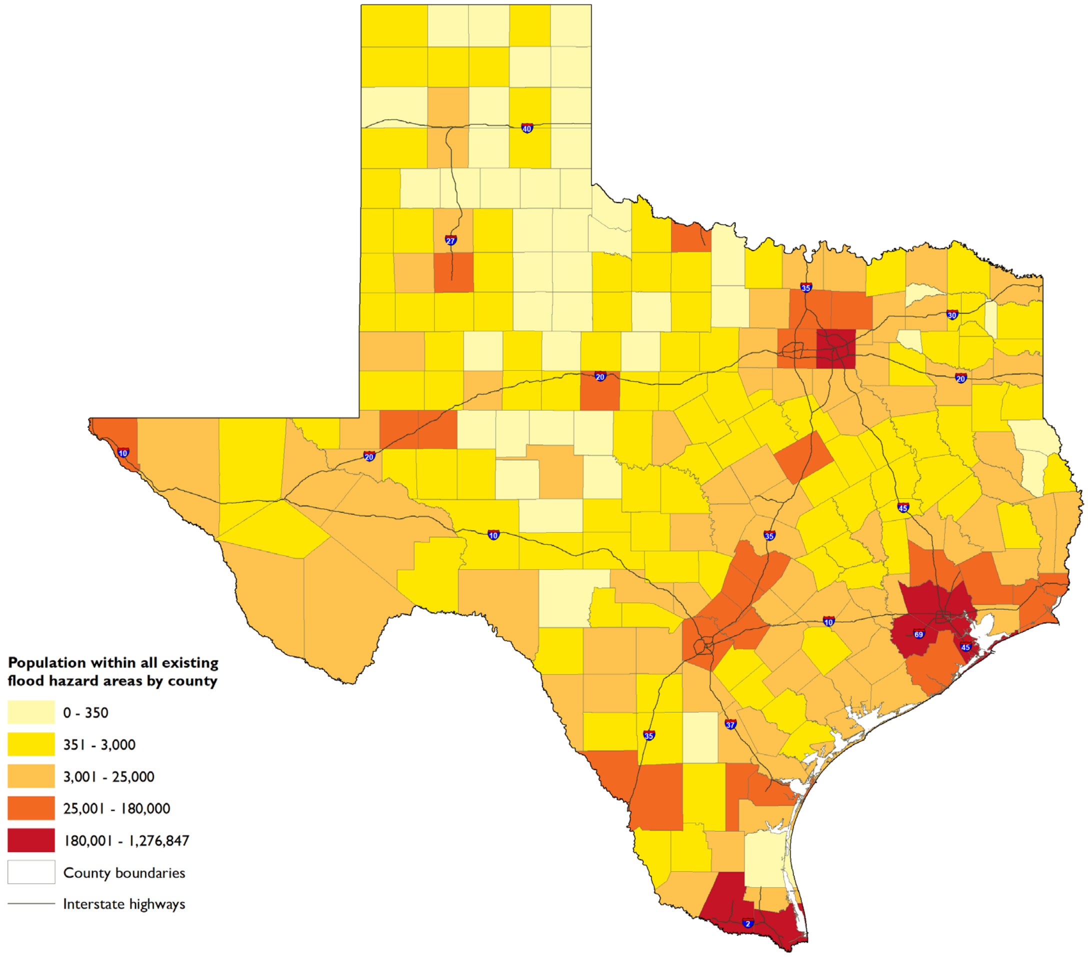


Figure 4-6. Populations within existing flood hazard areas by county



All buildings

The existing flood exposure analyses identified an estimated 1,789,840 buildings within identified flood hazard areas, of which 878,098 were identified within the 1 percent (100-year) flood hazard area, an additional 786,132 within the 0.2 percent (500-year) flood hazard area, and 125,610 more within the flood prone area (Table 4-5, Figure 4-7, and Figure 4-8). Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown. A high number of agricultural buildings located in flood hazard areas throughout the state, including barns, livestock operations, and grain silos, etc.

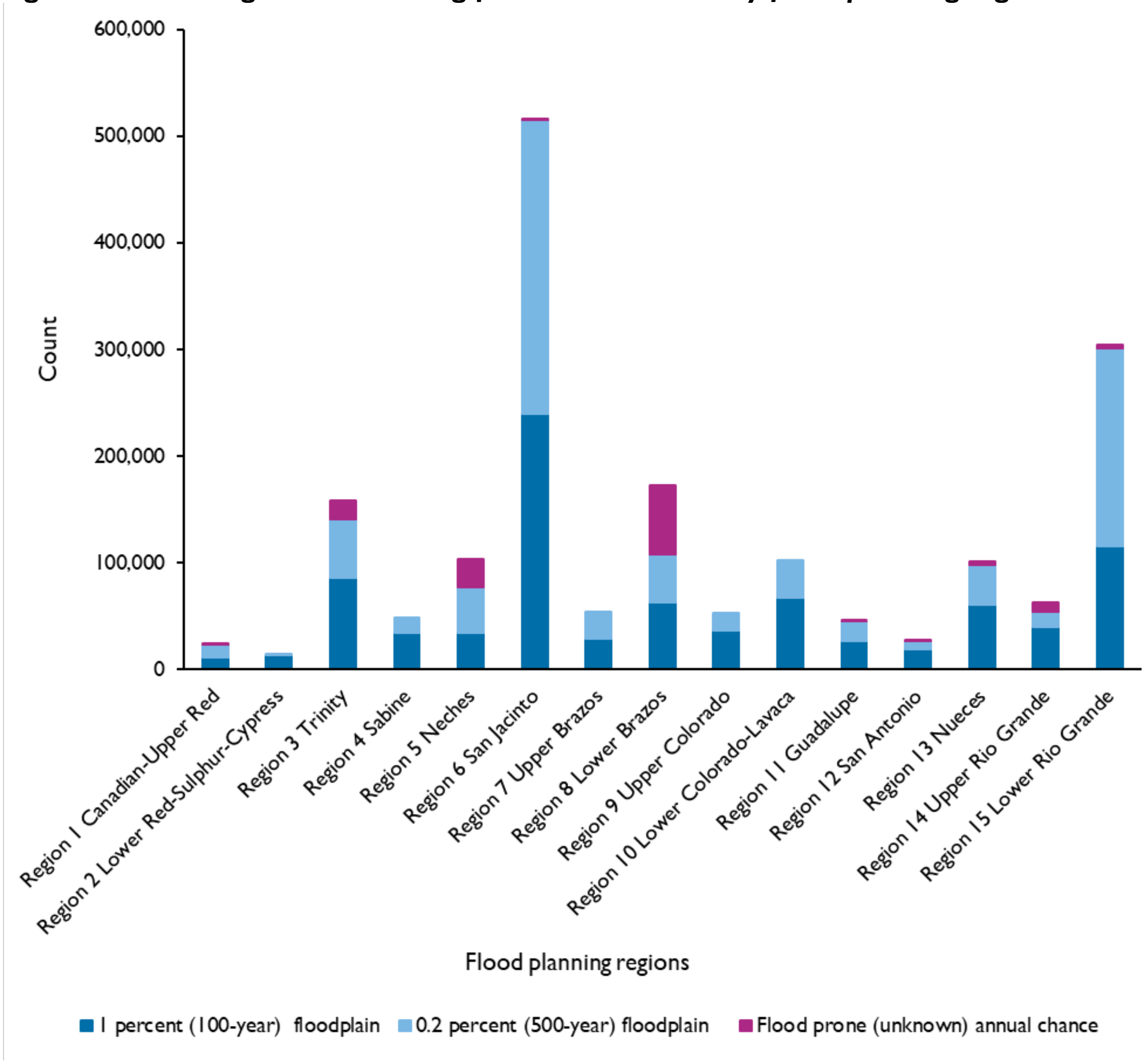
*Table 4-5. Buildings within existing flood hazard areas by flood planning region**

Region	Buildings within 1 percent (100-year) annual chance floodplain	Buildings within 0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance) buildings	Total
1	11,544	12,170	88	**23,802**
2	13,438	1,585		**15,023**
3	85,859	55,581	16,839	**158,279**
4	34,592	14,111		**48,703**
5	34,624	42,901	26,524	**104,049**
6	239,484	275,283	827	**515,594**
7	28,531	25,555		**54,086**
8	63,056	44,662	65,586	**173,304**
9	36,333	17,269		**53,602**
10	67,824	34,477		**102,301**
11	27,069	18,447	285	**45,801**
12	19,113	7,529	10	**26,652**
13	60,934	37,147	3,591	**101,672**
14	40,121	14,290	8426	**62,837**
15	115,576	185,125	3434	**304,135**
Total	**878,098**	**786,132**	**125,610**	**1,789,840**

Note: Blank cells do not always signify the absence of buildings within flood hazard areas; they may indicate that such buildings were not identified or reported by the regional flood planning groups.

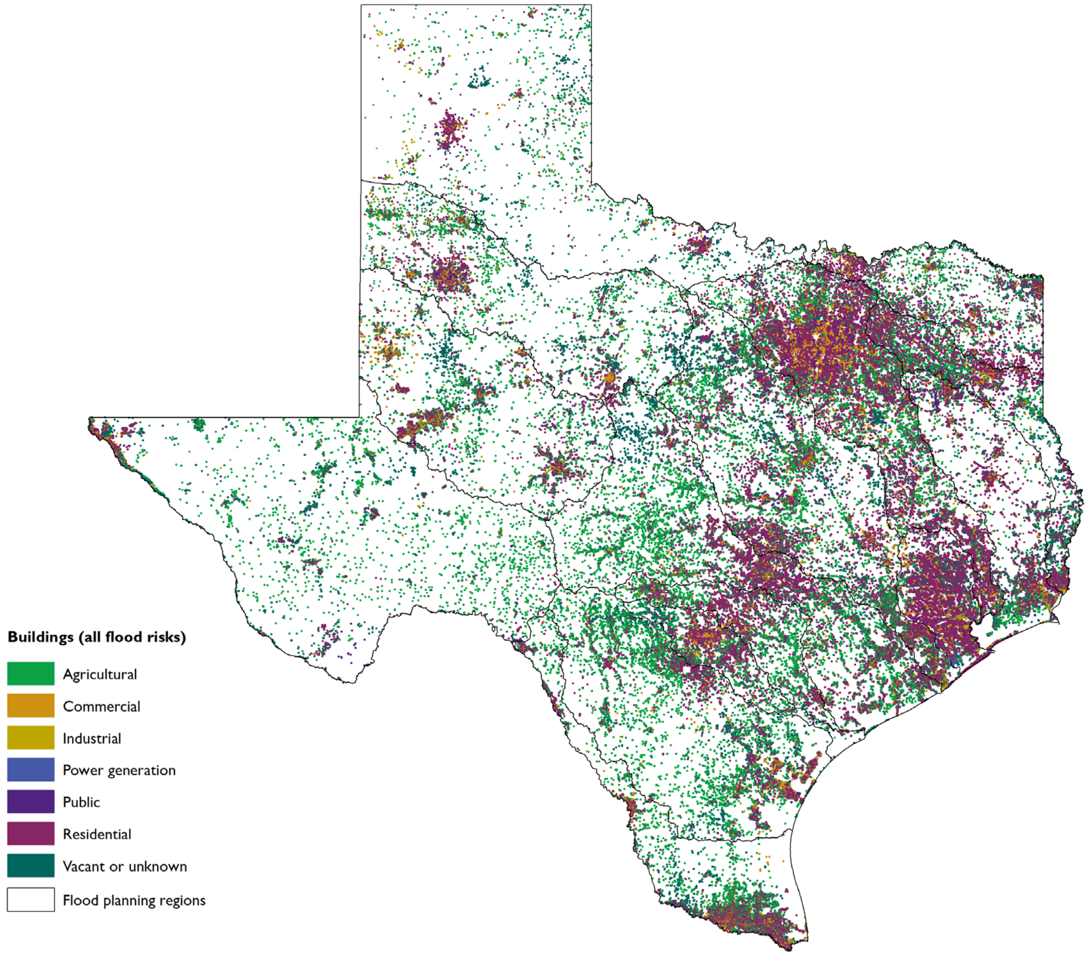
* *Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown*

Figure 4-7. Buildings within existing flood hazard areas by flood planning region*



* *Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown*

Figure 4-8. Locations of buildings and other resources within existing flood hazard areas



Residential buildings

Planning group analyses of existing flood exposure differentiated residential buildings from other types of structures within the 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas. The planning groups identified 662,107 residential buildings within the 1 percent, 633,563 additional residential buildings within the 0.2 percent, and 106,305 more in the flood prone areas (Table 4-6, Figure 4-9, and Figure 4-10).

Table 4-6. Residential buildings within existing flood hazard areas by flood planning region

Region	Residential buildings within 1 percent (100-year) annual chance floodplain	Residential buildings within 0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance) residential buildings	Total
1	6,885	8,622	61	**15,568**
2	8,069	1,012		**9,081**
3	72,930	36,454	12,636	**122,020**
4	24,066	10,773		**34,839**
5	25,145	35,176	21,563	**81,884**
6	199,789	242,715	760	**443,264**
7	19,838	17,170		**37,008**
8	42,646	36,523	59,595	**138,764**
9	23,637	11,848		**35,485**
10	45,799	25,444		**71,243**
11	18,879	12,952	271	**32,102**
12	13,692	5,519	8	**19,219**
13	42,976	27,730	2,319	**73,025**
14	24,931	9,106	6168	**40,205**
15	92,825	152,519	2924	**248,268**
Total	**662,107**	**633,563**	**106,305**	**1,401,975**

Note: Blank cells do not always signify the absence of structures in the floodplain; they may indicate that such structures were not identified or reported by the regional flood planning groups.

Figure 4-9. Locations of residential buildings within existing flood hazard areas

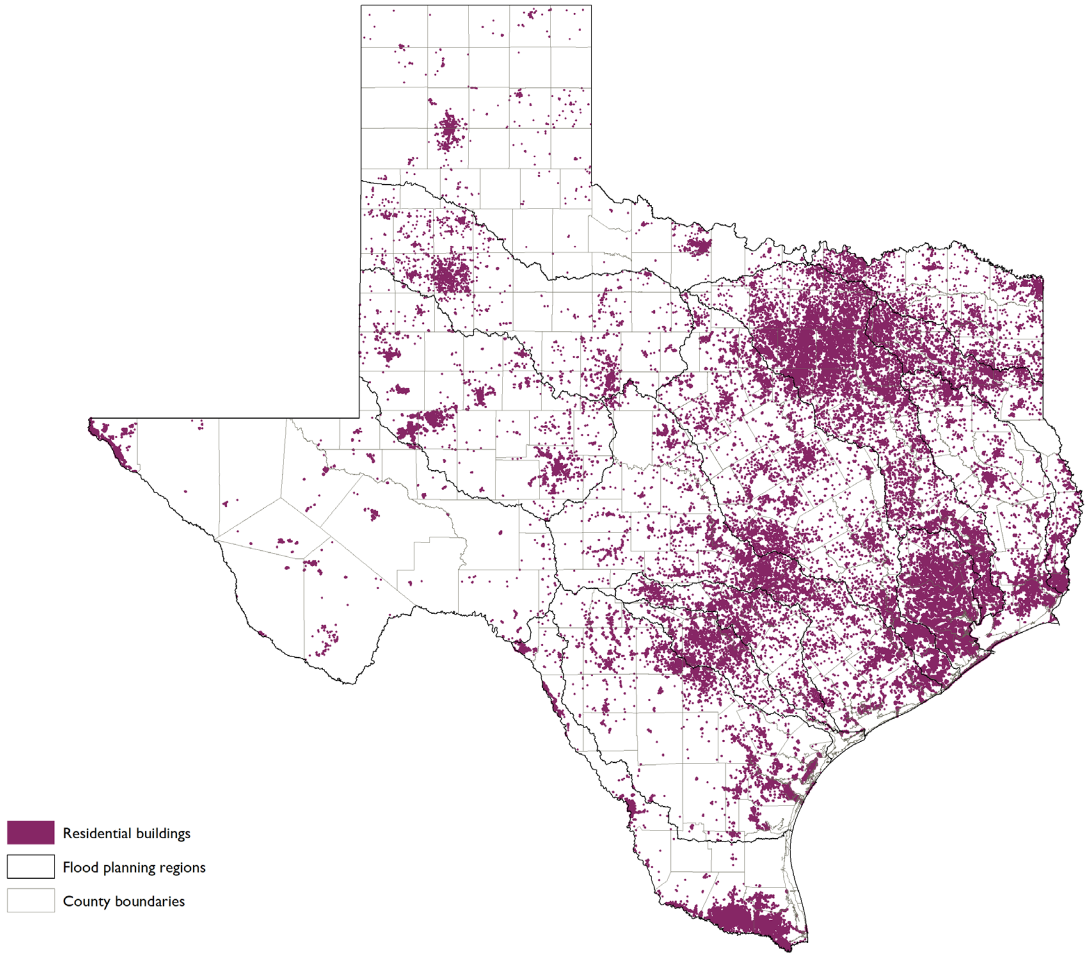
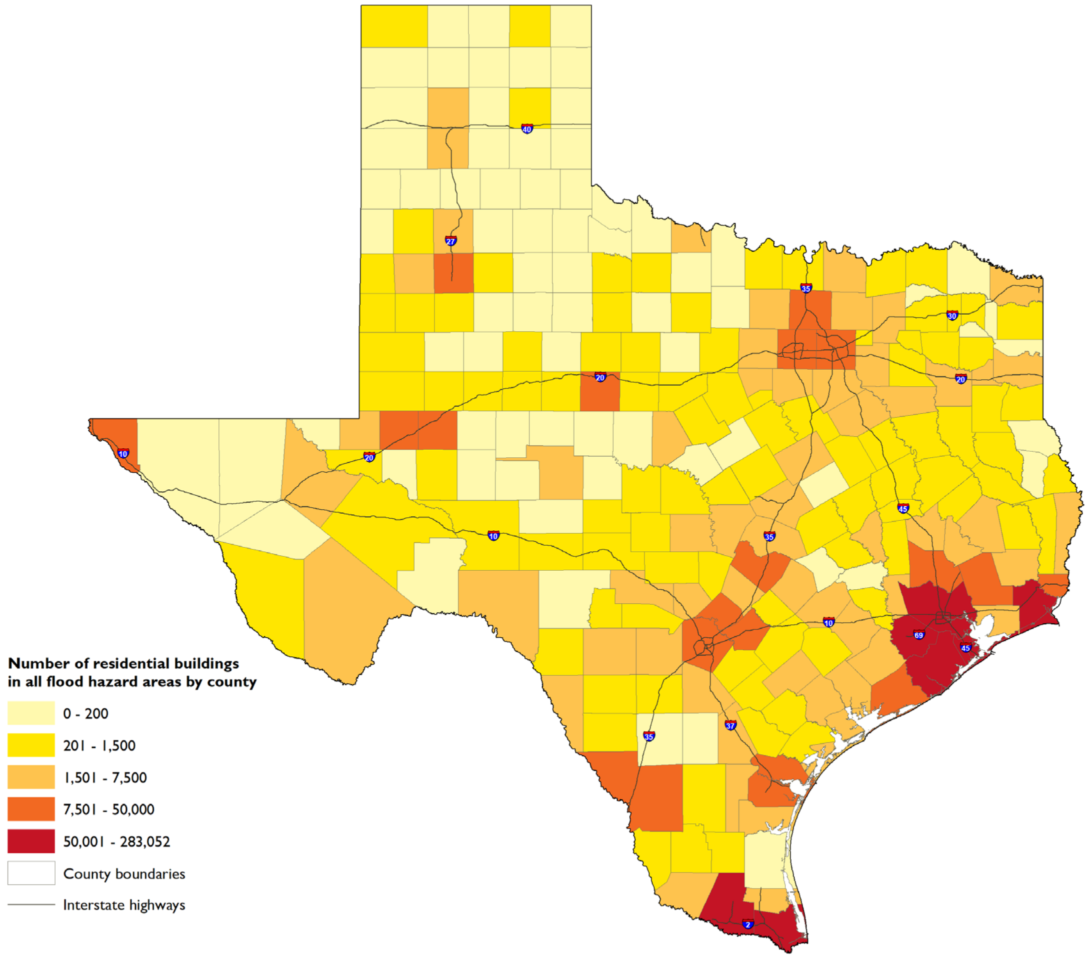


Figure 4-10. Number of residential buildings within all flood hazard areas by county.

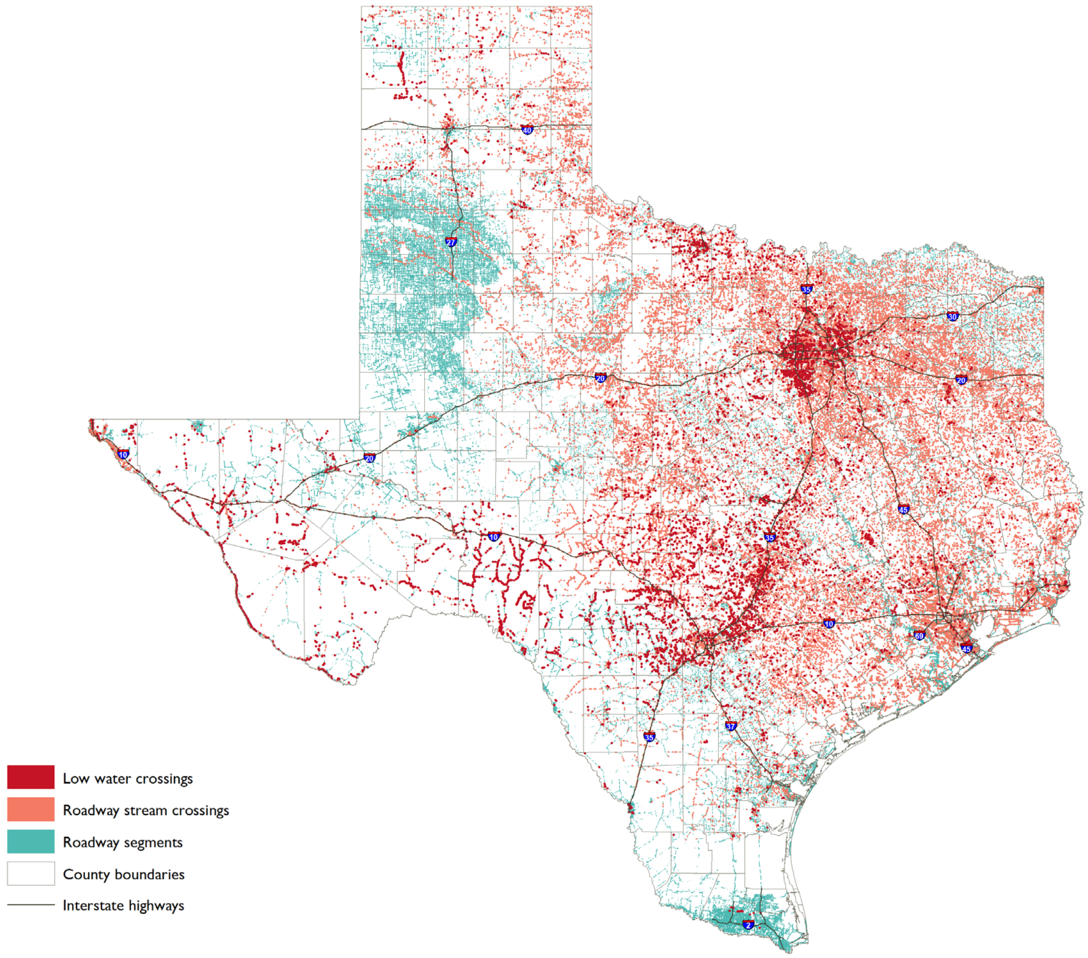


Roadways/transportation at flood risk

Approximately 70 percent of flood related fatalities occur on roadways (TXDOT 2024). Flooded roadways pose a direct threat to motorists, as demonstrated by the number of flood-related fatalities that have occurred when vehicles are driven into hazardous flood waters. And Texas consistently leads the nation in flood deaths and the majority of those deaths are in vehicles. Inundated roadways pose indirect threats to those attempting to escape from flooding, first responders, and flood victims trying to reach critical facilities. Many accidents, rescues, and deaths occur at low water crossings, and most occur at night. Determining the roadway crossings located in flood hazard areas required considering the water surface elevations during storm events and the deck elevation of the roadway crossing. The regional flood planning groups identified the number of low water crossings amongst all the roadway crossings in 1 percent (100-year) annual chance floodplains.

Some planning groups used roadway data from Texas Department of Transportation and other sources to assess the potential impacts on transportation infrastructure in their regions that could result from 1 percent or 0.2 percent (500-year) annual chance flood events. The Region 3 Trinity planning group used remote sensing, or LiDAR data, to determine bridge deck elevation and estimate flood exposure of road and railroad bridges at stream crossings. During the first planning cycle, most regional flood planning groups did not consider the deck elevation of the roadway crossing in determining whether it is in the flood hazard area. The results of the planning groups' analyses on roadways are presented in Figure 4-11.

Figure 4-11. Locations of roadways/transportation within existing flood hazard areas



- **Roadway stream crossings:** The planning groups identified each instance of roadway stream crossings, by intersecting the roadway layers with streams and flood hazard layers, and reported the roadway stream crossings within the 1 percent (100-year) annual chance floodplain, 0.2 percent (500-year) annual chance floodplain, and flood prone areas . The roadway stream crossings may or may not have been classified as low water crossings. A roadway stream crossing is any instance where a road crosses a stream, regardless of roadway elevation or structure type. This can include elevated bridges, box culverts, and traditional low water crossings. The flood planning groups identified 69,839 roadway crossings in the 1 percent annual chance floodplain, 7,669 in the 0.2 percent annual chance floodplain, and 1,012 in flood prone areas

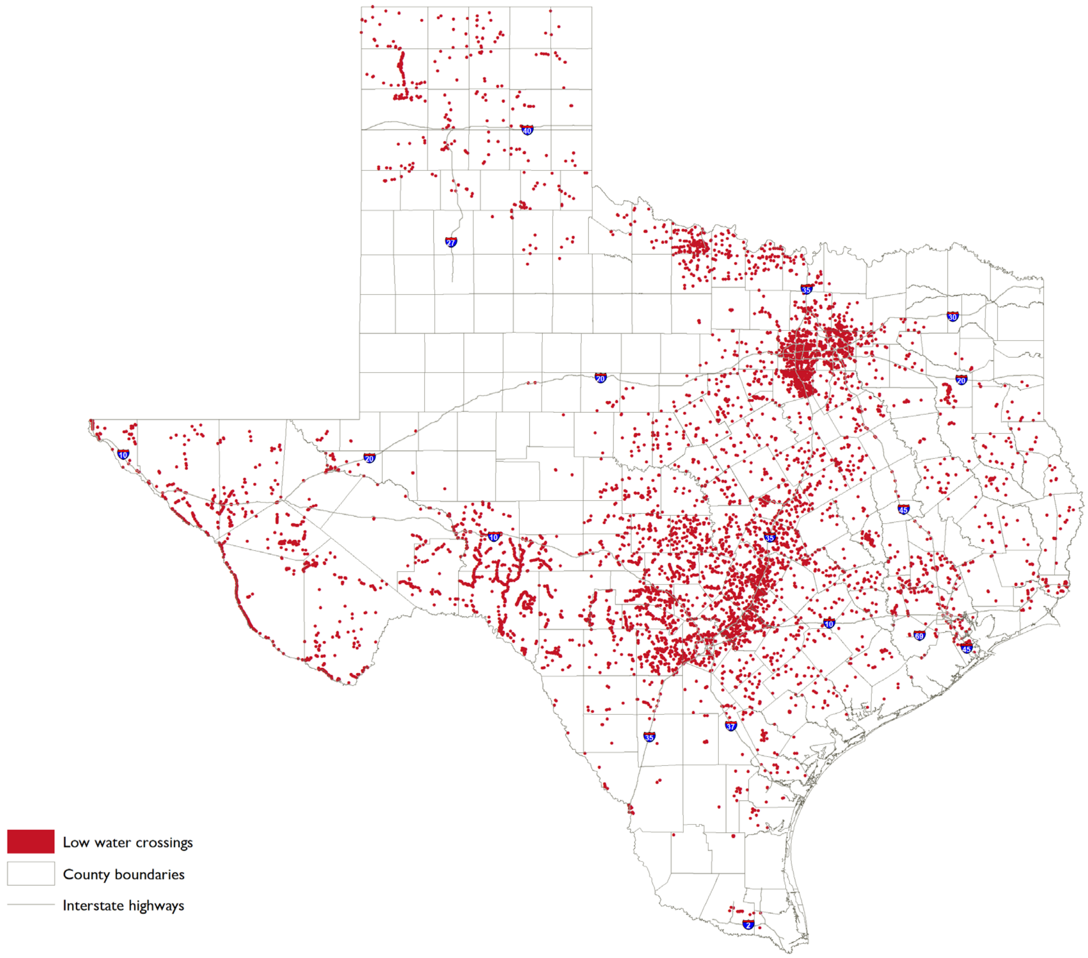
- **Low water crossings** are a subset of roadway stream crossings that are subject to frequent inundation during storm events or subject to inundation during a 50 percent (2-year) annual chance storm event. During the first planning cycle, the regional flood planning groups had the flexibility to utilize the community's discretion to identify a roadway stream crossing as a low water crossing. Low water crossings have elevations where water overtops the roadway frequently, making the roadway impassable even during smaller storm events. In the flood exposure analyses, a total of 9,322 low water crossings were identified by the regional flood planning groups that are in flood hazard areas. This number is lower than the 11,395 low water crossings identified by communities as existing flood infrastructure (Chapter 3). This may be due to some low waters crossing being located outside identified flood hazard areas. Of the 9,322 low water crossings, 8,810 were identified in the 1 percent (100-year) annual chance floodplain, an additional 333 in the 0.2 percent (500-year) annual chance floodplain, and 179 more in flood prone areas (Table 4-7, Figure 4-12).

Table 4-7. Low water crossings within flood hazard areas by flood planning region

Region	Low water crossings within 1 percent (100-year) annual chance floodplain	Low water crossings within 0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance) low water crossings	Total
1	569	54	164	**787**
2	114	2		**116**
3	1,626	110	1	**1,737**
4	107	6		**113**
5	165	8	10	**183**
6	221	6		**227**
7	284	8		**292**
8	915	29		**944**
9	243	12		**255**
10	1,109	23		**1,132**
11	636	25		**661**
12	430	11		**441**
13	503	23		**526**
14	1,764	14	4	**1,782**
15	124	2		**126**
Total	**8,810**	**333**	**179**	**9,322**

Note: Blank cells do not always signify the absence of low water crossings within flood hazard areas; they may indicate that such features were not identified or reported by the regional flood planning groups.

Figure 4-12. Locations of low water crossings within existing flood hazard areas



- **Roadway miles:** The planning groups identified 43,444 miles of roadways in the 1 percent (100-year) annual chance floodplain, 20,468 miles in the 0.2 percent (500-year) annual chance floodplain, and 1,856 miles of flood prone roadways (Table 4-8 and Figure 4-11). Identified roadways within flood hazard areas are represented in total miles rather than the number of specific locations where roadways intersect with streams.

Table 4-8. Roadway miles within existing flood hazard areas by flood planning region

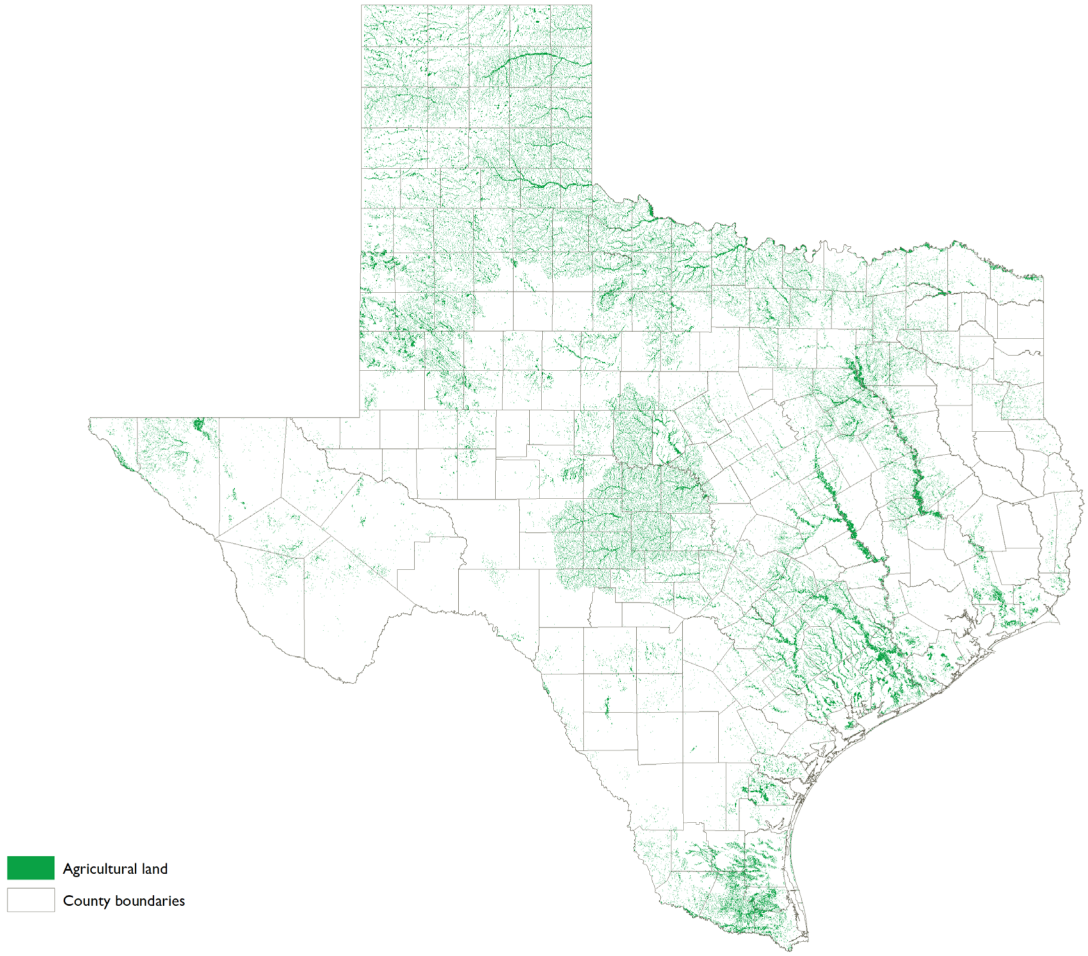
Region	Roadway miles within 1 percent (100-year) annual chance floodplain	Roadway miles within 0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance) roadway miles	Total
1	2,299	1,042	8	**3,350**
2	1,924	139		**2,063**
3	3,945	1,936		**5,881**
4	1,518	378		**1,897**
5	1,505	949	615	**3,069**
6	4,350	3,635	13	**7,998**
7	5,944	3,597		**9,541**
8	3,302	1,130	850	**5,281**
9	4,338	1,177		**5,516**
10	2,374	911		**3,285**
11	935	438	6	**1,379**
12	753	214	1	**969**
13	3215	1579	90	**4,883**
14	3047	746	178	**3,970**
15	3995	2596	94	**6,686**
Total	**43,444**	**20,468**	**1,856**	**65,768**

Note: Blank cells do not always signify the absence of roadways within flood hazard areas; they may indicate that such roadways were not identified or reported by the regional flood planning groups.

Agricultural areas

While a natural phenomenon which can benefit land fertility, flooding of cultivated farmland can have significant negative impacts to agricultural production and rural economies. The planning groups identified 10,200,323 acres of working agricultural area within the 1 percent (100-year) annual chance floodplain, an additional 2,453,832 acres within the 0.2 percent (500-year) annual chance floodplain, and 51,695 acres more within flood prone agriculture lands (Figure 4-13).

Figure 4-13. Locations of agricultural land within existing flood hazard areas



4.1.4 Existing condition vulnerability

Following the analysis of existing flood exposure, the regional flood planning groups identified the populations and structures within existing flood hazard areas to determine their vulnerability to flooding. This task required identifying the critical infrastructure in each region during the flood exposure analysis and computing the U.S Centers for Disease Control and Prevention **Social Vulnerability Index** value for each structure identified.

The planning groups were also required to determine the resilience of communities located in the flood prone areas.

Vulnerability and resilience are opposite sides of a coin. FEMA's definitions may be helpful:

- ***Vulnerability*** is susceptibility to physical injury, harm, damage, or economic loss. It depends on an asset's construction, contents, and economic value of its functions (FEMA, n.d.).
- ***Resilience*** is the capacity of individuals, communities, businesses, institutions, and governments to adapt to changing conditions and to prepare for, withstand, and rapidly recover from disruptions to everyday life, such as hazard events (FEMA, 2017).

Critical facilities

The flood planning groups identified 6,153 critical facilities located in the 1 percent (100-year) annual chance floodplain, 8,252 facilities in the 0.2 percent (500-year) annual chance floodplain, and an additional 693 facilities within flood prone areas (Table 4-9, Figure 4-14).

Critical facilities provide valuable services and functions essential to a community, especially during and following a disaster. The State of Texas defines critical infrastructure as "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." According to FEMA, "a critical facility should not be located in a floodplain if at all possible. If a critical facility must be located in a floodplain it should be provided a higher level of protection so that it can continue to function and provide services after the flood (FEMA, 2020)."

While the planning groups were given some flexibility in designating critical facilities in their regions, they generally identified the locations of hospitals, schools (K through 12), schools for children with special needs, fire stations, police stations, emergency shelters, water and wastewater treatment plants, power generating facilities, power facilities, assisted living facilities, and nursing homes. Of the total 15,098 critical facilities, 6,659 of these were identified as hospitals, emergency medical services, fire stations, police stations, and schools located within existing flood hazard areas (Figure 4-15).

Table 4-9. Critical facilities in existing flood hazard areas by flood planning region*

Region	Critical facilities within 1 percent (100-year) annual chance floodplain	Critical facilities within 0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance) critical facilities	Total
1	160	128		**288**
2	147	3		**150**
3	342	474	165	**981**
4	420	77		**497**
5	479	1,603	291	**2,373**
6	3,185	4,552	5	**7,742**
7	45	64		**109**
8	189	136	171	**496**
9	40	57		**97**
10	99	59		**158**
11	136	89		**225**
12	203	31		**234**
13	445	461	32	**938**
14	95	41	23	**159**
15	168	477	6	**651**
Total	**6,153**	**8,252**	**693**	**15,098**

Note: Blank cells do not always signify the absence of critical facilities within flood hazard areas; they may indicate that such critical facilities were not identified or reported by the regional flood planning groups.

* *Critical facilities include hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plants*

Figure 4-14. Locations of critical facilities within existing flood hazard areas

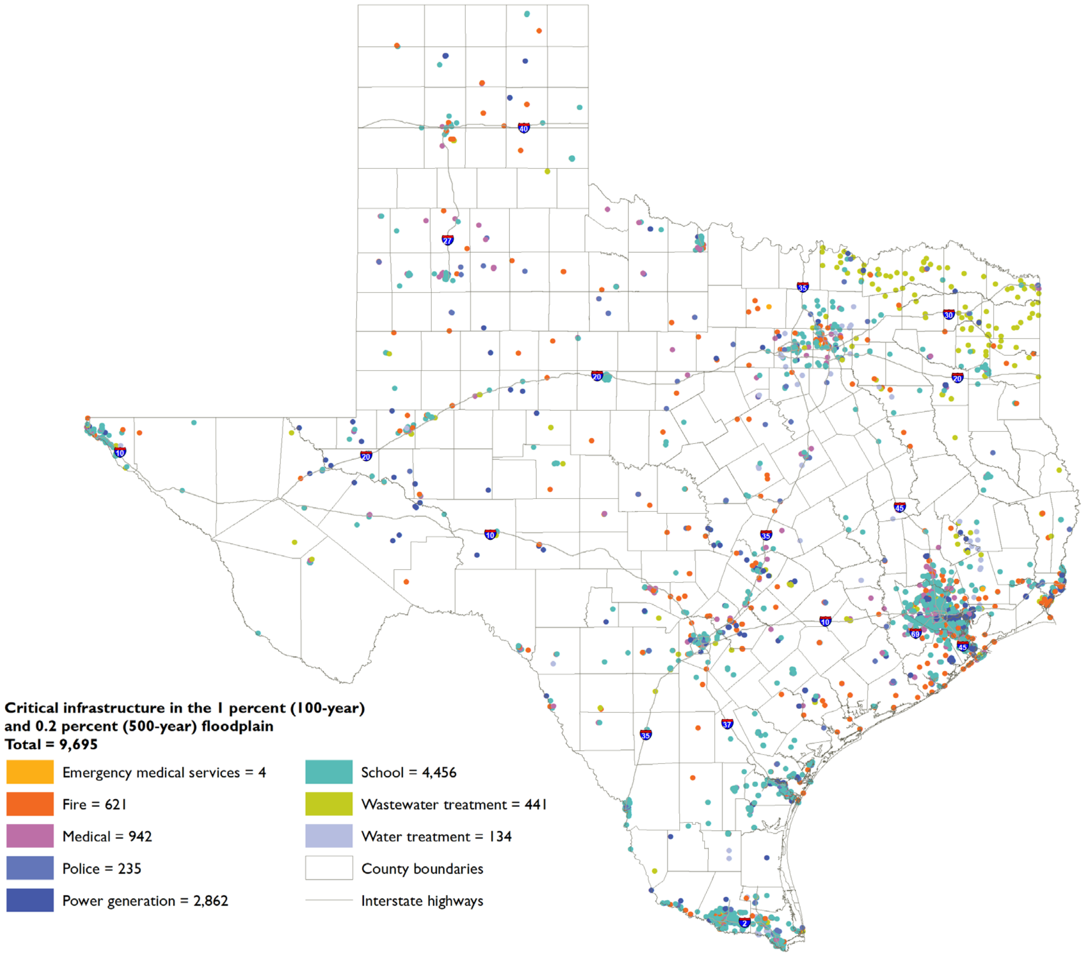
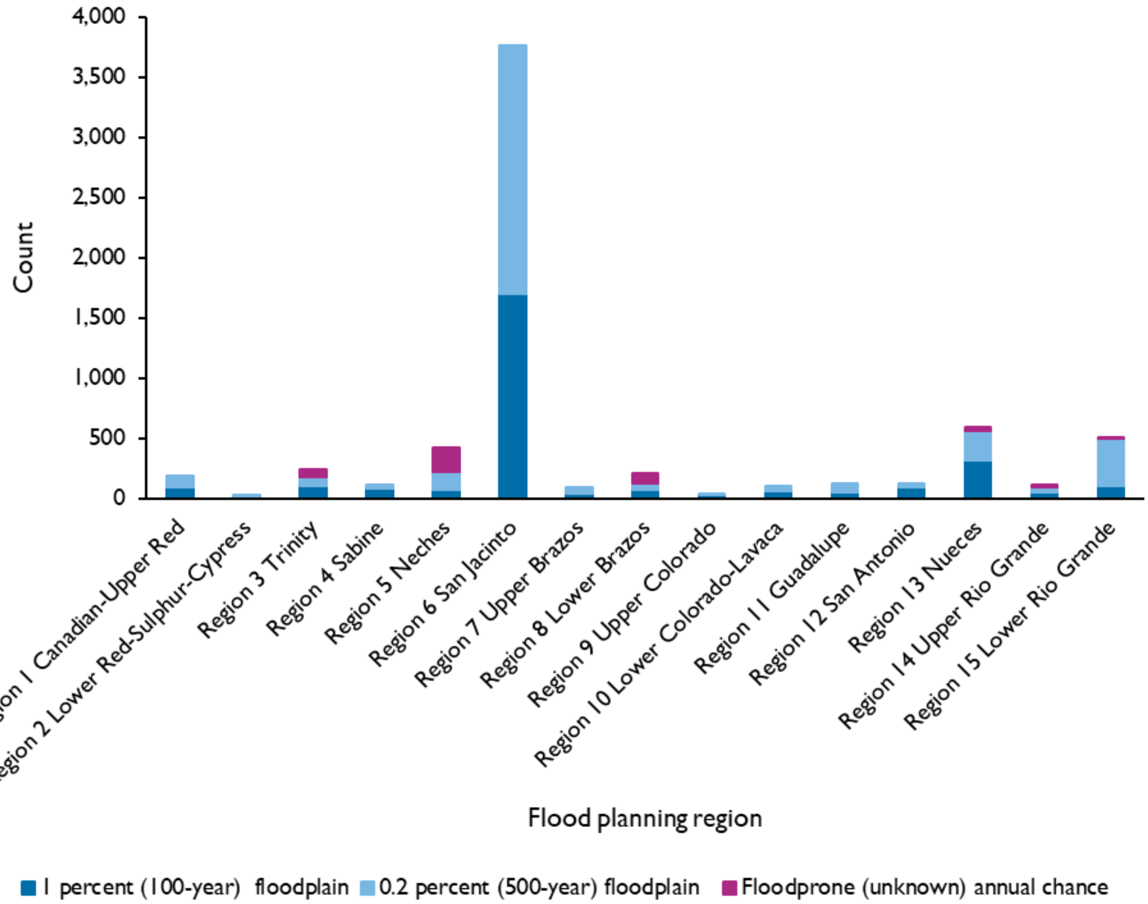


Figure 4-15. Count of hospitals, emergency medical services, fire stations, police stations, and schools within existing flood hazard areas



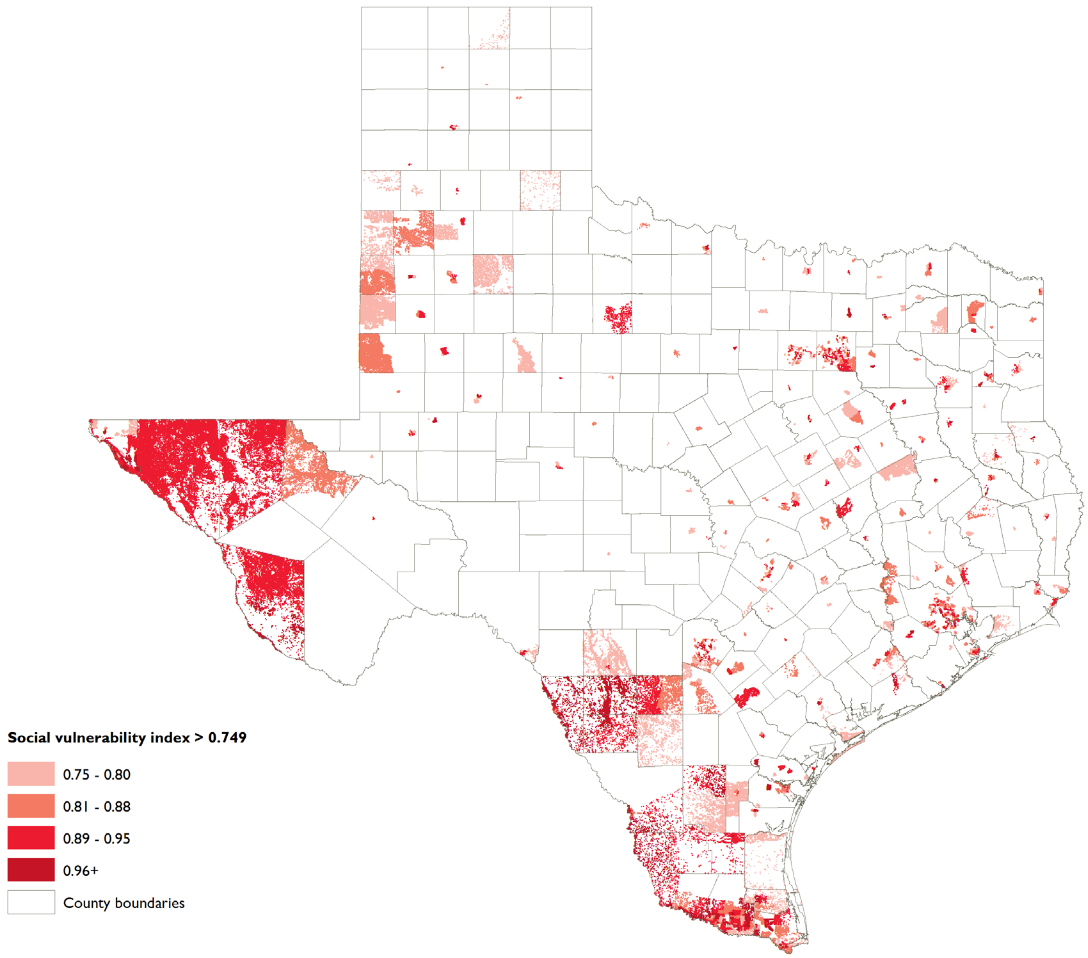
Communities

The U.S Centers for Disease Control and Prevention (CDC) uses a social vulnerability index as a means of helping local officials identify communities that may need the most support before, during, or after disasters (ATSDR, 2023). The CDC calculates the Social Vulnerability Index at the census tract level (roughly 4,000 people each) using 16 U.S. census variables grouped into four related themes, including socioeconomic status, household composition, race/ethnicity/language, and housing/transportation (CDC, n.d.). These social factors help estimate the degree to which one's life and livelihood are at risk from flood and other events (Mah and others 2023). The CDC's Social Vulnerability Index was employed as a reasonable proxy for community resilience during this first regional flood planning cycle.

Note that the TWDB has funded research to develop a social vulnerability index specifically related to the vulnerability of Texas communities facing flood hazards and anticipates making it available for the second cycle of regional flood planning.

The higher the social vulnerability index, the greater the vulnerability; the lower the social vulnerability index, the greater the resilience. The statewide average (calculated by census tract) social vulnerability index to all hazards is 0.48 on a scale of 0 to 1, with 0 being the lowest vulnerability and 1 being the highest. The TWDB considered a threshold of 0.75 to be a reasonable indicator for highly vulnerable areas. Vulnerable populations are spread across the state, with notably high densities in the west and south (Figure 4-16).

Figure 4-16. Locations of Texan communities within 1 percent (100-year) annual chance flood hazard areas and who are considered vulnerable



4.2 Future condition flood risk

Anticipating future flood risk is an essential component of comprehensive flood planning. As communities evolve, both in terms of population and infrastructure development, so can their susceptibility to potential flooding events. There is also an associated uncertainty regarding policy and development decisions that can impact future flood risk. For example, entirely limiting development within a high flood hazard area to avoid future flood risk as opposed to allowing some development within the floodplain may not only put the new development located in flood hazard areas but potentially increase the flood risk to downstream communities. With the added complexities of climate variability, shifting weather patterns, and increasing urbanization, it becomes imperative to not only understand the current flood risks but also to anticipate the challenges ahead.

To identify future condition flood hazards, the flood planning groups created scenarios based on projected increases in impervious cover, anticipated changes in relative sea level and/or land subsidence, anticipated sedimentation in flood control structures, and any other factors that may result in increased or altered flood hazards in the future. During the first planning cycle, the regional groups were limited to using the best available data and resources for their respective regions to determine future condition flood risk.

The planning groups were required to perform future condition flood risk analyses to determine the potential extent of both the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas looking ahead 30 years into the future (Figure 4-17). The future condition 1 percent (100-year) annual chance flood hazard area is projected to increase by 11 percent over the existing condition 1 percent (100-year) annual chance flood hazard area to an estimated total area of 62,245 square miles (Figure 4-18 and Figure 4-19). In addition to approximating the magnitude of potential future flood risk, these analyses are useful to better inform policy and long-term investment decisions:

1) Flood hazard analyses that determine location, magnitude, and frequency of flooding
2) Flood exposure analyses to identify who and what might be harmed within the region
3) Analyses to identify vulnerabilities of communities and critical facilities

4.2.1 Future condition flood hazard

The first step in determining the future extent of both the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas was to identify areas within each region where future condition hydrologic and hydraulic model results and maps were available. For areas where future condition flood hazard data was not available, the TWDB provided four methods for performing future condition flood hazard analyses. The method selected depended on such factors as topography, growth types and rates, and development rates, and included the following:

1) Increasing water surface elevation based on projected percentage population increase (as proxy for development of land areas)
2) Utilizing the existing condition 0.2 percent (500-year) annual chance floodplain as a proxy for the future 1 percent (100-year) level
3) A combination of methods 1 and 2 or another method proposed by the planning group
4) Planning groups could request that the TWDB perform a desktop analysis

Each of the 15 regional flood planning groups determined the most appropriate methodology for performing future condition flood hazard identification for its region. A summary of each region's approach is provided below (Table 4-10). A full summary of each region's methodology is provided in Appendix A.

Figure 4-17. Future condition flood hazard areas

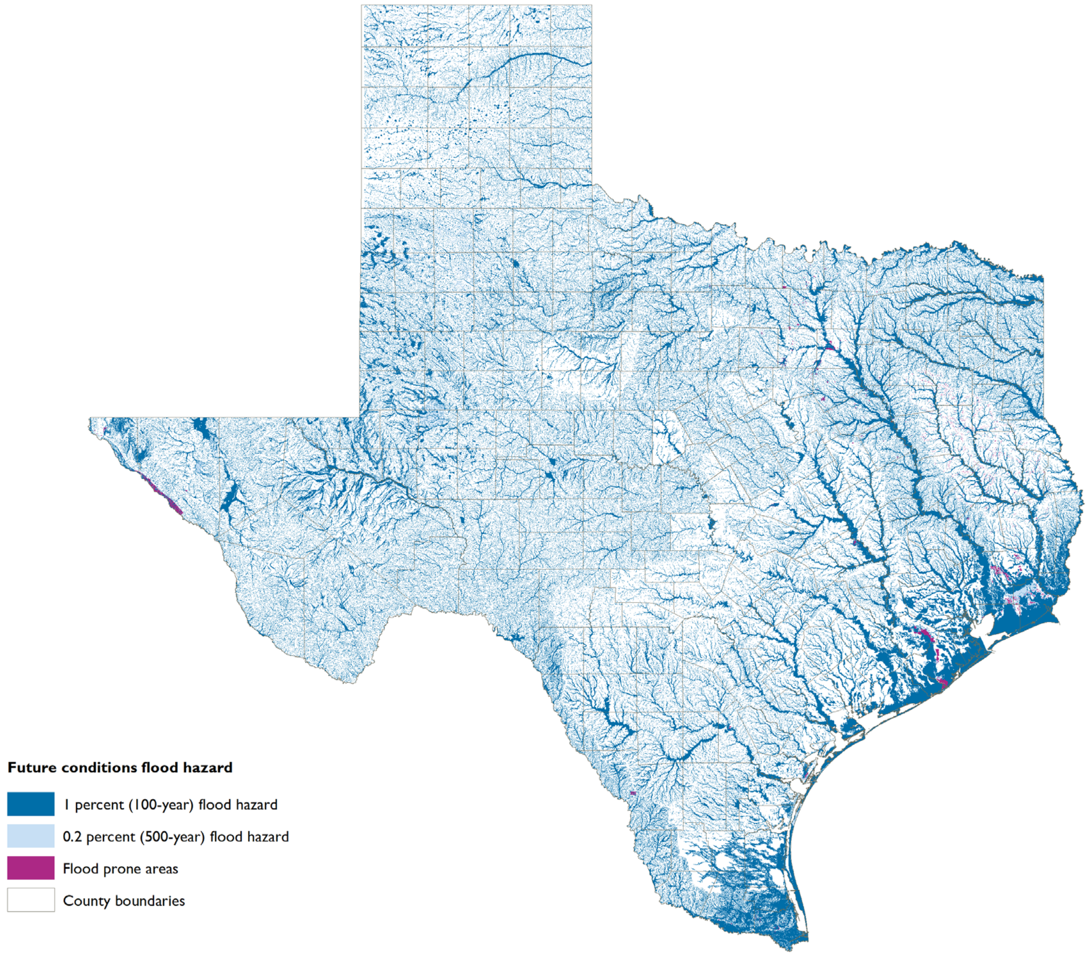
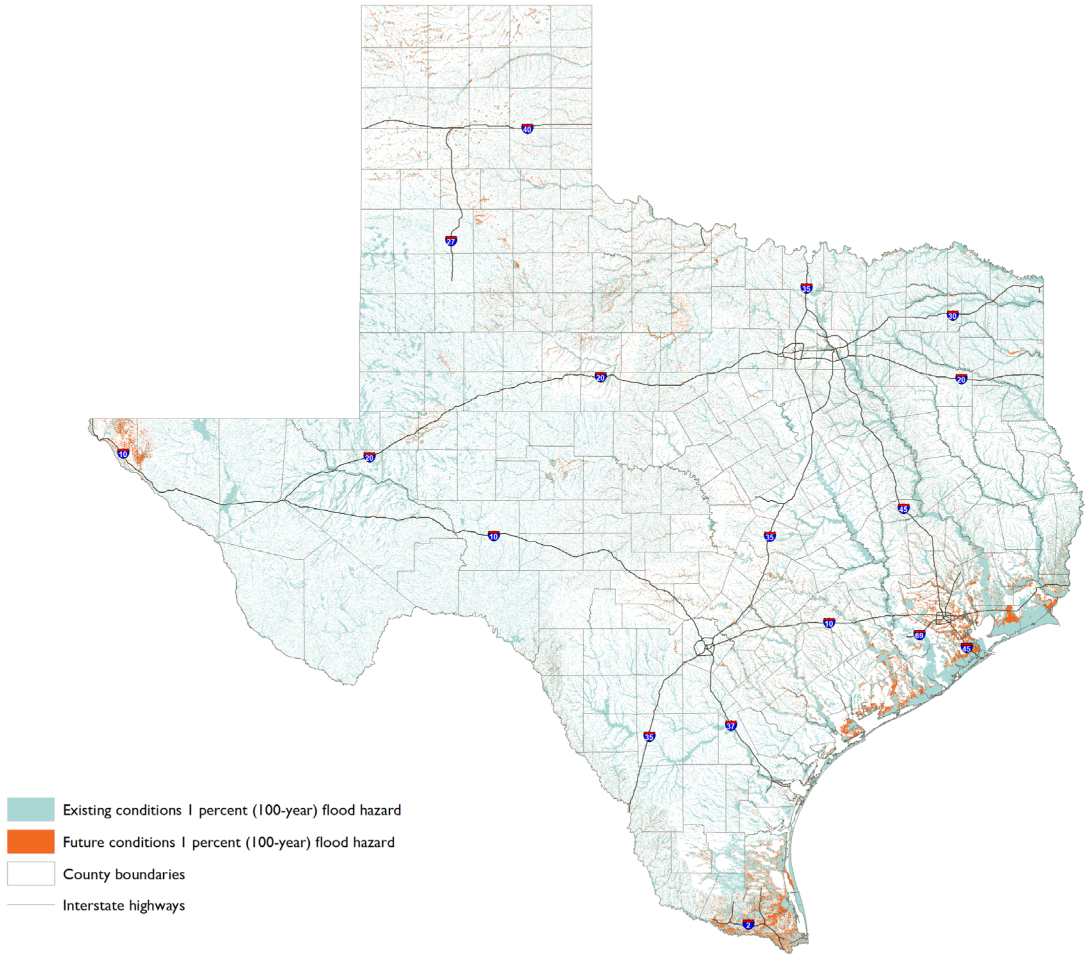
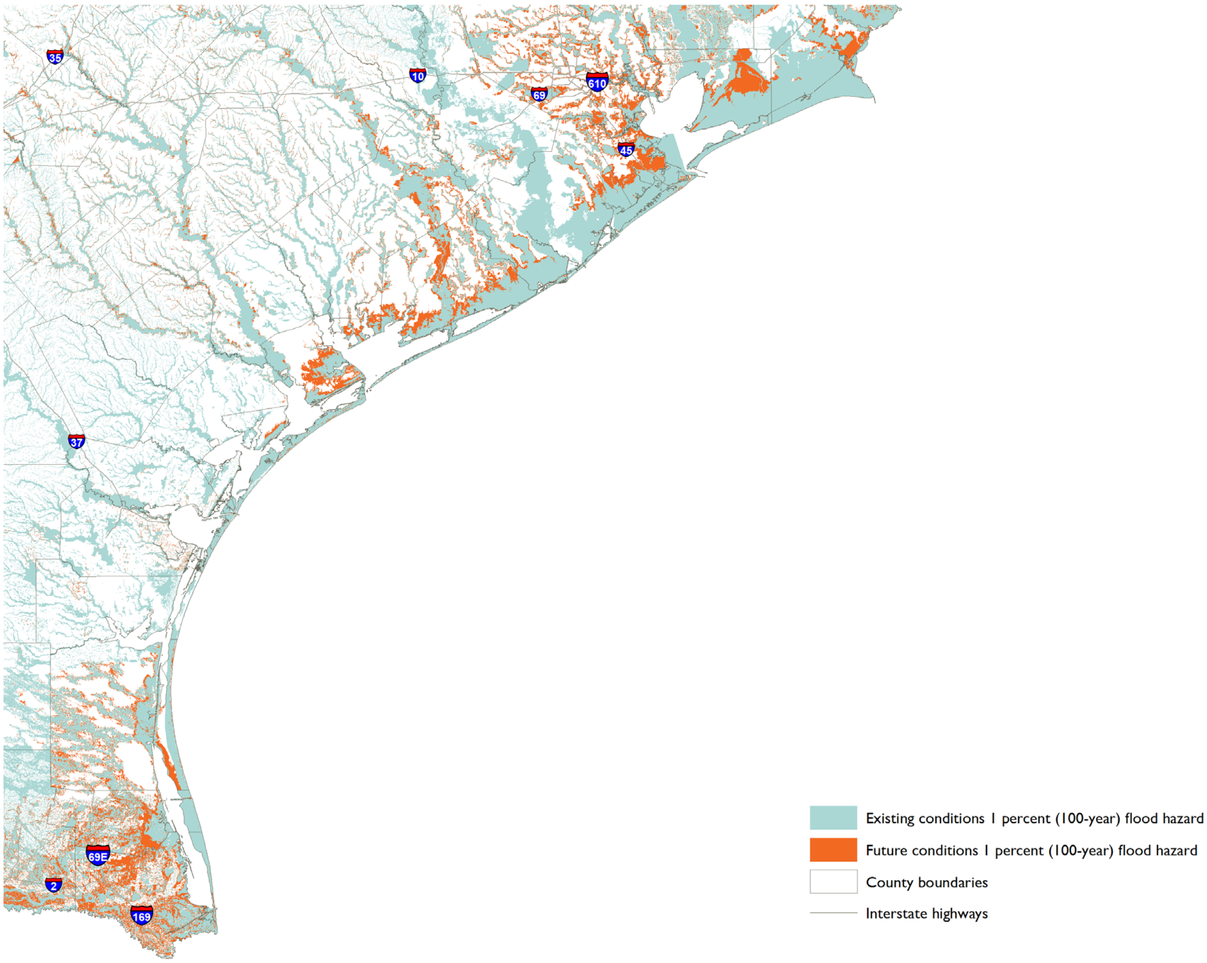


Figure 4-18. Comparison of existing and future conditions 1 percent (100-year) annual chance flood hazard area*



* *Extent of the projected future conditions 1 percent (100-year) annual chance flood hazard area includes the existing conditions 1 percent (100-year) annual chance flood hazard area.*

Figure 4-19. Comparison of existing and future conditions 1 percent (100-year) annual chance flood hazard area along the Texas Coast*



[*] *Extent of the projected future conditions 1 percent (100-year) annual chance flood hazard area includes the existing conditions 1 percent (100-year) annual chance flood hazard area.*

Table 4-10. Summary of future condition flood hazard analyses by region

Region	Method 1	Method 2	Method 3	Method 4
1		X		
2		X		
3		X		
4		X		
5			X	
6			X	
7			X	
8		X		
9		X		
10		X		
11		X		
12		X		
13			X	
14			X	
15		X		

Future condition flood hazard data gaps

The regional flood planning groups were asked to identify areas lacking future inundation boundary mapping after performing their future condition flood hazard analyses. They identified areas with, for example, clearly outdated future modeling and/or mapping, absence of future modeling and/or mapping, and areas with future modeling and/or mapping that require updates. In performing their analyses, several of the groups found that the flood hazard mapping and data gaps in their region coincided for both existing and future condition flood hazard boundaries. In general, the available future flood hazard mapping information was associated with heavily urbanized areas.

