# Characterization Report for Indicator Bacteria in the Big Creek Watershed

Segment: 1202J Big Creek


*Big Creek at Whaley-Long Point Road*

November 2019

# Characterization Report for Indicator Bacteria in the Big Creek Watershed

Segment

1202J, Big Creek

Prepared for
Total Maximum Daily Load Program
Texas Commission on Environmental Quality
MC–203
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# List of Acronyms and Abbreviations

| | |
|---|---|
| AU | Assessment Unit |
| CAFO | Concentrated Animal Feeding Operation |
| cfu | Colony-Forming Units |
| CRP | Clean Rivers Program |
| CWA | Clean Water Act |
| DMR | Discharge Monitoring Report |
| DO | Dissolved Oxygen |
| *E. coli* | *Escherichia coli* |
| FIB | Fecal Indicator Bacteria |
| EPA | (U.S.) Environmental Protection Agency |
| H-GAC | Houston-Galveston Area Council |
| IR | Texas Integrated Report of Surface Water Quality |
| LDC | Load Duration Curve |
| mL | Milliliter |
| MPN | Most Probable Number |
| MS4 | Municipal Separate Storm Sewer System |
| MUD | Municipal Utility District |
| NOAA | National Oceanic and Atmospheric Administration |
| NPDES | National Pollutant Discharge Elimination System |
| OSSF | On-site Sewage Facility |
| RMU | Resource Management Unit |
| SSO | Sanitary Sewer Overflow |
| SWQS | State Water Quality Standard |
| TCEQ | Texas Commission on Environmental Quality |
| TMDL | Total Maximum Daily Load |
| TPDES | Texas Pollutant Discharge Elimination System |
| TPWD | Texas Parks and Wildlife Department |
| USGS | United States Geological Survey |
| WWTF | Wastewater Treatment Facility |

# Section 1 - Introduction

## 1.1 Background

Big Creek and its tributaries drain an area of over 200 square miles of central Fort Bend County, Texas (Figure 1). The watershed for this tributary to the Brazos River contains a variety of land uses but is primarily rural and agricultural in character, with several large industrial users and small population centers. These existing land uses, the impacts of increased residential development pushing into the watershed from the north, and natural sources of pollution have led to a variety of water quality challenges for Big Creek. Elevated levels of fecal waste pose risks for recreation in the waterway, and levels of oxygen and habitat conditions in the waterway are sometimes insufficient to support its aquatic life.

Because of these water quality issues, the Houston-Galveston Area Council (H-GAC) was tasked by the Texas Commission on Environmental Quality (TCEQ) to prepare the Big Creek Watershed Characterization Report to assess the status and potential means to address water quality challenges in the creek. This approach sought to quantify and describe water quality trends, identify potential sources of pollution (particularly fecal bacteria), and develop information on which to base decisions about future approaches to improving water quality.

Additionally, this project supported and facilitated an initial public outreach effort designed to inform local stakeholders and seek feedback on subsequent steps of addressing water quality in the creek. Likely next steps are the development of a Total Maximum Daily Load (TMDL) study for indicator bacteria and subsequent Implementation Plan (I-Plan), with the potential for developing a locally-led Watershed Protection Plan to address additional stakeholder and TCEQ-identified water quality concerns.

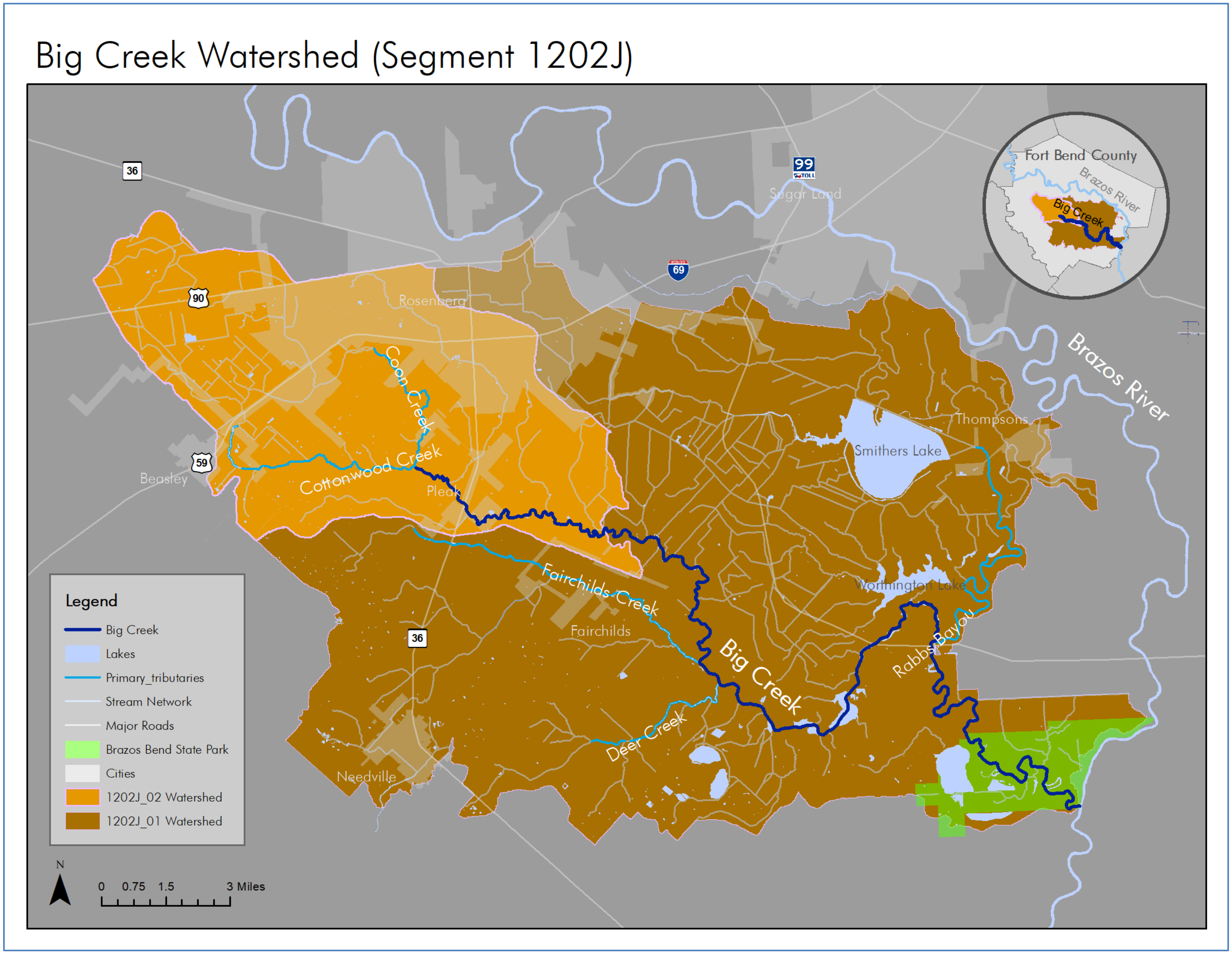


*Figure 1 - The Big Creek Watershed*

## 1.2 Water Quality Standards

Section 303(d) of the federal Clean Water Act (CWA) requires all states to identify waters that do not meet, or are not expected to meet, applicable water quality standards. State Water Quality Standards (SWQS) are developed based on the uses designated for each waterway.

These state standards are codified as state rules under Title 30, Chapter 307 of the Texas Administrative Code. The standards are written by the TCEQ under the authority of the CWA and the Texas Water Code. The U.S. Environmental Protection Agency (EPA) approves the Texas SWQS, which are designed to:

- designate the uses, or purposes, for which the state's water bodies should be suitable;
- establish numerical and narrative goals for water quality throughout the state; and
- provide a basis on which TCEQ regulatory programs can establish reasonable methods to implement and attain the state's goals for water quality.

The standards set explicit goals for the quality of streams, lakes, rivers, and bays throughout the region to protect the public's health and water supply, support aquatic life, and prevent degradation of water quality. Criteria for pollutants or conditions relevant to the standards (e.g., appropriate levels of DO, temperature, pH, dissolved minerals, toxic substances, and bacteria) are established to evaluate the ability of the waterways to support these uses.

The TCEQ meets the requirements of the CWA[1] by collecting and assessing water quality samples in its waterways. The assessments derived from this data are completed every two years[2] and are summarized in the Texas Integrated Report of Surface Water Quality (IR). Those water bodies that do not support one or more of the designated uses of the waterway, as measured by compliance with the SQWS, are included in the report's 303(d) list of impaired waterways.

The primary focus of this watershed characterization report are the elevated levels of fecal waste that affect Big Creek's ability to support the SWQS for contact recreation.

[1] Specifically, sections 350(b) and 303(d)
[2] Although this report references the approved 2014 IR, Draft 2016 and 2018 versions were in the review and approval process during this project. The 2016 IR was subsequently approved on August 6, 2019.

## 1.3 Contact Recreation and Bacteria

Pathogens in human and animal waste can cause gastrointestinal and other illnesses and represent a public health risk during contact recreation[3] in contaminated waterways. The presence of fecal waste is measured using indicator bacteria or other indicators common to all warm-blooded animals. The presence of fecal indicator bacteria (FIB) suggests that human and animal wastes are reaching a waterway from a variety of potential sources, including inadequately treated human wastewater, agricultural animals, domestic pets, and wildlife.

The SWQS for contact recreation in freshwater systems uses the bacterium species *Escherichia coli* (*E. coli*) as the indicator for criteria[4] to assess whether a waterway can meet its contact recreation use designation. *E. coli* bacteria are found in human and animal intestines and feces and are easily assessed and predictive of human health risk in freshwater systems. Elevated FIB concentrations represent the most common water quality impairment in Texas, and this issue is widespread in the greater Houston region.

On February 12, 2014, the TCEQ adopted revisions to the Texas SWQS including the categorical levels of recreational use and their associated criteria. Recreational use consists of five categories for freshwater. Big Creek is classified as having a Primary Contact Recreation[5] use designation. Therefore, its evaluation for compliance with the SWQS for contact recreation is based upon the criteria for that use designation[6], which are 126 cfu/100ml (for the geomean of the sampling data) and 399 cfu/100ml (for a single sample). Big Creek was first identified as being unable to support the contact recreation standard criteria in 2002 and has maintained an impairment for this standard through subsequent IRs.

[3] Contact recreation includes activities that pose a significant risk of ingestion of water (e.g., swimming, wading by children, water skiing, diving, tubing, surfing, and the following whitewater activities: kayaking, canoeing, and rafting).

[4] Criteria are expressed as the number of bacteria per 100 milliliters (mL) of water [in terms of colony-forming units (cfu), most probable number (MPN), or other applicable reporting measures].

[5] Waterbodies are designated for Primary Contact Recreation unless sufficient site-specific information demonstrates that elevated concentrations of FIB frequently occur due to sources of pollution that cannot be reasonably controlled by existing regulations; wildlife sources of bacteria are unavoidably high; there is limited aquatic recreational potential; or primary or secondary contact recreation is considered unsafe for other reasons such as ship and barge traffic.

[6] While this characterization report focuses on contact recreation impairment and FIB, it is also worth noting that aquatic life use standard for Big Creek is Minimal for AU 1202J_02 (upstream) but becomes High in AU 1202J_01 after flow appreciably increases after the confluence of several tributaries. Other concerns noted in the 2014 IR impact, or may impact, the aquatic life use.

*Figure 2 - Big Creek at Boothline Road*

## 1.4 Total Maximum Daily Load Program

As part of the CWA requirements, states must develop a TMDL for each pollutant that contributes to the impairment of a listed water body. The TCEQ is the lead agency responsible for developing TMDLs for impaired surface waters in Texas.

A TMDL is like a budget – it determines the amount of a pollutant that a water body can receive and still meet its applicable water quality standard. A TMDL is commonly expressed as a load with units of mass per unit of time but may be expressed in other ways. When a TMDL is established, an I-Plan is developed to identify the regulatory and voluntary management measures necessary to improve water quality and restore full use of the water body.

The TMDL Program is a major component of Texas's overall process for managing the quality of its surface waters. The program addresses impaired or threatened streams, reservoirs, lakes, bays, and estuaries (water bodies) in, or bordering on, the state of Texas. The primary objective of the TMDL Program is to restore and maintain the beneficial uses – such as drinking water supply, recreation, support of aquatic life, or fishing – of impaired or threatened water bodies. H-GAC is one of the partners that supports the TCEQ in the development of TMDLs and I-Plans within its 13-county region.

## 1.5 Characterization Report Purpose and Organization

This document will consider the extent and contributing factors related to the contact recreation impairment in Big Creek (Segment 1202J). The primary purpose of this report is to provide background information on watershed characteristics (geography, hydrology, land use, potential sources of contamination, and extent and character of the contact recreation impairment) to inform subsequent TMDL and I-Plan development processes. Other water quality issues and concerns raised by local stakeholders in the preliminary review and feedback phase of this project are included for context and reference.

The primary elements of this report are:

- introduction (Section 1);
- watershed description (Section 2);
- historical data review (Section 3);
- preliminary flow assessment (Section 4);
- identification of potential sources of contamination (Section 5); and
- summary of findings (Section 6).

*Figure 3 - Big Creek at Hartledge Road*

# Section 2 – Watershed Description

## 2.1 Description of the Big Creek System

### Segment Description

Big Creek (Segment 1202J) is an unclassified[7] stream segment located in the central Fort Bend County portion of the Brazos River Watershed[8] (Figure 4). The main stem of this freshwater stream is approximately 34 miles long. The headwaters of the waterway lie in ephemeral drainage and minor streams of the primarily rural areas south and west of Rosenberg. Additional headwaters areas south of the Sugar Land area feed tributaries (e.g. Rabbs Bayou) that enter the main channel lower in the system. The officially-designated segment itself starts at the confluence of Cottonwood and Coon Creeks and receives flow from a variety of other smaller tributaries in other parts of the system. For much of its length, the segment is a small to medium sized stream that has been heavily modified in many areas to act as a drainage conveyance or as part of agricultural improvements (e.g., berms in riparian edges of fields). The creek's terminal end is at its confluence with the Brazos River at the eastern edge of Brazos Bend State Park. Unlike the channel upstream, the waterway within the confines of the park is relatively unmodified and has more natural riparian areas.

TCEQ evaluates two separate portions of the waterway, called assessment units (AUs). These AUs (Figures 5 and 6) from downstream to upstream are:

1) 1202J_01 – the portion of Big Creek from its confluence with the Brazos River immediately east of Brazos Bend State Park upstream to a point just east of FM 2977 south of the City of Rosenberg; and
2) 1202J_02 – the portion of Big Creek upstream of 1202J_01 to its headwaters at the confluence of Cottonwood Creek and Coon Creek just west of Highway 36 and the City of Pleak.

The primary difference between the AUs are that 1202J_02 (upstream) is intermittent with pools, and has an intermediate aquatic life use designation, while 1202J_01(downstream) is a perennial stream with high aquatic life use designation. However, in consideration of the primary focus of this characterization effort, the AUs have the same contact recreation designation.

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[7] "Unclassified" is a designation given to stream segments that are tributaries to a primary, classified segment.
[8] Specifically, Big Creek falls within the watershed of Segment 1202, Brazos River Below Navasota River.

