HOUSTON PUBLIC WORKS

CITY OF HOUSTON

STORMWATER MASTER PLAN

EXECUTIVE SUMMARY


Prairie
BAYOU PLACE
Hard Rock

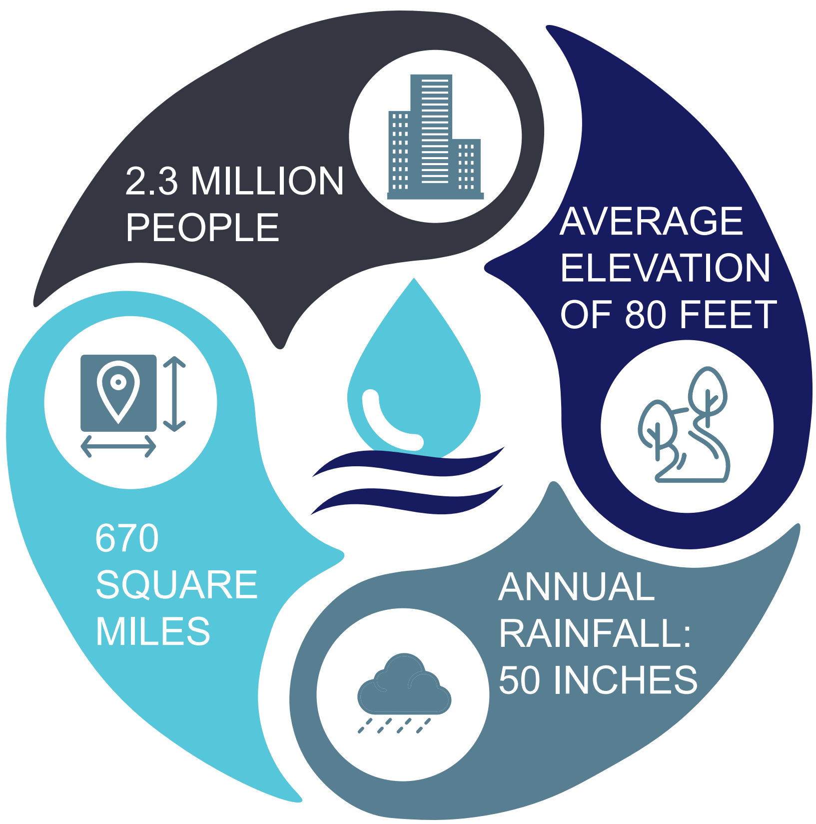
Contents

Introduction

PURPOSE

Spanning 670 square miles with over 2.3 million residents, the City of Houston is one of the largest cities in the United States. The size of the City, combined with its flat terrain, high annual rainfall totals, and sprawling development, create many unique drainage infrastructure challenges. The first step to addressing these challenges is understanding the nature and extent of the issues that the many pieces of the City's existing drainage system face including its existing capacity and ability to perform during both large and small rainfall events. This project was undertaken so that the information and models developed could begin the process of understanding and quantifying system performance so that the City can build upon these results and better plan, maintain, and expand the City's storm drainage systems.

CITY OF HOUSTON BY THE NUMBERS



The Stormwater Master Plan is the first phase of comprehensive drainage planning for the City of Houston. The information gathered allowed us to understand the City's stormwater infrastructure and effectively evaluate how water moves through neighborhoods. The City funded this project through partnerships with the Texas Water Development Board and General Land Office.

PROJECT GOAL

The goal of this project is to build a foundation to assist the City in enhancing flood management, prioritizing focus areas, streamlining project development, and improving community resilience. This foundation is developed through the following tasks:

DEVELOP A COMPREHENSIVE DRAINAGE MODEL OF THE CITY'S INFRASTRUCTURE.

PERFORM AN ASSESSMENT OF EXISTING FLOOD RISK THROUGHOUT THE CITY.

IDENTIFY FOCUS AREAS FOR FUTURE PLANNING OF PROJECTS AND STUDIES.

BACKGROUND

HISTORICAL STORMS

The City of Houston has experienced numerous significant storm events throughout the past century. Flooding from these events has been caused not only from overflows of the bayous, creeks, and rivers but also from local sources, including undersized infrastructure. Maps such as the Flood Insurance Rate Maps published by the Federal Emergency Management Agency (FEMA) illustrate flooding from overflows of bayous, creeks, and rivers.

DECEMBER 1935

Heavy rainstorms occurred upstream of the City causing the bayous to fill. Following this, 5 inches of rain fell within Harris County, overtopping the bayous and flooding most of downtown Houston.

AUGUST 1945

A hurricane hit the Gulf of Mexico bringing heavy rainfall and high winds to Houston. Rainfall totaled over 15 inches within 24 hours, causing flooding along the major bayous.

JUNE 1979

Twelve (12) inches of rainfall resulted from heavy storms in the Houston area, resulting in widespread flooding across the City with flood depths of over 6 feet in some areas.

SEPTEMBER 1998

Tropical Storm Frances dropped up to 21 inches of rainfall over Houston and Harris County.

JUNE 2001

Tropical Storm Allison resulted in 15-35 inches of rain in Houston causing significant damage to structures, vehicles, and facilities in the region.

SEPTEMBER 2008

Hurricane Ike dumped between 8 and 12 inches of rain in the Houston area and caused significant storm surges along the coast.

MEMORIAL DAY 2015

As much as 11 inches of rain fell overnight during a storm event, with an average rainfall of 5 inches across Harris County.

TAX DAY 2016

From April 17-18, almost 24 inches of rain fell over a 24-hour period in part of Harris and surrounding counties.

AUGUST 2017

Hurricane Harvey rainfall, totaling between 24 and 40 inches, fell across the City resulting in catastrophic flooding across all major bayous.

SEPTEMBER 2019

Tropical Storm Imelda rainfall, totaling 29 inches, resulted in flooding across the northern and western portions of the City.

Flooding from a 3-day storm in December of 1935 prompted the construction of the Addicks and Barker reservoirs to provide flood relief to downtown Houston.

Tropical Storm Allison was the costliest tropical storm not classified as a hurricane.

Intense flash flooding was seen across Houston during the Memorial Day flood of 2015.

The Tax Day flood of 2016 was a widespread event impacting many counties throughout Texas including Harris County.

Photo sources:Top left - https://www.houstoniamag.com/news-and-city-life/2017/07/houston-weather-flooding-storms-history; Top right - https://www.texasfreeway.com/houston/june-2001-flood-photos/; Bottom left - https://www.chron.com/news/houston-weather/article/Remembering-the-Memorial-Day-Flood-one-America-s-11176375.php; Bottom right - https://www.chron.com/news/houston-texas/houston/article/tax-day-flood-houston-2016-photos-looking-back-12832654.php

PLANNING EFFORTS

As severe storm events have become more common, the City of Houston has performed several citywide planning studies to better identify and quantify flood risk. Key drainage studies include:

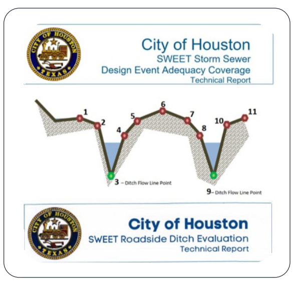
COMPREHENSIVE DRAINAGE PLAN (CDP) (1999)

- Citywide analysis
- Used GIS and Rational Method
- Analyzed storm sewer system capacity only for the 2-year event
- Used in CIP identification

REBUILD HOUSTON (2010)

- Developed drainage impact fee to fund drainage projects
- Created prioritization factor to conduct storm drainage planning studies
- Conducted various neighborhood planning studies

thumbs up for progress
REBUILD HOUSTON



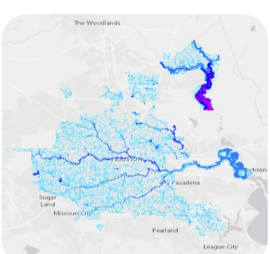
ROADSIDE DITCH DRAINAGE PLANNING (2016)

- Updated 1999 CDP analyzing both the storm sewer and open ditch systems and reviewed system capacities
- Created new outfall boundaries and lidar assessment of drainage infrastructure

MAAPNEXT (2019 - 2025)

- Led by Harris County Flood Control District (HCFCD)
- Developed new models for all HCFCD bayous, channels, and rivers in Harris County

MAAPnext



STORMWATER MASTER PLAN (CURRENT STUDY)

- Created a comprehensive, citywide assessment of drainage in the City of Houston applying Atlas 14 rainfall through a 2D hydraulic model
- Modeled movement of water for various storm events to identify potential structural impacts
- Developed Focus Area Analysis to identify areas for study of future projects

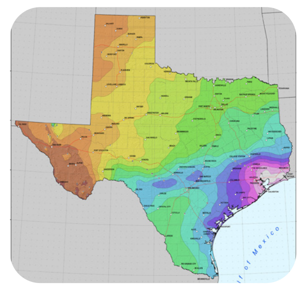
These previous studies have provided the City with flood risk data used to identify, prioritize, and garner funding for drainage improvement projects. However, since the last citywide study was performed in 2016, several major storm events and data enhancements have occurred reshaping the way flood risk is understood in the City.

STORM EVENTS

Tax Day 2016, Harvey 2017, and Imelda 2019 all produced larger rainfall within the City than any of the storm events preceding the Roadside Ditch Drainage Planning Study. The flood claims and other drainage information gathered from these events should be considered when evaluating flood risk for the City.

ATLAS 14 RAINFALL

Released in 2018, NOAA Atlas 14 redefined the precipitation statistics used for design storm simulations. Total rainfall depths for the 24-hour 100-year event increased by 30-35% in the City of Houston. The level of service provided by existing drainage infrastructure within the City should be analyzed based on these more accurate rainfall estimates.

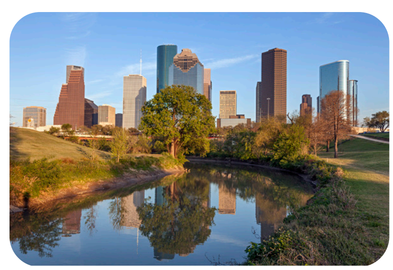


PROJECT IMPLEMENTATION

Several major projects have been implemented within the City since the last citywide study. These improvements impact drainage patterns and capacities throughout the City.

BASE DATA CHANGES

Model accuracy and precision is dependent on the quality of the base data (terrain, land use, soils, etc.). Incorporation of updated base layers is key to capture changes such as new developments, erosion, and technology enhancements that allow for more detailed characterization of the City.



To account for these changes and data developments, a new citywide master planning effort was initiated to provide a comprehensive baseline analysis of flood risk in the City.

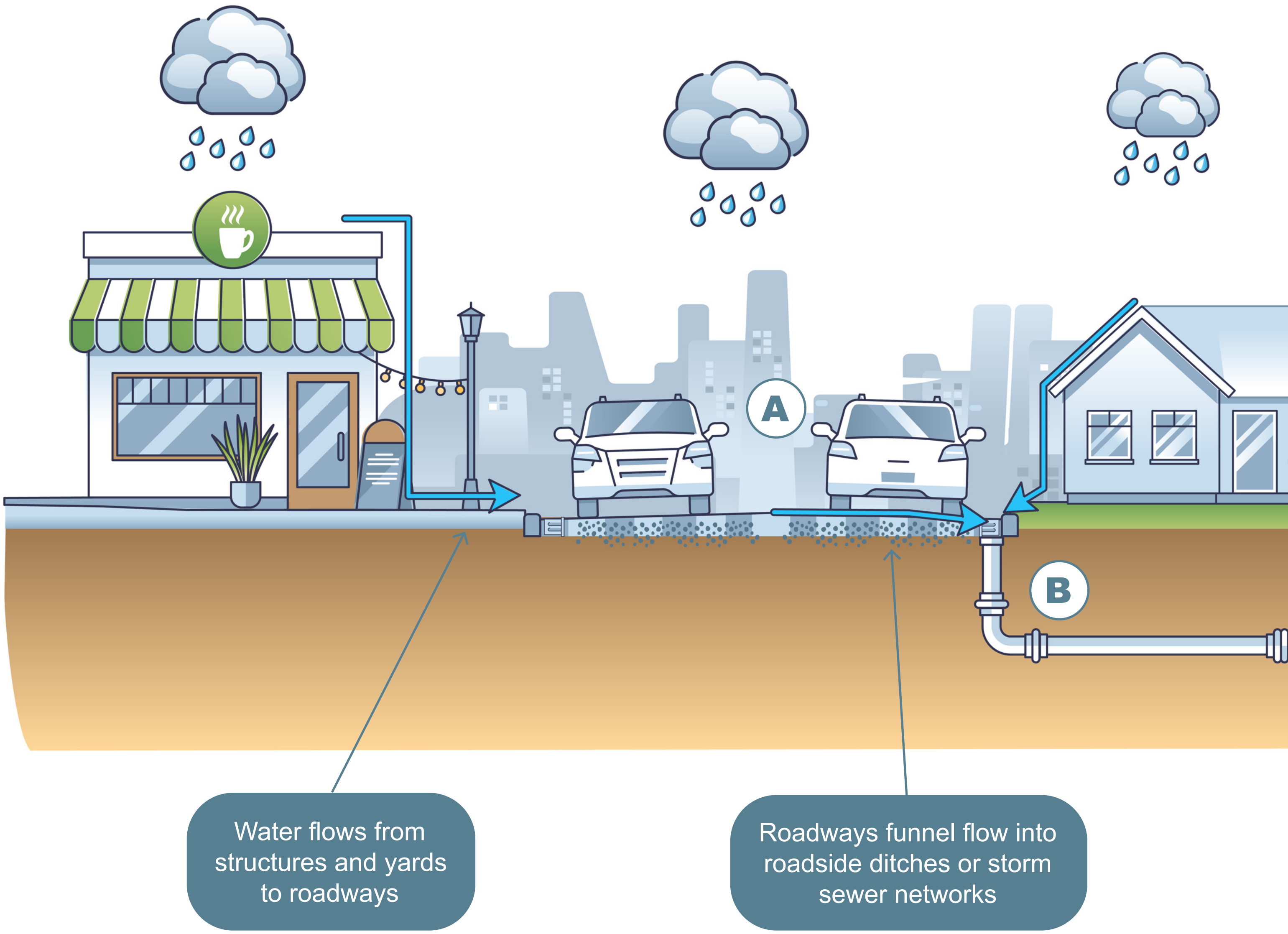
Photo Sources: Storm events - https://www.huffpost.com/entry/hurricane-harvey-houston-flood-aerial-photos_n_59a6e923e4b00795c2a3419f; Atlas 14 - https://www.noaa.gov/media-release/noaa-updates-texas-rainfall-frequency-values

