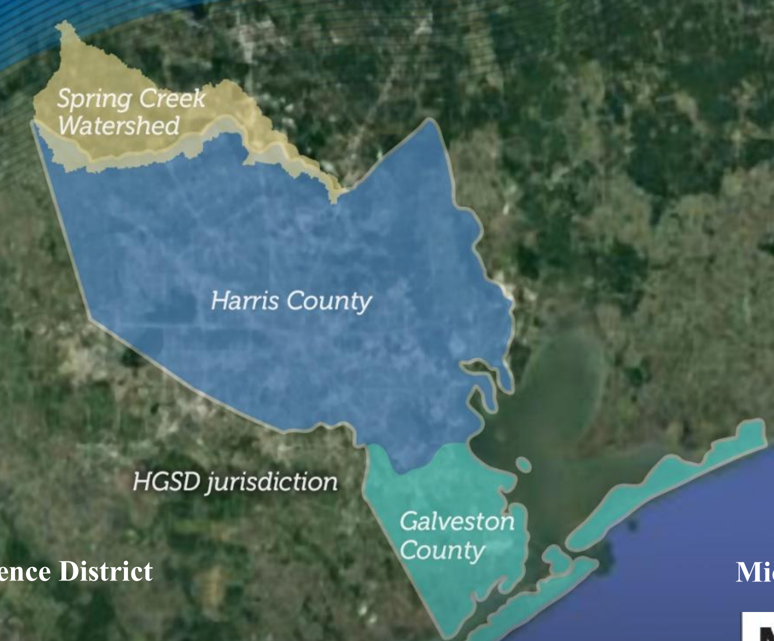
Evaluation of Subsidence Impacts in the Spring Creek Watershed

Data Collection Summary Report



Submitted to:

Harris-Galveston Subsidence District

HARRIS-GALVESTON SUBSIDENCE DISTRICT

STATE OF TEXAS
MANOJ KC
129638
LICENSED PROFESSIONAL ENGINEER
9/10/2025
Expires 12/31/2025

Submitted by:

Michael Baker International

Michael Baker INTERNATIONAL

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Michael Baker International, Inc.

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Under Contract No. PSA 2020-003

with Harris-Galveston Subsidence District

STATE OF TEXAS
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Abbreviations/ Acronyms

1D: One-dimensional
2D: Two-dimensional
AORC: Analysis Of Record for Calibration
BDF: Basin Development Factor
DEM: Digital Elevation Model
elev_ft:Elevation in feet
FEMA:Federal Emergency Management Agency
FFE: Finished Floor Elevation
FIRM: Flood Insurance Rate Map
FORE-SCE: FOREcasting SCEnarios of Land-use Change
GIS: Geographic Information System
H&H: Hydrology and Hydraulics
H-GAC: Houston-Galveston Area Council
HCFCD: Harris County Flood Control District
HEC-HMS: Hydrologic Engineering Center – Hydrologic Modeling System
HGSD:Harris Galveston Subsidence District
HUC: Hydrologic Unit Code
HWM: High-Water Mark
HWM_Elev: Elevation (in feet) of High-Water Mark
LAS: LASer
LULC: Land-Use and Land-Cover
LiDAR: Light Detection and Ranging
MBI: Michael Baker International
MRLC: Multi-Resolution Land Characteristic
MUD 119: Montgomery County Municipal Utility District 119
NFHL: National Flood Hazard Layer
NLCD:National Land Cover Database
NOAA: National Oceanic and Atmospheric Administration
NSI: National Structural Inventory
PDF: Portable Document Format
R: Storage Coefficient
SFHA: Special Flood Hazard Area
SI: Structure Inventory
SJRA: San Jacinto River Authority
SMCMUD: South Montgomery County Municipal Utility District
TNRIS: Texas Natural Resources Information System
TSDN: Technical Supporting Data Notebooks
Tc: Time of Concentration
TxDOT: Texas Department of Transportation
USACE: United States Army Corps of Engineers
USGS: United States Geological Survey
WGRFC: West Gulf River Forecasting Center
WW: Woodlands Water

1.0 Introduction

Michael Baker International (MBI) is evaluating the impacts of future subsidence in the Spring Creek watershed for the Harris Galveston Subsidence District (HGSD). The project aims to quantify flood risk and economic impacts attributable to current and future subsidence in the Spring Creek watershed and to provide insights on subsidence impacts from non-coastal flooding.

As part of Task 2, MBI has performed data collection, interagency coordination, and data review that will be utilized in the next phases of this study. As of the date of this report, MBI has conducted a kickoff meeting, various progress meetings, and workshops attended by representatives at HGSD, Harris County Flood Control District (HCFCD), and the sub-consultant, Seagull PME. MBI is one of the Harris County watershed modeling project consultant with HCFCD and was able to utilize the data from the HCFCD SharePoint as part of the data collection effort, with approval from HCFCD.

The data collection effort is generally classified into the following categories, which are explained in detail in the later sections of this report:

Section 1.0 Introduction

Section 2.0 Geographic, Political Boundaries, Hydrologic/Hydraulic Features, and Roadways

Section 3.0 Topographic Data

Section 4.0 Hydrology and Hydraulics (H&H Models)

Section 5.0 Modeling Support Data

Section 6.0 Existing Structures

Section 7.0 Soil Data

Section 8.0 Rainfall Data

Section 9.0 Utilities

Section 10.0 San Jacinto River Authority

Section 11.0 Investigation of Faulting

Section 12.0 Reference Materials

Section 13.0 Digital Attachments/Uploads

2.0 Geographic, Political Boundaries, Hydrologic/Hydraulic Features, and Roadways

The streamlines **(2a) (2b)**, individual subbasins **(2c) (2d),** and overall watershed boundaries were received from the HCFCD as shown in **Figure 1.** The number in parentheses refers to the data serial number in the Section **13.0.**

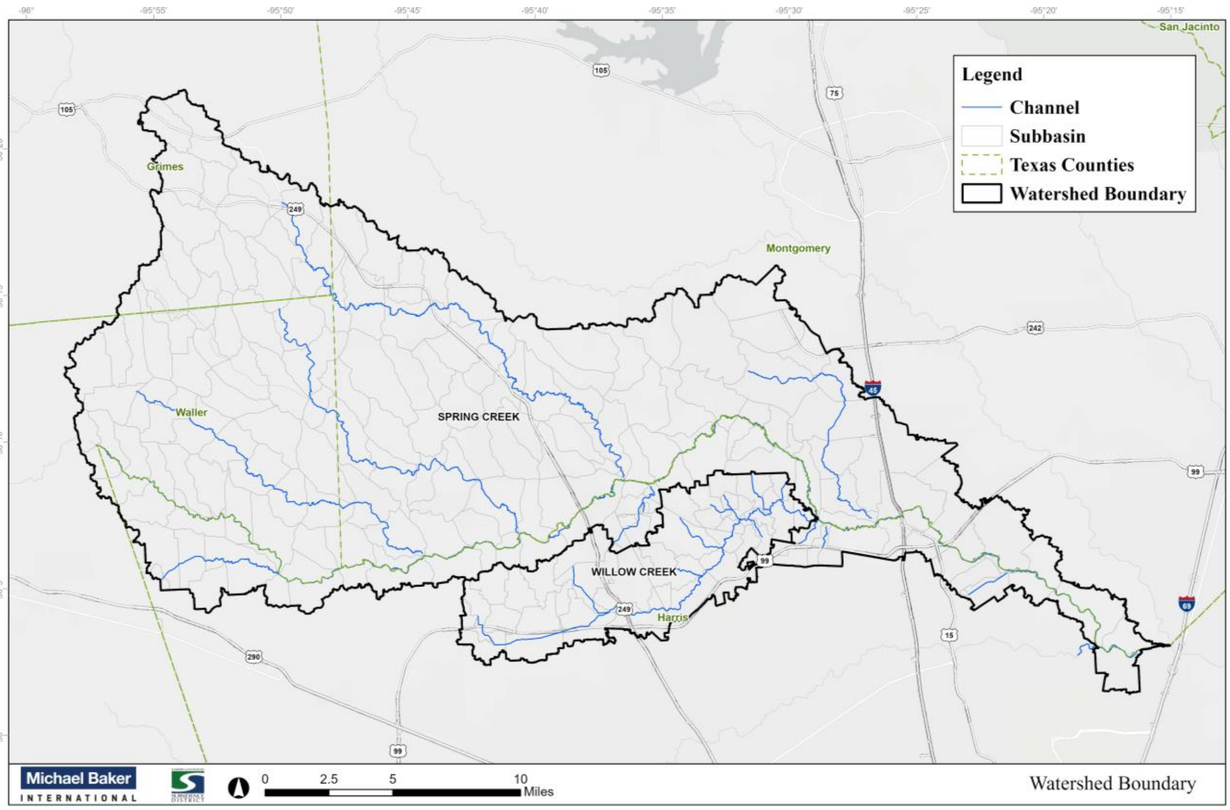

Figure 1 – Streams, Subbasins and Watershed Boundaries

A list of the downloaded data is listed below in **Table 1**:

Table 1 – Geographic and Political Boundaries Data Collection

Dataset	Source	Year
Spring Streamline **(2a)**	HCFCD SharePoint	2024
Willow Streamline **(2b)**	HCFCD SharePoint	2024
Spring Subbasin **(2c)**	HCFCD SharePoint	2024
Willow Subbasins **(2d)**	HCFCD SharePoint	2024
TxDOT City boundaries **(2e)**	https://gis-txdot.opendata.arcgis.com/datasets/09cd5b6811c54857bd3856b5549e34f0_0?geometry=-141.929%2C24.472%2C-58.301%2C37.601	2021

Dataset	Source	Year
Texas County boundaries **(2f)**	https://gis-txdot.opendata.arcgis.com/datasets/8b902883539a416780440ef009b3f80f_0?geometry=-141.891%2C24.531%2C-58.263%2C37.652	2016
Texas Congressional Districts **(2g)**	https://www2.census.gov/geo/tiger/TIGER2010/CD/111/	2010
Texas State Senate Districts **(2h)**	https://gis-txdot.opendata.arcgis.com/datasets/texas-state-senate-districts?geometry=-141.891%2C24.531%2C-58.263%2C37.652	2019
Texas State House Districts **(2i)**	https://gis-txdot.opendata.arcgis.com/datasets/texas-state-house-districts?geometry=-141.891%2C24.531%2C-58.263%2C37.652	2019
TxDOT Urbanized Areas **(2j)**	https://gis-txdot.opendata.arcgis.com/datasets/txdot-urbanized-areas?geometry=-141.940%2C24.425%2C-58.312%2C37.560	2021
TxDOT Districts **(2k)**	https://gis-txdot.opendata.arcgis.com/datasets/txdot-districts?geometry=-141.493%2C24.386%2C-57.865%2C37.526	2021
Texas School Districts **(2l)**	https://www2.census.gov/geo/tiger/TIGER2018/UNSD/	2018
H-GAC Major Lakes and Reservoirs **(2m)**	https://gishub-h-gac.hub.arcgis.com/datasets/hgac-major-lakes-and-reservoirs?geometry=-100.717%2C29.041%2C-90.264%2C30.708	2021
Texas Roadways **(2n)**	https://gis-txdot.opendata.arcgis.com/datasets/008906d83772435bb757cb76c9644e5d/explore?location=30.603625%2C-100.081515%2C5.79	2024
USGS HUC 02 Regions **(2o)**	https://gishub-h-gac.hub.arcgis.com/datasets/usgs-huc-02-regions?geometry=-119.140%2C26.934%2C-77.326%2C33.570	2020
USGS HUC 10 Watersheds **(2p)**	https://gishub-h-gac.hub.arcgis.com/datasets/usgs-huc-10-watersheds?geometry=-105.954%2C28.002%2C-85.047%2C31.342	2020
USGS HUC 12 Sub watersheds **(2q)**	https://gishub-h-gac.hub.arcgis.com/datasets/usgs-huc-12-subwatersheds?geometry=-105.821%2C27.871%2C-84.914%2C31.216	2020
NLCD Landcover and Imperviousness **(2r), (2s), (2t), (2v), (2w), (2x) (2x)**	https://www.mrlc.gov/data	2001, 2011 2016, and 2021

3.0 Topographic Data

- The terrain data for Spring Creek **(3a)** and Willow Creek watersheds **(3b)** was downloaded from the HCFCD SharePoint.
- The HCFCD model terrain data has a raster resolution (grid cell size) of 3' x 3' as well as 9' x 9' with bathymetry data merged into the Light Detection and Ranging (LiDAR) Digital Elevation Model (DEM). However, terrain data with a raster resolution of 3' x 3' was used for this project.
- INTERA Inc. developed the subsidence grid projections for Spring Creek and Willow Creek watersheds in June 2024. This is discussed in more detail in the Technical Memorandum 1: Methodology for Subsidence Grid Development.
- The subsided terrain data will be utilized in the development of subsidence scenarios as part of Task 4.

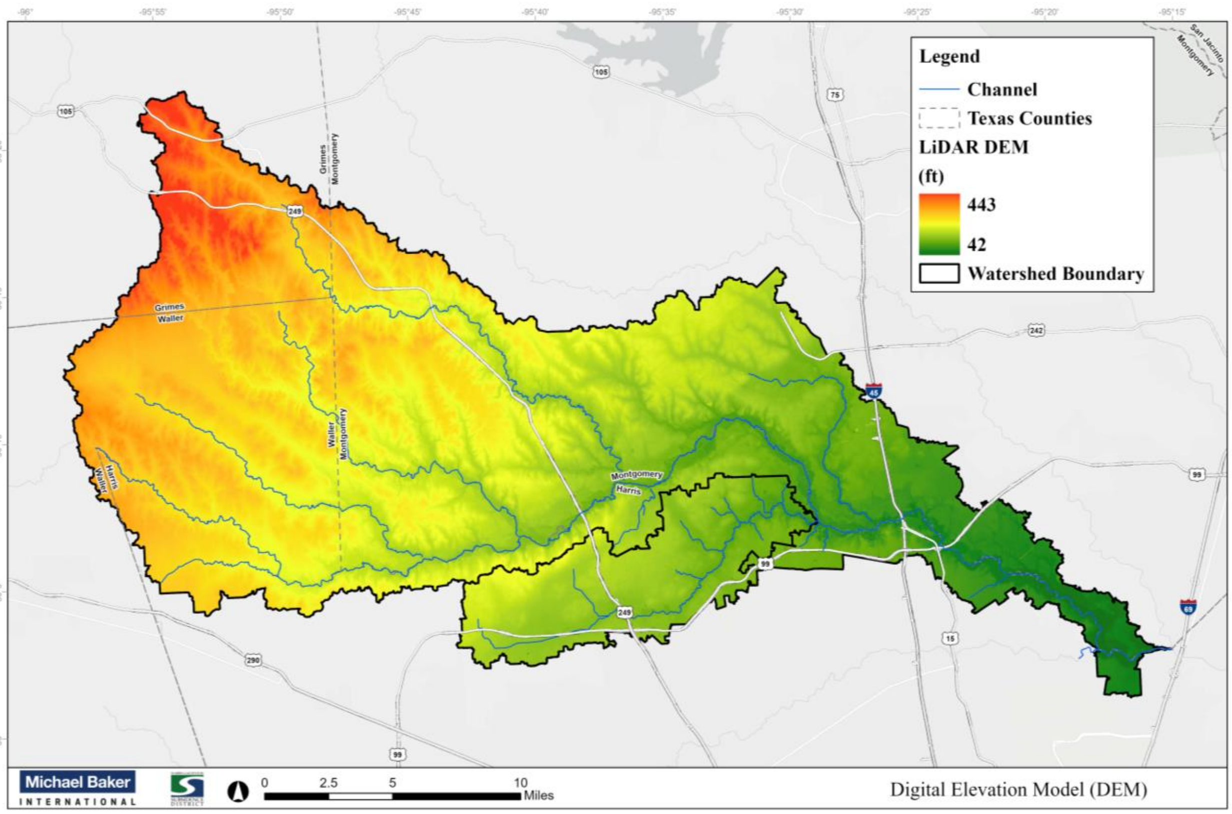

Figure 2 – LiDAR DEM

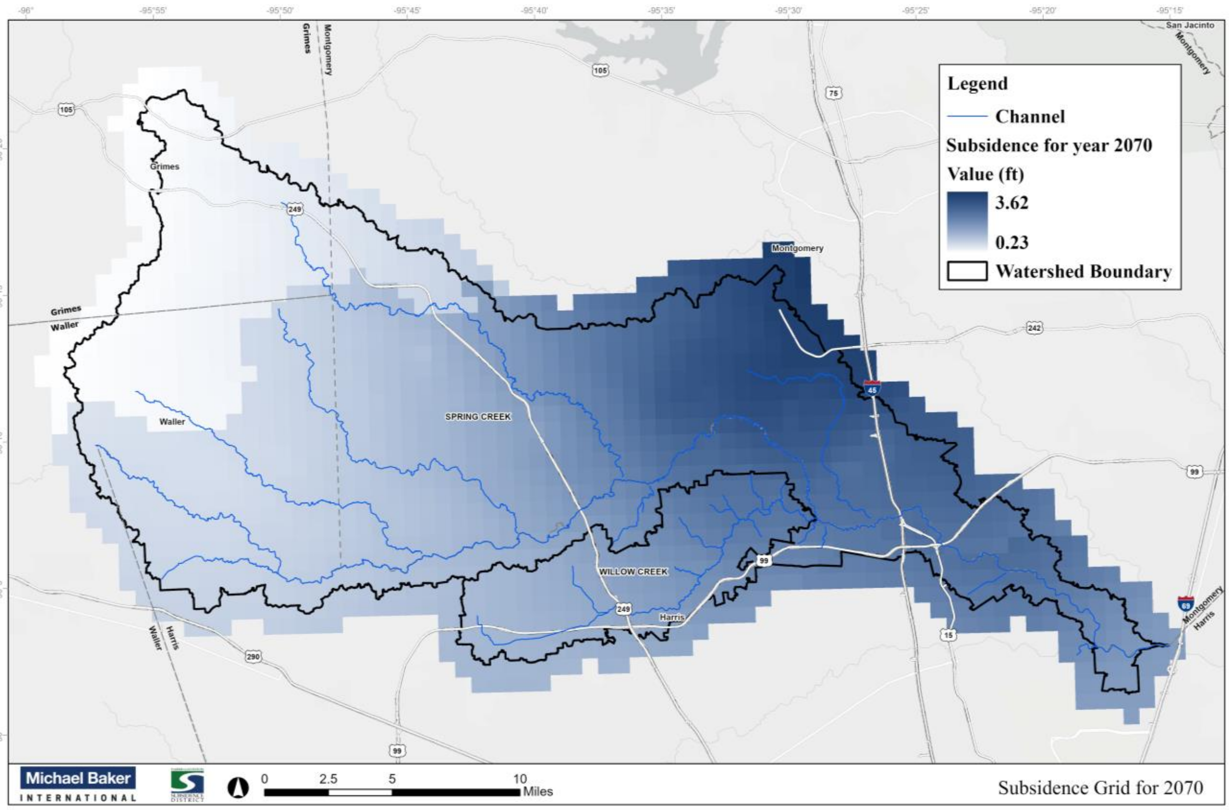

Figure 3 – Subsidence Projection for 2070

3.1 Additional Data

- MBI also received the DEM dataset that contains the raster value for bridge decks alone **(3c)** from HCFCD.
- The DEM is developed from the 2018 LiDAR LAS dataset, where the surface raster shows only the bridge decks.
- The dataset can be utilized for modeling bridges in the hydraulic model.

A list of the downloaded data is shown below (**Table 2**).

Table 2 – Topographic Data Collection

Dataset	Source	Year
Spring Terrain DEM **(3a)**	HCFCD SharePoint	2021
Willow Terrain DEM **(3b)**	HCFCD SharePoint	2021
Bridge Deck DEM **(3c)**	HCFCD SharePoint	2019

4.0 H&H Models

Based on the approval dated May 30, 2024, from HCFCD, MBI downloaded the updated HCFCD H&H model TSDN for Spring Creek and Willow Creek watersheds, which are the latest data for the HCFCD model for these two watersheds during the time this Data Collection Memorandum was written. MBI had used an earlier version of the HCFCD model downloaded dated February 3rd, 2021, which is now being updated with the latest version from 2024.

4.1 Spring Creek Watershed

- The Federal Emergency Management Agency (FEMA) effective (as of June 2025) model **(4a)** was downloaded from HCFCD's Model and Map Management System on January 15th, 2021.
- HCFCD model Interim Submittal 1 dated July 2023 was downloaded from HCFCD's SharePoint on May 30th, 2024.
- The final H&H TSDN **(4b)** was downloaded on May 30th, 2024, from HCFCD SharePoint. The data is further subject to review by HCFCD since it's an ongoing study.

4.2 Willow Creek Watershed

- FEMA effective model **(4c)** was downloaded from the HCFCD Model and Map Management System on January 15th, 2021.
- The HCFCD model submittal dated July 2023 containing the HCFCD model TSDN was downloaded from HCFCD's SharePoint site on May 30th, 2024.
- The final HCFCD model TSDN **(4d)** was downloaded on May 30th, 2024, from HCFCD SharePoint.

An additional 1D – 2D model for the San Jacinto River Basin Drainage Master Plan **(4e)** was collected, this model covers the Spring and Willow Creek watersheds. Any missing data, such as bridges, culverts, etc., in the HCFCD H&H model will be added by extracting the geometrical details of those structures from the effective and San Jacinto 1D- 2D models after careful review. The missing data will be chosen from either model based on the correctness of the data. The list of the downloaded data is shown in **Table 3**.

Table 3 – H&H Models and Data Collection

Dataset	Source	Year
FEMA effective model – Spring Creek **(4a)**	HCFCD's Model and Map Management System (https://www.hcfcd.org/Resources/Interactive-Mapping-Tools/Model-and-Map-Management-M3-System)	2007
Spring Creek final H&H TSDN **(4b)**	HCFCD SharePoint	2024
FEMA effective model – Willow Creek **(4c)**	HCFCD's Model and Map Management System (https://www.hcfcd.org/Resources/Interactive-Mapping-Tools/Model-and-Map-Management-M3-System)	2007
Willow Creek final H&H TSDN **(4d)**	HCFCD SharePoint	2024
San Jacinto River Basin Drainage Master Plan **(4e)**	HCFCD – C17 San Jacinto River Watershed Study (Appendix L) (https://www.hcfcd.org/Activity/Active-Projects/San-Jacinto-River/C-17-San-Jacinto-River-Watershed-Study#Download_Individual_Zip_Archives)	2020

5.0 Modeling Support Data

5.1 Population and Impervious Cover Projection Data

To develop a future development scenario, HGSD provided the population projection data **(5a)** from 2010 to 2070 of the 2013 regulatory plan update on November 4th, 2020. The Geographic Information System (GIS) shapefile covered the entire Harris and Montgomery County, with data divided into resolutions smaller than Census Tracts. This data has been reviewed and clipped to the watershed boundary of Spring Creek and Willow Creek watersheds. The population projection data for Waller and Grimes counties were not readily available from HGSD, which covered about 28% of the watershed. The data availability is shown in **Figure 4**.