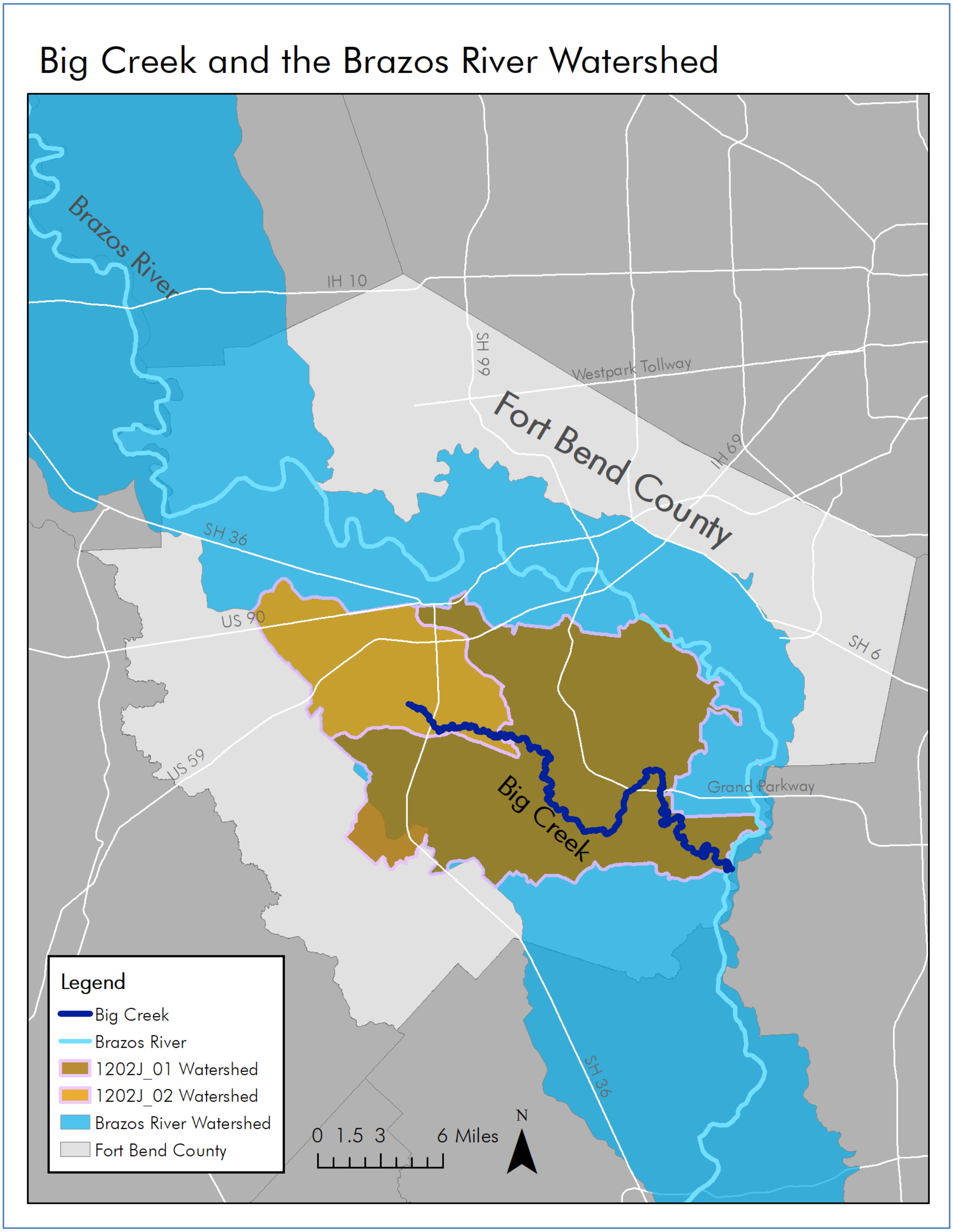


*Figure 4 - Big Creek and the Brazos River Watershed*

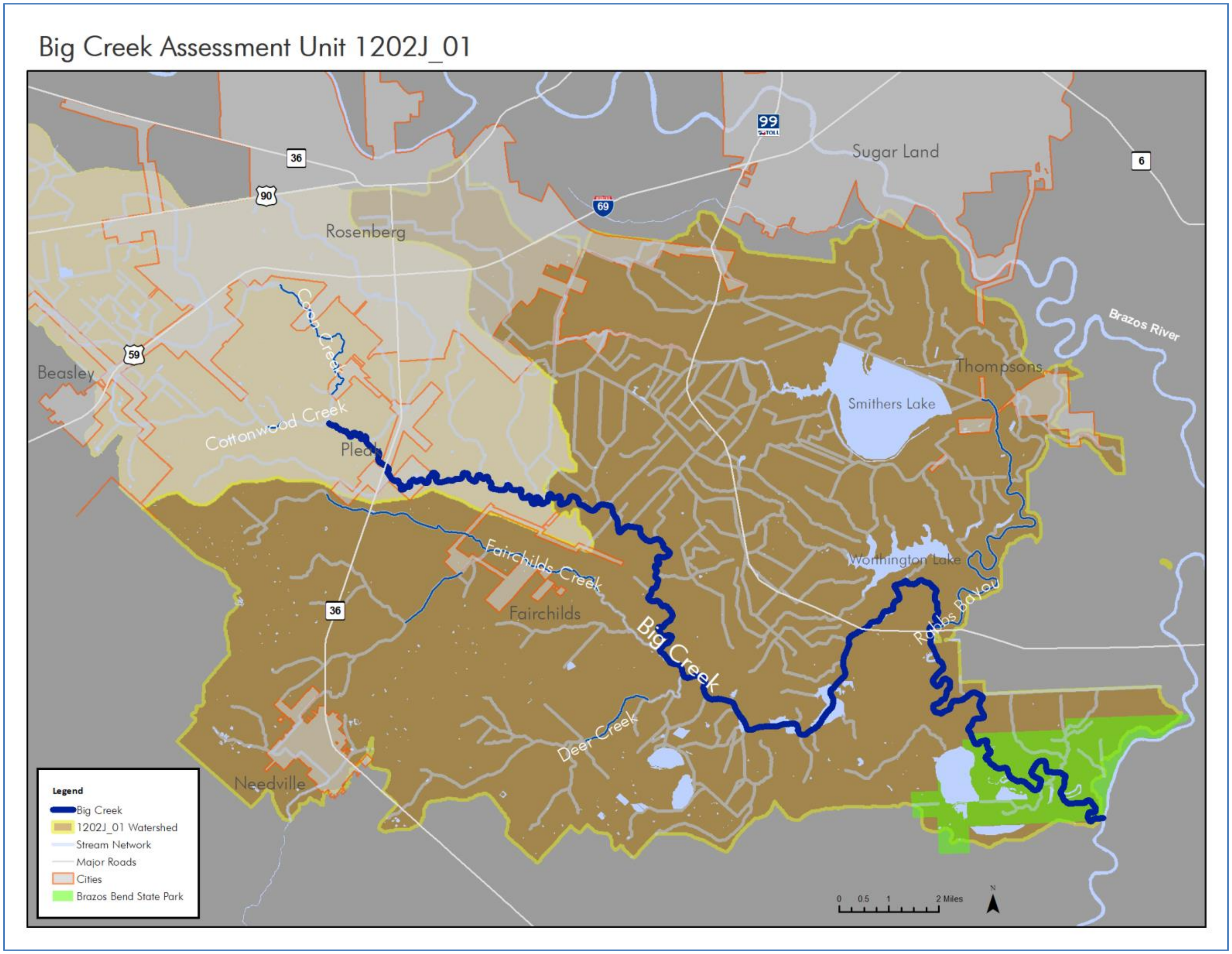


*Figure 5 - Big Creek Assessment Unit 1202J_01 (Downstream)*

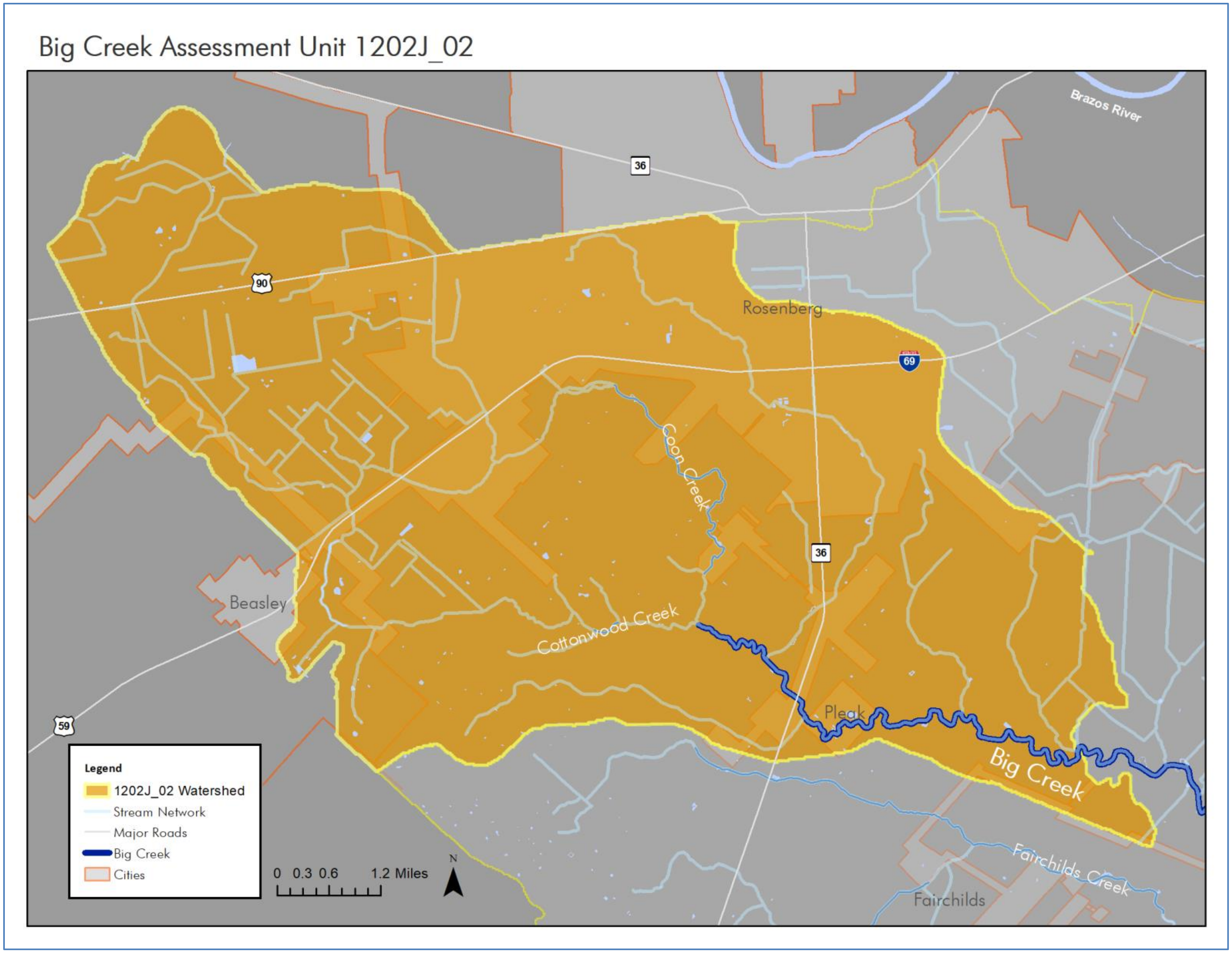


*Figure 6 - Big Creek Assessment Unit 1202J_02 (Upstream)*

## Stream Network

In addition to the 34 stream miles of Big Creek itself, its drainage network consists of an additional 414 miles of tributaries, impoundments, and drainage conveyances. There are six primary tributaries to the main channel: Coon Creek, Cottonwood Creek, Seabourne Creek, Fairchilds Creek, and Deer Creek in AU 1202J_02, and Rabbs Bayou in AU 1202J_01. In addition, AU 1202J_01 receives conditional flows from the outlets of Smithers and Worthington Lakes. Close to the end of AU 1202J_01, a large drainage bypass channel diverts flow from the main channel directly to the Brazos River during certain flow conditions. Figure 7 is a network diagram (not to scale) of the progression of tributaries and components of the system from upstream (left and top) to downstream (right), emphasizing the dual headwater areas of the system.

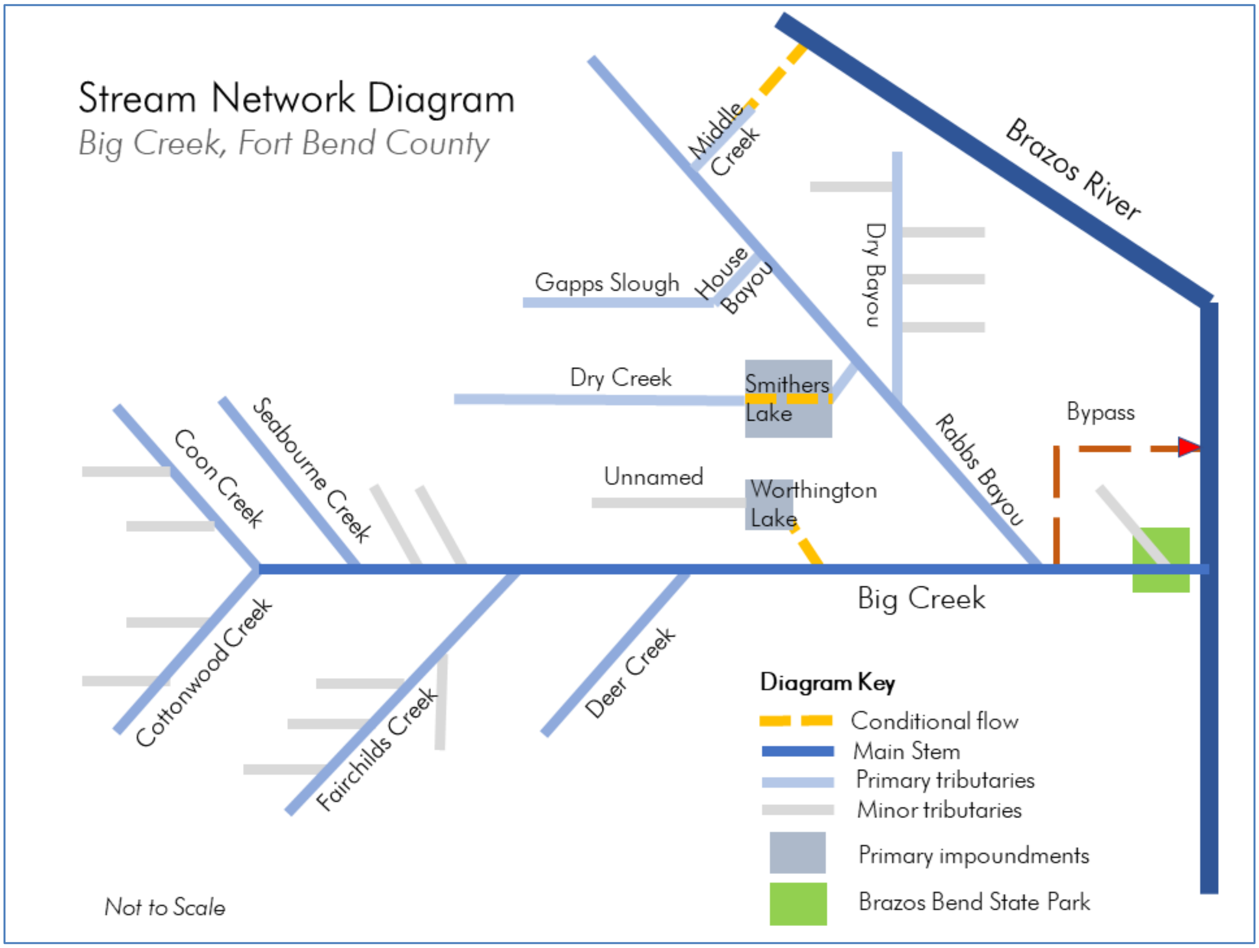


*Figure 7 - Stream Network Diagram of Big Creek*

## Primary Tributaries

*Coon Creek* – Coon Creek is a small, intermittent tributary draining an area of transitional mixed land use along the southwestern border of the City of Rosenberg. It is one of the two primary headwaters tributaries of AU 1202J_02.

*Cottonwood Creek* – Along with Coon Creek, Cottonwood Creek is the second primary headwaters tributary for Big Creek, whose official segment begins at their confluence. Most of the drainage area for this tributary is a mix of agricultural areas and light rural development. Its headwaters include several areas of historic or active oil production west of Rosenberg.

*Seabourne Creek* – Seabourne Creek originates immediately west of Rosenberg in agricultural field drainage. However, much of its length passes areas of suburban and exurban development before its confluence with Big Creek immediately downstream of the confluence of Cottonwood and Coon Creeks. Its most notable feature is the dense riparian buffer that is maintained around an appreciable portion of its middle sections.

*Fairchilds Creek* – Fairchilds Creek's headwaters are in the developed area of Needville, as well as agricultural and rural surrounding areas. Its immediate environs along its length have rural and agricultural uses typical of the watershed. As it approaches its confluence with Big Creek immediately west of FM 1994, its riparian forest cover and relatively natural floodplain broadens, although it remains a heavily modified and maintained drainage channel. Several natural and constructed impoundments intercept sheet flow in this area, providing potential treatment.

*Deer Creek* – Deer Creek is similar to the other tributaries described in this west/southwest area of the watershed. Its immediate riparian areas are a mix of rural and agricultural uses other than the very start of its flow in the area near Highway 36, east of Needville. It joins the Big Creek system immediately downstream of the Fairchilds Creek confluence (west of FM 1994) benefitting from the same natural and constructed wetland impoundments of this area.

*Rabbs Bayou* – The Rabbs Bayou system drains most of the watershed area east of Rosenberg and north and east of Smithers Lake. It includes flow from a variety of smaller tributaries, drainage from street systems and conveyances from the developing areas east of Rosenberg, and outflow from Smithers Lake. Its channel upstream of the confluence with the outflow from Smithers Lake is highly modified, while the stretch below this point is relatively more natural (though still historically modified and maintained as a drainage conveyance). The confluence of Rabbs Bayou and Big Creek is located directly upstream of the drainage bypass.