4.2.2 Future condition flood exposure

After identifying areas of future flood hazard in their regions, the planning groups were required to perform flood hazard exposure analyses to determine who and what may be harmed in the future 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas (Table 4-11). The flood exposure analyses considered exposure of different types of development within flood hazard areas:

1) Population
2) Buildings, including residential and nonresidential
3) Critical facilities
4) Roadways, including the estimated number of roadway stream crossings, low water crossings, and the total length of roadway
5) Agricultural areas, including the total area of farms and ranches

Table 4-11. Summary of statewide future condition flood exposure

	1 percent (100-year) annual chance floodplain	0.2 percent (500-year) annual chance floodplain	Flood prone (unknown annual chance)	Total
Population	5,052,378	3,124,151	655,838	**8,832,367**
Buildings[a]	1,618,617	914,219	120,904	**2,653,740**
Residential buildings	1,298,772	750,754	110,260	**2,159,786**
Roadways stream crossings (incl low water crossings)	78,320	22,606	923	**101,849**
Roadway miles	59,190	27,564	1,506	**88,260**
Agricultural areas (acres)	12,011,680	3,903,956	24289	**15,939,925**
Critical facilities[b]	14,581	7,395	545	**22,521**
Hospitals, emergency medical services, fire stations, police stations, and schools	6,182	3,825	286	**10,293**

Note: All values are counts unless otherwise labeled

[a] Buildings include all residential, agricultural, commercial, industrial, public, and vacant or unknown
[b] Critical facilities include hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plants

Population

The planning groups were required to include daytime and nighttime population estimates located within the future 1 percent (100-year) annual chance flood hazard area, 0.2 percent (500-year) annual chance flood hazard area, and flood prone areas. The higher of the daytime or nighttime estimates computed at each county level was utilized in estimating the total population in flood hazard areas. The planning groups identified an estimated 5,052,378 people within the future 1 percent, 3,124,151 people within the future 0.2 percent, and 655,838 people within future flood prone areas (Table 4-12 and Figure 4-19).

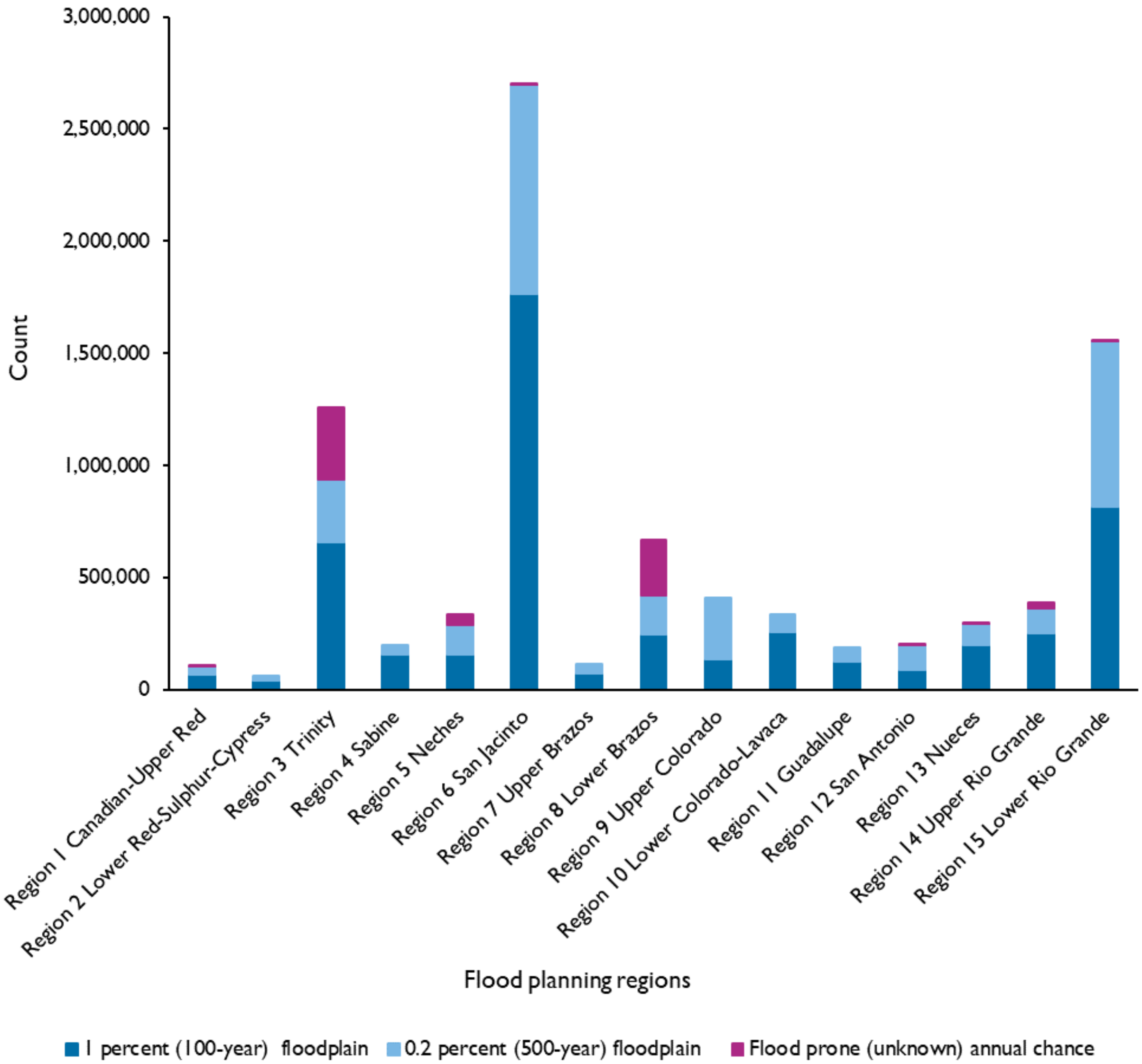
Table 4-12. Populations within future flood hazard areas by flood planning region*

Region	Population within future 1 percent (100-year) annual chance floodplain	Population within future 0.2 percent (500-year) annual chance floodplain	Future flood prone (unknown annual chance) population	Total
1	66,927	39,356	139	**106,422**
2	41,858	19,663		**61,521**
3	657,174	283,010	319,858	**1,260,042**
4	159,110	39,115		**198,225**
5	157,903	131,028	48,471	**337,402**
6	1,763,356	935,884	1,515	**2,700,755**
7	75,459	41,637		**117,096**
8	249,801	171,856	246,493	**668,150**
9	138,022	270,679		**408,701**
10	258,485	76,776		**335,261**
11	126,607	64,569		**191,176**
12	90,379	107,296	26	**197,701**
13	198,921	94,370	8,715	**302,006**
14	253,678	110,302	25,760	**389,740**
15	814,698	738,610	4,861	**1,558,169**
Total	**5,052,378**	**3,124,151**	**655,838**	**8,832,367**

Note: Blank cells do not always signify the absence of populations within flood hazard areas; they may indicate that such populations were not identified or reported by the regional flood planning groups

* *Values represent the maximum daytime or nighttime population provided by the regional flood planning groups*

Figure 4-20. Populations within future flood hazard areas by flood planning region



Buildings

Through their future condition flood exposure analyses, the planning groups identified 1,618,617 buildings within the future 1 percent (100-year), 914,219 structures within the future 0.2 percent (500-year) annual chance flood hazard areas, and 120,904 buildings in future flood prone areas (Table 4-13, Figure 4-21, Figure 4-22). Buildings include all structures classified as residential, commercial, agricultural, industrial, public, or other. There appears to be a large number of agricultural buildings located in the flood hazard areas throughout Texas. These buildings include barns, livestock operations, and grain silos, etc.

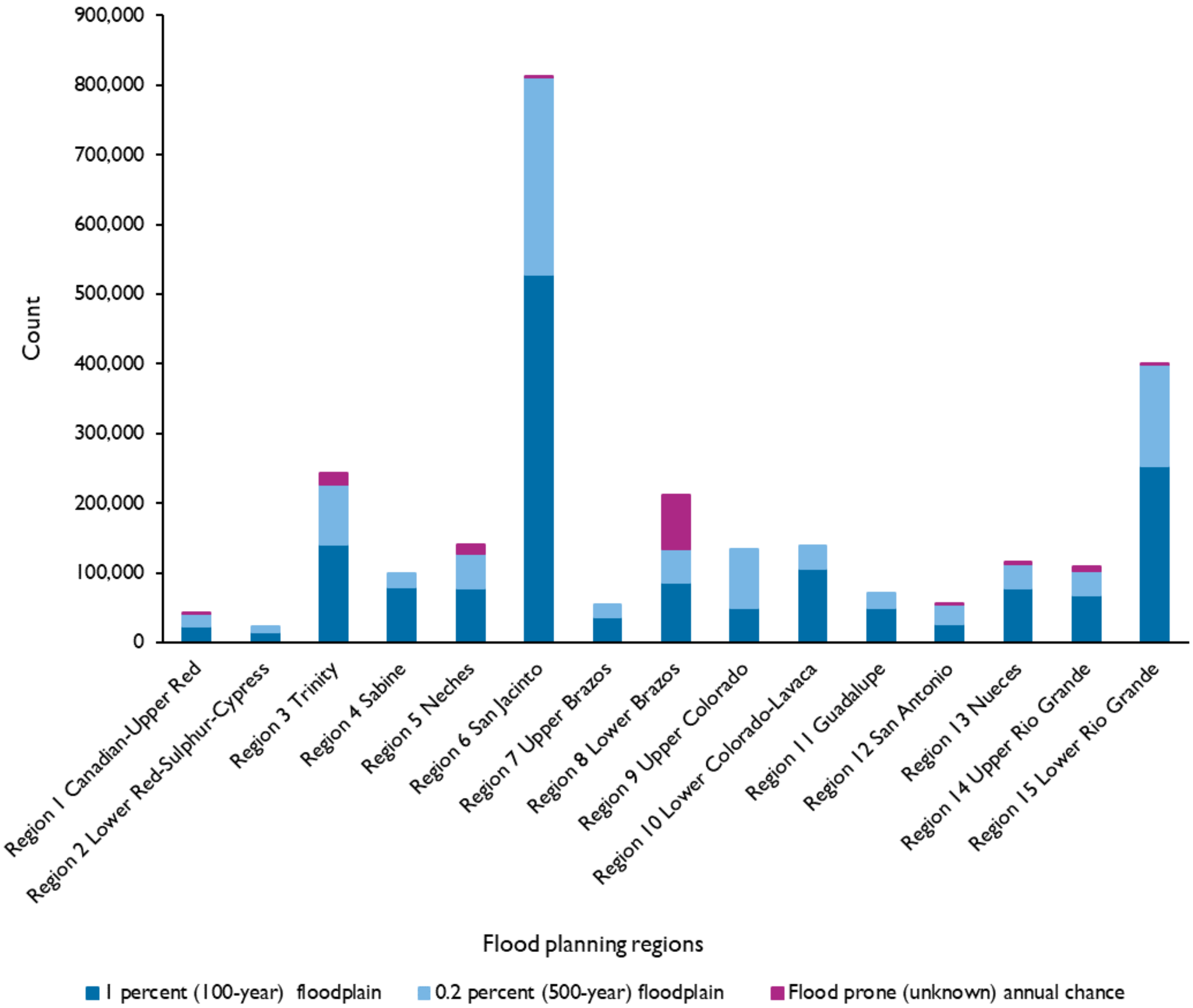
Table 4-13. Buildings within future flood hazard areas by flood planning region*

Region	Buildings within future 1 percent (100-year) annual chance floodplain	Buildings within future 0.2 percent (500-year) annual chance floodplain	Future flood prone (unknown annual chance) buildings	Total
1	23,718	17,480	78	**41,276**
2	15,023	8,601		**23,624**
3	141,440	85,410	16,839	**243,689**
4	79,674	19,576		**99,250**
5	77,317	50,382	13,333	**141,032**
6	528,442	283,258	479	**812,179**
7	35,955	18,131		**54,086**
8	85,738	48,481	78,326	**212,545**
9	49,218	84,697		**133,915**
10	106,636	32,648		**139,284**
11	49,736	21,765		**71,501**
12	26,642	28,830	10	**55,482**
13	77,821	34,551	3,423	**115,795**
14	67,134	35,167	6992	**109,293**
15	254,123	145,242	1424	**400,789**
Total	**1,618,617**	**914,219**	**120,904**	**2,653,740**

Note: Blank cells do not always signify the absence of buildings within flood hazard areas; they may indicate that such buildings were not identified or reported by the regional flood planning groups

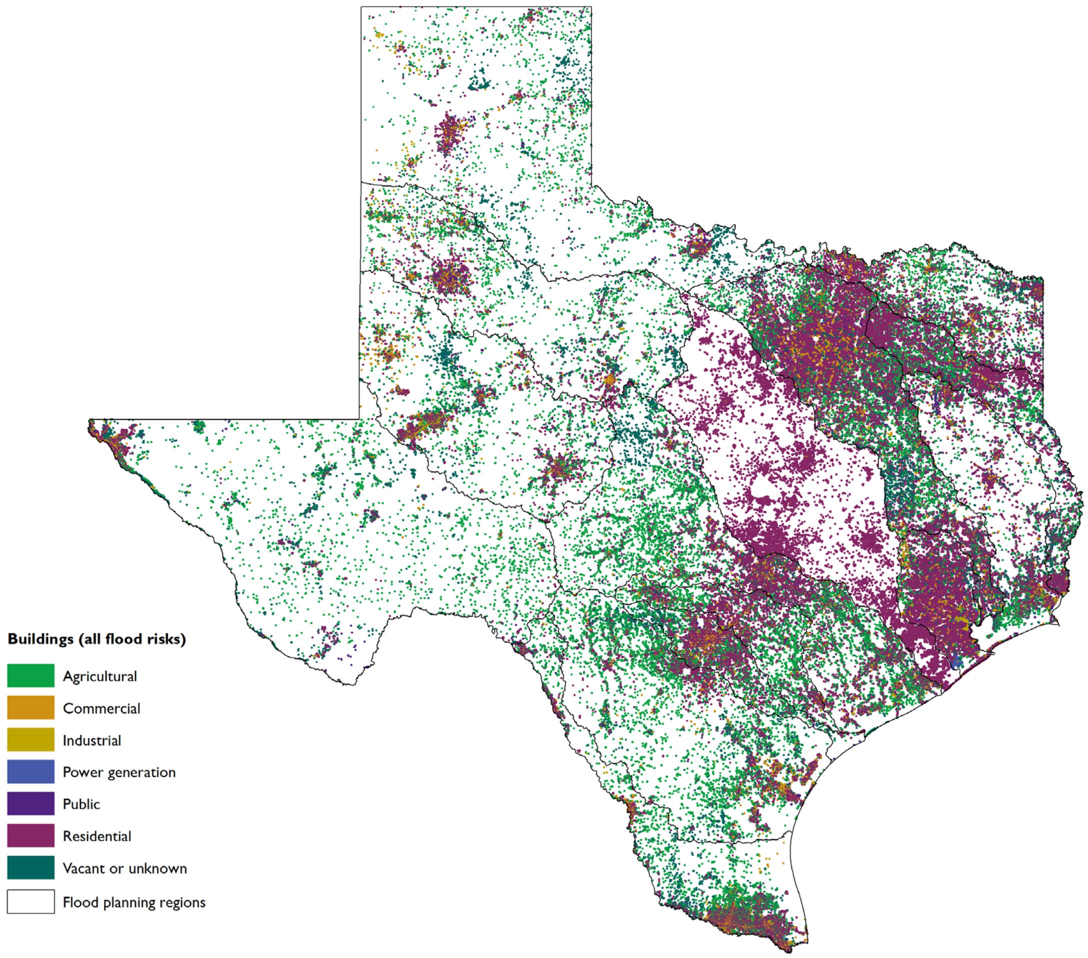
* *Includes all residential, agricultural, commercial, industrial, public, and vacant or unknown*

Figure 4-21. Buildings within future flood hazard areas by flood planning region*



* *Includes all residential, agricultural, commercial, industrial, public, and vacant or unknown*

Figure 4-22. Locations of buildings by type within future flood hazard areas



Residential structures

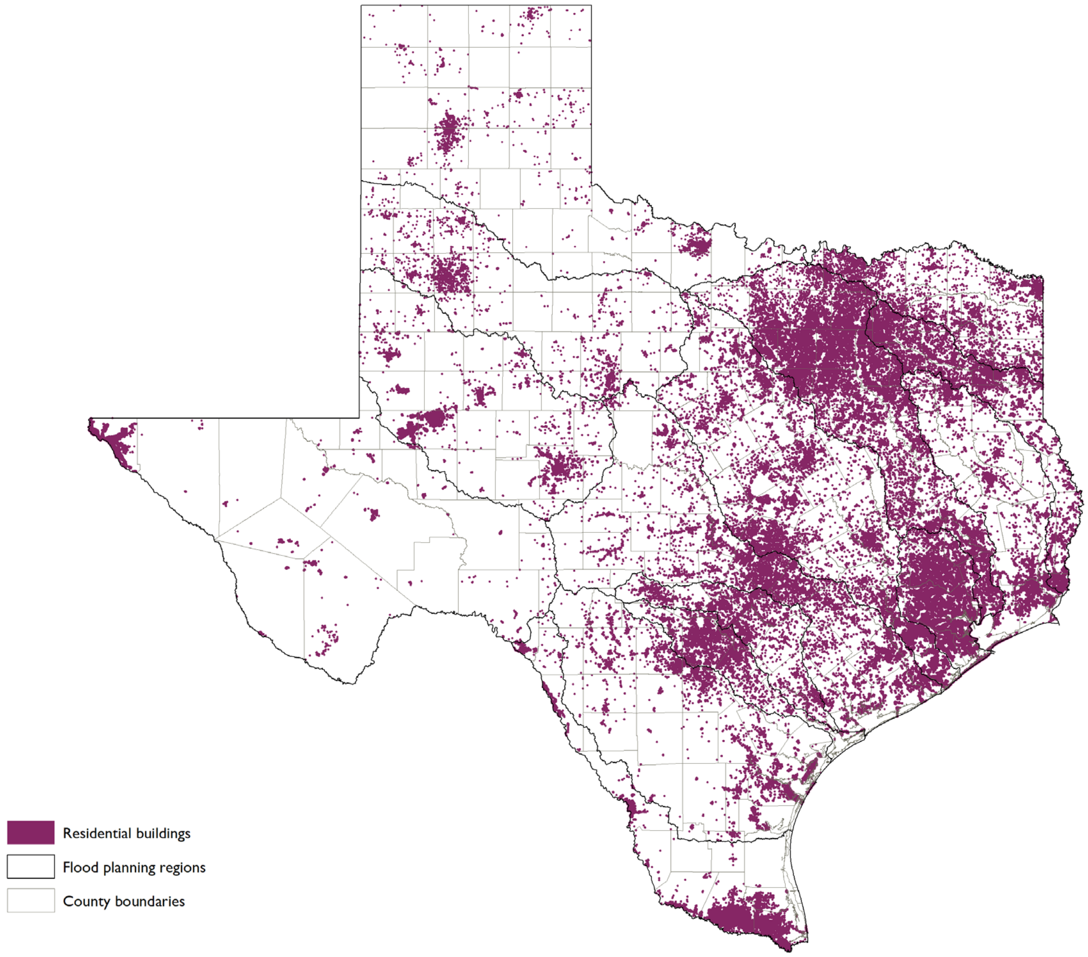
The planning groups identified 1,298,772 residential structures within the future 1 percent (100-year), 750,754 residential structures within the future 0.2 percent (500-year) annual chance flood hazard areas, and 110,260 residential structures in future flood prone areas (Table 4-14, Figure 4-23).

Table 4-14. Residential structures within future flood hazard areas by flood planning region

Region	Residential buildings within future 1 percent (100-year) annual chance floodplain	Residential buildings within future 0.2 percent (500-year) annual chance floodplain	Future flood prone (unknown annual chance) residential buildings	Total
1	15,536	10,820	53	**26,409**
2	9,081	5,740		**14,821**
3	109,384	70,067	12,636	**192,087**
4	65,689	15,050		**80,739**
5	60,167	40,357	10,245	**110,769**
6	454,237	249,918	447	**704,602**
7	24,646	12,362		**37,008**
8	85,629	48,395	78,249	**212,273**
9	33,105	62,990		**96,095**
10	74,045	24,136		**98,181**
11	36,035	16,981		**53,016**
12	19,211	23,627	8	**42,846**
13	57,037	25,347	2,191	**84,575**
14	46,488	27,441	5,250	**79,179**
15	208,482	117,523	1,181	**327,186**
Total	**1,298,772**	**750,754**	**110,260**	**2,159,786**

Note: Blank cells do not always signify the absence of buildings within flood hazard areas; they may indicate that such buildings were not identified or reported by the regional flood planning groups

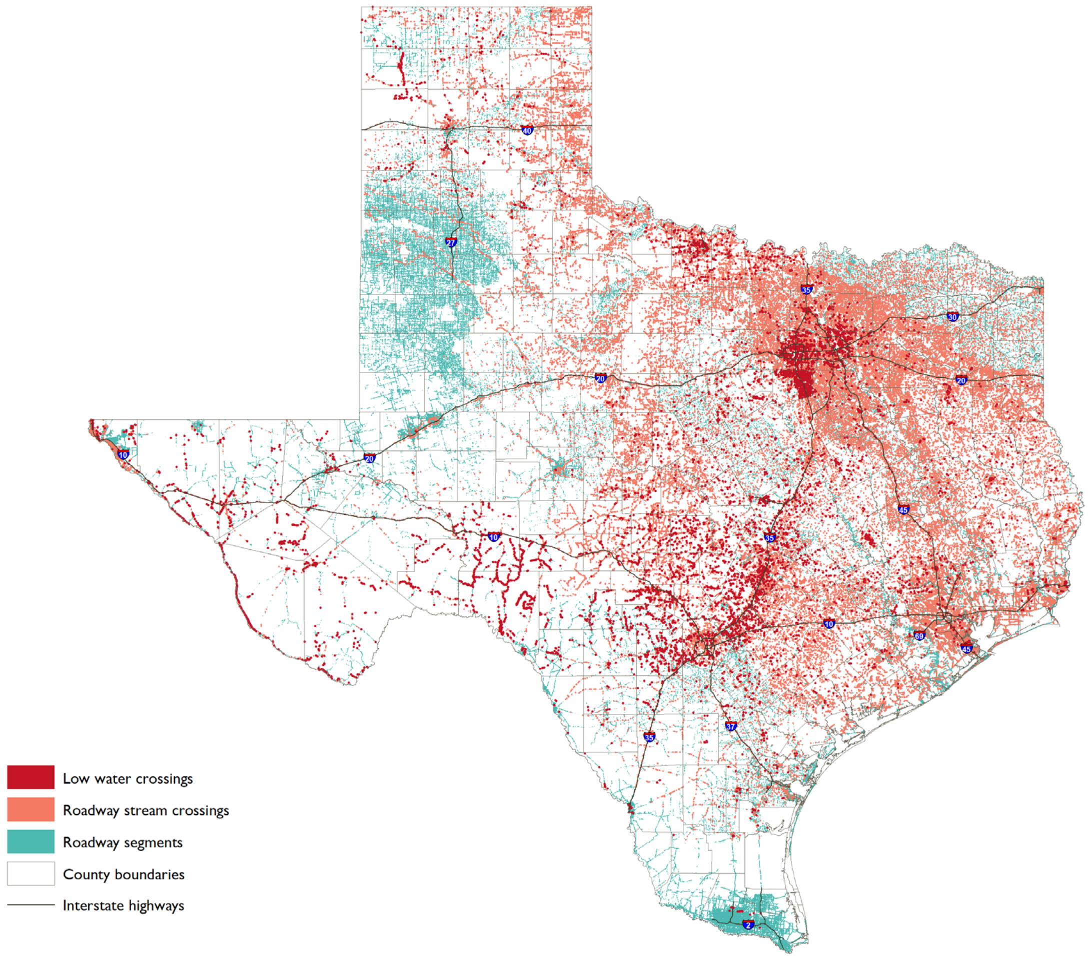
Figure 4-23. Locations of residential buildings within future flood hazard areas



Roadways/transportation at future flood risk

The regional flood planning groups repeated their analyses on roadways and transportation systems at flood risk using the data generated in their future flood hazard analyses. The locations of roadways located in flood hazard areas are presented in Figure 4-24.

Figure 4-24. Locations of roadways/transportation within future flood hazard areas



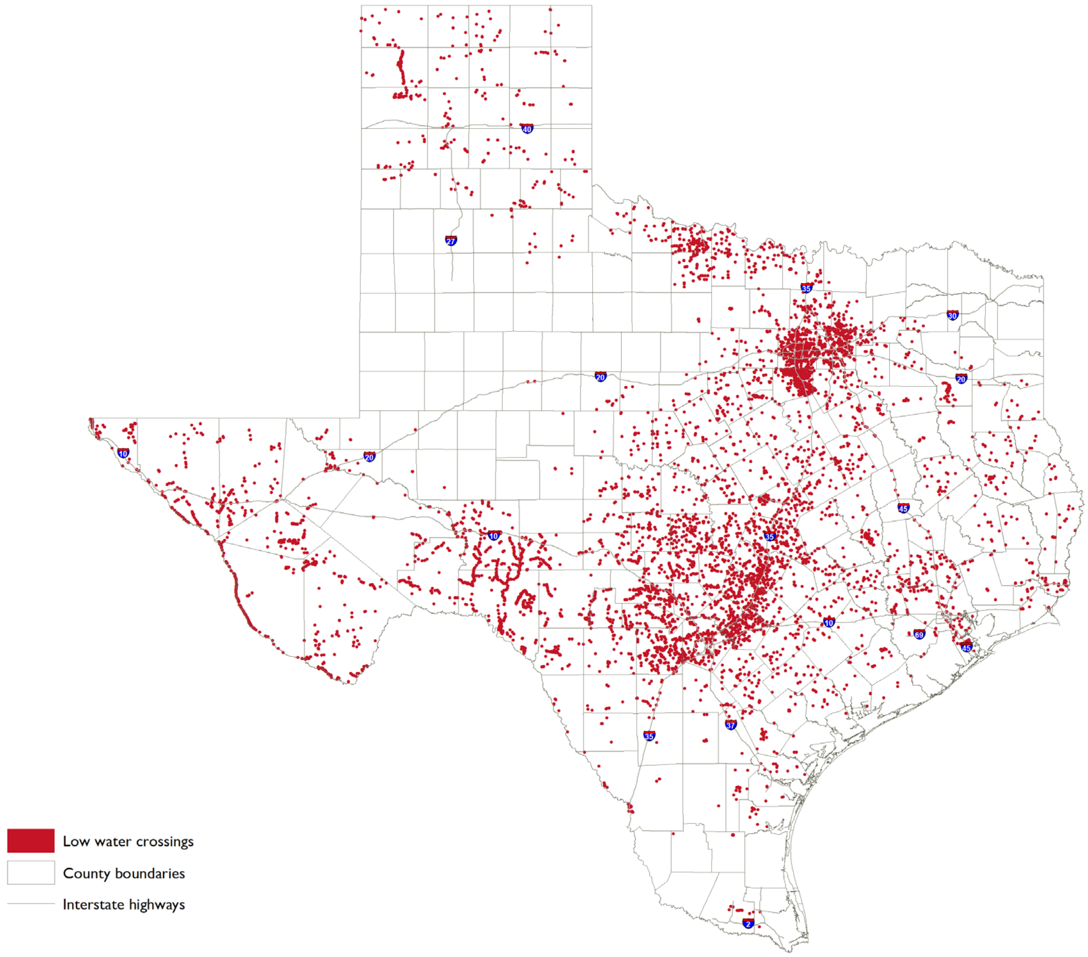
- **Roadway stream crossings**: The groups identified 78,320 roadway stream crossings within the future 1 percent (100-year) annual chance flood hazard area, 22,606 within the future 0.2 percent (500-year) annual chance flood hazard area , and 923 in flood prone areas.
- **Low water crossings:** The planning groups identified a total of 10,243 low water crossings at future flood risk. Of these, 9,456 were identified within the future 1 percent (100-year) annual chance flood hazard area, 653 within the future 0.2 percent (500-year) annual chance flood hazard area, and 134 in future flood prone areas (Table 4-15, Figure 4-25).

Table 4-15. Low water crossings within future flood hazard areas by flood planning region

Region	Low water crossings within future 1 percent (100-year) annual chance floodplain	Low water crossings within future 0.2 percent (500-year) annual chance floodplain	Future flood prone (unknown annual chance) low water crossings	Total
1	973	152	124	**1,249**
2	116	11		**127**
3	1,736	332	1	**2,069**
4	113	4		**117**
5	173	5	6	**184**
6	229	5		**234**
7	290	2		**292**
8	944	45		**989**
9	244	9		**253**
10	1,120	21		**1,141**
11	661	15		**676**
12	441	15		**456**
13	509	17		**526**
14	1,781	9	3	**1,793**
15	126	11		**137**
Total	**9,456**	**653**	**134**	**10,243**

Note: Blank cells do not always signify the absence of low water crossings within flood hazard areas; they may indicate that such features were not identified or reported by the regional flood planning groups.

Figure 4-25. Locations of low water crossings within future flood hazard areas



- **Roadway miles**: The planning groups identified 59,190 miles of roadways in the future 1 percent (100-year) annual chance floodplain, 27,564 miles in the future 0.2 percent (500-year) annual chance floodplain, and 1,506 miles of future flood prone roadways (Table 4-16).

Table 4-16. Roadway miles within future flood hazard areas by flood planning region*

Region	Roadway miles within future 1 percent (100-year) annual chance floodplain	Roadway miles within future 0.2 percent (500-year) annual chance floodplain	Future flood prone (unknown annual chance) roadway miles	Total
1	3,342	2,010	7	**5,358**
2	2,063	947		**3,010**
3	5,588	3,305		**8,894**
4	1,897	855		**2,752**
5	2,444	1,167	378	**3,988**
6	8,147	3,701	9	**11,858**
7	6,439	3,103		**9,541**
8	3,954	1,676	849	**6,479**
9	4,628	2,503		**7,131**
10	4,353	1,246		**5,599**
11	1,379	416		**1,795**
12	968	604	1	**1,573**
13	3,537	1,560	85	**5,183**
14	3,846	1,035	139	**5,020**
15	6,605	3,437	38	**10,079**
Total	**59,190**	**27,564**	**1,506**	**88,260**

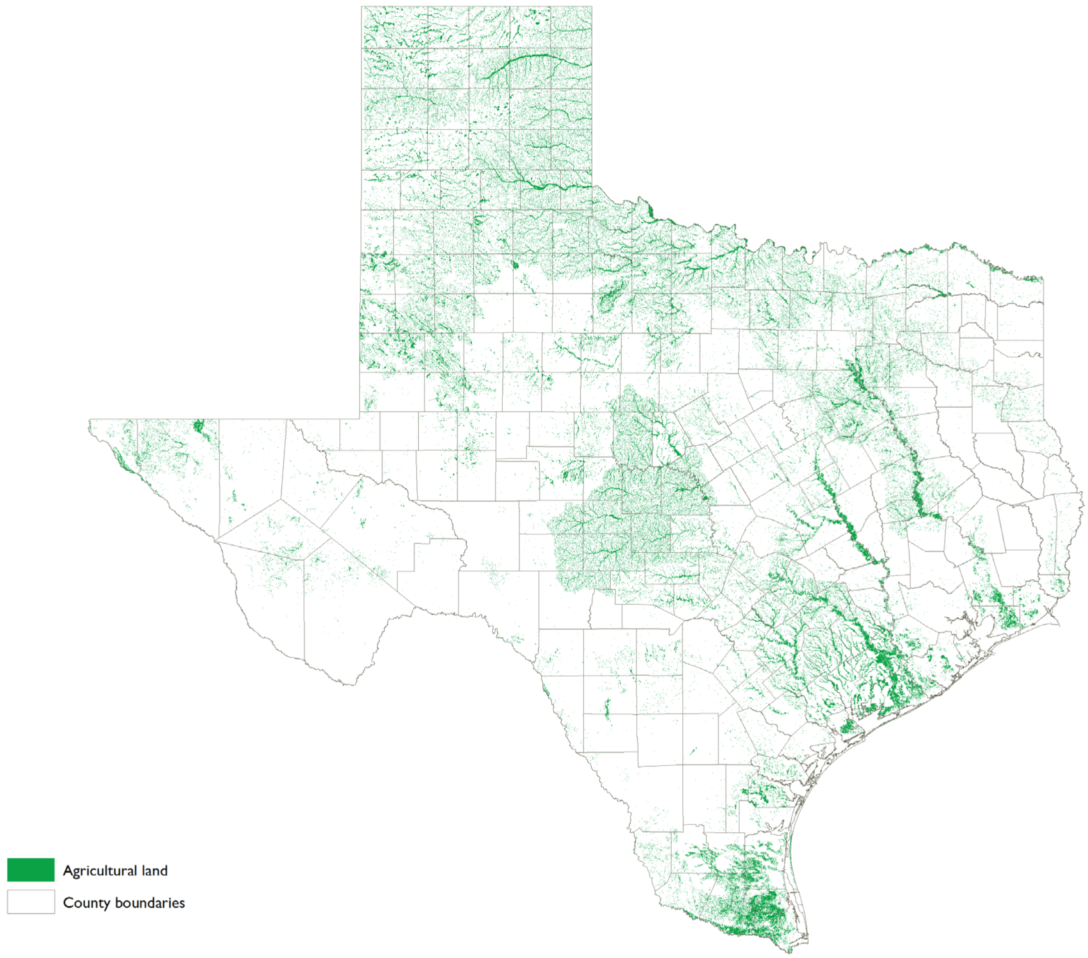
Note: Blank cells do not always signify the absence of roadways within flood hazard areas; they may indicate that such roadways were not identified or reported by the regional flood planning groups

* *All values are estimates rounded to the nearest whole number*

Agricultural areas

The planning groups identified 12,011,680 acres of agricultural area in the future 1 percent (100-year) annual chance flood hazard area, 3,903,956 acres in the future 0.2 percent (500-year) annual chance flood hazard area, and 24,289 acres of future flood prone agriculture (Figure 4-26).

Figure 4-26. Locations of agricultural land in future flood hazard areas



4.2.3 Future condition vulnerability

Once the future flood exposure analyses were completed, the regional flood planning groups were required to identify the resilience of communities located in those future flood prone areas. This task required them to identify the critical infrastructure amongst the items identified in the future flood exposure analyses and compute the social vulnerability index value for each structure.

Critical facilities

The flood planning groups identified 14,581 critical facilities in the future 1 percent (100-year) annual chance flood hazard area, 7,395 critical facilities in the future 0.2 percent (500-year) annual chance flood hazard area, and 545 critical facilities in future flood prone areas (Table 4-17, Figure 4-27). A total of 10,293 of these critical facilities were identified as hospitals, emergency medical services, fire stations, police stations, and schools within future flood hazard areas.

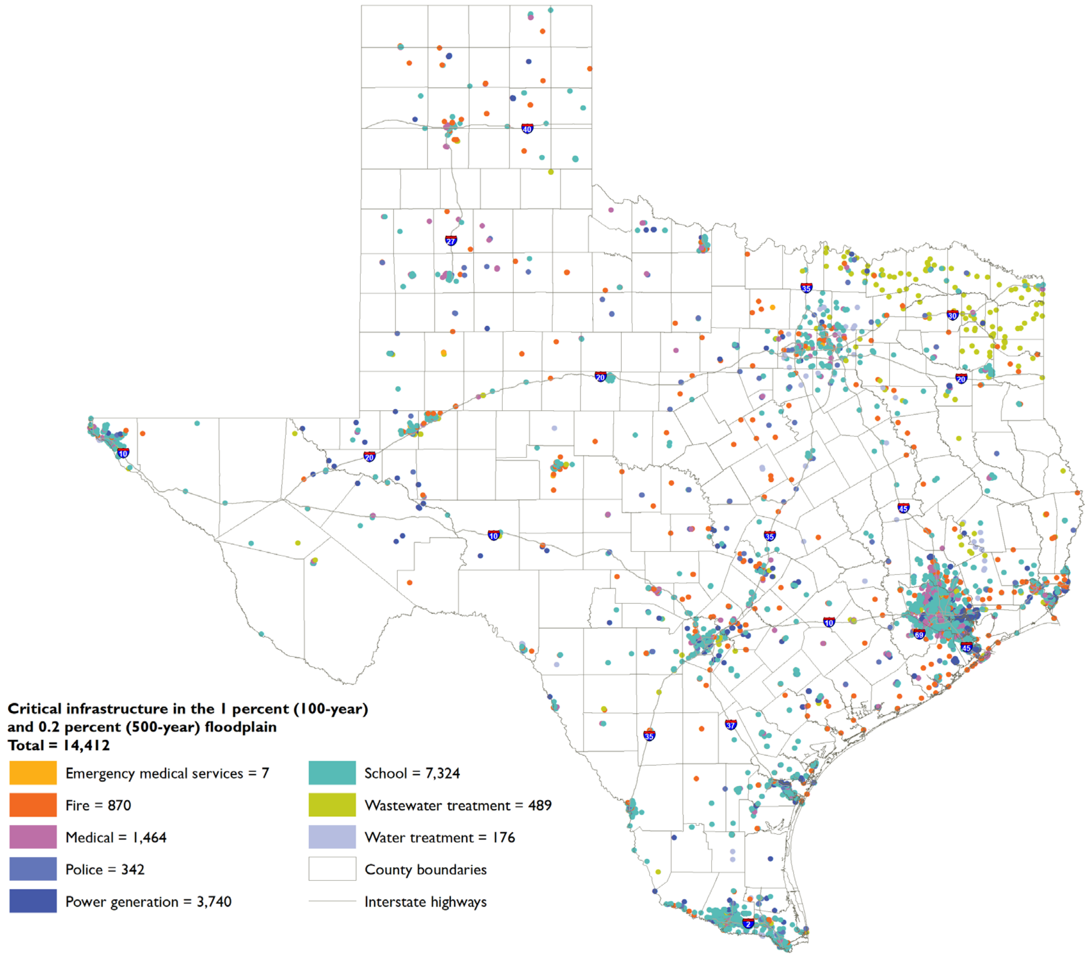
*Table 4-17. Critical facilities within future flood hazard areas by flood planning region**

Region	Critical facilities within future 1 percent (100-year) annual chance floodplain	Critical facilities within future 0.2 percent (500-year) annual chance floodplain	Future flood prone (unknown annual chance) critical facilities	Total
1	288	241		**529**
2	150	24		**174**
3	852	204	160	**1216**
4	497	64		**561**
5	2082	1,307	152	**3541**
6	8,311	3,524	1	**11,836**
7	64	45		**109**
8	321	212	180	**713**
9	156	371		**527**
10	177	33		**210**
11	225	88		**313**
12	234	185		**419**
13	642	493	32	**1,167**
14	179	56	18	**253**
15	403	548	2	**953**
Total	**14,581**	**7,395**	**545**	**22,521**

Note: Blank cells do not always signify the absence of critical facilities within flood hazard areas; they may indicate that such critical facilities were not identified or reported by the regional flood planning groups

* *Critical facilities includes hospitals, emergency medical services, fire stations, police stations, schools, shelters, power generation, and water and wastewater treatment plant*

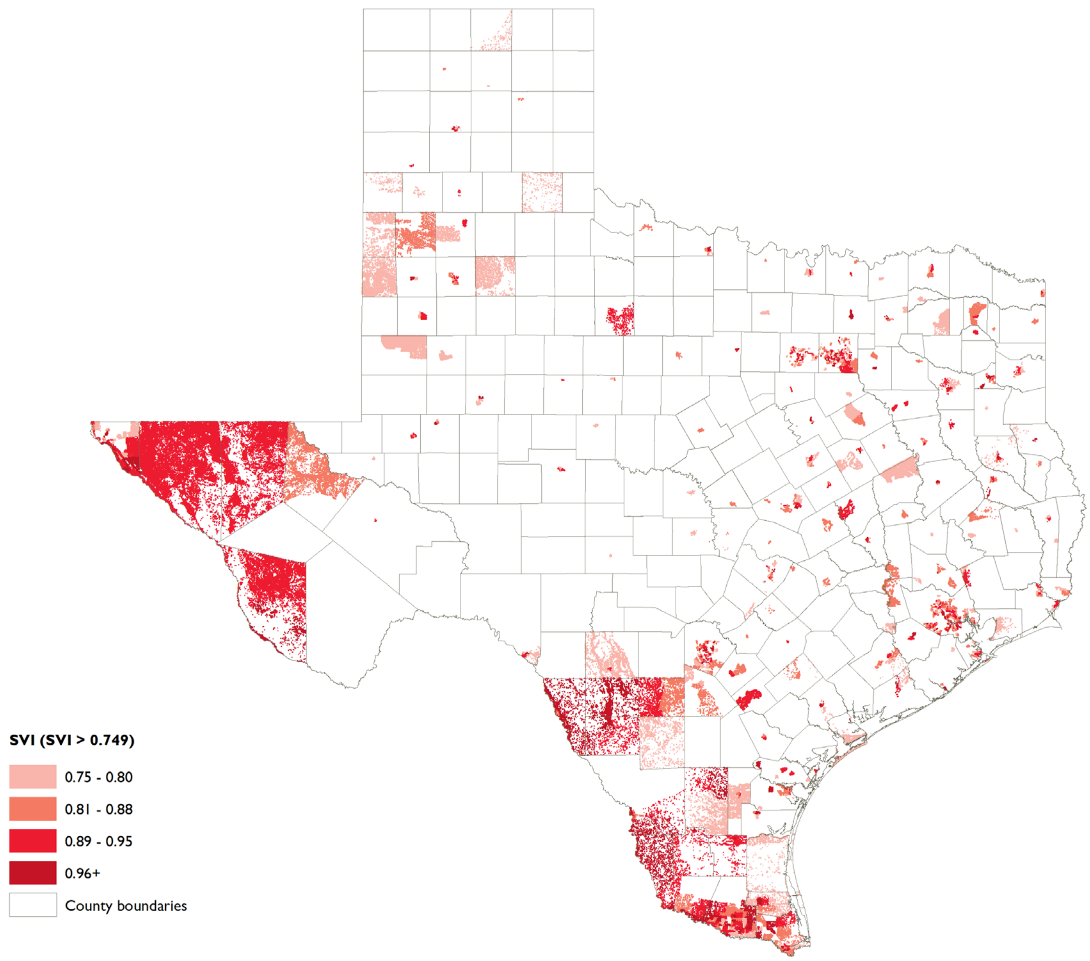
Figure 4-27. Locations of critical facilities within future flood hazard areas



Communities

Like the existing condition vulnerability analyses, the regional flood planning groups identified social vulnerability indices of all buildings located in the future condition flood hazard area. The statewide average estimate for the social vulnerability index for all buildings located in future condition flood hazard areas is 0.49—an increase of 0.01 over the existing social vulnerability index, as described under section 4.1.4. The TWDB considered a threshold of 0.75 to be a reasonable indicator for highly vulnerable areas. Like the findings from the existing condition vulnerability analyses, the planning groups identified vulnerable populations with a social vulnerability index at or above 0.75 to be spread across the state, with high densities in the west and south (Figure 4-28).

Figure 4-28. Locations of future Texan communities within a flood hazard area (100-year) and who are considered vulnerable



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5 Floodplain management practices

Quick facts

A total of 1,239 out of 1,473 counties and municipalities in Texas participate in the National Flood Insurance Program.

Of those 1,239 entities, more than 500 have floodplain management standards that exceed National Flood Insurance Program minimum standards.

Approximately 98 percent of Texas' population resides within communities that participate in the Federal Emergency Management Agency's National Flood Insurance Program.

The regional flood planning groups recommended 144 new floodplain management standards for consideration by Texas political subdivisions to help improve community resilience to flooding.

In Texas, floodplain management is a community-led effort by cities, counties, and political subdivisions with flood-related authority to prevent or reduce the risk and impact of flooding. Communities have various levels of floodplain management standards; some do not take an active role in regulating floodplain development, whereas others have robust standards for reducing flood impacts due to development and to keep citizens and property out of harm's way. Many communities in Texas follow rules and policies of the Federal Emergency Management Agency (FEMA), which manages the National Flood Insurance Program where minimum standards for development in and around the floodplain can be found. Cities and counties work with FEMA to create and update Flood Insurance Rate Maps and flood water surface elevations to define **special flood hazard areas** along rivers, streams, lakes, and coastal areas.

Communities that participate in the National Flood Insurance Program are required to use the Flood Insurance Rate Maps and flood water surface elevations provided in their floodplain permitting processes. In sparsely populated agricultural and ranch land, local governments may not have the resources to enact, adopt, and enforce specific floodplain management practices or work with FEMA to develop special flood hazard areas and Flood Insurance Rate Maps.

The state of Texas supports the National Flood Insurance Program through a state coordinating office at the Texas Water Development Board (TWDB). The TWDB serves in a coordinating role cooperating with both FEMA and Texas communities that have adopted ordinances or orders to participate in the National Flood Insurance Program.

Per Texas Administrative Code (TAC) § 361.35, the regional flood planning groups were required to evaluate existing floodplain management practices within each flood planning region and recommend best practices. Floodplain management, as well as land use, infrastructure design, and other practices, play a key role in accomplishing the intents of regional flood planning, specifically in preventing the creation of additional flood risk in the future.

5.1 Assessment of current floodplain management practices

Before adopting or recommending floodplain management practices within each flood planning region, the planning groups were required to first evaluate current floodplain management practices in their regions. To do so, they coordinated with political subdivisions, to the extent possible, to gather information on floodplain management regulations and policies in each region. Using this information, the planning groups made qualitative assessments of floodplain management, land use, infrastructure design, and other practices within and across the region. They provided summaries of key floodplain management practices by identifying entities (cities, counties, and political subdivisions with flood-related authority) with existing floodplain management practices, identifying common and contrasting practices within each region, and acknowledging locations that may lack appropriate floodplain management. Some information presented here differs from that in the respective regional flood plans in cases where the

TWDB received conflicting information for entities with jurisdictional boundaries shared by two or more regions and where the TWDB received corrective information from entities during public comment period. The following sections describe their findings.

5.1.1 Entities with flood-related authority

The planning groups were tasked with identifying political subdivisions with flood control authority in their regions. TAC § 361.10(bb) defines political subdivisions 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 Texas Water Code. The regional flood planning groups identified the subset of political subdivisions with flood-related authority in their respective regions. The majority are municipal or county governments, both of which exercise authority to set policies to mitigate flood risk. State law also provides for limited-purpose water supply and utility districts (known variously as municipal utility districts, municipal water districts, fresh water supply districts, special utility districts, and other related names). These districts may be in or adjacent to cities or in a county and may be involved in land reclamation and stormwater drainage management. One specific type of district was also included as these districts have a more direct relationship to flood management (water control and improvement districts), as outlined in Texas Water Code (TWC) Chapter 51. Although a multitude of these entities have the capability to exercise some degree of flood-related authority, many defer to a larger entity such as a county or municipality for regulatory floodplain management purposes, as larger cities often have unified development codes or floodplain management standards in place.

For political entities to participate in the National Flood Insurance Program, they must adopt a floodplain management ordinance and designate a floodplain administrator who will be responsible for understanding and interpreting local floodplain management regulations and reviewing them for compliance with National Flood Insurance Program standards. TWC § 16.3145 requires each city and county to adopt ordinances or orders necessary to be eligible to participate in the National Flood Insurance Program. In addition, TWC § 16.315 authorizes each political subdivision of the state, not just cities and counties, to take all necessary and reasonable actions that are not less stringent than the requirements and criteria of the National Flood Insurance Program. Some of the rights and responsibilities granted under the authority of TWC § 16.315 include the following:

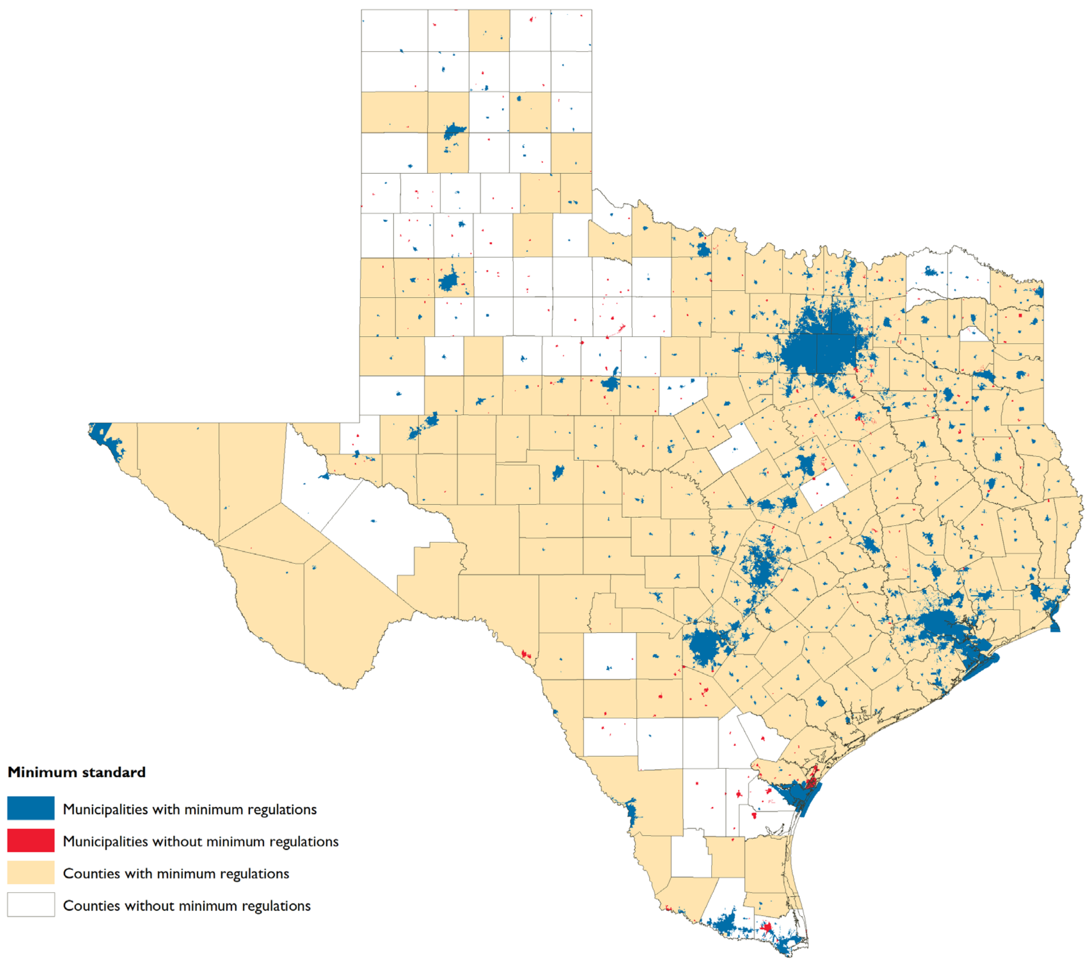
- Applying for grants and financing to support mitigation activities.
- Guiding the development of future construction away from locations threatened by flood hazards.
- Setting land use standards to constrict the development of land that is exposed to flood damage and minimize damage caused by flood 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 FEMA to assess adequacy of local structural and non-structural mitigation activities.

TWC § 16.314 and § 16.316 charge the TWDB as the state agency to act in a coordinating role for the National Flood Insurance Program for local, state, and federal programs. This coordination includes supporting communities that seek to apply to qualify to participate in the National Flood Insurance Program. It also includes evaluation of flood programs, carrying out floodplain studies and mapping programs, and coordinating grant funding.

5.1.2 Minimum floodplain management regulations

Minimum standards for floodplain management set a baseline of criteria for ensuring safe development in flood prone areas. Such criteria might include prohibiting construction within certain floodway zones, mandating elevation levels for buildings in flood zones, or requiring the use of flood-resistant construction materials. The regional flood planning groups reported a total of 1,173 entities with flood-related authority with at least minimum floodplain management regulations (Figure 5-1). Minimum floodplain management regulations are a requirement for participation in the National Flood Insurance Program; therefore, the data provided by the planning groups on National Flood Insurance Program participation is used in this plan as a proxy to demonstrate which entities have minimum floodplain management regulations.

Figure 5-1. Locations of entities with and without minimum floodplain management regulations*



** This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. For example, blank cells may not signify zero entities; relevant information may not have been available or reported to the regional flood planning groups.*

The National Flood Insurance Program was established when Congress passed the National Flood Insurance Act in 1968 to provide federally subsidized flood insurance protection. The National Flood Insurance Program is administered by FEMA, which provides subsidies for private flood insurance for property owners in communities that participate in the National Flood Insurance Program. The program has since been updated to strengthen it as well as provide fiscal soundness and inform the public of flood risk through insurance rate maps. The goal of the National Flood Insurance Program is to reduce the exposure to flood risk and protect public safety as well as prevent or minimize damage to property and public infrastructure. Title 44 of the Code of Federal Regulations includes the rules and regulations of the program; Part 60 within that Title establishes minimum criteria that FEMA requires for participation, which includes identifying special flood hazard areas within the participating community. The regional flood planning groups reported a total of 1,239 entities with flood-related authority that participate in the National Flood Insurance Program (Table 5-1 and Figure 5-2).