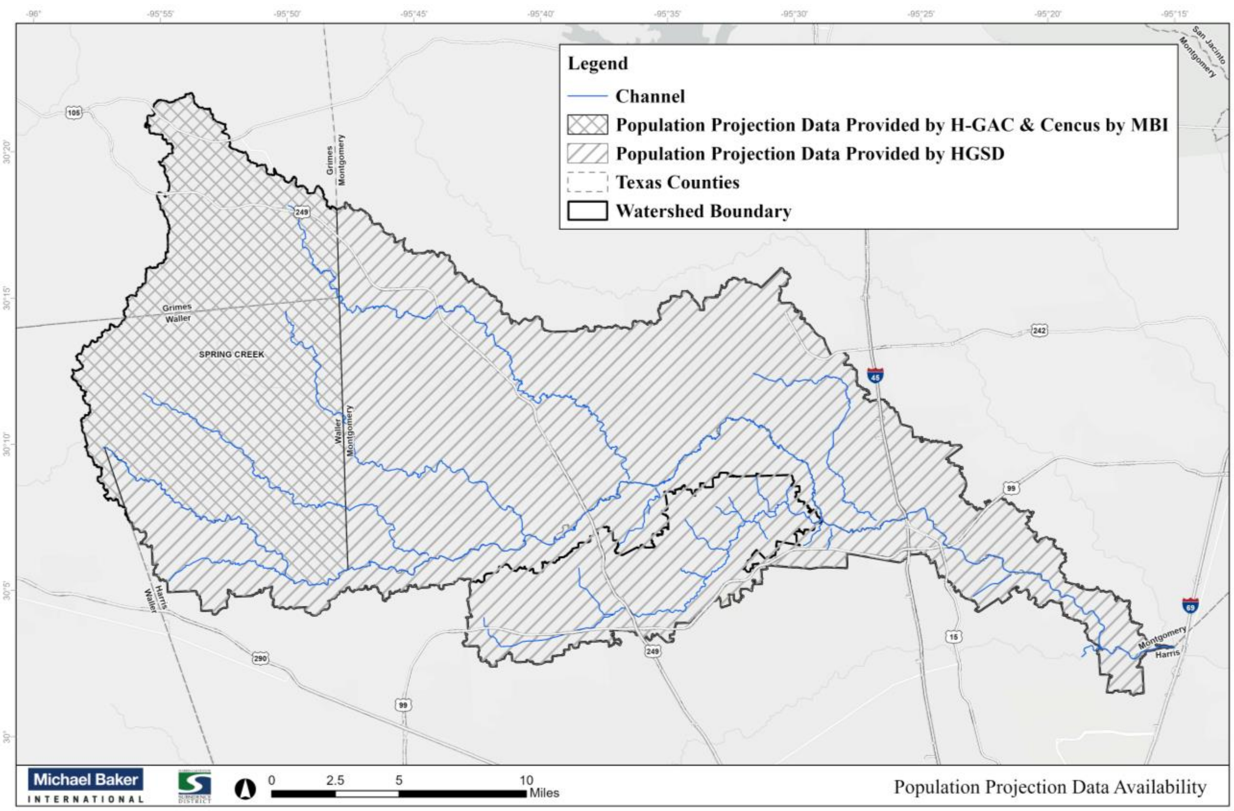

Figure 4 – Population Projection Data Availability

The 2018 Houston-Galveston Area Council (H-GAC) Annual Regional Growth Forecast[1] provides the projection of the population growth of Waller County from 2015 to 2045. The average annual rate of growth from 2015 to 2045 was estimated by averaging the annual growth rate for each five-year interval. The estimated average annual growth rate of 3.1% was adopted to further project the population from the year 2050 to 2070, as given in **Table 4**. The plot of the projected total population for Waller County shows exponential growth, as shown in **Figure 5**. Since the

[1] *https://datalab.h-gac.com/rgf2018/*

population projection is for the entire Waller County, it was required to project the population for each census tract to meet the requirements of the current study. This projection was developed from the 2010 TIGER/Line GIS Shapefiles with the 2010 Census block geography and the 2010 Census population and housing unit count **(5b)**. The 2010 population for each block was projected to 2020 and 2070 using an average growth rate of 3.1%.

Table 4 – Population Projection, Waller County

Year	Population	Annual Growth Rate
2010	43,274	-
2015	46,912	1.6%
2020	53,403	2.6%
2025	57,379	1.4%
2030	65,155	2.6%
2035	72,952	2.3%
2040	99,133	6.3%
2045	124,568	4.7%
Average Annual Growth Rate		**3.1%**
Year	**Projected Population**	
2050	144,970	**3.1%**
2055	168,713	**3.1%**
2060	196,345	**3.1%**
2065	228,502	**3.1%**
2070	265,926	**3.1%**

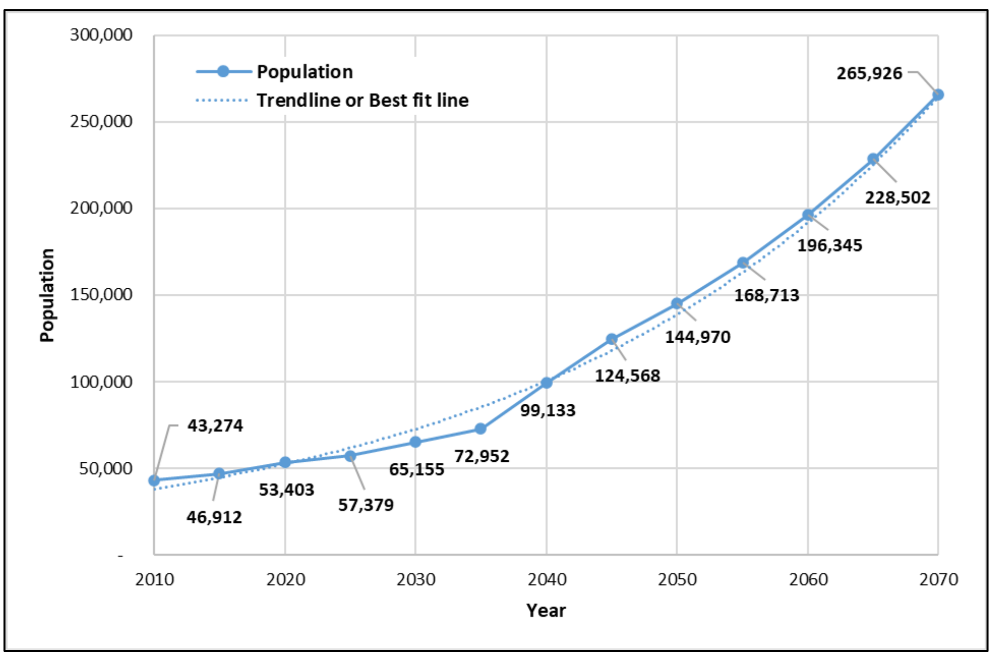

Figure 5 – Plot Population projection, Waller County

The H-GAC population forecast does not have projections for Grimes County. The population projection for 2019 was extracted from the Census Bureau's quick fact sheet[2]. The population data for the years 2010 and 2019 were available for Grimes County. The average annual growth rate of 0.9% was estimated and used to further project the population data from 2020 to 2070, as given in **Table 5**. The plot of the projected total population for Grimes County shows exponential growth, as shown in **Figure 6**. Similar to the Waller County population projection procedure, the 2010 population for each block was projected to 2020 and 2070 using an average growth rate of 0.9%.

Table 5 – Population Projection, Grimes County

Year	Population	Annual Growth Rate
2010	26,581	-
2019	28,880	0.9%
Average Annual Growth Rate		**0.9%**
Year	**Projected Population**	
2020	29,147	**0.9%**
2030	31,962	**0.9%**
2040	35,048	**0.9%**
2050	38,431	**0.9%**
2060	42,142	**0.9%**
2070	46,211	**0.9%**

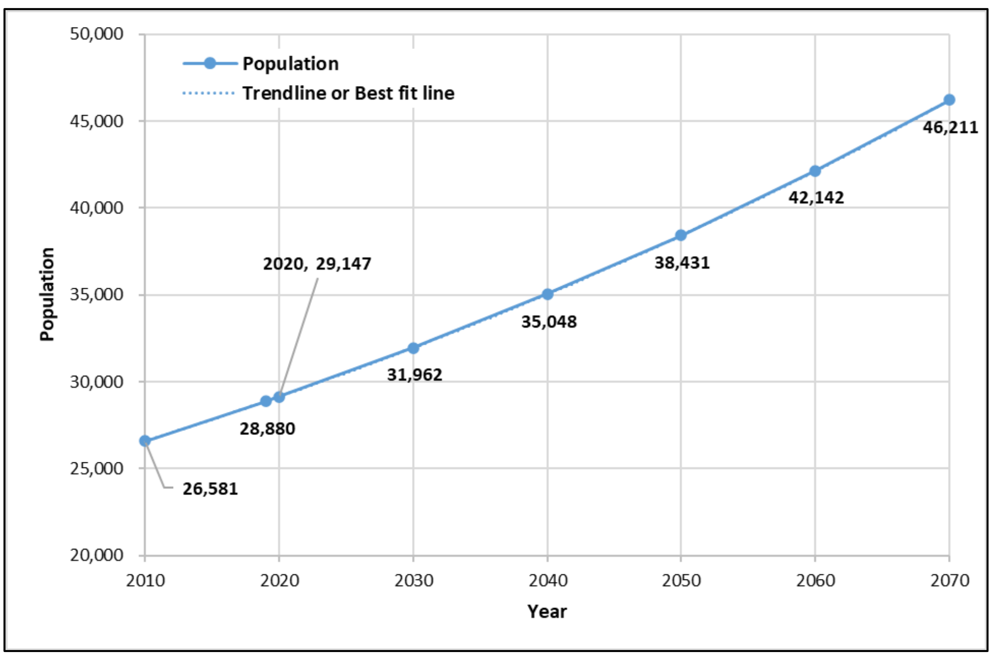

Figure 6 – Plot Population projection, Grimes County

[2] https://www.census.gov/ quickfacts/fact/table/grimescountytexas,US/PST045219

The processed population projection data **(5c)** for the years 2020 and 2070 for the watershed is shown in **Figure 7** and **Figure 8**.

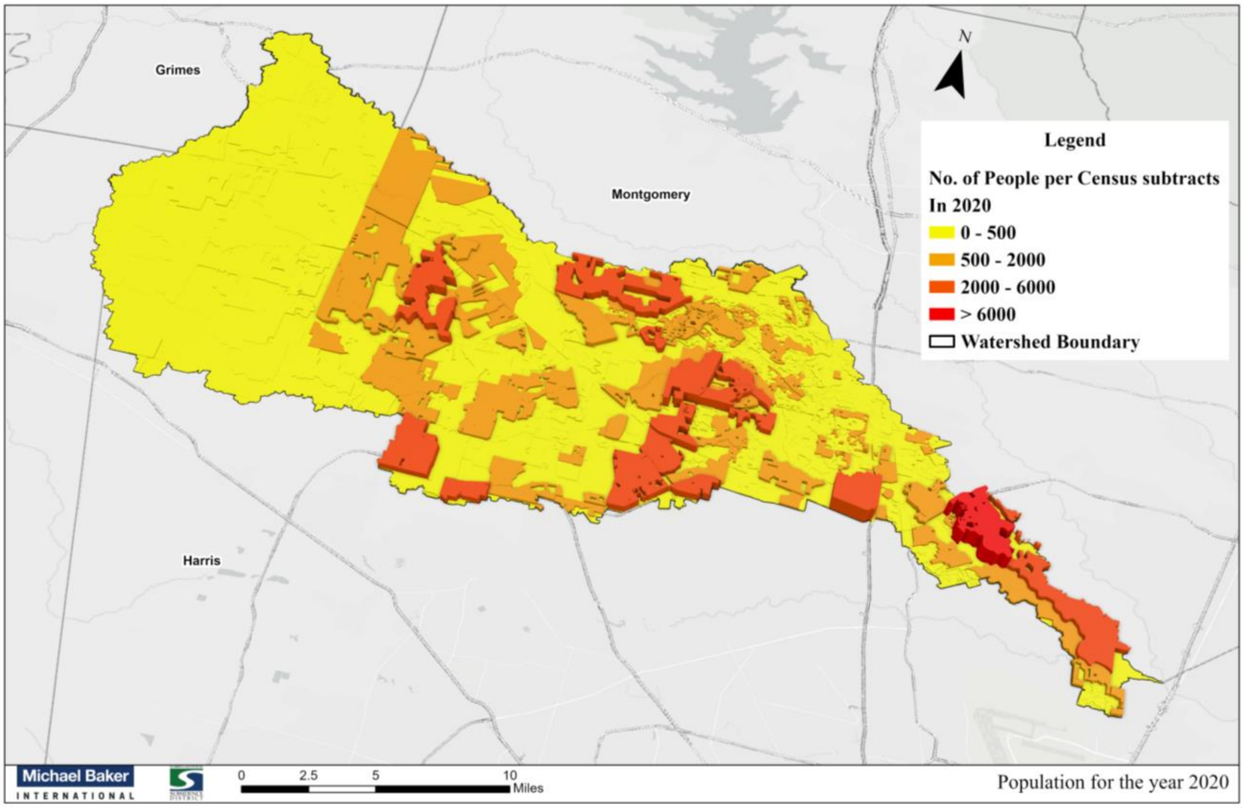

Figure 7 – Population for 2020 represented as the number of people per census subtracts

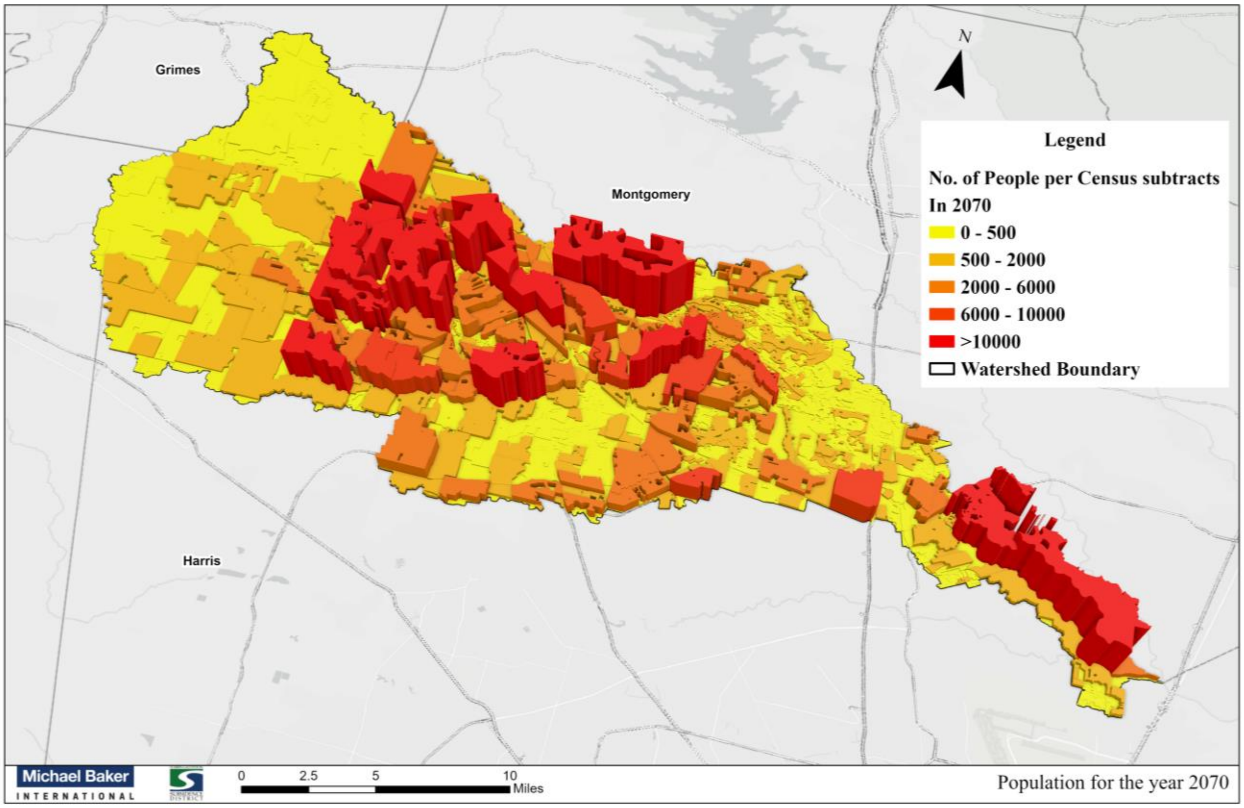

Figure 8 – Population for 2070 represented as the number of people per census subtracts

In the facilitated workshop dated February 3rd, 2021, MBI requested that HGSD and HCFCD provide for previous studies on impervious cover projection in the watershed. HCFCD provided MBI with a link to a study dated February 2019, done by HNTB **(5d)** on projecting the impervious cover of Spring Creek watershed for the year 2021 using 2001 and 2011 Impervious cover data. This data will be utilized along with the population projection data to develop a methodology to estimate the future impervious cover for the year 2070.

5.2 Additional Data Collected

MBI collected data from the National Land Cover Database (NLCD developed by the Multi-Resolution Land Characteristics (MRLC) Consortium:

5.2.1 NLCD Landcover

- NLCD landcover and Impervious data were downloaded for the years 2001, 2011, 2016, and 2021 (**Section 2.0**) with a resolution of 30 meters x 30 meters.
- The data was clipped to the watershed boundary.
- The impervious raster was processed to show an attribute column that distinguishes impervious cover from pervious cover.

- The NLCD data will be utilized to supplement the HNTB data used for impervious cover and BDF projection calculations for the Spring Creek watershed.
- The NLCD data for 2001, 2011, 2016, and 2021 will be used to project the impervious and BDF for the Willow Creek watershed, along with population projections.

5.2.2 United States Geological Survey (USGS) Landcover projection 1992 - 2100

The projection raster from the USGS's FORE-SCE model was downloaded[3]:

- A land-use and land-cover (LULC) projection for the conterminous United States from the year 1992 to 2100 was developed by USGS.
- The raster for the year 2010 **(5e)**, 2020 **(5f)**, 2030 **(5g)**, 2040 **(5h)**, 2050 **(5i)**, 2060 **(5j)** and 2070 **(5k)** was downloaded and clipped to the watershed boundary.
- The raster has a resolution of 250 meters x 250 meters.
- Upon review, the resolution was too coarse to be used for this study.

5.3 FEMA data

5.3.1 FEMA National Flood Hazard Layer

To understand the level of flood risk and type of flooding, the FEMA National Flood Hazard Layer (NFHL) dated February 12th, 2021, a GIS shapefile was downloaded from FEMA[4].

- The NFHL data incorporates all Flood Insurance Rate Map (FIRM) databases published by FEMA.
- The FIRM Database is the digital, geospatial version of the flood hazard information shown in the published paper FIRMs.
- The primary risk classifications used are the 1-percent-annual-chance flood event, the 0.2-percent-annual-chance flood event, and areas of minimal flood risk.
- The political area layer (S_POL_AR.shp) **(5l)** showing the existing population centers were extracted for the watershed boundary that will be utilized while projecting the existing conditions to future conditions in 2070.
- The Special Flood Hazard Area (SFHA) layer (S_FLD_HAZ_AR.shp) **(5m)** was extracted for the watershed boundary. This will be utilized for identifying areas of higher flood risk.
- The SFHA layer will be used to designate areas that are in the floodplain to have limited population growth for the year 2070. Thus, modifying the subbasin parameters accordingly for the future development scenario.

5.3.2 High Water Marks (HWM)

For better model calibration, an effort was made to collect the HWM within the watershed:

[3] https://www.sciencebase.gov/catalog/item/5b96c2f9e4b0702d0e826f6d
[4] https://www.fema.gov/flood-maps/national-flood-hazard-layer

- HWM GIS shapefile collected as part of the HCFCD model project was clipped to the watershed boundary **(5n)**. Attribute table "HWM_Elev" stores the HWM elevation for the points in feet.
- HWMs were also collected from the USGS flood event viewer **(5o)** and clipped to the watershed. Attribute table "elev_ft" stores the HWM elevation for the points in feet.

The HWMs for the watershed are shown in **Figure 9**.

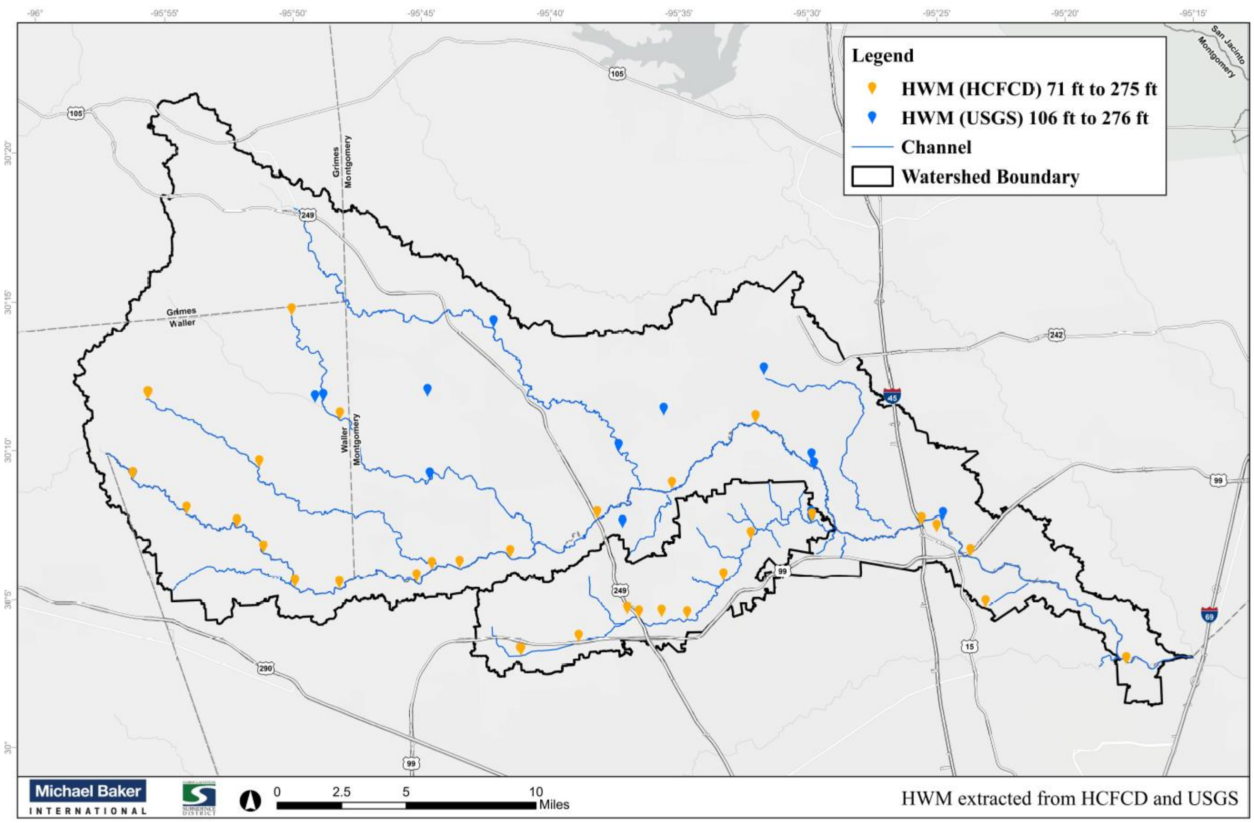

Figure 9 – HWM extracted from HCFCD and USGS

- HWMs for Harvey were also collected from the USGS and HCFCD (**Figure 10**) and clipped to the watershed. Attribute table "elev_ft" stores the HWM elevation for the points in feet.

