## ECOREGIONS 27, 29, AND 32 – SUBHUMID AGRICULTURAL PLAINS

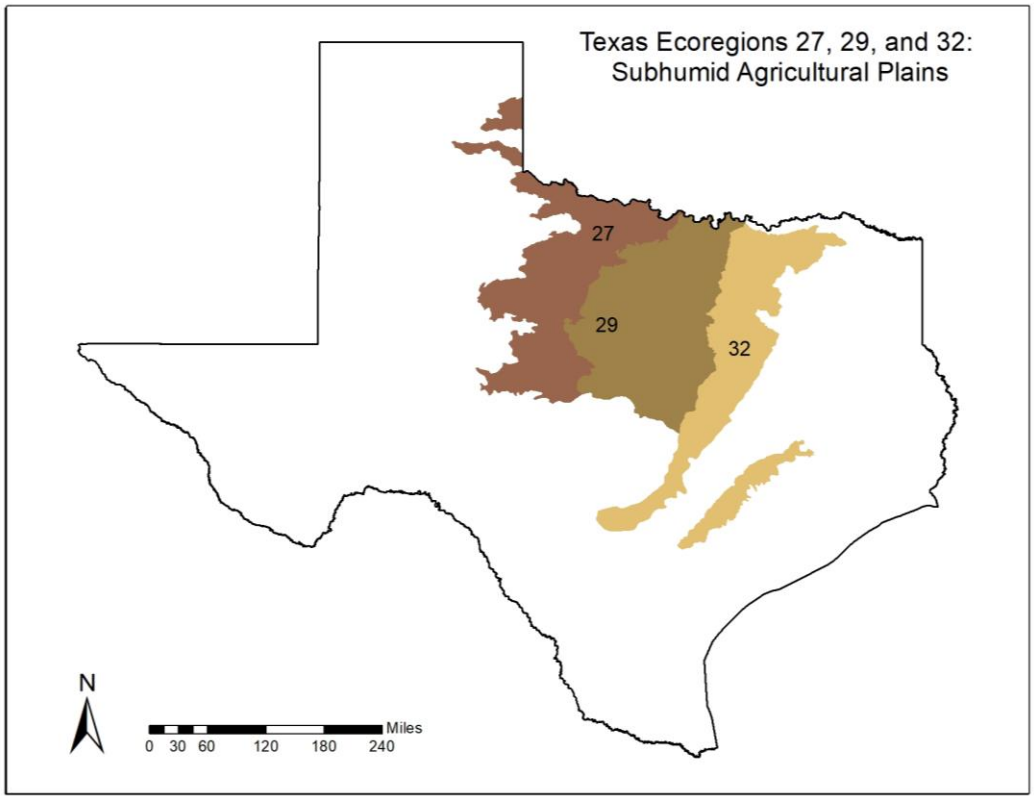


**Figure 80. Map of Texas aggregate Ecoregions 27, 29, and 32 – Subhumid Agricultural Plains.**

**Figure 81. Site photo from Sweetwater Creek.**

## Ecoregion 27 Characterization

In Texas, the Central Great Plains ecoregion covers approximately 46,695 sq km and encompasses all or part of 35 counties in the north central portion of the state (Figure 80). The ecoregion is bordered on the west by the Southwestern Tablelands (Ecoregion 26), on the east by the Cross Timbers (Ecoregion 29), by the Edwards Plateau (Ecoregion 30) to the south, and, for most of the northern border in Texas, by the Red River. Portions of the Red, Brazos, Canadian, and Colorado River Basins are included in the ecoregion. Beyond Texas, the ecoregion extends through central Oklahoma, and Kansas into central Nebraska.

Most of the ecoregion is currently cropland, replacing the grassland which historically predominated. Griffith et al. (2007) note the region historically formed a transition from the tallgrass to the east, and the shortgrass to the west. This reflects the precipitation pattern in the ecoregion which decreases from an annual average of 66-81 cm in the eastern portion to 51-71cm in the western portion of the ecoregion (Griffith et al. 2007). Streams in the ecoregion are generally relatively turbid and are often reddish in color due to transport of iron-rich sediments which characterize the prairie ecoregion. Riparian vegetation along these streams often includes pecan *Carya illinoensis*, cottonwood *Populus* sp., hackberry *Celtis* sp., cedar elm *Ulmus crassifolia*, and little walnut *Juglans micrcarpa.* Instream cover as well as stable substrate is often limited in streams in this ecoregion, especially in the western portion.

**Table 6. Streams sampled in Ecoregions 27.**

| | | |
|---|---|---|
| Cottonwood Creek | Elm Creek | Sweetwater Creek |
| Deadman Creek | Lelia Lake Creek | |

## COTTONWOOD CREEK

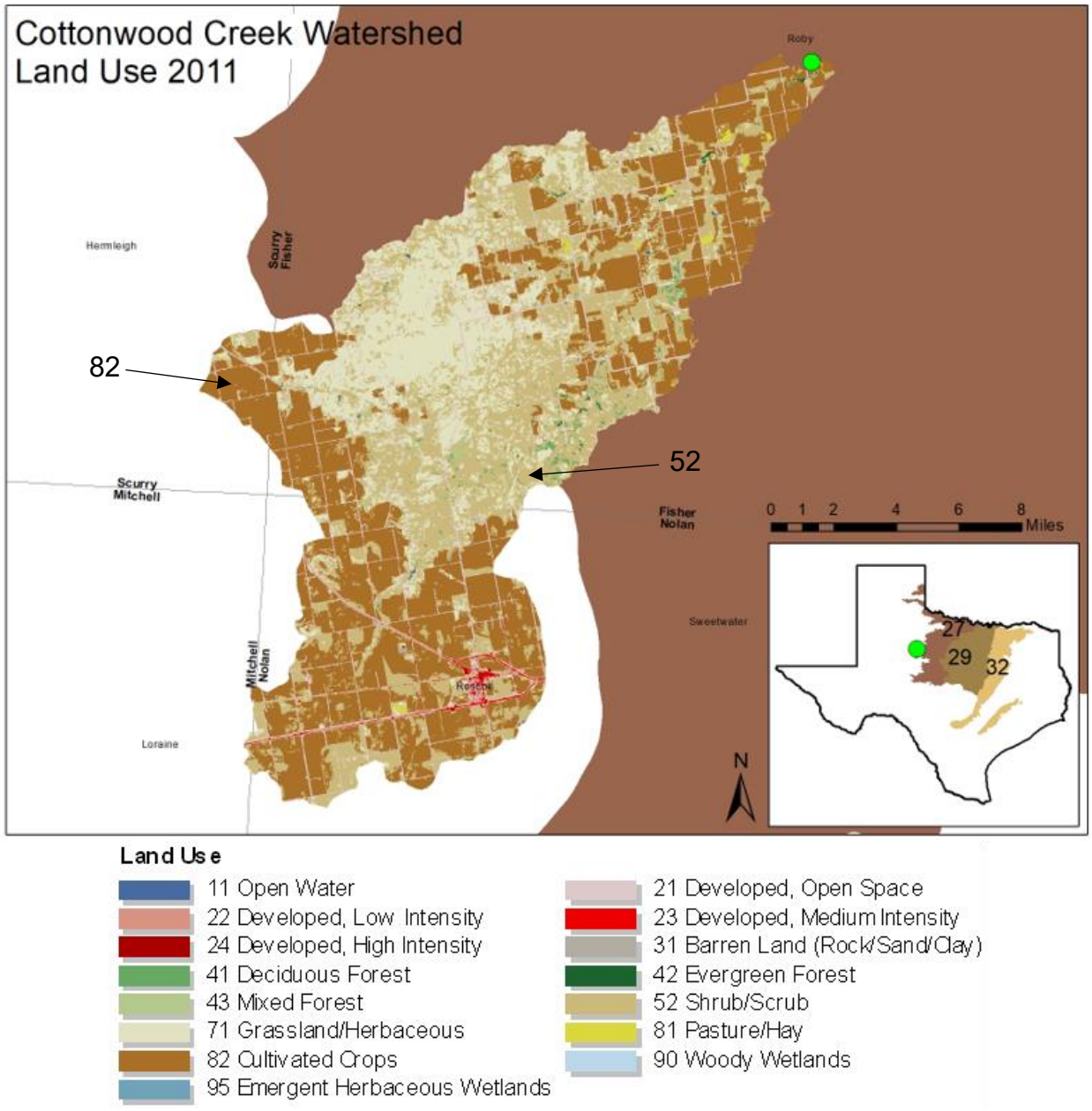


**Figure 82. Map of Cottonwood Creek watershed location and 2011 land use; cultivated crops and shrub/scrub were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | August 24, 1988 |
| Water Quality: | 8 sampling events |
| Fish: | August 24, 1988; April 5, 1989 |
| Benthic Invertebrates: | August 24, 1988 |

## Physical Characterization

### Watershed and Land Use

Cottonwood Creek lies within the Brazos River Basin. Sample site 11710 is located 1.19 km downstream of SH 70 near the City of Roby in Fisher County (Figure 82).

The Cottonwood Creek watershed at site 11710 is approximately 536.78 sq km. The station and lower half of the watershed is located in Level IV Ecoregion 27h, the Red Prairie, and the upper half of the watershed is located in Level IV Ecoregion 26b, the Flat Tablelands and Valleys. The dominant land cover in the watershed is cultivated crops at 40.57% and is present in the lower half and upper half the watershed (Homer et al. 2015; Figure 82 and Figure 83). Shrub is the secondary land cover encompassing 32.65% and is mostly located in the middle of the watershed. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 6.84%.

From 1992-2011 there was an 83.82 sq km decrease in cultivated crops and a 49.69 sq km decrease in pasture/hay. There was a 128.51 sq km increase in shrub and a 30.54 sq km increase in open space development (Figure 84).

There are no permitted wastewater outfalls within the Cottonwood Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Cottonwood Creek was evaluated on August 24, 1988. Cottonwood Creek is a tributary to the Clear Fork Brazos River. The riparian width was 30 meters. The riparian zone was dominated by grasses, which made up an average of 80% of the total riparian species, followed by trees and shrubs (10% each). The average percentage of tree canopy cover was 20%. The dominant substrate was silt except in riffles where gravel was dominant, and the average percent of substrate that was gravel size or larger was 24%. Average percent instream cover was 30%. Cottonwood Creek had an average depth of 0.2 meters and a maximum depth of 0.5 meters. The average width was 2.5 meters and average stream bank slope was 37 degrees. Stream flow at the site was 0.35 cfs. Average stream bank erosion potential was 23%. Six riffles were observed at the site and there were two total stream bends.

### Water Quality

Water samples were collected at station 11710 over eight sampling events from August 1988 through July 1999. Data were collected for temperature, flow, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Fourteen species (five families) were collected between the two sampling events. Eleven of the species were in the families Centrarchidae (six species) and Cyprinidae (five species). Red

Shiner was the most abundant species. The aquatic life use rated as high and intermediate for the 1988 and 1989 fish assemblages, respectively; however, when the coefficient of variability was applied to the 1989 sample it also attained a high rating. The major reasons for the creek not achieving an exceptional rating was the absence of benthic invertivore species, high percentage of tolerant individuals, and low percentage of piscivores.

**Benthic Macroinvertebrates**

A total of 2,208 individuals representing 37 taxa from nine orders of macroinvertebrates were collected in the Surber sample from Cottonwood Creek (Appendix E). Trichoptera, Diptera, Oligochaeta, Coleoptera and Ostracoda were the most commonly collected orders.

Results of the Ecoregions 27, 29, and 32 Surber BIBI fell in the high aquatic life use category for the sample collected in 1988.

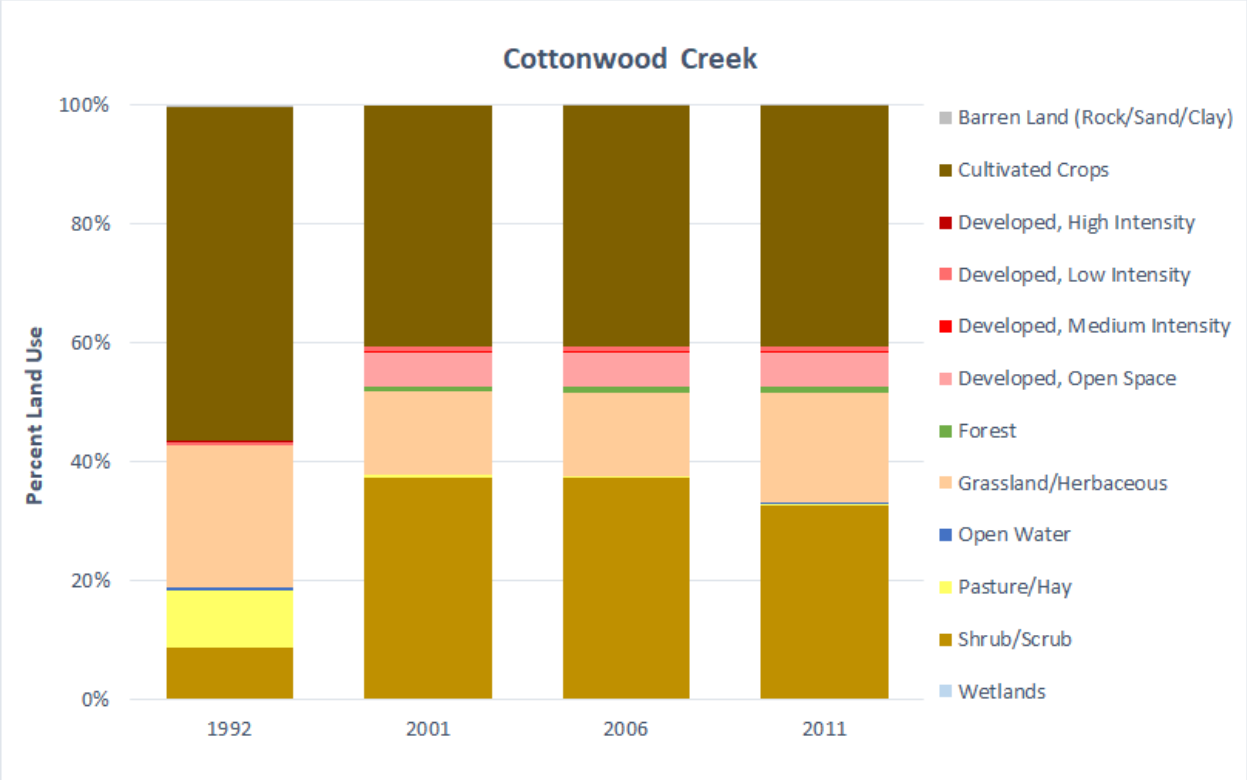


**Figure 83. Percent land use in the Cottonwood Creek watershed from 1992-2011.**

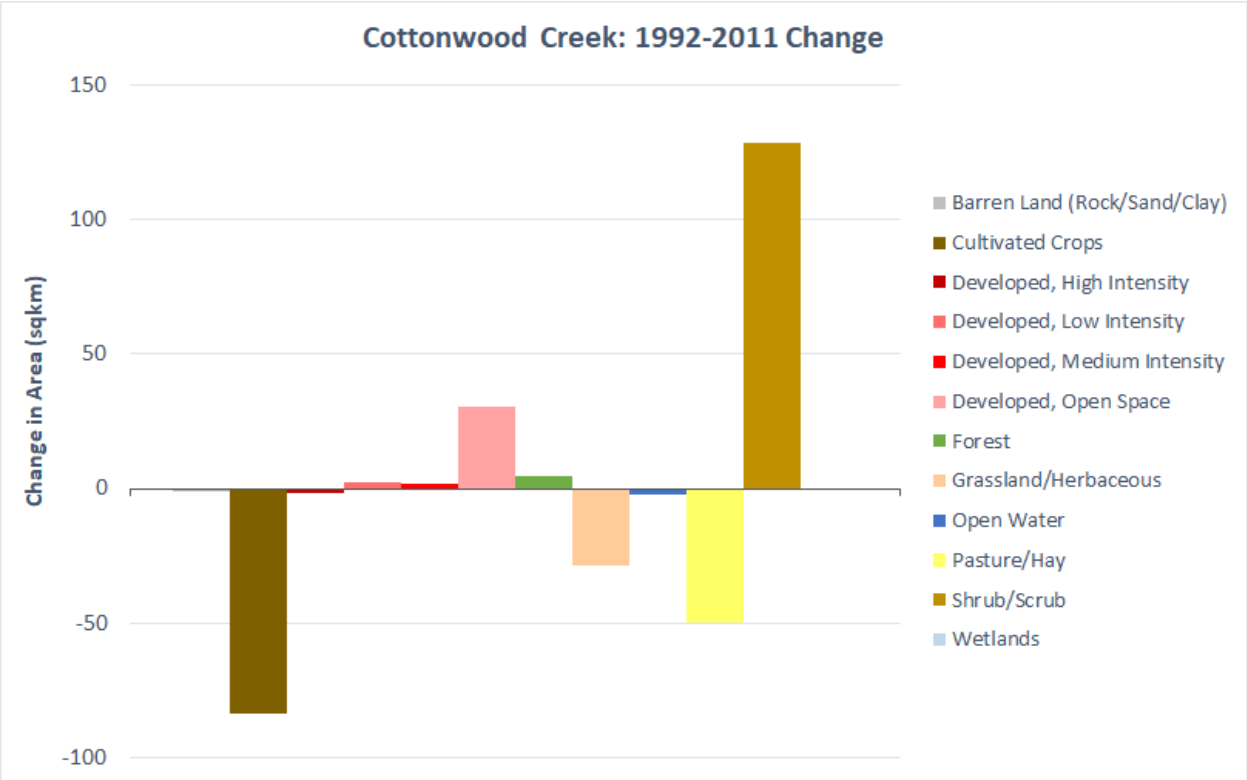


**Figure 84. Land use change in area (sq km) from 1992-2011 for the Cottonwood Creek watershed.**

## DEADMAN CREEK

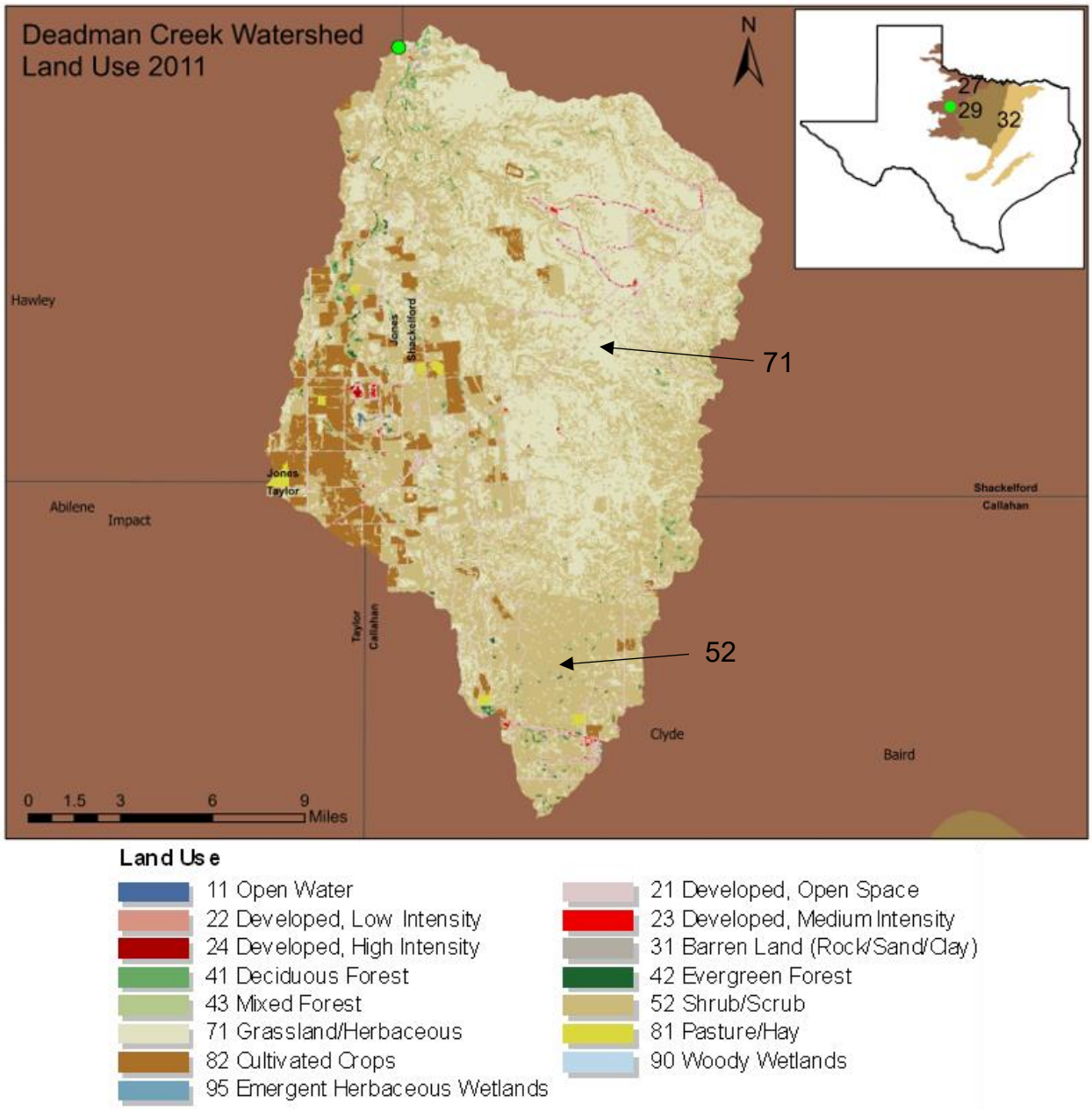


**Figure 85. Map of Deadman Creek watershed location and 2011 land use; shrub/scrub and grassland/herbaceous were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | August 24, 1988; June 28, 2005; August 29, 2005; July 11, 2018 |
| Water Quality: | 111 sampling events |
| Fish: | August 24, 1988; July 11, 2018 |
| Benthic Invertebrates: | August 24, 1988; June 28, 2005; August 29, 2005; July 11, 2018 |

## Physical Characterization

### Watershed and Land Use

Deadman Creek lies within the Brazos River Basin. Sample site 11696 is located 87 meters upstream of CR 303, approximately 5.15 km east of Nugent in Jones County (Figure 85).

The Deadman Creek watershed at site 11696 is approximately 455.88 sq km. The station and small portion of the watershed lies in Level IV Ecoregion 27h, the Red Prairie, while the majority of the watershed lies in Level IV Ecoregion 27j, the Limestone Plains. The dominant land cover in the watershed is shrub at 45.09% and is present throughout the watershed (Homer et al. 2015; Figure 85 and Figure 86). Grassland/herbaceous is the secondary land cover encompassing 40.51%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 5.20% and total cover for cultivated crops is 7.48%.

From 1992-2011 there was a 66.62 sq km decrease in pasture/hay and a 44.87 sq km decrease in grassland. There was a 119.33 sq km increase in shrub and a 20.59 sq km increase in open space development (Figure 87).

There is one industrial wastewater outfall (discharges ≥ 1 million gallons per day) within the Deadman Creek watershed permitted to the City of Abilene. The wastewater facility does not discharge directly into Deadman Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Deadman Creek was evaluated at three sites over four sampling events from 1988 to 2018. Deadman Creek is an intermittent stream with perennial pools that drains to the Clear Fork Brazos River north of Abilene. Habitat Quality Index scores are available for three sample events and indicate an intermediate to high aquatic life use rating (18.5-22). Riparian areas were well vegetated throughout the reach with an average riparian buffer ranging from 18 to 20 meters wide. The riparian zone was generally dominated by grasses followed by trees then shrubs. The average percentage of tree canopy cover ranged from 37% to 56%. The dominant stream substrate was silt although gravel, cobble, and boulders were also common and the average percent of substrate gravel size or larger varied from 26% to 51%. Average percent instream cover was 14% to 67% and instream cover types include overhanging vegetation, macrophytes, cobble, gravel, boulders, and algae. Deadman Creek ranged from 0.2-0.6 meters deep on average and 10-24 meters wide. Average stream bank slope ranged from 29-76 degrees. Stream flow at the sites was measured at a minimum value of 0.1 cfs and a maximum of 13 cfs. Average stream bank erosion potential was 13%-21%. The deepest pool measured at Deadman Creek was 1.0 meters. Number of riffles observed at the sites varied from one to two, and total number of stream bends ranged from one to three.

### Water Quality

Station 11697 is sampled quarterly by TCEQ. One hundred and eleven sampling events occurred between October 1981 and June 2020. Samples for this waterbody have also been collected at

station 11699 during one sampling event in August 1988. Data from station 11697 were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a. USGS gage 08084100 is located near station 11697, but no flow data was collected at this site.

## Biological Characterization

### Fish

Sixteen species (seven families) were collected between the two sampling events. Centrarchidae and Cyprinidae were the richest families with six and four species, respectively. Western Mosquitofish was the most abundant species in 1988 whereas Red Shiner was most abundant in 2018. The aquatic life use (based upon the fish assemblage) declined from high to intermediate between 1988 and 2018. The major reasons for the lower rating was due to a reduction in number of sunfish species, increase in percentage of omnivorous individuals, and a decrease in percentage of piscivorous individuals. Five sunfish species were collected in 1988. In 2018, only Bluegill and Longear Sunfish were found. Green Sunfish, Warmouth *Lepomis gulosus*, and White Crappie *Pomoxis annularis* were absent. Since these three species are piscivorous their absence also contributed to the decline in IBI metric score (from five to one) for percentage of piscivorous individuals. Two piscivorous species were added in 2018; however, single individuals of Flathead Catfish *Pylodictis olivaris* and Longnose Gar *Lepisosteus osseus* were insufficient to overcome the loss of the more abundant sunfish species. The slight increase in omnivores from 7% to 11% resulted in a decrease in IBI metric score from five to three.

### Benthic Macroinvertebrates

Considering the Surber sample collected August 24, 1988, and the RBP samples collected in 2005 and 2018, a total of 6,357 individuals representing 79 taxa from 15 orders of macroinvertebrates were collected from Deadman Creek (Appendix E). Pelecypoda, Trichoptera, Oligochaeta, Coleoptera, Diptera, Ostracoda, and Turbellaria were the most commonly collected orders. Odonata, Gastropoda, and Amphipoda were the only additional taxa with abundance greater than one percent of the collections.

Results of the Ecoregions 27, 29, and 32 Surber BIBI fell in the intermediate aquatic life use category for the sample collected in 1988, while the results for the July 2018 regionalized RBP BIBI fell in the exceptional aquatic life use category and the June and August 2005 samples fell in the high aquatic life use category.

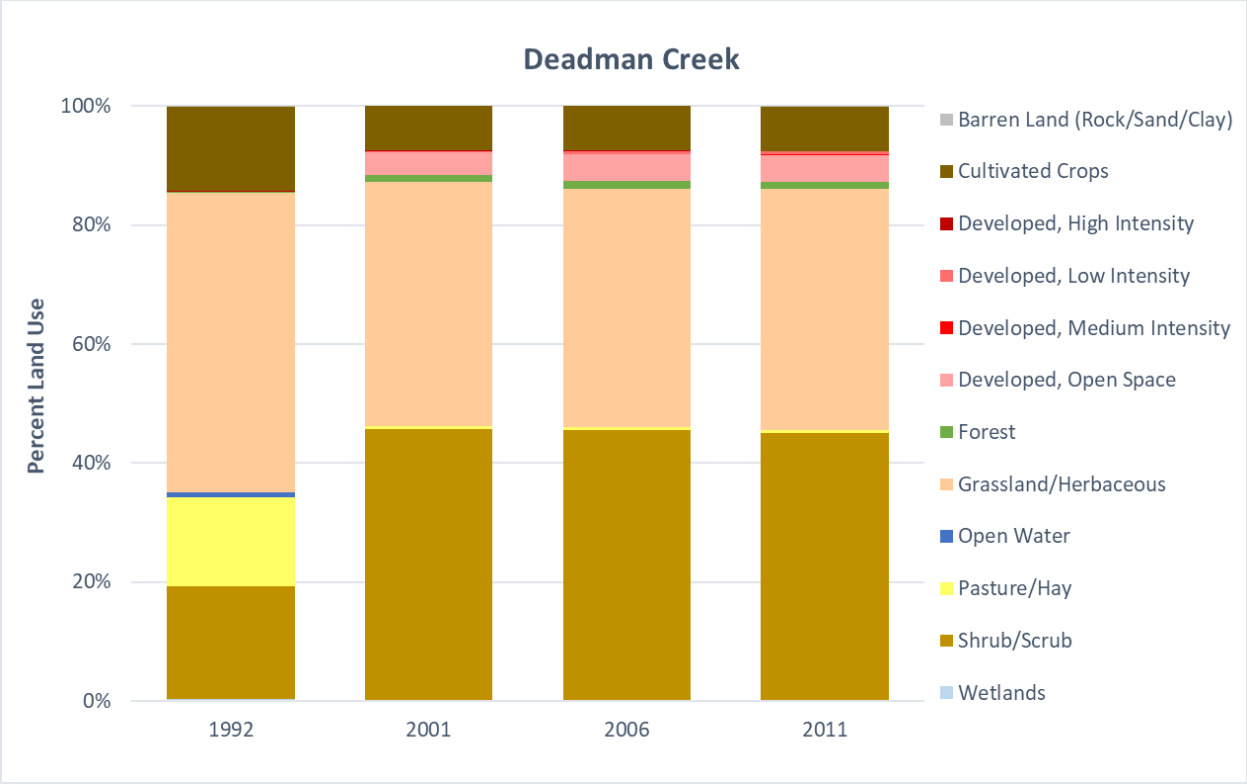


**Figure 86. Percent land use in the Deadman Creek watershed from 1992-2011.**

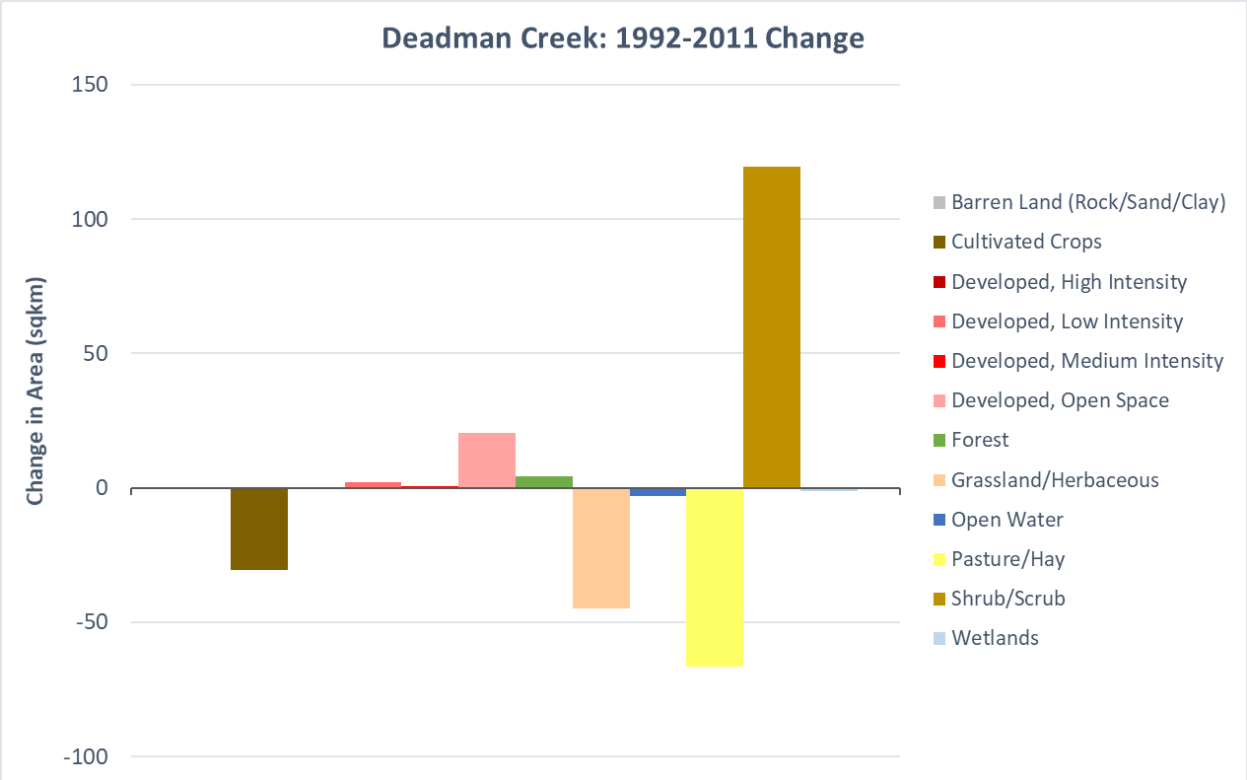


**Figure 87. Land use change in area (sq km) from 1992-2011 for the Deadman Creek watershed.**

## ELM CREEK

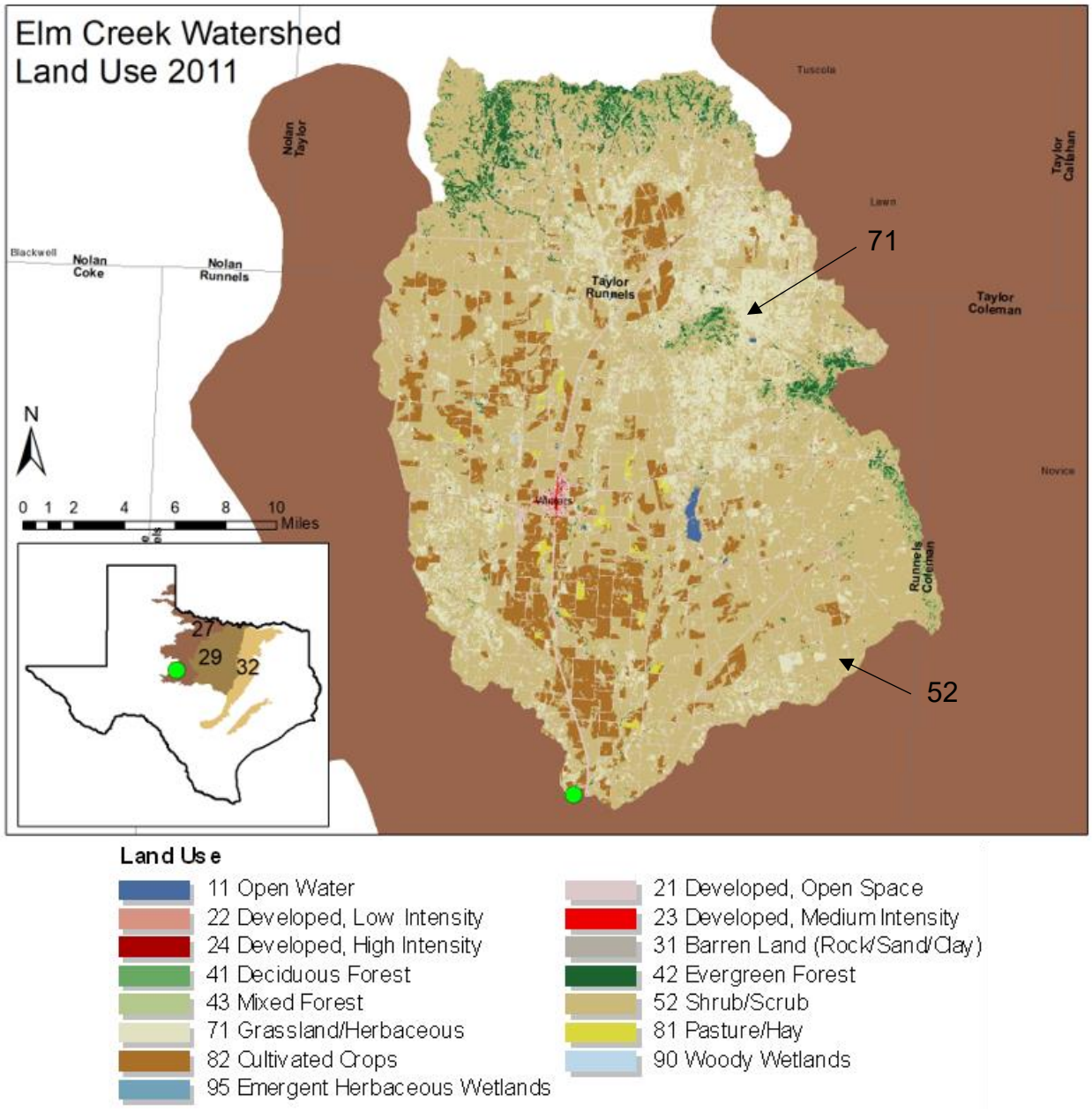


**Figure 88. Map of Elm Creek watershed location and 2011 land use; shrub/scrub and grassland/herbaceous were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | August 23, 1988 |
| Water Quality: | 99 sampling events |
| Fish: | August 23, 1988; April 4, 1989 |
| Benthic Invertebrates: | August 23, 1988 |

## Physical Characterization

### Watershed and Land Use

Elm Creek lies within the Colorado River Basin. Sample site 12207 is located approximately 15 m downstream of CR 330 north of Ballinger in Runnels County (Figure 88).

The Elm Creek watershed at site 12207 is approximately 1145.66 sq km. The station and most of the watershed lies in Level IV Ecoregion 27h, the Red Prairie, while another large portion lies in Level IV Ecoregion 27j, the Limestone Plains. A small portion of the upper watershed lies within Ecoregion 30. The dominant land cover in the watershed is shrub at 62.55% and is present throughout the watershed (Homer et al. 2015; Figure 88 and Figure 89). Grassland/herbaceous is the secondary land cover encompassing 14.22%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 7.09% and total cover for cultivated crops is 11.12%.

From 1992-2011 there was a 382.86 sq km decrease in cultivated crops and a 109.48 sq km decrease in grassland. There was a 445.45 sq km increase in shrub and a 76.83 sq km increase in open space development (Figure 90).

There are no permitted wastewater outfalls within the Elm Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Elm Creek was evaluated on August 23, 1988. Elm Creek is an intermittent stream with perennial pools that drains to the Colorado River below E. V. Spence Reservoir. It is impounded upstream of the sampling site to form Lake Winters. The riparian width was 23 meters. The riparian zone was dominated by trees, which made up an average of 80% of the total riparian species, followed by grasses (15%) then shrubs (5%). The average percentage of tree canopy cover was 14%. The dominant substrate was silt and silt covered bedrock, but gravel was common in riffles and the average percent of substrate that was gravel size or larger was 25%. Average percent instream cover was 25%. Elm Creek had an average depth of 0.6 meters and a maximum depth of 1.8 meters. The average width was 14 meters and average stream bank slope was 53 degrees. Stream flow at the site was 0.1 cfs. Average stream bank erosion potential was 54%. Three riffles were observed at the site and there were two total stream bends.

### Water Quality

Water samples were collected at station 12207 over 99 sampling events from August 1988 through August 2011. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Sixteen species (nine families) were collected between the two sampling events. Centrarchidae yielded the most species with five. Red Shiner was the most abundant species. The aquatic life use rating for both fish collections was only intermediate. The assemblage was dominated by tolerant species (54 to 85% of the individuals) and had very low numbers of piscivores.

**Benthic Macroinvertebrates**

A total of 4,380 individuals representing 48 taxa from 14 orders of macroinvertebrates were collected in the Surber sample from Elm Creek (Appendix E). Trichoptera, Coleoptera, Ephemeroptera, and Diptera were the most commonly collected orders.

Results of the Ecoregions 27, 29, and 32 Surber BIBI fell in the exceptional aquatic life use category.