## Conditional Flow Contributions

*Smithers Lake* – Smithers Lake is created by the impoundment of drainage from the center of the watershed to form an impoundment used by the W.A. Parish Generating Station, a large electric generating facility serving the region. Water levels on Smithers Lake are maintained by a control structure on its eastern end, supplemented from time to time by water supply canal flows. Flow through the Smithers Lake system is dependent on the lake level and operating needs of the plant. In discussions with stakeholders and county drainage district staff, flow from this system is not typically appreciable enough to greatly impact downstream hydrology.

*Worthington Lake* – Worthington Lake is another artificial impoundment but is not actively maintained. It intercepts a small amount of drainage, and outflow is dependent solely on lake level exceeding the impounding structure. Flow from this system is not appreciable even in overflow conditions.

## Other System Features

*Drainage Bypass* – A large drainage bypass structure (Figure 8) intercepts flow exceeding a static elevation at the confluence of Rabbs Bayou and Big Creek. It also intercepts flow coming south from the area east of Rabbs Bayou and west of the Brazos River (including Waters Lake Bayou), effectively removing this area from the Big Creek Watershed. At its eastern terminus, a flap gate control structure helps prevent backflow from the Brazos River. However, at high enough elevation, Brazos River water floods this low-lying area, and may move backward into the system at this point.

*WCA Fort Bend Landfill* – A series of small lakes and active landfill cells make up a large tract of land directly downstream of the confluence of Big Creek, Deer Creek and Fairchilds Creek, just east of FM 1994. Stormwater reaching the active face of the landfill is required to be handled separately and segregated from flows reaching Big Creek, but flow from the external areas continues through the non-active site to reach Big Creek. Many of the impoundments and features in this small area are remnants of previous activities on this property, including extensive sulfur mining in the area.

*Figure 8 - Drain Bypass Structure at the Confluence of Rabbs Bayou and Big Creek*

## Drainage Area/Watershed Delineation

Big Creek and its associated tributaries drain an area of 221 square miles in total. The watershed for the system was delineated using multiple geospatial datasets, aerial image evaluation, stakeholder feedback, and limited windshield survey reconnaissance. The starting point for delineating the watershed was the United States Geological Survey's (USGS) National Hydrography Dataset Plus, which provides granular catchment level delineation. Adjustments were made to this dataset to account for hydrologic barriers, change in flow on the ground due to new development, and the large drainage bypass along the southeastern portion of the watershed. The watershed was further delineated to represent the respective drainage areas of the two AUs (Figure 9).

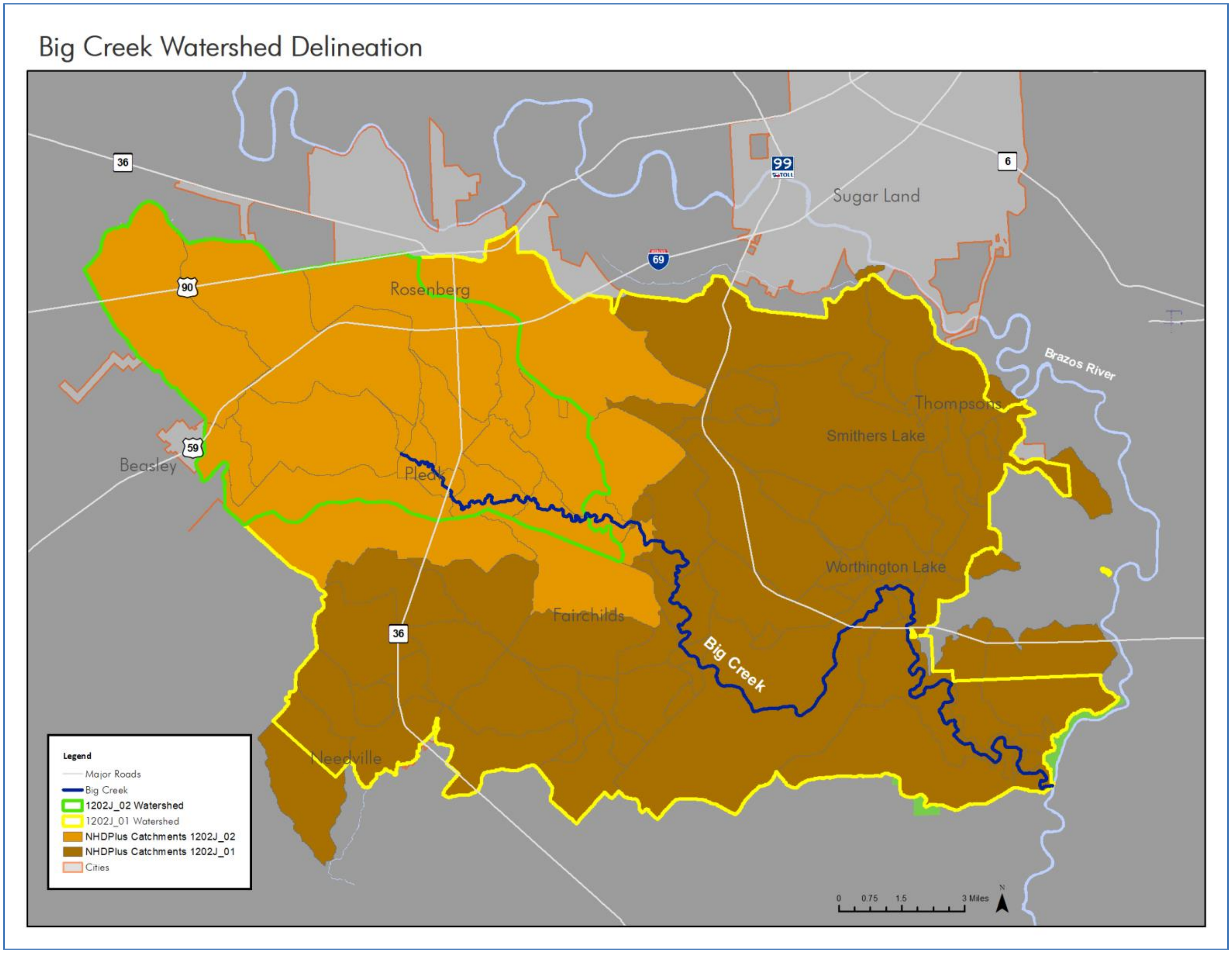


*Figure 9 - Big Creek Watershed Delineation*

## 2.2 Watershed Climate and Environmental Characteristics

### Precipitation and Temperature[9]

Average precipitation for the watershed is 47.78 inches per year over the last 10 years. This average obscures the impacts of several high rainfall events breaking historical records in recent years and exacerbates flooding issues in the watershed. Average monthly precipitation ranges from 2.80 to 5.00 inches. Rainfall occurs throughout the year with February and March seeing the least amount of rainfall while September and October stand out with the highest average rainfall, as those months correspond with tropical disturbances and the height of the hurricane season.

Average monthly air temperature ranges from slightly above 52ºF in January to slightly below 84ºF in the August.

### Elevation

There is little topographic change within the watershed, other than a gradual slope toward the southeast and the Brazos River, with approximately 40 meters of difference in overall elevation change. However, this overall difference overstates the average change in the watershed, as it includes the deepened conveyance profile of the creek and its channels. Many of the agricultural areas of the watershed have been specifically leveled for production, making overall elevation change less impactful to site-specific drainage. Additionally, flow within the system is less a function of overall elevation change, than specific, modified change within the waterways/channels themselves. In general, flow rates are typical of coastal plain waterways of this size.

### Water Usage

There are several adjudicated water rights within the Big Creek system. However, the only water right of appreciable volume is the impoundment and use of Smithers Lake water in electrical generation by the W.A. Parish Plant. Based on discussions with plant staff and Fort Bend County Drainage District staff, withdrawals from the impoundment do not have an appreciable impact on flows, or likely water quality impacts, downstream. For portions of AU 1202J_02, the waterway is dominated by wastewater effluent. The transition from groundwater to surface water in Fort Bend County may eventually impact water resources in the watershed but is not currently a factor in water usage patterns.

### Soils

Fine-textured soils dominate the county in general (Figure 10), with shallow, chalky, calcareous soils being common, limiting vegetative growth in some managed riparian areas and slopes.

[9] Based on National Oceanic and Atmospheric Administration (NOAA) weather station data for station GHCND:USC00418996, Thompsons 3 WSW, TX US. Data accessed on 7/14/2019 and 8/15/2019 at https://www.ncdc.noaa.gov/cdo-web/.

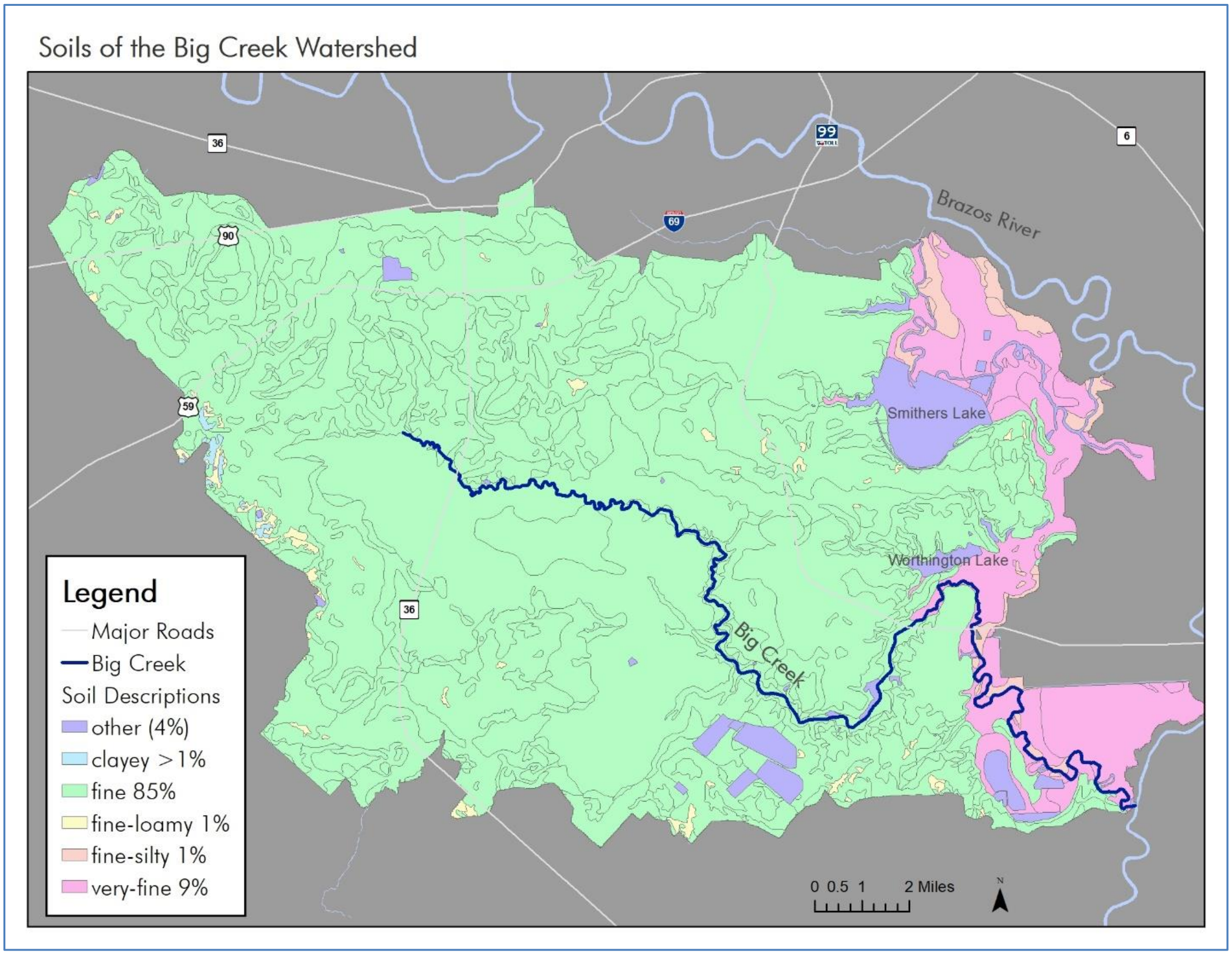


*Figure 10 - Soils of the Big Creek Watershed*

## Ecoregions

Big Creek falls primarily within the Northern Humid Gulf Coast Prairies area of the Western Gulf Coastal Plan, as defined by EPA's Level III and IV Ecoregion classifications[10] (Level IV Ecoregions in the watershed are shown in Figure 11). In its native state, these areas were characterized by extensive tallgrass prairie with small forested areas, often adjacent to riparian zones. A small portion of the eastern extent of the watershed falls within the Floodplains and Low Terraces region represented by the Brazos River floodplain. Typical native vegetation includes Little Bluestem, Switchgrass, and other dominant grasses, along with a variety of oak species, including native Live Oak. Centuries of development have altered much of the native species and habitat, with developed and agricultural areas being dominant over natural plant and animal communities in the areas outside relatively natural areas like Brazos Bend State Park. Even in its altered state, the area has a diverse array of animal life, with close to 300 bird species noted at Brazos Bend State Park. Areas in the watershed have had consistent issues with invasive

[10] Accessed from https://www.epa.gov/eco-research/level-iii-and-iv-ecoregions-state on 6/23/2019.

species like feral hogs (a specific concern for the focus of this effort) and various invasive plants (alligator weed, Chinese tallow, etc.).

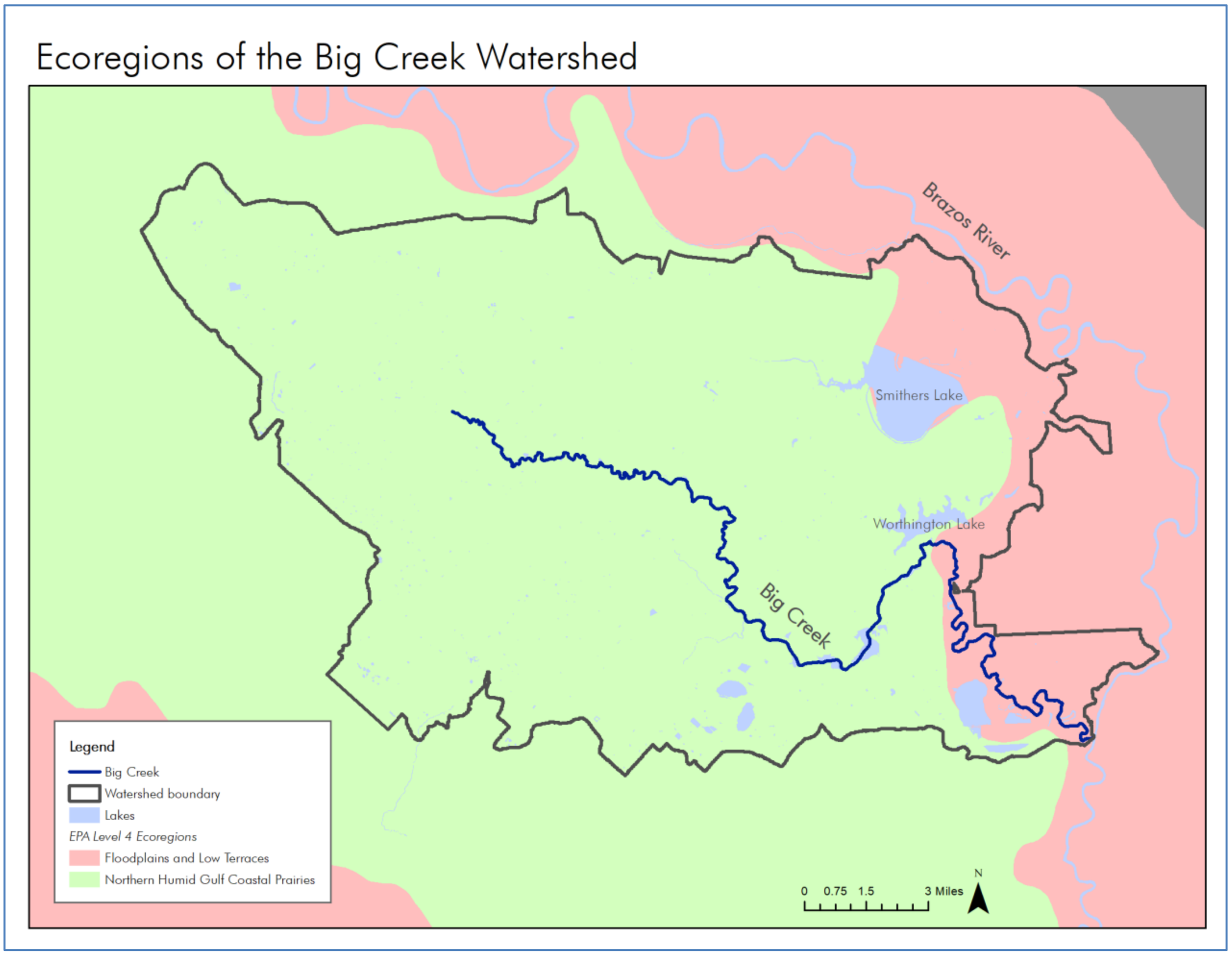


*Figure 11 - Level IV Ecoregions of the Big Creek Watershed*

## Local Political Geography

Big Creek falls wholly within Fort Bend County, and within the jurisdiction of the Fort Bend County Drainage District. It contains all or a portion of seven cities or census designated places, including the City of Sugar Land, the City of Rosenberg, the City of Needville, the Town of Thompsons, the City of Beasley, and the villages of Pleak and Fairchilds (Figure 12). Additional small communities without formal governmental structure exist in the area, although development outside of the suburban expansion of the Rosenberg area is generally closer to traditional small-town development patterns. There are 22 municipal utility districts (MUDs) in or partially in the watershed, all of which are clustered in areas directly adjacent to the City of Rosenberg. The other notable political jurisdictions in the watershed are Brazos Bend State Park, a portion of the West Fort Bend Management District, Lamar and Needville Independent School Districts and part of the service area of the Brazos River Authority.

