Water Quality and Environmental Characteristics of the Upper Perdido, Conecuh, Shoal and Yellow River Watersheds in 2022

Technical Report to Pensacola and Perdido Bays Estuary Program

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February 28, 2023

Author Note

Cite as Albrecht, B., & Caffrey, J.M. (2023). Water Quality and Environmental Characteristics of the Upper Perdido, Conecuh, Shoal and Yellow River Watersheds in 2022. Technical Report to Pensacola and Perdido Bays Estuary Program. February 28, 2023. Center for Environmental Diagnostics and Bioremediation, University of West Florida.

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Background

Northwest Florida is home to several large estuaries with watersheds that extend into Alabama. The Perdido, Escambia/Conecuh, Blackwater, Yellow/Shoal, and Choctawhatchee watersheds are considered modest in size and confined 'close' to the coast when compared to the larger Mobile Bay watershed to the west and the Apalachicola Bay watershed to the east. These systems begin as headwater creeks and seeps located in south Alabama.

Landforms – Geology, Soils, Elevations, and General Hydrology in the Study Area

This region, known as the Gulf Coastal Plain, was formed at the end of the Pleistocene era, roughly 11,000 years ago. Along the Gulf of Mexico, the glaciers from the Pleistocene epoch halted within roughly 100-150 miles of the coast, creating a gentle, sloping coastal plain. Materials deposited at the terminus of the glaciers have undergone weathering and transport throughout the region. The remnants of these weathered glacial deposits result in streams and rivers in Northwest Florida with shifting, quartz-sand bottoms. These fine sands are carried by rivers and streams, until settling and becoming stabilized by vegetation and root networks. They are the source of the white sandy beaches in Northwest Florida.

The Gulf Coastal Plain landscape includes low-lying, isolated wetlands, floodplains, and densely vegetated riparian zones. Deadfall from downed trees helped shape the Panhandle's many alluvial rivers by stabilizing creeks and stream banks and providing aquatic habitat (Livingston, 2003; Wallace, 1984). Seasonal precipitation, high energy storms (e.g., fronts, tropical storms, and hurricanes), high annual rainfall, drought periods, and forest fires have led to diverse flora and fauna and, consequently, the region is recognized as a biological hotspot

(Blaustein, 2008). The vegetation is adapted to low nutrients, high rainfall, and well-drained soils, including a dense root network. This root network can bring groundwater to the surface through transpiration. In this fire-adapted system, fire is less likely to reach waterbody margins due to the groundwater connection. Riparian zones and vegetative buffers are critically important as transition zones between upland areas and water bodies.

Soils and strata accumulate vegetative materials, minerals, and clays. Groundwater aquifers are fed by rainwater percolating through the soil. This water surfaces in low-lying wetlands, creeks, and river systems (Florida Geological Survey, 1965). The groundwater remains cooler year-round, flowing into creeks, streams, and rivers and maintaining their base flows during droughts. Where dense mineral layers such as clay lenses occur, rains infiltrating the soil tend to flow laterally and emerge as seeps. Seepage slopes and steephead systems were first recognized as unique systems to Northwest Florida in the 1970s. The seepage slopes are wetlands located on the sides of hills (Folkerts, 1982). Many carnivorous wetland plants occur in this region, as the seepage keeps soils moist year-round. Seepage slopes are common where the upland pine forest slopes downward towards streams. They are the origins of many headwater creeks, which flow together and converge into the larger riverine systems in Northwest Florida. Headwater creeks, originating in sunlight-starved valleys, are low in nutrients which create conditions that support primary and secondary productivity of the watersheds (Meyer et al., 2007).

The study area lies within the Southern Coastal Plain Major Land Resource Area (MLRA) (U.S. Department of Agriculture, Natural Resources Conservation Service, 2022). Most of the soils in this area are Ultisols, which are deep and naturally acidic, with sandy or loamy surface layers overlying argillic horizons (increases in clay percentage) within 2 m of the

surface. The predominant clay mineralogy is mixed or kaolinitic. Entisols, which are deep, sandy soils without argillic horizons, also occur in this region (Soil Survey Staff, 1999). Infiltration rates in the surface layers are generally high to moderately high. Permeability depends on depth and clay percentage of the argillic horizon (Hillel, 1982). Even with rapid infiltration rates, soil erosion can occur on slopes >5%. The Natural Resources Conservation Service (NRCS) has identified several threats in this region, including erosion, retention of soil organic matter, low productivity, control of surface water, artificial drainage, and management of surface compaction and soil moisture (U.S. Department of Agriculture, Natural Resources Conservation Service, 2022).