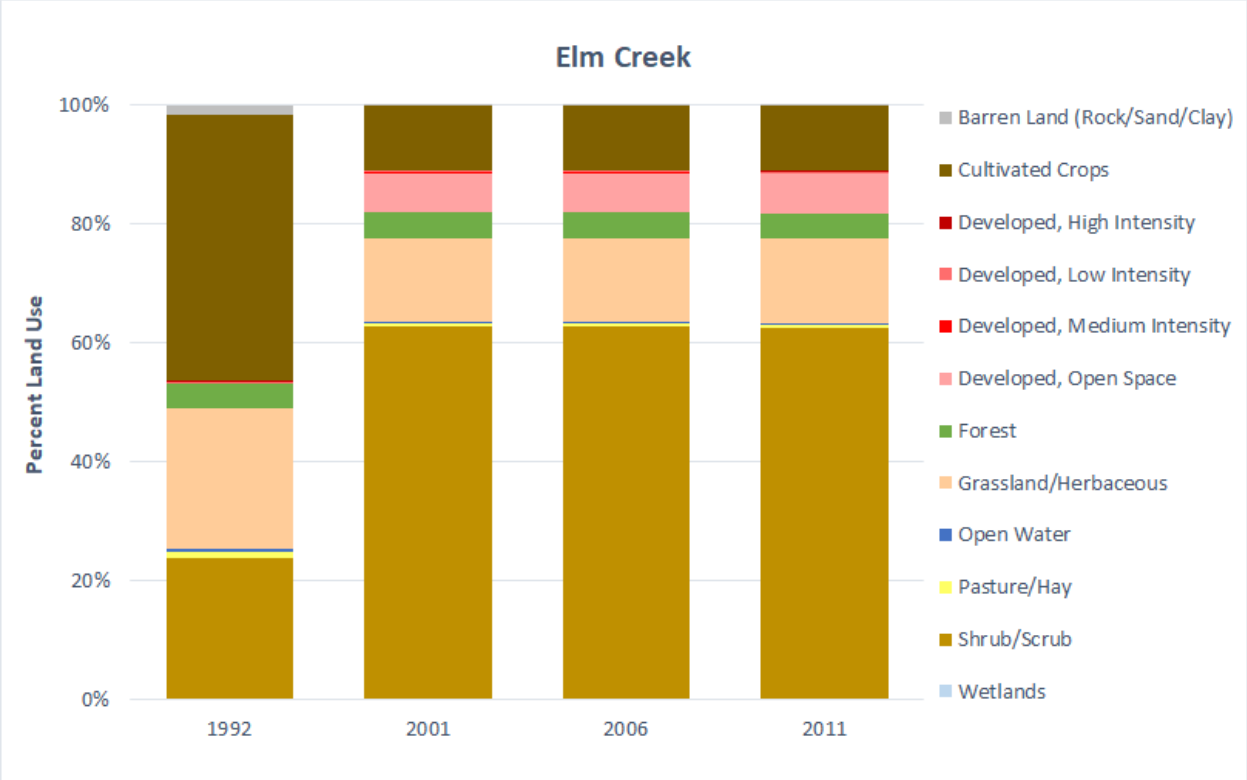


**Figure 89. Percent land use in the Elm Creek watershed from 1992-2011.**

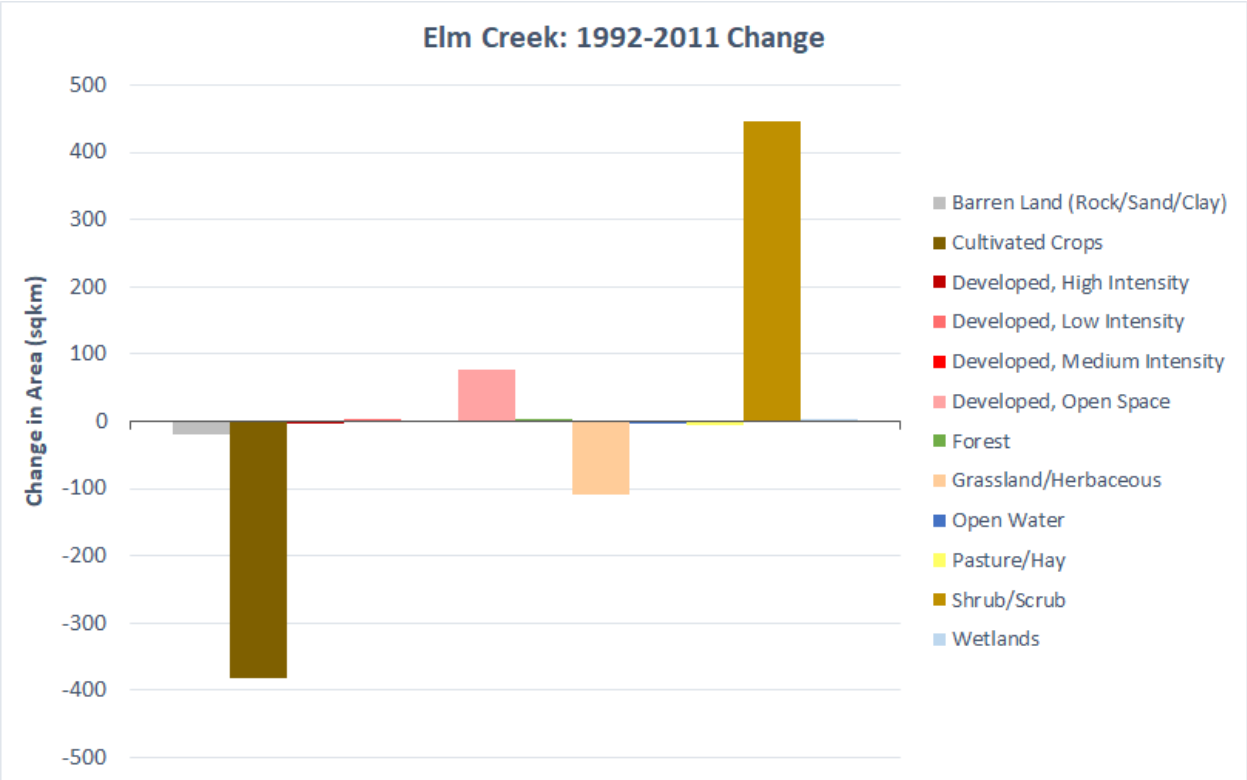


**Figure 90. Land use change in area (sq km) from 1992-2011 for the Elm Creek watershed.**

## LELIA LAKE CREEK

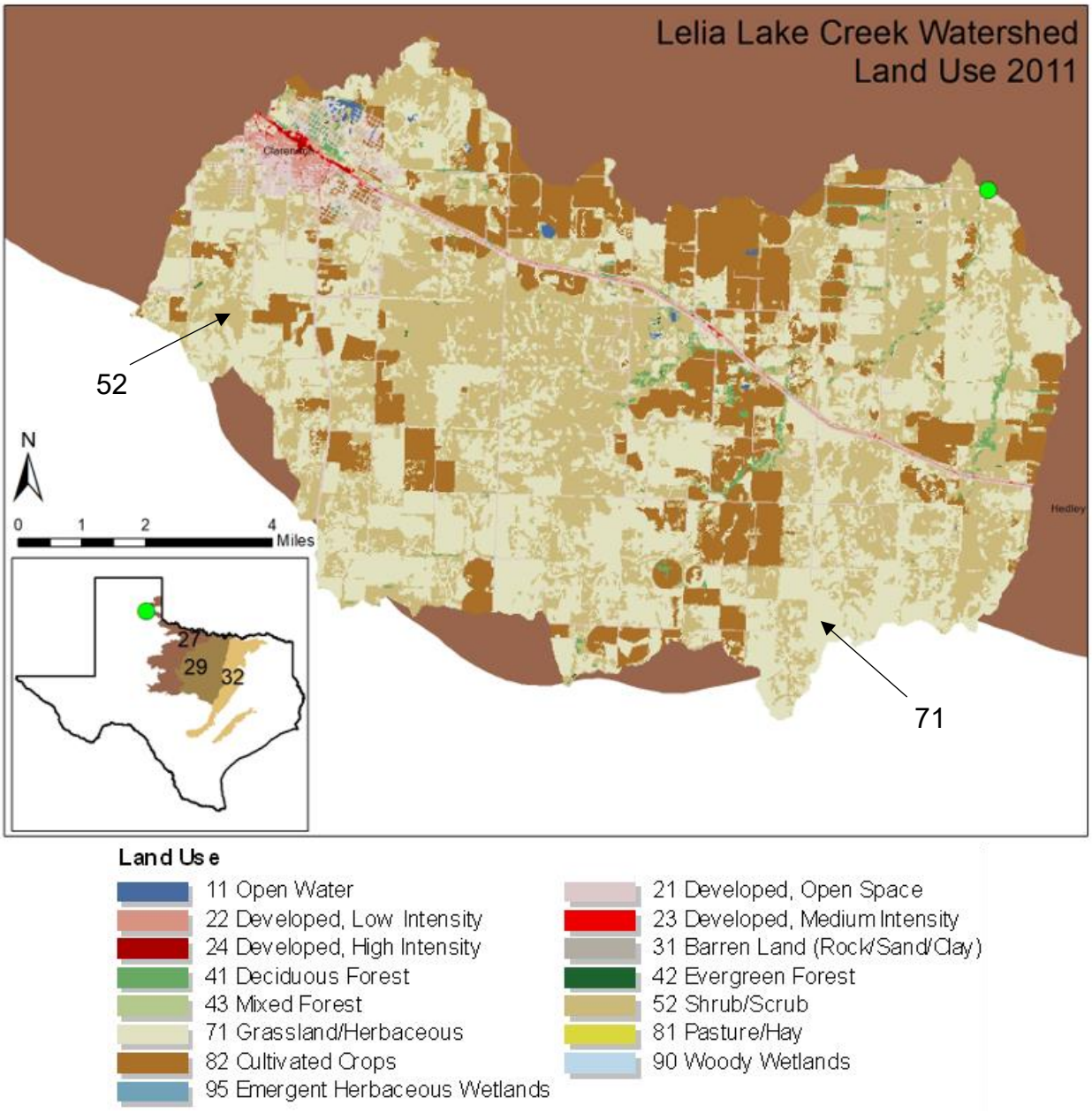


**Figure 91. Map of Lelia Lake Creek watershed location and 2011 land use; grassland/herbaceous and shrub/scrub were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | August 16, 1989 |
| Water Quality: | 96 sampling events |
| Fish: | August 16, 1989 |
| Benthic Invertebrates: | August 17, 1989 |

## Physical Characterization

### Watershed and Land Use

Lelia Lake Creek lies within the Red River Basin. Sample site 10076 is located at FM 2471, approximately 8 km north-northwest of Hedley in Donley County (Figure 91).

The Lelia Lake Creek watershed at site 10076 is approximately 249.36 sq km. The entire watershed lies within Level IV Ecoregion 27h, the Red Prairie. The dominant land cover in the watershed is grassland/herbaceous at 40.91% and is present throughout the watershed (Homer et al. 2015; Figure 91 and Figure 92). Shrub is the secondary land cover encompassing 34.30%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 5.65% and total cover for cultivated crops is 17.59%.

From 1992-2011 there was a 104.30 sq km decrease in cultivated crops and a 2.98 sq km decrease in pasture/hay. There was a 73.09 sq km increase in shrub and a 21.22 sq km increase in grassland (Figure 93).

There are no permitted wastewater outfalls within the Lelia Lake Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Lelia Lake Creek was evaluated on August 16, 1989. Lelia Lake Creek is a perennial stream that drains to the Salt Fork Red River. The riparian width was 16 meters. The riparian zone was dominated by grasses which made up an average of 60% of the total riparian species, followed by trees and shrubs (20% each). The average percentage of tree canopy cover was 0%. The dominant substrate was sand and gravel, and the average percent of substrate that was gravel size or larger was 27%. Average percent instream cover was 2%. Lelia Lake Creek had an average depth of 0.06 meters and a maximum depth of 0.12 meters. The average width was 7.4 meters and average stream bank slope was 25 degrees. Stream flow at the site was 4.5 cfs. Average stream bank erosion potential was 75%. Four riffles were observed at the site and there was one stream bend.

### Water Quality

Water samples were collected at station 10076 over 96 sampling events from August 1988 through December 2019. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a. No 24-hour data have been collected at this site.

Continuous flow data is available from USGS gage 07299890 (Figure 94). Between July 1997 through December 2019, the median flow was 1.2 cfs. Daily average flows ranged from 0 cfs to 318 cfs, though flows were greater than 100 cfs only 0.18 percent of the time in this period. Data have been log transformed to better visualize flow patterns.

## Biological Characterization

### Fish

The aquatic life use (based upon the fish assemblage) rated as limited; however, when the coefficient of variability is applied it rises to intermediate. Species richness was very low (only six species and four families), no benthic invertivores were collected, only one sunfish species (Green Sunfish, a tolerant species) was present, the assemblage was dominated by tolerant species (99% of the individuals), and the percentage of piscivorous individuals was low. The two most abundant species were Plains Killifish and Red Shiner.

### Benthic Macroinvertebrates

A total of 120 individuals representing 20 taxa from seven orders of macroinvertebrates were collected in the Surber sample from Lelia Lake Creek (Appendix E). Ephemeroptera, Diptera and Trichoptera were the most commonly collected orders, collectively accounting for 88 percent of the total number of individuals collected. Gastropoda, Odonata, Coleoptera, and Pelecypoda comprised the remaining orders collected.

The Ecoregions 27, 29, and 32 Surber BIBI fell in the high aquatic life use category for the sample.

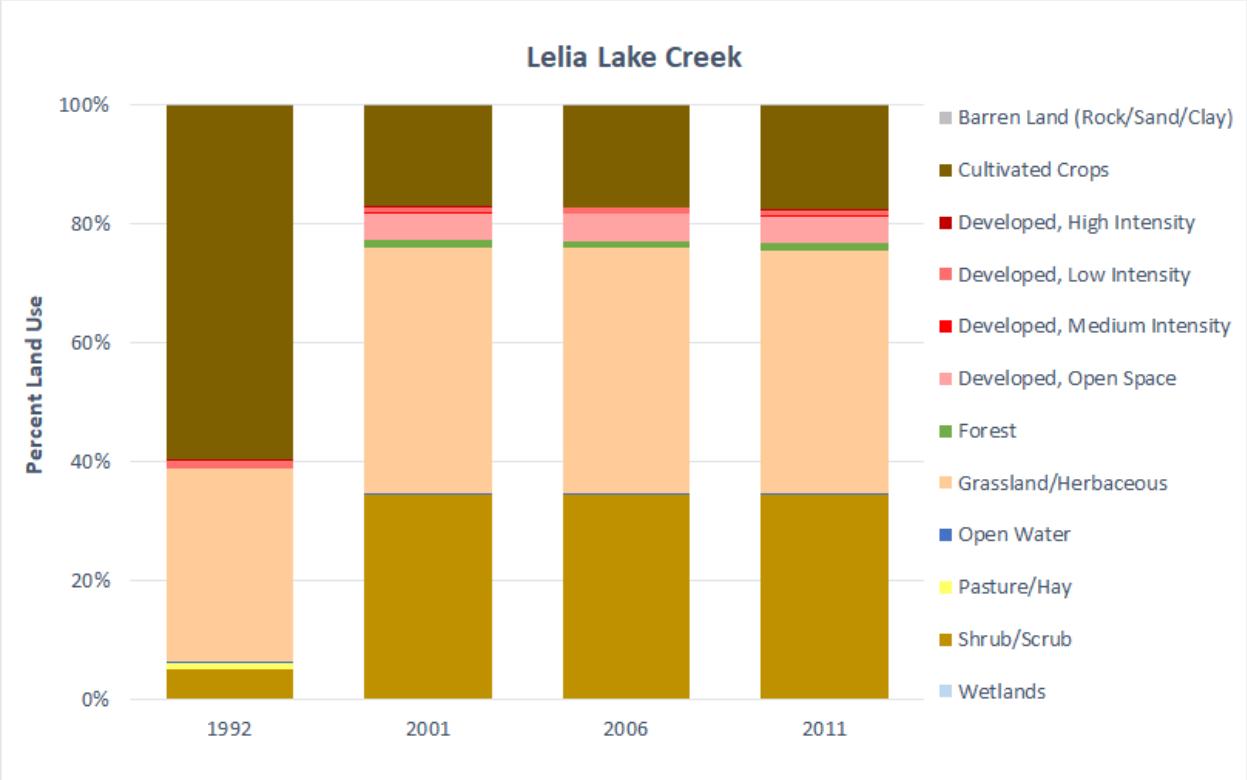


**Figure 92. Percent land use in the Lelia Lake Creek watershed from 1992-2011.**

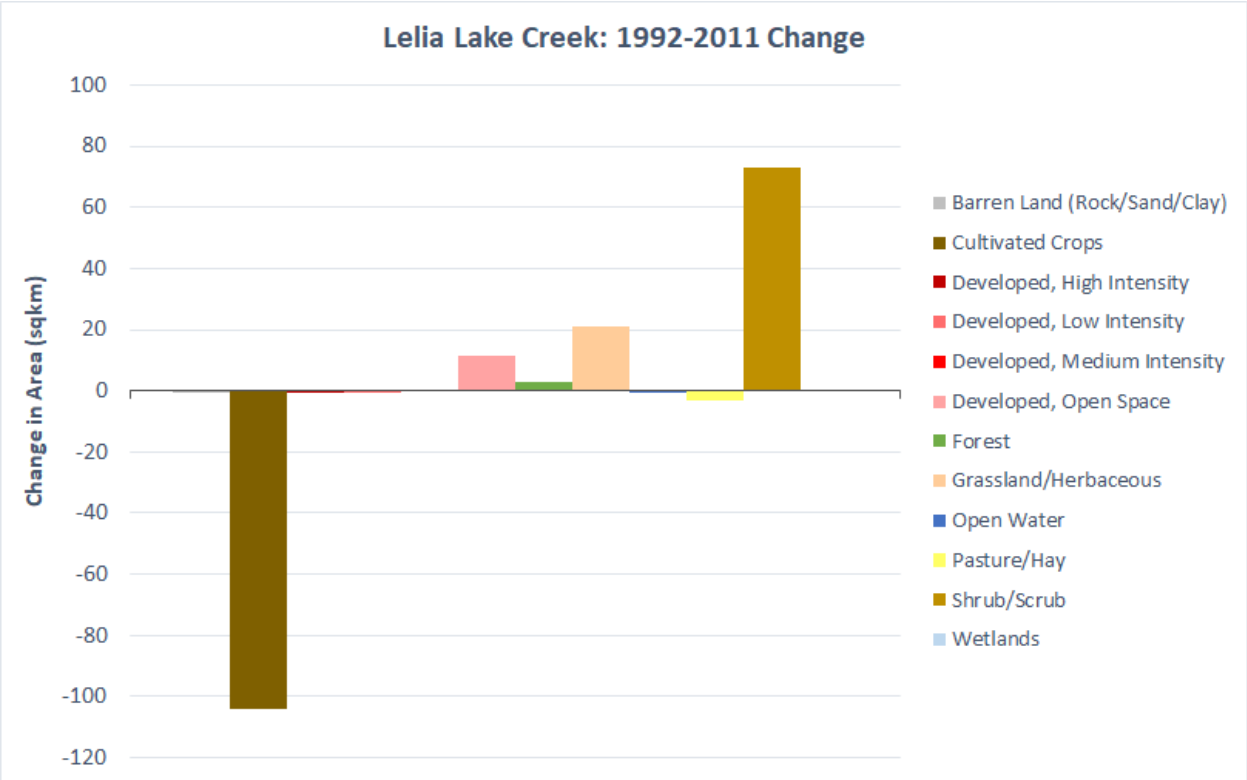


**Figure 93. Land use change in area (sq km) from 1992-2011 for the Lelia Lake Creek watershed.**

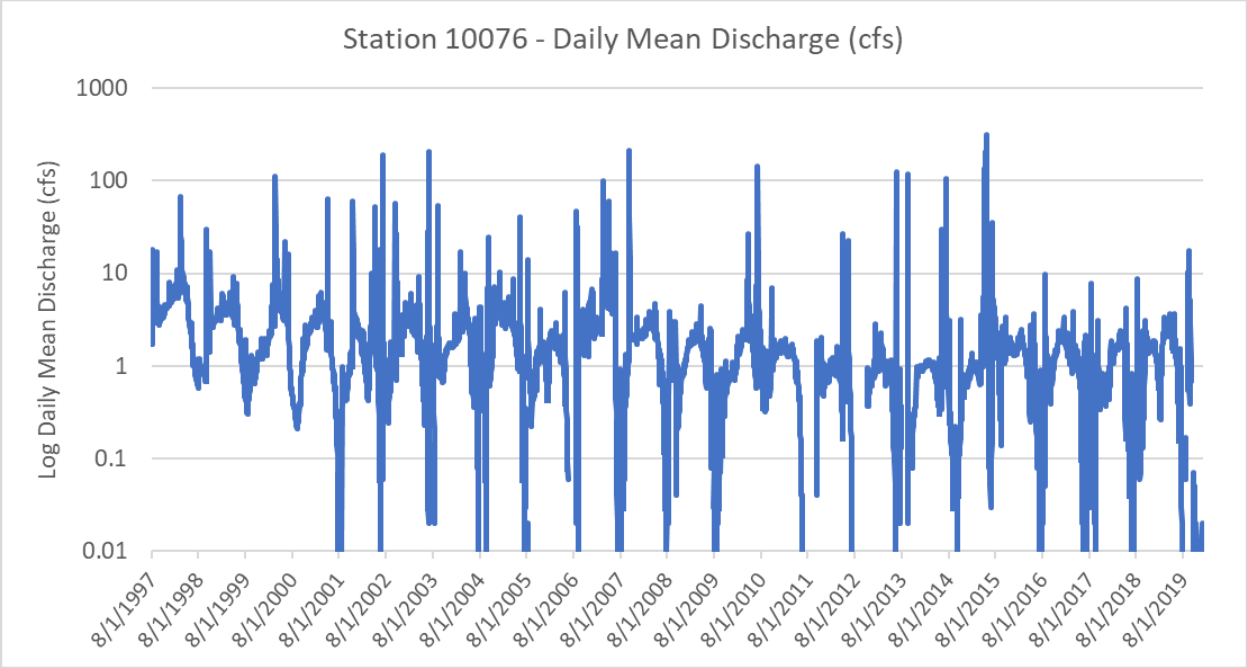


**Figure 94. Log transformed daily mean discharge for Lelia Lake Creek at station 10076.**

## SWEETWATER CREEK

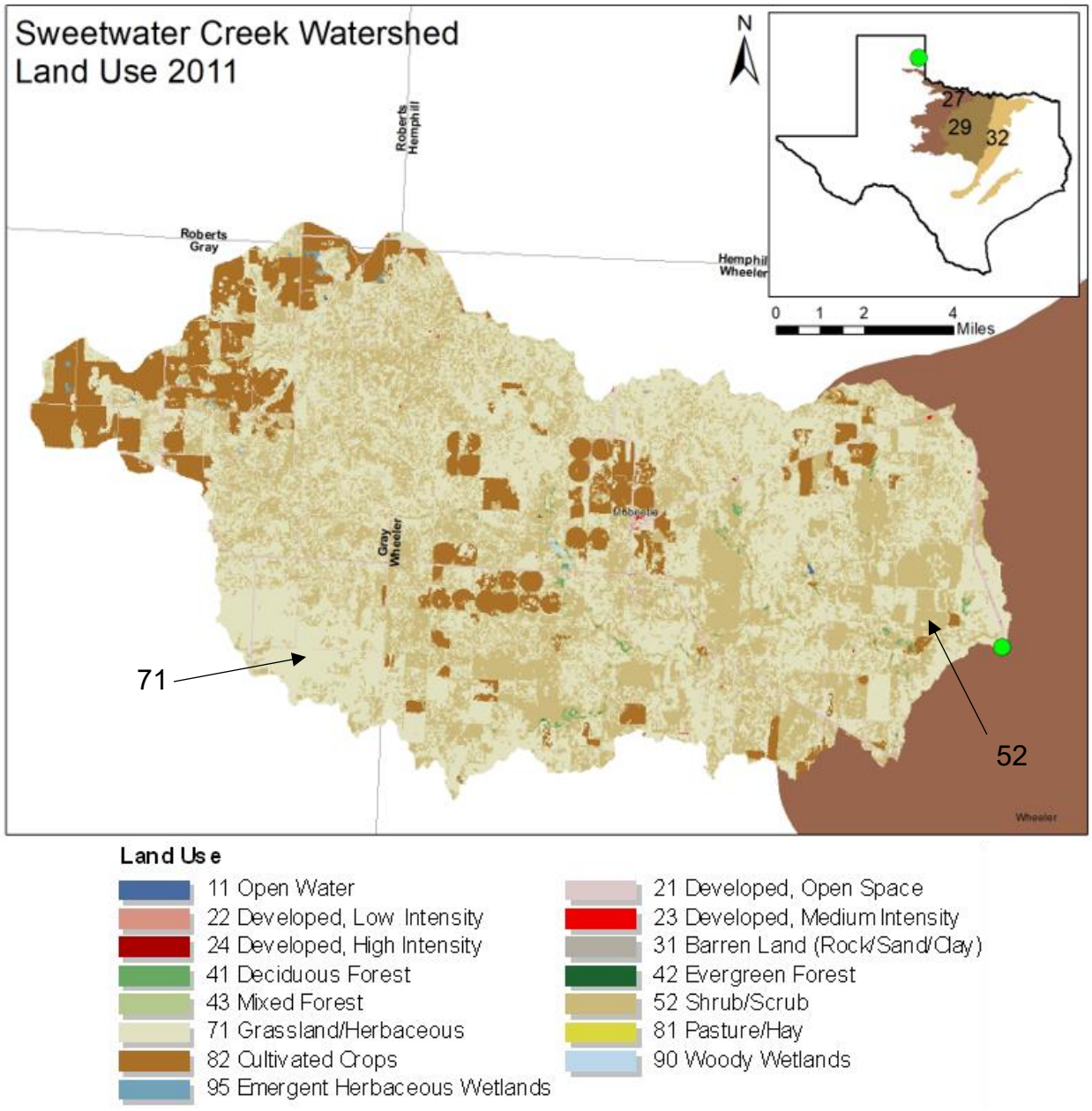


**Figure 95. Map of Sweetwater Creek watershed location and 2011 land use; grassland/herbaceous and shrub/scrub were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | September 8, 1987; May 8, 2018 |
| Water Quality: | 71 sampling events |
| Fish: | September 8, 1987; May 8, 2018 |
| Benthic Invertebrates: | September 9, 1987 (x2); May 8, 2018 |

## Physical Characterization

### Watershed and Land Use

Sweetwater Creek lies within the Red River Basin. Sample site 10072 is located at US 83, approximately 6.25 km north-northwest of Wheeler in Wheeler County (Figure 95).

The Sweetwater Creek watershed at site 10072 is approximately 433.19 sq km. The station and lower watershed are located in Level IV Ecoregion 27h, the Red Prairie, a large portion of the middle watershed lies in Level IV Ecoregion 26a, the Canadian/Cimarron Breaks, and the most upper portion of the watershed lies in Level IV Ecoregion 25i, the Llano Estacado. The dominant land cover in the watershed is grassland/herbaceous at 49.78% and is present throughout the watershed (Homer et al. 2015; Figure 95 and Figure 96). Shrub is the secondary land cover encompassing 35.36%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 2.12% and total cover for cultivated crops is 12.21%.

From 1992-2011 there was a 70.0 sq km decrease in cultivated crops and a 45.09 sq km decrease in grassland. There was a 114.63 sq km increase in shrub and an 8.46 sq km increase in open space development (Figure 97).

There are no permitted wastewater outfalls within the Sweetwater Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Sweetwater Creek was evaluated on September 8, 1987 and again on May 8, 2018. Sweetwater Creek is a perennial stream that drains to the North Fork Red River in Oklahoma. The following summary information is based on data collected during the most recent sampling event in 2018. The Habitat Quality Index score of 21 indicates a high aquatic life use rating. Riparian areas were well vegetated throughout the reach with an average riparian buffer measured at greater than 20 meters, although evidence of cattle grazing was present throughout the reach. The riparian zone was dominated by grasses, which make up an average of 60% of the total riparian species, followed by trees (25%) then shrubs (15%). The average percentage of tree canopy cover was 37%. The dominant substrate was sand, and the average percent of substrate that was gravel size or larger was 0%. Average percent instream cover was 88% and instream cover types include woody debris, algae, and abundant macrophytes (primarily Typha sp.). Sweetwater Creek was 0.24 meters deep on average and 5.5 meters wide. Average stream bank slope was 19 degrees and average stream bank erosion potential was 40.5%. The deepest pool measured at Sweetwater Creek was 0.6 meters. Stream flow at the site was measured at a minimum value of 1.2 cfs in 2018 and a maximum of 5.1 cfs in 1987. No riffles were observed at the site in 2018 and there were six total stream bends.

### Water Quality

Water samples were collected at station 10072 over 71 sampling events from September 1987 through October 2011. Data were collected for temperature, flow, transparency, specific

conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Fourteen species (four families) were collected between the two sampling events. All but two species were in the Cyprinidae or Centrarchidae families. The fish assemblage significantly shifted between the 1987 and 2018 collections from a more lotic based assemblage to one more lentic in nature. Of the fourteen species collected only four were present in both collections. These were Common Carp, Western Mosquitofish, Longear Sunfish, and Largemouth Bass *Micropterus salmoides*. Five native minnow species were collected in 1987 - Red Shiner, Blacktail Shiner *Cyprinella venusta*, Golden Shiner *Notemigonus crysoleucas*, Red River Shiner *Notropis bairdi*, and Bullhead Minnow. None were collected in 2018. Sunfish species increased from two to four, with the addition of Green Sunfish, Warmouth, and Bluegill (and the loss of Orangespotted Sunfish *Lepomis humilis*). The percentage of individuals as non-native species increased from 0.9% (metric score of 5) to 6.5% (metric score of 1). The most abundant species in 1987 was Western Mosquitofish. Longear Sunfish was the most abundant species in 2018. Based on the fish assemblage, the creek rated as having an intermediate aquatic life use; however, when the coefficient of variability was applied the rating for the 1987 sample increased to high.

### Benthic Macroinvertebrates

Considering the two September 9, 1987 Surber samples, and the May 8, 2018 RBP sample collectively, a total of 784 individuals representing 73 taxa from 13 orders of macroinvertebrates were collected from Sweetwater Creek (Appendix E). Diptera, Ephemeroptera, Odonata, and Coleoptera were the most commonly collected orders, collectively accounting for 87.6 percent of the total number of individuals collected. Trichoptera, Gastropoda, and Amphipoda were the only other orders which represented greater than one percent of the total collection.

The Ecoregions 27, 29, and 32 BIBI for the Surber samples collected September 9, 1987 both fell in the high aquatic life use category, while the regionalized BIBI for the RBP sample collected May 8, 2018 fell in the intermediate aquatic life use category.

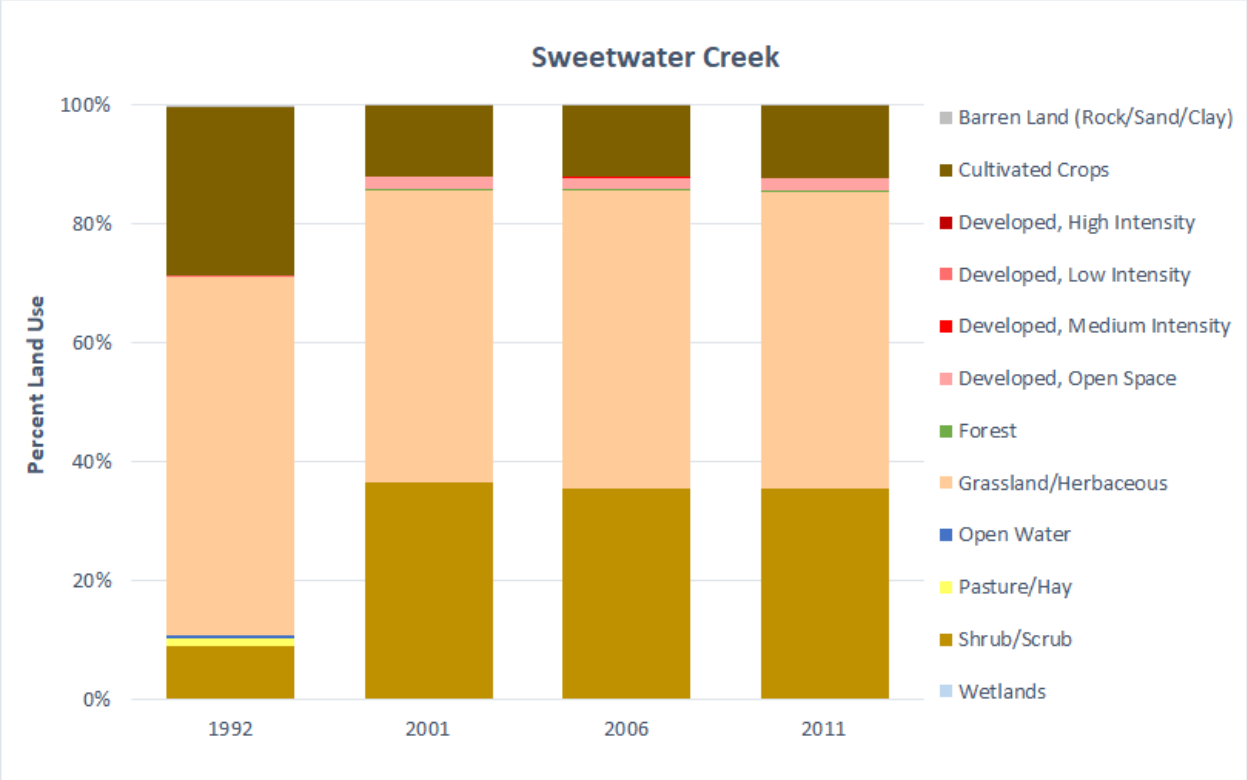


**Figure 96. Percent land use in the Sweetwater Creek watershed from 1992-2011.**

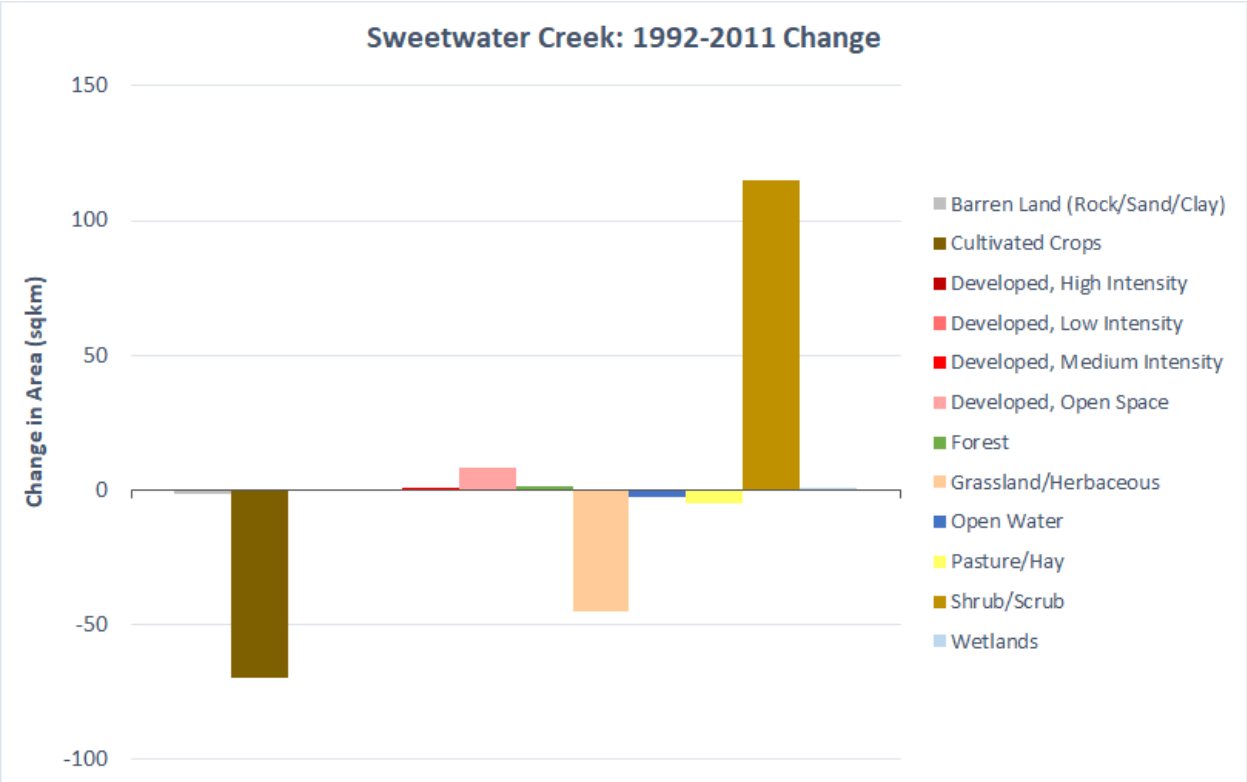


**Figure 97. Land use change in area (sq km) from 1992-2011 for the Sweetwater Creek watershed.**

## Ecoregion 29 Characterization

In Texas, the Cross Timbers ecoregion covers approximately 51,921sq km and encompasses all or part of 35 counties in the north central portion of the state (Figure 80). The ecoregion is bordered on the west by the Central Great Plains (Ecoregion 27), on the east by the Texas Blackland Prairies (Ecoregion 29), by the Edwards Plateau (Ecoregion 30) to the south, and to the north in Texas, by the Red River. Portions of the Red, Brazos, Trinity, and Colorado River Basins are included in the ecoregion. Beyond Texas, the ecoregion extends into southeastern Oklahoma.

The ecoregion is characterized by a mix of forest, woodland, savannah, and prairie and is used primarily as rangeland and pastureland (Griffith et al. 2007). Griffith et al. (2007) also note the region forms a transition from the once prairie, now winter wheat growing area to the west, to the forested low mountains or hills of eastern Oklahoma and Texas. Annual average precipitation in the ecoregion generally decreases from 84-94 cm in the eastern portions to 69-89 cm in the western portions. Riparian vegetation along streams in the ecoregion often includes pecan, black willow *Salix nigra,* cottonwood, sycamore *Platanus occidentalis*, boxelder *Acer negundo,* hackberry, and post oak *Quercus stellata.*

**Table 7. Streams sampled in Ecoregion 29.**

| | | |
|---|---|---|
| Bluff Creek | Ioni Creek | South Fork Rocky Creek |
| Clear Creek | Neils Creek | Steele Creek |
| Colony Creek | Reese Creek | |
| Cowhouse Creek | Rocky Creek | |

## BLUFF CREEK

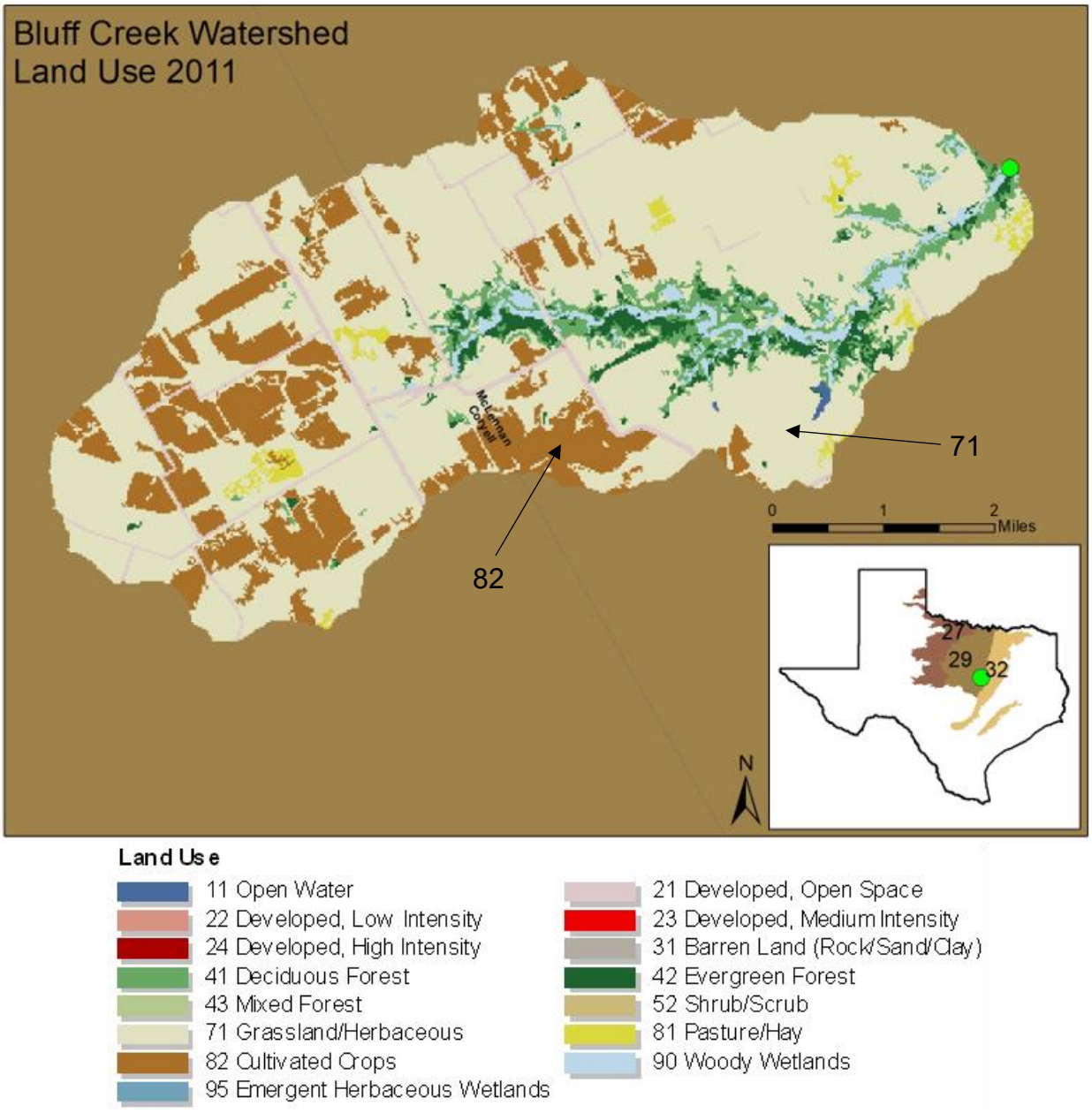


**Figure 98. Map of Bluff Creek watershed location and 2011 land use; grassland/herbaceous and cultivated crops were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 12, 1988 |
| Water Quality: | 3 sampling events |
| Fish: | July 12, 1988; April 18, 1989 |
| Benthic Invertebrates: | July 12, 1988 |

## Physical Characterization

### Watershed and Land Use

Bluff Creek lies within the Brazos River Basin. Sample site 11832 is located upstream of Prairie Chapel Road, approximately 4.5 km northwest of Crawford in McLennan County (Figure 98).

The Bluff Creek watershed at site 11832 is approximately 67.19 sq km. The entire watershed lies within Level IV Ecoregion 29e, the Limestone Cut Plain. The dominant land cover in the watershed is grassland/herbaceous at 65.88% and is present throughout the watershed (Homer et al. 2015; Figure 98 and Figure 99). Cultivated crops is the secondary land cover encompassing 18.39%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 3.37%.

From 1992-2011 there was a 14.02 sq km decrease in pasture/hay and an 8.77 sq km decrease in shrub. There was a 17.83 sq km increase in grassland and a 3.33 sq km increase in cultivated crops (Figure 100).

There are no permitted wastewater outfalls within the Bluff Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Bluff Creek was evaluated on July 12, 1988. Bluff Creek is a tributary to the Middle Bosque River. The riparian width was 76 meters. The riparian zone was dominated by trees, which made up an average of 60% of the total riparian species, followed by shrubs (30%) then grasses (10%). The average percentage of tree canopy cover was 43%. The dominant substrate was gravel, and the average percent of substrate that was gravel size or larger was 50%. Average percent instream cover was 42%. Bluff Creek had an average depth of 0.2 meters and a maximum depth of 0.5 meters. The average width was 5.7 meters and average stream bank slope was 36 degrees. Stream flow at the site was 0.04 cfs. Average stream bank erosion potential was 22%. Six riffles were observed at the site and there were four total stream bends.

