AN ASSESSMENT OF CROSS-SCALE

FLOODPLAIN POLICIES IN CENTRAL TEXAS

by

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Abstract

Humans have been managing rivers and floodplains since ancient times, but our relationship with riverine floodplains has changed over time. In the United States, social movements, natural disasters, and urbanization have driven floodplain policies and implementation. Specifically, this project examined floodplain policy change at four political scales, federal, state, county, and municipal. The State of Texas, Hays County, and the Cities of San Marcos, Wimberley, and Woodcreek were chosen as case studies within the US federalist system. At all scales, floodplains are primarily governed and managed for their relationship to development and flood-control. Levees and dams have been the most common structural flood-control strategies nationwide and statewide. However, the long-term costs and adverse environmental impacts have influenced the shift in flood mitigation to favor nonstructural methods. Text mining methods were used to with current policy documents using Atlas.ti (version 8 for Mac OS), a qualitative data analysis software (QDAS). The results show the distribution of floodplains in current regulatory codes and former periods of high and low floodplain policy activities. Trigger events were identified for each governmental scale. At the federal level, national disasters, such as the Great Flood of 1927 and Hurricane Katrina (2005), spurred flood-control policy reform as well as the environmental movement in the 1960s-1970s. The National Environmental Policy Act (1969), Clean Water Act (1972), and Environmental Species Act (1973) set national policies that influenced state and local floodplain management. Severe droughts drove water planning policy change that spread to include floodplains. Texas floodplain policy is changing and being implemented rapidly while the opposite is true at the federal level. The municipalities' floodplain regulations were impacted most directly by localized floods. Floodplain management has evolved through the 20th and 21st centuries, driven

by social movements, natural disasters, and urban and agricultural development. The mismatch of hydrologic and political boundaries produces planning and management challenges. Primarily, floodplains are governed and managed for their relationship to development and flood-control. Text mining techniques were used to assess policy documents using Atlas.ti (version 8 for Mac OS), a qualitative data analysis software (QDAS) to create a historical timeline of floodplain policy change for the United States of America, the State of Texas, Hays County, and the Cities of San Marcos, Wimberley, and Woodcreek. Reviewing past missteps and successes will inform better policy and management decisions for floodplains and other natural resources. With climate change and growing urban populations, proactive management and resilient strategies are more important than ever.

Table 1. List of Acronyms

Acronym	Long Title
BRA	Brazos River Authority
BWE	Board of Water Engineers
CEQ	Council on Environmental Quality
CoSM	City of San Marcos
CoW	City of Wimberley
CoWC	City of Woodcreek
CRA	Clean Rivers Act
CS	Called Session
CWA	Clean Water Act
DMA	Disaster Mitigation Act
EO	Executive Order
EPA	Environmental Protection Agency
ESA	Endangered Species Act
FCA	Flood Control Act
FEMA	Federal Emergency Management Agency
FIA	Federal Insurance Administration
FIFMTFA	Federal Interagency Floodplain Management Task Force
FDPO	Flood Damage Prevention Ordinance
FPMS	Flood Plain Management Service
FR	Federal Register
FWRPA	Federal Water Resources Planning Act

GLO	General Land Office
HB	House Bill
HCHCP	Hays County Habitat Conservation Plan
HD	House Document
HHFA	Housing and Home Finance Agency
HJR	House Joint Resolution
HUD	Department of Housing and Urban Development
NEPA	National Environmental Policy Act
NFIA	National Flood Insurance Act
NFIP	National Flood Insurance Program
NOAA	National Oceanic and Atmospheric Administration
NRCS	Natural Resources Conservation Service
NWS	National Weather Service
PL	Public Law
RHA	Rivers and Harbors Act
RHCP	Regional Habitat Conservation Plan
RS	Regular Session
RWPG	Regional Water Planning Group
SB	Senate Bill
SCS	Soil Conservation Services
SFA	State Flood Assessment
SWIFT	State Water Implementation Fund for Texas
SWIRFT	State Water Implementation Revenue Fund for Texas

SWP	State Water Plan
SWPB	State Water Pollution Control Board
TCEQ	Texas Commission on Environmental Quality
TDEM	Texas Division of Emergency Management
TDWR	Texas Department of Water Resources
TNRCC	Texas Natural Resource Conservation Commission
TNRIS	Texas Natural Resources Information System
TPWD	Texas Parks and Wildlife Department
TWC	Texas Water Commission
TWDB	Texas Water Development Board
TWQA	Texas Water Quality Act
TWQB	Texas Water Quality Board
TWRC	Texas Water Rights Commission
TWRPD	Texas Water Resources Planning Division
USACE	United States Army Corps of Engineers
USC	United States Code
USFA	United States Fire Administration
USFWS	United States Fish and Wildlife Service
USGS	United State Geologic Survey
WOTUS	Waters of the United States
WPA	Water Planning Act
WPCA	Water Pollution Control Act
WPCB	Water Pollution Control Board

WRC	Water Resources Council
WRDA	Water Resource Development Act
WRPA	Water Resources Planning Act

Introduction

As urban development expands, human-nature interactions become increasingly complicated. A warmer atmosphere can hold more moisture, and as the global climate changes, extreme weather events are becoming more frequent and intense Burby 2001; Olsen 2006). Any land cover and land-use change alter the watershed hydrology, but buildings, impervious surfaces, and built flood-control structures magnify the impact of altering natural drainage patterns. Because water flows downstream and to the lowest elevation, valleys, river channels, and floodplains are first to be inundated. Specifically, floodplains are critical to the flow of water in floods and provide invaluable habitat for aquatic and terrestrial species. Human intervention, or management, aims to maximize benefits and minimize costs, resulting in trade-offs and conflicts among policymakers, city managers, citizens, industry, and the environment (Larson and Plasencia 2001; Tingsanchali 2012; Marmorek et al. 2019). Watersheds and US political divisions are nested and interconnected but not aligned.

This report will review floodplain as hydrogeomorphic features and regulatory features to explore and untangle the relationship between the government and watersheds. Federal, state, county, and local governments are allotted different governing and managing authorities. Given the US political structure, urbanization, and crossing watershed boundaries,

- How do floodplain policies differ across city, county, state, and federal scales, using the cities of San Marcos, Wimberley, and Woodcreek, Hays County, the State of Texas, and the United States, respectively?
- What events have influenced floodplain policies?

Although specific governing and managing responsibilities are divided between federal and nonfederal (state, regional, and local) entities, jurisdictions overlap and leave gaps. “Policy” refers to the collection of ideas that are explicitly declared or inferred by ‘policy documents’ that include laws, statements, and plans. A ‘statement or declaration of policy’ directly addresses the legislative intent for a law. However, not all policy documents contain direct policy statements, so the policy is inferred and interpreted based on the whole document and specific excerpts. For example, the “Declaration of Goals and Policy” of the 1972 amendments to the Federal Water Pollution Act stated,

> “The objective of this Act is to restore and *maintain the chemical, physical and biological integrity of the Nation's waters*… It is the national goal that the discharge of pollutants into the navigable waters be eliminated by 1985; it is the national goal that wherever attainable, an interim *goal of water quality* which provides for the protection and propagation of fish, shellfish, and wildlife and provides for recreation in and on the water be achieved by July 1, 1983; it is the national policy that the discharge of toxic pollutants in toxic amounts be prohibited… it is the national policy that a *major research and demonstration effort be made to develop technology necessary* to eliminate the discharge of pollutants into the navigable waters, waters of the contiguous zone, and the oceans” (emphasis added) (PL 92-500).

Policies are vague, ideational statements, that, in this example, are “to maintain the chemical, physical and biological integrity of the Nation's waters,” “goal of water quality,” and to “develop technology” for “major research and demonstration efforts.” At the federal and state level, legislative documents include laws and statutes, while counties and municipalities promulgate ordinances and resolutions that reflect the management goals and societal values. Authorized by the legislative body, ‘implementing’ agencies create rules and regulations under either narrow or broad discretion to accommodate specialty knowledge and expertise.

Laws are implemented across governmental and spatial scales, so cross-scale cooperation is critical to effective floodplain management. While state and federal governments have a higher organizational capacity, they can oversimplify site-specific details due, in part, to the significantly larger jurisdictional area. Local and regional governments can tailor management strategies to the local environment but lack the funding and jurisdiction of state and federal governments. (Apple 2001; Burby 2001; Wurbs 2004; Hooper 2005; Olsen 2006; Ntelekos et al. 2010; McQuaid 2018). Despite the challenges, local communities are primarily responsible for the operational management of floodplain regulations (Brody, Kang, and Bernhardt 2010). A level of discretion is left to Texas municipalities when deciding floodplain policies that fall under development or flood-control regulations.

Floodplain development, impervious cover, and population growth put an increasing number of human lives and structures at risk, but mandatory flood insurance, permitting fees, and non-development zoning are feared to discourage economic growth (Baker 1975; Dingman and Platt 1977; Park and Miller 1982; Bath 1999; Dixon 2000; Olsen 2006; Hunt et al. 2012; Lee and Jung 2014; Earl and Vaughan 2015; Rubinstein 2015; Furl et al. 2018). Floodplain management strategies originate from the dichotomy of altering the floodplain or not altering the floodplain. The degree of alteration, level of restrictions, land use permissions, and engineering requirements stem from the initial decision by policymakers and managers that represent stakeholders.

Background and Literature Review

Hydrogeomorphic Floodplains

Generally, floodplains are flat, low-lying land outside of a water body that is subject to intermittent inundation (Kaiser 1987; Kusler and Larson 1993; Tocker and Stanford 2002;

DeBarry 2004; Estaville and Earl 2008; Brooks, Ffolliott, and Magner 2013). Hydrologic and geomorphologic processes, including flood pulses and sediment deposition, shape riverine floodplains (Swift 1984; Junk, Bayley, and Sparks 1989; Bayley 1995; Amoros and Bornette 2002; Tocker and Stanford 2002; Groffman et al. 2003; Meitzen et al. 2018).

In addition to the geomorphic properties of elevation, slope, soil, and natural levees, floodplain biota constantly reshape the biodiverse floodplain ecosystems (Junk, Bayley, and Sparks 1989; Naiman, Décamps, and Pollock 1993; Bayley 1995; Bolund 1999; Tockner and Stanford 2002; Poeppl et al. 2012). The riparian vegetation, or riparian buffer, line stream channels and can extend from the channel across the active floodplain, linking aquatic and terrestrial ecosystems (Swift 1984; Junk, Bayley, and Sparks 1989; Castelle, Johnson, and Conolly 1994; Tockner and Ward 1999; Nilsson and Svedmark 2002; Liao 2012; Poeppl et al. 2012). Floodplains provide critical habitat for fauna, but land modification reduces native species richness and increases exotic species populations (Knopf et al. 1988; Castelle, Johnson, and Conolly 1994; Bayley 1995; Chipps et al. 2006; Liao 2012).

Also, healthy floodplains provide numerous provisioning, regulating, and cultural ecosystem services that include improved water quality and clarity, nutrient cycling, bank stabilization, and recreation (Budd et al. 1987; Knopf et al. 1988; Gregory et al. 1991; Wilen and Bates 1995; Groffman et al. 2003; Brauman et al. 2007; Sanon et al. 2012; Bolund 1999; Poeppl et al. 2012). Above-ground, vegetation slows overland flow and reduces downstream flashiness, and underground, roots stabilize banks and reduce erosion and turbidity. Clearing the riparian vegetation for ‘productive’ land uses, such as agricultural use, resource extraction, or urban development, exacerbates the destructive impact of floodwaters.

Regulatory Floodplains

Though the idea of what it considered productive land has shifted to include land preservation, floodplain boundaries can be diffuse and change at a faster rate than regulatory maps. Additionally, floodplain maps delineate stark flood-risk zones based on statistical probabilities, not geomorphic features. Even within regulatory frameworks, floodplain definitions vary, and the inconsistency causes friction and confusion when managing floodplains across agencies and governing institutions. Table 2 lists different government institutions' and agencies' definitions.

Table 2. Regulatory Floodplain Definitions

Term	Definition	Author
Floodplain	"any land area susceptible to being inundated by floodwaters from any source"	FEMA
	"means any land susceptible to being inundated by water as a result of a specific frequency flood"	City of San Marcos
	"an area adjacent to a body of water"	Hays County
	"for the purposes of water quality buffer zones, this term shall mean either of one or the other following definitions: (1) A FEMA studied floodplain identified on the FIRM (Flood Insurance Rate Maps) as Zone AE or equivalent; or (2) a studied floodplain as provided through engineering data prepared and certified by a professional engineer."	City of Woodcreek
Floodplain (100-year)	"any area susceptible to inundation by flood waters from any source and subject to the statistical 100-year flood (has a 1% chance of flooding each year)"	State of Texas
	"a strip of relatively flat and normally dry land alongside a stream, river, or lake that is covered by water during a flood"	USGS

Floodplain or flood-prone area	"means any land area susceptible to being inundated by water from any source"	City of Wimberley
	"of a waterway and the adjacent land area subject to inundation during the design storm"	

FEMA and Hays County have broad definitions that use plain language. In contrast, the City of Woodcreek's definition is technical and defers FEMA flood-risk map delineations. The City of San Marcos and the State of Texas combine common phrasing with some jargon. Although the USGS uses familiar language, the term defined is the "100-year floodplain." The CoSM uses "*any* land," and Texas uses "*any* area" (emphasis added), which extends broad jurisdictional reach but also includes the scientific phrases "frequency flood" (CoSM) and "statistical 100-year flood" (Texas). The CoW has two definitions in separate chapters of the Code of Ordinances. The first is broad and uses the broad terms "any land" and "any source," akin to FEMA, Hays County, and USGS. The second definition is more similar to the CoSM and Texas definitions, including the phrases "land area" and "design storm." Federal regulatory floodplains are defined by annual flood risk for design floods (Dingman and Platt 1977; Dougal and Quinn 2018).

Flood-prone zones are founded on design floods, which are hypothetical floods based on engineering models developed from meteorological and hydrologic records. The annual probability of an area flooding is used in developing flood-control procedures and development regulations. (Jain and Singh 2003). FEMA defines Special Flood Hazard Areas (SFHA) on Flood Insurance Rate Maps (FIRMs) that are distributed to local governments (see table 3). Regions with a 1 percent probability of flooding in any year, also called a 100-year floodplain or base flood zone has been used as the standard regulatory floodplain. An area with a 0.2 percent chance of flooding, also referred to as a 500-year floodplain, extends beyond the 100-year floodplain and is subject to fewer flood insurance and development requirements. FIRMs and SFHAs define the high, moderate, and low-risk areas based on actuarial data, (un)known base-flood elevations, and former, current, and in-progress flood-control programs.

Table 3. Federal Emergency Management Agency (FEMA) Flood-Risk Zones

Flood-Risk Zones	Zone Label	Annual Flood-Risk	Flood Insurance
High Flood Risk	A, AO, AH, A1-A30, AE, A99, AR, AR/AE, AR/AO, AR/A1-A30, AR/A, V, VE, V1-V301	1 percent	Mandatory for property owners
Moderate or Low Flood Risk	B, X	0.2 percent	Optional
Undetermined Risk	D	Undetermined	Optional

Even though the 100-year floodplain is a standard in national-scale flood-risk mapping and insurance, the stiff regulatory delineation has been criticized as arbitrary, inaccurate, misleading, and outdated (Dingman and Platt 1977; Junk, Bayley, and Sparks 1989; Kunreuther and White 1994; Burby 2001; Larson and Plasencia 2001; Pinter 2005; Tingsanchali 2012; Brody et al. 2013; Highfield, Norman, and Brody 2013; Meitzen et al. 2018; Gori 2019). The flood insurance or building requirements that apply within the 100-year floodplain do not apply even one foot beyond the delineated boundary, even though the risk reduced is minor to absent (Dingman and Platt 1977; Kusler and Larson 1993; Burby 2001; Pinter 2005; Brody et al. 2013; Highfield, Norman, and Brody 2013). The maps do not account for urban population change, new construction, and land-use conversion. Nationwide updates are costly and time-consuming, which results in maps that do not reflect the local landscape and flood risk (Plate 2002; Ntelekos et al. 2010; Brody et al. 2013). Instead of statistical probabilities, floodplain maps should incorporate geomorphic features to delineate floodplains and flood-risk more accurately.

Floodplains and Flood Policy

Floods are inevitable, and urban monetary flood losses and human injuries exceed those in rural areas. The synergistic effects of climate change, impervious land cover, aging levees and dams, and higher population density result in a heightened risk to people and property (Burby 2001; Larson and Plasencia 2001; Tockner and Stanford 2002; Brody et al. 2008; Majewski 2008; Muñoz et al. 2018). Floods consistently cost billions of dollars, and Texas is no exception with more flood-induced property damage than any other US state (Brody, Kang, and Bernhardt 2010; Ntelekos et al. 2010). Holistically ranking floods is challenging because of the unique location and conditions; however, physical and social metrics are commonly used to describe and compare floods (Nunes Correia et al. 1998). For instance, meteorological floods are quantified by precipitation duration and intensity, inundation period, stage, and stream discharge. Socially, human injuries, casualties, and structural damage are frequently used to convey the severity of a disaster (Baker 1975; Brody et al. 2013; Rubenstein 2015).

Flood-control approaches are broadly sorted into three categories, (1) avoidance, (2), resistance, and (3) resilience. Avoidance includes proactive planning that aims to prevent damages before they occur rather than only reacting to a situation (DeBarry 2004). Resistant approaches include primarily structural projects that bar or divert floodwaters from their would-be path and include dams, levees, dikes, and flood channels. Artificial levees and dams provide an illusion of security that attracts development and adds land value. At the same time, floodplain regulations discourage development due to the increased cost of flood insurance and studies required for plats (Park and Miller 1982; Philipi 1994; Myers and Passerini 2000; Pinter 2005; Olsen 2006; Majewski 2008; McDonnell 2015; Alexander 2015; Rubenstein 2015). Federal and state governments can declare policy floodplain and flood-control recommendations policies, but local governments control the operation of on-site flood-control techniques. As opposed to ecological resiliency, which is defined by an environment's ability to recover after being destroyed, engineering resiliency seeks to minimize damage to humans through nonstructural techniques, including zoning restrictions, buyouts, floodplain restoration, and flood insurance.

