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LIVING WITH HOUSTON FLOODING

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Introduction

Many consider Houston a world-class city, but we do a poor job of publicly discussing our weaknesses, such as flooding. To be truly world class is to admit and then address weaknesses and to treat all citizens as equals, i.e., as partners with the government. Unequal information is a form of discrimination that is simply unacceptable. Honesty and transparency will pave the road to progress.

This paper is intended to address that deficiency by informing new and old Houstonians about flooding in Houston. The Houston region is a wonderful place, an ecological jewel set in a flat Texas coastal plain that also receives a lot of rain. A key to surviving and thriving in Houston is understanding these flood-related risks and learning to live with them.

Here on the Texas coast, we get intense rainfall events that cause flooding along our bayous, rivers, creeks, and roadways, and occasionally we get hurricanes with surge, which is water that is pushed ashore by the storm's rotating winds and forward movement. Both events are important, but of the two, surge tends to be the deadlier due to the presence of wind-driven waves on top of the surge water that together are very destructive. Either storm event, however, can affect the security of your property, your family, and yourself.

This paper is intended to spread the word about these risks and how to live with them. It is not about fixing these problems, but rather about understanding and surviving them. However, the chance of obtaining an effective fix is enhanced by a good understanding by our citizens, as well as a populace that demands better solutions from our elected officials.

Our guide to surviving Houston flooding is offered in the spirit of community—of helping each other. It is a spirit that is one of our best qualities, and was most recently displayed in the outpouring of assistance during Hurricane Harvey. Just as some arrived with boats and kayaks, others arrive with words and maps.

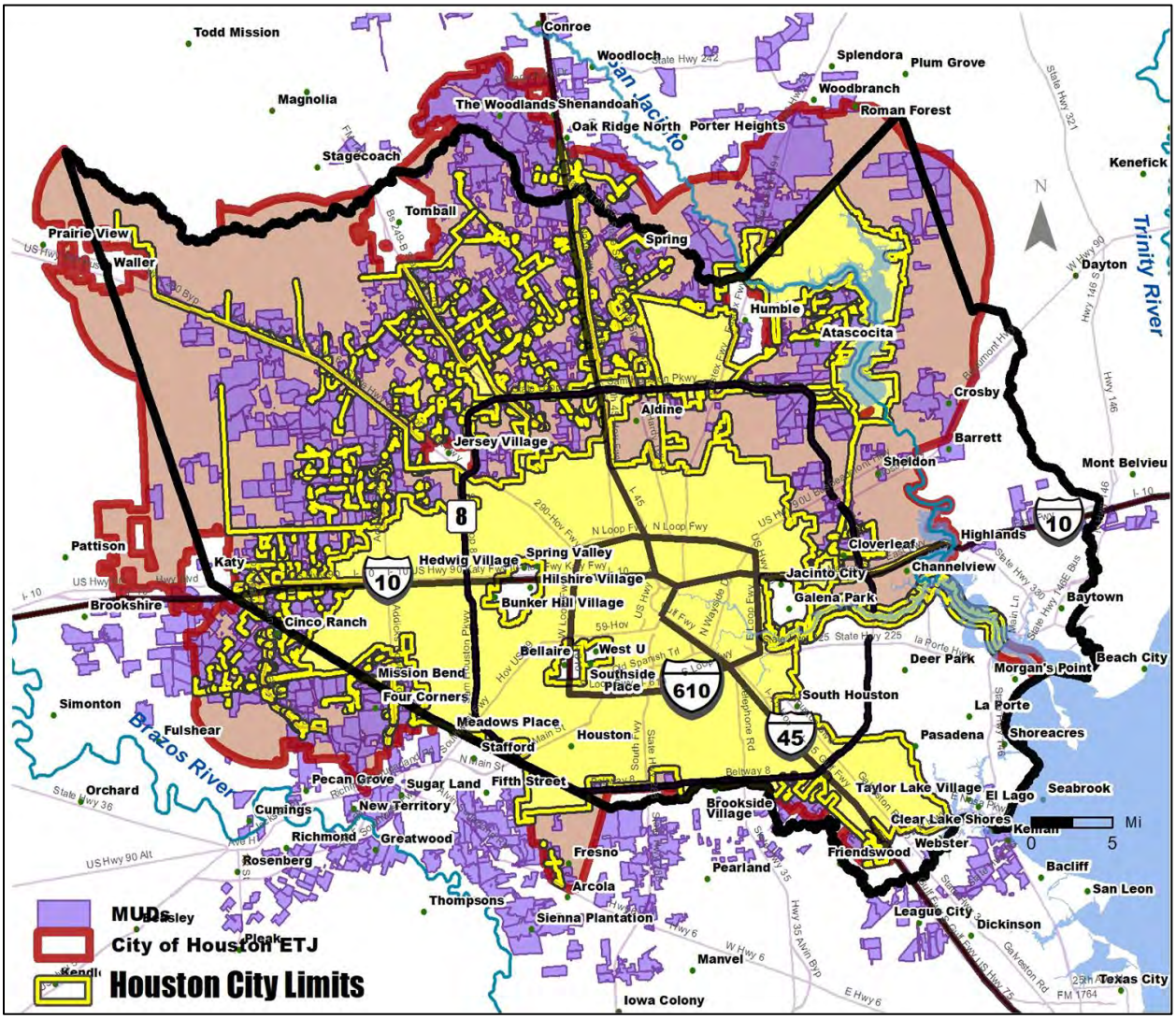
Rivers, Bayous, and Creeks

Harris County is home to about 4.5 million people who live in the City of Houston, in smaller cities mainly to the east and southeast, or in the remainder of the county, which is the unincorporated area where municipal utility districts deliver most essential services. The majority of the population is either within the City of Houston or an unincorporated area that would be the fourth or fifth largest city in Texas if incorporated as a city.

Figure 1 shows the portion of the county that is within the City of Houston, the portion that is in the Extraterritorial Jurisdiction (ETJ) of the City of Houston, and the portion that is governed by Municipal Utility Districts (MUDs). The area in white, but not in the ETJ, is within the jurisdiction of smaller cities such as Pasadena, Bellaire, West University Place, Hedwig Village, LaPorte, Webster, Deer Park, Seabrook, Taylor Lake Village and others which are noted on Figure 1. There are literally hundreds of MUDs in and around Harris County, and they are home to the majority of the approximately two million persons living

in unincorporated Harris County. The yellow lines expanding like a spider web west and north of the city boundaries denote strip annexation to expand the ETJ of the City of Houston. The ETJ extends five miles from the boundaries of the City of Houston (including those areas that were strip annexed) and preserves areas within the ETJ for future annexation by the city.

Figure 1. Harris County, City of Houston, and Extraterritorial Jurisdiction Boundaries



Note: Smaller cities are noted but not outlined.

Source: Courtesy of Christina Walsh

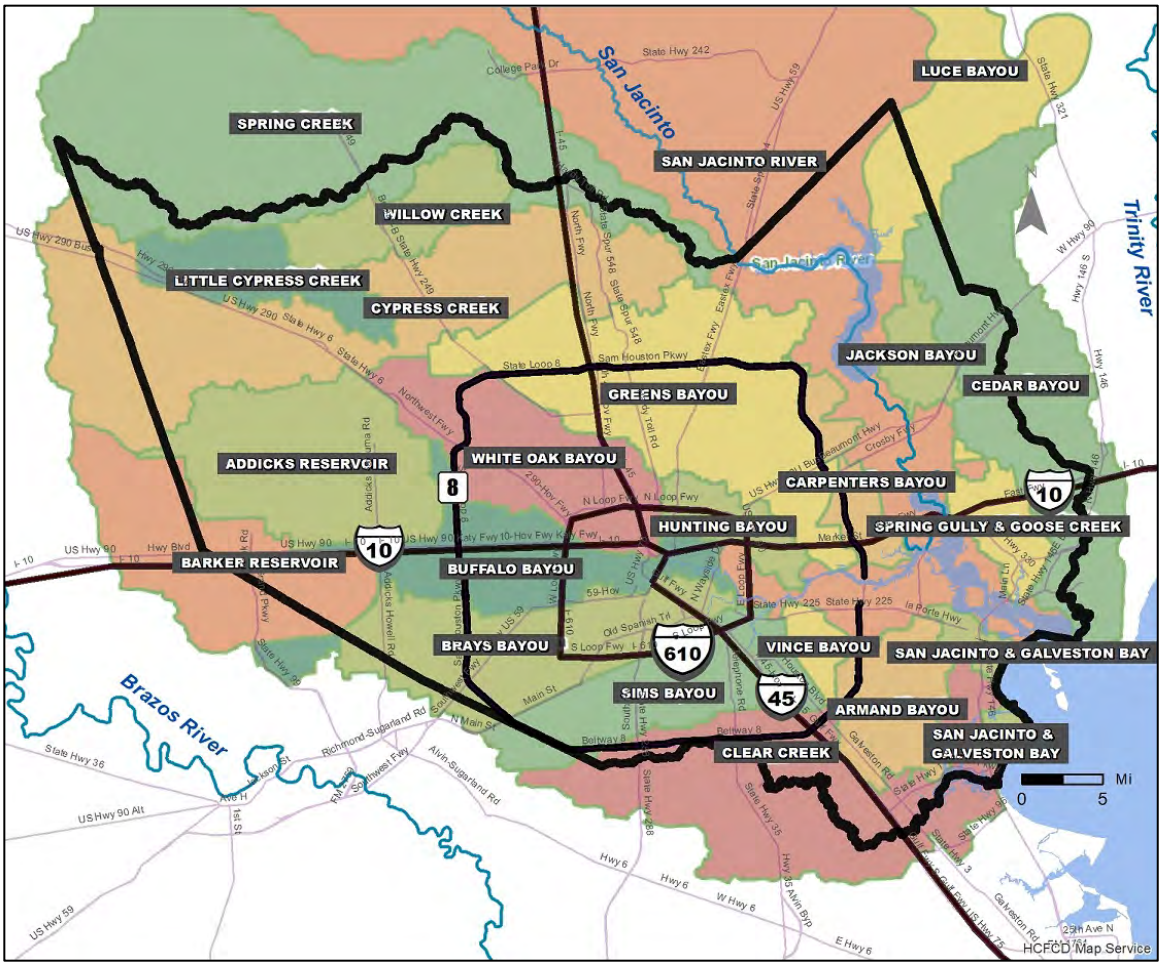
Although governmental jurisdictional boundaries are important, most of our flooding discussion centers around the bayous, streams, and rivers that lace through and around the community. All flood information revolves around the watersheds of these watercourses as well as the watercourses themselves. The term "watercourse" refers to a channel with a cut bank and a bed, and the term "watershed" refers to an area within which the water drains to a particular watercourse.

In Figure 2, the various watersheds of Harris County are shown. Please note that most are relatively small, with many totally contained within the boundaries of Harris County. This means that many of these creeks and bayous rise and fall very quickly during rainfall events. That is very important as will be explained later in this document.

Buffalo Bayou is the central water spine of Harris County and Houston. It rises in the prairie west of downtown Houston with its boundaries extending into Fort Bend and Waller counties. The bayou flows through two flood control reservoirs—Addicks and Barker—and then through the Memorial Drive area of town and downtown, and then becomes the industry-lined Houston Ship Channel that connects into Galveston Bay and then the Gulf of Mexico.

In Figure 2, the Addicks Reservoir and Barker Reservoir watersheds are broken out from the Buffalo Bayou watershed, emphasizing that these reservoirs receive runoff from distinctly different geographic areas. As we all learned in Harvey, these reservoirs have "flood pools" where water will be ponded behind the dams at different pool levels. As will be discussed later, a large portion of the maximum flood pool is developed and has homes, schools, and businesses in this part of the reservoir. Almost 300,000 people live in the Harris County portion of the Addicks watershed and almost 90,000 live in the Harris County portion of the Barker watershed, with thousands more residing in Fort Bend County. Almost 450,000 persons live in the portion of the Buffalo Bayou watershed shown on Figure 2 in dark green, parallel to Interstate 10.

Figure 2. Harris County Watersheds



Note: Each watershed is identified relative to the major and secondary road systems.
Source: Courtesy of Christina Walsh

Many of our remaining bayous within the City of Houston are tributaries of Buffalo Bayou. These include White Oak and Little White Oak, Greens and Halls, Hunting, Brays, Sims, Vince and Carpenters bayous. White Oak rises in northwest Harris County and flows adjacent to U.S. 290 into the city, traversing the Heights area along T.C. Jester and emptying into downtown Houston at Main Street. Little White Oak runs north-south parallel to Main Street. About 430,000 people live in the White Oak Bayou watershed.

Greens and Halls bayous rise in north-central Harris County and flow to the east and then south, with Halls being a tributary of Greens. Greens is roughly parallel to the north Beltway 8, then turns south where it is joined by Halls and then flows into the Houston Ship Channel near the Beltway 8 bridge over the Houston Ship Channel. Halls Bayou runs south of Greens between Beltway 8 and Loop 610 roughly parallel to Tidwell. About 530,000 people live in the Greens Bayou watershed (including Halls Bayou). Hunting

Bayou is a smaller watershed that drains the northeastern part of Houston near Loop 610, draining the Fifth Ward and the Kashmere Gardens neighborhood northeast of downtown, and is home to about 76,000 people.

Brays and Sims bayous flow from the southwest to the east through the southern parts of the county and the city. The Brays watershed extends from near the intersection of Beltway 8 and the Southwest Freeway through Meyerland and the Texas Medical Center to the Houston Ship Channel. Keegans Bayou is a major tributary of Brays in the western part of Harris County. Brays Bayou is home to about 720,000 people. Sims Bayou is the next bayou south of Brays, running parallel to the Southwest Freeway (59 South) and South Loop 610 from the Fort Bend County boundary to just north of Hobby Airport where it continues east and empties into the Houston Ship Channel. The population of the Sims Bayou watershed is about 285,000 people.