### Water Quality

Water samples were collected at station 11832 over three sampling events from July 1988 through July 1999. Data were collected for temperature, flow, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Only eight species (five families) were collected between the two sampling events. One-half of the species were within the family Centrarchidae. Western Mosquitofish was the most abundant species in the 1988 sample whereas Central Stoneroller *Campostoma anomalum* was the most abundant one in 1989. The aquatic life use ratings for the fish collections were only intermediate and limited for the 1988 and 1989 collections, respectively. When the coefficient of variability is

applied the aquatic life uses rise one category to high and intermediate. The lower ratings were mostly due to limited species richness, only one native cyprinid species being collected (Central Stoneroller) and catch per unit of effort being very low.

**Benthic Macroinvertebrates**

A total of 790 individuals representing 54 taxa from 12 orders of macroinvertebrates were collected in the Surber sample from Bluff Creek (Appendix E) on July 12, 1988. Diptera, Coleoptera, Trichoptera, Oligochaeta, and Ephemeroptera were the most commonly collected orders, collectively accounting for 94 percent of the total number of individuals collected. Plecoptera and Gastropoda were the only other orders which comprised at least one percent of the collection.

The Ecoregions 27, 29, and 32 Surber BIBI fell in the high aquatic life use category for the sample.

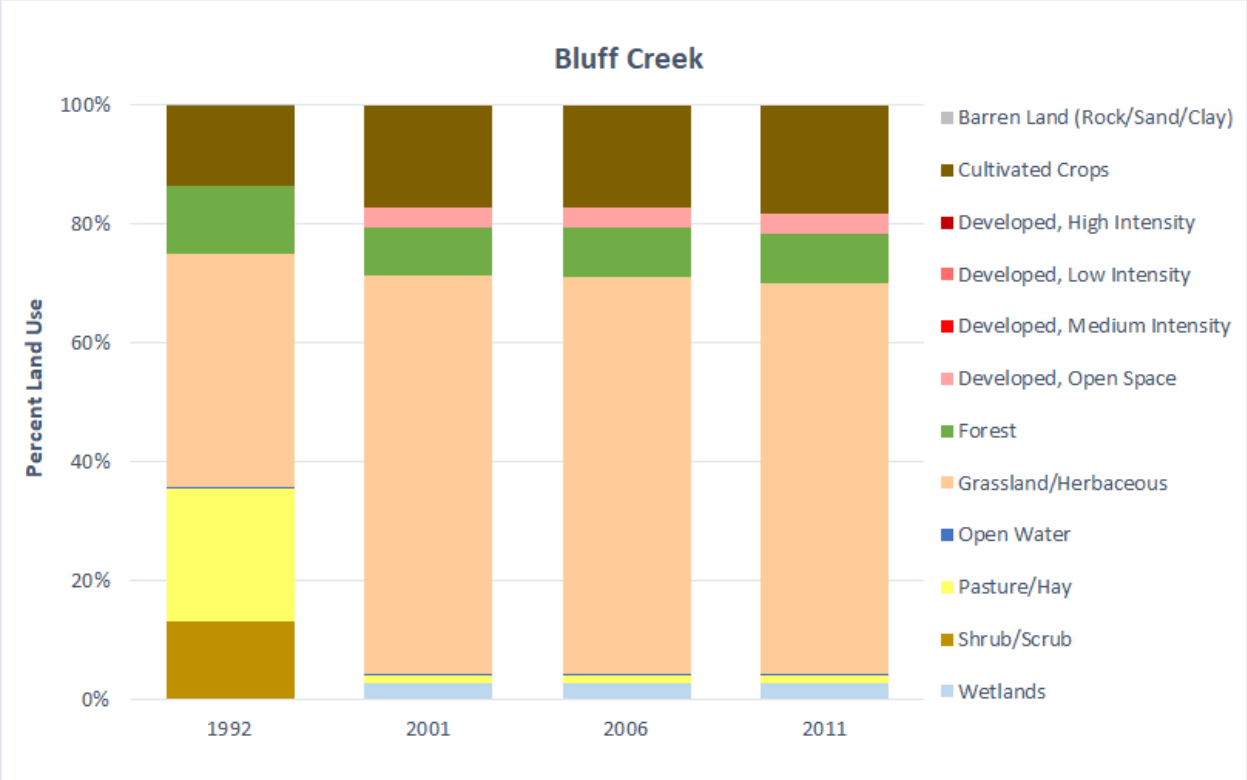


**Figure 99. Percent land use in the Bluff Creek watershed from 1992-2011.**

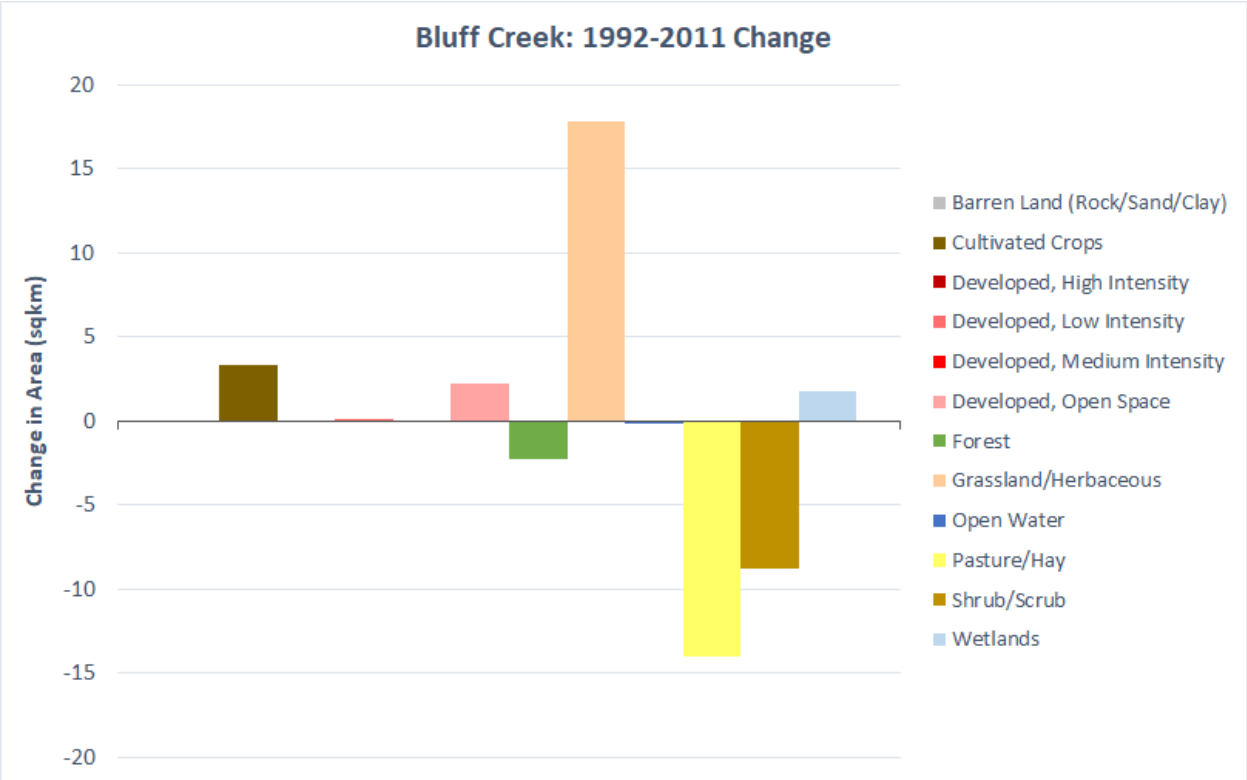


**Figure 100. Land use change in area (sq km) from 1992-2011 for the Bluff Creek watershed.**

## CLEAR CREEK

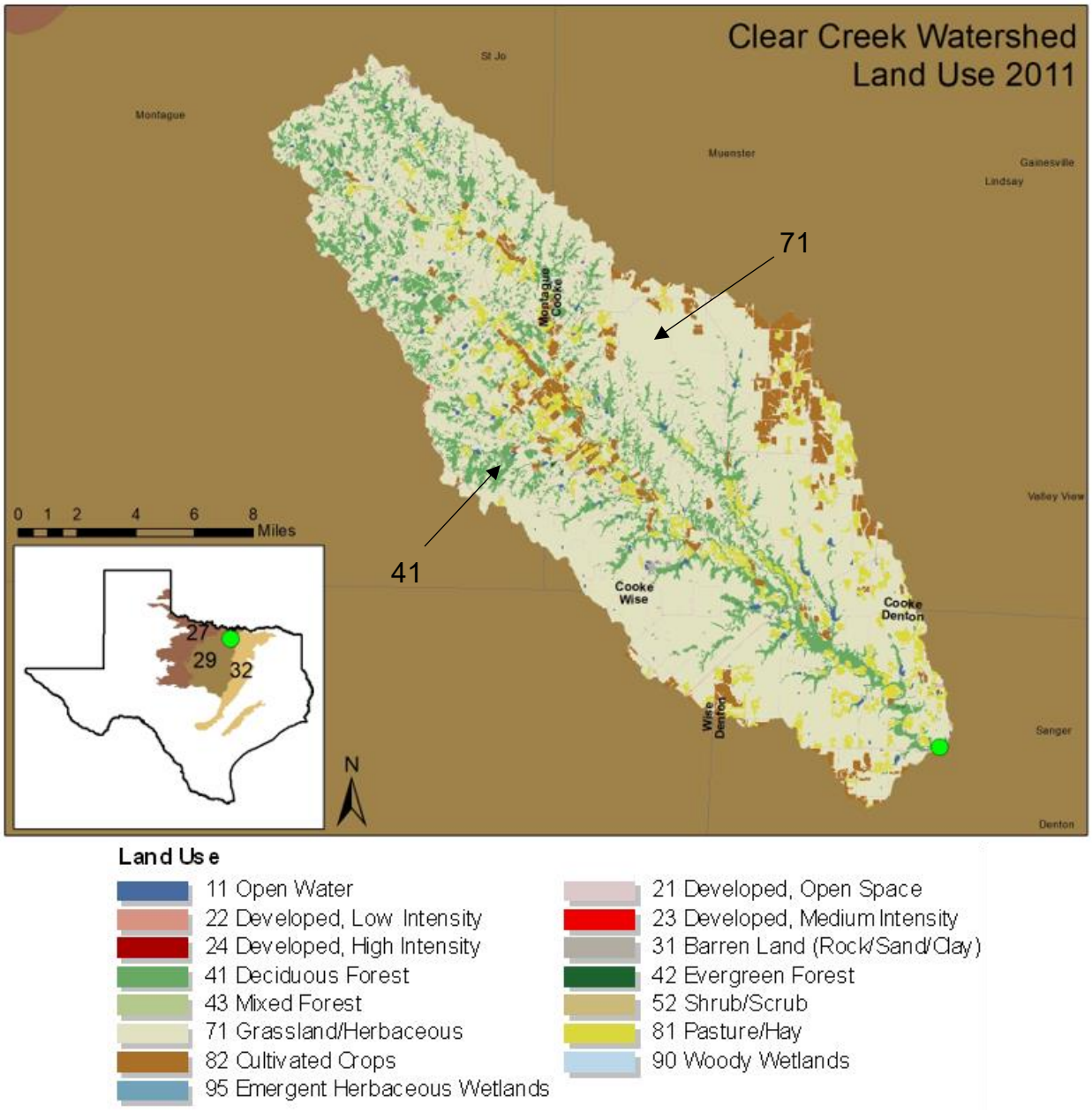


**Figure 101. Map of Clear Creek watershed location and 2011 land use; grassland/herbaceous and forest were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | August 2, 1989 |
| Water Quality: | 98 sampling events |
| Fish: | August 2, 1989; May 30, 2012 |
| Benthic Invertebrates: | August 2, 1989 (5/30/2012 benthic sample not located) |

## Physical Characterization

### Watershed and Land Use

Clear Creek lies within the Trinity River Basin. Sample site 10859 is located upstream of FM 455 west of Sanger in Denton County (Figure 101).

The Clear Creek watershed at site 10859 is approximately 634.50 sq km. The station and most of the lower watershed lies within Level IV Ecoregion 29d, the Grand Prairie, while the remaining watershed lies within Level IV Ecoregion 29c, Western Cross Timbers. The dominant land cover in the watershed is grassland/herbaceous at 66.74% and is present throughout the watershed (Homer et al. 2015; Figure 101 and Figure 102). Forest is the secondary land cover encompassing 14.93%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 4.23% and total cover for cultivated crops is 5.92%.

From 1992-2011 there was a 93.12 sq km decrease in pasture/hay and a 40.57 sq km decrease in shrub. There was a 131.88 sq km increase in grassland and a 24.72 sq km increase in open space development (Figure 103).

There are no permitted wastewater outfalls within the Clear Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Clear Creek was evaluated on August 2, 1989. Clear Creek is a perennial stream that drains to the Elm Fork Trinity River above Lake Lewisville. The riparian width was 5 meters. The riparian zone was dominated by trees, which made up an average of 50% of the total riparian species, followed by shrubs (30%) then grasses (20%). The average percentage of tree canopy cover was 25%. The dominant substrate was sand in pools and gravel in riffles, and the average percent of substrate that was gravel size or larger was 36%. Average percent instream cover was 21%. Clear Creek had an average depth of 0.6 meters and a maximum depth of 2.1 meters. The average width was 11.8 meters and average stream bank slope was 41 degrees. Stream flow at the site was 22.7 cfs. Average stream bank erosion potential was 61%. Five riffles were observed at the site and there were three total stream bends.

### Water Quality

Water samples were collected at station 10859 over 98 sampling events from August 1989 through September 2020. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Nineteen species (nine families) were collected between the two sampling events. Centrarchidae and Ictaluridae were the two most species rich families with five and four, respectively. Red Shiner was the most abundant species in the 1989 collection, whereas Orangethroat Darter

*Etheostoma spectabile* was the most abundant one in 2012. Central Stoneroller, River Carpsucker *Carpiodes carpio*, Bigscale Logperch *Percina macrolepida*, and Flathead Catfish were unique to the 1989 collection. Gizzard Shad *Dorosoma cepedianum*, Longnose Gar, and White Crappie were only collected in 2012. The aquatic life use (based upon the fish assemblage) rated as high for both collections.

**Benthic Macroinvertebrates**

A total of 934 individuals representing 40 taxa from 11 orders of macroinvertebrates were collected in the Surber sample from Clear Creek (Appendix E) on August 2, 1989. Trichoptera, Ephemeroptera, and Diptera, were the most commonly collected orders, collectively accounting for 96 percent of the total number of individuals collected. Coleoptera and Pelecypoda were the only other orders which comprised at least one percent of the collection.

The Ecoregions 27, 29, and 32 Surber BIBI fell in the exceptional aquatic life use category for the sample.

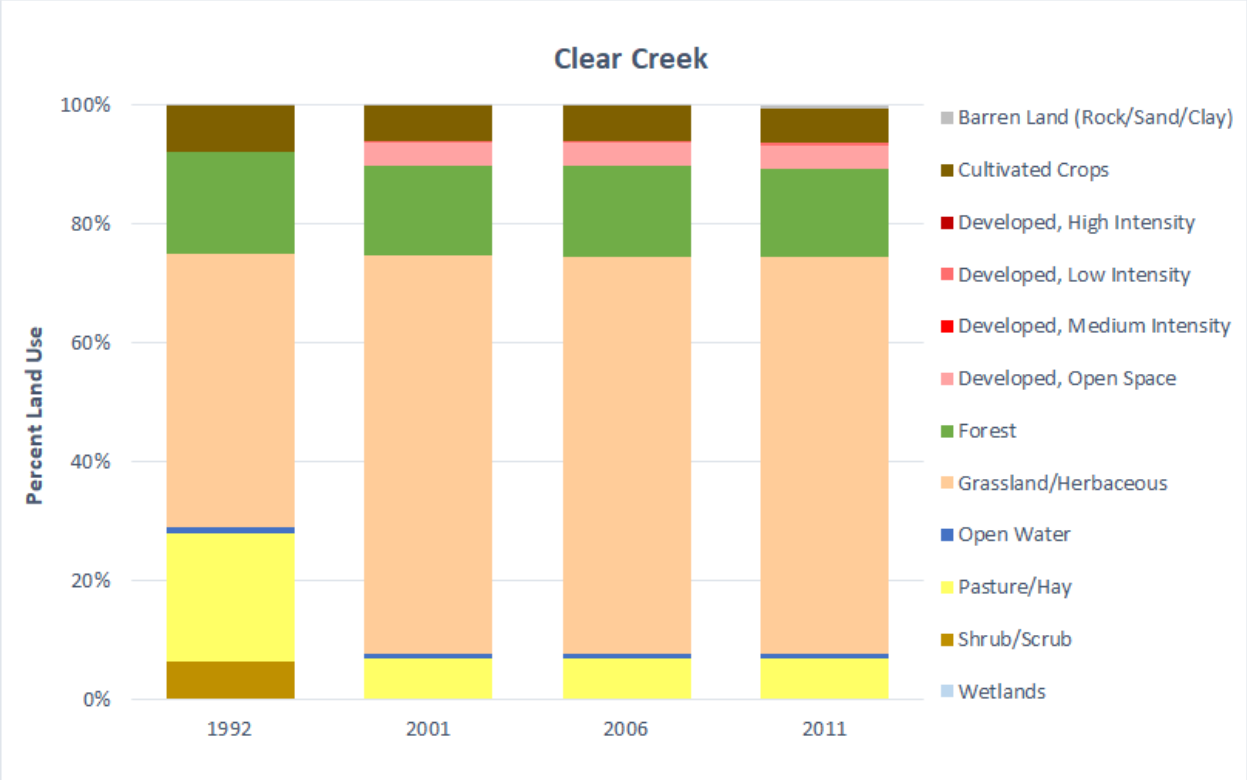


**Figure 102. Percent land use in the Clear Creek watershed from 1992-2011.**

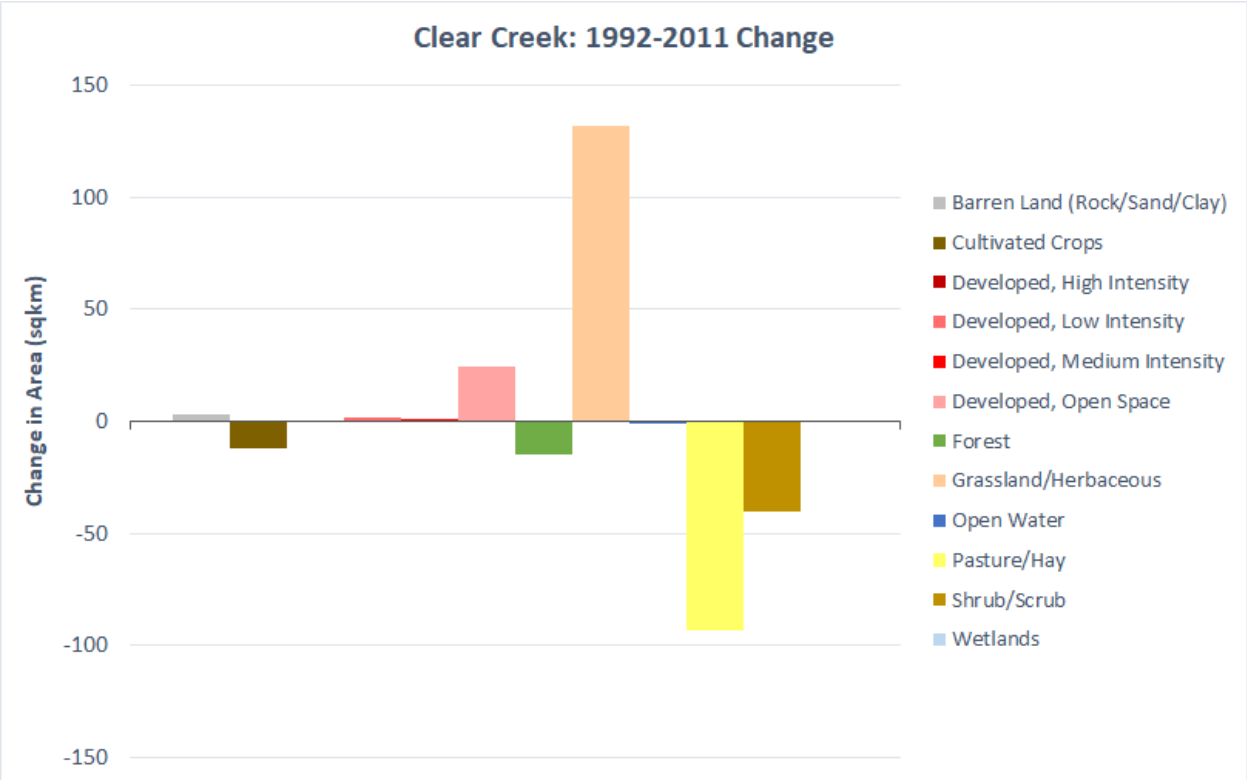


**Figure 103. Land use change in area (sq km) from 1992-2011 for the Clear Creek watershed.**

## COLONY CREEK

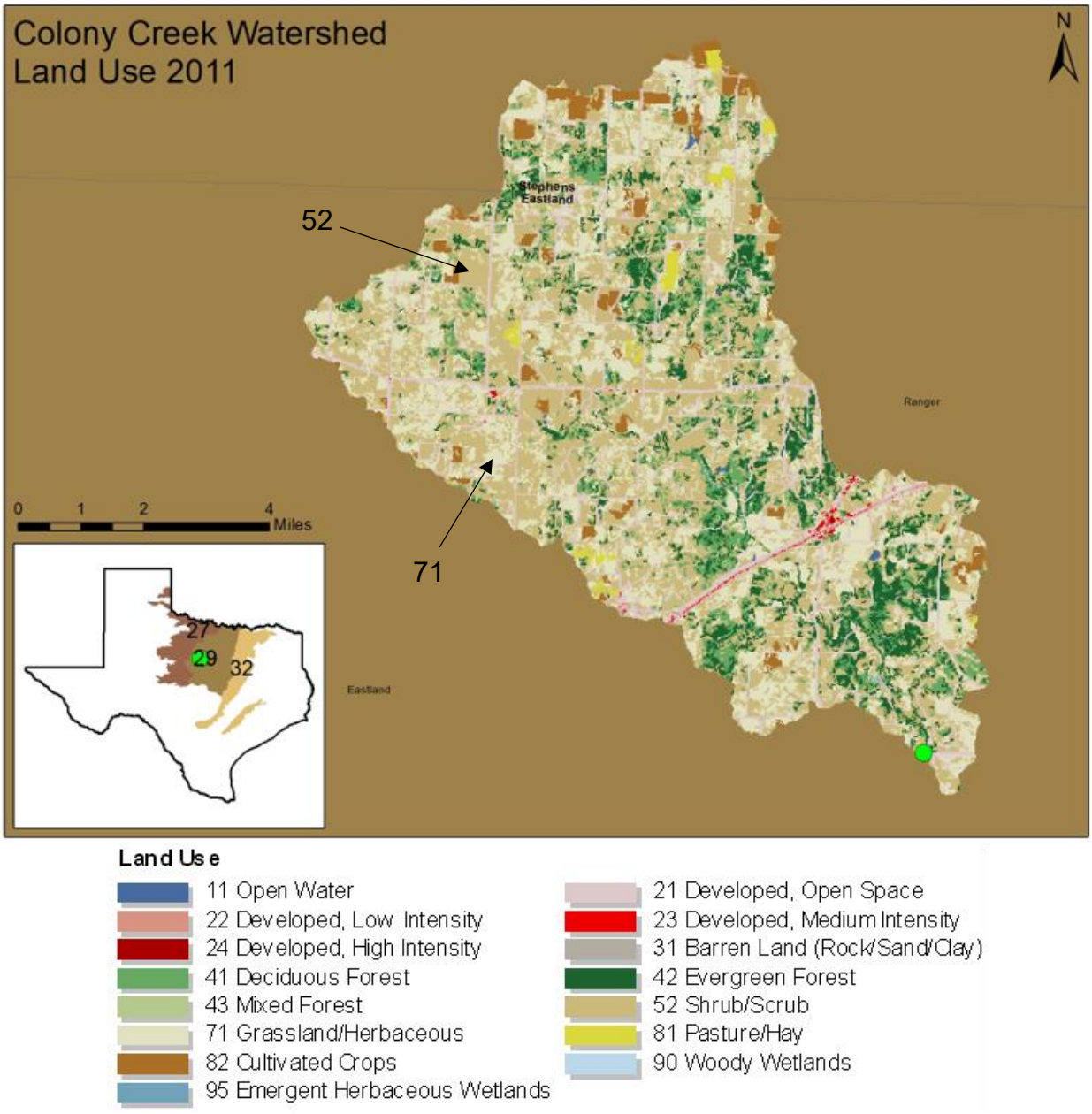


**Figure 104. Map of Colony Creek watershed location and 2011 land use; shrub/scrub and grassland/herbaceous were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 13, 1988 |
| Water Quality: | 14 sampling events |
| Fish: | July 13, 1988; April 19, 1989 |
| Benthic Invertebrates: | July 13, 1988 |

## Physical Characterization

### Watershed and Land Use

Colony Creek lies within the Brazos River Basin. Sample site 11837 is located upstream of FM 570, approximately 8.37 km south of Ranger in Eastland County (Figure 104).

The Colony Creek watershed at site 11837 is approximately 158.16 sq km. The entire watershed lies within Level IV Ecoregion 29c, the Western Cross Timbers. The dominant land cover in the watershed is shrub at 42.78% and is present throughout the watershed (Homer et al. 2015; Figure 104 and Figure 105). Grassland/herbaceous is the secondary land cover encompassing 25.52%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 9.43% and total cover for cultivated crops is 3.55%.

From 1992-2011 there was a 37.28 sq km decrease in grassland and a 25.70 sq km decrease in pasture/hay. There was a 38.08 sq km increase in shrub and a 14.65 sq km increase in forest (Figure 106).

There is one domestic wastewater outfall (discharges < 1 million gallons per day) within the Colony Creek watershed permitted to the Eastland County Water Supply District which discharges directly into Colony Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Colony Creek was evaluated on July 13, 1988. Colony Creek drains to the Leon River below Leon Reservoir. The riparian width was 38 meters. The riparian zone was dominated by shrubs, which made up an average of 40% of the total riparian species, followed by trees and grasses (30% each). The average percentage of tree canopy cover was 13%. The dominant substrate was gravel with some sand and exposed bedrock, and the average percent of substrate that was gravel size or larger was 50%. Average percent instream cover was 29%. Colony Creek had an average depth of 0.6 meters and a maximum depth of 1.6 meters. The average width was 11.2 meters and average stream bank slope was 48 degrees. Stream flow at the site was 1.4 cfs. Average stream bank erosion potential was 27%. Four riffles were observed at the site and there were two total stream bends.

### Water Quality

Water samples were collected at station 11837 over 14 sampling events from July 1988 through July 1999. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Fourteen species (six families) were collected between the two sampling events. Centrarchidae and Cyprinidae were the most species rich families with five and four, respectively. Red Shiner

was the most abundant species. The aquatic life use rated as high and intermediate for the 1988 and 1989 fish assemblages, respectively; however, when the coefficient of variability was applied to the 1989 sample it also attained a high rating.

**Benthic Macroinvertebrates**

A total of 1,193 individuals representing 40 taxa from 12 orders of macroinvertebrates were collected in the Surber sample from Colony Creek (Appendix E) on July 13, 1988. Trichoptera, Gastropoda, Diptera, and Pelecypoda were the most commonly collected orders, collectively accounting for 88 percent of the total number of individuals collected. Coleoptera, Oligochaeta, and Odonata were the only other orders which comprised at least one percent of the collection.

The Ecoregions 27, 29, and 32 Surber BIBI fell in the exceptional aquatic life use category for the sample.

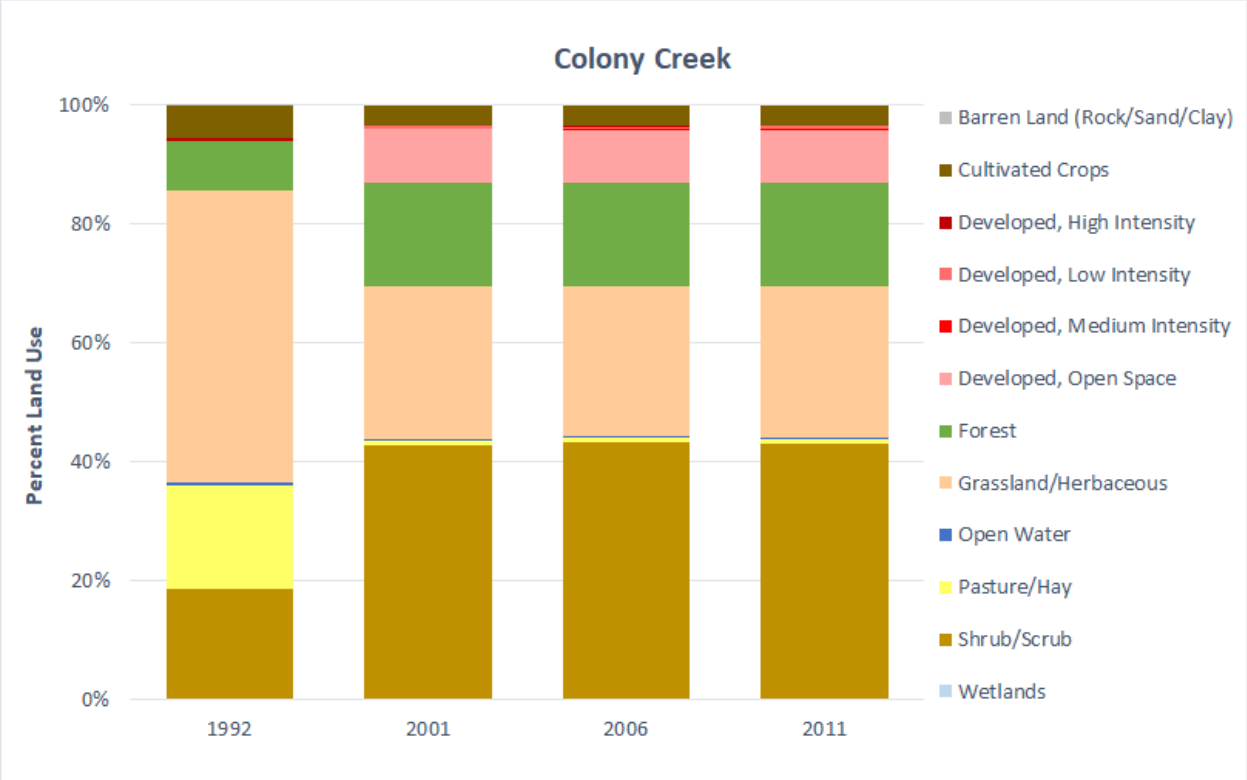


**Figure 105. Percent land use in the Colony Creek watershed from 1992-2011.**

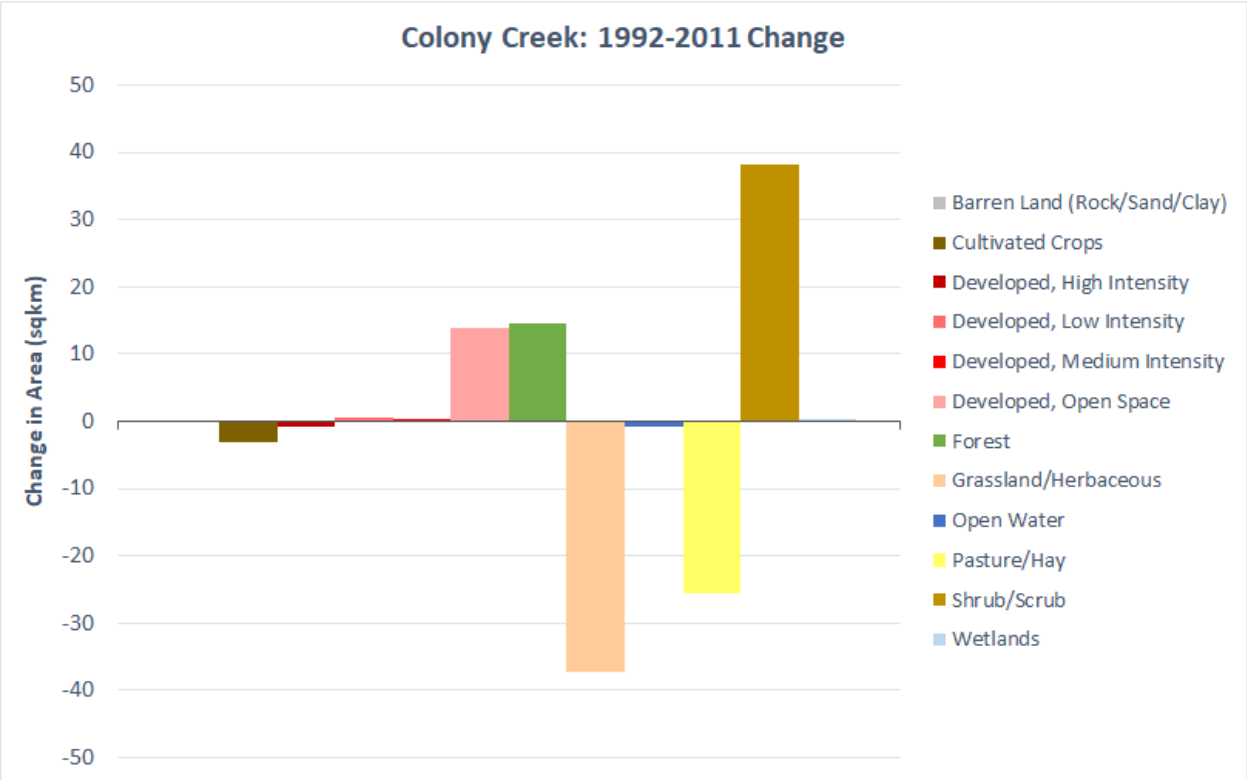


**Figure 106. Land use change in area (sq km) from 1992-2011 for the Colony Creek watershed.**

## COWHOUSE CREEK

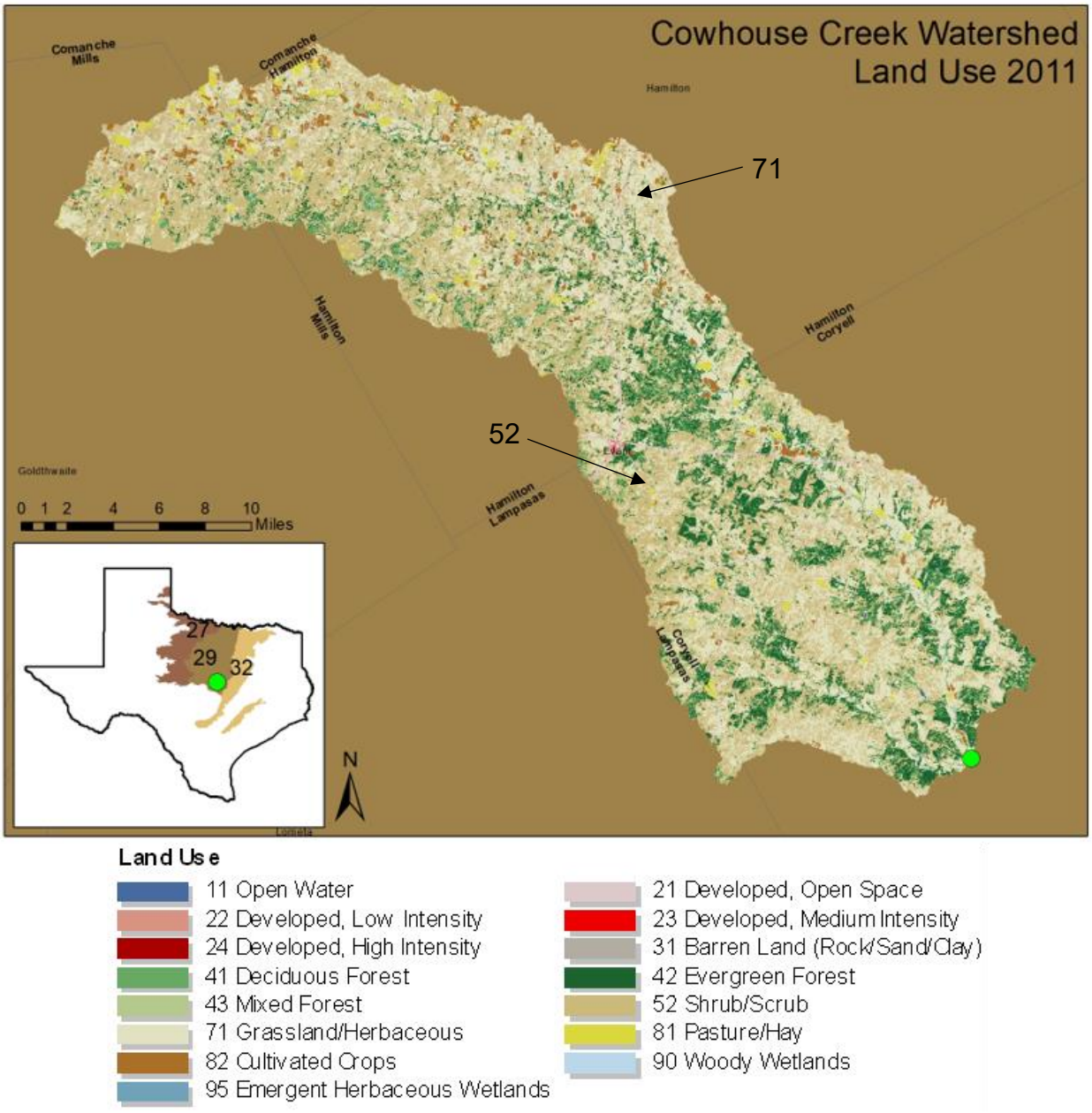


**Figure 107. Map of Cowhouse Creek watershed location and 2011 land use; shrub/scrub and grassland/herbaceous were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | June 21, 1989 |
| Water Quality: | 157 sampling events |
| Fish: | June 21, 1989 |
| Benthic Invertebrates: | June 21, 1989; September 17, 1990 |

## Physical Characterization

### Watershed and Land Use

Cowhouse Creek lies within the Brazos River Basin. Sample site 11805 is located 71 m downstream of FM 116 southwest of Gatesville in Coryell County (Figure 107).

The Cowhouse Creek watershed at site 11805 is approximately 1180.17 sq km. The entire watershed lies within Level IV Ecoregion 29e, the Limestone Cut Plain. The dominant land cover in the watershed is shrub at 40.77% and is present throughout the watershed (Homer et al. 2015; Figure 107 and Figure 108). Grassland/herbaceous is the secondary land cover encompassing 34.20%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 2.55% and total cover for cultivated crops is 2.29%.

From 1992-2011 there was a 62.91 sq km decrease in cultivated crops and a 38.41 sq km decrease in pasture/hay. There was a 66.33 sq km increase in grassland and a 28.57 sq km increase in open space development (Figure 109).

There is one domestic wastewater outfall (discharges < 1 million gallons per day) within the Cowhouse Creek watershed permitted to the City of Evant. The wastewater facility does not discharge directly into Cowhouse Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Cowhouse Creek was evaluated on June 21, 1989. Cowhouse Creek is an intermittent stream with perennial pools that drains to the Cowhouse Creek Arm of Belton Lake. The riparian width was 28 meters. The riparian zone was dominated by trees, which made up an average of 70% of the total riparian species, followed by shrubs (20%) then grasses (10%). The average percentage of tree canopy cover was 45%. The dominant substrate was gravel, and the average percent of substrate that was gravel size or larger was 57%. Average percent instream cover was 11%. Cowhouse Creek had an average depth of 0.8 meters and a maximum depth of 1.6 meters. The average width was 17.2 meters and average stream bank slope was 54 degrees. Stream flow at the site was 51.7 cfs. Average stream bank erosion potential was 49%. Four riffles were observed at the site and there were three total stream bends.

### Water Quality

Water samples were collected at station 11805 over 157 sampling events from June 1989 through June 2019. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

Continuous flow data is available from USGS gage 08101000 downstream of station 11805 (Figure 110). Between January 1985 through December 2019, the median flow was 10.2 cfs. Daily average flows ranged from 0 cfs to 25,600 cfs, though flows in that period were greater than 1000 cfs about 0.07 percent of the time. Data have been log transformed to better visualize flow patterns.

## Biological Characterization

### Fish

Eleven species (four families) were collected. The majority of the species were within the families Centrarchidae and Cyprinidae with five and four species represented, respectively. Blacktail Shiner was the most abundant species. The aquatic life use (based upon the fish assemblage) was high.

### Benthic Macroinvertebrates

Considering the two Surber samples collectively, a total of 858 individuals representing 64 taxa from 15 orders of macroinvertebrates were collected from Cowhouse Creek (Appendix E). Ephemeroptera, Trichoptera, and Diptera were the most commonly collected orders, collectively accounting for 82 percent of the total number of individuals collected. Odonata, Megaloptera, and Coleoptera were the only other orders which comprised at least one percent of the collections.

The Ecoregions 27, 29, and 32 Surber BIBI fell in the exceptional aquatic life use category for both samples.