Federal flood insurance is a nonstructural flood-mitigation strategy that lowers homeowners' economic loss but has been critiqued for fiscal, ethical, and inefficacy flaws (Burby 2001; Ntelekos et al. 2010; Lee and Jung 2014; McDonnell 2015). The NFIP provides discounted flood insurance premiums for participating communities at about half of the rate charged by private insurance companies. Not only has the program added billions of dollars to the national debt, but it presents the illusion of lower risk and allows property owners to rebuild in the same location. Whether the discounted insurance encourages in-floodplain development is debated, but it lessens the insurance expense of building and operating in a flood-prone area (Brody et al. 2013; McDonnell 2015). Flood protection techniques are most effective when used in combination. Public safety, environmental conservation, and economic growth do not have to compete in flood and floodplain management. The federal government has overarching floodplain policies, but the state, county, and city governments also apply their respective policies to their spatial and jurisdictional scale. To compare the institutional levels, the State of Texas, Hays County, and the Cities of San Marcos, Wimberley, and Woodcreek were chosen as case studies.

Study Area

The State of Texas has diverse environmental and social issues (Wurbs 2004). Texas is divided longitudinally into a wet, coastal east and dry, western uplands. Latitudinally, the state has a hot south and cooler north. Central Texas, colloquially known as the "Hill Country," includes a belt along the Balcones Escarpment known as "Flash Flood Alley" (fig. 1) due to its frequent and devastating flash floods (Dobie 1948; Baker 1975; Earl and Vaughan 2015; Saharia et al. 2017). Central Texas floods exceed the discharge magnitude of floods in similarly sized watersheds due to the synergistic effects of climate, topography, and urban development (Baker 1975; Earl 2007). Moreover, in recent decades (1970–1999), the magnitude and variability of high precipitation events have increased compared to historical records (1895-1969) (Hunt et al. 2012).

Figure 1. Map Showing Flash Flood Alley (Hernandez 2015)

Throughout the recorded history of central Texas, floods have significantly shaped the natural and social landscape (Caran and Baker 1986). The region's subtropical latitude receives moisture from the Gulf of Mexico, and the orographic rise releases precipitation seasonally with peaks in October and May. The region's fractured limestone bedrock, rugged topography, high drainage density, and thin topsoil amplify floods and flash floods (Caran and Baker 1986; Dixon 2000; Hunt et al. 2012; Earl and Vaughan 2015; Furl et al. 2018). As populations increase statewide, urban development encroaches into floodplains, threatening the natural environment and increasing the risk to human lives and structures (Larson and Plasencia 2001).

Within "Flash Flood Alley" is the Blanco watershed, which is characterized by hydrologic extremes (fig. 2) covers an area of 440 square miles (sq. mi.). Named for its main channel, the Blanco River is fed by headwater streams and one larger tributary, the aptly named Little Blanco River. The Blanco River watershed is technically two HUC 10 watersheds combined, the Upper Blanco and Lower Blanco Watersheds. However, it is managed by the Guadalupe-Blanco River Authority (GBRA) as one watershed unit.).

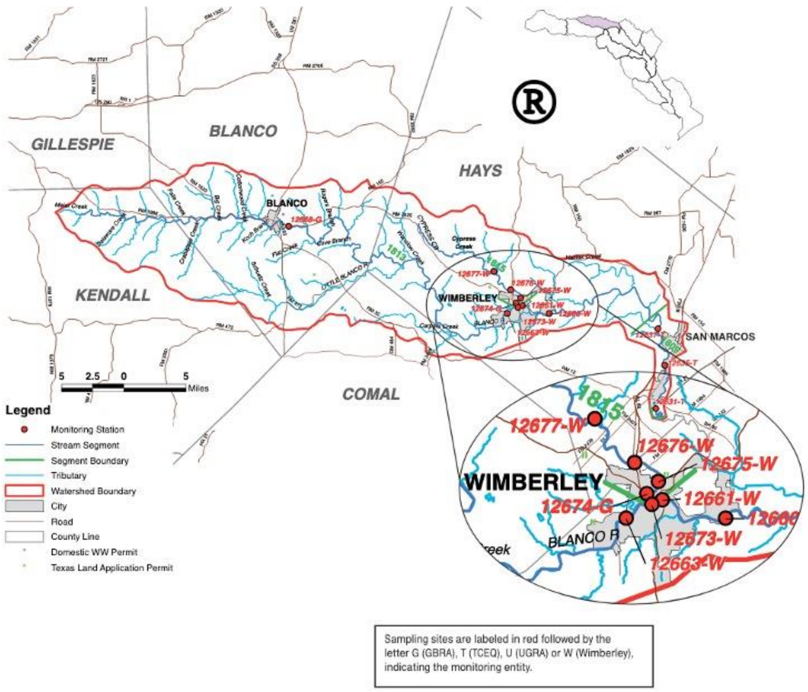

Figure 2. The Blanco River Watershed (Guadalupe-Blanco River Authority 2019)

The watershed crosses Blanco, Comal, Hays, and Kendall counties and includes the cities of Blanco, San Marcos, Wimberley, and Woodcreek along the main channel. The cities of San Marcos, Wimberley, and Woodcreek are uniquely connected hydrologically and politically. All three incorporated cities are within the same county, watershed, and along the Blanco River. Although the City of Blanco is incorporated and within the watershed, it is outside of Hays County. Incorporated municipalities have local governing rights that unincorporated towns and villages do not, so the incorporated status was essential to the case study cities. Since headwater activity and floodplain management can have compounding effects downstream, the cities' upstream-downstream connection along the same channel was also central. That being said, they vary in population, land area, and history (see tables 4 and 5).

Table 4. Municipalities' Basic Information

Municipality	Coordinates	Land Area Estimate (sq. mi.)	Year Incorporated	Type of Municipality
San Marcos	29_o 53’ 00” N, 97_o 56’ 29” W	30.0	1851	Home Rule
Wimberley	29_o 59’ 51” N, 98_o 05’ 55” W	9.0	2000	Type A General Law
Woodcreek	30_o 01’ 42” N, 98_o 06’ 40” W	1.1	1984	Type A General Law

Table 5. Municipalities' Population Change, 1990–2010 (US Census Bureau)

Municipality	1990	2000	2010	Percent Increase
San Marcos	28,743	34,733	44,894	56
Wimberley	2,403	3,797	2,626	8
Woodcreek	889	1,274	1,457	64
Combined Total	32,035	39,804	48,977	53

Texas municipalities have broad authority to promulgate and enforce their ordinances. However, counties are limited to specific responsibilities granted by Texas Legislative rules and have jurisdiction outside of city limits and extraterritorial jurisdiction (ETJ) (Tex. Const. art. XI; Tex. Loc. Govt. Code §9.001). Counties are responsible for floodplain permitting in the unincorporated territories that include towns, villages, and census-designated areas (CDA). Hays County defers to the Federal Emergency Management Agency’s (FEMA) Flood Insurance Rate

Maps (FIRM) and Special Flood Hazard Area (SFHA) designations, complying with the minimum standards.

In addition to population, territorial, and (un)incorporation status requirements, public elections decide whether a town will qualify for a municipality classification (Loc. Govt. Code, §6.001 et seq.). The legal status of municipalities determines statutory powers, the right to establish and amend a city charter, and election rights. The Texas Constitution and Local Government Code set conditions for Type A, B, and C General Law municipalities, Home Rule municipalities, and Special Law municipalities (Tex. Const. art. XI, §4; Tex. Loc. Govt. Code, §5.001 et seq.). Regulations are generally stricter in cities because of the power to create and implement ordinances by the governing personnel, city councils, and majors in municipalities and the Commissioners Court for Hays County.

Methods

Text mining aims to discover relationships and associations among unstructured data, as opposed to data mining based on structured, qualitative data (Rao and Dey 2011). The text-mining methods performed for other qualitative case studies were adapted to fit the needs, text forms, and sources for this project (Smit 2002; Lewis 2004; Sebök 2015; Paulus et al. 2017). Atlas.ti, a popular qualitative data analysis software(s) QDAS, was used to code and assign author-generated categories based on the content of the documents (Dey 1993; Smit 2002). QDAS are based on traditional qualitative analysis methods but include computer-assisted advantages, including quick-term identification and the flexibility of changing codes and code groups after the initial coding. On the other hand, image files (.jpg, .tiff, .png, and some .pdf) required manual hand-coding as the software did not read the text accurately, if at all. The files were imported and sorted within the project file or “hermetic unit” (Lewis 2004).

The documents were sorted by institutional level, author, and type of document. For example, the CoW’s document groups were ordinances, resolutions, plans, and codes, For the US Federal level, the US Code, Public Laws (PL), agency-authored documents (by the agency), and Executive Orders (EO) were grouped to describe and organize the mass of documents. Description is a basis for analysis, but first, the volume of text needed to be reduced to reduce noise. Although the goal is to distill the larger body of text, it is critical to start with a pool that includes all resources to avoid a drastically biased initial sample (Thomas and Harden 2008). Manual screening, text recognition, screening prioritization, in vivo coding, and document summarization were used to assess the documents.

The primary source documents were accessed through official government websites and databases, and query terms were used to filter documents and sections in the initial search of databases and the continued search in Atlas.ti. Only lawful documents were considered; any omitted, repealed, or failed bills were excluded. The methods were set on a premise of purposeful search, which introduces a level of bias, but considering the data source limitations, the bias was minimal (Thomas and Harden 2008; Thomas, McNaught, and Ananiadou 2011; Rao and Dey 2011). Information retrieval was used to systematically identify and extract text excerpts related to the question or topic (Thomas, McNaught, and Ananiadou 2011). Document summarization separates sentences into information fragments that are treated as independent, and those information fragments are coded verbatim.

For example, an excerpt from the TWDB 1968 State Water Plan (SWP) states,

> "Although *floods* generally cause serious *economic losses* in rural areas, the effects of severe *flooding in urban areas* in terms of human suffering, disruption of normal community life, and long-range economic losses result in public attention being focused largely on the flood problems of the cities" (emphasis added) (TWDB 1968, III-22).

The fragments, in italics, are 'floods,' 'economic losses,' and 'flooding in urban areas.' Fragments are not limited to single words but are used when modifiers are necessary for context. A certain level of discretion is required when deciding with words to include or exclude. 'Flooding' and 'urban areas' could be treated as independent fragments, but the connecting 'in' changes the meaning and context of 'flooding.' The excerpt is referring to flooding in urban areas, not flooding outside of urban areas, or flooding generally, and urban areas separate from flooding. Additionally, because 'in' is part of a preposition phrase modifying 'flooding,' it was appropriate to tag the phrase 'flooding in urban areas' as one fragment. The minutiae might seem insignificant with the entire excerpt displayed; however, in further steps, the fragments must convey the most accurate essence of the excerpt, subsection, or section. Including too many fragments and codes for a single subpart muddies the summarization to the point where they are useless. For example, both 'economic losses' and 'long-term economic losses' do not need to be extracted as fragments just as 'flooding in urban areas' and 'flood problems of the cities' do not need to both be included because they refer to the same topic

Screening (the manual document search), term recognition (the inclusion of documents and subparts based on relevance), and priority searching (the weighting of query terms) were used to create a timeline that provides a condensed record of policy changes and significant trigger events. Federal statutes were found using the Office of the Law-Revision Counsel of the United States (uscode.house.gov). The US Code includes current legislation and citations to its coordinating PL. The State of Texas's two statutory documents are the Texas Constitution and the Statutory Code (https://statutes.capitol.texas.gov/). Hays County and the Cities' documents were accessed through their respective online resources.

Query terms were designed to encompass pertinent sections but reduce excess entries that would slow the screening process. However, false positives are less important than false negatives. Starting with a large pool and eliminating false positives in the later stages is preferred to re-checking every source document or missing important text. Primary query terms, represented with an Arabic number, were established before the screening and informed by common and scientific definitions. Auxiliary terms refined the results under primary terms and were added using Boolean search parameters. Table 6 shows the query terms hierarchy.

Table 6. Query Terms

Primary Query Term		Secondary Query Term		Suffixes	
1	Floodplain A, B, C, H; a	A	Development a	a	-s
2	Flood plain A, B, C, H; a	B	Buffer a	b	-ment
3	Riparian B, C, D, E, H	C	Conservation	c	-mental
4	Wetland C, H; a	D	Vegetation	d	-ine
5	River B, C, D, H; a, d	E	Forest A	e	-ing
6	Flood F, I, K, L; a, e	F	Control		
7	Dam(m) A, G; a, e	G	Construction		
8	Levee a	H	Protection		
9	Environ b, c	I	Mitigation		

10	Green J	J	Space A		
11	Storm K, L	K	[space] Water		
		L	Water		

The query terms were screened by priority, from most directly (1) to least directly (11) connected with floodplain policy. Primary query terms were searched with and without the auxiliary terms. ‘Floodplain’ and ‘flood plain’ were treated as alternative spellings of the same primary query term although they contain a space character. The secondary query terms, represented by capital letters, were always paired with a primary term. They are not ranked by priority but ordered to parallel the primary terms list roughly. The suffixes, represented by lowercase letters, are not ranked by priority and may follow a primary or secondary term. Anything written in brackets represents a keyboard stroke, not the word written. If a primary term was combined with a secondary term or suffix, it is noted on the second line in the query term’s cell. For example, the primary query term would be “floodplain,” and a Boolean search using a primary and a secondary term would be “floodplain” AND “development,” which would only return entries with “floodplain development” in the text. The screening procedures were repeated with all government scales and documents.

For this project, a ‘document’ is the entire data set. A ‘section’ is a significant portion of the document, such as a chapter, and a ‘subsection’ is contained within a section. An ‘excerpt’ is a fragment of the subsection, the length of a sentence or a paragraph. Short documents were not divided into sections and subsections, but expansive documents need to be reduced to workable lengths. Table 7 shows an example using CoW’s Code of Ordinances.

Table 7. Document Subparts

Classification	Example	Word Count	Percentage of Document
Document	Code of Ordinances (CoW)	262,560	100
Section	Chapter 9 "Planning and Development Regulations"	132,405	50 (50.428)
Subsection	"Sec 9.02.008 "Definitions and interpretation"	4,905	1.9 (1.868)
Excerpt	"Floodplain. Channel of a waterway and the adjacent land area subject to inundation during the design storm"	17	0.006

The CoW's Code of Ordinances is a complete document and is not contained within a set of documents. Chapter 9, "Planning and Development Regulations," is a significant section but contains too much excess text. "Sec 9.02.008 'Definitions and interpretation' is a focused subsection, and "Floodplain. Channel of a waterway and the adjacent land area subject to inundation during the design storm" is a pinpoint excerpt implemented by the City. Of the 12 chapters in the Code of Ordinances, Chapter 9 is the largest, accounting for about 50 percent of the entire Code. The second-largest chapter is chapter 4, "Building Regulations," accounting for about 14 percent of the Code. Building and development regulations are a high priority and are more regulated than other city management areas. The cities use legal cataloging platforms for publishing their codes and ordinances. The codes were exported to text (.txt) or Microsoft Word (.docx) file formats then imported to Atlas.ti. The subpart containing the query term was read, excerpts and fragments were saved as a quotation, and coded. Although each city uses a different firm, standard features, allow the user to search, send, and save within the publishing site.

Codes were grouped into themes (e.g., development, conservation, or disaster management). For example, from the query term "floodplain," several themes emerged: development (e.g., permitting, construction), flood-mitigation (e.g., dams, zoning), and environmental quality (e.g., soil erosion, water quality). Table 8 lists the policy-making body with their respective documents.

Table 8. Policy-making Bodies and Documents

Policy-making Body	Documents
City of San Marcos	Code of Ordinances Hazard Mitigation Plan Land Development Code Ordinances
City of Wimberley	Code of Ordinances Comprehensive Plan Hazard Mitigation Plan Ordinances Parks and Recreation Master Plan Resolutions
City of Woodcreek	Code of Ordinances Hazard Mitigation Plan Ordinances Parks and Recreation Master Plan Resolutions
Hays County	Development Regulations Hays County 2015: Flooding Events After Action Report Hays County Parks, Open Space and Natural Areas: Master Plan Ordinances
Texas Legislature	House Bills Senate Bills Statutory Code Texas Constitution
Texas Water Development Board	State Flood Assessment State Water Plans
United States Congress	Executive Orders Federal Register Public Laws US Code

Results

The results are two-part. The text-mining methods were used to find and assess current policy documents and the events that have led to modern policy. The summarization of major policy documents was combined with basic institutional and date information to create the timeline entries, which were then cross-checked against other timelines and databases for consistency. Major trigger events were either referenced in the original document or informed by the literature (Hutchins 1961; Kaiser 1987; Knopf et al. 1988; Changnon 1996; Bath 1999; Miller and Miller 2000; Myers and Passerini 2000; DeBarry 2004; Wurbs 2004; Hooper 2005; Norwine, Giardino, and Krishnamurthy 2005; Burnett 2008; Estaville and Earl 2008; United States Army Corps of Engineers 2010; Rubenstein 2015; Legislative Reference Library n.d.). Minor amendments were excluded to reduce unnecessary noise, but major amendments are noted. The text-mining results include basic descriptive statistics of the federal, state, and municipal codes that describe the floodplain policies' placement in the respective governing and managing documents.