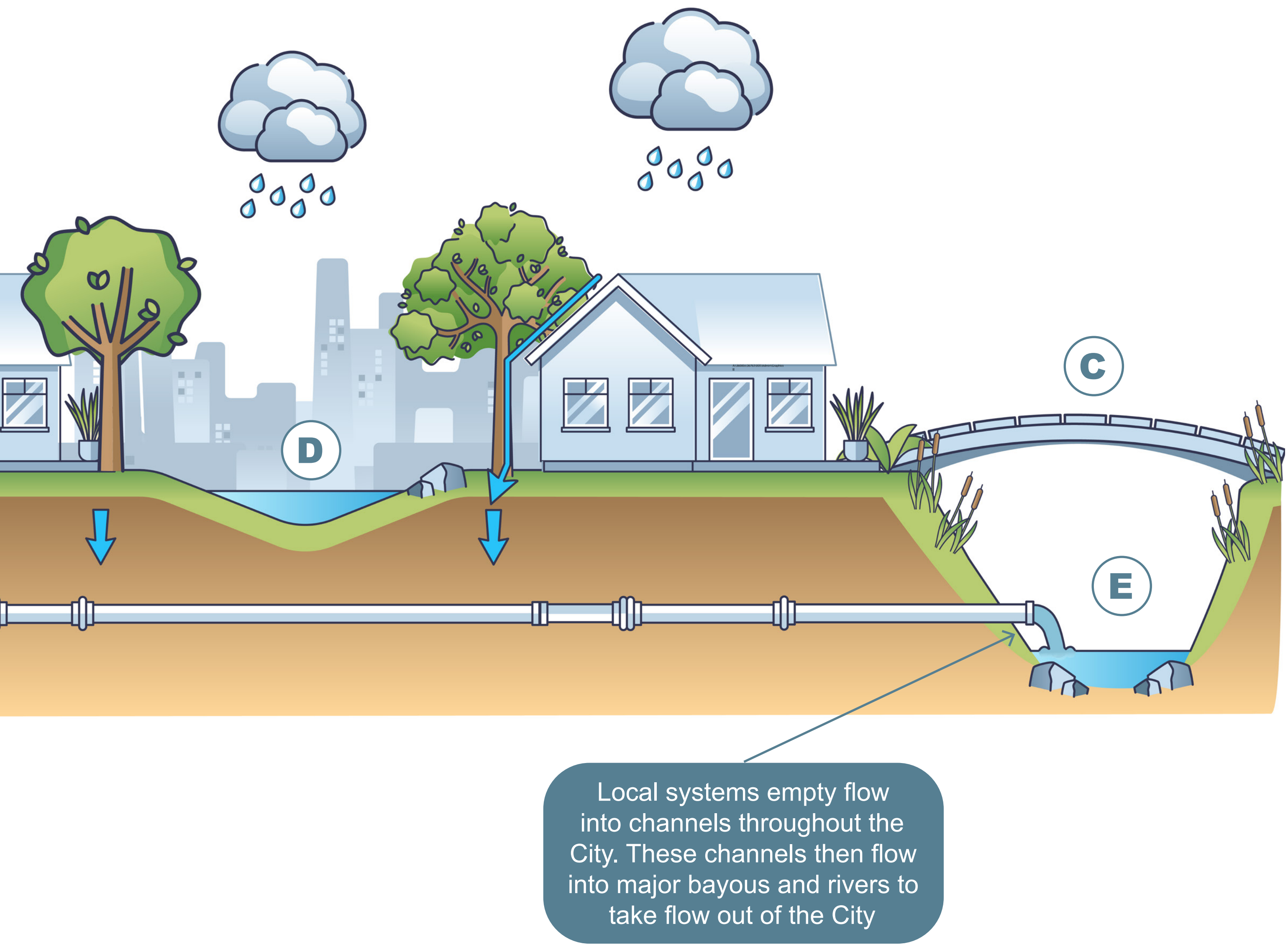
BASE INFORMATION

CITY INFRASTRUCTURE

Rainfall within the City is conveyed in multiple ways to the bayous and ultimately Galveston Bay. The City has one of the most diverse and expansive drainage infrastructure networks within the United States.

CITY STORMWATER DRAINAGE PATHWAYS




D
C
E
Local systems empty flow into channels throughout the City. These channels then flow into major bayous and rivers to take flow out of the City

A

Roads are one of the main routes for stormwater runoff to move from lots and businesses to storm sewers and channels. During typical rainfall events, the streets are designed to contain and carry the stormwater. However, during severe storm events, water may pond up to the limits of the right of way and beyond. Deep water within roadways can be a source of vehicular damage and low water crossings can cause loss of life.

B

After being funneled through roadways, or flowing across yards, parking lots, and open fields, runoff is typically collected by local drainage infrastructure. Consisting primarily of storm sewers and roadside ditches, localized drainage networks make up most of the drainage infrastructure within the City. Undersized or damaged local drainage infrastructure can contribute to flooding in urban areas. The local components of the drainage system are vital to moving stormwater efficiently and reducing excessive ponding as well as providing flood relief in more frequent events and providing a pathway to major drainage infrastructure in more severe storm events.

2,800 MILES OF ROADSIDE DITCHES MODELED

4,040 MILES OF STORM SEWER

1,900 MILES OF STORM SEWER MODELED

135 MODELED CROSSING STRUCTURES

350 MILES OF UNSTUDIED CHANNELS IN HOUSTON

C Bridges and culverts allow drainage to cross under roadways. These critical components of the drainage network can either hinder or assist in the positive flow of water depending on their adequacy of design and maintenance.

D Local drainage systems often empty into smaller channels that wind throughout the City. These channels are smaller than the major bayous and often begin and end within City limits. They provide interim conveyance between the local drainage systems and the larger bayous, creeks, and rivers.

500 MILES OF MODELED/STUDIED CHANNELS IN HOUSTON

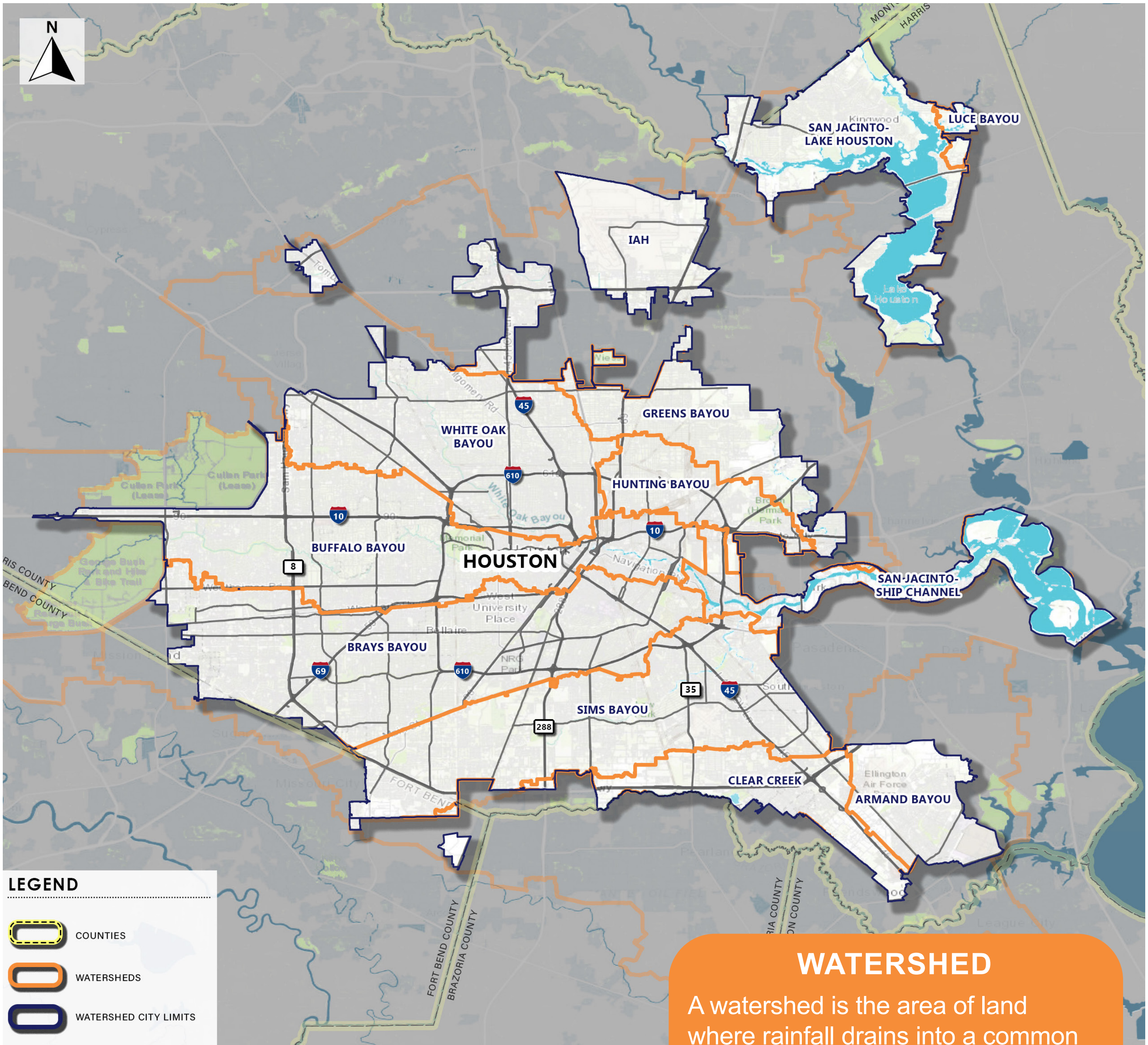
190 SQUARE MILES IN FEMA 100-YEAR FLOODPLAIN

E Throughout the City there are many primary bayous, creeks, and rivers that collect precipitation, runoff, and flow from smaller drainage systems. These primary conveyance systems also allow flow from upstream areas to pass through the City and continue to the coast. These systems were studied in detail as part of Harris County Flood Control District's Modeling Assessment and Awareness Project (MAAPnext), and data from these studies was incorporated into this analysis.

WATERSHEDS

There are nine major watersheds within the City, each with their own unique characteristics. The watersheds vary in size and coverage, ranging from 3 to 100 square mile areas within the City. Each watershed flows either to the Houston Ship Channel or the San Jacinto River eventually ending up in Galveston Bay. These watersheds provided key division points for segmenting the study of the City infrastructure.

CITY OF HOUSTON WATERSHEDS

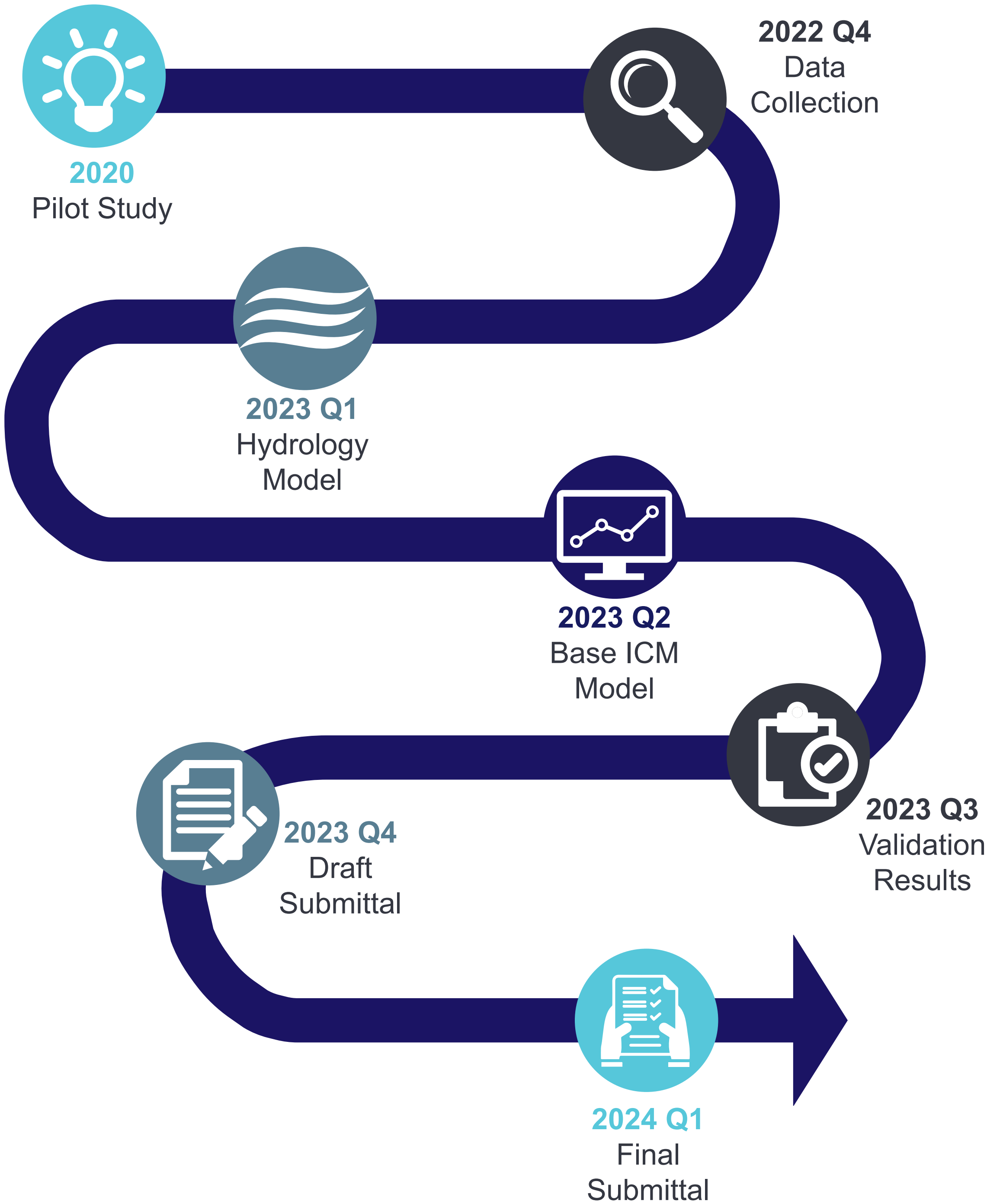


WATERSHED

A watershed is the area of land where rainfall drains into a common waterway.

PROJECT TIMELINE

The City of Houston Stormwater Master Plan was initiated in August 2020 and completed in 2024. The final models were developed following the processes and methodologies outlined in technical guidance developed specifically for the project. At the end of each stage, deliverables were provided to the City for review to ensure quality and consistency.

