Determination of Groundwater Withdrawal and Subsidence in Fort Bend County – 2021

by
Robert Thompson
Ashley Greuter, P.G.

Fort Bend Subsidence District Report 2022-01

Fort Bend Subsidence District
Richmond, TX
2022

MICHAEL J. TURCO

GENERAL MANAGER

The Fort Bend Subsidence District (District) has been monitoring water use, groundwater levels, and subsidence in Fort Bend, and adjacent counties since 1989. Subsidence, the lowering of land-surface elevation, is caused by the depressurization of our aquifers due to wide-spread use of groundwater as a primary water source. The mission of the District is to cease on-going subsidence and prevent the occurrence of future subsidence. As part of this effort, it is important for the District to provide consistent, high-quality information to the public regarding groundwater use, aquifer water-levels, and subsidence.

The information contained within this report is the compilation of the largest multi-agency effort in the State of Texas that leverages the resources of both the Fort Bend and Harris-Galveston Subsidence Districts with the City of Houston, the Lone Star Groundwater Conservation District, the Brazoria County Groundwater Conservation District, and the United States Geological Survey. This year alone, local, county, regional, and federal partnerships will publish the 32nd volume of this important data compilation. This report is intended to exceed the requirements of section 8834.104 of the District's enabling legislation.

On behalf of the Board of Directors of the Fort Bend Subsidence District, I would like to thank you for your interest in the District. We look forward to continuing to provide timely, accurate, high-quality data and research to inform the District's Regulatory Planning and water planning throughout the region.

Sincerely,

Michael J. Turco

General Manager

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Acknowledgements

The compilation of the data and analysis contained within this report would not be possible without the concerted effort of many that contributed to the 2021 Annual Groundwater Report. The authors would like to thank the staff of the Fort Bend Subsidence District for their diligent field work in collecting and verifying GPS and water use information, Wanda Sebesta and Brian Ladd (Fort Bend Subsidence District) for their processing and validation of water use data; Dr. Guoquan Wang (University of Houston) and his students for processing and archival of all of the raw GPS data; and the permittees, staff, and owners of the over 1,500 permitted wells in the District that submitted detailed water use information contained in this report.

Public Hearing Notice was posted on:	April 1, 2022
Draft Presentation Posted on District Website on:	April 28, 2022
Public Hearing held on:	April 28, 2022
Hearing Examiner:	Ms. Helen Truscott
Hearing Record held open for public comment until:	May 6, 2022
Approved by the Board of Directors:	tentative May 25, 2022

Conversions Factors and Datum

Multiply	By	To obtain
inch (in)	2.54	centimeter (cm)
mile (mi)	1.609	kilometer (km)
square mile (mi^2)	2.590	square kilometer (km^2)
gallon (gal)	3.785	liter (L)
million gallons per day (MGD)	3785.41	cubic meter (m^3)
million gallons per day (MGD)	3.0688	acre-feet (acre-ft)

List of Acronyms

BCGCD	Brazoria County Groundwater Conservation District
CORS	Continuously operating reference station
FBSD	Fort Bend Subsidence District
GNSS	Global navigation satellite system
GPS	Global positioning system
GRP	Groundwater reduction plan
HGSD	Harris-Galveston Subsidence District
LSGCD	Lone Star Groundwater Conservation District
MGD	Million gallons per day
NGS	National Geodetic Survey
NOAA	National Oceanic and Atmospheric Administration
NWS	National Weather Service
PAM	Periodically measured GPS station
POR	Period of record
TxDOT	Texas Department of Transportation
UH	University of Houston
USGS	United States Geological Survey

Executive Summary

Groundwater was the primary source of water for the municipal, agricultural, and industrial users over the last century. Rapid increase in population in the 1950s due to the expansion of the industrial complex in the Houston Ship Channel area led to a dramatic increase in water demand and groundwater withdrawal. The reliance on groundwater and subsequent subsidence that was caused by its regional development resulted in the creation of the Harris-Galveston Subsidence District (HGSD) in 1975 and the Fort Bend Subsidence District (District) in 1989. The District's mission is to regulate the use of groundwater in Fort Bend County, to cease ongoing and prevent future subsidence that can lead to infrastructure damage and contribute to flooding.

This report comprises the 32nd Annual Groundwater Report for the District. Pursuant to District Resolution No. 2022-449 passed on February 23, 2022, the Board of Directors held a public hearing at 2:30 p.m. on April 28, 2022. This report provides an overview of the information presented during the Public Hearing, including climatic conditions, groundwater use, groundwater levels and measured subsidence within the District through December 31, 2021.

Climate

Annual variations in precipitation can significantly impact the total water demand in the District. Groundwater use patterns fluctuate during periods of climatic variation, which results in changes in aquifer water-levels and potentially in subsidence rates. During periods of excessive rainfall, total water demand can decline; conversely, during periods of drought, water use can increase resulting in declining water-levels in the aquifer and increased rates of subsidence. The 2021 calendar year started out with below normal rainfall accumulations to mid-May, and above normal for the rest of the year. Overall, rainfall totals in 2021 ended 1.5 inches above normal.

Water Use

Since 1989, water users in the District have been working to change their source water from primarily groundwater to alternative sources of water that will not contribute to subsidence, primarily treated surface water. The percent of total water demand sourced from groundwater has dropped from about 60 percent in 1990 to about 48 percent in 2021. The three primary water uses in the District are public supply, industrial, and irrigation. Public supply groundwater use remains the largest single use category at 54.9 million gallons per day (MGD), a ten percent decrease from 2020, and accounts for 83 percent of groundwater used in the District. Since the last regulatory conversion milestone in 2014, public supply and industrial uses are generally unchanged, whereas irrigation uses have decreased by about 50 percent.

The District's Regulatory Plan requires permittees to convert to alternative water supplies in order to reduce their reliance on groundwater sources. The primary alternative water supply used in our region is surface water sourced from three river basins, the Brazos River Basin, the San Jacinto River Basin and the Trinity River Basin. Total alternative water usage for 2021 was 73.1 MGD, with the Brazos River remaining the single largest source of alternative water providing a total of 53.3 MGD in surface water supply. Groundwater remains the largest source of water supply within the District as a whole. The total water use for the District was determined to be 139.8 MGD in 2021, which is ten percent lower than 2020.

Groundwater Levels

Annually, since 1990, the United States Geological Survey (USGS) has measured the water level in hundreds of wells throughout the Houston region in cooperation with the District through a joint funding agreement along with additional cities, subsidence districts and groundwater conservation districts to monitor and provide reports on groundwater level altitude data for the Chicot, Evangeline and Jasper aquifers. Since aquifer water level is the best measure of the pressure in the aquifer, this information is also of vital importance to understanding the impact of changes in water use on subsidence.

The change in water level in the Chicot/Evangeline aquifer since 1990 shows the impact of District regulation on the aquifers. The area of rise with as much as 105 feet in the Chicot/Evangeline aquifer is a result of the reduction of groundwater use required by the District's Regulatory Plan. In northwestern Fort Bend County, water-levels continue to be significantly lower than the historical benchmark, with declines of 218 feet in the Chicot/Evangeline aquifer. These areas are growing rapidly and the conversion to alternative sources of water will not be completed in the District until 2025.

Subsidence

Since the mid 1990s, the District has been utilizing global positioning (GPS) stations to monitor the land surface elevation in the area. Working collaboratively with the University of Houston (UH) researchers, the monitoring network has grown to 227 GPS stations throughout the region that area operated by the District, the HGSD, the UH, the Lone Star Groundwater Conservation District (LSGCD), the Brazoria County Groundwater Conservation District (BCGCD), the City of Houston, the Texas Department of Transportation (TXDOT), and other local entities.

The average annual rate of movement is a useful measure to show the current activity at a GPS station. Subsidence rates greater than 2 centimeters (cm) per year were measured in north Fort Bend County, near the boundary to the Harris and Waller County line by Interstate 10. The southern portion of Regulatory A and all of Regulatory Area B show very little subsidence based on the subsidence rate averaged from 2017 to 2021.

Introduction

The Houston region has relied on groundwater as a primary source of water since the early 1900s. During and following the economic boom of the 1940s, rapid population expansion and increased water use resulted in potentiometric water-level declines in the Chicot and Evangeline aquifer of 250 to 300 feet (76 and 91 meters) respectively from 1943 to 1977 (Gabrysch, 1982). The potentiometric surface is the level to which water rises in a well. In a confined aquifer, this surface is above the top of the aquifer unit; whereas, in an unconfined aquifer, it is the same as the water table.

The reliance on groundwater and subsequent subsidence that was caused by its regional development resulted in the creation of the Harris-Galveston Subsidence District (HGSD) in 1975 and the Fort Bend Subsidence District (District) in 1989. The District's mission is to regulate the use of groundwater in Fort Bend County to cease ongoing and prevent future subsidence that can contribute to flooding and lead to infrastructure damage.

Purpose and Scope of Report

This document comprises the 32nd Annual Groundwater Report for the District. Pursuant to District Resolution No. 2022-449 passed on February 23, 2022, the Board of Directors held the Annual Groundwater Hearing beginning at 2:30 p.m. on April 28, 2022. The Public Hearing was held as an in-person and virtual meeting, with only in-person attendees able to ask questions and testify. The public hearing fulfills the requirements of Section 8834.104, Texas Special Districts Local Laws Code, which states that each year, the Board of Directors shall hold a public hearing for the purpose of taking testimony concerning the effects of groundwater withdrawals on the subsidence of land within the District during the preceding year.

Approximately 17 people attended the 2021 Groundwater Hearing including members of the USGS Texas-Oklahoma Water Science staff, along with members of the District's staff, two Board members, several interested parties and the public. Those giving testimony were Mr. Robert Thompson and Ms. Ashley Greuter of the District and Mr. Jason Ramage, Hydrologist, Gulf Coast Programs Office, Texas-Oklahoma Water Science Center, United States Geological Survey (USGS), Department of the Interior. District staff submitted in total, 18 exhibits including topics of precipitation, groundwater withdrawal, alternate-water usage, and subsidence measurements. Mr. Ramage presented 16 exhibits including topics of water-level altitudes, water-level changes, and aquifer compaction.

This report provides an overview of the information presented during the Public Hearing, including climatic conditions, groundwater use, groundwater levels and measured subsidence within the District through December 31, 2021. The **Appendix A** of this report includes the exhibits presented at the public hearing held on April 28, 2022.

Description of Study Area

The following section provides an overview of the study area, including the hydrogeology and the District's regulatory planning areas.