Text-mining Results

A total of 122 documents were included in the initial text body. The documents were published with subparts that were kept as the respective subpart divisions. The sections and subsections were relative to the document's total length, but excerpts remained within the same average word-count range (10-50 words). The initial query term search resulted in a wide range of false positives, depending on the query term and document. Expansive documents, such as the US Code, had more false positives than shorter documents, such as the State Water Plans and

City Code of Ordinances. Figure 3 shows the percentages of false positives in the US Code sorted by query term.

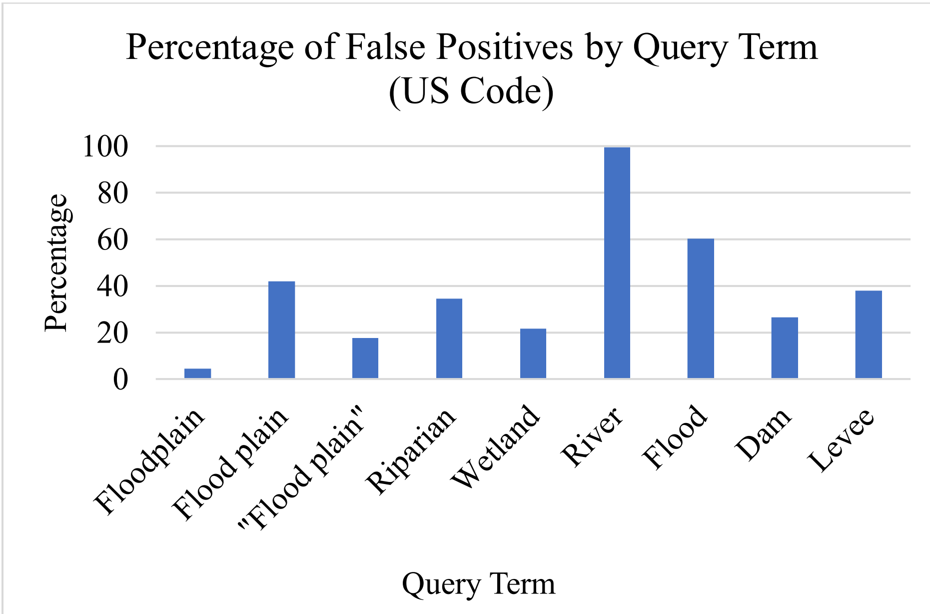

Figure 3. Percentage of False Positives by Query Term

In addition to the length of the document, the more specific the query terms led to the fewer false positives. The query term ‘river’ returned 99 percent false positives because of the multiple uses in individual river and river basin projects in the Code that were relevant to this study area. Although this indicates a policy of including provisions for rivers, such as the Mississippi River and Potomac River (Maryland), and river basins, including the Columbia River Basin (Pacific Northwest) and Erie River Basin (New York), it was too separated from this project to count as a true positive. The query term ‘flood plain’ in double quotations was the Boolean search term.

Three titles contained 85 percent of the true positives (fig. 4). About 43 percent were located in “The Public Health and Welfare” sections, largely due to the “National Flood Insurance Program,” “National Levee Safety Program,” and “Water Resources Planning” subsections. The section “Navigation and Navigable Waters” contained the subsections “Water Resources Development” and “Flood Control” that housed a lot of applicable floodplain codes and statutory citations. The “Conservation” section housed chapters on wetland conservation and resources, including the subsections “Wetland Resources” and “Erodible Land and Wetland Conservation and Reserve Program.”

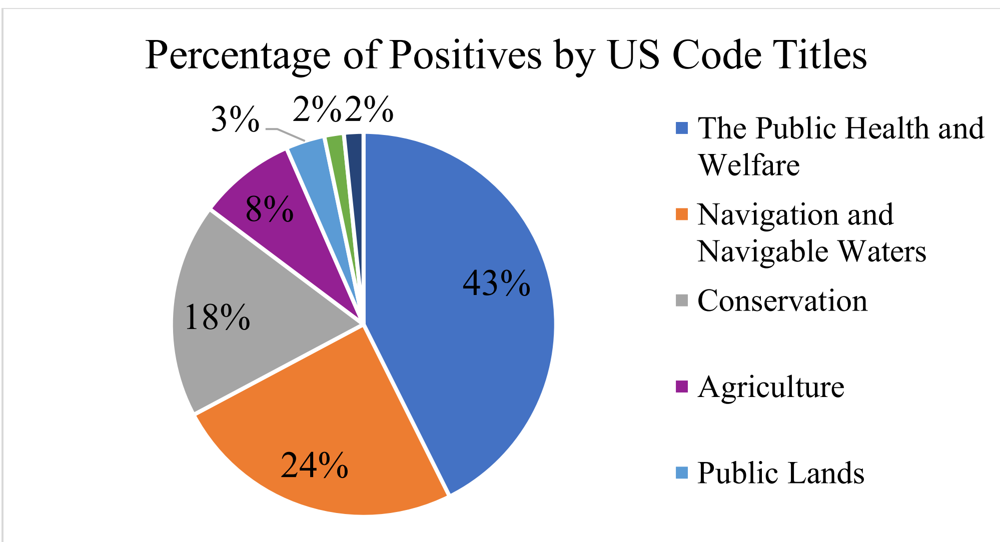

Figure 4. Percentage of Positives by US Code Title

Texas floodplain laws are divided into 15 sections (fig 5). The “Local Government Code” contains the most floodplain-related codes because local communities are primarily responsible for floodplain management. Among other subjects, the “Water Code” authorizes state and local water resource governing, managing, and planning.

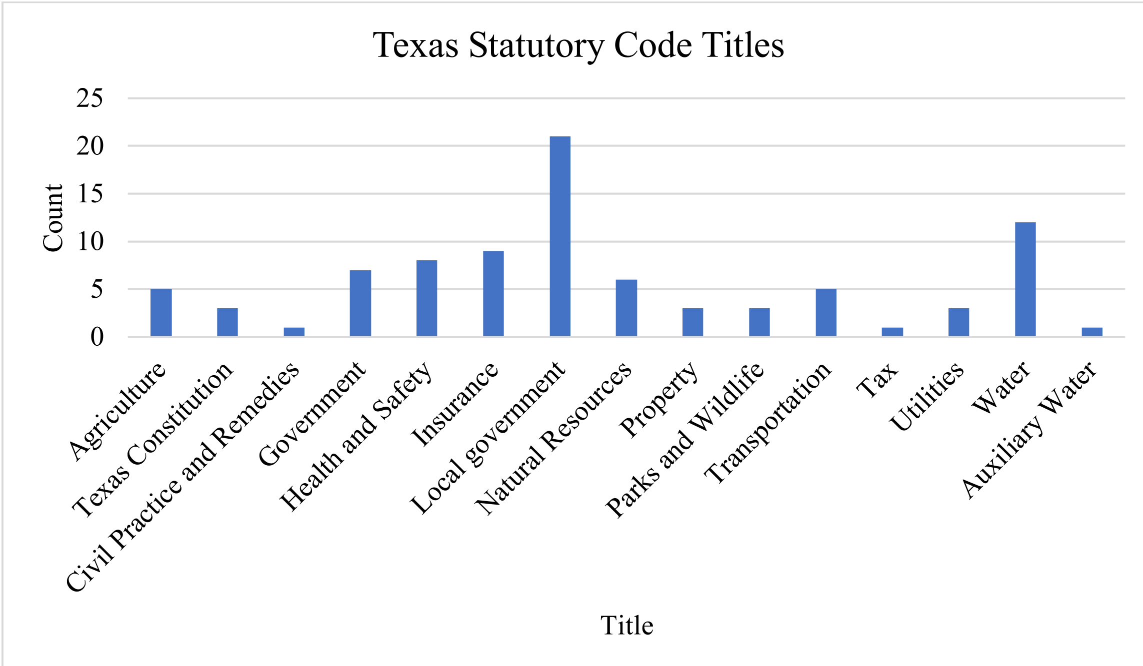

Figure 5. Positives by Texas Statutory Code Titles

At the local scale, each city had one chapter that contained most of the floodplain-related codes. 87 percent of The City of San Marcos's floodplain codes and ordinances were categorized with "Flood Damage Prevention" (fig. 6).

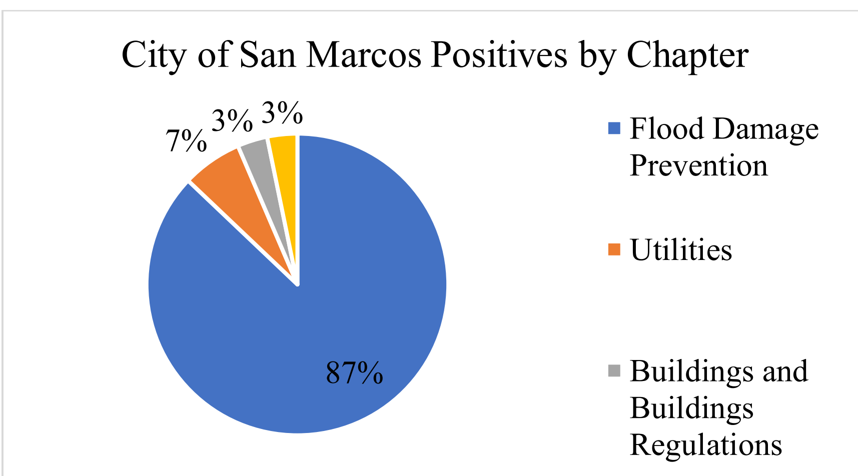

Figure 6. Percentage of City of San Marcos Positives by Chapter

In contrast to San Marcos, the City of Wimberley prioritized floodplain building and development procedures (fig. 7) using the 100-year floodplain as the prohibition boundary for floodplain development. The City of Wimberley mandates the minimum water quality buffer zone setback distance in “Zoning.”

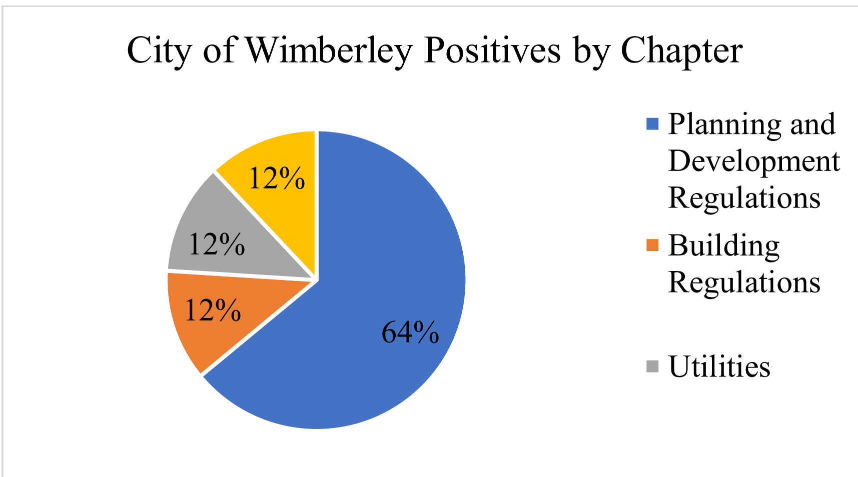

Figure 7. Percentage of City of Wimberley Positives by Chapter

Whereas the Cities of San Marcos and Wimberley have floodplain laws and regulations divided among a few sections, the City of Woodcreek manages floodplains across six categories. “Subdivisions,” “Zoning,” “Building Regulations; Construction,” and “Site Development” are closely related but distinguished by the City of Woodcreek (fig. 8). Like San Marcos, Woodcreek's primary floodplain management is related to "Flood Damage Prevention."

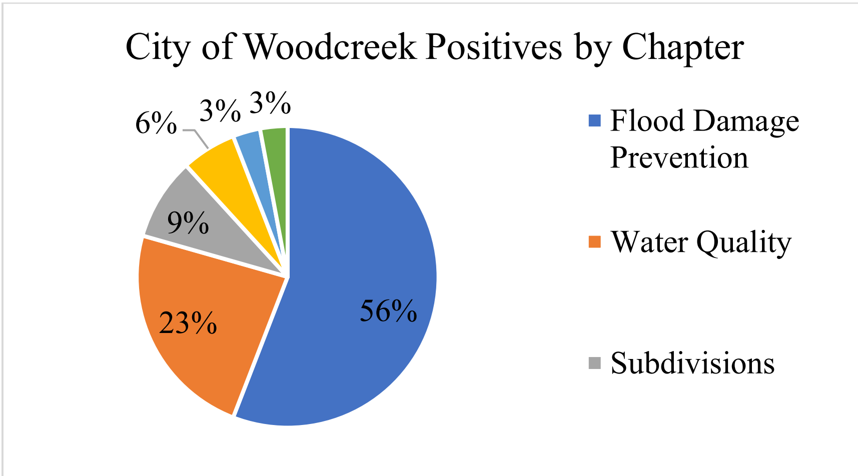

Figure 8. Percentage of City of Woodcreek Positives by Chapter

Timelines

The timelines are grouped by government level in descending order (federal, state, county, and city) and include milestone legislation, agency activity, and trigger events arranged in chronological order. A historical perspective contextualizes present policies in the United States at different political and spatial scales.

US Federal Timeline

The United States Congress is authorized to pass Public Laws (PL), which are added to the US Code. Lawmakers delegate the implementation and enforcement procedures to federal agencies or states. The US federal timeline includes natural disasters that indirectly impacted Texas's floodplain policies by influencing federal policy that applied to Texas. The timeline does not include every national natural disaster. Figures 9–16 show abbreviated timelines for the text entries.

1802 The United States Army Corps of Engineers (USACE) was reorganized as a branch of the federal government, after its initial creation in 1779.

1849 Large floods across the country prompted Congress to assign USACE to study river and wetlands conditions to design and construct flood-control solutions.

1850 An Act to enable the State of Arkansas and other States to reclaim the swamp lands within their limits" (ch. 84, 9 Stat. 519), also called the Swamps Lands Act, permitted the States to sell and drain wetlands for agricultural land use.

1861 The "levees-only" policy set by Congress and USACE put a heavy reliance on structural solutions, a policy that has lasted more than 100 years.

1879 Congress reconciled the federal government's responsibility to address flood control.

1899 The "Rivers and Harbors Act" (RHA) (ch. 425, §9, 30 Stat. 1151; 33 USC §§401, 403), prohibited the obstruction, excavation, filling, and any modification of obstructions of all navigable waters of the United States (WOTUS).

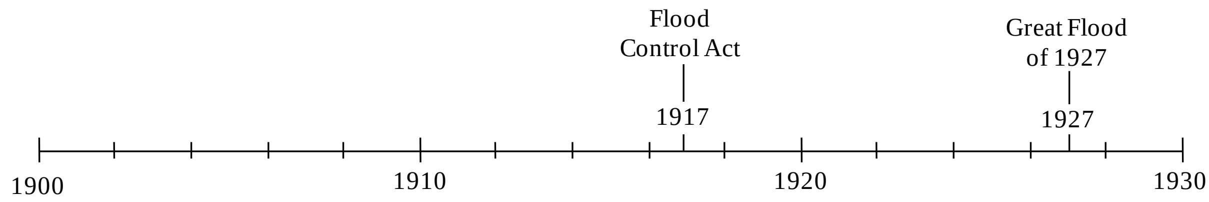

Figure 9. US Timeline, 1900-1930

1917 The Flood Control Act (Levee Act) of 1917 was designed to mitigate flood damage along the Mississippi, Ohio, and Sacramento Rivers. Despite the federal Act, local communities were responsible for 50 percent of the funding and future maintenance.

1927 The Great Flood of the Mississippi River brought national attention to flood-control techniques.

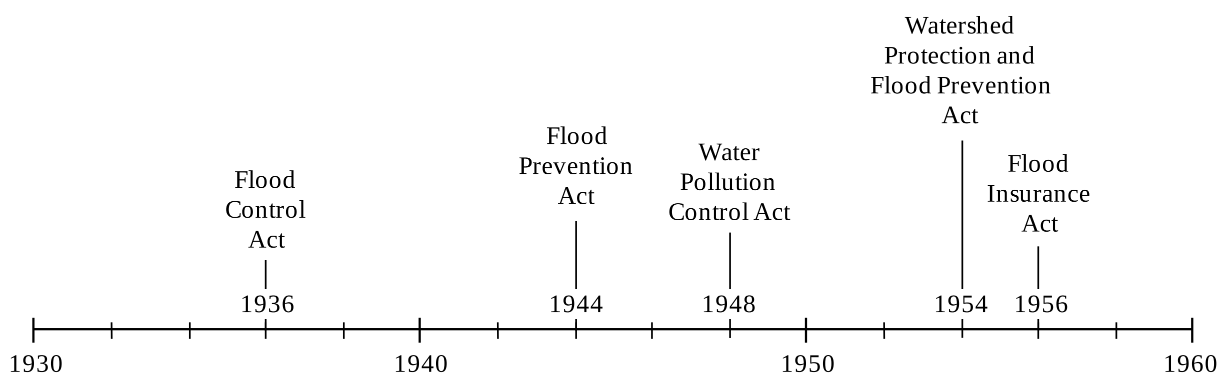

Figure 10. US Timeline, 1930-1960

1936 The Great Flood of 1927 (Mississippi River) spurred the creation of the Flood Control Act

(FCA) of 1936. Flood codes were intended to protect people and property, following the thousands of casualties and millions of dollars in damages. At this time, floodplain-specific regulations were not in place. The Act cemented flood mitigation as a national priority for federal lawmakers and agencies.

1939 Congress expanded USACE's authority to construct water supply and flood control structures.

1941 Allotment for rescue work (55 Stat. 650) set a maximum of $1 million per fiscal year to support flood-control projects. In 1946, it was amended from $1 million to $2 million, and 1950, $2 million was replaced with $15 million.

1944 The Flood Prevention Act (PL 78-354) authorized Soil Conservation Services (SCS) to collaborate with state and local governmental bodies to pursue upland soil erosion prevention techniques and watershed projects. SCS was allowed to work with state and local authorities, but state and local authorities were not mandated to consult SCS or other federal agencies. SCS was later renamed to Natural Resources Conservation Service (NRCS).