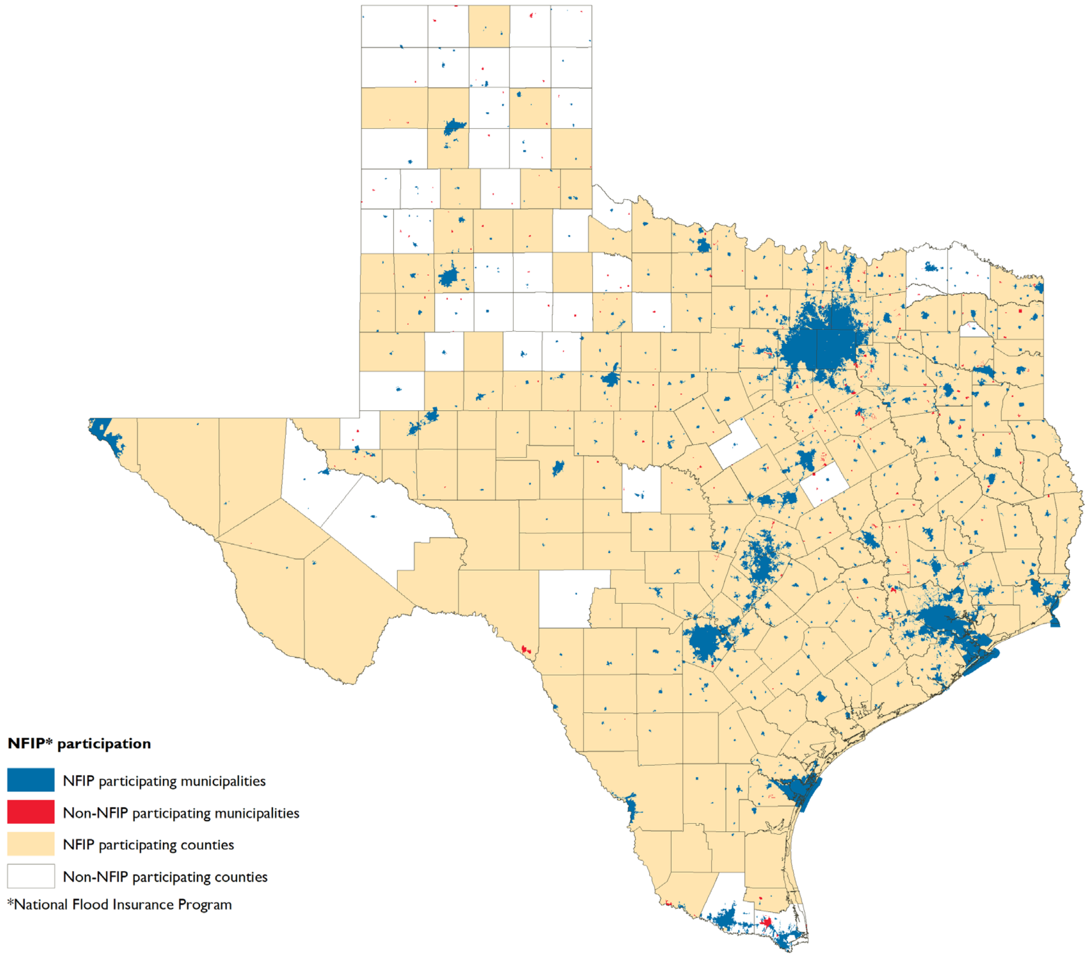
Table 5-1. Entities participating in the National Flood Insurance Program*

Entity type	Yes	No	Total
County	209	45	**254**
Flood district		18	**18**
Municipality	1,010	209	**1,219**
River authority		18	**18**
Other[a]	20	484	**504**
Total	**1,239**	**774**	**2,013**

[*] This table contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. For example, blank cells may not signify zero entities; relevant information may not have been available or reported to the regional flood planning groups.

[a] "Other" includes entities like municipal utility districts, drainage districts, etc.

Figure 5-2. Locations of entities participating in the National Flood Insurance Program*



** This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. Relevant information for some entities may not have been available or reported to the regional flood planning groups.*

Participating communities work with FEMA to create and update Flood Insurance Rate Maps and the base flood elevation to define the special flood hazard areas along rivers, streams, lakes, and coastal areas. Flood Insurance Rate Maps and base flood elevations are used by participating communities to establish elevations used in their floodplain permitting process.

When a community joins the National Flood Insurance Program, it must adopt a resolution of intent to participate and cooperate with FEMA. With the ability to establish their own policies, standards, and practices, communities can manage land use in and around areas of flood risk. These risks are mitigated by floodplain management and land use practices enacted through regulations and policies that are adopted by participating communities. Floodplain ordinances, building standards, zoning and land use policies are three general forms of regulations a community can use to mitigate flood risk.

A joining community must also adopt and submit a floodplain management ordinance or court order that meets or exceeds the minimum National Flood Insurance Program criteria. Minimum standards include the following:

- Adopt and enforce a flood damage prevention ordinance (or court order)
- Require permits for all types of development in floodplains

- Ensure that building sites are reasonably safe from flooding
- Estimate flood elevations for areas that lack FEMA determinations
- Require that new or substantially improved buildings be constructed at or above the base flood elevation
- Require elevation certificates to document compliance
- Require other buildings to be elevated or floodproofed
- Conduct inspections and cite violations
- Minimize variances
- Inform FEMA when updates to flood maps are needed

TWC § 16.3145 requires a city or county to adopt the necessary ordinances or orders for the city or county to be eligible to participate in the National Flood Insurance Program. Based on the data provided by the planning groups, about 1,173 have adopted minimum regulations pursuant to TWC § 16.3145, but 838 entities have not. A floodplain ordinance provides a community with the power to regulate development within the floodplain and the impact new or existing development can have in the floodplain. Building standards are used for construction within or adjacent to the floodplain. This can include the flood proofing of a structure as well as another means of regulating finished floor elevations. The use of zoning and land use policies can be utilized by the community to regulate the types of land use that are acceptable within and adjacent to the floodplain to promote safety by directly building away from these areas.

5.1.3 Higher floodplain management standards

FEMA encourages communities to adopt and enforce higher standards than the National Flood Insurance Program minimum standards to reduce flood risk to life and property. The planning groups reported that 511 communities/entities have higher standards, whereas 792 entities do not (Table 5-2 and Figure 5-3). There are many types of higher floodplain management standards, including the following:

Freeboard
FEMA defines *freeboard* as an additional height requirement above the base flood elevation that provides a margin of safety against flood risks, compensating for unknown factors that may affect flood depths (FEMA, 2005). While freeboard reduces the risk of flooding, it also makes the structure eligible for a lower flood insurance rate.

Detention and retention
Reducing the impact of increased runoff that results from development in a watershed is known as stormwater management. One way to reduce the impact of stormwater on new development is to require the developer to restrict the rate at which the increased runoff leaves the property. *Stormwater detention* stores and holds the water for release at a restricted rate after the storm subsides. In *stormwater retention*, the runoff of stormwater is held for later use in irrigation or groundwater recharge as well as reducing pollution. Water quality can also improve by utilizing stormwater management, as it reduces erosion and the entry of sediment and pollutants into receiving streams (FEMA, 2005).

Fill
Fill in floodplain or flood hazard areas is referred to as placing of obstructive materials, including sand and soil, to raise the level of the ground to change the flow of water or increase flood elevations. Fill can be used by itself or with other types of foundations to elevate the lowest floor of a building above the base flood elevation. There are restrictions on the use of fill in floodways where fill could cause an increase in flood heights and in coastal zones where fill would act as an obstruction to waves. Many communities that allow the use of fill in the floodplain also require that equal amounts of material be

excavated to maintain storage capacity. Ideally, fill placed in the floodplain should not increase water levels on others and must be proven through modeling. A community may require the developer or landowner to obtain a **Conditional Letter of Map Revision** before allowing the project to move forward (FEMA, 2005).

Community Rating System

FEMA established the Community Rating System in 1990 to encourage, recognize, and reward participating National Flood Insurance Program communities that have adopted floodplain management practices that exceed program minimums. In doing so, communities support the three goals of the Community Rating System:

1) Reduce flood damages to insurable properties;
2) Strengthen the insurance aspects of the National Flood Insurance Program; and
3) Support a comprehensive approach to floodplain management.

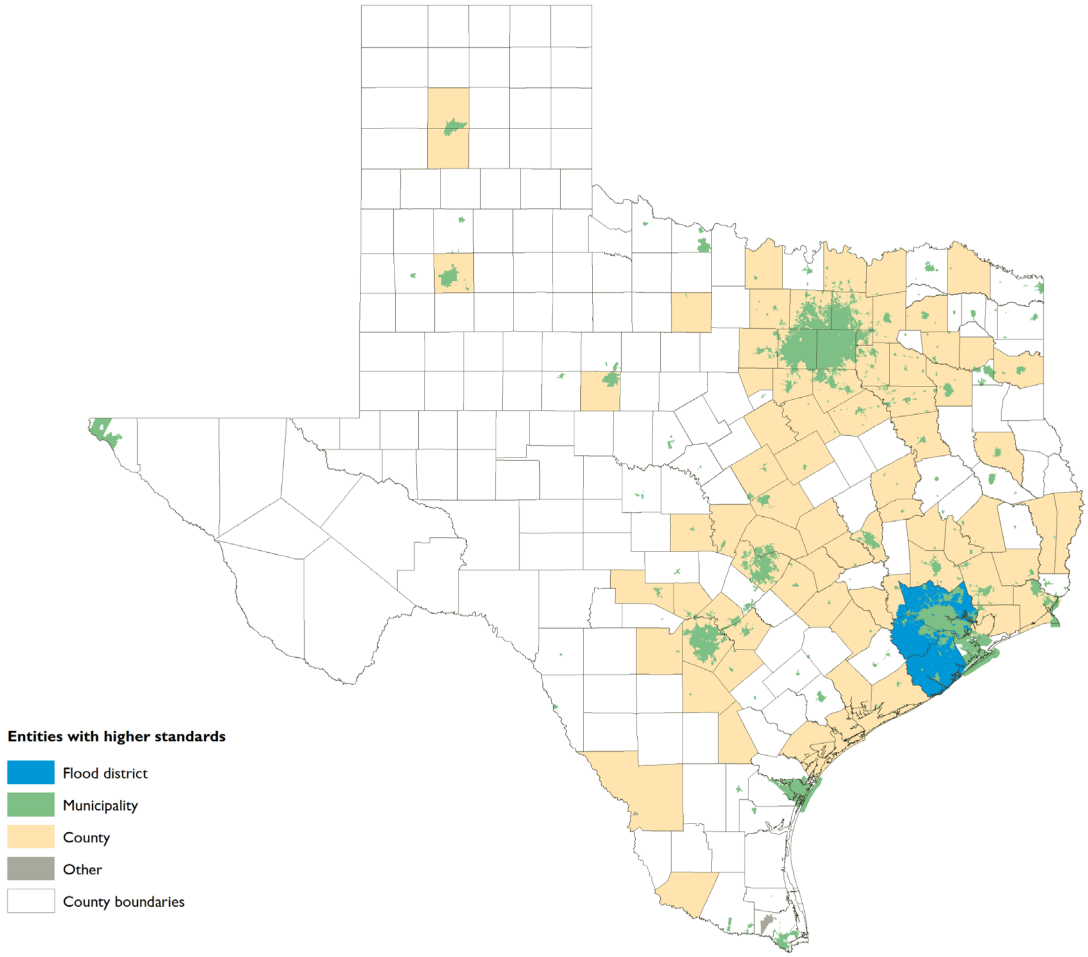
A community that is part of the Community Rating System receives discounted flood insurance premium rates that are awarded in 5 percent increments from Class 1 to Class 10. For example, a Class 1 community will receive a 45 percent discount whereas a Class 10 community receives no discount. As of 2023, 69 Texas communities participate in the National Flood Insurance Program Community Rating System.

Table 5-2. Entities with higher floodplain management standards*

Entity type	Yes	No	Unknown	Total
County	80	148	26	**254**
Flood district	7	11		**18**
Municipality	422	492	305	**1,219**
River authority	2	125	377	**504**
Other		16	2	**18**
Total	**511**	**792**	**710**	**2,013**

* *This table contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. For example, blank cells may not signify zero entities; relevant information may not have been available or reported to the regional flood planning groups.*

Figure 5-3. Locations of entities with higher floodplain management standards*



** This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. Relevant information for some entities may not have been available or reported to the regional flood planning groups.*

5.1.4 Level of floodplain management practices across Texas

A summary of the level of floodplain management practices was utilized by the planning groups to identify areas with existing floodplain practices and compare common practices within each region. The following criteria were provided to the planning groups to determine the level of floodplain management practices of communities within their regions:

- **None**, meaning no floodplain management practices are in place
- **Low**, meaning that regulations meet the minimum National Flood Insurance Program standards
- **Moderate**, meaning the community has adopted some higher standards, such as freeboard, detention requirements, or fill restrictions
- **Strong**, meaning the community has adopted and enforces significant regulation that exceeds the National Flood Insurance Program standards or the community belongs to the Community Rating System

A total of 521 entities throughout Texas were considered to have a low level of floodplain management practices as their current ordinances or regulations solely met the minimum requirements per the

National Flood Insurance Program (Table 5-3, Figure 5-4, and Figure 5-5). While the regional flood planning groups were able to gather a large amount of floodplain management information from entities across the state, there are still several entities whose level of floodplain management practices is unknown.

Table 5-3. Level of floodplain management practices across entity types*

Entity type	None	Low	Moderate	Strong	Unknown	Total
County	36	97	46	16	59	**254**
Flood district	5				13	**18**
Municipality	129	420	117	78	475	**1,219**
River authority	15				3	**18**
Other	100	4	1	3	396	**504**
Total	**285**	**521**	**164**	**97**	**946**	**2,013**

* *This table contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. For example, blank cells may not signify zero entities; relevant information may not have been available or reported to the regional flood planning groups.*

44 CFR § 60.3 outlines the minimum requirements for floodplain management criteria for flood prone areas, which are summarized as follows. These are also the minimum requirements for the National Flood Insurance Program and are classified as the "low" level in Table 5-3.

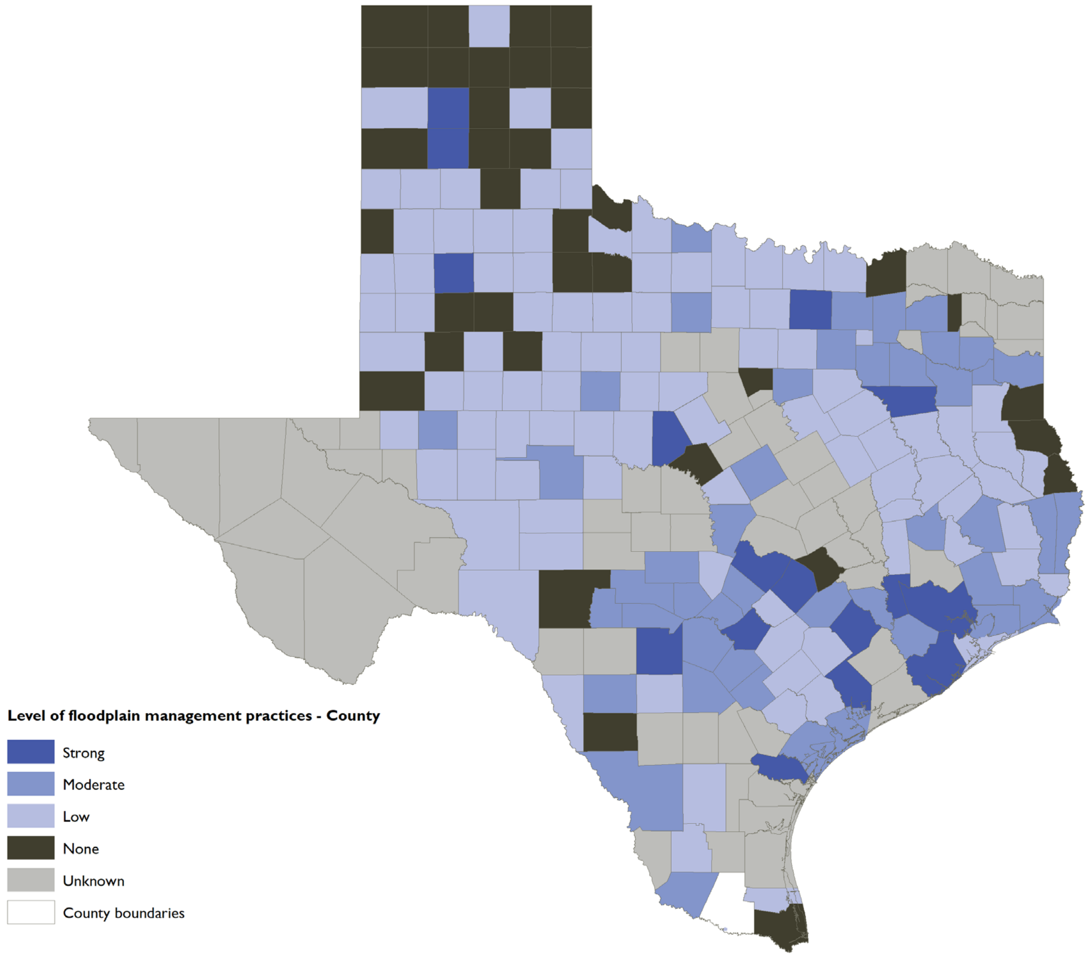
- Require permits for all proposed construction or other development in the community to determine whether such construction or other development is proposed within flood prone areas.
- Review proposed developent to assure that all necessary permits have been received from those governmental agencies from which approval is required by federal or state law.
- Review all permit applications to determine whether proposed building sites will be reasonably safe from flooding:
  - If a proposed building site is in a flood prone area, all new construction and substantial improvements shall be designed to adequately prevent flotation or collapse and be constructed with materials resistant to flood damage.
- Review subdivision proposals to determine whether such proposals will be reasonably safe from flooding:
  - If a subdivision proposal is in a flood prone area, any such proposals shall be reviewed to ensure consistency with the need to minimize flood damage within that area.
  - All public utilities and facilities, such as sewer, gas, electrical, and water systems must be located and constructed to minimize or eliminate flood damage.
- Provide adequate drainage to reduce exposure to flood hazards.
- Adopt and enforce a flood damage prevention ordinance.
- Require new or substantially improved homes and manufactured homes to be elevated above the base flood elevation.
- Require elevation certificates to ensure compliance.
- Conduct field inspections, cite violations, resolve non-compliance issues, and consider and manage variances.
- Require new and replacement water supply systems to be designed to minimize or eliminate infiltrations of flood waters into the system.

- Require new and replacement sanitary sewage systems to be designed to minimize or eliminate infiltrations of flood waters into the systems and discharges from the systems into flood waters and onsite waste disposal systems to be located to avoid impairment to them or contamination from them during flood events.

A total of 164 entities were considered to have a moderate degree of floodplain management practices as they exceeded the minimum requirements of the National Flood Insurance Program. These included higher standards such as detention requirements, compensatory fill requirements in the 1 percent (100-year) annual chance regulatory floodplain, and requirements that minimum finished floor elevations of new habitable structures exceed the base flood elevation.

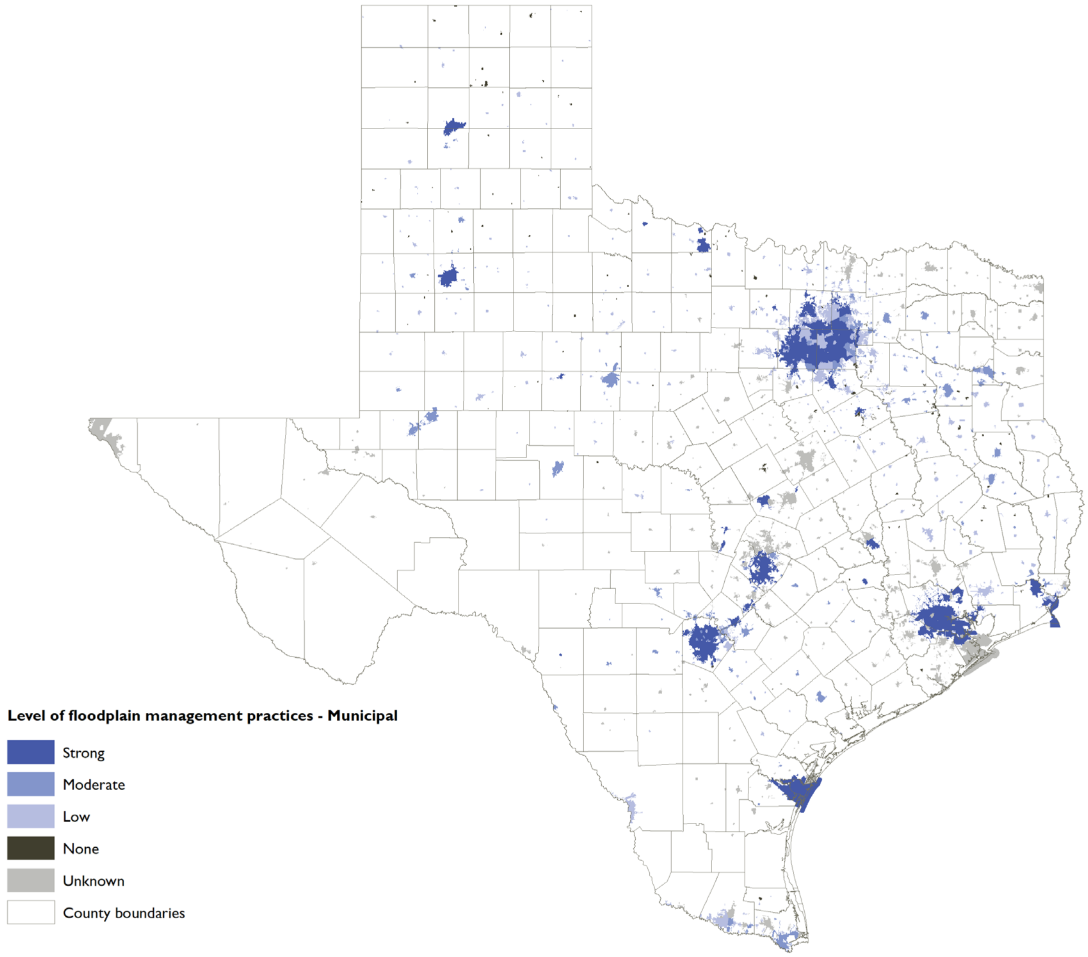
A total of 97 entities were identified by the flood planning groups as having a strong degree of floodplain management practices. Factors for this determination included entities that currently regulate to the effective 0.2 percent (500-year) annual chance floodplain or had adopted Atlas 14 rainfall data, which is the latest available data and depicts increased rainfall in many areas of Texas resulting in larger floodplains. The implemented regulations for these entities include requiring compensatory floodplain fill mitigation for fill placed within the effective 0.2 percent (500-year) annual chance floodplain as well as requiring the finished floor elevations of new habitable structures to be built above the 0.2 percent (500-year) annual chance floodplain elevation.

Figure 5-4. Texas counties with different levels of floodplain management practices*



** This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. Relevant information for some entities may not have been available or reported to the regional flood planning groups.*

Figure 5-5. Municipalities with different levels of floodplain management practices*



** This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. Relevant information for some entities may not have been available or reported to the regional flood planning groups.*

5.1.5 Level of enforcement

Through outreach, the regional flood planning groups identified the level of enforcement of floodplain regulations by entities with flood-related authority. While some flood planning regions collected this data from self-reported surveys, other regions reported enforcement based on level of National Flood Insurance Program participation. The following criteria were provided to the planning groups to determine the level of enforcement for their regions:

- **None**, meaning the entity does not enforce floodplain management regulations
- **Low**, meaning the entity provides permitting of development in the floodplain but may not perform inspections or issue fines or violations
- **Moderate**, meaning the entity enforces much of the ordinance, performs limited inspections, and is limited in issuing fines and violations
- **High**, meaning the entity actively enforces all adopted requirements, performs multiple inspections throughout the construction process, issues fines for violations as appropriate, and enforces substantial damage and improvement policies

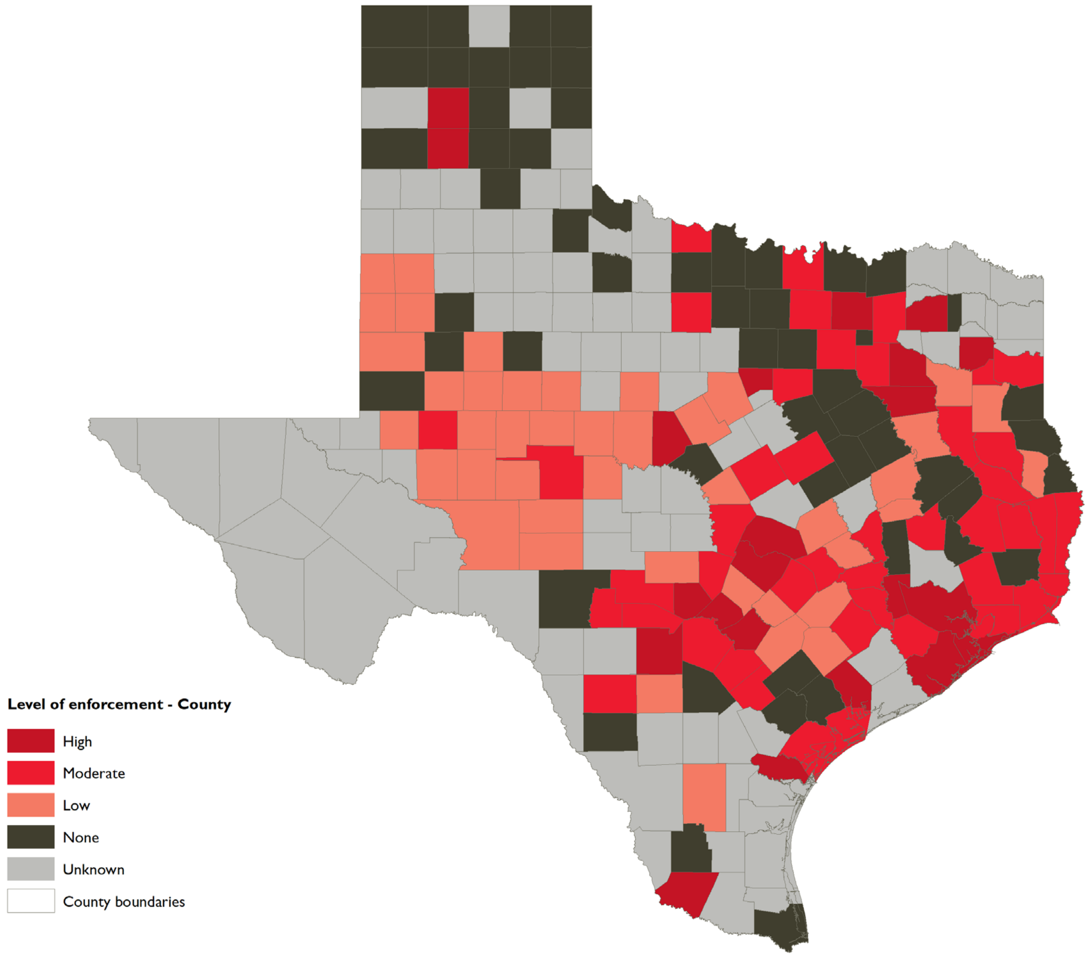
The planning groups reported 177 entities with a high level of enforcement, 167 entities with a moderate level of enforcement, and 110 with what was considered a low level of enforcement. The level of enforcement for 1,110 entities was reported as unknown (Table 5-4, Figure 5-6, and Figure 5-7). The regional flood planning groups noted that many communities may have been reluctant to share this information, fearing its potential impact on flood insurance.

Table 5-4. Level of enforcement*

Entity type	None	Low	Moderate	High	Unknown	Total
County	56	43	45	22	88	**254**
Flood district	5				13	**18**
Municipality	340	62	118	91	608	**1,219**
River authority	14				4	**18**
Other	94	5	4	4	397	**504**
Total	**509**	**110**	**167**	**117**	**1,110**	**2,013**

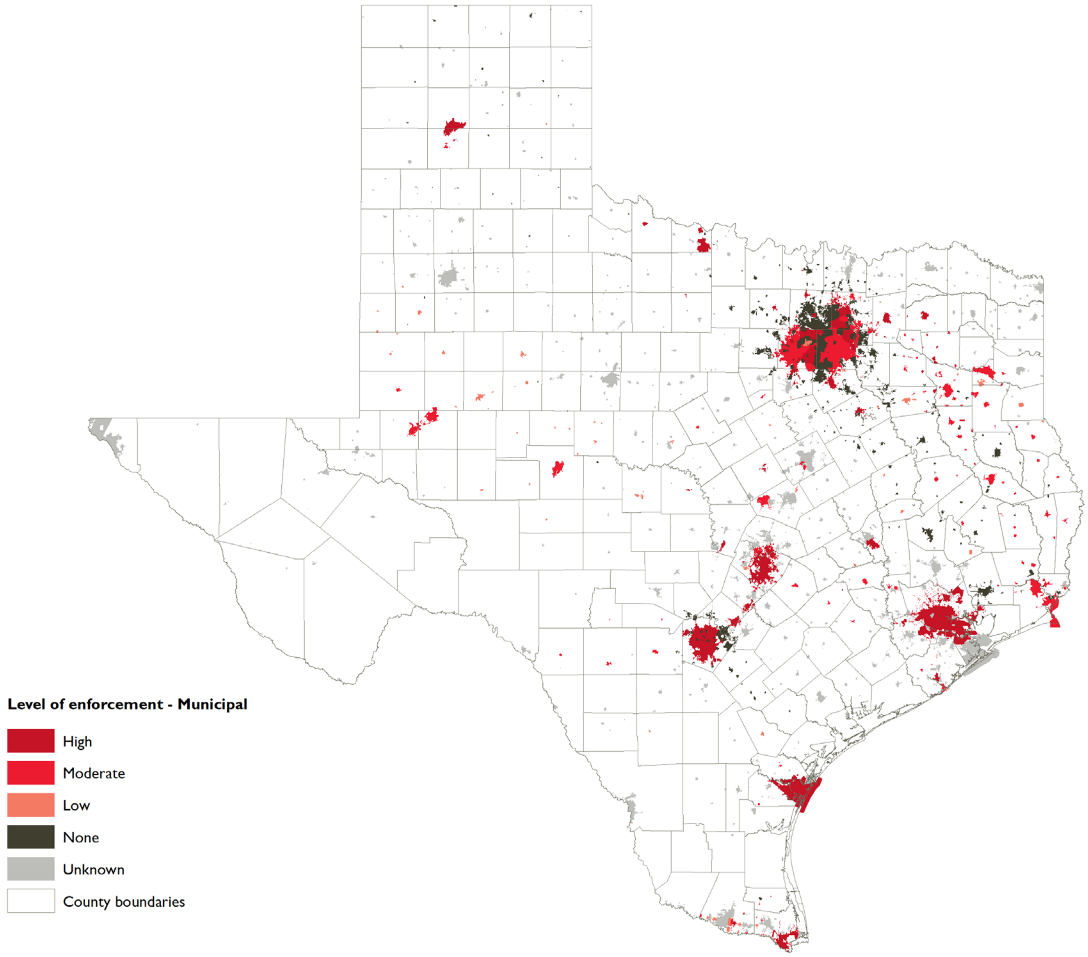
** This table contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. For example, blank cells may not signify zero entities; relevant information may not have been available or reported to the regional flood planning groups.*

Figure 5-6. Level of enforcement by county*



** This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. Relevant information for some entities may not have been available or reported to the regional flood planning groups.*

Figure 5-7. Level of enforcement by municipality*



** This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. Relevant information for some entities may not have been available or reported to the regional flood planning groups.*

5.1.6 Stormwater or drainage fees

Texas Local Government Code, Chapter 552 provides municipalities with the authority to establish stormwater utilities and assess stormwater utility fees, also referred to as drainage utility fees or drainage fees. Chapter 552, Municipal Utilities, also includes discussion of water, sewer, gas, and electric utility systems. Drainage utilities are typically the only municipal utility systems that do not have a dedicated charge or fee associated with use or benefit of the utility. Similarly, many municipalities do not have staff or services dedicated exclusively to support their drainage utility and instead commonly embed those services within public works or transportation departments.

Drainage utility assets are typically made up of open channels (ditches, creeks, rivers), closed conduits (storm sewers, culverts), ponds (dry or wet detention ponds, lakes), and levees/dams. These facilities are often bounded by drainage easements, road rights-of-way, or other forms of property ownership. As many of these assets relate to roadway systems, they are often maintained in tandem with the roadways. Notable exceptions are the larger drainage systems such as creeks, rivers, levees, and dams. Drainage utility fees are intended to provide a stable and dedicated funding mechanism to help maintain or improve these drainage utility assets. Improved or newly built drainage utility assets can provide additional flood mitigation opportunities.

Only municipalities can charge drainage fees, although there are certain districts, like drainage or levee districts, that also have fee mechanisms associated with maintaining their assets. At least one city, Longview, collects a sales tax instead of a drainage fee to fund drainage projects and maintenance. In general, counties do not have statutory authority to charge drainage fees in Texas (Texas Attorney General Opinion GA-0366 [2005]).

Drainage fees are not currently tracked by a state or federal agency; therefore, it is difficult to get an accurate assessment of the number of actual municipalities with drainage fees in Texas. Six of the 15 regional flood plans identified 87 municipalities with drainage utility fees (Table 5-5 and Figure 5-8). Of these, approximately 70 percent (63) were identified within Region 3 Trinity, or more specifically, within the Dallas-Fort Worth metro area.

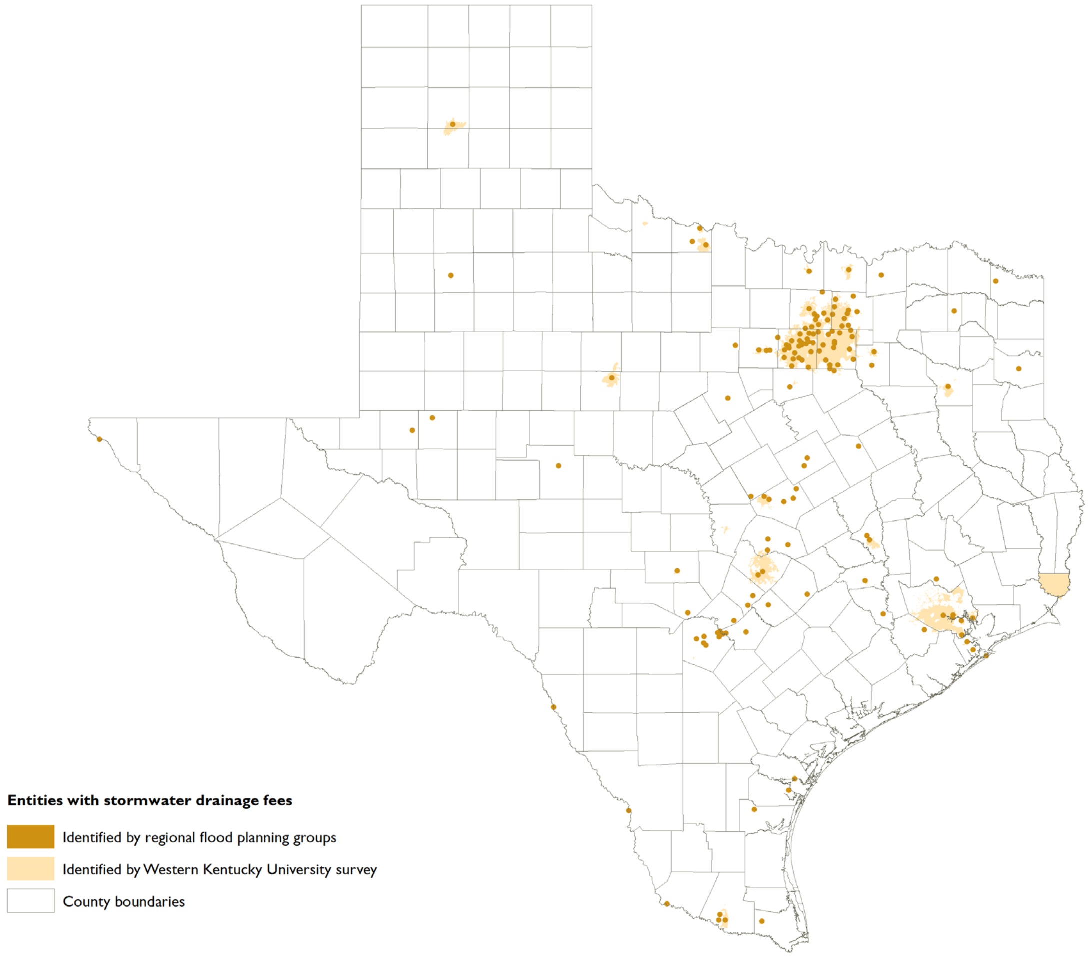
Table 5-5. Texas entities with drainage fees*

Entity type	Yes	No	Unknown	Total
County		174	80	**254**
Flood district		14	4	**18**
Municipality	87	625	507	**1,219**
River authority		66	438	**504**
Other		8	10	**18**
Total	**87**	**887**	**1,039**	**2,013**

* *This table contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. For example, blank cells may not signify zero entities; relevant information may not have been available or reported to the regional flood planning groups.*

It is possible that there are additional communities in Texas with drainage fees that are not captured in the data reported by the regional flood planning groups. For example, a 2023 Western Kentucky University study identified 145 communities in Texas with drainage fees, also with a significant majority located in the Dallas-Fort Worth area (Campbell and Davis, 2023). The total count of Texas communities with drainage fees in Texas reported in the regional flood plans displayed in Figure 5-8 varies slightly from the Texas portion of the Western Kentucky University information.

Figure 5-8. Entities in Texas with stormwater drainage fees*



[*] This figure contains self-reported information obtained by the regional flood planning groups through outreach surveys to entities throughout the state. Relevant information for some entities may not have been available or reported to the regional flood planning groups.

Drainage fees are typically based on some assessment of a property's relative impact to the drainage system. Like water or electric metering, municipalities attempt to estimate usage of the drainage system when assessing fees. Common approaches to estimate usage include an assessment of impervious cover, use of an equivalent residential unit to normalize structure sizes, or a tiered system. Some municipalities simply collect a flat fee. Regardless, drainage fees are an option for municipalities to provide a stable and consistent revenue source to maintain and improve their drainage assets, which can result in reducing flood risk within their communities.

5.1.7 Addressing future population growth and development

In the face of population growth and changing land use patterns in Texas, the future of floodplains and flood risk are uncertain. Due to increasing impervious cover, rising sea level, and other factors, the future base flood elevations will likely increase at many locations, thereby expanding the horizontal extent of floodplains. Moreover, variability in floodplain management practices across the state introduces an escalating level of flood risk as the population continues to expand. While some of the current floodplain ordinances and standards may prove effective in safeguarding future populations and properties, their successful implementation is crucial. Entities that currently use future flood conditions as part of their design criteria provide a safety factor that reduces future flood hazard exposure for new and existing developments, whereas areas lacking comprehensive or up-to-date flood risk information, including floodplain maps and models, or areas with inadequate implementation of floodplain management standards, are particularly vulnerable to heightened flood risks.

Anticipated increases in future base flood elevations and the subsequent expansion of floodplains necessitate proactive measures. By adopting comprehensive measures and incorporating floodplain considerations into community planning, Texas can effectively address the potential risks associated with future flood hazards.

5.2 Regional flood planning group recommendations for floodplain management practices

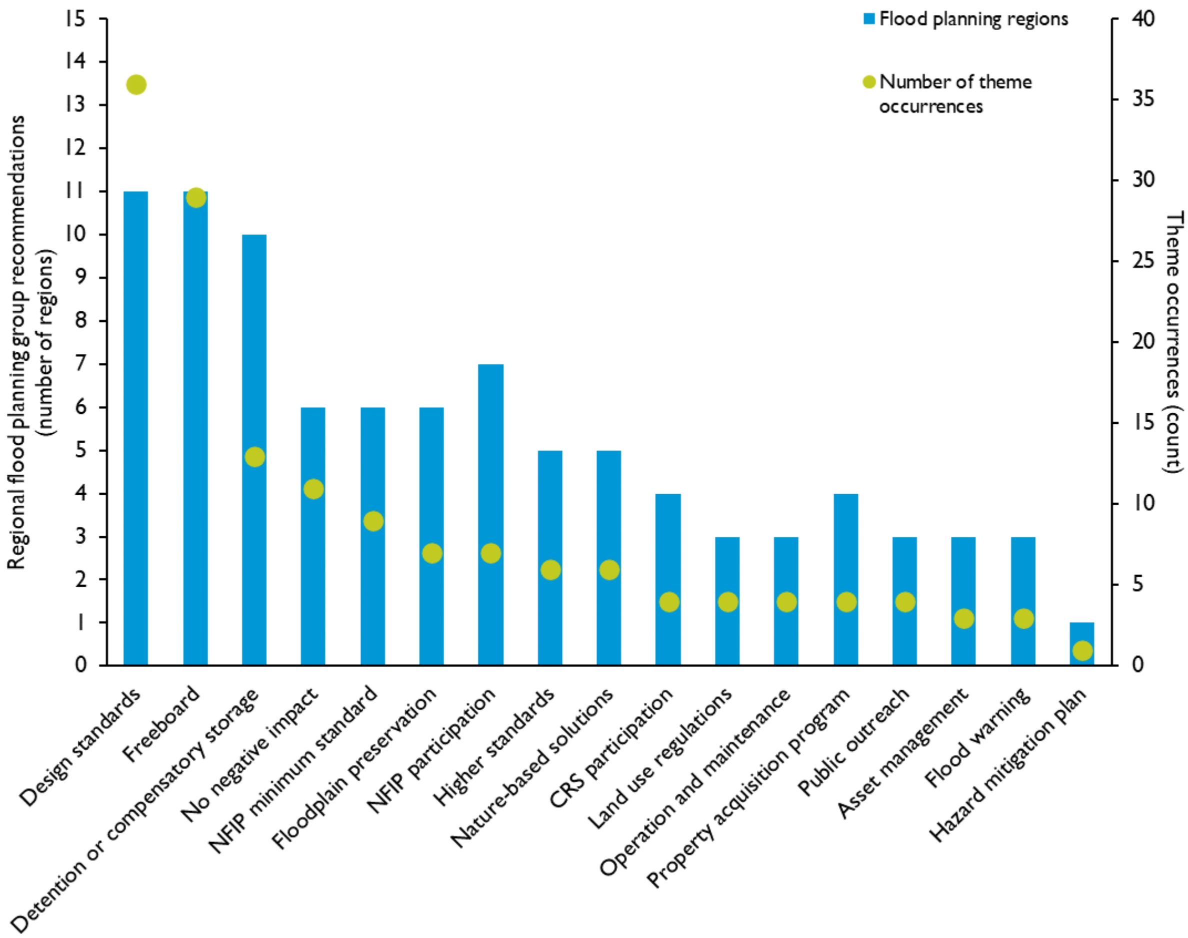
In addition to evaluating existing floodplain management practices within their regions, the planning groups were required to make general recommendations and/or adopt specific minimum floodplain management standards, to achieve more consistent approaches across the region(s). Each regional flood plan was required to clearly state whether the standards are recommendations for consideration by local entities or planning group-adopted, region-specific minimum standards required to be adopted by local entities. If the latter, the standards must be adopted prior to the planning group including in its regional flood plan any flood management evaluations, flood mitigation projects, or flood management strategies sponsored by or that will otherwise be implemented by such entities.

All 15 of the flood planning regions concluded that standards produced as part of the flood planning effort should be classified as recommendations for general consideration by entities and communities within the flood planning region. Although standards for adoption are not proposed for any of the first cycle regional flood plans, it is conceivable that some planning groups may eventually adopt standards during future cycles of regional flood planning.

A total of 144 floodplain management standards were recommended by the planning groups for consideration by local entities (Figure 5-9). The major themes of these recommendations include the following:

- Asset management
- Participation in the Community Rating System
- Design standards
- Detention or compensatory storage
- Flood warning
- Floodplain preservation
- Freeboard
- Hazard mitigation plan
- Higher standards
- Land use regulations
- Mapping
- Nature-based solutions
- National Flood Insurance Program minimum standards
- No negative impact
- Operations and maintenance
- Property acquisition
- Public outreach

Figure 5-9. Floodplain management recommendations by flood planning region



CRS – Community Rating System

NFIP – National Flood Insurance Program

5.2.1 Summaries by region

Some regions made regionwide recommendations for floodplain management practices while some divided their region into multiple groups for specific recommendations for consideration by local entities. Brief summaries of recommendations for each of the 15 regional flood planning groups are provided in the proceeding sections. Complete lists of all recommendations are available in each planning group's 2023 regional flood plan, available on the Texas Water Development Board (TWDB) website.[31]

Region 1 Canadian-Upper Red

Region 1 Canadian-Upper Red recommended four key minimum standards to help the region maintain the natural flood attenuation benefits provided by the playas and promote naturally occurring processes within playas. These recommendations covered the following themes: No negative impact, freeboard,

[31] https://www.twdb.texas.gov/flood/planning/plans/2023a/index.asp

design standards, detention or compensatory storage, operation and maintenance, and floodplain preservation.

Region 2 Lower Red-Sulphur-Cypress

The Lower Red-Sulfur-Cypress planning group recommended minimum standards for the region, which can be grouped into four themes: freeboard, design standards, detention or compensatory storage, and no negative impact. The Neches planning group chose to recommend minimum standards for the region.

Region 3 Trinity

The Trinity planning group approved six recommended region-wide floodplain management standards: National Flood Insurance Program minimum standard, National Flood Insurance Program participation, higher standards, floodplain preservation, land use regulations, and detention or compensatory storage.

Region 4 Sabine

The Sabine planning group recommended region-wide floodplain management standards aimed at implementing basic floodplain management practices across the watershed. These recommendations include asset management, design standards, no negative impact, detention or compensatory storage, freeboard, and nature-based solutions.

Region 5 Neches

The Neches planning group recommended minimum standards for the region, which can be summarized into National Flood Insurance Program minimum standards, property acquisition, operation and maintenance, public outreach, design standards, hazard mitigation plan, flood warning, no negative impact, detention or compensatory storage, freeboard, and nature-based solutions.

Region 6 San Jacinto

Because there is already wide-spread community participation in the National Flood Insurance Program, the San Jacinto planning group focused its floodplain management recommendations on higher standards. These recommendations fell under eight major themes: National Flood Insurance Program minimum standards, National Flood Insurance Program participation, participation in the Community Rating System, no negative impact, freeboard, design standards, detention or compensatory storage, and floodplain preservation.

Region 7 Upper Brazos

The Upper Brazos planning group recommended practices to encourage entities with flood control responsibilities to establish minimum floodplain management standards to reduce or eliminate potential flooding risk. These recommendations included freeboard, design standards, detention or compensatory storage, and property acquisition.

Region 8 Lower Brazos

The Lower Brazos planning group chose to recommend floodplain management standards by zone, or subregion, to better tailor recommendations to diverse areas throughout the region with varying flood risk. Each zone differs from the next in terms of natural hydrography, topography, climatological effects, and demographics throughout the river basin. The recommended zone-level standards include design standards, no negative impact, flood warning, public outreach, property acquisition, operation and maintenance, floodplain preservation, detention or compensatory storage, and National Flood Insurance Program participation.

Region 9 Upper Colorado

While the Upper Colorado region has approximately 74 percent National Flood Insurance Program participation, 86 percent of the region either lacks effective floodplain data or has outdated detailed studies. To address the main flooding concerns for the watershed, the Upper Colorado planning group provided four recommendations that fall under two main themes: design standards and freeboard.

Region 10 Lower Colorado-Lavaca

The Lower Colorado-Lavaca region has nearly 100 percent National Flood Insurance Program participation. Because of this, the planning group chose to focus its floodplain management recommendations on those that exceeded current regional practices. These recommendations include National Flood Insurance Program participation, higher standards, freeboard, detention or compensatory storage, National Flood Insurance Program minimum standards, and land use regulations.

Region 11 Guadalupe

The Guadalupe planning group's recommendations generally focused on the adoption of higher standards and participation in the Community Rating System. Overall, the planning group's recommendations fall under these themes in priority order: nature-based solutions, floodplain preservation, land use regulations, detention or compensatory storage, design standards, higher standards, freeboard, National Flood Insurance Program minimum standards, National Flood Insurance Program participation, and participation in the Community Rating System.

Region 12 San Antonio

The San Antonio planning group decided to encourage floodplain management and land use practices in addition to adopting higher standards.

Region 13 Nueces

The Nueces planning group's floodplain management recommendations for local entities with flood-related authority fell under the following themes: freeboard, participation in the Community Rating System, higher standards, nature-based solutions, floodplain preservation, and asset management.

Region 14 Upper Rio Grande

The Upper Rio Grande planning group recommendations fell under public outreach, flood warning, asset management, higher standards, participation in the Community Rating System, nature-based solutions, design standards, National Flood Insurance Program participation, and National Flood Insurance Program minimum standards.

Region 15 Lower Rio Grande

The Lower Rio Grande planning group opted to recommend floodplain management standards that include design standards, property acquisition, and freeboard.

5.3 TWDB recommendations for floodplain management best practices for Texas communities

There are a wide variety of means by which state agencies and local communities can implement floodplain management practices that may result in reduced flood risk. The TWDB developed several recommendations based on a combination of regional flood planning group recommendations as well as recommendations based on TWDB staff experience working directly with Texas communities. Some recommendations indicate potential actions by the TWDB; or other regional, state, and federal entities, while other recommendations indicate actions by local communities. Each recommended action is preceded by a designation to whom it is most applicable. All recommendations are optional and subject to available funding and official adoption by a given agency or community. Regional flood planning groups that supported recommendations in their regional flood plans are included at the end of each recommendation, as applicable.

TWDB recommendations are divided into five broad categories:

1) **Floodplain management**

   a. [Communities] Communities are encouraged to develop, designate, and enforce floodplain management standards as recommended in Chapter 2 floodplain management recommendation A.

   b. [Communities and TWDB] Encourage National Flood Insurance Program participation and adoption of minimum floodplain management practices for all Texas communities. Consistent statewide adoption for minimum floodplain management standards helps ensure all Texas communities are on a level playing field and minimizes the risk of development within one community affecting flood risk in another community. This could be achieved through the following strategies:

      i. [Communities] Utilize base level engineering models and maps to improve local permitting processes and ensure development is in line with current flood risk assessments. Since many current FEMA regulatory maps are out of date, base level engineering is often considered the best available flood hazard data for some areas *[Recommended by Regions 4, 5, 10, 11, 15]*.

   c. [Communities and TWDB] Encourage use of higher floodplain management standards for communities who already have minimum or National Flood Insurance Program standards in place. The National Flood Insurance Program minimum standards only consider existing conditions (not future development) and do not account for uncertainty or variability of existing flood hazard estimates. In addition to reducing risk, adopting higher standards can provide discounts on flood insurance costs at each property if the community participates in the Community Rating System program. This could be achieved through the following strategies:

      i. [TWDB] Develop template ordinances with specific, State-recommended higher standards. Centralizing sets of recommended standards would help ensure consistency and uniformity across regions, which can be helpful for streamlining regulatory processes. Templates may also help communities more easily adopt and implement standards, reducing the burden on local resources *[Recommended by Regions 1, 4, 5, 6, 7, 11, 13]*.

      ii. [TWDB] Encourage regional, state, and federal agencies to provide incentives for community adoption and consistent adherence to higher standards. *[Recommended by Regions 6, 11]*.

      iii. [TWDB] Encourage and facilitate community adoption of consistent building codes. The United States does not have a national building code, nor does Texas have a state building code. International building codes are often developed and updated in response to lessons learned from recent natural disasters, like flooding, as well as advancements in technology. Adopting the latest codes can help communities ensure their infrastructure is equipped to handle potential flood risks *[Recommended by Regions 6, 13]*.

d. [Communities, TWDB, and other state agencies[32]] Develop and incentivize State-recommended higher standards for floodplain management, such as:

   i. [TWDB] Provide clear guidance for how communities may formally adopt base level engineering or other new flood modeling and mapping products to ensure access to the most accurate flood risk data available. Connect varying uncertainty in flood risk with varying freeboard recommendations to further refine local strategies and make communities more resilient to flood vulnerabilities *[Recommended by Regions 2, 3, 8, 9, 12, 13]*.

   ii. [Communities and other state agencies] Treat all coastal FEMA flood hazard zones (**Zone V and VE**) as areas potentially subject to high velocity wave action so buildings are more resilient and better able to resist the damaging force of waves.

   iii. [TWDB] Develop statewide guidance on accounting for flood velocities in riverine areas. Local adoption of this guidance would help standardize how communities assess and mitigate flood risks to protect areas from the dynamic and erosive force of high velocity flows. One example approach to assess severity of high velocity flows would be to consider the combination of flood depth times flood velocity.

   iv. [TWDB] Improve guidance on how to assess flood impacts in approximate **Zone A** areas, or other special flood hazard areas without base flood elevations. Develop guidance on how to determine best available data. Through this enhanced guidance, communities can better achieve a more accurate and comprehensive understanding of flood risks, allowing for more informed decision-making.

   v. [Communities] Improve community floodplain management and development permitting for RV parks in the floodplain. RV parks often lack permanent infrastructure, making them particularly vulnerable to flood events. Enhancing floodplain management in these areas can help ensure protective measures are in place and that development occurs in safer areas to reduce the risk to life and property.

   vi. [Communities] Adopt cumulative substantial damage regulations for communities. Tracking and addressing property damages over time can help communities recognize structures that are repeatedly at risk and may require proactive interventions and incentivize safety and sustainability over expensive short-term fixes.

   vii. [Communities and other state agencies] Implement regulations that require an additional 2 to 3 feet of freeboard above the base flood elevation (or known flood height + 2-3ft) where properties are identified as both substantially damaged and either repetitive loss or severe repetitive loss. Substantially damaged and repetitive loss properties have a demonstrated history of vulnerability to flooding. Requiring additional elevation reduces future risk to lives and property while reducing the financial burden of high insurance premiums on the property owner and community resources.

[32] Other State agencies may include but are not limited to Texas Division of Emergency Management, Texas General Land Office, Texas Department of Transportation, Texas Commission on Environmental Quality, and Texas State Soil and Water Conservation Board

e. [TWDB] Develop consistent statewide drainage and floodplain-related design and construction standards that are not otherwise covered with National Flood Insurance Program floodplain management regulations. Develop templates for local community adoption into ordinances or drainage criteria manuals. Align these efforts with existing components in place from the Texas Department of Transportation and other state agencies. *[Recommended by Regions 1, 2, 3, 4, 6, 7, 8, 9, 11, 12, 14]*.

f. [TWDB and other state agencies] Consider explicitly adopting National Flood Insurance Program regulations for State-owned properties. Further, consider adopting higher standards for State-owned properties. Many State-owned properties serve vital public functions that should be safeguarded to ensure continuity of essential services. Adopting minimum and/or higher standards for these properties sets an example for local communities while improving infrastructure resiliency, demonstrating good fiscal responsibility, and potentially reducing the burden on taxpayers to fund recovery efforts. FEMA is evaluating the few states that currently have not adopted National Flood Insurance Program regulations for State-owned properties and is considering imposing restrictions or penalties (such as loss of disaster grant funding opportunities).

g. [TWDB and other state agencies] Enhance coordination among state agencies for floodplain management. Improve education for state agencies that perform a variety of permitting functions, such as the Texas Parks and Wildlife Department for park properties, the Texas Department of Licensing and Regulation for mobile home installations, and the Railroad Commission of Texas for propane tank installations. Coordination ensures a streamlined and consistent approach to floodplain management while reducing overlaps and gaps in responsibilities *[Recommended by Regions 13, 14]*.

2) **Nature-based solutions**

a. [TWDB] Provide guidance on how communities can better maintain adequate flood flow conveyance capacities using nature-based techniques. Water needs space to flow. Leaving adequate space for water to flow can prevent it from creating its own space and causing flood risk to life and property. Adequate space can also better maintain the ecological health of creek and river systems.

b. [TWDB, communities, and other state agencies] Seek ways to provide additional incentives to nature-based solutions, such as open space preservation or reduced use of impervious cover approaches for development or drainage projects. Examples include improved Flood Infrastructure Fund prioritization or set-aside funding for nature-based solution projects. *[Recommended by Regions 5, 13]*.

3) **Asset management**

a. [TWDB] Generate and maintain a statewide inventory and assessment of major flood infrastructure. This is a large effort that will require dedicated resources and funding at the local level. [33]

b. [TWDB] Provide guidance on how to best manage drainage and floodplain assets to help all communities, regardless of their location or resources, benefit from consistent approaches to asset management. Providing clear, standardized guidance may also allow the State to direct resources more efficiently *[Recommended by Regions 3, 14]*.

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[33] May require additional resources to implement, including through the TWDB

4) **Education and outreach**

   a. [Communities, TWDB, and other state agencies] Seek to improve awareness and ways to mitigate risk at low water crossings. Examples include improved mapping of locations, improved flood warning, and increased or prioritized grant funding. Low water crossings remain one of the leading causes of flood-related fatalities in the state. By enhancing awareness, residents and travelers can make better informed decisions, reducing the risk of incidents *[Recommended by Regions 7, 9, 10, 11]*.

   b. [Communities, TWDB, and other state agencies] Improve public flood education, outreach and coordinated messaging between federal, state, regional, and local agencies. Increase targeted marketing campaigns through avenues like social media, print media, TV media, and billboard media. Public information campaigns can help Texans better understand flood risk and prepare for future flood events *[Recommended by Regions 8, 11, 13, 14]*.

   c. [Communities, TWDB, and other state agencies] Improve training and professional development activities for floodplain practitioners like floodplain administrators, as well as floodplain-related professions such as planning, development, real estate, and insurance. Floodplain management approaches are continually evolving with advances in technology, research, and best practices. Improved training can help incorporate those changes into existing activities. *[Recommended by Region 13]*.

   d. [Communities, TWDB, and other state agencies] Increase regional and statewide activities related to flood warning. Support the National Weather Service's release of new flood inundation mapping products. Improve guidance and outreach related to developing flood warning systems and flood sensors. Flood warning systems enhance preparedness and response time in emergencies, potentially saving lives and reducing property damage. Bolstering flood warning activities can also help communities gather and analyze data more comprehensively, helping to refine prediction models *[Recommended by Regions 11, 12, 14]*.