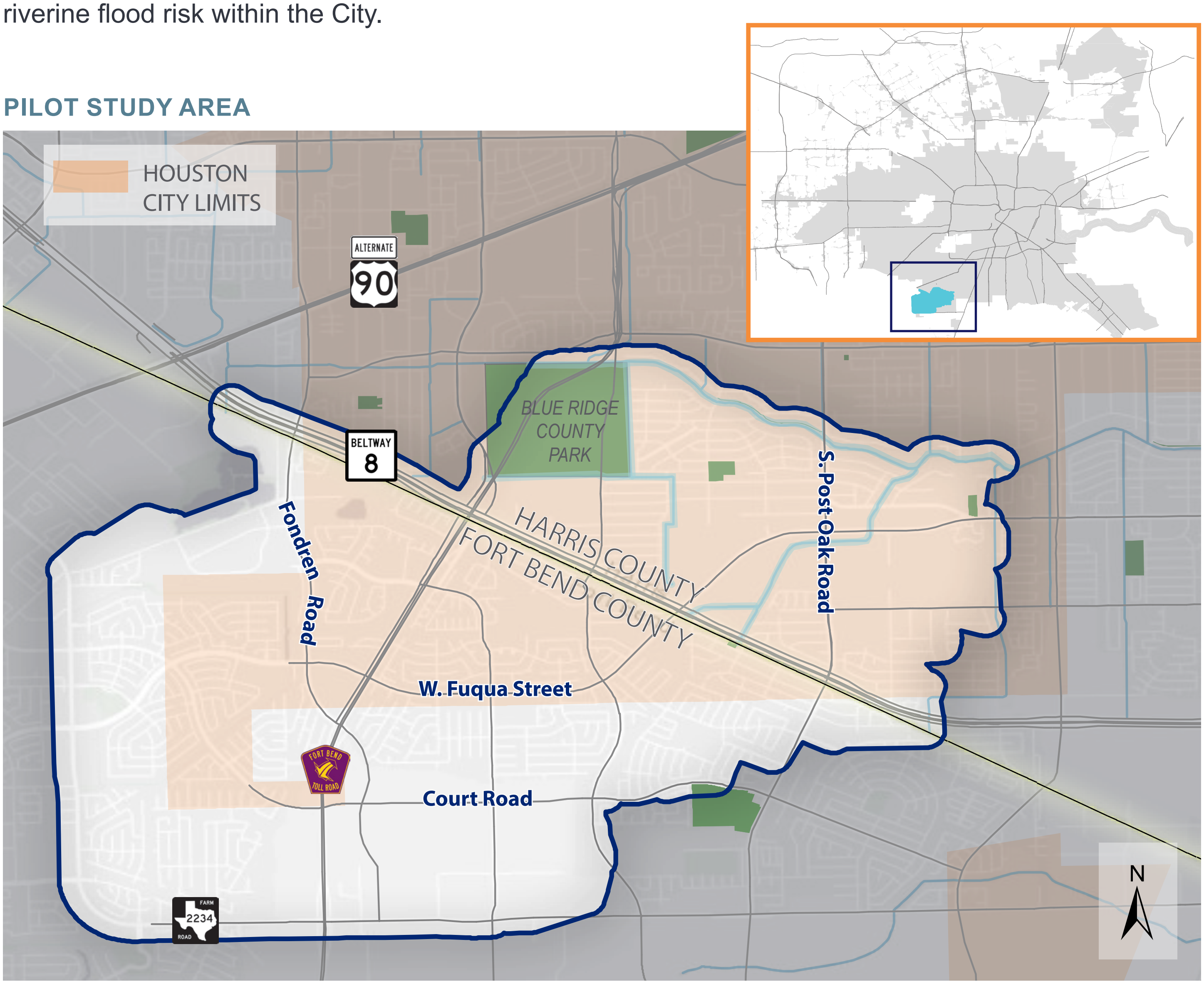


PILOT STUDY

A pilot study was performed prior to the initiation of the citywide analysis to develop a technically sound and consistent approach to modeling. The pilot study covered a 15 square mile area within the Sims Bayou watershed located in the southwestern portion of the City. The location was chosen for its representation of different land uses, drainage systems, roads, and terrains. Several modeling softwares and approaches were tested within the pilot study area to determine the best fit for analyzing urban and riverine flood risk within the City.

Based on the research performed during the pilot study, Technical White Papers were developed outlining how to develop, simulate, and validate flood risk models for the City. These documents were used as the governing guidance throughout the stormwater master planning process to ensure consistent and accurate modeling results across the different watersheds. The documents were updated as needed during the analysis as additional challenges were encountered in each watershed.

PILOT STUDY AREA



Approach

Based on the Technical White Papers, all watersheds were modeled using the same software, methods, and general level of detail to ensure consistent analysis across the City. This uniform approach allows for an equitable comparison of results across the City. Any changes necessary to accurately portray specific watershed characteristics were documented in detail within the respective watershed reports.

TECHNICAL WHITE PAPERS

- Data Collection
- Naming Conventions
- Hydrology
- 2D Model Development
- ID Model Development
- Roadside Ditches
- Boundary Conditions
- Model Validation
- 2D Flow Exchanges

WHAT IS MODELING?

Drainage modeling is the process of creating a virtual representation of how water flows through an area, such as a neighborhood, city, or larger region. Modeling helps identify where rainwater goes after it falls including how it moves across the ground, enters storm sewers and bayous, or is absorbed into the soil.

InfoWorks ICM software was used to evaluate the flows, water surface elevations, depths, and performance of the infrastructure within the City. This software has the capability to simulate flow through storm sewers, channels, ditches, and bayous as well as more complex systems that can include overland sheet flow, bridges, culverts, and detention facilities.

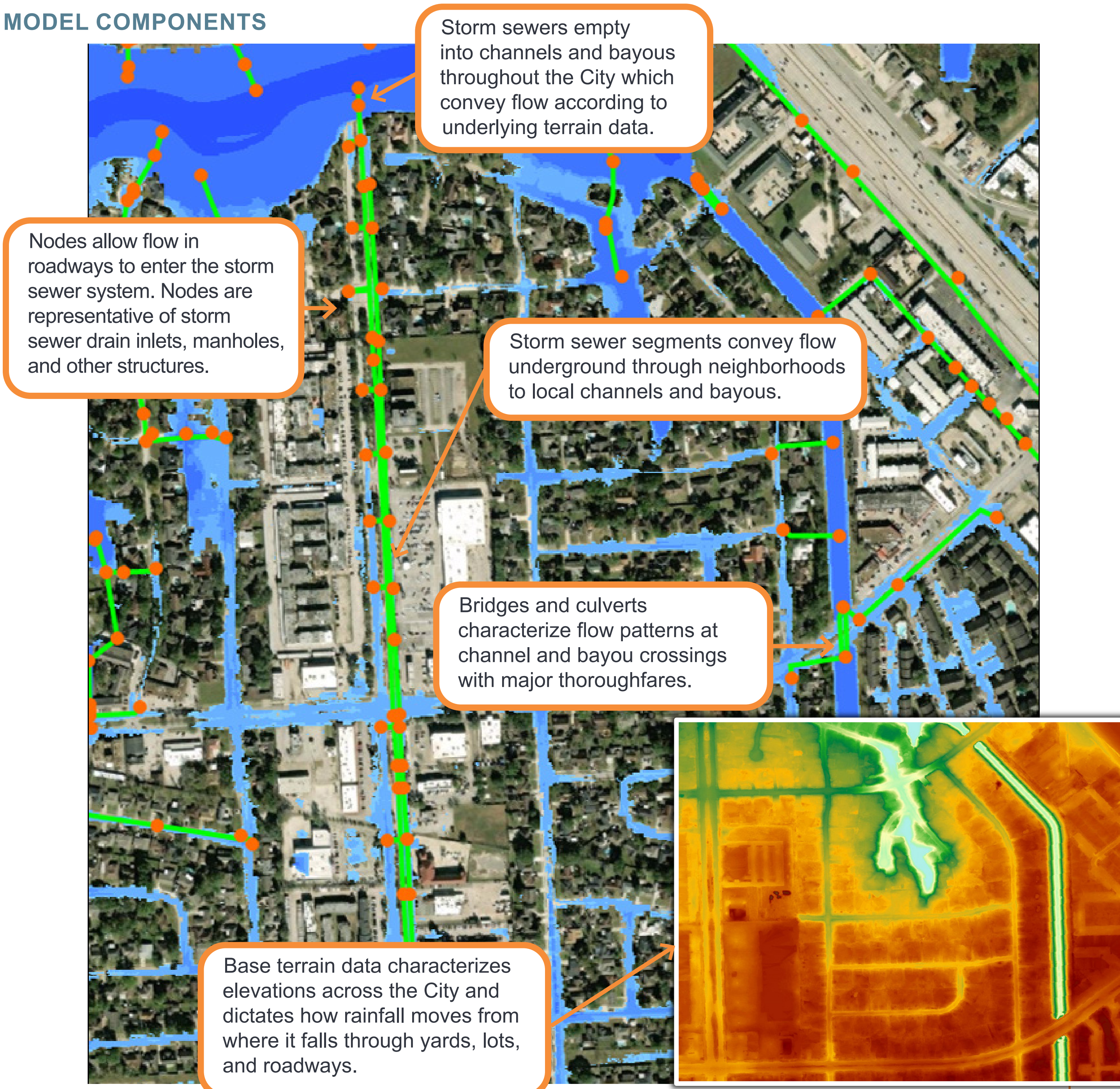
CITY OF HOUSTON STATISTICS			
Size	670 sq. mi.	Storm Sewer*	1,900 mi.
Population	2.3 million	Roadside Ditch*	2,800 mi.
Structures*	550,200	Channels*	500 mi.

Representative of modeled infrastructure

WHAT WAS MODELED?

With the primary goal of providing the first comprehensive analysis of flood risk, this study incorporated storm sewers, ditches, channels, bayous, and overland sheet flow into the models. Data from previous evaluations, including the City's prior drainage assessments, the robust GIS infrastructure database, and the MAAPnext study of major bayous, were collected and incorporated where available. The modeling methods chosen reflected the complex nature of drainage within the City. Within the City limits, the drainage models included any storm sewer 36 inches or larger in diameter, all roadside ditches, all unstudied channels, all studied channels and bayous, and the entire extent of the City's overland flow patterns. This provided the comprehensive approach to understanding flood risk within the City.

MODEL COMPONENTS

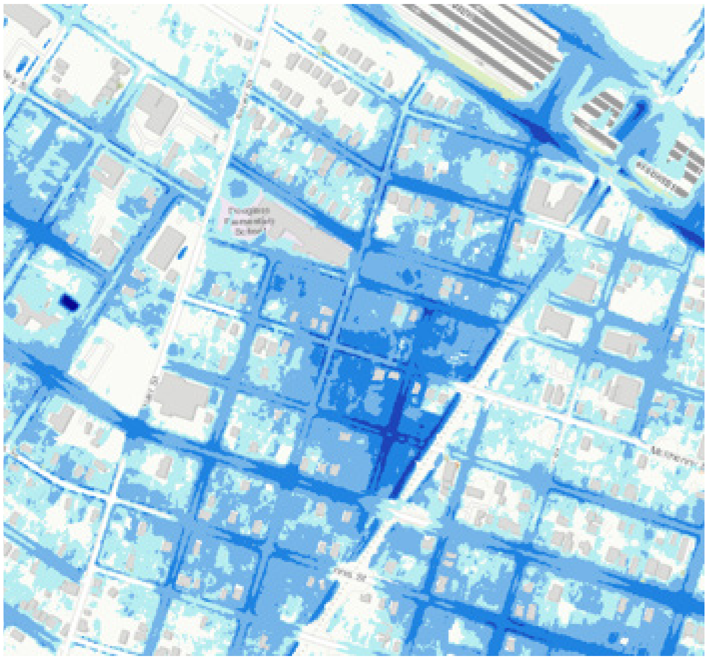


VALIDATION

Model validation is used to provide confidence in modeling results. This process utilizes historical data such as flood damage claims and complaints and photos as a comparison point to determine the accuracy of modeling results.

Three historical storms were simulated for each watershed to validate the modeling results. Recorded rainfall data was used to replicate the precipitation intensity and spatial distribution of the experienced event. Results from these simulations were compared to historical claims data for each event to see how accurately the models portray drainage conditions throughout the City.

Adjustments were made to the models where significant variances between the claims data and model results were found. After making adjustments, results from the simulated storms were found to provide a reasonable match to the recorded claims, confirming that the models reflect drainage conditions and produce reliable results.



Results

Following model development and validation, annual chance events were simulated to identify the level of flood risk throughout the City for both frequent and major events. The robust modeling provided a useful method of characterizing existing flood risk in the City of Houston.

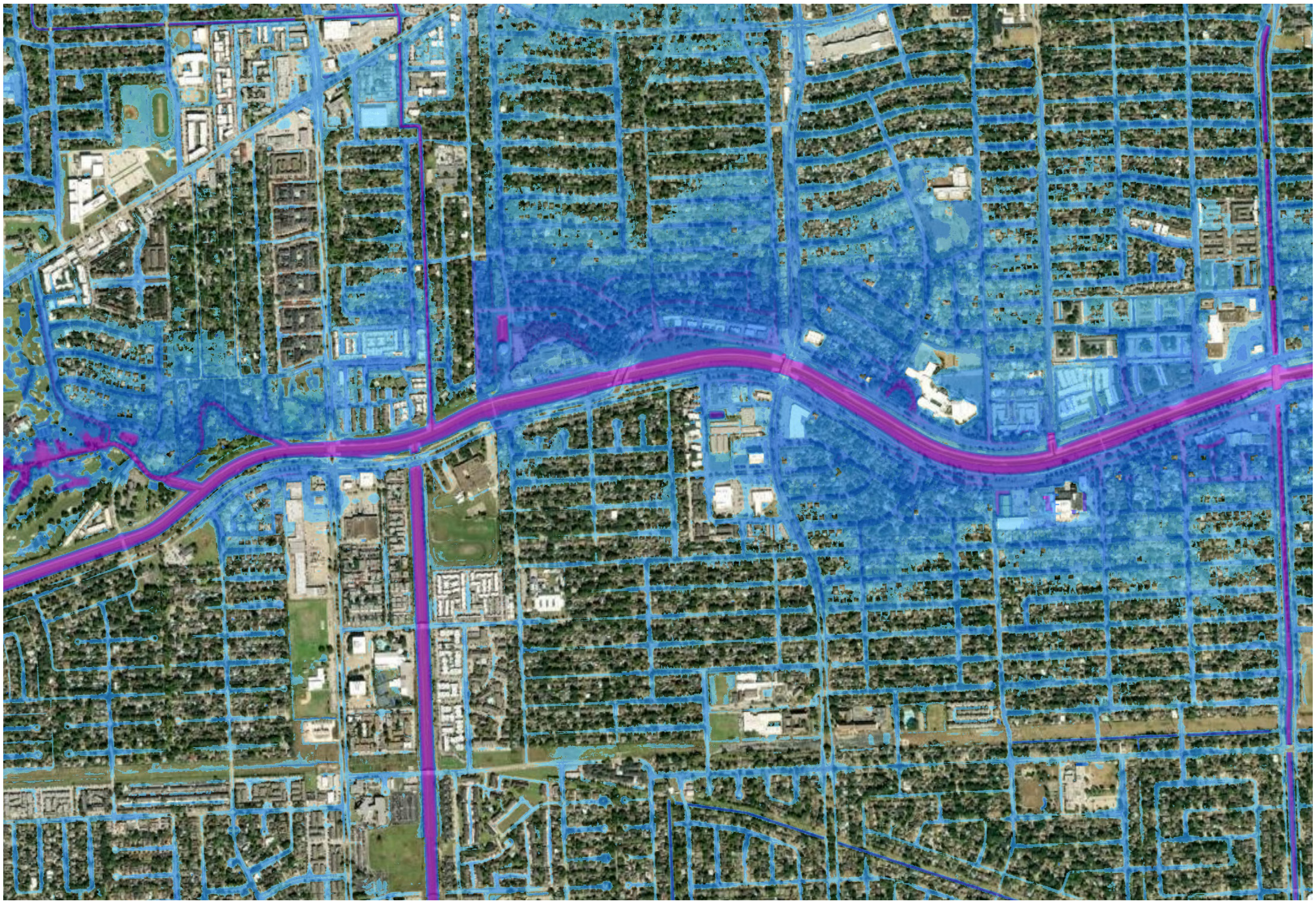
CITYWIDE RESULTS

Results for the modeled storm events were used to determine the extents of ponding throughout the City. Ponding depths and water surface elevations were developed for the entire City including both the riverine and channel systems as well as the local drainage infrastructure. These results provided a comprehensive look at flooding across the City.