1948 The Water Pollution Control Act (WPCA) set regulations for water quality standards for pollutant discharges into a WOTUS.

1950s Flood damages and frequencies increase as urban centers grow.

1954 The Watershed Protection and Flood Prevention Act (PL 83-566) adopted the federal and nonfederal joint efforts to erosion and flood damages by managing soil and water at the watershed scale. It also authorized federal cost-sharing for wetland and floodplain easements.

1956 Federal Flood Insurance Act (PL 84-1016) established a federal insurance program through the Housing and Home Finance Agency (HHFA)to provide financial relief for losses from floods and tidal disasters. The HHFA established the Federal Flood Indemnity Administration to implement the Act. This is an example of the division between policymakers and implementing bodies.

1958 Seven states had adopted and implemented floodplain management plans.

1959 The United States Geologic Society (USGS) created and published flood-inundation maps that made floodplain boundaries and flood-frequency probabilities accessible to the public. It also marked the era of using flood-frequency as a lateral boundary (e.g., 100-year floodplain).

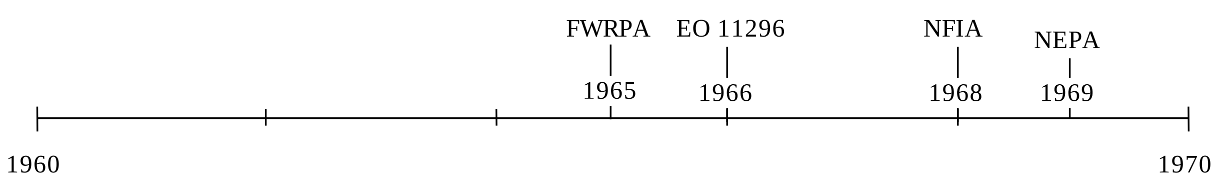

Figure 11. US Timeline, 1960-1970

1960 The amended FCA of 1936 (PL 86-645 §206) mandated that the USACE was required to organize and distribute flood and flood damage information to the requesting state or local body. The USACE created the Flood Plain Management Service (FPMS) to provide technical expertise in floodplain and watershed planning.

1965 The Federal Water Resources Planning Act (WRPA) (PL 89-90) created the Water Resources

Council (WRC) to implement the Act, review, and study water resources.

1966 The Bureau of the Budget's Task Force on Federal Flood Control Policy and created the milestone report, "A Unified National Program for Managing Flood Losses" (HD 465). This marked a critical point in floodplain management by addressing the consequences of in-floodplain development. The report emphasized five central, nonstructural goals and recommendations for success.

1966 EO 11296, Flood Hazard Evaluation, was issued and addressed the need to develop a framework of statutes and agencies to evaluate flood hazards and designate as a primary factor in the use and development of floodplains. The WRC was tasked with implementing the Unified National Program. EO 11296 was later revoked by EO 11988 (1977).

1968 The National Flood Insurance Act (NFIA) (PL 90-448) created the National Flood

Insurance Program (NFIP), which provided flood insurance to communities that adopted and enforced minimum floodplain ordinances. The first insurance policies were sold in 1969. The Act also required the mapping of flood-risk zones in flood-prone areas. This flood-risk-based area mapping has persisted to modern times. The program was established under the leadership of the Department of Housing and Urban Development and was implemented by the Federal Insurance Administration (FIA).

1968 The USGS began to use topographic maps to delineate floodplain boundaries and created flood insurance studies and flood-risk maps for FIA.

1969 The 100-year floodplain is used as the standard for special flood-risk areas. Local communities were required to consider the 100-year floodplain area when designing and applying floodplain management practices.

1969 National Environmental Policy Act (NEPA) (PL 91-190) established environmental quality as a national priority and set legislative and administrative frameworks for evaluating and regulating environmental impact. NEPA covered many environmental issues and policies.

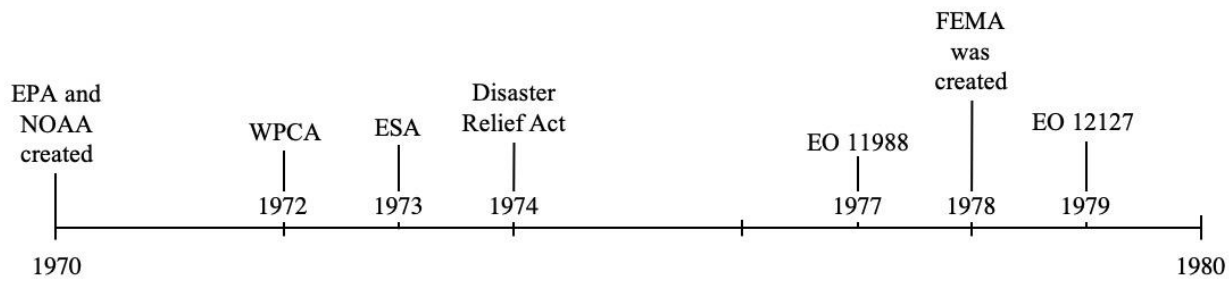

Figure 12. US Timeline, 1970-1980

1970 EO 11514 (35 FR 4247) clarified agency responsibilities of Council on Environmental Quality (CEQ) and those set in NEPA in addition to amending EO 11472 of 1969, "Establishing the Cabinet Committee on the Environment and the Citizens' Advisory Committee on Environmental Quality" (34 FR 8693).

1970 The Environmental Protection Agency (EPA) was created by executive order Reorganization Plan No. 3 of 1970 (35 FR 15623), which organized and outlined the responsibilities of the EPA.

1970 The National Oceanic and Atmospheric Administration (NOAA) was established in executive order Reorganization Plan No. 4 of 1970 (35 FR 15627).

1972 The WPCA was significantly reorganized, amended, and is known as the Clean Water Act (CWA) (PL 92-500). although the short title was officially amended in the 1977 amendments. Section 404 added wetland dredge and fill provisions and expanded USACE jurisdiction over all US wetlands. More than 95 percent of nontidal wetlands are within floodplains, so the sec. 404 amendment indirectly expanded CWA jurisdiction and regulation to floodplains.

1973 The Endangered Species Act (PL 93–205) (ESA) authorized the federal government to create and amend a list of species classified as threatened or endangered. The Act prohibits any taking or harm to a listed species, established cooperative agreements for financial assistance, and set statutory authority for criminal and civil penalties in case of violation.

1974 The Disaster Relief Act of 1974 (PL 93-288) established the statutory authority for the emergency relief system for presidentially declared disasters. It was amended and renamed to the Disaster Relief and Emergency Assistance Amendments of 1988, also known as the Robert T. Stafford Disaster Relief and Emergency Assistance Act.

1977 EO 11988 (42 FR 26951) furthered the precedent of the NEPA, NFIA, and Flood Disaster Protection Act (FDPA). EO 11988 set the policy to avoid floodplain development and explore alternative management strategies. The Federal Emergency Management Agency (FEMA) began implementing EO 11988 in 1980.

1978 The Emergency Watershed Program (PL 95-334, §406) authorized floodplain and watershed protection techniques, including purchasing floodplain easements, reducing surface runoff, and minimizing soil erosion.

1978 The EO Reorganization Plan No. 3 of 1978 (43 FR 41943) created the Federal Emergency Management Agency (FEMA) as an independent agency under the Executive Branch.

1979 EO 12127 (44 FR 19367) consolidated several emergency disaster agencies and administrations, including the FIA.

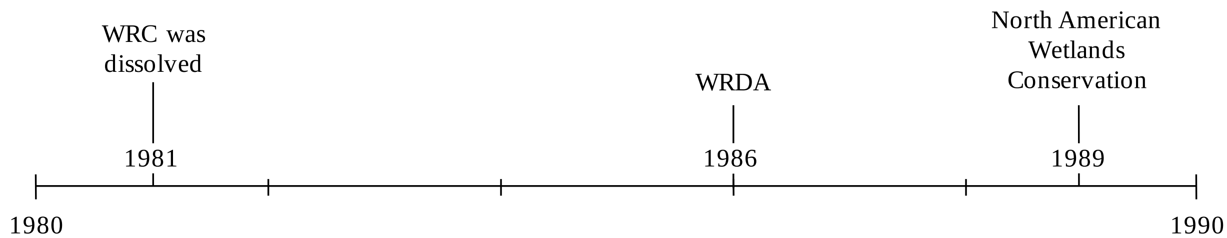

Figure 13. US Timeline, 1980-1990

1980 FEMA required that state and local governments pay 25 percent of the public assistance program costs. Previously, state and local contributions were negotiable.

1981 The WRC was dissolved and replaced by a Cabinet Committee on Natural Resources and the Environment, which was dissolved in 1985. The responsibilities were transferred to the President's Domestic Council.

1986 Water Resources Development Act (WRDA) of 1986 (PL 99-662) significantly changed the federal and local relationship in water resource-related dealings. The Act changed the cost-sharing structure where nonfederal bodies were held more responsible for financial and planning decisions.

1989 In reaction to more than 50 percent wetland loss, the North American Wetlands Conservation Act (PL 101-233) protected migratory birds and wetland ecosystems.

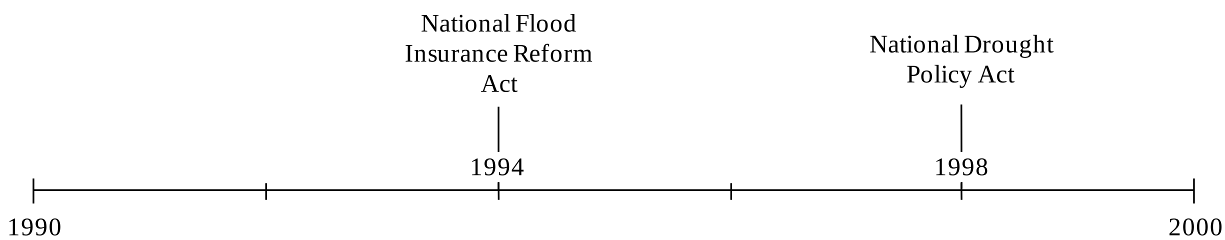

Figure 14. US Timeline, 1990-2000

1993 The Great Flood of 1993 (Mississippi River Basin). The Federal Interagency Floodplain Management Task Force (FIFMTF) was created after the Great Flood of 1993, but there was little implementation of the FIFMTF report's recommendations.

1994 National Flood Insurance Reform Act (PL 103-325) empowered the NFIP and clarified participation requirements, authority, goals, and funding as well as providing incentives.

1999 The WRDA of 1999 (PL 105-53) included the USACE's authority over water resource projects that include bank stabilization, riverine ecosystem restoration, and protection. The Act also assigned the responsibilities of FEMA, nonfederal entities, and interagency agreements.

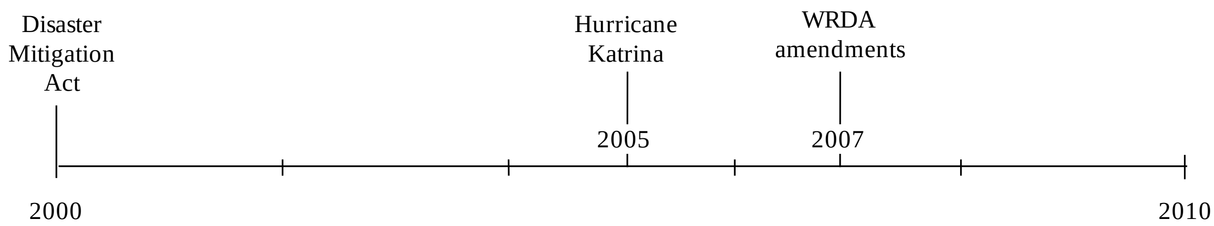

Figure 15. US Timeline, 2000-2010

2000 The Disaster Mitigation Act (DMA) (PL 106-390) established the legal foundation for FEMA planning requirements for mitigation grants. DMA repealed the mitigation planning provisions in the Robert T. Stafford Disaster Relief and Emergency Assistance Act of 1988.

2005 Hurricane Katrina (August 23-31) was one the deadliest and costly natural disasters in the recorded history of the United States. Covering 93,000 sq. mi., it destroyed 350 mi of levees, and hundreds of thousands of buildings. Injury and casualty estimates range from fewer than 1,000 to more than 3,000. The tragedy highlighted weakness in floodplain maps, flood-control structures, and emergency response which elicited national committees, studies, and statutory reform.

2007 The WRDA of 2007 (PL 110-114) amended the previous WRDA and created the National Levee Safety Program implemented by the USACE. A national database about all federal and nonfederal levees, including location, height, general condition, and the calculated risk in case of failure.

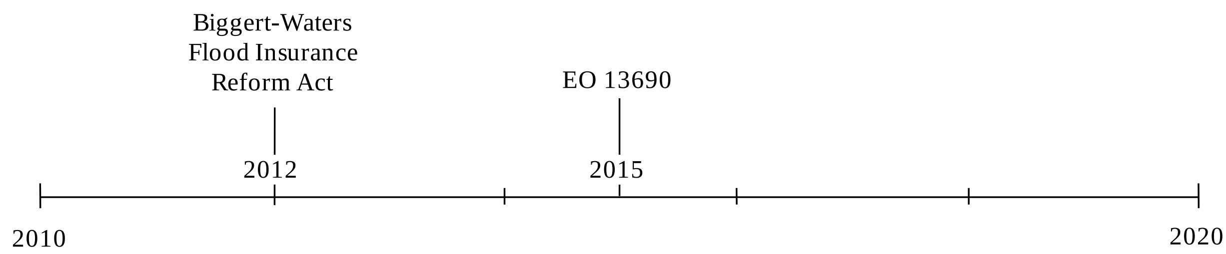

Figure 16. US Timeline, 2010-2020

2012 Biggert-Waters Flood Insurance Reform Act of 2012 expanded the NFIP and required significant reform of the program's rules and implementation.

2015 EO 13690, "Establishing a Federal Flood Risk Management Standard and a Process for Further Soliciting and Considering Stakeholder Input," (80 FR 6425) created new standards for federally-funded flood mitigation projects to set a framework focused on resiliency and preserving the natural state of floodplains.

2015 FEMA published a detailed guide for implementing EOs 11988 and 13690 that cover each section individually for nonfederal enforcement.

2017 EO 13866, "Expediting Environmental Reviews and Approvals for High Priority Infrastructure Projects," (84 FR 12853) and EO 13807, "Establishing Discipline and Accountability in the Environmental Review and Permitting Process for Infrastructure Projects," (82 FR 40463) were enacted and revoked EO 13690 (2015).

State of Texas Timeline

From Texas's admittance as a state in 1845 to 2020, the timeline covers statutory, agency, and administrative changes with the trigger events that incited policy change by state authorities. The State of Texas has two statutory documents, the Texas Constitution and the Statutory Code (https://statutes.capitol.texas.gov/). The Texas Legislature meets every two years, the most recent being the 86th Legislative Session (2019). The timeline includes bills passed from Regular Sessions (RS) and Called Sessions (CS). It does not include trigger events or policy from any other government scale. Figures 17–24 show abbreviated timelines for the text entries.

1845 Texas was admitted as the 28th state.

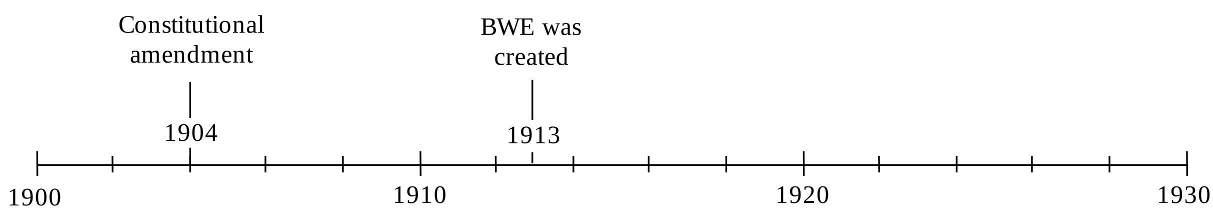

Figure 17. Texas Timeline, 1900-1930

1904 A constitutional amendment authorized the public development of water resources for the state.

1913 The Board of Water Engineers (BWE) was created to oversee statewide water issues, including the appropriation of water rights.

1914 The BWE published the first set of rules and regulations.

1916- 1918 Severe droughts renewed interest in water resource planning and prompted the "conservation amendment" in 1917.

1917 Tex. Const. art. XVI, sec. 59, also known as the "conservation amendment," established the State's ability to regulate and conserve natural land and water resources, which set the statutory authority for future state management of land and water resources, including floodplains.

1929 Texas Legislature created the first river authority (HB 197, 41st Leg. 2nd CS). The Brazos River Conservation and Reclamation District was later renamed to the Brazos River Authority (BRA). This was the first state agency that was solely responsible for managing the water resources for a river basin.

1930s Texas municipalities grew with industry and irrigation practices.

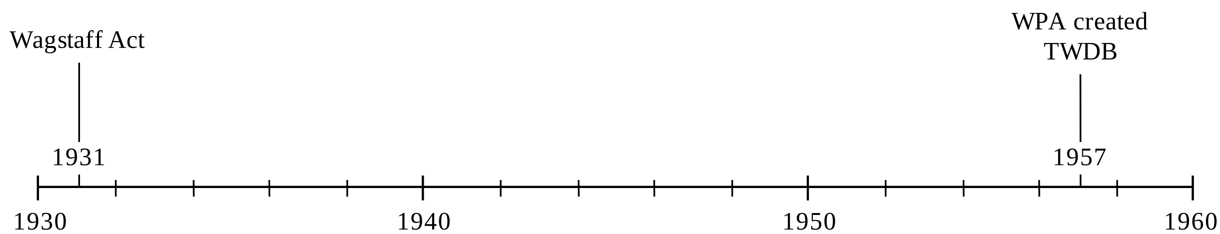

Figure 18. Texas Timeline, 1930-1960

1931 The Wagstaff Act (SB 93, 42nd Leg. RS) determined that certain beneficial uses of water take priority over others. Although the Wagstaff Act was never applied, it prompted the construction of new reservoirs to support the state's growing water demands.