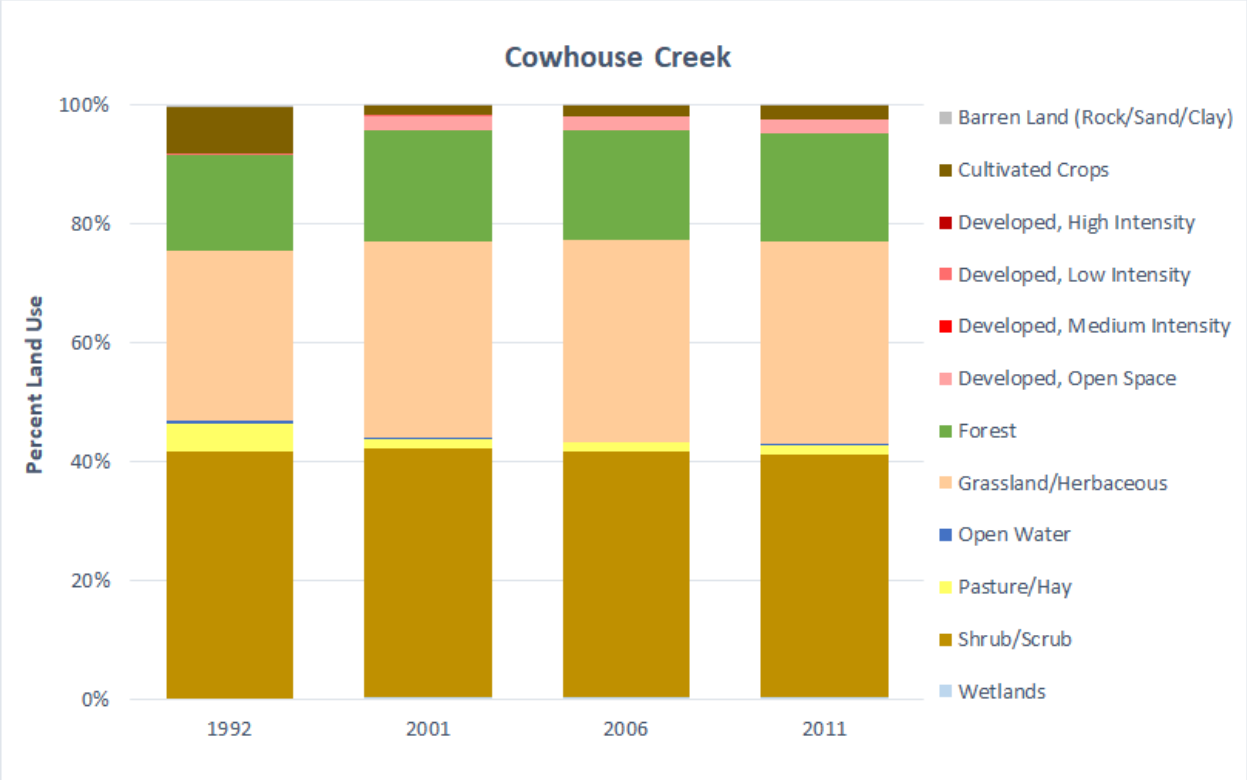


**Figure 108. Percent land use in the Cowhouse Creek watershed from 1992-2011.**

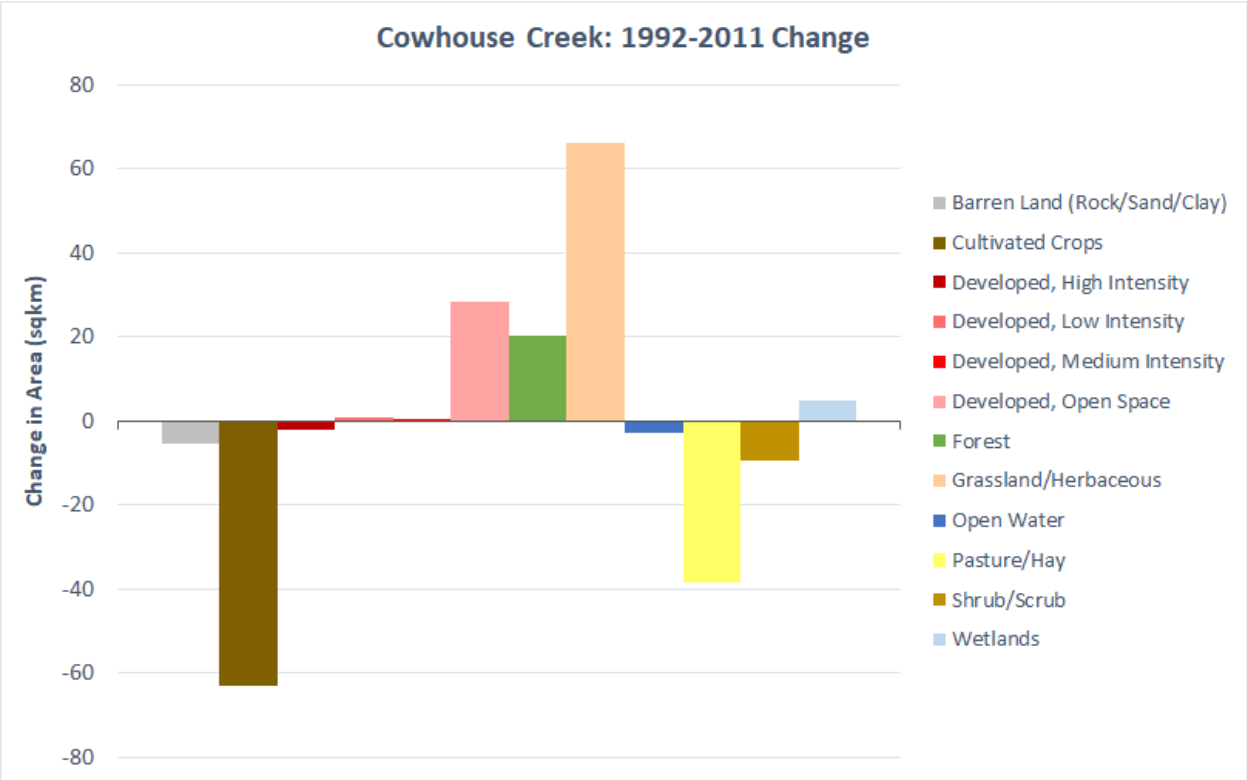


**Figure 109. Land use change in area (sq km) from 1992-2011 for the Cowhouse Creek watershed.**

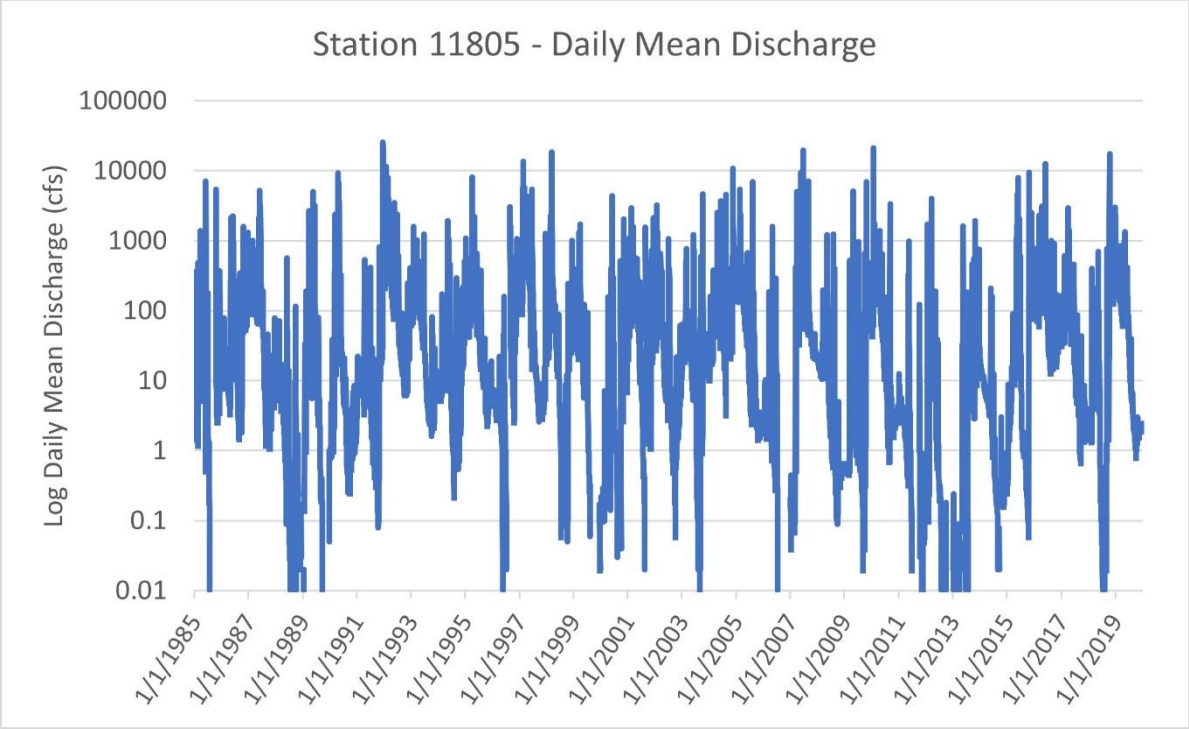


**Figure 110. Log transformed daily mean discharge for Cowhouse Creek at station 11805.**

## IONI CREEK

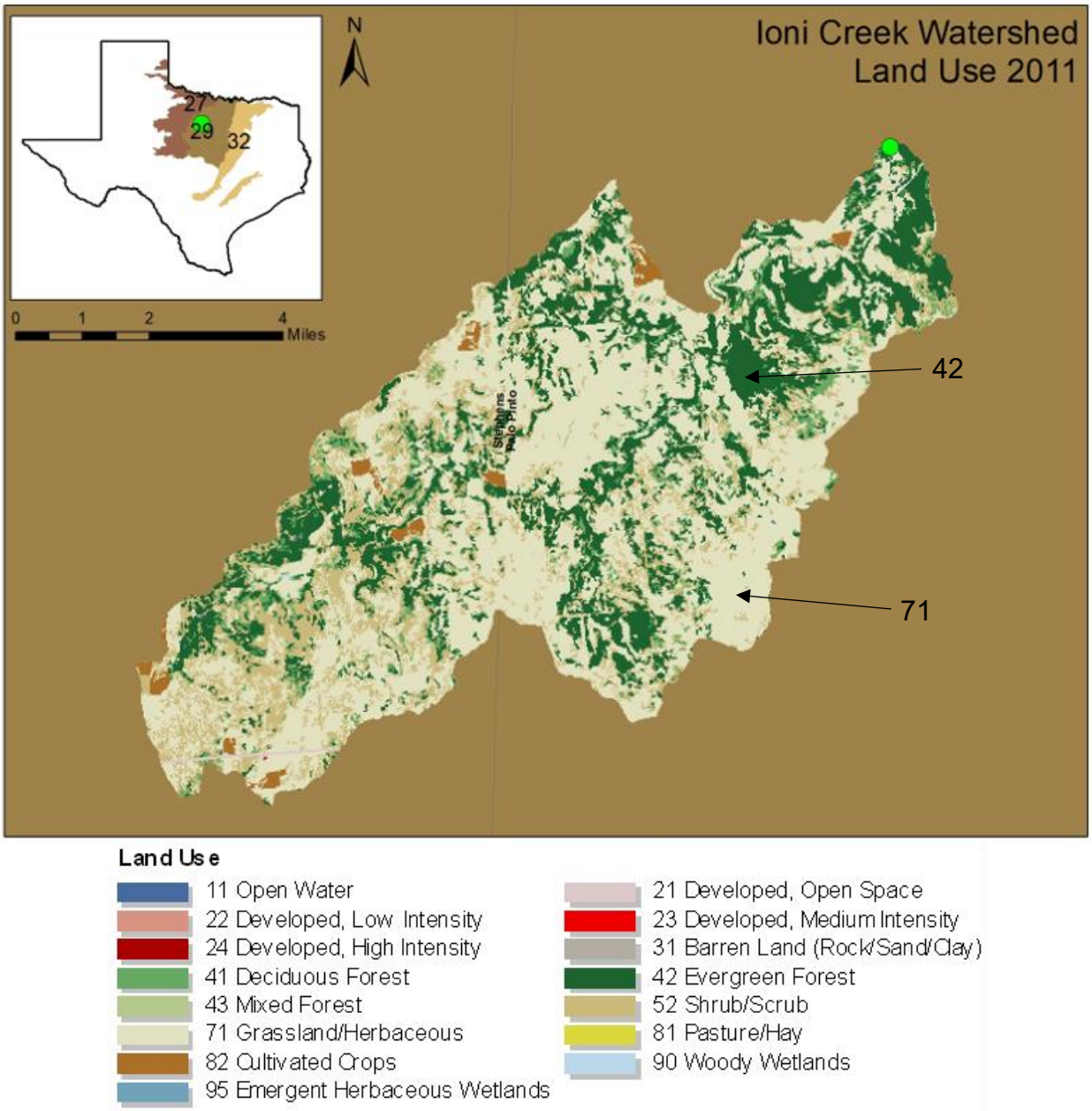


**Figure 111. Map of Ioni Creek watershed location and 2011 land use; grassland/herbaceous and forest were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 13, 1988 |
| Water Quality: | 14 sampling events |
| Fish: | July 14, 1988; April 19, 1989 |
| Benthic Invertebrates: | July 14, 1988 |

## Physical Characterization

### Watershed and Land Use

Ioni Creek lies within the Brazos River Basin. Sample site 11716 is located 0.40 km upstream of SH 16, approximately 19.96 km west of Palo Pinto in Palo Pinto County (Figure 111).

The Ioni Creek watershed at site 11716 is approximately 146.07 sq km. The entire watershed lies within Level IV Ecoregion 29f, the Carbonate Cross Timbers. The dominant land cover in the watershed is grassland/herbaceous at 50.50% and is present throughout the watershed (Homer et al. 2015; Figure 111 and Figure 112). Forest is the secondary land cover encompassing 28.66%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 0.36% and total cover for cultivated crops is 1.33%.

From 1992-2011 there was a 16.51 sq km decrease in forest and a 4.65 sq km decrease in pasture/hay. There was a 15.89 sq km increase in grassland and a 5.35 sq km increase in shrub (Figure 113).

There are no permitted wastewater outfalls within the Ioni Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Ioni Creek was evaluated on July 13, 1988. Ioni Creek is a tributary to the Brazos River below Possum Kingdom Lake. The riparian width was 46 meters. The riparian zone was dominated by trees, which made up an average of 70% of the total riparian species, followed by shrubs (20%) then grasses (10%). The average percentage of tree canopy cover was 40%. The dominant substrate was gravel, and the average percent of substrate that was gravel size or larger was 50%. Average percent instream cover was 10%. Ioni Creek had an average depth of 1.1 meters and a maximum depth of 2.1 meters. The average width was 15 meters and average stream bank slope was 49 degrees. The stream was not flowing on July 13, 1988, but a large spring fed pool was present. Average stream bank erosion potential was 28%. No riffles or stream bends were observed at the site.

### Water Quality

Water samples were collected at station 11716 over 14 sampling events from July 1988 through July 1999. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Thirteen species (seven families) were collected between the two sampling events. Centrarchidae yielded the greatest number of species with four. Juvenile sunfish were the most abundant taxa in the 1988 sample, closely followed by Blacktail Shiner which was the most abundant species in 1989. The aquatic life use (based upon the fish assemblage) rated as high and intermediate for

the 1988 and 1989 collections, respectively; however, when the coefficient of variability was applied to the 1989 sample it also attained a high rating.

**Benthic Macroinvertebrates**

A total of 1,007 individuals representing 48 taxa from 15 orders of macroinvertebrates were collected in the Surber sample from Ioni Creek (Appendix E) on July 14, 1988. Ephemeroptera, Oligochaeta, Diptera, and Trichoptera were the most commonly collected orders, collectively accounting for 83 percent of the total number of individuals collected. Coleoptera, Turbellaria, Ostracoda, Odonata, and Amphipoda were the only other orders which comprised at least one percent of the collection.

The Ecoregions 27, 29, and 32 Surber BIBI fell in the high aquatic life use category for the sample.

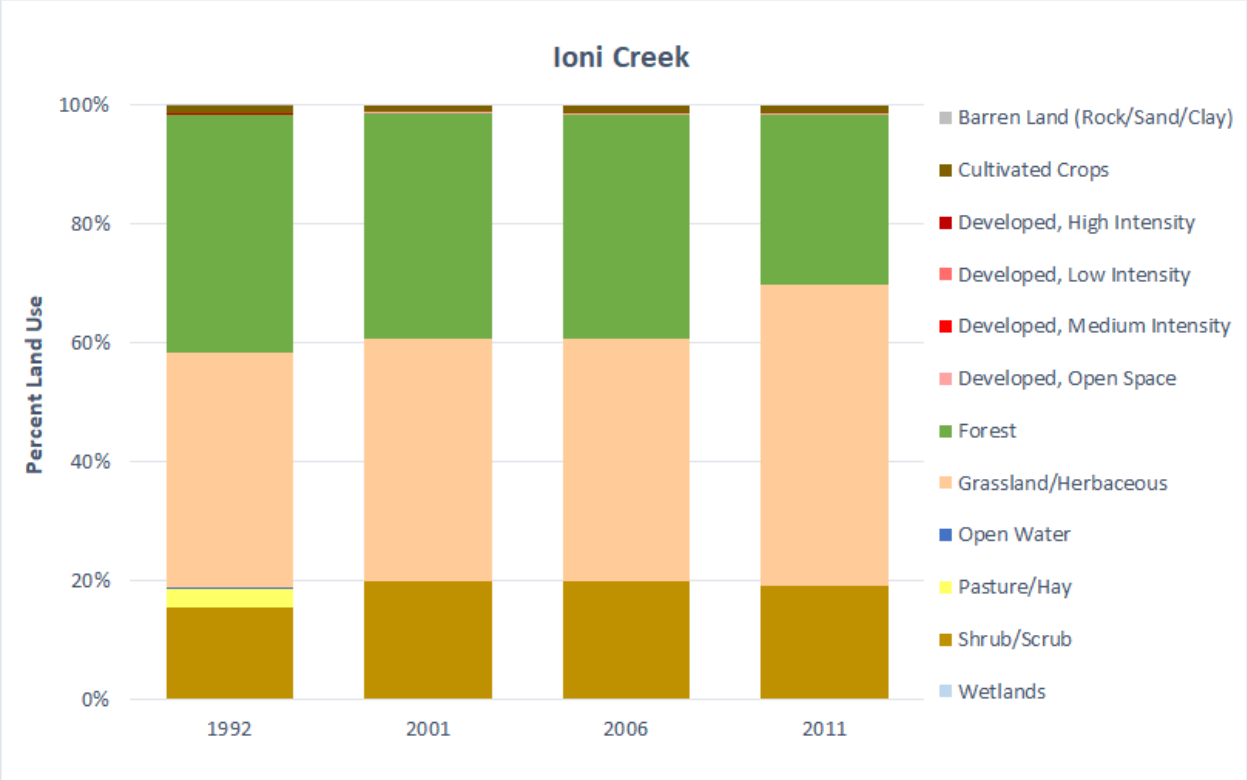


**Figure 112. Percent land use in the Ioni Creek watershed from 1992-2011.**

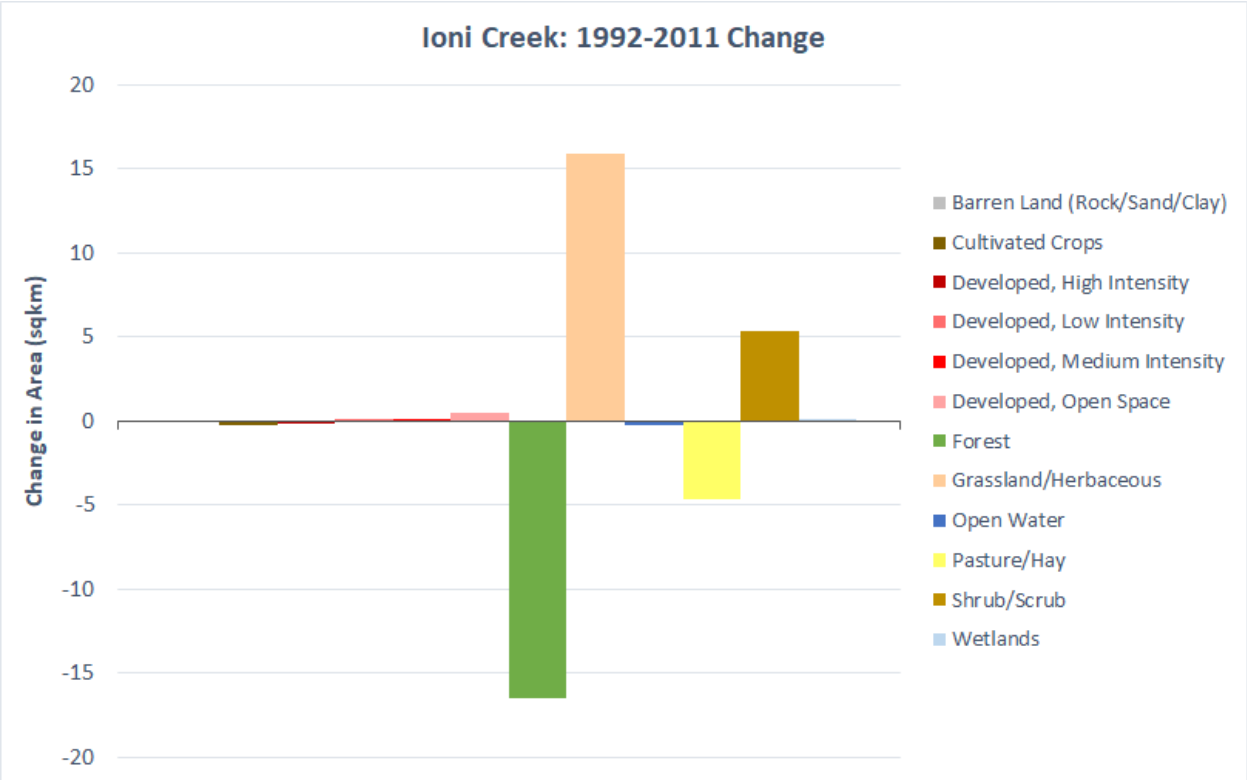


**Figure 113. Land use change in area (sq km) from 1992-2011 for the Ioni Creek watershed.**

## NEILS CREEK

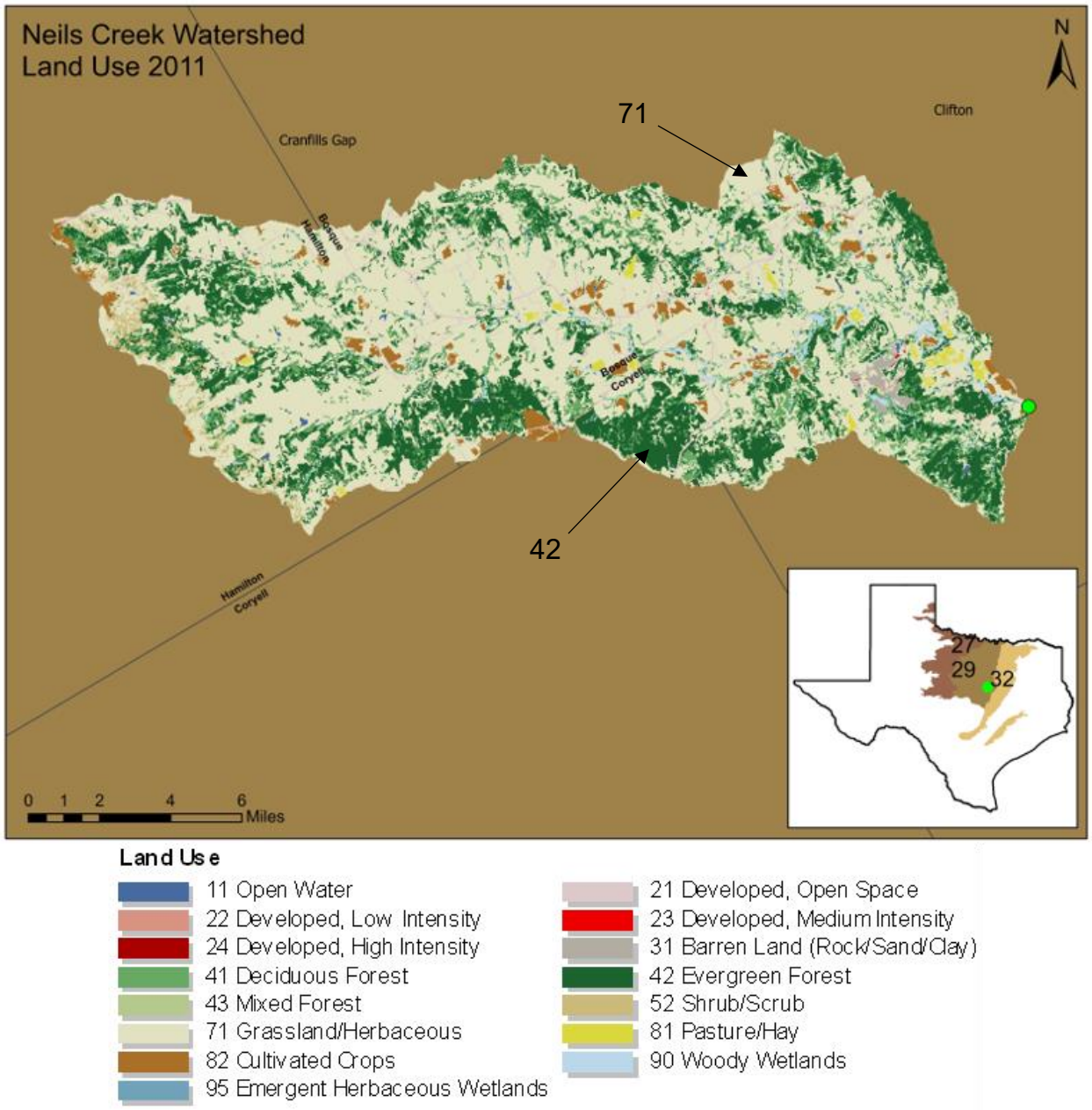


**Figure 114. Map of Neils Creek watershed location and 2011 land use; grassland/herbaceous and forest were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 19, 1989; July 18, 2017 |
| Water Quality: | 742 sampling events |
| Fish: | July 19, 1989; July 18, 2017 |
| Benthic Invertebrates: | July 19, 1989; July 18, 2017 |

## Physical Characterization

### Watershed and Land Use

Neils Creek lies within the Brazos River Basin. Sample site 11826 is located at SH 6 southeast of Clifton in Bosque County (Figure 114).

The Neils Creek watershed at site 11826 is approximately 355.43 sq km. The entire watershed lies within Level IV Ecoregion 29e, the Limestone Cut Plain. The dominant land cover in the watershed is grassland/herbaceous at 55.03% and is present throughout the watershed (Homer et al. 2015; Figure 114 and Figure 115). Forest is the secondary land cover encompassing 34.70%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 3.02% and total cover for cultivated crops is 2.73%.

From 1992-2011 there was a 67.41 sq km decrease in shrub and a 13.73 sq km decrease in pasture/hay. There was a 63.80 sq km increase in grassland and a 9.93 sq km increase in open space development (Figure 116).

There are no permitted wastewater outfalls within the Neils Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Neils Creek was evaluated on July 19, 1989 and again on July 18, 2017. Neils Creek is an intermittent stream with perennial pools that drains to the North Bosque River south of Clifton. The following summary information is based on data collected during the most recent sampling event in 2017. The Habitat Quality Index score of 20.5 indicates a high aquatic life use rating. The riparian zone was moderately vegetated throughout the reach with an average riparian buffer measured at 4.75 meters. The riparian zone was dominated by grasses, which made up an average of 35% of the total riparian species, followed by trees (30%) then shrubs (22.5%), with the remaining 12.5% composed of cultivated fields. The average percentage of tree canopy cover was 69%. The dominant substrate was gravel, and the average percent of substrate that was gravel size or larger was 91%. Average percent instream cover was 35% and instream cover types include woody debris, undercut banks, roots, cobble, gravel, boulders, macrophytes, overhanging vegetation, and bedrock ledges. Neils Creek was 0.4 meters deep on average and 18 meters wide. Average stream bank slope was 32 degrees, and average stream bank erosion potential was 60%. The deepest pool measured at Neils Creek was 1.5 meters. Stream flow at the creek was measured at a minimum value of 1.2 cfs in 2017 and a maximum of 7.9 cfs in 1989. Four riffles were observed at the site in 2017 and there were three total stream bends.

### Water Quality

Water samples were collected at station 11826 over 741 sampling events from July 1989 through August 2018. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a. Water samples and data were also

collected for the Least Disturbed Streams biological sampling event in July 2017 at station 21999, which is upstream of station 11826.

## Biological Characterization

### Fish

Sixteen species (six families) were collected between the two sampling events. Centrarchidae and Cyprinidae yielded the highest number of species with six and five, respectively. Blacktail Shiner was the most abundant species in both collections. Several species were only collected in 1989. These included Yellow Bullhead *Ameiurus natalis*, Red Shiner, Bullhead Minnow, and Spotted Bass *Micropterus punctulatus*. Their absence from the 2017 collection does not reflect any significant issue, especially given that each were collected in very low numbers in 1989. Two species unique to the 2017 sample were Central Stoneroller and Mimic Shiner *Notropis volucellus*, which was the second most abundant species. Mimic Shiner is listed as an intolerant species (Linam and Kleinsasser 1989). Their addition to the fish assemblage could be an indication of improved water quality. The aquatic life use (based upon the fish assemblage) rated as high for both collections; however, when the coefficient of variability was applied the 2017 sample obtained an exceptional rating.

### Benthic Macroinvertebrates

Considering the Surber sample and the RBP sample collectively, a total of 341 individuals representing 48 taxa from 12 orders of macroinvertebrates were collected from Neils Creek (Appendix E). Trichoptera, Ephemeroptera, Diptera, and Odonata were the most commonly collected orders, collectively accounting for 93 percent of the total number of individuals collected. Megaloptera, Hemiptera, Plecoptera and Coleoptera were the only other orders which comprised at least one percent of the collections.

The Ecoregions 27, 29, and 32 BIBI for the 1989 Surber sample, as well as the 2017 RBP sample, fell in the exceptional aquatic life use category.

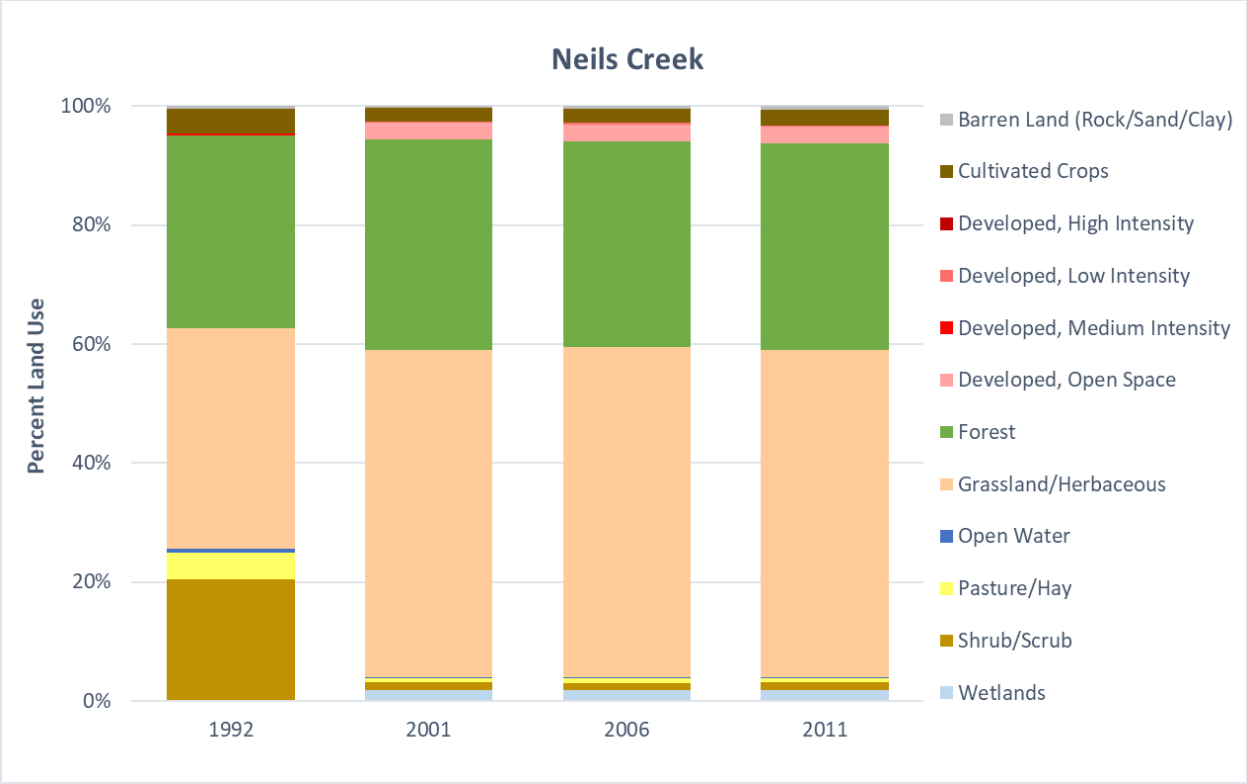


**Figure 115. Percent land use in the Neils Creek watershed from 1992-2011.**

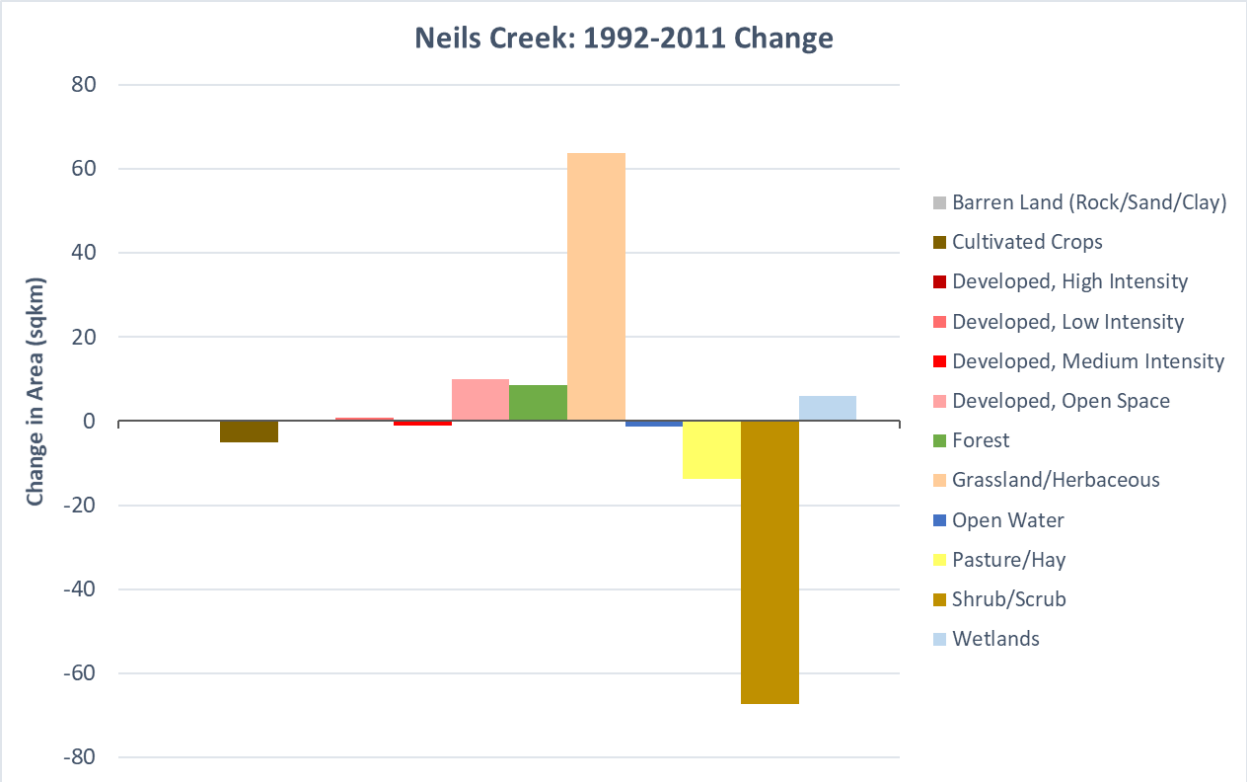


**Figure 116. Land use change in area (sq km) from 1992-2011 for the Neils Creek watershed.**

## REESE CREEK

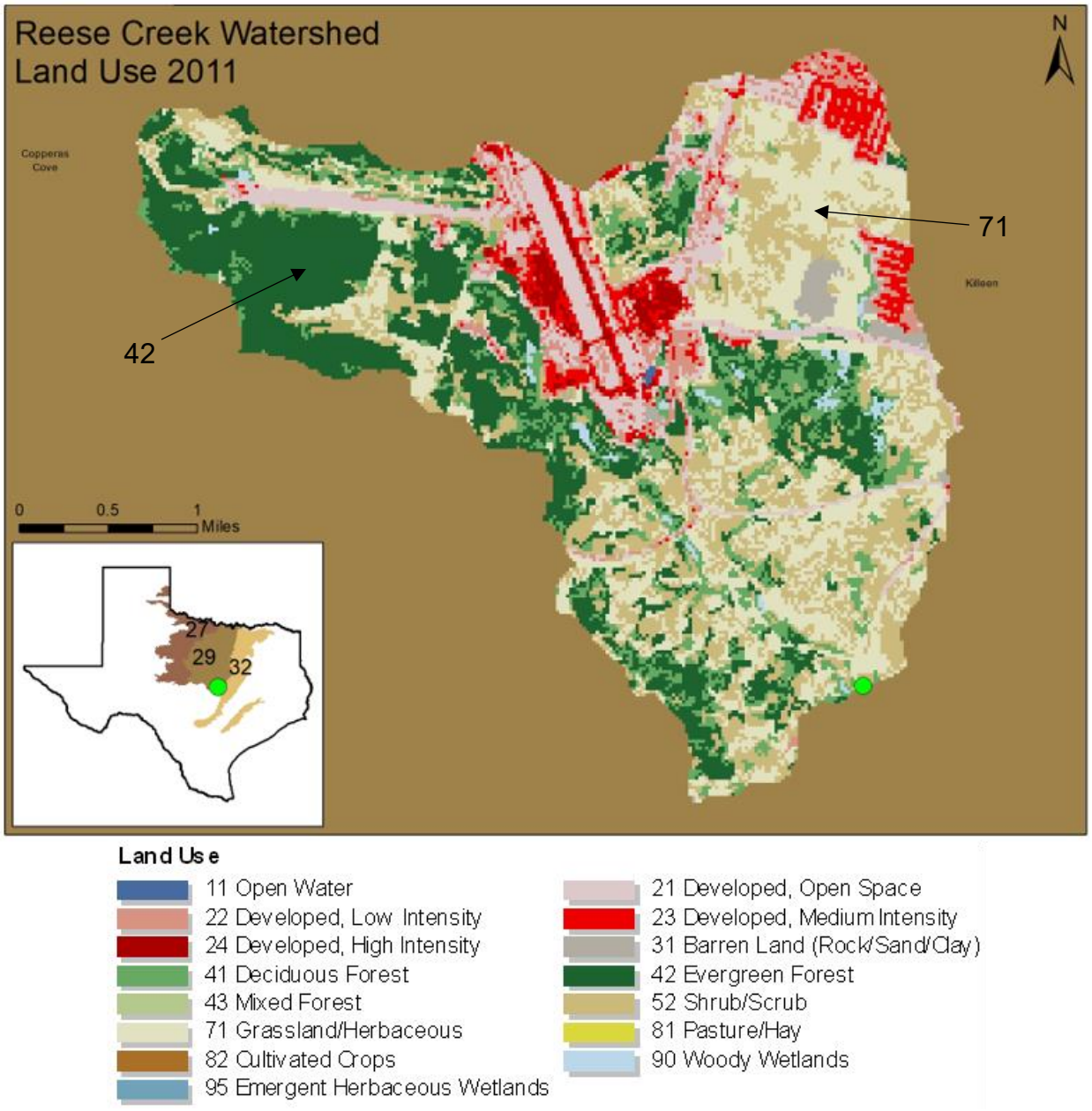


**Figure 117. Map of Reese Creek watershed location and 2011 land use; forest and grassland/herbaceous were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | April 19, 2006; September 17, 2007 |
| Water Quality: | 2 sampling events |
| Fish: | June 5, 2006; September 21, 2007 |
| Benthic Invertebrates: | June 5, 2006; September 21, 2007 |

## Physical Characterization

### Watershed and Land Use

Reese Creek lies within the Brazos River Basin. Sample site 18850 is located 360 m downstream of Maxdale Road, approximately 4.09 km south-southwest of Killeen in Bell County (Figure 117).

The Reese Creek watershed at site 18850 is approximately 25.86 sq km. The entire watershed lies within Level IV Ecoregion 29e, the Limestone Cut Plain. The dominant land cover in the watershed is forest at 33.98% and is present mostly in the middle and upper portion of the watershed (Homer et al. 2015; Figure 117 and Figure 118). Grassland/herbaceous is the secondary land cover encompassing 22.57%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 21.02% and there is no cultivated crop cover present within the watershed.

From 1992-2011 there was a 3.47 sq km decrease in grassland and a 0.92 sq km decrease in barren land (rock/sand/clay). There was a 2.24 sq km increase in shrub and a 1.14 sq km increase in medium intensity development (Figure 119).

There are no permitted wastewater outfalls within the Reese Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Reese Creek was evaluated during two sampling events from 2006 to 2007. Reese Creek is a perennial stream that drains to the Lampasas River above Stillhouse Hollow Lake. Habitat Quality Index scores indicate a high aquatic life use rating (21.5 and 23). Riparian areas were generally well vegetated throughout the reach with an average riparian buffer ranging from 12 to 18 meters wide. The riparian zone was dominated by trees followed by grasses then shrubs. The average percentage of tree canopy cover ranged from 36% to 75%. The dominant stream substrate was cobble and bedrock, and the average percent of substrate gravel size or larger varied from 40% to 60%. Average percent instream cover was 21% to 45%. Reese Creek ranged from 0.1-0.3 meters deep on average and 3.2-4.1 meters wide. Average stream bank slope ranged from 22-50 degrees. Stream flow at the site was measured at 0.06 cfs in 2007. Average stream bank erosion potential was 14%-31%. The deepest pool measured at Reese Creek was 0.8 meters. Seven riffles were observed at the site for both sampling events, and the total number of stream bends ranged from four to six.

### Water Quality

Water samples were collected at station 18850 over two sampling events in June 2006 and September 2007. Data were collected for temperature, flow, transparency, total Kjeldahl nitrogen, total nitrogen, phosphorus, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Ten species (four families) were collected. The families Cyprinidae and Centrarchidae tied for most species with four each. Central Stoneroller was the most abundant species. The aquatic life use (based upon the fish assemblage) rated as intermediate in 2006 and high in 2007; however, when the coefficient of variability is applied the 2006 aquatic life use rises to high.