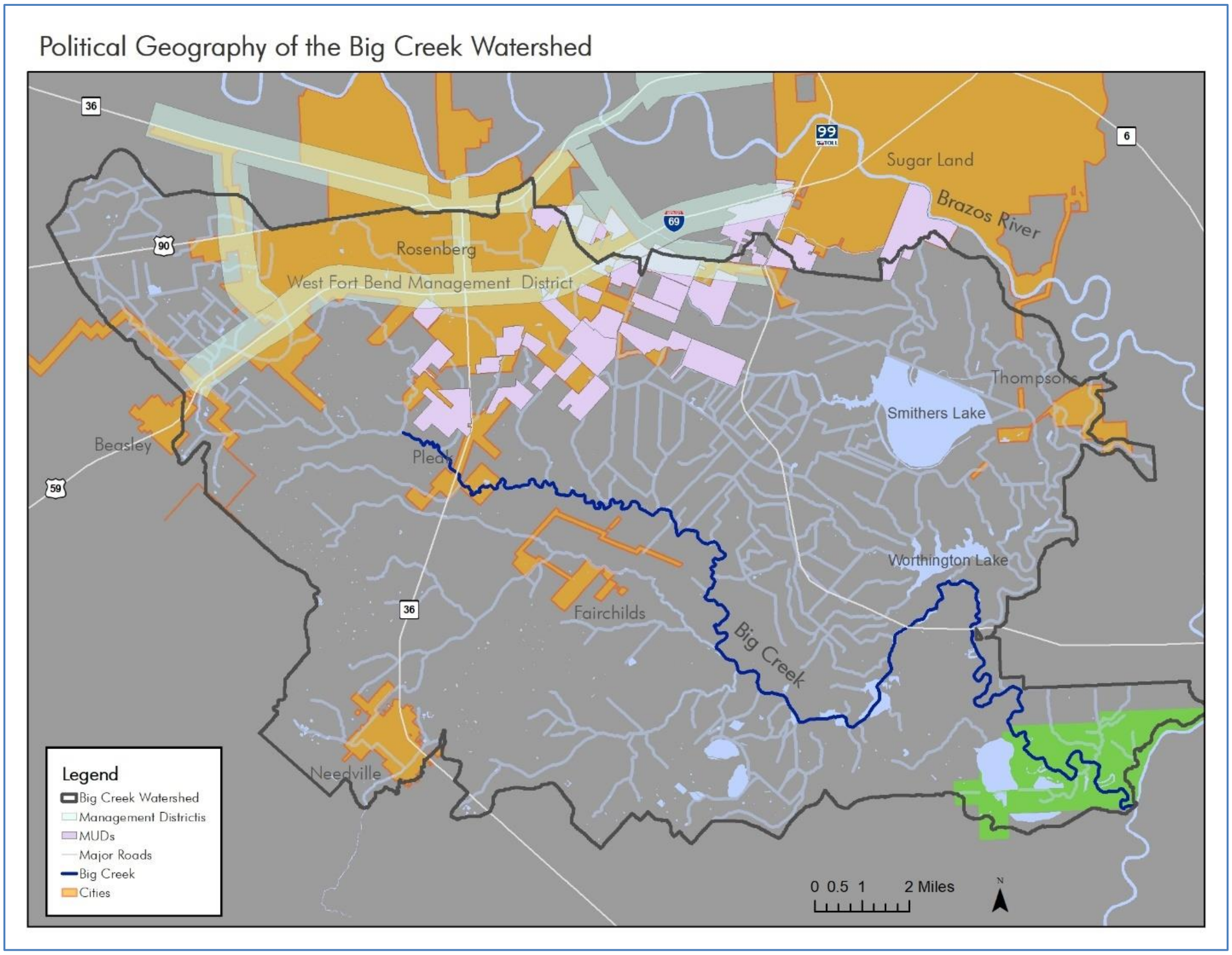


*Figure 12 - Political Geography of the Big Creek Watershed*

## 2.3 Watershed Population and Population Projections

The Big Creek Watershed contained a population of 58,442, representing 24,080 households, in 2018 (Table 1). Based on the H-GAC Regional Growth Forecast[11] demographic projections, the population of the watershed is expected to increase dramatically by 2040, at which point it will be 275,650, representing 103,130 households. This represents a net gain of 217,208 additional residents, a 372 percent increase.

*Table 1 – Population and Population Projections in the Big Creek Watershed*

| Year | 2018 | 2020 | 2030 | 2040 |
|---|---|---|---|---|
| **Population** | 58,442 | 65,108 | 163,556 | 275,650 |
| **Percent change, year to year** | - | 11% | 151% | 68% |

[11] More information on the Regional Growth Forecast can be found at http://www.h-gac.com/regional-growth-forecast/default.aspx.

Like other areas in the county and region, growth is generally pushing out from urban centers and along transportation corridors. However, the availability of MUDs and other districts as funding mechanisms for new development means development will not necessarily continue to expand in a contiguous manner.

*Figure 13 - Stormwater Management Structure near Seabourne Creek Park*

## 2.4 Land Cover and Land Use

Land cover describes the physical land type of an area, such as forest or open water, while land use describes how people are using the land[12]. Change in either the physical surface of the land or the way in which it is used can impact water quality. Both land cover and land use have gone through iterations of change across the history of the watershed but are currently changing most rapidly in portions of its northern and western areas around Rosenberg and major transportation corridors.

### Land Cover

The project area was historically a mix of tallgrass prairies, oak mottes, and low-lying wetlands. After several hundred years of successive waves of human occupation, much of the native landscape has been converted to other uses. Since the early settlement of the area, widespread agricultural production has been the dominant land cover (and land use) type. Recent decades have seen a more rapid transition to denser urban and suburban development (Figure 14).

[12] From "What is the Difference between Land Cover and Land Use?" Available online at: https://oceanservice.noaa.gov/facts/lclu.html. Accessed on May 13, 2019.

Land cover data[13] in the watershed indicates that the most predominant land cover type is still agricultural lands, with the combination of cultivated crops and pastureland comprising 51.4 percent of the area in both segments (Table 2). However, developed areas of varying intensity are common in the watershed (35.6 percent), especially in the aforementioned high growth areas, and an appreciable acreage of "natural"[14] areas still exist (11.3 percent). Figure 15 shows the distribution of land cover in the watershed. The balance of land cover types in the watershed is expected to continue to shift toward developed uses in the future, in line with the population and household projections in Section 2.3.

*Table 2 - Land Cover by Category*

| Land Cover Category | % of Total Land Cover | Acres |
|---|---|---|
| Open Water | 1.6% | 2,235 |
| High Intensity Developed | 0.8% | 1,091 |
| Medium Intensity Developed | 24.4% | 34,576 |
| Low Intensity Developed | 7.8% | 10,983 |
| Developed Open Space | 2.6% | 3,710 |
| Barren Areas | 0.0% | 14 |
| Forests and Shrublands | 7.5% | 10,670 |
| Pasture and Grasslands | 32.6% | 46,148 |
| Cultivated Crops | 18.8% | 26,604 |
| Wetlands | 3.8% | 5,410 |
| **Total** | **100%** | **141,441**[15] |

[13] Land cover data was derived from NOAA National Land Cover Dataset data for historic datasets, and H-GAC 10-class land cover converted from LANDSAT imagery for 2018 ("current") data.
[14] For the purposes of this description, "natural" means areas not in active production or developed uses. This includes open water, second growth forests, barren areas, etc. It does not indicate undisturbed wilderness.
[15] Unclassified areas

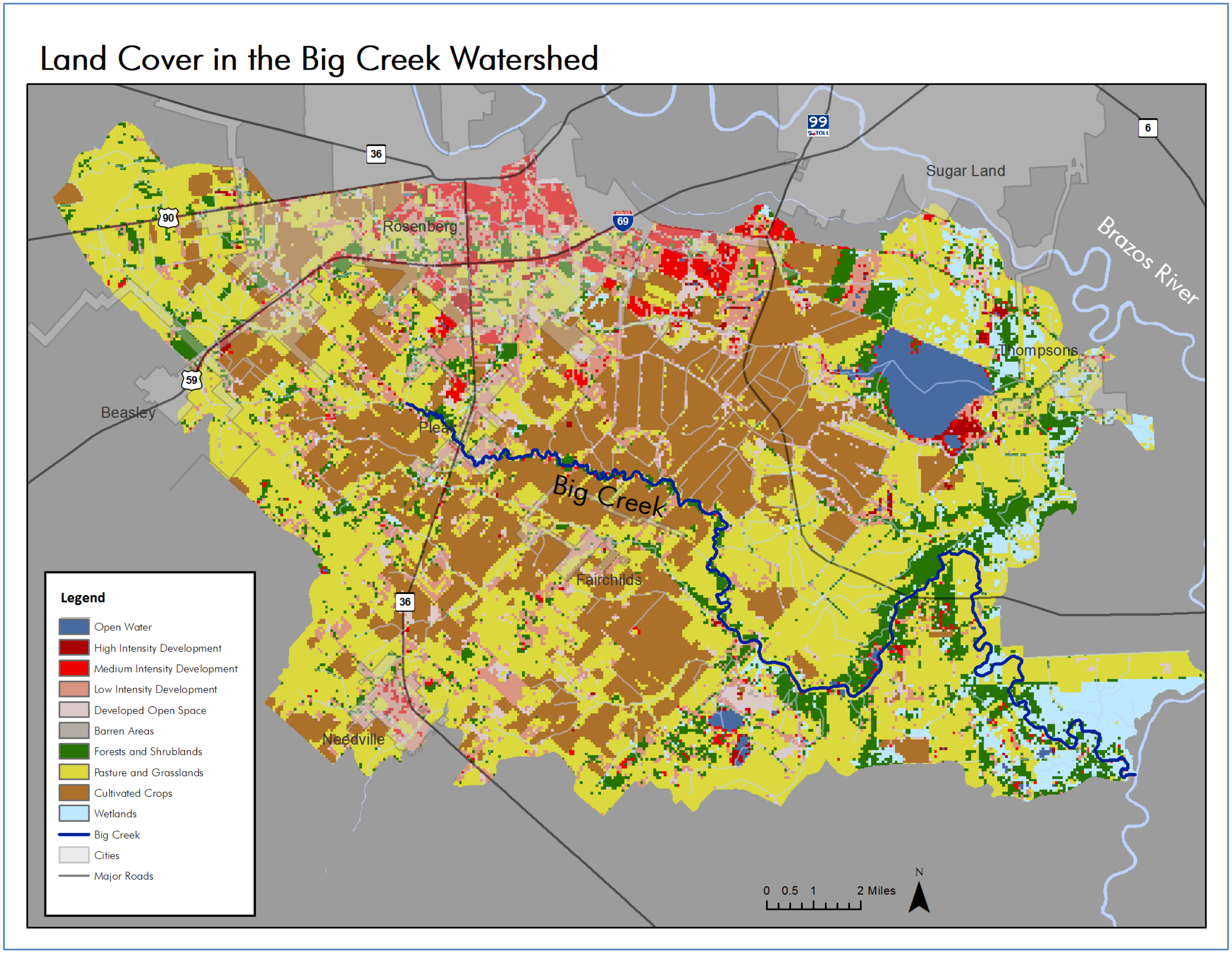


*Figure 14 - Land Cover in the Big Creek Watershed*

## Land Use

To analyze land use patterns, change between current and future (2045) land use data (Figures 15 and 16, respectively) from H-GAC's regional demographic analyses[16] provide a picture of a watershed in transition, while still highly rural in character for the time being (Table 3).

Land use in this area is predominantly agricultural or not currently in use with the potential for development. Residential areas are the next most common land use, reflecting the current presence of urban centers and suburban expansion in the area. By 2045, however, developed uses (residential, commercial, and multiple use areas) have increased to over 40 percent of the watershed area in total.

*Table 3 - Land Use in the Big Creek Watershed, 2018 and 2045*

| Land Use Type | 2018 - Acres | 2018 - % of Total Area | 2045 - Acres | 2045 - % of Total Area |
|---|---|---|---|---|
| Commercial | 828 | 0.6% | 1,089 | 0.8% |
| Industrial | 966 | 0.7% | 55 | 0.0% |
| Residential | 15,972 | 11.8% | 34,172 | 25.3% |
| Governmental/Medical/Educational | 175 | 0.1% | 496 | 0.4% |
| Multiple | 4,800 | 3.6% | 27,383 | 20.3% |
| Other | 55 | 0.0% | 1,772 | 1.3% |
| Parks/Open Spaces | 5,697 | 4.2% | 5,697 | 4.2% |
| Vacant Developable (includes Farming) | 100,243 | 74.3% | 58,072 | 43.1% |
| Undevelopable | 5,266 | 3.9% | 5,266 | 3.9% |
| Unknown | 826 | 0.6% | 826 | 0.6% |
| **Total** | **134,828** | **100%** | **134,828** | **100%** |

Land uses in the watershed reflect the land cover, but also point to projections for the future of developing areas (Figures 16 and 17, respectively). Consideration of future impacts to water quality should consider the additional source load from human and domestic animal waste sources, the reduction in legacy agricultural sources, and especially the potential change in hydrological character of the drainage area due to increased impervious cover.

[16] Acreage totals for these analyses are lower than the total acreage for the watershed because the underlying data do not include some large bodies of water (Smithers Lake, etc.).