Threats and Stressors to Watershed Systems

Degradation of air and water quality in the mid-1960s led to the passage of the Clean Air and Water Acts and creation of the United States Environmental Protection Agency (EPA) in the early 1970s. Wastewater discharges and other inputs of contaminants in Northwest Florida resulted in negative environmental impacts such as fish kills, hypoxia, and PCB contamination in Escambia Bay (Olinger et al., 1975). Increasing agriculture and other land use changes have also occurred throughout the watershed. Land use changes, particularly changes from forests, wetlands, grasslands and shrublands to hardened landscapes, alter the water flow by increasing velocity and decreasing infiltration, cause habitat smothering through sedimentation, and create creek bank instability.

Road crossings can have a significant influence on local hydraulics and sediment transport (Johnson et al., 2002). Creek and river crossings and bridges generally have a 40- to 50-year life span. Many bridge designs and maintenance activities are undertaken to convey water off the land, carrying sediment, stormwater, and debris downstream. Bridges may also

become pinch points that increase flooding in upstream areas. Fragmentation across waterways, as observed with bridge crossings or culverts, can create conditions where eroded soil enters the waterbody during storm events. Thus, stream and river management projects designed to improve water quality, stream function, and aquatic habitat may be hampered by negative impacts from road construction and infrastructure.

Objectives of Project

One outcome of the compilation of data by the University of Florida (UF) and the University of West Florida (UWF) for the Florida RESTORE Act Centers of Excellence Program (FLRACEP) grant was the realization that limited water quality data exist for the upper portions of the Perdido, Conecuh, and Yellow/Shoal watersheds. Thus, more water monitoring is needed for the upper reaches of the Pensacola and Perdido watersheds. This study was conducted to fill some of the gaps and focuses on four major areas: water quality, creek bank vegetation, stream bed condition, and site characteristics.

Water quality variables measured in this study include several standard indicators of water quality used by EPA and other state and federal agencies to assess conditions in rivers and streams. For example, conductivity, total nitrogen, total phosphorus, and chlorophyll-*a* are used in the EPA National Rivers and Streams Assessment (U.S. EPA, 2000; U.S. EPA 2020. Dissolved oxygen criteria for freshwater were established in 1986 (U.S. EPA, 1986). *E. coli* has been used by EPA and other agencies as an indicator of fecal contamination in freshwater environments. These standards and baseline values are included for context in the results section for these parameters. *E. coli* indicator bacterial standards are determined based on an individual sample value on a single sample date (not to exceed 410 MPN/100 mL) and calculation of the geometric mean from multiple sampling dates (not to exceed 126 MPN/100 mL).

Study Design and Methods

The Bream Fishermen Association (BFA) monitoring design was used to prioritize sampling locations. Twenty-four sites in the Perdido, Conecuh, and Yellow/Shoal watersheds were selected based on land use categories (Figure 1). The Conecuh and Yellow/Shoal River stations were divided into two different sampling runs for logistical reasons: one for northern stations (upper run) and one for southern stations (middle run). The Conecuh River watershed was the largest sampled with eleven stations, while the Yellow/Shoal River watershed had five stations, and the Perdido River watershed had eight stations (Table 1). Sampling was conducted from June 6 through November 15, 2022. Each station was sampled five times (about every 5 weeks). The Indian Creek site in the Conecuh River watershed went dry in October and November and could not be sampled.

Sampling was designed to take place on land, as many of these sites cannot be accessed by boat. Easy access points to these streams via bridges and stream locations were chosen based on safety considerations. The first sampling event was used as a trial run, confirming ease and safety of access, ground-truthing representation of the watershed, and identifying time constraints (Table 1). For example, Dyas Creek could not be safely sampled, so Bushy Creek was sampled instead. Bushy Creek is a tributary that flows into Dyas Creek and joins the Perdido River as a large tributary. Similarly, the Conecuh C location, originally near the community of Gantt, AL was moved upstream to the Goshen, AL location because of high volume of traffic (specifically semitrucks) on Hwy 29, near the Central Generation Company (a power company). The third and last modification to a sampling location occurred during the first visit to the Shoal River. The distance between the Shoal River and the laboratory became an issue because it meant the entire set of bacterial analyses for that day would be outside of holding times. The

Shoal River was originally sampled on FL CR 393 near the community of Dorcas, FL. During the first sampling day, the team realized a site further upstream could be accessed by interstate more quickly and a day prior to the sampling of the upper portions of the same watershed. This became the protocol for the remaining four sampling events. Detailed descriptions of each sampling location are in Appendices A (Perdido watershed), B (Conecuh watershed) and C (Yellow/Shoal watershed).