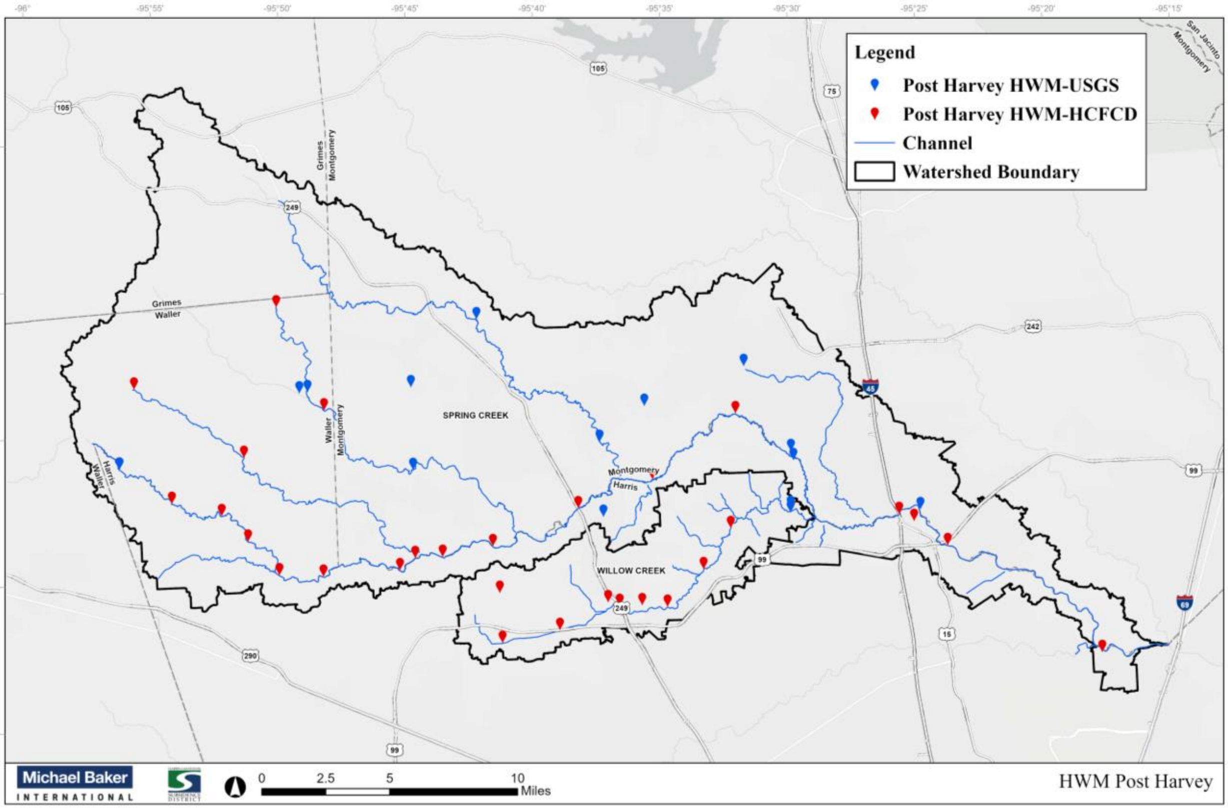

Figure 10 – HWM for Hurricane Harvey

5.3.3 Historical Flooding Data

The historical flooding data was collected for the watershed (**Table 6**):

- FEMA Claims dated December 2017 (AllClaimsDec2017.shp) **(5q)** were collected and clipped to the watershed.
- Repetitive loss GIS shapefile **(5r)** collected as part of the HCFCD project was clipped to the watershed.

The data will be utilized for economic impact estimation. The collected historical flooding data will be utilized in the future phase of the project. The list of the modeling support data collected is shown in **Table 6**.

Table 6 – Modeling Support Data Collection

Dataset	Source	Year
Montgomery and Harris County Population Projection data **(5a)**	HGSD	2020
GIS Shapefiles with the 2010 Census block geography and the 2010 Census population and housing unit count (**5b**)	https://www2.census.gov/geo/tiger/TIGER2010BLKPOPHU/tabblock2010_48_pophu.zip	2011
HNTB study Report **(5d)**	HCFCD	2019
USGS Landcover projection raster 2010 **(5e)**, 2020 **(5f)**, 2030 **(5g)**, 2040 **(5h)**, 2050 **(5i)**, 2060 **(5j)** and 2070 **(5k)**	https://www.sciencebase.gov/catalog/item/5b96c2f9e4b0702d0e826f6d	2018
FEMA political area layer **(5l)**	https://www.fema.gov/flood-maps/national-flood-hazard-layer	2021
FEMA SFHA layer **(5m)**	https://www.fema.gov/flood-maps/national-flood-hazard-layer	2021
HWM **(5n)**	HCFCD SharePoint	2019
HWM **(5o)**	USGS Flood event viewer https://stn.wim.usgs.gov/FEV/	2021
HWM **(5p)**	HCFCD	2017
FEMA All Claims **(5q)**	HCFCD Project	2017
FEMA Repetitive Losses **(5r)**	HCFCD Project	2017

6.0 Existing Structures

To account for economic loss due to structural flooding and structural damage, the Structural Inventory (SI) dataset and building footprints were collected (**Table 7**):

6.1 SI and Building Footprints

6.1.1 Structural Inventory Dataset

Structural Inventory - HCFCD

- MBI requested and received the Structure Inventory (SI) dataset for Harris County from HCFCD that has the Finished Floor Elevation (FFE) for each insurable structure in the watershed **(6a)**.
- The SI dataset was clipped to the watershed boundary.

National Structure Inventory - USACE

- National Structure Inventory[5] (NSI) Data was downloaded from the US Army Corps of Engineers. The NSI data, which is dated 2022, provides a base national dataset of structure points and characteristics **(6c)**.

6.1.2 Building Footprints

2018 LiDAR dataset

- The building footprint data developed from the 2018 LiDAR dataset by H-GAC, Texas Natural Resources Information System (TNRIS), and USGS was downloaded from the H-GAC Regional Data Hub **(c).**
  The data was clipped to the watershed boundary.

Building footprints for all 50 US states

- A dataset that has computer-generated building footprints for all 50 US states was downloaded from Microsoft GitHub[6] **(6d)**.
- The data was clipped to the watershed boundary.

6.1.3 Data review

- The HCFCD SI Dataset from HCFCD already has the FFE. Therefore, this data will be used for analyses wherever available.

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[5] https://nsi.sec.usace.army.mil/downloads/
[6] https://github.com/microsoft/USBuildingFootprints

- The dataset from Microsoft GitHub will be used for analysis in areas that are not covered by the HCFCD SI Dataset in the watershed, especially for Montgomery, Grimes, and Waller counties.

6.1.4 Data Processing

- The building footprints polygons will be processed to have a ground elevation, extracted from the LiDAR, for each footprint.
- A combined footprint will be developed from the HCFCD and building footprints datasets.

6.2 County Appraisal District Data

The tax parcels GIS shapefile delineates the area according to land ownership and it is important information in determining the type of development that is expected in the neighborhood.

- The tax parcels for Harris **(6e)**, Montgomery **(6f)**, Waller **(6g),** and Grimes County **(6h)** were downloaded from TNRIS[7].
- The data was clipped to the watershed boundary.
- The data will be used along with the population projections to estimate the future impervious cover and BDF for the watershed.
- The data has the building and land value for each parcel. This information will be spatially joined with the building footprints for economic loss analysis.

6.3 Critical Infrastructure

Critical infrastructure is vital to flood response activities or critical to the health and safety of the public before, during, and after a flood. These were downloaded from the Texas General Land Office website (**6i**). The facilities that are vital before, during, and after a flood are hospitals, emergency operations centers, electric substations, police stations, fire stations, nursing homes, schools, vehicle and equipment storage facilities, and shelters. Those that, if flooded, would make the flood problem and its impacts much worse are hazardous materials facilities, power generation facilities, water utilities, and wastewater treatment plants. The list of existing structures data collected is shown in **Table 7**.

[7] *https://data.tnris.org/collection/2679b514-bb7b-409f-97f3-ee3879f34448*

Table 7 – Existing Structures Data Collection

Dataset	Source	Year
Harris County SI Dataset **(6a)**	HCFCD	2020
Building Footprint **(6b)**	H-GAC Regional Data Hub https://gishub-h-gac.hub.arcgis.com/datasets/lidar-building-footprints-2018-1	2020
NSI Data (**6c**)	https://nsi.sec.usace.army.mil/downloads/	2022
Building Footprint **(6d)**	Microsoft GitHub https://github.com/microsoft/USBuildingFootprints	2021
Tax parcels for Harris **(6e)**, Montgomery **(6f)**, Waller **(6g)** and Grimes County **(6h)**	TNRIS	2019
Critical Facilities **(6i)**	The Texas General Land Office https://services9.arcgis.com/FF3qnCUixr5w9JQi/arcgis/rest/services/Assets_and_Facilities2_WFL1/FeatureServer	2021

7.0 Soil Data

The soil map **(7a)** for the watershed was downloaded from the USGS web soil survey website[8] using the area of interest as the watershed. The soil map was processed to include the hydrologic soil groups, as shown in **Figure 11** and the soil type as shown in **Figure 12**.

The Spring Creek watershed has sandy soil with higher conductivity than adjacent watersheds. While subsidence may not change infiltration rates, future development and impervious cover may have an impact on infiltration rates, and consequently, change runoff characteristics in areas subject to future development.

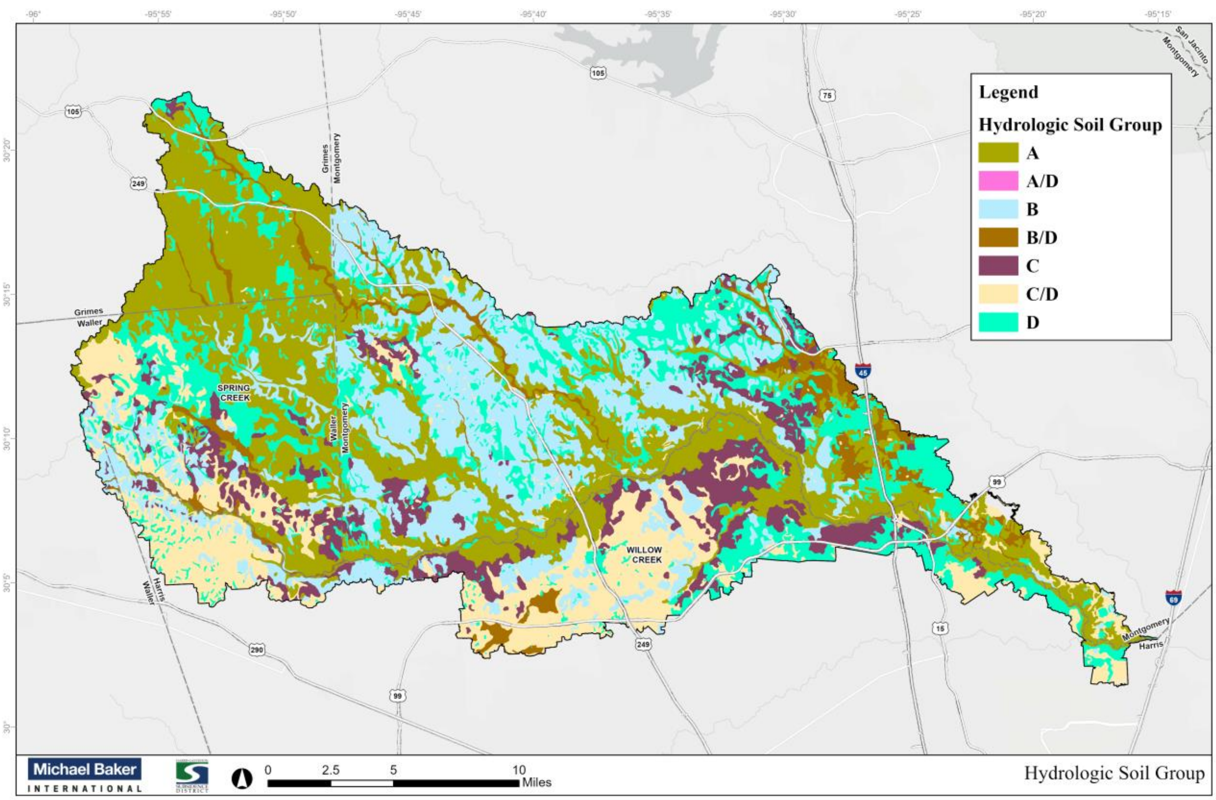

Figure 11 – Soil Map (Hydrologic Soil Group)

[8] https://esri.maps.arcgis.com/apps/View/index.html?appid=cdc49bd63ea54dd2977f3f2853e07fff#!

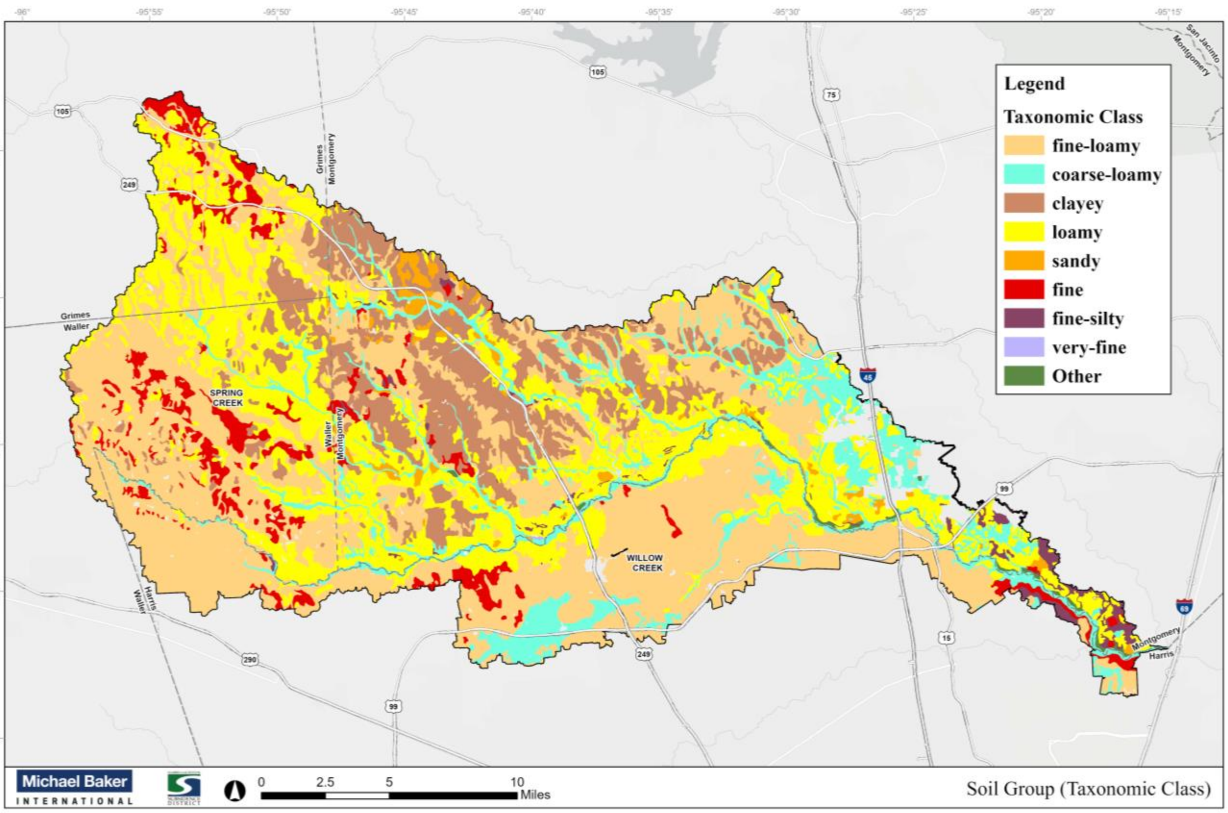

Figure 12 – Soil Map (Taxonomic Class)

8.0 Rainfall Data

8.1 Rainfall Data from NOAA ATLAS 14

The updated Atlas 14 rainfall data was collected from the HCFCD document on Rainfall Depths and Intensities in Harris County dated 03/21/2019 **(8a)**. Spring and Willow Creek watersheds lie in the hydrologic Region 1 of Harris County, as shown in **Figure 13,** and therefore, the rainfall data as shown in **Figure 14** will be used for the H&H analysis. In the HCFCD model, Region 1 rainfall depths were applied for areas in the watershed that fall outside Harris County limits, including Waller, Grimes, and Montgomery Counties.

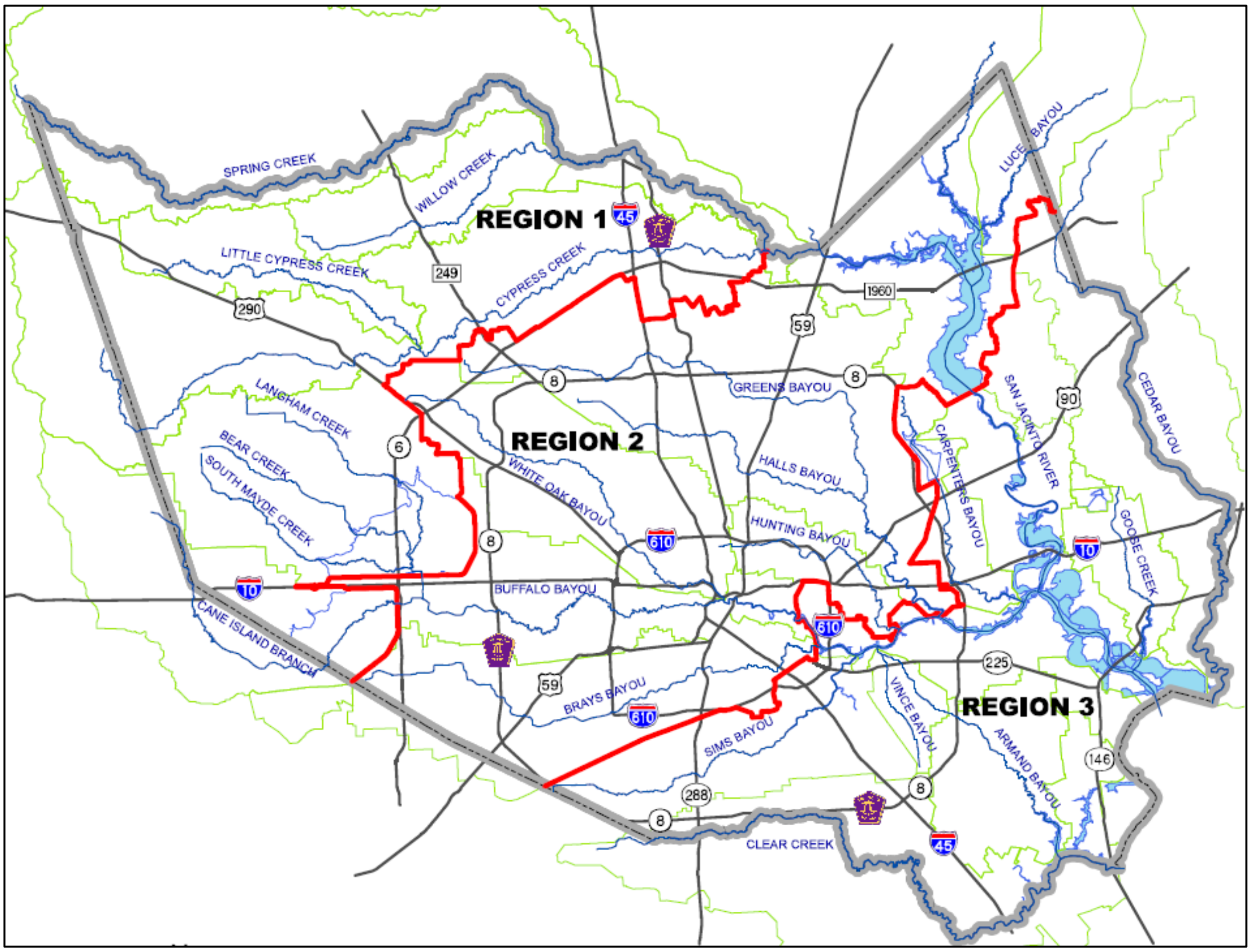

Figure 13 – Rainfall Regions in Harris County

Exhibit 1: Harris County Hydrologic Region No. 1

Annual Exceedance Probability Rainfall Data for Harris County (Partial Duration)

Duration	50% AEP	20%AEP	10% AEP	4% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	200-Year	500-Year	1000-Year
5-min	0.57	0.70	0.81	0.96	1.07	1.19	1.31	1.49	1.63
10-min	0.90	1.11	1.29	1.53	1.71	1.90	2.09	2.34	2.54
15-min	1.14	1.40	1.62	1.91	2.13	2.36	2.60	2.95	3.22
30-min	1.63	1.99	2.29	2.69	2.98	3.29	3.64	4.17	4.61
60-min	2.16	2.66	3.07	3.64	4.06	4.51	5.05	5.87	6.58
2-hr	2.69	3.40	4.03	4.94	5.67	6.49	7.49	9.04	10.40
3-hr	3.01	3.86	4.66	5.85	6.84	7.99	9.38	11.50	13.40
6-hr	3.58	4.69	5.79	7.47	8.94	10.70	12.70	15.90	18.60
12-hr	4.18	5.56	6.95	9.13	11.10	13.40	16.10	20.10	23.60
24-hr	4.83	6.50	8.22	10.90	13.40	16.30	19.50	24.20	28.10
2-day	5.58	7.59	9.67	13.00	16.10	19.50	23.00	27.70	31.40
3-day	6.08	8.28	10.50	14.10	17.40	21.10	24.60	29.30	32.80
4-day	6.45	8.74	11.10	14.70	18.00	21.70	25.30	30.00	33.50
7-day	7.27	9.65	12.00	15.70	19.10	22.70	26.30	31.00	34.60
10-day	7.95	10.40	12.80	16.50	19.90	23.50	27.00	31.80	35.40
20-day	10.10	12.90	15.40	19.10	22.30	25.60	29.00	33.70	37.40
30-day	11.80	15.00	17.60	21.40	24.30	27.40	30.70	35.40	39.00
45-day	14.40	18.00	20.90	24.80	27.80	30.80	33.90	38.20	41.40
60-day	16.80	20.60	23.80	27.90	31.10	34.10	37.00	40.80	43.60

Intensity-Duration-Frequency Data for Harris County (Partial Duration)

Duration (minutes)	50% AEP	20%AEP	10% AEP	4% AEP	2% AEP	1% AEP	0.5% AEP	0.2% AEP	0.1% AEP
	2-Year	5-Year	10-Year	25-Year	50-Year	100-Year	200-Year	500-Year	1000-Year
5	6.82	8.40	9.72	11.51	12.84	14.28	15.72	17.88	19.56
10	5.41	6.66	7.74	9.18	10.26	11.40	12.54	14.04	15.24
15	4.56	5.60	6.48	7.64	8.52	9.44	10.40	11.80	12.88
30	3.26	3.98	4.58	5.38	5.96	6.58	7.28	8.34	9.22
60	2.16	2.66	3.07	3.64	4.06	4.51	5.05	5.87	6.58
120	1.35	1.70	2.02	2.47	2.84	3.25	3.75	4.52	5.20
180	1.00	1.29	1.55	1.95	2.28	2.66	3.13	3.83	4.47
360	0.60	0.78	0.97	1.25	1.49	1.78	2.12	2.65	3.10
720	0.35	0.46	0.58	0.76	0.93	1.12	1.34	1.68	1.97
1440	0.20	0.27	0.34	0.45	0.56	0.68	0.81	1.01	1.17
2880	0.12	0.16	0.20	0.27	0.34	0.41	0.48	0.58	0.65
4320	0.08	0.12	0.15	0.20	0.24	0.29	0.34	0.41	0.46
5760	0.07	0.09	0.12	0.15	0.19	0.23	0.26	0.31	0.35
10080	0.04	0.06	0.07	0.09	0.11	0.14	0.16	0.18	0.21
14400	0.03	0.04	0.05	0.07	0.08	0.10	0.11	0.13	0.15
28800	0.02	0.03	0.03	0.04	0.05	0.05	0.06	0.07	0.08
43200	0.02	0.02	0.02	0.03	0.03	0.04	0.04	0.05	0.05
64800	0.01	0.02	0.02	0.02	0.03	0.03	0.03	0.04	0.04
86400	0.01	0.01	0.02	0.02	0.02	0.02	0.03	0.03	0.03

Figure 14 – Rainfall Data

8.2 Rainfall Data from NOAA AORC

The Analysis of Record for Calibration (AORC) dataset is a relatively new gridded dataset of near-surface weather conditions produced by the Office of Water Prediction (OWP) of the National Weather Service (NWS) of the National Oceanic and Atmospheric Administration (NOAA). It covers the continental United States and has been publicly available to download from 1979 to the present. AORC gridded dataset consists of eight variables, including hourly total precipitation, temperature, specific humidity, terrain-level pressure, downward longwave and shortwave radiation, and west-east and south-north wind components. There are two resolutions of the AORC dataset (1-kilometer and 4-kilometer in AORC version 1.1), out of which only the 4-kilometer version is available publicly for precipitation and temperature variables. The important characteristic of AORC data is that it was constructed from over a dozen individual sources using the best available input dataset for each of the constituent weather conditions variables at any time or location.