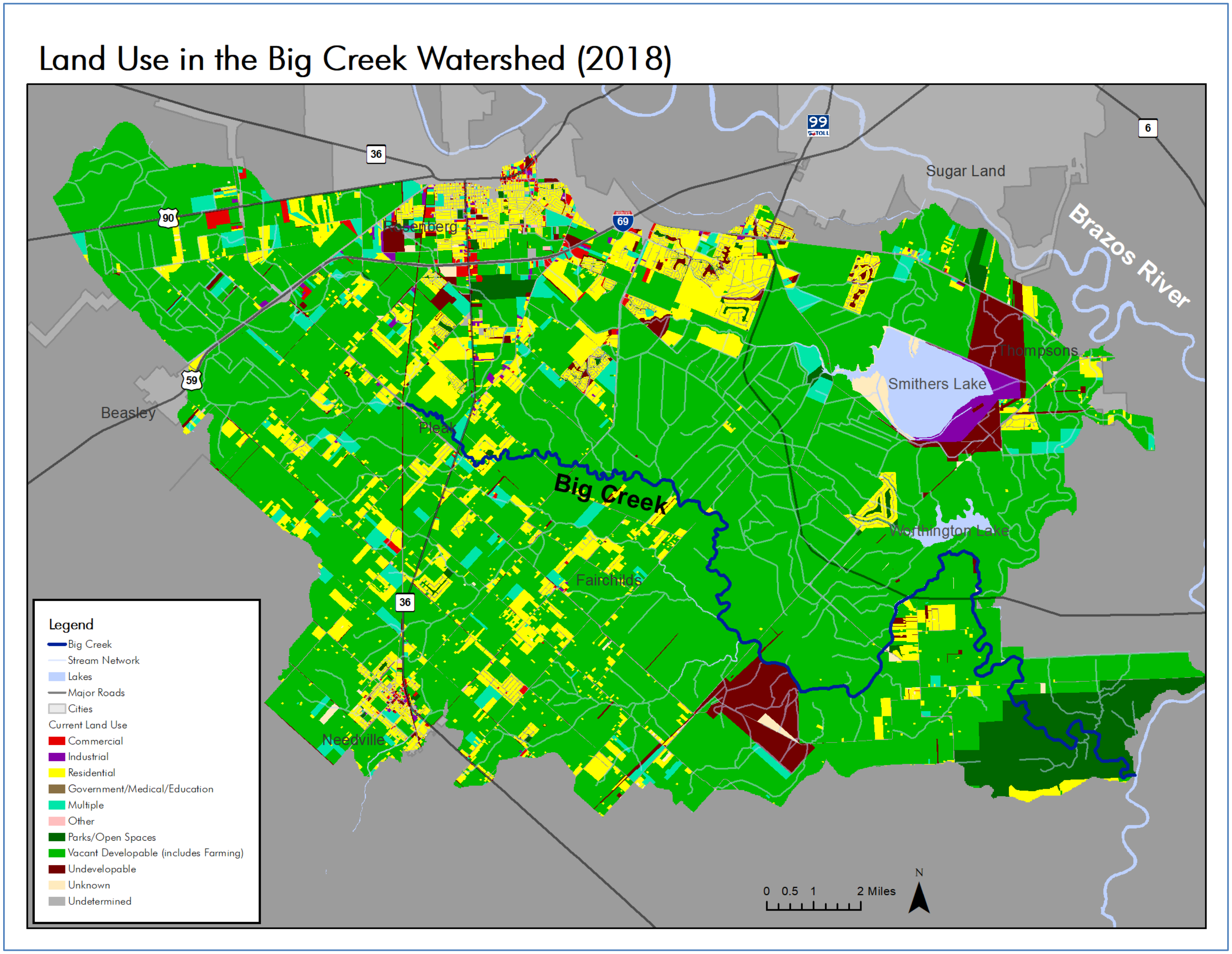


*Figure 15 - Land Use in the Big Creek Watershed (2018)*

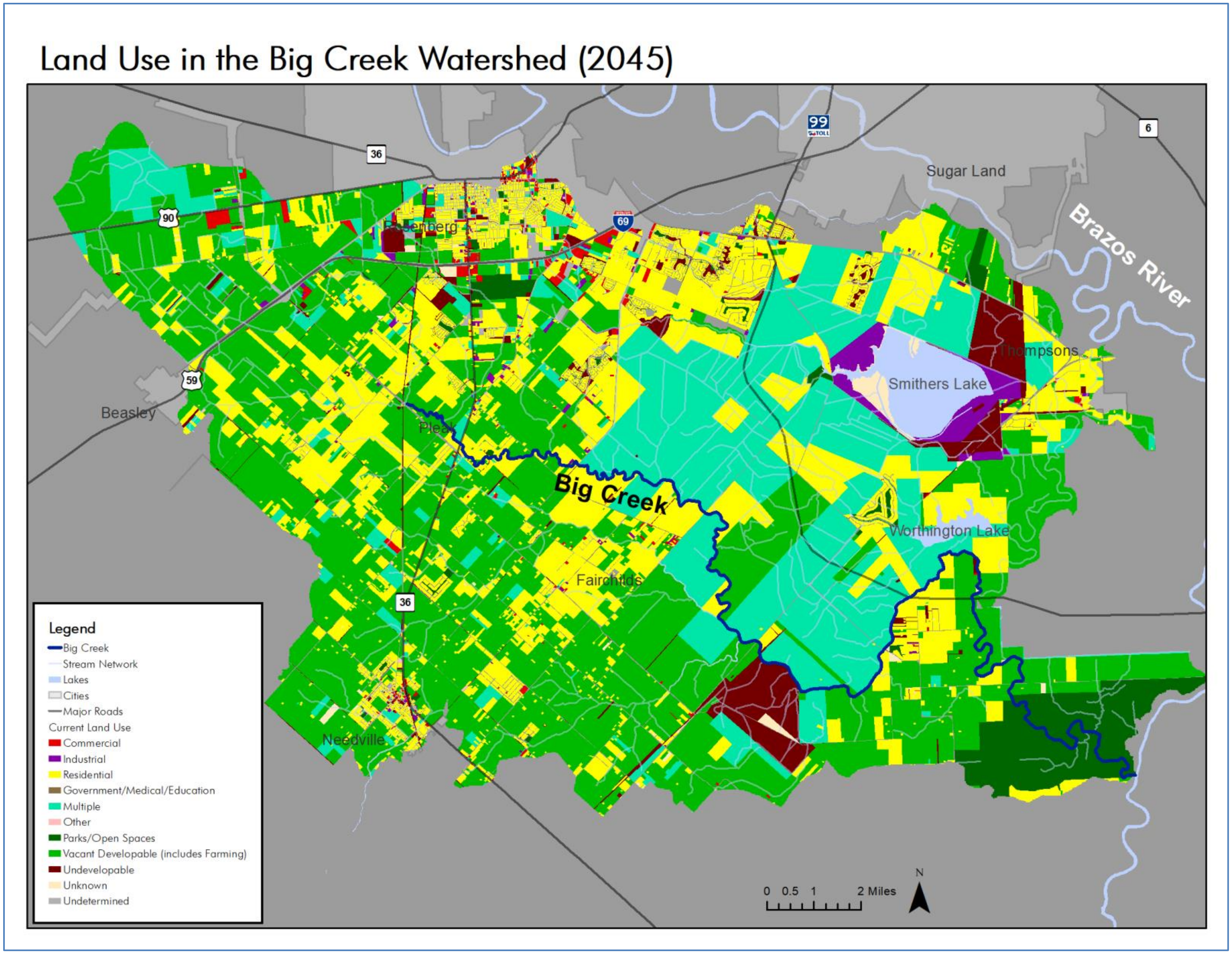


*Figure 16 - Land Use in the Big Creek Watershed (2045)*

# Section 3 – Review of Historical Data

## 3.1 Historical Data Sources Overview

Contact recreation impairments in a waterway can represent a variety of conditions and arise from several different sources. Combined with an evaluation of the relationship between pollutant loads and flow (Section 4), potential sources of pollution (Section 5), and stakeholder feedback, historical water quality data sources helps provide a more precise understanding of the extent and conditions under which fecal pollution may be occurring. The data reviewed in this characterization include ambient monitoring data collected under the Clean Rivers Program (CRP), discharge monitoring reports (DMRs) from wastewater treatment facilities (WWTFs) in the watershed, and sanitary sewer overflow (SSOs) reports from wastewater collection systems. The parameters reviewed for each data source is based on the current status of Big Creek on the TCEQ's 2014 IR[17], including the contact recreation impairment and concerns[18] for depressed DO, nitrate nitrogen, and total phosphorus.

## 3.2 Ambient Monitoring Data

### Data Acquisition

Up to 13 years of data for bacteria, nitrogen compounds, total phosphorus, DO, and total suspended solids were obtained from the TCEQ Surface Water Quality Monitoring Information System. The data are currently collected at one station in AU 1202J_01 (station 16353) but have been collected historically at several stations in the watershed (Figure 17). For the purpose of this review, three stations (two historical and one current) were evaluated. These stations were selected based on sufficiency of existing data, currency of data, and representativeness of their AU or portion of the watershed. Each station was evaluated for bacteria (*E. coli)*, nitrate nitrogen, total phosphorus, and DO (grab samples) parameters. Table 4 indicates the extent of data available for each station and parameter.

[17] Although the 2014 IR is used as the basis, the parameters of concern remain an issue in the approved 2016 IR and the Draft 2018 IR.

[18] These parameters are included as supplemental indicators of waterway health. They are not the primary focus of this report.

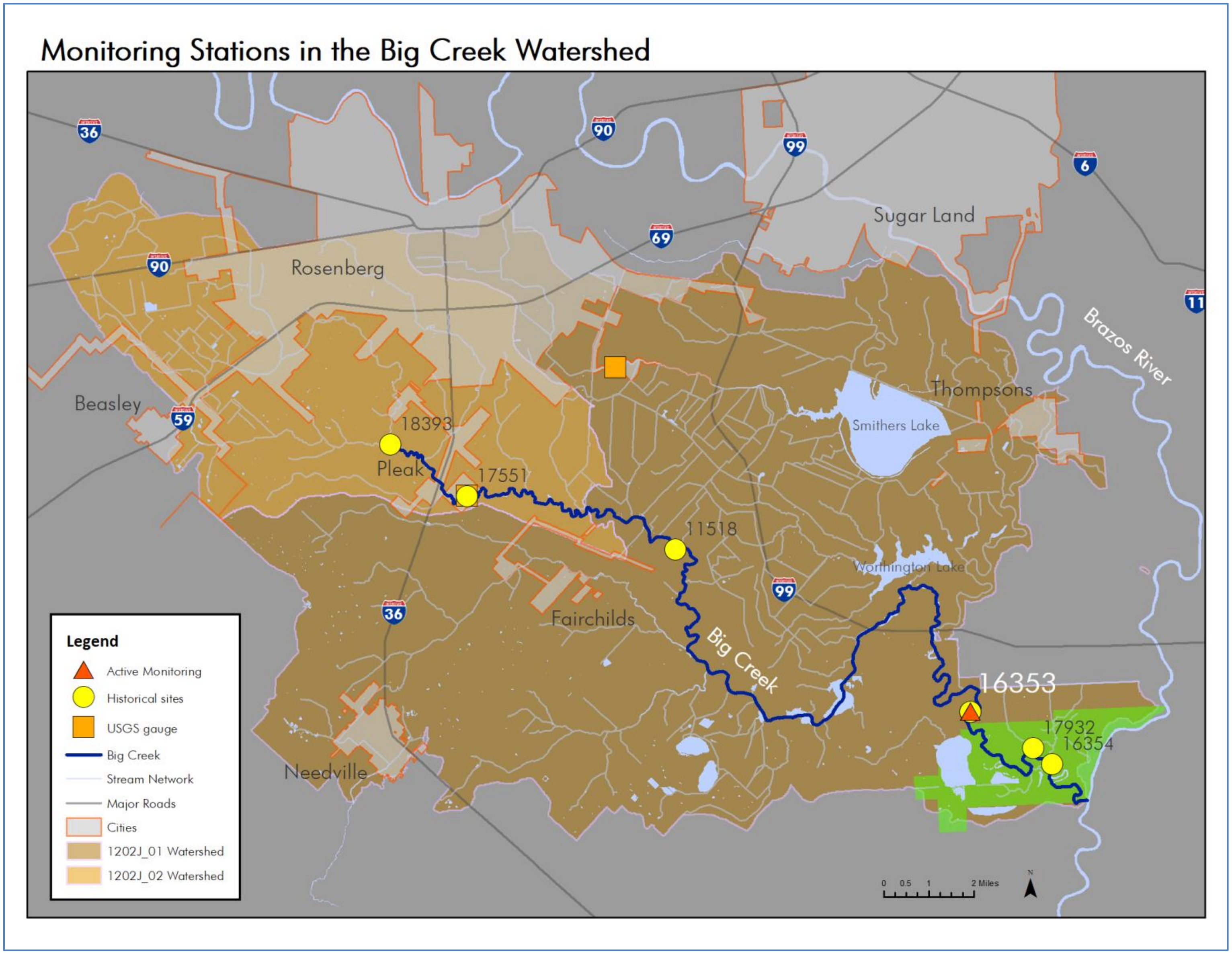


*Figure 17 - Monitoring Stations in the Big Creek Watershed*

*Table 4 - Years of Available Monitoring Data by Representative Station*

| Parameter | Years of available Data | | |
|---|---|---|---|
| | Station 16353 | Station 17551 | Station 17932 |
| *E. coli* | (2009-2018) | (2004-2012) | (2004-2008) |
| Total Phosphorus | (2009-2018) | (2004-2012) | (2004-2008) |
| DO (grab) | (2009-2018) | (2004-2012) | (2004-2008) |
| Nitrate Nitrogen | (2015-2018) | (2004-2012) | (2004) |

## Analysis of *E. coli* Data

The 2014 IR lists Big Creek as impaired for contact recreational use due to elevated levels of fecal waste, based on the FIB species *E. coli*. This segment was first listed as impaired in 2002. The 2014 IR shows the geomean for *E. coli* in AU 1202J_01 to be 155.03 cfu/100ml, and within AU 1202J_02 to be 109.56 cfu/100mL[19]. The data indicated that, at that time, AU 1202J_01 was not supportive of the standard while AU 1202J_02 was. Data review for this project included monitoring results between 2009 and 2018, which incorporates a later set of data than the current IR. The results of the review are displayed in Table 5, by station. Review of the data indicated that AU 1202J_01 was likely still not supporting the SWQS. Data for years 2013-2018 was not available for AU 1202J_02, so it does not support an evaluation of current trends. A pattern of high variability is present in both AUs, as represented by the maximum values which greatly exceed the geomean. Figure 18 shows the relationship of sample results by station for the whole time period of the sampling dataset.

*Table 5 - E. coli Results by Monitoring Station*

| Station | AU | Number of *E. coli* samples | Maximum value | Geomean | % in Violation |
|---|---|---|---|---|---|
| 16353 | 1202J_01 | 70 | 14,000 | 241.14 | 61.4% |
| 17551 | 1202J_02 | 30 | 2,419 | 105.69 | 53.3% |
| 17932 | 1202J_01 | 16 | 3,448 | 97.19 | 37.5% |

The lack of current data for stations other than 16353 in both AUs is problematic for comparing current trends, or relative health of the different portions of the watershed. Using station 16353 as a sole indicator for all Big Creek indicates that water quality near the end of the system is roughly twice the SWQS criteria but has high variability and times in which levels are an order of magnitude higher than the standard or more. These data indicate that the water quality issues leading to the contact recreation impairment are still present in the watershed.

[19] While this report references the most current approved IR (2014) at the time of the project development, it should be noted that the subsequently-approved 2016 IR and the 2018 draft show geomeans with higher values for both AUs (e.g., the 2018 Draft IR indicates a geomean of 246.16 for AU 1202J_01 and 178.05 for AU 1202J_02).

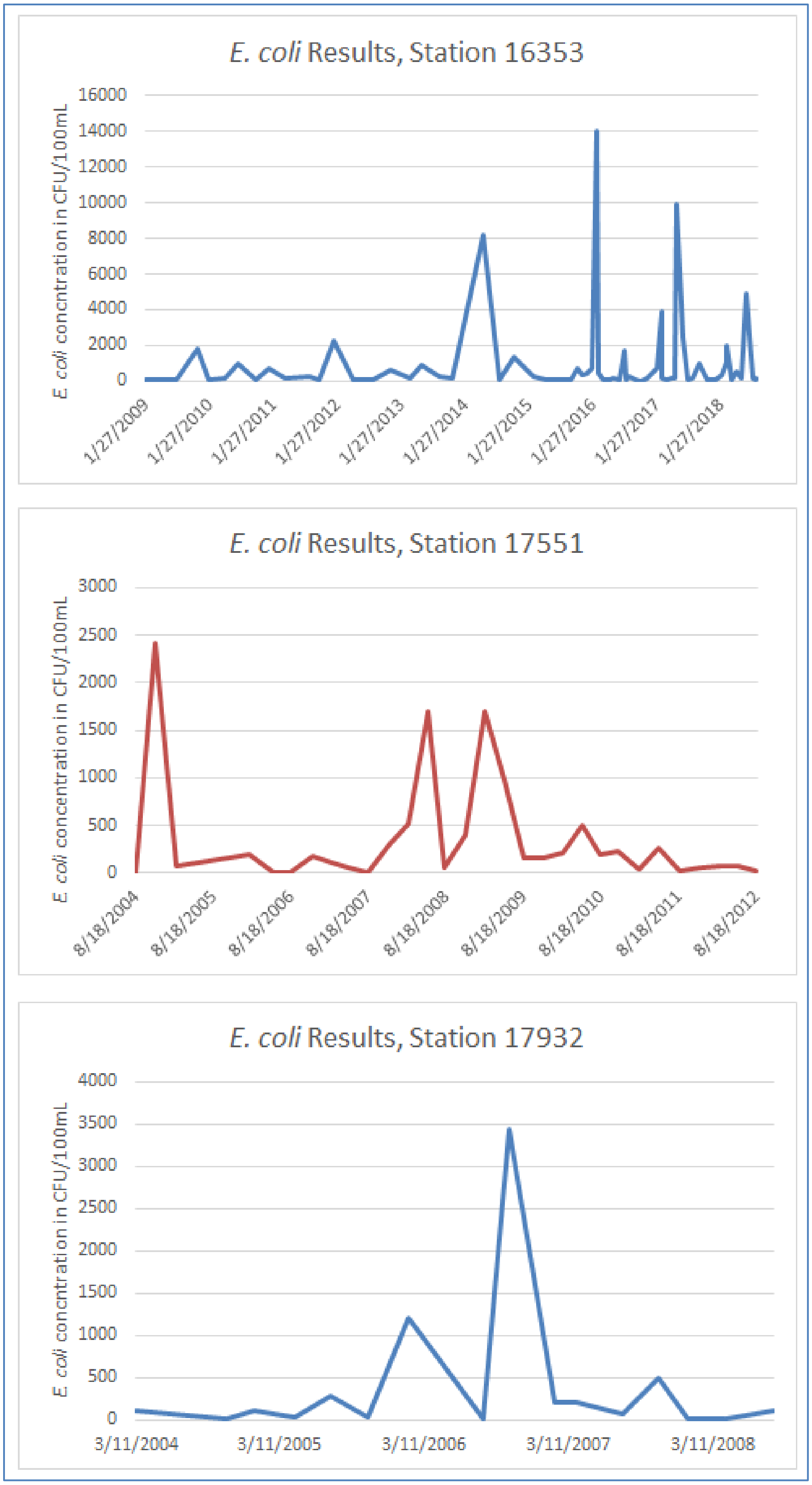


*Figure 18 - E. coli Results by Station*

## Analysis of Other Parameters

This characterization focuses on FIB, but also evaluates other parameters for which a concern exists in the IR. The data in the ambient sampling, including data more current than the approved 2014 IR, indicates that these concerns still exist in the watershed. Table 6 includes the results for DO (grab), nitrate nitrogen, and total phosphorus.