1945 Texas Legislature gave the Texas Department of Health the authority to enforce drinking water quality and supply standards.

1949-1956 The State suffered a historical period of droughts that spurred interest in long-term water planning, notably the Water Planning Act (WPA) in 1957.

1953 The Texas Water Pollution Advisory Council was created and charged with the development of a comprehensive program to control surface water pollution (HB 448, 53rd Leg. RS).

1953 HB 454 (53rd Leg. RS) created the Water Resources Committee to develop a long-term water policy and conservation plan for the state.

1957 The WPA (SB 1, 55th Leg. 1st CS) was the culmination of historic droughts in the 1950s, and the heavy spring rains in 1957. The WPA set a formal procedure for future water planning. The Act also created the Texas Water Resources Planning Division (TWRPD) within the BWE and was assigned water resource planning responsibilities for the state.

1957 The Texas Water Development Board (TWDB) was created by HB 161 (55th Leg. RS), which also set the legislative backing for HJR 3. Constitutional amendment HJR 3, 55th Leg. RS established a trust of $200 million in state bonds to create the Texas Water Development Fund (Tex. Const. art. III, sec. 49-c) to fund local and regional water development and conservation programs.

1960 The Governor requested that the TWDB assume leadership in water planning and prepare a state plan to meet needs.

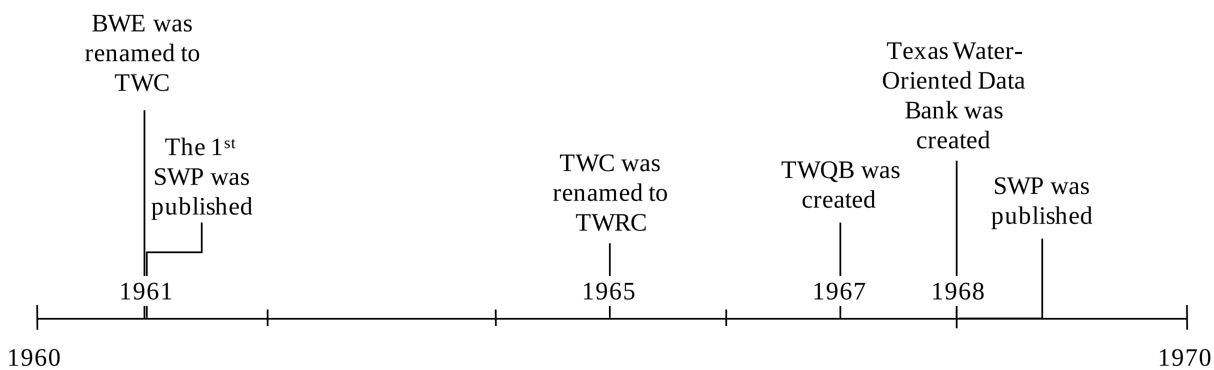

Figure 19. Texas Timeline, 1960-1970

1961 The BWE was reorganized and renamed to Texas Water Commission (TWC).

1961 The State Water Pollution Control Board (SWPB) was created by HB 24 (57th Leg. RS) to monitor and control water pollution in state waters.

1961 The first State Water Plan (SWP) was published by the TWDB. The 1961 SWP acknowledged the need for local attention given the vast diversity within Texas. The plan addressed surface water supply and planning to meet the state's needs until 1980, maintaining a flexible policy to account for future uncertainty.

1963 The Texas Basins Project was part of the Bureau of Reclamation and Corps of Engineers' series of reports that documented the conditions of specific river basins, including dams, navigational features, water bodies, and flood control.

1965 Texas Legislature reorganized the water planning responsibilities under the WPA amendments. TWC was renamed to Texas Water Rights Commission (TWRC).

1966 A Constitutional amendment (Proposition 2) increased the Water Development Fund to $400 million and the approved uses of the fund.

1967 The Texas Water Quality Board (TWQB) was created by the Texas Water Quality Act (TWQA) (SB 204, 60th Leg. RS) to comply with the Federal Water Pollution Control Act of 1948. The TWQB assumed the responsibilities and powers of the Water Pollution Control Board (WPCB).

1968 The 1968 SWP was published and set goals and recommendations to 2020.

1968 The Texas Water-Oriented Data Bank was created by the Texas Legislature.

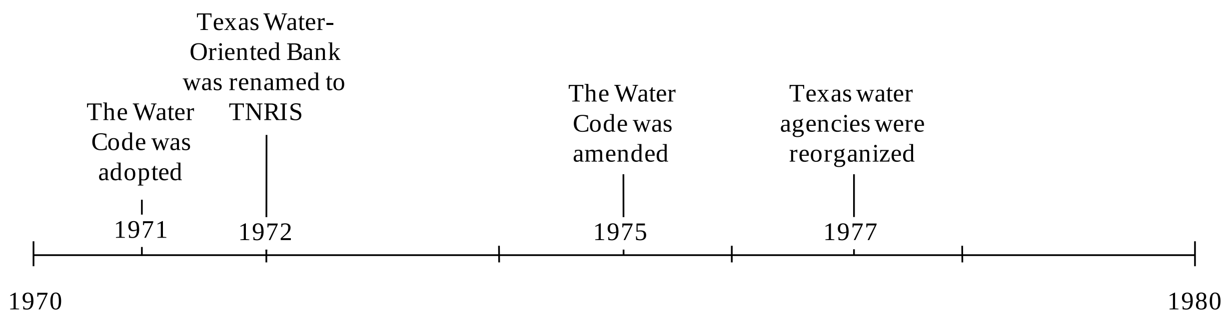

Figure 20. Texas Timeline, 1970-1980

1971 HB 343 (62nd Leg. RS) adopted the Water Code, a formal restructured and amended record of the statutes related to water rights, development, quality, and general laws.

1972 The federal WPCA amendments established waste treatment plans for river basins, including 15 Texas basins that were approved by 1975.

1972 The Texas Water-Oriented Data Bank was renamed to the Texas Natural Resources Information System (TNRIS) after reforming and expanding.

1975 SB 137 (64th Leg. RS) amended the Water Code to include the maintenance of the ecological health of the state's natural resources and directed the state agencies TWRC, TWDB, TWQB, General Land Office (GLO), Texas Parks and Wildlife Department (TPWD) to account for freshwater inflows and conduct thorough environmental impact investigations before granting permits or impacting the natural environment. SB 137 also repealed any laws in conflict with the amendments and made appropriations.

1976 “Flood Plain Management Criteria for Flood-Prone Areas” (44 CFR 60.3) outlined special flood hazard zones, FEMA Administrator responsibilities, and floodplain mapping requirements.

1977 The Texas Department of Water Resources (TDWR) was created to consolidate programs. The TWDB remained as the policy-making body. The Water Rights Commission was renamed to the Texas Water Commission (TWC) and served as a quasi-judicial body to rule on permits. Texas Legislature abolished the TWQB, and it was absorbed into the TDWR.

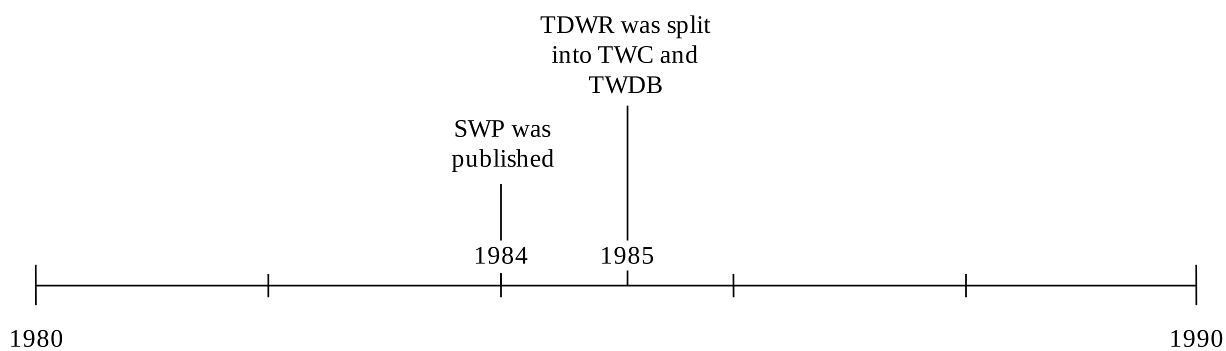

Figure 21. Texas Timeline, 1980-1990

1984 The third SWP was published.

1985 The TDWR was divided into the TWC and TWDB.

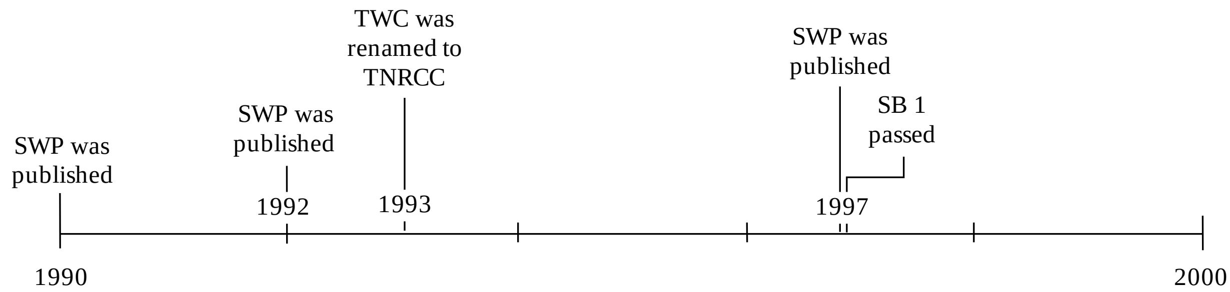

Figure 22. Texas Timeline, 1990-2000

1990 The 1990 SWP was published.

1991 The Clean Rivers Act (CRA) (SB 818, 72nd Leg. RS) established water quality and water quality management standards.

1992 The 1992 SWP was published.

1993 The TWC was renamed to the Texas Natural Resource Conservation Commission (TNRCC).

1996 A statewide drought prompted SB 1 in 1997.

1997 SB 1 (75th Leg. RS) was passed and covered broad areas of State water planning and management. SB 1 charged local entities with developing 50-year regional plans every five years and required the TWDB to include each regional plan into a comprehensive statewide plan for the development, management, and conservation of water resources. The regional plans should include the localities' plan to provide sufficient water in times of drought.

1997 The TWDB set general rules and guidelines to the format, funding, document production, and definitions of mandated interests for 16 Regional Water Planning Areas, which were later renamed to Regional Water Planning Groups (RWPG).

1997 The 1997 SWP was published.

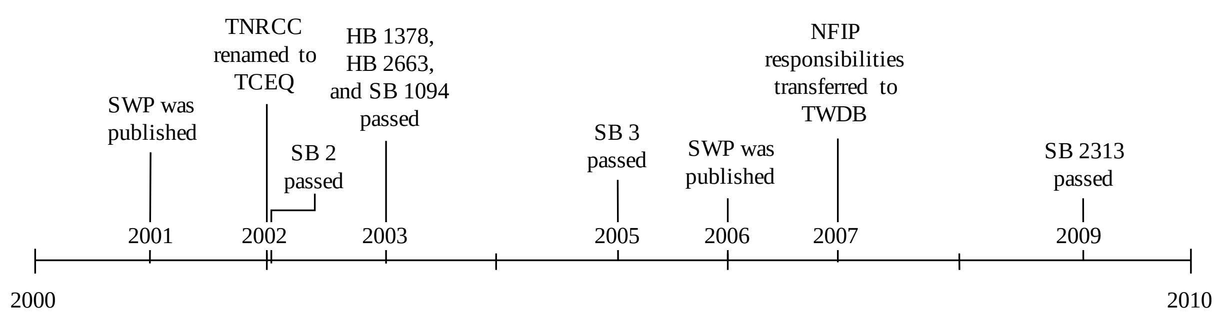

Figure 23. Texas Timeline, 2000-2010

2001 SB 2 (77th Leg. RS) was an extension and successor of SB 1 that amended regional water planning, instream flow provisions, and established the Rural Water Assistance Fund, Water Infrastructure Fund, and Texas Water Advisory Council.

2001 The first SWP after SB 1 was published.

2001 The first RWPG “Water Plans” were published, to be revisited every 5 years.

2002 The TNRCC was officially renamed to the Texas Commission on Environmental Quality (TCEQ).

2003 The 78th Legislative Session included HB 1378, which assigned and clarified water planning and development responsibilities, HB 2663 that created quantifiable metrics for assessing drought contingency plans, and SB 1094, which created the Water Conservation Implementation Task Force to evaluate water conservation needs and strategies to increase water use efficiency.

2004 The Senate Select Committee on Water Policy was created by the Lieutenant. Governor.

2005 SB 3 (79th Leg. RS) based water resource recommendations on the Senate Select Committee on Water Policy (2004) and emphasized water planning frameworks set by SB 1 (75th Leg. RS) and SB 2 (77th Leg. RS.).

2006 Texas EO No. RP-50 established the Environmental Flows Advisory Committee, which was tasked with developing recommendations to balance environmental flows with human water needs using a regional planning approach.

2006 The 2007 SWP was adopted.

2006 The 2006 RWPG plans were published.

2007 SB 3 (80th Leg. RS) established state policy for water resource development, management, and conservation. It repealed the Texas Water Advisory Council and created the Joint Committee on State Water Funding.

2007 The NFIP responsibilities were transferred from the TCEQ to the TWDB.

2009 SB 2313 (81st Leg. RS) passed and established eligibility requirements for funds from the TWDB Water Infrastructure Fund.

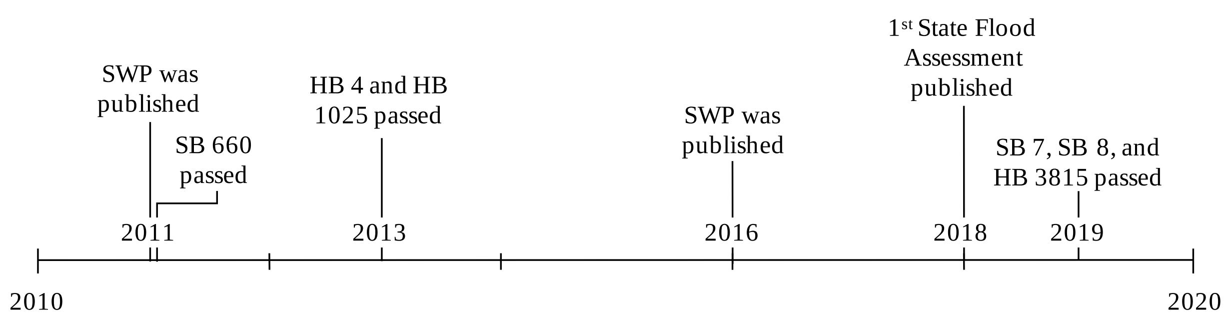

Figure 24. Texas Timeline, 2010-2020

2011 The 2012 SWP was adopted.

2011 The 2011 RWPG plans were published.

2011 SB 660 (82nd Leg. RS) authorized the TWDB to issue bonds without additional constitutional amendments.

2013 Texas Legislature approved HB 4 and HB 1025 (83rd Leg. RS) that authorized a transfer of $2 billion from the Economic Stabilization Fund to the State Water Implementation Fund for Texas (SWIFT) and the State Water Implementation Revenue Fund for Texas (SWIRFT). The purpose was to set aside funding for state water projects for timely execution. Legislature also appointed a special advisory committee to manage SWIFT and SWIRFT.

2016 The 2017 SWP was published.

2016 The RWPG plans were published.

2018 The TWDB published the first State Flood Assessment (SFA).

2019 HB 3815 (86th Leg. RS) included the disclosure requirements of a seller for residential property in or near floodplains, floodways, and reservoirs.

2019 Texas Infrastructure Resiliency Fund created is a special infrastructure fund (SB 7, 86th Leg. RS) for flood mitigation and planning projects.

2019 The Texas Infrastructure Fund Amendment (SB 8, 86th Leg. RS, 16.061) and mandated that a State Flood Plan be completed by September 1, 2024 and every five subsequent years.

2020 Authorized by SB 8 (86th Leg. RS), the TWDB designated 15 regional "flood planning regions" that roughly follow river basin boundaries (fig. 25).

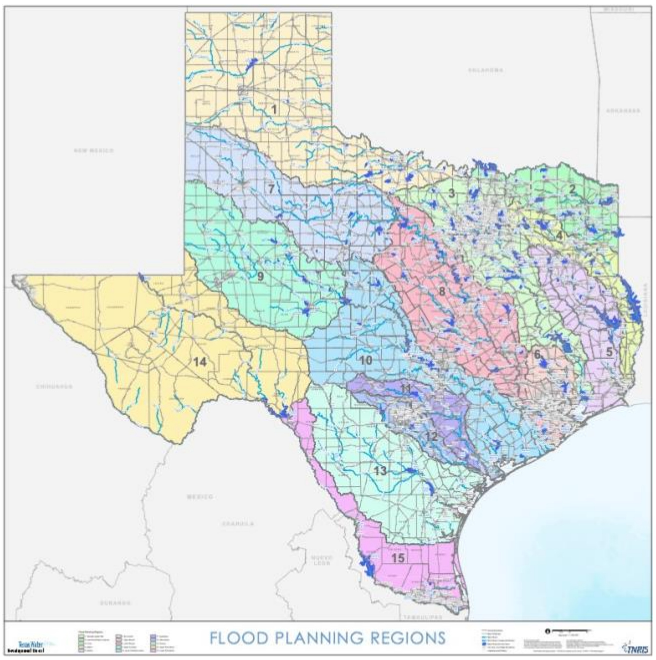

Figure 25. Texas Flood Planning Regions (TWDB 2020)

Hays County Timeline

Hays County has limited power to create and enforce policy headed by the Commissioners Court of Hays County (Commissioners Court or Court). The four commissioners and one county judge are the policymakers at the county scale. Although the county area encompasses multiple cities, it does not have the same top-down jurisdictional authority that the state and federal governments have. Figures 26–28 show abbreviated timeline figures for the following timeline entries.