The smaller Vince and Carpenters bayous are on the east side of the county. Most of the watershed of Vince Bayou lies in the cities of Pasadena and South Houston, and it flows south to north from about Genoa-Red Bluff Road to the Ship Channel. Carpenters Bayou rises east of Lake Houston and runs south to the Houston Ship Channel just west of Beltway 8. It parallels Greens Bayou on the east. The population of the Vince Bayou watershed is about 90,000 and the population of the Carpenter Bayou watershed is about 60,000.

The northern portion of Harris County is defined by three major watercourses—Cypress Creek, Spring Creek, and the San Jacinto River. Both Cypress and Spring creeks join the San Jacinto River at the headwaters of Lake Houston, the principal drinking water supply for the City of Houston. Cypress Creek rises in the prairies of eastern Waller and northwestern Harris counties. It bisects much of northern Harris County, running roughly parallel to, and north of, FM 1960 for much of its length. The Harris County portion of this watershed is home to about 350,000 people. Spring Creek forms the northern boundary between Harris and Montgomery counties. It rises in western Montgomery County and flows through rolling, sandy, forested terrain into Lake Houston. It has a population of about 40,000 in Harris County and many more in Montgomery County. Willow Creek, a tributary of Spring Creek, is identified as a separate watershed in Harris County and flows from southwest to northeast between Cypress and Spring creeks in the middle of the northern portion of Harris County. The population of the Willow Creek watershed is about 45,000.

The San Jacinto River drains much of Montgomery County and portions of east Harris County and is joined at Lake Houston by Cypress and Spring creeks and by Buffalo Bayou at the Houston Ship Channel. The San Jacinto River watershed shown in Figure 2 includes areas surrounding Lake Houston and also land areas draining through even smaller bayous into the Houston Ship Channel. The population of the San Jacinto River watershed in Harris County is about 200,000.

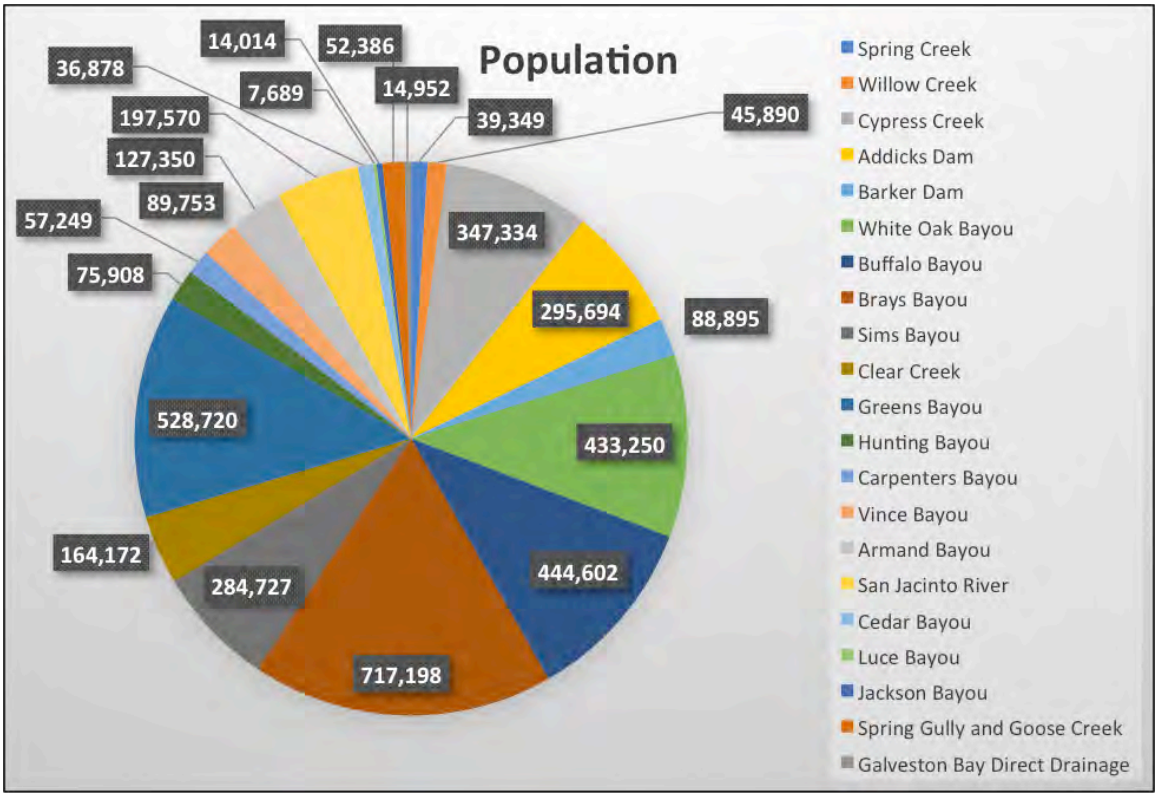
Cedar Bayou is the eastern boundary of Harris County with Chambers and Liberty counties. It flows north to south from north of Barbers Hill in Chambers County to Baytown in Harris County and is home to about 40,000 people in Harris County. There

are four additional watersheds in northeast Harris County: Luce Bayou, Jackson Bayou, Spring Gully, and Goose Creek. Luce Bayou drains from east to west, terminating in Lake Houston. It has about 7,700 people living in the Harris County portion of the watershed. Jackson Bayou is just east of Lake Houston and serves the Newport and Crosby areas of Harris County with a population of just over 14,000. The Spring Gully watershed drains south from Highlands Reservoir to the Burnett Bay on the Ship Channel, and Goose Creek drains Baytown south into Tabbs Bay along the Channel. The population of these two watersheds is just over 52,000.

The southern boundary between Harris and Galveston counties is defined by Clear Creek, which rises first in Fort Bend County, then flows in Brazoria County and eventually across 45-South into Clear Lake and Galveston Bay. It is joined on the north by Armand Bayou, which is classified a separate watershed that rises in the City of Pasadena south of the Houston Ship Channel and joins the Clear Creek watershed at Clear Lake. Clear Creek is home to about 165,000 people in Harris County and Armand Bayou is home to about 130,000.

In all, these 22 watersheds define drainage in Harris County. The relative population distribution by watershed is shown in Figure 3.

Figure 3. Harris County Population by Watershed



Source: Author, with population figures from the Harris County Flood Control District

Floodplain Maps

The concept of a "floodplain" is very straightforward. It is the area that is flooded when a bayou, creek, or river overflows its banks. The bed and banks of the watercourse are incised by the "normal" flow or base flow that is present most of the time. Large rains occur periodically and they generate more runoff than the watercourse can hold. These rainfall events, which have a return frequency determined by statistical analyses, can generate floods. The areas that are flooded by the more severe, less frequent rain events are called floodplains.

There are more frequently inundated floodplains, and there are those that flood much less frequently. These different frequencies of flooding are assigned a percent chance of occurrence in any one year. In this way, the 50% chance flood (e.g., a 50% chance of occurring in any year) is said to be the two-year flood (e.g., expected to recur on average once every two years) and the 1% chance storm (1% chance of occurring in any given year) is said to be the 100-year flood (e.g., recurs on average once every 100 years). Similarly, the 0.2% chance storm has a 1 in 500 chance of occurring in any year and is called the 500-year flood.

These risks are translated into recurrence intervals in an attempt to help us understand the risks and set policy around them. However, there is no guarantee that an event will not happen again until a given number of years have passed. Instead, the year after a 100-year rain, there is simply a 1% chance that it will occur again.

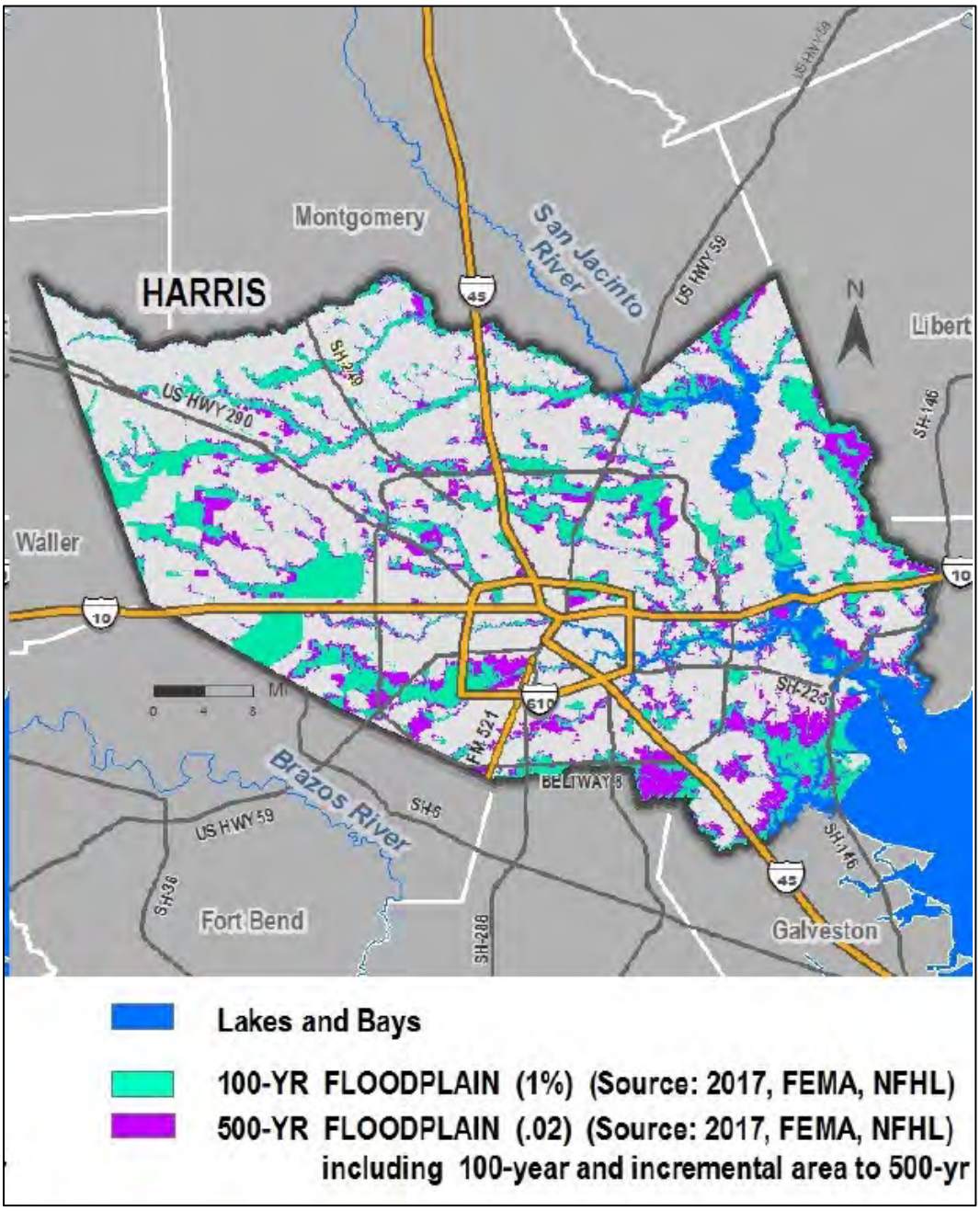
The 100-year floodplain became a planning tool because the federal government used it as the standard for the Federal Flood Insurance Program that provides (at least as of November 2017) subsidized flood insurance. In order to make a community eligible for the subsidized insurance, the community had to agree to impose minimum regulations on development within the 100-year floodplain. In this way, the 100-year floodplain became the regulatory standard for the United States.

The floodplain maps are published by the Federal Emergency Management Agency (FEMA), which regulates the federal flood insurance program. FEMA hires subcontractors to do the mapping. Early in the implementation of the program, Harris County convinced FEMA to allow it to prepare much of the mapping for Harris County. For this reason, Harris County is very involved in mapping of our floodplain boundaries, which became very politicized documents due to the land use regulations that attached to these areas.

The map of the current 100- and 500-year floodplains in the entire county is shown in Figure 4, below. As can be seen, the floodplains differ in shape and extent in the various watersheds. Of particular note are the Brays, White Oak, and Greens Bayou floodplains that occupy relatively greater portions of the watershed in certain areas.

The maps shows that over 25% of Harris County is in the 100-year floodplain and over 33% in the 500-year floodplain.