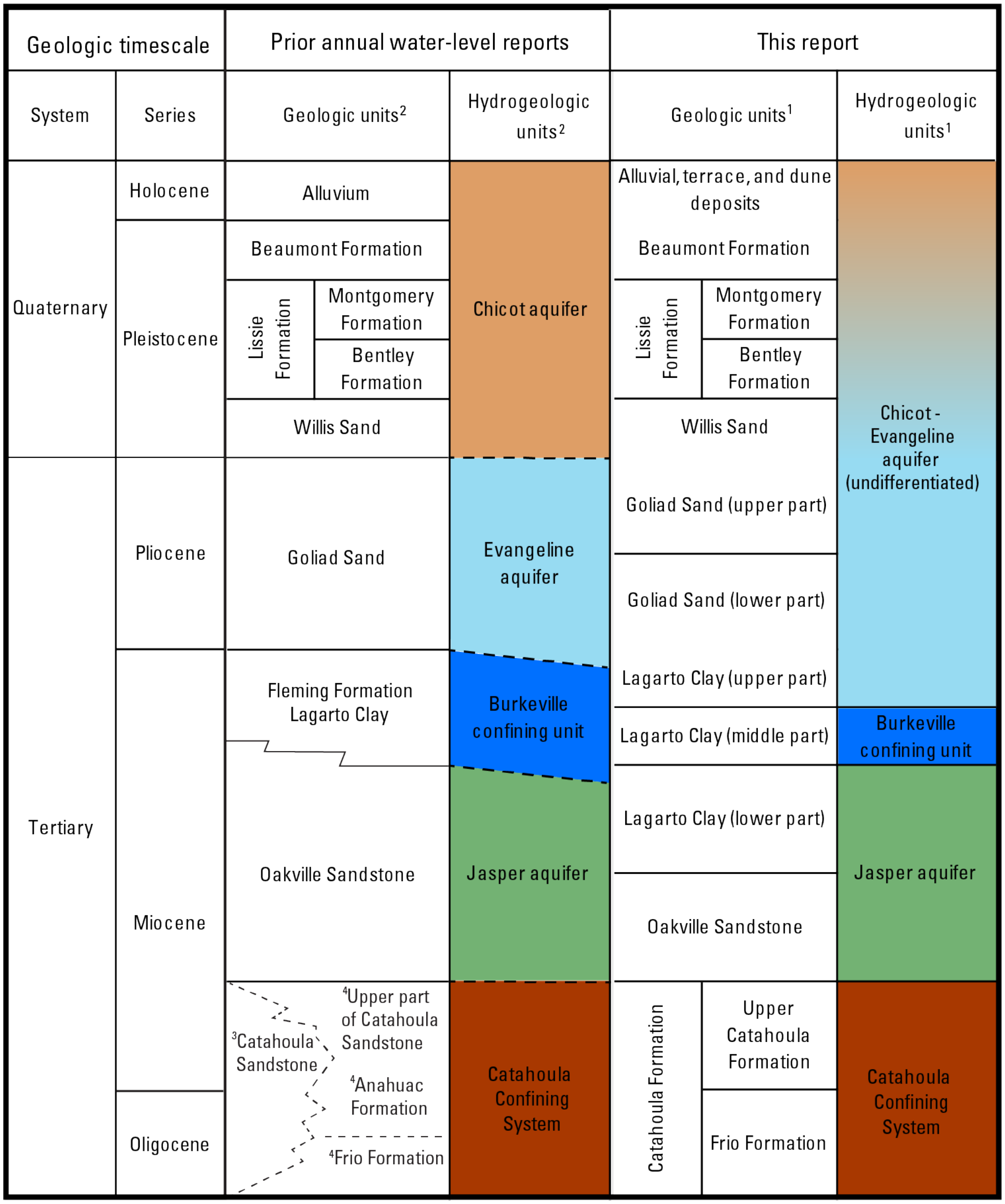
Hydrogeology

The Gulf Coast Aquifer exists as an accretionary wedge of unconsolidated sediments composed primarily of sand, silt, and clay. Indicative of a transgressive-regressive shoreline, the interbedded sands and clays are not horizontally or vertically continuous at larger than a local scale. From youngest to oldest, these hydrogeologic units include the Chicot, Evangeline, Burkeville Confining Unit, Jasper, and Catahoula Sandstone aquifers.

The two-primary water-bearing units located within the District include the Chicot and Evangeline aquifers. The Chicot and the Evangeline aquifers comprise the shallow system of aquifers. These aquifers are hydrologically connected, allowing for the free flow of water between the two units. Historically, nearly all of the groundwater production in the Gulf Coast Aquifer System in the District occurred in the shallow system. Recently, an updated stratigraphic approach incorporated new data from approximately 650 geophysical logs and adjusted the bottom of the Chicot aquifer by extending it deeper (Young & Draper, 2020). This updated approach changed aquifer designations for several wells measured annually as part of the groundwater level survey. As a result of this update, the Chicot and Evangeline aquifers have been combined into an undifferentiated shallow aquifer system called the Chicot/Evangeline (Undifferentiated) in this report (**Figure 1**).

The Jasper aquifer is the deepest of the three (3) primary water bearing units and is isolated by the regionally persistent Burkeville confining unit. Currently, there is only one well completed in the Jasper aquifer, and has only been in use on a limited basis. In the region, the Catahoula Sandstone, deepest water bearing unit in the Gulf Coast Aquifer system and the Burkeville confining unit are utilized as a groundwater supply in areas to the north and west of the District where these units may produce appreciable amounts of water.

Most of the subsidence that has occurred in the District can be sourced to clay compaction in the shallow water-bearing units associated with long-term water use and the decline in the potentiometric surface. Because of the significant amount of clay material in the primary water bearing units of the aquifer, the risk of compaction is high in areas where the developed portions of the aquifers are within about 2000 feet of land surface (Yu, et al., 2014) under high stress from groundwater development, and have had sustained potentiometric water-level declines.



[1]Modified from Young and Draper (2020) and Young and others (2010; 2012)
[2]Modified from Baker (1979)
[3]Located in the outcrop
[4]Located in the subcrop

Figure 1. Updated stratigraphic column of the Gulf Coast Aquifer System in Harris and adjacent counties, Texas. (From Braun and Ramage, 2022 (in press) to be published in June).

Regulatory Planning

The District's Regulatory Plan was developed to reduce groundwater withdrawal to a level that ceases ongoing subsidence and prevents future subsidence within the District. The District utilizes a novel approach to regulating groundwater withdrawal to prevent subsidence by allowing a portion of the total water demand of a groundwater user to be sourced from groundwater. Total water demand is defined as the total amount of water used by an entity from all sources including groundwater, treated surface water, reclaimed water, etc. The District adopted the most recent Regulatory Plan on January 23, 2013 and it was subsequently amended on August 28, 2013.

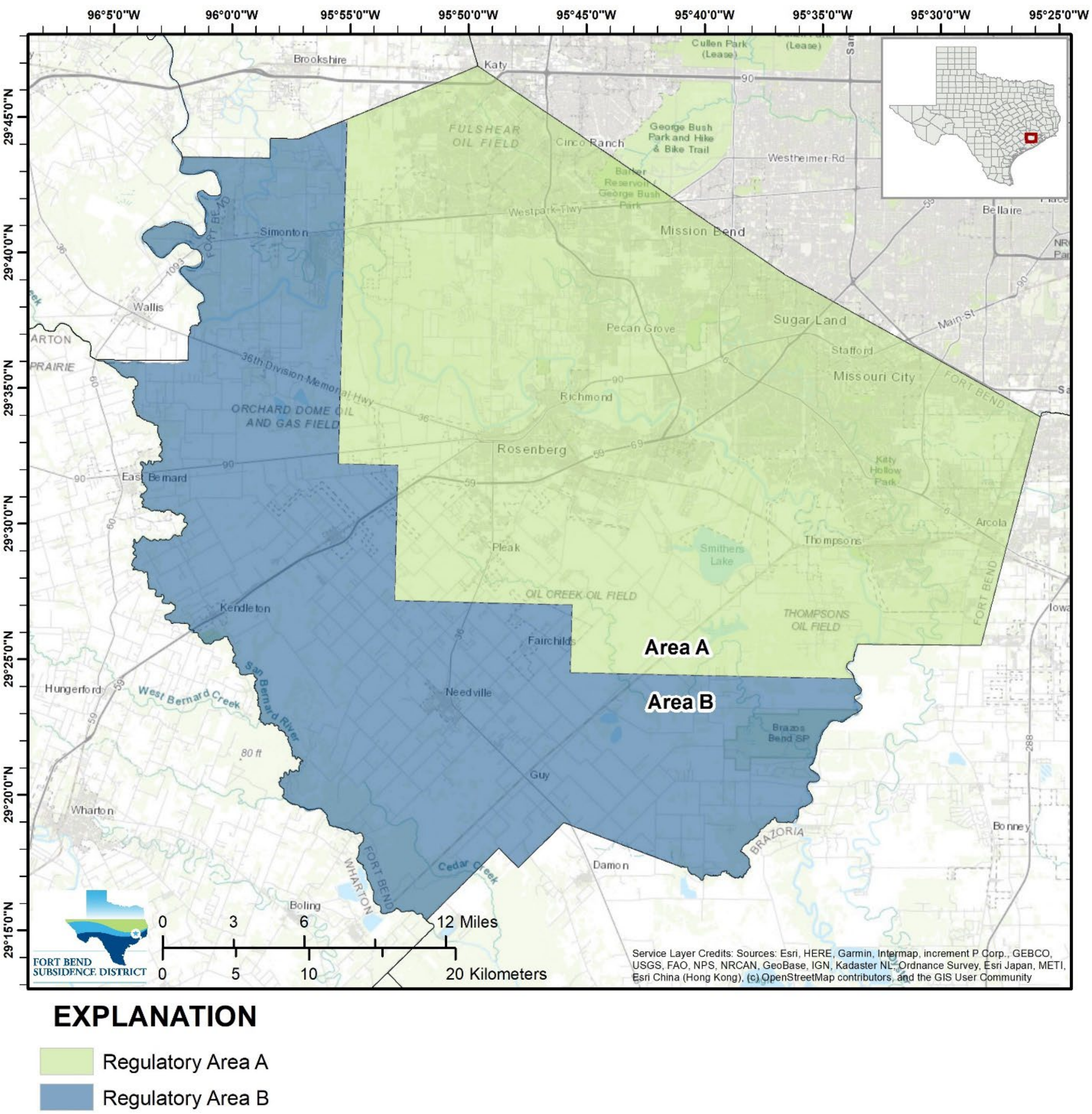


Figure 2. Location of the Fort Bend Subsidence District Regulatory Areas.

The District has historically used regulatory areas to guide groundwater conversion deadlines and regulations. The 2013 Regulatory Plan has subdivided Fort Bend County into two regulatory areas (**Figure 2**). Regulatory Area A includes the northeastern portion of the county, including all of the major cities. Permittees in this area are required to have no more than 40 percent of their total water demand from groundwater sources. Reduction in groundwater use for Regulatory Area A began once the District adopted its Regulatory Plan in 2003. This area will not be fully converted until the next groundwater reduction in 2025. At that time, permittees will be required to reduce their pumpage by an additional 30 percent, bringing the area to 60 percent converted to alternate water supplies. All other permittees in Regulatory Area A (i.e., those without a Groundwater Reduction Plan (GRP)) were required to reduce their groundwater withdrawals so that no more than 40 percent of their total water demand was sourced from groundwater, beginning in 2008 for those permitted for more than 10.0 MGY and without a GRP. And by 2013 for those without a GRP and less than 10.0 MGY.

Regulatory Area B covers primarily the southern and western portions of the county. Currently, there are no restrictions on groundwater pumpage in this area, except that water from Area B cannot be transferred to Area A.

Surficial Hydrology

The District's regulatory plan requires permittees to convert to alternative water supplies in order to reduce their reliance on groundwater sources. The primary alternative water supplies used in our region is surface water sourced from three river basins: the Brazos River Basin, the San Jacinto River Basin and the Trinity River Basin (**Figure 3**)**.**

The Brazos River Basin is the largest river basin in Texas, covering over 45,000 square miles (4,180 square meters) according to the Texas Water Development Board (TWDB). The headwaters of the Brazos River are located near the Texas-New Mexico border and the river travels over 800 miles (1,287 km) to discharge into the Gulf of Mexico near Freeport, Texas. The Brazos River Authority manages the eleven reservoirs within this basin, eight of which are owned by the Brazos River Authority and three are owned by the U. S. Army Corps of Engineers (Region H Water Planning Group, 2016).