The precipitation and temperature AORC dataset is publicly available for the West Gulf River Forecasting Center (WGRFC). Since the Spring Creek watershed falls in the WGRFC region (**8b**), the precipitation dataset for the watershed was downloaded from August 2017 to September 2017 from the NWS website. Hurricane Harvey continued to produce record-breaking rainfall from 25-29 August 2017, causing significant damaging winds and flooding to South Texas, and causing catastrophic, historical, devastating, and deadly flooding over Southeast Texas. The 4-kilometer gridded precipitation data is available as a 1-hour accumulation. This rainfall data will be used for calibration of the Harvey event for pluvial rainfall analysis.

9.0 Utilities

Utilities include water supply, storm sewer, and sanitary sewers. The dataset of utilities for the entire watershed was not available. HGSD contacted various county Municipal Utility Districts (MUDs) and local agencies. Utility data was provided to HGSD by representatives of the following agencies:

(i) Woodlands Water (WW)– GIS Shapefiles **(9a)**
(ii) South Montgomery County Municipal Utility District (SMCMUD) – GIS Shapefile **(9b)**
(iii)Montgomery County Municipal Utility District 119 (MUD 119) – PDFs **(9c)**

These data were not available publicly. GIS data for WW and SMCMUD has information on the material, diameter, upstream and downstream flowline elevations, and length. This will be used for evaluating the economic loss of damaged utilities due to subsidence. GIS data was not available for MUD-119; instead, PDF files of pipeline location and sizes, overall utility with manholes, sewer lines, inlets, and boundary, and some AutoCAD drawings of inspections were received. These drawings will be used to the best to find the economic loss to damaged utilities in MUD 119. The list of the downloaded data is shown below.

Table 8 – Utilities Data Collection

Dataset	Source	Year
WW Utilities Shapefile **(9a)**	Woodlands Water	N/A
SMCMUD Utilities Shapefile **(9b)**	SMCMUD	N/A
MUD 119 Utilities Shapefile **(9c)**	MUD 119	N/A

10.0 San Jacinto River Authority

The San Jacinto River Authority (SJRA) is a public entity created by the Texas Legislature whose mission is to develop, conserve, and protect the water resources of the San Jacinto River basin. SJRA provides treated water to Montgomery, Waller, and Grimes County, and it excludes Harris County. The shapefile delineating the area supplied by SJRA treated surface water in Montgomery County was downloaded[9]. The GIS shapefile **(10a)** was used to delineate the SJRA serviced area in the watershed, as shown in **Figure 15**. It is to be noted that not all areas delineated as SJRA serviced areas receive surface water. This area was considered while projecting the subsidence terrain in the watershed by INTERA Inc.

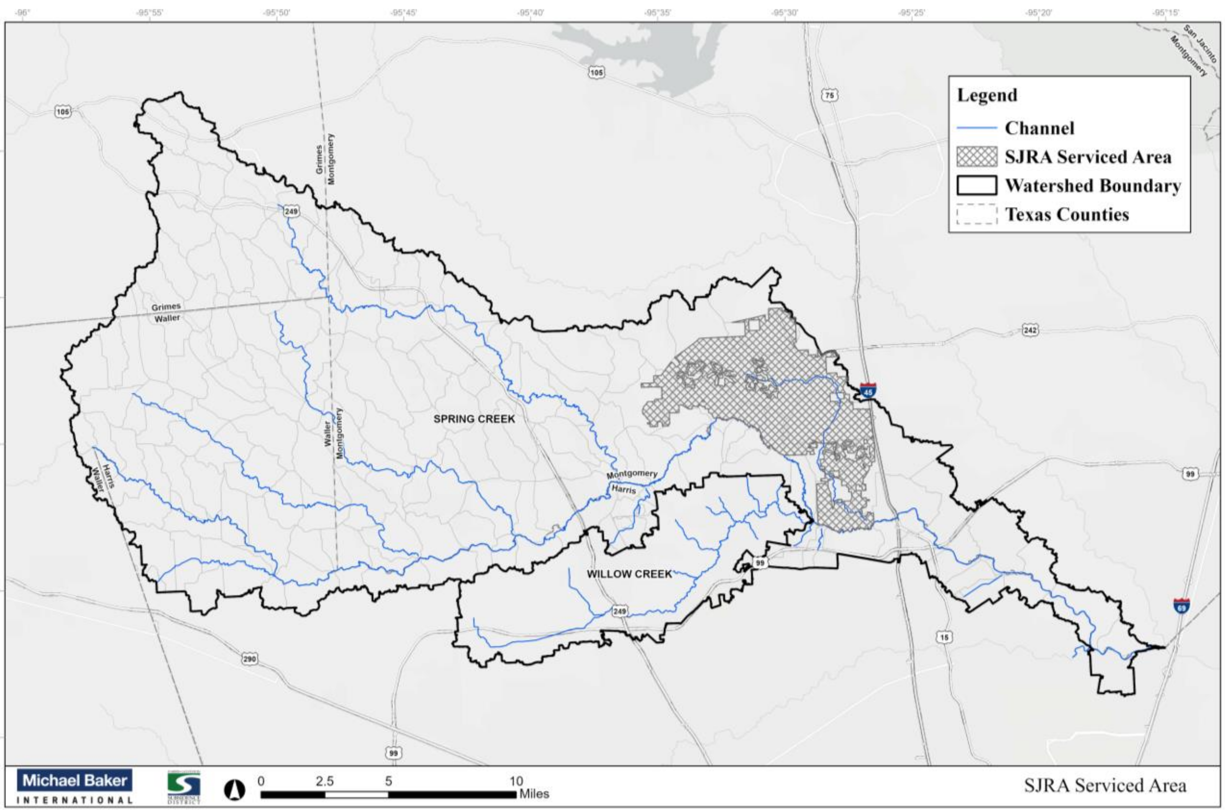

Figure 15 – SJRA Serviced Area

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[9]*https://www.arcgis.com/home/webmap/viewer.html?url=https://services2.arcgis.com/w2TRse9XgbPXdXc6/ArcGIS/rest/services/ParticipantsPV_AGOL/FeatureServer&source=sd*

11.0 Investigation of Faulting

Dr. Shuhab Khan, with SK Geosciences, is a sub-consultant to Michael Baker for this study. He conducted a study to identify the faults present within the watershed using analysis of LiDAR data in the watershed. Dr. Khan's report can be found in **Appendix A1**. **Figure 16** below, extracted from the report, shows the locations of faults from his analysis. A larger-scale figure that references all fault scarps researched with each system identified on the map using a different color is enclosed as **Exhibit A2**. Two systems of faults extending from southwest to northeast can be seen in the results. The locations of the faults are already known. No new fault scarp(s) in this watershed were detected. Locations of the subsurface salt domes are also shown.

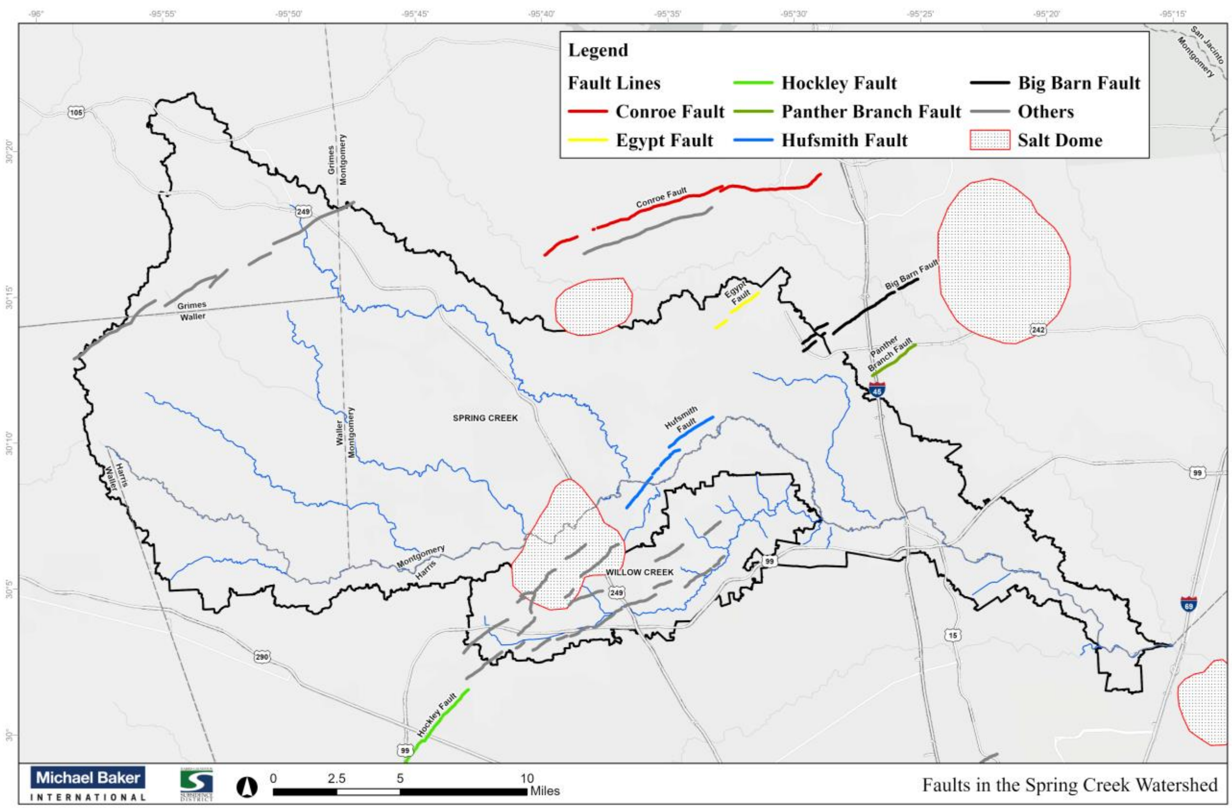

Figure 16 – Faults in the Spring Creek Watershed

12.0 Reference Materials

Reference materials are various sources that provide background information or quick facts on any given topic. To understand current or historical events, conditions, or practices, manuals, study reports, and research journals about subsidence were collected and documented. These reference materials will be used in the course of the study as required. Some of the references downloaded to date are listed in **Table 9**.

Table 9 – Reference Materials Collection

Reference Material	Source	Date Modified/ Published
Harris County Flood Control District - Hydrology and Hydraulics Manual 2009 **(12a)**	https://www.hcfcd.org/Resources/Technical-Manuals/Hydrology-and-Hydraulics-Guidance-Manual?folderId=16301&view=gridview&pageSize=10	Nov 2020
Land Subsidence Effects on Bridges in the World **(12b)**	http://ibc.aut.ac.ir/wp-content/uploads/2019/12/DD101-Land-Subsidence-Effects-on-Bridges-in-the-World.pdf	Dec 2019
Land subsidence in Houston correlated with flooding from Hurricane Harvey **(12b)**	https://doi.org/10.1016/j.rse.2019.03.022	May 2019
Present-day land subsidence rates, surface faulting hazard and risk in Mexico City with 2014–2020 Sentinel-1 IW InSAR **(12b)**	https://doi.org/10.1016/j.rse.2020.112161	Feb 2021
Framework for economic cost assessment of land subsidence **(12b)**	https://doi.org/10.1007/s11069-021-04520-3	Feb 2021

13.0 Digital Attachments/Uploads

Ref. No.	Filename	Description	Upload
2	**Geographic/Political Boundaries, Hydrologic/Hydraulic Features and Roadways**		
2a.	Spring_Streamline.shp	Spring Creek Stream Centerline	☒
2b.	Willow_Streamline.shp	Willow Creek Stream Centerline	☒
2c.	Spring_Subbasin.shp	Spring Creek Subbasins	☒
2d.	Willow_Subbasins.shp	Willow Creek Subbasins	☒
2e.	Texas_City_Boundary.shp	Boundary of Texas Cities	☒
2f.	Texas_County.shp	County Boundary	☒
2g.	Texas Congressional District.shp	Texas Congressional District boundary	☒
2h.	Texas_State_Senate_Districts.shp	Texas State Senate Districts boundary	☒
2i.	Texas_State_House_District.shp	Texas State House District boundary	☒
2j.	TxDOT_Urbanized_Area.shp	Urbanized Area boundary in the watershed	☒
2k.	TxDOT_Districts.shp	District boundaries	☒
2l.	Texas School Districts.shp	School Districts Boundary	☒
2m.	H-GAC_Major_Lakes_and_Reservoirs.shp	Major Lakes and Reservoirs	☒
2n.	TxDOT_Roadways.shp	Roadways	
2o.	USGS_HUC_02_Regions.shp	HUC 02 Regions	☒
2p.	USGS_HUC_10_Watersheds.shp	HUC 10 Watersheds	☒
2q.	USGS_HUC_12_Subwatersheds.shp	HUC 12 Subwatersheds	☒
2r.	NLCD_2001_Impervious.shp	2001 Impervious cover from NLCD	☒

Ref. No.	Filename	Description	Upload
2s.	NLCD_2011_Impervious.shp	2011 Impervious cover from NLCD	☒
2t.	NLCD_2016_Impervious.shp	2016 Impervious cover from NLCD	☒
2u.	NLCD_2021_Impervious.shp	2021 Impervious cover from NLCD	☒
2v.	NLCD_2001_Landcover.tif	2001 landcover from NLCD	☒
2w.	NLCD_2011_Landcover.tif	2011 landcover from NLCD	☒
2x.	NLCD_2016_Landcover.tif	2016 landcover from NLCD	☒
2y.	NLCD_2021_Landcover.tif	2021 landcover from NLCD	☒
3	**Topographic Data**		
3a.	Spring Creek Terrain Data (3ft x 3ft)	DEM downloaded from HCFCD for Spring Creek Watershed	☒
3b.	Willow Creek Terrain Data (3ft x 3ft)	DEM downloaded from HCFCD for Willow Creek Watershed	☒
3c.	Bridge_Deck_DEM_3ft.tif	DEM showing only the deck of the bridges in the watershed	☒
4	**H&H Models**		
4a.	J_Spring_FEMA_Effective	Effective model downloaded from FEMA for Spring Creek Watershed	☒
4b.	HCFCD Spring Creek TSDN	Final H&H Model and TSDN downloaded from HCFCD SharePoint for Spring Creek	☒
4c.	M_Willow_FEMA_Effective	Effective model downloaded from FEMA for Willow Creek Watershed	☒
4d.	HCFCD Willow Creek TSDN	Final H&H Model and TSDN downloaded from HCFCD SharePoint for Willow Creek	☒
4e.	SJRDMP_Model	1D 2 D Model for San Jacinto River Basin Drainage Master Plan	☒
5	**Modeling Support Data**		

Ref. No.	Filename	Description	Upload
5a.	RGUP_BLK_PROJECTIONS.gdb	Population Projection provided by HGSD for Harris and Montgomery Counties	☒
5b.	tabblock2010_48_pophu.shp	Base 2010 population data downloaded from US Census Bureau for Waller and Grimes Counties	☒
5c.	Population_Projected.shp	Projected population from 2020 to 2070 for the entire watershed (A combination of 5a and processed 5c)	☒
5d.	Spring Creek and West Fork Study - Sealed	HNTB study report received from HCFCD	☒
5e.	CONUS_B2_y2010.tif	Landcover projections done by USGS for year 2010	☒
5f.	CONUS_B2_y2020.tif	Landcover projections done by USGS for year 2020	☒
5g.	CONUS_B2_y2030.tif	Landcover projections done by USGS for year 2030	☒
5h.	CONUS_B2_y2040.tif	Landcover projections done by USGS for year 2040	☒
5i.	CONUS_B2_y2050.tif	Landcover projections done by USGS for year 2050	☒
5j.	CONUS_B2_y2060.tif	Landcover projections done by USGS for year 2060	☒
5k.	CONUS_B2_y2070.tif	Landcover projections done by USGS for year 2070	☒
5l.	S_POL_AR.shp	Political area boundaries downloaded from FEMA National Flood Hazard Layer	☒
5m.	S_FLD_HAZ_AR	Special Flood Hazard Layer downloaded from FEMA National Flood Hazard Layer	☒
5n.	HWM_HCFCD.shp	High water mark downloaded from HCFCD models	☒
5o.	HWM_USGS.shp	High water mark downloaded from USGS	☒
5p.	HWM_Harvey.shp	High water mark downloaded from HCFCD	☒
5q.	AllClaimsDec2017.shp	All Claims dataset	☒

Ref. No.	Filename	Description	Upload
5r.	Repetitive_Loss.shp	Repetitive Loss Dataset	☒
6	**Existing Structures**		
6a.	SI_Harris_County.shp	Structural Inventory Dataset for Harris County	☒
6b.	NSI_2022.shp	National Structure Inventory, USACE	
6c.	LiDAR_Building_Footprints_2018.shp	Building Footprints downloaded from H-GAC database	☒
6d.	Texas_Building_Footprints.shp	Building Footprints downloaded from Microsoft GitHub	☒
6e.	Harris_Parcel.shp	Tax Parcels of Harris County	☒
6f.	Montgomery_Parcel.shp	Tax Parcels of Montgomery County	☒
6g.	stratmap19-landparcels_48185_grimes_201904.shp	Tax Parcels of Grimes County	☒
6h.	stratmap19-landparcels_48473_waller_201903.shp	Tax Parcels of Waller County	☒
6i.	Critical_Infrastructure.gdb	Critical Infrastructures in the Watershed	☒
7	**Soil Data**		
7a.	Soil_Map.shp	Soil Map downloaded from Web Soil Survey containing Hydrologic Soil Groups	☒
8	**Rainfall Data**		
8a.	Rainfall Depths and Intensities in Harris County dated 03/21/2019	Rainfall data downloaded from HCFCD	☒
8b.	AORC Data	Rainfall data downloaded from NOAA	☒
9	**Utilities**		

Ref. No.	Filename	Description	Upload
9a.	WoodlandsWater.zip Sanitary_Lines_13in.zip Sanitary_MH.zip	6 shapefiles: waterlines, water valves, storm outfalls, storm inlets, storm lines, and hydrants for The Woodlands area Sanitary Sewer lines for The Woodlands area	☒
9b.	SMC_MUD.zip	Water, sanitary, and stormwater lines for South Montgomery County Municipal Utility District	☒
9c.	MC_MUD_119.zip	Water lines, sanitary sewer, outfalls, and boundary for Montgomery County MUD 119	☒
10	**San Jacinto River Authority**		
10a.	SJRA_ServiceAreas.zip	Area supplied by SJRA treated surface water in Montgomery County	☒
12	**Reference Materials**		
12a.	Harris County Flood Control District - Hydrology and Hydraulics Manual 2009	H&H Manuals downloaded from HCFCD	☒
12b.	**Research Journals** • Land Subsidence Effects on Bridges in the World • Land subsidence in Houston correlated with flooding from Hurricane Harvey • Present-day land subsidence rates, surface faulting hazard and risk in Mexico City with 2014–2020 Sentinel-1 IW InSAR • Framework for economic cost assessment of land subsidence	Research Journals downloaded to date	☒

Appendix A1: Fault Study in Spring Creek

(Report by Dr. Shuhab Khan, SK GeoSciences)

Faults Study in Spring Creek

This report provides a summary of geological study for finding fault(s) in Spring Creek Watershed in the Spring subbasin of Texas-Gulf region (HUC 1204010202) located north and northwest of Houston in Harris, Montgomery, Grimes, and Waller counties (Figures 1 and 2).

Background on faulting in Houston and Surroundings

Houston is located on the northern coastline of the Gulf and Mexico. The opening of the Gulf of Mexico, which separates North America and South America, began around the Triassic (~200 million years ago) (Pilger Jr, 1981). Extensive salt provinces were deposited during the Jurassic (~150 million years ago) (Humphris Jr, 1979; Salvador, 1987). The Houston Embayment, a salt basin, is bounded by the Talco, Mexia, and Luling fault zones that strike northeast-southwest and are extensional structures that slide sediments toward the Gulf Coast (Ewing and Lopez, 1991). The Gulf of Mexico is a salt basin where gravity-driven normal faulting and salt movement have contributed to surface deformation (Rowan et al., 1999). The normal faulting dominantly strikes northeast-southwest, and the faults associated with the salt domes are radial faults that propagate outwards from the impact of salt tectonics (Worrall and Snelson, 1989; Wu et al., 1990; Diegel et al., 1995; Peel et al., 1995; Rowan et al., 1999; Saribudak, 2011). The surface deformation caused by faults along the Texas coast between Beaumont and Victoria has been active since the Pleistocene and was continuous throughout the Holocene (Verbeek, 1979). Near-surface dip for most of these faults is around 70º (Norman, 1991). Many of these faults are active. The rate of movement for these faults varies from 0.5 to 3 cm/yr (Norman and Howe, 2011; Worrall and Snelson, 1989).

Faults in Spring Creek Watershed

This site was assessed for the presence of surface fault(s) using the following data:

1. Five peer-reviewed published maps of Faults in Houston and surrounding areas. These include:
   A. Verbeek, E.R., 1979, Surface faults in the gulf coastal plain between Victoria and Beaumont, Texas. Tectonophysics, Volume 52, Issues 1–4, 373-375.
   B. Shaw, S., and Lanning-Rush, J., 2005, Principal faults in the Houston, Texas, metropolitan area: U.S. Geological Survey Scientific Investigations Map 2874.
   C. Engelkemeir, R. Khan, S.D. 2008, LiDAR mapping of faults in Houston, Texas, USA. Geosphere, 4(1):170–182

D. Khan, S.D., Stewart, R.R., Otoum, M., Chang, L., 2013, A geophysical investigation of the active Hockley Fault System near Houston, Texas. Geophysics 78(4): B177–B185
E. Qu, F., Lu, Z., Kim, J., Zheng, W., 2019. Identify and Monitor Growth Faulting Using InSAR over Northern Greater Houston, Texas, USA. Remote Sens. 2019, 11, 1498; doi:10.3390/rs11121498

2. Faults mapped by Dr. Carl Norman for this area were also checked in a field guidebook (Norman, C.E.; 1991. Active faults in north Harris County and south-central Montgomery County, Texas. In Environmental and Engineering Geology of North Harris and South Montgomery Counties Texas-Guidebook; Houston Geological Society: Houston, TX, USA, Volume 19, pp. 13–27).
3. Faults mapped by Fugro Consultants Inc. for San Jacinto River Authority (Fugro Consultants, I. Geologic Fault Delineation Study SJRA Distribution Lines-Route w1 San Jacinto River Authority Montgomery County, TX; Report No. 04.12110014-9; Fugro Consultants, Inc.: Sacramento, CA, USA, 2012).

4. Aerial Photographs of 60 cm resolutions acquired from May 2018 to April 2019 were also used (USDA, 2018).

5. Digital Elevation Model (DEM), hillshade, and slope maps derived from LiDAR data acquired in 2008 and 2018 are utilized. Merrick and Company collected LiDAR data in 2008 with a horizontal accuracy of ±0.7 m and vertical accuracy of ±9.25 cm (H-GAC, 2008). The recent 2018 LiDAR data is part of the Texas Strategic Mapping Program (StratMap), titled "Upper Coast LiDAR" (StratMap, 2018). These LiDAR data have a horizontal accuracy of ±0.20 m and vertical accuracy RMSE ≤ 0.1 cm.