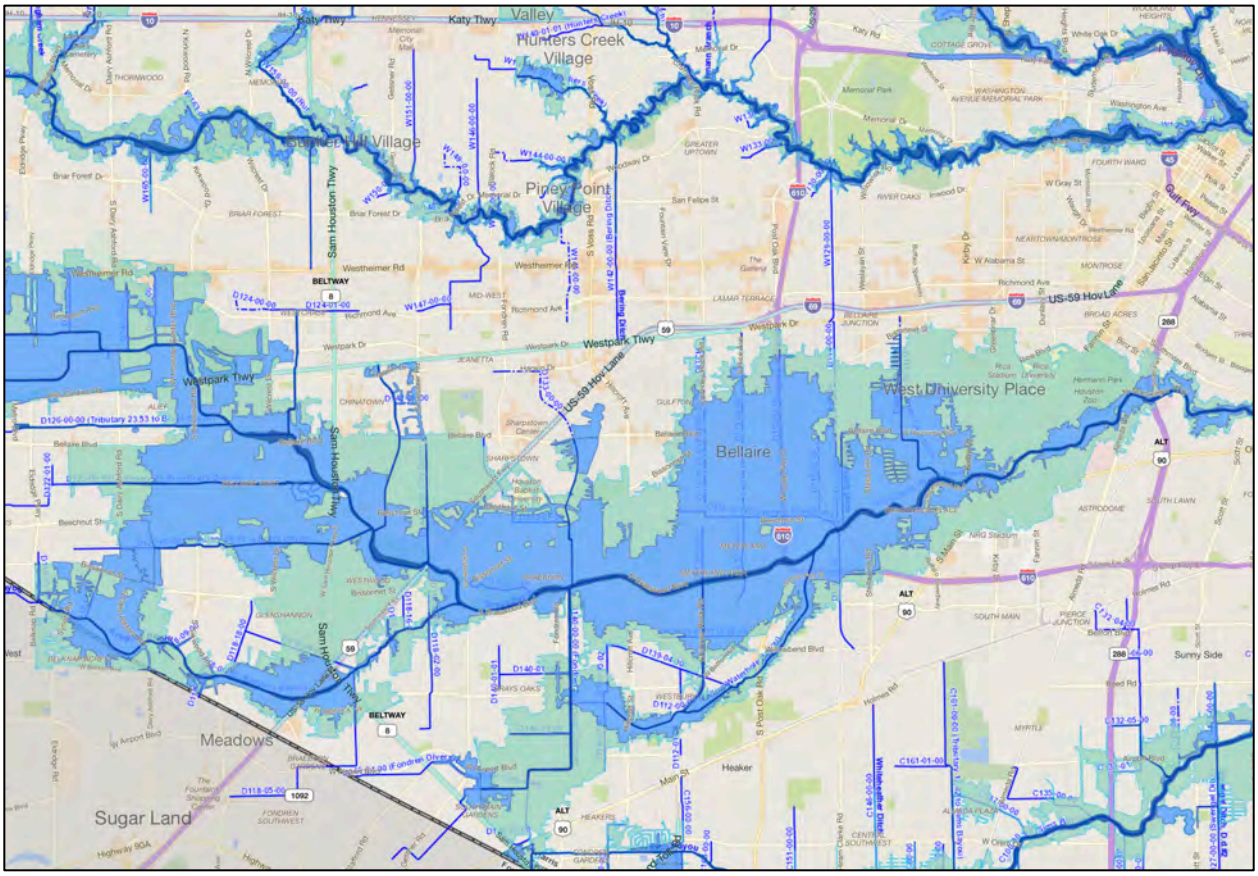
Figure 4. Harris County's 100- and 500-year Floodplains



Source: Courtesy of Christina Walsh

In order to find the detailed 100- and 500-year floodplain in your area, the map of interest is called the Flood Insurance Rate Map (FIRM). The easiest site to read and access such a map is maintained by Harris County Flood Control District at http://www.harriscountyfemt.org/. The resulting map found at this site looks like the figure below (Figure 5), showing the 100- and the 500-year floodplains. Frankly, the FEMA website was very hard to use and did not generate useful information for this report, which is a very sad commentary. You are welcome to try FEMA's website at https://msc.fema.gov/portal#wcm-survey-target-id.

Figure 5. A Flood Insurance Rate Map of 100- and 500-year Floodplains



Note: This is a December 2017 screenshot of the floodplain for Buffalo and Brays bayous as indicated by FEMT, a Harris County Flood Control District web tool. The blue area shows the 100-year floodplain while the green area shows the 500-year floodplain.

Source: Harris County Flood Control District

Many aspects of these flood maps are important to understand, and they are not straightforward. There is much more to the story of flooding in Houston than is revealed by these maps. While the maps provide valuable information, they should not be the sole guide relied upon to predict and understand flooding in Houston and Harris County. As much as 50% of the flood damage in Harris County occurs outside the mapped 100-year floodplain.

The first issue is rainfall amount, or in the case of coastal flooding, the recurrence frequency of tropical storms and hurricanes. The current 100-year rainfall amount used for floodplain mapping in Harris County averages about 13 inches in 24 hours; the 500-year amount is 19 inches in 24 hours. However, these amounts have been exceeded so many times in the past two decades that they have become a source of dark humor in the community. Our rainfall frequencies must be updated and the maps revised for them to be more reliable. For this reason, the areas shown as the 100- and 500-year floodplains are not as large as they would be if the rainfall frequencies were updated. Until this happens, beware of relying on these maps. They likely underrepresent the true and current risk of flooding. Indeed, as of November 2017, Harris County has proposed utilizing the 500-year floodplain as an interim regulatory tool until the data can be updated. It should be noted that the National Weather Service recently issued draft updated rainfall frequencies for Texas, including Harris County, that show significant increases in such rainfall amounts for the county.

The second issue is the way that these floodplains are determined. Generally speaking, FEMA is concerned about overbank flooding of major watercourses, as described above. However, there are other forms of flooding. Most drainage is provided by storm sewers, which are underground pipe systems connected to the streets by grated openings that allow the storm water to drop into the pipes. Generally, these storm sewers are supposed to be able to handle up to about a two-year storm event. When more rain falls than can enter the storm sewer, our streets fill up with water. If the bayous are full, the underground pipes cannot flow, and water continues to back up into the street and then into yards. Our streets supposedly can hold up to about a 25-year rainfall. After that, the water rises onto our yards and begins to flow with gravity toward lower parts of the watershed (if there is any appreciable slope in the area). In this way, a home may be flooded by water rising from the street up to and above the foundation or by flow coming down the streets from the higher portions of the watershed to the lower. This type of flooding is generally not shown on maps. At the least, the slab of a home should be 18 inches to two feet above the street, as is the case in many of the newer parts of town. Unfortunately, in many of the older parts of the city, the house slabs are close to the ground and not much higher than the street.

Third, along Galveston Bay, FEMA floodplain mapping has not accurately or fully represented the risk of hurricane surge flooding. There are various technical reasons for this, but the bottom line is that many homeowners moving near Galveston Bay are not alerted that they are at risk of flooding from significant hurricane surge. This important information is discussed later in this report, but be careful of surge flood levels when buying land near the coast below an elevation of 25 feet.

The fourth issue is that someone can change these maps with relative ease. It is possible for FEMA to issue a Letter of Map Revision (LOMR) on the basis of documents prepared and sealed by engineering firms. The purpose of an LOMR is to alter the published floodplain map, usually by providing “better information.” This process exists because map preparers can make errors; the LOMR process is essentially a method of correcting such errors. However, this process also can be, and has been, abused. And unfortunately, this LOMR

process does not provide for any review and comment by the general public. It would be useful to learn if a letter of map revision has been issued in the area you are interested in, although it is often difficult to impossible to obtain the information easily. The county and the city are both involved in the LOMR process and should keep a list of approved LOMRs along with maps showing where the LOMRs have been approved.

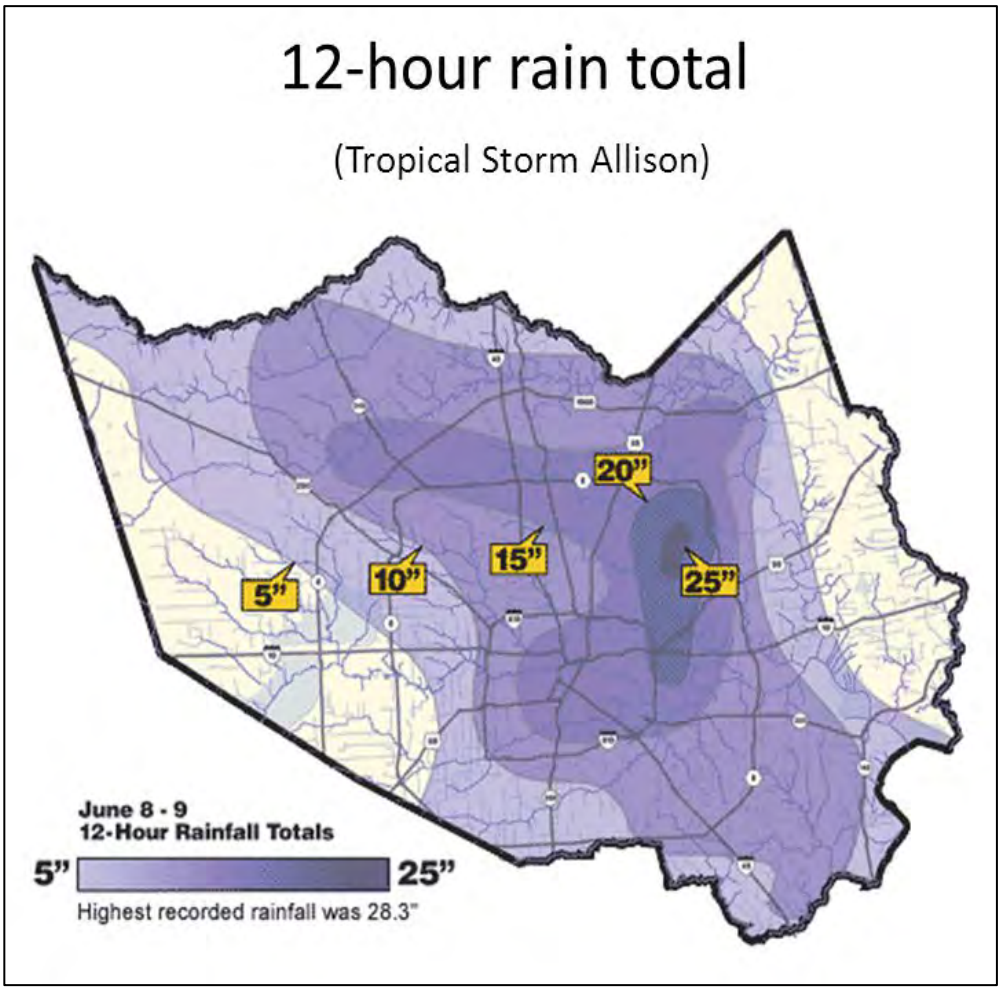
It is hard to overstate the importance of these floodplain maps. The flood elevations from them are used to determine the elevation of home slabs and foundations both within and outside of the 100-year floodplain. In addition, all hazardous waste sites, sewage treatment plants, and sanitary landfills for garbage disposal must be either located outside of the 100-year floodplain or otherwise protected from the 100-year flood. We as a community should take steps to ensure that these maps are accurate or we run the risk that every home, business, industry, or disposal site that we build or permit according to these maps will be flooded in the future much more frequently than indicated.

Rainfall and Severe Storms

Flooding, it seems, is routine for Houston. Those who have lived in Houston for any period of time are well aware of frequent reports of flooding somewhere in the area. Weather.com reports that "according to NOAA's National Climatic Data Center, there were 86 days with reports of flooding or flash flooding in Harris County from 1996 through 2014. This equates to an average of 4-5 days of flooding each year over that time period." All of these floods are not 100-year-plus events, but many have been considered as such.

In the last several decades, the severity of rainfall events in Houston and Harris County has seemingly increased substantially, and since 2000, several storms have come to define our rainfall dilemma. In 2001, Tropical Storm Allison came ashore, rained on our area, proceeded north to about Huntsville and stalled, then reversed course and came back over Houston from north to south. In the process, Allison set record-breaking rainfall amounts to the extent that Harris County produced a booklet on Allison titled "Off the Charts" to indicate the unprecedented size of the rainfall event. Rainfall amounts associated with Allison were reported as high as 26 inches in 24 hours, well beyond the 500-year rainfall level of 19 inches currently used by Harris County. The distribution of Allison's rainfall, which was most severe in northern Harris County, is shown in Figure 6. About 74,000 homes were flooded by Allison in Harris County.

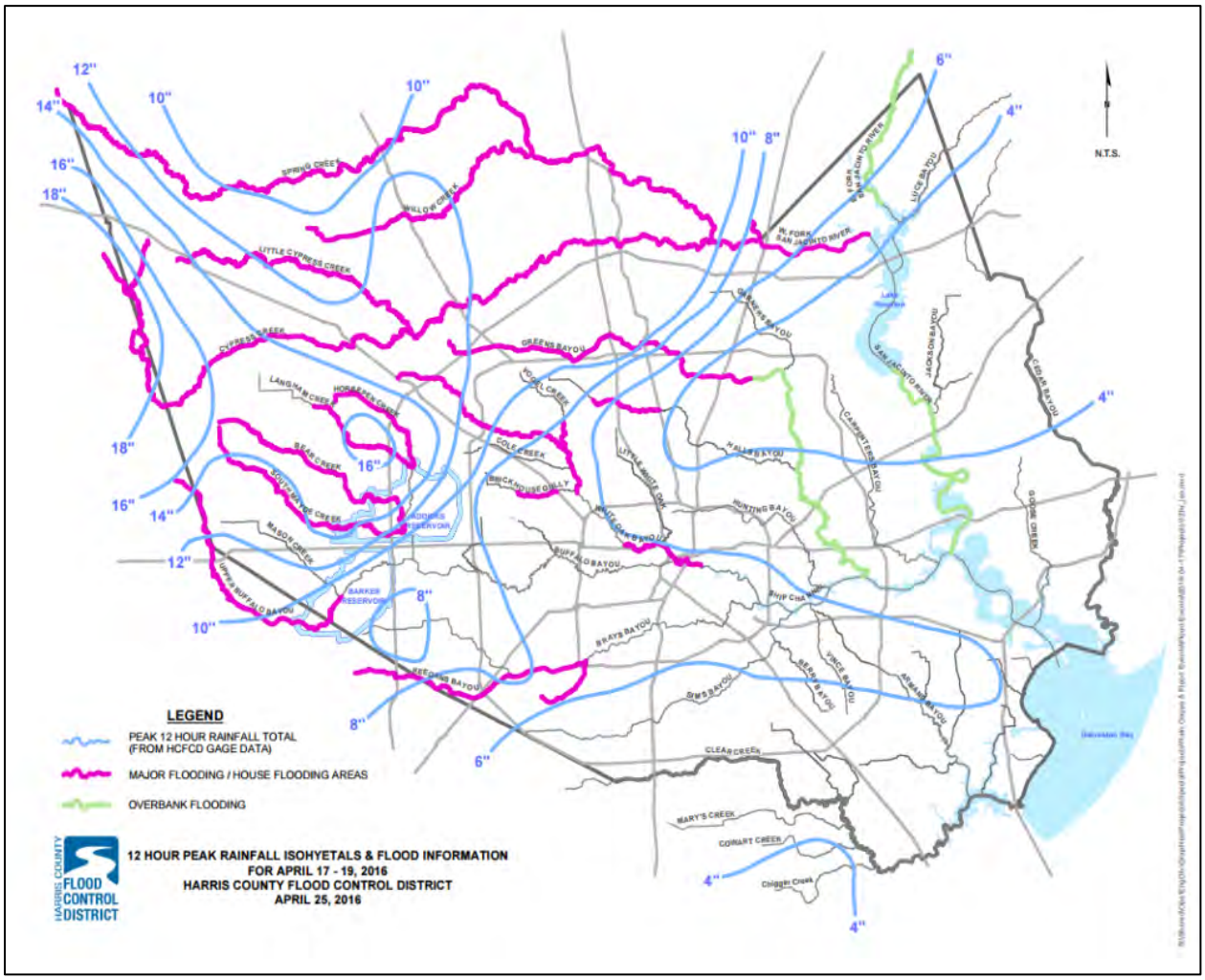
Figure 6. Harris County Rainfall Distribution from Tropical Storm Allison



Note: The heaviest rain from this storm was centered in the northeastern part of the county.
Source: Data from Harris County Flood Control District

The next major event was on July 14, 2012, about a decade after Allison. In this storm, over 14 inches of rain fell in 24 hours, primarily in the northern and western parts of Harris County; this exceeded our 100-year rainfall amount of 13 inches in 24 hours. In May 2015, we had the first of two Memorial Day floods. This storm dropped about 11 inches over 12 hours on the Brays Bayou watershed and the Meyerland area near Loop 610; Brays Bayou experienced the first of three major flooding events to impact the area. Eight persons died in this storm and there were 531 water rescues. In April 2016, we had what has come to be called the Tax Day Flood. This event was not tropical in nature but rather associated with an April cold front. The storm dumped 15 to almost 17 inches in 12 hours, making it a 500- to 1,000-year rainfall in western Harris County. This storm caused most streams and bayous in west Harris County to experience serious flooding, as shown in Figure 7, which also shows the lines of equal rainfall.