5) **State flood planning**

   a. [TWDB and other state agencies] Maintain coordination between Texas Division of Emergency Management's state hazard mitigation planning and the TWDB's state flood planning processes. Seek to incorporate state flood planning into other statewide planning processes such as Texas Department of Transportation planning, Texas Parks and Wildlife Department planning, and Texas Facilities Commission planning. Integrating planning processes can ensure a more cohesive and comprehensive approach to addressing flood risk in the state while helping to eliminate overlaps and gaps in planning efforts.

References

Campbell, Warren and Davis, Emily G., 2023, Western Kentucky University Stormwater Utility Survey 2023, SEAS Faculty Publications. Paper 8. https://digitalcommons.wku.edu/seas_faculty_pubs/8, accessed September 2023

FEMA (Federal Emergency Management Agency), 2005, National Flood Insurance Program Floodplain management requirements, http://www.fema.gov/sites/default/files/documents/fema-480_floodplain-management-study-guide_local-officials.pdf

6 Goals

Quick facts

A total of 350 flood planning goals were adopted across all 15 regional flood planning groups.

Of those, 187 were short term (by 2033) and 163 were long term (by 2053).

The overarching goals of Texas' state and regional flood planning process as set forth in Texas Water Code § 16.061 are:

- to provide for the orderly preparation for and response to flood conditions;
- to protect against the loss of life and property;
- to be a guide to state and local flood control policy; and
- to contribute to water development where possible, all without making flooding conditions worse for neighboring areas.

The regional and state planning administrative rules provide a common framework and technical guidance for each regional flood planning group to develop common goals while considering a variety of local interests and the entities that regulate floodplain development and will implement the projects. Ideally, the development of common, shared regional flood planning goals will improve basin-wide floodplain and flood risk management.

6.1 Regional flood planning goal requirements

Identifying and setting goals is an important step in any planning process and helps ensure that plans are developed and implemented to work towards specific and achievable results. Goals demonstrate commitment to the success of the greater regional and state flood planning process. The statewide flood plan is a cyclical effort recurring every five years, during which the regional planning groups will review the goals they set for their region during preceding cycles and consider how much of each goal was achieved. Along the way, the planning groups may also modify, add, or remove goals.

The regional flood planning groups are self-governing entities with considerable latitude in setting goals for their respective regions. The administrative rules in 31Texas Administrative Code § 361.36,[34] Flood Mitigation and Floodplain Management Goals, specify the required structure and presentation of goals and the regional flood plan components that must be considered when identifying these goals. Additional considerations are listed in the state and regional flood planning guidance principles under 31 Texas Administrative Code § 362.3. The guidance principles include several references to goals, including specific requirements that state and regional flood plans

- include flood management strategies and projects recommended by the regional flood planning groups that are based upon identification, analysis, and comparison of all flood management strategies the regional flood planning groups determine to be potentially feasible to meet flood mitigation and floodplain management goals; and
- consider land use and floodplain management policies and approaches that support short- and long-term flood mitigation and floodplain management goals.

The regional flood planning groups were required to define specific and achievable flood mitigation and floodplain management goals for their regional flood plans that, when implemented, would demonstrate progress towards the overarching objective "to protect against the loss of life and property," as set forth in the flood planning guidance principles. The regional flood planning groups were asked to consider the unique weather related and geographic characteristics of their respective flood planning

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[34] https://texreg.sos.state.tx.us/public/readtac$ext.ViewTAC?tac_view=5&ti=31&pt=10&ch=361&sch=C&rl=Y

regions, their existing and future condition flood risk, and the existing floodplain management practices across their region, while setting goals.

Regional flood planning groups were required to establish goals considering short-term (within 10 years by 2033) and long-term (within 30 years by 2053) planning horizons. Setting short- and long-term goals helps to outline a progressively successful path forward in meeting identified flood risk needs.

As goals are generally broad statements, the regional flood planning groups were asked to limit the geographical scope of the goals to a single subbasin level (a map boundary that is defined by the U.S. Geological Survey as a medium-sized river basin coded with the term Hydrologic Unit Code, or HUC, 8) (USGS, n.d.).

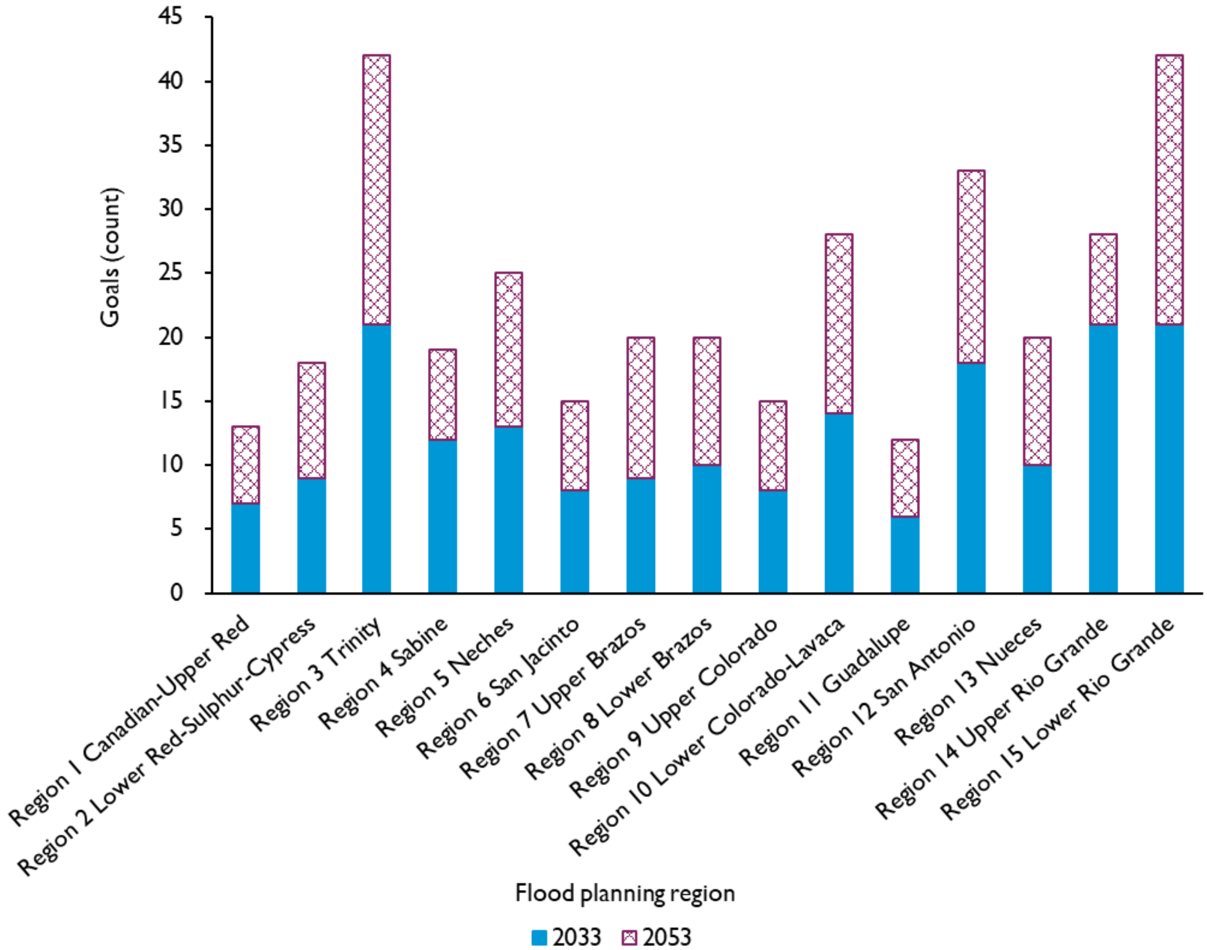
In addition to administrative rules, each regional flood planning group approached the process of defining its region-specific goals using detailed technical guidelines provided by the Texas Water Development Board (TWDB), which provided flexibility to consider unique regional characteristics and flood risk information developed in previous tasks. Examples of unique regional characteristics include geographic features, such as playas in the Panhandle region, high percentages of rural or urban communities, or steep elevation changes that could lead to flash flooding.

The regional flood planning groups devoted time during public meetings over several months for deliberations on appropriate flood mitigation and floodplain management goals for their respective areas. Each regional flood planning group gathered input regarding the selection of goals using different formats, ranging from public input meetings to online questionnaires and surveys that gathered responses and categorized priorities. Most planning groups discussed goals four to five times during the plan development and generally followed a similar pattern of goal development: 1) introduction to goals, 2) categorization of goals, 3) prioritization of recommended goals, and 4) adoption of goals.

6.2 Summary of regional flood planning goals

The 15 planning groups identified and adopted a total of 350 goals reflecting the unique conditions and needs of their regions. Of these, 187 are short-term goals and 163 are long term. Not every short-term goal has an equivalent long-term goal. In some cases, a goal could be achieved in the short term and, therefore, would not require a long-term equivalent or vice versa. For example, if full participation of every municipality in the National Flood Insurance Program was a short-term goal, no long-term goal would be needed once all the municipalities are participating. Figure 6-1 shows a numerical summary of short-term and long-term goals adopted by each region.

Figure 6-1. Count of short- and long-term flood planning goals by flood planning region



The varying geographic size, population, and environmental and hydrologic conditions resulted in a variation in the number of goals per region. Region 15 Lower Rio Grande and Region 3 Trinity have the greatest number of goals (42), while Region 11 Guadalupe identified the fewest (12). The average number of goals per region was 17. The total number of goals per region does not reflect the volume or quality of related work but rather that regions are unique, and each planning group crafted its goals within specific contexts and at varying levels of resolution.

Regional flood planning groups were required to associate their recommended flood management evaluations, projects, and strategies in their regional flood plans with their adopted goals. In concept, the recommendations should all work toward achieving the region's flood mitigation goals.

Regional flood planning groups shaped their goals to be measurable by comparing the current flood risk to what they want to achieve in the future, either using percentages or number counts. For example, one region might aim to reduce the percentage of communities without adequate floodplain standards by 25 percent. Another region might aim to increase the number of counties with digital flood maps by five. Progress toward both goals will be tracked in future iterations of the flood plans.

6.3 Key themes of the planning goals

The TWDB analyzed the collective 350 goals for similarities to determine if any trends or themes could be identified. This analysis involved selecting keywords to attempt to group the collective goals based on the intended result of each goal if implemented. These summary keywords were then collated and given a theme. This exercise was intended to gain an overall sense of what the regional flood planning groups aim to accomplish while recognizing that overlap remains between some of the goals and themes. It would be difficult to assign goals into groups in a meaningful way due to these overlaps.

An example of this overlap can be seen with Region 13 Nueces' goals to 1) identify dedicated funding sources, including state funding opportunities, for 20 percent of the communities and 30 percent of the counties and 2) develop a strategy for public engagement on flood-related issues, including a list of flood mitigation funding programs and potential opportunities for communities to participate in programs to support flood risk reduction (such as the FEMA Community Rating System) to serve as a template for rural and underserved communities by 2030. This goal includes the themes "stakeholder and public outreach," "policy/higher floodplain management," and "funding sources."

The TWDB identified 13 overarching themes from the flood planning goals adopted by the flood planning groups:

1) Conducting flood risk reduction studies
2) Reduce structures and population in the 1 percent (100-year) and 0.2 percent (500-year) annual chance event floodplains
3) Implementing flood risk reduction projects
4) Stakeholder and public outreach, education, and training
5) Higher floodplain management standards/policies
6) Roadway safety and early warning systems
7) Infrastructure assessment, maintenance, and rehabilitation
8) Nature-based solutions, green infrastructure, and preservation
9) Funding
10) Reducing flood risk to critical facilities
11) Water supply
12) Non-structural flood risk reduction
13) Multiple themes[a]

[a] Approximately 69 percent (242) of all regional flood planning goals belonged to more than one theme.

6.3.1 Conducting flood risk reduction studies

Approximately 21 percent (74) of all goals seek to reduce flood risk through studies (Figure 6-2). This includes goals for performing studies to analyze unmapped areas, increase flood risk data coverage and availability, and studies to advance flood mitigation project development (Table 6-1).

Figure 6-2. Goals to implement flood risk reduction studies by flood planning region

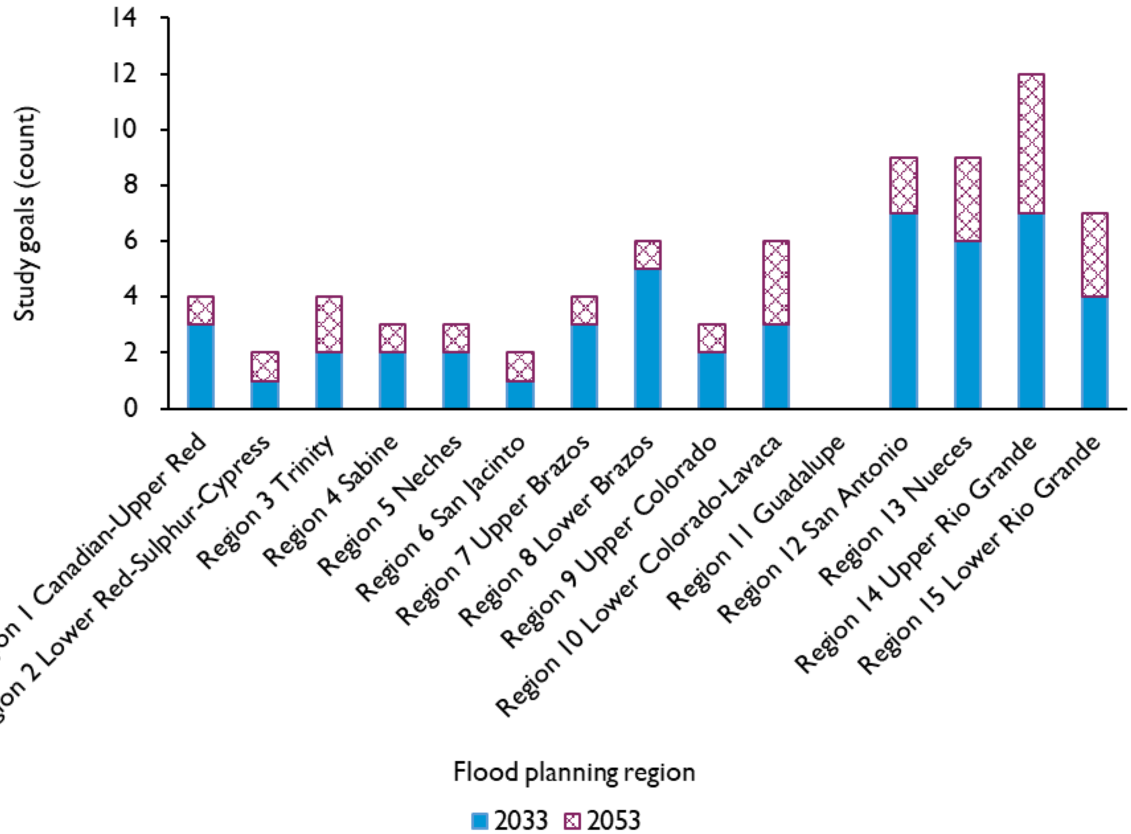


Table 6-1. Examples of goals related to risk reduction studies

Region	Goal	Term of goal	Target year
8	Reduce the gap in the accuracy of flood hazard data in the flood planning region by performing detailed studies using the best available terrain, land use, and precipitation data to reduce gaps in floodplain mapping.	Long term (30 year)	2053
13	Identify structures within existing floodplain with 1 percent annual chance flood risk for 100 percent of the basin, including areas that have been updated with more accurate mapping. Prepare a list of high-hazard buildings based on function, critical function, repetitive loss, or other community-related importance, summarize and distribute results to affected floodplain management entities. Reduce the number of high-hazard structures within the 1 percent existing floodplain by 50 percent.	Long term (30 year)	2053
15	Decrease the average age of FEMA Flood Insurance Rate Maps used to define special flood hazard areas in the region by 30 to 40 percent.	Short term (10 year)	2033

Note: All goals listed here and throughout were adopted by regional flood planning groups

6.3.2 Reduce structures and population in the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains

The goals in this theme aim to reduce the number of structures located in flood hazard areas, thereby reducing the population at risk of flooding. Approximately 16 percent (57) of all goals seek to reduce flood risk and exposure in the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains (Figure 6-3). This includes goals to remove, relocate, or reduce the number of structures and critical facilities in the floodplain and goals to reduce the risk of flooding to agricultural lands (Table 6-2).

Figure 6-3. Goals related to risk and exposure reduction in the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains (including structural improvements, land acquisition, and agricultural land) by flood planning region

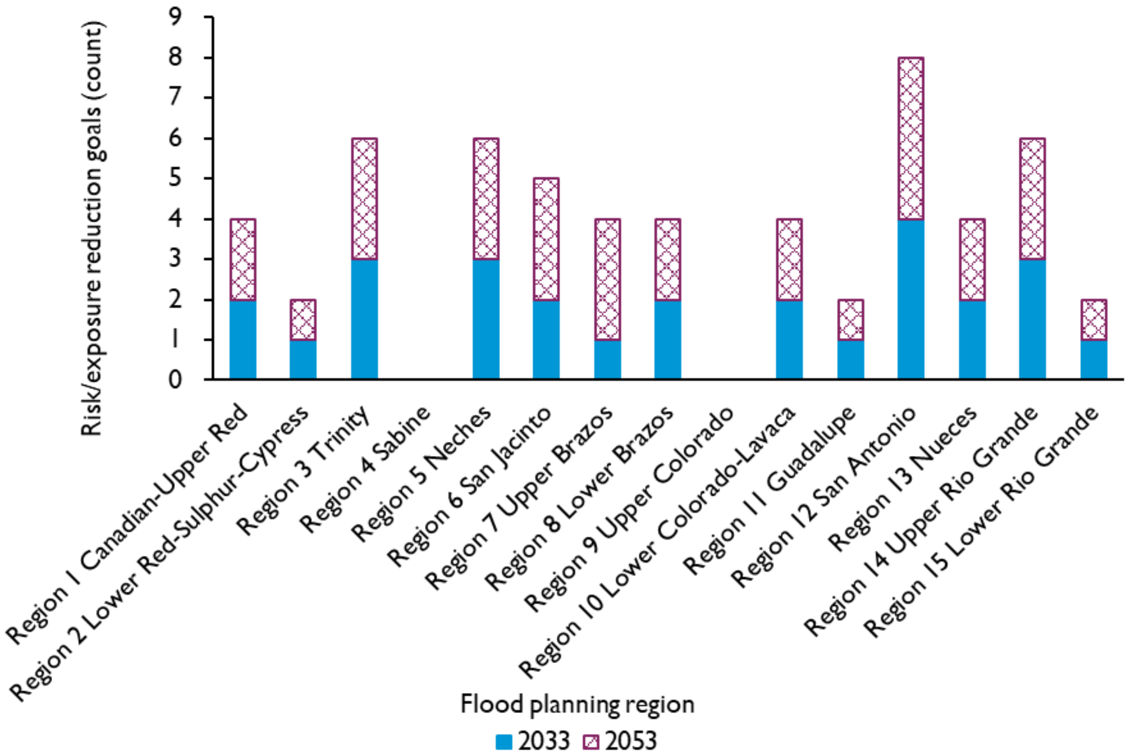


Table 6-2. Examples of goals related to reducing structures and population in the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains (including structural improvements, land acquisition, and agricultural land)

Region	Goal	Term of goal	Target year
1	Reduce number of habitable structures within the 1 percent existing flood hazard layer by 20 percent.	Short term (10 year)	2033
5	An average of 25 percent of the new regional infrastructure projects between 2033 and 2053 will utilize larger storm events (>100-year) as the basis of their design.	Long term (30 year)	2053
6	Reduce the number of structures subject to inundation during the 100-year event by 25 percent by 2053.	Long term (30 year)	2053

6.3.3 Implementing flood risk reduction projects

Approximately 41 percent (142) of all goals relate to implementing flood risk reduction projects (Figure 6-4). This applies to implementing structural and non-structural projects, including construction and land acquisition (Table 6-3).

Figure 6-4. Goals related to implementing flood risk reduction projects (including acquisition and construction) by flood planning region

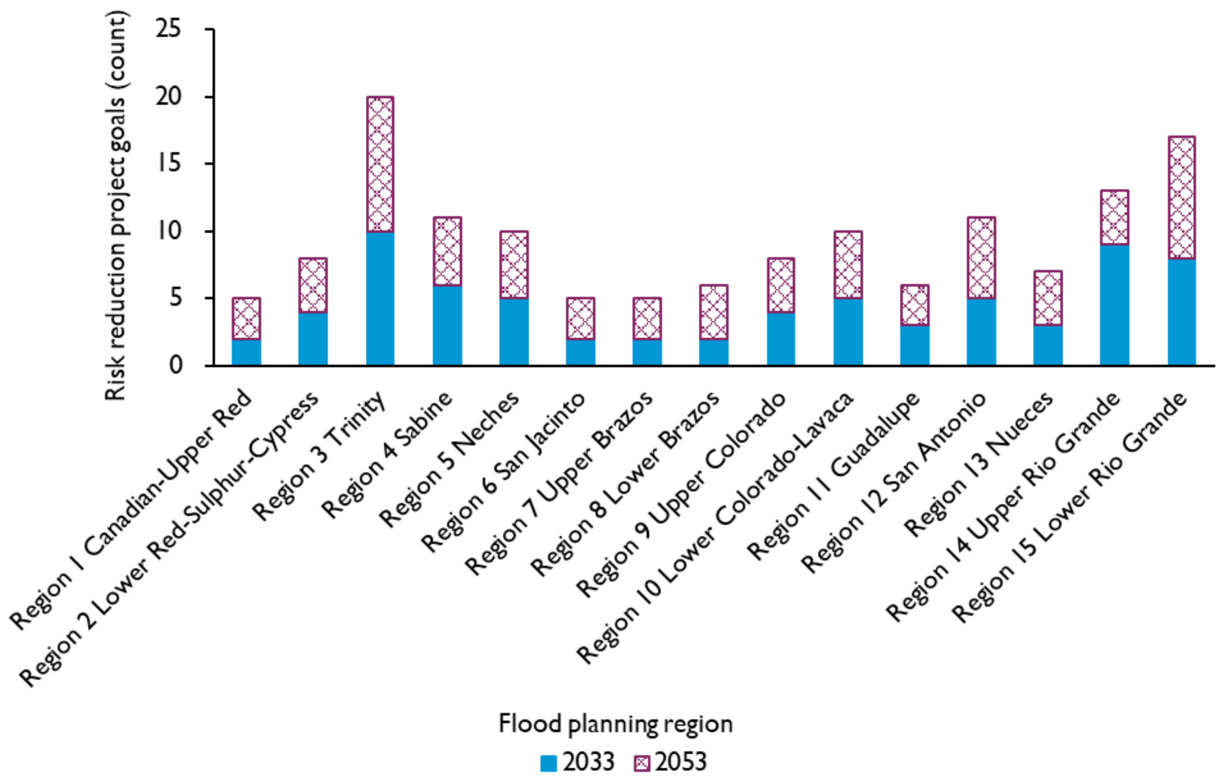


Table 6-3. Examples of goals related to implementing flood risk reduction projects (including acquisition and construction)

Region	Goal	Term of goal	Target year
3	Reduce the number of structures within the 1 percent floodplain by 10 percent (i.e. through structural projects, property buyouts, acquisitions, elevations, and/or relocations.)	Long term (30 year)	2053
4	Reduce exposure of existing structures in flood prone areas by elevating, acquiring, relocating, or otherwise providing flood protection to 10 percent of structures.	Short term (10 year)	2033

6.3.4 Stakeholder and public outreach, education, and training

Approximately 37 percent (129) of all goals relate to enhancing public outreach and stakeholder engagement (Figure 6-5). This includes efforts to increase public participation in the regional flood planning process, providing and promoting training opportunities, and efforts to promote regional and interjurisdictional coordination on flood planning (Table 6-4).

Figure 6-5. Stakeholder and public outreach, education, and training goals (including coordinated planning and response) by flood planning region

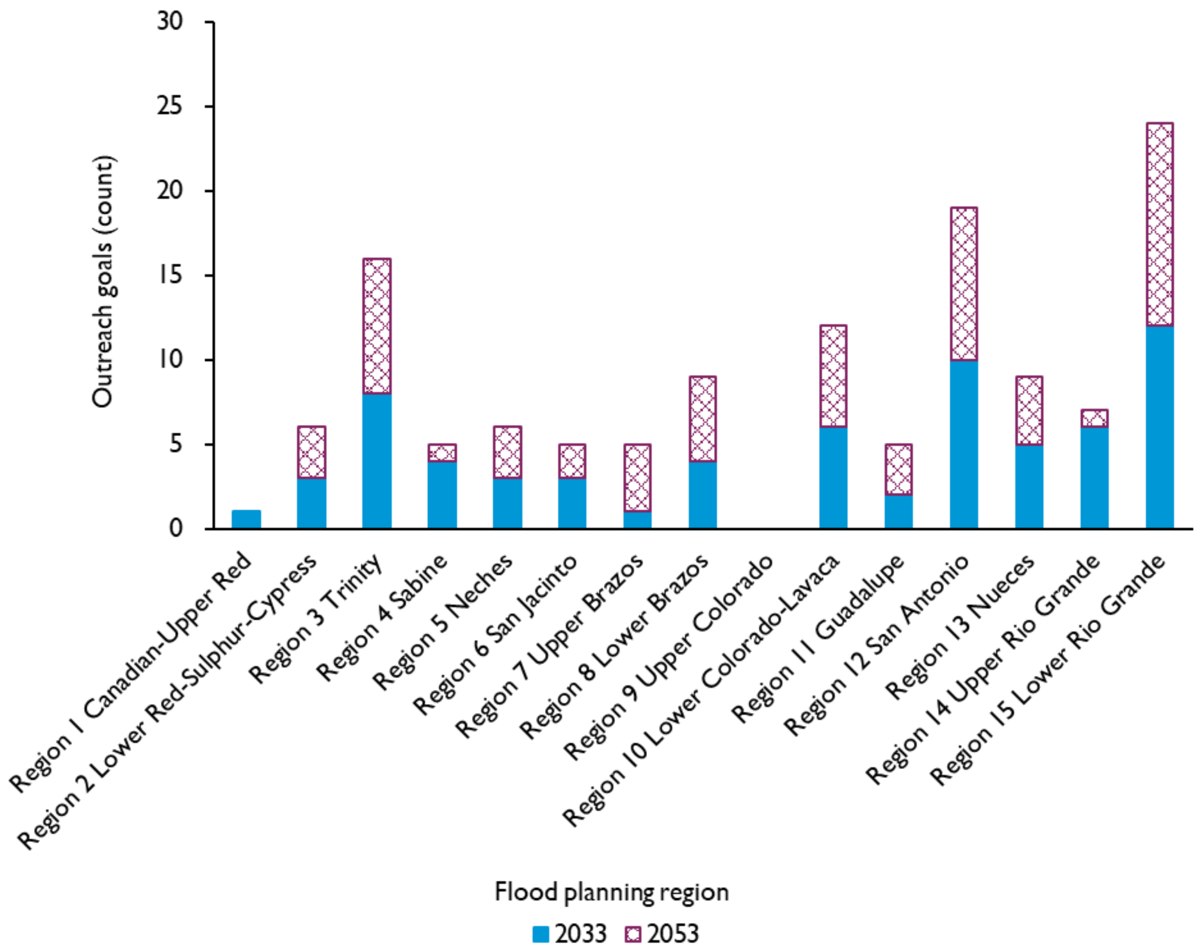


Table 6-4. Examples of goals related to stakeholder and public outreach, education, and training (including coordinated planning and response)

Region	Goal	Term of goal	Target year
2	For each planning cycle, hold three public outreach and education activities (in multiple locations within the region) to improve awareness of flood hazards and benefits of flood planning.	Short term (10 year)	2033
7	Encourage annual public outreach and education activities to improve awareness of flood hazards, flood planning, and projects associated with emergency response associated with flooding.	Long term (30 year)	2053
14	Establish community-led flood outreach and awareness programs (addressing risk, resiliency, and mitigation) in 90 percent of communities in the region.	Long term (30 year)	2053

6.3.5 Higher floodplain management standards/policies

Approximately 23 percent (79) of all goals seek to improve or increase the higher floodplain management standards adopted and implemented by communities (Figure 6-6). This includes efforts to increase National Flood Insurance Program participation and flood insurance policies, develop enhanced floodplain management and design standards applicable across a flood planning region and/or the state, and increase the utilization of best available data by communities (Table 6-5).

Figure 6-6. Goals related to higher floodplain management standards/policies (including National Flood Insurance Program participation, higher standards, flood insurance, design standards) by flood planning region

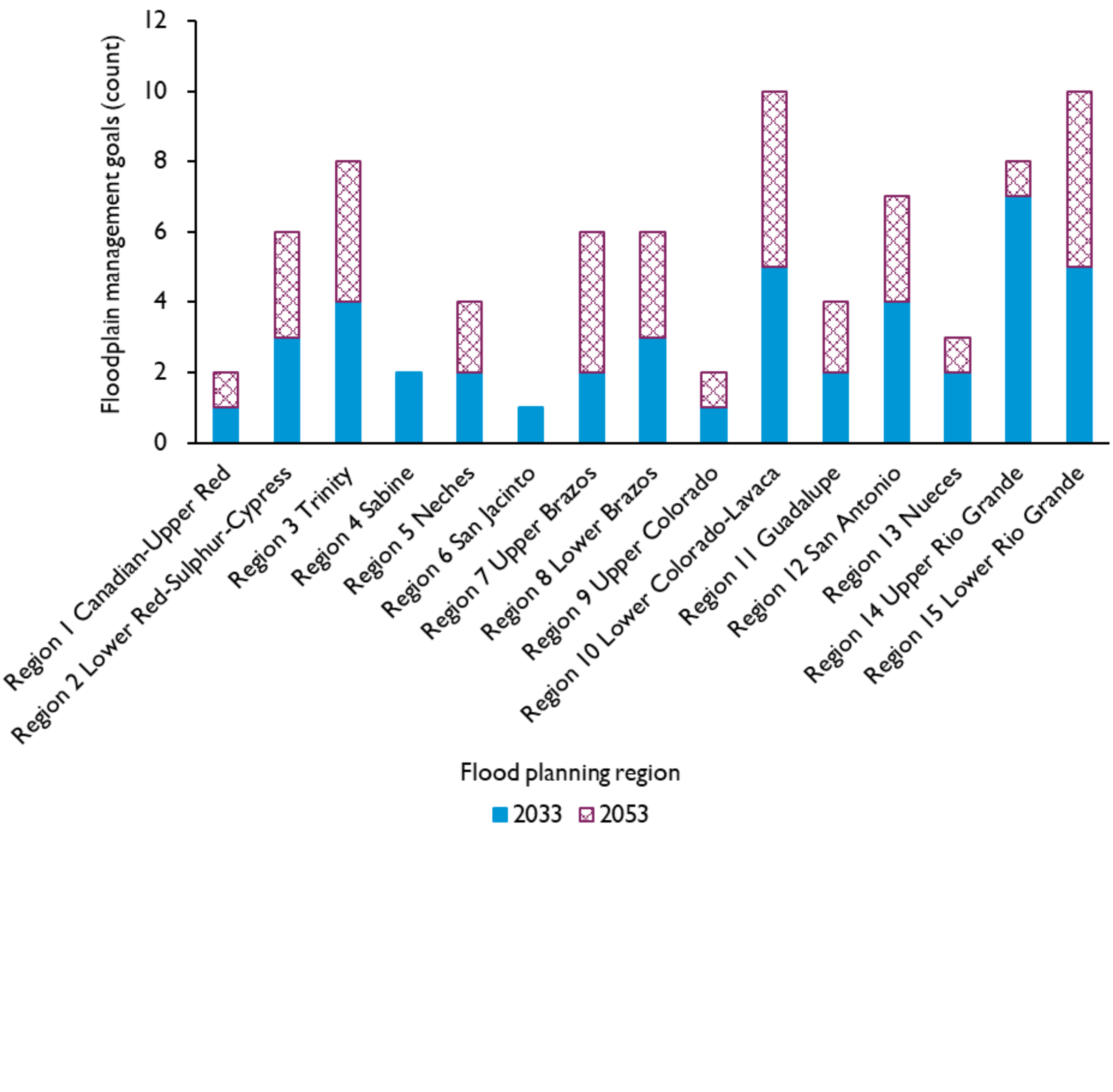


Table 6-5. Examples of goals related to higher floodplain management standards/ policies (including National Flood Insurance Program participation, higher standards, flood insurance, design standards)

Region	Goal	Term of goal	Target year
5	An average of 25 percent of the new regional infrastructure projects between 2033 and 2053 will utilize larger storm events (>100-year) as the basis of their design.	Long term (30 year)	2053
6	All flood regulatory authorities within the region will adopt standards equal to or exceeding minimums as recommended by the San Jacinto regional flood planning group in the first cycle of regional flood planning.	Short term (10 year)	2033
9	Increase to 90 percent of cities and 90 percent of counties with National Flood Insurance Program or equivalent standards	Short term (10 year)	2033

6.3.6 Roadway safety and early warning systems

Approximately 17 percent (61) of all goals seek to address flood risk related to roadways (Figure 6-7). This includes goals to improve safety at low water crossings, improve the level of service for exposed roadway segments, and increase the implementation of flood early warning systems for roadways and flood prone areas (Table 6-6).

Figure 6-7. Goals related to roadway safety and early warning systems (including low water crossings and other vulnerable roadways, signage, flood gauges, real-time reporting) by flood planning region

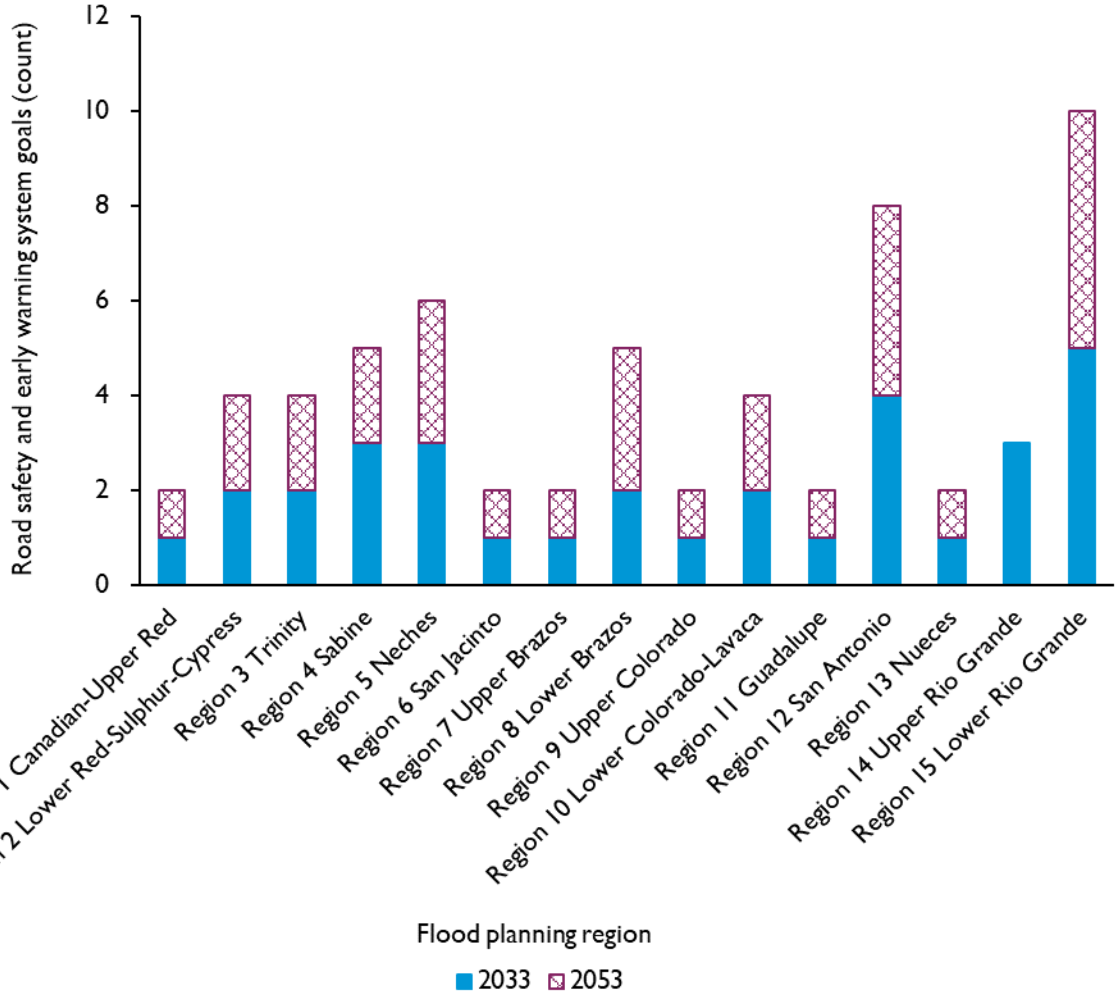


Table 6-6. Examples of goals related to roadway safety and early warning systems (including low water crossings and other vulnerable roadways, signage, flood gauges, real-time reporting)

Region	Goal	Term of goal	Target year
5	Give notice to 100 percent of affected units of local government and improve 50 percent of low water crossings identified in the latest regional flood plan by installing warning devices.	Short term (10 year)	2033
11	Improve safety beyond minimal signage at 90 percent of low water crossings through automatic flood gates and/or flood level passed.	Long term (30 year)	2053

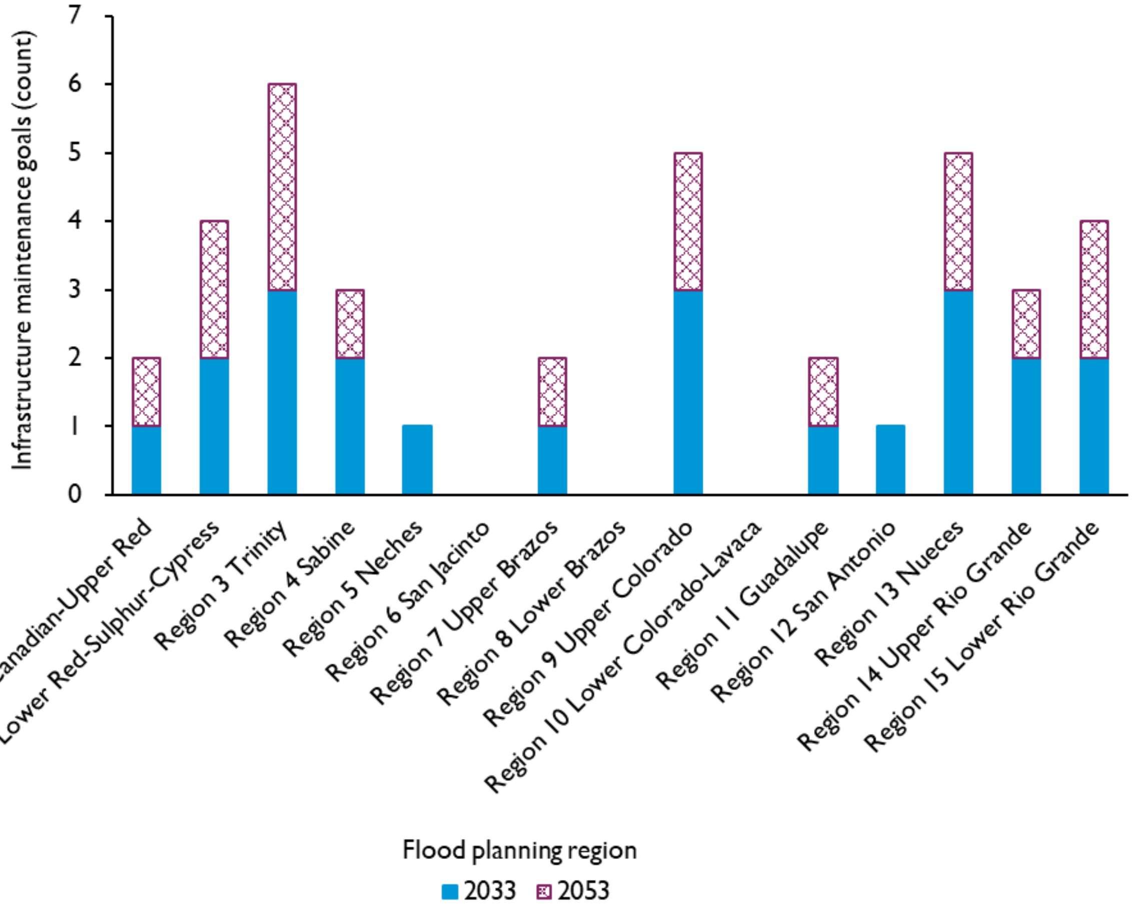
Of these 61 goals, approximately 20 percent (12) refer to flood gauges or technology related to monitoring rainfall, stream, and flood levels within the region (Table 6-7).

Table 6-7. Example of roadway safety and early warning system goals related to refer to flood gages or technology related to monitoring rainfall, stream, and flood levels

Region	Goal	Term of goal	Target year
4	Increase number of monitoring gauges and associated real-time reporting technology installed and maintained in the region to one in 50 percent of Hydraulic Unit Code 10s.	Short term (10 year)	2033
8	Perform an evaluation on the number of basins in the region and establish a baseline of where additional gauges (rainfall, stream, reservoir, etc.) are needed.	Short term (10 year)	2033
12	Increase the number of flood gauges (rainfall, stream, reservoir, etc.) in the region to provide localized information to emergency responders and storage and accessibility of data to agencies by 50 percent.	Long term (30 year)	2053

6.3.7 Infrastructure assessment, maintenance, and rehabilitation

Figure 6-8. Infrastructure assessment, maintenance, and rehabilitation goals (including dams and levees) by flood planning region



Approximately 11 percent (38) of all goals seek to repair, rehabilitate, or replace aging, deficient, and/or non-functional flood infrastructure (Figure 6-8). This includes goals to address high-hazard dams, unaccredited levees, low water crossings, and many other types of flood, stormwater, and drainage infrastructure (Table 6-8).

Table 6-8. Examples of goals related to infrastructure assessment, maintenance, and rehabilitation (including dams and levees)

Region	Goal	Term of goal	Target year
4	Increase number of monitoring gauges and associated real-time reporting technology installed and maintained in the region to one in 50 percent of Hydraulic Unit Code 10s.	Short term (10 year)	2033
8	Perform an evaluation on the number of basins in the region and establish a baseline of where additional gauges (rainfall, stream, reservoir, etc.) are needed.	Short term (10 year)	2033

6.3.8 Nature-based solutions, green infrastructure, and preservation

Approximately 9 percent (33) of all goals aim to increase the number of nature-based flood mitigation solutions, green flood infrastructure, and land implementing preservation, conservation, and/or restoration practices (Figure 6-9). These include goals for increased consideration of green and nature-based solutions when selecting flood infrastructure and mitigation projects and goals to increase the area of land naturally preserved, conserved, and/or restored for flood risk reduction and ecosystem co-benefits (Table 6-9).

Figure 6-9. Goals related to nature-based solutions, green infrastructure, and preservation by flood planning region

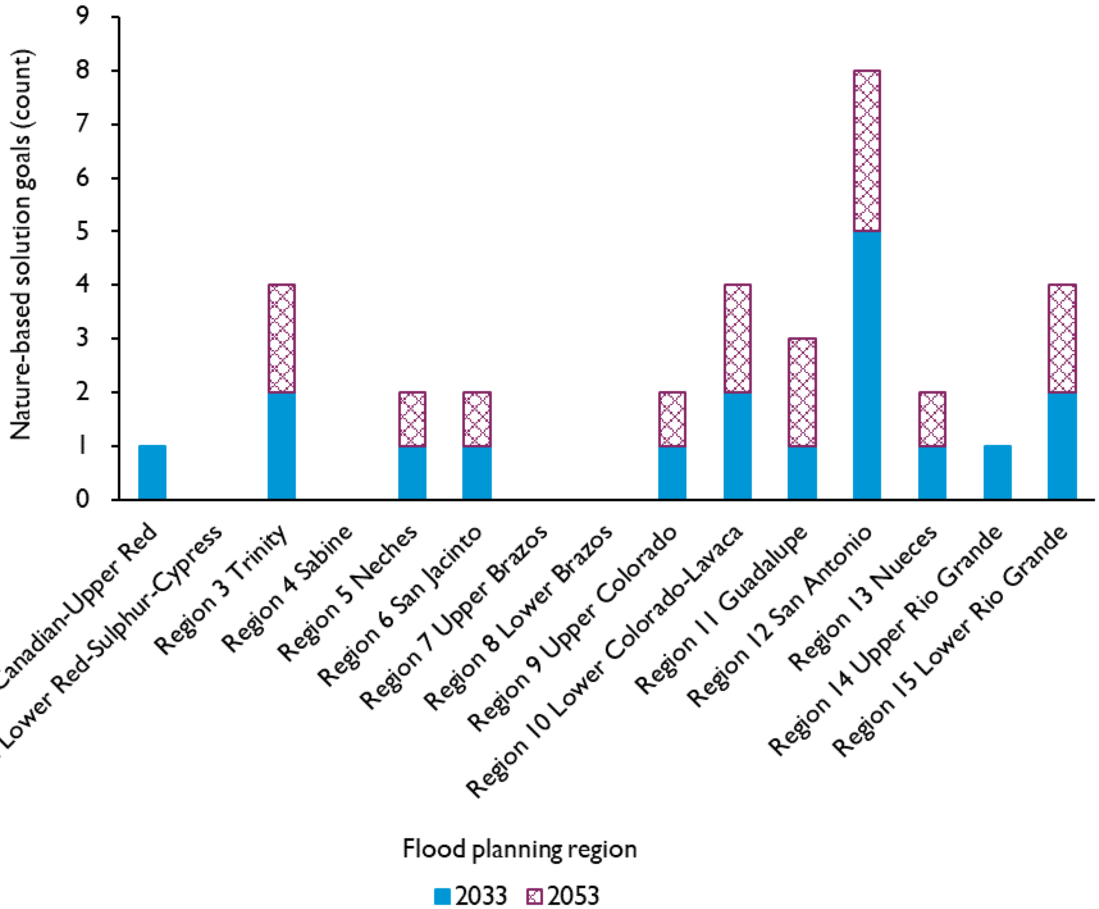


Table 6-9. Examples of goals related to nature-based solutions, green infrastructure, and preservation

Region	Goal	Term of goal	Target year
6	At least 90 percent of flood management strategies and flood mitigation projects identified within the regional floodplain will incorporate nature-based practices by 2053.	Long term (30 year)	2053
11	Consider and incorporate nature-based practices when acreage exceeds one acre (low-impact development, green infrastructure, natural channel design) in 50 percent of flood mitigation projects and strategies recommended in the regional flood plan.	Long term (30 year)	2053

6.3.9 Funding

Approximately 9 percent (31) of all goals seek to increase potential funding opportunities for flood mitigation and floodplain management (Figure 6-10). This includes identifying potential sources of state and federal funding for capital projects and studies and goals to increase the amount and number of communities with dedicated, continuous funding mechanisms, such as stormwater fees to support capital, operations, and maintenance costs (Table 6-10).

Figure 6-10. Funding goals (including identification of possible sources and locating dedicated sources) by flood planning region

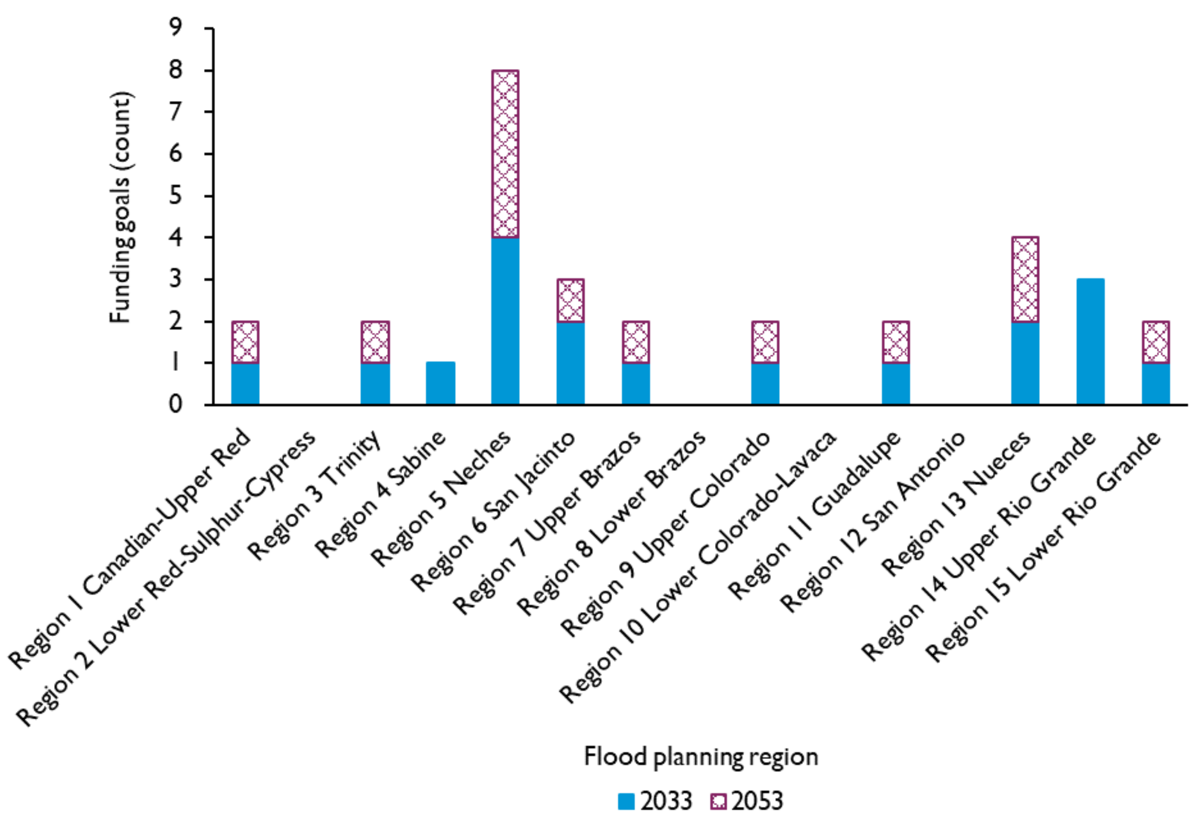


Table 6-10. Examples of goals related to funding (including identification of possible sources and locating dedicated sources)

Region	Goal	Term of goal	Target year
5	Seventy-five percent of the region's population is part of an entity that has a dedicated drainage charge, fee, or other continuous funding mechanism for the maintenance and/or restoration of flood infrastructure.	Long term (30 year)	2053
13	Dedicated funding sources, including state funding opportunities to support operations and management for 20 percent of the communities and 30 percent of the counties in Region 13.	Short term (10 year)	2033

6.3.10 Reducing flood risk to critical facilities

Approximately 4 percent (15) of all goals specifically called upon the active efforts to mitigate flood risk toward critical facilities (Figure 6-11). These include efforts to increase community access routes to critical facilities, reduce new critical facility construction in the 1 percent (100-year) annual chance hazard areas, and improve flood protection for critical facilities in flood prone areas (Table 6-11).

Figure 6-11. Goals to reduce flood risk to critical facilities by flood planning region

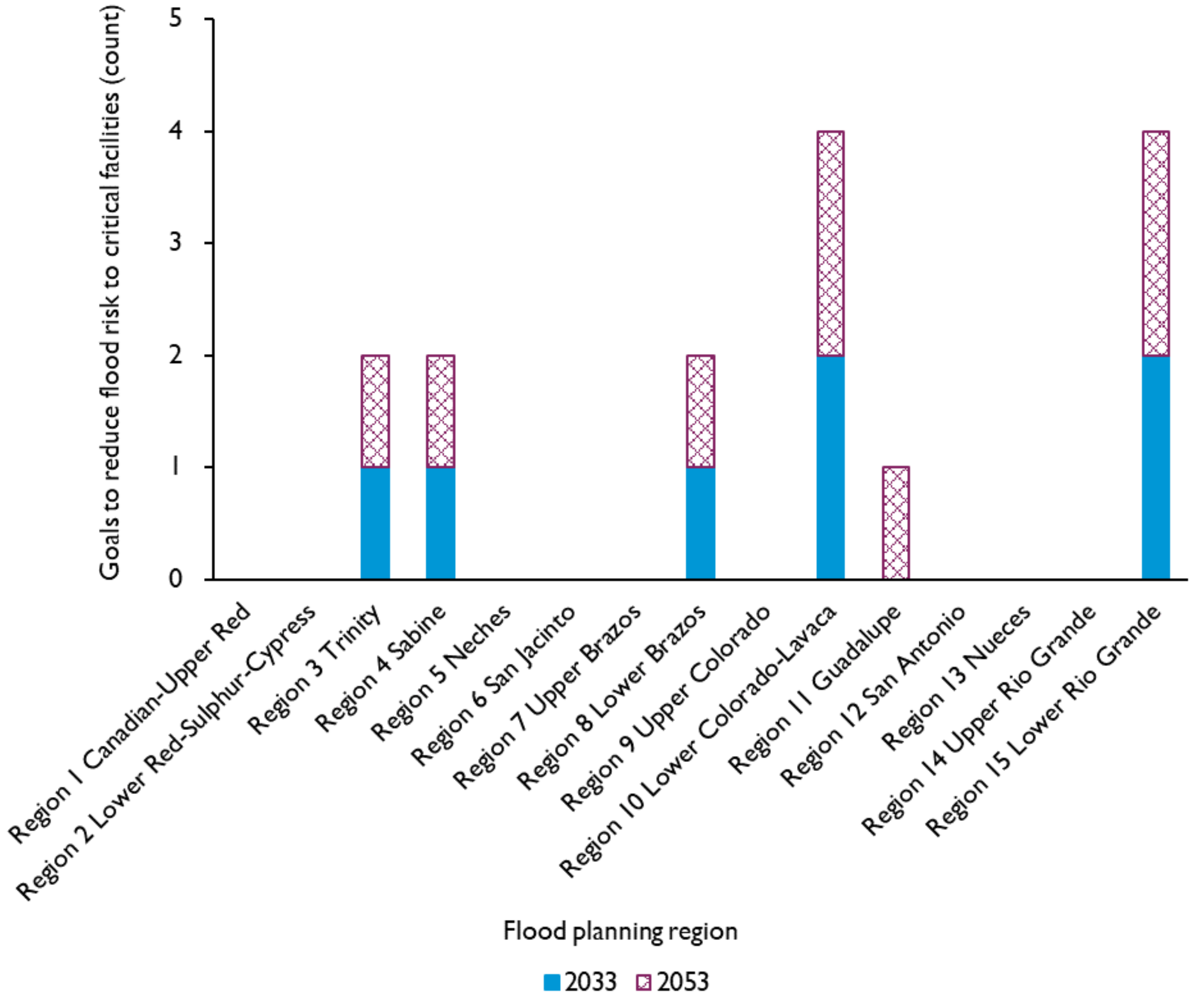


Table 6-11. Examples of goals related to reducing flood risk to critical facilities

Region	Goal	Term of goal	Target year
11	Reduce number of vulnerable buildings/structures/critical facilities within the 1percent existing flood hazard layer by 50 percent.	Long term (30 year)	2053
13	Reduce the number of critical facilities within the 1 percent floodplain.	Short term (10 year)	2033

Water supply

Approximately 1 percent (3) of all goals pursue opportunities for contributions to water supplies through elements of regional flood planning (Figure 6-12). These include efforts to establish dual-purpose regional storage facilities for flood mitigation and water supply and goals increasing the number of entities providing flood/stormwater detention that could be used for water reuse applications (Table 6-12).

Figure 6-12. Water supply goals by flood planning region

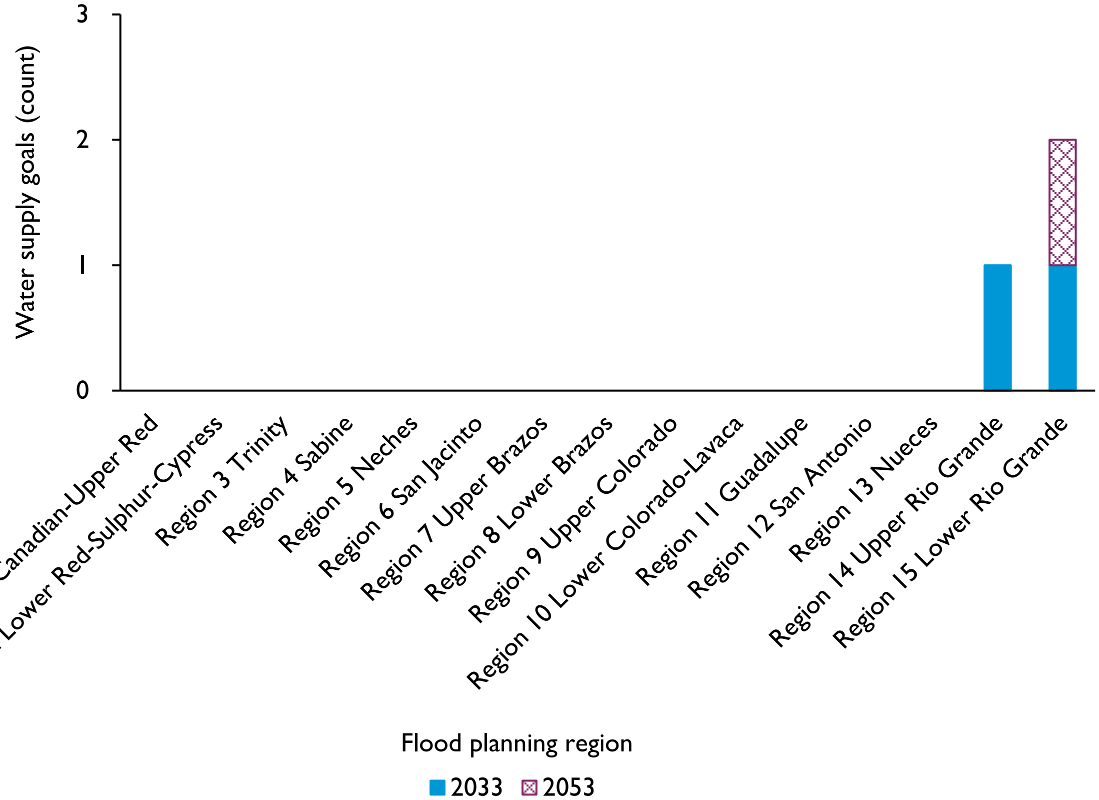


Table 6-12. Examples of goals related to water supply

Region	Goal	Term of goal	Target year
14	Establish dual usage regional storage facilities for flood mitigation and water supply.	Short term (10 year)	2033
15	Increase the number of entities that provide regional detention that could be used for water reuse applications or as part of their floodplain management program by over 60 percent.	Long term (30 year)	2053

6.3.11 Non-structural flood risk reduction

Approximately 18 percent (64) of all goals were related to pursuing opportunities for mitigating flood risk through non-structural approaches (Figure 6-13). These include efforts to establish flood early warning systems, flood gauges, and real-time reporting mechanisms (Table 6-13).