Based on the analyses of the above datasets, several surface faults are mapped. These are normal faults and generally trend southwest-northeast direction and dip in a southeast direction. A smaller fault (Panther Branch Fault) is an antithetic fault and dips in the northwest direction (Figures 3-6). Figures 3 shows DEM showing elevation ranging from 11-315 meters. Figures 4 and 5 show hillshade images derived from the LiDAR data. The hillshade image in figure 4 is created by illuminating light from the northwest direction at an altitude of 45º degrees above the horizon. While the hillshade image in Figure 5 is generated by combing light from six different directions. Hillshading highlights linear features. These are the main techniques used to map faults in Houston and other urban areas with low relief using LiDAR data. Figure 6 shows a slope map in degree. Areas with a sharp change in slope were assessed for fault, and elevation profiles were generated. Zoomed-in displays of fault scarps are shown in Figures 7 and 8 with and without fault traces. Figure 9 shows the elevation profile across Hufsmith Fault as an example.

Faults mapped in this study match with existing published maps of faults for this region (Verbeek, 1979; Norman, 1991; Shaw & Lanning-Rush, 2005; Engelkemeir & Khan 2008; Fugro, 2012; Khan et al., 2013; Qu et al., 2019). Maps from Qu et al., (2019) Fugro (2012), and Norman (2011) are shown in figures 10, 11, and 12, respectively. Detailed investigations involving field observations and geophysical surveys and interpretation of well logs are required to confirm these faults.

Hillshade images for the surrounding areas of Spring Creek were also assessed. Conroe Fault can be seen north of Spring Creek. Hockley Fault System extends in both the southwest and northeast direction. The locations of subsurface salt domes (Lopez, 1995) are also plotted.

No new faults were found in this study. Hillshade images highlighted roads, streams, building footprints, but no evidence for the surface disturbance caused by faults can be detected.

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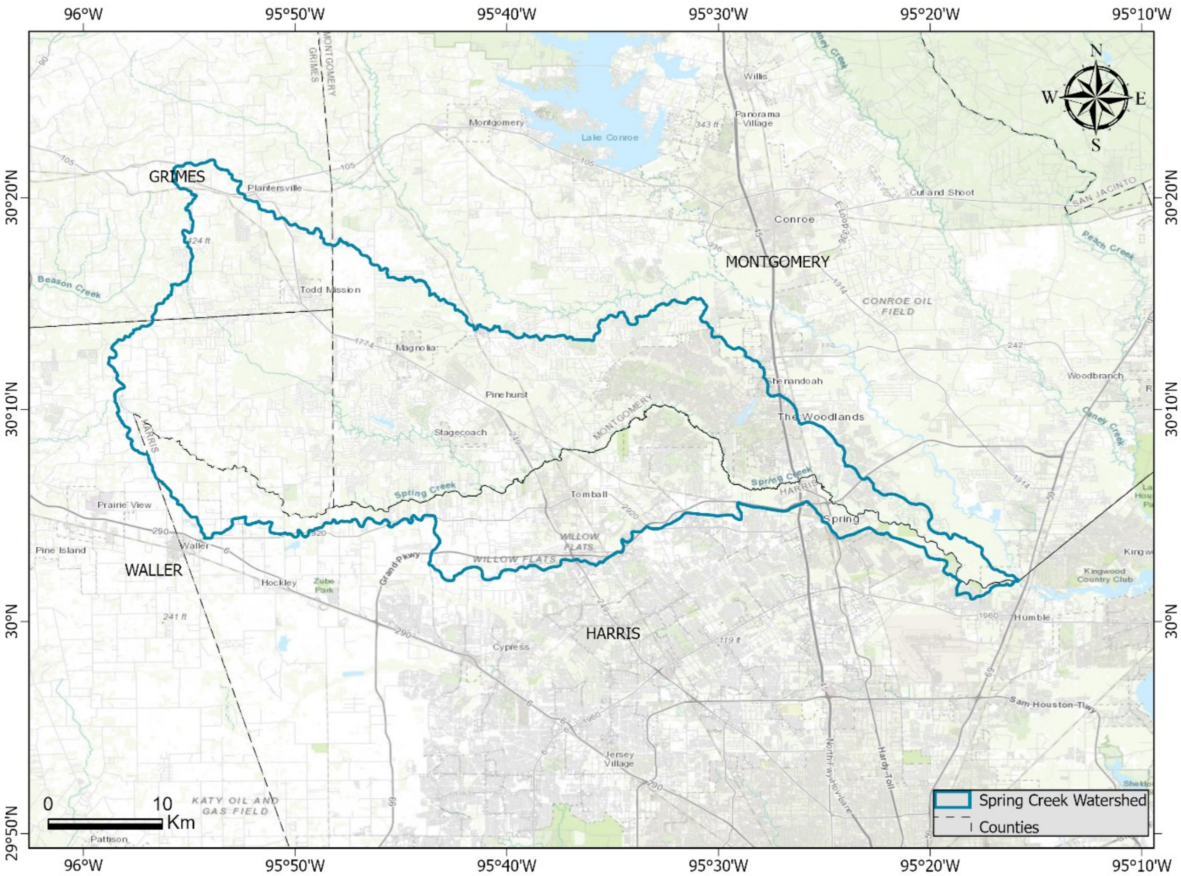


Figure 1: Location of Spring Creek Watershed in Grimes, Harris, Montgomery, and Waller counties

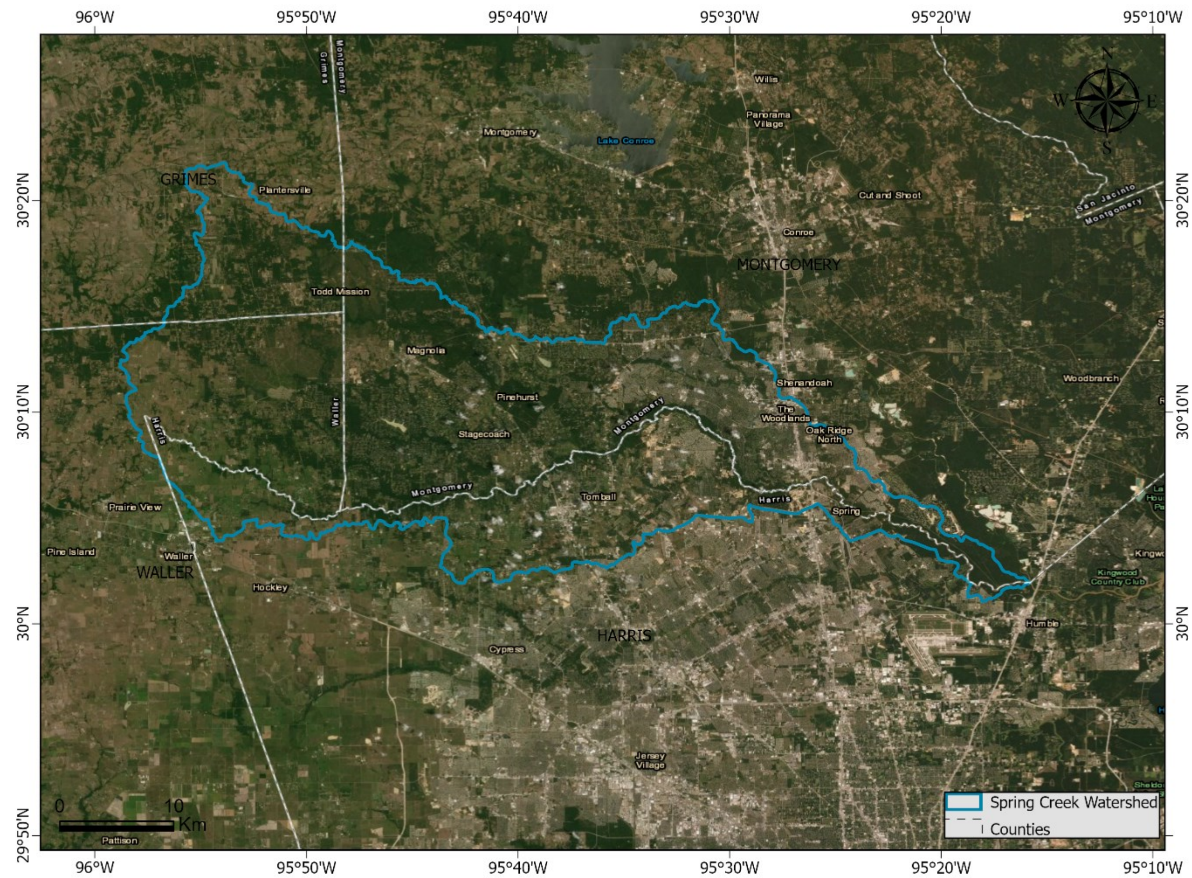


Figure 2: Location of study site marked on aerial photographs. Digital Orthophotos (DOQQ) acquired in 2018-2019 (USDA 2018).

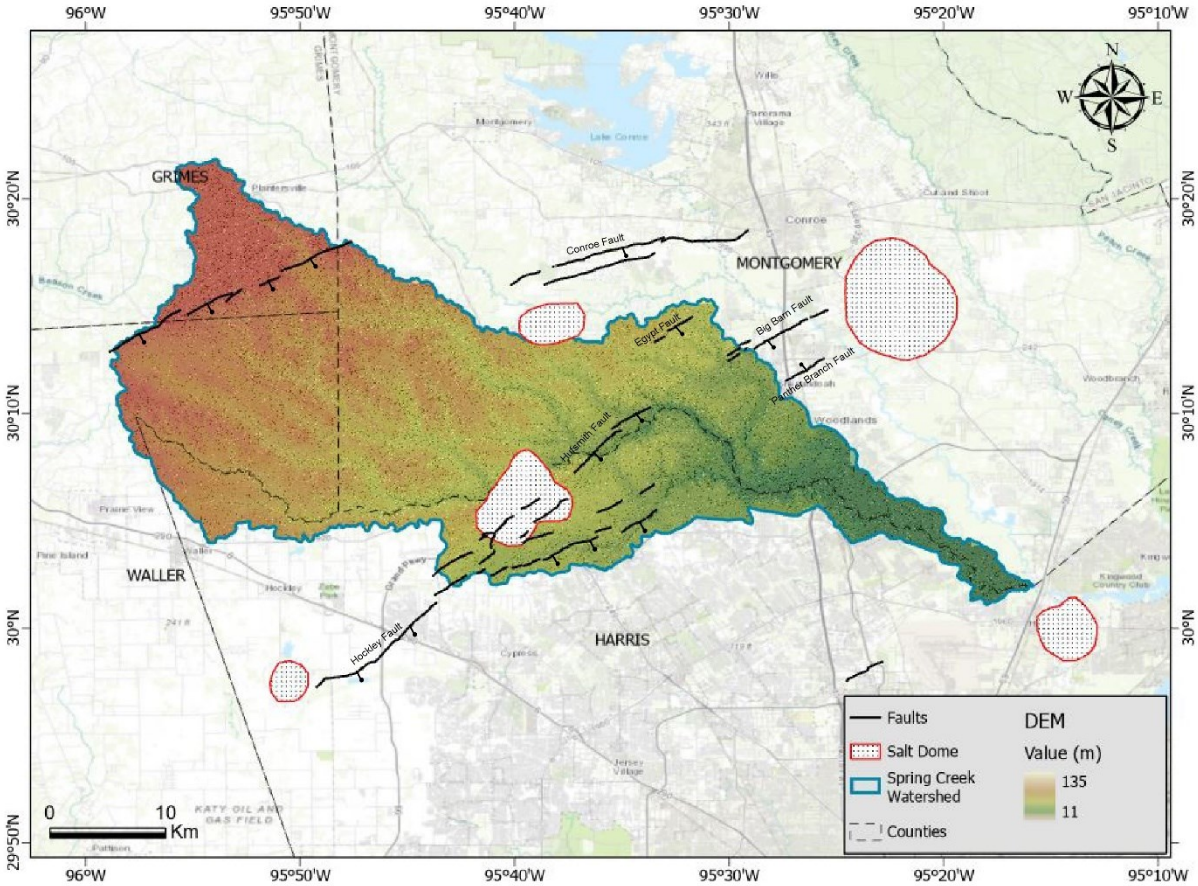


Figure 3: LiDAR DEM data for Spring Creek watershed. Several faults extending from southwest to northeast can be mapped. Sites of the faults are already known. No new fault scarp(s) in this image can be detected. Locations of the subsurface salt domes are also shown.

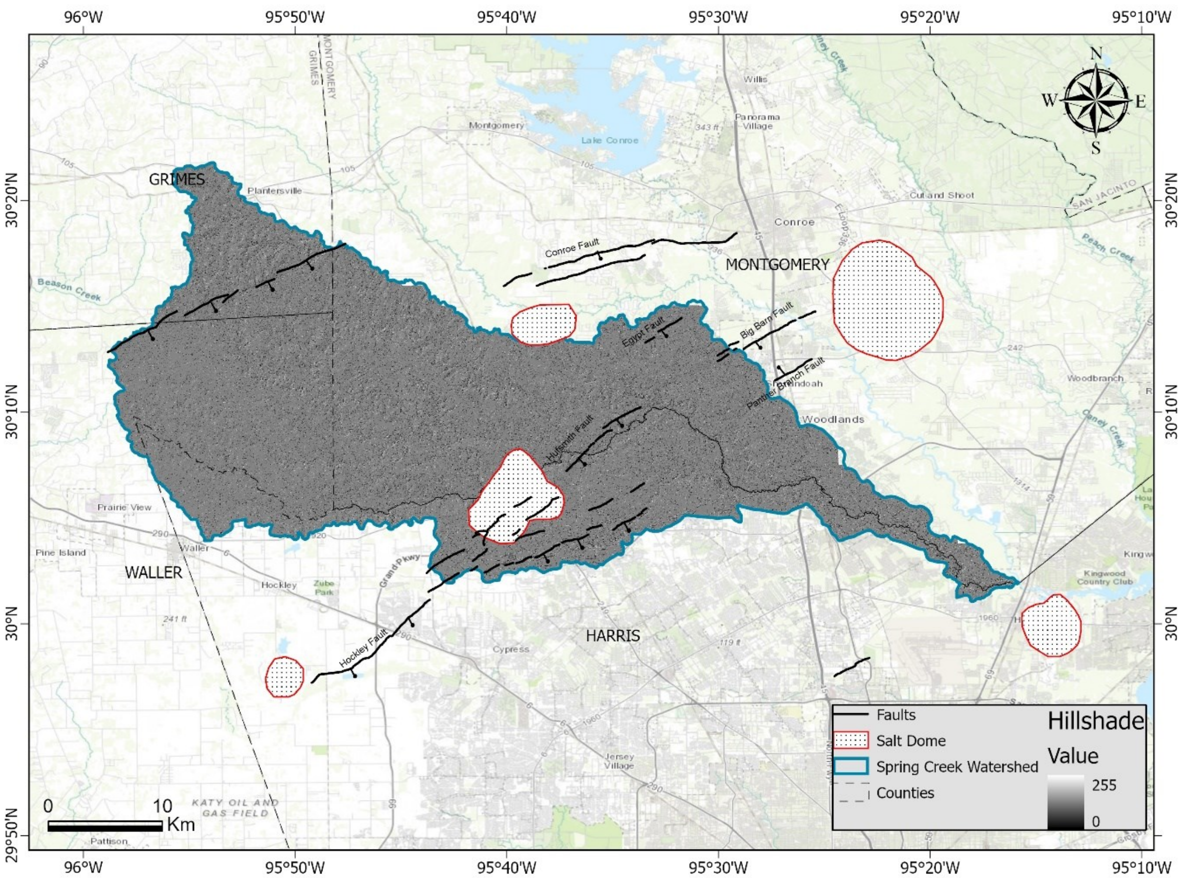


Figure 4: Traditional hillshade image derived from LiDAR DEM data of 2018. Several faults extending from southwest to northeast can be mapped. Locations of the faults are already known. No new fault scarp(s) in this image can be detected.

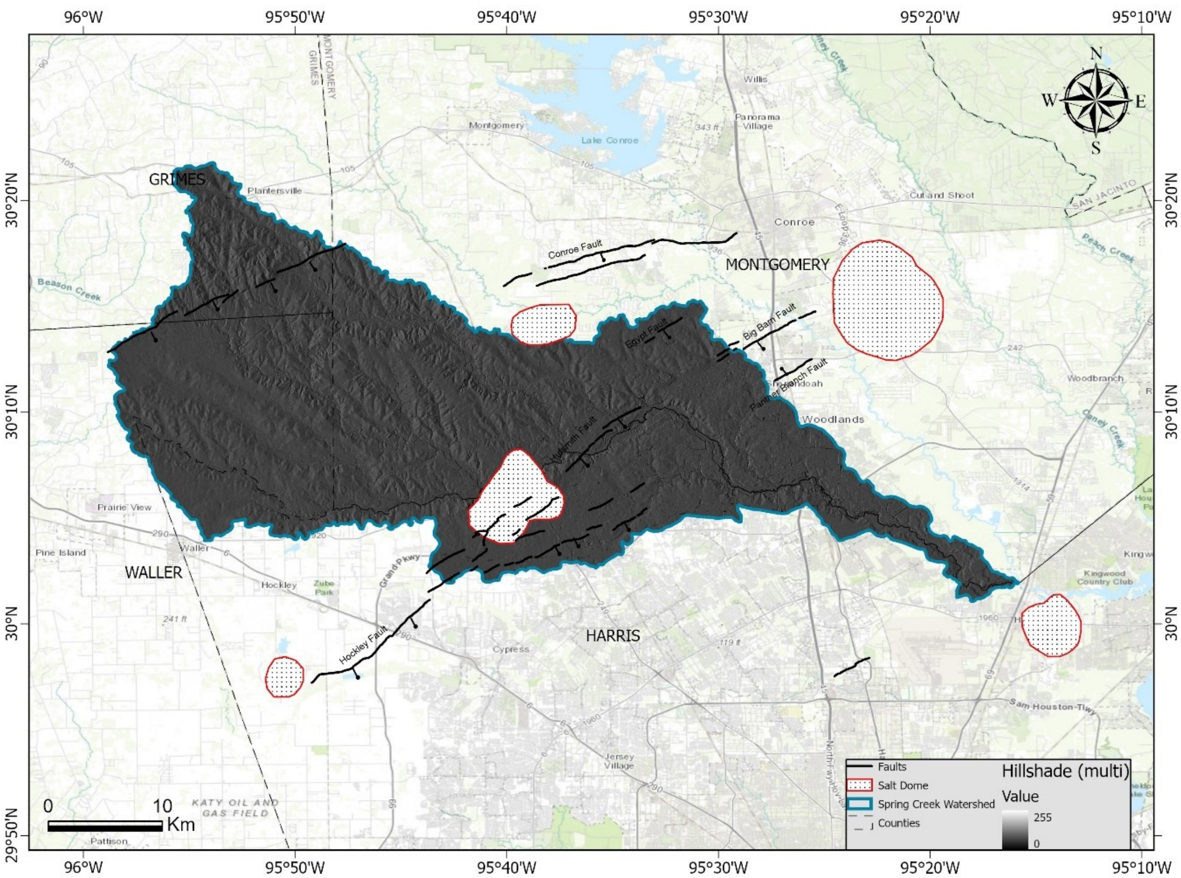


Figure 5: Multidirectional hillshade image derived from LiDAR DEM data of 2018. Several faults extending from southwest to northeast can be mapped. Locations of the faults are already known. No new fault scarp(s) in this image can be detected.

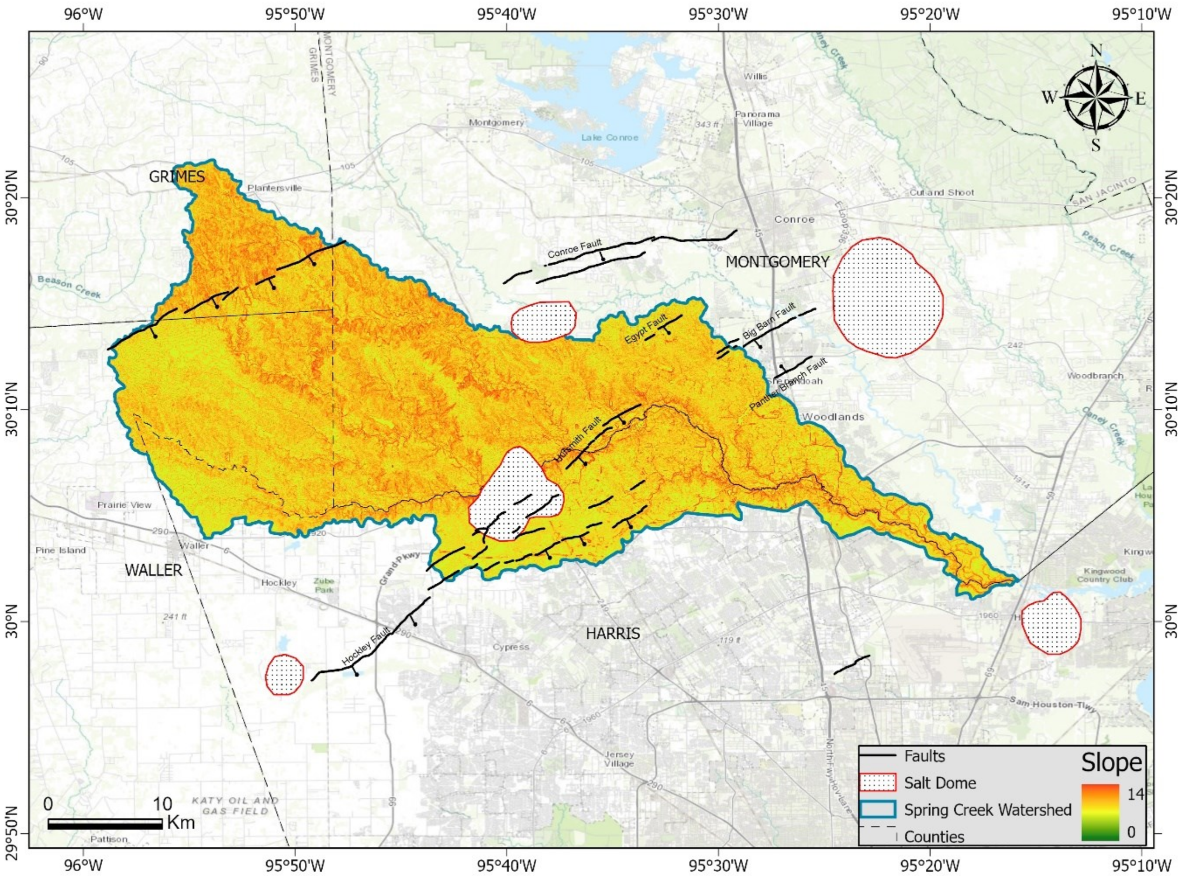


Figure 6: Slope in degrees derived from LiDAR DEM data of 2018 (StratMap, 2018). Several faults extending from southwest to northeast can be mapped. Locations of the faults are already known. No new fault scarp(s) in this image can be detected.