The San Jacinto River Basin is the smallest river basin in Texas, covering almost 4,000 square miles (371 square meters) according to (TWDB 2020). Lake Conroe and Lake Houston are the two water supply reservoirs located within the San Jacinto River Basin. Lake Conroe is jointly owned by the City of Houston and the San Jacinto River Authority. The San Jacinto River Authority operates Lake Conroe and provides water supply to Harris and Montgomery Counties. Lake Houston is owned by the City of Houston and operated by the Coastal Water Authority.

The Trinity River Basin covers almost 18,000 square miles (1,672 square meters) with headwaters of the basin located in north central Texas (TWDB, 2020). The Trinity River flows through the Dallas-Fort Worth metroplex, traversing 550 miles (885 km) until the river discharges into Trinity Bay near Anahuac, Texas. There are numerous reservoirs located on the Trinity River which are owned and operated by several different agencies, including Lake Livingston which is owned and operated by Trinity River Authority.

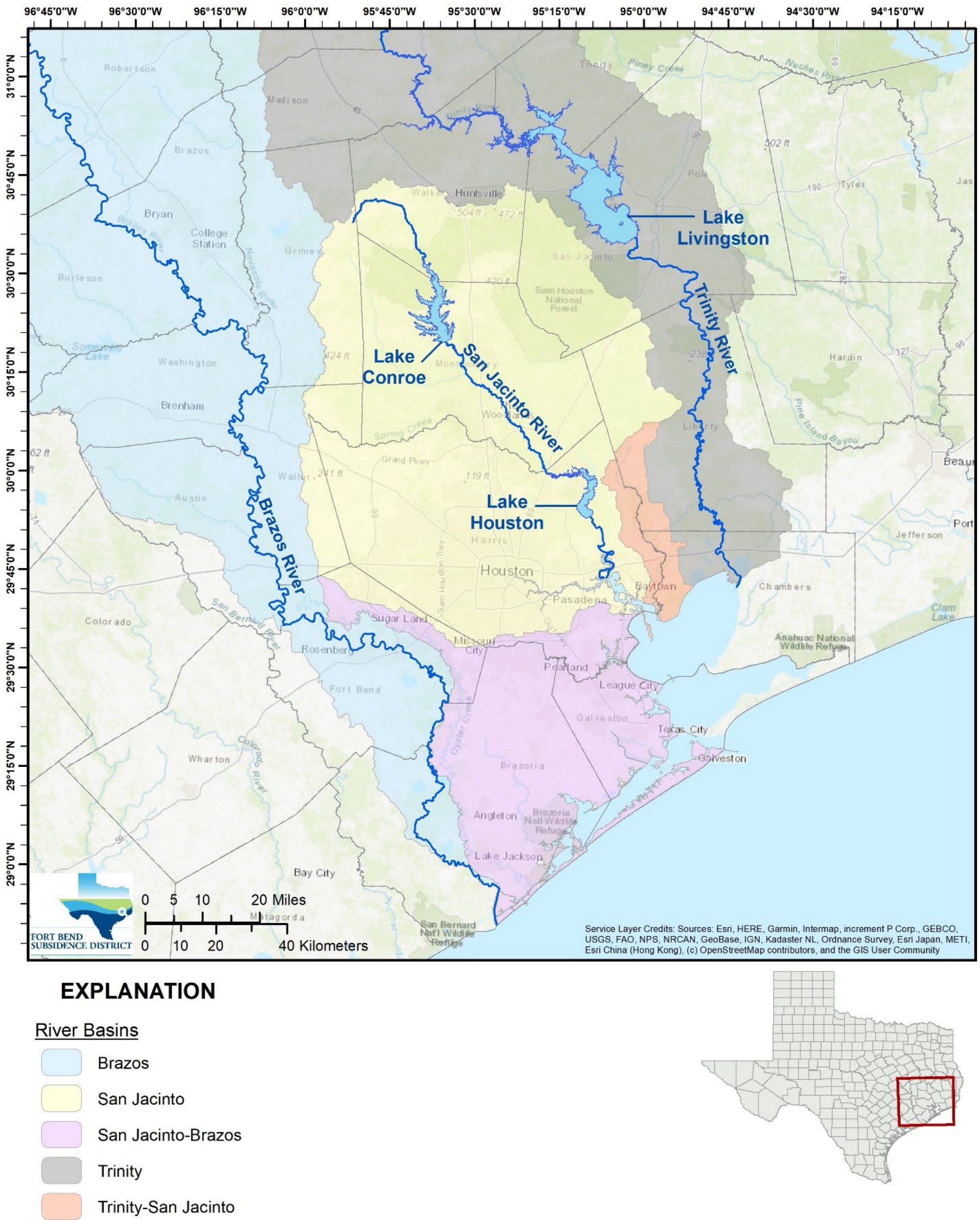


Figure 3: River basins that supply alternative water to Fort Bend, Galveston, and Harris Counties, Texas.

Alternative Source Waters

In the 1950s, the City of Houston along with other entities in the region began the development of several water supply reservoirs to provide water for the rapidly growing region within the San Jacinto and Trinity River Basins. The water treatment plants served by these surface water sources are operated by the City of Houston, City of Sugar Land, City of Missouri City, City of Richmond, the Gulf Coast Water Authority, the Brazosport Water Authority, and others.

To meet the Fort Bend Subsidence District's regulatory requirements to convert from groundwater to surface water, the City of Houston and four regional water authorities—the North Fort Bend Water Authority, North Harris County Regional Water Authority, Central Harris County Regional Water Authority, and West Harris County Regional Water Authority (collectively, the Water Authorities) began working together to implement a GRP for the planning, design, financing, and construction of several major infrastructure projects.

Three projects are underway to develop the necessary alternative water supply and distribution infrastructure to facilitate the District's future conversion requirements:

- Luce Bayou Interbasin Transfer: will pump untreated surface water from the Trinity River through a series of canals and water pipelines along Luce Bayou to Lake Houston.
- Northeast Water Purification Plant Expansion: will expand the existing surface water treatment plant located on Lake Houston from 80 MGD up to 400 MGD, in order to treat the raw surface water conveyed by the Luce Bayou Interbasin Transfer project.
- The Surface Water Supply Project: will convey treated water from the expanded Northeast Water Purification Plant into western Harris County and northeastern Fort Bend County.

In addition to the three projects described above, the City of Houston and the Water Authorities are each designing and constructing their own distribution systems to convey the treated surface water to their customers. These interrelated regional projects are planned to be completed by 2025, when the next conversion requirements of the District go into effect. **Figure 4** shows the extent of these projects.

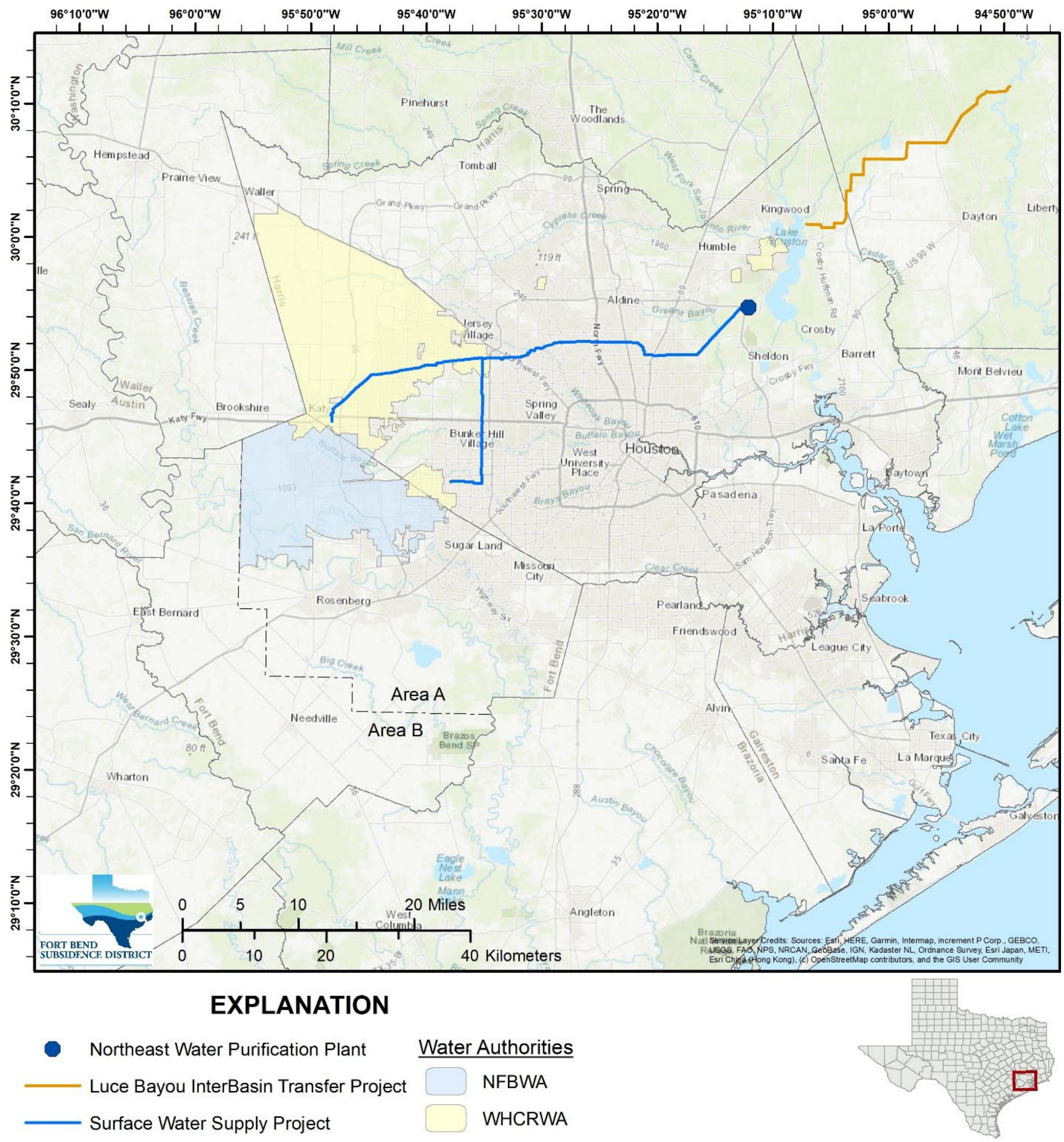


Figure 4: Alternative water supply and infrastructure distribution projects in the greater Houston region.

2021 Climate Summary

The District reviews local climatic data provided by the National Oceanic and Atmospheric Administration (NOAA) – National Weather Service (NWS) climate stations within and around the District (**Figure 5**). Variation in local precipitation, specifically deviation from historical normal, is important to the District because it has a direct impact on the magnitude of the total water demand of water users in the region and the availability of alternative water supplies. During periods of above normal precipitation in the region, total water demand remains typically near normal or below normal due to reduced municipal and agricultural water uses. Conversely, during periods of below normal precipitation, the total water demand of the region will typically increase due to increased water use. Additionally, during prolonged periods of below normal precipitation, natural limits on alternative supplies may require additional groundwater use – and subsequently result in additional lowering of groundwater aquifer levels, compaction of the aquifer materials, and subsidence observed at land surface.

Figure 5. Location of National Oceanic and Atmospheric Administration (NOAA) National Weather Service (NWS) climate stations, in the greater Houston-Galveston region, Texas.