**Benthic Macroinvertebrates**

Considering the two RBP samples collectively, a total of 457 individuals representing 26 taxa from 10 orders of macroinvertebrates were collected from Reese Creek (Appendix E). Trichoptera, Diptera, Ephemeroptera, and Odonata were the most commonly collected orders, collectively accounting for 97 percent of the total number of individuals collected. Coleoptera was the only other order which comprised at least one percent of the collections.

The Ecoregions 27, 29, and 32 BIBI for the 2006 RBP sample fell in the intermediate aquatic life use category while the RBP BIBI for the sample collected in 2007 fell in the high aquatic life use category.

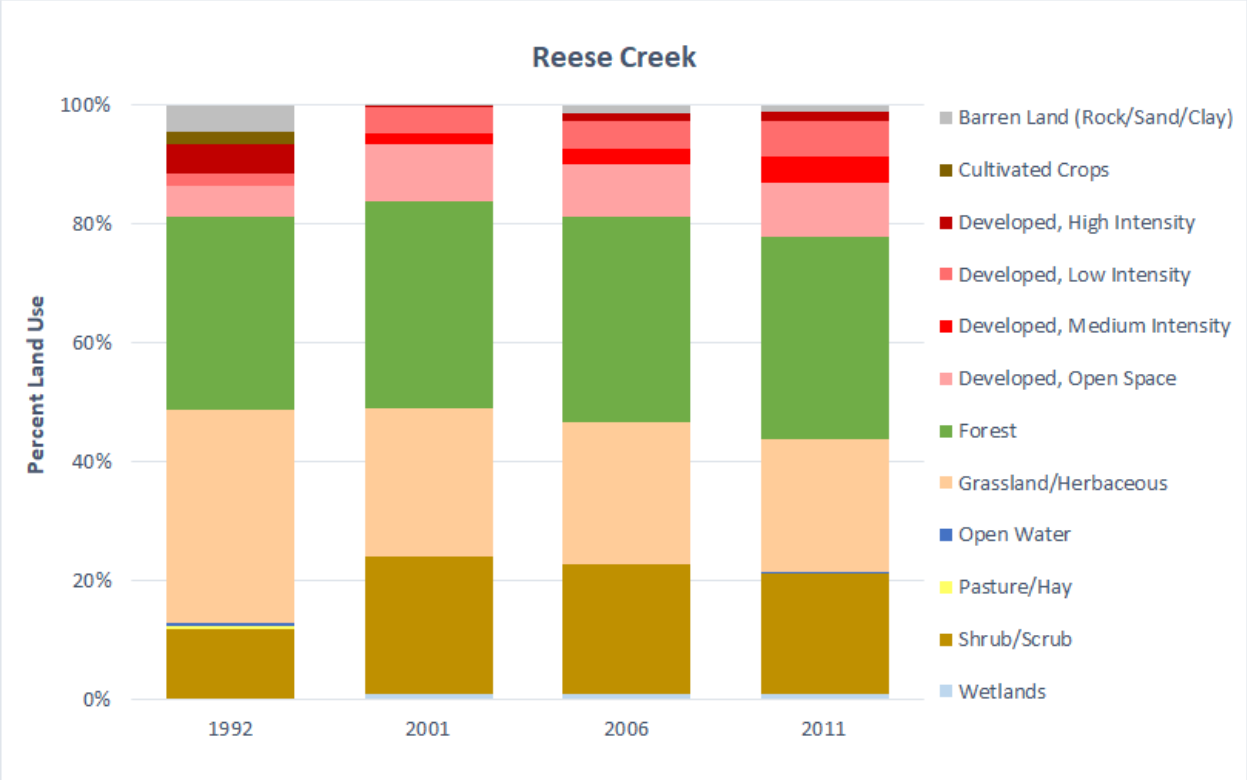


**Figure 118. Percent land use in the Reese Creek watershed from 1992-2011.**

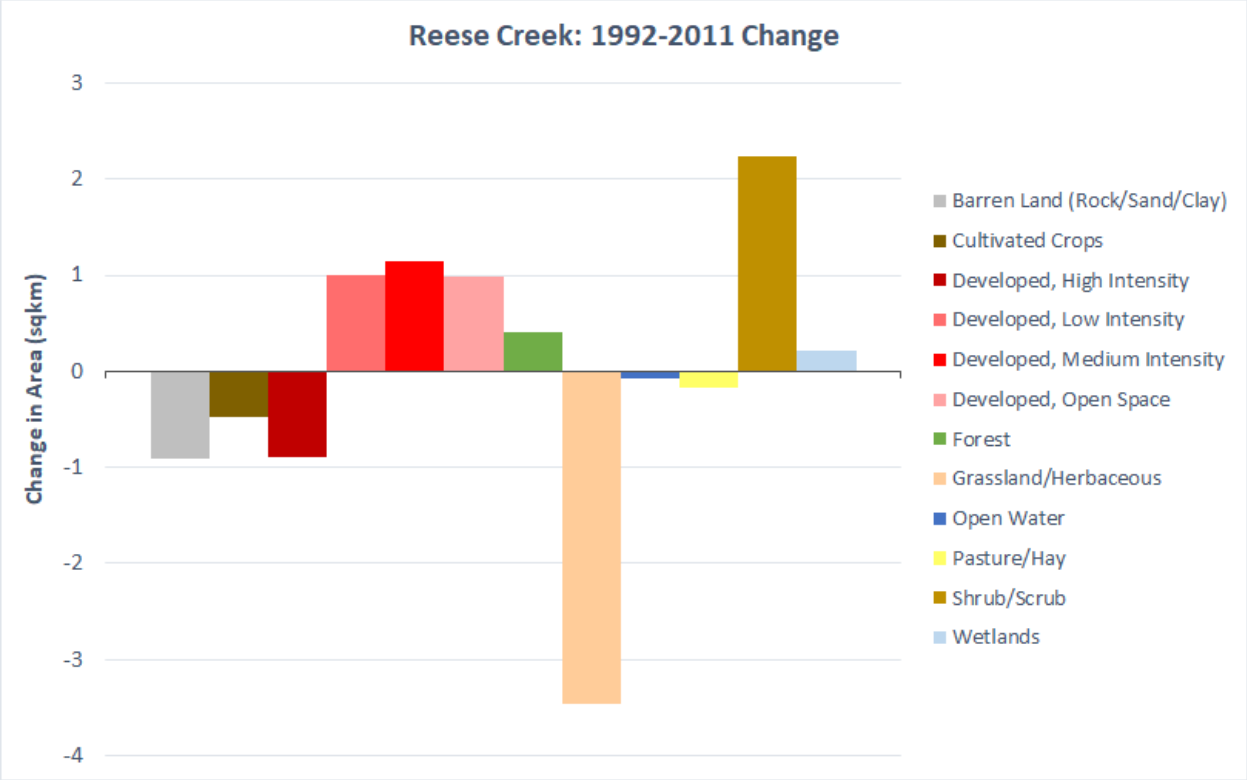


**Figure 119. Land use change in area (sq km) from 1992-2011 for the Reese Creek watershed.**

## ROCKY CREEK

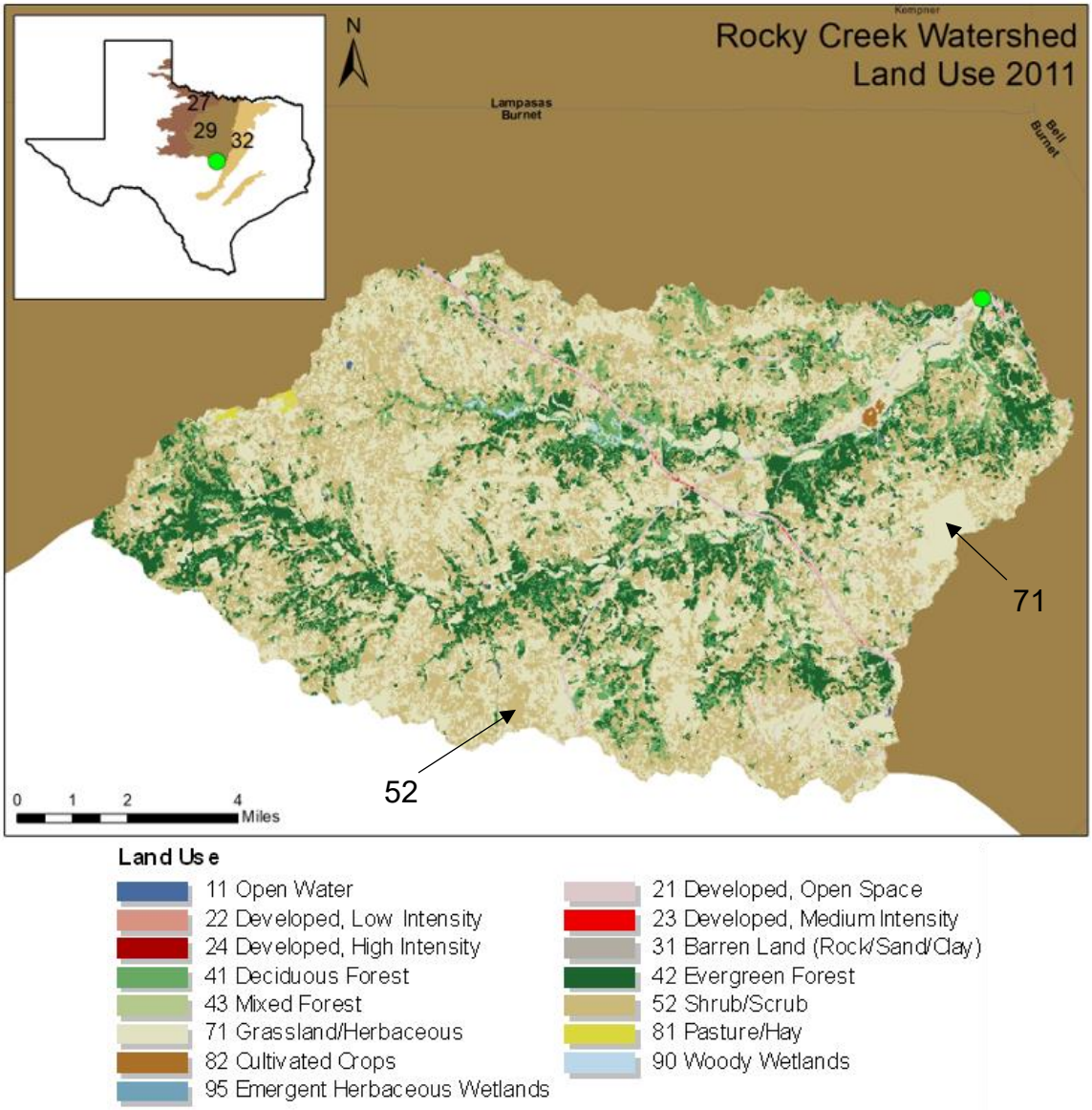


**Figure 120. Map of Rocky Creek watershed location and 2011 land use; grassland/herbaceous and shrub/scrub were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | June 30, 1988; August 3, 2002; April 16, 2003; August 20, 2003; May 5, 2004; August 16, 2004 |
| Water Quality: | 108 sampling events |
| Fish: | June 30, 1988; March 23, 1989; August 7, 2002; April 16, 2003; August 20, 2003; May 3, 2004; August 30, 2004 |
| Benthic Invertebrates: | June 30, 1988; August 6, 2002; April 16, 2003; August 20, 2003; May 5, 2004; August 18, 2004 |

## Physical Characterization

### Watershed and Land Use

Rocky Creek lies within the Brazos River Basin. Sample site 11724 is located at FM 963, approximately 1.26 km upstream of the Lampasas River near Oakalla in Burnet County (Figure 120).

The Rocky Creek watershed at site 11724 is approximately 294.98 sq km. The station and vast majority of the watershed are located in Level IV Ecoregion 29e, the Limestone Cut Plain, while a small portion of the watershed boundary crosses into Ecoregion 30. The dominant land cover in the watershed is grassland/herbaceous at 36.98% and is present throughout the watershed (Homer et al. 2015; Figure 120 and Figure 121). Shrub is the secondary land cover encompassing 35.72%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 2.47% and total cover for cultivated crops is 0.10%.

From 1992-2011 there was a 13.43 sq km decrease in grassland and a 3.99 sq km decrease in forest. There was a 12.91 sq km increase in shrub and a 6.65 sq km increase in open space development (Figure 122).

There are no permitted wastewater outfalls within the Rocky Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Rocky Creek was evaluated during six sampling events from 1988 to 2004. Rocky Creek is an intermittent stream with perennial pools that drains to the Lampasas River above Stillhouse Hollow Lake. Habitat Quality Index scores are available for five events and indicate an intermediate to high aquatic life use rating (18-24). Riparian areas were generally well vegetated throughout the reach with an average riparian buffer ranging from 15-18 meters wide. The riparian zone was dominated by trees followed by shrubs then grasses. The average percentage of tree canopy cover ranged from 25% to 40%. The dominant stream substrate was bedrock, and the average percent of substrate gravel size or larger varied from 50% to 90%. Average percent instream cover was 17% to 56%. Rocky Creek ranged from 0.12-0.35 meters deep on average and 8-17 meters wide. Average stream bank slope ranged from 38-45 degrees. Stream flow at the site was measured at a minimum value of 0.02 cfs and a maximum of 75 cfs. Average stream bank erosion potential was 21%-42%. The deepest pool measured at Rocky Creek was 0.8 meters. Number of riffles observed at the site varied from two to five and there were three stream bends.

### Water Quality

Water samples were collected at station 11724 over 108 sampling events from June 1988 through June 2019. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Twenty-four species (eight families) were collected over the course of the seven sampling events. Centrarchidae and Cyprinidae yielded the greatest species richness with eight and seven, respectively. Blacktail Shiner was the most abundant species in every collection except the one from May 2004 where Orangespotted Sunfish outnumbered it. Two species, Blacktail Shiner and Mimic Shiner, were present in every collection. Every fish assemblage rated as having either an exceptional or high aquatic life use. When the coefficient of variability was applied, every collection except August 2004 rated as exceptional. This most recently collected sample yielded fewer sunfish species (three verses 4-6) and many fewer species overall (nine verses 13-16) resulting in scores of three rather than five for those specific IBI metrics. Though it did not affect the metric score, the August 2004 sample also yielded the lowest number of cyprinid species and smallest percentage of piscivores.

### Benthic Macroinvertebrates

Considering the one Surber sample and five RBP samples collectively, a total of 979 individuals representing 93 taxa from 19 orders of macroinvertebrates were collected from Rocky Creek (Appendix E). Diptera, Hemiptera, Ephemeroptera, Trichoptera, Basommatophora, Coleoptera, and Odonata were the most commonly collected orders, collectively accounting for 91.4 percent of the total number of individuals collected. Plecoptera, Veneroida, Megaloptera, and Oligochaeta were the only other orders which comprised at least one percent of the collections.

The Central Bioregion Surber BIBI for the 1988 Surber sample fell in the exceptional aquatic life use category. The Ecoregions 27, 29, and 32 BIBI for the April 2003 and May 2004 samples fell in the high aquatic life use category, while the samples from August 2002 and August 2004 fell in the intermediate aquatic life use category. The August 2003 RBP sample fell in the limited aquatic life use category.

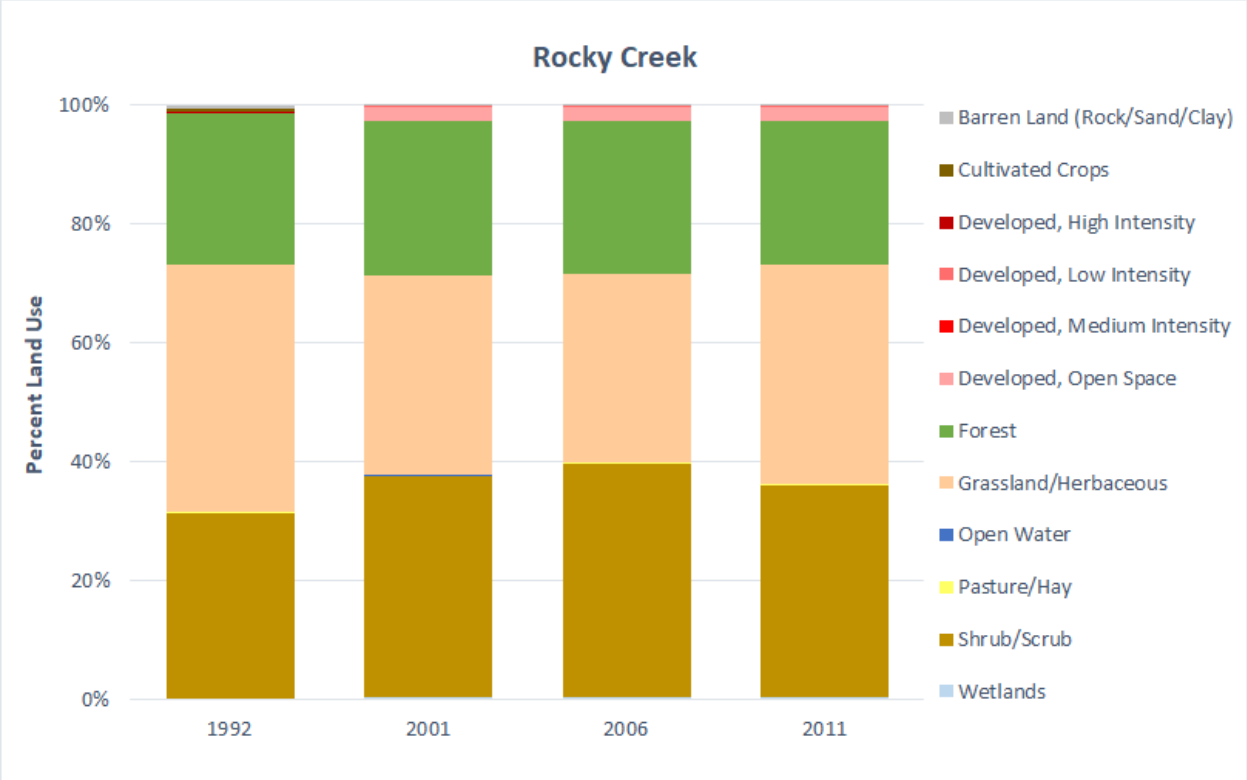


**Figure 121. Percent land use in the Rocky Creek watershed from 1992-2011.**

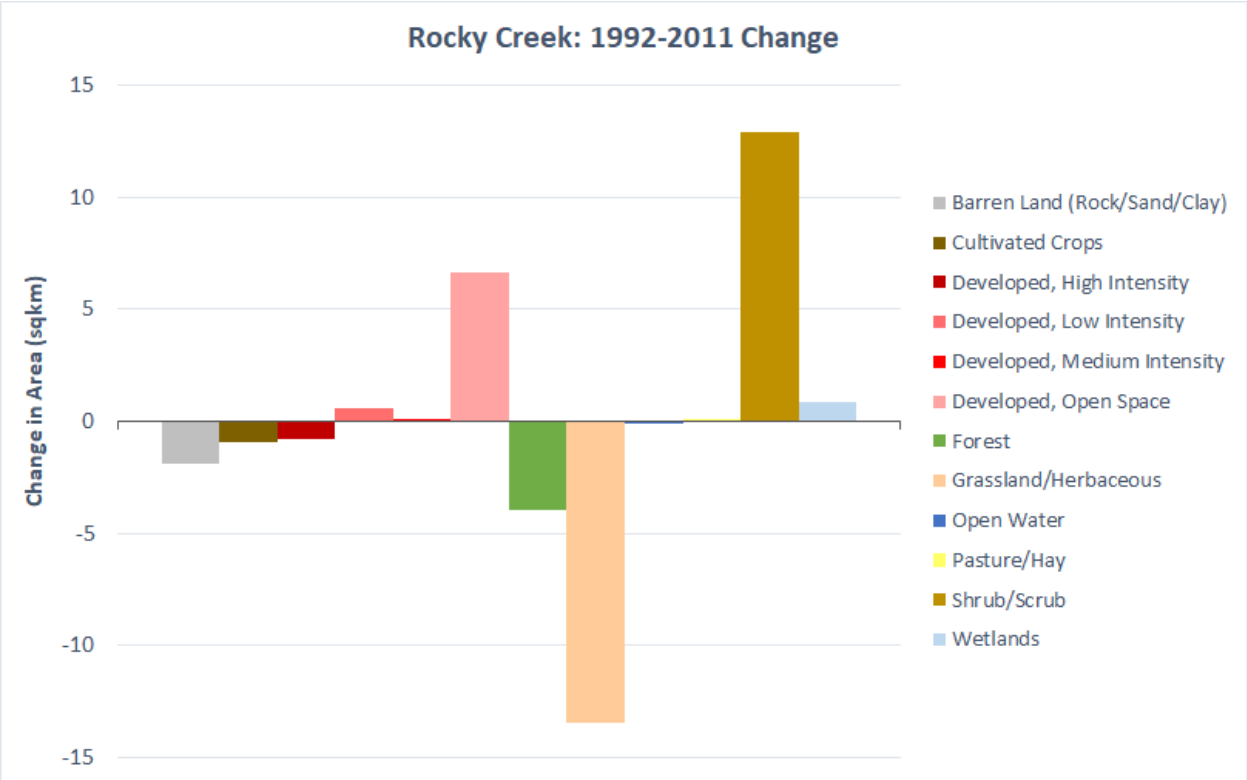


**Figure 122. Land use change in area (sq km) from 1992-2011 for the Rocky Creek watershed.**

## SOUTH FORK ROCKY CREEK

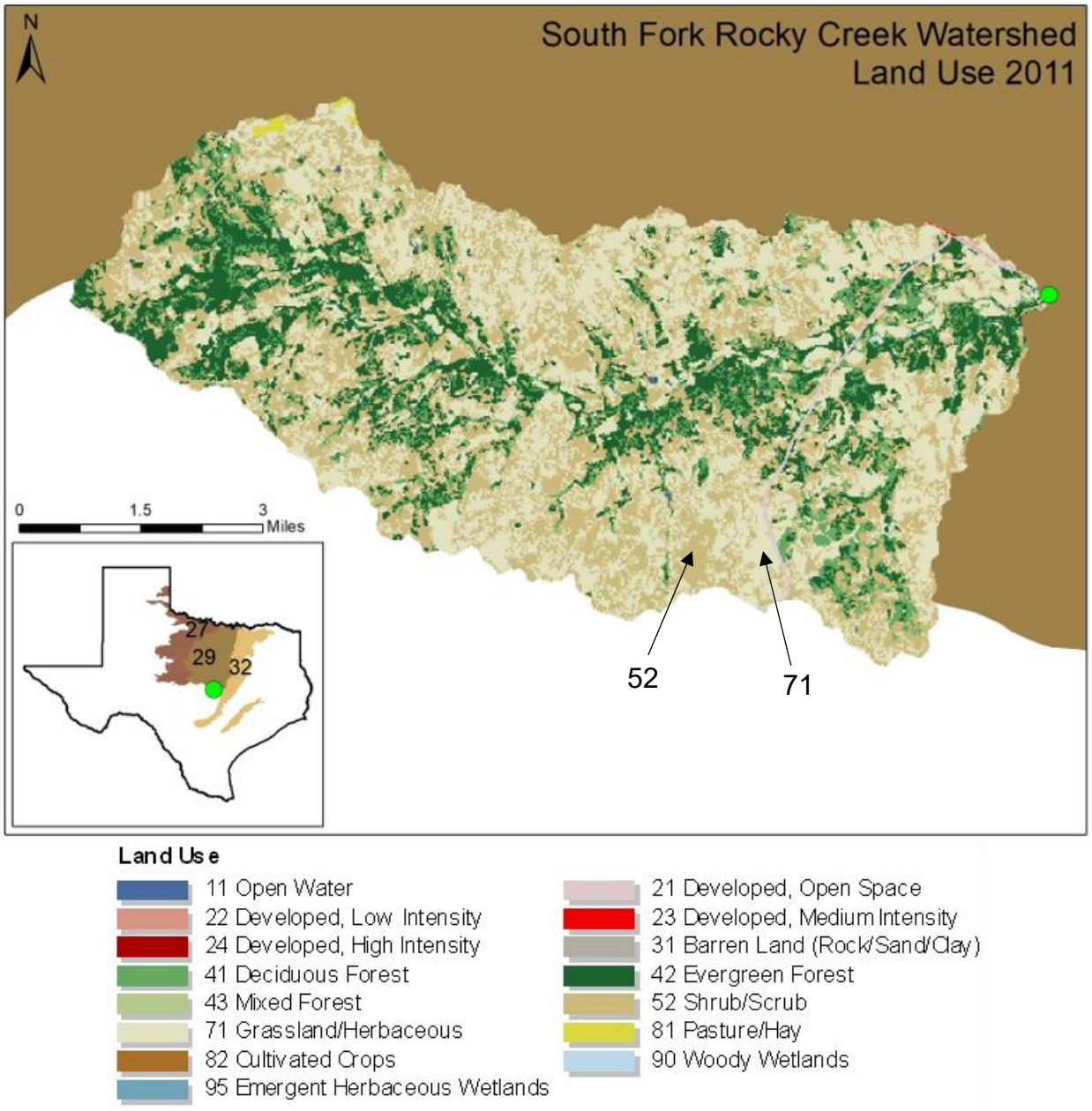


**Figure 123. Map of South Fork Rocky Creek watershed location and 2011 land use; grassland/herbaceous and shrub/scrub were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | April 18, 2003; August 19, 2003; May 5, 2004; September 24, 2007 |
| Water Quality: | 19 sampling events |
| Fish: | April 18, 2003; August 19, 2003; May 4, 2004; September 24, 2007 |
| Benthic Invertebrates: | August 7, 2002; April 18, 2003; May 5, 2004; August 20, 2004; September 24, 2007 |

## Physical Characterization

### Watershed and Land Use

South Fork Rocky Creek lies within the Brazos River Basin. Sample site 18333 is located 405 m upstream of US 183 near Watson in Burnet County (Figure 123).

The South Fork Rocky Creek watershed at site 18333 is approximately 120.72 sq km. The station and vast majority of the watershed are located in Level IV Ecoregion 29e, the Limestone Cut Plain, while a small portion of the watershed boundary crosses into Ecoregion 30. The dominant land cover in the watershed is grassland/herbaceous at 37.28% and is present throughout the watershed (Homer et al. 2015; Figure 123 and Figure 124). Shrub is the secondary land cover encompassing 35.54%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 0.73% and there is no cultivated crop cover present within the watershed.

From 1992-2011 there was a 4.91 sq km decrease in forest and a 4.50 sq km decrease in shrub. There was a 9.26 sq km increase in grassland and a 0.82 sq km increase in open space development (Figure 125).

There are no permitted wastewater outfalls within the South Fork Rocky Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for South Fork Rocky Creek was evaluated during four sampling events from 2003 to 2007. South Fork Rocky Creek is an intermittent stream with perennial pools that drains to Rocky Creek in northern Burnet County. Habitat Quality Index scores are available for all four events and indicate an intermediate to exceptional aquatic life use rating (19-26). Riparian areas were variable with an average riparian buffer ranging from 3.4 meters wide in April 2003 to greater than 20 meters wide in 2004 and 2007. The riparian zone was generally dominated by trees followed by shrubs then grasses. The average percentage of tree canopy cover ranged from 5% to 28%. The dominant stream substrate was cobble and bedrock, and the average percent of substrate gravel size or larger varied from 34% to 90%. Average percent instream cover was 13% to 82%. South Fork Rocky Creek ranged from 0.2-0.4 meters deep on average and 6.8-11.7 meters wide. Average stream bank slope ranged from 33-50 degrees. Stream flow at the site was measured at a minimum value of 0 cfs and a maximum of 20 cfs. Average stream bank erosion potential was 27%-48%. The deepest pool measured at South Fork Rocky Creek was 1.8 meters. Number of riffles observed at the site varied from one to seven, and total number of stream bends ranged from three to four.

### Water Quality

Water samples were collected at station 18333 over 19 sampling events from August 2002 through March 2020. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Fifteen species (six families) were collected over the course of the four sampling events. Centrarchidae was the richest family with seven species. Five species were collected in every sample. These included Blacktail Shiner, Orangethroat Darter, Green Sunfish, Bluegill, and Longear Sunfish. The aquatic life use (based upon the fish assemblage) rated as high for all four collections. When the coefficient of variability was applied the 2004 sample reached exceptional.

### Benthic Macroinvertebrates

Considering the five RBP samples collectively, a total of 620 individuals representing 54 taxa from 16 orders of macroinvertebrates were collected from South Fork Rocky Creek (Appendix E). Ephemeroptera, Trichoptera, Diptera, Odonata, and Hemiptera were the most commonly collected orders, collectively accounting for 91.8 percent of the total number of individuals collected. Plecoptera, Neoophora, Coleoptera, and Oligochaeta were the only other orders which comprised at least one percent of the collections.

The Ecoregions 27, 29, and 32 BIBI for the 2007 RBP sample fell in the exceptional aquatic life use category while the RBP BIBI for the sample collected in 2002 fell in the high aquatic life use category. The RBP samples from 2003 and 2004 fell in the intermediate aquatic life use category.

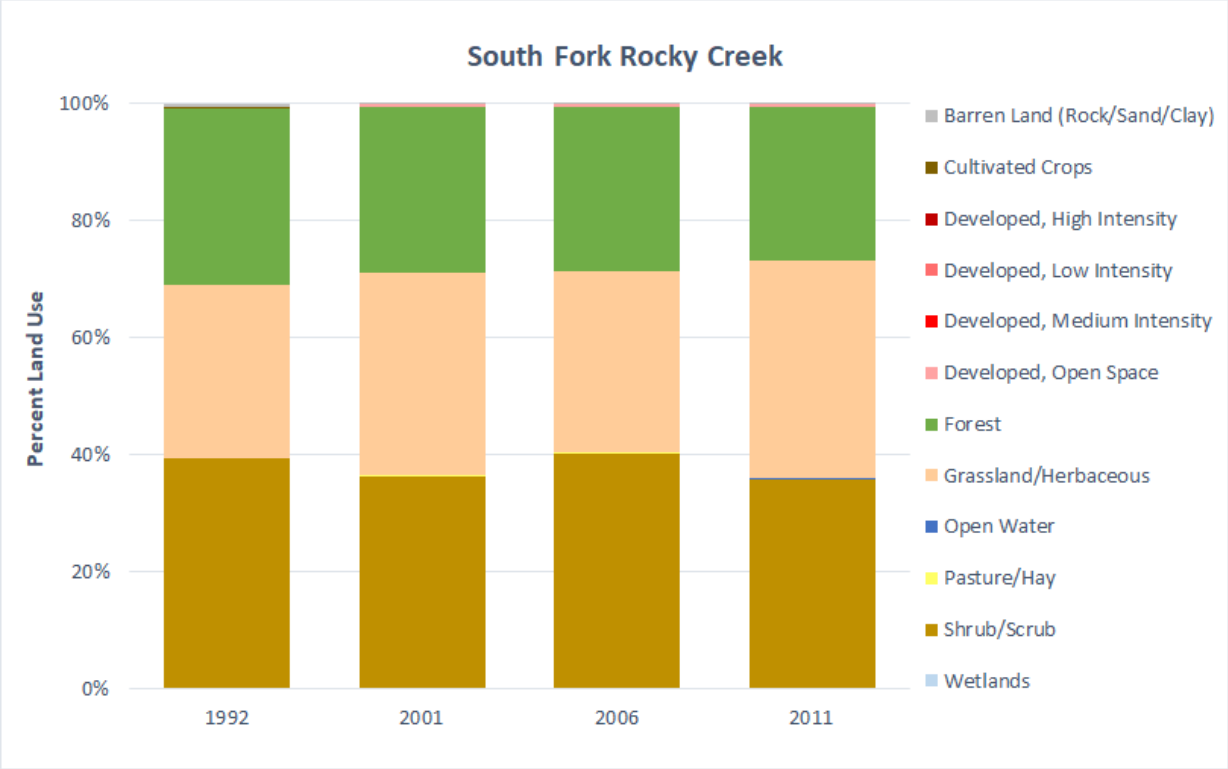


**Figure 124. Percent land use in the South Fork Rocky Creek watershed from 1992-2011.**

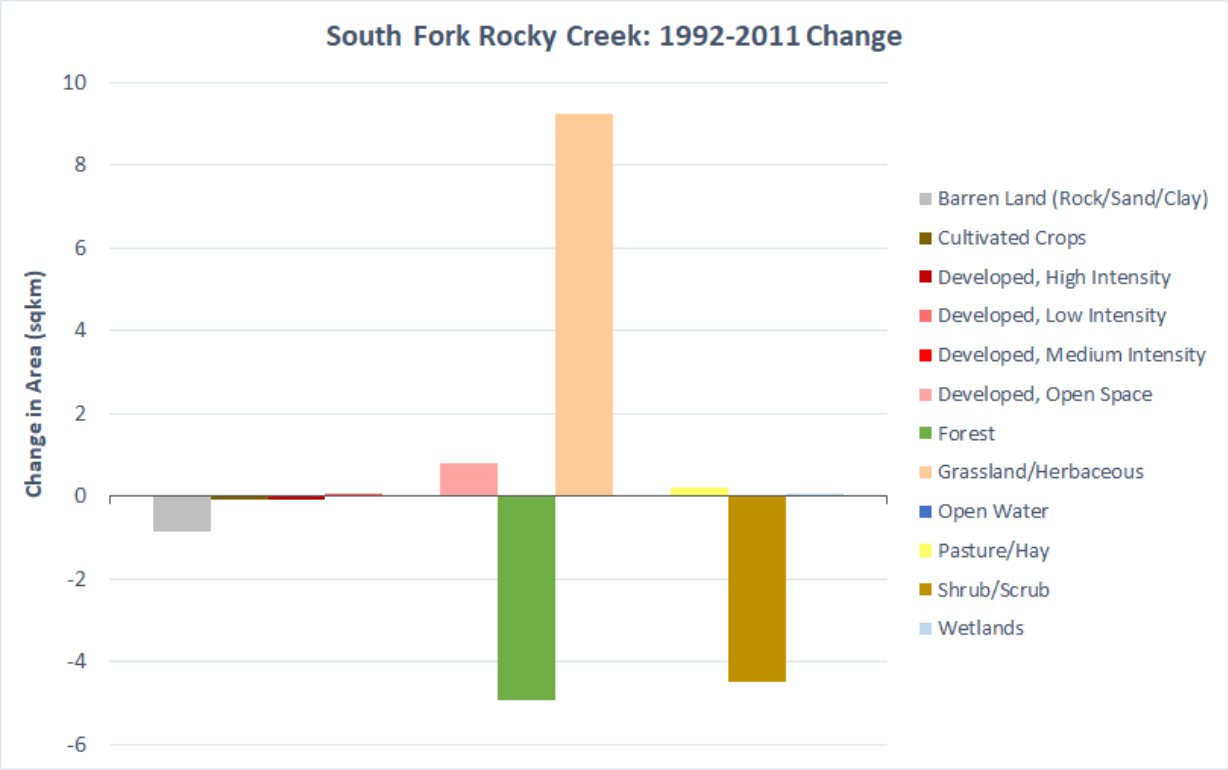


**Figure 125. Land use change in area (sq km) from 1992-2011 for the South Fork Rocky Creek watershed.**

## STEELE CREEK

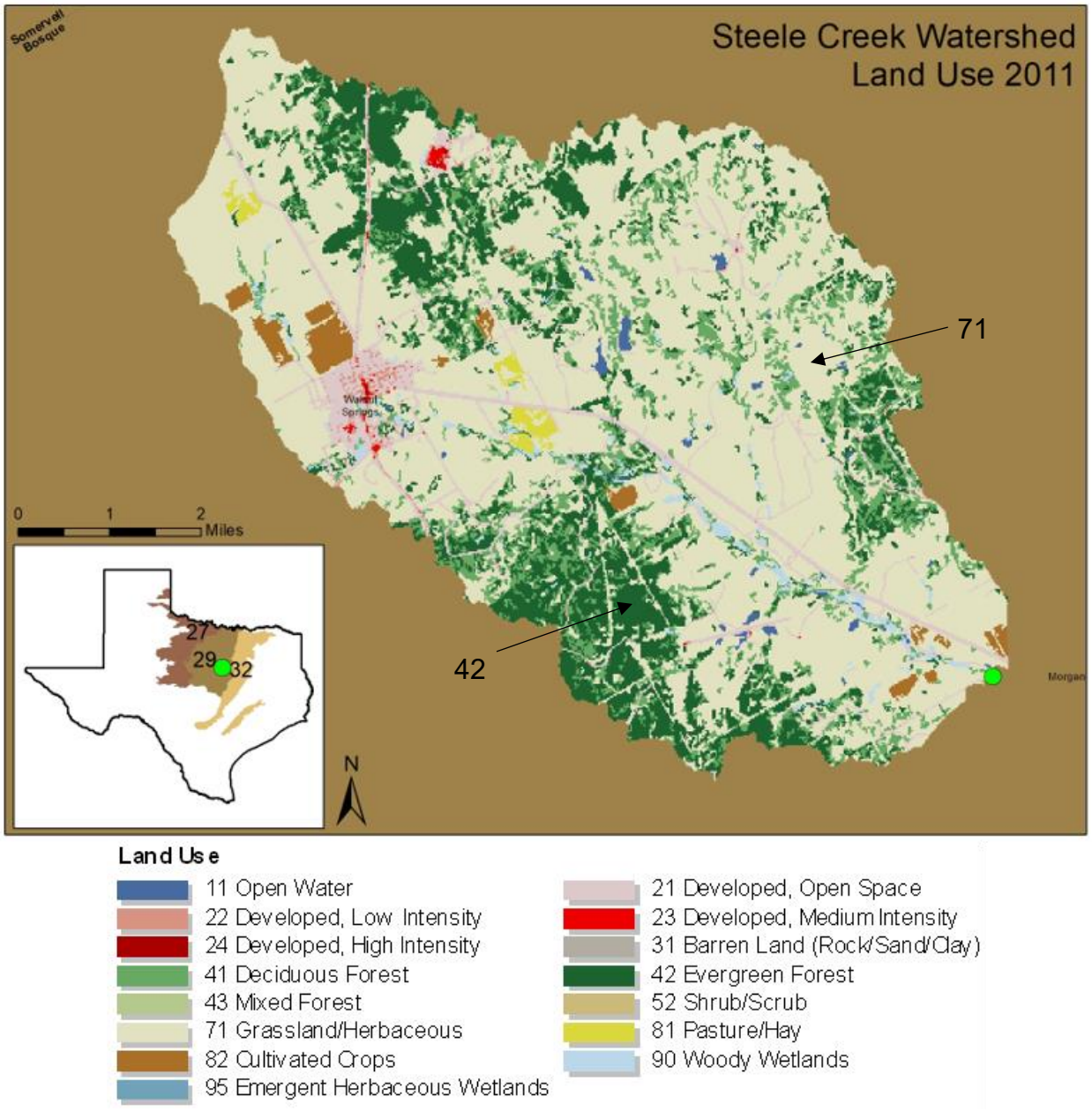


**Figure 126. Map of Steele Creek watershed location and 2011 land use; grassland/herbaceous and forest were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 12, 1988 |
| Water Quality: | 3 sampling events |
| Fish: | July 13, 1988; April 18, 1989 |
| Benthic Invertebrates: | July 13, 1988 |

## Physical Characterization

### Watershed and Land Use

Steele Creek lies within the Brazos River Basin. Sample site 11836 is located 639 m upstream of CR 2620, approximately 1.93 km west of Morgan in Bosque County (Figure 126).

The Steele Creek watershed at site 11836 is approximately 113.46 sq km. The entire watershed lies within Level IV Ecoregion 29e, the Limestone Cut Plain. The dominant land cover in the watershed is grassland/herbaceous at 60.18% and is present throughout the watershed (Homer et al. 2015; Figure 126 and Figure 127). Forest is the secondary land cover encompassing 29.19%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 6.47% and total cover for cultivated crops is 1.57%.

From 1992-2011 there was a 22.81 sq km decrease in shrub and an 8.36 sq km decrease in pasture/hay. There was an 18.63 sq km increase in grassland and a 6.86 sq km increase in forest (Figure 128).

There is one domestic wastewater outfall (discharges < 1 million gallons per day) within the Steele Creek watershed permitted to the City of Walnut Springs which discharges directly into Steele Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Steele Creek was evaluated on July 12, 1988. Steele Creek is a perennial stream that drains to the Steele Creek Arm of Lake Whitney. The riparian width was 30 meters. The riparian zone was dominated by trees, which made up an average of 40% of the total riparian species, followed by shrubs and grasses (30% each). The average percentage of tree canopy cover was 10%. The dominant substrate was bedrock in riffles/runs with gravel and sand in pools, and the average percent of substrate that was gravel size or larger was 18%. Average percent instream cover was 8%. Steele Creek had an average depth of 0.4 meters and a maximum depth of 0.8 meters. The average width was 10.5 meters and average stream bank slope was 30 degrees. Stream flow at the site was 0.7 cfs. Average stream bank erosion potential was 28%. Five riffles were observed at the site and there were two total stream bends.

### Water Quality

Water samples were collected at station 11836 over three sampling events from July 1988 through July 1999. Data were collected for temperature, flow, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Fifteen species (six families) were collected between the two sampling events. Centrarchidae and Cyprinidae yielded the greatest species richness with five and four, respectively. Blacktail Shiner

was the most abundant species. The aquatic life use rated as exceptional and high for the 1988 and 1989 fish assemblages, respectively.

**Benthic Macroinvertebrates**

A total of 270 individuals representing 41 taxa from 10 orders of macroinvertebrates were collected in the Surber sample from Steele Creek (Appendix E) on July 13, 1988. Diptera, Ephemeroptera, Odonata, Trichoptera, and Coleoptera were the most commonly collected orders, collectively accounting for 91.5 percent of the total number of individuals collected. Basommatophora and Hoplonemertea were the only other orders which comprised at least one percent of the collection.

The Ecoregions 27, 29, and 32 Surber BIBI fell in the high aquatic life use category for the sample.