ANNUAL CHANCE EVENT

An "annual chance event" in relation to flooding refers to the probability of a flood occurring in any given year. It is expressed as a percentage. For example, a flood with a 1% annual chance event (also known as a "100-year flood") means there is a 1 in 100 chance of that magnitude of flooding to occur in any given year.

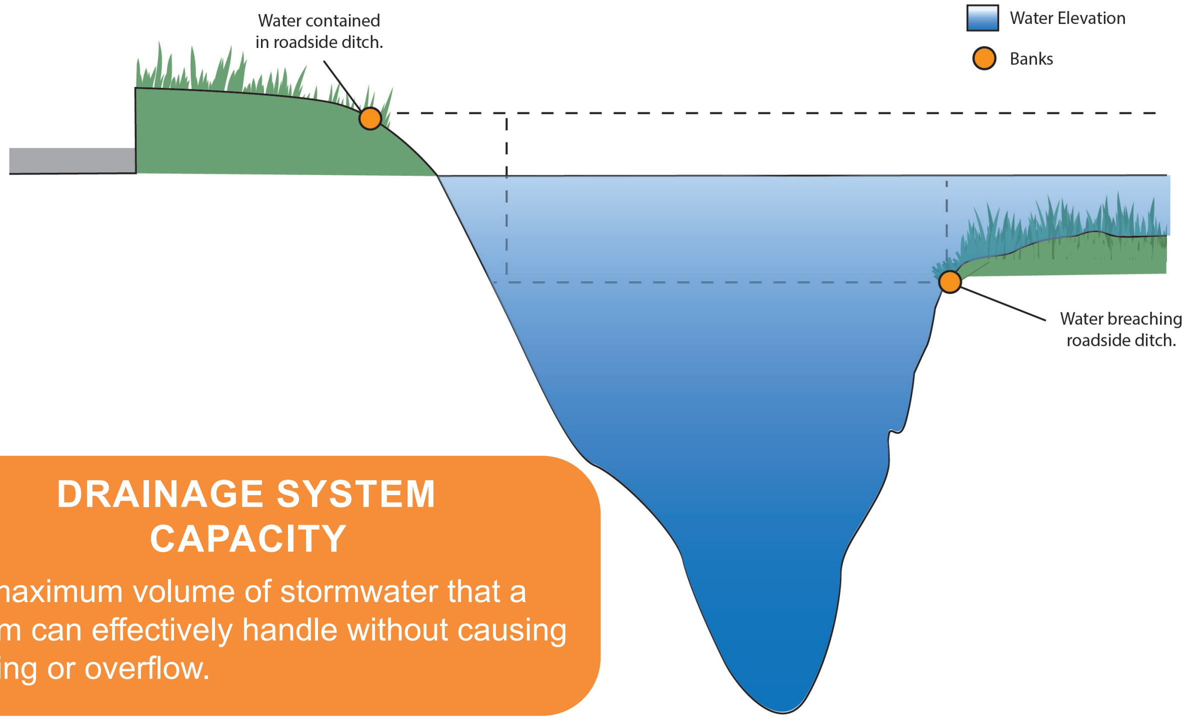
PONDING EXTENTS



DRAINAGE SYSTEM CAPACITY

Identifying the capacity of the drainage system provides an understanding of where the existing drainage infrastructure is potentially undersized, causing significant ponding within the City. Each segment of storm sewer and roadside ditches was assessed to determine which storm event exceeds City design requirements. Roadside ditches were determined to provide adequate capacity if neither of the banks were breached by the flow being conveyed within the ditch.

ROADSIDE DITCH CAPACITY



DRAINAGE SYSTEM CAPACITY

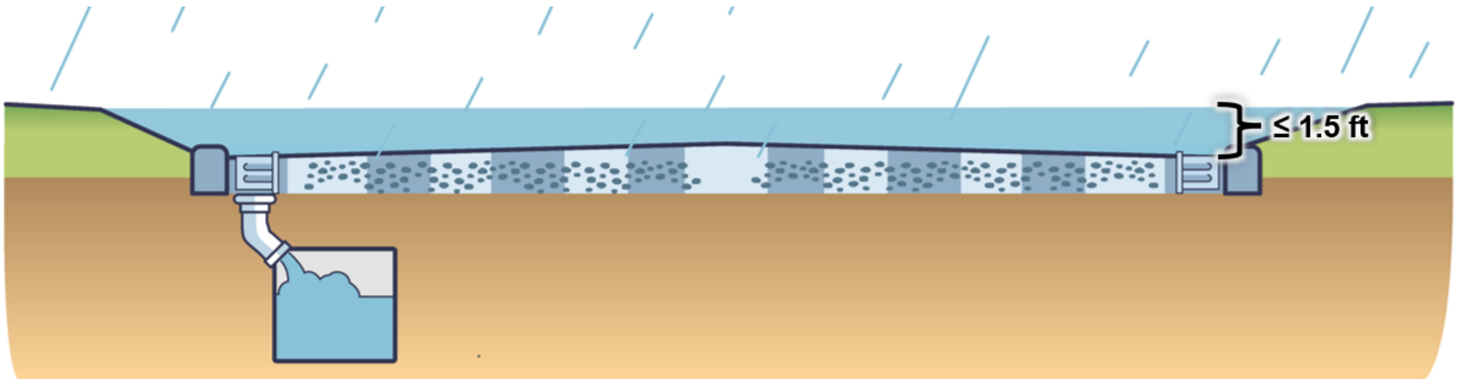
The maximum volume of stormwater that a system can effectively handle without causing flooding or overflow.

ROADSIDE DITCH DRAINAGE SYSTEM CAPACITY	
2-Year	63%
5-Year	50%
10-Year	39%
25-Year	30%
50-Year	23%
100-Year	19%
500-Year	10%

Percentage is calculated for the total system; i.e. 63% of the roadside ditches in the City have a 2-year capacity, 50% have a 5-year capacity, etc.

Storm sewer was determined to provide adequate capacity if the depth of flow above the analyzed segment would be contained within the roadways without extending onto private property (assumed as depths less than 1.5 feet).

STORM SEWER CAPACITY



STORM SEWER DRAINAGE SYSTEM CAPACITY	
2-Year	52%*
5-Year	68%
10-Year	58%
25-Year	48%
50-Year	40%
100-Year	33%
500-Year	21%

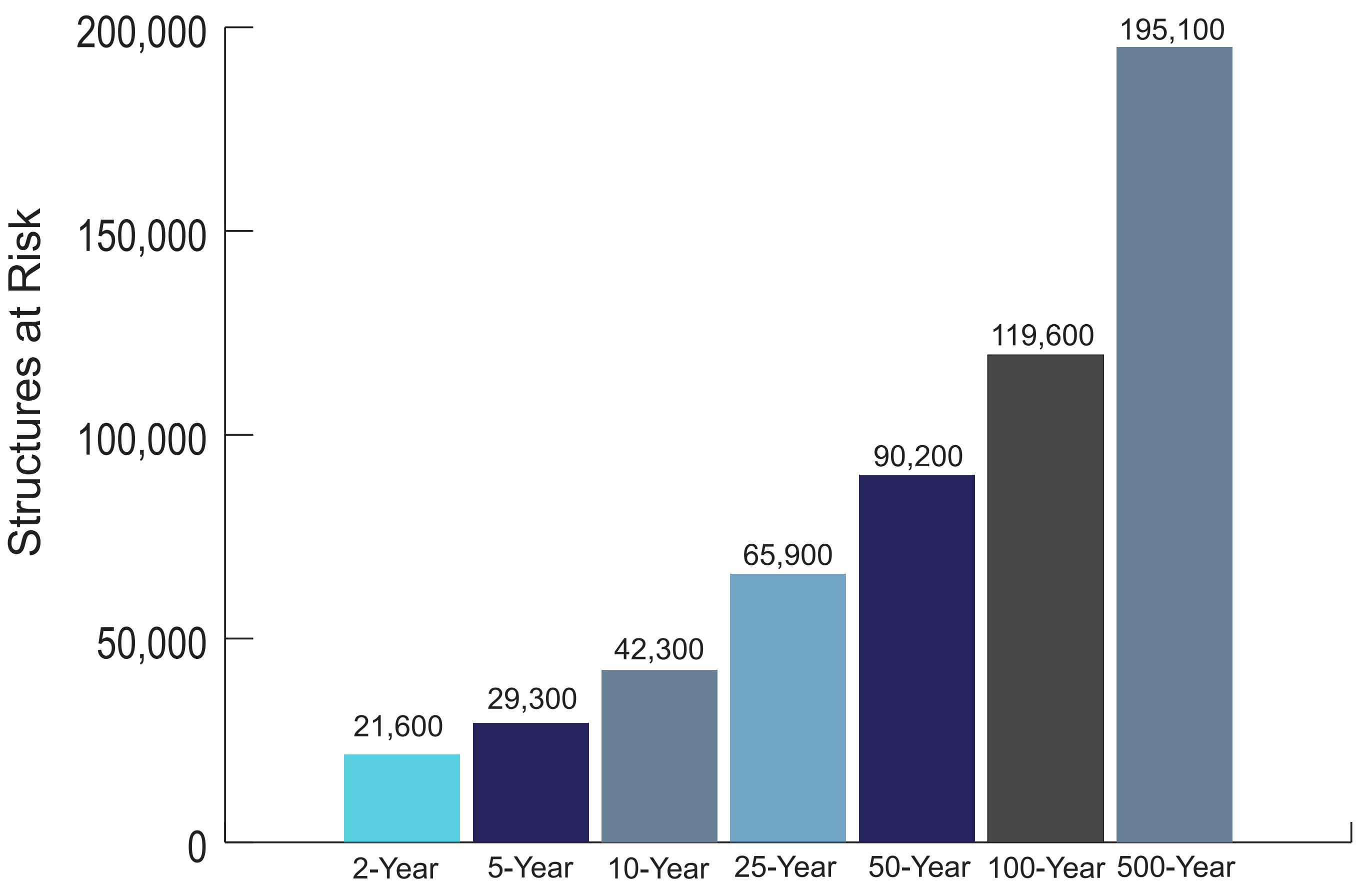
**2-year capacity was evaluated based on any ponding above ground rather than 1.5 feet above ground*

Percentage is calculated for the total system; i.e. 52% of the storm sewers in the City have a 2-year capacity, 68% have a 5-year capacity, etc.

FLOOD RISK ASSESSMENT

Modeled flood extents and depths were used to assess the structures, population, roadways, and critical facilities potentially at risk of flooding. Residential structures potentially at risk of flooding within the City limits were identified for each modeled storm event. For the 100-year storm, 22% of the modeled structures within the City were identified as being at flood risk. Estimated populations were associated with each modeled structure to identify the number of residents potentially affected by the modeled events. Estimations of populations and structures at flood risk help characterize the safety and economic impacts that could be experienced during the simulated storm events. Finished floor elevations were estimated based on mobile lidar data throughout the City. Structures were assumed to be flooded if the modeled water surface elevation was greater than the finished floor elevations.

POTENTIALLY AT-RISK STRUCTURES



Excessive flooding of roads, especially major thoroughfares, can prevent resident mobility during storm events. In addition, if there are no passable lanes in a storm event, access to emergency services such as police, ambulance, and fire fighters can be restricted for residents within affected areas. Roadway flooding was tabulated for all sections of the City to identify areas where flooding could be detrimental and influence City planning. Roadways were considered as flooded if ponding exceeded six inches at the crown of the road.

Flooding of critical facilities can also cause significant short-term and long-term impacts to the City infrastructure and residents. At-risk facilities considered within this analysis are summarized below. These facilities provide critical services throughout the City of Houston. If impacted during a storm event, the loss of the services for the public could prove detrimental to residential and economic health.