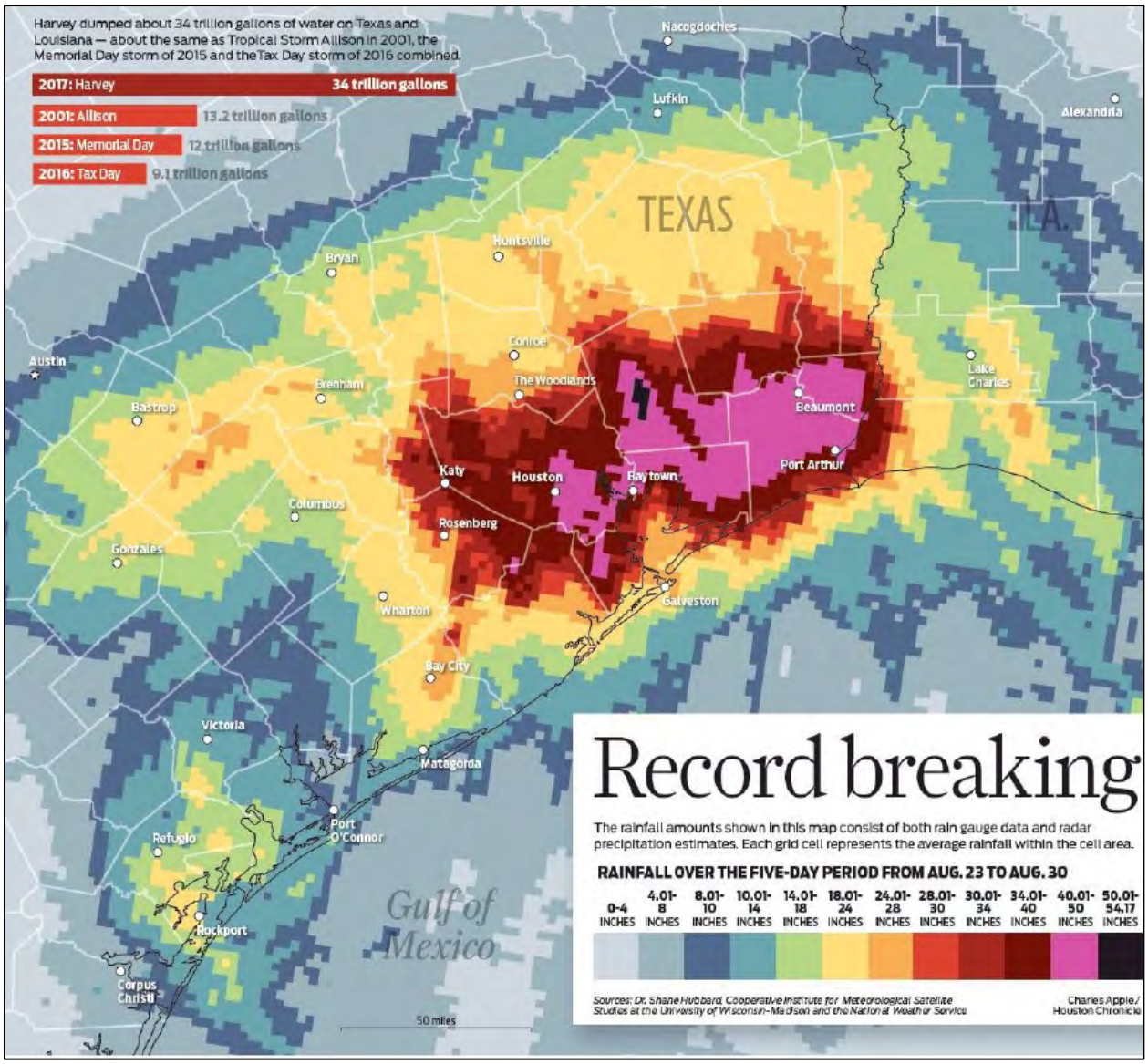
Figure 7. 12-hour Peak Rainfall and Flooding in Harris County, April 17-19, 2016



Source: Harris County Flood Control District

And then there is Hurricane/Tropical Storm Harvey. Harvey set a national record for the amount of rainfall over a four-day period. As shown in the map below from the Houston Chronicle (Figure 8), much of southeast Texas received over 40 inches of rain, with most of Harris County receiving at least 30 inches or more over this time period. For comparison, the 500-year, four-day storm event is 21 inches, a number far exceeded by Harvey. As of the date of this guide, the damages from Harvey are still being compiled, but estimates for Texas range from $80 billion to almost $200 billion (using different methodologies). Over 130,000 homes were flooded by the storm, and more than 700,000 persons have sought federal assistance of some kind. Although Harvey affected much more of the upper Texas coast than Harris County, extensive flooding occurred along virtually every watershed in the county. A map showing the Harvey rainfall distribution is shown below.

Figure 8. Rainfall Distribution of Hurricane/Tropical Storm Harvey



Note: The highest recorded rainfall amount was 60 inches over four days in Nederland, Texas, between Beaumont and Port Arthur.

Source: Courtesy of the Houston Chronicle

There are many more examples of large rainfall events going back to the 1970s—events that occurred, as the ones discussed above, more frequently than indicated by the statistical methods used to predict our 1% rainfall event. Hydrologists and climatologists are attempting to revise these statistics in light of recent events and that effort will likely be finalized in 2018. In fact, recent data published in the Proceedings of the National Academy of Sciences includes an analysis indicating that in areas such as Houston, the storms

previously considered to have a 500-year recurrence frequency (0.2% risk) are now considered to be 5-year (20% risk) storms, an assessment that needs further study.

This is powerful information that forces reconsideration of all of our thinking about flooding—a reconsideration that makes much of our current thinking about flood control obsolete. We should no longer be talking about flood control but rather, flood management. No city in the world can "control" over 40 inches of rain in four days, but we can learn to live with these storm events. But first and foremost, we need to take this new information seriously and use it wisely.

Most climate scientists are convinced that this increase in severe storm events is related to climate change. For years, documents produced by blue ribbon science panels at both the national and international level have been clear that more severe weather events are to be expected as the Earth warms, and that prediction is being borne out. Unfortunately, it is difficult to have a science-based discussion about climate change in our region due to strongly held personal and political opinions. That reluctance to speak openly and honestly about what science is telling us will lead us to under-predict the rainfall of the future, virtually guaranteeing that we will not get ahead of this problem to the extent needed to have a truly resilient city. Until we can have open discussions about the science, one might hear much discussion of "weird weather" or the "new norm."

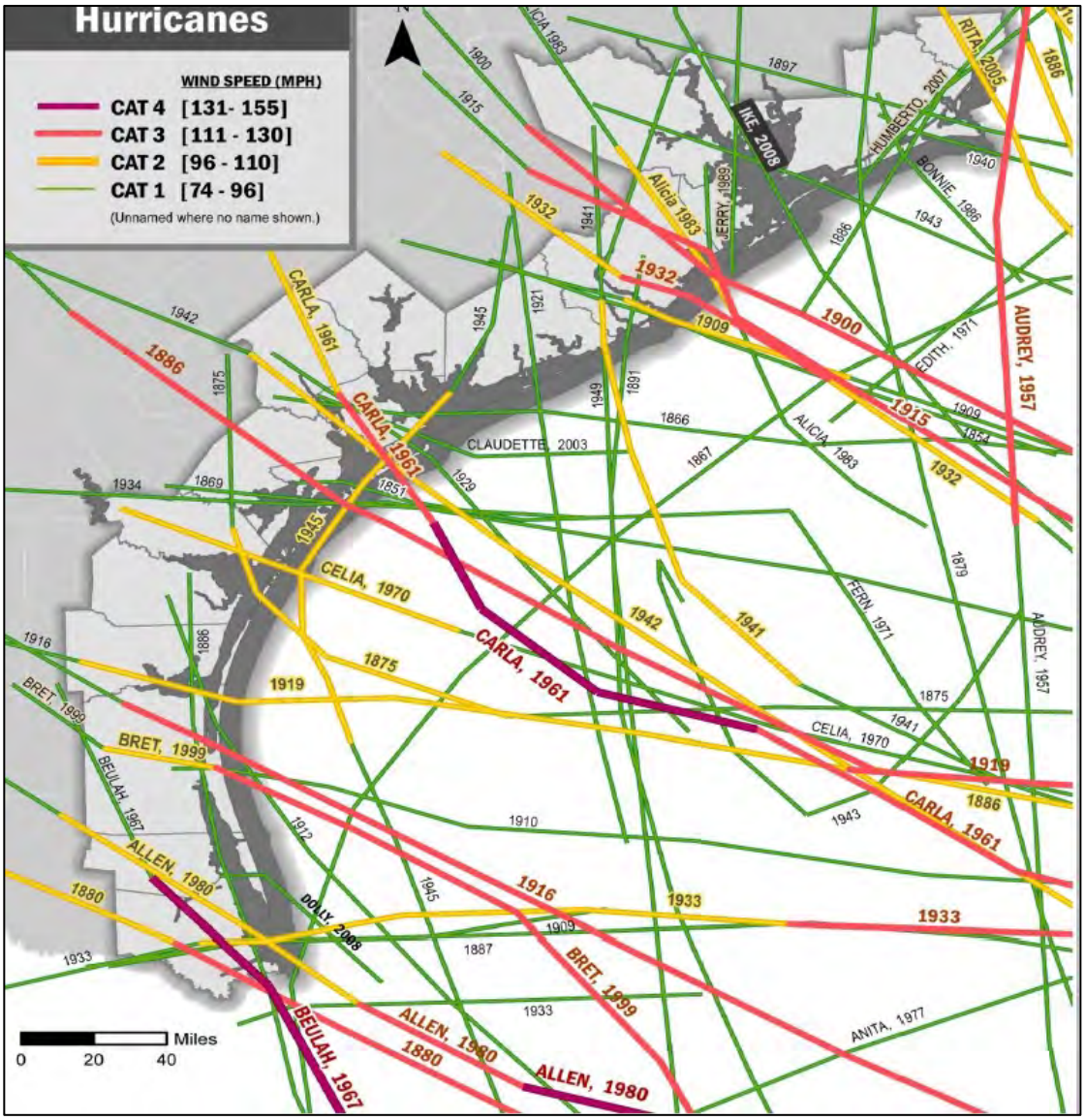
This new information also leads to the conclusion that construction that minimally meets the current (2017) standard for building elevation in the 100-year floodplain is simply not trustworthy for the future. At the least, we should be using the currently mapped 500-year floodplain pending re-study of the "new norm" of rainfall. Harris County is currently considering using the 500-year floodplain for its regulatory program. If our new maps are based on this new rainfall information, the new 100-year floodplain could be even larger than the currently mapped 500-year floodplain, given that some researchers have shown the current 500-year storm, which is now a 5-year flood. That would mean that between 40–50% of the county is likely subject to a 1% or greater flood.

Hurricanes and Surge

Hurricanes have been a fact of life on the Texas coast for centuries. Hurricanes destroyed the early Texas trading ports of Copano and Indianola on the middle coast in the 1870s and devastated Galveston in 1900. The Texas coast is littered with reminders of the misery caused by past hurricanes, yet we do not yet seem willing to accept their strength and plan for it. Instead, we generally fail to provide high quality information and good advice about these storms and their relative risk. This guide seeks to change that fact.

Below is a map of the paths of major hurricanes to have struck the Texas coast in the last century (Figure 9). As can be seen, the storms have come ashore in all portions of the Texas coast over time, but there is slightly higher chance of a strike on the upper coast than the lower coast.