Figure 6-13. Non-structural flood risk mitigation goals by flood planning region

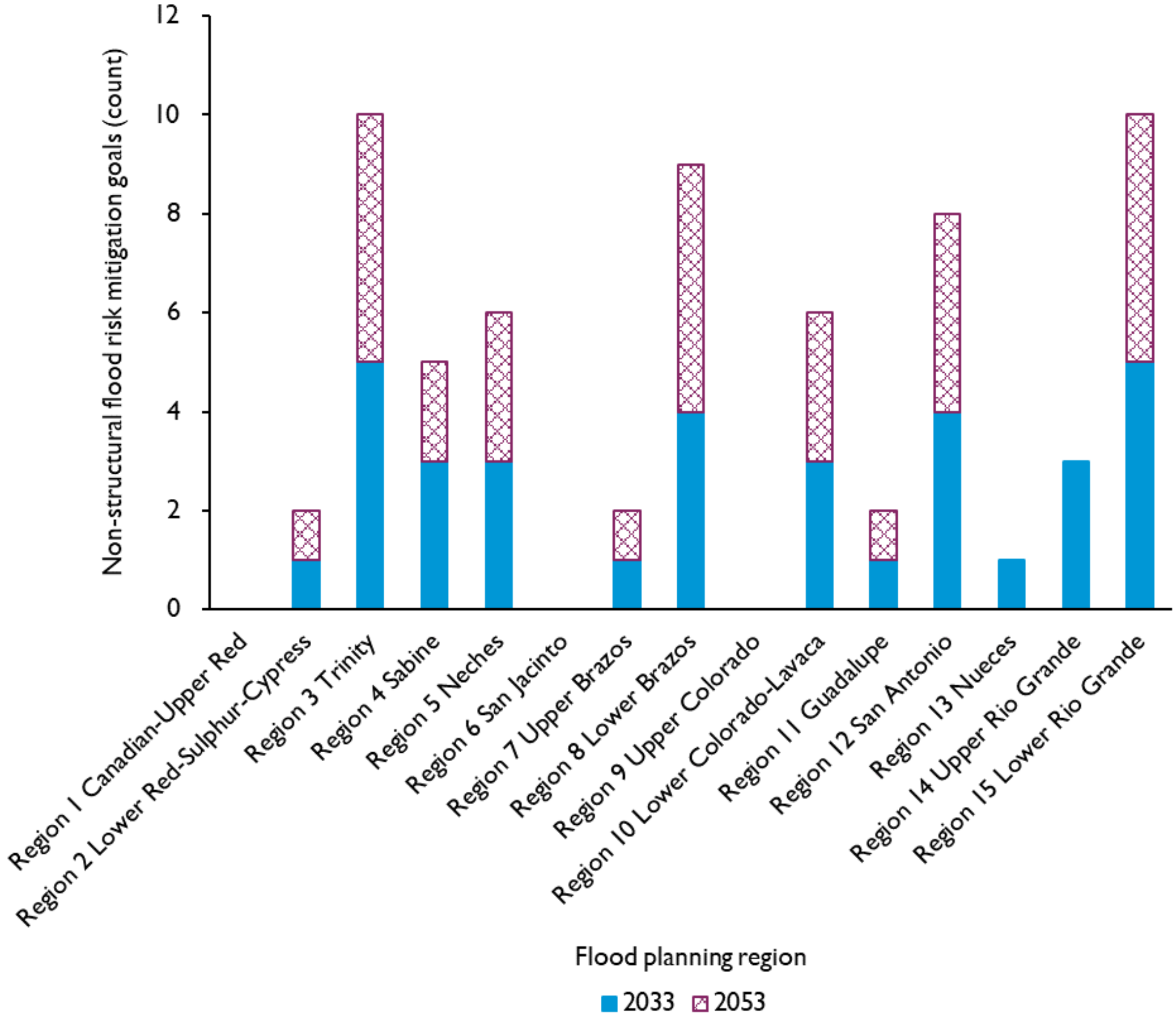


Table 6-13. Examples of goals related to non-structural flood risk mitigation

Region	Goal	Term of goal	Target year
13	Improve regional coordination, data collection/sharing of flood events and impacts, and implementation of flood warning systems.	Long term (30 year)	2053
15	Develop a regionally coordinated warning and emergency response program that can detect the flood threat and provide timely warning of impending flood danger to more than 70 percent of the most populated areas of the region.	Long term (30 year)	2053

6.3.12 Multiple themes

While an attempt was made to categorize goals into 12 themes based on the many similarities in regional flood planning group goals, the uniqueness of the regions and planning group membership led to many variations and perspectives (Table 6-14). Approximately 69 percent (242) of all regional flood planning goals belonged to more than one theme.

Table 6-14. Examples of goals that belonged to more than one theme

Region	Goal	Description	Term of goal	Target year
10	Increase the number of communities with warning and emergency response capabilities, or that participate in regional flood warning systems (e.g., Lower Colorado River Authority, Hydromet, City of Austin Early Warning System), that can detect flood threats in real time and provide timely warning of impending flood danger.	(1) Risk and exposure reduction in the 1 percent and 0.2 percent floodplains (including structural improvements, land acquisition, and agricultural land) (2) Stakeholder and public outreach, education, and training (including coordinated planning and response) (3) Roadway safety and early warning systems (low water crossings and other vulnerable roadways, signage, flood gauges, real-time reporting) (4) Non-structural flood risk reduction (flood early warning systems, flood gauges, real-time reporting)	Short term (10 year)	2033
15	Increase community access to critical facilities and evacuation routes during and after a flooding event by performing a study to establish a baseline.	(1) Risk reduction studies (including mapping, data collection, and project development), (2) Stakeholder and public outreach, education, and training (including coordinated planning and response), (3) Roadway safety and early warning systems (low water crossings and other vulnerable roadways, signage, flood gauges, real-time reporting), and (4) Reduce flood risk to critical facilities.	Short term (10 year)	2033

The most prevalent theme, representing approximately 41 percent (142) of all goals, is to implement flood risk reduction projects. The least prevalent theme of the goals is water supply, accounting for approximately 1 percent (3). We can extrapolate meaning from these quantities to understand that regional flood planning groups may choose to connect more with the public and other stakeholders in future cycles to increase participation in the planning process. Planning groups have fewer goals for water supply, as the conceptualization of dual-purpose retention basins will require more studies and environmental evaluation to become a practical and achievable goal.

6.4 Residual risk

It is important to note that even with the achievement of flood risk reduction goals, it is not possible to protect against all potential flood risks. To conceptualize this limitation, the term "residual risk" is used. Residual risk refers to the risk that remains after efforts have been made to reduce the risk or impact of a hazard. Planning groups were asked to recognize and clearly state the levels of residual risk that will remain in the region, even after the stated flood mitigation goals are fully met. For example, if a regional goal was to reduce the miles of major roadways subject to flooding during a serious rain event (1 percent chance of happening any given year), the residual risks could include flooding risks associated with amounts of rain that exceed the 1 percent (100-year) annual chance event or new risks, such as levee failure. More specific descriptions of residual risk are available in Chapter 8.

6.5 Future cycles

A task is included in the standard regional flood planning group scope of work to analyze the progress made toward each goal since the previous planning cycle. This will include a general description of how the new regional flood plan differs from the previous plan, including the status of achieving the goals. The first assessment will occur during the 2023–2028 cycle of regional flood planning. Planning groups will assess progress for each goal, identifying obstacles that may be impeding progress. Making necessary adjustments by the end of the second cycle is crucial as environmental and regulatory circumstances can change over time, and goals that were once relevant and achievable may become outdated or unattainable. Re-evaluating their goals allows planning groups to adapt to the changing circumstances and make adjustments to ensure the full plan aligns with the overarching goal of protecting life and property from flood damage. The experience gained by the regional flood planning groups during the first cycle of regional flood planning will help them improve upon their goals in future cycles.

References

USGS (United States Geologic Survey), n.d., Hydrologic Unit Codes (HUCs) explained, nas.er.usgs.gov/hucs.aspx

7 Recommended flood risk reduction solutions

Quick facts

The regional flood planning groups identified and evaluated a total of 5,342 flood risk reduction solutions for consideration in the regional flood plans—4,609 of those were recommended as follows:

- A total of 3,097 flood management evaluations with a total estimated cost of more than $2.6 billion.
- A total of 615 flood mitigation projects with a total estimated cost of more than $49.1 billion.
- A total of 897 flood management strategies with a total estimated implementation cost of more than $2.8 billion. Of those, 771 are strategies with non-recurring, non-capital costs with a total non-recurring, non-capital cost of $313 million which are the only strategies and costs eligible for the Flood Infrastructure Fund.

All recommend evaluations (3,097), projects (615), and strategies with non-recurring, non-capital costs (771) are included in ranked lists.

The regional flood planning groups were tasked with identifying and evaluating a wide range of potential solutions to reduce the risk and impact of flooding across the state. They identified and categorized them into three types of flood risk reduction solutions: flood management evaluations, flood mitigation projects, and flood management strategies.

- **Flood management evaluation** — A proposed study to identify, assess, and quantify flood risk or identify, evaluate, and recommend flood risk reduction solutions.
- **Flood mitigation project** — A proposed structural or non-structural flood project that has a non-zero capital cost or other non-recurring cost and, when implemented, will reduce flood risk or mitigate flood hazards to life or property.
- **Flood management strategy** — Ideas and strategies that do not belong in the flood management evaluation or flood mitigation project categories. Examples may include regulatory enhancements, development of entity-wide buyout programs, and public outreach and education.

Each planning group approved its respective approaches and processes to identify and evaluate potential flood risk reduction solutions, as described in the following sections, at a public meeting. These approaches were documented in their technical memorandums (midway progress reports) and submitted to the Texas Water Development Board (TWDB) in January 2022. Once the planning groups evaluated all identified flood risk reduction solutions, the voting members reviewed and considered their merits before recommending them in the final and amended regional flood plans submitted to the TWDB in January and July 2023, respectively.

7.1 Summary of recommended flood risk reduction solutions

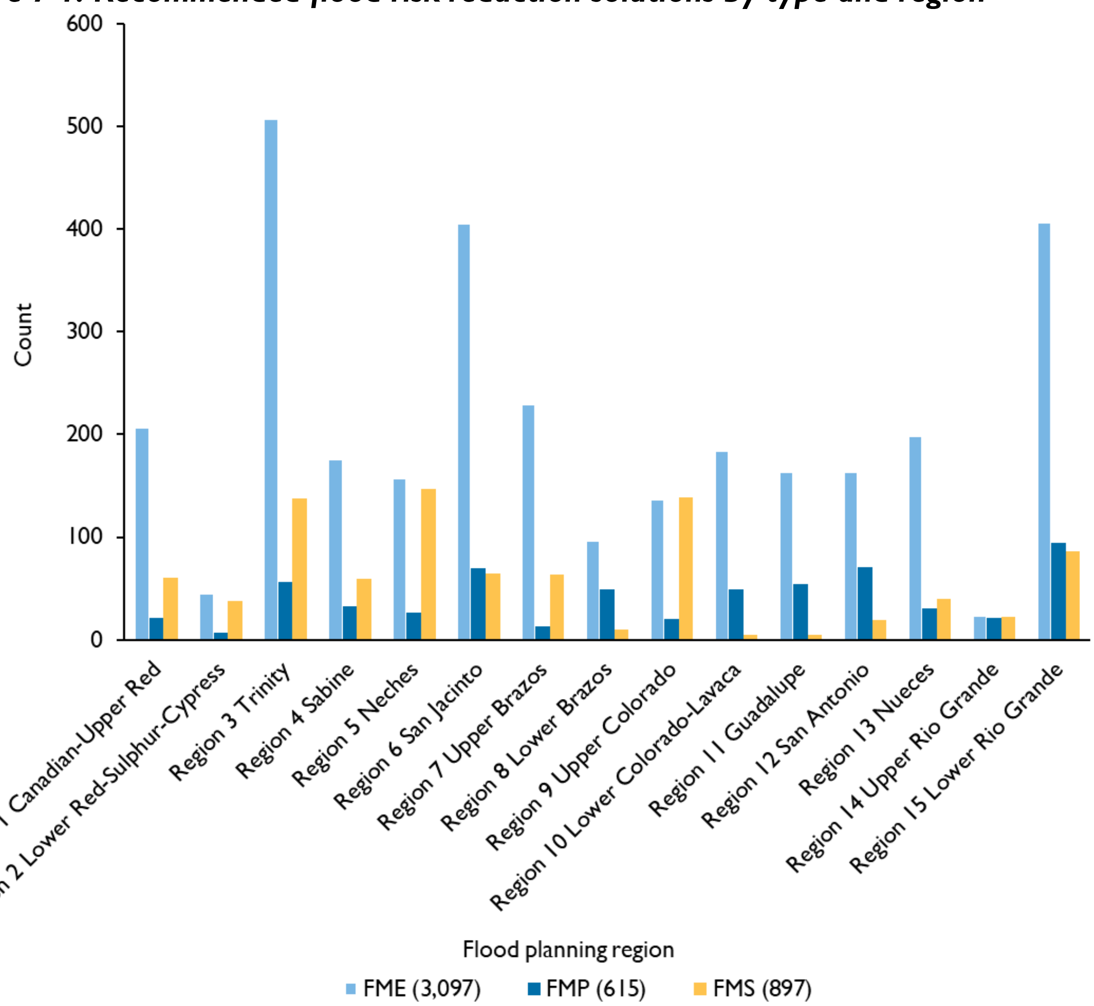
A total of 4,609 flood risk reduction solutions from all 15 flood planning regions were recommended at an estimated cost of approximately $54.5 billion (Table 7-1). Approximately 49 percent ($24 billion) of that total cost is associated with Galveston Bay Surge Protection Coastal Storm Risk Management project. The recommended solutions include 771 flood management strategies with non-recurring, non-capital costs for an estimated total cost of $2.8 billion. A summary of recommended solutions by type and flood planning region is presented in Figure 7-1, while a summary of costs is noted in Figure 7-2 and Figure 7-3. All recommended flood management strategies and their implementation costs are presented; however, only flood management strategies with non-recurring, non-capital costs are included in the ranking for the state flood plan. More detailed descriptions of the recommended flood risk reduction solutions are provided later in this chapter.

Table 7-1. Count and cost of recommended flood risk reduction solutions

	Count	Cost
Flood management evaluations	3,097	$2.6B
Flood mitigation projects	615	$49.1B
Flood management strategies[a]	771	$2.8B
Total	**4,483**	**$54.5B**

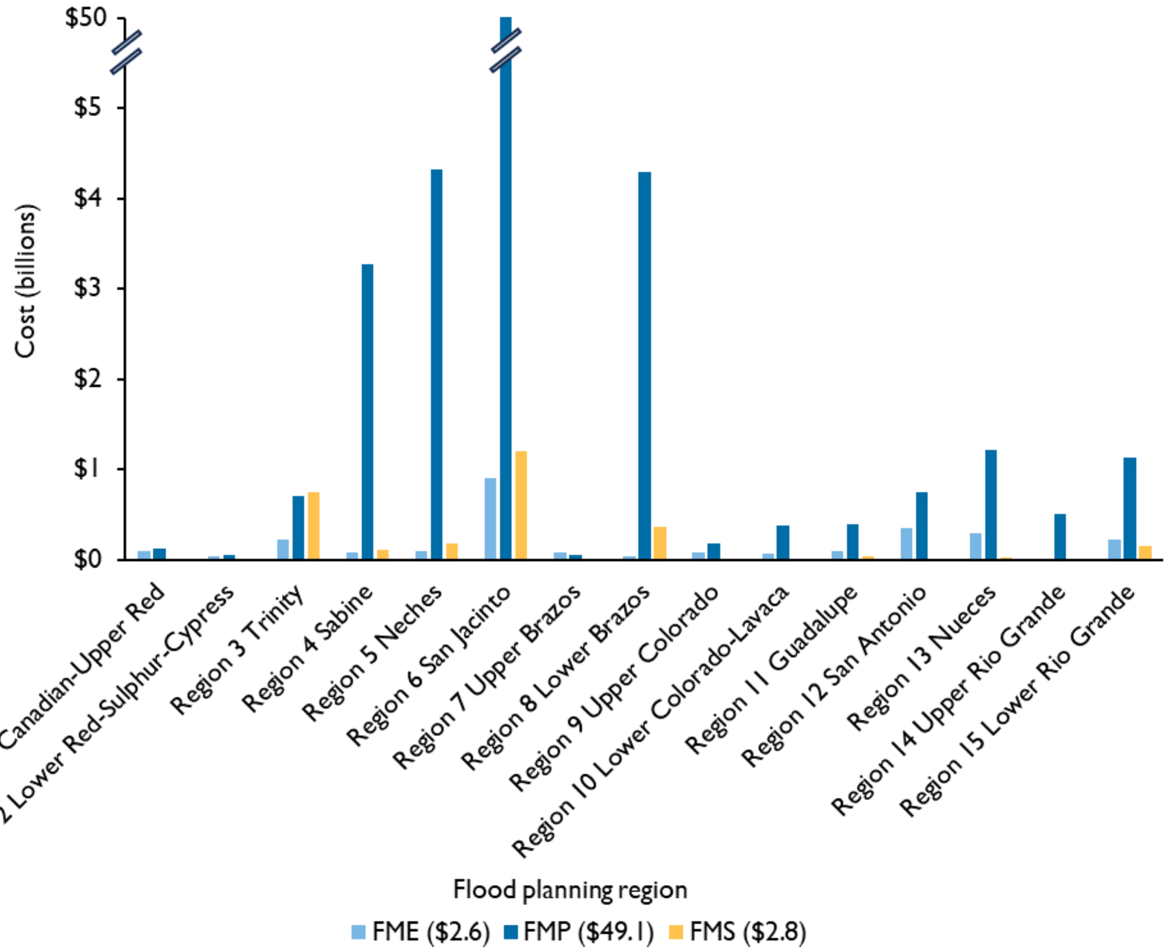
[a] *Includes both implementation costs and non-recurring non-capital costs*

Figure 7-1. Recommended flood risk reduction solutions by type and region



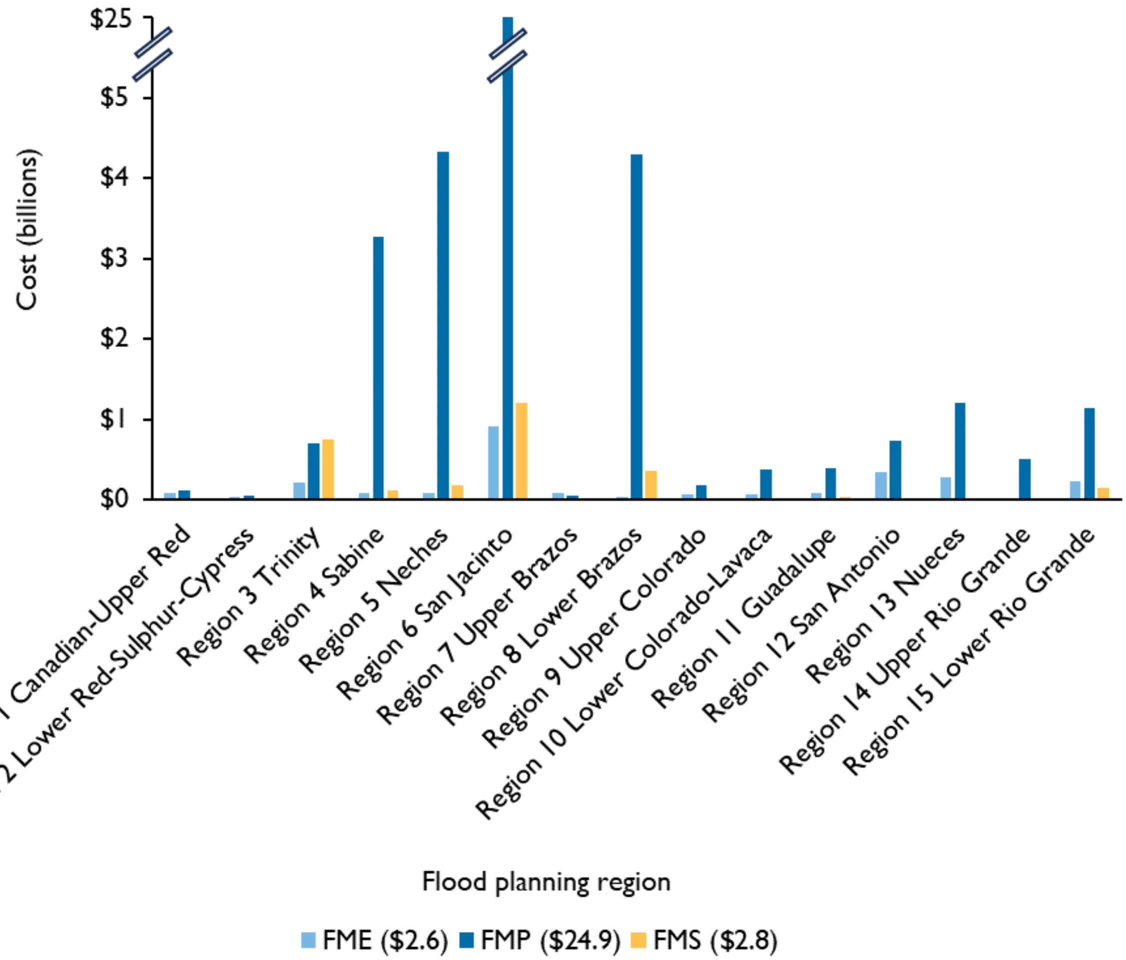
FME = Flood management evaluation; FMP = Flood mitigation project; FMS = Flood management strategy

Figure 7-2. Estimated cost of all recommended flood risk reduction solutions by region



FME = Flood management evaluation; FMP = Flood mitigation project; FMS = Flood management strategy

Figure 7-3. Estimated cost of recommended flood risk reduction solutions by region, without the Region 6 Galveston Bay Surge Protection Coastal Storm Risk Management project*



FME = Flood management evaluation; FMP = Flood mitigation project; FMS = Flood management strategy

** The figure excludes the Region 6 Galveston Bay Surge Protection Coastal Storm Risk Management project with a reported estimated cost of $24 billion.*

During the first cycle of regional and state flood planning, the planning groups struggled to incorporate fully formulated flood mitigation projects into the regional plans that met all the program requirements due to the short timeframe. In response, and to maximize the number of flood risk reduction solutions recommended in the first state flood plan, the TWDB extended the initial grant contracts by six months and allocated additional grant funding for the planning groups to carry out the following tasks:

- Perform additional outreach to regional stakeholders to collect data, models, and other relevant technical information;
- Perform flood management evaluations to determine flood risks in areas with limited flood risk data;
- Evaluate flood risk reduction solutions, including feasibility studies and preliminary engineering, to help identify, evaluate, and recommend additional flood mitigation projects; and
- Prepare and submit amended regional flood plans to incorporate new data and information.

The additional time and funding provided to the regional flood planning groups tripled the number of flood mitigation projects identified and significantly increased the number of recommended flood risk reduction solutions that the flood planning groups included in their first regional flood plans. The flood risk reduction solutions identified and recommended in the state flood plan represent a snapshot in time based on best available data. The need for flood risk reduction solutions in the state is greater than what is identified and recommended in the inaugural cycle of regional and state flood planning.

7.2 Identifying and evaluating flood risk reduction solutions

The planning groups followed a multi-step process to identify, evaluate, and recommend flood risk reduction solutions in their regional flood plans. More flood risk reduction solutions were initially identified than were recommended in their final plans. Each planning group determined a process for paring down all the potentially feasible flood risk reduction solutions to meet the technical and programmatic requirements as well as the needs of the communities that will sponsor and benefit from the solutions.

7.2.1 Identifying flood risk reduction solutions

Identifying potential flood risk reduction solutions began with an analysis of flood mitigation needs to identify areas across the state where the greatest gaps in knowledge about flood risk exist and where the planning groups should consider identifying potentially feasible flood risk studies as flood management evaluations. Next, the groups identified areas of greatest known flood risk, thus requiring flood mitigation through recommended flood mitigation projects and flood management strategies.

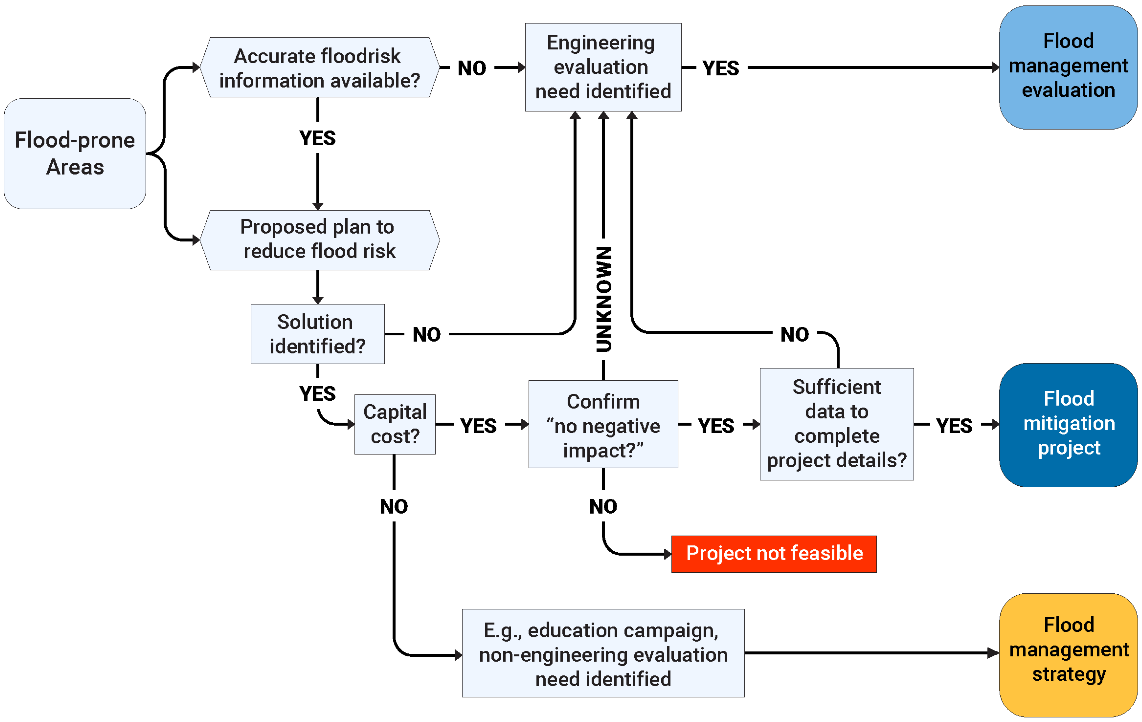
To identify areas most prone to flooding that threatens life and property, the planning groups used data to perform geospatial analyses that the TWDB then assigned scoring metrics with factors deemed most relevant to flood risk reduction, including but not limited to the number of structures, population, historic flood events, social vulnerability, critical facilities, current floodplain management practices, land use policies, and infrastructure. In determining the greatest flood risk mitigation needs, the planning groups considered ongoing and planned flood risk reduction projects with and without funding.

Following the results of the flood risk mitigation needs analyses, the planning groups used varied data sources, including the list below, to develop lists of flood risk reduction solutions to potentially assess and address each region’s needs:

- Existing flood infrastructure, including condition and functionality
- Existing and future condition exposure and vulnerability
- Regional flood planning group-generated floodplain management and flood protection goals
- Unfunded flood studies and projects
- Capital improvement plans
- Drainage master plans
- Hazard mitigation plans
- Information obtained through stakeholder engagement

The flood planning groups were tasked with categorizing identified flood risk reduction solutions into one of the three types of solutions: flood management evaluations, flood mitigation projects, or flood management strategies. The TWDB provided a flow chart (Figure 7-4) as a guide.

Figure 7-4. Flood risk reduction solution classification process



Flood management evaluation: A flood management evaluation is a proposed flood study of a specific flood prone area to assess flood risk and/or determine if potentially feasible flood mitigation projects or flood management strategies are needed. There are four general categories of flood management evaluations: (1) project planning, (2) studies on flood preparedness, (3) watershed planning, and (4) other. The flood management evaluations in these four categories serve as assessments to identify and quantify flood hazard studies or to evaluate and recommend flood risk reduction solutions. The level of flood management evaluations may range from studies initially identifying areas of flood risk to studies considering specific mitigation solutions that may have up to a 30 percent level of design. Identified flood management evaluations and descriptions are provided in Table 7-2.

Table 7-2. Number and types of flood management evaluations identified by the regional flood planning groups

FME type	Description	Identified (count)	Cost range
Engineering project planning	The process of strategically organizing and establishing a framework for the successful implementation of flood-related projects. This planning phase focuses on defining the basic structure and direction of the project, providing a general understanding of the project's requirements and feasibility at the early stages of design. These studies fall into two main categories: feasibility assessments and preliminary engineering.	2,251	\$2,000–\$65,673,000
Flood preparedness studies	Comprehensive assessments to evaluate the level of readiness and resilience of a community or area facing potential flooding events. These studies aim to identify existing strengths and weaknesses in terms of flood preparedness and response capabilities. It typically involves analyzing various factors, such as the local flood history, vulnerability of infrastructure and critical facilities, emergency management systems, communication networks, hurricane evacuation plans, flood warning systems, and coordination among relevant stakeholders.	91	\$10,000–\$3,799,000
Watershed planning	Studies that quantify flood risk in areas where significant flood risk is thought to exist but where there is insufficient or no flood risk data. Examples of this type of flood management evaluation include hydrologic and hydraulic modeling, flood risk mapping, and regional watershed studies.	1,077	\$14,500–\$92,079,000
Other	This category includes additional types of studies or assessments, not captured in the previous categories, needed to either identify and quantify flood hazard and studies or evaluate and recommend flood risk reduction solutions. The types of studies in this category vary across regions but generally included dam evaluations, developing geographic information system inventories on existing infrastructure, and other general data collection.	167	\$25,000–\$2,000,000

FME = Flood management evaluation

Flood mitigation project: A flood mitigation project is a proposed project, either structural or non-structural, that has capital or other non-recurring costs and, when implemented, will reduce flood risk and mitigate flood hazards to life and/or property. The regional flood planning groups were strongly encouraged to consider nature-based flood risk reduction solutions, which also fall into this category.

Statute requires that potential projects have "no negative impact" on neighboring areas for planning groups to recommend them in the regional flood plans. Essentially, reducing the flood risk to one location cannot increase the risk of flooding to neighboring upstream or downstream locations. In addition, a potential flood mitigation project must be permittable, constructable, and implementable if included in a regional flood pan. Flood mitigation projects are generally categorized as either structural or non-structural:

Structural flood mitigation projects involve building or modifying infrastructure to reduce flood risk. These projects may require an advanced level of analysis and design prior to construction and/ or implementation. The structural flood mitigation projects identified by the planning groups are detailed in Table 7-3.

Table 7-3. Structural flood mitigation projects identified by the 15 planning groups*

Structural FMP type	Identified (count)	Cost range
Low water crossings or bridge improvements	101	$38,000–$57,548,152
Infrastructure (channels, ditches, ponds, stormwater pipes, etc.)	174	$73,000–$421,681,184
Regional detention	74	$224,000–$550,000,000
Regional channel improvements	82	$258,023–$994,000,000
Storm drain improvements	50	$511,000–$72,072,000
Dam improvements, maintenance, and repair	5	$1,705,000–$28,000,000
Flood walls and levees	5	$300,000–$2,270,099,968
Coastal protections	2	$1,200,168,960–$24,107,063,296
Nature-based projects (**living levees**, increasing storage, dune management, river restoration, etc.)	8	$120,000–$2,719,130
Comprehensive regional project – includes a combination of projects intended to work together	83	$642,000–$1,150,000,000

FMP = Flood mitigation project

* *Not all available types of structural flood mitigation projects were identified by the flood planning groups*

Non-structural flood mitigation projects are actions that reduce the impact of flooding without relying solely on physical infrastructure. These projects focus on strategies that do not involve constructing physical barriers or altering the natural flow of water. The general types of non-structural flood mitigation projects that the planning groups considered are included in Table 7-4.

Table 7-4. Non-structural flood mitigation projects identified by the 15 planning groups*

Non-structural FMP type	Identified (count)	Cost range
Property or easement acquisition	13	$550,000–$56,159,648
Elevation of individual structures	4	$894,000–$10,000,000
Flood readiness and resilience	55	$11,000–$826,000
Other	3	$21,000–$37,238,000

FMP = Flood mitigation project

* *Not all available types of non-structural flood mitigation projects were identified by the flood planning groups*

Flood management strategy: A flood management strategy is a proposed plan to reduce flood risk or mitigate flood hazards to life or property that is not a flood management evaluation or flood mitigation project. Flood management strategies may require implementing associated flood mitigation projects. The planning groups were given some flexibility on how they used flood management strategies in the regional flood planning process. For example, the planning groups could choose not to recommend any flood management strategies. Table 7-5 includes general descriptions of each flood management strategy type as well as the number of each type initially identified and evaluated by the planning groups.

Also, the planning groups included the total costs and the non-recurring, non-capital costs for flood management strategies in their regions. Total costs include the initial one-time, non-recurring, non-capital costs and eventual capital costs needed to implement a recommended strategy as a flood mitigation project. One-time, non-recurring, non-capital costs are those necessary to develop and/or implement the strategy; examples include program development cost, education campaign cost, such as non-engineering studies as floodplain regulation development, flood authority or revenue raising studies, and public awareness programs, amongst others. These are the only costs associated with flood management strategies that will be eligible for TWDB funding and, thus, were the only strategies included in the ranked list described later in this chapter.

Table 7-5. Flood management strategies identified by the 15 planning groups

FMS type	Description	Identified (count)	Cost range
Education and outreach	Creation and implementation of programs to educate and/or inform the public on the hazards and risks of flooding.	137	$500–$4,000,000
Flood measurement and warning	Installation and operation of stream gauges, monitoring stations, and early warning alert systems to provide flood hazard information to the public and decision-makers.	145	$500–$9,541,000
Infrastructure programs	Establishing a program, plan, or standards to facilitate future flood infrastructure projects.	127	$5,000–$360,000,000
Property acquisition and structural elevation program	Program administration to acquire, remove, or elevate structures currently within flood hazard areas.	85	$50,000–$500,000,000
Regulatory and guidance	Creating ordinances, development criteria, building codes, and/or design standards to help prevent an increase to flood risk through new development.	348	$500–$50,000,000
Other programs	May include maintenance and inspection programs of flood infrastructure to ensure design level of service is maintained.	255	$500–$30,000,000

FMS = Flood management strategy

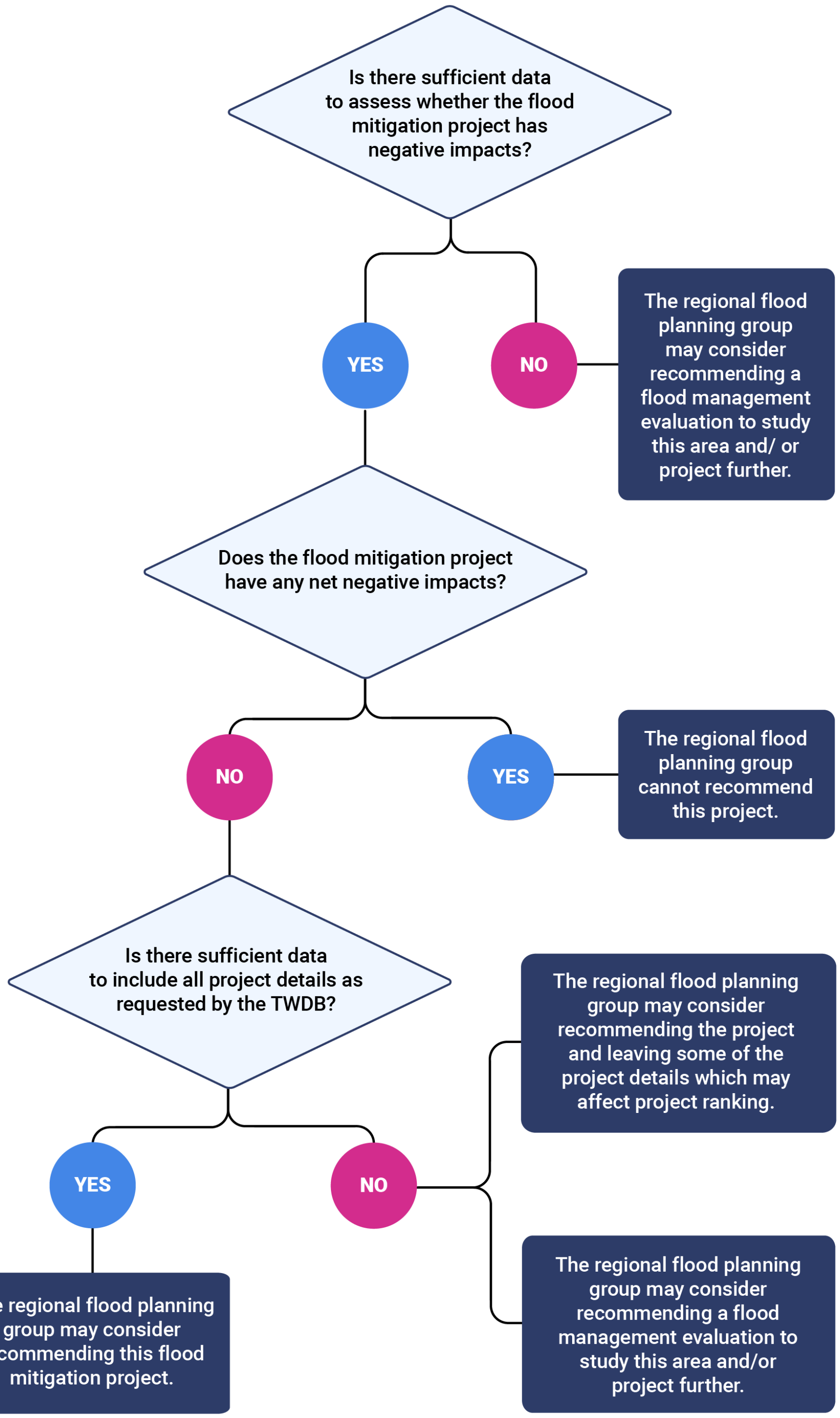
7.2.2 Screening and evaluating identified flood risk reduction solutions

The regional flood planning groups identified a total of 5,342 flood risk reduction solutions. However, not every flood management evaluation, flood mitigation project, or flood management strategy was recommended in the regional flood plans. Before making their recommendations, the groups were required to develop and adopt a process for evaluating the feasibility of each potential solution to ensure it met all technical requirements so that limited resources could be directed efficiently to implement those solutions.

As a result, this process varied by region within the overall TWDB rule and guidance framework. For example, some planning groups relied on technical committees to develop and recommend a process for the group's approval, while others relied on several full-group meetings to come to a consensus. These processes were documented and included in the draft and final adopted regional flood plans.[35] Despite these variations, each group's process generally included the same types of screening and evaluation criteria (Figure 7-5).

[35] https://www.twdb.texas.gov/flood/planning/plans/index.asp

Figure 7-5. Example process of how regional planning groups screened flood risk reduction solutions



Stakeholder outreach

The initial screening process often began with direct stakeholder outreach regarding identified potential solutions to ensure all information was correct and up to date. For example, planning groups disqualified potential flood management evaluations, flood mitigation projects, and flood management strategies if they were already completed or no longer needed or wanted by the sponsoring community. The planning groups were required to identify who would sponsor each potential solution, which includes direct financing and implementation. Flexibility was granted with sponsorship, as both financing and implementation could involve more than one entity and funding source.

Screenings based on rules, technical guidelines, and other criteria

Each potential flood risk reduction solution was screened and evaluated based on a variety of factors and criteria derived from the TWDB rules and guidance requirements and other factors that the planning groups considered relevant. This generally included:

1) **Flood mitigation and floodplain management goals**: The groups evaluated whether the potential solution aligned with a short-term flood mitigation or floodplain management goal. All recommended flood management evaluations, flood mitigation projects, and flood management strategies were required to be associated with short-term goals adopted by the regional flood planning groups (see Chapter 6 for more on goals).
2) **Emergency need**: The planning groups were given the flexibility during the first cycle of regional flood planning to determine whether a potential solution met an emergency need in the region. Determining emergency need varied significantly from region to region.
3) **Drainage area**: The planning groups were directed to consider flood risk reduction solutions with a contributing drainage area greater than or equal to one square mile, 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 planning groups.
4) **No negative impact**: TWDB rules define "negative effect" (referred to in this plan as "negative impact") as an increase in flood-related risks to life and property, either upstream or downstream of the proposed project. A determination of no negative impact, therefore, means that a flood risk reduction solution will not increase flood risk of surrounding areas. The planning groups were asked to measure any increases in flood risk by the 1 percent (100-year) annual chance storm event water surface elevation and peak discharge using the best available data. For the purposes of flood planning, a determination of no negative impact was required to recommend a flood mitigation project. The following criteria were required to establish no negative impact, as applicable:
    a. Stormwater does not increase inundation in areas beyond the public right-of-way, project property, or easement.
    b. Stormwater does not increase inundation of storm drainage networks, channels, and roadways beyond design capacity.
    c. Maximum increase of 1-D water surface elevation must round to 0.0 feet (< 0.05 feet) measured along the hydraulic cross section.
    d. Maximum increase of 2-D water surface elevations must round to 0.3 feet (< 0.35 feet) measured at each computational cell. Maximum increase in hydrologic peak discharge must be < 0.5 percent measured at computational nodes (sub-basins, junctions, reaches, reservoirs, etc.). This discharge restriction does not apply to a 2-D overland analysis.
    e. Note that potential negative impacts of a solution could be internally mitigated as part of an overall flood mitigation project.

The regional flood planning groups had flexibility to accommodate additional 'negative impact' for requirements listed above based on engineer's professional judgement and analysis given any affected stakeholders are informed and accept the impacts.

5) **Feasibility:** The regional flood planning groups were required to confirm that all recommended flood mitigation projects are permittable, constructable, and implementable.

6) **Water supply benefit:** The regional flood planning groups were required to evaluate whether a potentially feasible flood risk reduction solution had any impact (positive or negative) on water supply development. Recommended flood mitigation projects and flood management strategies may not negatively impact an entity's water supply. Further, recommended flood mitigation projects that will contribute to water supply may not result in an overallocation of a water source based on the water availability allocations in the most recently adopted state water plan.

7) **Flood risk reduction:** To be considered for recommendation, each flood mitigation project and flood management strategy must demonstrate a flood risk reduction benefit. Multiple criteria were used to measure the flood risk reduction benefit of each potentially feasible project and strategy after implementation, including reduction of land area at risk of flooding; reduction and removal of structures at risk of flooding; reduction and removal of residential structures at risk of flooding; removal of population at risk of flooding; removal of critical facilities at risk of flooding; removal of road miles at risk of flooding; reduction of road closures at risk of flooding; removal of active farmland and ranchland acres at risk of flooding; estimated reduction in flood-related fatalities, when available; estimated reduction in flood-related injuries, when available; reduction in expected annual damages from residential, commercial, and public property; and other benefits as deemed relevant by the regional flood planning group, including those related to the environment, navigation, recreation, agriculture, erosion, and sedimentation.

8) **Benefit-cost analysis**: A benefit-cost analysis was required for each recommended flood mitigation project, when applicable, which is the method used to determine the future benefits of a hazard mitigation project compared to its costs. The result is a benefit-cost ratio, a numerical expression of the cost-effectiveness of a project, calculated by a project's total benefits divided by its total costs. A solution is generally considered cost effective when the benefit-cost ratio is 1.0 or greater, indicating the benefits of a prospective hazard mitigation project are sufficient to justify the costs (FEMA, 2009). The planning groups utilized previously calculated benefit-cost ratios when available; however, they were given a user-friendly, TWDB-developed benefit-cost analysis input tool for projects lacking an existing calculation. Some groups also chose to utilize the FEMA benefit-cost analysis toolkit to generate benefit-cost ratio values. While it is preferrable that planning groups recommend flood mitigation projects with a benefit-cost ratio greater than 1.0, they were given the flexibility to recommend projects with a benefit-cost ratio score of less than 1.0 with additional justification.

Project details

Project details are more complex project scores computed by planning groups using raw data. To enable the state flood project ranking and inform the planning groups' screening and evaluation process, optional project details were generated for each recommended flood risk reduction solution, including but not limited to the following:

- Flood severity metrics
- Flood risk and damage metrics
- Flood solution benefits
- Estimated capital, operation, and maintenance costs
- Benefit-cost ratio values

- Environmental benefits and impacts
- Implementation constraints
- Water supply benefits

Information on identified flood management evaluations, flood mitigation projects, and flood management strategies deemed infeasible by the regional flood planning groups is available on the State Flood Plan Viewer.[36]

7.3 Recommended flood management evaluations

The planning groups screened and evaluated all identified potential flood management evaluations. Recommendations were made for the flood management evaluations that met programmatic requirements, including alignment with regional flood planning group goals and sponsorship.

The planning groups identified and evaluated a total of 3,586 potential flood management evaluations. Of those, 3,097 were ultimately recommended in the amended regional flood plans, representing a combined total of approximately $2.6 billion in flood management evaluation needs across the state. A map of recommended flood management evaluations is presented in Figure 7-6. The full list of recommended flood management evaluations is included in the ranked list and their supporting technical data, including location and sponsorship, are included in the State Flood Plan Viewer.

[36] Texasstatefloodplan.org

Figure 7-6. Locations of flood management evaluations recommended by the regional flood planning groups

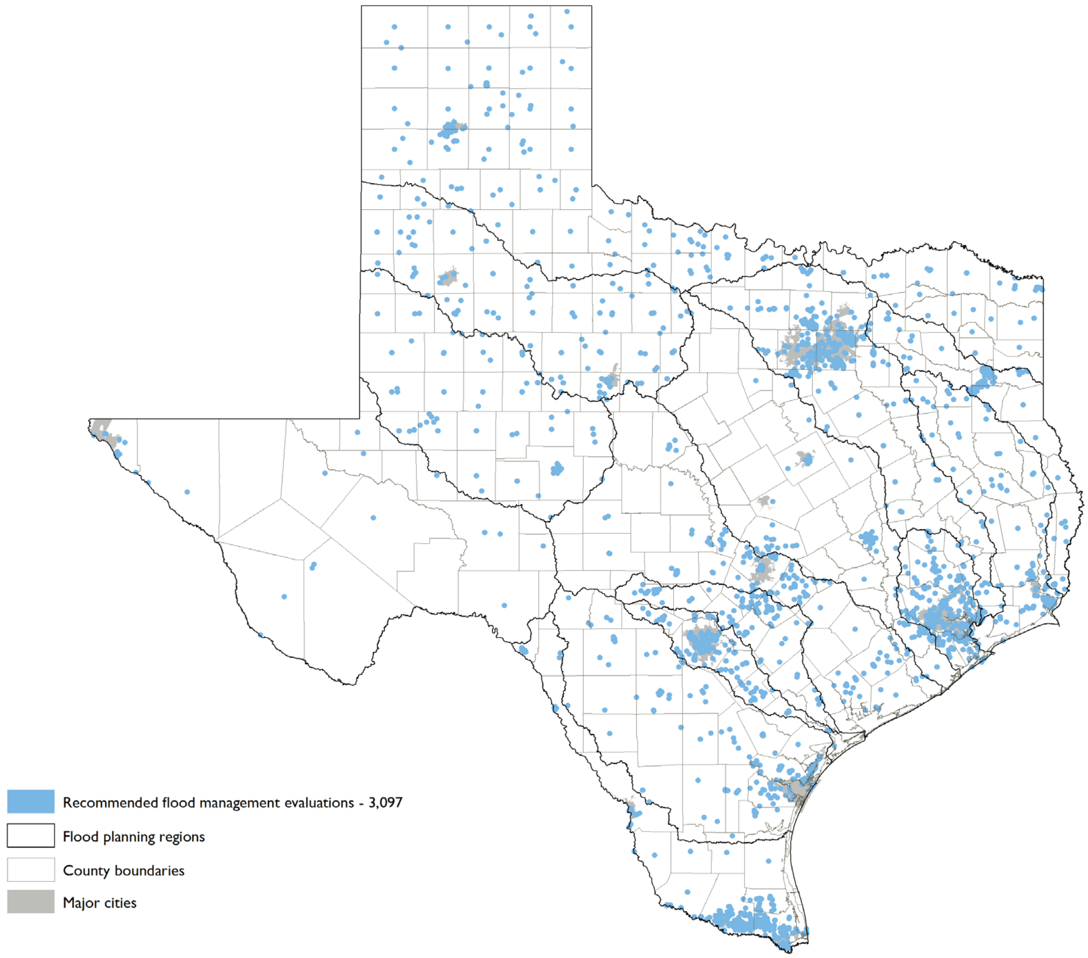
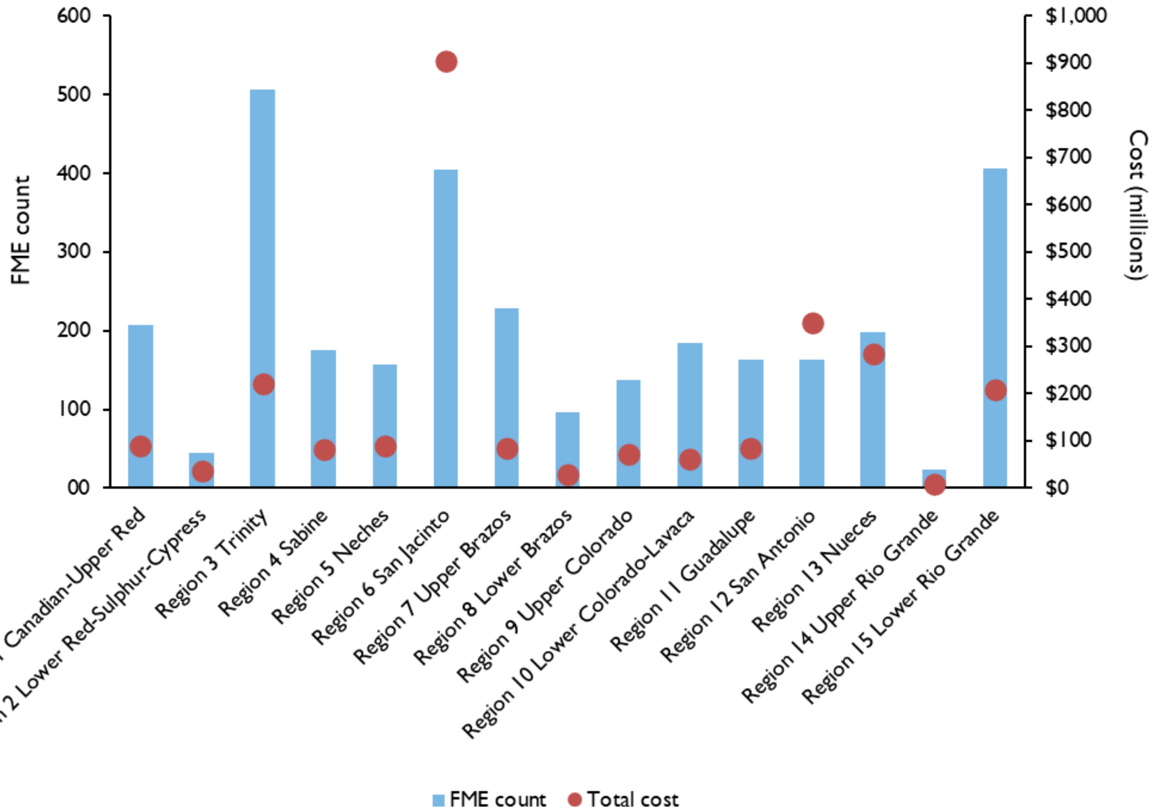


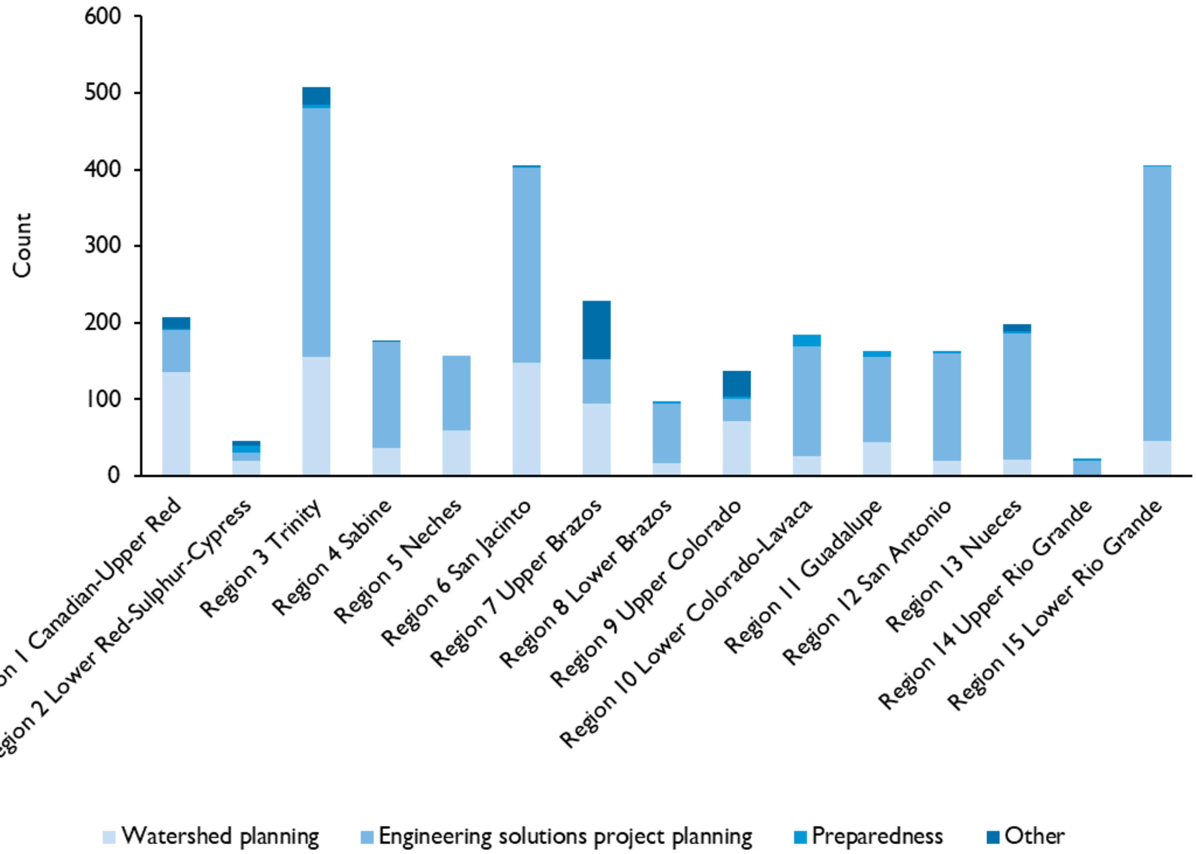
Figure 7-7 shows the number of recommended flood management evaluations and the total approximate cost to implement all recommended evaluations per region. While Region 3 Trinity and Region 15 Lower Rio Grande recommended the most evaluations, at 507 and 406, respectively, Region 6 San Jacinto and Region 12 San Antonio have the highest cumulative costs for implementing their recommended flood management evaluations. The number and types of flood management evaluations recommended by the planning groups are summarized in Figure 7-8.

Figure 7-7. Count and cost of recommended flood management evaluations by flood planning region



FME = Flood management evaluation

Figure 7-8. Types of recommended flood management evaluations by flood planning region



7.4 Recommended flood mitigation projects

Of the 659 projects initially identified and evaluated as potentially feasible, the regional flood planning groups ultimately chose to recommend a total of 615 in the 15 regional flood plans at a total cost of approximately $49.1 billion. Figure 7-9 shows the location of all recommended flood mitigation projects across the state. Figure 7-10 shows the number of recommended flood mitigation projects and the total approximate cost to implement all recommended projects per region. The full list of recommended flood mitigation projects is included in the ranked list and their supporting technical data, including location and sponsorship, are included in the State Flood Plan Viewer.