As shown in **Figure 6**, precipitation for 2021 started out with below normal rainfall accumulations to mid-May, and above normal for the rest of the year. Overall, rainfall totals in 2021 ended 1.5 inches above normal.

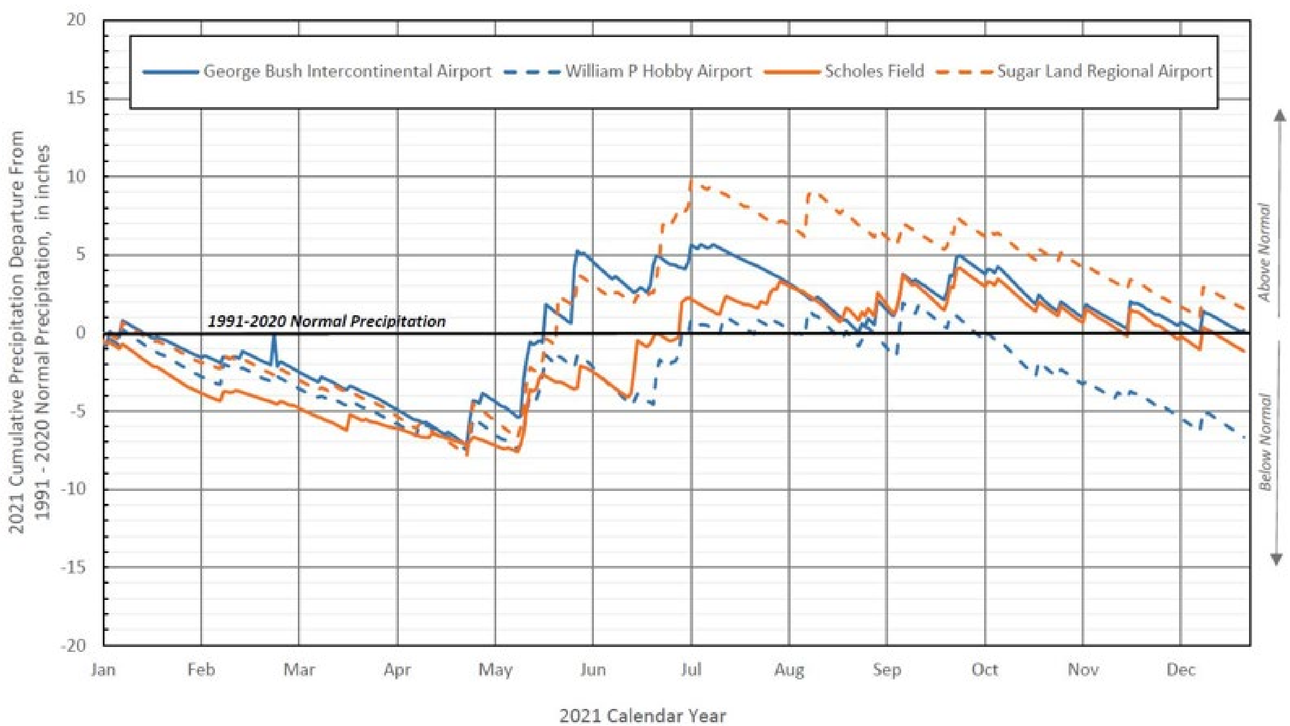


Figure 6. Cumulative precipitation, in inches, departure from 1991-2020 normal precipitation sourced from https://www.ncei.noaa.gov/data/normals-daily/1991-2020/access/) at selected NOAA-NWS Climate Stations in the greater Houston region. Individual climate station data are sourced from NOWData – NOAA Online Weather Data accessed via https://www.weather.gov/wrh/Climate?wfo=hgx.

The largest cumulative rainfall recorded at the selected NWS climate stations was 51.2 inches (130.2 cm) at Sugar Land Regional Airport which is 1.5 inches (4.2 cm) above the 1991-2020 normal annual precipitation. The year ended with William P. Hobby airport having the greatest departure from normal at 6.7 inches (17 cm) below normal.

2021 Water Use

The District collects groundwater and alternative water supply use annually from our permittees and other suppliers in the area. This information provides an understanding of how much groundwater is being used within the District, how our permittees are using groundwater and a perspective on the conversion from groundwater to surface water for the regulatory areas.

In 2021, there were a total of 1,572 permitted wells in the District. As of April 2022, a total of 1,470 of these permittees had submitted their annual water use data for the District to compile and use in this report. The groundwater withdrawals associated with these missing reports was estimated based on permitted allocations to be 0.4 MGD which equates to 0.6 percent of the reported withdrawals. Approximately 102 wells did not report pumpage in 2021.

In addition to providing water use data for 2021, this report also provides updated groundwater withdrawal totals for the previously reported year of 2020. These changes are made during the normal permitting and reporting process as part of the exchange between the District and its permittees. The changes include updating estimated amounts with actual amounts, correction of data entry errors, and errors in the submitted data. There was an increase of 0.1 MGD from the previous 2020 figure.

The following sections provide a summary of the information presented at the Public Hearing held on April 28, 2022. The exhibits used to provide testimony during the hearing are included in **Appendix A – Exhibits Presented at Public Hearing held on April 28, 2022**.

Overall Water Use

The three primary water uses in the District are public supply, industrial, and irrigation. The total amount of groundwater withdrawal for 2020 is 66.7 MGD, a decrease from 2020 (**Table 1)**, with public supply being reported to be 83 percent of the overall use. As a result of the District's Regulatory Plan, groundwater withdrawals have increased slightly since the District's inception in 1989 (**Figure 7**), with a 22 percent increase from 62.6 MGD in 1990 to 66.7 MGD in 2021. Patterns in groundwater use have shifted over time, resulting in reduced groundwater use for industrial and agricultural needs compared with the 1990s and 2000s.

The District is divided into two regulatory areas that define how much groundwater may be utilized as a percentage of the total water demand. The groundwater withdrawals are grouped by regulatory area in **Figure 8**. This chart shows the impact of the District's Regulatory Plan, requiring conversion from groundwater to surface water over time and as a result the reduction in groundwater withdrawals in Regulatory Area A. Currently, wells located in Regulatory Area B have no restrictions on their permits.

Table 1. Summary of Reported Groundwater Use (in MGD) by Regulatory Area.

Water Use Category	Area A			Area B			Total		
	2020	2021	Change between 2020 and 2021	2020	2021	Change between 2020 and 2021	2020	2021	Change between 2020 and 2021
Public	58.9	53.3	-10%	2.1	1.7	-21%	61.1	54.9	-10%
Industrial	3.6	3.9	7%	0.1	0.1	14%	3.7	4.0	7%
All Irrigation	4.8	3.3	-31%	7.2	4.5	-37%	12.0	7.8	-35%
Total	67.4	60.4	-10%	9.4	6.3	-33%	76.7	66.7	-13%

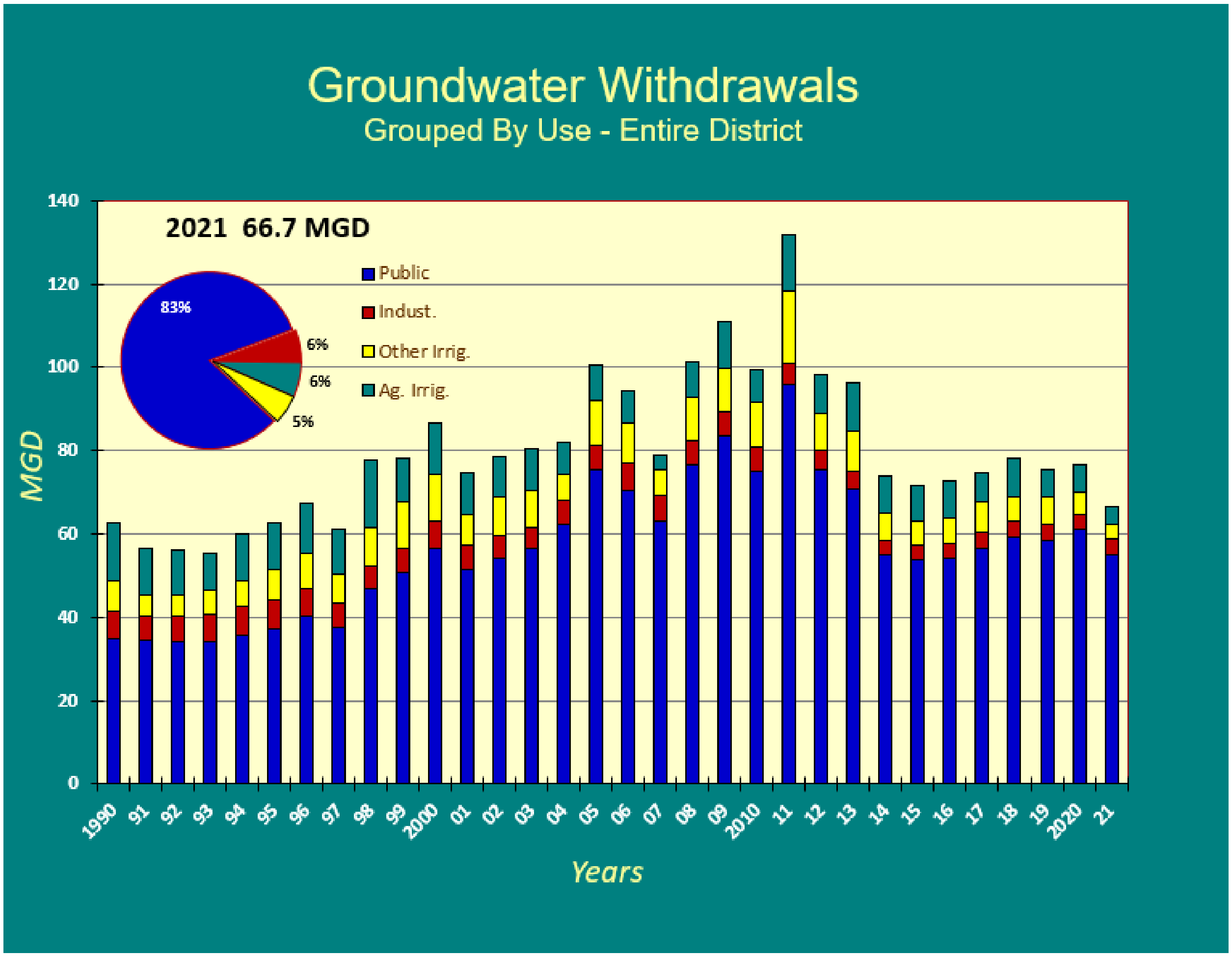


Figure 7: Groundwater withdrawals, in million gallons per day, by water use category from 1990 to 2021. The total groundwater used in the District was 66.7 MGD in 2021, with 83 percent of the use being public supply.