1848 Hays County was created from a portion of Travis County with San Marcos as the county seat.

1876 The Texas Constitution was adopted, which mandated that every county have a commissioners court of four precinct commissioners and a county judge. Tex. Const. art. V, sec. 18(b) authorized the commissioner's court to conduct county business. However, the definition of county business was vague.

1933 The home rule allowed any county with a population of at least 62,000 to adopt a County Home Rule Charter (Tex. Const. art. IX, sec. 3). However, the rule was not applied and repealed in 1969.

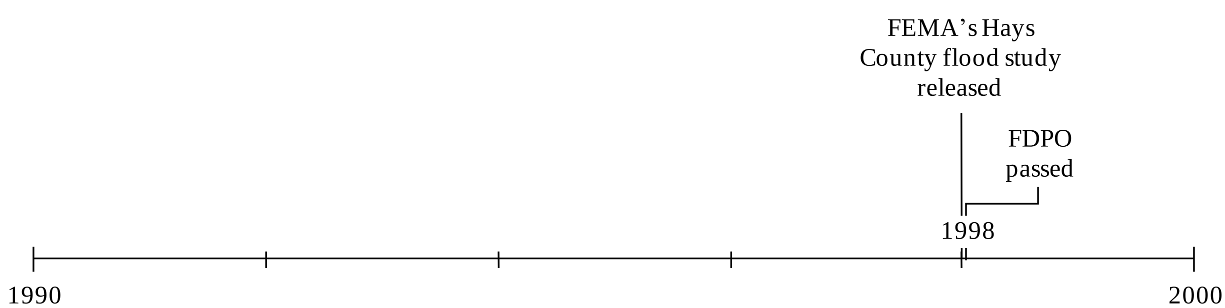

Figure 26. Hays County Timeline, 1990-2000

1998 FEMA released a technical report, “The Flood Insurance Study for Hays County,” and accompanying FIRMs and FBFMs. The scientific report and official maps were integrated into the Flood Damage Prevention Ordinance.

1998 The Flood Damage Prevention Ordinance (FDPO) passed by the Commissioners Court under the Tex. Water Code’s statutory authority (§§§16.313, 16.315, and 16.318). The comprehensive ordinance outlined County management priorities, enforcement, and permitting procedures.

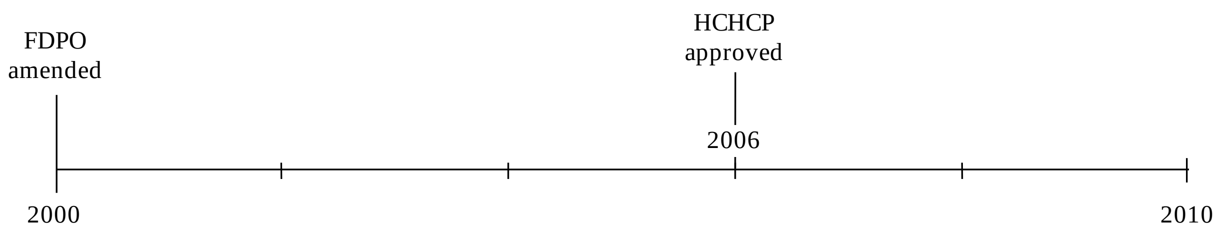

Figure 27. Hays County Timeline, 2000-2010

2001 The FDPO was amended to include the requirements designated by the 1977 Flood Control Insurance Act (65th Leg. RS ch. 870, §1; Tex. Water Code, §16.312).

2005 The FDPO was minorly amended, simplifying and reordering purpose statements as well as revising the office of the floodplain administrator without altering the position’s responsibilities.

2006 The Commissioners Court approved the work plan for the Hays County Habitat

Conservation Plan (HCHCP), which was renamed to Regional Habitat Conservation Plan (RHCP) in 2008.

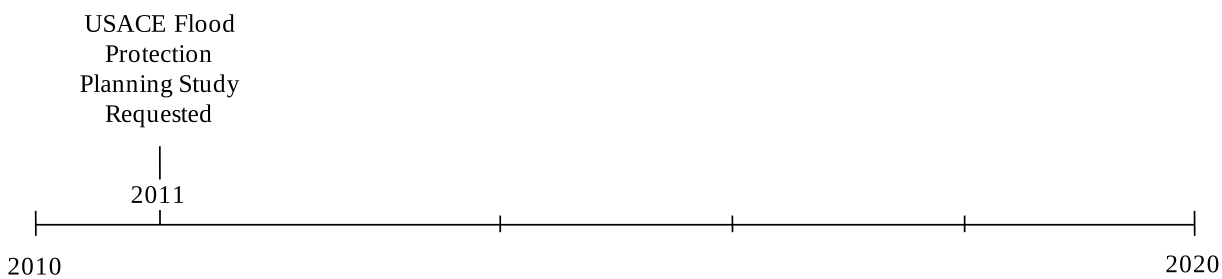

Figure 28. Hays County Timeline, 2010-2020

2011 Hays County officially recognized the Flood Safety Awareness Week (FSAW) Proclamation. The Governor declared March 14-18th 2011 as FSAW with the Texas Division of Emergency Management (TDEM) and National Weather Service (NWS).

2011 Hays County requested USACE conduct a Flood Protection Planning Study for northern Hays County to assess flood risk, damage-reduction techniques, and utilize the information as a decision-making tool.

2012 The Hays County Parks, Open Space and Natural Areas: Master Plan recognized the preservation of natural areas and “water corridors” as a planning priority. The Plan cited flood zones, riparian buffers, and wetlands as critical features.

2013 The Commissioners Court voted unanimously to streamline the implementation of their federally approved RHCP. The RHCP was planned following TPWD and USFWS rules and sought guidance from the Nature Conservatory. The statutory authorization was found in the ESA §10(a)(1)(B) and TPWD code 83.019.

City of San Marcos Timeline

Anglo-Americans initially settled the City of San Marcos (CoSM or San Marcos) in the mid-19th century. Its position along the Blanco River and spring-fed San Marcos River made the location desirable (Dobie 1948; The Daily Record and Free Press 2001; Greene 2010). In modern years (1950-2020), the city's position between Austin and San Antonio, tourist attractions, and university (Texas State University) have contributed to the growth. Unlike the other two cities, San Marcos lies directly on I-35, directly connecting it to the rest of the I-35 corridor. Figures 29-30 show abbreviated timelines for the City of San Marcos timeline entries.

1851 The City of San Marcos was incorporated.

1968 The City Council, Commissioners Court of Hays County, and representatives from SCS and USACE met to discuss the construction of a series of small flood-control dams north of San Marcos. Cross-The city approved the flood plan, but it was not implemented due to lack of funds.

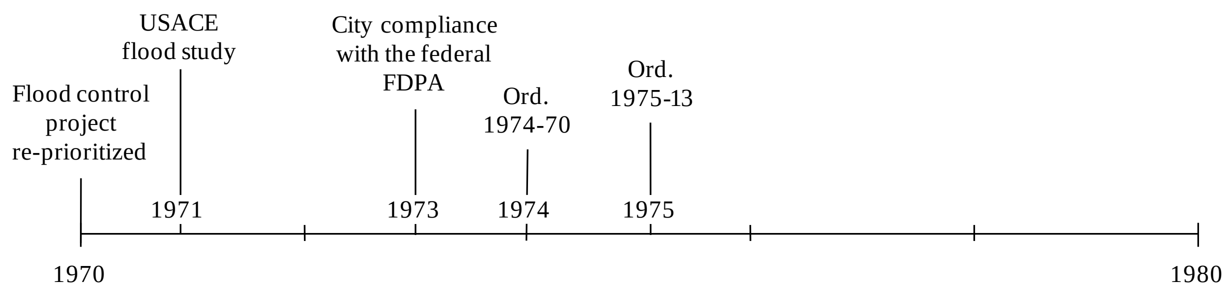

Figure 29. City of San Marcos Timeline, 1970-1980

1970 (May) San Marcos experienced a flood that resulted in two casualties, tens of homes damaged or destroyed and estimated damages of $2 million.

1970 The flood control project was prioritized following the May 1970 flood, and the City Council unanimously approved San Marcos's participation in NFIP. Residents were offered voluntary participation four months after the vote.

1971 USACE presented the City with a study of flood causes in the San Marcos River Watershed, which is south of the Blanco River Watershed, and discussed the City's NFIP eligibility and requirements, such as controlling development in the floodway.

1973 In compliance with the federal Flood Disaster Protection Act of 1973, San Marcos mandated flood insurance for residencies within the floodplain. Mortgage lenders required that applicants have flood insurance.

1974 Ord. 1974-70 set the FIA's flood hazard maps, minimum elevations of first floors, flood flow restrictions, new construction standards, and floodway provisions.

1975 Ord. 1975-13 established positional limitations on lots neighboring or within the FIA-designated floodplain. For example, plats were not permitted unless a study showed that it would not increase the flood risk to the plat and those surrounding it.

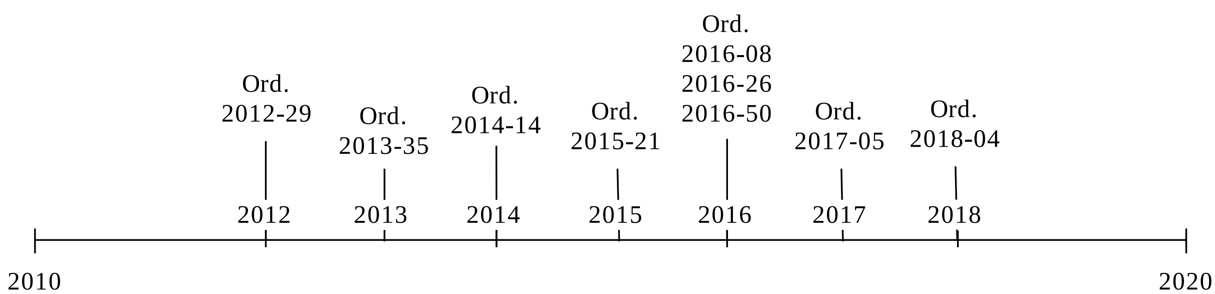

Figure 30. City of San Marcos Timeline, 2010-2020

2012 Ord. 2012-29 repealed the sections "Floodplain Permit" (ch. 1 art. 9, div. 4) and "Floodplain Development " (ch. 5 art. 4) from the City Code of Ordinances and replaced them with "Flood Damage Prevention" (ch. 39).

2013 Ord. 2013-35 amended land development code and implemented ordinance 2013-16. 2013-35 provided permitting procedures and approval processes for structures developed in floodplains as well as other sensitive areas.

2014 Ord. 2014-15 authorized development amendments, including the expiration of approved permits if no progress has been made after two years. It also approved the Watershed Protection Plan and regulations on development, which included the prohibition of scouring, cutting, or otherwise removing vegetation within the San Marcos River Corridor.

2015 May 23-24 received a maximum of 12-13 in of rain for 4-6 hours in the headwaters of the Blanco watershed. 6-8 in of rain was widespread around the Blanco watershed and surrounding areas. The two USGS gages registered peak stages of more than 40 ft with an estimated discharge of 175,000 cfs at USGS 08171000.

2015 FEMA opened a Disaster Recovery Center in San Marcos as a result of the May 2015 floods (DR-4223), serving 47 counties.

2015 The CoSM was awarded a $24 million Community Development Block Grant (CDBG-MIT) to develop flood mitigation procedures after the 2015. The CDBG-MIT was allocated by the HUD to prepare proactive action for future disasters.

2015 Ord. 2015-21 pertained to development permits and necessary compliance for contractors when building in floodplains.

2016 Ord. 2016-08 amended the code to require property owners to notify renters in special flood zones of the potential damage on or before the execution of the lease.

2016 Ord. 2016-26 outlines site development standards that include a mandatory drainage analysis of the 100-year floodplain for any Watershed Protection Plan or Comprehensive Site Plan.

2016 Ord. 2016-50 amended several sections of the flood damage chapter to reduce flood losses. Ord. 2016-50 added higher base flood elevation standards using the higher of either the Working Flood Model or the FIRM. This ordinance also added the excavation or removal of floodplain vegetation and the addition of fill material as subject to regulation, and prohibited encroachments and mandated the no net loss of natural floodplain storage.

2017 Ord. 2017-05 outlined development site fees, including floodplain fees. It was amended in ordinances 2018-05 and 2018-13, but floodplain fees remained unchanged. For a single-family permit, $29, a commercial permit application $168, single family infill's city flood analysis fee of $1,000, for commercial floodplain development flood analysis is $1,500 plus $50 per acre within the floodplain.

2018 Ord. 2018-04 amended § 39.050 of the city code regarding the preservation of natural features. The mitigation plan developed in compliance with federal and state requirements for the reduction of stormwater runoff, stabilization of banks, and improvement of water quality. This section also prohibits the reclamation of wetlands, water quality zones, buffer zones, and other significant natural features.

City of Wimberley Timeline

The City of Wimberley (CoW or Wimberley) was settled by Anglo-Americans in the 1850s, anchored by a gristmill, but was not incorporated until nearly 150 years later. Of the three cities, Wimberley had the most prolonged period between settlement and incorporation (Dobie 1948; Wimberley Kerbow 2010; Wimberley Valley Chamber of Commerce n.d.). The timeline begins the year of incorporation because although inhabited, the community did not promulgate or implement their ordinances. Figure 31 shows an abbreviated timeline of the entries from 2010 to 2020.

2000 City of Wimberley was incorporated.

2007 Resolution Number (Res. No.) R-01-2007 unanimously supported the development and conservation of the Jacob's Well Natural Area and adoption of the mission of the Wimberley Valley Watershed Association.

2008 Res. No. R-08-2008 adopted the Parks and Recreation Master Plan to preserve the Wimberley's natural parks, . It also repealed all resolutions that partially or wholly conflicted. The Plan cited the use of floodplain land for new parks and natural lands. In a survey, about 90 percent of Wimberley residents agreed that riparian buffers for flood protection was moderately to extremely important.

2009 Res No. R-02-2009 approved the city's support for the Hays County Flood Protection

Planning Study and appropriate matching funds to a TWDB grant for flood protection and planning.

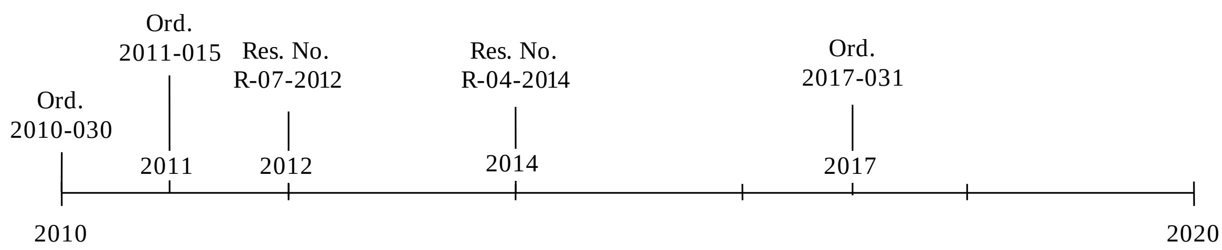

Figure 31. City of Wimberley Timeline, 2010-2020

2010 Ord. 2010-030 supported the prohibition of structure, including lodges, recreation vehicles (RV), and mobile homes within 150 feet of the Blanco River.

2012 Res. No. R-07-2012 adopted the Hays County Hazard Mitigation Plan as the official city plan.

2014 Res. No. R-04-2014 approved the dredging of the Blanco River, Cypress Creek, and Pierce Creek in response to the October 2013 floods that deposited gravel and sediment in the stream channels. $50,000 was allocated for the dredging project.

2015 Three new stream gages were installed in the Blanco watershed headwaters after the May 2015 flood (fig. 44).

2017 Ord. 2017-031 outlined the updated development fees, including the cost of floodplain permits, $45 for residential and $90 for commercial with a floodplain determination letter fee of $25.00.

City of Woodcreek Timeline

The City of Woodcreek (CoWC or Woodcreek) was settled in the 1970s as a suburban residential community and incorporated in the 1980s. In contrast to the other two cities, Woodcreek is younger in the has a significantly smaller area and population (City of Woodcreek. n.d.; Dobie 1948; Jasinski 2010). Figures 32-34 display the abbreviated timeline entries.

1984 The City of Woodcreek was incorporated.

1985 Ordinance (Ord.) 85-12C is the "Subdivision Ordinance of the City of Woodcreek, Texas" and covers the procedures for any subdivision erected in the City of Woodcreek jurisdictional area. Ord. 85-12C enforces the HUD Flood Hazard Boundary Maps authorized by EO 11988, and the HUD's rules 59 FR 19107 and 78 FR 68719.

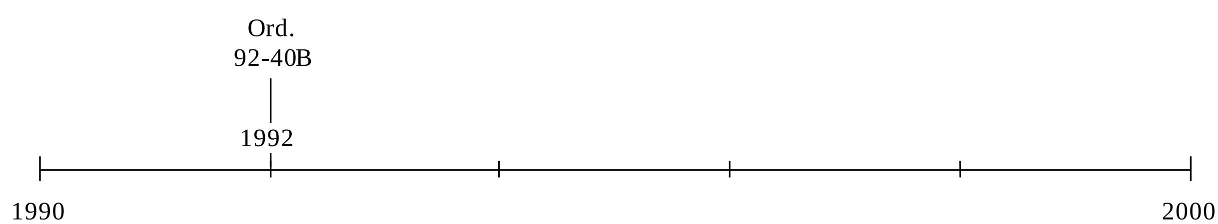

Figure 32. City of Woodcreek Timeline, 1990-2000

1992 Ord. 92-40B is applied to chapter 153, "Flood Damage Prevention," and outlines flood hazards to the area and methods of reducing flood damage by limiting the alteration of the natural floodplain, restricting in-filling, and preventing flood barriers that would change the natural flow of floodwaters.