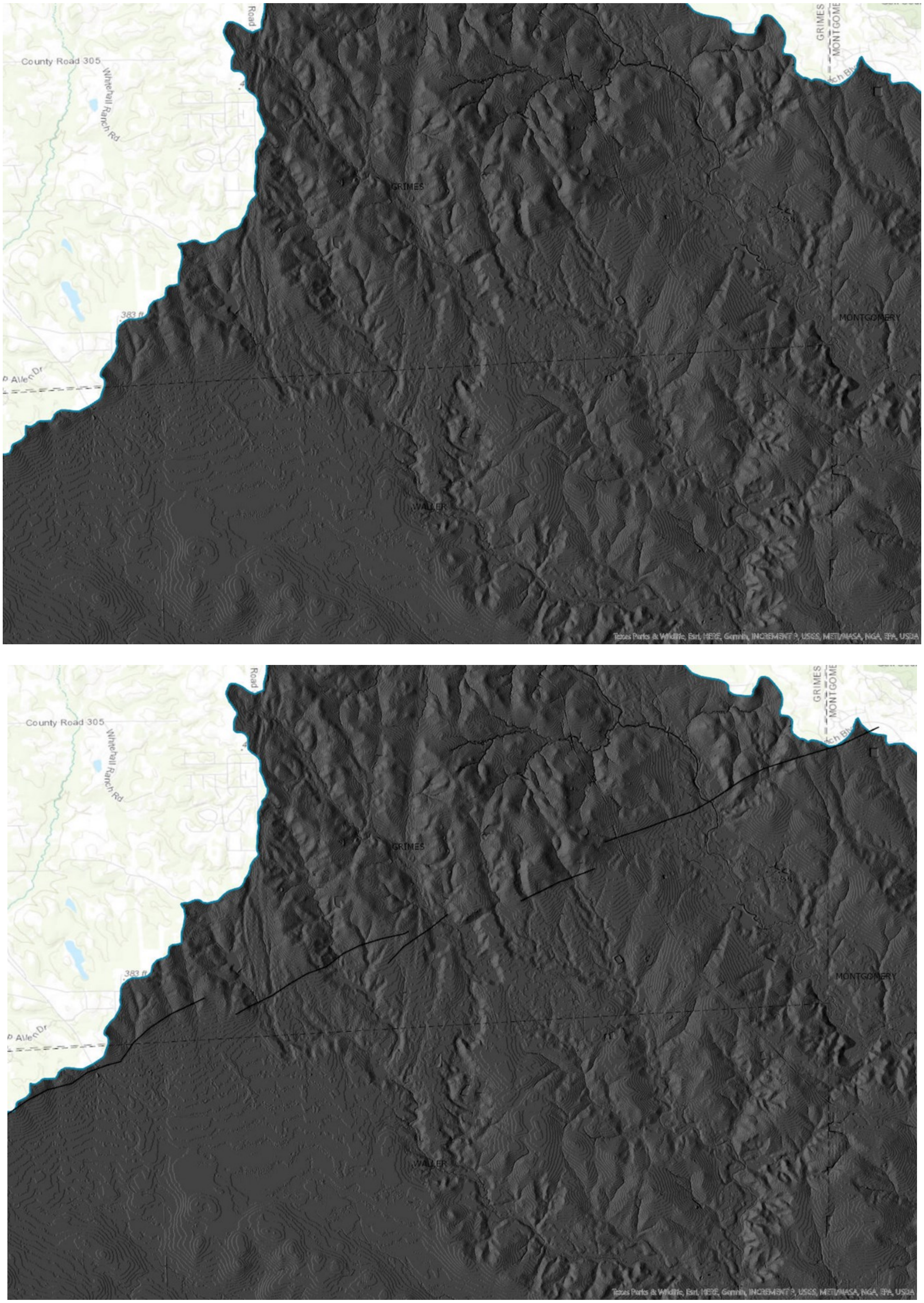


Figure 7: Zoomed in view of fault scarp northwest of the study area

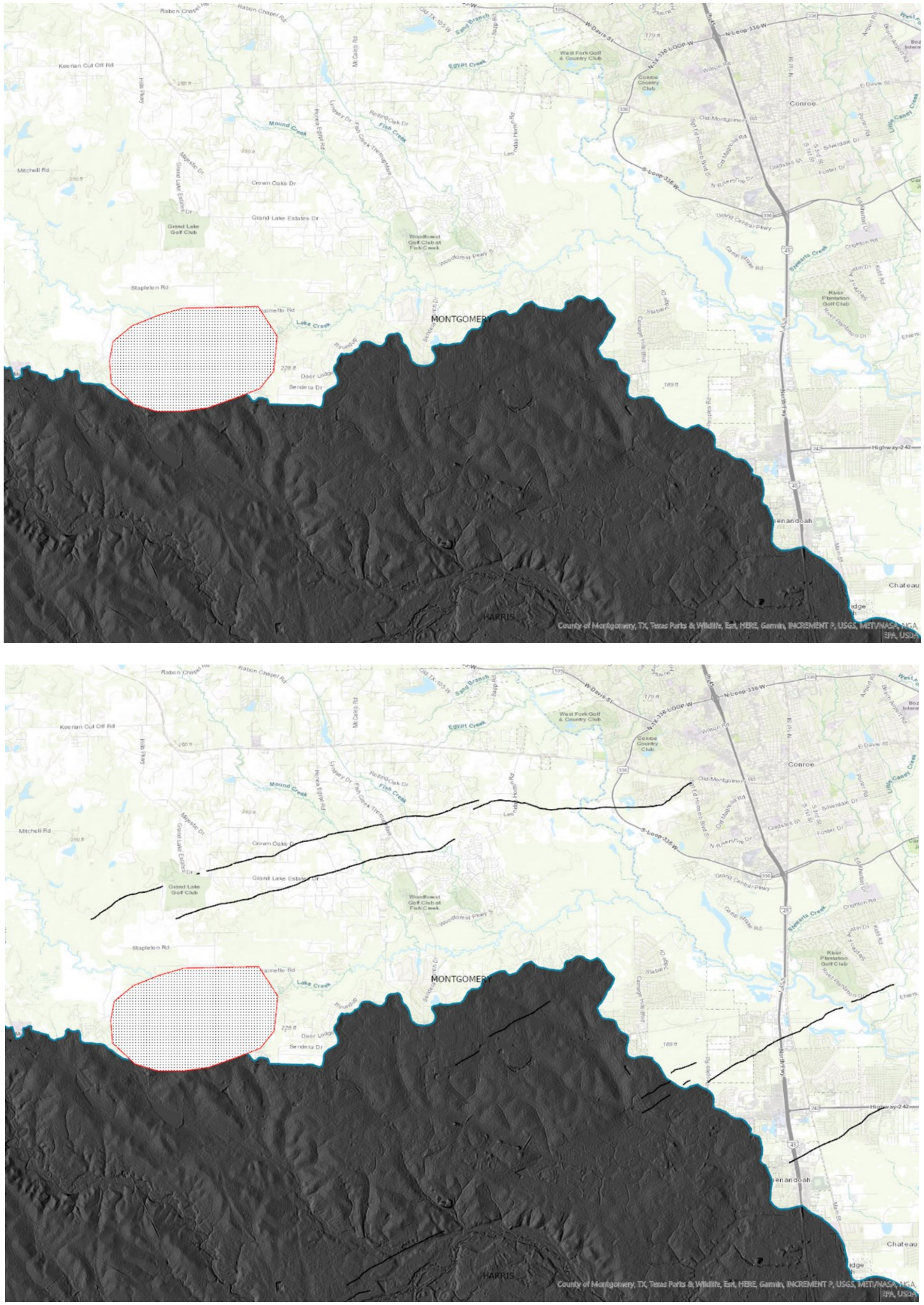


Figure 8: Zoomed in view of fault scarps center and east of the study area

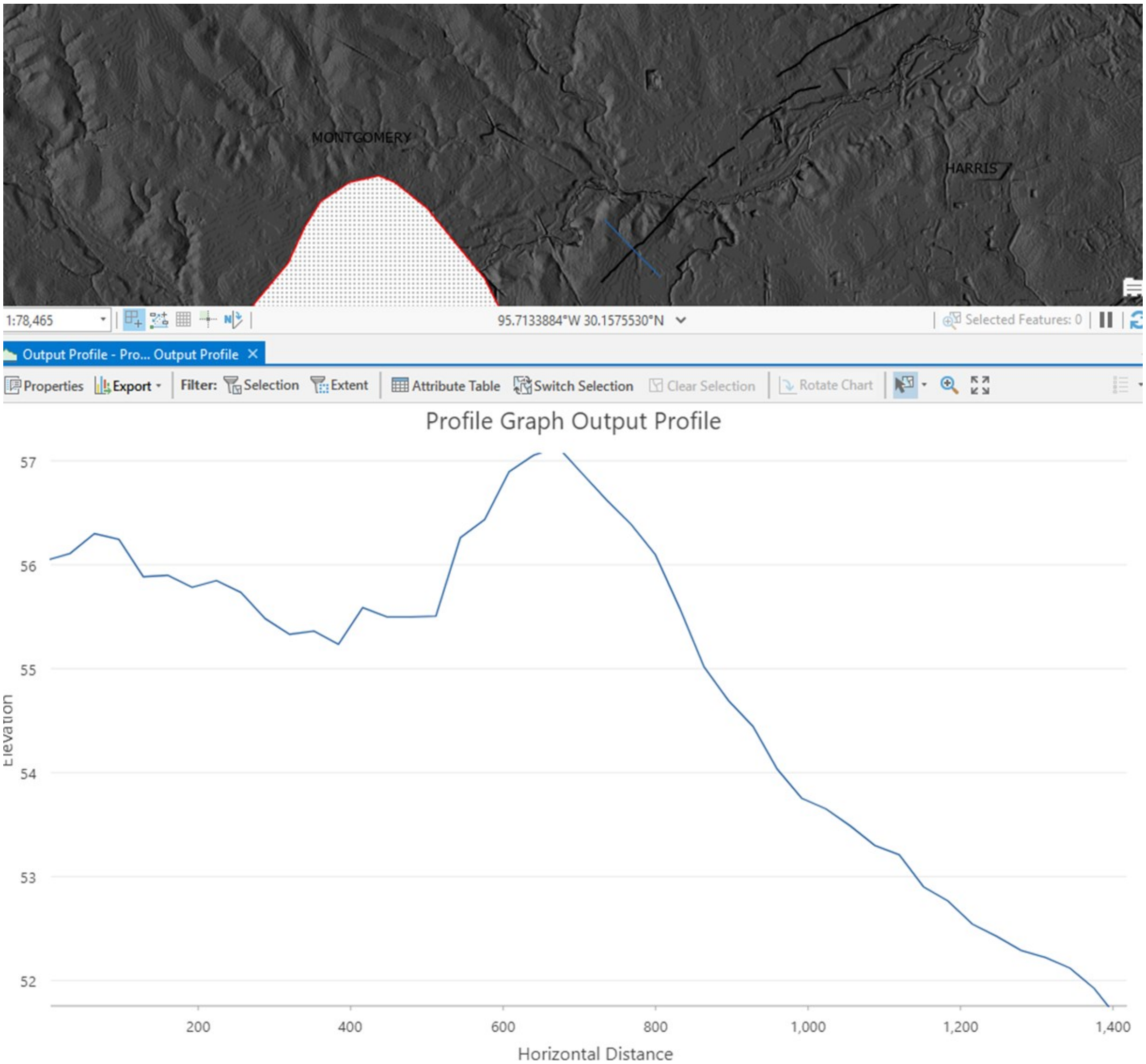


Figure 9: Elevation profile across Hufsmith Fault

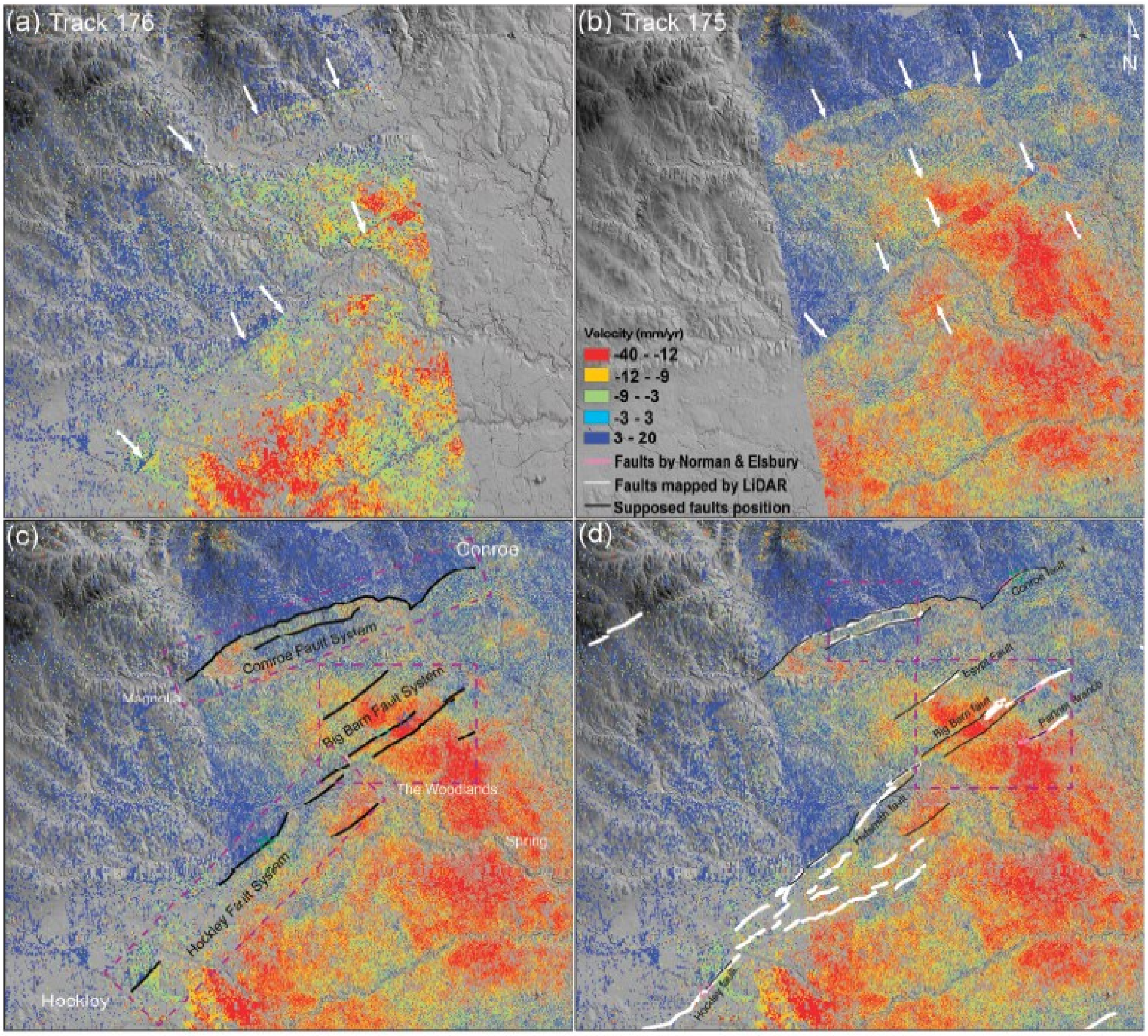


Figure 10: Fault map created by compilation of previous work and Interferometric Synthetic Aperture Radar data by Qu, et al. (2019; figure 5) for the Greater Houston area

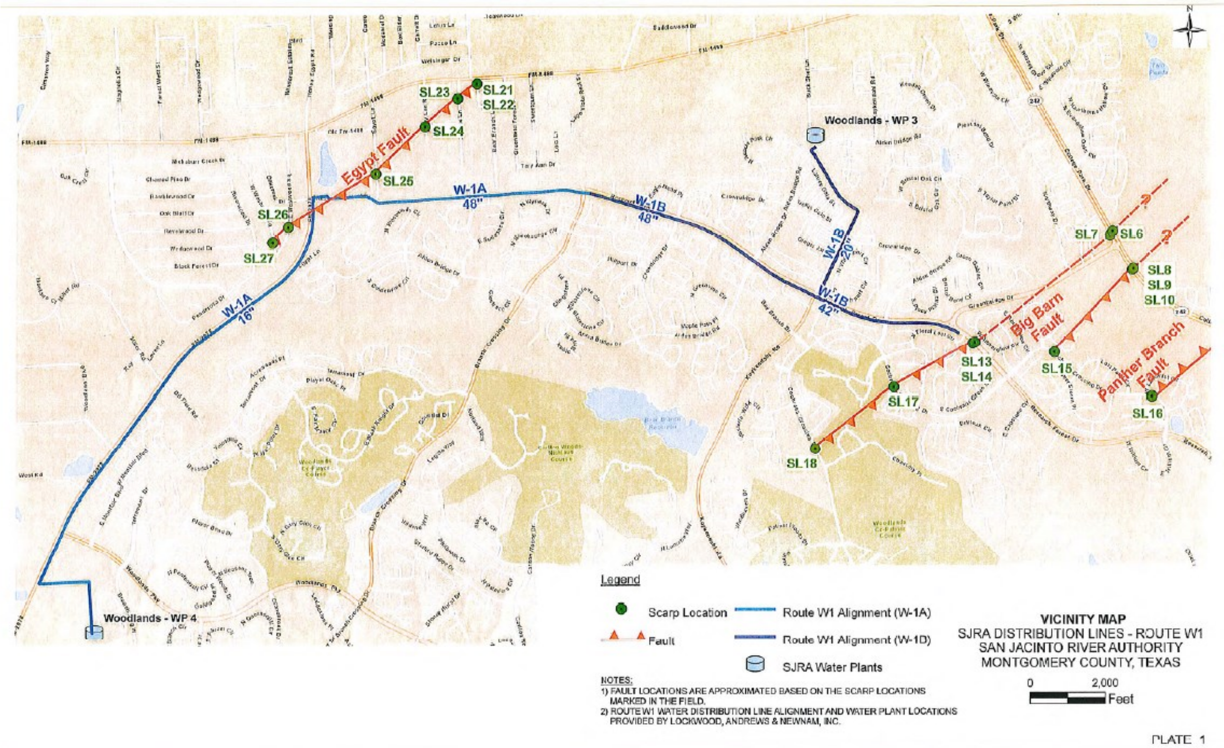


Figure 11: Fault map for Route 1, San Jacinto River Authority by Fugro (2012; plate 1)

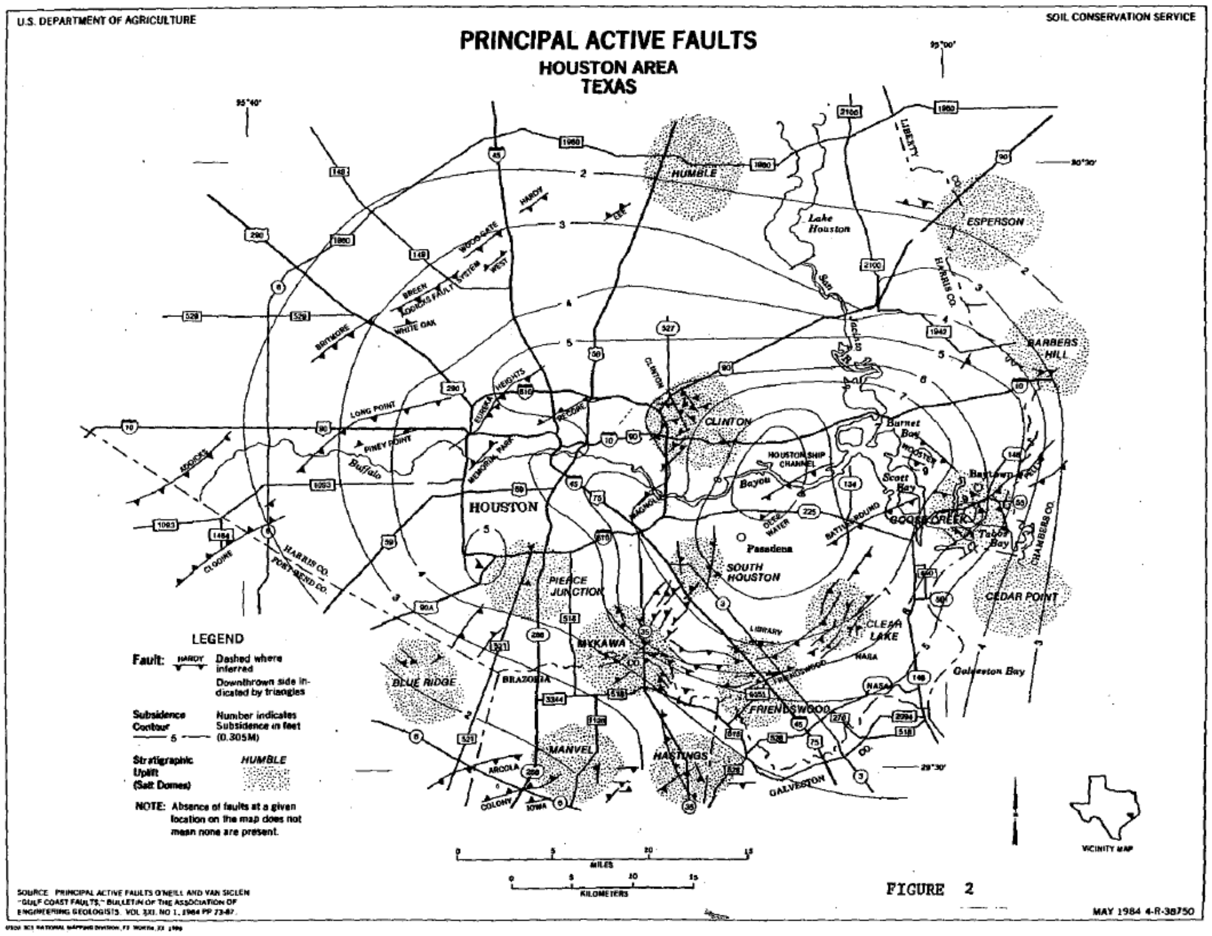
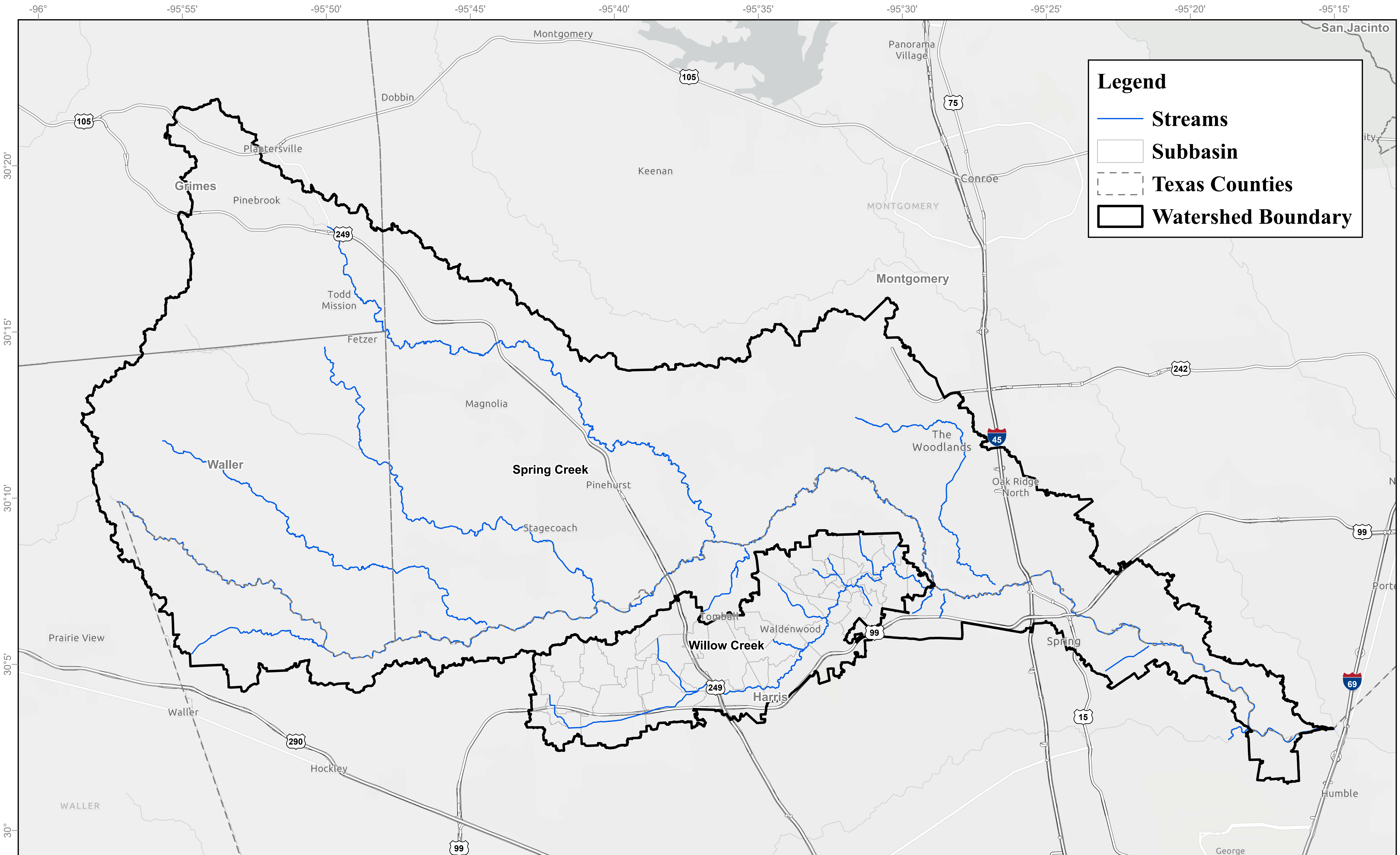