Figure 9. Historical Hurricane Tracks on the Texas Coast



Note: The legend shows that the relative size of the storm is indicated by the color of the track line.
Source: Christina Walsh in *A Texan Plan for the Texas Coast*

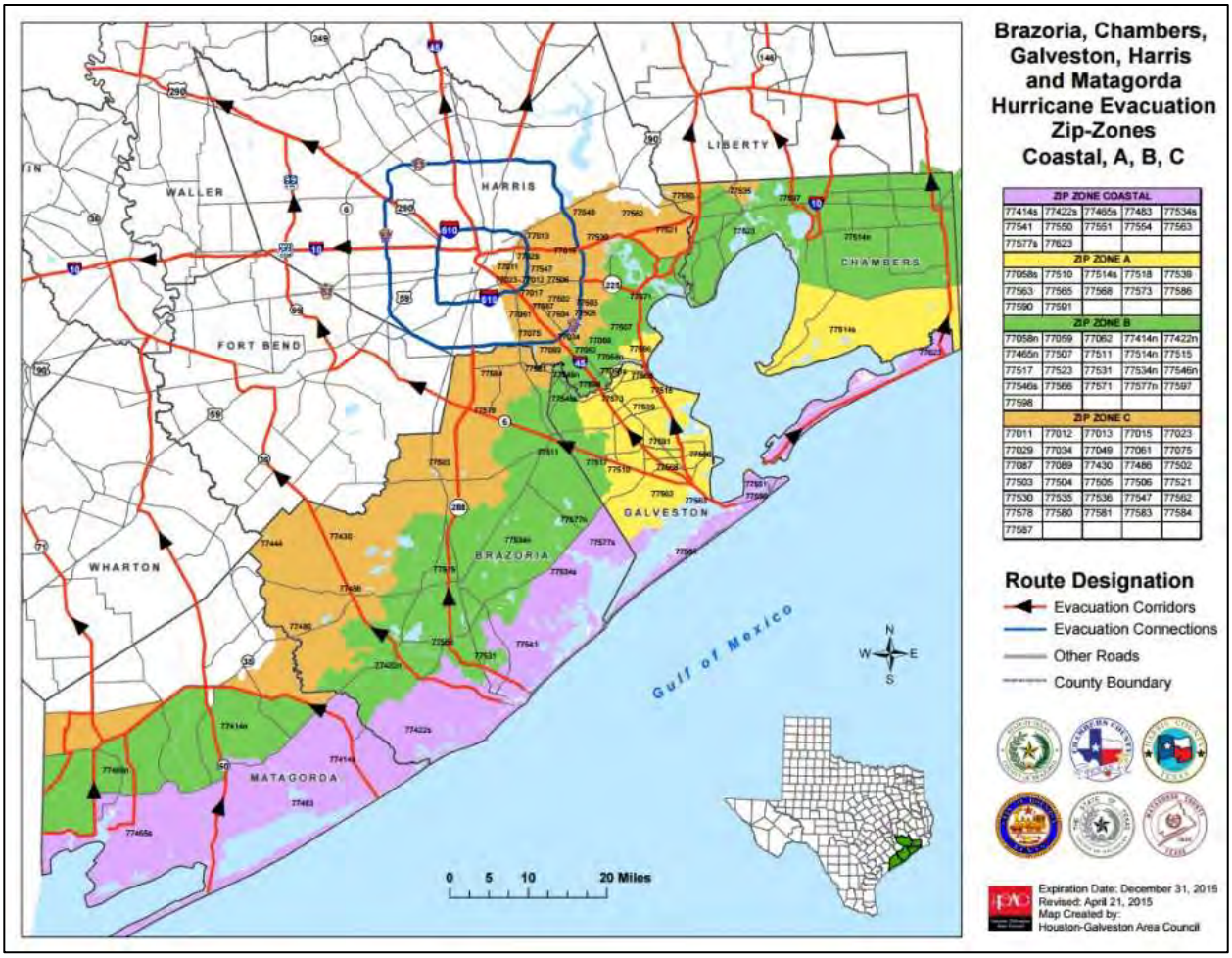
Hurricanes have three important elements: extremely high winds, frequently large rainfall events, and surge flooding. Rainfall from these storms has been discussed above, but the most dangerous of these elements is often surge flooding. Surge flooding occurs when hurricane winds move counterclockwise against the water's surface, causing the water to pile up as the storm travels across the ocean and is eventually pushed ashore. Surge flooding is enhanced on the upper Texas coast by the presence of a relatively large continental shelf offshore from Galveston County north to the Sabine River. These surge events are extremely dangerous, given that waves are formed atop the surge, pounding houses and other buildings that stand in their way as the storm pushes the water inland.

Additionally, surge is heightened by the funneling effects of bays, meaning that the surge in Galveston Bay will be higher than the surge along the coast— particularly to the right of the eye as the storm makes landfall, an area known as the "dirty" side of the storm.

In the Houston-Galveston area, governmental entities have identified areas that should be evacuated when a hurricane is moving toward the coast. These areas are called evacuation "zip zones" because they are delineated by zip code. Figure 10 shows the four zones—purple, yellow, green, and orange—in the Houston-Galveston area. In the past, the zones were based on the category of a storm. There are five categories, each related to wind speed, ranging from Category 1 (at or beyond 75 mile-per-hour winds) to Category 5 (157 mph winds or more. Today, both the wind speed and the projected surge height are used to trigger evacuations depending on an area's color code and zip code. Local authorities announce the extent and timing of an evacuation.

As a general proposition, those living in the yellow area should evacuate earlier than the others and should leave with the approach of any hurricane—although many choose to stay, often unwisely. The green area is the second evacuation tier that is triggered in the event of Category 3 storms. Residents of this area are are generally notified to evacuate after the yellow zone to allow those located in lower elevations to pass. The third evacuation zone—the orange zone—is triggered by truly large storm events. A list of zip codes by evacuation zone for the Houston-Galveston-Brazoria and Chambers area is shown below.

Figure 10. Hurricane Evacuation Map by Zip Code



Note: Zip code zones are shown for Brazoria, Chambers, Galveston, Harris, and Matagorda counties.
Zip Code Legend:

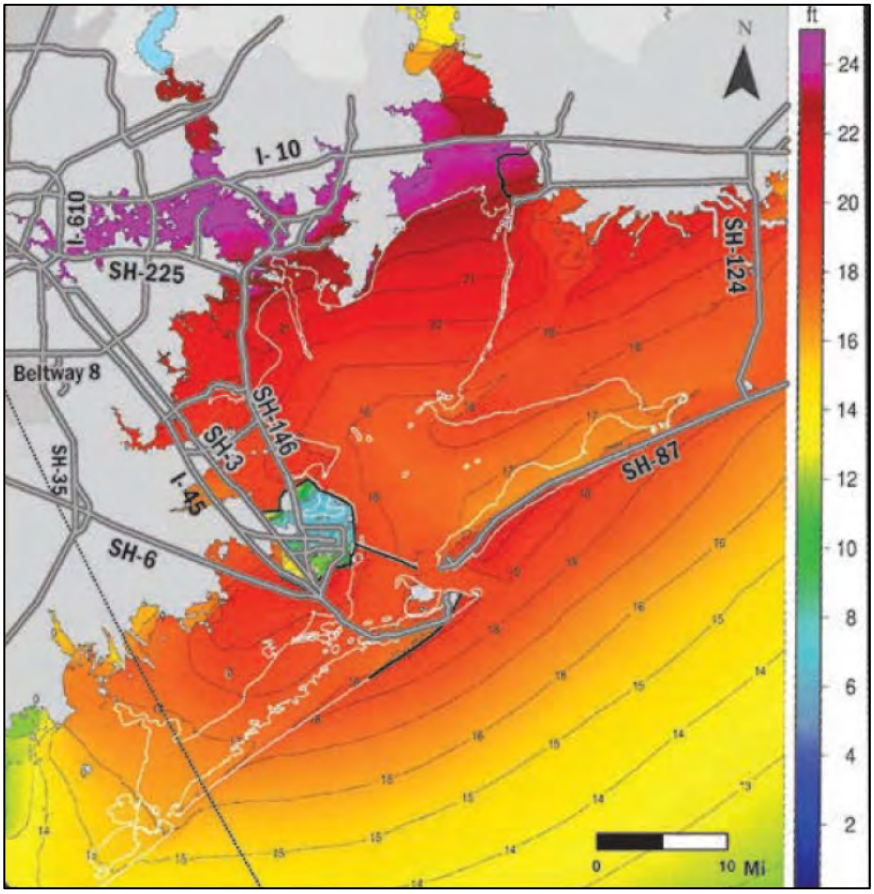
- Zip Coastal (Purple): 77414s, 77422s, 77466s, 77483, 77534s, 77541, 77550,77551, 77554, 77563, 77577s, 77623
- Zip Zone A (Yellow): 77058(s), 77510, 77514s, 77518, 77538, 77563, 77565, 77568, 77573, 77586, 77560, 77501
- Zip Zone B (Green): 77058n, 77059, 77062, 77414n, 77422n, 77466n, 77507, 77511, 77514n, 77515, 77517, 77523, 77531, 77534n, 77546n, 77546s, 77566, 77571, 77577n, 77597, 77598
- Zip Zone C (Orange): 77011, 77012, 77013, 77015, 77023, 77029, 77034, 77049, 77061,77075, 77087, 77089, 77430, 77456, 77502, 77503, 77504, 77505, 77506, 77521, 77530, 77535, 77536, 77547, 77562, 77578, 77580, 77581, 77583, 77584, 77587

Source: Houston-Galveston Area Council

These evacuation maps are not widely known to exist or widely distributed. If you are buying a home in an evacuation zone, no one—not the seller, not the real estate agent, not the title company, not the lawyer—is required to tell you that you are buying in an evacuation zone. Often, the majority of evacuation zones are not in the 100-year floodplain, but the existence of the 100-year floodplain is the only information required at real estate closings.

Computer modeling completed at the Severe Storm Prediction, Education, and Evacuation from Disaster (SSPEED) Center at Rice University indicates the extent of surge flooding associated with a storm considered by center researchers to be reasonably foreseeable: a large Category 3 storm the size of Hurricane Ike, but coming ashore about 30 miles south of the City of Galveston. This storm will generate a 20-foot surge at the coastline and upwards of 25 feet in the upper portions of Galveston Bay and Houston Ship Channel. Most of the Clear Lake-NASA area will be put under water by this storm, with many areas inundated by more than 10 feet of water. The Ship Channel will be substantially flooded, as most facilities are only protected to about 15 to 16 feet of elevation. The storm shown in Figure 11 will likely: kill thousands of people (depending upon the success of the evacuation), flood up to 200,000 homes, and inundate most industries along the Houston Ship Channel, releasing almost 100 million gallons of oil and hazardous substances, making this a disaster worse than Harvey. It is a truly frightening event that we are not prepared for at this time (2017).

Figure 11. Predicted Surge from a Reasonably Likely Storm



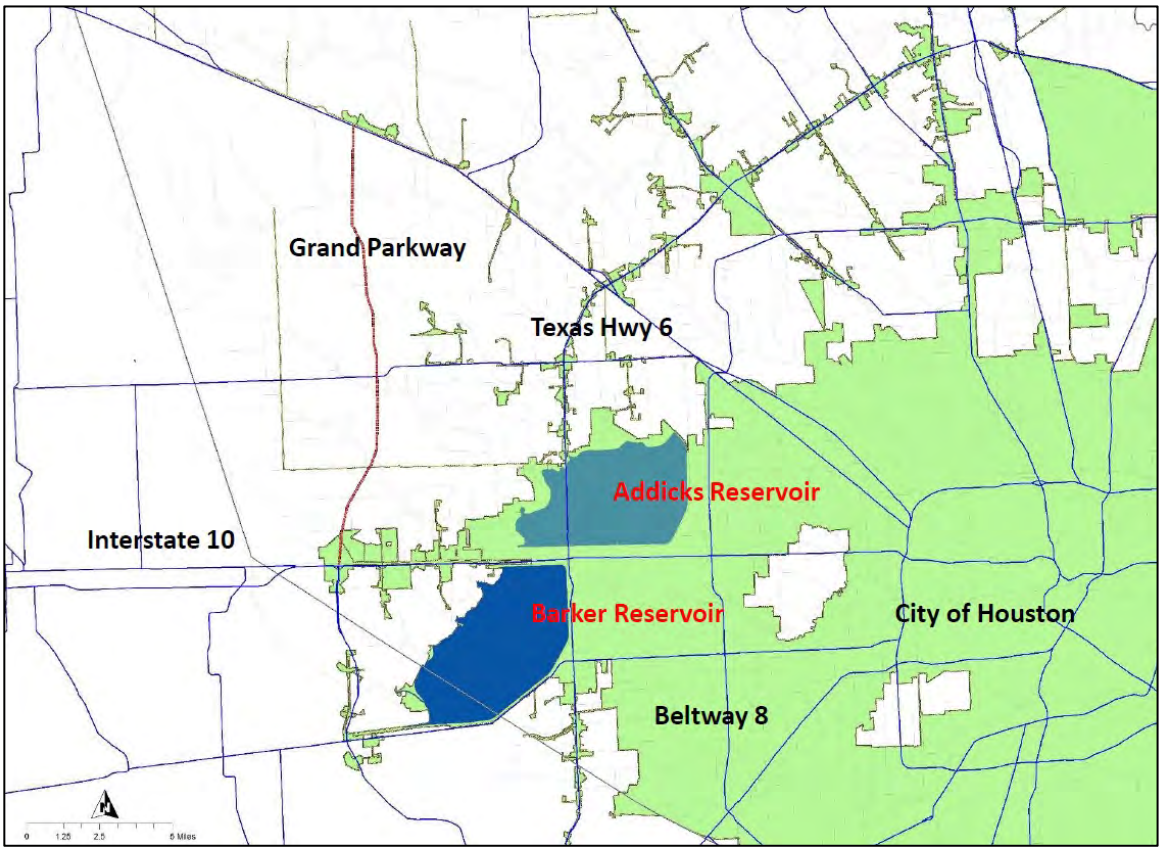
Note: Graphic shows the surge from a storm 15% stronger than Hurricane Ike coming ashore near San Luis Pass.