*Table 6 - Other Water Quality Parameter Analyses*

| **Station** | **Violations of Criteria/Screening Levels by Parameter (*percent of total samples*)** | | | |
|---|---|---|---|---|
| | Nitrate Nitrogen | Total Phosphorus | DO (grab, minimum) | DO (grab, screening level) |
| 16353 | 5% | 8% | 6% | 30% |
| 17551 | 75% | 72% | 3% | 14% |
| 17932 | 0% | 0% | 5% | 14% |

Spatially, the data indicates that nutrient issues are most pronounced in AU 1202J_01. Under 10 percent of samples for all stations were unable to support the DO minimum, but larger percentages were unable to meet the screening levels. While the exceedances were most pronounced in AU 1202J_01, downstream, it should be noted that AU 1202J_01 has a less strict standard than AU 1202J_02. The relative preponderance of nutrient exceedances in AU 1202J_02 was not proportional to DO exceedances.

*Figure 19 - Big Creek at FM 762, near Paw Paw Ranch*

## 3.3 Wastewater Treatment Facility Discharge Monitoring Reports

### Data Acquisition

There are a variety of WWTFs, including both public and private facilities. Data from 10 years (2008-2018) of DMRs[20] from facilities in the watershed (Figure 20) assisted in characterizing the long-term water quality in their discharges. There are 18 active outfalls that discharge to Big Creek, representing 12 facilities. Nine of the facilities had *E. coli* data available for evaluation under this project.

### DMR Data Review – *E. coli*

There were no WWTFs with DMR data that had chronic issues meeting either of their permit limits for *E. coli*. Of the 717 results (based on the daily average limits) in the 10-year period, only five (0.7 percent) were in excess of the facility's standard. While portions of AU 1202J_02 are effluent dominated, the ability of plants in the AU to meet their standard on the average indicates that WWTFs do not appear to be a chronic source of load, even if they may be acute loading sources in certain conditions.

### DMR Data Review – *Other Parameters*

In addition to the fecal bacteria results, the DMRs also contained results for DO, biochemical oxygen demand, ammonia nitrogen, and total suspended solids that were pertinent to water quality issues in Big Creek. In a review of the results for these tests, no widespread or facility-specific pattern of exceedance were found. No DO violations were found, while less than one percent (0.14 percent, 0.33 percent, and 0.81 percent, respectively) of all other parameters exceeded the facility's limits.

## 3.4 Sanitary Sewer Overflow Reports

### Data Acquisition

Overflows, leaks, and unpermitted discharges from the collection systems of WWTFs can be an acute source of untreated fecal waste. Project staff evaluated seven years of SSO reports (2011-2017[21]) from TCEQ for the watershed area. There were 19 SSOs during that timeframe representing five facilities. Total volume was estimated at 62,110 total gallons. The reported causes for the SSOs were dominated by rainwater inflow and infiltration (58 percent); human error (16 percent); other blockages (10 percent).

[20] DMR data was provided by TCEQ, as last accessed on 4/9/2019.
[21] 2018 data was not available during the development of this report.

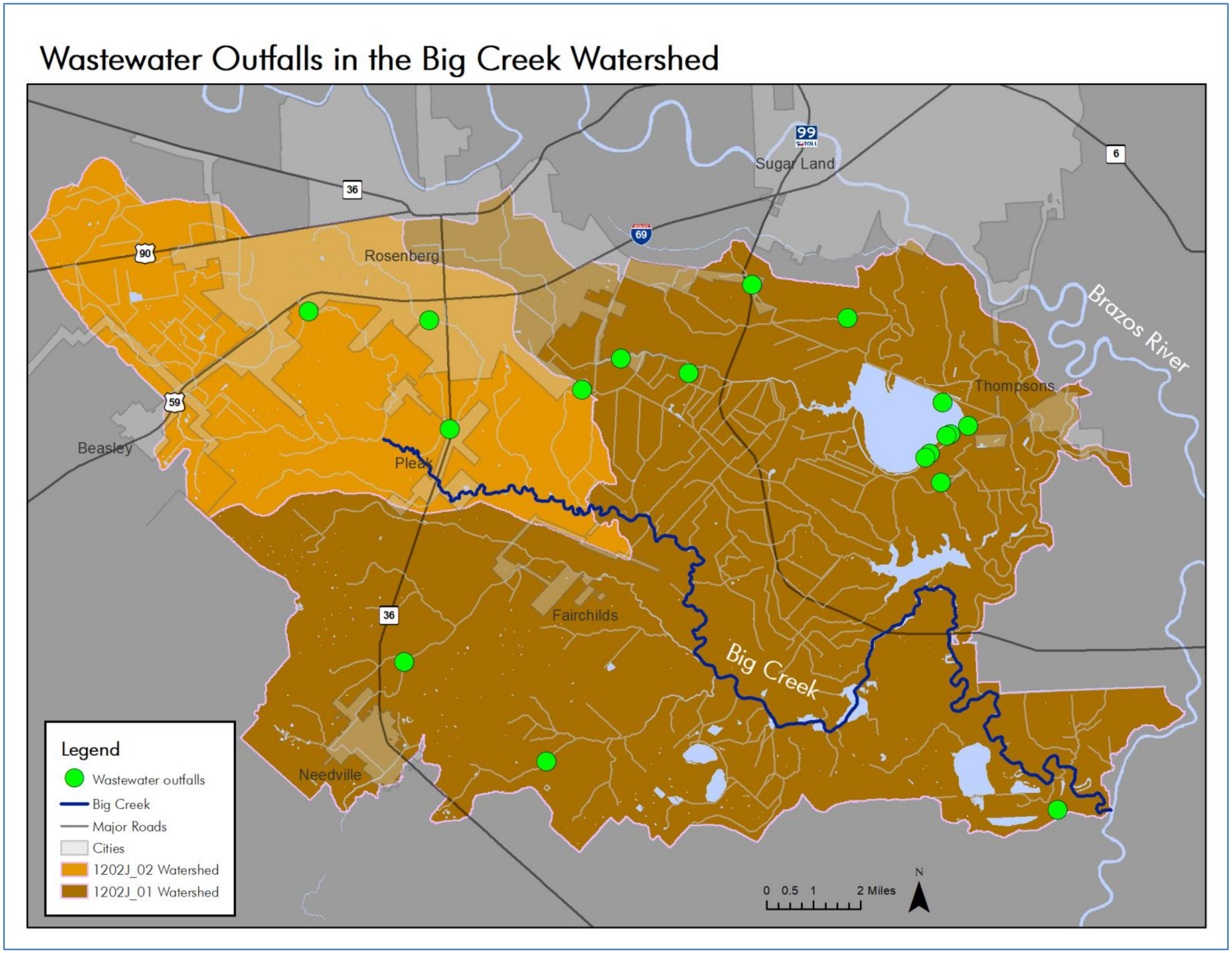


*Figure 20 - Wastewater Outfalls in the Big Creek Watershed*

# Section 4 – Preliminary Flow Assessment

## 4.1 Evaluating Flow and *E. coli* Loading

The flow conditions under which fecal waste reaches waterways provide clues to the origins of potential sources of contamination, and to potential best practices to address them. High fecal bacteria levels in correspondingly high flow conditions may indicate primarily nonpoint sources of contamination reaching the waterways via stormwater flows. Conversely, high bacteria levels in low flow conditions may indicate steady contributions from point sources unrelated to storm flows.

Load duration curves (LDCs) are an evaluation tool that assess the flow conditions under which bacteria loads are reported. LDCs use flow duration curves, showing the percent of time each level of flow (e.g., high flows) are present in the waterbody, combined with observed or modeled FIB results. The resulting curve shows where and to what extent bacteria loads persist, and to what extent reduction is needed to meet the SWQS, in different flow conditions. In addition to identifying potential categories of sources, LDCs can provide reduction goals by assessing the difference between projected loads at the contact recreation standard criteria's concentration, and those in the observed FIB data. This characterization effort used LDCs as a preliminary tool for understanding fecal bacteria loading in the watershed[22].

### Data Acquisition

Both flow data (observed or modeled) and bacteria results are necessary to develop LDCs. USGS flow gauges are a typical source of flow data as they represent long-term, continuous flow data which is easily adapted to a curve. H-GAC evaluated data for all CRP monitoring stations in the watershed to determine the most representative sites for developing LDCs. One LDC was developed for each AU. In AU 1202J_02, station 17551 (Figure 17, Section 3.2) corresponds with a USGS flow gauge, and is the most downstream site in the AU, making it the most representative site with the most sufficient data. Observed bacteria data does not include data after 2012, but there were no other more representative sites in the AU. However, the lack of current data should be taken as a caveat in the applicability of station 17551's LDC. In AU 1202J_01 there are no USGS flow gauges that correlate in position to CRP monitoring stations. Based on breadth and currency of CRP data, station 16353 (Figure 17, Section 3.2) is the most representative station in the watershed. While there are stations further downstream, they have less available data, are more likely to be influenced by mixing from the confluence with the Brazos River and are less representative of conditions upstream as they benefit from the more natural areas in and surrounding Brazos Bend State Park. Because of the lack of continuous flow

[22] These LDCs should not be taken as formal planning efforts or regulatory processes by TCEQ. They are used in the context of this characterization report solely as a conceptual tool for improving knowledge of fecal contamination in the watershed. Future development of a TMDL(s) will entail a more in-depth modeling process whose results may differ from those presented here.

data from a USGS gauge, the LDC for station 16353 was developed using flow data extrapolated from observed data at the station, and modeled data based on the extent of the watershed drainage area upstream. These data sources are sufficient for the conceptual nature of this analysis and are based on the more stringent data requirements of other formal watershed-based planning efforts.

### Load Duration Curves for Big Creek

The developed LDCs include five flow categories: high flows (present less than 10 percent of the time), moist conditions (present less than 40 percent of the time), mid-range conditions (present less than 60 percent of the time), dry conditions (present less than 90 percent of the time), and low flow conditions (minimum volumes present between 90-100 percent of the time). A flow curve is plotted showing flow volumes across each of these categories. The SWQS criterion for *E. coli* is then added as a curve, showing *E. coli* loads that correspond to the flow volume (i.e. the load produced by multiplying observed concentrations by the flow volume). While the geomean criteria is the focus of this characterization, the single sample criterion (399 cfu/100mL) was also plotted as a reference. Lastly, a curve based on *E. coli* data from CRP monitoring shows how observed bacteria levels relate to allowed levels across flow categories. Where the observed data (load regression curve) exceeds the criteria curve (water quality standard – geomean), a reduction is needed.

The LDC for AU 1202J_02 (station 17551) indicates that while there are exceedances throughout the various flow conditions, the area of greatest exceedance and needed reduction begins in the midrange conditions but is greatest in the moist and high flow conditions (Figure 21). This may indicate that nonpoint sources have the greatest impact on compliance with the SWQS. However, given that portions of AU 1202J_02 are effluent dominated, point source contribution in high flow conditions are also potential factors.

The LDC for AU 1202J_01 (station 16353) shows a broader pattern of exceedance, with the load regression curve in excess of the criteria curve starting with the average for the midrange conditions and persisting through the rest of the increasing flow categories (Figure 22). This suggests the potential contribution of a broader range of sources, but may also reflect the cumulative nature of loading, as it includes flow and loading from AU 1202J_02 upstream.

Table 7 indicates the amount of potential reduction needed at each station in each flow category.

*Table 7 - Potential Fecal Indicator Bacteria Reductions, by Station*

| AU/Station | High Flow | Moist | Midrange | Dry | Low Flow |
|---|---|---|---|---|---|
| AU1202J_02/17551 | 73% | 21% | - | - | - |
| AU1202J_01/16353 | 94% | 52% | 16% | - | - |