Figure 11: Map of active faults in Houston area by Norman (2011)

Appendix A2: Exhibits

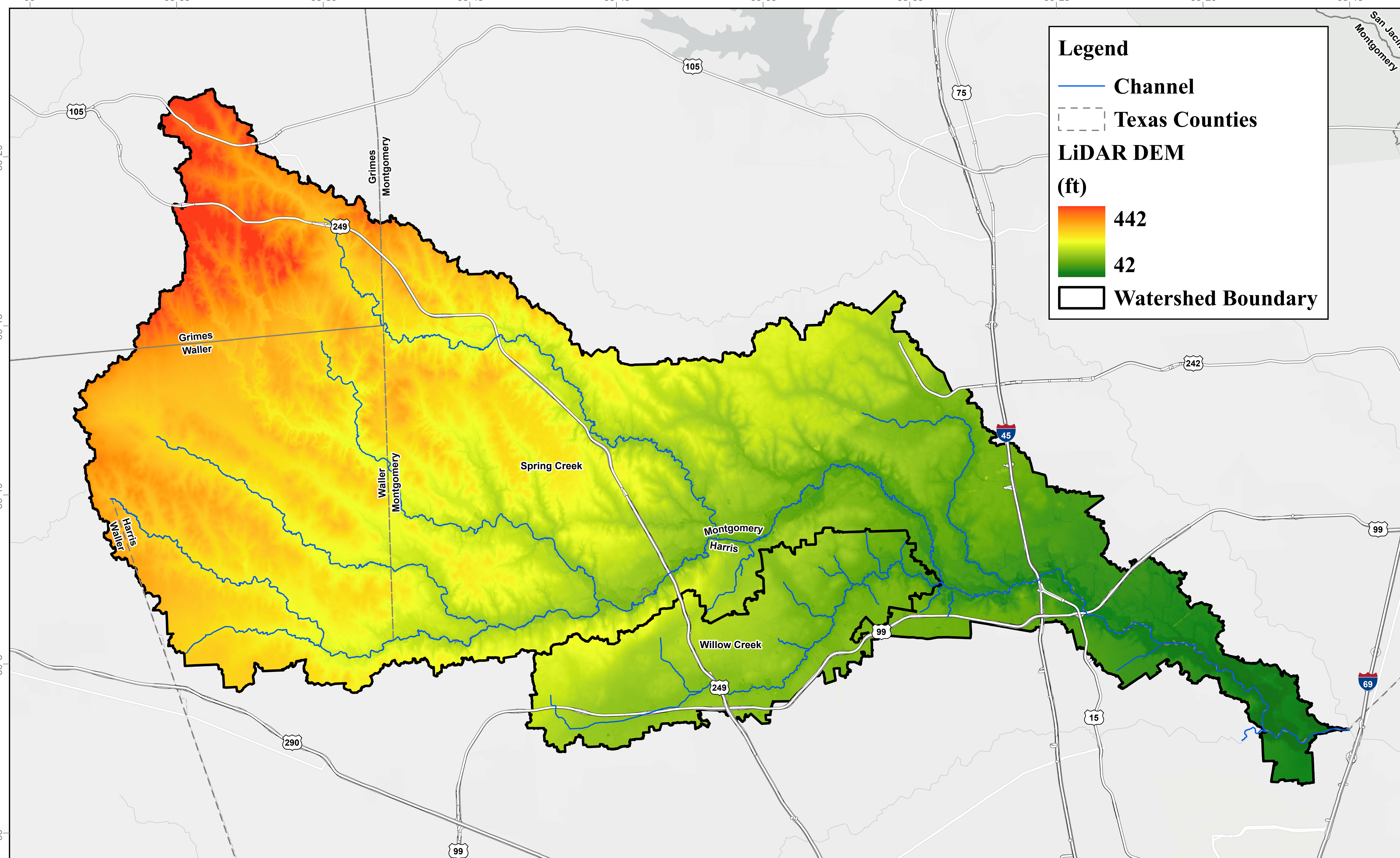


Michael Baker INTERNATIONAL

HARRIS-GALVESTON SUBSIDENCE DISTRICT

0 2.5 5 10 Miles

Watershed Boundary

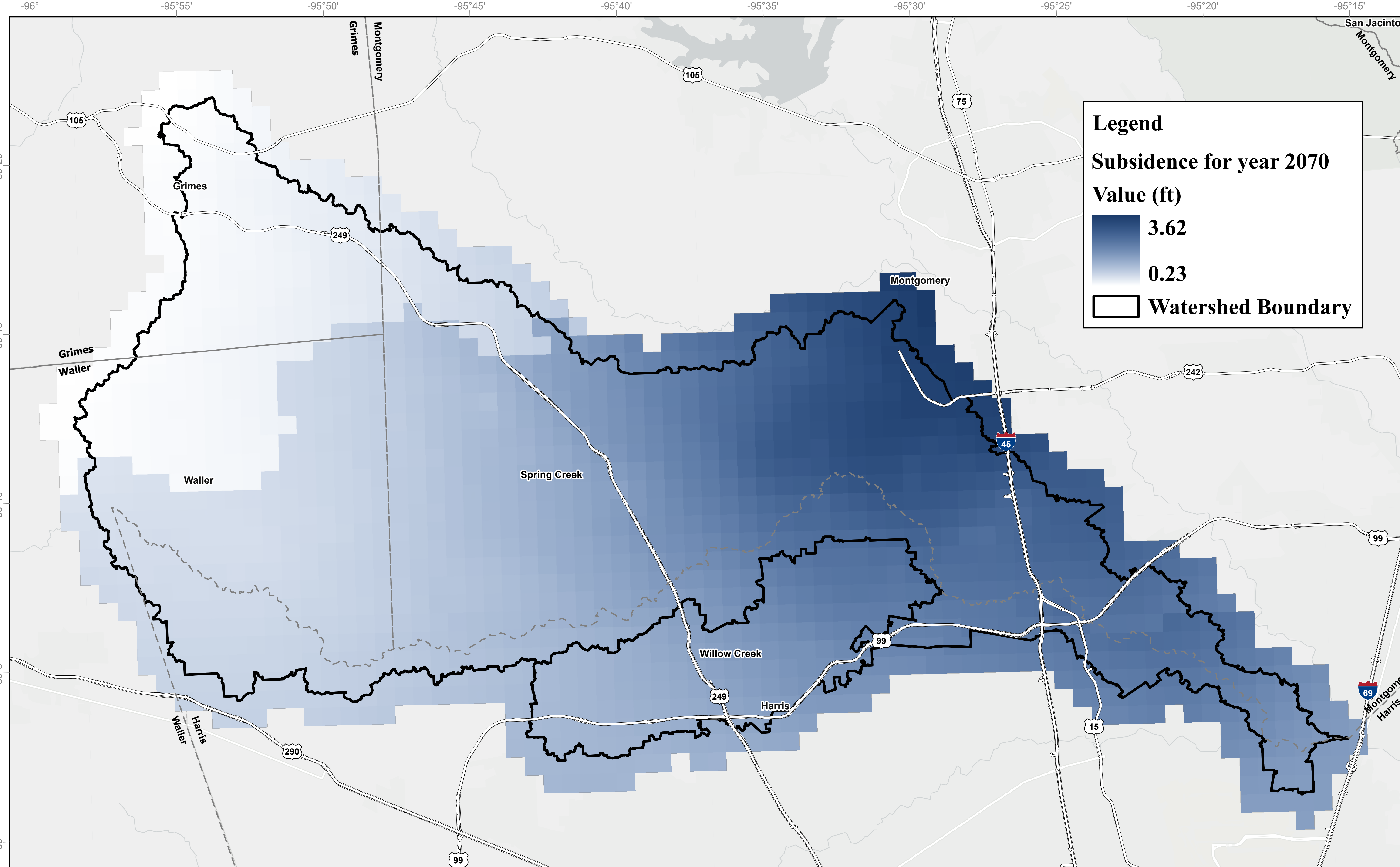


Michael Baker INTERNATIONAL

Harris-Galveston Subsidence District

0 2.5 5 10 Miles

Digital Elevation Model (DEM)

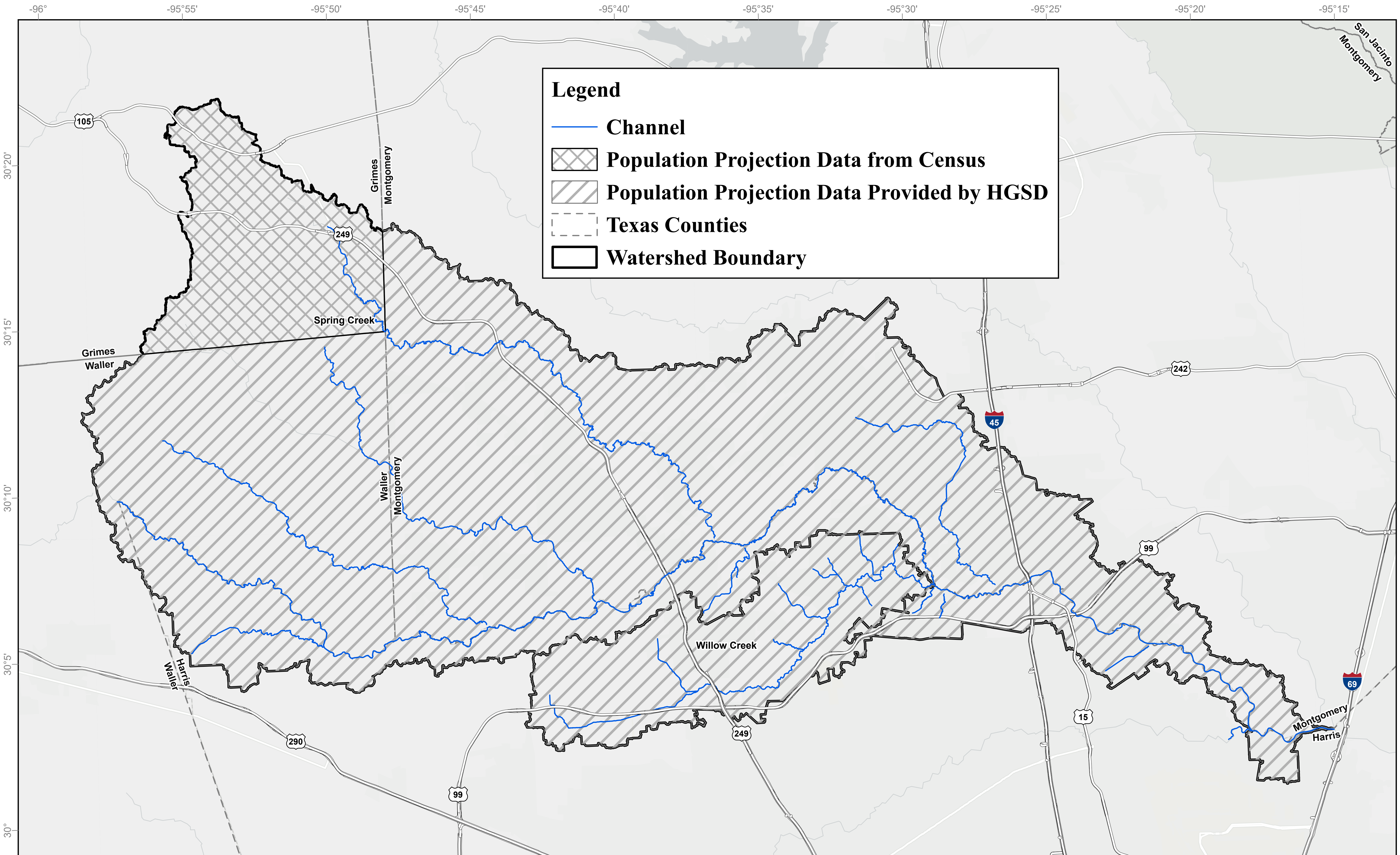


Michael Baker INTERNATIONAL

Harris-Galveston Subsidence District

0 2.5 5 10 Miles

Subsidence Grid for 2070



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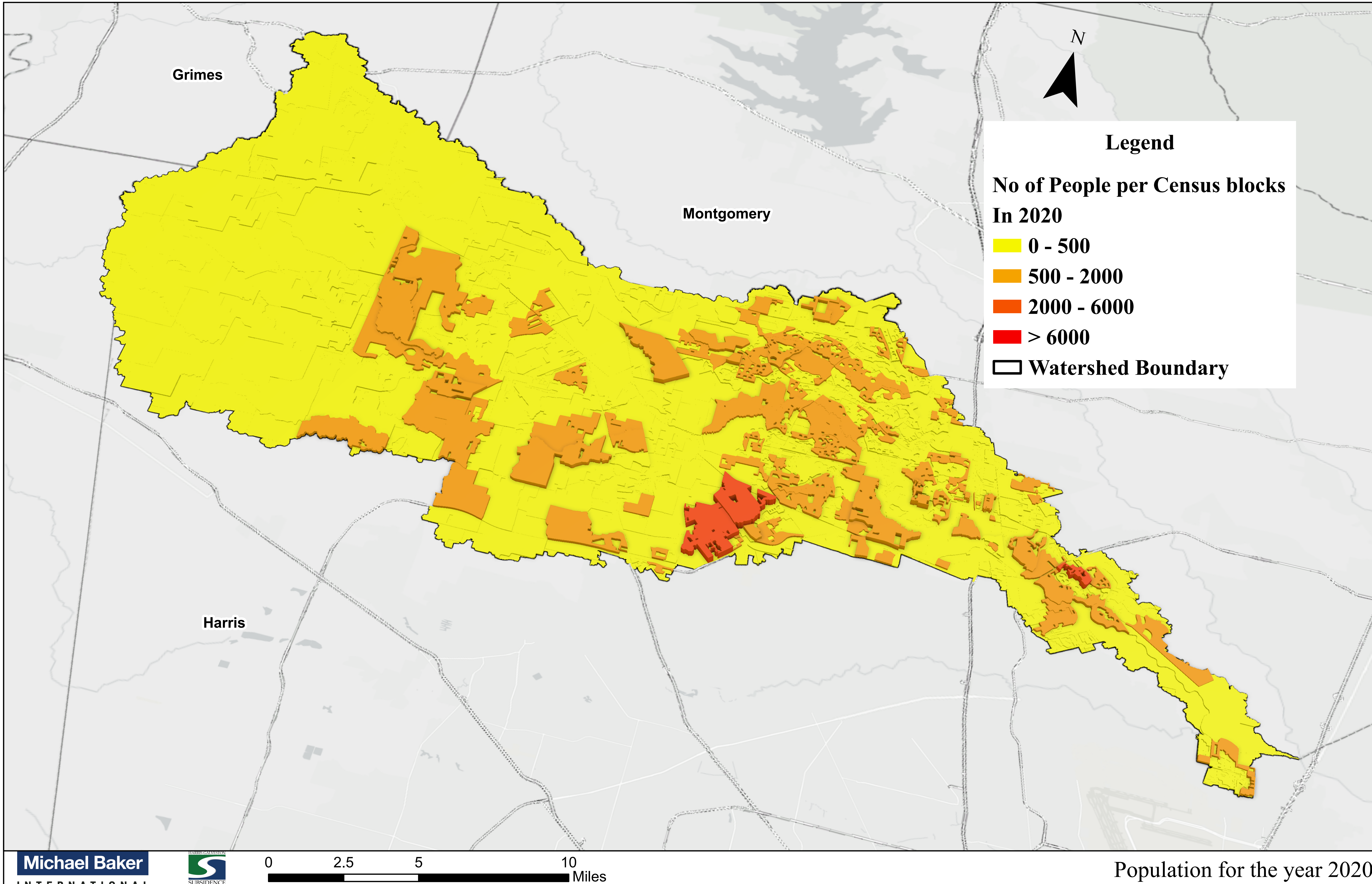
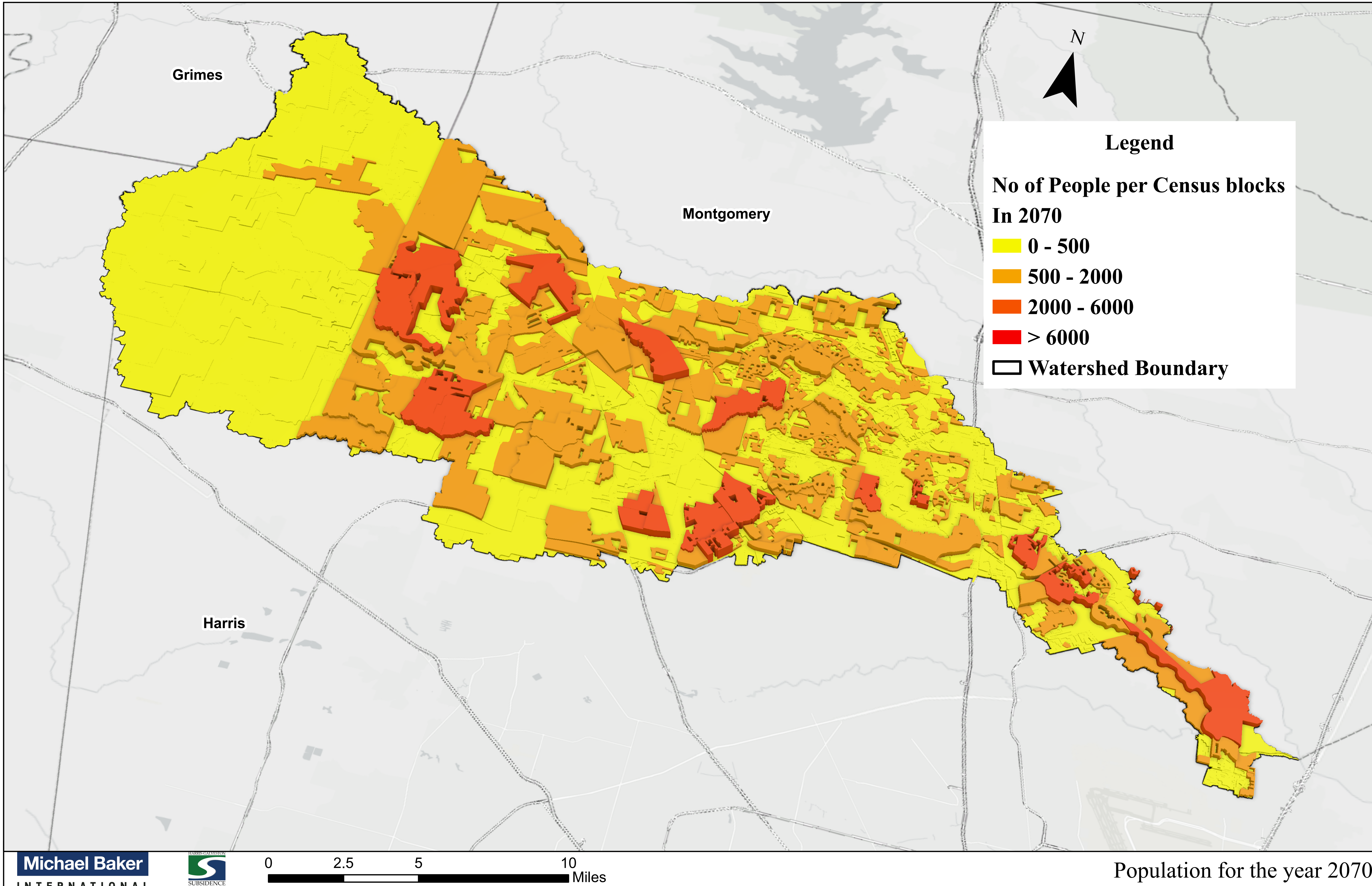
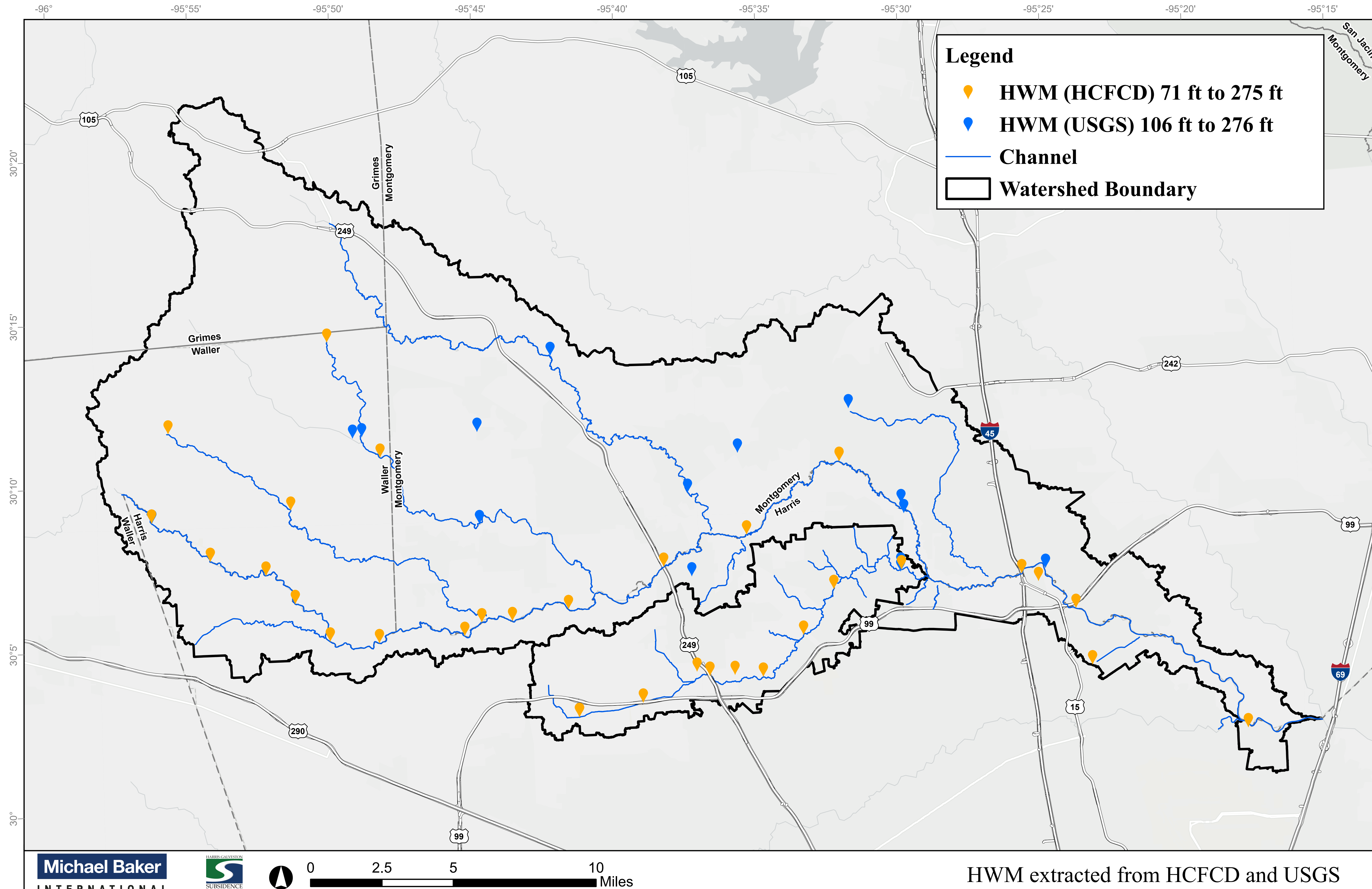
HARRIS-GALVESTON SUBSIDENCE DISTRICT