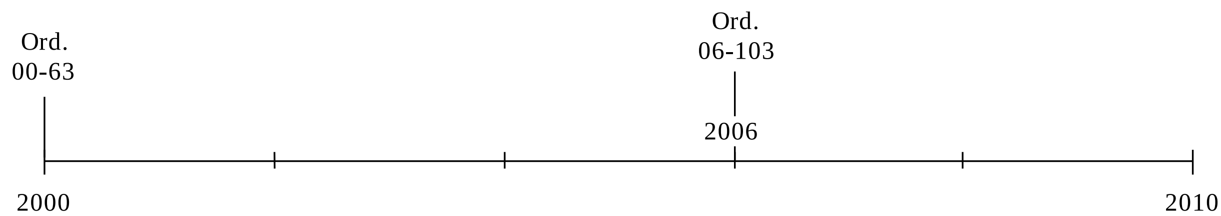

Figure 33. City of Woodcreek Timeline, 2000-2010

2000 Ord. 00-63, and amended in 2002 (Ord. 00-63A), the “Building Ordinance of the City of Woodcreek” holds general building standards within city limits. The ordinance includes details on permitting procedures, site preparation, debris removal, and erosion control.

2006 Ord. 06-104 “Site Development Ordinance” and describes the mandatory development procedures within city limits and ETJ, which are less restrictive than the in-city regulations.

2006 Ord. 06-103 was adopted as the “Water Quality Protection Ordinance”. The City of Woodcreek set water quality protections as authorized by Sec. 26.177 of the Texas Water Code. It was amended in 2006 (Ord. 06-103A), 2010 (Ord. 10-139), and 2019 (Ord. 19-256, 19-278).

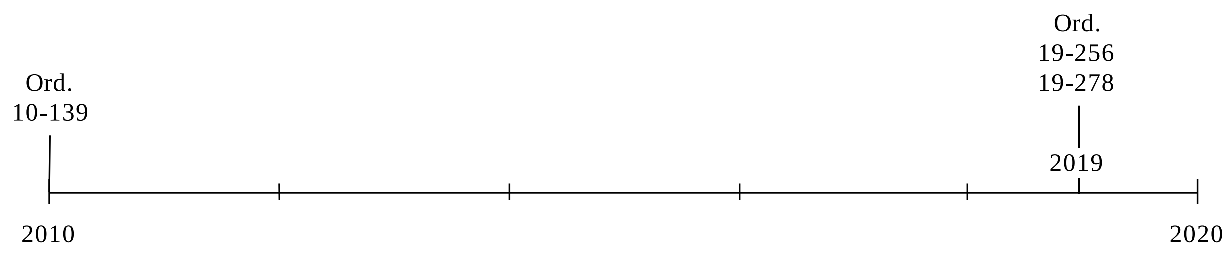

Figure 34. City of Woodcreek Timeline, 2010-2020

Discussion

US Federal Timeline Discussion

Figure 35 shows only the policy changes from 1900 to 2020 for the federal timeline. However, pre-1900s, the “Swamp Lands Acts” in the mid-1800s set an early policy that extended the right to drain and fill wetlands for “productive use,” widely agriculture and settlements (Bogue 1951). From the 19th century to the mid-20th century, at least 50 percent of wetlands were destroyed. In the midwestern states, as much as 98 percent of inland wetlands were drained and filled (Wilen and Bates 1995; Schneider 1996; Dahl 2011; Tocker and Stanford 2002). Coastal and isolated wetlands are included, but most nontidal wetlands are in floodplains, which were then irreversibly altered.

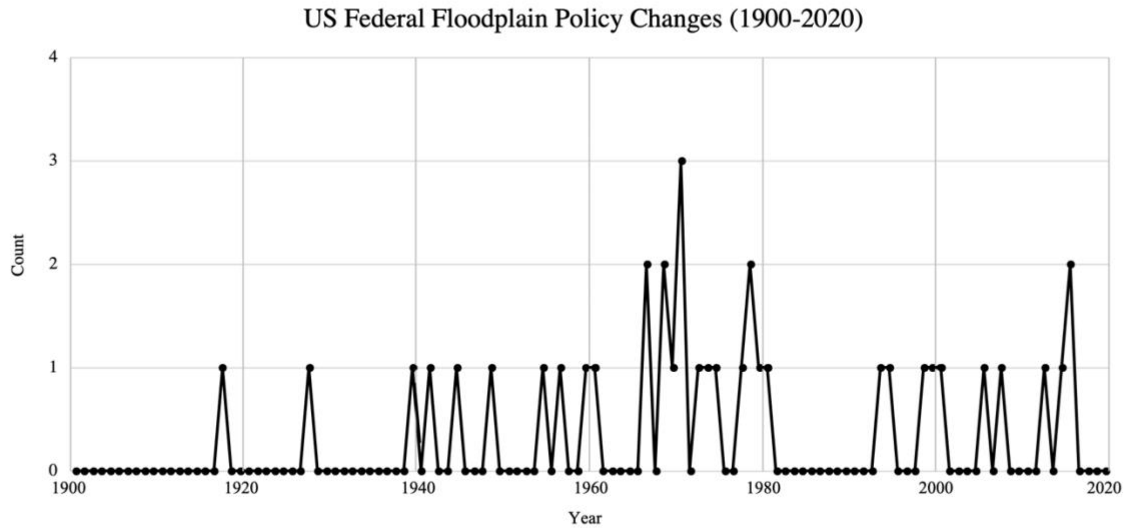

Figure 35. US Federal Floodplain Policy Changes (1900–2020)

In addition to land-use change, natural disasters have significantly altered national floodplain policy. Triggered by severe flooding across the US in the 19th century, the USACE's "levee-only" policy was the first national approach to flood control by the federal government which has persisted as a dominating strategy (Myers and Passerini 2000). The Great Flood of 1927 was a monumental flood that led to the Flood Control Act of 1936 and exemplified the early period of federal flood-control and indirectly floodplain policy (Brody, Kang, and Bernhardt 2010; Opperman et al. 2017). In the 1930s, limited regulations were enacted by the federal government and enforced by the USACE. The wetland drain-and-fill policy co-occurred with the prioritization of artificial levees and dams, which altered millions of square miles of watersheds and floodplains. Nearly 70 years later, the Great Flood of 1993 again devastated parts of the Mississippi River Basin and spurred federal interest in preventing flood losses and dedicating funding to flood control (Philippi 1994; Larson and Plasencia 2001; Tartlock 2012).

The Great Flood of 1993 received a lot of media attention as a "500-year" flood, which planted the idea that a flood of that magnitude only occurs every 500 years (Philippi 1994).

Hurricane Katrina (2005) devastated the Gulf of Mexico coastal regions with New Orleans, LA, at the center. One of the costliest natural disasters in US history, Hurricane Katrina exposed FEMA floodplain mapping and structural flood-control tactics. Although Hurricane Katrina directly impacted a region of the US, the magnitude and media attention invoked nonregional empathy that changed national and state flood and floodplain policies (Philippi 1994; Brody, Kang, and Bernhardt 2010; Liao 2012).

Although natural disasters have brought a lot of attention to disaster mitigation procedures, social issues drove the largest peak in federal policy change. Federal floodplain policy reform peaked in the 1970s during the environmental movement and new era of administrative regulations and the creation of overruling agencies. Over the following decades, those agencies grew into their roles and set new rules and regulations to implement the laws enacted in the 1960s-1970s. The EO 13690 cemented policy that had been in place, but it was revoked only two years later. EOs have been instrumental in setting floodplain policies for federal agencies.

With the national "no net loss" of wetlands policy, came the need to map the wetlands to assess them as a natural resource. However, despite the conservation goals and permitting procedures set by the CWA §404, net loss continued due, in part, to the difficulty enforcing and monitoring at the national scale (Wilen and Bates 1995; Dahl 2011; Cole and Shafer 2002). States are able to take control of their CWA programs and exceed minimums, but Texas is not one of them.

Texas Timeline Discussion

High organizational capacity is characterized by the level of commitment of resources and passed laws. An entity with high organizational capacity can move quickly and create a lasting impact because of dedicated personnel, paid and volunteer, financial resources, technical expertise, and legal authority (Bourget 2002). The state's incremental addition of organizational elements can be tracked over time by the laws enacted, the agencies created, allocation of funds for water projects, and dedicated personnel (fig 36). Just as the floodplain physically shares space with water and land, it also shares the regulatory water and land space. Currently, the TWDB is the chief state water planning agency, and the TCEQ is assigned permitting and water rights responsibilities, which are not the focus of this report, but the state has divided, consolidated, and renamed water agencies repeatedly.

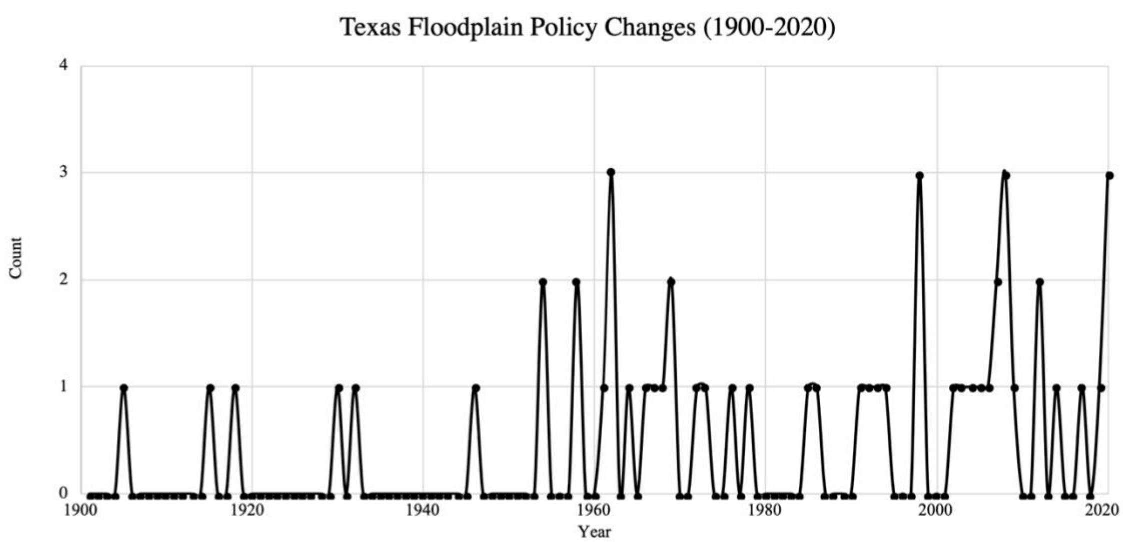

Figure 36. Texas Floodplain Policy Changes (1900–2020)

The droughts of the 1950s and heavy spring rains in 1957 led to an interest in long-term water resource planning. At this time, the primary concern was securing a water supply. In 1967, the Water Rights Adjudication Act marked a turning point where the state's water was becoming more regulated by dedicated agencies. At the same time, Texas's water pollution control policy was emerging, co-occurring with the national demand for water quality regulation. Pollution control and water quality objectives, combined with the recognition of ecosystem science, evolved into floodplain buffers for water quality and wetland protection requirements.

At the turn of the 21st century, The Texas Water Development Board oversaw the creation of the Regional Water Planning Groups (RWPG) and region-specific plans. Although the hydrological diversity was addressed in the first State Water Plan (SWP) in 1961, 1997 was a turning point in that set the planning framework for the current state water planning regime. In 1997, the SWP declared a "bottom-up" planning approach, which emphasized local needs and stakeholders, as opposed to "top-down" planning, in which the State would initiate planning. Local authorities are given broad discretion, but regional plans are subject to final TWDB approval.

Figure 37 shows parallel trends among the terms 'river,' 'flood,' and 'dam' in the State Water Plans. The peak is the 1984 SWP that followed the floods of the 1970s and 1980s. Although nonstructural approaches were being incorporated at the state level, dams were still recommended for water supply and flood-control reservoirs, and the trough is the milestone 1997 SWP.

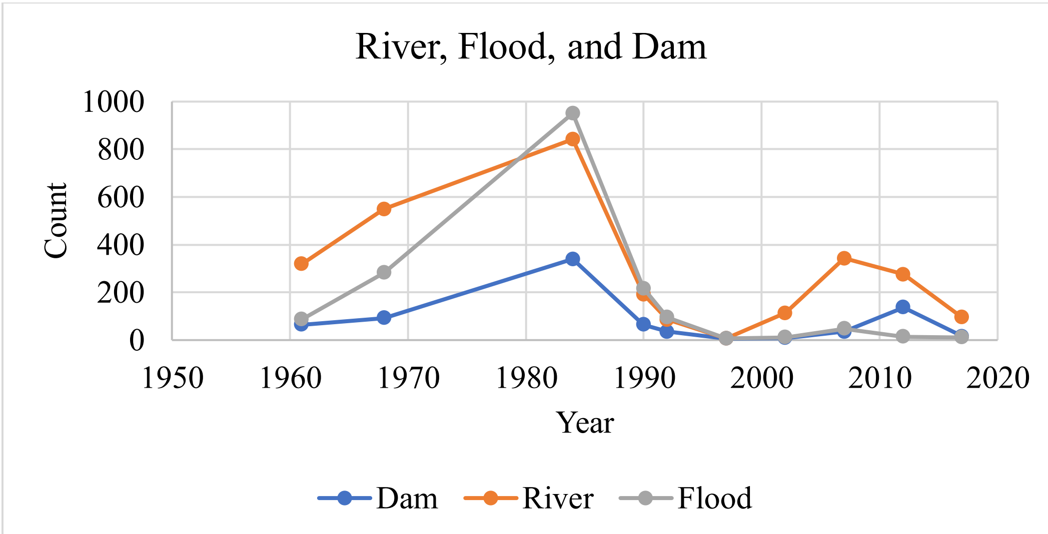

Figure 37. River, Flood, and Dam Counts in the State Water Plan (1961–2017)

Recent years indicate that floods and floodplains are trending toward the forefront of water resource planning in Texas (fig. 36). The first State Flood Assessment was published in 2018 and featured an entire chapter to floodplain management that addressed the misnomer of the 100-year floodplain and the risk of relying on it. The following year, the 86th Leg. RS passed SB 7, SB 8, and HB 3815, solidifying floodplain policy progress. Because local governments are responsible for implementing and enforcing floodplain policies, county and municipal policy documents and local histories are critical to assessing floodplain management.

Local Timelines Discussion

At the community scale, localized events are more impactful on local policy than national, nonregional disasters (Plate 2002; Saharia et al. 2017). For example, the Great Flood of 1993 impacted federal flood-control policy but did not impact the City of San Marcos's local flood-control policy like the May 2015 flood. After the floods in 2015, the City passed ord.

2016-50 that significantly changed local floodplain development regulations and flood mitigation practices.

The response to the October 1998 flood occurred at the county level instead of the individual cities (fig. 38), and since 1998, the county has taken a more active role in floodplain management. Recently, the 2000-2010 population spike of the county prompted the county to request a new flood study by the USACE. This exemplifies the need for cross-scale cooperation and the impact of organizational capacity. While the county recognizes the need, it does not have the resources or funding to conduct a study and relies on a federal agency. The county catered mitigation plans to each city but did not have the authority to impose the plan on them, but instead, cities need to vote to adopt them.

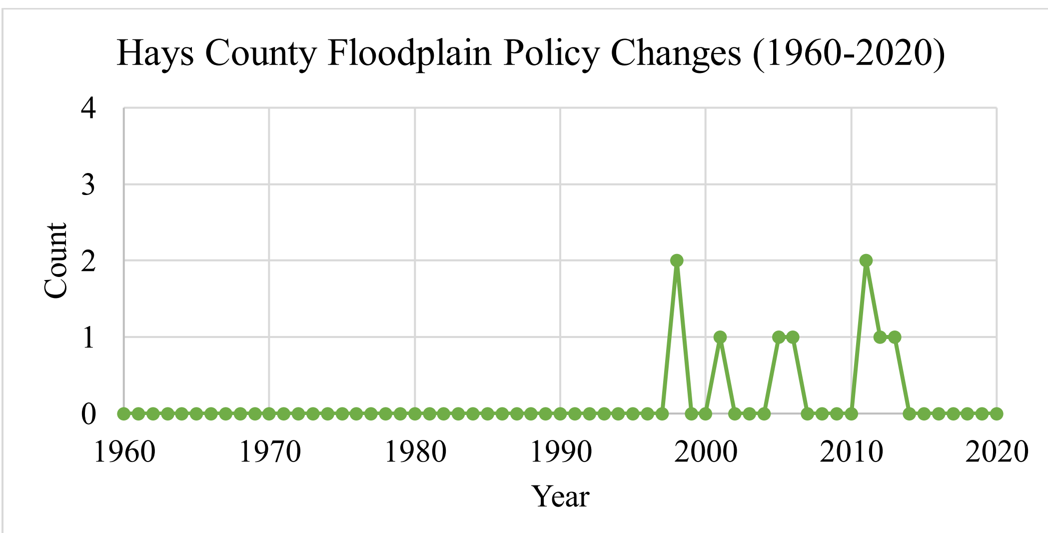

Figure 38. Hays County Floodplain Policy Changes (1960–2020)

According to Hays County (2012), 73 percent of Hays County residents work outside of the county. The distance traveled between home and work necessities unique flood-control strategies, especially considering that most flood-related deaths are vehicular (Drobot 2007;

Sharif et al. 2012). Floodplain policy change in the CoSM was primarily driven by local floods, namely the May 1970 flood and the May 2015 flood. Although the May 2015 flood impacted all three cities, the CoSM showed a unique pattern of activity in 2015-2016 (fig. 39). The May 2015 flood of record revealed weaknesses in local early warning systems, and new stream gages were installed in the headwaters to improve warning forecasts and inundation mapping. Table 10 lists the gages in chronological order of the period-of-record beginning date, and figure 42 shows a map of the stream gages labeled by their respective map number. Although the disaster was local, federal agencies in partnership with local entities provided equipment and funding.