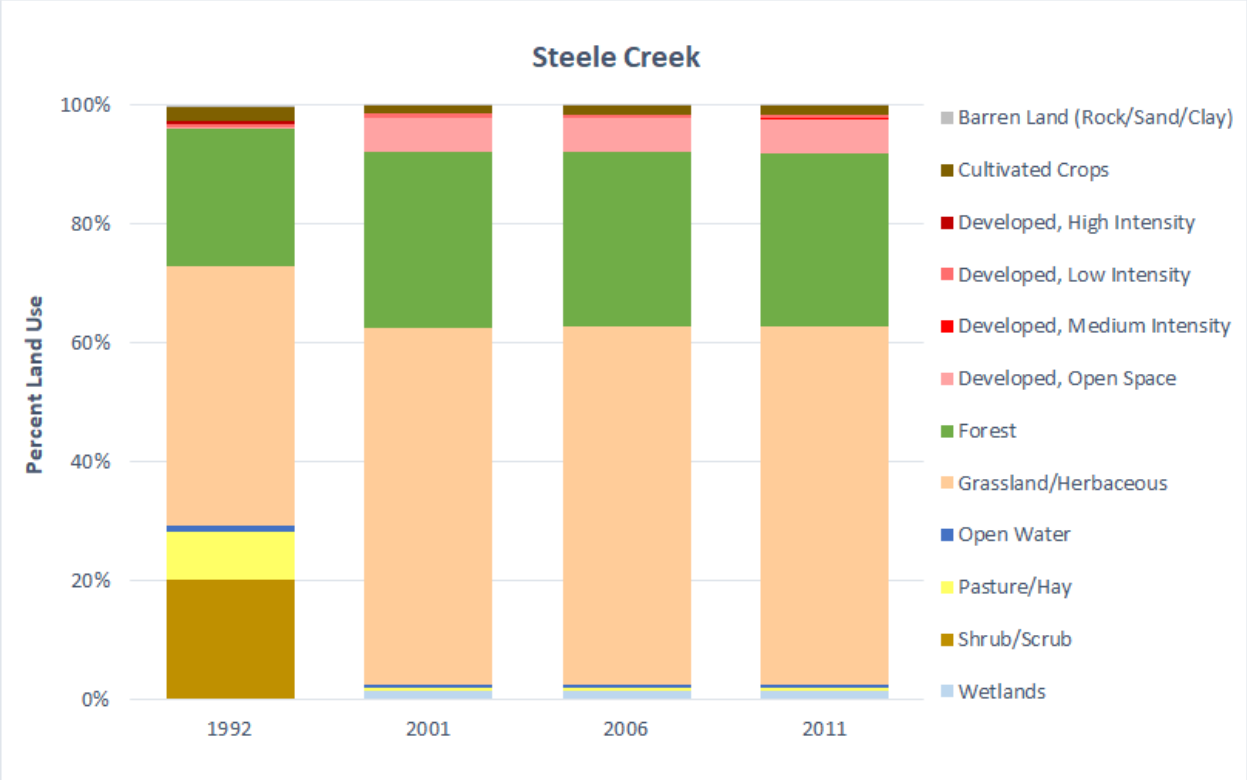


**Figure 127. Percent land use in the Steele Creek watershed from 1992-2011.**

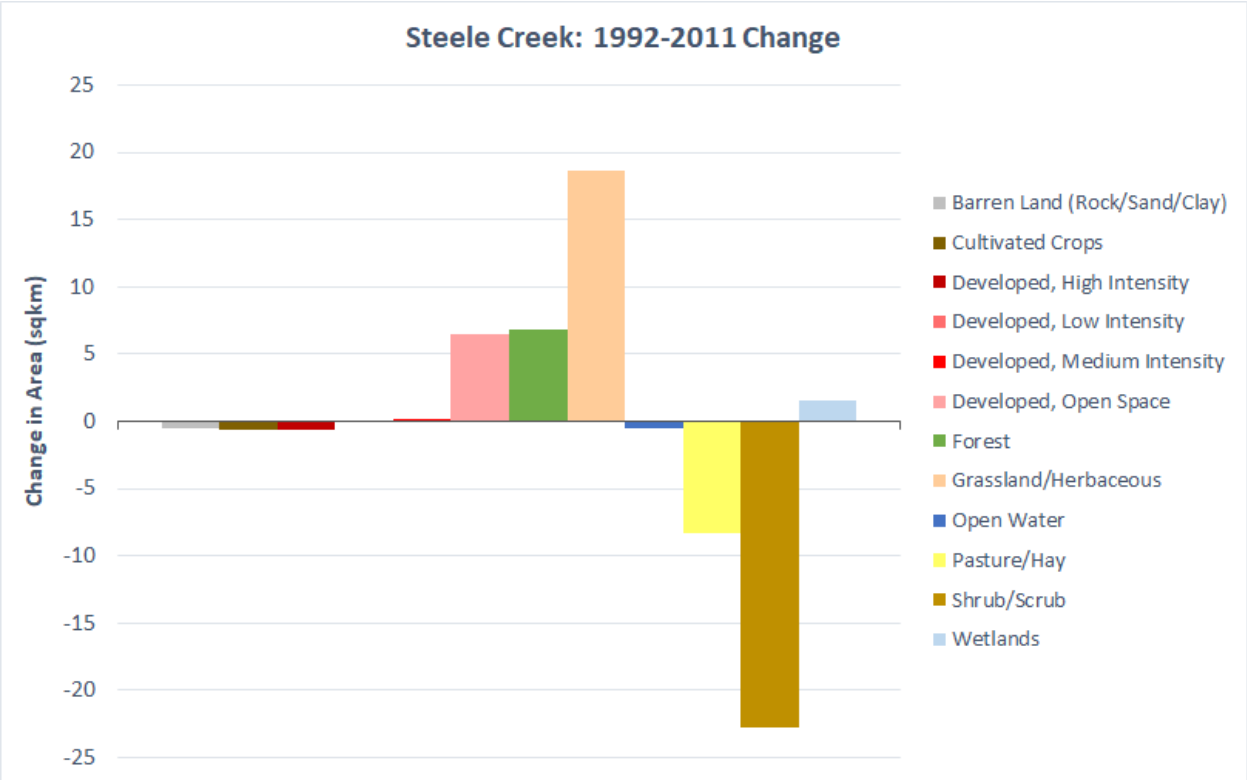


**Figure 128. Land use change in area (sq km) from 1992-2011 for the Steele Creek watershed.**

## Ecoregion 32 Characterization

The Texas Blackland Prairies ecoregion is comprised of two parallel bands separated by the East Central Texas Plains ecoregion (Ecoregion 33) and extending from southern Texas north to very near the Oklahoma border. The ecoregion covers approximately 43,380 sq km and encompasses all or part of 42 counties in the swath the ecoregion cuts across the central part of the state (Figure 80). The ecoregion is bordered on the west by the Cross Timbers (Ecoregion 29), the Edwards Plateau (Ecoregion 30), and by a small stretch adjacent to the Southern Texas Plains (Ecoregion 31). The East Central Texas Plains (Ecoregion 33) forms the southern, eastern, and northern extent of the blackland prairies. Portions of the Red, Brazos, Trinity, San Antonio, and Colorado River Basins are included in the ecoregion. The ecoregion is contained entirely within the state.

The ecoregion was historically prairie with grasses such as little bluestem *Schizachyrium scoparium*, big bluestem *Andropogon gerardi*, yellow Indiangrass *Sorghastrum nutans*, and switchgrass *Panicum virgatum* remaining in areas that have not been converted to cropland, pasture, and forage production (Griffith et al. 2007). Griffith et al. (2007) also note the ecoregion is experiencing growth in urban areas. Annual average precipitation in the ecoregion generally ranges from 71-107 cm. Riparian vegetation along streams in the ecoregion often includes bur oak *Quercus macrocarpa*, Shumard oak *Q. shumardii,* hackberry, elm, ash *Fraxinus* sp., cottonwood, and pecan.

**Table 8. Streams sampled in Ecoregion 32.**

| | | |
|---|---|---|
| Auds Creek | Deer Creek | Willis Creek |
| Cow Bayou | Geronimo Creek | Wilson Creek |

## AUDS CREEK

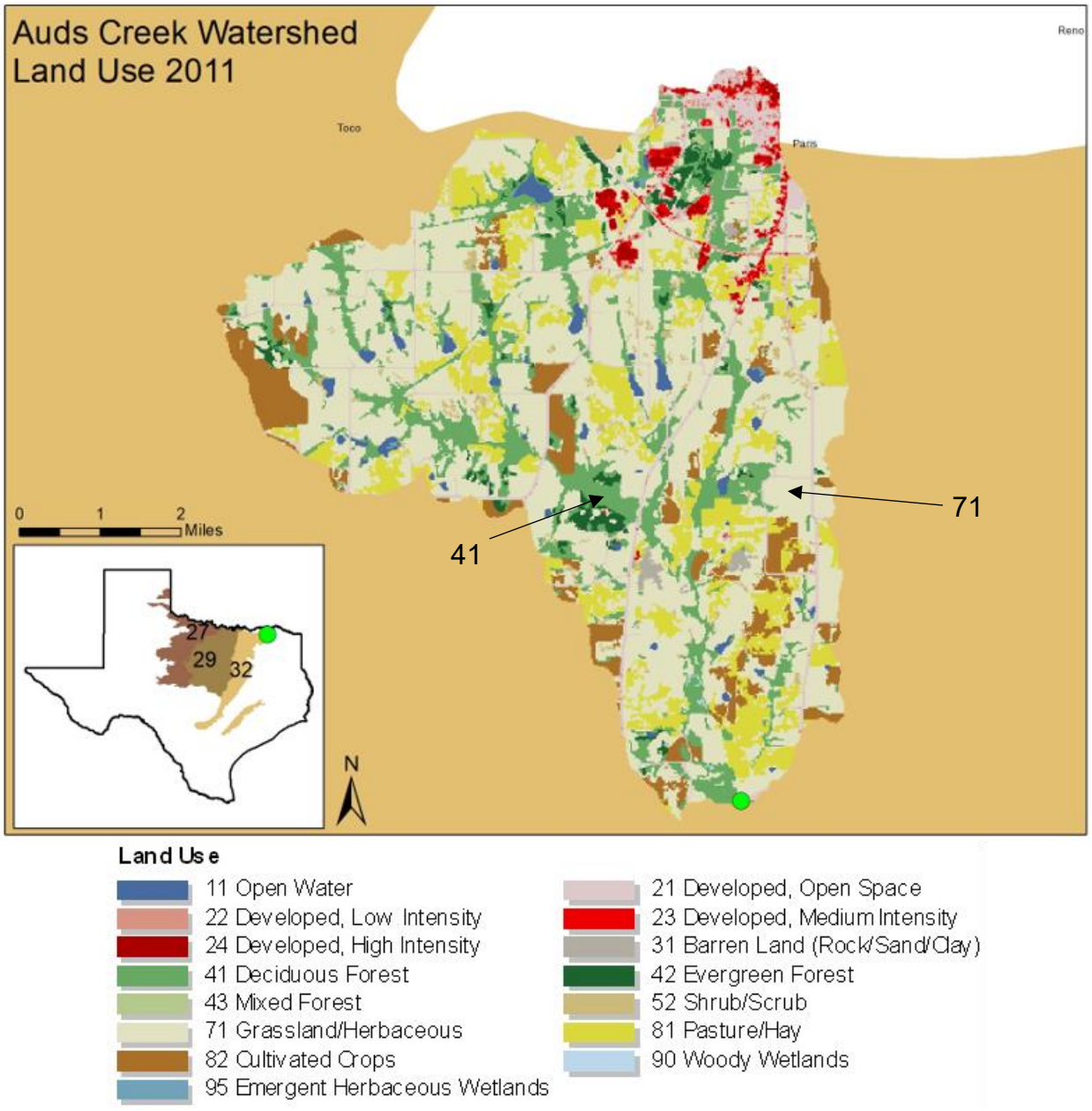


**Figure 129. Map of Auds Creek watershed location and 2011 land use; grassland/herbaceous and forest were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | August 1, 1989; May 22, 2002 |
| Water Quality: | 12 sampling events |
| Fish: | August 2, 1989; May 22, 2002; July 4, 2002 |
| Benthic Invertebrates: | August 2, 1989; May 22, 2002; July 4, 2002 |

## Physical Characterization

### Watershed and Land Use

Auds Creek lies within the Sulphur River Basin. Sample site 10197 is located at FM 1184 south of Paris in Lamar County (Figure 129).

The Auds Creek watershed at site 10197 is approximately 103.92 sq km. The vast majority of the watershed lies within Level IV Ecoregion 32a, the Northern Blackland Prairie. There is a small portion of the upper watershed that crosses into Ecoregion 33. The dominant land cover in the watershed is grassland/herbaceous at 48.40% and is present throughout the watershed (Homer et al. 2015; Figure 129 and Figure 130). The secondary land cover is forest at 17.57%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 8.80% and total cover for cultivated crop is 7.44%.

From 1992-2011 there was a 35.68 sq km decrease in pasture/hay and a 21.72 sq km decrease in cultivated crops. There was a 50.29 sq km increase in grassland/herbaceous and a 5.65 sq km increase in open space development (Figure 131).

There are five industrial wastewater outfalls (discharges ≥ 1 million gallons per day) and three stormwater outfalls within the Auds Creek watershed. The stormwater outfalls and one industrial wastewater facility are permitted to Kimberly Clark Corporation, an American multinational personal care corporation that produces mostly paper-based consumer products. Two of the industrial wastewater outfalls are permitted to La Frontera Holdings, LLC which is a natural gas generation facility, another facility is permitted to Lamar Power Partners, an electricity generation power plant, and the final facility is permitted to Turner Industries Group, LLC a company involved with construction, pipe, module, and vessel fabrication. None of these facilities or stormwater outfalls discharge directly into Auds Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Auds Creek was evaluated on August 1, 1989 and again on May 22, 2002. Auds Creek is a perennial stream that drains to the North Sulphur River south of Paris. The following summary information is based on data collected during the most recent sampling event in 2002. The Habitat Quality Index score of 18 indicates an intermediate aquatic life use rating. Riparian areas were generally well vegetated throughout the reach with an average riparian buffer measured at 13 meters, and there was evidence that the stream had been terraced and channelized in the distant past. The riparian zone was dominated by grasses followed by trees then shrubs. The average percentage of tree canopy cover was 8%. The dominant substrate was silt, and the average percent of substrate that was gravel size or larger was 39%. Average percent instream cover was 30%. Auds Creek was 0.3 meters deep on average and 9 meters wide. Average stream bank slope was 27 degrees, and average stream bank erosion potential was 53%. No pools were measured on Auds Creek in 2002. Stream flow at the site was measured at a minimum value of 1.3 cfs in 1989 and a maximum of 2.6 cfs in 2002. Two riffles were observed at the site in 2002 and there were two well defined stream bends.

### Water Quality

Water samples were collected at station 10197 over 12 sampling events from August 1989 through July 2002. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Sixteen species (four families) were collected over the course of three sampling events. The family with the most species represented was Centrarchidae with seven. Red Shiner, a tolerant species, was the most abundant species collected. The aquatic life use rating for all fish collections was only intermediate; however, when the coefficient of variability is applied, the 2002 collections rise to high. The primary reasons for the lower aquatic life use ratings were the absence of benthic invertivore species, the assemblage being dominated by tolerant species (greater than 85% of the individuals), and the low catch rate.

### Benthic Macroinvertebrates

Considering the one Surber sample and two RBP samples collectively, a total of 403 individuals representing 34 taxa from 12 orders of macroinvertebrates were collected from Auds Creek (Appendix E). Ephemeroptera, Diptera, Trichoptera, and Odonata were the most commonly collected orders, collectively accounting for 92.6 percent of the total number of individuals collected. Coleoptera, Veneroida, and Hemiptera were the only other orders which comprised at least one percent of the collections.

The Central Bioregion Surber BIBI for the 1989 Surber sample fell in the high aquatic life use category. Similarly, the Ecoregions 27, 29, and 32 BIBI for the two 2002 RBP samples fell in the intermediate aquatic life use category.

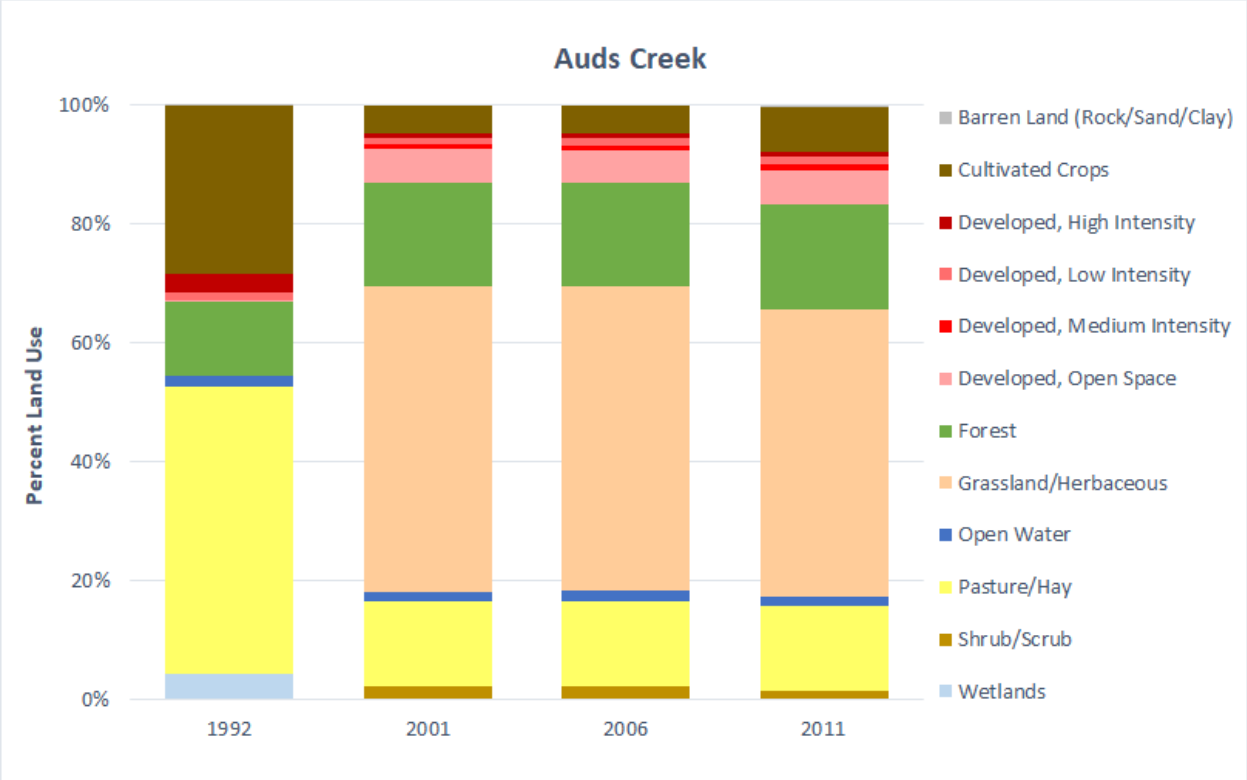


**Figure 130. Percent land use in the Auds Creek watershed from 1992-2011.**

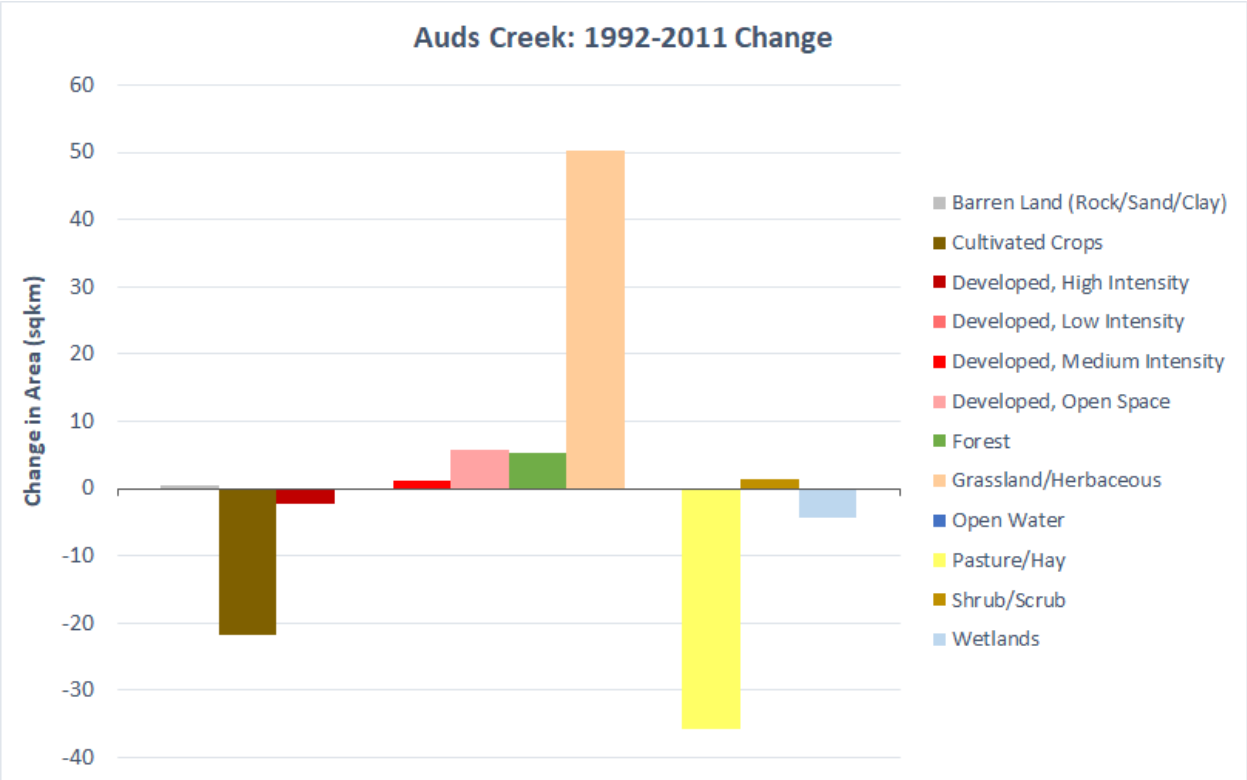


**Figure 131. Land use change in area (sq km) from 1992-2011 for the Auds Creek watershed.**

## COW BAYOU

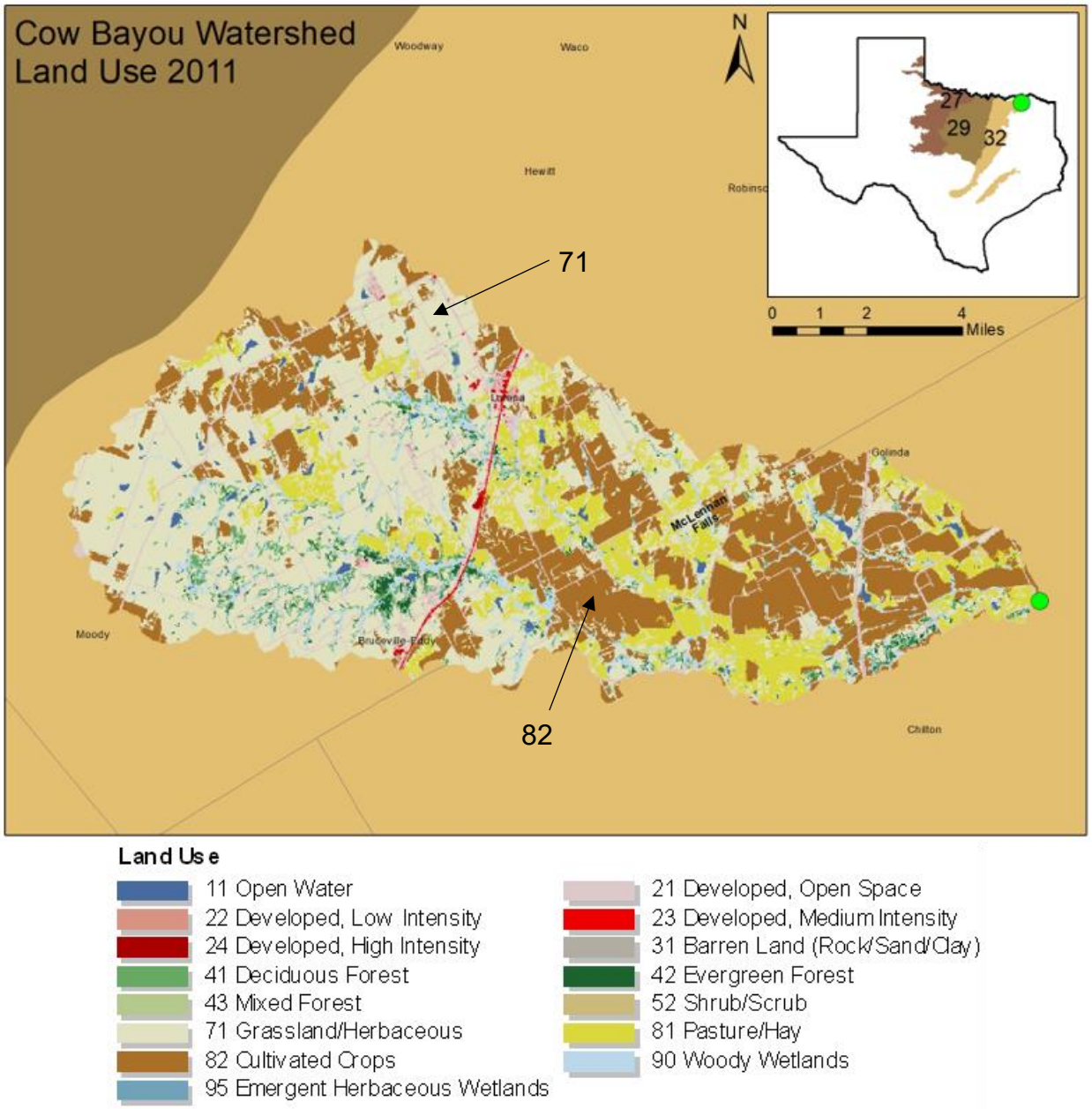


**Figure 132. Map of Cow Bayou watershed location and 2011 land use; grassland/herbaceous and cultivated crops were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 14, 1987; April 29, 2010 |
| Water Quality: | 4 sampling events |
| Fish: | July 14, 1987; April 30, 2010; July 26, 2010 |
| Benthic Invertebrates: | July 16, 1987 (two locations); April 30, 2010; July 26, 2010 |

## Physical Characterization

### Watershed and Land Use

Cow Bayou lies within the Brazos River Basin. Sample site 11717 is located downstream of CR 417, approximately 2.57 km south of Satin in Falls County (Figure 132).

The Cow Bayou watershed at site 11717 is approximately 289.11 sq km. The entire watershed lies within Level IV Ecoregion 32a, the Northern Blackland Prairie. The dominant land cover in the watershed is grassland/herbaceous at 42% and is mostly present in the upper watershed (Homer et al. 2015; Figure 132 and Figure 133). Cultivated crops is the secondary land cover encompassing 26.56%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 7.61%.

From 1992-2011 there was a 41.48 sq km decrease in shrub and a 20.32 sq km decrease in forest. There was a 51.56 sq km increase in grassland and a 19.34 sq km increase in open space development (Figure 134).

There is one domestic wastewater outfall (discharges < 1 million gallons per day) within the Cow Bayou watershed permitted to the City of Bruceville-Eddy. This facility does not discharge directly into Cow Bayou.

### In Channel and Riparian Physical Habitat

Physical habitat for Cow Bayou was evaluated on July 14, 1987 and again on April 29, 2010. Cow Bayou is a perennial stream that drains to the Brazos River in Falls County. The following summary information is based on data collected during the most recent sampling event in 2010. The Habitat Quality Index score of 20.5 indicates a high aquatic life use rating. Riparian areas were well vegetated throughout the reach with an average riparian buffer measured at 18 meters wide. The riparian zone was dominated by grasses, which made up an average of 62% of the total riparian species, followed by trees (18%) then shrubs (15%). The average percentage of tree canopy cover was 64%. The dominant substrate was sand, and the average percent of substrate that was gravel size or larger was 28%. Average percent instream cover was 6%. Cow Bayou was 0.3 meters deep on average and 8 meters wide. Average stream bank slope was 32 degrees, and average stream bank erosion potential was 34%. The deepest pool measured at Cow Bayou was 1.2 meters. Stream flow at the site was measured at a minimum value of 6.7 cfs in 1987 and a maximum of 32 cfs in 2010. Two riffles were observed at the site in 2010 and there were four total stream bends.

### Water Quality

Water samples were collected at station 11717 over 4 sampling events from July 1987 through July 1999. Data were collected for temperature, flow, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Twenty-seven species (eight families) were collected over the course of the three sampling events. Cyprinidae and Centrarchidae were the most species rich families, yielding eight and seven species, respectively. Blacktail Shiner was the most abundant species in the 1987 collection, whereas Red Shiner was the most abundant species in both 2010 collections. Based upon the fish assemblage, Cow Bayou rated as having a high aquatic life use in 1987 and April 2010 and an exceptional aquatic life use in July 2010. When the coefficient of variability is applied the 1987 sample rises to exceptional.

### Benthic Macroinvertebrates

Considering the two Surber samples and two RBP samples collectively, a total of 667 individuals representing 69 taxa from 17 orders of macroinvertebrates were collected from Cow Bayou (Appendix E). Diptera, Trichoptera, Ephemeroptera, Odonata, Veneroida, and Plecoptera were the most commonly collected orders, collectively accounting for 91.9 percent of the total number of individuals collected. Coleoptera, Tricladida, and Megaloptera were the only other orders which comprised at least one percent of the collections.

The Central Bioregion Surber BIBI for the 1987 Surber samples at Falls County Road and FM 2643 fell in the exceptional and high aquatic life use categories, respectively. The Ecoregions 27, 29, and 32 BIBI for the April and July 2010 RBP samples fell in the intermediate and high aquatic life use categories, respectively.

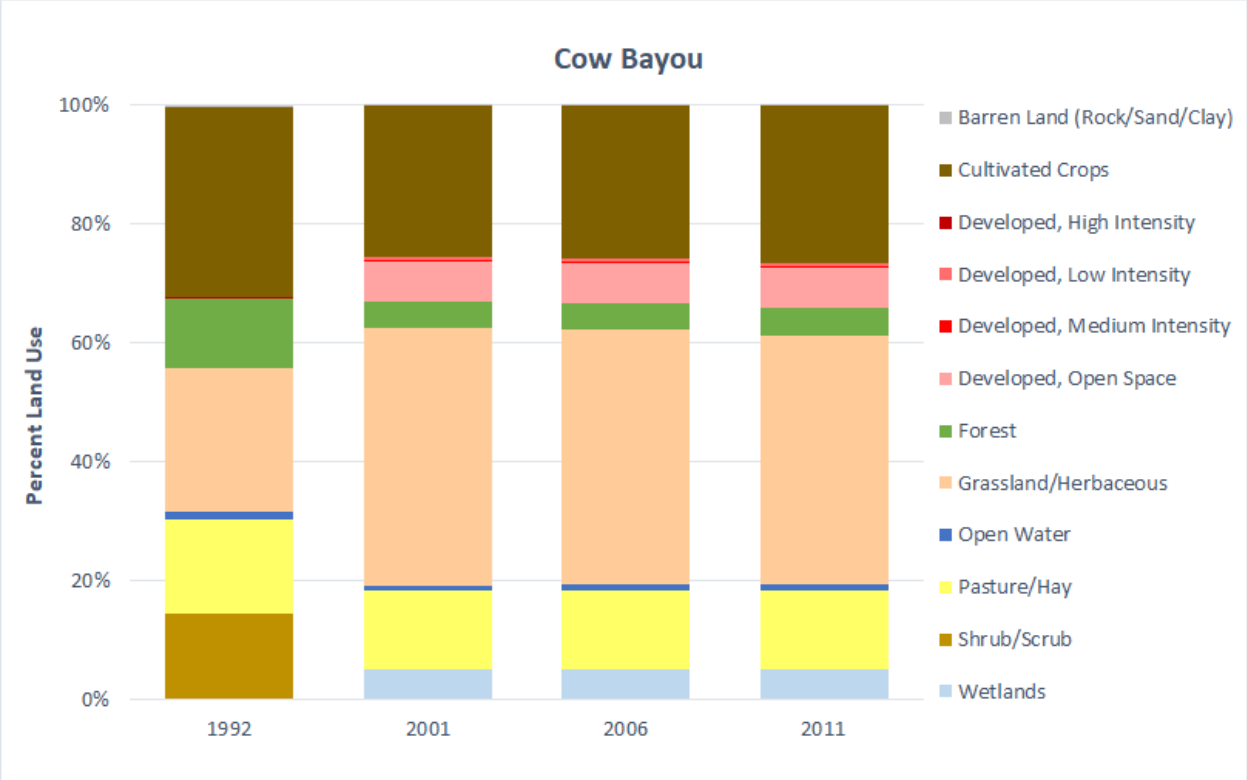


**Figure 133. Percent land use in the Cow Bayou watershed from 1992-2011.**

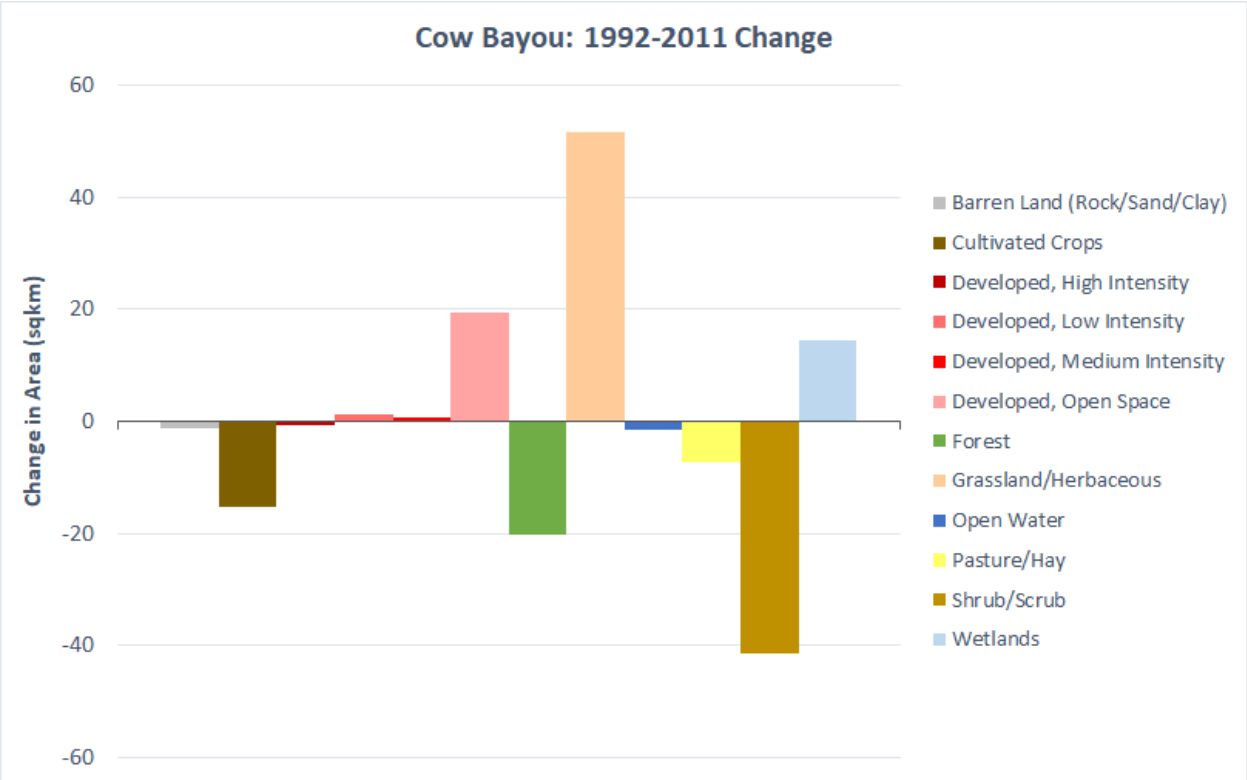


**Figure 134. Land use change in area (sq km) from 1992-2011 for the Cow Bayou watershed.**

## DEER CREEK

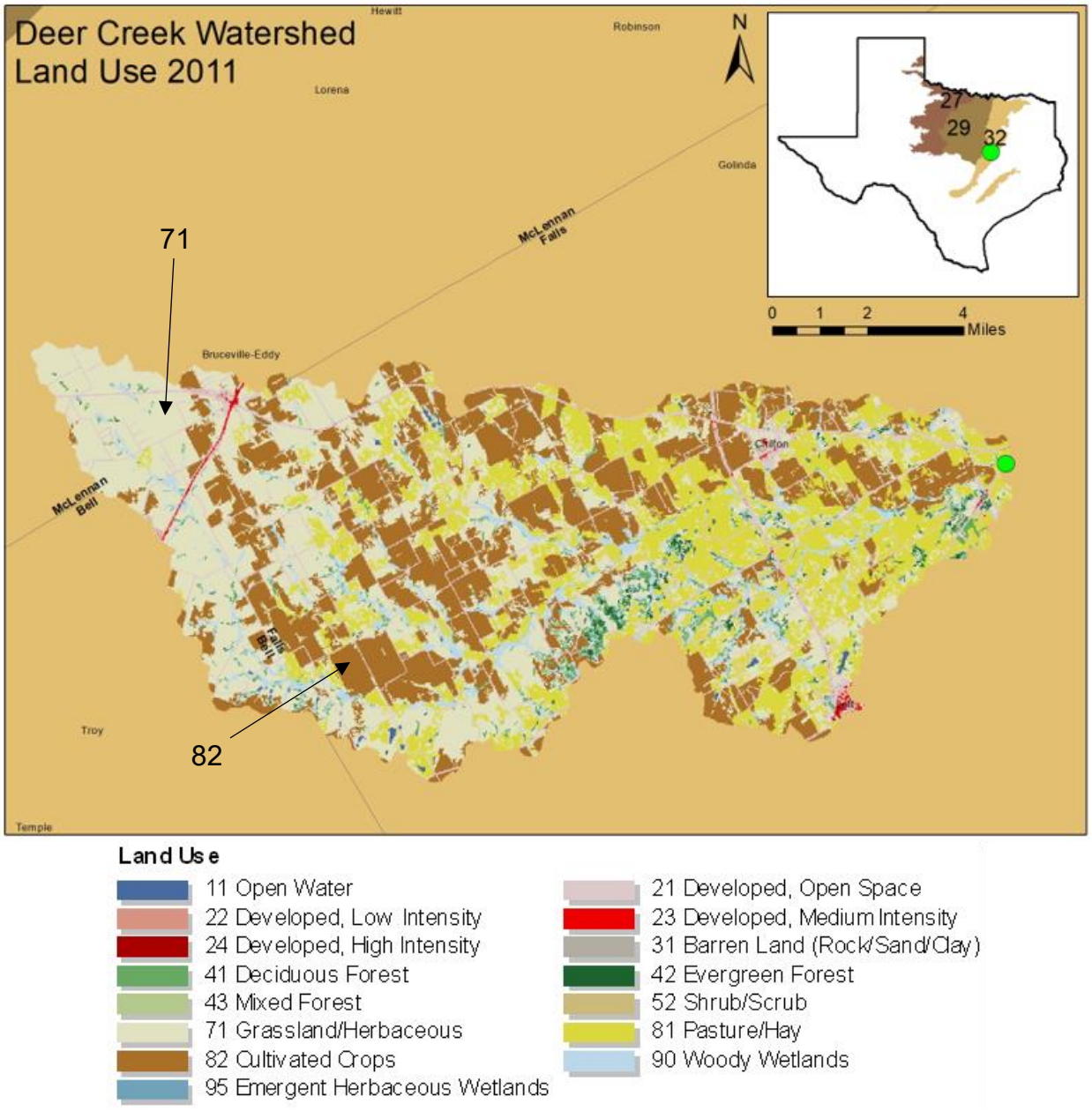


**Figure 135. Map of Deer Creek watershed location and 2011 land use; grassland/herbaceous and cultivated crops were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 18, 1989; March 31, 2004; July 21, 2004 |
| Water Quality: | 101 sampling events at two stations |
| Fish: | July 18, 1989; March 31, 2004; July 21, 2004 |
| Benthic Invertebrates: | July 18, 1989; March 31, 2004; July 21, 2004 |

## Physical Characterization

### Watershed and Land Use

Deer Creek lies within the Brazos River Basin. Sample site 11723 is located downstream of SH 320 west of Marlin in Falls County (Figure 135).

The Deer Creek watershed at site 11723 is approximately 296.93 sq km. The vast majority of the watershed lies within Level IV Ecoregion 32a, the Northern Blackland Prairie, the station and a very small portion of the lower watershed lies in Level IV Ecoregion 32c, the Floodplains and Low Terraces. The dominant land cover in the watershed is grassland/herbaceous at 34.97% and is mostly present in the upper watershed (Homer et al. 2015; Figure 135 and Figure 136). Cultivated crops is the secondary land cover encompassing 27.07%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 8.50%.

From 1992-2011 there was a 47.81 sq km decrease in shrub and a 30.46 sq km decrease in forest. There was a 32.88 sq km increase in grassland and a 23.29 sq km increase in open space development (Figure 137).

There are two domestic wastewater outfalls (discharges < 1 million gallons per day) within the Deer Creek watershed permitted to the City of Lott and Chilton Water Supply and Sewer Service Corporation. These facilities do not discharge directly into Deer Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Deer Creek was evaluated during three sampling events, one in 1989 and two in 2004. Deer Creek is a perennial stream that drains to the Brazos River in Falls County. The following summary information is based on data collected during the two most recent sampling events in 2004. Habitat Quality Index scores indicate an intermediate to high aquatic life use rating (19 and 21.5). Riparian areas were well vegetated throughout the reach with an average riparian buffer ranging from 17 to 21 meters wide. The riparian zone was generally dominated by shrubs followed by trees then grasses. The average percentage of tree canopy cover ranged from 17% to 19%. The dominant stream substrates were clay and bedrock, and the average percent of substrate gravel size or larger varied from 10% to 28%. Average percent instream cover was 2% to 9%. Deer Creek ranged from 0.3-0.4 meters deep on average and 14.8-15.4 meters wide. Average stream bank slope ranged from 36-40 degrees. Stream flow at the site was measured at a minimum value of 6 cfs and a maximum of 8.5 cfs. Average stream bank erosion potential was 36%-49%. The deepest pool measured at Deer Creek was 1.1 meters. Number of riffles observed at the site varied from five to six, and there was one well defined stream bend.