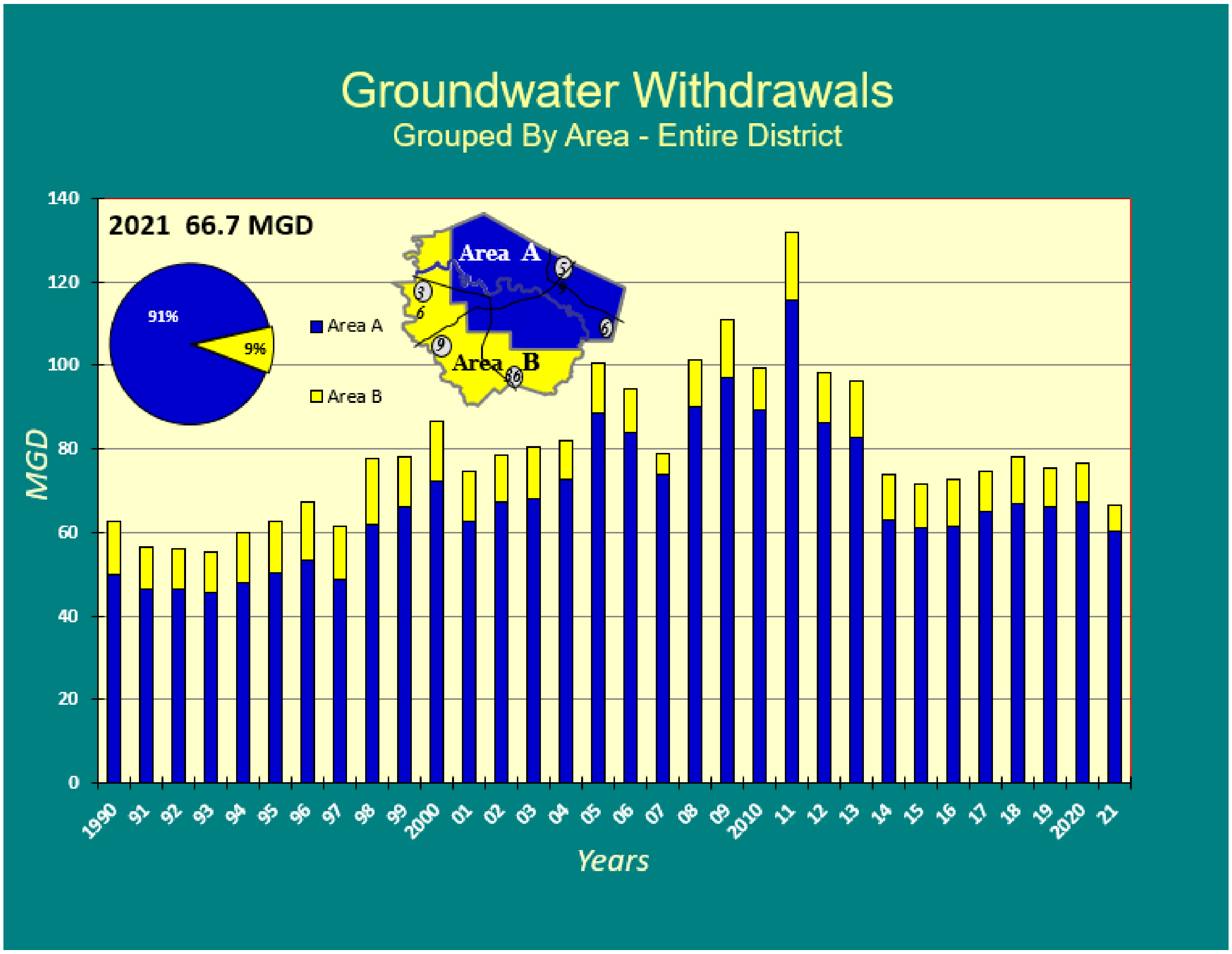


Figure 8: Groundwater withdrawals, in million gallons per day, by regulatory area from 1990 to 2021. In 2021, a total of 60.4 MGD of groundwater was used in Regulatory Area A, with 6.3 MGD used in Regulatory Area B.

Regulatory Area A

Regulatory Area A covers the northeastern portion of Fort Bend County. Cities and entities include Arcola, Cinco MUD 1, Fulshear, Houston, Katy, Meadows Place, Missouri City, Pearland, Pleak, Richmond, Rosenberg, Sienna Plantation, Sugar Land, and Thompsons. This area began its conversion to alternate water sources back in 2011, when North Fort Bend Water Authority began taking water from the City of Houston.

In 2021, total groundwater withdrawal in Regulatory Area A was 60.4 MGD, a ten percent decrease from the previous year (**Figure 9**). The majority of groundwater use in Regulatory Area A is associated with public supply use, which comprises over 88 percent of the use in the area. Industrial use is about half of what it was in 1990, and it increased slightly in 2021. Irrigation use is typically correlated to climate and rainfall patterns. The amount of groundwater used for irrigation decreased by 31 percent in 2021 to 3.3 MGD, but is much lower than the 16.9 MGD used during the 2011 drought.

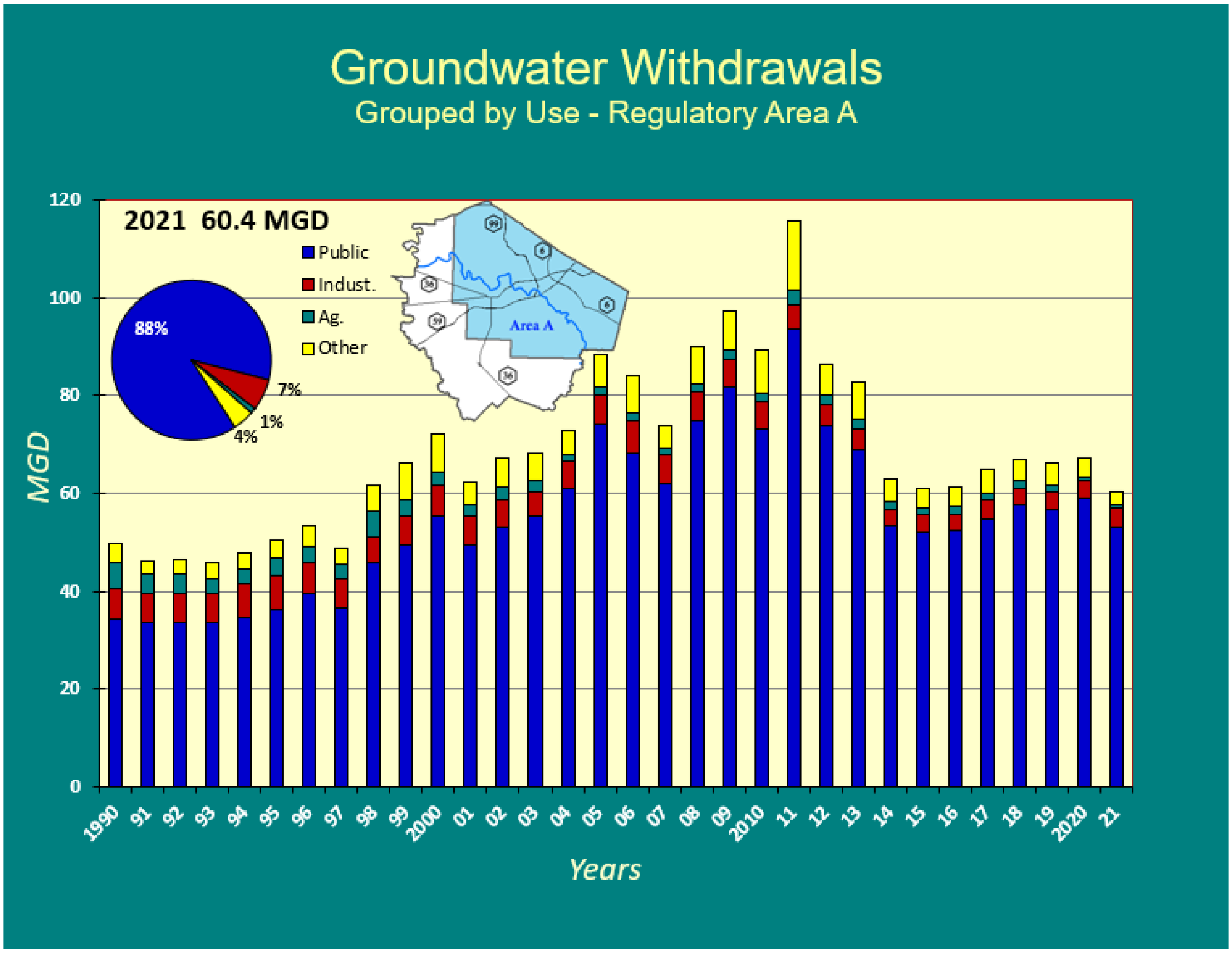


Figure 9: Groundwater withdrawals for Regulatory Area A, in million gallons per day, by water use category from 1990 to 2021. A total of 60.4 MGD of groundwater was used in Regulatory Area A in 2021, with 88% of the withdrawals being used for public supply.

Regulatory Area B

Regulatory Area B covers the western and southern areas of the District. Cities, villages and entities include Beasley, Fairchilds, Kendleton, Needville, Orchard, Simonton, and Weston Lakes.

Total groundwater withdrawal decreased in Regulatory Area B from 9.4 MGD in 2020 to 6.3 MGD in 2021 with public supply and irrigation use accounting for most of the decrease (**Figure 10**). Public supply groundwater use decreased by 21 percent over 2021 to 1.7 MGD. Industrial groundwater usage remained largely the same at 0.1 MGD and irrigation usage decreased to 4.5 MGD, a 37 percent decline in use. Groundwater withdrawals have remained generally even in Regulatory Area B.

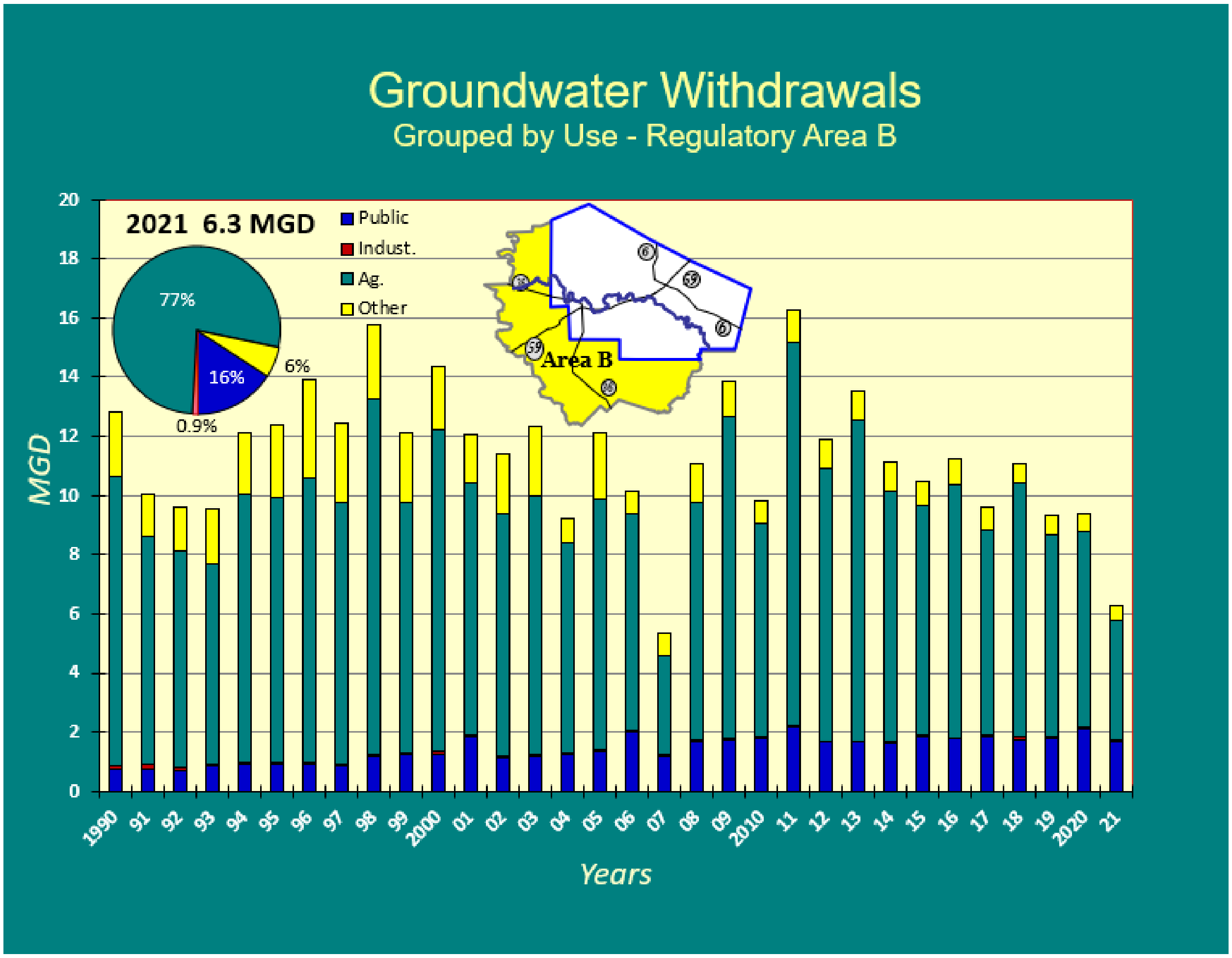


Figure 10: Groundwater withdrawals for Regulatory Area B, in million gallons per day, by water use category from 1990 to 2021. A total of 6.3 MGD of groundwater was used in Regulatory Area B in 2021, with 77% of the withdrawals being used for agricultural purposes.