FIRE STATIONS

EMERGENCY SHELTERS

POLICE STATIONS

POWER PLANTS

HOSPITALS

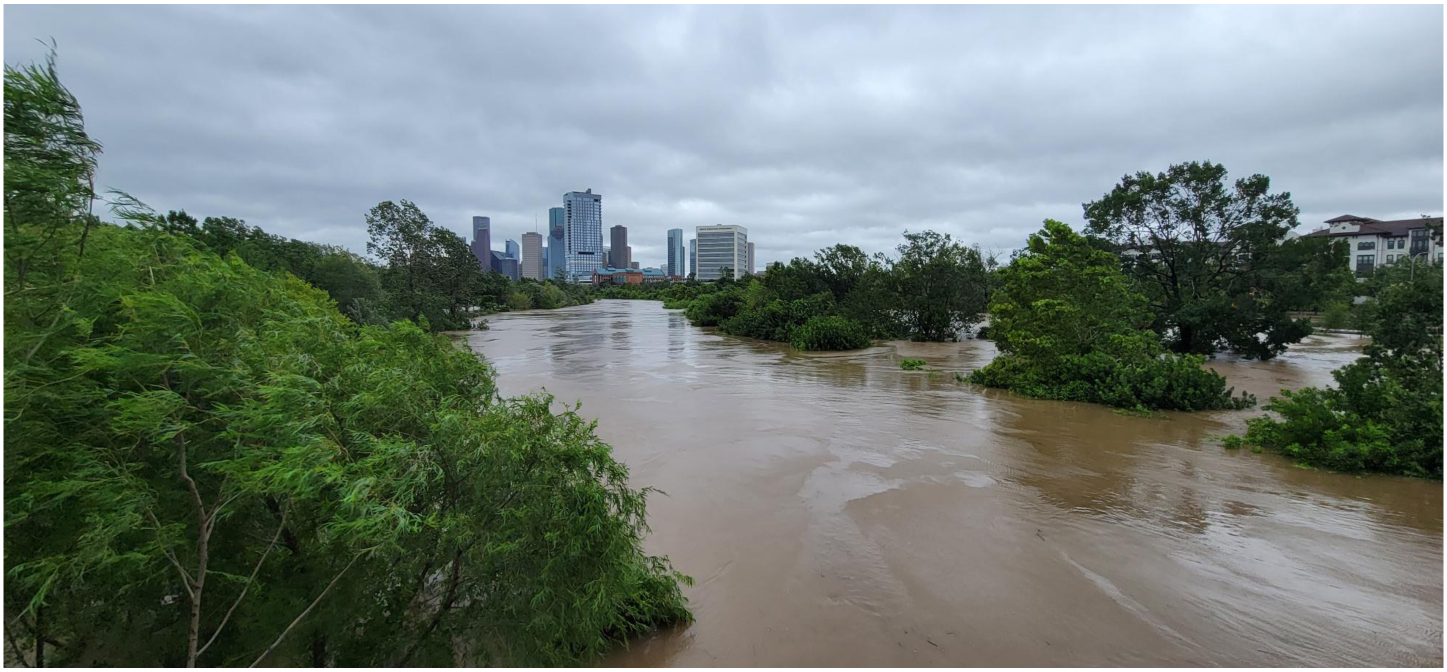
WATER TREATMENT PLANTS

SCHOOLS

WASTEWATER TREATMENT PLANTS

WATERSHED FACT SHEETS

In addition to analyzing existing conditions for the City as a whole, flood risk was evaluated on a watershed-by-watershed basis. This more detailed analysis allows for flood risk trends and patterns to be more easily identified.



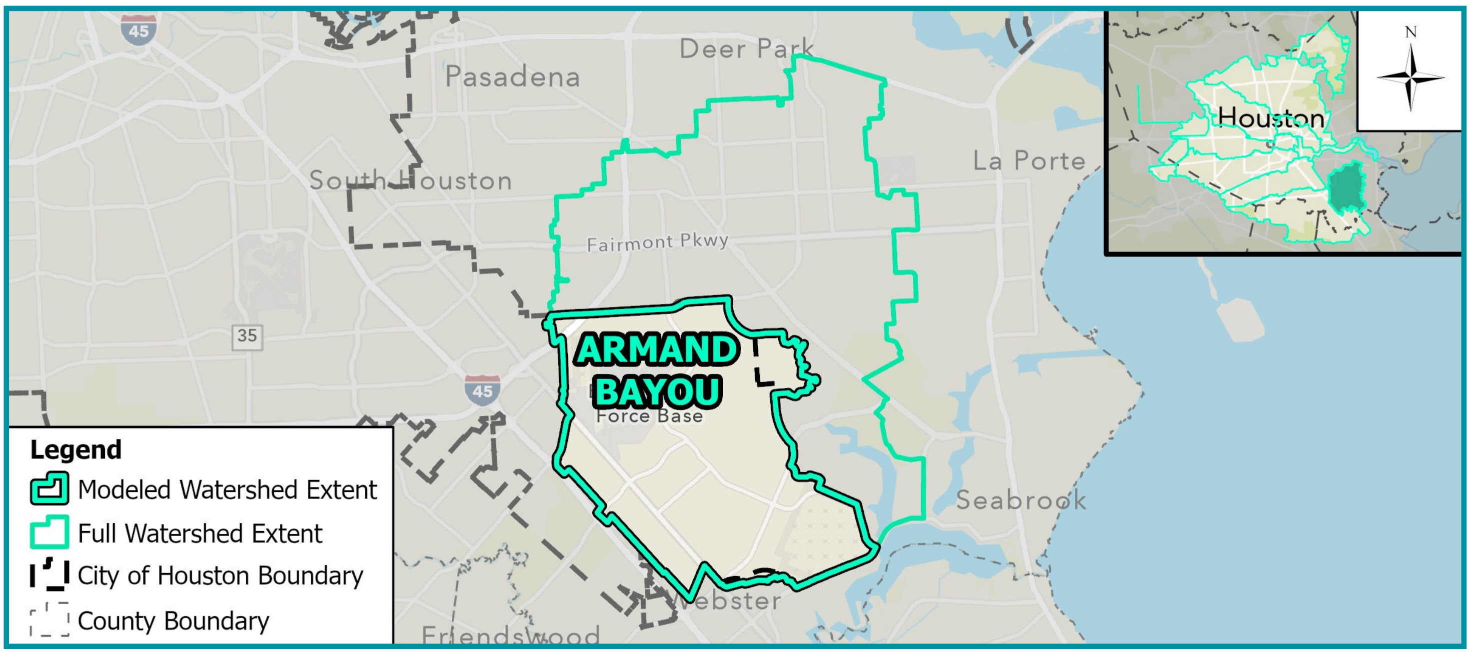
Armand Bayou Watershed

SIZE: 59 square miles

CONVEYANCE INFRASTRUCTURE:
80 miles

DESCRIPTION: The Armand Bayou watershed is located in the southeast region of the City between Vince Bayou and Clear Creek. Armand Bayou flows southeast into Clear Creek. About one third of the watershed falls within City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of small-lot, single family residential development.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	0%
36” ≤ Pipe Diameter < 60”	37%
Pipe Diameter ≥ 60”	13%
Roadside Ditch	13%
Studied Channel	11%
Unstudied Channel	26%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
10 sq. mi.

Structures at 100-year Flood Risk
1,400

Storm Sewer with 2-year Capacity
24%

Roadside Ditch with 2-year Capacity
85%

FLOOD DESCRIPTION:

Modeling results indicate the channels within Armand Bayou completely contain the 2– and 5-yr storm events. Flooding is largely attributed to insufficient ditch capacity in the area east of Bay Area Blvd.

Brays Bayou Watershed

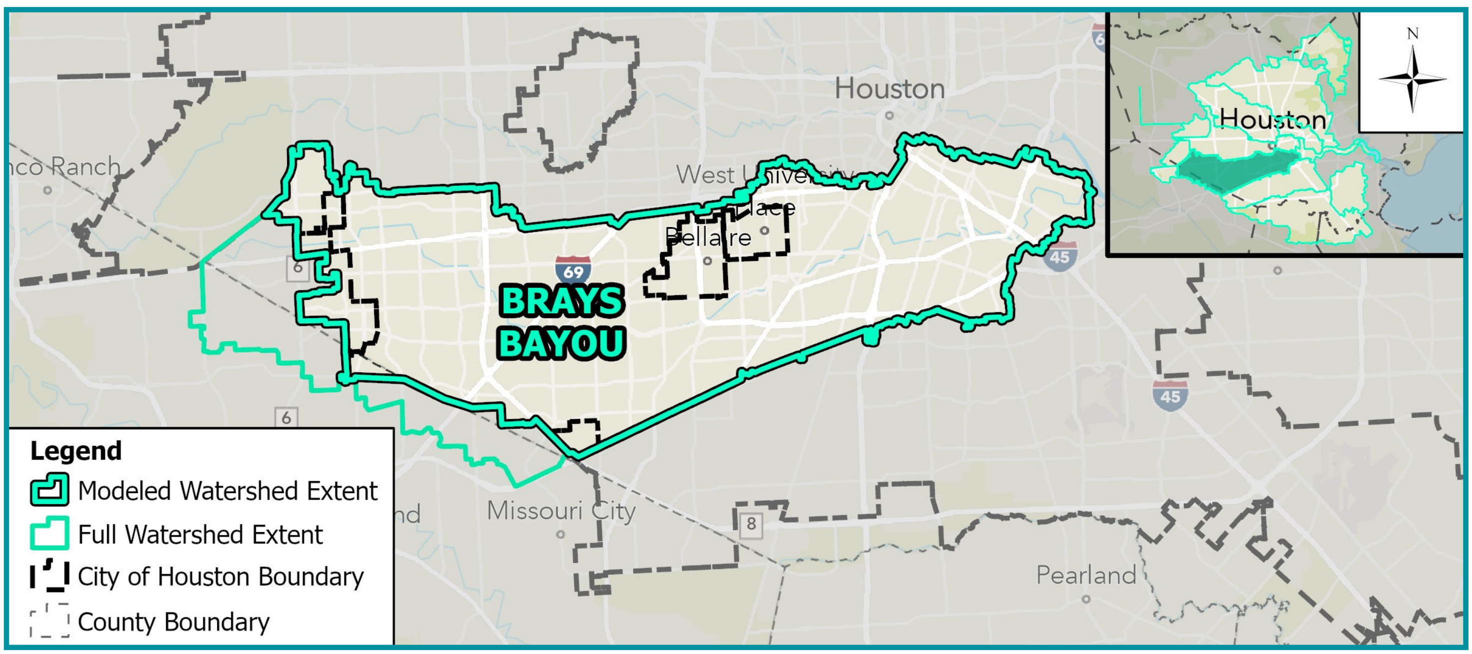
HOUSTON PUBLIC WORKS

SIZE: 127 square miles

CONVEYANCE INFRASTRUCTURE:
1,830 miles

DESCRIPTION: The Brays Bayou watershed is located in the southwest region of the City between Buffalo Bayou and Sims Bayou. Brays Bayou flows east into the Buffalo Bayou - Houston Ship Channel. Most of the watershed falls within City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of small-lot, single family residential and heavy commercial development.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	48%
36” ≤ Pipe Diameter < 60”	25%
Pipe Diameter ≥ 60”	10%
Roadside Ditch	10%
Studied Channel	4%
Unstudied Channel	3%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
55 sq. mi.

Structures at 100-year Flood Risk
43,900

Storm Sewer with 2-year Capacity
48%

Roadside Ditch with 2-year Capacity
76%

FLOOD DESCRIPTION:

Modeling results indicate Brays Bayou is generally contained within its banks for more frequent events, but causes widespread flooding in larger events. Many neighborhoods within the watershed experience flooding caused by undersized roadside ditch systems.

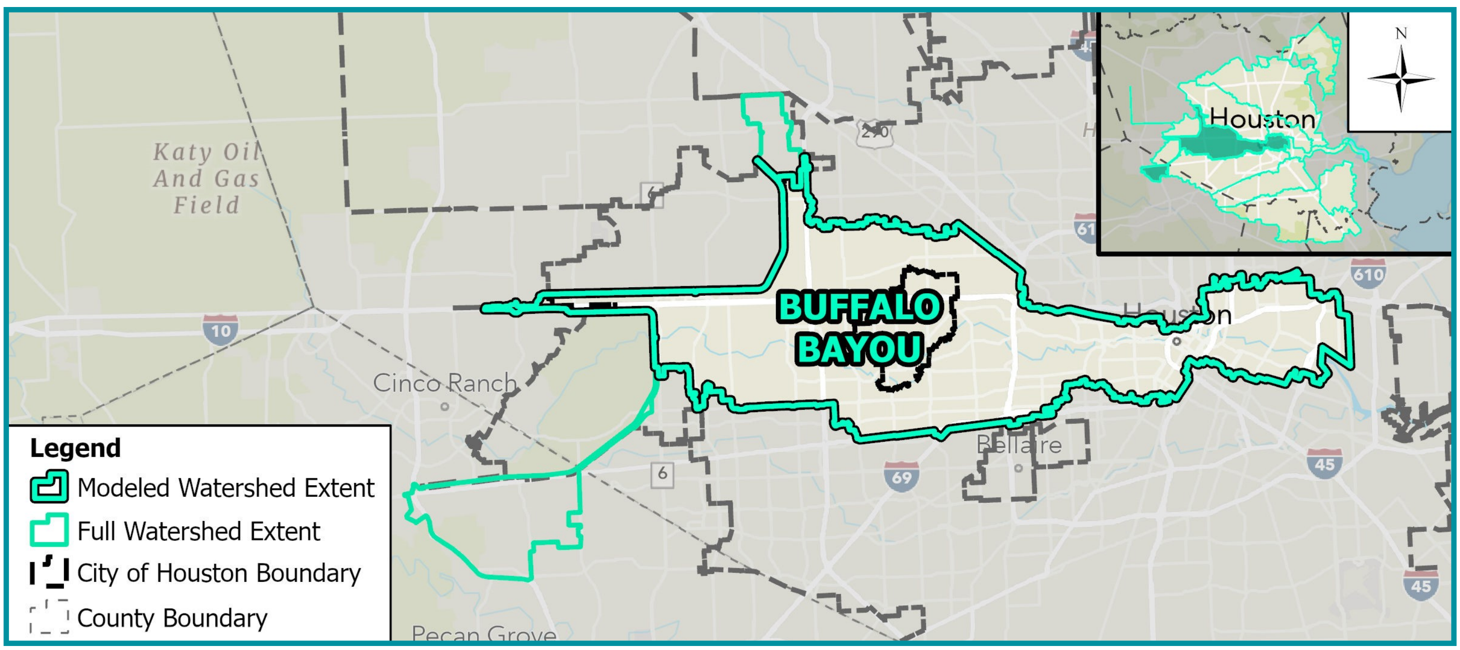
Buffalo Bayou Watershed

SIZE: 106 square miles

CONVEYANCE INFRASTRUCTURE:
1,170 miles

DESCRIPTION: The Buffalo Bayou watershed is located in the west region of the City between Brays Bayou and Clear Creek. Buffalo Bayou drains east into the Houston Ship Channel. Most of the watershed falls within City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of small -lot, single family, residential development.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	31%
Pipe Diameter ≥ 36” & < 60”	20%
Pipe Diameter ≥ 60”	15%
Roadside Ditch	22%
Studied Channel	9%
Unstudied Channel	3%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
35 sq. mi.

Structures at 100-year Flood Risk
17,600

Storm Sewer with 2-year Capacity
50%

Roadside Ditch with 2-year Capacity
78%

FLOOD DESCRIPTION:

Modeling results indicate Buffalo Bayou is generally contained within its banks up to the 10-yr storm event. Flooding is generally present in areas such as Memorial Park, Downtown, Midtown, Montrose, and the area north of IH-10.