Source: Courtesy of SSPEED Center and Christina Walsh

Addicks and Barker Reservoirs

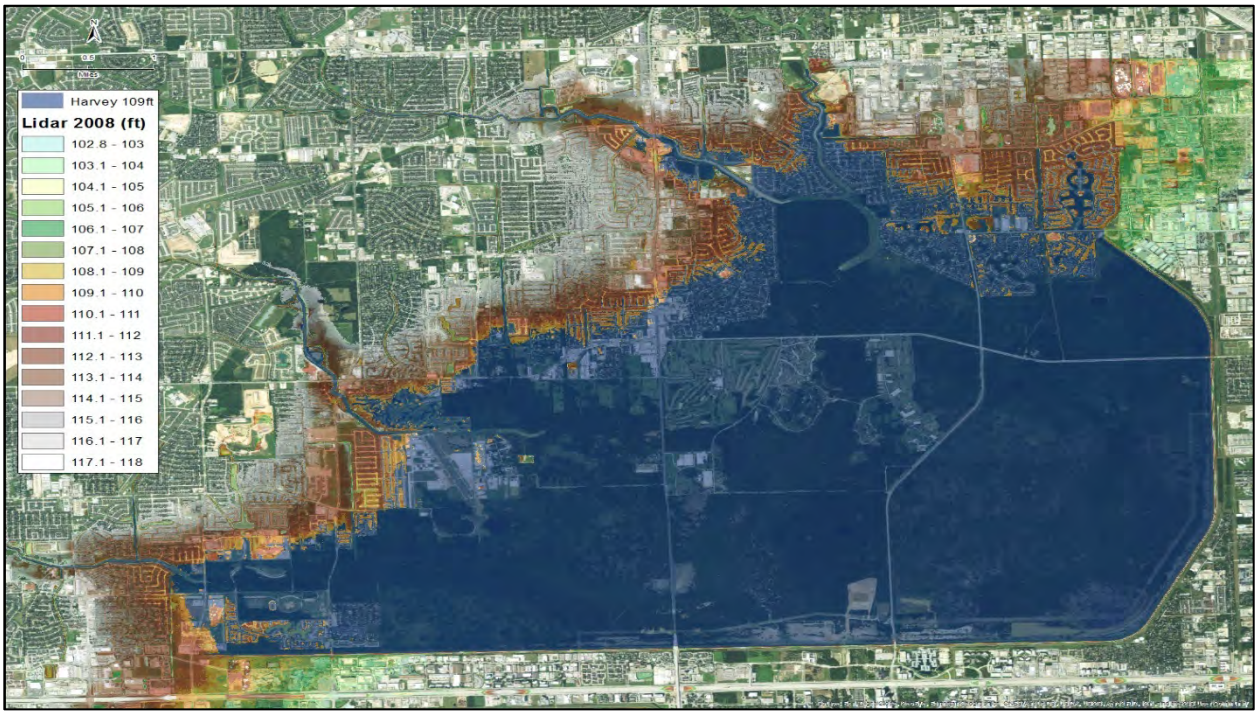
There are different types of problems in different watersheds. Most of the problems have to do with understanding the way in which rainfall runs off in a particular area and the location and extent of the floodplains as discussed above. However, some watersheds have unique problems—and the Addicks and Barker reservoirs are certainly unique.
Addicks and Barker are two dams in the Buffalo Bayou watershed. Addicks Dam lies north of IH-10 and east of Texas Highway 6. Barker Dam lies south of IH-10 and west of Highway 6. Both of these dams—designed and constructed in the late 1940s and early 1950s—were meant to protect downtown Houston and the west side along Buffalo Bayou from flooding after the damaging floods of the 1930s. Around 2009, these dams were classified as two of the six most dangerous dams in the United States operated by the Corps of Engineers due to the risk of structural failure and its potential impact on people or property. As a result, the operational plan for the reservoirs was temporarily changed to allow for increased releases based on water elevations within the reservoirs until adequate safety measures and repairs could be made.

Figure 12. Location of Addicks and Barker Reservoirs



During Harvey, there was substantial flooding both upstream of Addicks and Barker dams within their reservoirs and downstream of Addicks and Barker. Each of these flooding situations is different—they are caused by fundamentally different fact situations. Upstream, homes were constructed within the design flood pool of Addicks and Barker because condemnation for the dams was controversial, and the government stopped short of condemning all of the land that it knew would be flooded if the reservoirs filled to capacity. This land remained in private hands and was ultimately developed for homes as well as businesses and schools. Most of this land is not within the 100-year floodplain although some is. Home sales that occurred for lots within the flood pool generally lacked any type of disclosure to the homebuyer. It is reasonable to assume that the upstream houses within the flood pool will flood anytime that Addicks or Barker fills to the reservoir's capacity.

Figure 13. Flooded Areas Behind Addicks Reservoir After Tropical Storm Harvey



Note: Elevation is 109 feet.

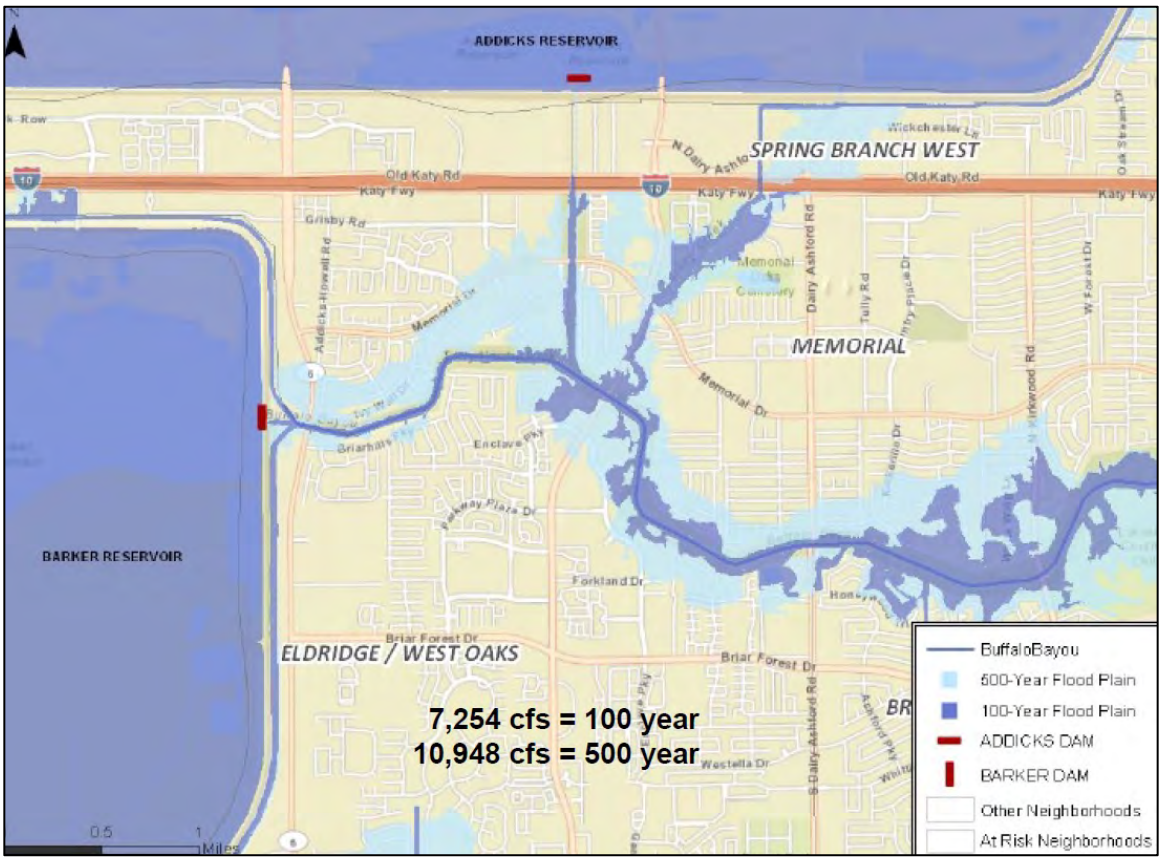
Source: SSPEED Center, Rice University

By contrast, the flooding downstream was due to the operation of Addicks and Barker dams. Since 2009 (when these dams received a risk of catastrophic failure designation), the Corps of Engineers has been developing special operating plans for Addicks and Barker to go along with their standard plans for operating these reservoirs. Together, the plans call for more releases downstream than in past severe events, even to the point of scheduling major releases while rain is falling downstream of the reservoirs. These dams were not

designed to hold water for extended periods of time, and they need to be drained sooner rather than later.

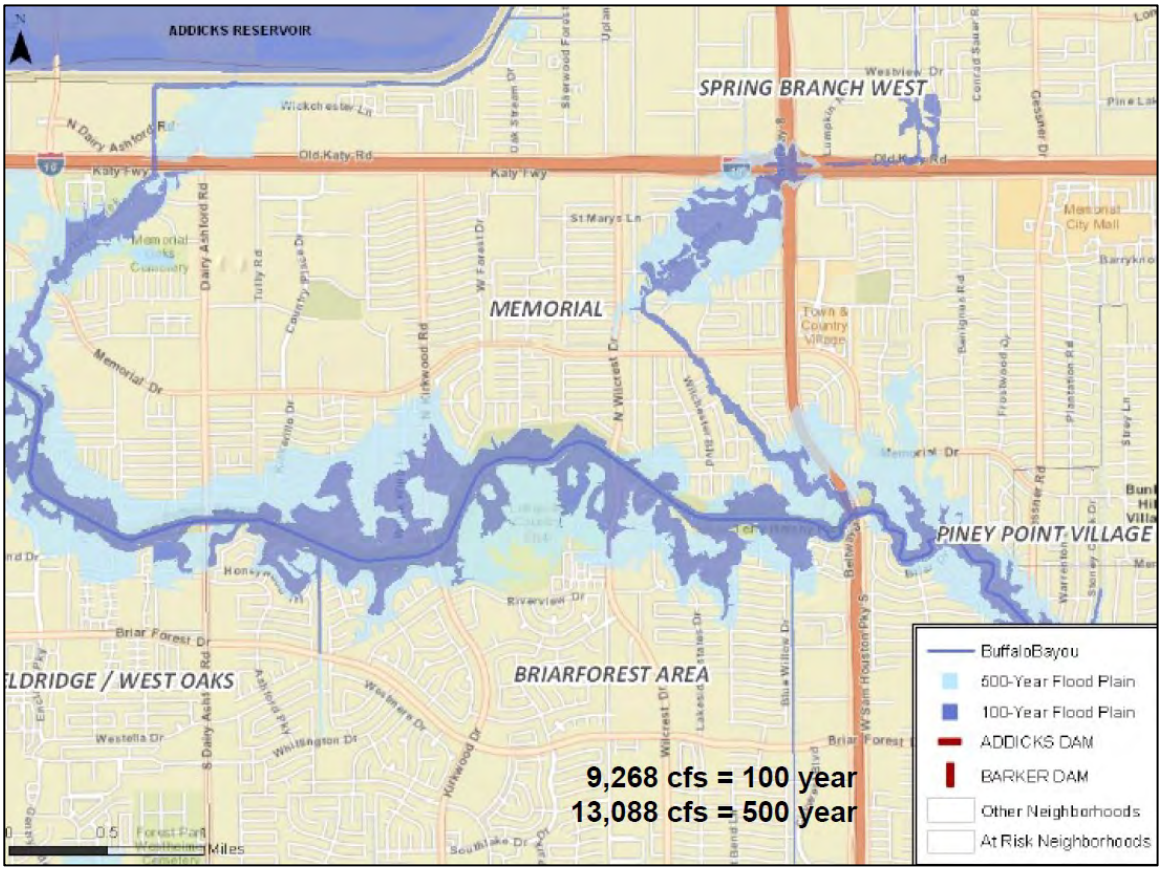
During Harvey, as much as 15,000 cubic feet per second of water was released from the gated outlets of Addicks and Barker dams. As can be seen from Figures 14 and 15, these releases were larger than the 500-year flood flows used by FEMA for mapping the 500-year floodplain on Buffalo Bayou just downstream of Addicks and Barker. Until improvements are made to Addicks and Barker or a third reservoir is added upstream, these problems can be expected to recur with a rainfall of the magnitude of Harvey. However, as a general proposition, this portion of the Buffalo Bayou has performed better than several other bayous during large, shorter-term rainfall events.

Figure 14. The 100- and 500-year Floodplains on Buffalo Bayou, Downstream of the Barker and Addicks Reservoir Inflows



Note: The flow used to determine the extent of the 100- and 500-year flood is shown in bold print.

Figure 15. The 100- and 500-year floodplains on Buffalo Bayou, downstream of the Addicks Reservoir inflow to just past Beltway 8



Note: Flow used to determine extent of the 100- and 500-year flood shown in bold print.
Source: FEMA flood insurance rate map for Buffalo Bayou, Harris County, Texas.