Figure 7-9. Locations of recommended flood mitigation projects

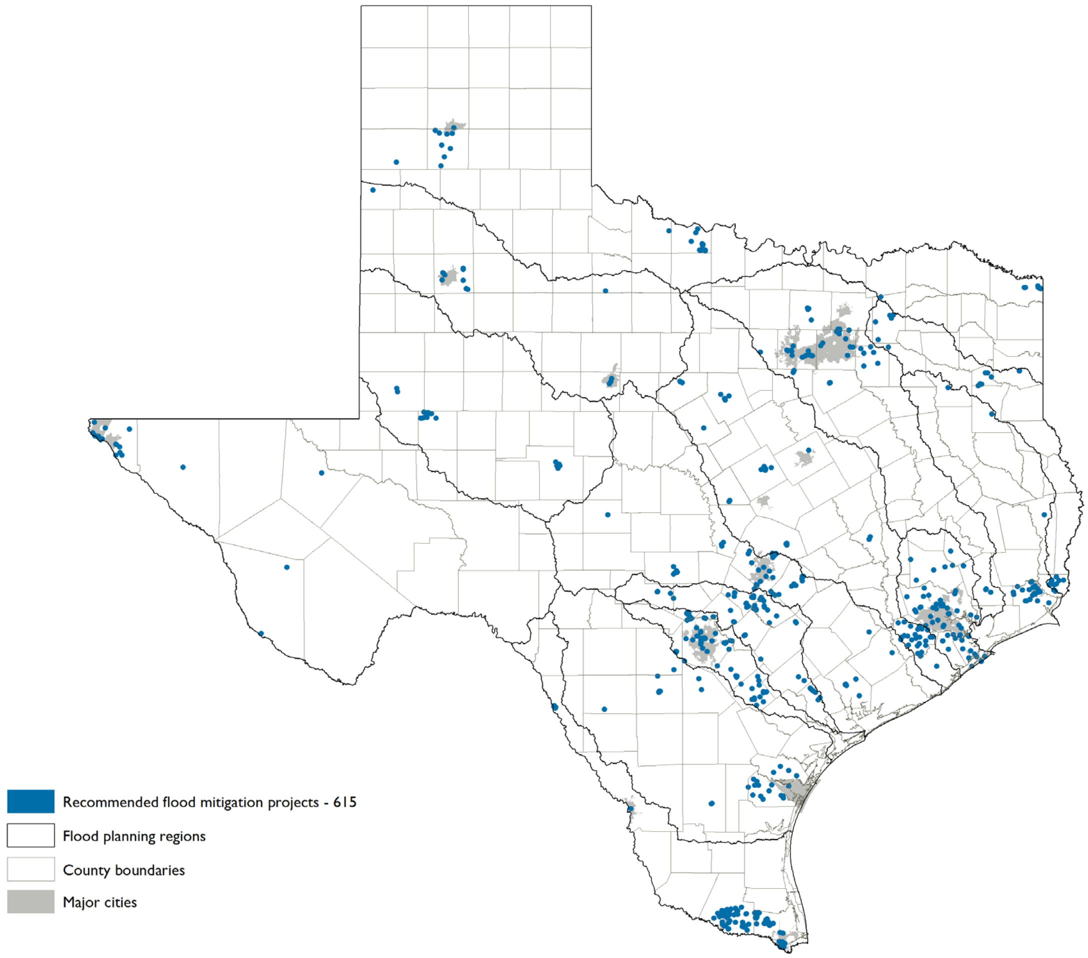
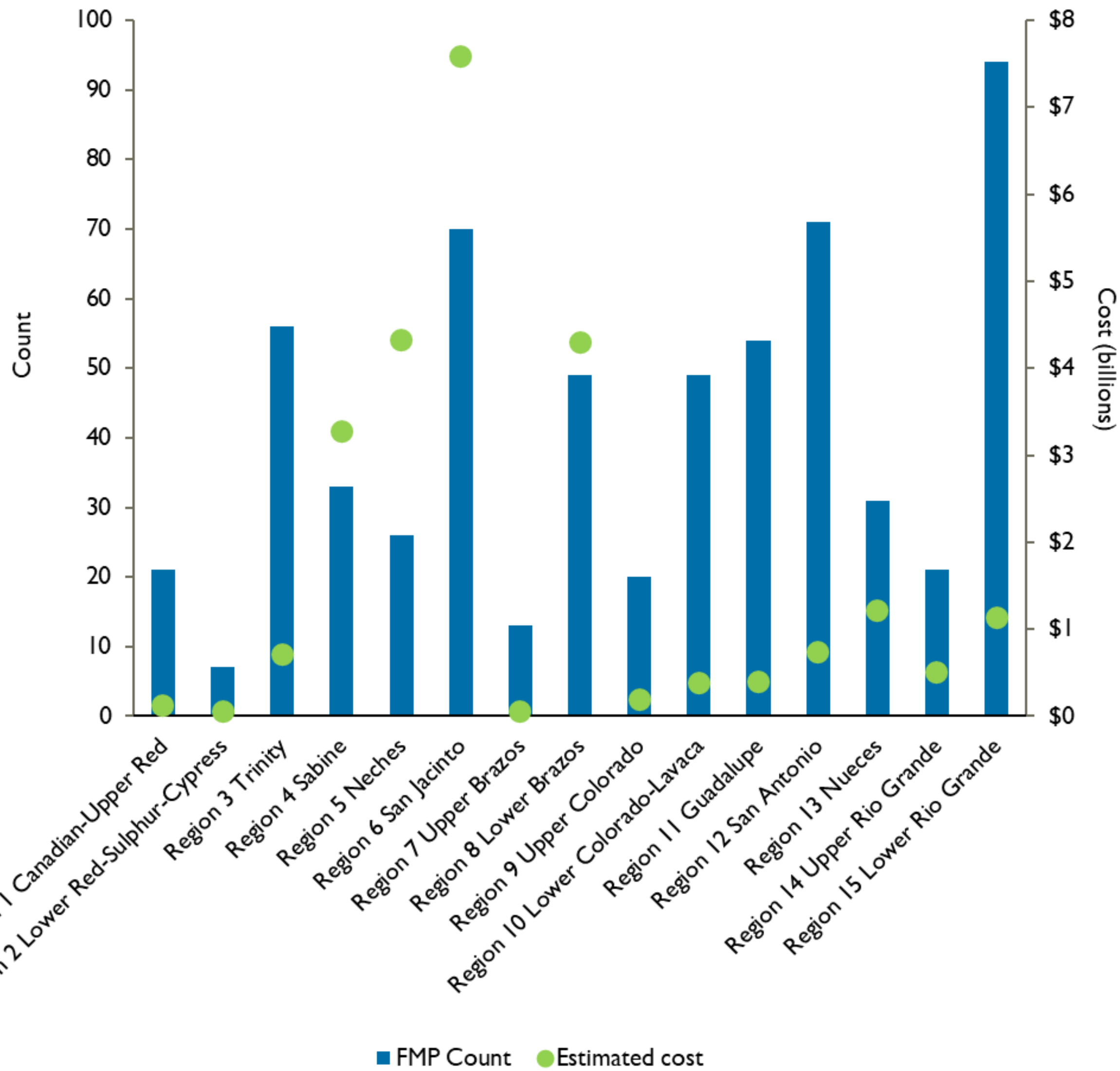


Figure 7-10. Count and cost of recommended flood mitigation projects by flood planning region*



FMP = Flood mitigation project

* *Figure 7-10 does not include Region 6 San Jacinto project ID 063000127, "Galveston Bay Surge Protection Coastal Storm Risk Management project," with a cost of approximately $24 billion (49 percent of the total cost of recommended flood mitigation projects)*

No negative impact determination

As required by statute, a determination of no negative impact was required for all recommended flood mitigation projects. "No negative impact" means that a project will not increase the flood risk of surrounding properties. For the purposes of the flood planning effort, using best available data, the increase in flood risk was required to be measured by the 1 percent annual chance event water surface elevation and peak discharge.

A determination of no negative impact could be established if stormwater did not increase inundation of infrastructure such as residential and commercial buildings and structures for a 1 percent (100-year) annual chance storm event. Additional requirements and flexibility associated with inundation areas, peak discharge and water surface elevation are listed in Section 7.2.2.

The no negative impact defined here is for the purpose of flood planning and does not have any regulatory impact related to FEMA, local, or other regulatory requirements due to the approximate nature of planning. Determinations of no negative impact for each recommended flood mitigation project were submitted to the TWDB as signed and sealed statements by a professional engineer, either from the original engineer that modeled/studied the proposed project or from the technical consultants at the time of regional flood plan development. None of the recommended flood mitigation projects were reported as causing a negative impact to neighboring areas if implemented.

Water Supply

Statute requires the TWDB to determine that each regional flood plan adequately provides for the development of water supply sources, where applicable, before the TWDB may approve a regional plan. Regional flood plans must include region-wide summaries and a list of the flood management strategies and flood mitigation projects that would contribute to, negatively impact, or measurably reduce water supply. Of the 615 recommended flood mitigation projects, 37 were reported to provide at least some water supply benefit if implemented. These projects include detention ponds, aquifer recharge, and natural area conservation easements, wherein the source of water supply benefits range from contributions to natural aquifer recharge to additional surface water inflows directed to reservoirs. These were recommended by Region 11 Guadalupe, Region 12 San Antonio, and Region 15 Lower Rio Grande. A discussion of the contributions to and impacts on water supply development, overall flood risk benefits, and other impacts of recommended flood risk reduction solutions is provided in Chapter 8.

7.4.1 Recommended structural flood mitigation projects

Of the 615 flood mitigation projects recommended by the planning groups, 542 were classified as structural (Table 7-6, Table 7-7, Figure 7-11). A discussion of implementing all recommended flood risk solutions is provided in Chapter 8.

Tables 7-6a. Summary of recommended structural flood mitigation projects by flood planning region

Region	Coastal	Flood walls and levees	Dams	Nature-based solutions	Storm drains
1	0	0	0	0	6
2	0	0	0	0	0
3	0	0	2	0	11
4	0	1	0	0	1
5	0	0	0	0	0
6	1	0	0	0	0
7	0	0	1	2	0
8	0	0	0	0	4
9	0	0	0	0	1
10	0	3	1	0	1
11	0	0	1	5	2
12	0	0	0	1	14
13	0	0	0	0	2
14	0	0	0	0	1
15	0	0	0	0	4
Total	**1**	**4**	**5**	**8**	**47**

Table 7-6b. Summary of recommended structural flood mitigation projects by flood planning region (continued)

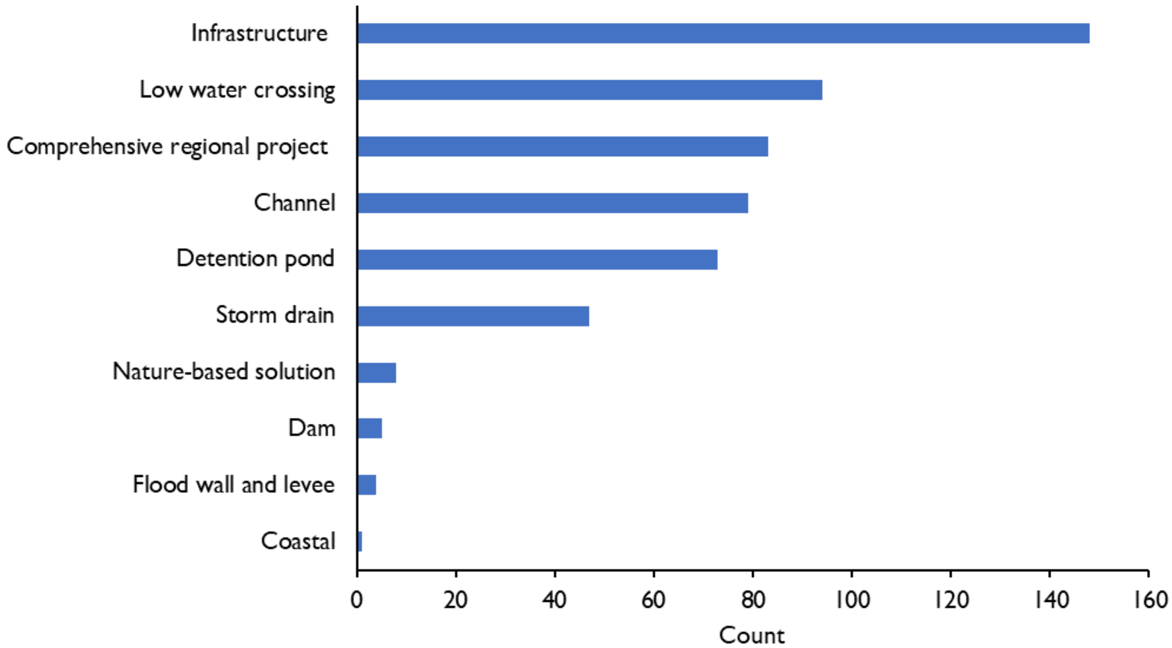
Region	Detention ponds	Channels	Regional projects	Low water crossings	Infrastructure	Grand total
1	0	0	1	8	5	**20**
2	2	2	0	1	1	**6**
3	4	0	0	1	33	**51**
4	12	6	0	8	0	**28**
5	4	6	16	0	0	**26**
6	14	3	25	0	7	**50**
7	0	2	0	2	4	**11**
8	1	25	8	10	0	**48**
9	2	15	0	0	1	**19**
10	1	5	0	15	0	**26**
11	6	4	11	12	5	**46**
12	5	5	3	34	5	**67**
13	4	3		3	19	**31**
14	14	1	3	0		**19**
15	4	2	16	0	68	**94**
Total	**73**	**79**	**83**	**94**	**148**	**542**

Table 7-7. Count and approximate total cost of structural flood mitigation projects (FMP) by project type

FMP type	Recommended FMP count	Total FMP cost[a]	Notes
Low water crossings or bridge improvements	94	$475 million	These structural flood mitigation projects included projects to improve low water crossings or bridges at risk of flooding. Unsurprisingly, most of the recommended improvements for low water crossings are in regions with the highest proportion of low water crossings across the state: Region 8 Lower Brazos, Region 10 Lower Colorado-Lavaca, Region 11 Guadalupe, and Region 12 San Antonio—all regions within Flash Flood Alley.
Infrastructure	148	$2.8 billion	These projects varied across regions and included improvements to storm sewers and roadside ditch systems as well as the construction of detention basins, bridge elevation, channel grading, and street reconstruction.
Regional detention ponds	73	$3.7 billion	Regional detention ponds are designed for the temporary or permanent retention of storm runoff. The areas of these recommended flood mitigation projects vary in size from approximately 9,319 square feet to more than 408 square miles.
Regional channel improvements	79	$5.5 billion	These projects generally aim to restore, maintain, and/or enhance stormwater flow capacity to mitigate flooding in adjacent drainage areas or detention basins.
Storm drain improvements	47	$443 million	These flood mitigation projects largely consist of installing, repairing, and upgrading stormwater drainage systems.
Dam improvements, maintenance, and repair	5	$68.5 million	These projects help address aging dam infrastructure through repair and maintenance actions.
Flood walls and levees	4	$2.4 billion	These projects focus on constructing or improving flood walls and levees—embankments to prevent overflow from the adjacent water body.
Coastal protections	1	$24 billion	Coastal protection flood mitigation projects include sea wall improvements, ecosystem restoration, bayou gates, and other structural and non-structural measures to increase flood protection along Texas' coastline.
Nature-based solutions	8	$6.9 million	These projects include playa improvements, conservation easement acquisition, and detention facilities enhanced with natural features.
Comprehensive regional projects	83	$9.2 billion	This category includes projects intended to work together to achieve flood risk reduction, such as plans to construct levees, floodwalls, pump stations, drainage structures, detention ponds, or other flood mitigation infrastructure.

[a] *Costs are approximate*

Figure 7-11. Count of recommended structural flood mitigation projects by project type



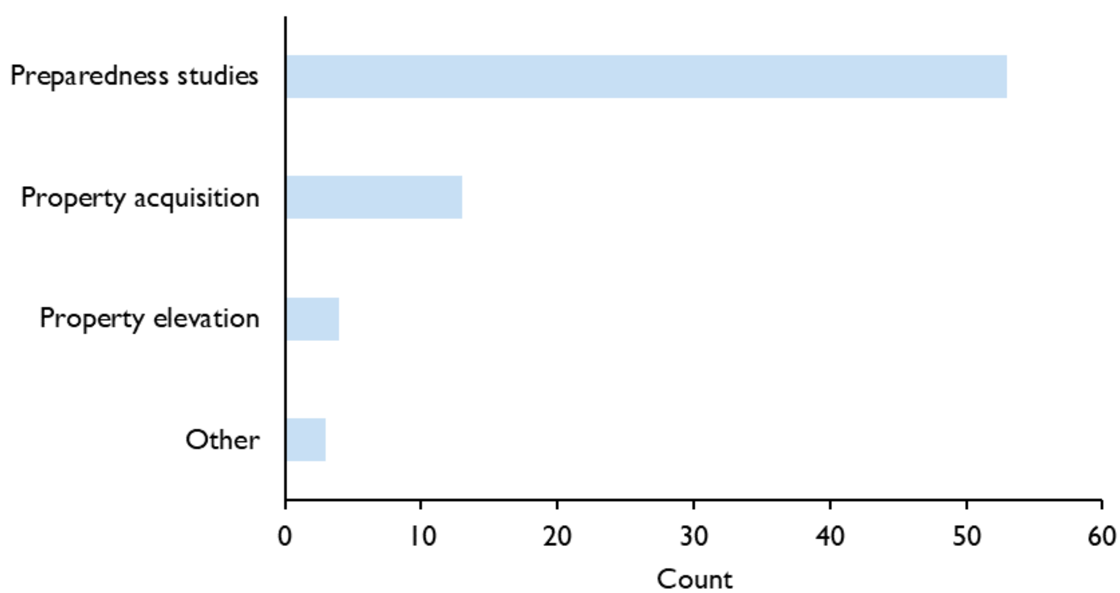
7.4.2 Recommended non-structural flood mitigation projects

Of all the projects recommended by the regional flood planning groups, 73 were classified as non-structural (Table 7-8, Figure 7-12). Non-structural flood mitigation projects reduce the impact of flooding without relying solely on physical infrastructure solutions.

Table 7-8. Summary of recommended non-structural flood mitigation projects by flood planning region

Region	Preparedness studies	Property acquisition	Property elevation	Other	Total
1	1	0	0	0	**1**
2	1	0	0	0	**1**
3	2	3	0	0	**5**
4	0	3	1	0	**4**
5	0	0	0	0	**0**
6	20	0	0	1	**21**
7	1	1	0	0	**2**
8	0	1	0	0	**1**
9	0	0	0	1	**1**
10	19	1	3	0	**23**
11	7	1	0	0	**8**
12	1	3	0	0	**4**
13	0	0	0	0	**0**
14	1	0	0	1	**2**
15	0	0	0	0	**0**
Total	**53**	**13**	**4**	**3**	**73**

Figure 7-12. Summary of recommended non-structural flood mitigation projects by project type



Preparedness studies

There were 53 non-structural flood mitigation projects recommended under this category with a total estimated cost of approximately $11.2 million. The variety of projects include

- adopting or updating regulations and ordinances for enhanced hazard mitigation strategies;
- improving local databases to better track properties with repetitive loss; and
- installing sensors, gauges, and early detection systems to provide early warning before imminent road flooding.

Property or easement acquisition

There were 13 non-structural flood mitigation projects recommended under this category with a combined estimated cost of approximately $162 million. These projects generally focused on buyouts, the purchase of private residential properties at risk for recurring flood damage and/or loss of life.

Elevation of individual structures

There were four non-structural flood mitigation projects recommended under this category with a combined estimated cost of approximately $20.6 million. Elevating a structure involves physically raising it above the base flood elevation. According to FEMA, this method of flood risk reduction may be achieved through a variety of methods, including "elevating on continuous foundation walls; elevating on open foundations, such as piles, piers, posts or columns; and elevating on fill" (FEMA, n.d.).

Other non-structural projects

There were three non-structural flood mitigation projects recommended under this category with a total cost of approximately $911,000. These projects include efforts to disperse National Flood Insurance Program materials, developing floodplain ordinances at the county-level, and playa improvements.

7.5 Recommended flood management strategies

The planning groups were required to demonstrate that each recommended flood management strategy meets the following criteria, as applicable:

- Reduces the potential impacts of flooding.
- Mitigates for flood events associated with a 1 percent (100-year) annual chance storm event; if mitigating for 1 percent (100-year) annual chance storm events is not feasible, the planning groups may recommend, with an explanation, flood management strategies that mitigate more frequent events.
- Includes measurable reductions in flood impacts in support of the region's specific flood mitigation and/or floodplain management goals.
- If contributing to water supply, the strategy must not result in an overallocation of a water source based on the water availability allocations in the most recently adopted state water plan.

Of the 1,097 flood management strategies initially identified and evaluated by the regional flood planning groups, 897 were ultimately recommended for inclusion in the 2023 regional flood plans with a total estimated cost of approximately $2.8 billion (Figure 7-13, Figure 7-14). There were 771 recommended flood management strategies with non-recurring, non-capital costs, totaling over $313 million.

While most of the planning groups chose to approach flood management strategies community by community, several regions chose to recommend broad, regional strategies and initiatives. Of these, the most notable are Region 10 Lower Colorado-Lavaca and Region 11 Guadalupe, each of which recommended five region-wide strategies. The reasoning was to make each strategy inclusive of all communities within the region and encourage collaboration between sponsors, particularly neighboring communities. Table 7-9 summarizes the recommended flood management strategies by category across each planning region. Figure 7-15 summarizes all recommended flood management strategies by category.

Figure 7-13. Locations of all recommended flood management strategies

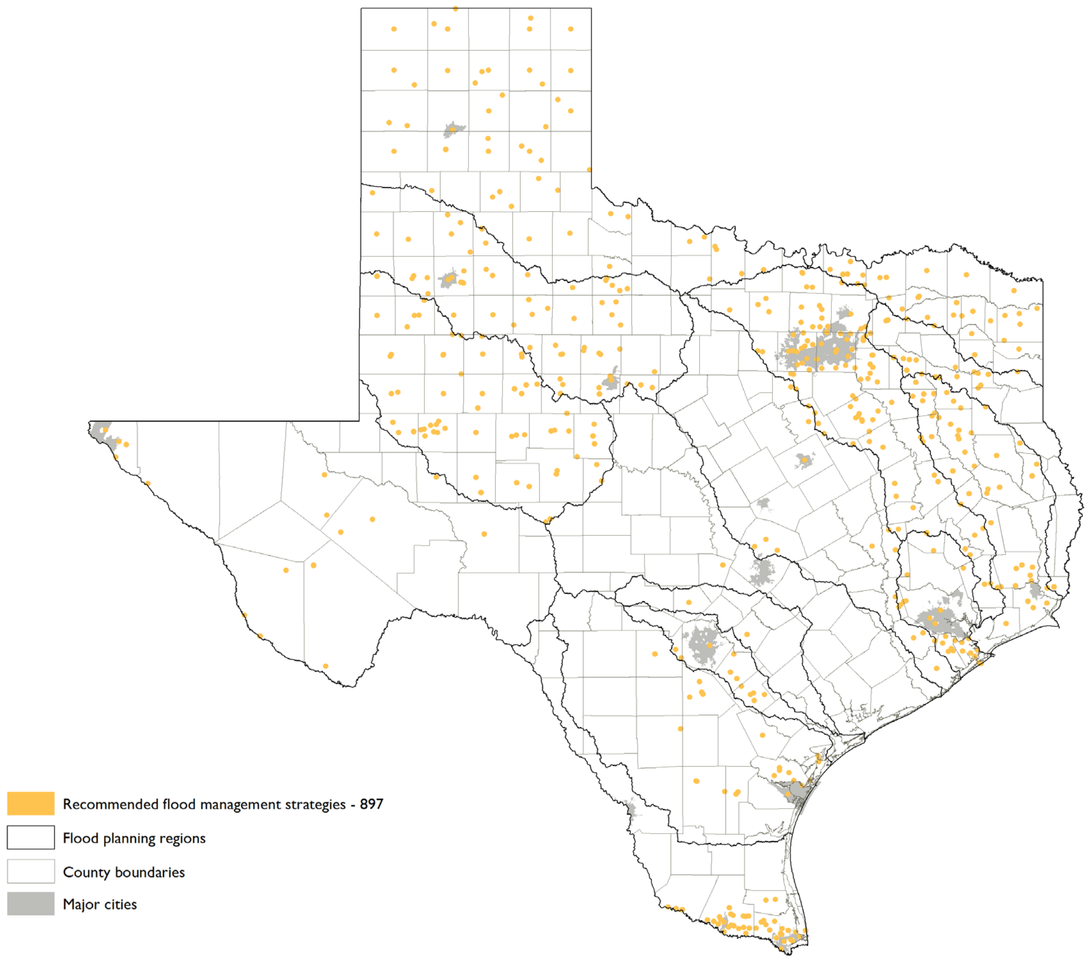


Figure 7-14. Count and cost of all recommended flood management strategies by flood planning region

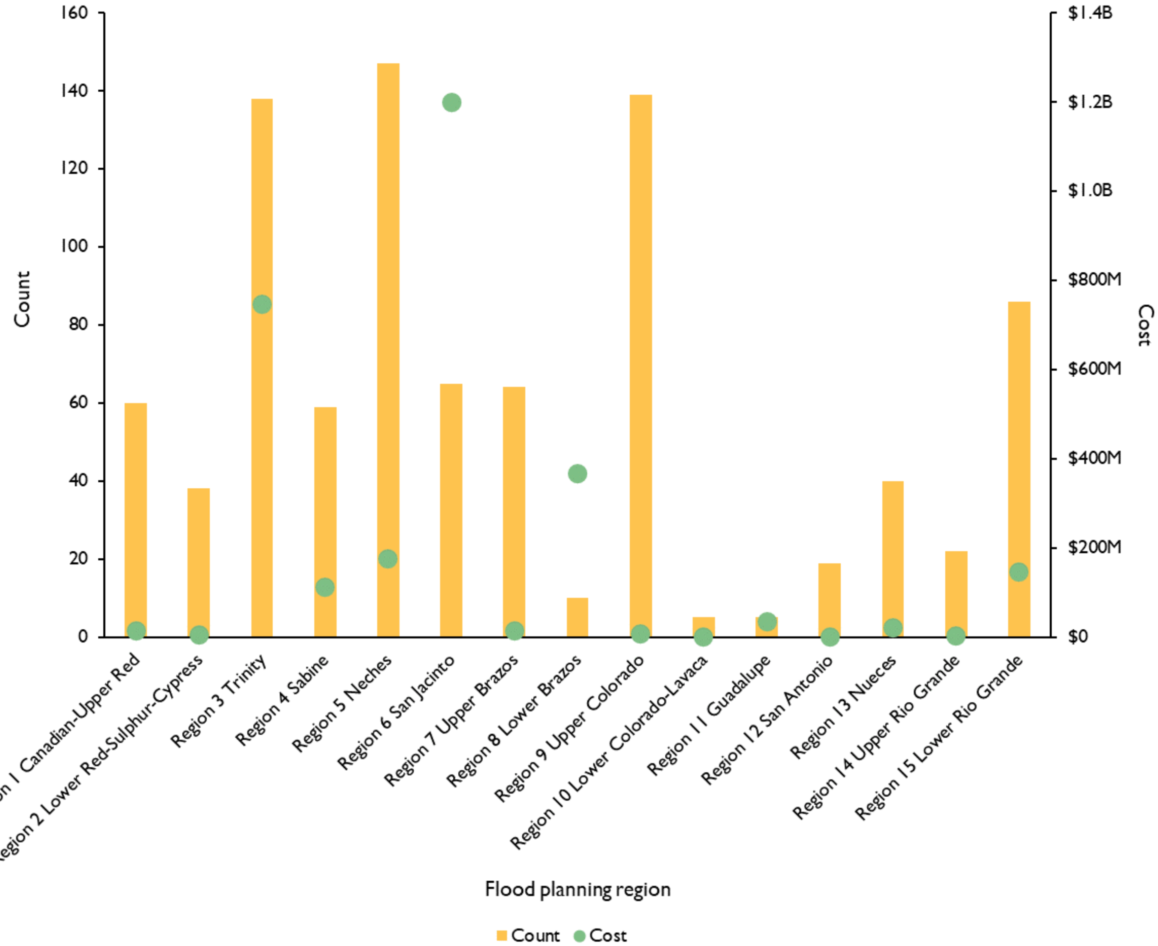
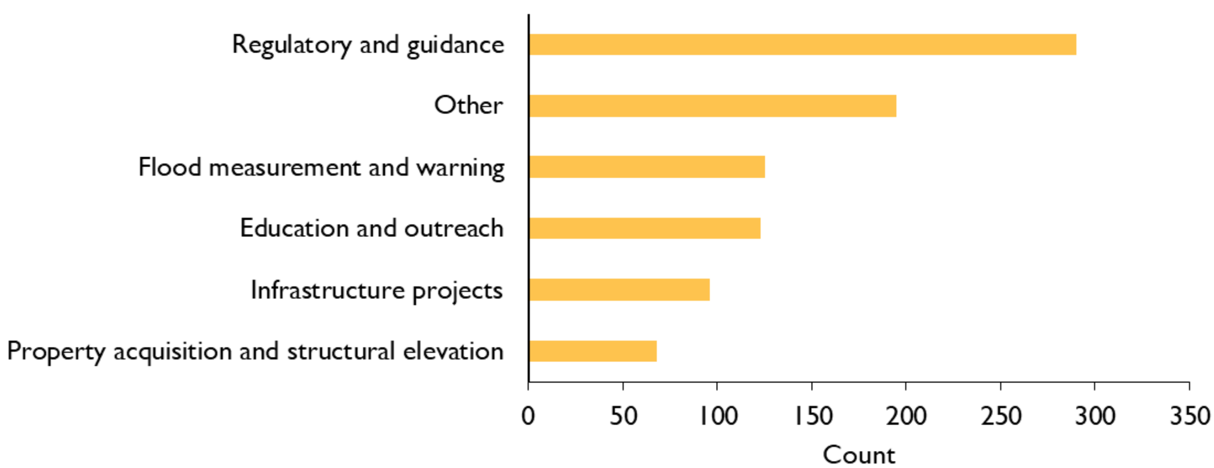


Table 7-9. Recommended flood management strategy categories by flood planning region

Region	Education and outreach	Flood measurement and warning	Infrastructure projects	Property acquisition and structural elevation	Regulatory and guidance	Other	Total
1	2	3	1	1	52	1	**60**
2	3	3	0	1	31	0	**38**
3	19	20	5	20	59	15	**138**
4	16	9	1	4	19	10	**59**
5	25	17	54	18	31	2	**147**
6	15	6	8	17	10	9	**65**
7	10	5	11	0	37	1	**64**
8	0	2	2	2	1	3	**10**
9	0	1	0	0	0	138	**139**
10	2	1	1	1	0	0	**5**
11	1	1	1	1	1	0	**5**
12	11	1	0	0	7	0	**19**
13	9	4	2	3	17	5	**40**
14	2	7	3	0	6	4	**22**
15	8	45	7	0	19	7	**86**
Total	**123**	**125**	**96**	**68**	**290**	**195**	**897**

Figure 7-15. Summary of all recommended flood management strategies by category



None of the recommended flood management strategies are anticipated to have a negative impact on neighboring areas, and one recommended strategy reported a water supply benefit, if implemented.

Some regions chose to categorize potential construction projects as flood management strategies versus flood mitigation projects if they were unable to meet the technical evaluation threshold of a flood mitigation project, such as the benefit-cost analysis.

7.6 Ranking recommended flood risk reduction solutions

Texas Water Code § 16.061 requires the state flood plan to include a ranked list of all recommended flood risk reduction solutions. Ranking flood risk reduction solutions for this purpose primarily focused on flood risk and flood risk reduction to life and property. Per TWDB rules, the state flood plan includes three ranked lists of flood risk reduction solutions for evaluations, projects, and strategies with non-recurring, non-capital costs[37] (Table 7-10).

Table 7-10. Summary of recommended flood risk reduction solutions and associated eligible costs included as ranked lists in Appendix B

	Count	Cost
Flood management evaluations	3,097	$2,626,511,560
Flood mitigation projects	615	$49,055,365,644
Flood management strategies[a]	771	$2,825,000,885
Total	**4,483**	**$54,506,878,089**

[a] *With non-recurring non-capital costs*

7.6.1 Background

The overarching goal of the regional and state flood plans is to protect against the loss of life and property by (1) identifying and reducing the risk and impact to life and property that already exists, and (2) avoiding increasing or creating new flood risks by addressing future development within areas known to have existing or future flood risks.

The ranking criteria and methodology are generally intended to:

- identify areas with the worst existing risk of flooding in the 1 percent (100-year) annual chance floodplain;
- identify flood risk reduction solutions that may result in greater overall reduction in flood risk;
- and primarily focus on projects with the greater potential to mitigate the risk to life and property.

In spring 2023, the TWDB developed a proposed methodology for ranking flood management evaluations, flood mitigation projects, and flood management strategies in separate lists and solicited stakeholder feedback. The TWDB provided to stakeholders an explanation of the methodology and considerations, the ranking Excel workbooks, and other supporting documents for review. The TWDB considered the valuable stakeholder feedback and made several changes, including adjusting criteria weights and normalizing scores using an inverse hyperbolic sine function,[38] which resulted in a score spread that better served smaller communities.

Although a significant factor used in prioritizing Flood Infrastructure Fund financial assistance for the state fiscal year 2024–2025 cycle, the methodology was not developed directly for the purpose of

[37] 31 TAC § 362.4 (c)(5))

[38] The inverse hyperbolic functions are inverses of the hyperbolic functions, such that $\operatorname{arcsinh}(z) = \log(z + \sqrt{1 + z^2})$. For the purpose of the state flood plan ranking, inverse hyperbolic sine normalization distributed the number ranges in a manner similar to the logarithmic scale where it prevents the largest projects from receiving very high scores while the vast majority of remaining projects receive very few points and cluster together at the low end of the ranking scale.

allocating state funding. Agency funding decisions occur through a separate TWDB process as funds are appropriated by the Texas Legislature. How the state flood plan project ranking may be considered in any future Flood Infrastructure Fund project funding prioritization and allocation remains to be determined, although the TWDB anticipates it may play a role.

The draft proposed state flood plan ranking was utilized for the draft intended use plan for the state fiscal year 2024–2025 Flood Infrastructure Fund cycle. In January 2024, as part of the public comment period for the draft intended use plan for the state fiscal year 2024–2025 Flood Infrastructure Fund cycle, the TWDB received additional stakeholder feedback on the modified version of the ranking methodology that would play a significant role in the funding prioritization scoring. The comments received were helpful in informing the ranking, but they did not result in any further changes to the ranking criteria or methodology used in the final intended use plan prioritization.

7.6.2 Ranking methodology

The TWDB's ranking methodology for state flood plan flood risk reduction solutions is intended to provide a consistent approach for use across Texas to systematically address flood hazard with the population, properties, and critical facilities most at risk during a 1 percent (100-year) annual chance storm event. The ranking process aims to focus on severity of flood risk and reducing flood risk and impact to life and property as described by the legislature.

The basic approach was to ensure that by the end of the first regional flood planning cycle the TWDB would collect enough comparable data from all 15 regions to provide an adequate basis for developing a meaningful ranking method that could be applied consistently to all recommended flood solutions.

In keeping with the bottom-up approach of regional flood planning, the state flood plan ranking only utilizes data provided by planning groups in their regional flood plans. However, there is one ranking factor that was calculated by the TWDB using data reported by the regional flood planning groups: percent of structures removed from 1 percent (100-year) annual chance floodplain.

The ranking criteria generally focused on flood risk and flood risk reduction to people, structures, critical facilities, low water crossings, farm and ranch land, and several other relevant and/or statutory factors, including water supply benefits, nature-based solutions, mobility, and environmental benefits, amongst others (Figure 7-16). During review, the TWDB noted some significant data inconsistencies across several regions in the planning group-reported datasets; therefore, certain data categories were not used in the state flood plan ranking.

To rank flood risk reduction solutions with a focus on technical merit, the TWDB only considered data submitted by the planning groups in its adopted ranking methodology. This methodology includes considering initial feedback received from the TWDB Flood Technical Advisory Group and two rounds of flood planning stakeholder input prior to publishing the initial draft state flood plan. While some potential criteria considered for ranking were ultimately not adopted, they were still included in the stakeholder feedback materials for transparency.

Select reported data criteria was normalized using an inverse hyperbolic sine function to transform the raw data to a range of 0 to 10.[39] This approach was used to more evenly distribute scores over the full range of potential points for each criterion and prevent the largest solutions from receiving very high scores while the vast majority of remaining solutions receive very few points and cluster together at the low end of the ranking scale (Figure 7-17).

[39] For example, a score of 10 was assigned to all values greater than a certain higher end number for each reported criterion that was normalized.

Figure 7-16. Criteria and associated weights used to rank recommended flood management evaluations (FME), flood mitigation projects (FMP), and flood management strategies (FMS)*

		Criterion	Criterion type	Criteria grouping	FME ranking criterion?	FME ranking weight	FME grouping weight	FMP ranking criterion?	FMP ranking weight	FMP grouping weight	FMS ranking criterion?	FMS ranking weight	FMS grouping weight	Max score
Reported data from FME, FMP, and FMS GIS feature classes	1	Estimated structures at 1 percent (100-year) flood risk**	Flood risk	Life, safety, and property	Yes	15.0%	75.0%	No	0.0%	0.0%	Yes	10.0%	40.0%	10
	2	Estimated population at 1 percent (100-year) flood risk**	Flood risk		Yes	15.0%		No	0.0%		Yes	10.0%		10
	3	Critical facilities at 1 percent (100-year) flood risk**	Flood risk		Yes	25.0%		No	0.0%		Yes	10.0%		10
	4	Low water crossings at flood risk**	Flood risk		Yes	20.0%		No	0.0%		Yes	10.0%		10
	5	Estimated road closures**	Flood risk	Mobility	Yes	5.0%	15.0%	No	0.0%	0.0%	Yes	5.0%	15.0%	10
	6	Estimated road miles at 1 percent (100-year) flood risk**	Flood risk		Yes	10.0%		No	0.0%		Yes	10.0%		10
	7	Estimated farm & ranch land at 1 percent (100-year) flood risk (acres)**	Flood risk	Agriculture	Yes	10.0%	10.0%	No	0.0%	0.0%	Yes	5.0%	5.0%	10
	8	Structures removed from 1 percent (100-year) floodplain**	Flood risk reduction	Life, safety, and property				Yes	5.0%	45.0%	Yes	10.0%	25.0%	10
	9	Percent structures removed from 1 percent (100-year) floodplain (Calculated by TWDB from reported data)	Flood risk reduction					Yes	10.0%		No	0.0%		10
	10	Residential structures removed from 1 percent (100-year) floodplain**	Flood risk reduction					Yes	2.5%		Yes	5.0%		10
	11	Estimated population removed from 1 percent (100-year) floodplain**	Flood risk reduction					Yes	10.0%		Yes	10.0%		10
	12	Critical facilities removed from 1 percent (100-year) floodplain**	Flood risk reduction					Yes	10.0%		No	0.0%		10
	13	Low water crossings removed from 1 percent (100-year) floodplain**	Flood risk reduction					Yes	7.5%		No	0.0%		10
	14	Estimated roadway miles removed from 1 percent (100-year) floodplain**	Flood risk reduction	Mobility				Yes	5.0%	5.0%	No	0.0%	0.0%	10
	15	Estimated farm & ranch land removed from 1 percent (100-year) floodplain (acres)**	Flood risk reduction	Agriculture				Yes	5.0%	5.0%	No	0.0%	0.0%	10
	16	Percent nature-based solution (by cost)	Other					Yes	5.0%		Yes	7.5%		10
	17	Benefit-cost ratio	Other					Yes	2.5%					10
	18	Water supply benefit (Y/N)	Other					Yes	5.0%		Yes	5.0%		10
	19	FMP project type (10 points) Low water crossing (4 points) Preparedness	Other					Yes	2.5%		No	0.0%		
	20	FMS project type (10 points) Flood measurement and warning (8 points) Regulatory and guidance (6 points) Education and outreach (4 points) Property acquisition and structural elevation (4 points) Infrastructure projects (2 points) Other	Other					No	0.0%		Yes	2.5%		10
		Subtotal					**100.0%**			**70.0%**			**100.0%**	
FMP project details scoring (computed by the regional flood planning groups)***	21	Score 1: Severity - Pre-project average depth of flooding (100-year)	Flood risk					Yes	5.0%					10
	22	Score 2: Severity - Community need (percent population)	Flood risk					Yes	5.0%					10
	23	Score 6: Life and safety	Flood risk reduction					Yes	5.0%					10
	24	Score 8: Social vulnerability	Other					Yes	5.0%					10
	25	Score 10: Multiple benefits	Other benefits					Yes	2.5%					10
	26	Score 13: Environmental benefit	Other benefits					Yes	2.5%					10
	27	Score 15: Mobility	Other benefits					Yes	5.0%					10
		Subtotal					**0.0%**			**30.0%**			**0.0%**	
		Total (must add to 100 percent)					**100.0%**			**100.0%**			**100.0%**	

Note: All flood risk and risk reduction information are for 1 percent (100-year) annual chance storm. Grey cells indicate the criterion is not applicable for that flood risk reduction solution type.

* Only recommended flood management strategies with non-recurring, non-capital costs were ranked in the 2024 State Flood Plan

** Indicates that select reported data were normalized on the curve (ArcSinh), scoring 0-10

*** Project details criteria are described below. Refer to "project details scoring" for a description of all data included in project details available here: www.twdb.texas.gov/flood/planning/planningdocu/2023/doc/04_Exhibit_C_TechnicalGuidelines_April2021.pdf

Score 1: Severity - Pre-project average depth of flooding (100-year): Ranking of severity based on the baseline/pre-project average 100-year flood depth.

Score 2: Severity - Community need (percent population): Ranking of severity based on a community's need by percentage of project community affected by population.

Score 6: Life and safety: Ranking of reduced flood risk by percentage of structures removed from the 100-year floodplain in post-project condition.

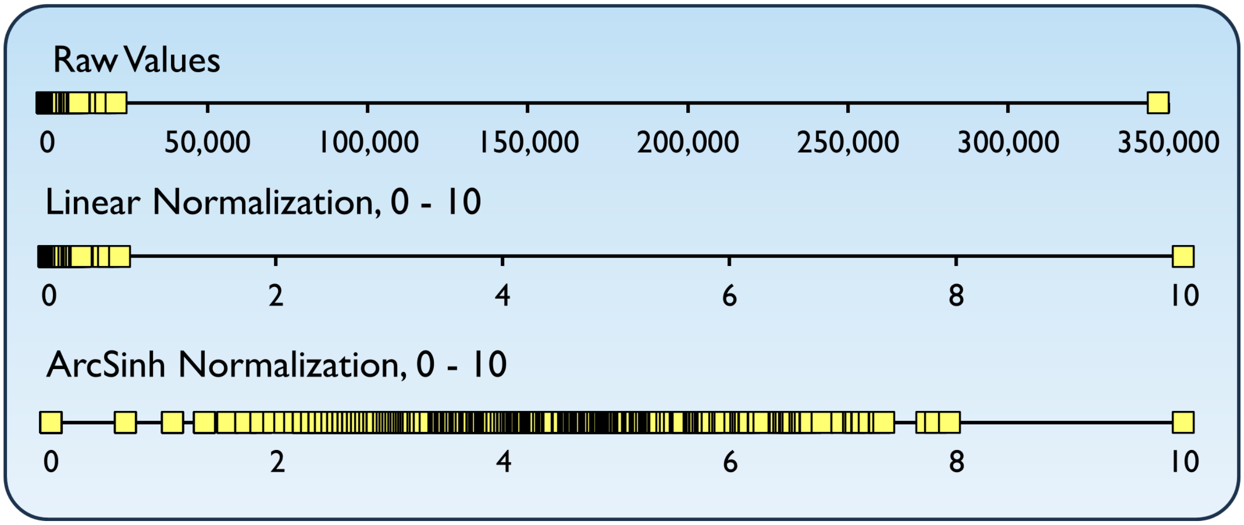
Score 8: Social vulnerability: Ranking based on the Center for Disease Control SVI data for Texas, by calculating an average project SVI by census tract and classifying the vulnerability level.

Score 10: Multiple benefits: Ranking a project based on the reporting of significant, measurable, expected benefits to: recreation, transportation, social and quality of life, local economic impacts, meeting sustainability goals, and/or project resilience goals.

Score 13: Environmental benefit: Ranking of expected level of environmental benefits to be delivered by project to water quality, cultural heritage, habitat, air quality, natural resources, agricultural resources, and soils/erosion and sedimentation.

Score 15: Mobility: Ranking project improvement and protection of mobility during flood events, with particular emphasis on emergency service access and major access routes.

Figure 7-17. Effect of inverse hyperbolic sine normalization methods for ranking using estimated population removed from 1 percent (100-year) annual chance floodplain



There are three sets of prioritizations by flood risk reduction solution type:

Flood management evaluations: The ranking criteria for flood management evaluations are limited to the identification of flood risk in the 1 percent (100-year) annual chance floodplain, which relied on reported raw data included for each of the recommended flood mitigation projects. These criteria were grouped into three major themes: (1) life, safety, and property; (2) mobility; and (3) agriculture. The associated proposed weights for these criteria show an emphasis on areas of greatest risk to life and property, including areas with low water crossings and structures.

Flood mitigation projects: These ranking criteria primarily focus on flood risk reduction in the 1 percent (100-year) annual chance floodplain in addition to several other benefit indicators, including nature-based solution, benefit-cost ratio, and water supply benefit. The ranking criteria for flood mitigation projects are split into two major categories:

- Reported data: Raw data included for each recommended project. Criteria in this category are grouped into three major themes: (1) life, safety, and property; (2) mobility; and (3) agriculture and comprise 70 percent of the total weight for flood mitigation projects. Only one of these criteria, "percent of structures removed from 1 percent (100-year) annual chance floodplain," was calculated by the TWDB using reported data. This criterion is intended to give additional weight to projects with a bigger impact on smaller communities.
- Project details: More complex project scores computed by planning groups using raw data. While reported data was required for all recommended flood mitigation projects, not all planning groups had pertinent information available during this planning cycle. In these events, planning groups were advised to leave fields blank, in which, the criteria were scored as zero. Criteria obtained from the project details category comprises 30 percent of the total weight for flood mitigation projects. The project details template is an Excel worksheet intended to acquire detailed project data for each recommended flood mitigation project in the regional flood plan. For details on how scores were calculated, refer to Section 3.9 of TWDB Exhibit C: Technical

Guidelines for Regional Flood Planning and the Project Details Workbook available on the TWDB website.[40]

Flood management strategies: The flood management strategies ranking criteria focus on risk identification in the 1 percent (100-year) annual chance floodplain and flood risk reduction. These criteria relied on reported raw data included for each of the recommended flood management strategies, which were grouped into three major themes: (1) life, safety, and property; (2) mobility; and (3) agriculture. While there is potential for flood management strategies to share the same flood risk reduction criteria as projects, the TWDB found a general lack of data provided to that effect as many recommended strategies are non-structural.

7.6.3 Ranking results

The results of TWDB flood risk reduction solution rankings are included in Appendix B and available to review or download via the Interactive State Flood Plan Viewer.[41] The spreadsheets used to develop the rankings are also available on the 2024 State Flood Planning website.

References

FEMA (Federal Emergency Management Agency), n.d., Structure elevation, www.fema.gov/hmgp-appeal-categories/structure-elevation#:~:text=Structure%20Elevation%20is%20an%20eligible,by%20FEMA%20or%20local%20ordinance

[40] www.twdb.texas.gov/flood/planning/planningdocu/2023/index.asp

[41] Texasstatefloodplan.org

8 Benefits and impacts of implementing the plan

Quick facts

An estimated 640,507 people, 155,905 buildings, and 199 low water crossings would be removed from the 1 percent (100-year) annual chance floodplain if all 615 recommended flood mitigation projects are implemented.

An estimated 202,832 people, 58,387 buildings, and 378 low water crossings would be removed from the 1 percent (100-year) annual chance floodplain if all 897 recommended flood management strategies are implemented.

Three regions (Region 11 Guadalupe, Region 12 San Antonio, and Region 15 Lower Rio Grande) identified potential water supply benefits for 37 recommended flood mitigation projects with an estimated water supply amount of 2,001 acre-feet per year. One region (Region 14 Upper Rio Grande) recommended a flood management strategy with potential water supply benefit with an estimated water supply amount of 70 acre-feet per year.

Together, implementing the recommended flood risk reduction solutions (Chapter 7) and the floodplain management recommendations (Chapters 2 and 5) will help reduce current flood risk and, importantly, prevent the creation of or increase in future flood risk.

Each regional flood planning group was tasked with summarizing the impacts and contributions that its regional flood plan could have if the plan is implemented as recommended based on before-and-after comparisons. These comparisons estimate how much the region's existing flood risk will be reduced by implementing the plan. To quantify the impact, these comparisons were performed for the 1 percent (100-year) annual chance flood event. All 15 planning groups determined that their plan, when implemented, will not negatively affect neighboring areas located near the flood planning regional boundaries.

8.1 Benefits of implementing recommended flood risk reduction solutions

While flood mitigation projects, flood management strategies, and flood management evaluations mitigate flood risk in different ways, the combined effect of all these recommended actions will, directly or indirectly, reduce flood risk and protect life and property throughout the state. Implementation of this plan describes conditions if all recommended flood risk reduction solutions are fully funded and completed.

For clarity and brevity, this chapter summarizes implementing all the recommended mitigation solutions with a focus on the resulting flood risk reduction benefits associated with a 1 percent (100-year) annual chance flood event.

8.1.1 Benefits of recommended flood management evaluations

For many flood planning regions, the data compilation step of the first region-wide planning process resulted in identifying significant data gaps in areas of potentially high flood risks that didn't have floodplain management or enforcement, detailed hydrologic and hydraulic models, or accurate flood inundation mapping. Lack of data or outdated information can lead to unanticipated exposure to flood hazard and, therefore, lack of awareness, general unpreparedness, and greater vulnerability.

The planning groups developed and recommended flood management evaluations to address people and property exposed to existing flood risks within the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains. While studies themselves don't directly mitigate flood risk, they do encompass a large expanse of people and property that could potentially benefit from knowing their flood risk and implementing mitigation solutions identified by these studies.

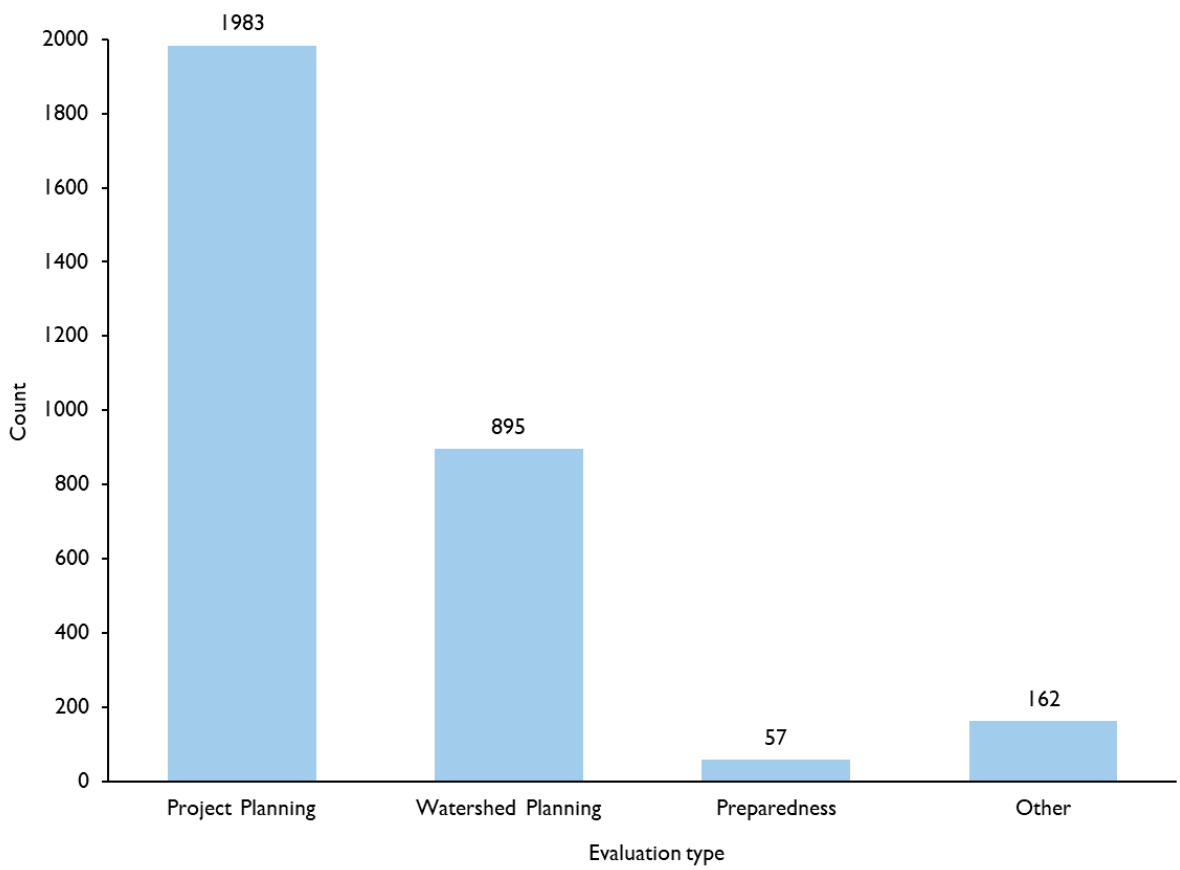
The large number of flood management evaluations highlights the work needed throughout the state to assess the general flood risk. The number of studies also underscores the need to better define flood risk and identify and implement risk reduction solutions.

Many of the recommended flood management evaluations have overlapping boundaries resulting in duplicated data, including affected population and structures within the 1 percent (100-year) annual chance floodplain. Total recommended flood management evaluation boundaries cover approximately 81 percent (217,415 square miles) of the total land area of Texas (268,697 square miles).

Performing the recommended flood management evaluations would represent significant progress in addressing flood data knowledge gaps and high flood risk areas. Many parts of the state have limited and/or outdated floodplain mapping.

In the amended regional flood plans, the regional planning groups recommended a total of 3,097 flood management evaluations that are organized into four broad categories: engineering project planning; flood preparedness studies; watershed planning; and other (Figure 8-1). The overall impacts of each recommended flood management evaluation will vary and depend on whether specific on-the-ground mitigation solutions can be identified and implemented. However, until all recommended flood management evaluations are performed, their ultimate impacts may not be fully known. Taken together, these flood management evaluations represent the areas across the state that regional flood planning groups considered most in need of flood risk identification.

Figure 8-1. Summary of recommended flood management evaluations by evaluation type



Engineering project planning

Approximately 64 percent (1,983) of the flood management evaluations recommended by the regional flood planning groups were categorized as engineering project planning evaluations. The total study area of all engineering project planning flood management evaluations is 85,561 square miles, or approximately 32 percent of the land area of Texas. These studies fall into two main categories, feasibility assessments and preliminary engineering. These studies investigate, identify, recommend, and formulate specific, best flood risk reduction solutions for particular flood risks. The preliminary engineering studies may include up to 30 percent of engineering project design. Examples of evaluations include storm drain upgrades, culvert upsizing, and channel modifications. Typical impacts or outcomes from projects identified through such evaluations include reducing properties at risk of flooding, reducing existing facilities exposure, and reducing roadway overtopping.

Watershed planning

Approximately 29 percent (895) of the recommended flood management evaluations were categorized as watershed planning evaluations, or studies that identify the risk of flooding, refine and update outdated flood risk information in the watershed, identify, evaluate and recommend flood risk reducation solutions. They also help establish accurate floodplain modeling and mapping and evaluation of potential flood mitigation measures, as well as include watershed studies, flood insurance studies, and city-wide or county-wide drainage master plans. Watershed planning can help to better distribute resources equitably throughout the region to implement plans, programs, and projects that maintain watershed function and prevent adverse flood effects.

Other

Approximately 5 percent (162) were categorized as other flood management evaluations. This category was reserved for additional types of studies or assessments needed to either identify and quantify flood hazard or evaluate and recommend flood risk reduction solutions. The types of studies in this category varied across regions but generally included dam evaluations, property acquisition evaluations, developing geographic information system inventories on existing infrastructure, and other general data collection. While these activities may not directly mitigate flooding issues, they support increased awareness of the condition of stormwater infrastructure, leading to better prioritization for the maintenance, repair, and associated flood risk mitigation benefits. Typical impacts or eventual outcomes of these types of evaluations include

- projects that reduce the impact of flooding on people and structures through acquisition of repetitive loss areas;
- potential increase of green space, functioning floodplains, and recreational areas; and
- meaningful reductions in flood risk resulting from maintenace and repair to existing infrastructure.

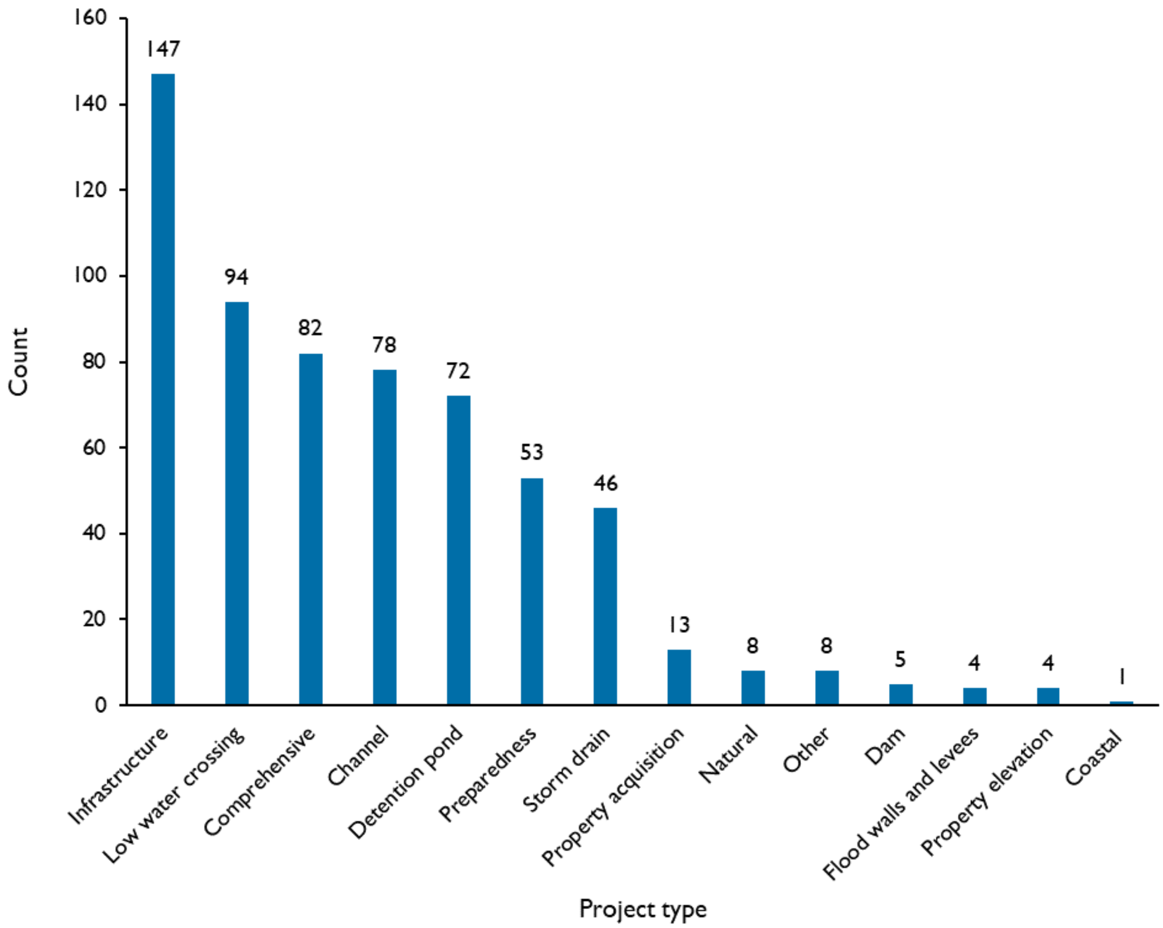
Flood preparedness studies

Approximately 2 percent (57) were categorized as flood preparedness studies. These involve comprehensive assessments to evaluate the level of readiness and resilience of a community or area in the face of potential flooding events. Assessments may include conducting pre-emptive evaluations and strategies to better prepare an area or community in the event of flood and can include inundation studies, dam compliance assessments, and hazard/vulnerability assessments.