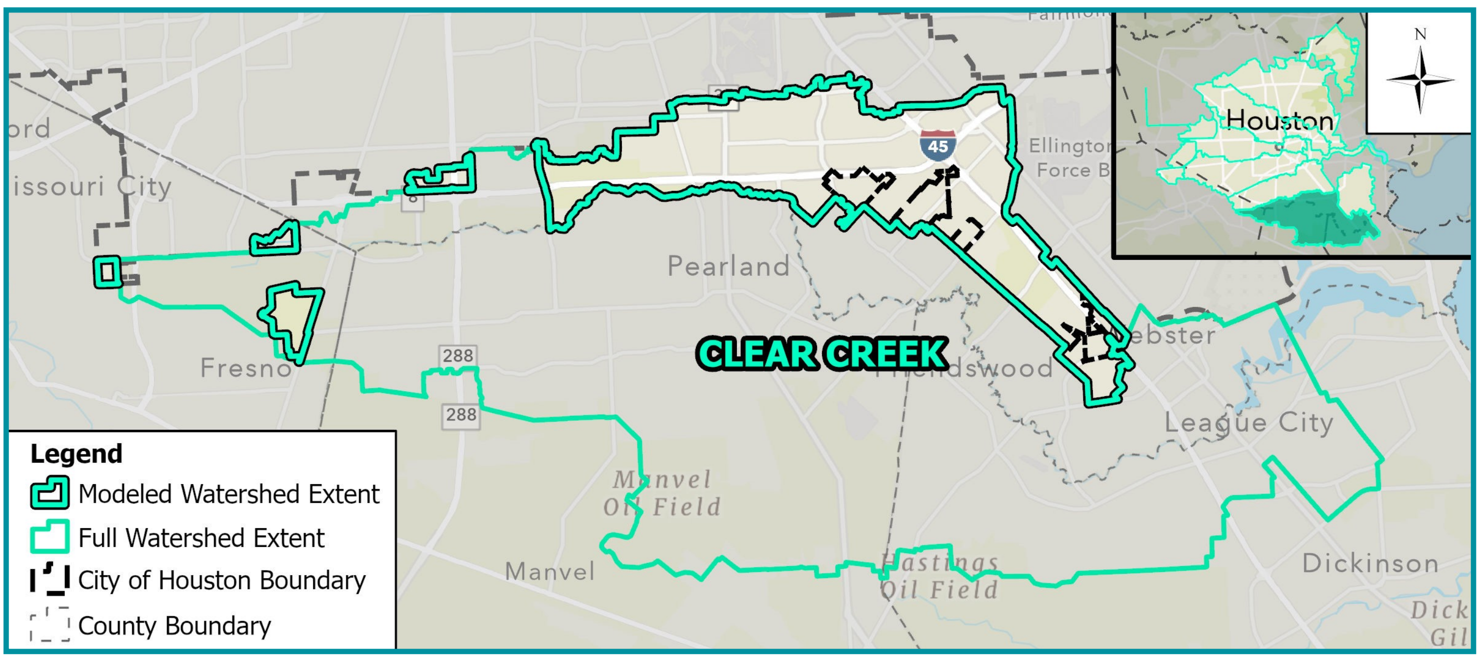
Clear Creek Watershed

SIZE: 201 square miles

CONVEYANCE INFRASTRUCTURE:
230 miles

DESCRIPTION: The Clear Creek watershed is located in the south region of the City adjacent to Sims Bayou and Armand Bayou. Clear Creek flows east to Galveston Bay. Most of the watershed falls outside City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of small-lot, single family residential development.

Conveyance Infrastructure	Percent of Total Conveyance System
24" ≤ Pipe Diameter < 36"	32%
36" ≤ Pipe Diameter < 60"	12%
Pipe Diameter ≥ 60"	5%
Roadside Ditch	36%
Studied Channel	6%
Unstudied Channel	9%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
15 sq. mi.

Structures at 100-year Flood Risk
4,700

Storm Sewer with 2-year Capacity
48%

Roadside Ditch with 2-year Capacity
83%

FLOOD DESCRIPTION:

Modeling results indicate Clear Creek watershed is generally contained within its channels up to the 5-yr storm event except in areas along Sagecreek Dr. to Scarsdale Blvd. Areas west of Gulf Freeway showed significant flooding for the 25-yr storm event.

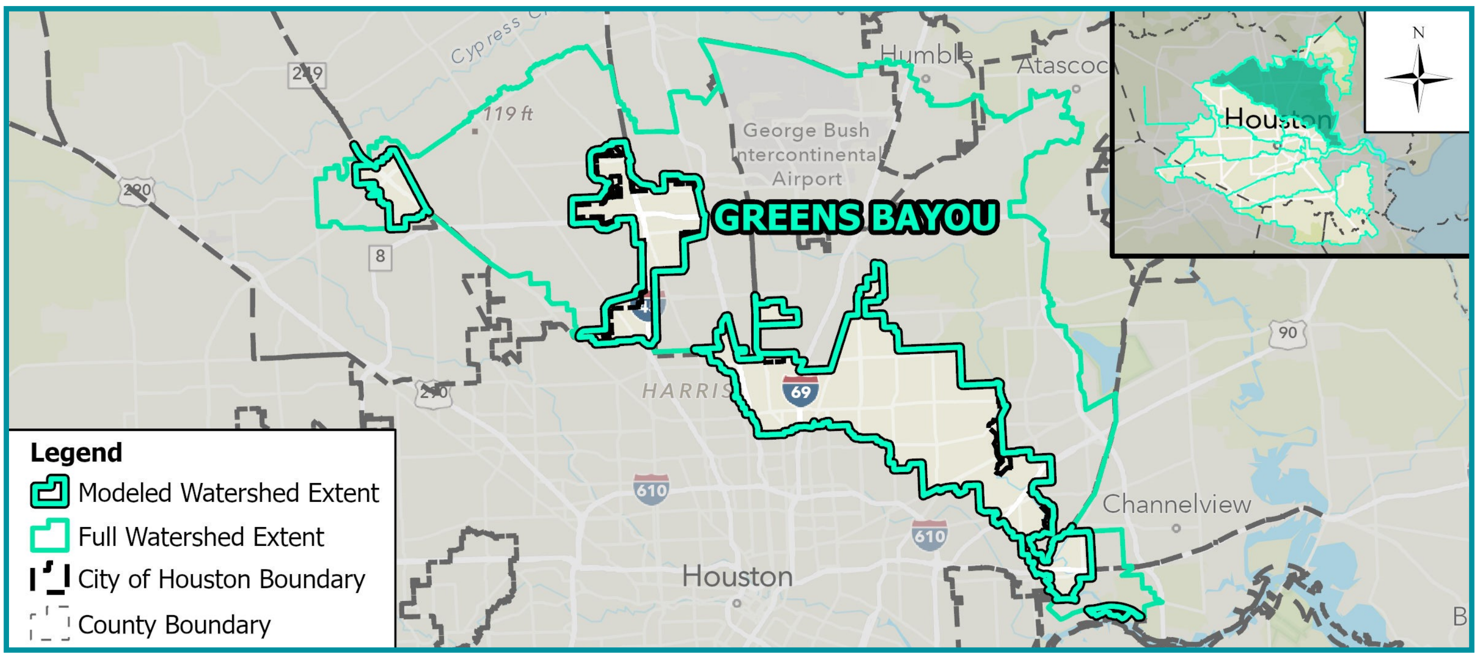
Greens Bayou Watershed

SIZE: 210 square miles

CONVEYANCE INFRASTRUCTURE:
230 miles

DESCRIPTION: The Greens Bayou watershed is located in the north region of the City between the San Jacinto River and Hunting Bayou. Greens Bayou flows southeast into the Houston Ship Channel. Most of the watershed falls outside City limits, with a generally flat terrain. The watershed is mainly developed, consisting of residential development, pasture/grasslands, and commercial spaces.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	19%
36” ≤ Pipe Diameter < 60”	10%
Pipe Diameter ≥ 60”	5%
Roadside Ditch	46%
Studied Channel	14%
Unstudied Channel	6%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
30 sq. mi.

Structures at 100-year Flood Risk
8,400

Storm Sewer with 2-year Capacity
60%

Roadside Ditch with 2-year Capacity
72%

FLOOD DESCRIPTION:

Modeling results indicate Greens Bayou is generally contained within its banks for the 2– and 5-yr storm events. Areas near Brock Park, Harris County Cemetery and Texaco Country Club experience flooding during the 2-yr storm event.

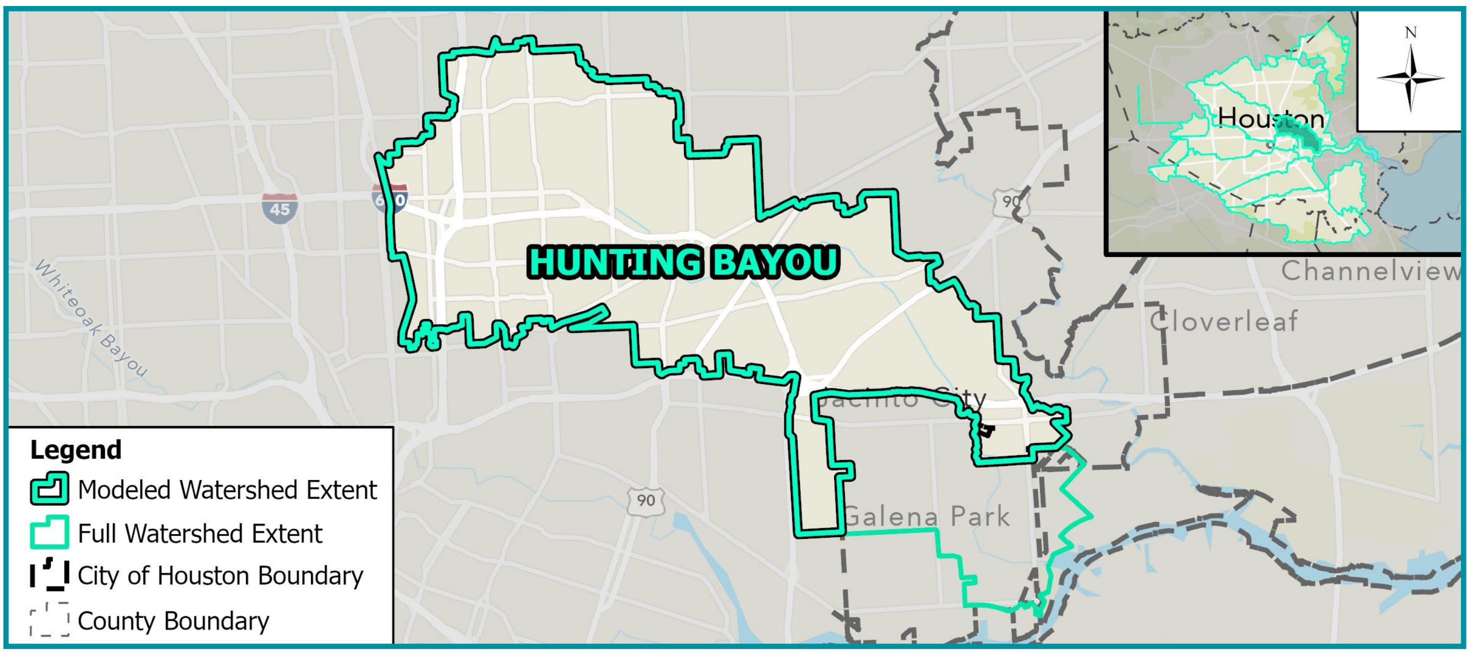
Hunting Bayou Watershed

SIZE: 30 square miles

CONVEYANCE INFRASTRUCTURE:
490 miles

DESCRIPTION: The Hunting Bayou watershed is located in the north east region of the City between Greens Bayou and Buffalo Bayou. Hunting Bayou flows southeast into the Houston Ship Channel. Most of the watershed falls within City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of low and medium intensity residential development.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	20%
36” ≤ Pipe Diameter < 60”	12%
Pipe Diameter ≥ 60”	6%
Roadside Ditch	52%
Studied Channel	6%
Unstudied Channel	4%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
10 sq. mi.

Structures at 100-year Flood Risk
4,600

Storm Sewer with 2-year Capacity
33%

Roadside Ditch with 2-year Capacity
79%

FLOOD DESCRIPTION:

Modeling results indicate Hunting Bayou is generally contained within its banks for the 2– and 5-yr storm events, except in areas near IH-10 and Jacinto City and south of Pyburn Elementary and Market Street Rd. Almost all of Hunting Bayou is overtopped in the 100-yr storm event.

IAH (Greens) Watershed

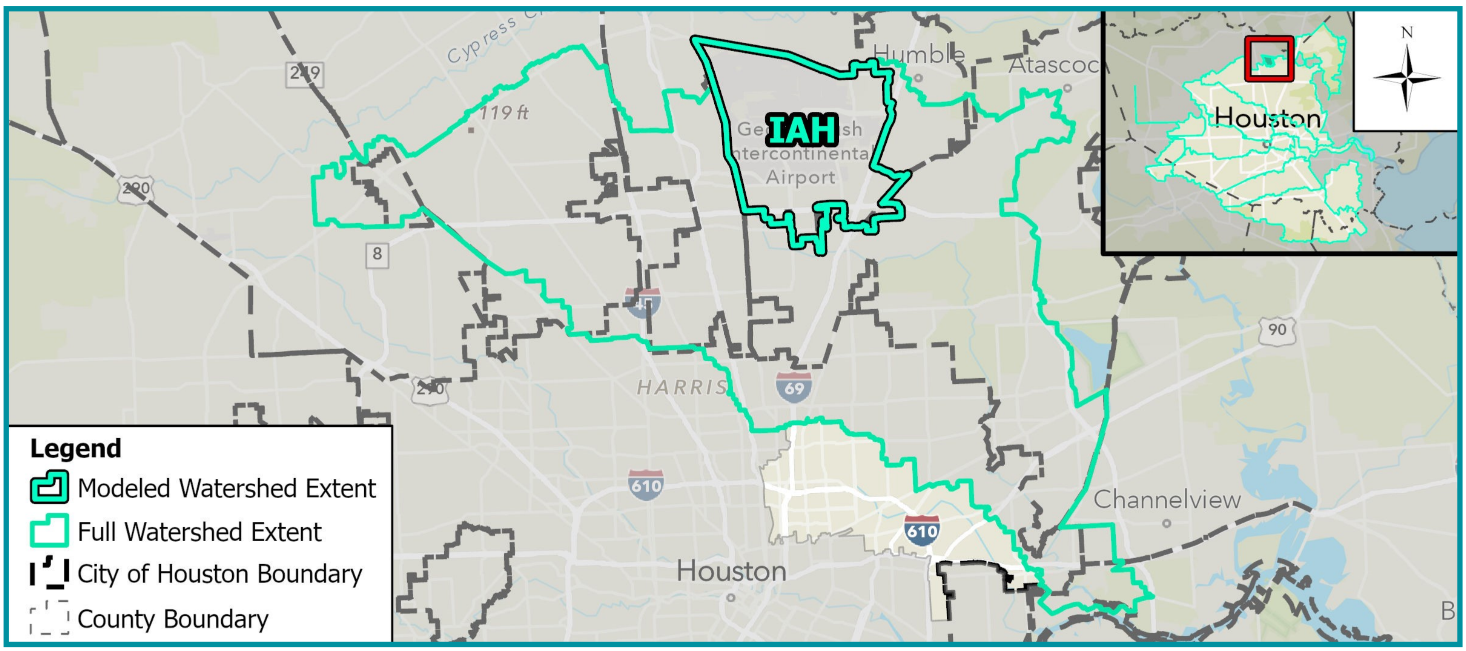
HOUSTON PUBLIC WORKS

SIZE: 27 square miles

CONVEYANCE INFRASTRUCTURE:
170 miles

DESCRIPTION: The IAH (Greens) watershed is located in the north region of the City within the Greens Bayou watershed. IAH (Greens) watershed flows south east to Greens Bayou. The watershed falls within City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of small-lot, single family residential development and commercial land use.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	2%
36” ≤ Pipe Diameter < 60”	12%
Pipe Diameter ≥ 60”	11%
Roadside Ditch	59%
Studied Channel	8%
Unstudied Channel	8%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
15 sq. mi.