Roadways

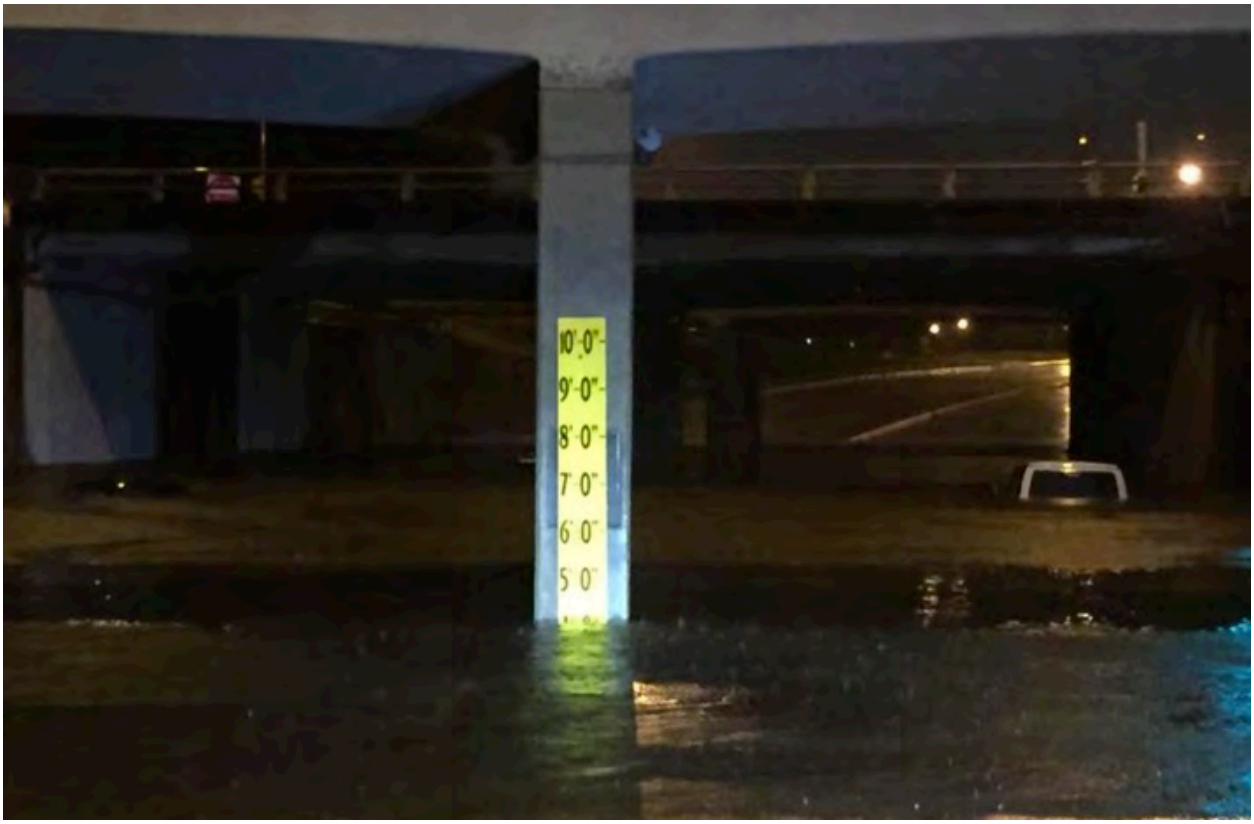
The roadways in Houston serve as secondary drainage systems. Our roads fill with water during intense rainfall events. Most any road in Houston can and will flood. Some drain better than others. Some have low spots that are deeper than you think. Some underpasses are simply deadly. During heavy rains, always look for depth indicators on underpasses. In general, do not enter a flooded underpass. Hopefully, the city and the county will install flood gates at such underpasses, as well as develop mobile phone app devices that will give information about street flooding conditions, including streets to avoid and those that are safe to travel.

It is difficult to give definitive advice about street flooding in all areas. The best way to learn about an area's accessibility is to talk to your neighbors. Ask what roads are the first to flood during rains, which intersections to avoid, and which roads to use during a flood.

Most of us who have lived here for awhile have a general idea of which routes are better during intense rains. Know your routes from home to work and school and investigate them to determine if they are flood prone. It will pay off during a heavy storm. And many of us simply put off driving during severe rain events if we can.

If you get caught out in a storm and the roads fill up with water, pull into a parking lot as soon as you can. Do not drive into flooded roads that are unfamiliar. Take your time. A lot of cars have been flooded and ruined because the driver assumed they could just push on. And drivers do drown every so often, so be safe out there.

Figure 16. A Flooded Underpass in Houston



Note: This image shows a typical underpass in Houston with the depth of flooding indicated as well as the car that seemingly disregarded that information.
Source: Image courtesy of KHOU

Buying Real Estate

There is no simple formula for figuring out where to buy or rent a home. However, there are some common sense suggestions that may help you make a better decision. This is not legal advice or advice about any particular property. I recommend consulting an attorney, an engineer, and/or a realtor to help you in this process.

Ask about the flooding history of the home or commercial property you are considering purchasing. Buyers are obligated to fully disclose such information when asked. Similarly, talk to the neighbors. Find out about past floods, if any, and the history of street flooding in the area in terms of accessibility. But most importantly, ask the sellers or landlords direct questions about flooding and get written statements prior to purchase or lease. These statements might be valuable later.

Consult the floodplain maps for your area. Look at the elevation of the floodplain and then compare the slab elevation of your home. Currently, Harris County is proposing to use the 500-year floodplain for regulatory purposes pending remapping. This is a reasonable guide. Houston/Harris County has had two 500-year floods in the last three years. It is a reasonable guide to use. If you are within the 500-year floodplain, the elevation of the home should be above the 500-year flood elevation. At this time, the 100-year floodplain maps are not true indicators of the current 1% risk of flooding in any area of town. These areas are much more likely to flood than indicated by the 1% risk. I recommend against buying in the 100-year floodplain or buying any home whose elevation is below the 500-year flood level.

If purchasing on the Texas coast or on the east or southeast side of Houston and Harris County, consult the hurricane evacuation zip code map to determine if you are in an evacuation area. It is important to understand the risks of these areas above and beyond those indicated in floodplain maps, which often do a poor job of expressing the risk of hurricane surge flooding. If you are below an elevation of 25 feet in the eastern and southeastern portion of Harris County, there will be a higher risk of surge flooding than at higher elevations. Unless and until a coastal barrier is constructed, I would avoid these areas or be elevated above 25 feet.

Check the elevation of the slab of the house above the crown of the street in the City of Houston, where the streets are the secondary drainage system. During more intense rain events, the streets fill up and spill over into the yard. I would not purchase a home where the slab is even with or just slightly higher than the crown of the street. This may be the case in many parts of town. Preferably the slab should be two feet or more above the crown of the street.

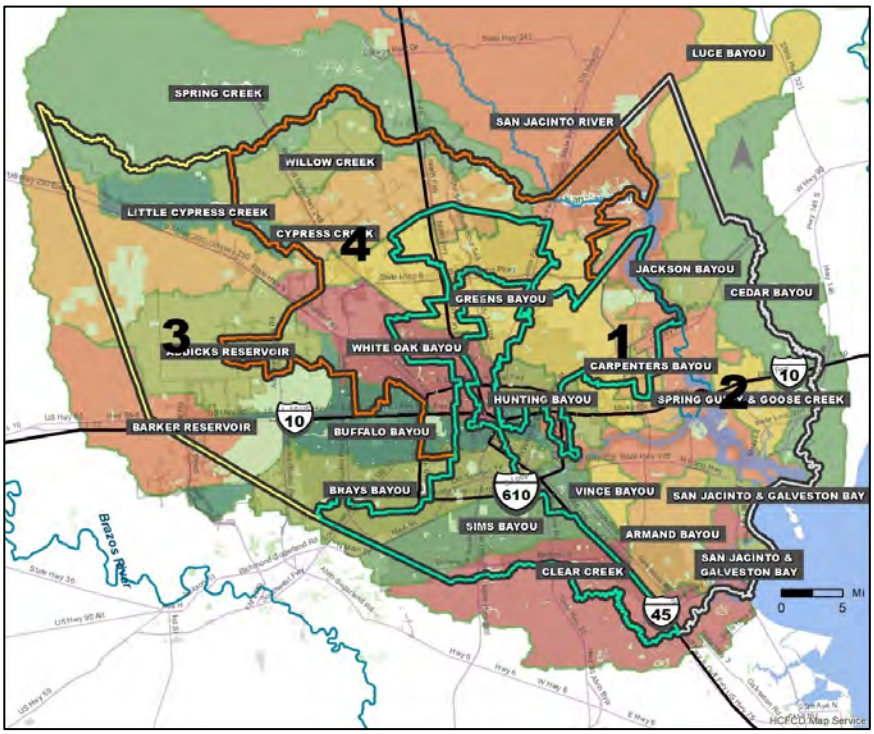
Regardless of where you live in this town, I would purchase federal flood insurance as long as the rates are subsidized. This is particularly true if you are located in the 100- or 500-year floodplain, are below the 25-foot elevation level, are located within the Addicks or Barker reservoirs, or have a home that is flat with the crown of the street. The rains we have seen in the recent past suggest that localized areas may be subjected to incredibly strong rain. Many have discovered that this insurance is the best buy in Houston, at least until the federal government removes the subsidized rates (which is likely to happen in the future given the current financial problems of the program).

Governmental Involvement in Flooding-related Activities

The local, state, and federal governmental systems are all involved in flooding to various degrees. Historically, the Harris County government has been most involved in flooding issues, with the Harris County Flood Control District (HCFCD) having primary responsibility for our flood management policies and concepts. The HCFCD is also the local sponsor that is often required for federal or state-funded projects.

The Harris County Commissioners Court governs Harris County and oversees HCFCD. The Commissioners Court is administered by the county judge, a position held (as of November 2017) by Ed Emmett. Emmett is the chief administrator of Harris County and is responsible for the day-to-day operation of many county functions. There are also four commissioners, each with their own precincts. Precinct 1 is presided over by Rodney Ellis, Precinct 2 by Jack Mormon, Precinct 3 by Steve Radack, and Precinct 4 by Jack Cagle. These commissioners are very powerful in their districts and have substantial budgets for road and drainage work. The county judge and the commissioners are elected to four-year terms. In November 2018, Emmett, Mormon, and Cagle are up for re-election. Ellis and Radack will not stand for re-election until 2020. The map below shows these county precincts relative to the various watersheds. Please note that some of these boundaries are rather difficult to follow as they have been defined in the political process.

Figure 17. County Commissioner Precincts and Watersheds in Harris County

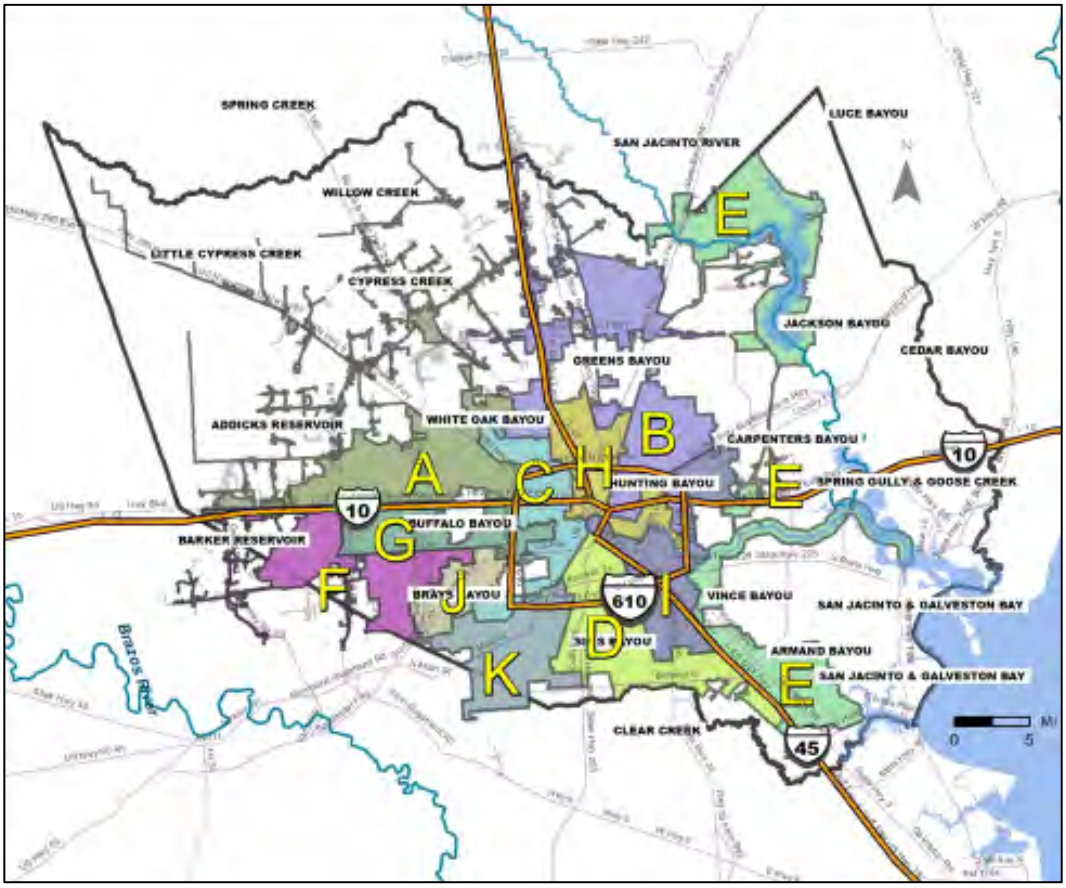


Source: Courtesy of Christina Walsh

The City of Houston has not exercised as much of a role in flooding matters as it could, choosing instead to often defer to the county on policy matters. The city does administer a floodplain regulatory system, as does the county outside of city boundaries. The City of Houston is responsible for storm sewer construction and street drainage. Harris County has these roles in the unincorporated area outside the boundary of any city. The city could take a much stronger role in development regulation and floodplain policy if it chose to do so.

The City of Houston is administered by Mayor Sylvester Turner who, under our strong mayoral form of government, essentially runs the day-to-day business of the city. The city is also governed by five at-large council members and 11 council members representing various districts. These councilmembers are, as of November 2017: District A, Brenda Stardig; District B, Jerry Davis; District C, Ellen Cohen; District D, Dwight Boykins; District E, Dave Martin; District F, Steve Le; District G, Greg Travis; District H, Karla Cisneros; District I, Robert Gallegos; District J, Mike Laster; and District K, Larry Green. There are also five at-large council members: At-Large 1, Mike Knox; At-Large 2, David Robinson; At-Large 3, Michael Kubosh; At-Large 4, Amanda Edwards; and At-Large 5, Jack Christie.