8.1.2 Benefits of implementing recommended flood mitigation projects

The recommended flood mitigation projects are intended to reduce the risk and impact of flooding through structural and non-structural solutions. The regional flood planning groups recommended 615 flood mitigation projects spanning 14 project categories (Figure 8-2). These proposed projects have capital costs or other non-recurring costs and reduce flood risk. By removing or reducing flood risk exposure, flood mitigation projects reduce flood risk for people, property, and infrastructure. Implementing these projects could have a profound, long-term impact on reducing flood risk and flooding impacts.

Figure 8-2. Summary of recommended flood mitigation projects by project type



To the extent possible within the time and resource constraints of the first planning cycle, the planning groups developed and recommended flood mitigation projects to address exposure to existing flood risks within the 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains (Table 8-1). Many of the population and structures within the recommended project areas may benefit from implementation of the projects. In some cases, structures would be entirely removed from the flood risk. In other instances, the flood mitigation projects may only lessen the flooding impact on a structure (e.g., lowering the maximum flood water elevation).

Types of structural projects

Approximately 87 percent (537) of all recommended flood mitigation projects were classified as structural projects. Many of these typically include advanced analysis with 30 percent to 100 percent level of engineering design. They include, for example, improvements to storm sewers, roadside ditch systems, detention basins, bridge elevations, channel grading, street reconstruction, and detention ponds.

Types of non-structural projects

Approximately 13 percent (78) of the recommended flood mitigation projects were classified as non-structural projects, which reduce the impact of flooding without relying solely on physical infrastructure solutions. These projects focus on strategies that do not involve constructing physical barriers or altering the natural flow of water. Non-structural flood mitigation includes, but is not limited to, measures such as acquisition of floodplain land for use as public open space, acquisition and removal of buildings located in a floodplain, relocation of residents of buildings removed from a floodplain, flood warning systems, educational campaigns, land use planning policies, watershed planning, flood mapping, and acquisition of conservation easements.[42]

Benefits to population and structures at flood risk

The benefits of implementing the recommended flood mitigation projects include removing people, private property, and public infrastructure from the1 percent (100-year) annual chance floodplain. These benefits would also include avoided injuries and deaths, although that is very difficult to estimate. Reducing flood risk to roadways, for example, will improve public safety at low water crossings, improve evacuation routes, and provide access to emergency services and critical facilities during flood events.

Project implementation would remove existing structures, those inundated for short periods or extended periods, located within flood hazard areas. Community members benefit from removing structures that are at risk of flooding, including residences, workplaces, industries, and critical infrastructure (Table 8-1). Several of the recommended flood mitigation projects appear to have overlapping boundaries, therefore the flood risk reduction benefits described are as reported by the flood planning groups and may contain overlaps.

During the first planning cycle, regional flood planning groups had the flexibility to utilize the community's discretion to identify a roadway creek crossing as a low water crossing. Life and property will be saved as the number of low water crossings are reduced, also reducing the frequency and duration of road closures due to severe flooding.

To determine if a project would create adverse flood impacts, planning groups evaluated flood risk reduction benefits for each. All recommended flood mitigation projects, when implemented, will not negatively affect areas located within their flood planning regional boundaries or neighboring areas. It will ultimately be the responsibility of local project sponsors and their engineers to ensure that final designs during construction do not result in any negative flood impacts.

[42] 31 TAC 363.402

Table 8-1. Anticipated benefits of flood mitigation project implementation on population and structures currently exposed to 100-year flood risk within project area

	Existing exposure within project area	Flood risk reduction[a]	Remaining flood risk
Population	1,974,127	640,507	1,333,620
All buildings[b]	637,178	155,905	481,273
Residential buildings	486,767	112,609	374,158
Critical facilities[c]	10,055	2,597	7,458
Low water crossings	1,060	199	861
Roadway miles	12,779	2,329	10,450
Road closures	19,251	5,567	13,684

Note: Quantities are as reported by the flood planning groups and may contain overlap between flood mitigation project boundaries

[a] As identified by the regional flood planning groups
[b] Includes all residential, agricultural, commercial, industrial, public, and vacant or unknown
[c] Includes hospitals, emergency medical services, fire stations, police stations, and schools

8.1.3 Benefits of implementing recommended flood management strategies

The regional flood planning groups recommended a total of 897 flood management strategies, each with associated implementation costs, across six broad categories (Figure 8-3). A subset of the recommended flood management strategies also included non-recurring, non-capital costs. For example, a community may recommend a strategy to buy out all properties located in the 1 percent (100-year) annual chance floodplain within its jurisdiction and require a study with a one-time cost to develop the program that would identify the properties and cost, etc. There are 771 recommended strategies that include non-recurring, non-capital costs, which are included in the list of ranked flood management strategies and are eligible for future state funding.

The recommended flood management strategies can reduce the risk and impact of flooding by improving floodplain management and public awareness, encouraging better floodplain management policies, educating people about the risks of flooding, providing warnings of current and potential flooding, and reducing the frequency and severity of flooding of roads and structures. The potential benefits of the recommended flood management strategies, as identified by the regional flood planning groups, are summarized in Table 8-2.

Figure 8-3. Summary of recommended flood management strategies by strategy type

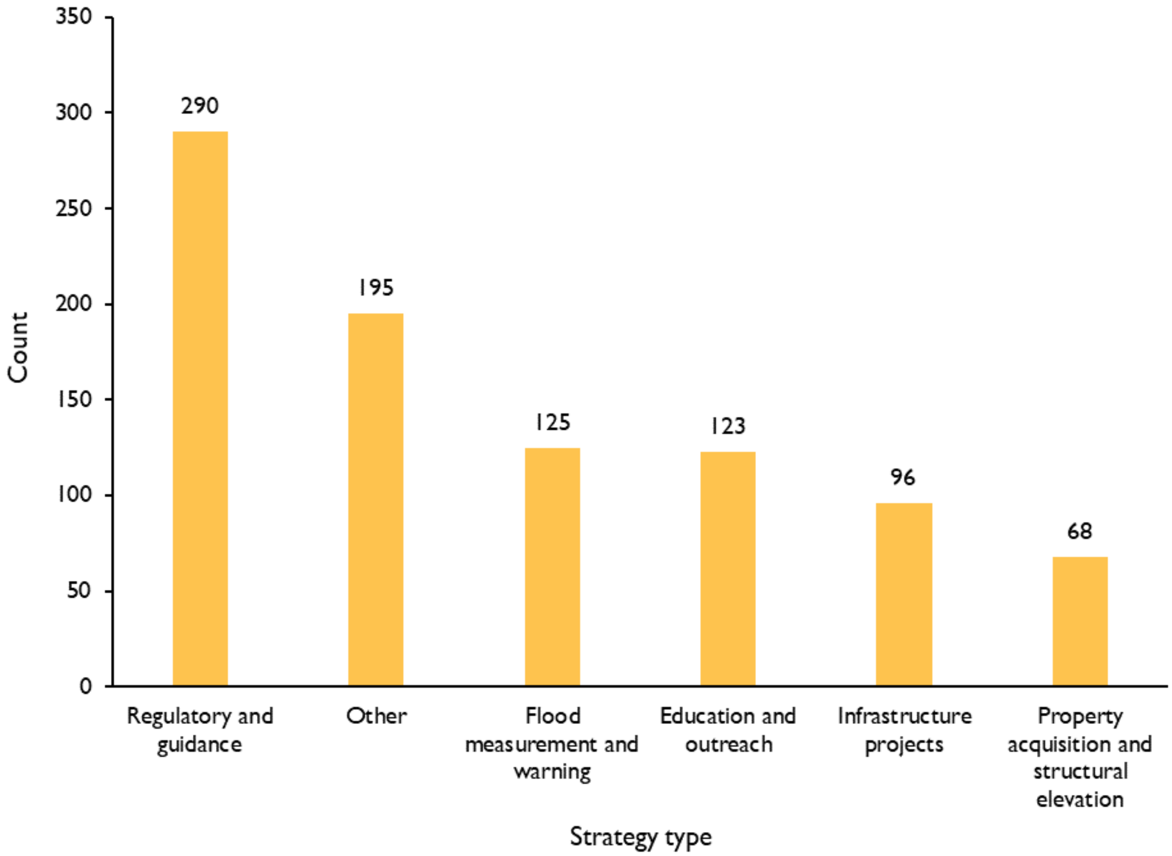


Table 8-2. Anticipated benefits of recommended flood management strategy implementation on existing 100-year flood event exposure

Flood exposure	Existing risk	Risk reduction[a]	Residual risk
Population	15,283,833	202,832	15,081,001
All buildings[b]	4,608,800	58,387	4,550,413
Residential buildings	3,632,286	40,137	3,592,149
Critical facilities	31,477	84	31,393
Low water crossings	34,391	378	34,013
Roadway miles	180,661	5,874	174,787
Road closures	54,648	199	54,449
Agricultural areas (acres)	36,924,302	974,284	35,950,018

Note: All quantities are counts unless otherwise noted. Quantities are approximate and may contain overlap between some strategy boundaries.

[a] As identified by the regional flood planning groups
[b] Includes all residential, agricultural, commercial, industrial, public, and vacant or unknown

Regulatory and guidance

Approximately 32 percent (290) of the recommended flood management strategies are considered regulatory and guidance strategies, which can play an important role in reducing current and future flood risk by improving regulation of development, stormwater regulations, and floodplain management practices.

These strategies may include participation in FEMA's National Flood Insurance Program, stormwater utility fee development, and stormwater management criteria, like higher standards, floodplain management staff acquisition and training, ordinance, land use and zoning, and green infrastructure programs.

Property acquisition and structural elevation

Eight percent (68) of the recommended flood management strategies relate to property acquisition and elevation. Property acquisition and structural elevation strategies remove or reduce exposure to flood risk. These types of strategies can feature voluntary buyout programs and structural elevation assistance programs. It is relevant to note that the property acquisition and elevation strategies include studies to develop programs for property acquisition. The actual projects to implement buyout or property acquisition or elevation are included with the flood mitigation projects.

Education and outreach

Fourteen percent (123) of the recommended flood management strategies are related to education and outreach. Public outreach creates community engagement and collaboration and may include public awareness or flood insurance campaigns and flood safety education for residents, elected officials, real estate agents, and developers.

Flood measurement and warning

Fourteen percent (125) of the strategies are related to flood warning systems that alert the public about impending dangerous conditions. Such systems can minimize injury and protect life by encouraging people to avoid flooded roads, seek appropriate shelter, and receive status updates on current weather and flooding conditions.

Infrastructure

Approximately 11 percent (96) of the strategies are related to traditional infrastructure projects to reduce peak flow rates and lower water surface elevations and that require ongoing maintenance to support effectiveness and functionality of drainage systems. Flood management strategies in this category include studies to formulate infrastructure projects. The actual projects to construct infrastructure would have capital costs associated with them and are included with flood mitigation projects.

8.2 No negative impact

The TWDB is statutorily required to determine that each regional flood plan, and by extension the state flood plan, does not negatively affect a neighboring area before the TWDB may approve a regional plan. For regional flood planning purposes, this *negative impact* is defined as an "increase in flood-related risks to life and property, either upstream or downstream of the proposed project." The regional flood planning groups were required to evaluate and/or assess and certify that each recommended flood mitigation project and their overall plans would not cause flood-related negative impacts to surrounding areas based on criteria the TWDB developed and provided.

Local project sponsors and their engineers will be responsible for confirming that final designs and any modifications made during construction do not result in adverse flood impacts.

Potential negative effects are also a consideration for flood management evaluations and strategies. The planning-level assessment for these two categories included a review of the potential impacts based on the limited data available. The flood management evaluations (studies to be performed) must, as an inherent part of the work performed, consider potential negative effects of any proposed flood risk mitigation.

8.3 Contributions to and impacts on water supply

Statute requires the TWDB to determine that each regional flood plan adequately provides for the development of water supply sources, where applicable, before the TWDB may approve a regional plan. Regional flood plans must include region-wide summaries and a list of the flood management strategies and flood mitigation projects that would contribute to, negatively impact, or measurably reduce water supply.

Four planning groups recommended flood risk reduction solutions that may provide water supply benefits (Table 8-3). The source of the water supply benefits ranged from contributions to natural aquifer recharge to additional surface water inflows directed to reservoirs.

Regions 11 (Guadalupe), 12 (San Antonio) and 15 (Lower Rio Grande) identified potential water supply benefits for 37 recommended flood mitigation projects. Based on regional flood planning dataset, Region 11 estimated a water supply benefit amount of 1,204 acre-feet per year from 10 projects, which will inform the state water plan. Regions 12 and 15 did not identify water supply benefit amounts in the geodatabase; these regions identify estimated amounts for several projects in the body of the regional flood plans, totaling an unverified and approximate amount of 797 acre-feet per year.

Region 14 Upper Rio Grande recommended one flood management strategy with potential water supply benefit estimated at 70 acre-feet per year.

Examples of flood mitigation projects with potential water supply benefit identified by the flood planning groups include detention ponds, aquifer recharge, and natural area conservation easements. The proposed projects would need to proceed through feasibility, preliminary engineering, and final design phases to prove up the final quantities of water supply from these projects. This information is being shared with the TWDB's Water Supply Planning program and the regional water planning groups for their consideration in developing the 2026 regional water plans and the 2027 State Water Plan. While these represent modest potential contributions to water supply, the TWDB anticipates that future flood plans will identify additional potential water supply benefits as regional flood planning groups and water suppliers collaborate to identify innovative and synergistic strategies. Regional flood planning groups were also required to consider and report any impacts their plans may have on water supply, water availability, or projects in the state water plan. No plans reported any negative impacts.

Table 8-3. Recommended flood risk solutions with anticipated water supply benefit

Region	Project or strategy	Count	Estimated volume (acre-feet/year)	Example
11	Project	10	1,204	Edwards Aquifer Authority and San Marcos River Foundation Katz Recharge Conservation Easement
12	Project	2	177[a]	Currey Creek Regional Detention Facility
14	Strategy	1	70	Irrigation and Recharge Application of Captured Rainwater Runoff at Alpine
15	Project	25	620[a]	Weslaco Stormwater Improvement Plan - Texas Boulevard to Airport Drive, South of Business 83
Total		**38**	**2,071**	

[a] *Indicates where estimated water supply volumes are unverified and approximate*

8.4 Other impacts of plan implementation

Flooding is a natural process that has many benefits to both human and natural systems. For example, floodplain preservation promotes native species, maintains vital ecosystem services, and reduces the chance of flooding elsewhere. In addition to evaluating the benefits of implementing flood risk mitigation solutions, the planning groups generally described implementation impacts related to socioeconomics, the environment, agriculture, recreational resources, water quality, erosion and sedimentation, and navigation.

8.4.1 Socioeconomic impacts

Floods have well-known and sometimes long-lasting socioeconomic impacts. They are the most pervasive among natural disasters, yet their costs are routinely underestimated. The cost of recovering and rebuilding from a flood event is exorbitant compared to the resources spent to prepare and prevent flooding (NIBS, 2019).

Flooding not only results in destroyed infrastructure and property damage, but also has an adverse social impact on residents including lost work hours, impacts to essential services, and the cultural fabric of communities. The long- and short-term impacts of flooding on affected citizens' physical and mental health can even result in socioeconomic disparities. Implementing the 2024 State Flood Plan will improve the lives of Texans and provide significant benefits to the state's economy by alleviating negative impacts from floods.

8.4.2 Environmental impacts

Flooding, and flood solutions of all types, can impact the environment in a variety of ways. In addition to flood control, water quality, erosion, and sedimentation benefits, floodplain preservation and other nature-based solutions also support the environment by promoting habitat development for native plant and animal species. By removing structures from flood risk, property acquisition strategies will help prevent the release of pollutants, such as viruses, bacteria, and mold, associated with flooded homes and septic systems.

While land acquisition and development regulations can have a positive impact on the environment, recommended structural projects have the potential to harm ecosystems in undeveloped land, which receives nutrients from flooding on a regular basis. Local, state, and federal permitting requirements will help ensure compliance with applicable regulations.

Texas Water Code § 5.506[43] ensures ecological soundness by providing adequate protection of the state's streams, rivers, and bays and estuaries. When developing flood mitigation projects and flood management strategies, some planning groups considered how recommended strategies or projects might support flows to satisfy its subsistence and base flow standards.

8.4.3 Agricultural impacts

Implementation of the recommended flood risk reduction solutions would remove approximately 1,020,496 acres of farm and ranchland from the 1 percent (100-year) annual chance floodplain statewide. While agricultural lands can benefit from seasonal flooding when fertile sediment is deposited in the floodplain, floodwater also has the potential to damage valuable crops and livestock, including drowned animals, delayed planting and harvesting, topsoil erosion, and damaged farm equipment.

Implementation of recommended flood management strategies may mitigate adverse impacts of flooding by reducing excessively high flows in rivers and streams and preventing floodwaters from inundating agricultural lands beyond their natural boundaries. Structural solutions like small flood control ponds and natural channels may serve dual purposes by mitigating floods and providing water supply for agricultural needs. The application of non-structural practices like conservation tillage, cover crops, and furrow dikes may also contribute to the reduction of peak flows, minimizing surface runoff, and enhancing soil infiltration. Additional regulatory measures and watershed planning initiatives can also improve flood risk awareness among agricultural stakeholders, facilitate insurance availability for structures, and manage future development within flood prone areas, thus safeguarding agricultural operations.

8.4.4 Recreational resources

The implementation of recommended flood risk reduction solutions statewide can significantly reduce flood risks while also enhancing recreational opportunities. Nature-based solutions within flood projects often offer the dual benefits of flood control and recreation enhancement. In recent years, usage of detention and retention spaces as recreational facilities, such as parks, and sports fields has become more commonplace. Waterfront parks designed to withstand flooding events can serve as safe recreational spaces while restoration efforts focusing on aquatic habitats improve flood resilience and the potential for outdoor recreation like fishing. Flood risk reduction solutions that incorporate nature-based solutions also often promote public awareness and education of flooding and flood risk.

8.4.5 Water quality impacts

The regional flood planning groups described a variety of potential impacts to water quality due to differing factors, such as the concentration of recommended flood risk reduction solutions near residential areas and away from bodies of water, as well as varied environmental permitting regulations and protective drainage and floodplain development criteria.

Flood mitigation solutions can reduce risk to water and wastewater treatment plants, which lowers the likelihood that treatment plants will flood and overflow, improving overall water quality downstream. In regions where mitigating flooding on agricultural land is a significant goal, water quality may also improve by reducing fertilizer in runoff and addressing nutrient load issues.

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[43] https://statutes.capitol.texas.gov/Docs/WA/htm/WA.5.htm

Similarly, **floodproofing** and structural flood mitigation projects can limit overflow from sanitary lift stations and the ensuing release of untreated sewage. Floodproofing and hardening buildings and public utilities further lowers the risk of structural flooding and the release of contaminants.

Some structural projects can improve the quality of water supply reservoirs by capturing stormwater runoff and pollutants. More time in stormwater retention facilities can allow contaminants and particulates to settle before the water is discharged back into the waterway and allowed to flow downstream. Some flood risk mitigation solutions may reduce the release of contaminants from industrial facilities during flood events. Water quality measures can be incorporated into many structural flood mitigation projects, such as installing trash racks or prepackaged stormwater treatment devices.

Other solutions that positively affect water quality include floodplain preservation and regulations and ordinances. Preserving natural floodplains promotes the natural filtration and treatment of water through the creation of natural riparian habitat with native vegetation adjacent to streams. Pollution prevention regulations and ordinances emphasize the proactive prevention of pollution at the source.

8.4.6 Erosion and sedimentation impacts

Erosion and sedimentation are complex issues that are interrelated with water quality. While water quality often relates to nutrient and bacterial loading, it also includes turbidity, which relates to sediment load.

Erosion and sediment control measures that limit high velocities and protect the functionality of drainage infrastructure are considerations when designing and constructing flood mitigation projects. Maintenance will also be required to address long-term sedimentation, which reduces the conveyance capacity of storm sewers and channels.

Non-structural solutions like conservation practices can also reduce erosion and sediment transport at the source and in large downstream reservoirs. Protecting undisturbed areas or returning flood-impacted properties to a natural state also reduces erosion and sedimentation by reintroducing natural drainage and ecological processes.

8.4.7 Navigational impacts

Implementing recommended flood mitigation projects should not have any meaningful impact or relevance to navigation. There are some areas of potential commercial navigation impacts, such as the Houston Ship Channel, which is closely associated with Region 6 San Jacinto's recommended Galveston Bay Surge Protection Coastal Storm Risk Management project. Included in that project are several significant structural improvements aimed at increasing coastal protection and reducing flood risk throughout the region. Other important navigable waterways, like the Sabine-Neches waterway, are not expected to experience any impacts from the recommended flood risk mitigation solutions.

Canoeing, kayaking, and other recreational water activities can be impacted by flood mitigation, for example, when reservoir levels are actively managed to mitigate flood risk or when the rivers and reservoirs are at or above flood stage. Structural flood management strategies or flood mitigation projects that recommend building flood control structures or any other measures that capture the additional water could potentially increase recreational navigation.

8.5 Residual flood risk

The recommended flood risk reduction solutions will reduce the impact and extent of future flood-related damage. However, it's important to recognize that while we can reduce the risk and impact of flooding and prepare for these events, we can almost never eliminate the risk of flooding. There will always be a residual risk, which is risk that could not economically be addressed or risk that was never targeted. For example, mitigating risk for a structure for only a 1 percent (100-year) annual chance flood event could mean that the same structure remains exposed to the risk of a 0.2 percent (500-year) annual chance flood event.

Flood risk reduction solutions must be designed for certain storm frequencies. Protecting against larger (and less frequent) storm events is more expensive, and a balance must be found between seeking protection from larger storm events and the available resources to do so. If a storm event occurs that is larger than the designed flood control infrastructure, flooding is inevitable and understanding that residual risk is extremely important. This is the nature of probabilistic risk and the impossibility of mitigating against less likely events.[44]

Predicting the exact nature, scale, and frequency of floods is inherently uncertain. Natural events can be more extreme than historical records indicate or than models predict. Even the most robust flood mitigation projects may be insufficient to handle unprecedented flood events. Flood risk reduction solutions are often engineered to address, manage or protect against certain design storm events or floods. These storm events, such as the 1 percent (100 year) annual chance storm event, are determined based on historical rainfall data. The relatively short period of record for some rainfall and stream gauges results in additional statistical uncertainty when estimating the larger and less frequent events. Additionally, while flood risk reduction solutions may be engineered based on historical data, a variable climate can alter flood patterns over time, leading to unexpected scenarios that might not have been accounted for during the initial solution design.

Common sources of residual flood risk are associated with flood events that exceed the design capacity of a levee, dam, or drainage system, as opposed to those resulting from actual structural failure. In these cases, the flood mitigation infrastructure itself, for example a levee built to protect against riverine flooding, can pose a new, residual risk—the unlikely hazard of catastrophic failure. While the new risk is less likely to occur than the risk it was built to protect against, the new risk poses a far greater threat if it occurs (e.g., sudden life-threatening flooding). Though quantifiable, residual risk often is presumed to be negligible or non-existent, creating a false sense of security for decision makers and the public. The National Levee Database identifies nearly two million Texans who are subject to residual flood risk associated with levees (USACE, n.d.). No available data exists for the residual risk associated with dams.

Unrecognized flood risk is effectively residual risk. Old and outdated flood hazard maps and flood risk information can create a false sense of safety and a perceived lack of flood risk in places with existing flood risk. Because flood risk maps represent the flood risk at the time the map was created, any land use, development, or mitigation changes that occur after the map is published are not accounted for. Further, the binary presentation of flood risk on Flood Insurance Rate Maps often conveys the false belief that areas outside the demarcated 1 percent (100-year) annual chance floodplain do not face flood risk.

Ultimately, while flood mitigation plans and projects can substantially decrease the risk of flood damage, a certain level of risk will always remain due to unpredictable factors and the challenges of accounting for future flood risks. This makes it imperative not only to design and proactively fund effective mitigation measures but also to incorporate adaptive strategies and proactive floodplain management to ensure new vulnerabilities are not inadvertently created.

[44]One way of determining the most economical level of mitigation is to consider the costs of various levels of mitigation versus the expected annual flood damage to the protected asset, which involves aggregating all potential damage to the asset from all flood event frequencies.

References

NIBS (National Institute of Building Sciences), National Institute of Building Sciences Issues Interim Report on the Value of Mitigation, 2019, www.nibs.org/news/national-institute-building-sciences-issues-interim-report-value-mitigation

USACE (United States Army Corps of Engineers), National Levee Database, n.d., https://levees.sec.usace.army.mil/#/

9 Cost and financing needs

Quick facts

The total estimated cost of the 3,097 recommended flood management evaluations is more than $2.63 billion, and the regional flood planning groups identified $71 million in available funding (may include local, state, or federal).

The total estimated cost of the 615 recommended flood mitigation projects is more than $49 billion, and the flood planning groups identified $10.5 billion in available funding (may include local, state, or federal).

The total estimated cost of the 897 recommended flood management strategies is more than $2.84 billion, and the planning groups identified $84 million in available funding (may include local, state, or federal).

The regional flood planning groups indicated that, overall, local sponsors of flood risk reduction solutions would require up to 80 to 90 percent in state and/or federal financial assistance to implement every recommended flood risk reduction solution included in this plan.

As part of the process of developing their plans, the regional flood planning groups were required to estimate the costs of their recommended flood risk reduction solutions. This included both the costs for studies required to quantify flood risk in locations where the risk remains unknown and to identify associated mitigation projects. They were also required to assess the associated financial needs of the sponsors who will be responsible for implementing the recommended flood mitigation solutions.

Identifying investments in flood risk mitigation is approached from a very different perspective than efforts to plan for water supply or roadway investments. Whereas the need for public investments in additional water and road infrastructure typically grows over time with a growing population, the same is not necessarily true for public investments in flood mitigation. One of the key goals of flood planning is to avoid increasing flood risks, and thus costs, in the future. In theory—aside from environmental changes that may increase future flood risk, like changes in rainfall or sea level rise (see Section 4.2)— if we reduce all current flood risks and, more importantly, avoid increasing or creating new risks through strong floodplain management practices, the need for future flood mitigation investment could potentially be eliminated or focused on further reducing the level of residual flood risk (see Section 8.5).

Much of the total cost estimate for flood mitigation in this plan represents an accumulation of various flood risks over a long period of time combined with a lack of recognition and/or a backlog in investments to address it. In a perfect world with strong floodplain management and a stable climate pattern, this cost would not grow significantly larger.

9.1 Costs of implementing the state flood plan

The regional flood plans identified statewide flood risks and estimated the magnitude of the cost of potential mitigation solutions needed to reduce the risk and impact of flooding in Texas. Even after the first cycle of regional flood planning, not all flood risk or flood risk reduction solutions could be identified. As flood management evaluations are funded and performed, additional flood mitigation projects will be identified. Those studies will, in turn, identify specific projects that can be implemented to reduce identified flood risk.

Aside from one-time costs for activities like studies, the estimated total **capital costs** of all flood risk reduction solutions recommended by the 15 regional flood planning groups in this plan amount to approximately $54.5 billion dollars. Note that approximately $24 billion of this cost is for the Galveston Bay Surge Protection Coastal Storm Risk Management projects, towards which the Texas Legislature allocated $265 million between 2022 and 2023 (GCPD, 2024). The U.S. Congress allocated $500,000 in the U.S. Army Corps of Engineers' work plan in May 2024 towards the Galveston Bay Surge Protection

Coastal Storm Risk Management projects. Capital costs are those costs for which projects sponsors typically would borrow funds and establish repayment through annual debt service.

9.2 Financial assistance required to implement the state flood plan

The flood planning groups were required to indicate how local governments, regional authorities, and other political subdivisions sponsoring efforts in their region propose to fund the region's flood plan recommendations. The planning groups administered a funding survey toward the end of the planning cycle to estimate the amount of state financial assistance that local or regional entities might require to implement the recommended flood risk solutions.

This effort required obtaining information from sponsors of the recommended flood management evaluations, flood mitigation projects, and flood management strategies, especially for projects with large capital costs. The resulting information was provided to the regional flood planning groups with an indication of potential funding needs required to implement the regional flood plans.

The survey response rate of project sponsors varied but was generally low, so some planning groups extrapolated the limited survey responses to all projects within their region. The range of financial assistance needs reported on individual projects varied from "100 percent other funding required" to "no funding assistance needed" (Table 9-1) Overall, the planning groups indicated that many local sponsors of flood risk reduction solutions may require 80-90 percent of the costs in financial assistance to implement projects (Figures 9-1, 9-2). This result is not surprising and generally in line with what the Texas Water Development Board (TWDB) learned when developing the 2019 State Flood Assessment.[45] Identified available funding included various bonds, ad valorem taxes, community development block grants, and drainage, permitting and stormwater fees. Funding sources are described in section 9.3.1.

[45] texasfloodassessment.org

Table 9-1. Estimated cost, reported available funding, and unmet need for all recommended flood risk reduction solutions as identified by the regional flood planning group*

	Flood management evaluations[a]			Flood mitigation projects			Flood management strategies		
Region	Estimated cost	Available funding	Unmet need	Estimated cost	Available funding	Unmet need	Estimated cost	Available funding	Unmet need
1	$89.0M	$24.5M	$64.5M	$121.0M	$34.4M	$86.6M	$13.4M	$175.0K	$13.2M
2	$37.9M	$0.0	$37.9M	$52.2M	$0.0K	$52.2M	$4.5M	$0.0	$4.5M
3	$220.6M	$24.9M	$195.6M	$703.5M	$70.3M	$633.1M	$745.4M	$81.2M	$664.2M
4	$81.3M	$0.0	$81.3M	$3.3B	$836.5M	$2.4B	$112.4M	$0.0	$112.4M
5	$88.9M	$12.5M	$76.4M	$4.3B	$1.0B	$3.3B	$175.0M	$0.0	$175.0M
6[b]	$905.4M	$2.3M	$903.0M	$31.7B	$8.5B	$23.2B	$1.2B	$2.4M	$1.2B
7	$84.3M	$1.0M	$83.3M	$48.8M	$15.5M	$33.3M	$13.2M	$0.0	$13.2M
8	$29.6M	$0.0	$29.6M	$4.3B	$0.0	$4.3B	$366.4M	$0.0	$366.4M
9	$73.0M	$440.0K	$72.5M	$184.7M	$1.5M	$183.2M	$7.6M	$0.0	$7.6M
10[c]	$62.2M	$0.0	$62.2M	$379.2M	$0.0	$379.2M	$0.0K	$0.0	$0.0K
11	$85.7M	$0.0	$85.7M	$394.2M	$0.0	$394.2M	$33.5M	$0.0	$33.5M
12	$349.4M	$0.0	$349.4M	$739.0M	$0.0	$739.0M	$999.0K	$0.0	$999.0K
13	$284.5M	$4.8M	$279.7M	$1.2B	$0.0	$1.2B	$20.3M	$0.0	$20.3M
14	$7.6M	$636.2K	$7.0M	$507.8M	$4.8M	$502.9M	$3.6M	$263.1K	$3.3M
15	$227.2M	$0.0	$227.2M	$1.1B	$0.0	$1.1B	$145.0M	$0.0	$145.0M
Total	**$2.6B**	**$71.2M**	**$2.6B**	**$49.1B**	**$10.5B**	**$38.6B**	**$2.8B**	**$84.1M**	**$2.8B**

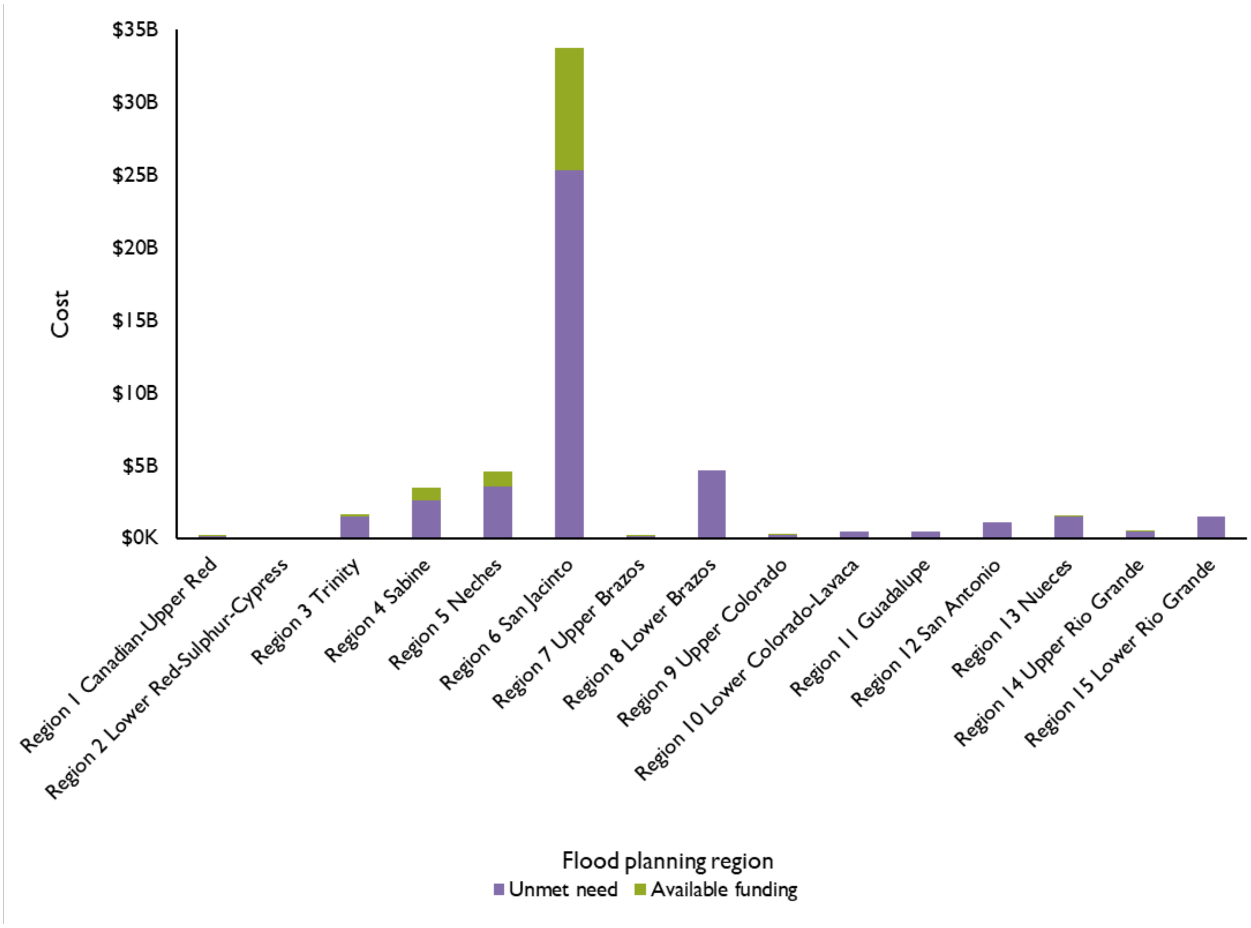
[*] Zero or low available reported funding may be partially due to lack of survey responses

[a] For flood management evaluations, estimated cost includes only the non-construction costs. However, for some flood management evaluations in regions 1, 5, 7 and 9, available funding includes the local sponsor share for the total of non-construction and construction costs.

[b] Value includes the Region 6 San Jacinto-recommended Galveston Bay Surge Protection Coastal Storm Risk Management project with an estimated cost of $24B

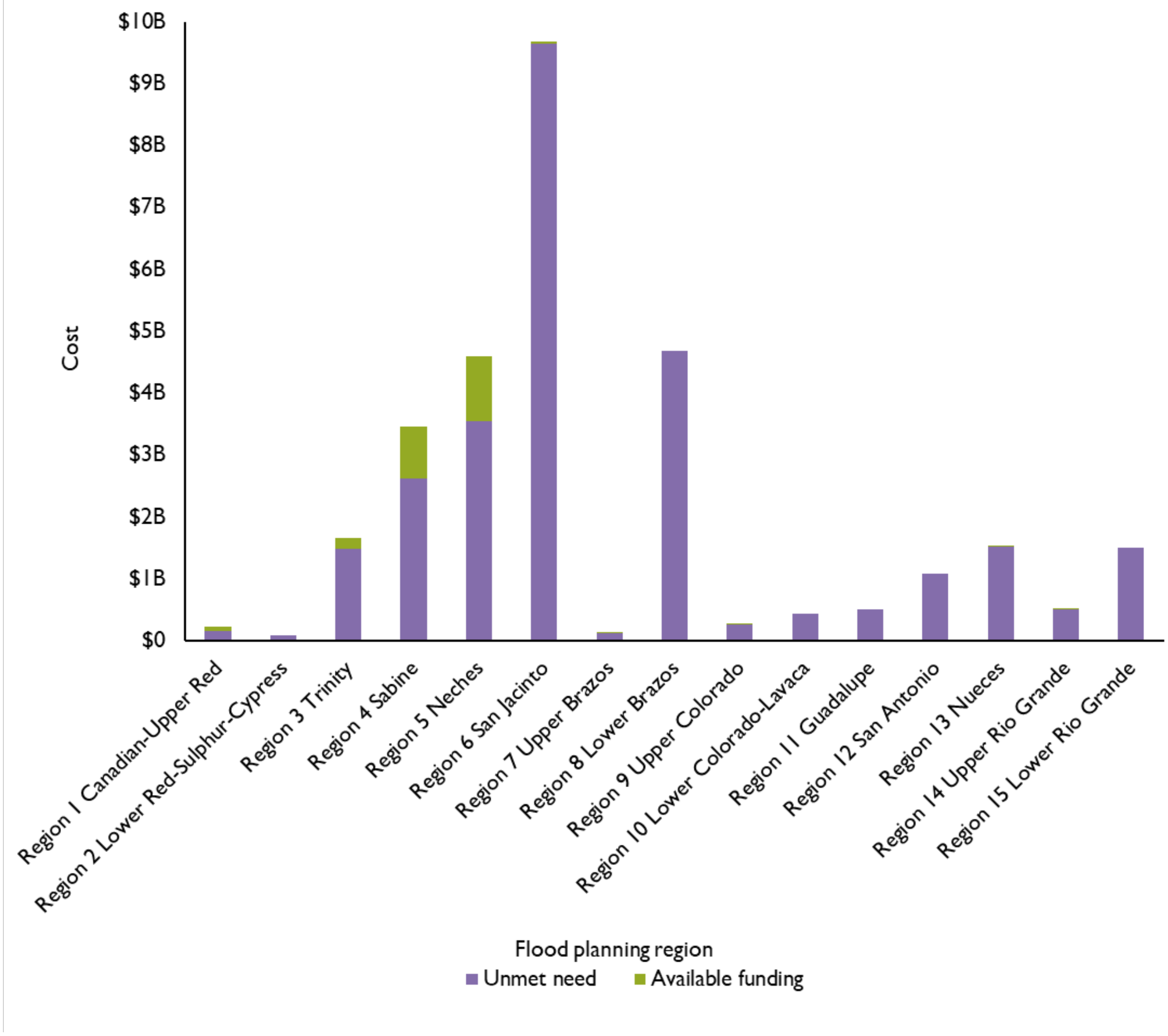
[c] Region 10 did not include cost information for its recommended flood management strategies

Figure 9-1. Available funding versus unmet need for recommended flood risk reduction solutions by region*



** Figure includes information on the Region 6 San Jacinto-recommended Galveston Bay Surge Protection Coastal Storm Risk Management project, with an estimated cost of $24B*

Figure 9-2. Available local funding versus unmet need for recommended flood risk reduction solutions by region*



* *Figure excludes information on the Region 6 San Jacinto-recommended Galveston Bay Surge Protection Coastal Storm Risk Management project, with an estimated cost of $24B*

9.3 Financing the state flood plan and other flood-related projects

Financing public projects generally involves the expenditure or borrowing of funds through loans or the sale of bonds, for example, that must be repaid by the sponsoring entity. The ability to raise funds for flood projects, including debt repayment, is an ongoing challenge for many public entities and is at least partially responsible for what might be considered a significant backlog of flood mitigation studies and project implementation.

The financial assistance programs summarized in this chapter are categorized as state or federal based on the original source of funds. Some federal programs are administered at the state level and may include a state contribution. Appendix C contains a list of key federal and state funding sources.

9.3.1 Common local sources for funding flood mitigation

Flood infrastructure is often difficult to fund locally and, in many cases, may be under-funded at least partly because, unlike water supply projects, drainage and flood mitigation projects do not generate revenue. Local and regional governments often need multiple public and private funding sources to finance expensive projects and support wider implementation of flood mitigation, including projects and floodplain management strategies.

Common sources of local funds used to pay for flood activities, including debt repayments, vary by entity and may include the following:

General funds: General fund revenue is largely from property, sales, and other taxes, which provides a substantial amount of funding for all municipal programs but often limited portions for drainage maintenance and flood mitigation.

Stormwater utility fees: Over the past several decades, the stormwater utility model has increasingly been used as a tool to raise local funding for stormwater management in Texas and across the United States. Creation of a stormwater utility allows a municipality to have a dedicated revenue stream for stormwater management that is directly based on how much a property contributes to stormwater runoff.

Transportation fees: While transportation fees are focused on maintaining the transportation system, many drainage systems are often contained within the transportation right of way, such as roadside ditches, inlets, and storm sewer systems. Costs associated with maintenance and upgrades of the drainage systems in the right of way are often part of the overall transportation system budgets.

Bonds: Communities typically use stormwater revenue bonds or general obligation bonds for this type of funding. Bonds can fund various flood mitigation activities, such as regional detention systems, waterway improvements, home buyouts, upgraded early warning systems, and infrastructure repairs.

Ad valorem taxes and permitting or impact fees: Though less frequently a source of funding, ad valorem taxes, impact fees, or permitting fees may be used to fund flood mitigation activities. For example, communities can fund their floodplain management program through floodplain development permitting fees. Impact fees are sometimes assessed as a one-time payment for new developments to offset their anticipated impact on the community. Another program is a fee-in-lieu system in which developers pay a fee to the community rather than building a site-specific stormwater mitigation project within their development. The accumulated fees may be saved on a watershed or community-wide basis for larger, regional stormwater mitigation projects.

Special tax districts: Special tax districts are sometimes used to tax only the portion of the population that will benefit from a specific project. However, only a few communities in Texas have implemented such tax districts for flood mitigation.

Private sector funding: With limited funding sources, communities may seek funding from the private sector to make flood mitigation projects possible. This could include donation of land, resources, and services or funding a portion of the mitigation activity through mechanisms like development agreements and public-private partnerships.

9.3.2 TWDB financial assistance

Through its state and federally supported financial assistance programs, the TWDB provides financial assistance for eligible water-related projects, including components of water supply, wastewater (sewage) conveyance and treatment, flood control, and agricultural water conservation. Prior to the creation of the state's Flood Infrastructure Fund program in 2019, the TWDB's ability to finance flood mitigation activities was very limited.

In addition to its administration of the Flood Infrastructure Fund, the TWDB facilitates the Flood Information Clearinghouse Committee,[46] which is an ongoing multi-agency effort to maximize the effective utilization of public funding resources and help communities identify the funding source(s) they would like to pursue for a given project. The TWDB works collaboratively with the Texas General Land Office, Texas Division of Emergency Management, and other state agencies to assist communities in determining which of the available funding sources for flood-related projects is the best fit for them.

Flood Infrastructure Fund

The 86th Texas Legislature passed several bills entrusting the TWDB with new responsibilities related to funding flood mitigation projects and planning for future flood events. On November 5, 2019, Texas voters approved Proposition 8, a constitutional amendment providing for the creation of the Flood Infrastructure Fund to assist with financing drainage, flood mitigation, and flood control projects, including

- planning and design activities;
- work to obtain necessary regulatory approvals; and
- construction and/or implementation of flood projects.

In accordance with statute, only recommended flood management evaluations, flood management strategies, and flood mitigation projects included in this state flood plan, including future amendments, are eligible for funding from the Flood Infrastructure Fund once the state flood plan has been adopted.[47] Prior to adopting this first state flood plan, the TWDB had already committed approximately $643 million to 140 projects through the first cycle of the Flood Infrastructure Fund.

In 2023, the 88th Texas Legislature appropriated an additional $625 million in funding that will go towards new Flood Infrastructure Fund projects under the 2024–2025 Flood Infrastructure Fund Intended Use Plan.

The Flood Infrastructure Fund provides financial assistance through loans and grants for a wide variety of flood-related projects by eligible applicants, including cities, counties, and any district or authority created under Article III, Section 52, or Article XVI, Section 59, of the Texas Constitution,[48] Flood Infrastructure Fund program funding is allocated using an application and multi-factor prioritization process that determines the projects to receive funding and the relative grant allocation each project may be eligible to receive.

Flood Infrastructure Fund statutes, rules, and the intended use plan allow for a wide range of eligible flood projects, including structural and non-structural projects as well as nature-based solutions.

Other TWDB state-funded programs

Texas Water Development Fund

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[46] www.texasfloodclearinghouse.org/

[47] Texas Water Code § 15.534(c)

[48] Specific to Flood Infrastructure Fund Category 1, "Flood Protection Planning for Watersheds" only, eligible political subdivision applicants include a city, county, district, or authority 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

The Texas Water Development Fund has funding available through the agency's existing $6 billion **evergreen general obligation bonding** authority. Financial assistance for flood control may include structural and non-structural flood protection improvements. Since 2013, approximately $9 million has been distributed to projects with flood-related components through the Texas Water Development Fund program.

TWDB federally funded programs

State Revolving Funds

The TWDB administers the Clean Water State Revolving Fund and Drinking Water State Revolving Fund, programs that were established to provide low-cost financing for wastewater and water infrastructure projects. The Clean Water State Revolving Fund can fund flood-related (pre-disaster) mitigation projects, but applicants must compete with wastewater projects. The TWDB has also allocated funds in the Clean Water and Drinking Water state revolving funds since 2017 to provide post-disaster funding options to communities for projects related to water supply, wastewater, or stormwater management facilities with urgent need situations. Since 2013, approximately $138.7 million of funding has been distributed to projects with flood-related components through the Clean Water State Revolving Fund and approximately $72.8 million through the Drinking Water State Revolving Fund.

Flood Mitigation Assistance

The Flood Mitigation Assistance grant program under FEMA provides annual federal funding to help states and communities pay for cost-effective ways to reduce or eliminate the long-term risk of flood damage to repetitive loss and severe repetitive loss structures that are insured under the National Flood Insurance Program. The TWDB administers the Flood Mitigation Assistance grant program for the State of Texas on behalf of FEMA. Since 2015, the program has provided more than $526.1 million of total funding benefitting 129,000structures.[49]

Goals of the Flood Mitigation Assistance program include reducing or eliminating:

- repeated claims under the NFIP; and
- the dependence on taxpayer-funded federal disaster assistance for disaster recovery.

The Flood Mitigation Assistance program is a nationally competitive grant program with an annual application cycle. FEMA announces the opening of each application cycle with the issuance of a "Notice of Funding Opportunity" on grants.gov. Eligible cities, counties, special districts, and other political subdivisions develop an application (referred to as a sub-application) on behalf of the entity and its citizens for submission to the TWDB through the FEMA GO grant system. Property owners cannot apply directly to the TWDB or FEMA for a Flood Mitigation Assistance grant. Interested property owners may contact their local floodplain official or other area representatives to find out about their community's interest in applying for a Flood Mitigation Assistance grant.

9.4 Other flood mitigation funding opportunities

Historically, federal grant programs related to floodplain management, planning, mitigation, and mapping activities typically offer greater financial assistance than what is available at the local or state level. Some federal programs are not tied to a specific disaster and are open annually as the U.S. Congress authorizes funding. Texas competes with other states for funds from programs such as Cooperating Technical Partners, Flood Mitigation Assistance, and Building Resilient Infrastructure and Communities. In some cases, flood-related projects also compete with other types of non-flood-related projects, such

[49] https://www.twdb.texas.gov/financial/programs/FMA/index.asp

as wildfire management, earthquake preparedness, and backup power generation. Other funding programs are tied to specific declared disasters (e.g., Hurricane Harvey), such as the Hazard Mitigation Grant Program and the Community Development Block Grant – Disaster Recovery program.

The following list includes examples of other state and federal flood funding programs, but it is not an exhaustive list of potential state and federal funding sources for flood mitigation. There are many other programs that focus on different areas of need in communities, such as transportation, research, or public education, but the funding may also support activities associated with flood mitigation. Additional references to seek more information on potential funding sources include the Texas Flood Information Clearinghouse,[50] American Flood Coalition,[51] and the Texas General Land Office's MATCH Tool[52] that is currently under development.

Building Resilient Infrastructure and Communities - Administered by the Texas Division of Emergency Management, the Building Resilient Infrastructure and Communities program supports states, local communities, tribes, and territories as they undertake hazard mitigation projects reducing the risks of disasters and natural hazards. Building Resilient Infrastructure and Communities is a FEMA pre-disaster hazard mitigation grant program that replaced the Pre-Disaster Mitigation program.

Community Development Block Grant (Disaster Recovery) - Administered by the Texas General Land Office, Community Development Block Grant - Disaster Recovery funds are used to address unmet recovery needs that contribute to the long-term recovery and restoration of housing as well as the repair and enhancements of local infrastructure.

Community Development Block Grants (Mitigation) - The Texas General Land Office is administering more than $4 billion in U.S. Department of Housing and Urban Development Community Development Block Grants – Mitigation funding for areas of the state impacted by Hurricane Harvey and the 2015, 2016, and 2018 flood events. The funding is being used to build and implement structural and non-structural projects, programs, and partnerships throughout Texas that reduce the risks and impacts of future natural disasters.

Community Development Block Grant program for rural Texas - The Texas Community Development Block Grant program, administered by the Texas Department of Agriculture, provides grants for community planning and small infrastructure projects, including water, wastewater, stormwater, and street infrastructure.

Corps Water Infrastructure Financing Program - The U.S. Army Corps of Engineers' Corps Water Infrastructure Financing Program is authorized by the Water Infrastructure Finance and Innovation Act to provide long-term, low-cost loans for non-federal dam safety projects to maintain, upgrade, remove, and repair dam) identified in the National Inventory of Dams. Projects must be creditworthy, technically sound, economically justified, and environmentally acceptable. To be eligible for a Corps Water Infrastructure Financing Program loan, project costs must be a minimum of $20 million; however, numerous small projects may be bundled together to meet the minimum.

Emergency Watershed Protection Program - The U.S. Department of Agriculture's Natural Resources Conservation Service administers the Emergency Watershed Protection Program, a federal emergency recovery program that responds to emergencies created by natural disasters. The program offers technical and financial assistance to help communities alleviate imminent threats to life and

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[50] www.texasfloodclearinghouse.org/

[51] www.floodcoalition.org/fundingfinder/#home

[52] www.match-tool-hub-dewberry.hub.arcgis.com/

property caused by floods, fires, windstorms, and other natural disasters that impair a watershed. The Emergency Watershed Protection Program does not require a disaster declaration by federal or state government officials for program assistance to begin. The Natural Resources Conservation Service state conservationist can declare a local watershed emergency and initiate Emergency Watershed Protection Program assistance in cooperation with an eligible sponsor.

Flood control dam infrastructure projects (supplemental funding) - The 86th Texas Legislature appropriated funding to the Texas State Soil and Water Conservation Board to repair and rehabilitate flood control structures through grants to local sponsors of flood control dams, including soil and water conservation districts.

Hazard Mitigation Grant Program - Following a presidential disaster declaration, the FEMA Hazard Mitigation Grant Program, administered by the Texas Division of Emergency Management, provides disaster response and recovery assistance to prevent or reduce future loss of lives and property through identifying and funding cost-effective mitigation measures and to minimize the costs of future disaster response and recovery. All applicants must have a FEMA-approved Hazard Mitigation Plan at the time the project is submitted to FEMA, with the exception of planning projects.

Public Assistance Program - FEMA's Public Assistance Program provides grants to state, territorial, local, and federally recognized tribal governments and certain private non-profit entities to assist with responding to and recovering from disasters. Specifically, the program provides assistance for debris removal, emergency protective measures, and permanent repair, restoration, reconstruction, or replacement of eligible public facilities and infrastructure damaged or destroyed in a disaster.

Rehabilitation of High Hazard Potential Dam Grant Program - FEMA's Rehabilitation of High Hazard Potential Dam Grant Program, administered by the Texas Commission on Environmental Quality, provides technical, planning, design, and construction assistance in the form of grants for rehabilitation of eligible high hazard potential dams.

Structural Dam Repair Grant Program - Administered by the Texas State Soil and Water Conservation Board, the program provides state grant funds for 100 percent of the cost of allowable repair activities on dams constructed by the U.S. Department of Agriculture - Natural Resources Conservation Service, including match funding for federal projects through the National Dam Rehabilitation Program, administered by FEMA, and the Emergency Watershed Protection Program of the Texas Natural Resources Conservation Service.

Watershed Protection and Flood Prevention Operations Program - The U.S. Department of Agriculture's Natural Resources Conservation Service administers the Watershed Protection and Flood Prevention Operations Program, which helps projects sponsors from federal, state, local, and federally recognized tribal governments protect and restore watersheds. The program provides technical and financial assistance to states, local governments, and tribal organizations to help plan and implement authorized watershed projects for the purpose of flood prevention, watershed protection, public recreation, public fish and wildlife, agricultural water management, municipal and industrial water supply, and water quality management.

Watershed Rehabilitation Program - The U.S. Department of Agriculture's Natural Resources Conservation Service administers the Watershed Rehabilitation Program, which helps project sponsors rehabilitate aging dams that are reaching the end of their design life and/or no longer meet federal or state safety criteria or performance standards. Since 1948, the Natural Resources Conservation Service has assisted local sponsors in constructing more than 11,850 dams. These rehabilitation efforts, authorized by Public Law 83-566 and 78-534, address critical public health and safety concerns should a dam failure occur.

References

GCPD (Gulf Coast Protection District), 2024, Personal communication

TWDB (Texas Water Development Board), 2019, State Flood Assessment: Report to the 86th Texas Legislature, www.twdb.texas.gov/publications/reports/special_legislative_reports/doc/State-Flood-Assessment-report-86th-Legislation.pdf

10 Ongoing efforts, challenges, and looking ahead

Since Hurricane Harvey in 2017, Texas has greatly increased resources for flood planning and mitigation, resulting in significant and much-needed efforts by a wide variety of parties. It has been imperative for agencies and others to coordinate and collaborate during this flood planning process, and many state and federal agencies have successfully engaged to advance flood mitigation efforts that either directly or indirectly relate to this planning effort. This inaugural state flood planning cycle taught many lessons and laid the groundwork for future planning.

10.1 Ongoing flood efforts

In flood management, multiple local, state, and federal entities play important roles in developing and implementing flood mitigation strategies across the state.

10.1.1 Flood mapping, financing, and research efforts

Base level engineering[53]

Passed during the 86th Legislature in 2019, Senate Bill 500[54] allocated funds to the Texas Water Development Board (TWDB) to develop and update Texas flood risk maps using best available data and technology standards, supporting the creation of the state flood plan.[55] As such, the TWDB's efforts involve improving statewide flood modeling and mapping, conducting flood research activities, and utilizing a combination of available and future condition datasets.

One available dataset is base level engineering, a flood hazard mapping approach that provides credible flood hazard data at various geographic scales, complementing existing Flood Insurance Rate Map data and serving as the primary source for areas without flood mapping information. Base level engineering flood map data is not inherently a regulatory product but rather an advisory data set, unless local jurisdictions choose to adopt it as a regulatory map or require its use as “best available” data. New efforts were initiated by FEMA in 2023 to begin converting base level engineering products into Flood Insurance Rate Maps. Progress in Texas is shown online.[56]

Community Assistance Program

The Community Assistance Program administered by the TWDB provides floodplain management support to communities. This includes coordinating and providing statewide training and education, consistent outreach through various avenues, and providing on-call technical support. The Community Assistance Program team is partially funded by FEMA’s Community Assistance Program – State Support Services Element grant program, which seeks to ensure National Flood Insurance Program flood loss reduction goals are met, build state and community floodplain management capabilities, and leverage state expertise in working with communities. The TWDB’s Community Assistance Program also provides disaster recovery support to communities in the days and months following disasters to support substantial damage assessments and floodplain permitting activities, as well as floodplain management expertise and support to statewide flood planning activities and to other state agencies.

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[53] www.twdb.texas.gov/flood/science/ble.asp

[54] capitol.texas.gov/billlookup/text.aspx?LegSess=86R&Bill=SB500

[55] www.twdb.texas.gov/flood/science/ble-status.asp

[56] www.femar6.github.io/ble_firm/

FEMA flood assistance grants

The Flood Mitigation Assistance grant program, administered by the TWDB[57] on behalf of FEMA, offers federal funding to states and communities for cost-effective measures that reduce or eliminate flood risks to structures insured under the National Flood Insurance Program. The program aims to minimize repeated National Flood Insurance Program claims and reduce reliance on federal disaster assistance. It follows an annual application cycle, and eligible cities, counties, and special districts submit applications on behalf of citizens.

Flood Funding Information Clearinghouse[58]

The TWDB collaborates with the Texas General Land Office and Texas Division of Emergency Management to guide communities in identifying the most suitable funding sources for their flood-related projects. The ongoing multi-agency initiative known as the Flood Information Clearinghouse Committee aims to optimize the utilization of public funding resources and help communities determine their preferred funding source.