### Water Quality

Water samples were collected at station 16407 over 69 sampling events from June 1998 through August 2007. Station 11723 was sampled over 32 water sampling events from July 1989 to February 2020. Data were collected for temperature, flow, transparency, specific conductivity,

dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Twenty-one species (eight families) were collected over the course of the three sampling events. Centrarchidae and Cyprinidae were the most species rich families with six and five species, respectively. Red Shiner was the most abundant species collected in each sampling event. Based on the fish assemblage, Deer Creek only attained a limited aquatic life use rating in 1987. No benthic invertivores were collected, the percentage of tolerant and omnivorous individuals was high, and the percentage of piscivorous individuals was low. However, when the coefficient of variability was applied the rating increased to intermediate. Both samples from 2004 attained high aquatic life use ratings. Three benthic invertivore species were collected and the percentage of omnivorous individuals significantly declined.

### Benthic Macroinvertebrates

Considering the one Surber sample and two RBP samples collectively, a total of 1,071 individuals representing 44 taxa from 10 orders of macroinvertebrates were collected from Deer Creek (Appendix E). Trichoptera, Diptera, and Ephemeroptera the most commonly collected orders, collectively accounting for 97.3 percent of the total number of individuals collected. No other orders comprised one percent or more of the collections.

The Central Bioregion Surber BIBI for the 1989 Surber sample fell in the high aquatic life use category. The Ecoregions 27, 29, and 32 BIBI for the March and July 2004 RBP samples fell in the intermediate and high aquatic life use categories, respectively.

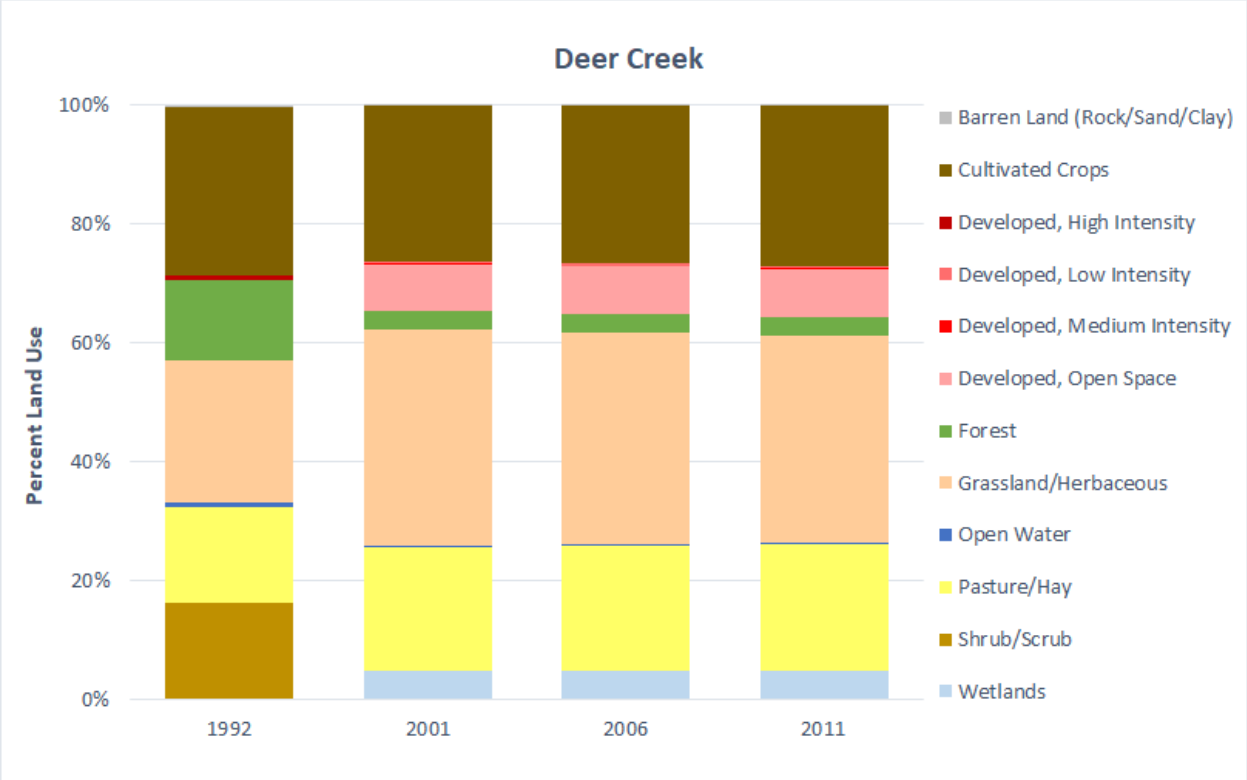


**Figure 136. Percent land use in the Deer Creek watershed from 1992-2011.**

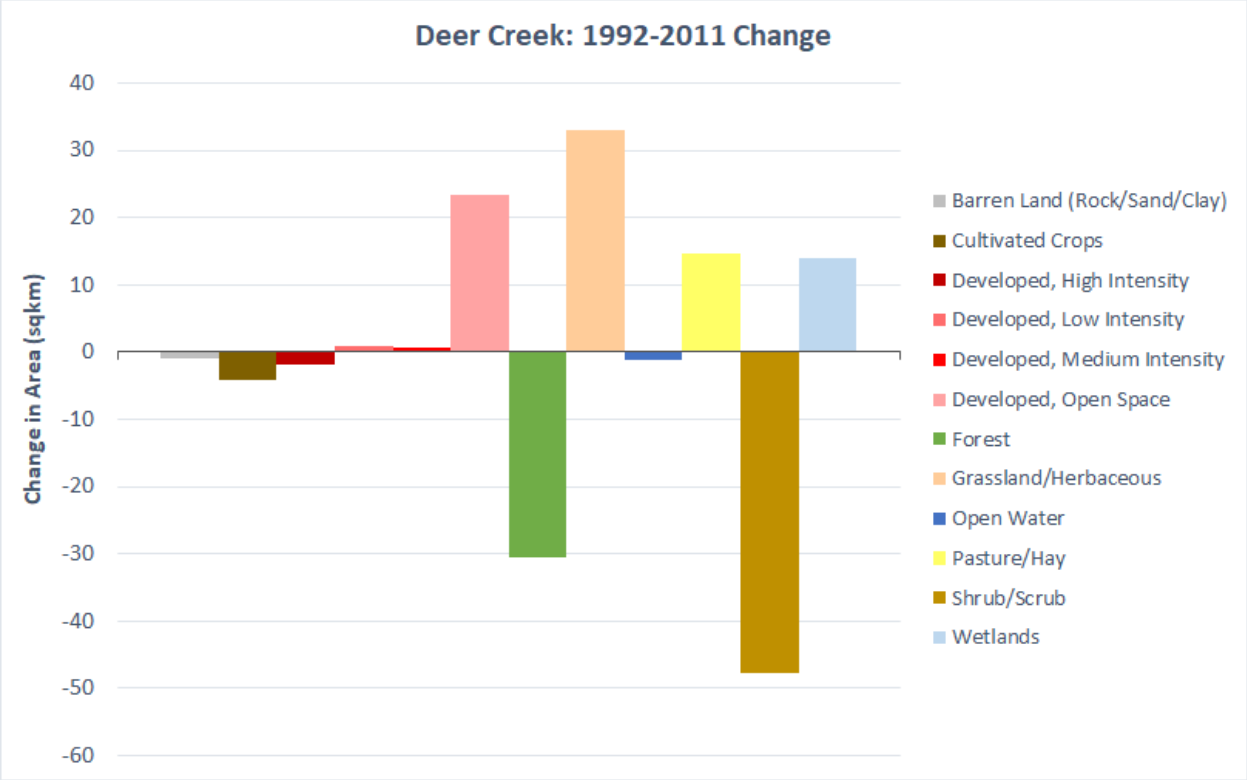


**Figure 137. Land use change in area (sq km) from 1992-2011 for the Deer Creek watershed.**

## GERONIMO CREEK

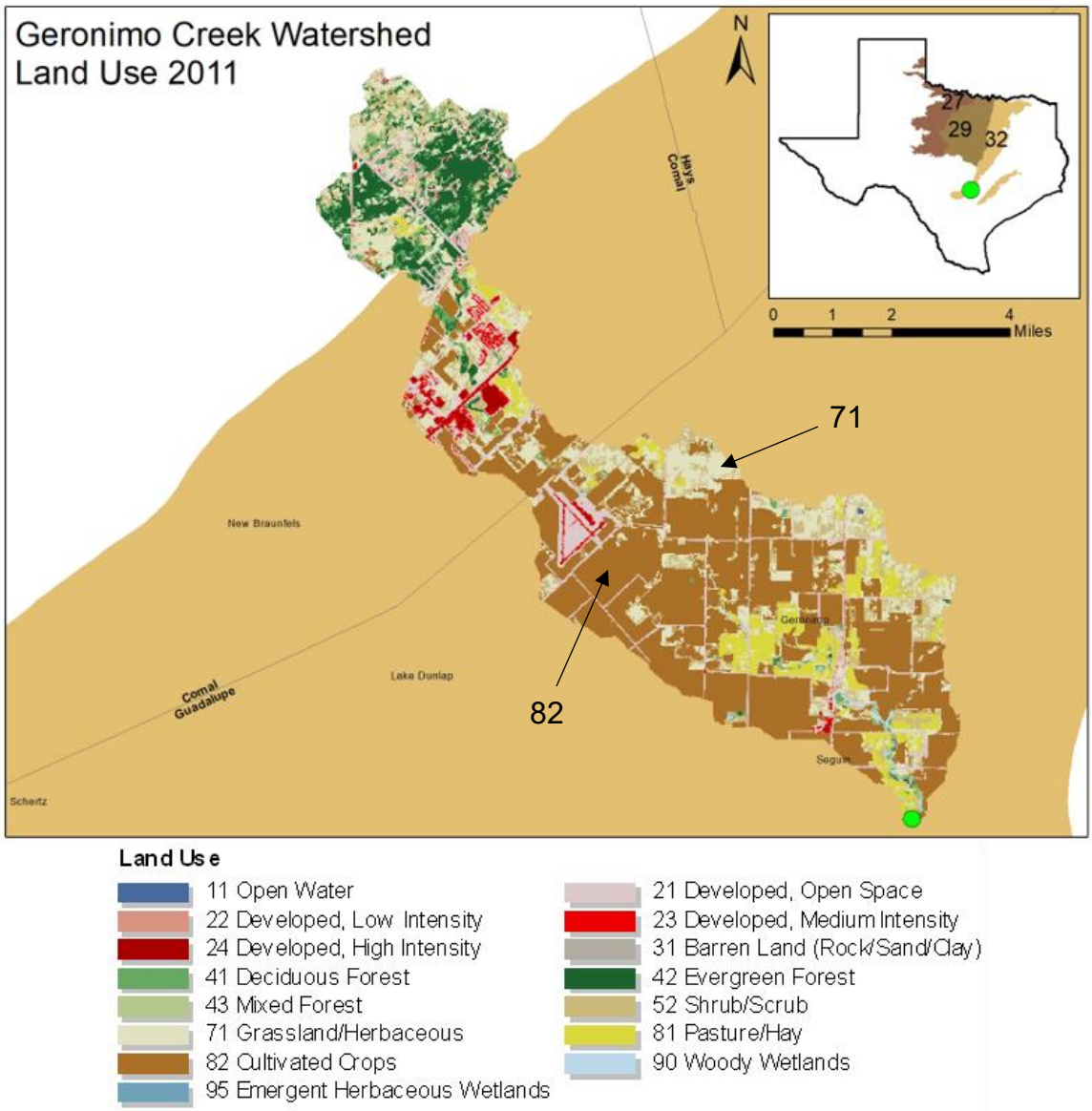


**Figure 138. Map of Geronimo Creek watershed location and 2011 land use; cultivated crops and grassland/herbaceous were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | June 29, 1988; August 16, 2010; July 15, 2011; July 24, 2012; June 17, 2013; August 2, 2013 |
| Water Quality: | 227 sampling events |
| Fish: | June 29, 1988; March 14, 1989; August 16, 2010; July 15, 2011; June 17, 2013; August 2, 2013 |
| Benthic Invertebrates: | June 29, 1988; August 16, 2010; July 15, 2011; July 24, 2012; June 17, 2013; August 2, 2013 |

## Physical Characterization

### Watershed and Land Use

Geronimo Creek lies within the Guadalupe River Basin. Sample site 12576 is located at Haberle Road, approximately 4.82 km south of Geronimo in Guadalupe County (Figure 138).

The Geronimo Creek watershed at site 12576 is approximately 106.94 sq km. The station and majority of the watershed lies within Level IV Ecoregion 32a, the Northern Blackland Prairie, the most upper part of the watershed crosses into Ecoregion 30. The dominant land cover in the watershed is cultivated crops at 41.21% and is present in the lower and middle watershed (Homer et al. 2015; Figure 138 and Figure 139). Grassland/herbaceous is the secondary land cover encompassing 18.39%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 12.56%.

From 1992-2011 there was a 17.57 sq km decrease in pasture/hay and an 8.34 sq km decrease in forest. There was an 8.08 sq km increase in open space development and a 7.89 sq km increase in grassland (Figure 140).

There is one domestic wastewater outfall (discharges < 1 million gallons per day) permit pending within the Geronimo Creek watershed. This facility does not discharge directly into Geronimo Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Geronimo Creek was evaluated during six sampling events from 1988 to 2013. Geronimo Creek is a perennial stream that drains to the Guadalupe River southeast of Seguin. Habitat Quality Index scores are available for five sample events and indicate a high aquatic life use rating (22-24). Riparian areas were well vegetated throughout the reach with an average riparian buffer ranging from 16 meters wide to greater than 20 meters. The riparian zone was generally dominated by trees followed by grasses then shrubs. The average percentage of tree canopy cover ranged from 79% to 95%. The dominant stream substrate was cobble and gravel, and the average percent of substrate gravel size or larger varied from 66% to 91%. Average percent instream cover was 38% to 54% and instream cover types include roots, gravel, undercut banks, woody debris, macrophytes, algae, and overhanging vegetation. Geronimo Creek ranged from 0.3-0.6 meters deep on average and 5-7 meters wide. Average stream bank slope ranged from 91-122 degrees. Stream flow at the site was measured at a minimum value of 2.4 cfs and a maximum of 8.6 cfs. Average stream bank erosion potential was 12%-33%. The deepest pool measured at Geronimo Creek was 1.1 meters. Number of riffles observed at the site varied from two to three and there were three stream bends.

### Water Quality

Water samples were collected at station 12576 over 227 sampling events from June 1988 through December 2019. Data were collected for temperature, flow, transparency, specific conductivity,

dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Twenty-six species (nine families) were collected over the course of the six sampling events. Ten species were collected within the family Centrarchidae, more than were collected within any other family. Texas Shiner was collected in every sample and was the most abundant species in all but the 2011 and August 2013 collections. Redbreast Sunfish *Lepomis auritus*, a non-native species first appearing in the 2010 collection, and Channel Catfish *Ictalurus punctatus* were the most abundant species for those two dates, respectively. Red Shiner and Longear Sunfish were also present in every sampling event. Intermediate aquatic life use ratings were produced by the 1988 and August 2013 fish assemblages. When the coefficient of variability was applied, the aquatic life use rating increased to high for the 2013 collection. All other dates achieved a high or exceptional rating. Low catch per unit effort was noted in every collection.

### Benthic Macroinvertebrates

Considering the one Surber sample and five RBP samples collectively, a total of 1,212 individuals representing 85 taxa from 17 orders of macroinvertebrates were collected from Geronimo Creek (Appendix E). Coleoptera, Ephemeroptera, Trichoptera, Hemiptera, and Odonata were the most commonly collected orders, collectively accounting for 90.6 percent of the total number of individuals collected. Diptera and Veneroida were the only other orders which comprised at least one percent of the collections.

The Central Bioregion Surber BIBI for the 1988 Surber sample fell in the exceptional aquatic life use category. The Ecoregions 27, 29, and 32 BIBI for the 2010, 2011, 2012, June 2013, and August 2013 RBP samples all fell in the exceptional aquatic life use category as well.

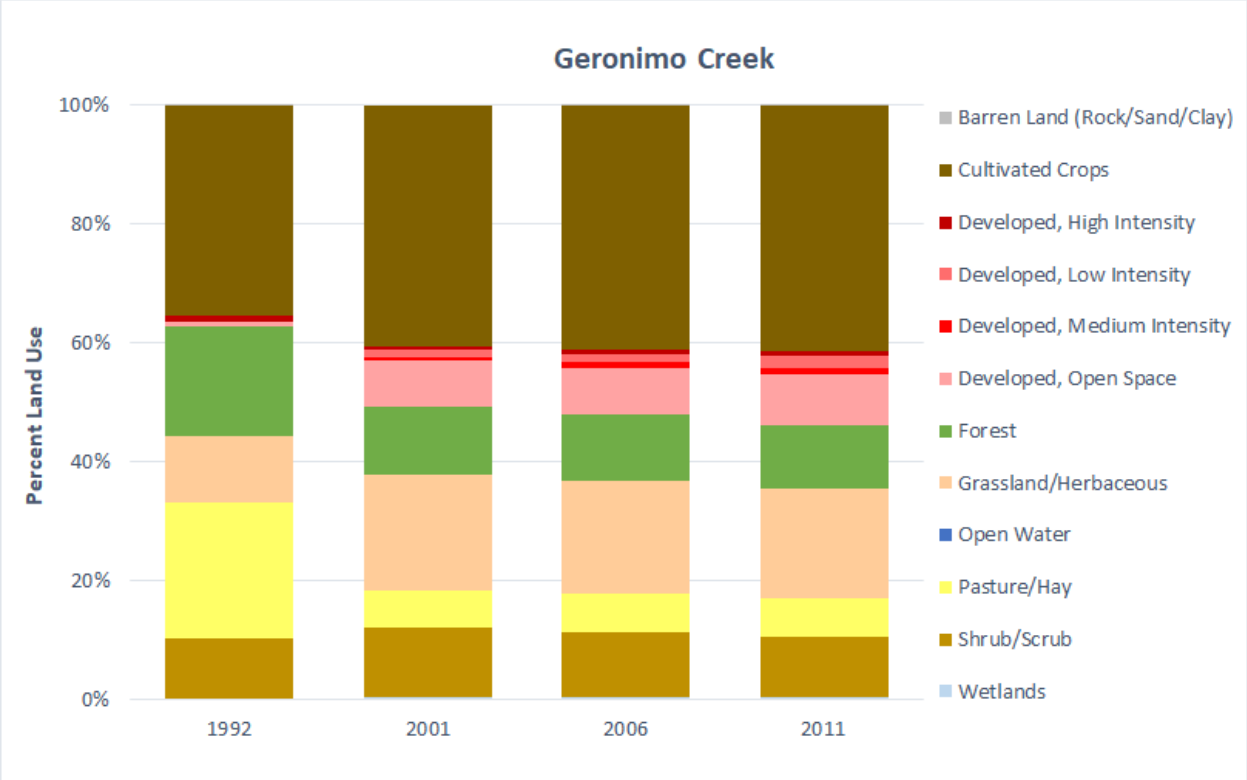


**Figure 139. Percent land use in the Geronimo Creek watershed from 1992-2011.**

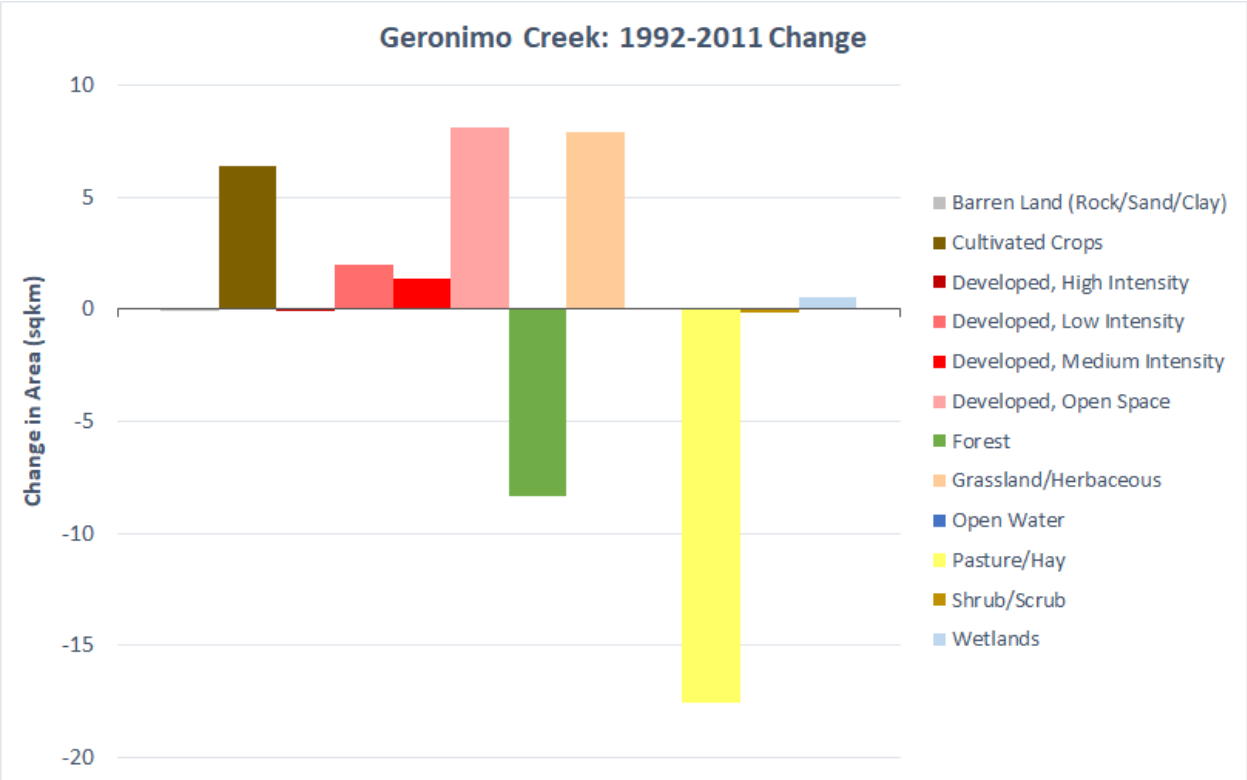


**Figure 140. Land use change in area (sq km) from 1992-2011 for the Geronimo Creek watershed.**

## WILLIS CREEK

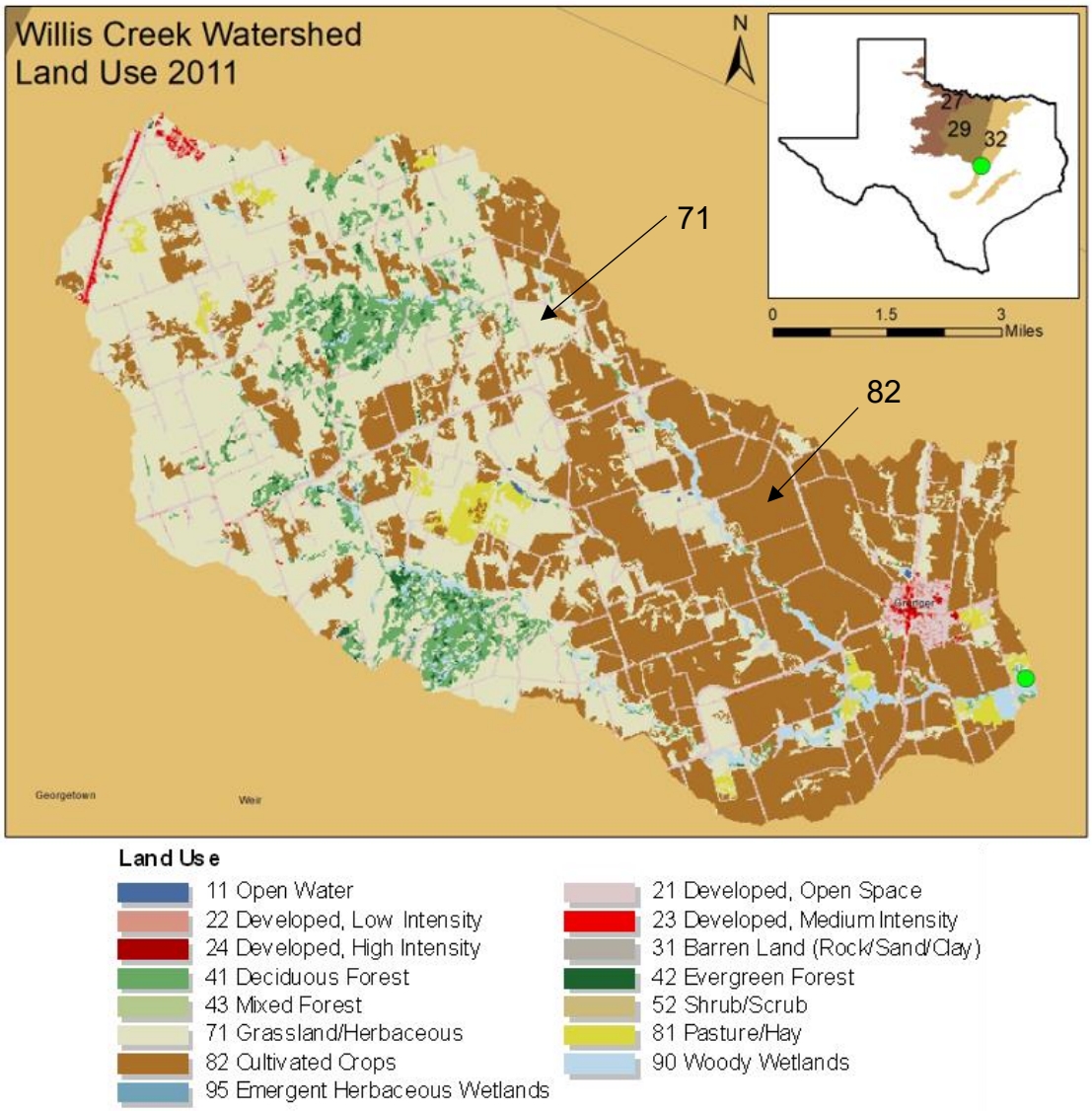


**Figure 141. Map of Willis Creek watershed location and 2011 land use; grassland/herbaceous and cultivated crops were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | July 18, 1989; April 20, 2004; July 13, 2004; June 3, 2008; July 8, 2008; August 12, 2008 |
| Water Quality: | 75 sampling events at station 11573, 9 sampling events at station 20022 |
| Fish: | July 18, 1989; April 20, 2004; July 13, 2004; May 8, 2007; June 4, 2008; July 8, 2008; August 12, 2008 |
| Benthic Invertebrates: | July 19, 1989; April 20, 2004; July 13, 2004; June 4, 2008; July 8, 2008; August 12, 2008 |

## Physical Characterization

### Watershed and Land Use

Willis Creek lies within the Brazos River Basin. Sample site 20022 is located 810 m downstream of CR 348, approximately 2.5 km southeast of Granger in Williamson County (Figure 141).

The Willis Creek watershed at site 20022 is approximately 171.36 sq km. The entire watershed lies within Level IV Ecoregion 32a, the Northern Blackland Prairie. The dominant land cover in the watershed is grassland/herbaceous at 42.83% and is present mostly in the upper watershed (Homer et al. 2015; Figure 141 and Figure 142). Cultivated crops is the secondary land cover encompassing 38.36%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 9%.

From 1992-2011 there was a 24.10 sq km decrease in shrub and a 19.55 sq km decrease in pasture/hay. There was a 31.20 sq km increase in grassland and a 13.53 sq km increase in open space development (Figure 143).

There is one domestic wastewater outfall (discharges < 1 million gallons per day) within the Willis Creek watershed permitted to the City of Granger. This facility does not discharge directly into Willis Creek.

### In Channel and Riparian Physical Habitat

Physical habitat for Willis Creek was evaluated at two sites during six sampling events from 1989 to 2008. Willis Creek is a perennial stream that drains to the Willis Creek arm of Granger Lake. Habitat Quality Index scores are available for five sample events and indicate a high aquatic life use rating (20-24). Riparian areas were well vegetated throughout the reach with an average riparian buffer ranging from 19 to 21 meters wide. The riparian zone was generally dominated by trees followed by shrubs then grasses. The average percentage of tree canopy cover ranged from 75% to 92%. The dominant stream substrate was gravel, and the average percent of substrate gravel size or larger varied from 41% to 75%. Average percent instream cover was 6% to 20%. Willis Creek ranged from 0.2-0.4 meters deep on average and 3-6 meters wide. Average stream bank slope ranged from 30-45 degrees. Stream flow at the site was measured at a minimum value of 0.1 cfs and a maximum of 7.4 cfs. Average stream bank erosion potential was 44%-62%. The deepest pool measured at Willis Creek was 2 meters. Number of riffles observed at the site varied from one to seven, and total number of stream bends ranged from seven to nine.

### Water Quality

Water samples were collected at stations 11573 and 20022 totaling 84 sampling events from July 1989 through August 2010. There were 75 sampling events at station 11573 from July 1989 through August 2010, and 9 sampling events at station 20022 from April 2007 through August 2010. Data were collected for temperature, flow, transparency, specific conductivity, dissolved

oxygen, pH, alkalinity (only at station 11573), ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Twenty-five species (nine families) were collected over the course of the seven sampling events. The families Cyprinidae and Centrarchidae each yielded seven species, making them the most species rich families. Longear Sunfish was the most abundant species in all but the 1989 and June 2008 collections, where Western Mosquitofish and Red Shiner were the most abundant ones. Five species were collected in every sampling event and included Red Shiner, Blacktail Shiner, Bullhead Minnow, Green Sunfish, and Longear Sunfish. All fish collections (except for May 2007) rated as having a high aquatic life use. The 2007 sample rated as intermediate, even after applying the coefficient of variability. This collection was the only one without benthic invertivore species. The aquatic life use for the April 2004 and August 2008 fish assemblages rise to exceptional when the coefficient of variability is applied.

### Benthic Macroinvertebrates

Considering the one Surber sample and five RBP samples collectively, a total of 1,706 individuals representing 106 taxa from 22 orders of macroinvertebrates were collected from Willis Creek (Appendix E). Ephemeroptera, Diptera, Trichoptera, Odonata, Haplotaxida, Coleoptera, and Amphipoda were the most commonly collected orders, collectively accounting for 90.7 percent of the total number of individuals collected. Basommatophora, Plecoptera, Veneroida, Hemiptera, and Tricladida were the only other orders which comprised at least one percent of the collections.

The Central Bioregion Surber BIBI for the 1989 Surber sample fell in the exceptional aquatic life use category. The Ecoregions 27, 29, and 32 BIBI for the five RBP samples fell in either the high aquatic life use category (April 2004, August 2008) or the exceptional life use category (July 2004, June 2008, July 2008).

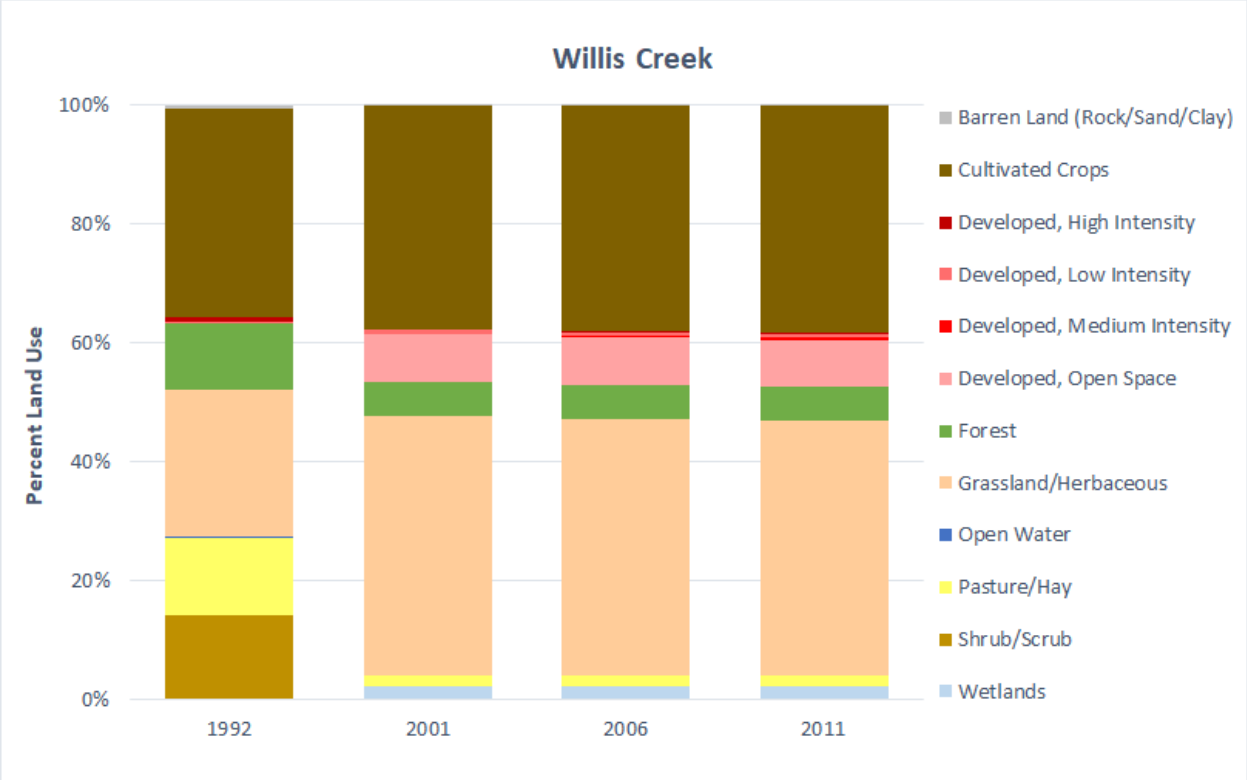


**Figure 142. Percent land use in the Willis Creek watershed from 1992-2011.**

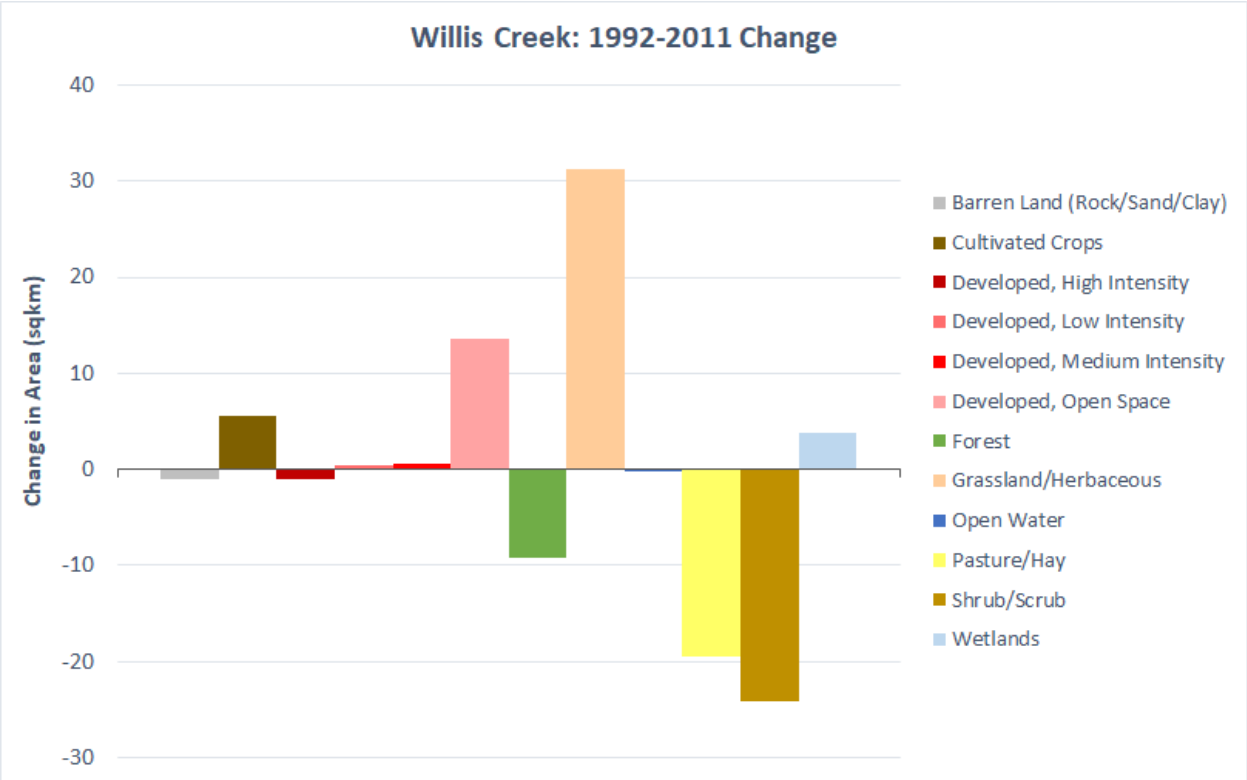


**Figure 143. Land use change in area (sq km) from 1992-2011 for the Willis Creek watershed.**

## WILSON CREEK

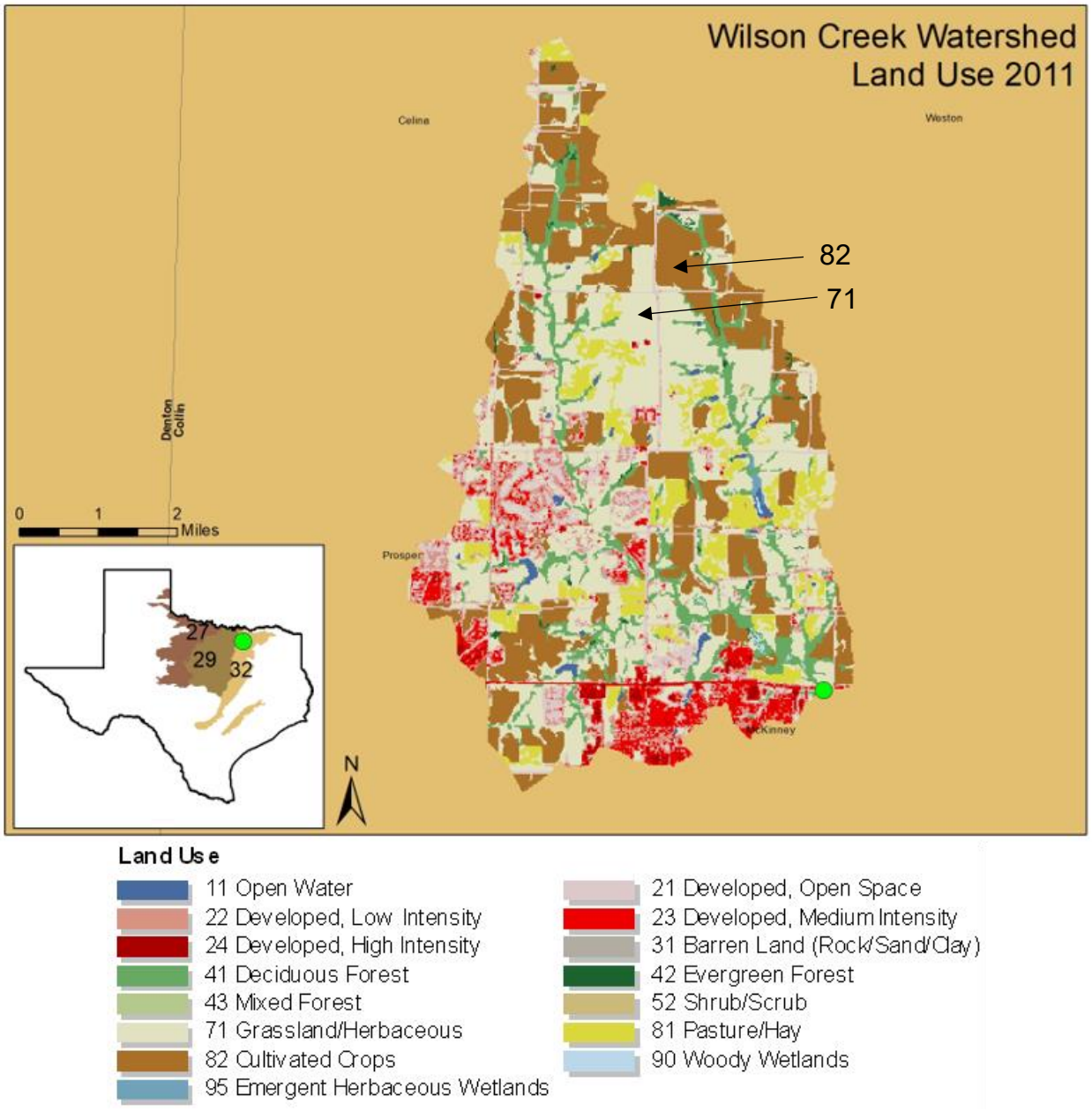


**Figure 144. Map of Wilson Creek watershed location and 2011 land use; grassland/herbaceous and cultivated crops were the most common land uses.**

### Sampling Dates

| | |
|---|---|
| Physical Habitat: | August 1, 1989; June 17, 2003; August 6, 2003 |
| Water Quality: | 90 sampling events |
| Fish: | August 1, 1989; June 17, 2003; August 6, 2003; May 31, 2012; August 7, 2012 |
| Benthic Invertebrates: | August 1, 1989; June 17, 2003; August 6, 2003 |

## Physical Characterization

### Watershed and Land Use

Wilson Creek lies within the Trinity River Basin. Sample site 10777 is located 45 m downstream of US 380, west of McKinney in Collin County (Figure 144).