Alternative Water Supply and Total Water Use

The District's Regulatory Plan requires permittees to convert to alternative water supplies in order to reduce their reliance on groundwater sources. The primary alternative water supply used in our region is surface water sourced from three river basins, the Brazos River Basin, the San Jacinto River Basin and the Trinity River Basin (**Table 2**). The San Jacinto and Trinity River totals have been lumped together because it is not possible to get the exact number by basin.

Groundwater remains the largest source of water supply within the District as a whole. The Brazos River, as it has been since 1990, is still the single largest source of alternative water used within the district. Reclaimed water is also used as an alternative water supply, but to a much smaller degree. Compared with 2020, use of the Brazos River Basin supply was down by seven percent, while reported reclaimed water use was higher than 2020, although the amount of reclaimed water use is quite small overall.

Table 2. Summary of Reported Alternative Water Supply Use and Total Water Use (in MGD)

Source		2020	2021	Change between 2020 and 2021
Alternative Supplies	Brazos River Basin	57.3	53.3	-7%
	San Jacinto/Trinity River Basin	16.6	15.4	-7%
	Reuse	3.9	4.4	13%
	Subtotal	77.8	73.1	-6%
Groundwater		76.7	66.7	-13%
Total Water Use		154.5	139.8	-10%

Use of the Brazos River Basin supply has increased over time, from 41.6 MGD in 1990 to 53.3 MGD in 2021 (**Figure 11**). The total water use for the District was determined to be 139.8 MGD in 2021, which is ten percent lower than 2020.

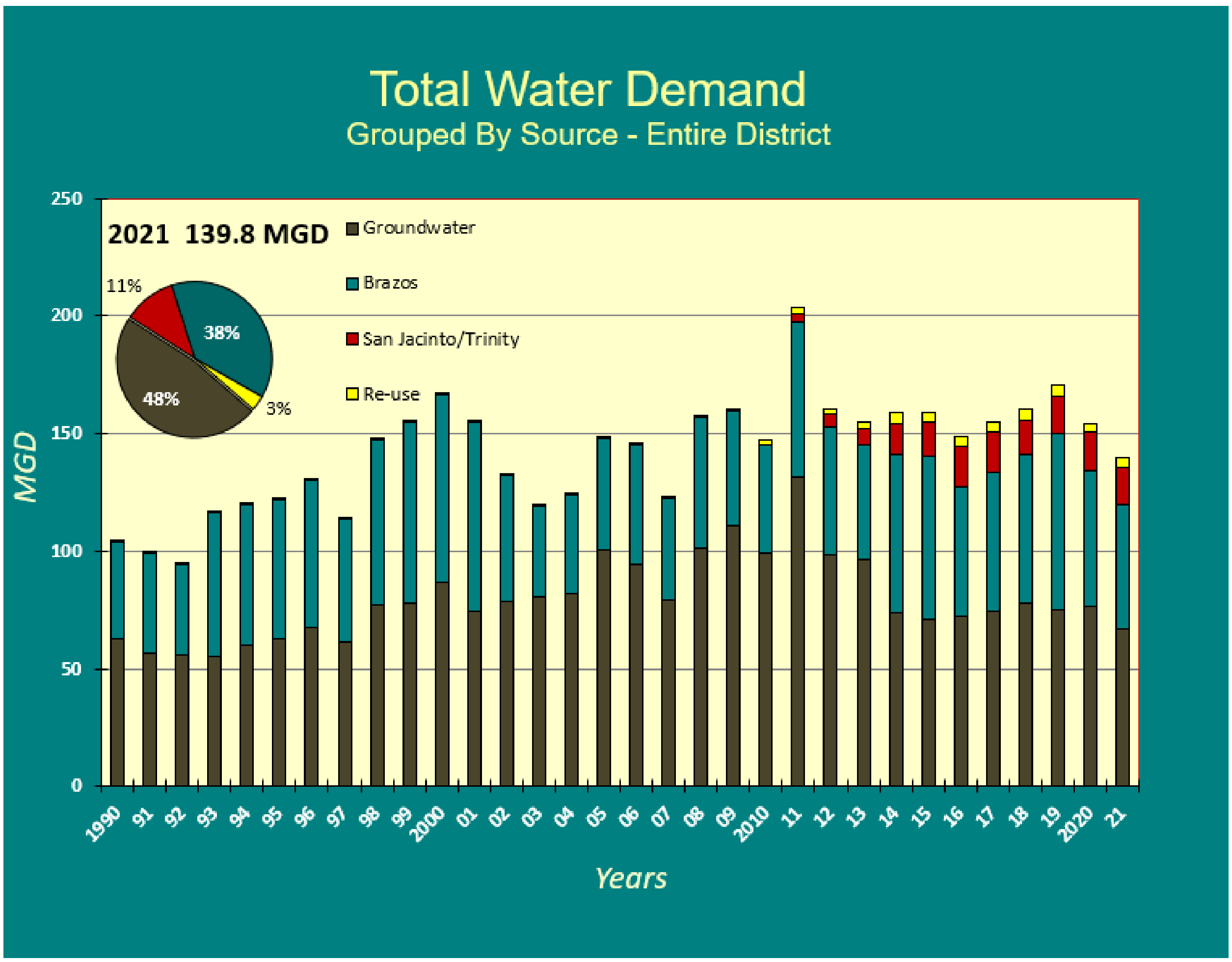


Figure 11: Total water use for the District, in million gallons per day, by source water, from 1990 to 2021. The total water use reported for the District in 2021 was 139.8 MGD.

2021 Groundwater Level Summary

All groundwater used in the District is sourced from the Gulf Coast Aquifer System, which is comprised of three-primary water bearing units. The two units most widely used in the District are the Chicot and Evangeline aquifers. The Chicot is the shallowest aquifer in the District which is directly connected to the Evangeline aquifer immediately below. The Burkeville confining unit lies beneath the surficial aquifers and isolates the third primary aquifer, the Jasper aquifer. The Jasper aquifer is not widely used in the District but is a primary source of water for other counties.

Annually, since 1975, the USGS has measured the water level in hundreds of wells throughout the Houston Region in cooperation with the Harris-Galveston Subsidence District through a joint funding agreement along with additional cities, subsidence districts and groundwater conservation districts to monitor and provide reports on groundwater level altitude data for the Chicot, Evangeline and Jasper aquifers. Since aquifer water level is the best measure of the pressure in the aquifer, this information is also of vital importance to understanding the impact of changes in water use on subsidence.

In 2020, the hydrostratigraphy of the Gulf Coast Aquifer was updated by the District as part of the Joint Regulatory Plan Review (Young & Draper, 2020). This information was used to support the development of an updated groundwater-flow model, named GULF 2023, for southeastern Texas in a project funded by the District and the HGSD, incorporated new data from approximately 650 geophysical logs, and adjusted the bottom of the Chicot aquifer by extending it deeper. As a result of this update, the Chicot and Evangeline aquifers have been combined into an undifferentiated shallow aquifer system called the Chicot/Evangeline (Undifferentiated) in this report. This updated approach also changed aquifer designations for several wells measured annually as part of the groundwater level survey.

The 2022 potentiometric surface (i.e., the interpolated surface from water level data) from the Chicot/Evangeline aquifer show the areas of primary stress on the aquifer occurs in northwestern Fort Bend County (**Figure 12**). Generally, Regulatory Area A has seen a significant decline in the potentiometric water level of more than 200 feet in the Chicot/Evangeline (**Figure 13**) aquifer in the Katy/Cinco Ranch area in 2022. This area is growing rapidly and the conversion to alternative sources of water will not be completed in the District until 2025.

The information presented in this section are a brief summary of the provisional data presented at the Public Hearing held on April 28, 2022. The exhibits used to provide testimony during the hearing are included in **Appendix A – Exhibits Presented at Public Hearing held on April 28, 2022**. A USGS Scientific Investigation Report will be released later this year documenting the status of groundwater level altitudes and the long-term changes in the Chicot/Evangeline (Undifferentiated) and Jasper aquifers.