Flood Infrastructure Fund

The TWDB's Flood Infrastructure Fund program[59] was passed by the legislature and approved by Texas voters through a constitutional amendment in 2019. The program offers financial support through loans and grants for a range of flood studies and mitigation projects. Flood intended use plans outline the structure of each associated funding cycle. Only flood risk reduction solutions (flood management evaluations, flood mitigation projects, and flood management strategies) recommended in the state flood plan will be eligible for funding consideration through the Flood Infrastructure Fund.

Modeling and mapping program[60]

The TWDB operates a state flood mapping program to provide reliable flood data for informed decision-making at state, regional, and local levels. Following Senate Bill 500 in 2019, the TWDB formed the Flood Science and Community Assistance Division, which includes the Flood Modeling and Flood Mapping departments responsible for delivering statewide base level engineering mapping and providing technical support for other flood-related programs.

At the federal level, the TWDB serves as the state Cooperating Technical Partner for FEMA's Cooperating Technical Partners program. This program promotes local involvement in developing and updating Flood Insurance Rate Maps and associated geospatial data. The TWDB also supports FEMA's Risk Mapping, Assessment, and Planning program.

10.1.2 Other coordination, studies, and efforts

Army Corps of Engineers

The U.S. Army Corps of Engineers collaborates extensively with local, state, and federal entities in Texas through its Albuquerque, New Mexico; Fort Worth; Galveston, and Tulsa, Oklahoma, districts, including on vital missions such as flood risk management and emergency operations. The U.S. Army Corps of Engineers oversees 32 multi-purpose dams and was integral during major flood events like Hurricane

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[57] www.twdb.texas.gov/financial/programs/FMA/index.asp

[58] www.texasfloodclearinghouse.org/

[59] www.twdb.texas.gov/financial/programs/FIF/index.asp

[60] www.twdb.texas.gov/flood/science/programs.asp

Harvey by producing real-time flood maps and managing significant levee systems, including the historic Fort Worth and Dallas Floodways.

Simultaneously, the U.S. Army Corps of Engineers is developing coastal flood resilience initiatives and refining flood resiliency tools. A prime example of its collaborative efforts is the partnership with entities like the Texas General Land Office and the U.S. Geologic Survey on the Texas Integrated Flooding Framework Project.

National Weather Service

The National Weather Service, a component of the National Oceanic and Atmospheric Administration, provides vital weather, water, and climate data, forecasts, and impact-based decision support services to safeguard life and property and bolster the national economy. The National Weather Service operates through a vast infrastructure comprising nine national centers and 122 field offices that offer broad weather, water, and climate insights. The organization encompasses the National Water Center and 13 River Forecast Centers that execute hydrologic forecasting and development, including approximately 3,600 forecasts nationwide. This forecasting aids local National Weather Service meteorologists in issuing flood alerts and providing support for decision-makers such as emergency managers and first responders. For these reasons, the National Weather Service is persistently enhancing its offerings, notably real-time flood inundation mapping for improved flood forecast communication and a commitment to advance water research through the Cooperative Institute for Research to Operations in Hydrology, supporting the National Oceanic and Atmospheric Administration's vision for a weather-ready nation.

Texas Department of Agriculture

The Texas Department of Agriculture plays a supportive role in flood risk reduction. Staff actively participate as non-voting members in all 15 flood planning groups, ensuring alignment with broader agricultural concerns. The Texas Department of Agriculture is affiliated with various committees and councils, such as the Texas Water Conservation Advisory Committee and the Galveston Bay Council, which indirectly address flood matters. In emergency scenarios, the Texas Department of Agriculture collaborates with Texas AgriLife on water contamination issues and joins forces with the Texas Animal Health Commission during livestock-related flood crises. One ongoing initiative involves partnering with the Texas Agricultural Council and the U.S. Department of Agriculture to implement best practices addressing water-related challenges, including floods.

Texas Commission on Environmental Quality

The Texas Commission on Environmental Quality Dam Safety Program oversees private and public dams, focusing on those with high or significant hazard potential. The agency inspects these dams and offers safety recommendations to owners. Twice per year, the Texas Commission on Environmental Quality shares a list of dams, detailing their condition and Emergency Action Plan status, with local emergency management and councils of government officials. Furthermore, the agency requires that dam operators with gated spillways must notify local emergency operation centers when releasing floodwaters, ensuring downstream communities are informed and can alert the public to potential flood risks. TWDB staff coordinated with the Texas Commission on Environmental Quality regarding a state flood plan legislative recommendation. Agency staff also participate in each of the 15 regional flood planning groups as non-voting members.

Texas Division of Emergency Management

The Texas Division of Emergency Management is responsible for maintaining and updating the State Hazard Mitigation Plan. The State Hazard Mitigation Plan enables the state to identify natural hazards, identify actions and activities to which will reduce losses from those hazards, and establish a coordinated process to implement the plan using a wide range of resources. The State Hazard Mitigation Plan serves as the foundation for all other plans and planning processes in the state to integrate resilience and long-term risk reduction, as well as guiding guides decision-makers to reduce the effects of natural hazards as resources are committed. The Texas Division of Emergency Management routinely works closely with the TWDB to synchronize projects and funding across the multiple grant sources available for mitigation activities. The Texas Division of Emergency Management also supports jurisdictions during the creation of their local hazard mitigation plans, including serving as the liaison between jurisdictions and FEMA and providing grant funding for local plan creation. Agency staff also participate in each of the 15 regional flood planning groups as non-voting members.

TexasFlood.org

After what became known as the 2015 Memorial Day Flood in South and Central Texas, authorities identified a need for accessible flood preparation resources for the public. Many available tools were tailored for experts, but information specifically geared to the public was scattered across multiple platforms with inconsistent messaging. To address this, the TWDB launched TexasFlood.org, initially a consolidated webpage on the TWDB site. Recognizing the need for more comprehensive resources, a standalone TexasFlood.org website was released in August 2021 in collaboration with other Texas agencies. The site now offers essential flood risk and emergency preparation information in a user-friendly format to serve Texans in their flood awareness and preparation endeavors.

Texas General Land Office

The Texas General Land Office's Community Development and Revitalization Division initiated the Combined River Basin Flood Studies in response to recent extreme weather events and their devastating flooding impacts. The Combined River Basin Flood Studies is a one-time planning effort divided into four regions covering counties affected by Hurricane Harvey and flooding in the Lower Rio Grande Valley. It aims to evaluate flood risks, empower Texans with flood risk information, develop cost-effective mitigation strategies, determine funding sources for future projects, and engage stakeholders. The strategic framework includes stakeholder engagement, data collection, risk analysis, alternatives analysis, and funding/technical assistance, with a focus on collecting accurate data to inform modeling and funding efforts. The data produced will support Texas' regional and state flood planning efforts and inform the Texas Disaster Information System for disaster recovery and mitigation planning at the community level. General Land Office staff also participate in each of the 15 regional flood planning groups as non-voting members.

Texas Integrated Flooding Framework Planning Project

The Texas Integrated Flooding Framework Planning Project,[61] funded by the Texas General Land Office, is a collaborative effort led by the TWDB, U.S. Army Corps of Engineers, and U.S. Geological Survey. The project aims to develop guidelines and processes for implementing an integrated framework to model, visualize, and plan for the risk of compound flooding in coastal regions. By enhancing data collection, modeling capabilities, and coordination among agencies, the Texas Integrated Flooding Framework will enable more effective planning and long-term resilience strategies to mitigate the impacts of coastal flooding in Texas (USGS, n.d.a).

Texas Parks and Wildlife Department

The Texas Parks and Wildlife Department plays a collaborative role in regional flood planning. Staff from the Wildlife, Inland Fisheries, and Coastal Fisheries divisions participate as non-voting members on each

[61] https://www.texasflood.org/tools-library/tiff/index.html

regional flood planning group and advise on potential impacts to wildlife and fish to ensure that the needs of these species are considered.

Additionally, the Texas Parks and Wildlife Department encourages voluntary conservation through programs like the Landowner Incentive Program and the Watershed Conservation Team. The agency also has regulatory responsibilities, necessitating coordination or permitting for flood projects that could impact public waters, aquatic life, or involve nuisance plant management. Key regulatory programs include the Kills and Spills Team; the Marl, Sand, Gravel, Shell Permit Program; and the Ecological and Environmental Planning Program, which reviews and advises on a range of flood-related projects.

Texas State Soil and Water Conservation Board

The Texas State Soil and Water Conservation Board[62] oversees a robust flood mitigation program aimed at managing floodwaters through the construction of more than 2,000 floodwater-retarding structures or dams in Texas. These earthen dams, built with the assistance of the U.S. Department of Agriculture's Natural Resources Conservation Service, reduce floodwater velocity, and protect lives and property. With an increasing need for maintenance and rehabilitation due to aging infrastructure and rapid urbanization, the Texas State Soil and Water Conservation Board administers grants to soil and water conservation districts and other local sponsors (local units of government) for operation, maintenance, and structural repairs to ensure the safety and effectiveness of these vital flood mitigation structures. Agency staff also participate in each of the 15 regional flood planning groups as non-voting members.

United States Geological Survey

The U.S. Geological Survey developed the Flood Decision Support Toolbox[63] in collaboration with the federal Interagency Flood Risk Management team, consisting of the U.S. Geological Survey, FEMA, U.S. Army Corps of Engineers, and National Weather Service. The toolbox is a comprehensive resource that utilizes digital geospatial flood inundation mapping to assist in making informed decisions regarding flood risk management. It encompasses various tools and functionalities aimed at enhancing flood preparedness, communication, warning systems, response strategies, and mitigation efforts, enabling officials to assess and prioritize flood-related actions (USGS, n.d. b).

10.2 Challenges

During the inaugural cycle of regional flood planning, several challenges emerged which highlighted opportunities for focus and growth in subsequent planning cycles. The most prominent challenges identified include

- uncertainties surrounding predicting future flood risks;
- engaging rural areas and evaluating their flood risk;
- difficulty integrating nature-based solutions into flood risk reduction solutions;
- obtaining information regarding the condition of major flood infrastructure;
- challenges associated with computing benefit-cost ratios; and, at times,
- limited community/public engagement and participation.

Feedback from the planning groups was instrumental in our understanding of the first planning cycle and, together with the TWDB's own experiences and observations, informed preparations for the second planning cycle, as described in this section. The Texas Legislature's charge to develop the first state

[62] www.tsswcb.texas.gov/programs/flood-control-program

[63] www.webapps.usgs.gov/infrm/fdst/?region=tx

flood plan within three years was an immense challenge. Embracing the lessons learned, the TWDB recognizes that each challenge presents an opportunity for growth, innovation, and improvement in the evolution of Texas' flood planning process.

10.2.1 Uncertainty associated with future flood risk

To help guide development of their flood plans, it was important that the regional planning groups also look ahead to consider future flood risks. Accordingly, (see Chapter 4) the regional flood planning groups were required to perform flood risk analyses looking 30 years into the future, which included

1) determining the location, magnitude, and frequency of flooding;
2) identifying who and what might be harmed within the region; and
3) identifying vulnerabilities of communities and critical facilities.

Forecasting future flood risk under any circumstances is difficult due to variables like weather patterns, topography (e.g., subsidence), sea level rise, land use changes, and human activities. Flood data primarily relies on historical records and assumptions about future scenarios, potentially not accounting for a shifting climate. Accurate flood risk predictions depend on models using these assumptions under varied conditions. However, uncertainty prevails, as assumptions may not always align with actual future events, like extreme weather or demographic shifts, affecting the precision of flood risk forecasts (Meresa and others, 2021).

For regional flood groups that lacked detailed flood risk information for *existing* conditions, their efforts to forecast *future* flood risk were especially challenging, despite several alternative approaches that were offered for their use.

To improve the overall quality of future condition flood risk analyses, ensure more consistent statewide consideration of future flood risk, and reduce the effort and cost required to do so, the TWDB funded a project to develop and provide regional flood planning groups with a comprehensive statewide future condition flood hazard dataset for the year 2060. This dataset will consider probable land use changes, future climate, sea level rise, and land subsidence. Like the existing flood risk data provided to the planning groups by the TWDB during the first planning cycle, the future condition flood risk data will include complete, but approximate, flood risk coverage for Texas developed from nationwide 2D hydrodynamic modeling. Although this data will be considered approximate, it will be available to the flood planning groups for their use during the second cycle of regional flood planning and the 2029 regional flood plans.

10.2.2 Small, remote, and rural communities

The definition of "smaller communities" utilized by the planning groups included factors like low population, rural jurisdictions, socioeconomic disadvantages, or areas of persistent poverty. Each planning group used the definition it considered most appropriate for its region yet still identified several significant challenges in striving to involve small, remote, and rural communities in the flood planning process.

First, these communities often face barriers to engaging in basic floodplain management and flood risk mitigation. Due to limited funding, a lack of revenue streams, and stiff competition for state and federal support, many started the planning cycle with less flood risk information. Secondly, the planning groups grappled with accurately identifying flood risk and mitigation strategies for these communities due to outdated or absent models, data gaps, and limited local resources. Finally, there was relatively low engagement in the regional flood planning process, which was not entirely surprising due to their limited resources, and this required significant outreach efforts by the flood planning groups.

The planning groups were challenged with finding current flood risk information like hazard mapping or flood modeling for smaller, remote areas within their regions. Across many rural areas, the planning groups identified large gaps in current flood data, which made identifying or describing flood risk difficult in the regional plans. Even with the flood data quilt provided by the TWDB, many regions had to extrapolate their flood risk based on limited data and models that inaccurately reflect their risks.

Many communities in smaller, resource limited, or rural areas do not have any dedicated or regular funding sources for stormwater infrastructure or floodplain management activities. For example, more sparsely populated regions or those where the majority population has a household income below the state median often face an uphill battle to identify their needs and obtain resources to do so. There may also be limited knowledge of funding sources and/or a lack of expertise or resources to apply for available state and federal funding programs. Unlike other infrastructure types, flood projects typically do not generate revenue, making flood mitigation even more difficult for these resource-limited communities. Even communities able to apply for state and federal funding do so in an extremely competitive environment.

As a result, and even within the new regional flood planning process, many planning groups considered the detailed requirements difficult for smaller, rural communities to elevate a flood management study to a flood mitigation project or constructable infrastructure.

Accordingly, 14 of the 15 flood planning groups recommended some form of directed assistance towards smaller communities for floodplain management (see Chapter 2 policy recommendations). Engaging and supporting rural entities will likely require a sustained and resourced effort to assist these communities in addressing their unique flood risks.

10.2.3 Integrating nature-based solutions

Nature-based solutions are included in 14 of the 15 regional flood plans. Nature-based solutions are sustainable planning, design, environmental management and engineering practices that weave natural features or processes into the built environment to promote adaptation and resilience (FEMA, 2021). Some examples of nature-based solutions with flood risk reduction benefits include floodplain preservation, dual-use stormwater parks such as detention areas used for sports fields or recreation areas, interconnected systems of natural areas and open space, rainfall capture, and coastal solutions such as living shorelines, wetland restoration, etc. These solutions not only help to reduce the risk of flooding but may also provide other co-benefits, like improving water quality, enhancing biodiversity, reducing heat island effects, offering aesthetic value, and providing recreational opportunities for communities.

Several planning groups noted challenges to recommending more flood risk reduction solutions that incorporated nature-based components. These included:

- inadequate incentives and funding for land conservation easements, property acquisitions, and buyout programs;
- the need for expert guidance on designing and implementating projects that incorporate nature-based solutions; and
- the need for guidance on inclusion of land preservation/conservation projects.

To assist communities and the regional flood planning groups during the second cycle of flood planning, the TWDB is implementing a flood priority research project (expected to be completed April 2025) to consolidate guidance on the use of nature-based flood mitigation solutions into a single, statewide manual for Texas. With the manual, the TWDB aims to make it easier to address flood risk through nature-based solutions or to employ nature-based solutions in combination with traditional flood mitigation infrastructure. More focused, practical guidance that considers the efficacy of nature-based solutions within the various geographic regions of Texas is needed to support regional and statewide flood planning efforts and to help Texas communities better understand and utilize these approaches.

The project will examine and describe the efficacy and cost effectiveness of various nature-based solutions for different regions in Texas. The focus of this research is to identify the range of nature-based solutions best suited for floods of varying magnitudes; the types of associated flood mitigation benefits, including additional co-benefits within social, ecologic, and economic categories; and the various methods by which these benefits may be described and quantified.

10.2.4 Assessing existing major flood infrastructure

Regional flood planning groups were required to evaluate the condition and adequacy of flood mitigation infrastructure for their regions. They did so by inventorying the existing major flood infrastructure within each planning region and assessing, as best as they could, the functionality and condition of the identified infrastructure. This requirement is intended to assist the planning groups in making informed decisions regarding where investment may be needed to address existing deficiencies, enhance functionality, and ensure that Texas' prior investments in infrastructure perform as designed to protect against the risk and impact of flooding. The first cycle of regional flood planning produced a robust catalog of existing flood infrastructure—both natural and constructed—across the state. However, it became apparent that assessing the condition and functionality of existing infrastructure was a difficult task for the regional flood planning groups to perform.

One of the primary limiting factors was that the planning groups and their technical consultants had to rely on available data from local entities regarding their existing infrastructure conditions. The flood planning groups do not have the resources to identify and assess individual flood infrastructure components in the field and, therefore, must rely on infrastructure owners in the region. Depending on each entity's resources, level of expertise, and engagement in the process, many did not or could not provide useful information to the planning groups regarding the functionality of their infrastructure.

To assist local entities and the planning groups in future flood planning cycles, the TWDB funded a flood priority project to develop planning-level infrastructure condition assessment methods for local entities to use and provide to the planning groups. This includes a toolkit for assessing the condition of flood infrastructure at a regional planning level for future planning cycles. Once the toolkit is developed, it is expected that regional flood planning groups and local entities will be better able to assess the condition and functionality of major flood infrastructure and build upon the initial inventory developed during the first planning cycle.

10.2.5 Benefit-cost analysis

Benefit-cost analysis is a method that determines the future risk reduction benefits of a hazard mitigation project and compares those benefits to its costs. By comparing the benefits and costs, the benefit-cost analysis process helps decision-makers determine if the project is economically viable and whether the benefits are worth the costs. Projects with a benefit-cost ratio of 1.0 or greater are generally considered cost effective because the benefits are expected to outweigh the cost.

The process of conducting a benefit-cost analysis typically involves identifying and measuring the benefits and costs associated with the project. Benefits include factors like reducing the likelihood of damage or loss of life, while costs include the financial expenses needed to implement the project and provide long-term maintenance (FEMA 2023).

During the first cycle of regional flood planning, several of the flood planning groups encountered significant challenges with integrating the benefit-cost analysis into their flood mitigation project evaluations. Anticipating this potential issue, the TWDB had already funded and guided the development of a user-friendly benefit-cost analysis tool in the form of a spreadsheet that works in conjunction with the FEMA Benefit-Cost Analysis Toolkit.[64] This tool was completed in time for the first cycle and shared with the planning groups and their technical consultants to meet the associated planning requirements.

The complexity and limits of the analysis remained particularly pronounced for non-structural projects, where the benefits were more difficult to quantify than structural projects. For example, some groups found that traditional benefit-cost analyses often fell short in adequately scoring certain projects and that the existing criteria failed to adequately recognize the full scope of benefits from stormwater and flood-related solutions.

A general sentiment emerged that there was a need to revise and broaden the benefit-cost analysis criteria to better capture benefits from certain types of flood mitigation solutions. Some planning groups and local entities perceived the benefit-cost analysis requirement as a stumbling block, hindering them from recommending potentially beneficial flood mitigation projects.

Planning groups were encouraged to recommend projects with a benefit-cost analysis of 1.0 or greater, because a benefit-cost ratio greater than 1.0 is frequently a requirement for state and federal financial assistance. However, the TWDB permitted the planning groups to recommend flood risk reduction solutions with benefit-cost ratios less than 1.0 in their regional flood plans if additional justification was provided.

In its ongoing efforts to improve the quality of benefit-cost analyses for flood risk mitigation solutions, the TWDB contracted with a consultant to develop benefit-cost analysis guidance[65] that identifies easier and scalable approaches to benefit-cost analysis and an expanded range of damage/benefit tables to support communities and professionals. This includes detailed benefit-cost analyses for specific, identified projects seeking financial assistance as well as broader benefit-cost analyses for general planning purposes. This guidance document will be available in 2024.

10.2.6 Public outreach and participation

Many flood planning groups reported low response rates to their community outreach efforts regarding information about current floodplain management practices, existing infrastructure, existing flood hazard, and a flood mitigation financing survey. The lack of engagement and limited participation in the regional flood planning process may be attributed to several causes:

- This was the first cycle of an entirely new state flood planning effort;
- The regional flood plans were developed within a short timeframe and mostly during a global pandemic;
- While the regional flood planning groups held more than 550 public meetings (all with opportunities for public comment and input), most were necessarily virtual, which likely discouraged some potential participants;

During the first flood planning cycle, much of Texas experienced drought conditions ranging in severity from abnormally dry to exceptional drought.[66] Flooding was likely not at top of mind for many Texans during this period. For those reasons, it is not surprising that it was difficult to deploy robust outreach and engagement to all Texas communities, especially those in more rural or remote areas. In addition,

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64 www.fema.gov/grants/tools/benefit-cost-analysis#toolkit

65 www.twdb.texas.gov/flood/research/benefit-cost-analysis-guidance/index.asp

66 www.drought.gov/states/texas

many smaller, remote, or rural communities may have a limited role in floodplain management in their areas, often due to lack of resources, so participation in regional flood planning was not made a priority.

In response to these factors, stakeholder surveys, and information contained in the regional flood plans, there appears to be a desire for a comprehensive guide on stakeholder outreach and engagement as well a need for more concentrated effort on the behalf of all participants, including the TWDB, to expand awareness about flood planning and increase stakeholder engagement at all levels.

Aside from providing greater grant funding and a longer timeframe in which to complete the next regional plans, the TWDB is considering several options to further assist and support the regional flood planning groups in their efforts to increase participation in the flood planning process. One idea is to facilitate or support an online workshop where planning group sponsors, chairs, and technical consultants can share their best practices and lessons learned.

10.3 Looking ahead

The first cycle of regional and state flood planning laid a solid foundation for future flood planning efforts. The TWDB will continue to value stakeholder input and work hard to provide strong support and innovative resources to the regional flood planning groups. The TWDB intends to ensure that future flood planning efforts deploy State funds efficiently and that planning groups successfully and meaningfully mitigate existing and future flood risk in the state.

10.3.1 Identifying and recommending flood risk reduction solutions

During the first cycle of regional flood planning, the TWDB and the regional flood planning groups faced an expedited timeframe during which the planning groups were expected to identify, evaluate, and recommend flood risk reduction solutions in their 2023 regional flood plans. A flood project can only receive funding through the Flood Infrastructure Fund if it's recommended in the regional and state flood plans. Many stakeholders expressed the desire to have a greater opportunity to develop projects for recommendation in the regional plans, which will become part of the state flood plan. In response, the TWDB extended and expanded the grant contracts by providing the planning groups with an additional $10 million in funding and six extra months to amend their initial plans with more projects. Allowing the planning groups to amend their initial regional flood plans resulted in roughly tripling the number of projects for inclusion in the state flood plan. In total, the planning groups added 763 flood management evaluations, 410 flood mitigation projects, and 51 flood management strategies.

The second cycle of regional and state flood planning will provide the planning groups with the benefit of a longer planning period in which they will build on the information gathered during the first cycle. The next cycle will also benefit greatly from the updated agency rules and technical guidance that the TWDB has since developed based on lessons learned. We look forward to seeing more flood risk evaluations and recommended flood mitigation solutions in the next set of regional flood plans.

10.3.2 Additional assistance for smaller and rural communities

The first cycle of regional and state flood planning made clear the inherent challenges in involving small, remote, and rural communities in the regional flood planning process. For example, some smaller communities experienced difficulties in procuring the appropriate or sufficient flood risk information required for planning groups to recommend flood mitigation projects on the communities' behalf that would also meet statutory requirements. As a result, the planning groups reported a significant need for many flood management evaluations to assess flood risks and, in turn, identify potential projects to mitigate that risk.

To address the unique challenges faced by small and rural communities, the TWDB has introduced and is expecting to implement two initiatives during the second planning cycle. The first is additional planning group grant funding (made available through 2023appropriations from the Texas Legislature) to enhance the scope of work to perform additional flood management evaluations. Second, the TWDB obtained additional funding and agency staff capacity from the 88th Texas Legislature to create a new flood management evaluation initiative. The TWDB will perform a limited number of flood risk studies, *as identified and selected by the regional flood planning groups,* and provide the results, including potential flood mitigation project information, to the respective regions and communities for their consideration. Both initiatives are designed to help the planning groups to identity and recommend new flood risk reduction solutions for smaller and rural entities.

Due to the large number of studies identified, the regional flood planning groups will select which evaluations to pursue with study oversight from the TWDB to maximize the volume of studies that can be performed with the limited funding while ensuring technically credible results.

10.3.3 Flood planning and floodplain management awareness

The next cycle of regional flood planning promises to be more comprehensive and robust for several key reasons. First, it is anticipated that general awareness of the flood planning process is growing across Texas thanks to the first cycle of flood planning and the ongoing Flood Infrastructure Fund program. As the program progresses, the TWDB hopes to continue reaching all communities across the state, including the most remote and underserved areas. Widespread understanding, knowledge, and engagement will help ensure that more communities, particularly in small, remote, and rural regions, will actively participate in developing flood risk reduction solutions for their own areas.

The important linkage between state flood funding and participation in the regional planning process is becoming clearer to stakeholders. As the second intended use plan of the Flood Infrastructure Fund is released in 2024, Texas communities will better understand that to qualify for flood evaluation and project funding opportunities through the Flood Infrastructure Fund, their projects must be recommended in both the regional and state flood plans. This direct tie between funding and planning participation will likely act as a strong incentive to motivate communities to be proactive in both their local and regional flood planning efforts. Implementing flood mitigation solutions on the ground is the best way to draw in participation to the regional planning process, which is already reflected in stakeholders' growing interest.

Lastly, although none of the regional flood planning groups mandated communities to adopt specific floodplain management standards to be able to incorporate their flood risk reduction solutions in the regional flood plans, communities will have greater awareness of and access to floodplain discussions, management best practices, and associated recommendations for their region. With a deeper understanding and, hopefully, involvement in the planning process and access to floodplain management for their region, the expectation is that communities will establish effective floodplain management systems to reduce existing flood risks and avoid increasing future flood risk.

10.3.4 A guide to state and local flood control policies

As the state's guide to state and local flood control, the policy and floodplain management recommendations contained in this 2024 State Flood Plan will likely lead to discussions, new initiatives, and potentially direct funding for important flood mitigation activities. The TWDB is committed to exploring and implementing any of the Chapter 2 recommendations or any other state flood initiatives that the Texas Legislature prioritizes.

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Glossary

Acre-foot
Volume of water needed to cover 1 acre to a depth of 1 foot. It equals 325,851 gallons.

Ad valorem taxes and other fees
Though less frequently a source of funding, these impact fees, permitting fees, or ad valorem taxes may be used to fund activities. For example, communities can fund their floodplain management program through floodplain development permitting fees. Impact fees are sometimes assessed as a one-time payment for new developments to offset their anticipated impact to communities. Another program is a fee-in-lieu in which developers pay a fee to the community rather than building a site-specific stormwater mitigation project in their development.

Aquifer
Geologic formation that contains sufficient saturated permeable material to yield significant quantities of water to wells and springs. The formation could be sand, gravel, limestone, sandstone, or fractured igneous rocks.

Atlas 14
Dataset released in 2018 by the National Weather Service's Hydrometeorological Design Studies Center (under the National Oceanic and Atmospheric Administration) that provides precipitation frequency information for the U.S. states and territories.

Availability
Maximum amount of raw water available from a source during the drought of record, regardless of whether the supply is physically or legally available to water user groups.

Base flood elevation
Elevation of the 1 percent (100-year) annual chance flood, which is determined by statistical analysis for each local area. Base flood engineering is the basis of the insurance and floodplain management requirements of the National Flood Insurance Program.

Base level engineering
An automated riverine hydrologic and hydraulic modeling approach that builds on lessons learned to produce a baseline understanding of a community's flood risk.

Benefit-cost analysis
A benefit-cost analysis was required for each recommended flood management project and, as applicable, the method by which the future benefits of a hazard mitigation project are determined and compared to its costs. The end result is a benefit-cost ratio, which is calculated by a project’s total benefits divided by its total costs. The benefit-cost ratio is a numerical expression of the "cost-effectiveness" of a project. A solution is generally considered to be cost effective when the benefit-cost ratio is 1.0 or greater, indicating the benefits of a prospective hazard mitigation project are sufficient to justify the costs.

Bonds
Communities typically use either stormwater revenue bonds or general obligation bonds for this type of funding. Bonds can fund various activities, such as home buyouts, upgraded early warning systems, and infrastructure repairs.

Capital cost
Portion of the estimated cost of a flood risk reduction solution that includes both the direct costs of constructing facilities, such as materials, labor, and equipment, and the indirect costs associated with

construction activities, such as engineering studies, legal counsel, land acquisition, contingencies, environmental mitigation, interest during construction, and permitting.

Coastal flooding
Strong winds combined with changes in water surface elevation can produce a storm surge that drives ocean water inland across the flat coastal plain. High tide events also may cause frequent, localized flooding of low-lying coastal lands.

Coastal infrastructure
Structures, systems, and facilities built along coastlines for the purpose of flood protection.

Community rating system
A voluntary incentive program that recognizes and encourages community floodplain management practices that exceed the minimum requirements of the National Flood Insurance Program.

Conditional Letter of Map Revision
FEMA's comment on a proposed project that would, upon construction, affect the hydrologic or hydraulic characteristics of a flooding source and thus result in the modification of the existing regulatory floodway, the effective Base Flood Elevations, or the Special Flood Hazard Area. The letter does not revise an effective National Flood Insurance Program map, it indicates whether the project, if built as proposed, would be recognized by FEMA.

Critical facilities
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.

Deficient infrastructure
The flood infrastructure or natural feature is in poor structural or non-structural condition and needs replacement, restoration, or rehabilitation.

Detention
Stormwater detention stores the water and is held for release at a restricted rate after the storm subsides. In stormwater retention, the runoff of stormwater is held for later use in irrigation or groundwater recharge as well as reducing pollution.

Drought
Generally applied to periods of less-than-average precipitation over a certain period of time. Associated definitions include meteorological drought (abnormally dry weather), agricultural drought (adverse impact on crop or range production), and hydrologic drought (below-average water content in aquifers and/or reservoirs).

Drought of record
The period of time when historical records indicate that natural hydrologic conditions provided the least amount of water supply.

Estuary
Bay or inlet, often at the mouth of a river and may be bounded by barrier islands, where freshwater and seawater mix providing for economically and ecologically important habitats and species and that also yields essential ecosystem services. Estuaries provide flood mitigation benefits by shielding the coast from storm surges and wave action.

Evergreen general obligation bond
Voter-approved authority to issue general obligation bonds that do not expire and replenishes as bonds are paid off.

Fill
Obstructive materials, including sand and soil, used to raise the level of the ground to change the flow of water or increase flood elevations.

Flash flood
A flood caused by heavy or excessive rainfall in a short period of time, generally less than 6 hours.

Flash Flood Alley
Flash Flood Alley is the region that follows the curve of the Balcones Escarpment from Dallas to Austin and extends just southwest of San Antonio. This area is called Flash Flood Alley because of the area's steep terrain, shallow soil, and intense rainfall rates. Heavy rains can quickly transform into walls of fast-moving water with great destructive potential.

Flood
An overflow of water onto normally dry land.

Flood infrastructure
Natural or constructed systems and structures that manage flooding, including dams, levees, floodplains, and storm drain systems.

Flood Infrastructure Fund
The TWDB's Flood Infrastructure Fund program[67] was passed by the legislature and approved by Texas voters through a constitutional amendment in 2019. The program offers financial support through loans and grants for a range of flood studies and mitigation projects. Flood intended use plans outline the structure of each associated funding cycle. Only flood risk reduction solutions (flood management evaluations, flood mitigation projects, and flood management strategies) recommended in the regional flood plans are eligible for Flood Infrastructure Funding.

Flood Insurance Rate Map
Official map of a community on which FEMA has delineated the special flood hazard areas, the base flood elevations, and the risk premium zones.

Flood risk
A combination of the probability (likelihood or chance) of a flood event happening and the impact if it occurred.

Flood management evaluation
A proposed flood study of a specific, flood prone area needed to assess flood risk and/or determine whether there are potentially feasible flood mitigation projects or flood management strategies.

Flood mitigation project
A proposed project, either structural or non-structural, that has nonzero capital costs or other non-recurring cost and when implemented will reduce flood risk, mitigate flood hazards to life or property.

[67] www.twdb.texas.gov/financial/programs/FIF/index.asp

Flood management strategy
A proposed plan to reduce flood risk or mitigate flood hazards to life or property. The regional flood planning group has some flexibility on how they choose to utilize strategies in the regional flood planning process. For example, regional flood planning groups could choose not to recommend any strategies. At a minimum, regional flood planning groups should include as flood management strategies any proposed action that the group would like to identify, evaluate, and recommend that does not qualify as either a flood management evaluation or flood mitigation project.

Floodplain
The land adjacent to a water body that is subject to inundation during a flood.

Floodproofing
Any combination of structural and non-structural additions, changes, or adjustments to structures that reduce or eliminate flood damage to real estate, water and sanitary facilities, structures and their contents.

Floodplain quilt
An initial ranking or hierarchy of flood planning data sets provided by the TWDB for flood risk analyses.

Fluvial (or riverine) flooding
Flooding that occurs when rivers overflow their banks and flow into surrounding areas.

Fluvial geomorphology
A subdiscipline of geomorphology that investigates how flowing water shapes and modifies Earth's surface through erosional and depositional processes.

Freeboard
An additional amount of height above the base flood elevation used as a factor of safety in determining the height at which structure's lowest floor must be elevated.

Functional infrastructure
The flood infrastructure is serving its intended design level of service.

General fund
General fund revenue is largely from property, sales, and other taxes, that provides a substantial amount of money

Hydrologic unit code
A hydrologic unit system used to identify any hydrologic area using a two- to 12-digit number that uniquely identifies each of the six levels of classification within six two-digit fields.

Interactive state flood plan viewer
TWDB website (Texasstatefloodplan.org) which allows users statewide take an up-close look at data in the 2024 State Flood Plan.

Levee
Man-made structures comprised of long mounds of earth, concrete, and other materials built up along the banks of rivers to contain flood flows within a restricted floodplain.

Living levee
Sometimes called "horizontal levees," these are earthen levees that slope gently downwards to allow for natural, gradual transitions down to open water.

Low water crossing
Roadway creek crossings that are subject to frequent inundation during storm events or to inundation during a 50 percent (2-year) annual chance storm event.

Major reservoir
Reservoir with a storage capacity of 5,000 acre-feet or more.

National Flood Hazard Layer
Geospatial database that contains current effective flood hazard data.

National Flood Insurance Program
A program created by Congress in 1968 and managed by FEMA to reduce future flood damage through floodplain management and to provide people with flood insurance through individual agents and insurance companies.

Natural feature
Referring to the ecological characteristics and functions of the physical landscape that mitigate flood risk.

Natural floodplain
A floodplain whose boundaries can change with each flood event as sediments are scoured and deposited within the river channel and upon adjacent lands.

Nature-based solution
Sustainable planning, design, environmental management and engineering practices that weave natural features or processes into the built environment to promote adaptation and resilience.

Navigable waters
Waters of the United States that are subject to the ebb and flow of the tide and/or are presently used, or have been used in the past, or may be susceptible for use to transport interstate or foreign commerce.

Non-functional infrastructure
The flood infrastructure is not providing its intended or design level of service.

Non-deficient infrastructure
The flood infrastructure or natural feature is in good structural or non-structural condition.

Non-recurring, non-capital costs
Costs necessary to develop and/or implement the strategy. Examples include a program development cost, education campaign cost, non-engineering studies such as floodplain regulation development, flood authority or revenue raising studies, and public awareness programs.

Non-structural flood mitigation projects
Actions that reduce the impact of flooding without relying solely on physical infrastructure solutions. These projects focus on strategies that do not involve constructing physical barriers or altering the natural flow of water.

Playa lakes
Shallow, clay-lined depressions in the otherwise flat landscape act as natural water detention areas of rainfall and irrigation runoff.

Pluvial flooding
Inflow of stormwater in urban areas that exceeds the capacity of drainage systems to infiltrate stormwater or carry it away, often caused by heavy rainfall, land development, and undersized stormwater systems.

Ponds
Land depressions that store water and can facilitate natural infiltration of water into the ground.

Recharge
Water that infiltrates to the water table of an aquifer.

Regional flood planning group
Group designated pursuant to Texas Water Code § 16.053. There are 15 flood planning groups in Texas responsible for developing regional flood plans that are guided by statute, rules, contracts, members of the planning groups, and the general public. Each group has diverse members with various economic, social, and environmental interests in their areas.

Regulatory floodplain
A floodplain whose boundaries are determined by modeling a specific storm event and depicting the boundaries of inundation.

Resilience
The capacity of individuals, communities, businesses, institutions, and governments to adapt to changing conditions and to prepare for, withstand, and rapidly recover from disruptions to everyday life, such as hazard events.

Reservoir
Man-made lakes often created by installing dams across rivers or tributaries to capture and store water for a variety of purposes, including water supply.

Revetment
Components of flood protection infrastructure incorporated along riverbanks and coastal areas to reduce flood risk by preventing erosion and stabilizing the water's edge.

Riverine flooding
Rivers exceed flow capacity resulting in overtopping and large volumes of runoff, often caused by high-intensity rainfall.

Roadway stream crossing
A location where a road or highway interacts with a stream or watercourse that may be susceptible to floodwater during periods of heavy rain or other flood events.

Sedimentation
The action or process of depositing sediment in a reservoir - usually silts, sands, or gravel.

Sinkholes
Geological formations characterized by the collapse or subsidence of the Earth's surface, often caused by the dissolution of soluble rocks, such as limestone.

Structural flood mitigation projects
Building or modifying infrastructure to reduce flood risk. These projects typically include advanced analysis with 30 to 100 percent level of design, including project objectives, scope, timelines, cost estimates, and deliverables.

Social vulnerability index
A numerical value intended as the proxy for resilience, or the capacity to weather, resist, or recover from the impacts of a hazard in the long term as well as the short term. Vulnerability depends upon many factors such as land use, extent and type of construction, contents and use, the nature of populations (mobility, age, health), and warning of an impending hazardous event and willingness and ability to take responsive actions.

Special flood hazard areas
Flood hazard areas identified on FEMA Flood Insurance Rate Maps that will be inundated by the 1 percent (100-year) annual chance flood event.

Special tax districts
Special tax districts are sometimes used to tax only the portion of the population that will benefit from a specific project. However, only a few communities in Texas have implemented such tax districts for flood mitigation.

Storage
Natural or artificial impoundment and accumulation of water in surface or underground reservoirs, usually for later withdrawal or release.

Stormwater detention
Basins that store and hold the water for release at a restricted rate after the storm subsides.

Stormwater retention
Stormwater runoff is held for later use in irrigation or groundwater recharge as well as reducing pollution.

Stormwater utility fees
Over the past several decades, the stormwater utility model has increasingly been used as a tool to raise local funding for stormwater management both in Texas and the country. Creating a stormwater utility that requires fees allows a municipality to have a dedicated revenue stream for stormwater management that is directly based on how much a property contributes to stormwater runoff.

Stormwater management systems
Designed to manage the excess water generated during rainfall events to prevent flooding, erosion, and water pollution.

Structural failure flooding
Failure of man-made infrastructure, such as dams or levees, when intense or extensive rainfall results in the uncontrolled release of floodwaters.

Transportation fees
While transportation fees are focused on maintaining the transportation system, many drainage systems are often contained within the transportation right-of-way, such as roadside ditches, inlets, and storm sewer systems. Costs associated with maintenance and upgrades of the drainage systems in the right-of-way are often mixed in and part of the overall transportation system budgets.

Urban flooding (also: stormwater or pluvial flooding)
Localized flooding that occurs when rainfall overwhelms the capacity of engineered drainage systems to carry away rapidly accumulating volumes of water.

Vulnerability
The susceptibility to physical injury, harm, damage, or economic loss. It depends on an asset's construction, contents, and economic value of its functions.

Weir
Low-lying barriers built across waterways that gauge the volume of water flowing through a canal and can serve as flood management infrastructure by capturing water upstream and slowing its downstream flow during times of peak discharge.

Wetlands, marshes, and swamps
Natural systems found near lakes, rivers, and oceans that are often inundated by water, either permanently or seasonally during rainy seasons.

Zone A
Other special flood hazard areas without base flood elevations.

Zone AE
The base floodplain where base flood elevations are provided.

Zone VE
Coastal areas with 1 percent or greater chance of flooding and an additional hazard associated with storm waves.

Appendices

Appendix A Regional summaries of future condition analysis methodologies

As described in Chapter 4, the first step in determining the future extent of both the 1 percent (100-year) and 0.2 percent (500-year) annual chance event flood hazard areas was for the regional flood planning groups to identify areas within each region where future condition hydrologic and hydraulic model results and maps were available. For areas where future condition flood hazard data was not available, the TWDB provided four methods for performing future condition flood hazard analyses. The methods available to the regional flood planning groups for estimating future flood risk included:

- Method 1 - Increasing water surface elevation based on projected percentage population increase (as proxy for development of land areas);
- Method 2 - Utilizing the existing condition 0.2 percent (500-year) annual chance floodplain as a proxy for the future 1 percent (100-year) level;
- Method 3 - A combination of methods 1 and 2 or another method proposed by the planning group; and
- Method 4 - Planning groups could request that the TWDB perform a desktop analysis.

A summary of each region's approach is as follows.

Region 1 Canadian-Upper Red
Region 1 Canadian-Upper Red utilized Method 2 to identify the future 1 percent (100-year) annual chance flood hazard areas. Region 1 was unique in that it combined the 0.1 percent annual chance cursory floodplain data provided in July 2021 with the 0.2 percent (500-year) annual chance cursory data provided by the TWDB in October 2021. Discrepancies due to varied topography and sampling densities were reconciled by adopting the larger boundary from either the 0.1 percent (100-year) or 0.2 percent (500-year) annual chance flood hazard areas as the new flood hazard boundary, ensuring that the future 0.2 percent (500-year) annual chance flood hazard area will always be equal to or larger than the future 1 percent (100-year) annual chance flood hazard area.

Region 2 Lower Red-Sulphur-Cypress
Region 2 Lower Red-Sulphur-Cypress utilized Method 2 to identify the future 1 percent (100-year) annual chance flood hazard area. The future 0.2 percent (500-year) annual chance flood hazard area was established based on the difference in widths between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas.

Region 3 Trinity
Region 3 Trinity utilized Method 2 to identify the future 1 percent annual chance flood hazard area. A 40-foot buffer extending from the 1 percent (100-year) annual chance flood hazard area was selected to serve as the potential maximum 0.2 percent (500-year) chance flood hazard area.

Region 4 Sabine
Region 4 Sabine utilized Method 2 to identify the future 1 percent (100-year) annual chance flood hazard area. Where surface water elevation data is available, a vertical buffer consistent with the difference between the 1 percent (100-year) and 0.2 percent (500-year) annual chance water surface elevations was added to the future 1 percent (100-year) water surface elevation to determine the 0.2 percent (500-year) water surface elevation. In areas without water elevation data, horizontal buffer widths were estimated to determine the difference between the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas. This difference was applied as a horizontal buffer to the future 1 percent (100-year) annual chance flood hazard area to determine the extents of the future 0.2 percent (500-year) annual chance flood hazard area. The horizontal buffer used varied from 5 to 20 meters depending on the existing topography.

Region 5 Neches
Due to the presence of flood control reservoirs in the region, Region 5 Neches utilized more than one method for determining the future 1 percent (100-year) annual chance flood hazard area. Downstream of the Sam Rayburn Reservoir, the existing flood hazard extent will be maintained for future flood hazard areas. For tributaries feeding into larger rivers within the Neches Basin, the existing 0.2 percent (500-year) annual chance flood hazard area was used as the future 1 percent (100-year) annual chance flood hazard area. This approach was utilized in all streams present in the region, barring the segment of the Neches River downstream of the Sam Rayburn Reservoir. In areas where base level engineering (BLE) data is determined to be the best available, the elevation difference between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance water surface elevations was used as the vertical buffer between the future 1 percent (100-year) and 0.2 percent (500-year) water surface elevations. Where National Flood Hazard Layer (NFHL) Effective data is considered the best available, a horizontal buffer based on the distance between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance floodplains was used to establish the future 0.2 percent (500-year) annual chance flood hazard area.

Region 6 San Jacinto
Region 6 San Jacinto utilized Method 3 to identify the future 1 percent (100-year) annual chance flood hazard area. This meant using the existing 0.2 percent (500-year) annual chance flood hazard area for much of the future 1 percent (100-year) annual chance flood hazard area extent, with the addition of a subsidence buffer and a sea level rise buffer that is applied, as needed, throughout the region. For the future 0.2 percent (500-year) annual flood hazard area, the existing 0.2 percent (500-year) annual chance flood hazard area was buffered by either 500-feet or 850-feet, based on the zone within the region. Additional horizontal buffers accounting for subsidence and sea level rise were applied where applicable.

Region 7 Upper Brazos
Region 7 Upper Brazos applied two different methods for estimating future flood hazard areas, as determined by whether the location is on or off the Caprock, a geological feature in the Texas Panhandle, marking the southern edge of the High Plains. The portion of the river basin that is on the Caprock will maintain the existing flood hazard area for both the future 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas. For the area off the Caprock, the potential future 1 percent annual chance flood hazard area was approximated as a range between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas. The planning group opted to hold the existing 0.2 percent (500-year) annual chance flood hazard area as the future 0.2 percent (500-year) annual chance flood hazard area until further studies are available.

Region 8 Lower Brazos
Region 8 Lower Brazos utilized Method 2 to identify the future 1 percent (100-year) annual chance flood hazard area. In areas where water surface elevation data is available, a vertical buffer based on the difference between existing 1 percent (100-year) and 0.2 percent (500-year) water surface elevations was applied to the future 1 percent (100-year) water surface elevation to approximate the future 0.2 percent (500-year) annual chance water surface elevation. For other areas, the future 1 percent annual chance flood hazard area was set to match the existing 0.2 percent (500-year) annual chance flood hazard area. Then, typical horizontal buffer widths were estimated in each Hydrologic Unit Code (HUC-8) watershed for rivers, major tributaries, and local streams to determine the thickness of the existing 0.2 percent (500-year) annual chance flood hazard area. This buffer was applied to the future 1 percent (100-year) annual chance flood hazard area to determine the extent of the future 0.2 percent (500-year) annual chance flood hazard area. The planning group determined that the flood hazard areas along the mainstem of the Brazos River should not be modified from existing to proposed conditions due to the large size of the watershed, attenuation of floodwaters by large flood control reservoirs and floodplains,

and results from a 2021 study which concluded that drastic changes in discharge would be necessary to significantly increase the 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas.

Region 9 Upper Colorado

Region 9 Upper Colorado utilized Method 2 to identify the future 1 percent (100-year) annual chance flood hazard area. In urban areas, the future 0.2 percent (500-year) annual chance flood hazard area was estimated by adding the average difference between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas to the future 1 percent (100-year) annual chance flood hazard area. Population is not projected to increase significantly in the rural portions of the region, so the future 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard area occupy the same extent as existing flood hazard areas.

Region 10 Lower Colorado

Region 10 Lower Colorado utilized Method 2 to identify the future 1 percent annual chance flood hazard area. The future 0.2percent (500-year) annual chance flood hazard area was estimated using a buffer based on the measured difference between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas.

Region 11 Guadalupe

Region 11 Guadalupe utilized Method 2 to identify the future 1 percent (100-year) annual chance flood hazard area. The planning group elected to use base level engineering (BLE) data as a starting point for the analysis due to the full coverage of the dataset throughout the basin. The difference in water surface elevation between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas was added to the existing 0.2 percent (500-year) base level engineering water surface elevation as a vertical buffer, then mapped against the existing terrain to create the future 0.2 percent (500-year) annual chance flood hazard area. In select areas where the extent of the future 0.2 percent (500-year) flood hazard area was smaller than the existing 0.2 percent (500-year) flood hazard area, a horizontal buffer based on the difference between the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard areas was added to the existing 0.2 percent (500-year) annual chance flood hazard area to create the boundary for the future 0.2 percent (500-year) flood hazard area.

Region 12 San Antonio

Region 12 San Antonio utilized Method 2 to identify the future 1 percent annual chance flood hazard area. The future 0.2 percent (500-year) annual chance flood hazard area was estimated based on hydraulic modelling that considered predicted increases in precipitation and subsequent increased peak stormflow during 0.2 percent (500-year) annual chance events. Four horizontal buffers resulted from this analysis based on subregion: Medina, Upper, Mid, and Coastal. The horizontal buffer was applied to each side of the existing 0.2 percent (500-year) annual chance flood hazard area to develop the future 0.2 percent (500-year) annual flood hazard area.

Region 13 Nueces

Region 13 Nueces utilized Method 3 to estimate the future 1 percent (100-year) and 0.2 percent (500-year) Annual Chance Event flood hazard area. In the more densely populated portions of the region, the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard area was buffered based on the estimated percent population increase to determine the future 1 percent (100-year) and 0.2 percent (500-year) flood hazard areas. In the less populated areas, population is not anticipated to significantly increase and thus the existing flood hazard extents were used for the future 1 percent (100-year) and 0.2 percent (500-year) flood hazard areas. The coastal portions of the region were divided into five zones based on their primary river system and further divided based on observed topography.

The planning group used the National Oceanic Atmospheric Administration 2022[68] intermediate sea level rise estimate of 1.1 foot and applied an appropriate offset to the existing 1 percent (100-year) and 0.2 percent (500-year) annual chance coastal flood inundation boundaries to determine the future 1 percent (100-year) and 0.2 percent (500-year) flood hazard areas in coastal zones.

Region 14 Upper Rio Grande

Region 14 Upper Rio Grande utilized Method 3 to estimate the future 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard area. Different future conditions analysis methods were utilized for El Paso County and for the remainder of the Upper Rio Grande region outside of El Paso County. In El Paso County, future condition flood risk was estimated by developing new future condition 2D models with considerations for future land use and precipitation. Outside El Paso County, future condition flood risk was identified by estimating areas of future development and by using the existing condition floodplains as a proxy for future condition floodplains within those areas. Subsequently, future flood hazard areas in El Paso County were increased by a significantly greater degree than those outside of El Paso County. Where the future condition adjustments within El Paso County resulted in a total future condition flood hazard area between 1.5 – 2 times the size of the total existing condition flood hazard area, adjustments outside of El Paso County resulted in only a 1 percent increase in the flood hazard area change.

Region 15 Lower Rio Grande

Region 15 Lower Rio Grande utilized Method 2 to identify the future 1 percent (100-year) and 0.2 percent (500-year) annual chance flood hazard area. Typical horizontal buffer widths were estimated in each hydrologic unit-8 for "hilly" terrain and flat coastal areas to determine the existing thickness of the 0.2 percent (500-year) annual chance flood hazard area. The buffer was then applied to the future 1 percent (100-year) annual chance flood hazard areas to determine the extent of the future 0.2 percent (500-year) annual chance flood hazard area.

[68] https://oceanservice.noaa.gov/hazards/sealevelrise/sealevelrise-tech-report.html

Appendix B Ranked lists of recommended flood risk reduction solutions

Texas Water Code § 16.061 requires the state flood plan to include a ranked list of all recommended flood risk reduction solutions. Ranking methodologies primarily focused on criteria related to flood risk and flood risk reduction to life and property.

The overarching goal of the regional and state flood plans is to protect against the loss of life and property by (1) identifying and reducing the risk and impact to life and property that already exists, and (2) avoiding increasing or creating new flood risks by addressing future development within areas known to have existing or future flood risks. The ranking criteria and methodology are generally intended to

- identify areas with the worst existing risk of flooding in the 1 percent (100-year) annual chance floodplain;
- identify flood risk mitigation solutions that may result in greater overall reduction in flood risk;
- and primarily focus on projects with the greater potential to mitigate the risk to life and property.

The TWDB's state flood plan flood risk reduction solutions ranking methodology is intended to provide a consistent approach for use across Texas to systematically address flood hazard with the population, properties, and critical facilities most at risk during a 1 percent (100-year) annual chance event. The ranking process aims to focus on severity of flood risk and reducing flood risk and impact to life and property as described by the legislature. The basic approach is described in Chapter 7 of this text.

The results of TWDB flood risk reduction solutions rankings as described in Chapter 7 include three ranked lists of flood risk reduction solutions

- B.1 Recommended flood management evaluations;
- B.2 Recommended flood mitigation projects; and
- B.3 Recommended flood management strategies with non-recurring, non-capital costs.

These ranked lists are available for review and download on the 2024 State Flood Plan website: https://www.twdb.texas.gov/flood/planning/sfp/index.asp.

Appendix C Summary of available key federal and state funding sources

Historically, federal grant programs related to floodplain management, planning, mitigation, and mapping activities typically offer greater financial assistance than what is available at the local or state level. Some federal programs are not tied to a specific disaster and are open annually as the U.S. Congress authorizes funding. Texas competes with other states for funds from programs such as Cooperating Technical Partners, Flood Mitigation Assistance, and Building Resilient Infrastructure and Communities. In some cases, flood-related projects also compete with other types of non-flood-related projects, such as wildfire management, earthquake preparedness, and backup power generation. Other funding programs are tied to specific declared disasters (e.g., Hurricane Harvey), such as the Hazard Mitigation Grant Program and the Community Development Block Grant – Disaster Recovery program.

The financial assistance programs summarized in Chapter 9 are categorized as state or federal based on the original source of funds. Some federal programs are administered at the state level and may include a state contribution. The following table includes examples of other state and federal flood funding programs, but it is not an exhaustive list of potential state and federal funding sources for flood mitigation. There are many other programs that focus on different areas of need in communities, such as transportation, research, or public education, but the funding may also support activities associated with flood mitigation. Additional references to seek more information on potential funding sources include the Texas Flood Information Clearinghouse,[69] American Flood Coalition,[70] and the Texas General Land Office's MATCH Tool[71] that is currently under development.

[69] http://www.texasfloodclearinghouse.org/

[70] http://www.floodcoalition.org/fundingfinder/#home

[71] http://www.match-tool-hub-dewberry.hub.arcgis.com/

Table C-1. Summary of available key federal and state funding sources

Source	Federal agency	State agency	Program name	Grant/loan /both	Post-disaster	Cost share (federal or state/local)	Benefit-cost analysis required
Federal	FEMA	TWDB	Flood Mitigation Assistance Grant program	X	-	Yes	Yes
	FEMA	TDEM	Building Resilient Infrastructure and Communities	X	-	Yes	Yes
	FEMA	TDEM	Safeguarding Tomorrow through Ongoing Risk Mitigation	X	-	Yes	No
	FEMA	TCEQ	Rehabilitation of High Hazard Potential Dam Grant Program	X	-	Yes	No
	FEMA	TDEM	Hazard Mitigation Grant Program	X	X	Yes	Yes
	FEMA	TDEM	Public Assistance	X	X	Yes	Yes
	FEMA	-	Cooperating Technical Partners	X	-	Yes	No
	HUD	GLO	Community Development Block Grant - Mitigation	X	X	Yes	Maybe[a]
	HUD	GLO	Community Development Block Grant Disaster Recovery Funds	X	X	Yes	No
	HUD	TDA	Community Development Block Grant Program for Rural Texas	X	-	Yes	No
	USACE	-	Continuing Authorities Program	X	-	Yes	Indirect[b]
	USACE	Varies	Partnerships with USACE, funded through Water Resources Development Acts or other legislative vehicles[c]	Varies	Varies	Varies	Varies
	EPA	TWDB	Clean Water State Revolving Fund	X[d]	-	No	No
	NRCS	-	Watershed and Flood Prevention Operations	X	-	Yes	Indirect[b]
	NRCS	-	Emergency Watershed Protection Program	X	X	Yes	No
	NRCS	TSSWCB	Watershed Rehabilitation	X		Yes	Indirect[b]
	NRCS	-	Wetland Reserve Easement Program	X		Yes	No
	US EDA	Varies	Various	X	Varies[e]	Yes	No
	US Congress	Varies	Community Project Funding	X	-	Yes	Maybe[f]
	US Congress	Varies	Water Resources Development Act	X	-	Yes	Indirect[b]
State	-	TSSWCB	Structural Dam Repair Grant Program	X	-	Yes	No
	-	TWDB	Flood Infrastructure Fund	X	-	Yes	Yes[g]
	-	TWDB	Texas Water Development Fund	X	-	No	No
	-	TSSWCB	O&M Grant Program	X	-	Yes	No
	-	TSSWCB	Flood Control Dam Infrastructure Projects - Supplemental Funding	X	-	Maybe	Maybe
Local	Not applicable		General Fund Stormwater or Drainage Utility Fee Special-Purpose District Taxes and Fees Tax Applications Bonds	n/a			Varies

[a] Community Development Block Grant - Mitigation only requires a benefit-cost analysis for covered projects (cost over $100 million, Community Development Block Grant funds over $50 million)
[b] These programs don't require a benefit-cost at application but may require coordination between applicant and funding agency to populate benefit-cost analyses in development of the project
[c] 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.
[d] The Clean Water State Revolving Fund program offers principal forgiveness, which is like grant funding.
[e] US EDA provides assistance through various initiatives, some tied to disaster supplementals, some through other means
[f] Benefit-cost analysis may not be required depending on what phase of project is appropriate for using Environmental Infrastructure through Community Project Funding.
[g] Benefit-cost ratios are not required to be provided for eligible studies that are aimed at identifying potential projects. Nor are benefit-cost ratios required for Flood Early Warning Systems or Flood Response Plans.

FEMA - Federal Emergency Management Administration
HUD - United States Department of Housing and Urban Development
NRCS - Natural Resources Conservation Service
USACE - United States Army Corps of Engineers
US EDA - United States Economic Development Administration
GLO - Texas General Land Office
TDA - Texas Department of Agriculture
TDEM - Texas Division of Emergency Management
TSSWCB - Texas State Soil and Water Conservation Board