Structures at 100-year Flood Risk
900

Storm Sewer with 2-year Capacity
55%

Roadside Ditch with 2-year Capacity
75%

FLOOD DESCRIPTION:

Modeling results indicate IAH (Greens) watershed experiences flooding in its neighborhood areas at and above the 2-yr storm event. These regions are affected by flooding in the adjacent Reinhardt and Garners Bayous.

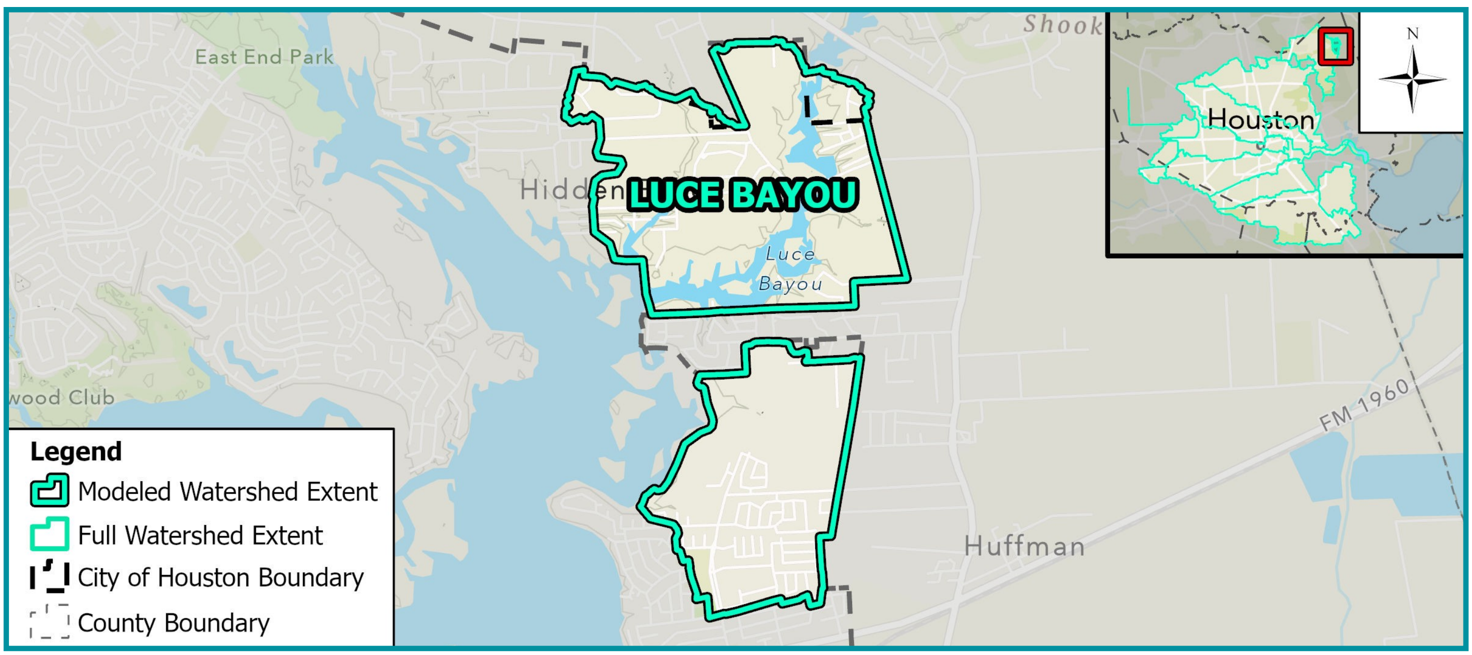
Luce Bayou Watershed

SIZE: 75 square miles

CONVEYANCE INFRASTRUCTURE:
20 miles

DESCRIPTION: The Luce Bayou watershed is located in the northeast region of the City, east of the San Jacinto River. Most of the watershed falls outside of City limits, with a generally flat terrain. The watershed is primarily undeveloped, with some small-lot, single family residential development. Numerous neighborhoods utilize roadside ditches for drainage.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	0%
36” ≤ Pipe Diameter < 60”	2%
Pipe Diameter ≥ 60”	1%
Roadside Ditch	62%
Studied Channel	12%
Unstudied Channel	23%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
1 sq. mi.

Structures at 100-year Flood Risk
52

Storm Sewer with 2-year Capacity
28%

Roadside Ditch with 2-year Capacity
71%

FLOOD DESCRIPTION:

Modeling results indicate Luce Bayou is completely contained for the 2– and 5-yr storm events. The northern portion of the watershed is susceptible to widespread flooding starting with the 10-yr storm event.

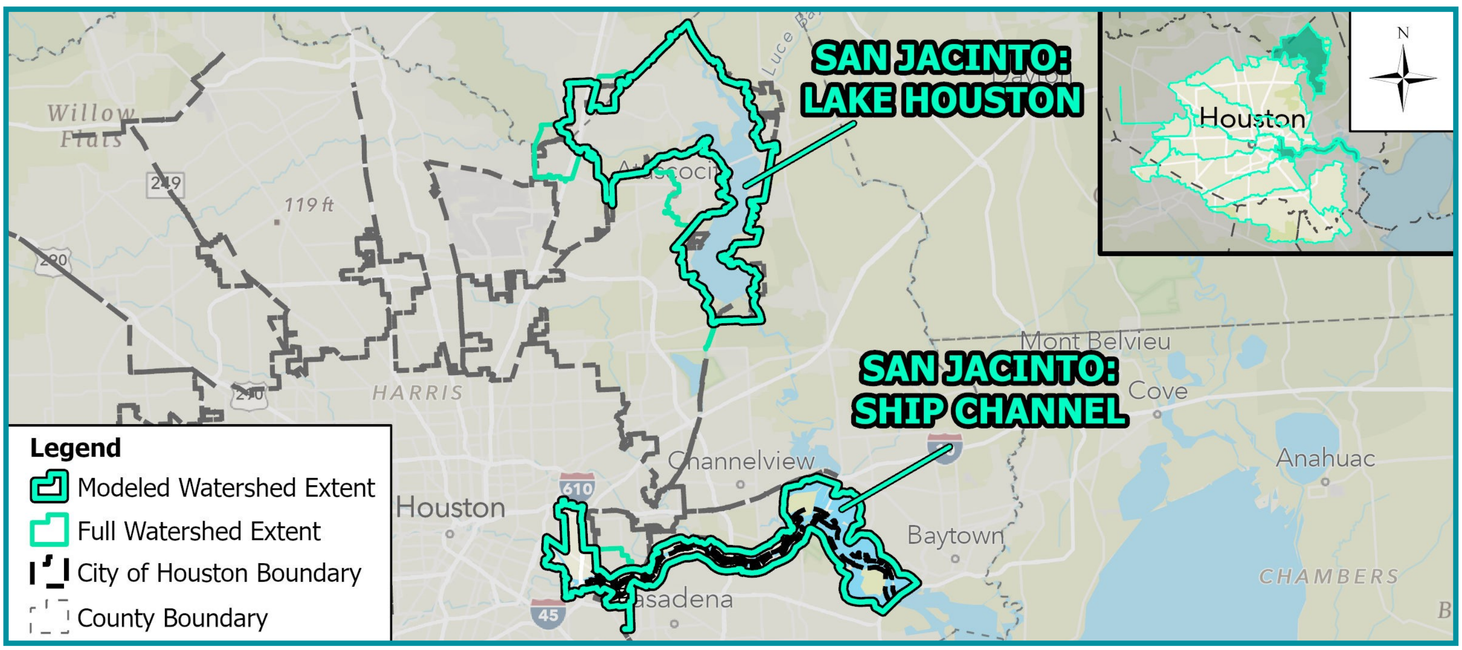
San Jacinto River Watershed

SIZE: 91 square miles

CONVEYANCE INFRASTRUCTURE:
630 miles

DESCRIPTION: The San Jacinto watershed stretches from the north to the east side of the city. The San Jacinto River flows through Kingwood to the Gulf of Mexico. Most of the watershed falls within City limits, largely covered in open water. The watershed is mostly developed, consisting primarily of small-lot, single family residential, and commercial development.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	29%
36” ≤ Pipe Diameter < 60”	10%
Pipe Diameter ≥ 60”	5%
Roadside Ditch	35%
Studied Channel	15%
Unstudied Channel	6%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
55 sq. mi.

Structures at 100-year Flood Risk
2,500

Storm Sewer with 2-year Capacity
62%

Roadside Ditch with 2-year Capacity
83%

FLOOD DESCRIPTION:

Modeling results indicate riverine flooding along the San Jacinto is seen in the larger events for both Lake Houston and the Ship Channel. In frequent events, undersized storm sewer and roadside ditch systems cause pockets of flooding.

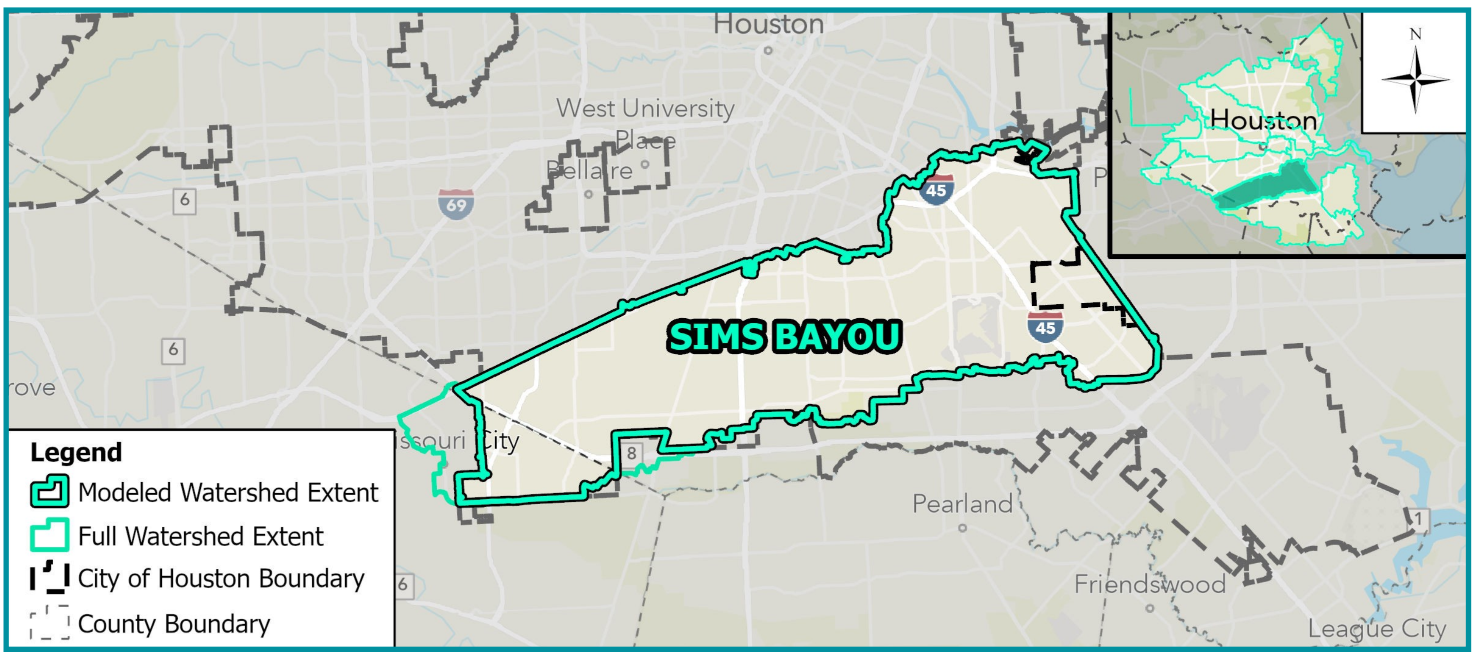
Sims Bayou Watershed

SIZE: 94 square miles

CONVEYANCE INFRASTRUCTURE:
1,230 miles

DESCRIPTION: The Sims Bayou watershed is located in the south region of the City between Brays Bayou and Clear Creek. Sims Bayou flows east into the Buffalo Bayou - Houston Ship Channel. Most of the watershed falls within City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of small-lot, single family residential development.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	32%
36” ≤ Pipe Diameter < 60”	17%
Pipe Diameter ≥ 60”	6%
Roadside Ditch	33%
Studied Channel	7%
Unstudied Channel	5%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
40 sq. mi.

Structures at 100-year Flood Risk
14,800

Storm Sewer with 2-year Capacity
49%

Roadside Ditch with 2-year Capacity
72%

FLOOD DESCRIPTION:

Modeling results indicate Sims Bayou is generally contained within its banks except between Hiram Clarke Drive and Almeda Road. Flooding is generally influenced by tailwater from channels or local infrastructure with insufficient capacity.