The Wilson Creek watershed at site 10777 is approximately 80.34 sq km. The entire watershed lies within Level IV Ecoregion 32a, the Northern Blackland Prairie. The dominant land cover in the watershed is grassland/herbaceous at 34.56% and is present throughout watershed (Homer et al. 2015; Figure 144 and Figure 145). Cultivated crops is the secondary land cover encompassing 24.47%. The combined land cover for developed land use (open space and low, medium, and high intensity) totals 22.53%.

From 1992-2011 there was a 19 sq km decrease in pasture/hay and a 16.85 sq km decrease in cultivated crops. There was a 16.88 sq km increase in grassland and a 7.23 sq km increase in open space development (Figure 146).

There are no permitted wastewater outfalls within the Wilson Creek watershed.

### In Channel and Riparian Physical Habitat

Physical habitat for Wilson Creek was evaluated during three sampling events from 1989 to 2003. Wilson Creek is an intermittent stream with perennial pools that drains to the East Fork arm of Lake Lavon. Habitat Quality Index scores are available for two sample events and indicate an intermediate aquatic life use rating (15 and 17). Riparian areas were well vegetated throughout the reach with an average riparian buffer measured at greater than 20 meters. The average percentage of tree canopy cover ranged from 68% to 85%. The dominant stream substrate was gravel and cobble, and the average percent of substrate gravel size or larger varied from 45% to 52%. Average percent instream cover was 33% to 42% and instream cover types include leaf packs, algae, woody debris, cobble/gravel, and undercut banks. Wilson Creek ranged from 0.2-0.3 meters deep on average and 5-7 meters wide. Average stream bank slope ranged from 42-49 degrees. Stream flow at the site was measured at a minimum value of 5 cfs and a maximum of 7 cfs. Average stream bank erosion potential was 45%-63%. No pools were documented at Wilson Creek during the most recent sampling events in 2003. Three riffles observed at the site in 2003 and there were four total stream bends.

### Water Quality

Water samples were collected at station 10777 over 90 sampling events from October 1988 through January 2019. Data were collected for temperature, flow, transparency, specific conductivity, dissolved oxygen, pH, alkalinity, ammonia, total Kjeldahl nitrogen, total nitrogen, phosphorus, total organic carbon, chloride, sulfate, and chlorophyll-a.

## Biological Characterization

### Fish

Sixteen species (six families) were collected over the course of the five sampling events. Centrarchidae and Cyprinidae yielded the two highest species richnesses by family with five and four, respectively. Yellow Bullhead, Central Stoneroller, Red Shiner, Blackstripe Topminnow *Fundulus notatus*, Western Mosquitofish, Green Sunfish, Bluegill, and Longear Sunfish were collected in every sampling event. Two species, Channel Catfish and Orangespotted Sunfish, were only collected in 1989, albeit in small numbers. One River Carpsucker and two Tadpole Madtoms *Noturus gyrinus* were collected during 2012. Several Spotted Sucker *Minytrema melanops* were also collected in 2012 but showed up in a 2003 sample as well. Every fish assemblage sample rated as having an intermediate aquatic life use except for the August 2003 and May 2012 collections which rated as limited and high, respectively. When the coefficient of variability is applied, the June 2003 aquatic life use rises to high, and the August 2003 sample rises to intermediate.

**Benthic Macroinvertebrates**

Considering the one Surber sample and two RBP samples collectively, a total of 349 individuals representing 34 taxa from 11 orders of macroinvertebrates were collected from Wilson Creek (Appendix E). Trichoptera, Diptera, Ephemeroptera, and Coleoptera were the most commonly collected orders, collectively accounting for 92.3 percent of the total number of individuals collected. Odonata and Plecoptera were the only other orders which comprised at least one percent of the collections.

The Central Bioregion Surber BIBI for the 1989 Surber sample fell in the intermediate aquatic life use category. The Ecoregions 27, 29, and 32 BIBI for the two RBP samples fell in the intermediate aquatic life use category (June 2003) and the limited aquatic life use category (August 2003).

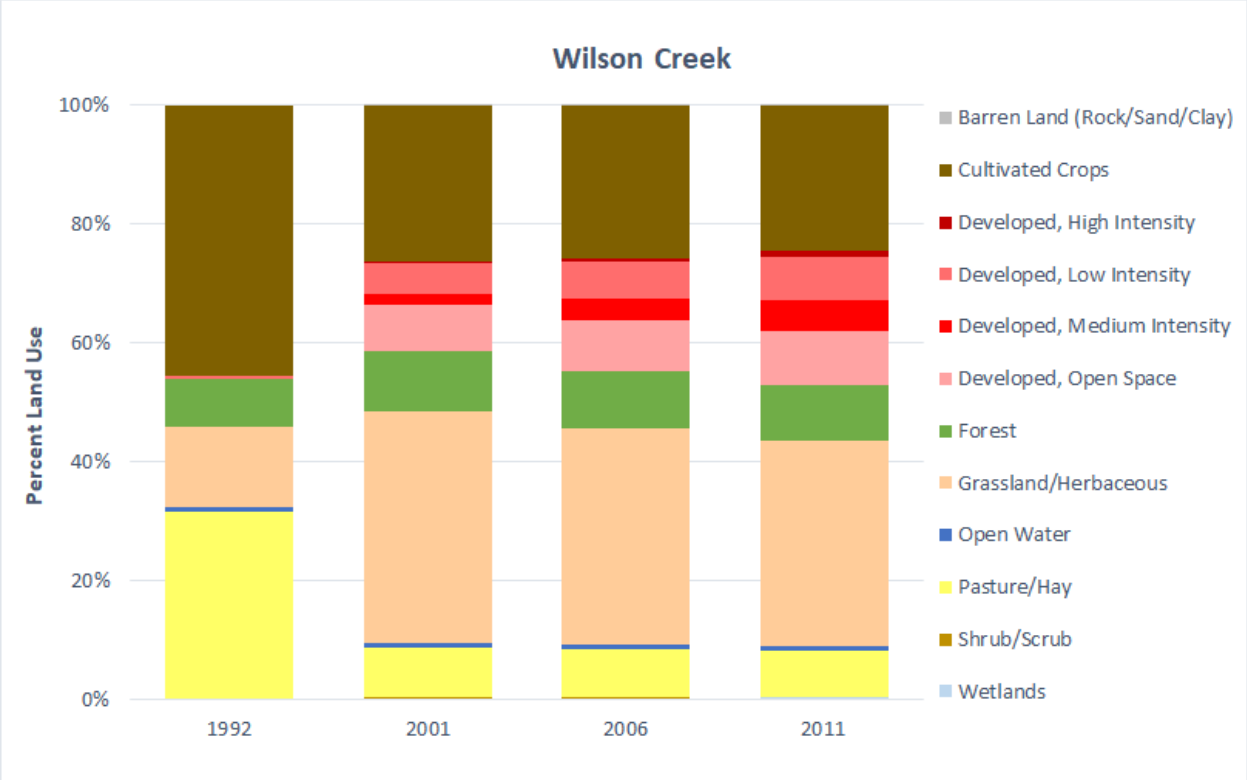


**Figure 145. Percent land use in the Wilson Creek watershed from 1992-2011.**

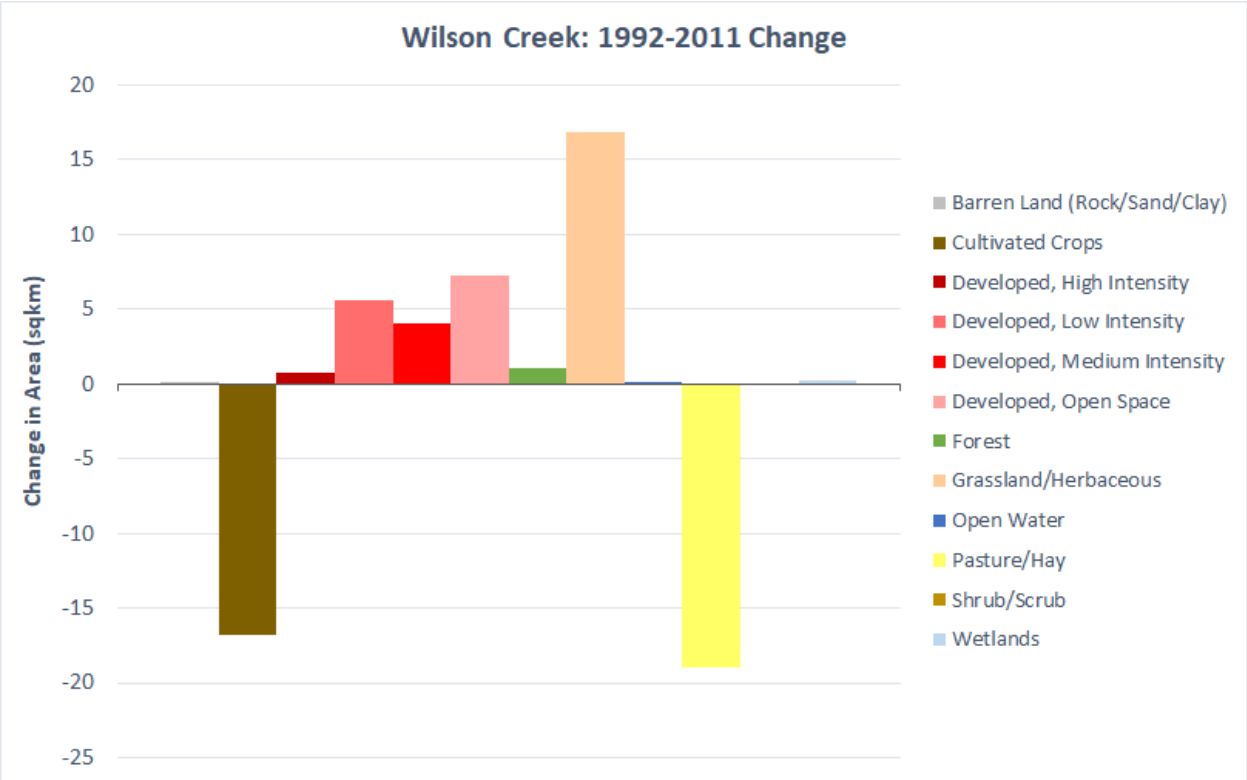


**Figure 146. Land use change in area (sq km) from 1992-2011 for the Wilson Creek watershed.**

## Ecoregions 27, 29, and 32 Summary and Historical Characterization

### Watershed and Land Use

Ecoregion 27 was historically grassland with scattered shrubs in the southern portion of the region. Most of the area is now cropland to grow cotton, wheat, and grain sorghum (Griffith et al. 2007). In 2011 the most common land covers in the study watersheds were grassland and shrub. Between 1992-2011, cultivated crop decreased in combined land cover area across all watersheds (~640.98 sq km) and shrub experienced the greatest increase (~881.01 sq km).

Ecoregion 29 was historically prairie to the west and forested hills to the east. The area to the west is now wheat cropland and to the east is mostly rangeland. Oil and gas production have been a major activity for nearly a century (Griffith et al. 2007). In 2011 the overall primary land cover in the study watersheds was grassland and the secondary cover was forest. Between 1992-2011, pasture/hay decreased in combined land cover area across all watersheds (~107.14 sq km) and grassland experienced the greatest increase (~323.62 sq km).

Ecoregion 32 was historically prairie grassland; however, pasture and forage production for livestock is now common. Additionally, much of the region is being converted to urban and industrial areas (Griffith et al. 2007). In 2011 the overall primary land cover in the study watersheds was grassland and the secondary land cover was cultivated crop. Between 1992-2011, shrub experienced the largest decrease in combined land cover across all watersheds (~113.39 sq km) and grassland experienced the largest increase (~182.81 sq km).

### In Channel and Riparian Physical Habitat

Physical habitat for the Subhumid Agricultural Plains was evaluated at 21 streams over 51 sampling events from 1987 to 2018. Watershed area varied from a minimum of 26 sq km at Reese Creek to a maximum of 1,180 sq km at Cowhouse Creek. The sites generally had well vegetated riparian zones, and the riparian buffer was measured at a minimum of 3 meters and maximum of 76 meters. Trees were the dominant riparian species, followed by grasses then shrubs, and average percent tree canopy coverage varied from 0% to 95%. Dominant substrate at the sites was generally cobble/gravel or bedrock. Average percentage of substrate gravel sized or larger for all three ecoregions combined was 50%, and varied from a minimum of 0% to a maximum of 91%. Average percent instream cover was 30% and common instream cover types include overhanging vegetation, woody debris, macrophytes, cobble/gravel, boulders, algae, undercut banks, roots, leaf packs, and bedrock ledges. Average stream depth and width measurements were 0.4 meters and 9 meters, respectively. Average stream bank slope was 47 degrees and erosion potential was moderate, with an average of 37% which was reflected in the average bank stability HQI score (1.4) indicating moderately stable to moderately unstable stream banks. Maximum pool depth ranged from a minimum of 0.1 meters to a maximum of 2.7 meters. Total number of riffles varied from zero to ten, and total number of stream bends ranged from zero to nine. Additional in-channel and riparian physical habitat attributes are summarized in Appendix B.

HQI scores are available for 32 events and range from a maximum score of 26 (exceptional) at South Fork Rocky Creek in May 2004 to a minimum score of 15 (intermediate) at Wilson Creek in August 2003. Of the 32 sampling events with an HQI score, one (3%) received a habitat assessment rating of exceptional, 23 (72%) received a rating of high, and the remaining eight (25%) received a rating of intermediate. The highest scoring HQI metrics for the Subhumid Agricultural Plains were the bottom substrate stability metric and the number of riffles metric. The lowest scoring HQI metrics on average were the bank stability metric and the channel sinuosity metric.

**Water Quality**

Water quality data from ecoregions 27, 29 and 32 had a mean temperature of 23 degrees Celsius with a range from 0.5 to 35.4 degrees Celsius, and specific conductivity ranged from 62 to 7,560 us/cm. The secchi values had a median value of 0.6 meters with a range from 0.01 to 1.52 meters. The pH values had a range of 6.9 to 8.98. Chlorophyll-a data was highly variable between stations with a range of 0.25 to 190.3 ug/L. Additional water quality variables are summarized in appendix C of the report.

**Fish**

A total of 28,414 individuals consisting of 14 families and 55 species have been documented in 62 sampling events across 21 streams in the Subhumid Agricultural Plains from 1987 to 2018 (Appendix D - 3). For individual sites, taxa richness ranged from 27 species at Cow Bayou across three sampling events from 1987 to 2010 to a low of six species at Lelia Lake Creek from one sampling event in 1989. Taxa richness at each site was somewhat correlated with the number of sampling events during the period of record. The most abundant species collected across all sites and sampling events were Red Shiner (n = 9,169), Blacktail Shiner (n = 4,758), Western Mosquitofish (n = 2,852), Longear Sunfish (n = 2,319), and Central Stoneroller (n = 2,016).

Index of biotic integrity scores across all sites and sampling events ranged from 31 to 52 resulting in aquatic life use categories of limited (n = 4), intermediate (n = 19), high (n = 32), and exceptional (n = 7; Figure 147). Of the 62 sampling events in this ecoregion aggregate, 63% received an ALU rating of high or exceptional; 37% received an ALU of intermediate or limited. Most sites that were sampled multiple times received ALUs in at least two different categories. All sites received one ALU score of intermediate or better except for Lelia Lake Creek which received an ALU score of limited only.

Overall, IBI scores and individuals metrics 1,2,4 and 6-8 did not change through time (Figure 148; Figure 149; Figure 150); however, the number of benthic invertivores, percentage of individuals as piscivores, number of individuals per minute electrofishing, and percentage of individuals as non-native species significantly increased through time (Figure 149(3): $R^2 = 0.08$, $p = 0.03$; Figure 150(9): $R^2 = 0.09$, $p = 0.02$; Figure 150(10eshock): $R^2 = 0.15$, $p < 0.01$; Figure 150(11): $R^2 = 0.07$, $p = 0.04$) and the number of individuals per seine haul and percentage of individuals with disease/anomaly significantly decreased through time (Figure 150(10seine): $R^2$

= 0.09, p = 0.02; Figure 150(12): $R^2$ = 0.07, p = 0.03). Although these were significant relationships, $R^2$ values were very low.

The increase in percentage of individuals as non-native species is mostly attributable to high numbers of Redbreast Sunfish collected during 2010 and 2011 in Geronimo Creek. In these two samples, 15 and 24.3%, of the fish collected were non-native. Two collections from Geronimo Creek in 2013 yielded no non-natives. When the 2010 and 2011 samples are removed the mean percentage declines from 1.5 to 0.3, which is more in line with the mean percentage calculated for the early samples (0.0). The increase in benthic invertivores, piscivores, and number of individuals per minute electrofishing is due to a combination of things, including the influence of the new waterbodies that were sampled as well as possible improvements in streams that were resampled. The mean number of benthic invertivore species collected from waterbodies that were not resampled was only 0.5 while the mean for newly added waterbodies was 1.3. When comparing waterbodies that were resampled, the mean number of benthic invertivore species collected during the early period was 1.1 compared to 1.6 in the more recent time period. Similar results are reflected for piscivores and number of individuals per minute electrofishing. The highest mean percentage of piscivores (9.7) was collected from the newly added waterbodies while the lowest mean percentage (5.3) was found in the waterbodies that were not resampled. For waterbodies that had historical and recent collections, the mean percentage of individuals as piscivores was 7.7% compared to 8.5% for the more recent samples. The mean number of individuals collected per minute of electrofishing from waterbodies that were not resampled was 4.3 while the mean for newly added waterbodies was 7.0. When comparing waterbodies that were resampled, the mean number collected per minute during the early time period was 4.4 compared to 6.9 in the more recent time period.

The decline in number of individuals per seine haul is attributed to two creeks that were not resampled (Cottonwood and Elm creeks). These creeks yielded the three highest catches per seine haul (greater than 300 fish per haul). Had these creeks been resampled it is very likely that no significant change would have been detected given that the 11 waterbodies that were resampled had nearly the identical value for the early and more recent time periods (37.4 verses 42.4, respectively). The decrease in the proportion of individuals with a disease/anomaly is likely due to sampler bias rather than a significant change in disease/anomaly. This is a characteristic that is often overlooked while in the field.

**Benthic Macroinvertebrates**

A total of 26,706 individuals representing 37 orders of aquatic macroinvertebrates were collected in the 22 Surber samples, and 35 RBP samples from 21 streams in the Subhumid Agricultural Plains over the interval from July 1987 to July 2018. The Trichoptera, Veneroida, Diptera, Ephemeroptera, and Coleoptera were the most abundant orders, collectively representing 81% of the total collection from the Subhumid Agricultural plains.

The fingernail clam *Sphaerium sp.,* the filtering caddisfly *Cheumatopsyche sp*., the oligochaete *Limnodrilus sp*., and the riffle beetle *Stenelmis sp*. were the most abundant genera, collectively

representing 46% of the total number of individuals collected at all sites. Other genera that were relatively abundant include the chironomid *Polypedilum sp*., the mayfly *Tricorythodes sp*., the caddisfly *Chimarra sp*., the mayfly *Caenis sp*., and the damselfly *Argia sp*.

The Chironomidae, and the riffle beetle *Stenelmis sp*. were the most widely distributed taxa, occurring in 54, and 53 of the 57 total samples respectively. Other widely distributed genera include the damselfly *Argia sp*., the chironomid *Polypedilum sp.*, and the mayfly *Fallceon sp.* each of which were present in over half of the total number of samples in the ecoregion.

Eleven of 35 RBP IBI scores for kicknet samples fell in the exceptional aquatic life use category, 10 RBP IBI scores indicated high, 12 intermediate, and two samples collected from Rocky Creek and Wilson Creek in August 2003 fell in the limited aquatic life use category (Figure 151; Figure 152). Related to the limited aquatic life use indicated for single samples at each of these two streams, other samples indicated higher integrity. Of the five samples collected from station 11724 on Rocky Creek, only the August 2003 sample indicated limited aquatic life use, while the RBP IBI score for the samples collected in August 2002, and August 2004 indicated intermediate, and the samples collected in April 2003, and May 2004 fell in the high aquatic life use category. Eleven of 22 Surber sample BIBI scores fell in the exceptional aquatic life use category, nine BIBI scores fell in the high category, and two BIBI results fell in the intermediate category. None of the Surber BIBI results indicated a limited aquatic life use category (Figure 151; Figure 152).

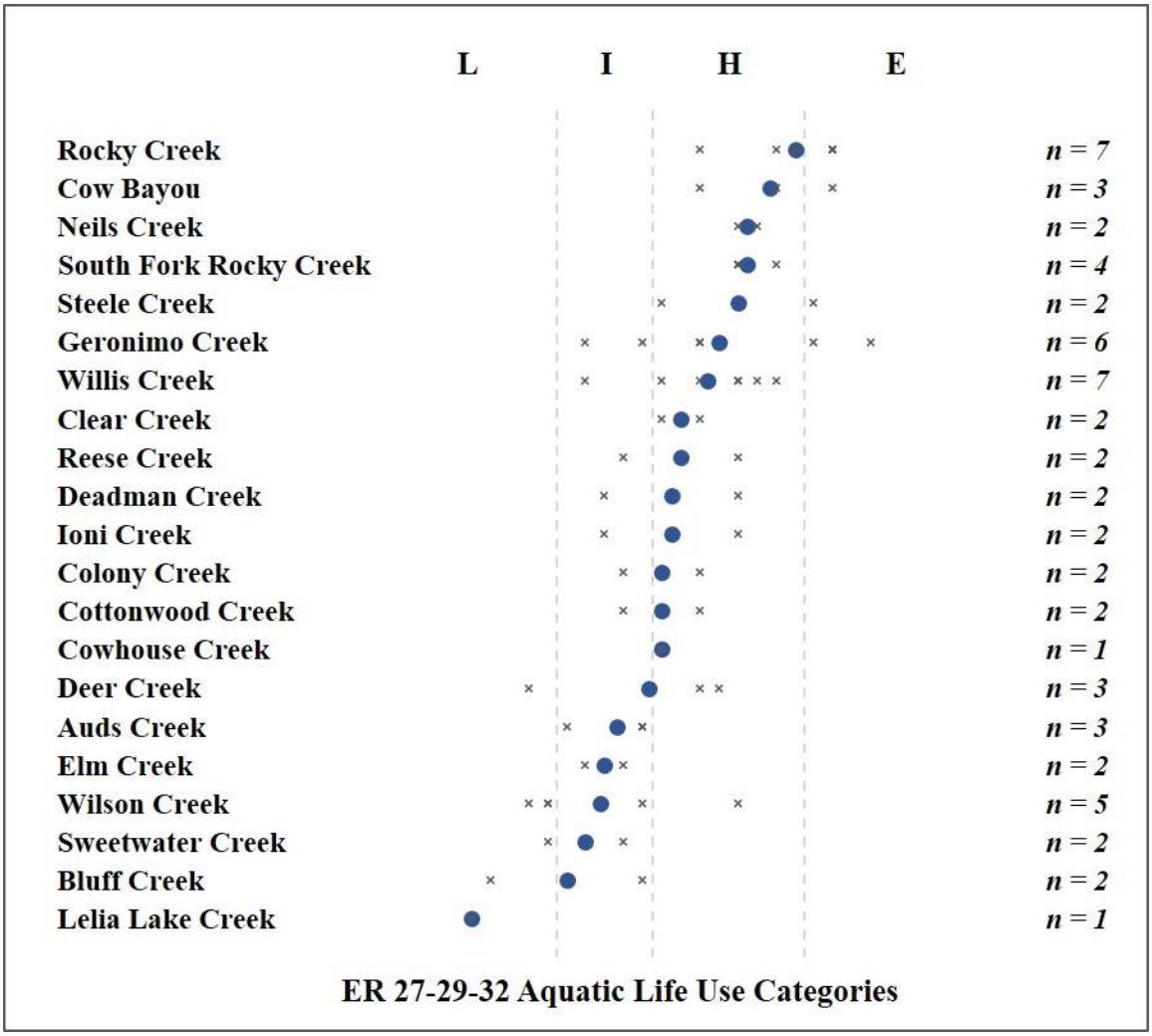


**Figure 147. Aquatic life use categories (L – limited; I – intermediate; H – high; E – exceptional) for all fish sampling events in Ecoregions 27, 29, and 32 grouped by site and ranked by mean ALU score (blue dot); number of sampling events per site noted on right.**

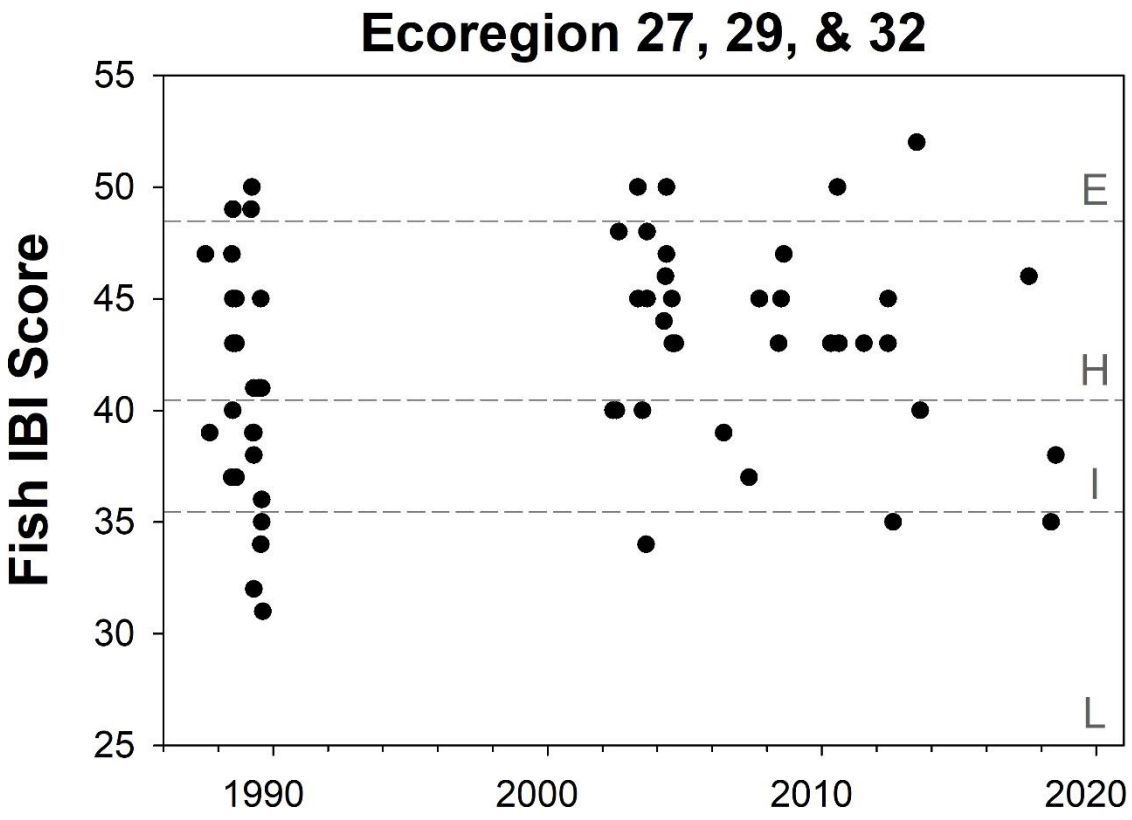


**Figure 148. Fish index of biotic integrity scores through time for all sampling events in Ecoregions 27, 29, and 32; break lines for aquatic life use categories (i.e., limited, intermediate, high, and exceptional) shown on each graph for reference (see Linam et al. 2002).**

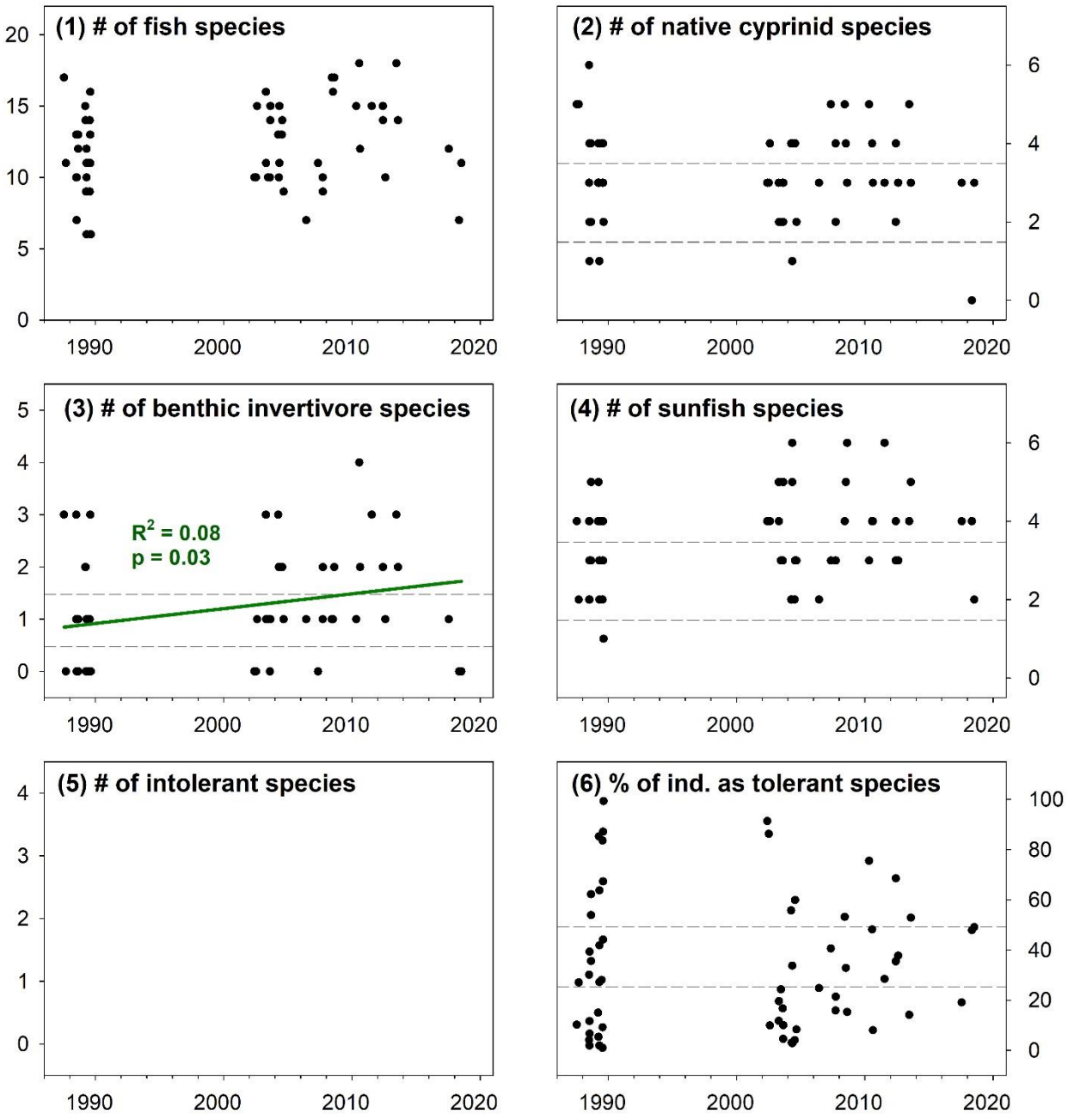


**Figure 149. Raw values for fish index of biotic integrity metrics 1-6 through time for all sampling events in Ecoregions 27, 29, and 32; break lines for scoring criteria (i.e., 1, 3, and 5) shown on each graph for reference (see Linam et al. 2002); metrics that are not included in the IBI for this aggregated ecoregion are blank.**

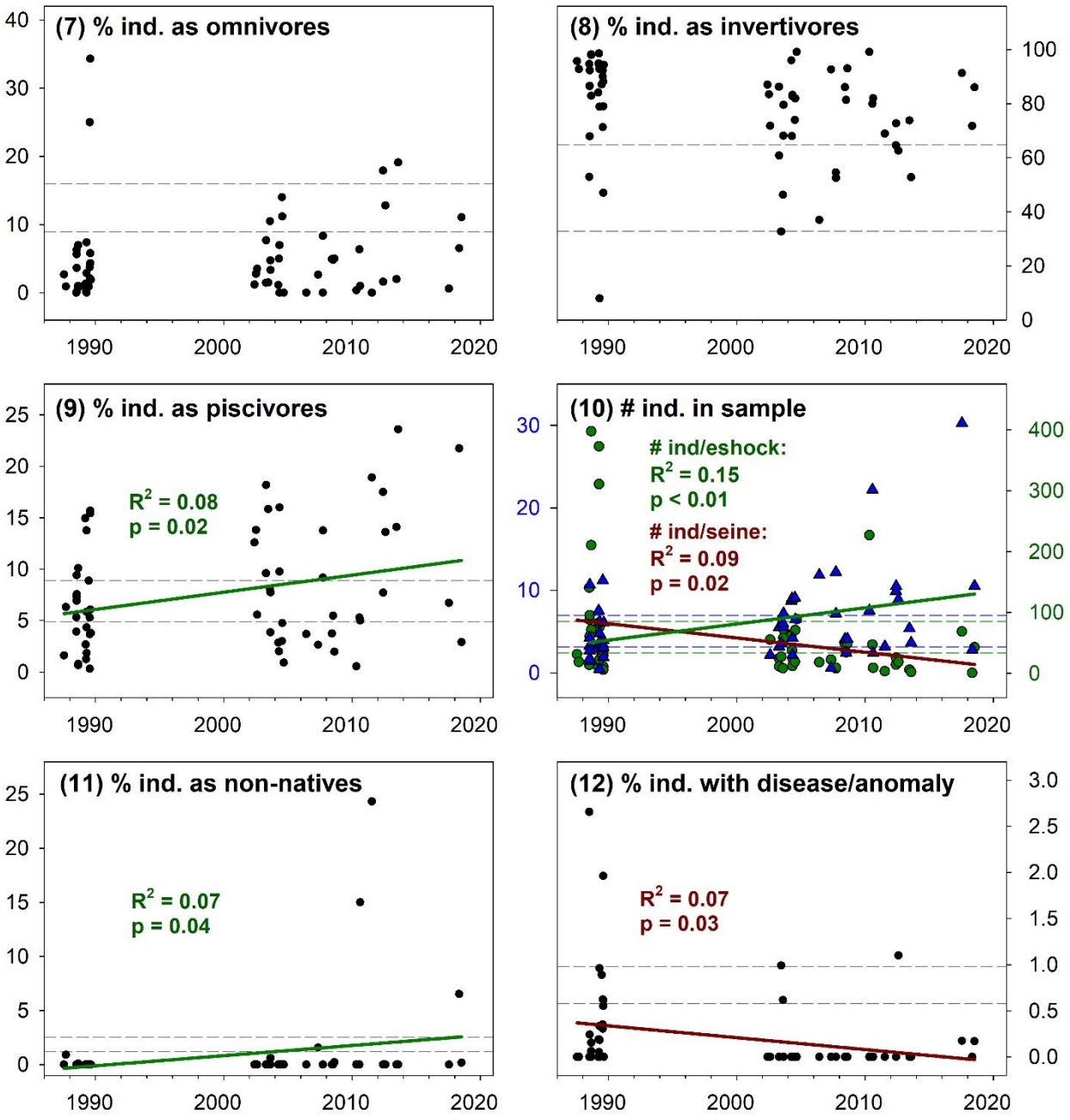


**Figure 150. Raw values for fish index of biotic integrity metrics 7-12 through time for all sampling events in Ecoregions 27, 29, and 32; break lines for scoring criteria (i.e., 1, 3, and 5) shown on each graph for reference (see Linam et al. 2002); number of ind./seine haul represented by green circles and number of ind./min electrofishing represented by blue triangles for metric number 10.**

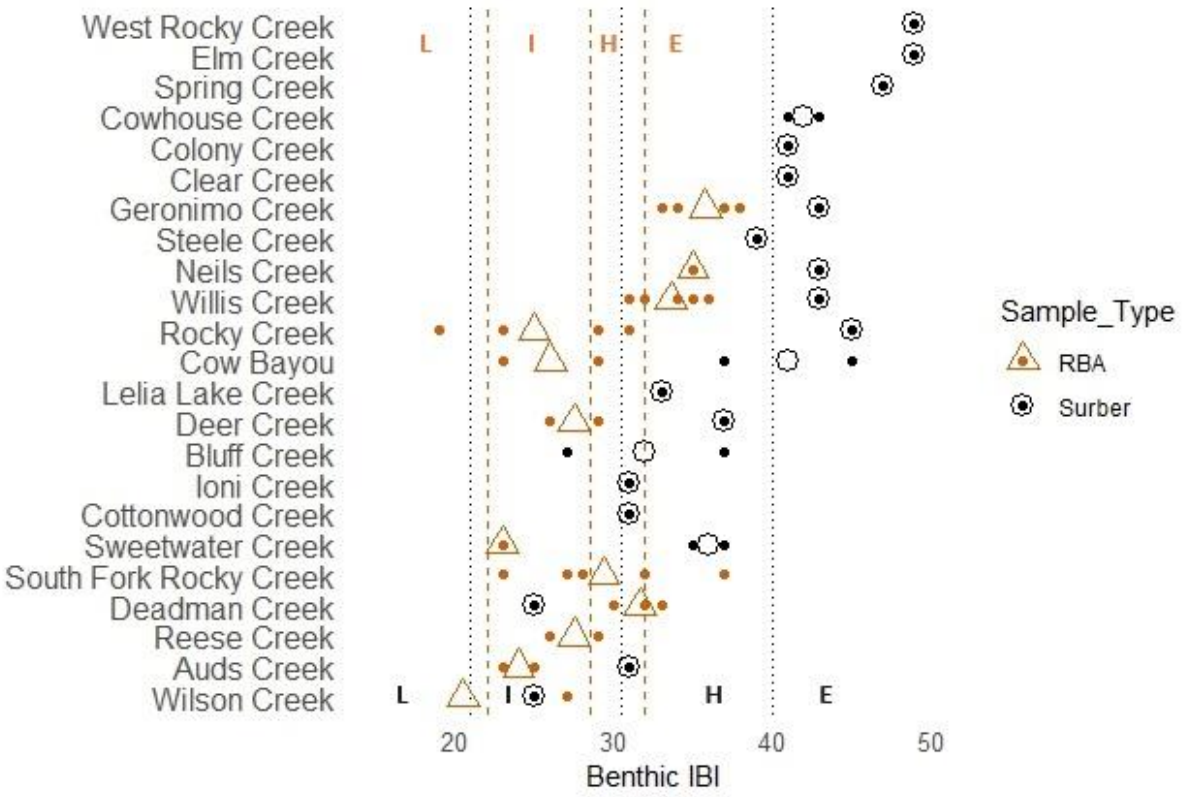


**Figure 151. Benthic IBIs and aquatic life use categories (L – limited; I – intermediate; H – high; E – exceptional) for all benthic sampling events in Ecoregions 27, 29, and 32 grouped by site and ranked by mean IBI score. Site scores are solid circles, and mean scores are hollow circles for Surber IBI sample and hollow triangles for RBP IBI samples. RBP IBI ALU cut offs are red dashed lines and Surber ALU cutoffs are in black dotted lines.**

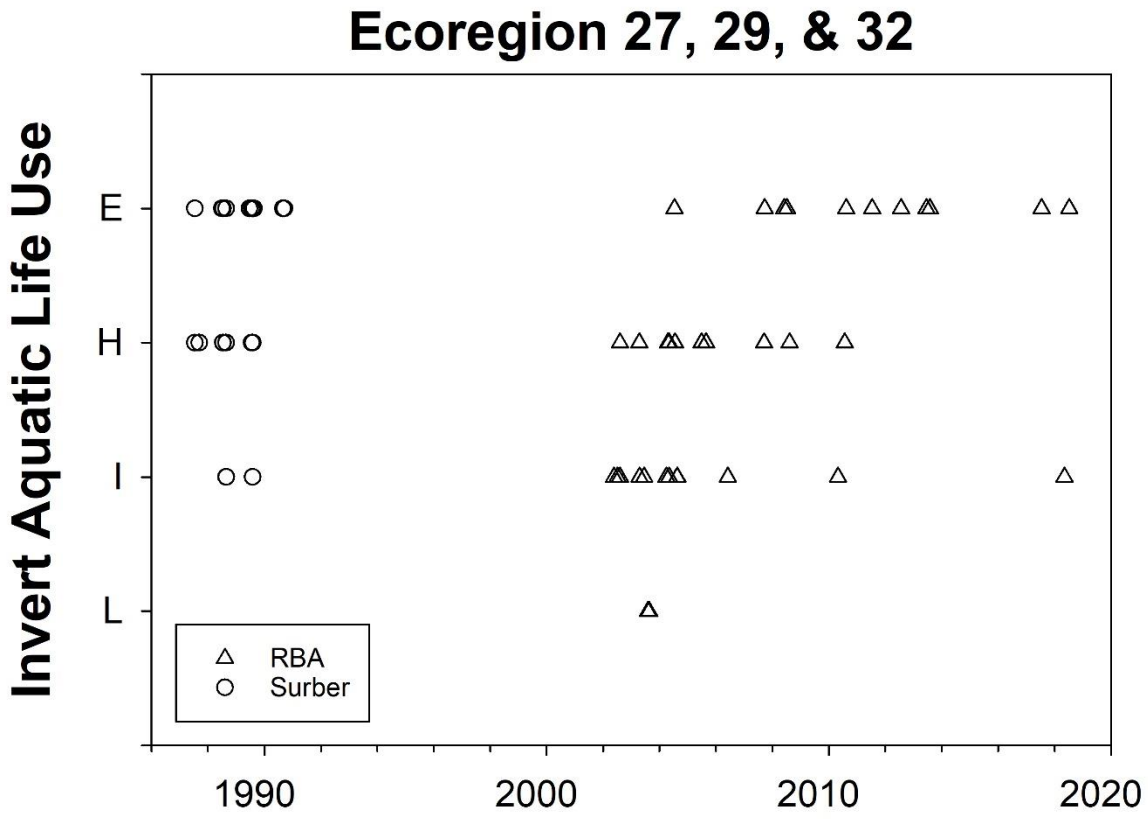


**Figure 152. Benthic aquatic life use (ALU) categories through time for all sampling events in Ecoregions 27, 29, and 32; Surber ALUs are noted by circles and RBP ALUs are noted by triangles.**