Population Projection Data Availability

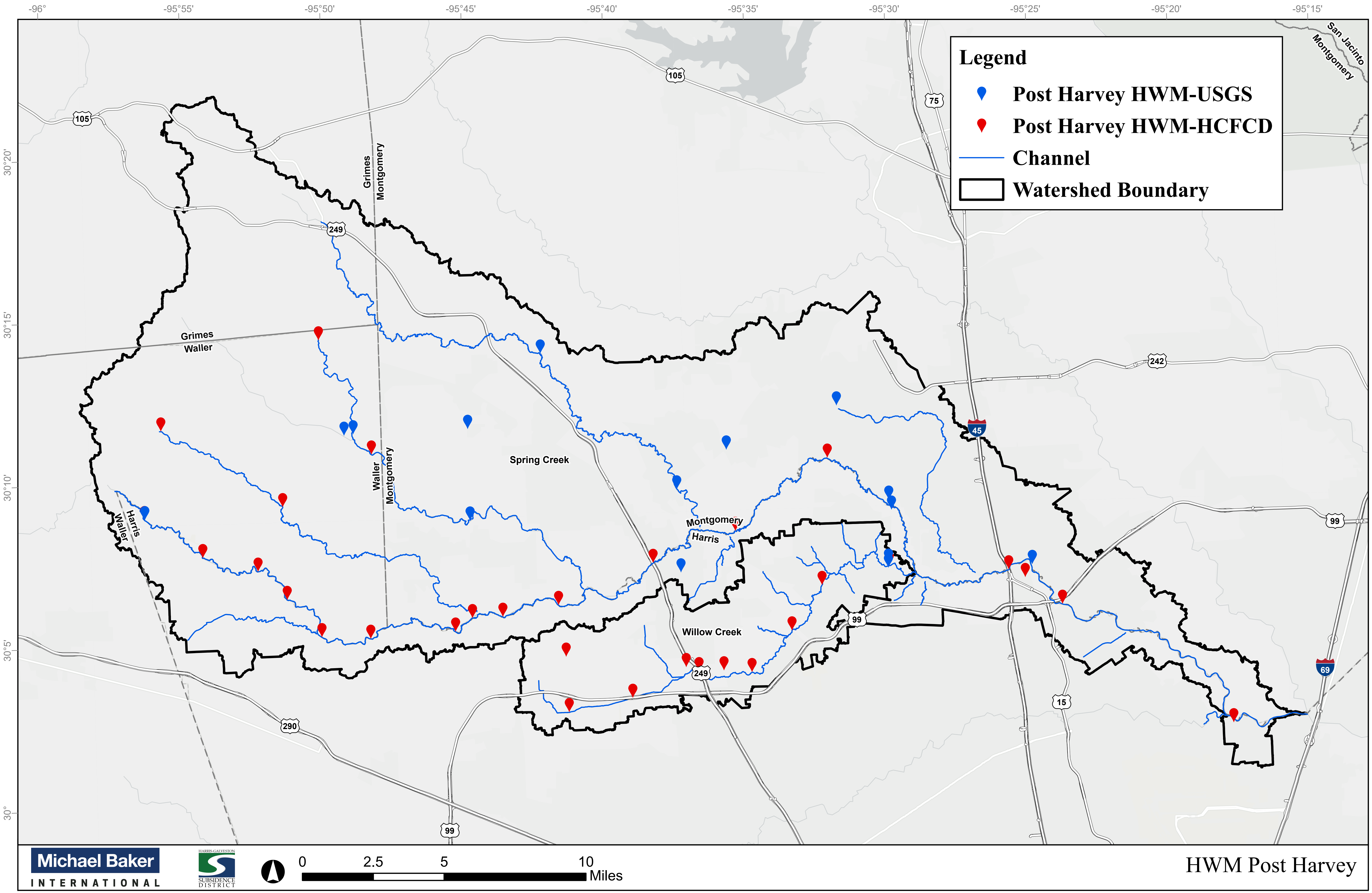


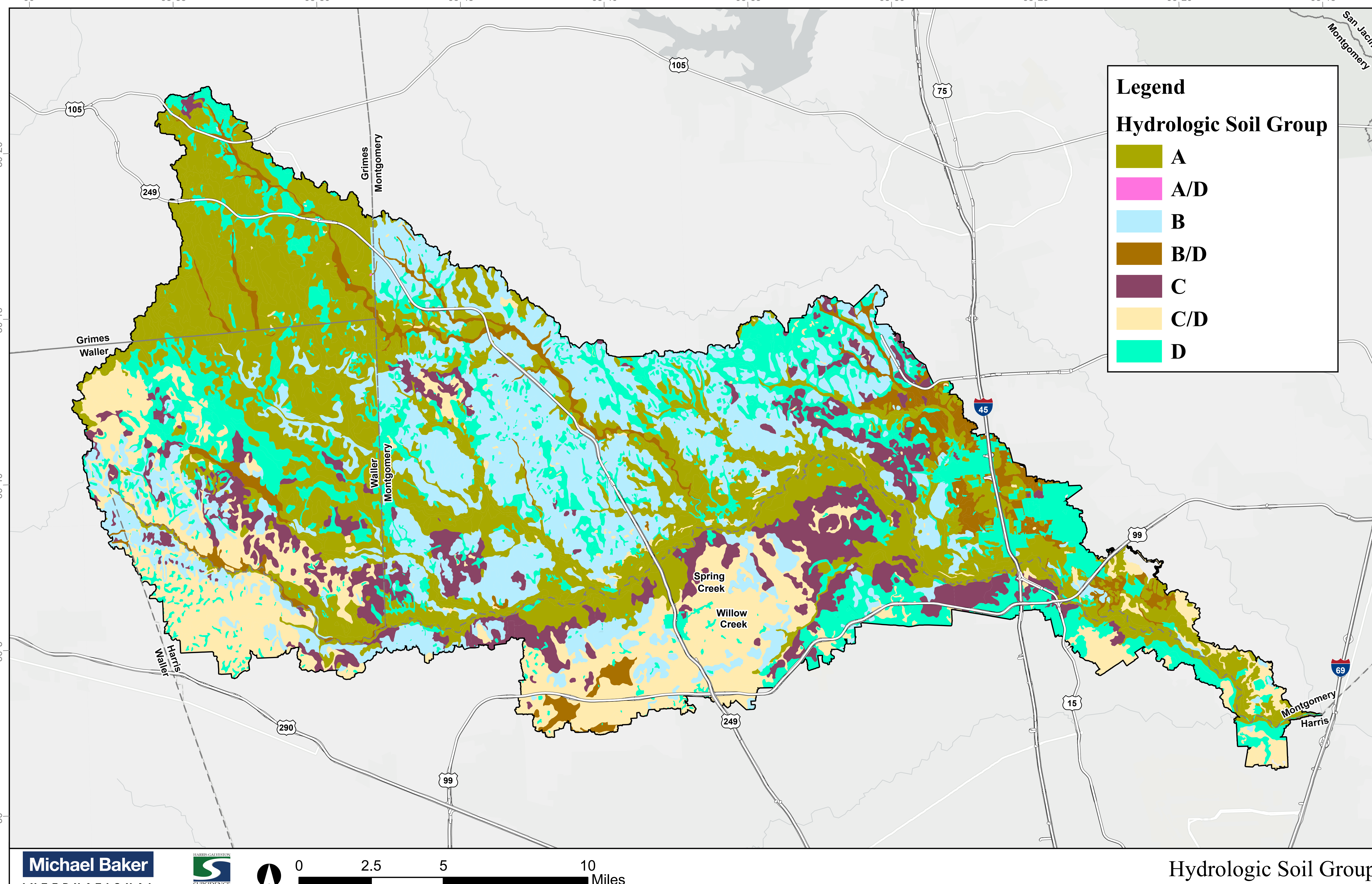
Population for the year 2020


Grimes
Montgomery
Harris
N
Legend
No of People per Census blocks
In 2070
0 - 500
500 - 2000
2000 - 6000
> 6000
Watershed Boundary
Michael Baker
INTERNATIONAL
0
2.5
5
10
Miles
Population for the year 2070



HWM extracted from HCFCD and USGS


Legend
Post Harvey HWM-USGS
Post Harvey HWM-HCFCD
Channel
Watershed Boundary
Spring Creek
Willow Creek
Grimes
Waller
Montgomery
Harris
San Jacinto
-96°
-95°55'
-95°50'
-95°45'
-95°40'
-95°35'
-95°30'
-95°25'
-95°20'
-95°15'
30°20'
30°15'
30°10'
30°5'
30°
0 2.5 5 10
Miles
Michael Baker
INTERNATIONAL
HWM Post Harvey



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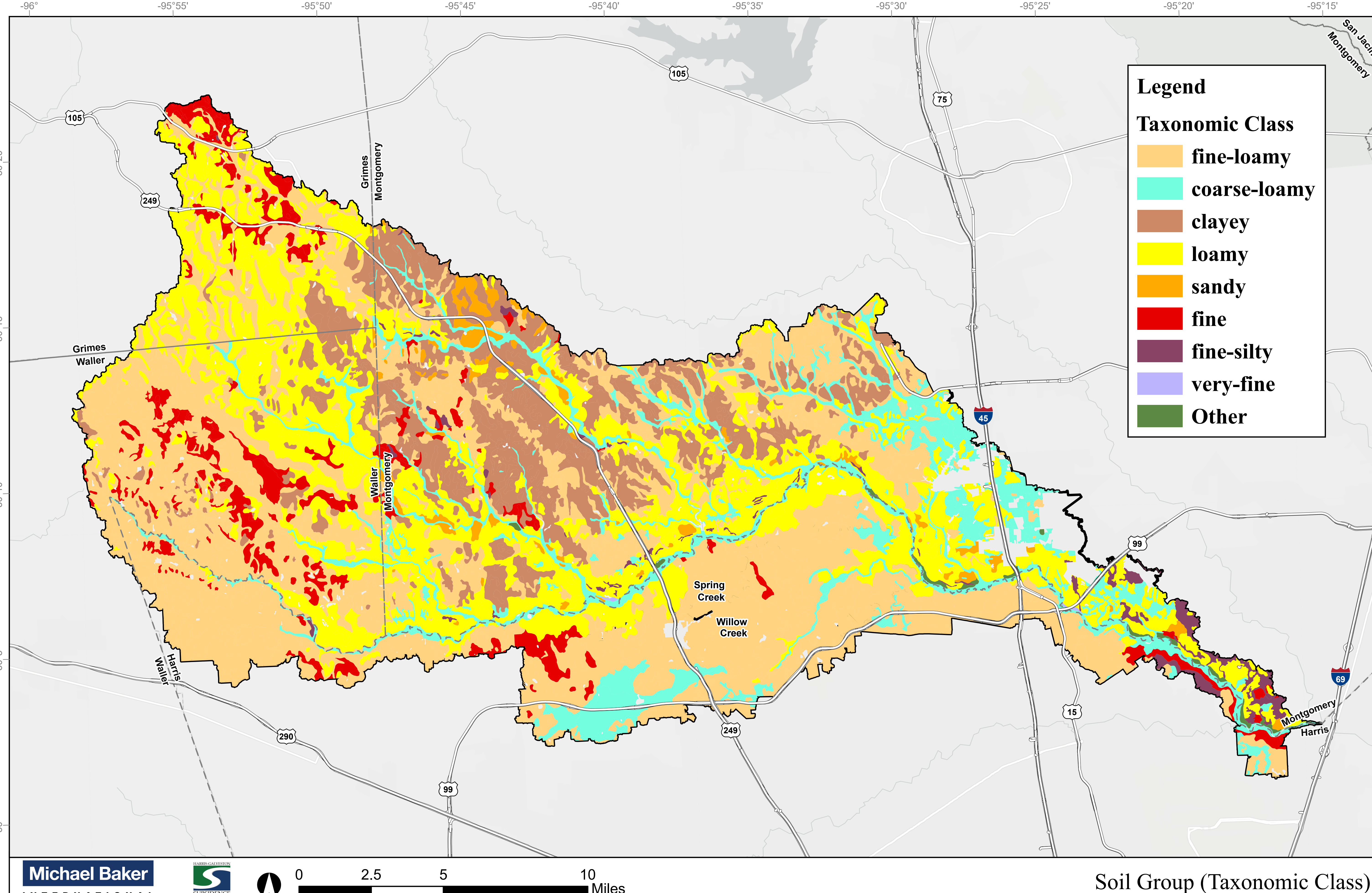
Harris-Galveston Subsidence District

Hydrologic Soil Group



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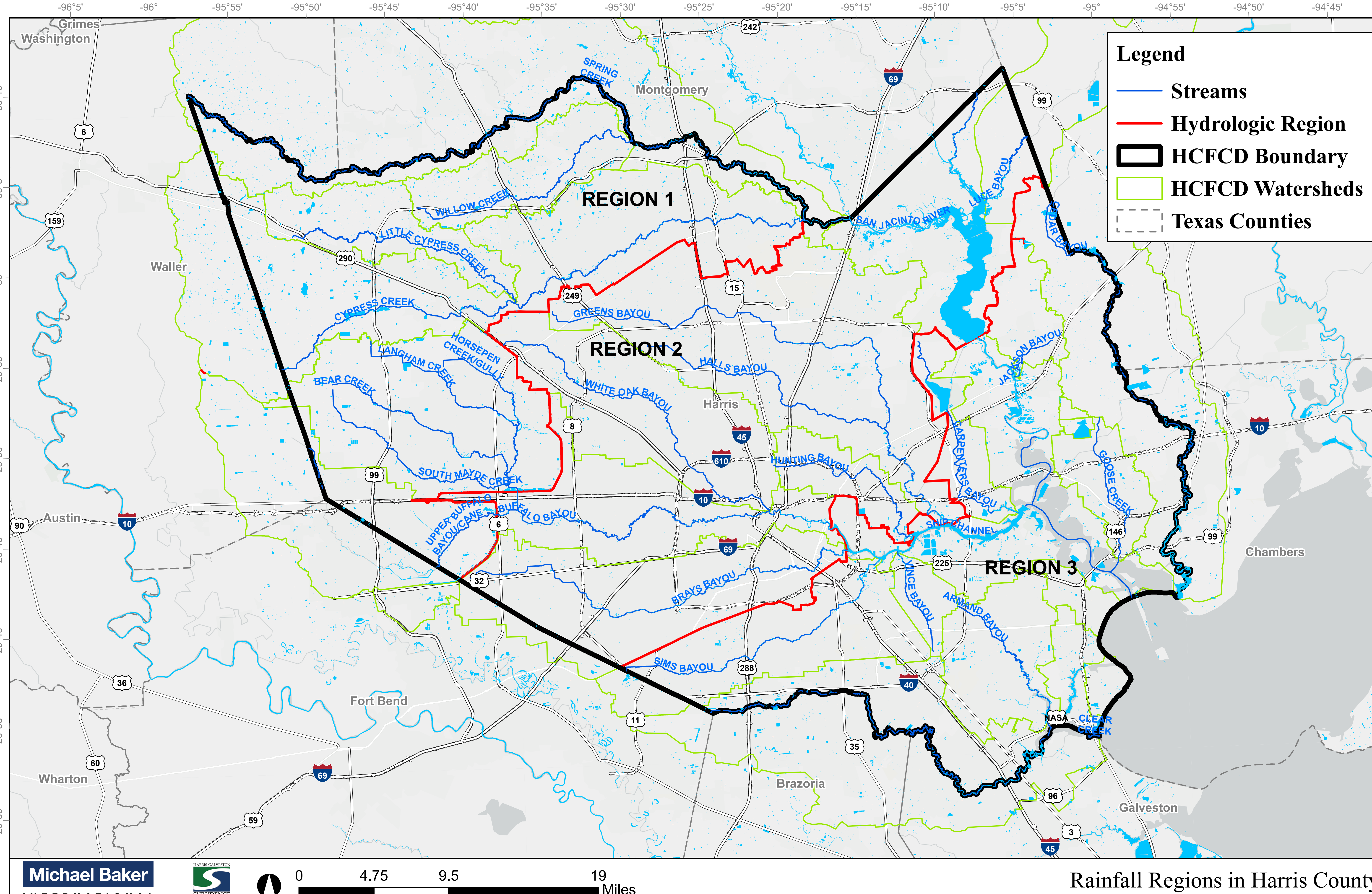
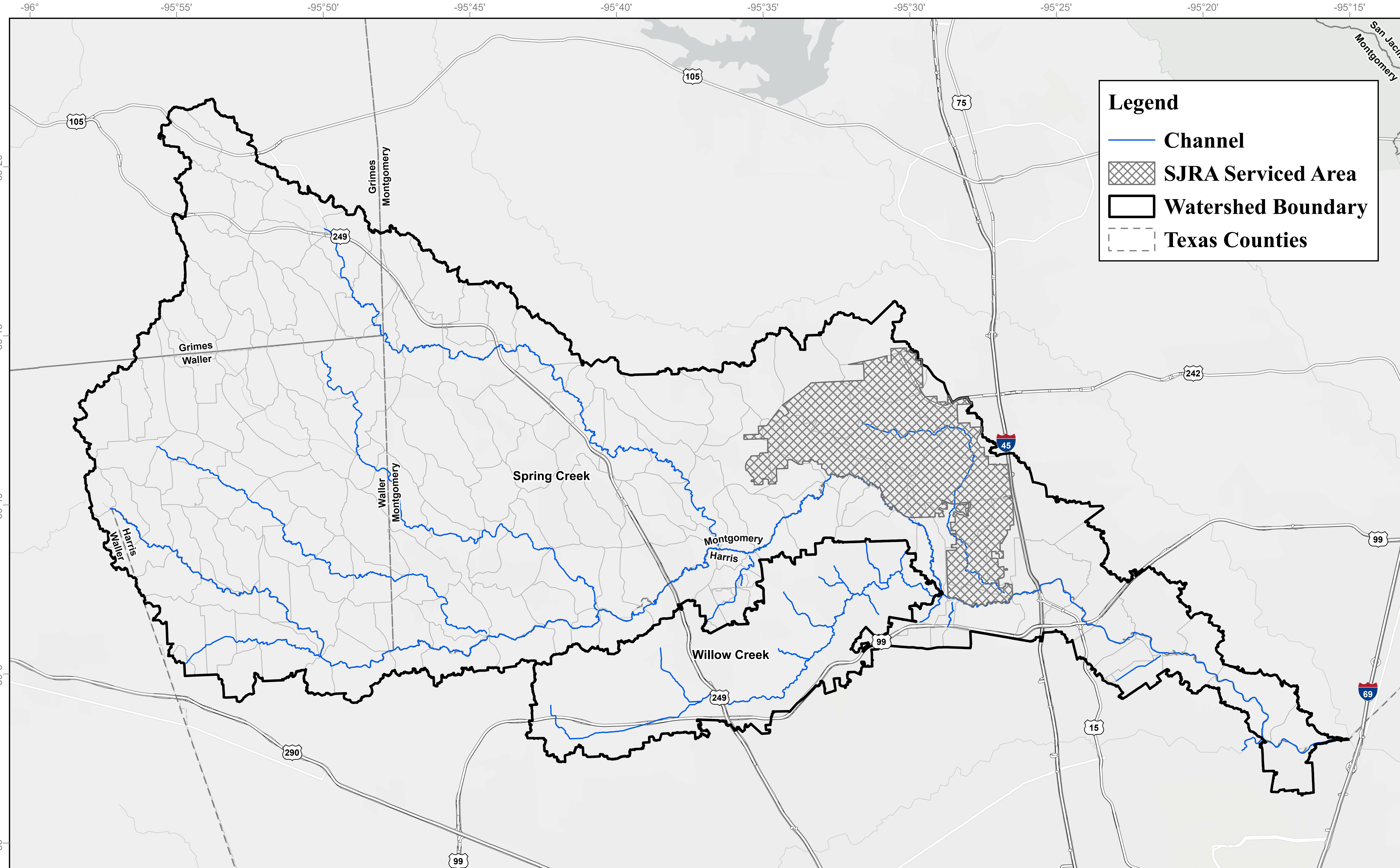
Soil Group (Taxonomic Class)



Rainfall Regions in Harris County

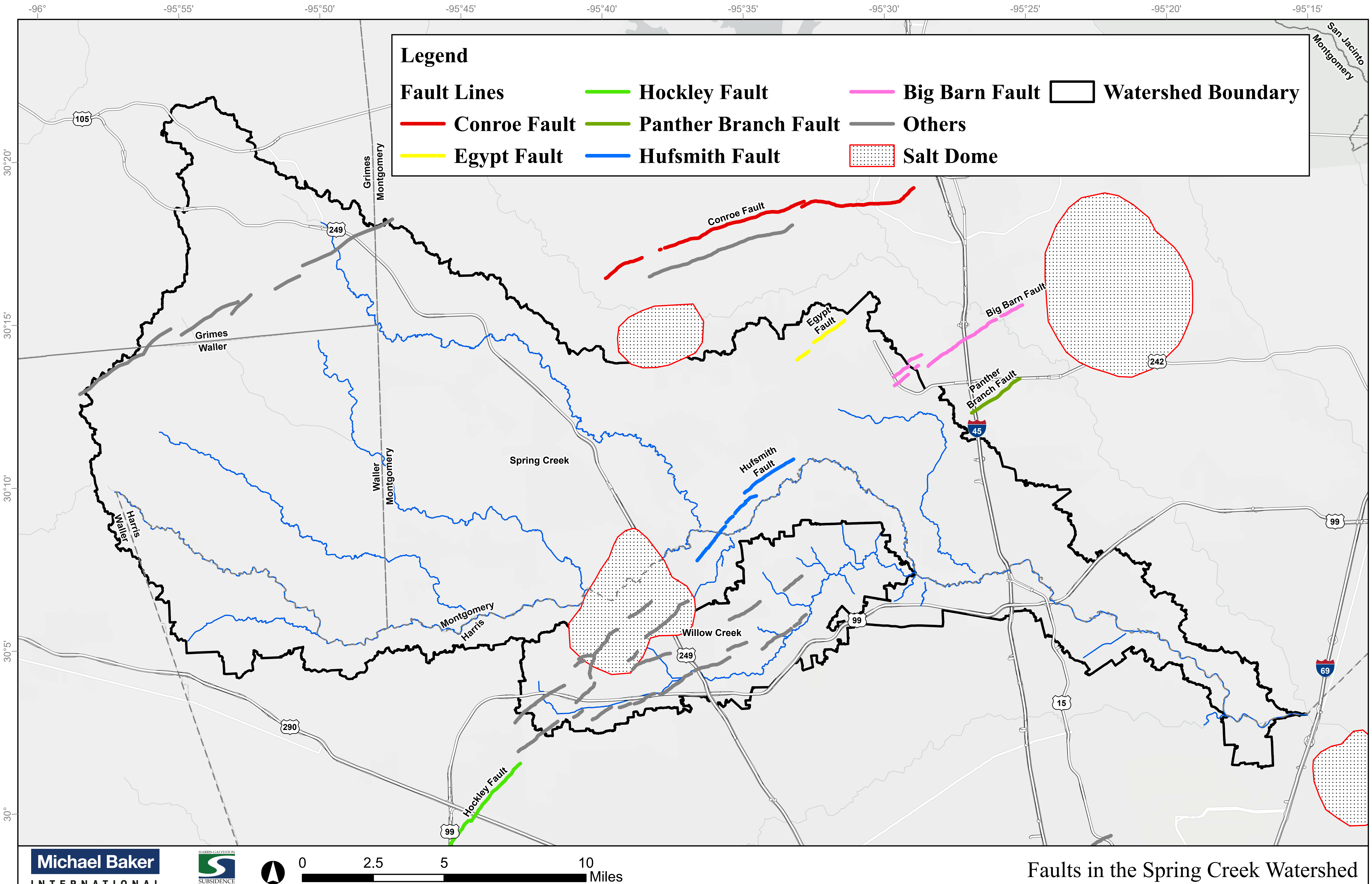


Michael Baker INTERNATIONAL

HARRIS-GALVESTON SUBSIDENCE DISTRICT

0 2.5 5 10 Miles

SJRA Serviced Area



Faults in the Spring Creek Watershed