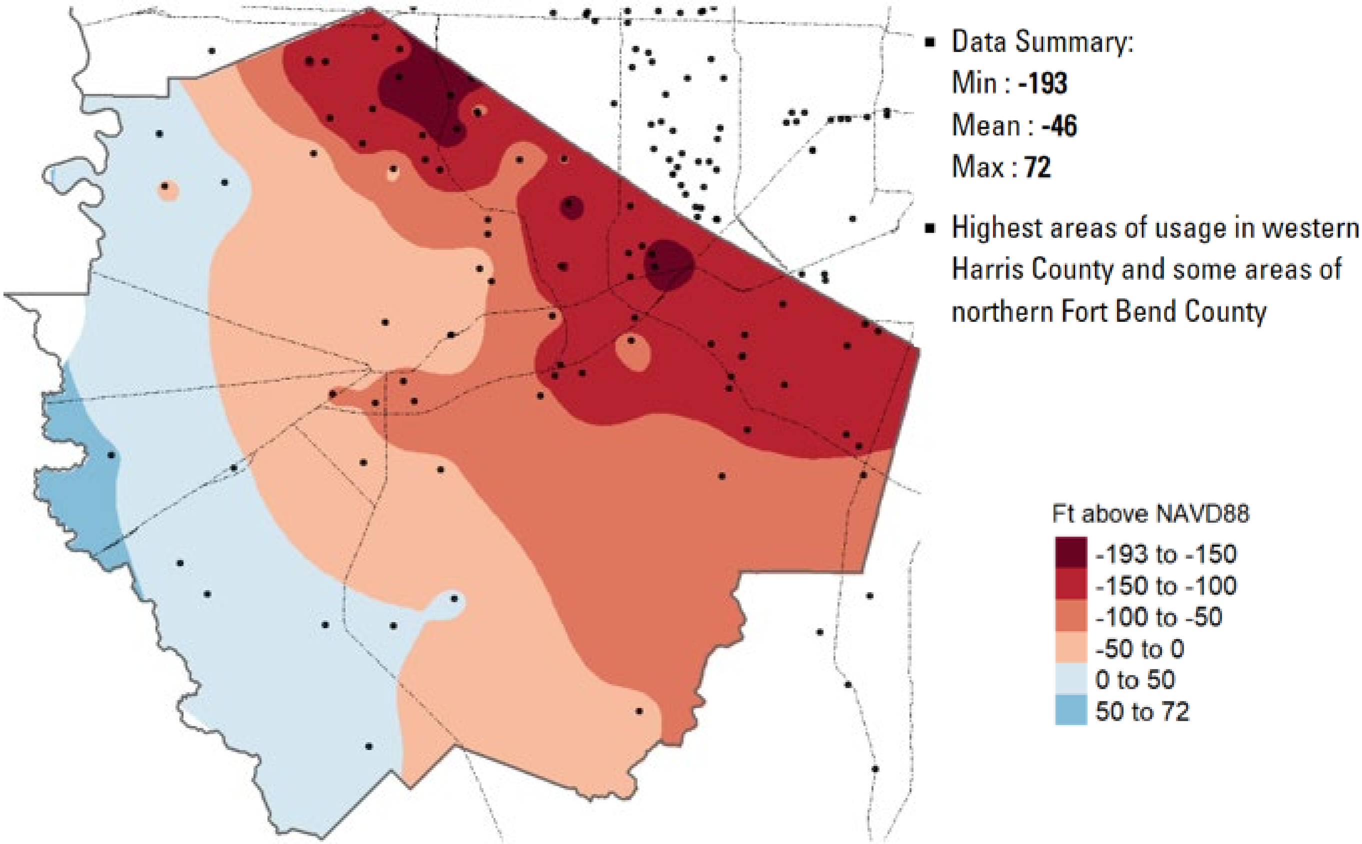


Figure 12: Altitude of the potentiometric surface determined from water levels measured in tightly cased wells screened in the Chicot/Evangeline (Undifferentiated) aquifer, Fort Bend County, Texas, 2022 (Source: USGS provisional data – preliminary and subject to change).

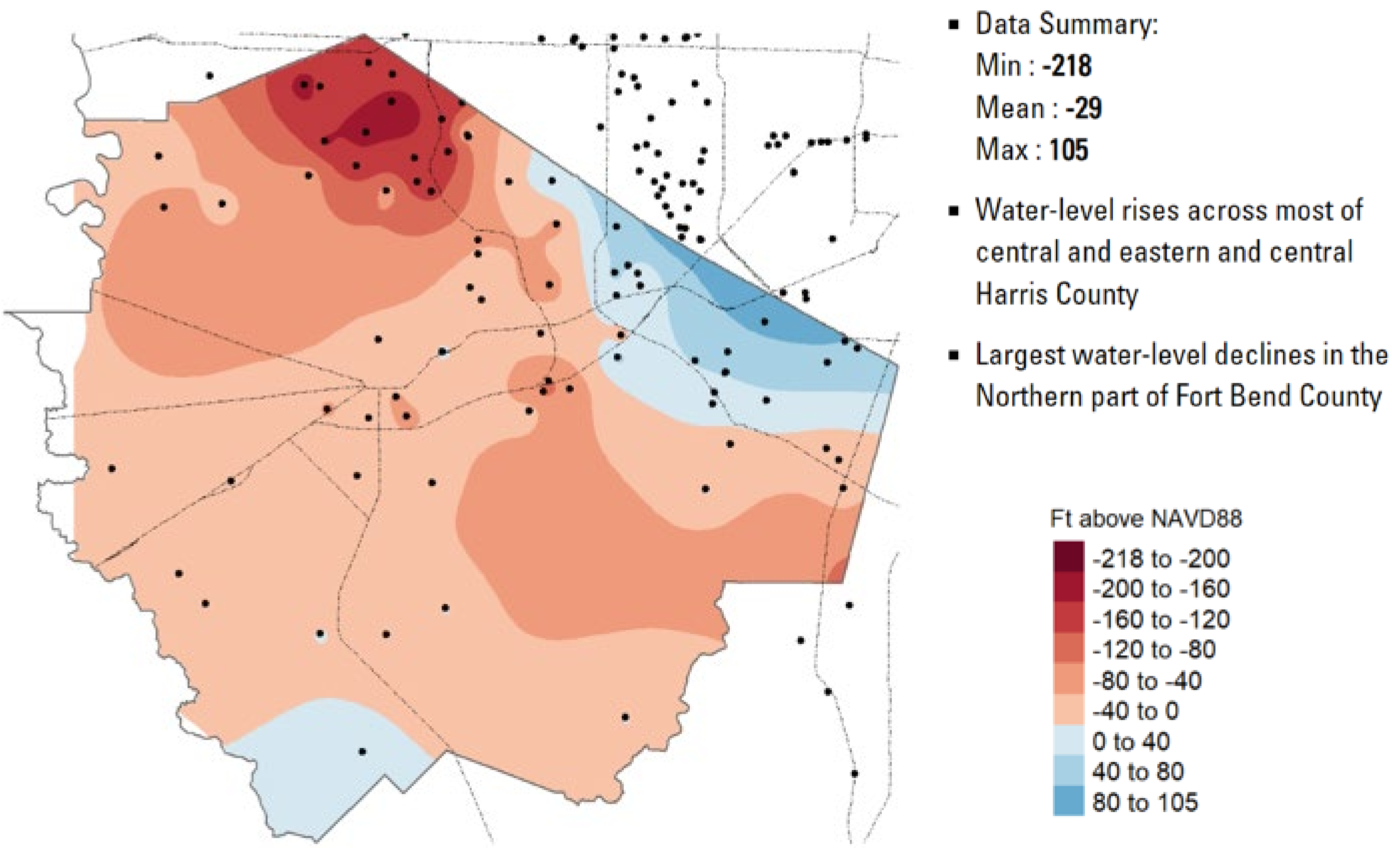


Figure 13: Potentiometric water-level change at wells screened in the Chicot/Evangeline (Undifferentiated) aquifer, Fort Bend County, Texas, 1990 to 2022 (Source: USGS provisional data – preliminary and subject to change).

Subsidence Trend Analysis

Subsidence is the lowering of land surface elevation. In the Houston-Galveston region, subsidence occurs from the compaction of clays due to groundwater withdrawal for municipal, industrial, and irrigation water supply. As the water level of the aquifer declines, fine-grained sediments, such as silt and clay, in the aquifer depressurize and compact in order to fill the void space created by the extracted water. This compaction results in the lowering of overlying stratigraphic units and is observed as subsidence at the land surface.

Global positioning system (GPS) stations have been installed in various locations across southeast Texas in order to track subsidence since the 1990s. This GPS network consists of a collaboration between the District, the HGSD, the UH, the LSGCD, the BCGCD, the NGS, the USGS, the City of Houston, and the TXDOT. The GPS network has grown to 227 stations throughout the region. Additional information on the GPS network is provided in **Appendix B – Subsidence Monitoring Network and Data** and **Appendix C – Period of Record Data.**

Satellite signals are collected every thirty seconds and averaged over 24 hours by global navigation satellite system (GNSS) antenna and receiver into one raw data file. Raw data files are processed by Dr.

Guoquan Wang at the UH and are compared to a stable regional reference frame designated as Houston20 that uses 25 continuously operating GPS stations which have a long history (greater than eight years) and are located outside the greater Houston area (Agudelo, et al., 2020). Additional details on the GPS data processing methodology are provided in **Appendix B**.

The District uses these GPS data in two ways: 1) period of record and 2) as an average annual subsidence rate to understand subsidence trends within the GPS network. Additional information on the average annual subsidence rate and period of record data for each GPS station are provided in **Appendix C**.

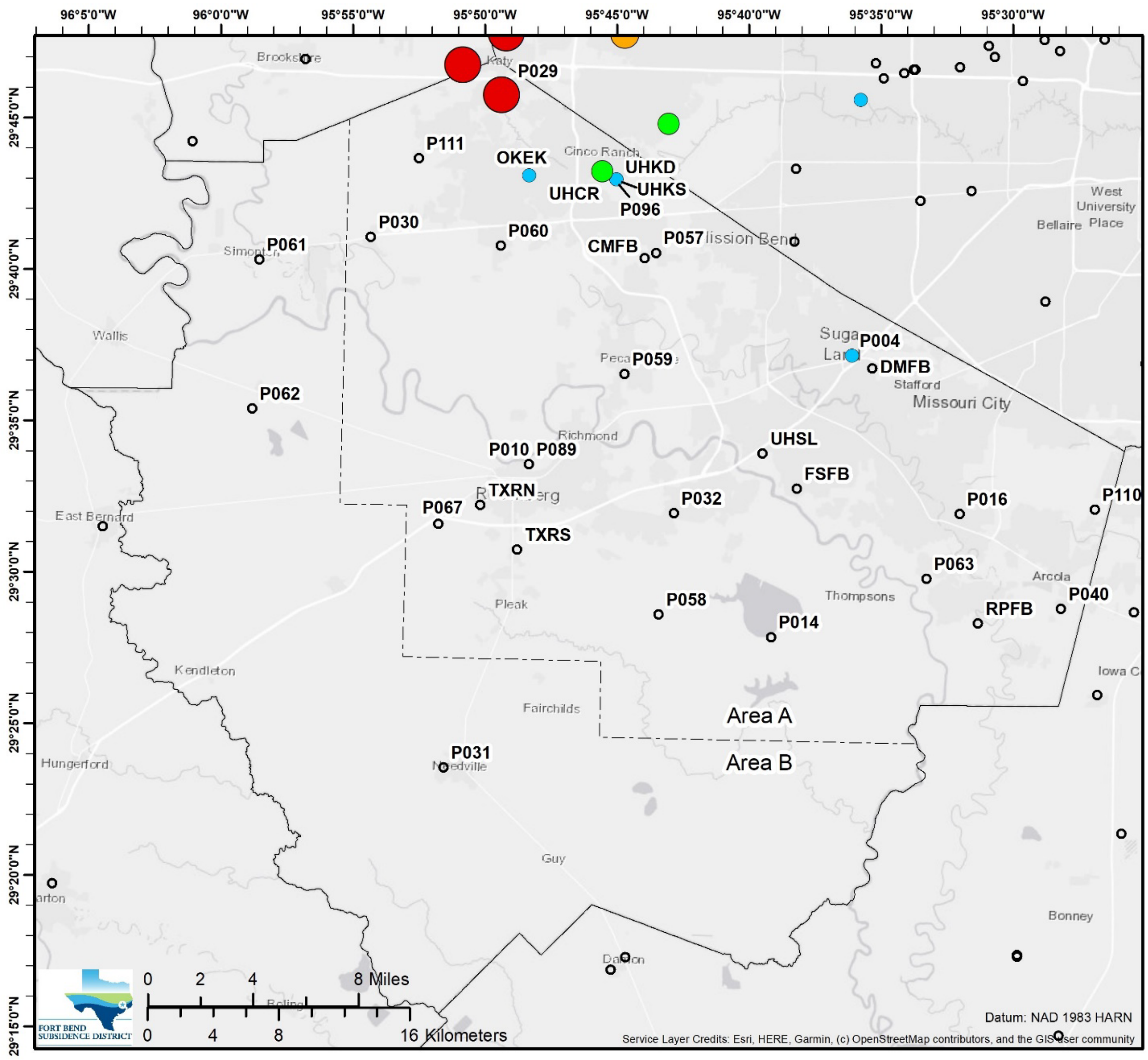
Period of Record Data

The period of record includes GPS measurements of the ellipsoidal height that are collected over the lifespan of each GPS station. It is used to track the full history of the land-surface deformation and is represented as a vertical displacement time series. The vertical displacement is determined by the change in ellipsoidal height, which is the distance from a point on the earth's surface to the reference ellipsoid. The reference ellipsoid is a mathematical representation of the earth's surface as a smoothed ellipsoid. Although the ellipsoid height is not the same as elevation, or the orthometric height, research as shown that linear trends of vertical displacement at GPS stations over the same time interval were the same for both ellipsoidal and orthometric heights (Wang & Soler, 2014). Therefore, ellipsoidal heights are used to estimate vertical displacement of the land surface. Period of record plots give a historical context to understand local to regional subsidence trends. Period of record plots for each GPS station in the subsidence monitoring network are provided in **Appendix C**.