Figure 18. Houston City Council Districts and Watersheds

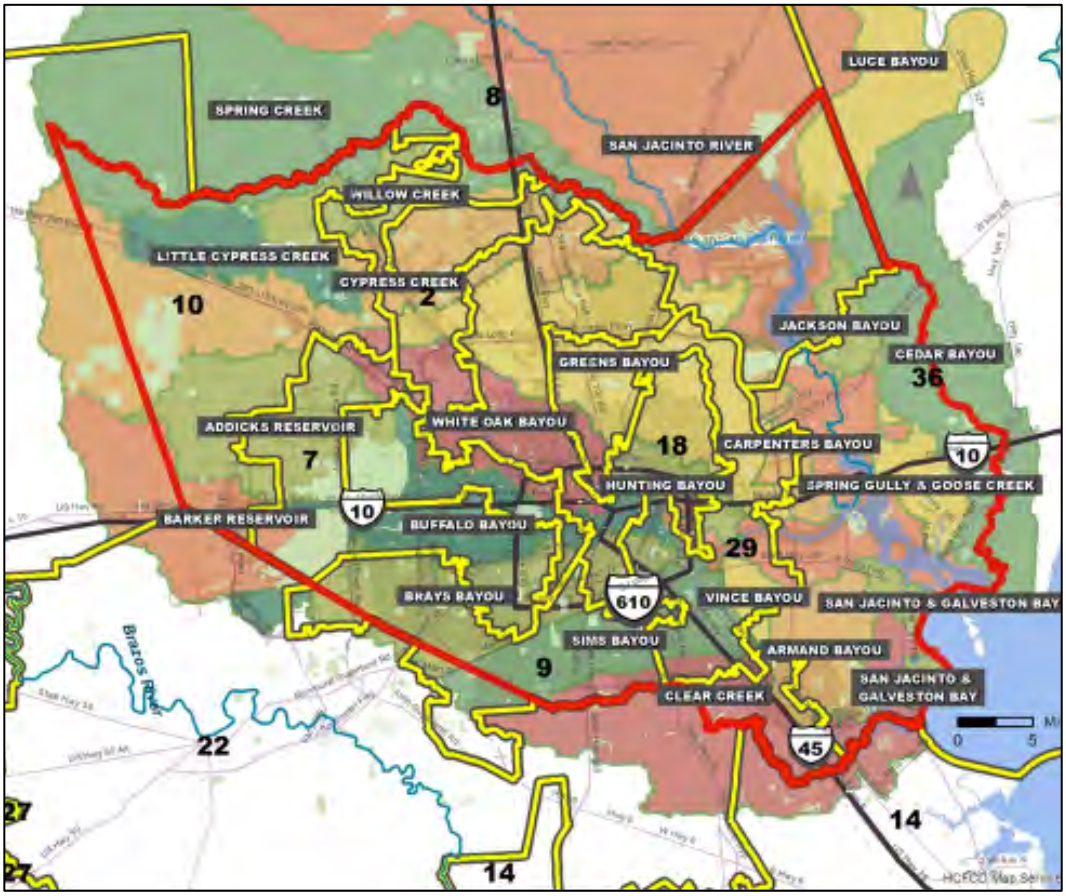


Note: Colors denote the district boundaries.

Source: Courtesy of Christina Walsh

The federal government is very involved in flooding issues in Houston and Harris County. The Addicks and Barker reservoirs are operated by the U.S. Army Corps of Engineers. The corps is also the federal sponsor for many other flood control projects in the county. FEMA is responsible for emergency relief and the federal flood insurance program, and the Department of Housing and Urban Development helps provide disaster-related funding, including block grants that can be used for buyouts, among other things. Texas, like every state, has two U.S. Senators. Ours are John Cornyn and Ted Cruz. Cruz is up for re-election in November 2018. Houston's U.S. representatives are elected every two years. The U.S. representatives for the Houston-Harris County area are: 2nd District, Ted Poe (retiring in 2018); 7th District, John Culberson; 8th District, Kevin Brady; 9th District, Al Green; 10th District, Mike McCaul; 14th District, Randy Weber; 18th District, Sheila Jackson Lee; 22nd District, Pete Olson; 29th District, Gene Green (retiring in 2018); and 36th District, Brian Babin. Figure 19 shows the district boundaries relative to the various watersheds. Please note that some of these boundaries are rather difficult to follow as they have been defined in the political process.

Figure 19. Houston-Harris County Area Congressional Districts and Watersheds

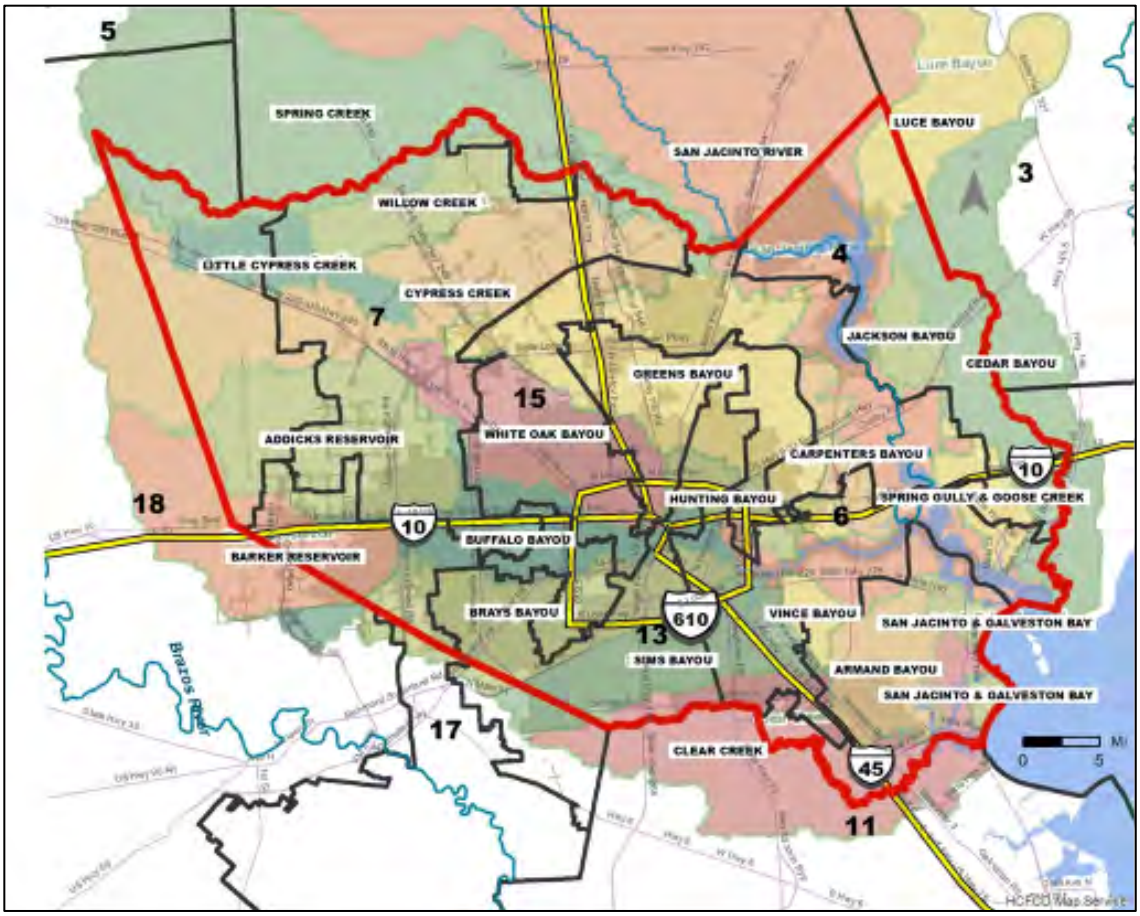


Note: District numbers are shown inside the boundaries.

Source: Courtesy of Christina Walsh

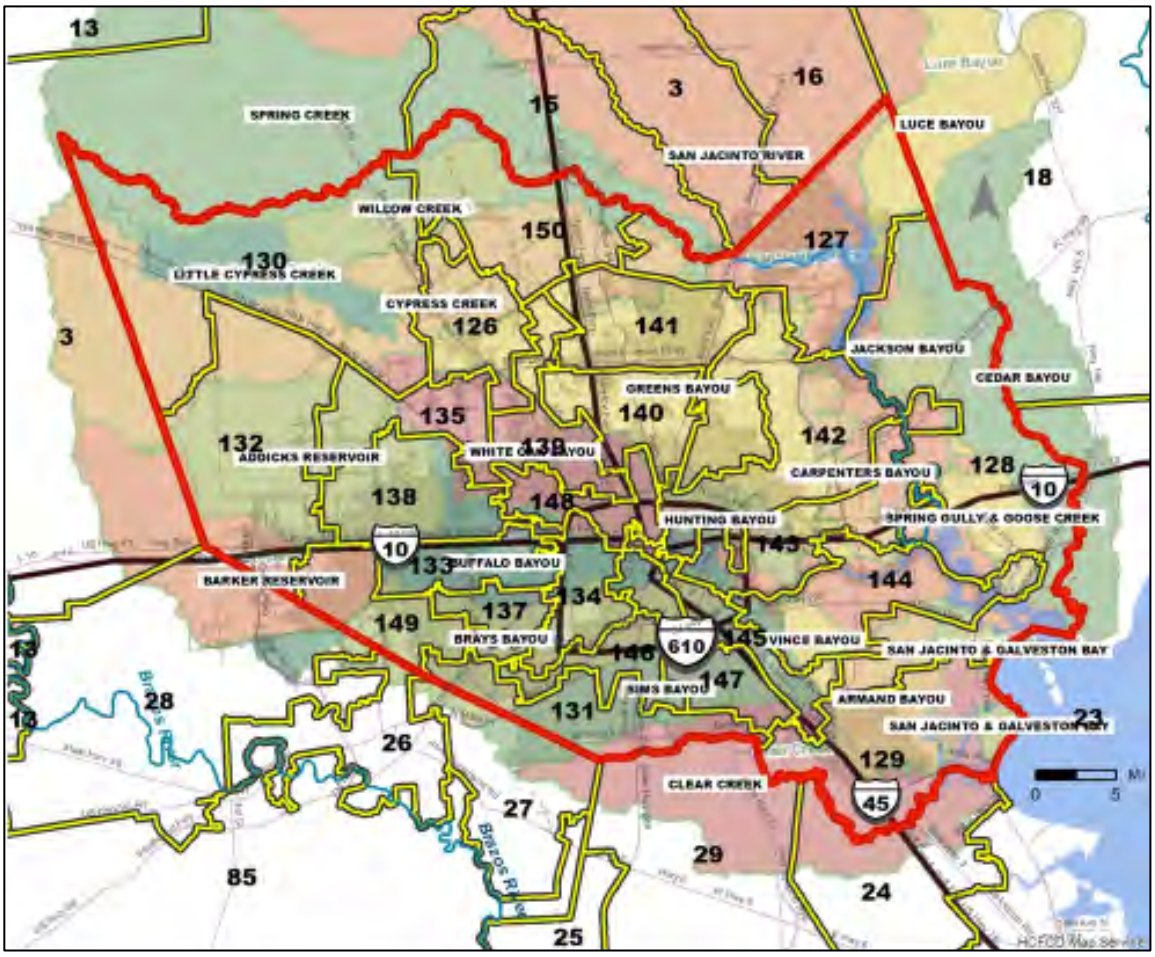
State government has not taken a large role in Harris County and Houston flooding issues in the recent past. There is no doubt that the Texas Legislature could address many issues associated with flooding, including a stronger role for state agencies in flooding oversight as well as state funding to assist in recovery and future buyouts. Texas state government is presided over by Gov. Greg Abbott and the Lt. Gov. Dan Patrick. The governor appoints many administrative agency boards and is the policy leader for the state. The lieutenant governor presides over the Texas Senate where he has a powerful oversight role. Both Abbott and Patrick stand for election again in November 2018. Additionally, Texas' numerous state senators and representatives could affect flood policy in the future. Their districts are shown in the figures below.

Figure 20. State Senatorial Districts and Watersheds in Houston-Harris County



Source: Courtesy of Christina Walsh

Figure 21. Texas House of Representative Districts and Watersheds in Houston-Harris County



Source: Courtesy of Christina Walsh

A Vision for the Future

There is much work to be done in this community to have a world-class, livable city in the years ahead. The themes and ideas in this paper will be developed and expanded in the future. However, here are the basics of what is required, at least in one person's opinion.

Flood-smart Citizens Who Participate

If many of the flooding-related problems in our community are to be fixed, we need to have an informed, flood-literate, and engaged populace. We get the government that we demand. It seems that many of us assumed that men and women who knew better than us were taking care of these issues. Now we know that such faith was not well founded. We have to take responsibility for, and get involved in, all future flood-related aspects. If we

don't demand and fight for a high-quality flood management, we will not get it. Governmental processes need to be transparent, and we must participate in that system. For too long, we have been dormant, willing to take what we have been given. Now is the time to ask for—and get more—than we have in the past.

Make Room for the Bayous and Creeks

We need to make more room for water in our community. Our philosophy of flood control in the past has involved an attempt to confine the water to concrete and earthen channels. However, we need to learn the lessons our failed policies. We have built too close to most of the area's bayous and creeks. We need to buy out the homes in much of the current 100-year floodplain. It is simply not safe for housing. These homes or the people who live there, particularly those deepest into the floodplain, cannot be protected. We should not continue to make the same mistakes over and over. First responders should not be asked to once again risk life and health because we refuse to admit that the water needs more room. If water is given more space, we will discover, much like the Dutch, that we can co-exist with the water. But we should always respect it.

Flood-literate Politicians

We need politicians that are flood-literate, who can think for themselves about these issues. We are all learning about flooding, and that is particularly true of those elected to represent us. Our elected representatives, senators, council members, mayor, county commissioners, and county judge must to represent the people of Houston and Harris County on flooding issues, which is the number one threat to public health, life, and economic prosperity in this area.

Focus on Those Who Are Here Now

Our leaders must focus on those who live here now rather than those who are coming. We were more concerned about building the Grand Parkway to assist new development than fixing the dangerously deteriorating Addicks and Barker dams. That focus needs to change. Our attention should be on fixing the problems of existing, developed areas.

Transparency

Nothing is more important going forward than transparency in our flood control efforts and thinking. For decades, much of the county's and city's policy deliberations have been behind closed doors, out of the view of the citizens. This must change if we are to get on top of these issues.

This document should be considered as a beginning—an attempt to put in one place the type of information that will help Houston and Houstonians come out of the next flood in reasonably good shape. Suggestions to improve and expand this guide are welcome.