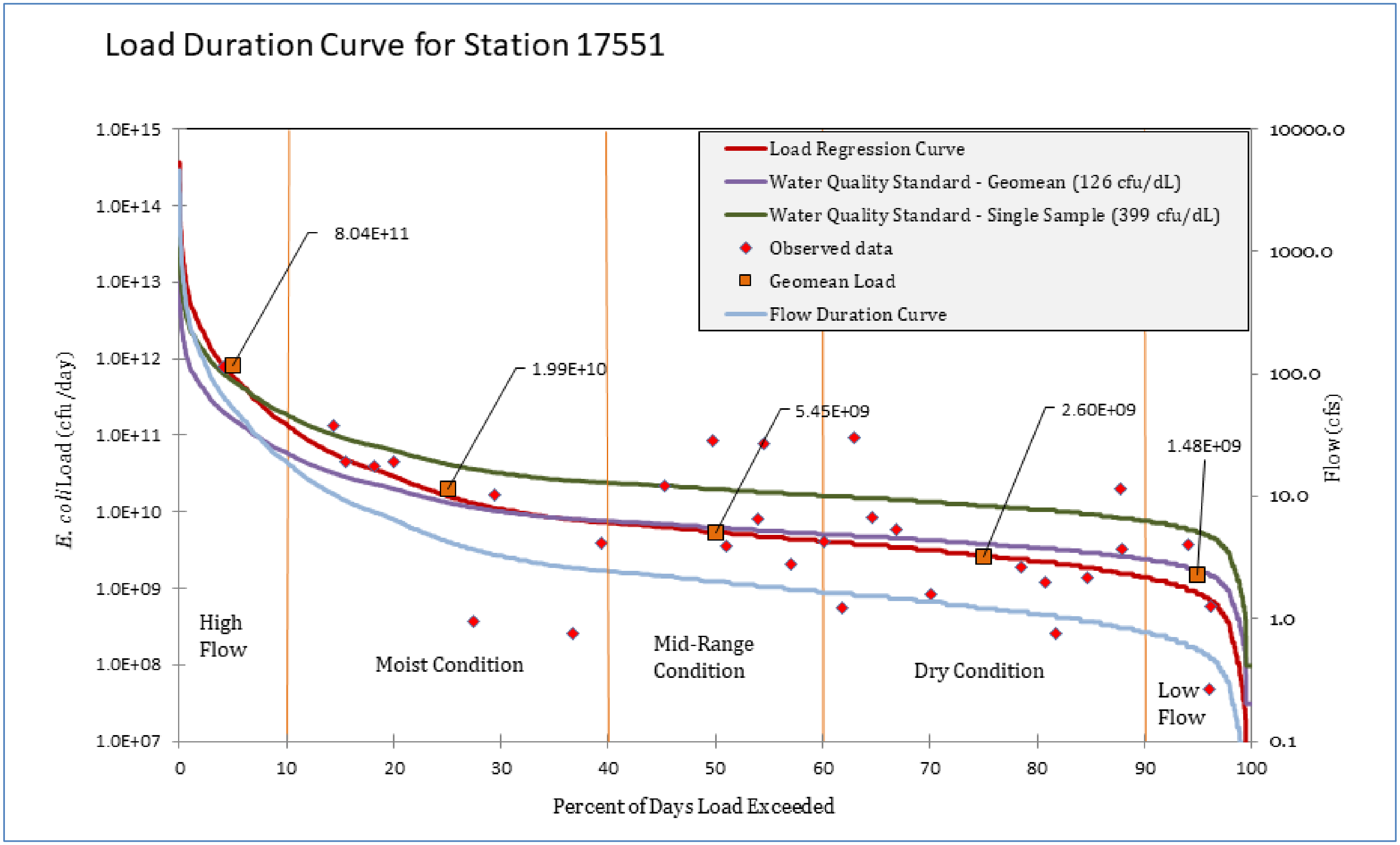


*Figure 21 - LDC for AU 1202J_02, Station 17551*

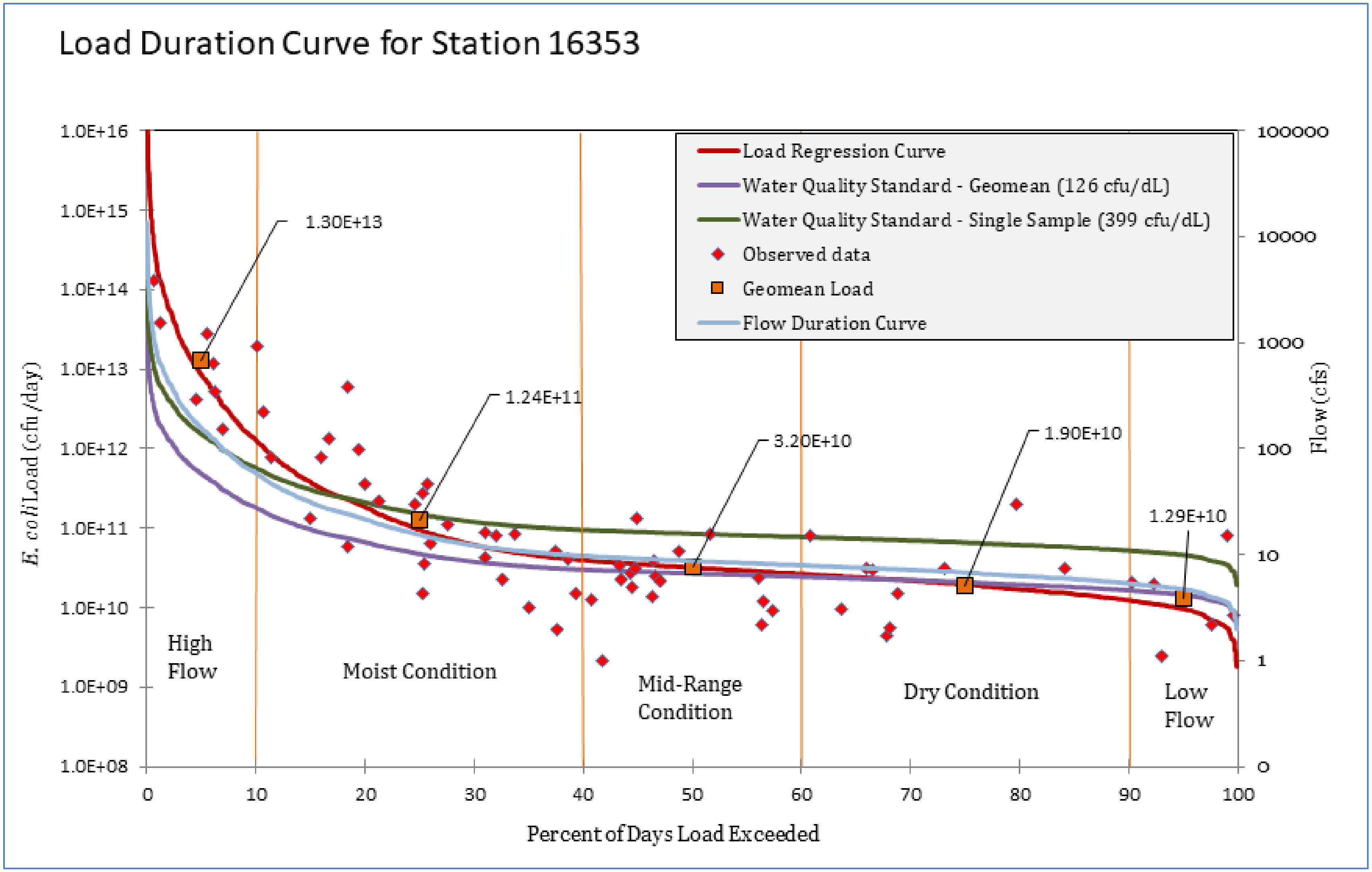


*Figure 22 - LDC for AU 1202J_01, Station 16353*

# Section 5 – Potential Sources of Contamination

## 5.1 Identifying Potential Sources

Water quality data and LDCs provide an overview of fecal bacteria loading in the waterway, and (in the case of LDCs) may hint at categories of sources (i.e. point or nonpoint) that are responsible. However, fecal waste comes from a variety of sources in a watershed. Addressing waste sources to improve water quality requires a more specific review of what sources exist in the watershed, to what extent, and what their likely prominence as loading sources are under given conditions. For the purpose of this characterization effort, preliminary source identification efforts included a general source survey of potential sources, and specific estimation of the extent of those sources[23]. General categories include four main waste sources: human, domestic animals, agricultural animals, and wildlife. These waste streams may enter waterways through multiple vectors (e.g. human waste may enter through SSOs, failing aerobic and septic systems (on-site sewage facilities, or OSSFs), or even direct deposition), so additional consideration and categorization is given to sources as either regulated or non-regulated. Table 8 shows the anticipated presence and potential extent of sources based on data investigations, ground reconnaissance, and feedback from local stakeholders.

*Figure 23 - Horses in the Big Creek Watershed*

[23] All information in this section is based on potential sources. Any discussion of relative prominence or link to observed conditions is intended as conceptual in nature. No specific load modeling or fate and transport considerations for bacteria sources was conducted. Further consideration may be part of future efforts to develop TMDL(s) or other formal watershed planning efforts.

*Table 8 - Potential Source Survey*

| Potential Source | Means of measurement | Potential Relative Contribution |
|---|---|---|
| Sanitary Sewer Systems | SSO reports; DMR data; land application projects. | Minor (discharge) to periodically moderate (overflows) |
| Septic and Aerobic Systems (OSSFs) | Presence in OSSF database (permitted); presence of houses outside sanitary service areas (recon., aerials, feedback). | Moderate to major. |
| Domestic Pets | Based on literature value (0.8 dogs per household[24]) and actual households. | Moderate |
| Livestock | USDA Agricultural Census data[25]; stakeholder feedback. | Moderate |
| Feral Hogs | Texas A&M Literature value based on land cover; local feedback. | Minor to Moderate. |
| Other Wildlife | Texas Parks and Wildlife Department (TPWD) Resource Management Unit (RMU) literature values (deer); anecdotal (other wildlife) | Minor to Moderate. |
| Landfills | Regulatory compliance; stakeholder feedback | Minor |
| Illegal Dumping | Anecdotal information | Minor |

These potential contributions are based on the mix of land cover/land use throughout the watershed. However, the specific mix of land uses and land cover in any given area may results in a source profile that varies greatly from the overall mix of sources for the watershed.

These considerations reflect current sources, and do not project for future growth. The assessment is specific to fecal waste contamination and does not consider appreciable sources of nutrients (fertilizers for agricultural operations and domestic landscaping), sediment (erosion and development), or impacts to aquatic habitat and species profundity (hydrological changes, pesticides, etc.). Changes to flow conditions with increasing development (e.g., greater volumes of stormwater at higher velocities with decreased filtration) are an underlying factor influencing all bacteria sources and other water quality issues.  Future consideration of best practices to

[24] Referenced at www.avma.org/KB/Resources/Statistics/Pages/Market-Research-statistics-US-Pet-Ownership.aspx on 5/15/19.
[25] Referenced at https://www.nass.usda.gov/AgCensus/ on 5/20/19.

reduce sources may need to consider these elements to maximize efficiency in dealing with multiple water quality challenges.

## 5.2 Regulated Sources

WWTFs and stormwater discharges[26] from industries, construction, and municipal separate storm sewer systems (MS4s) are examples of regulated sources permitted under the Texas Pollutant Discharge Elimination System (TPDES) and National Pollutant Discharge Elimination System (NPDES) programs[27].

### Domestic and Industrial Wastewater Treatment Facilities

There are 18 active, permitted outfalls in the watershed representing 12 permitted facilities. While acute overflows or exceptional events (e.g., Hurricane Harvey) may occur, their self-reported discharge monitoring data indicates that they are generally able to meet their permit limits for *E. coli.* However, because their permit limit for daily average corresponds to the SWQS, they are a minor source of load at times even when in compliance with their limits. More information on these facilities can be found in Section 3.3. While WWTFs do not appear to represent an appreciable portion of the fecal waste local in the system, they are of specific concern because human waste sources have an elevated risk to human public health[28].

### Sanitary Sewer Overflows

SSOs are relatively uncommon in the watershed (see Section 3.4) and do not represent appreciable volumes. However, they may represent periodic acute loading on a localized basis and are likely to correspond to already elevated loading in high flow conditions.

### Dry Weather Discharges/Illicit Discharges

In addition to stormwater, regulated entities under TPDES and NPDES permits must identify and correct dry weather discharges/illicit discharges that contribute effluent to the MS4 but have not been approved via permit or resulted from emergency firefighting activities. Examples of illicit discharges to the storm sewer include home sanitary pipes connected directly to the storm sewer, cross connections between a municipal sanitary sewer and a storm sewer, a leaking sanitary sewer leaching into a storm sewer, and failing OSSFs leaking into a storm sewer. No known data was available for this watershed, but it is likely that these discharges exist to some degree in MS4 areas.

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[26] Stormwater discharges are considered as a vector, rather than a specific source, as they contain a conglomeration of nonpoint source domestic animal, human, and wildlife wastes in their discharge.
[27] While many OSSFs operate under a permit from a local authorized agent, they are treated as unregulated sources for the purpose of this effort.
[28] Based on research done by Texas A&M University staff on quantitative microbial risk assessment, as referenced at https://oaktrust.library.tamu.edu/bitstream/handle/1969.1/158640/GITTER-THESIS-2016.pdf?sequence=1&isAllowed=y on 6/10/19.

## TPDES General Wastewater Permits

The TCEQ regulates certain types of facilities that process wastewater, some of which potentially contain fecal waste. General wastewater permit types include:

- TXG110000 – concrete production facilities;
- TXG130000 – aquaculture production facilities;
- TXG340000 – petroleum bulk stations and terminals;
- TXG670000 – hydrostatic test water discharges;
- TXG830000 – water contaminated by petroleum fuel or petroleum substances;
- TXG920000 – concentrated animal feeding operations; and
- WQG20000 – livestock manure compost operations.

A review of active general permit coverage (TCEQ Central Registry, August 15, 2019) in the Big Creek Watershed found five concrete production facilities and one aquaculture facility under general permit within the watershed (Table 9). No other active general wastewater permit facilities or operations were found.

*Table 9 - General Wastewater Permits - Concrete Operations*

| Authorization number | Permit Type | Permittee/Registrant | City |
|---|---|---|---|
| TXG111258 | TXG110000 – concrete production facilities | L. Guerrero & Sons Ready-Mix Company | Rosenberg |
| TXG111575 | TXG110000 – concrete production facilities | Williams Brothers Construction Co., Inc. | Rosenberg |
| TXG111756 | TXG110000 – concrete production facilities | Cemex Construction Materials Houston, LLC | Richmond |
| TXG111970 | TXG110000 – concrete production facilities | Williams Brothers Construction Co., Inc. | Rosenberg |
| TXG111978 | TXG110000 – concrete production facilities | Alleyton Resource Company, LLC | Rosenberg |
| TXG130058 | TXG130000 – aquaculture production facilities | Mackys Farm LLC | Needville |

## TPDES General Stormwater Permits

Regulated stormwater is permitted by the state under TPDES and is considered a point source by the state. Stormwater from unregulated areas is considered a nonpoint source and will be discussed under unregulated sources in a subsequent section. Discharges of stormwater from a Phase II urbanized area, industrial facility, construction site, or other facility involved in certain activities are required to be covered under the following TPDES general permits:

- TXR040000 – stormwater Phase II MS4 general permit for urbanized areas;
- TXR050000 – stormwater multi-sector general permit for industrial facilities;
- TXR150000 – stormwater from construction activities disturbing more than one acre;

There are several construction stormwater permits in the watershed[29], but the primary focus of this characterization effort is stormwater that has a high likelihood of containing fecal waste. A review of active permits covering MS4s in the TCEQ Central Registry found that there are five active Phase II MS4 permits in the watershed (Table 10).

*Table 10 - MS4 Phase II Permits in the Big Creek Watershed*

| Permit | Entity | City |
|---|---|---|
| TXR040272 | City of Rosenberg | Rosenberg |
| TXR040383 | Fort Bend County Drainage District | Sugar Land |
| TXR040480 | Fort Bend County MUD 155 | Richmond |
| TXR040481 | Fort Bend County MUD 159 | Rosenberg |
| TXR040551 | Fort Bend County MUD 167 | Rosenberg |

## Other Permitted Facilities and Operations

In addition to the permitted facilities discussed above, there are several other large-scale facilities or areas of operation worth noting in the watershed.

- The WCA Waste Corporation operates the Fort Bend Regional Landfill. This Type I landfill accepts municipal and other wastes that may include fecal wastes. In discussions with landfill staff and review of aerials, tributaries and sheet flow can traverse the landfill property and flow into Big Creek. However, by their permit requirements, any stormwater reaching the active face of the landfill needs to be sequestered and removed.
- NRG Energy operates the W.A. Parish Generating Station, a dual-fired power plant occupying over 4,500 acres of the central watershed, and impounding drainage flows (and supplemental water supply) in Smithers Lake, before discharging from the Lake to the Rabbs Bayou system. Based on conversations with plant staff and Fort Bend County Drainage District staff, flow variation from the discharge does not have a notable impact on downstream volumes. Water quality impacts from fecal waste are not likely appreciable; most of the discharged volume from the plant is process/cooling water.
- There are several active and legacy oil fields in the watershed, due to the presence of several salt domes (Figure 24[30]). While these are not sources of fecal waste, they are worth noting as areas of specific use in the watershed that may contribute to ancillary water quality issues. The Orchard Dome Oil Field is in the headwaters of Seabourne Creek in AU 1202J_02, the Oil Creek Oil Field north of the confluence of Fairchilds Creek and Big Creek, and Thompsons Oil Field north of the drainage diversion on the eastern side of the watershed.

[29] As of 8/20/19, there are 316 records for Fort Bend County, including many in the Rosenberg area.
[30] Data reflected in Figure 24 was accessed from the Texas Railroad Commission's Public GIS Viewer for oil wells at https://gis.rrc.texas.gov/GISViewer/. More information on the specific symbols shown can be viewed at this location.