Average Annual Subsidence Rate

The average annual subsidence rate is a useful measure to show the recent change in land surface deformation at each GPS station. The subsidence rate, presented in this report, is determined by using linear regression (i.e., the statistically determined best fit straight line through a scatter plot of data points) of the last five years of data for GPS station with at least three years of GPS data. **Figure 14** depicts the average annual subsidence rate from 2017 to 2021 for 32 GPS stations located in Fort Bend County as well as additional GPS stations in the subsidence monitoring network.

Regulatory Area A has the highest subsidence rates (greater than 1.0 centimeters per year) in the northern areas of Fort Bend County. The southern areas of Regulatory Area A show very minor subsidence with subsidence rates below half a centimeter per year. Similarly, in Regulatory Area B, GPS stations measured very little subsidence with subsidence rates below half a centimeter per year. Based on the GPS data collected in Fort Bend County, subsidence is occurring in the northern portions of Regulatory Area A, as this area is still undergoing conversion to alternative water supplies and population is growing.



EXPLANATION

Annual Subsidence Rate (cm/yr) from 2017 to 2021

- Greater than 2.0
- <2.0 - 1.5
- <1.5 - 1.0
- <1.0 - 0.5
- Less than 0.5 or period of record less than 3 years

Figure 14: Annual subsidence rate, measured in centimeters per year, referenced to Houston20 and estimated from three or more years of GPS data collected from GPS stations in Fort Bend and surrounding counties, Texas, averaged from 2017 to 2021.

GPS station P029, located in Katy, has the greatest subsidence rate estimated at 2.19 cm per year. As shown in **Figure 15**, P029 has experienced a subsidence rate greater than 1 cm per year since monitoring began in 2007.

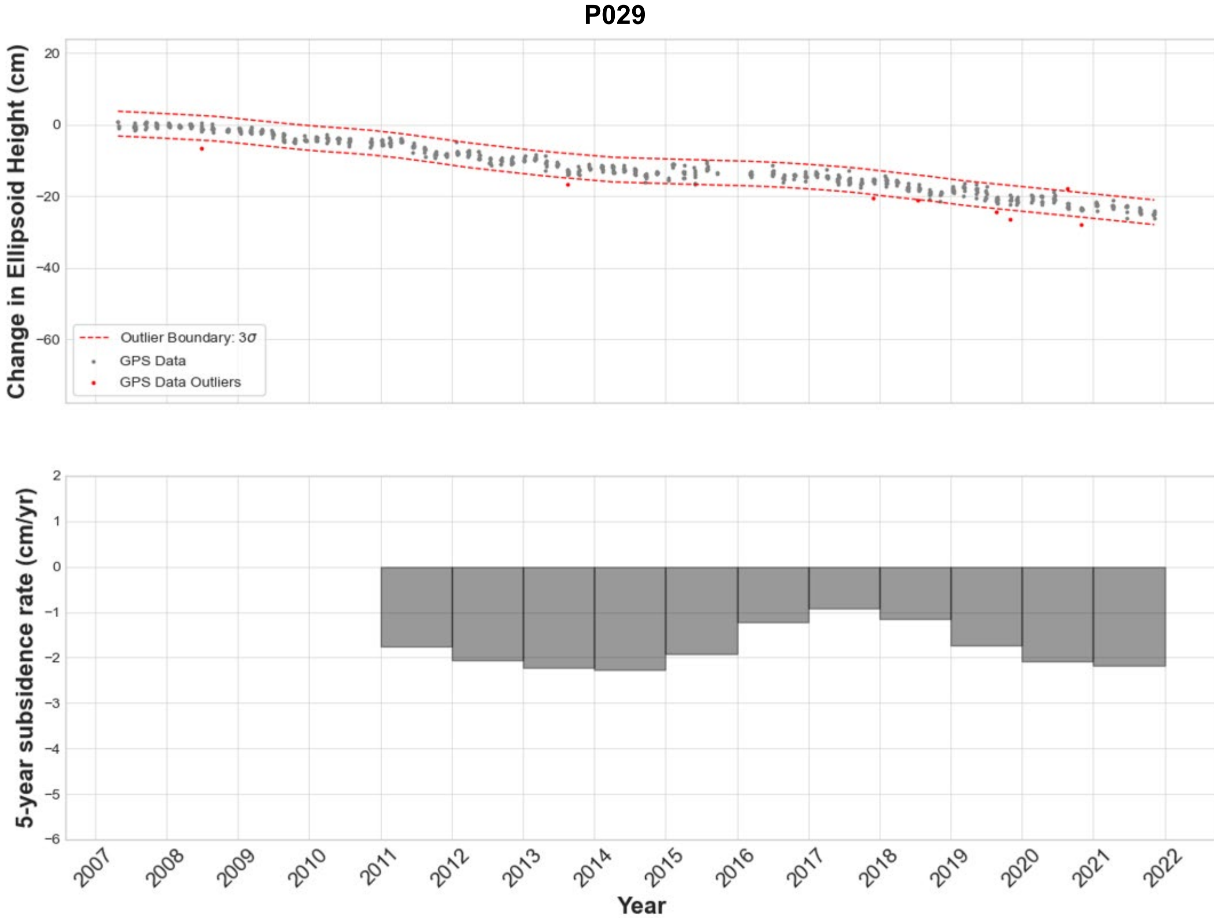


Figure 15: Period of record plot for P029 located in Katy, Texas, 2007 to 2021. This station measured 23.8 cm of subsidence over 14 years and the annual subsidence rate is 2.19 cm per year. The location of P029 is southwest of the intersection between I-10 and SH-99. Processed GPS data (gray circles) located inside the outlier boundary (red dashed line) are used when calculating subsidence rates. Processed GPS data identified as outliers (red circles) are not considered by HGSD when calculating subsidence rates and are shown for informational purposes only.

Regulatory Area A also contains GPS station P004, located in Sugar Land, that has measured the greatest total subsidence at 27.3 cm in Fort Bend County. **Figure 16** includes the GPS data for P004 and shows a steep declining trend from 1994 to 2010, then a flattening from 2010 to 2016, and a gentle decline from 2015 to 2021.

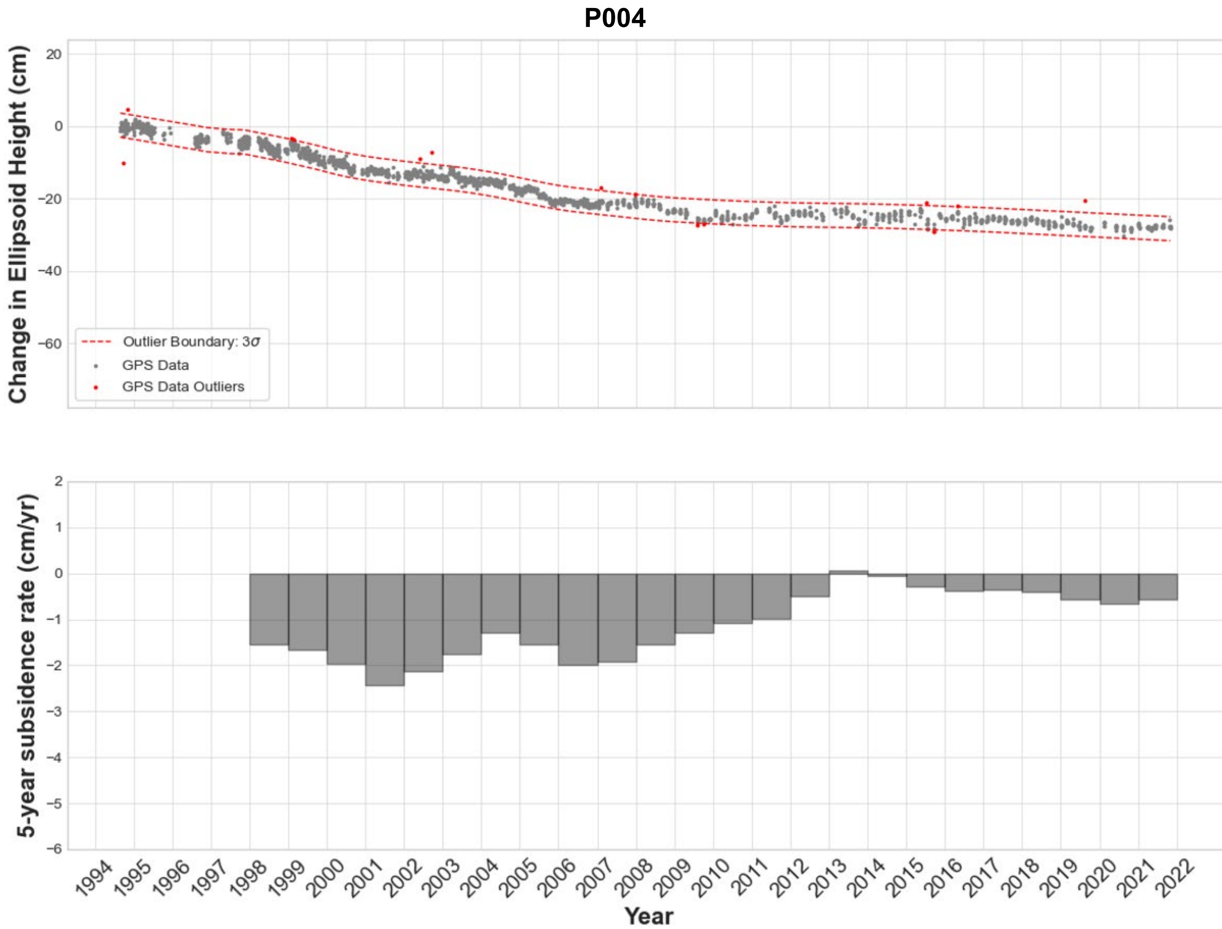


Figure 16: Period of record plot for P004 located in Sugar Land, Texas, 1994 to 2021. This station measured 27.3 cm of subsidence over 27 years and the annual subsidence rate is 0.58 cm per year. The location of P004 is northwest of the intersection between I-69 and Highway 90A. Processed GPS data (gray circles) located inside the outlier boundary (red dashed line) are used when calculating subsidence rates. Processed GPS data identified as outliers (red circles) are not considered by HGSD when calculating subsidence rates and are shown for informational purposes only.

Ms. Truscott asked for additional testimony. There was no additional testimony given.

Ms. Truscott opened it up for questions. There were no questions from the public.

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Appendix A – Exhibits Presented at Public Hearing held on April 28, 2022

Appendix B – Subsidence Monitoring Network and Data

Appendix C – Period of Record Data

A comprehensive table is provided which includes the Map ID (Figure 4 in Appendix B), GPS station name, coordinates, dates of operation, sample count, total vertical displacement over the period of record, change in ellipsoidal height over the period of record, and annual rate of change in ellipsoidal height from 2017 to 2021. A period of record plot is also included for each GPS station.