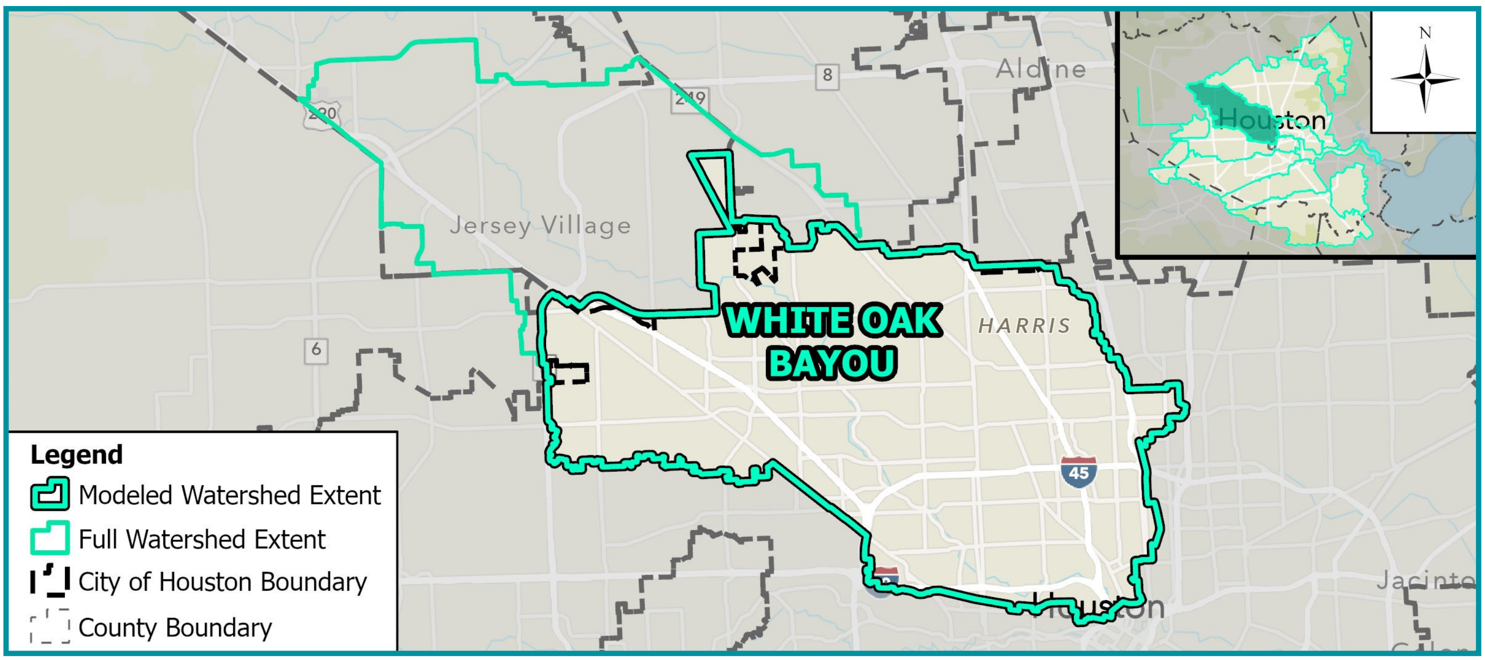
White Oak Bayou Watershed

SIZE: 111 square miles

CONVEYANCE INFRASTRUCTURE:
1,030 miles

DESCRIPTION: The White Oak Bayou watershed is located in the northwest region of the City between Buffalo Bayou and Greens Bayou. White Oak Bayou flows southeast into the Buffalo Bayou - Houston Ship Channel. Most of the watershed falls within City limits, with a generally flat terrain. The watershed is mostly developed, consisting primarily of small-lot, single family residential development.

Conveyance Infrastructure	Percent of Total Conveyance System
24” ≤ Pipe Diameter < 36”	2%
36” ≤ Pipe Diameter < 60”	15%
Pipe Diameter ≥ 60”	10%
Roadside Ditch	65%
Studied Channel	4%
Unstudied Channel	4%



EXISTING CONDITIONS FLOOD RISK

Area at 100-year Flood Risk
35 sq. mi.

Structures at 100-year Flood Risk
21,200

Storm Sewer with 2-year Capacity
61%

Roadside Ditch with 2-year Capacity
78%

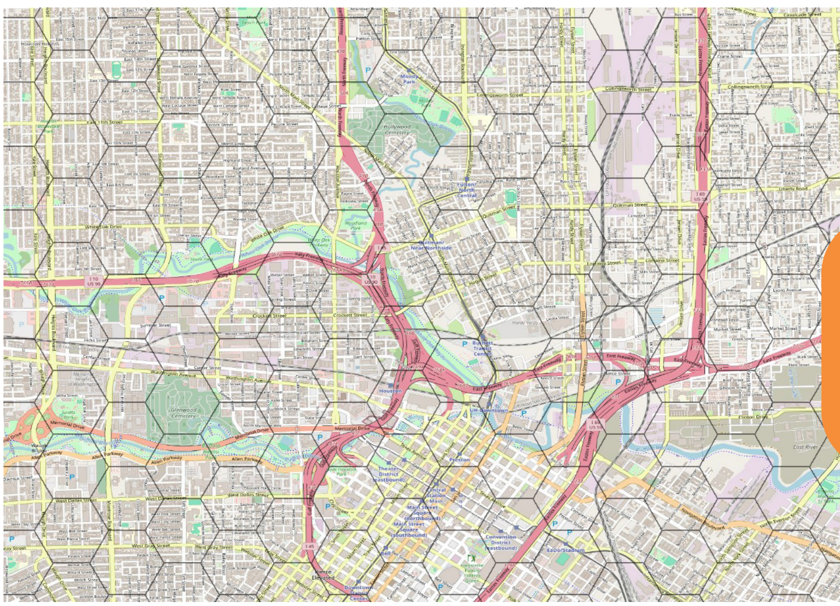
FLOOD DESCRIPTION:

Modeling results indicate White Oak Bayou is generally contained within its banks for the 2-yr storm event. Flooding generally occurs between Loop 610 southward and IH-10 and west of Shepherd Dr. for the 10-yr storm events and greater.

FOCUS AREA EVALUATION

Categorizing flood risk within the City is challenging due to its size and complex drainage infrastructure. The Stormwater Master Plan provides essential information on flood risk, which can be used to identify future study areas and project implementations. These areas highlight locations with severe and frequent flooding, identified based on various factors, including impacts on people, property, and critical facilities.

The City of Houston Flood Focus Area Evaluation compiled several metrics including at-risk structures, population, roads, and critical facilities for each evaluated storm event. To uniformly analyze the City, it was divided into evenly distributed hexagonal grids. The severity of flood risk in the identified categories was evaluated for each hexagon and a cumulative “score” was assigned. These scores can be used to identify locations in the City with more or less severe flooding and assist in the prioritization and distribution of funding and other resources.



HEXAGONAL GRID

The City was divided into evenly distributed hexagonal grids, as shown in this image, to uniformly analyze several metrics across the City.

The weighting of the flood risk factors used to score the hexagons is a flexible metric that can be updated within the analysis. As specific funding sources or City goals are identified, the Focus Area Evaluation can be updated to prioritize flood risk metrics related to the intended use. Additional classification can also be performed to account for other factors that influence which areas may be selected for further study or project implementation.

Current Uses

The modeling effort for the Stormwater Master Plan yields valuable data for various aspects of drainage planning, engineering, and permitting. The information provided can be categorized into:

MODELS

The detailed ICM models offer the first comprehensive model of stormwater conditions within the City. These models were simulated for a range of storm events to understand the ponding for both frequent and significant events. The submission includes all ICM databases for each watershed, consisting of a series of models discussed in each watershed report.

USES:

- The models establish baseline conditions throughout the City, which can be used to streamline future study efforts. The data in the models includes terrain, storm sewer information, model build features, structures, bridges, and culverts corroborated by validation against historic events.
- All major storm sewers within the City have been modeled, including elevations for a wide range of storm events. This information can be used in design projects to establish a downstream tailwater that accurately represents existing conditions, accounting for downstream storm sewer and channel capacity.
- The models can provide insights into the potential causes of flooding in high-risk areas. Storm sewer profiles, ditch depths, flow paths, and other model attributes can be reviewed to identify capacity constraints and potential solutions before a detailed study is conducted.

GIS OUTPUT

The deliverables include detailed outputs such as depth and water surface elevation rasters, model network data, model output, and level of service shapefiles. This data can be utilized within the City to enhance drainage management.

USES:

- The rasters developed through the modeling offer depth and water surface elevation information for the entire City. While this data is intended for planning purposes, it can be used to inform development permitting and planning.
- Data outputs include the identification of flooding hotspots throughout the City through a flood focus area analysis. This analysis is directly derived from the hydraulic models and can be adjusted to reflect model updates or specific City planning efforts. Additionally, the level of service shapefiles can confirm system capacity issues within the identified hotspots.
- The output provides depths throughout the City for all roadways. This information can be used by emergency personnel when identifying areas of potential high water and evacuation routes for both smaller and larger storm events.

Future Use

LEVERAGE RESULTS

The results of the City of Houston Stormwater Master Plan efforts provide substantial amounts of data to be leveraged in the evaluation of existing flood risk throughout the City. In addition, the models provide a solid foundation to build upon with further studies and projects.

STUDY AND PROJECT IDENTIFICATION

Results of the modeling and Focus Area Evaluation provide a baseline analysis of existing flood risk for the City that can be used to:

- Identify priority areas to target with studies and projects.
- Provide a baseline understanding of flood risk sources.
- Inform development of funding applications.
- Assist in the identification of potential partnerships with the HCFCD.

CONTINUED DEVELOPMENT OF MODELS

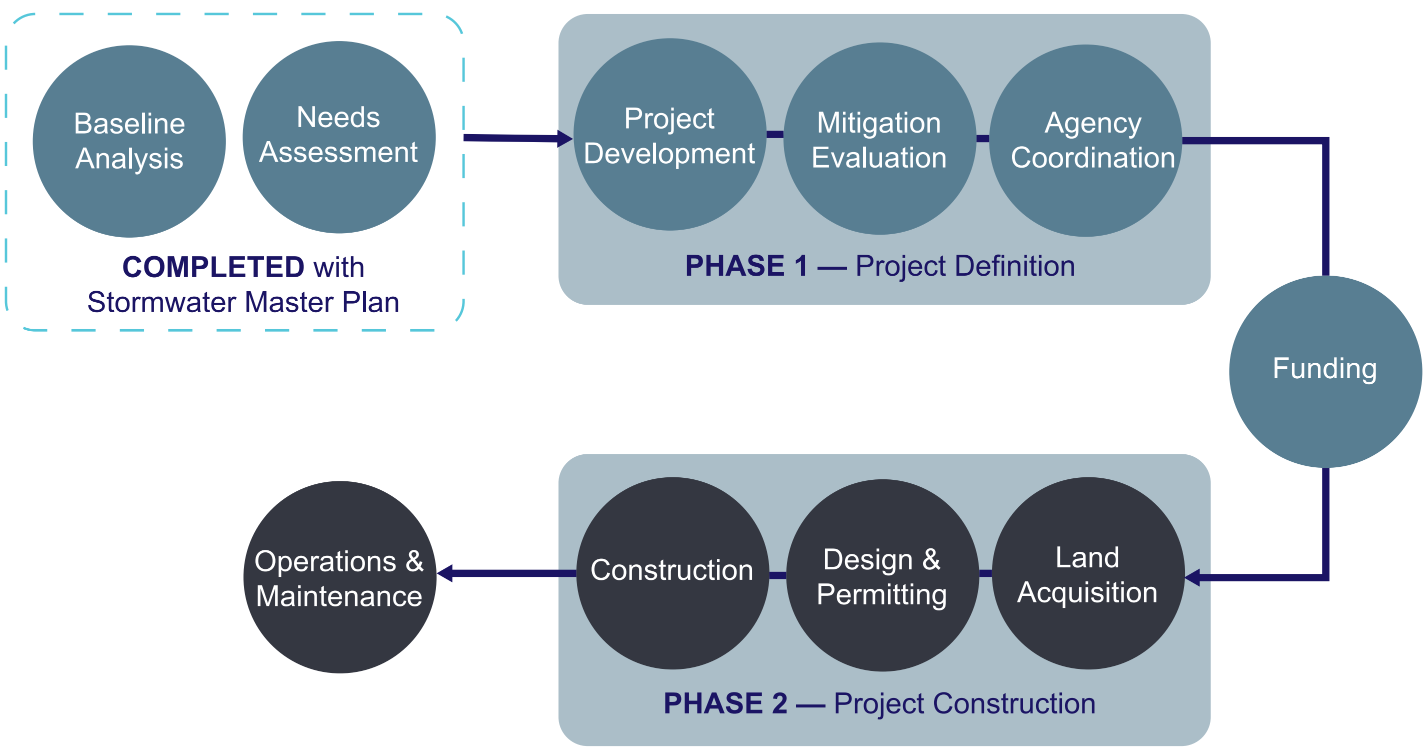
The models provide a solid baseline assessment of flood risk throughout the City. As detailed studies are performed for areas identified as having severe flood risk, the models generated for this study can be used as a basis for these evaluations. Additional intricacies, such as smaller segments of storm sewer, driveway culverts, and terrain peculiarities, can be added to the models to generate more detailed results to be leveraged in project identification and evaluations. Utilizing these models as a starting point will help to standardize the models across watersheds, and will also help to save time and effort in creating models from scratch for every project.

As data changes with the implementation of drainage projects, new developments, or availability of newer and more detailed baseline information, the models should be updated. Incorporating these changes will allow the models to stay relevant and continue to provide a baseline assessment for flood risk throughout the City of Houston.

Conclusion

The goal of this project was to build a foundation to assist the City in enhancing flood management, streamlining project development, and improving community resilience. The existing conditions assessment and evaluation provided by the Citywide stormwater infrastructure models provided this base by establishing an understanding of existing flood risk through a comprehensive drainage analysis and identification of focus areas for future planning of projects and studies. This effort was an important first step to developing and implementing projects within the City and completed the initial phase of the project lifecycle.

CITY OF HOUSTON
STORMWATER MASTER PLAN



NEXT STEPS

The next phases of the planning and project cycle will include identifying and evaluating both local and regional projects. The modeling and focus area analyses completed as part of the Stormwater Master Plan will provide a basis for the selection of study areas and the development of detailed modeling for future project analysis.

In addition to project implementation, public awareness campaigns, and continued planning will be bolstered by the information gained through this study.

LOCAL PROJECTS

- Finalize local focus areas to establish future studies and projects
- Leverage existing models to conduct neighborhood studies to identify local project needs that supplement regional projects
- Coordinate with regional entities and cities to implement projects
- Establish capital improvement plans for necessary projects

REGIONAL PROJECTS

- Finalize regional focus areas to establish future studies and projects
- Leverage existing models to conduct watershed-wide planning studies to identify regional project needs and watershed detention
- Coordinate with the HCFCD regarding watershed mitigation needs and identify areas for regional solutions
- Identify and consistently apply for funding from various sources

AWARENESS

- Develop real time inundation mapping using data to provide residents understanding of flood risk based on real data
- Establish local evacuation routes along key thoroughfares to provide access to major highways during storm events
- Develop a flood risk dashboard to show residents urban flood risk potential within the City
- Identify frequently flooded structures for a potential voluntary buyout program

CONTINUE PLANNING

- Regular updates to model and plan based on Capital Improvement Projects (CIP), changes in rainfall, and changes in base data to continue to understand and effectively plan for ongoing changes within the City
- Coordination with the TWDB for flood planning changes based on needs and information provided by the most recent plan

Acknowledgements

CITY OF HOUSTON

Paresh Lad, ENV SP

Jesse Rose

Johana Clark, PE, PTOE

Mayuri Das, ENV SP

HALFF

Andrew Moore, PE, CFM

Rachel Herr, PE, CFM

Jenna Blohm, EIT, CFM

Megan Gallego

Craig Maske, PE, CFM, ENV SP

Lauren Fox, PE, CFM

Johnny Kim, PE, CFM

Whitney Linder, AICP-C


Prairie
BAYOU PLACE