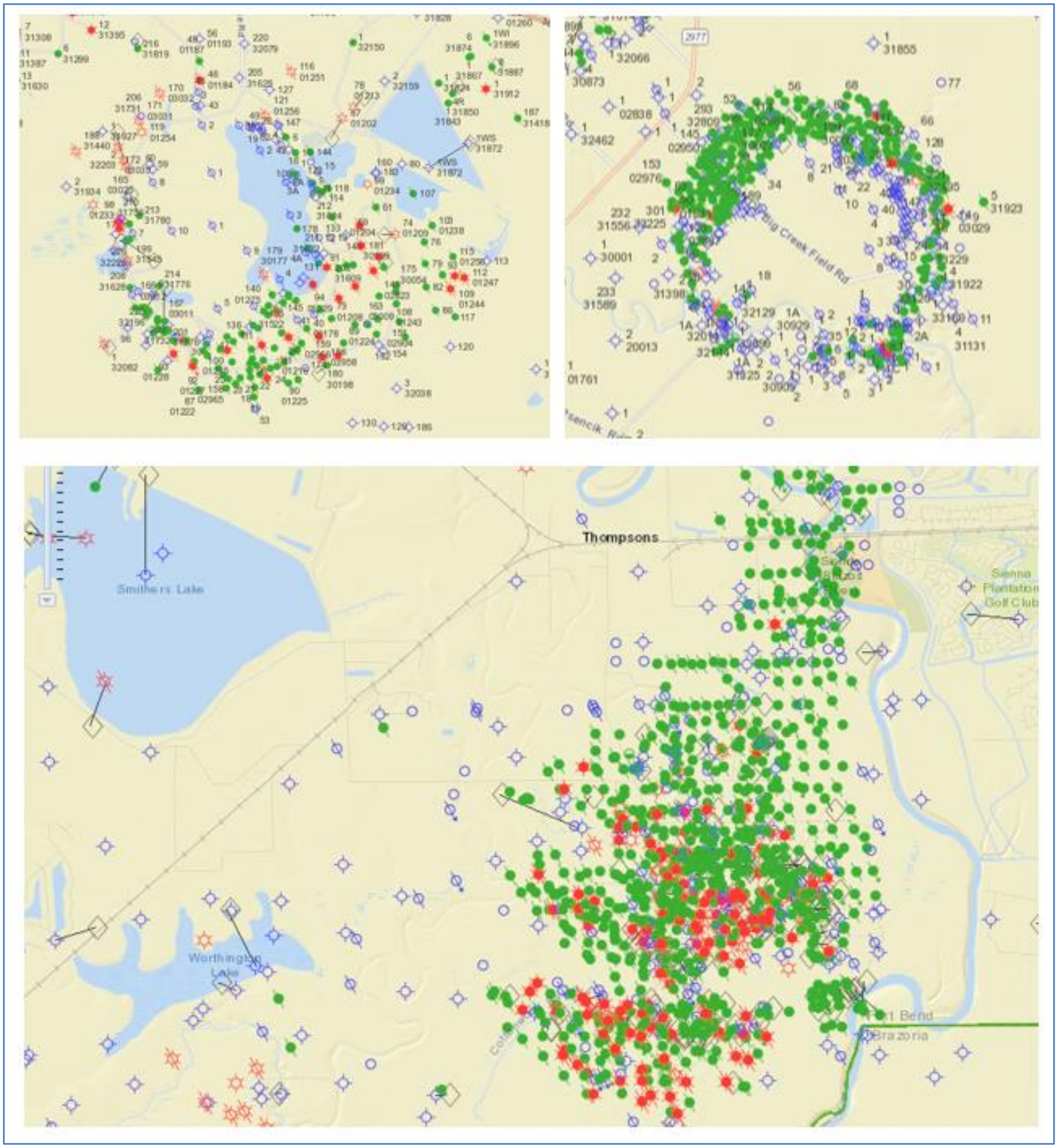


*Figure 24 - Oil Fields (Orchard Dome, Oil Creek, Thompsons)*

## 5.3 Unregulated Sources

Nonpoint sources of fecal waste are often unregulated because they come from diffuse accumulations rather than a single discrete source. OSSFs[31], certain agricultural activities, land application fields, urban runoff not covered under a permit, pet wastes, and wildlife wastes are examples of unregulated sources.

### On-site Sewage Facilities

Away from municipal centers where more centralized public wastewater treatment is common, rural and low-density suburban residences and stand-alone commercial and industrial businesses within the county or a city's extraterritorial jurisdiction are more likely to use owner-operated OSSFs, often referred to as septic systems, though also including modern aerobic systems and other on-site treatment technology. When not sited or functioning properly, OSSFs can be an appreciable source of fecal waste, especially when they are in areas adjacent to waterways. The likelihood of failure can be influenced by soil type, design, age, and maintenance. Literature values suggest failure rates for OSSFs in Texas are approximately 12 percent on average[32]. In similar areas, failure rates of 10-20 percent have been used, although some areas in the greater Houston region have reached failure rates in excess of 70 percent.

The number and location of permitted OSSFs has been compiled by H-GAC in coordination with authorized agents in H-GAC's service region, which includes the Big Creek Watershed. There are 3,142 records of permitted OSSFs in the Big Creek Watershed. H-GAC developed an OSSF geographic information database to identify potential unpermitted OSSFs in H-GAC's service area using known OSSF locations, county parcel data, and WWTF service boundaries (used to exclude addresses on centralized service). Based on this data, there are likely another 2,372 unpermitted OSSFs in the watershed. Combined, there are an estimated 5,514 OSSFs within the watershed (Figure 26).

Based on a conservative estimate of a 12 percent failure rate range, there would be an expected 662 failing systems in the watershed. Failing OSSFs, like wastewater systems, are a specific concern because of the greater health risk posed by human fecal waste.

[31] Some OSSFs in the watershed are operated under permit, while some are grandfathered. For the purpose of this characterization report, OSSFs are treated as unregulated due to the nature of their permit, the lack of regular reporting, and their generally diffuse nature.
[32] Reed, Stowe and Yanke, LLC. 2001. Study to Determine the Magnitude of, and Reasons for, Chronically Malfunctioning On-site Sewage Facility Systems in Texas. Texas Onsite Wastewater Treatment Council.

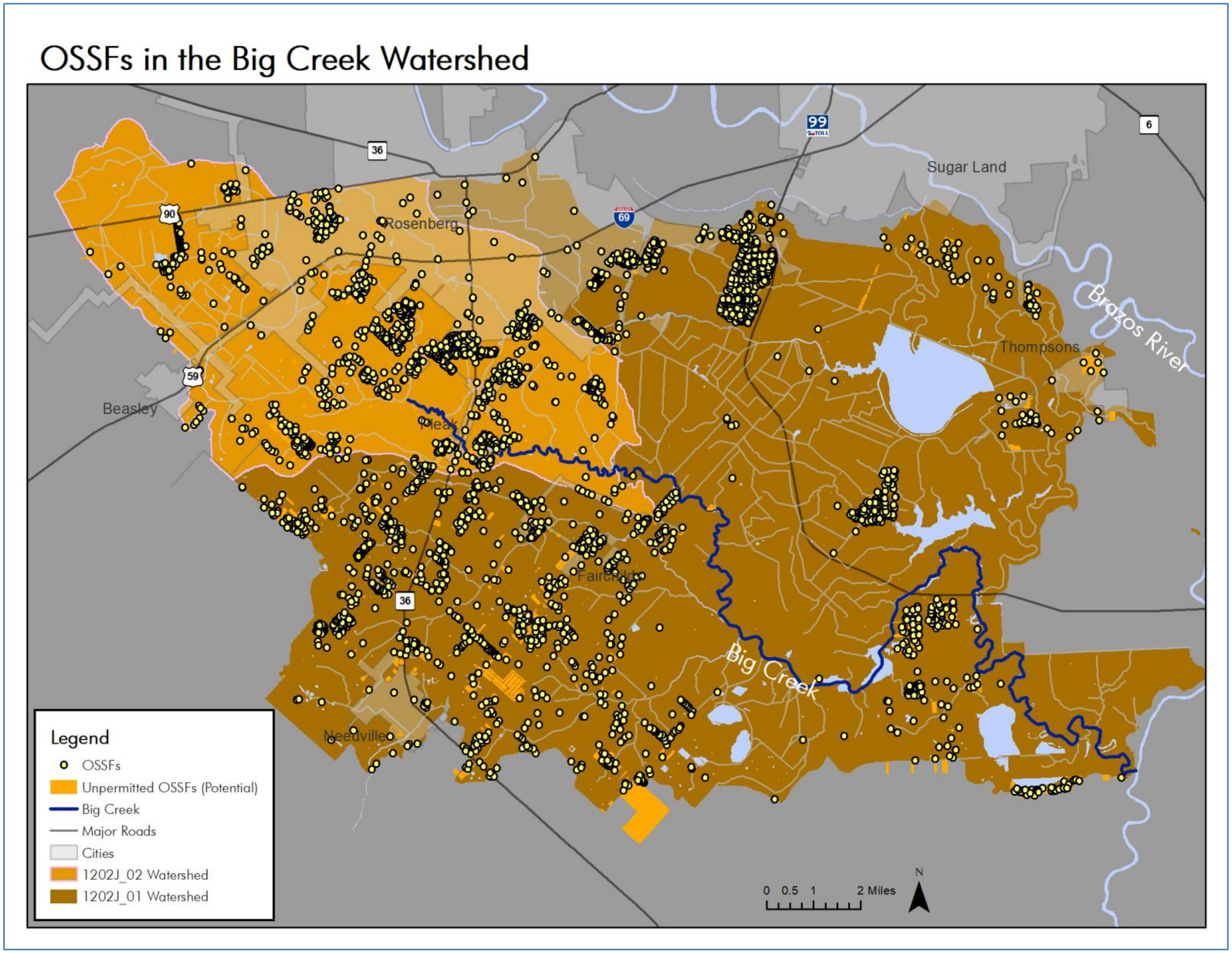


*Figure 25 - OSSFs in the Big Creek Watershed*

## Agriculture

Agriculture production remains a large economic base for much of the watershed. The primary source of fecal waste from agricultural activities is domestic livestock, including cows, sheep and goats, horses, pigs, and chickens. There are no permitted Concentrated Animal Feeding Operations (CAFOs) in the watershed[33], but there are significant numbers of livestock still in production. Fecal waste from agriculture can reach water bodies from direct deposition by livestock and via land applications of manure as fertilizer during crop production. Descriptions of agricultural animal populations are included as Table 11.

Livestock population numbers were estimated based on the United States Department of Agriculture's 2017 Census of Agriculture data. Numbers for the Big Creek Watershed were derived from Fort Bend County data, reduced to reflect the proportional size of the watershed.

*Table 11 - Agricultural Animal Populations in the Big Creek Watershed*

| Farms | Cattle | Pigs/Hogs | Sheep | Goats | Poultry | Horses[34] |
|---|---|---|---|---|---|---|
| 288 | 7,892 | 13 | 103 | 143 | 698 | 506 |

There are no reliable data available for extent of manure spreading on fields. However, as much of that manure is expected to arise from the animals represented above, specific acreage is not necessary to estimate at this level of analysis.

## Domestic Pets

Pets are another commonly unregulated source of fecal waste in urban and rural settings. Literature values provide a general estimate of pet populations, with an expected dog ownership value of 0.8 dogs per household[35]. Dogs are the specific concern as potential sources, as waste from cats is typically deposited inside and sequestered. Both current and future dog population estimates are presented in Table 12. Feral dog and cat populations cannot be estimated from available data or anecdotal reports, but should be considered as a potential source, especially in urban areas with greater access to food sources.

[33] Based on review of CAFO permits for Fort Bend County accessed on 6/23/19 at TCEQ's Water Quality General Permits & Registration Search – Advanced Search portal, at https://www2.tceq.texas.gov/wq_dpa/index.cfm.

[34] Agricultural census data may not fully reflect horse populations in the watershed, as non-farm horses are not fully accounted for (e.g. equestrian horses, etc.)

[35] Referenced at www.avma.org/KB/Resources/Statistics/Pages/Market-Research-statistics-US-Pet-Ownership.aspx, 5/15/19. American Veterinary Medicine Association produces pet ownership statistics that include a range of ownership averages for national and state contexts. The 0.8 dogs per household number reflects a higher end of the range, but one that coincided with stakeholder feedback and prior projects in the area.

The Big Creek Watershed contained a population of 58,442, representing 24,080 households, in 2018 (Table 1). Based on the H-GAC Regional Growth Forecast[36] demographic projections, the population of the watershed is expected to increase dramatically by 2040, at which point it will be 275,650, representing 103,130 households.

*Table 12 - Dog Populations, Current and Future*

| Statistic | 2018 | 2040 |
|---|---|---|
| Households | 24,080 | 103,130 |
| Dogs | 19,264 | 82,504 |

This estimate treats all households equivalently and does not reflect differences in fate and transport of fecal waste between urban areas with high impervious cover and rural areas.

## Wildlife and Invasive Animals

The Big Creek Watershed supports a diverse population of wildlife species, along with non-domestic invasive animals like feral hogs. Deer, coyotes, rodents, migratory waterfowl and other bird species, amphibians and reptiles (including large numbers of American Alligator), and other animal species are found both in natural areas like Brazos Bend State Park and in developed areas. Warm-blooded animals are the primary focus of this assessment. While the potential to impact human health varies by animal type, all warm-blooded animals produce FIB that can show up in monitoring data and may have fecal pathogens that can cause disease. Wildlife and invasive animal fecal waste can enter the waterway through direct deposition or in stormwater.

Literature values or specific data sources exist for deer and feral hogs, but estimating other wildlife is an uncertain process due to the lack of available literature values and standing data sources for many of the wildlife species present in the watershed (e.g. coyote, migratory birds, etc.). Based on bacteria/microbial source tracking efforts reviewed in other similarly rural watersheds, including the Upper Oyster Creek Watershed in Fort Bend County[37], wildlife loads can be an appreciable, but highly variable, part of the fecal waste load entering a rural waterway.

White-tailed deer populations are estimated by TPWD as part of their RMU program data, using an estimate of one deer for every 40.2 acres, yielding 3,518 deer in the watershed.

Feral hogs, a nonnative, invasive species, are unique in their ability to adapt to a variety of habitats and have high reproductive rates. Feral hogs have been identified as a large contributor to fecal waste in riparian areas which provide transportation corridors and wallowing sites. Feral hog density rates suggest that there are roughly 1.3 to 2.45 hogs per square mile in areas with

[36] More information on the Regional Growth Forecast can be found at http://www.h-gac.com/regional-growth-forecast/default.aspx.
[37] Technical data referenced at https://www.tceq.texas.gov/waterquality/tmdl/25-oystercreek.html, 5/22/19.

suitable habitat[38]. Based on best professional judgement and feedback from stakeholders, feral hog estimates were based on populating hogs at a density of 1.3 per square mile in low intensity developed; 2.0 per square mile in developed open space, bare land and cultivated land; 2.45 per square mile in pasture/grasslands, forests/shrubs, and wetlands; and no hogs in developed areas or open water (Table 13).

*Table 13 - Feral Hog Populations in the Big Creek Watershed*

| **Animal** | Deer | Feral Hogs |
|---|---|---|
| **Population** | 3,518 | 355 |

Fort Bend County, including areas in and around Brazos Bend State Park, are local hotspots (Figure 26) for birds year-round, but have greatly increased numbers during migration. Seasonal visitors like migratory waterfowl and swallows also visit the watershed in substantial numbers. No specific data exists to estimate population numbers, but anecdotal reports from sources like Ebird, Audubon Christmas Bird Count results, and other data conglomeration efforts suggest that bird populations are significant[39].

*Figure 26 - Great Blue Heron at Brazos Bend State Park*

[38] Referenced at https://agrilifecdn.tamu.edu/feralhogs/files/2011/05/FeralHogFactSheet.pdf on 5/21/19.
[39] Additional information can be referenced at www.ebird.com, www.audubon.com, or www.inaturalist.org. The Audubon Brazos Bend Christmas Bird Count occurs within the bounds of the watershed (www.brazosbendcbc.com).

# Section 6 – Findings and Recommendations

## 6.1 Summary

The 221-square mile watershed of Big Creek includes a mix of land cover types, land uses, and potential sources of pollution. The water quality impairment and concerns present for the creek in the 2014 and 2016 IRs are likely to be exacerbated by continuing development, absent implementation of any measures to mitigate pollutant sources.

Fecal waste is the primary pollutant of concern for this characterization, and the source profile for the watershed is varied and in transition from traditional rural and natural sources to increased inputs from developed areas and human wastes.

## 6.1 Findings and Recommendations

The analyses conducted under this report characterized the natural and human factors that influenced water flow and pollutant loading in the watershed. Key findings from the report include:

- Projected development and population growth will have an appreciable impact on land cover and land use in the watershed in the coming decades;
- Sources in the watershed are in a similar transitional period, with legacy agricultural sources projected to be displaced by developed area sources.
    - Recommendation – additional source identification and modeling, with feedback from stakeholders, is necessary to provide more robust evaluation of relative contribution of fecal waste to instream loads.
- Water quality analyses indicate impairments and concerns noted in the 2014 ad 2016 IRs (and the Draft 2018 IR) and still prevalent in the watershed, and not likely to decrease in the near future (absent intervention). Current data shows an increasing trend for *E. coli.*
    - Recommendation – additional data will be needed in AU 1202J_02 to support future assessments.
- Fecal waste sources are likely to remain varied, even through the developmental transition period. Wildlife population numbers are the least certain of current estimations.
    - Recommendation – additional source identification and modeling, with feedback from stakeholders, is necessary to provide more robust evaluation of relative contribution of fecal waste to instream loads.
    - Recommendation – estimates for overall loading from other wildlife should be developed based on prior source tracking work on local and other projects.

- High flow conditions relate strongly to exceedances in AU 1202J_02. SWQS exceedances in AU 1202J_01 are less specific to high flow conditions, but do also favor higher flows in general, with exceedances less prevalent in lower flow conditions.
    - Recommendation – formal LDCs or similar modeling should be conducted as part of a TMDL or other watershed-based planning efforts.
- Flooding remains a major challenge for the watershed, with significant effort in developing and maintaining drainage conveyances likely to continue for the foreseeable future.
    - Recommendation – future planning efforts should consider both the challenges the watershed's drainage situation represent, as well as opportunities for coordinating water quality best practices with flood mitigation efforts.

*Figure 27 - Maintained Channel in Big Creek*