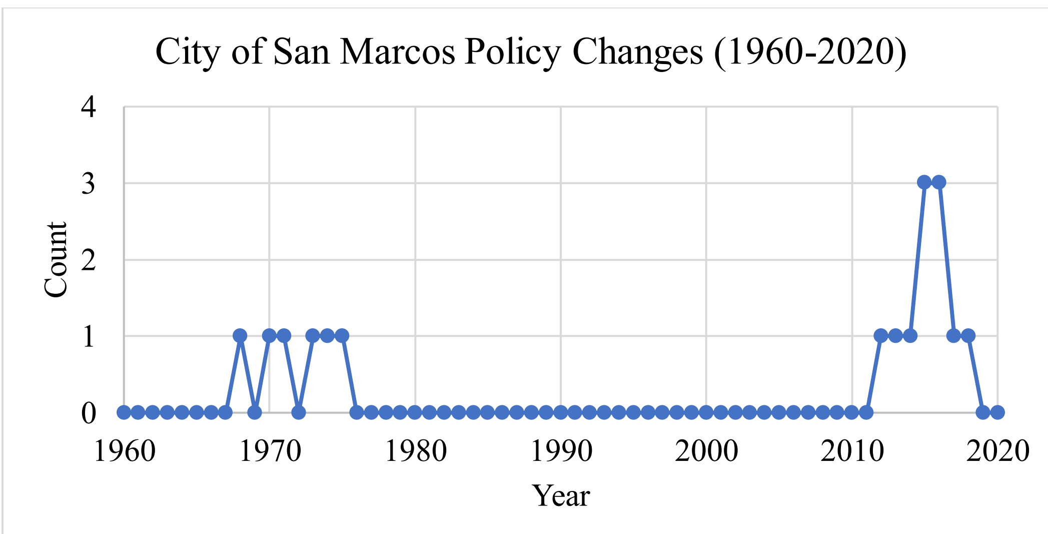

Figure 39. City of San Marcos Policy Changes (1960–2020)

Federal relief funds were awarded to the city. However, a condition was to incorporate resiliency into proactive disaster plans for the city that indicates the priority of nonstructural mitigation techniques from the HUD and the required implementation of that policy by the City. Most of the budget (66.63 percent) is dedicated to "repetitive loss infrastructure" that includes the removal of structural barriers to floodwater, buyouts, and "green infrastructure." The plan is required to prioritize low-moderate income areas as the City allocates funding to planning, land preservation, and warning system improvements (City of San Marcos 2020).

Wimberley's policy changes were clustered in a peak after a long period of inactivity (fig. 40). However, opposed to San Marcos, Wimberley was incorporated in 2000. Wimberley resolution R-01-2007 (2007) officiated the City's alignment with the Wimberley Watershed Association, a non-governmental organization whose mission is to foster a "future with clean, plentiful water flowing from Jacob's Well into Cypress Creek, a healthy ecosystem essential to the culture and economy of the Wimberley Valley" (n.d.). However, the City had the least restrictive floodplain development regulations. The City did make strides in 2009–2010. The City restricted the placement of RVs and mobile homes in the Blanco River floodplain in 2010 and adopted the Hays County Hazard Mitigation Plan and recommendations in 2012.

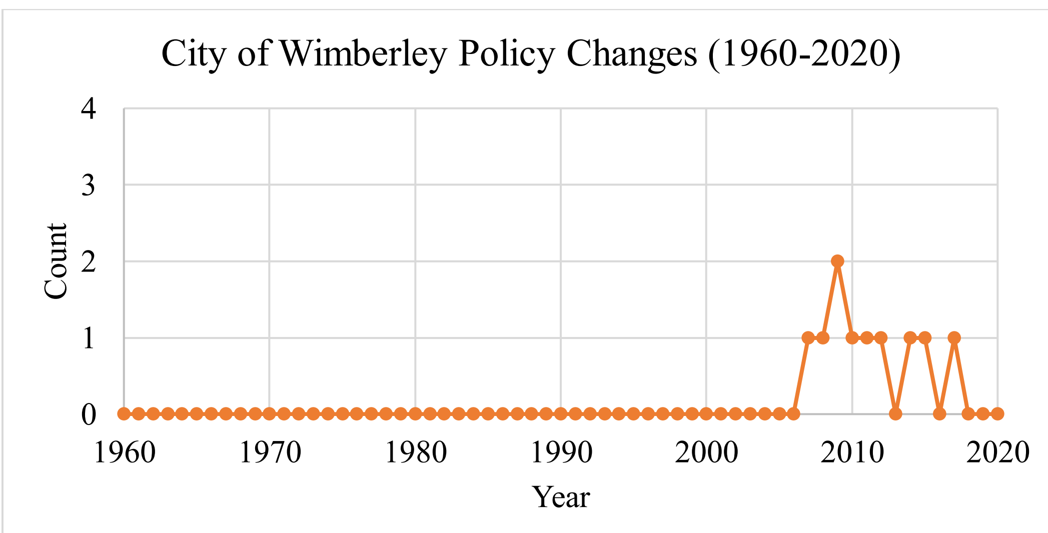

Figure 40. City of Wimberley Policy Changes (1960–2020)

The City of Woodcreek is the smallest in land area and population. Despite its size and volunteer committees, Woodcreek had the most restrictive floodplain development requirements based on “water quality buffer zones.” The city’s headwater position could have a detrimental impact on lower stream cities without high buffer requirements. Woodcreek’s policy pattern (fig. 41) shows small peaks and gaps on an average of 5-6 years (5.67), which contrasts heavily with San Marcos and Wimberley.

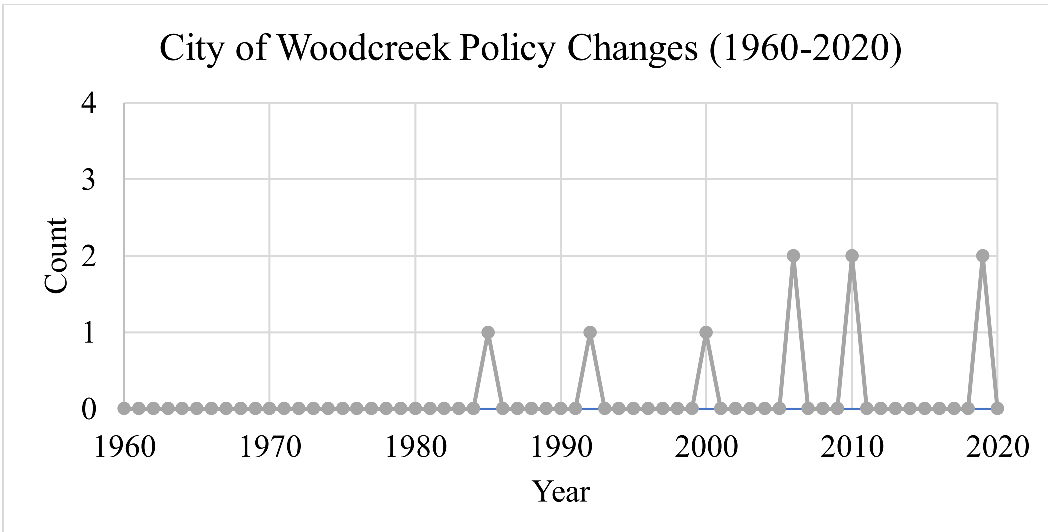

Figure 41. City of Woodcreek Policy Changes (1960–2020)

Table 9. Blanco River and Little Blanco River Stream Gages (USGS)

Map Marker Number	Period of Record Start Date	Gage Name	Gage Number	Location Coordinates
1	1924-08-06	Blanco Rv at Wimberley, TX	08171000	29°59'39" N, 98°05'19" W
2	1956-05-29	Blanco Rv nr Kyle, TX	08171300	29°58'45" N, 97°54'35" W
3	2008-12-19	Blanco Rv at Halifax Rch nr Kyle, TX	08171290	30°00'20" N, 97°57'09" W
4	2015-01-22	Blanco Rv at San Marcos, TX	08171350	29°52'46.24" N, 97°54'38.71" W
5	2016-08-30	Blanco Rv at Fischer Store Rd nr Fischer, TX	08170950	30°00'02.1" N, 98°12'01.3" W

6	2016-10-20	Little Blanco Rv at FM 32 nr Fischer, TX	08170890	30°01'14.9" N, 98°19'50.0" W
7	2017-05-08	Blanco Rv at Crabapple Rd nr Blanco, TX	08170800	30°06'09.3" N, 98°30'38.4" W

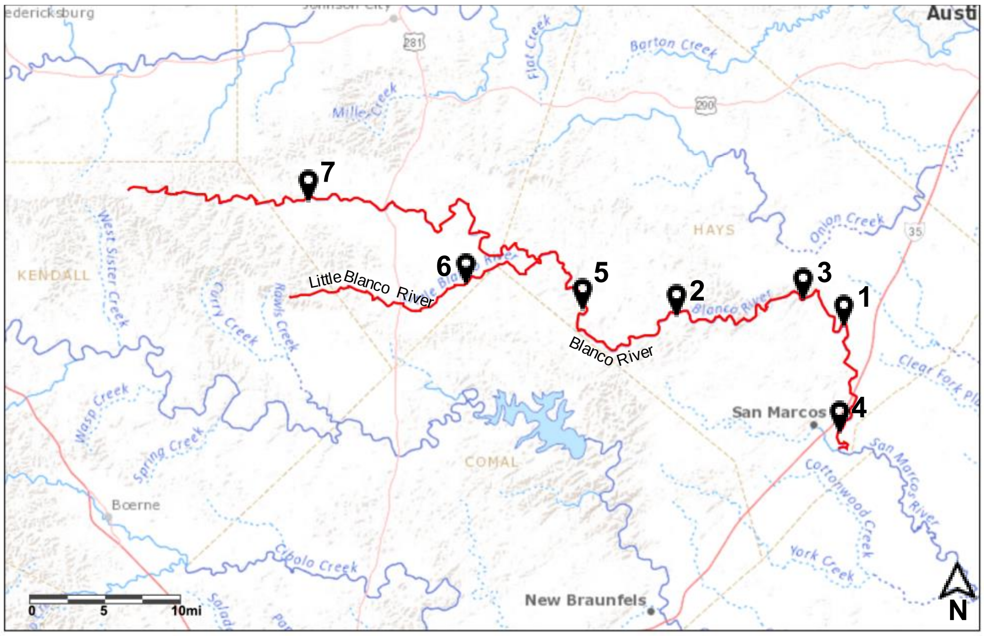

Figure 42. Blanco River and Little Blanco River Stream Gage Locations (USGS)

Cross-scale Timeline Discussion

Legislative changes were slower at the federal level than the state, but federal laws have a broader jurisdiction. Jurisdictional reach becomes central in common, nonstationary resources. For example, the ESA had a profound impact on Texas state water laws, and has led to federal (legislative and judicial) mandates that apply to all states (Irvine 2018). On the other hand, states can oversee their own CWA and NEPA programs that meet or exceed federal requirements. The 1972 amendments broadened the definition of navigable waters, as mentioned in the RHA (McQuaid 2018).

Major droughts drove Texas water policy change because of their long duration, areal extent, and impact on all industries and municipalities in Texas. Although droughts and floods are on opposite ends of the water problem spectrum, the water resource legislative changes and agency activity included in the timeline extended to floodplain policy reform. Droughts that did result in floodplain policy reform were not included in the timeline because they were too distanced from floodplain policy.

The magnitude of trigger events is relative to the spatial and institutional scale (Caran and Baker 1986). Instead of "bottom-line" precipitation, financial damages, duration, and injuries numbers, disasters should be adjusted for the land area and organizational capacity of the area affected as a ratio. Natural and regulatory floodplain boundaries should be more aligned when mapping flood-risk areas. Ideally, regulatory delineations would be tiered with buffers to account for future change, depending on topography, urban development, and climate change. Improved technology, including warning systems, Geographic Information Systems (GIS), and hydrologic and hydraulic modeling, should be more accessible to local planners to tailor the floodplain maps to the scale at which floods occur (Miller and Miller 2000; Sene 2013).

Text-mining Discussion

A basic understanding of natural floodplains was essential to designing query terms to screen the data and assess the subparts for relevance. Of the documents surveyed, two main themes emerged: development and flood-control. Within the policy space, floodplains are managed to either allow or prohibit development. Floodplain maps designed to outline high and moderate flood-risk areas were used throughout the development codes.

The main challenge with text mining was balancing concision with context. Quotations were coded with multiple descriptors when the excerpt contained multiple topics while avoiding over-coding, using too many codes to the point of uselessness. Converting the unstructured text data from the original word-sentence structure to a consistent, standard structure was challenging and required revisiting some of the quotations to re-code. The multitude of false positives from the query term "river" was surprising. The false positives were contained to proper noun phrases, such as "Colorado River Basin" and "Guadalupe-Blanco River Authority." Unfortunately, the word-cruncher, auto-coding, and co-occurrence functions were not utilized because they could not be conducted across all documents reliably or at all because of the file format of the documents.

Conclusion

Texas is continuously in a position of "too much" or "too little" water. Floods have punctuated periods of drought, and climate change threatens to increase the frequency and intensity of these events. As urban development increases, more people and property risk encroaching into flood-prone areas. Floodplain policies differed across governmental and spatial scales reported as statutes, public law, federal, state, and local codes, and agency plans. Land-use change and natural disasters drove policy reform at all scales. In Texas, statewide disasters prompted state legislation and planning that did not heavily impact the other scales. Although the Great Floods of 1927 and 1993 and Hurricane Katrina (2005) were not in Texas, they drove national policy change that then mandated state and local amendments. As water planning enters a new era, floodplains will play an increasingly important role at the local and regional scales in Texas. Future floodplain management will need to be adaptive and resilient to accommodate for urbanization and climate change. The quickly changing environment demands more cross-scale cooperation to streamline local floodplain projects and more effectively govern at higher institutional levels. Nonstructural mitigation techniques are more sustainable and cost-effective than structural flood-protection methods and should be encouraged and implemented by federal and state government agencies for sweeping change. Local communities should be tooled with improved mapping and predictive technologies to inform city planning decisions. Future directions should incorporate more green infrastructure to take advantage of floodplains' ecosystem services and minimize harm to humans and the environment. While mistakes and natural disasters are inevitable, floodplains are more prominent in policy discussions now and will continue to improve.

Appendix

Table 10. Central Texas Floods

This table is not comprehensive and only includes a sample of major floods relevant to the study area. The information included was explicitly addressed in the literature cited. Some information was unavailable or unverified, and that missing information is indicated by a dash. It was compiled using literature and government reports (United States Geologic Survey 1947; United States Geologic Survey 1999; Burnett 2008; Estaville and Earl 2008; National Climatic Data Center 2014; Rubenstein 2015; National Oceanic and Atmospheric Association n.d.-a; National Oceanic and Atmospheric Association n.d.-b; National Weather Service n.d; United States Geologic Survey n.d.).

Date (YYYY-MM-DD)	River	River Basin	City	County
1869-07-03	Colorado, Pedernales	Colorado	Austin, Bastrop	Travis, Bastrop
1913-10-01	Colorado, Guadalupe, San Antonio	Colorado, Guadalupe, San Antonio	San Antonio, San Marcos	Bexar, Hays
1913-12-01	Brazos, Colorado, San Marcos	Brazos, Colorado, Guadalupe	Austin, San Marcos	Travis, Hays
1921-09-09	Colorado, Guadalupe, San Antonio	Colorado, Guadalupe, San Antonio	Austin, San Antonio	Bexar, Hays, Travis, Williamson
1929-05-27	Blanco, Pedernales, San Marcos	Colorado, Guadalupe	Austin, Blanco, San Marcos, Wimberley	Blanco, Hays, Travis
1935-06-15	Colorado	Colorado	Austin	Travis
1952-09-11	Blanco, Pedernales	Colorado, Guadalupe	San Marcos, Wimberley, Woodcreek	Blanco, Gillespie, Hays
1958-05-02	Blanco	Guadalupe	Wimberley	Hays

1970-05-15	Blanco, San Marcos	Guadalupe	San Marcos, Wimberley, Woodcreek	Hays
1972-05-11	Comal	Guadalupe	New Braunfels	Comal
1975-05-23	-	Colorado	Austin	Travis County
1970-05-20	San Marcos	Guadalupe	San Marcos	Hays
1981-05-27	Colorado, Shoal Creek	Colorado	Austin	Travis
1981-06-14	-	Colorado, Guadalupe	Austin, San Marcos	Hays, Tavis
1997-06-21	Colorado, Guadalupe, Llano	Colorado, Guadalupe	Austin, Llano	Llano, Travis
1998-10-17	Blanco, Colorado, Comal, San Marcos	Colorado, Guadalupe, San Antonio	New Braunfels, San Antonio, San Marcos, Wimberley, Woodcreek	Comal, Gillespie, Hays, Travis
2001-11-15	Blanco	Colorado, Guadalupe	Wimberley	Hays, Travis, Williamson
2013-10-31	Guadalupe, San Marcos, Onion Creek	Colorado, Guadalupe	Austin, New Braunfels, San Marcos, Wimberley, Woodcreek	Comal, Hays, Travis

2015-05-24	Blanco, San Marcos	Guadalupe	Blanco, Johnson City, San Marcos, Woodcreek, Wimberley	Blanco, Comal, Gillespie, Hays
2016-09-27	San Antonio, San Marcos	Colorado, Guadalupe, San Antonio	San Antonio, San Marcos	Bexar, Comal, Hays

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