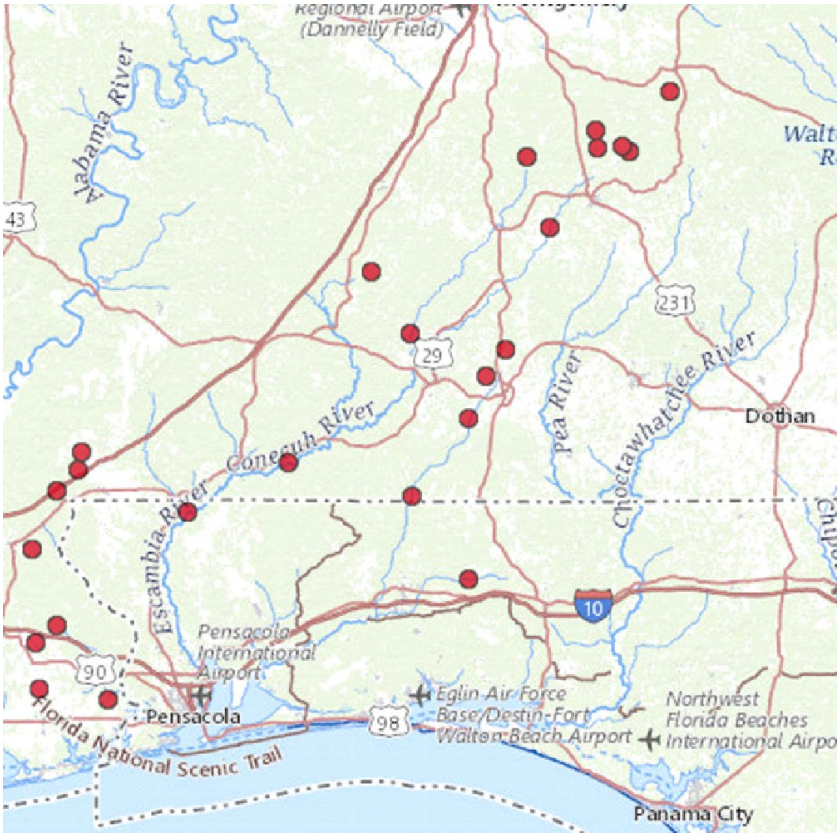


Figure 1 - *Map Showing Sampling Locations as red circles. Map created in ERMA 2015*

Table 1 - *Station Locations, Watershed, Latitude, Longitude, Land Use Type, County, and State*

Watershed*	Station name	Latitude	Longitude	Land Use Type	County, State
Perdido[A]	Perdido Creek	31.12509	-87.56354	Rural	Escambia, AL
Perdido[A]	Perdido River	31.08163	-87.57012	Rural	Escambia, AL
Perdido[A]	Bushy Creek	31.02143	-87.02143	Suburban	Baldwin, AL
Perdido[A]	Hollinger Creek	30.86851	-87.71728	Rural	Baldwin, AL
Perdido[A]	Styx River	30.66405	-87.63924	Rural	Baldwin, AL
Perdido[A]	Blackwater	30.61866	-87.7028	Suburban	Baldwin, AL
Perdido[A]	Negro Creek	30.49443	-87.69163	Suburban	Baldwin, AL
Perdido[A]	Narrow Gap Creek	30.46336	-87.48052	Rural	Baldwin, AL
Yellow/Shoal[B]	Shoal River	30.78548	-86.35876	Rural	Walton County, FL
Yellow/Shoal[B]	Poley Creek	31.32619	-86.30121	Suburban	Covington, AL
Yellow/Shoal[B]	Lightwood Knot Creek	31.39677	-86.24295	Rural	Covington, AL
Yellow/Shoal[B]	Yellow Upper	31.21379	-86.35746	Rural, Ag	Covington, AL
Yellow/Shoal[B]	Yellow Lower	31.01033	-86.53727	Rural	Covington, AL
Conecuh[B]	Conecuh B	31.0969	-86.91926	Rural	Escambia, AL
Conecuh[B]	Conecuh A	30.96731	-87.23376	Rural	Escambia, FL
Conecuh [C]	Conecuh E	32.08169	-85.73517	Rural	Bullock, AL
Conecuh [C]	Conecuh D	31.9223	-85.86093	Rural	Pike, AL
Conecuh [C]	Log Creek	31.9376	-85.88347	Agriculture	Pike, AL
Conecuh [C]	Manning Creek	31.93379	-85.95758	Silviculture	Pike, AL
Conecuh [C]	Indian Creek	31.97675	-85.96422	Silviculture	Pike, AL
Conecuh [C]	Conecuh C	31.71972	-86.10745	Suburban	Pike, AL
Conecuh [C]	Persimmon	31.60539	-86.66365	Rural	Butler, AL
Conecuh [C]	Patsaliga Creek Upper	31.9078	-86.17527	Rural	Pike, AL
Conecuh [B]	Patsaliga Creek Lower	31.44095	-86.53748	Rural, Ag	Covington, AL

Note. *Sampling run: A – Perdido run; B – Middle run (Southern stations); C – Upper run (Northern stations)

At each site, water quality parameters were measured with a YSI Professional Plus multiparameter instrument. The YSI was calibrated for conductivity, pH, and dissolved oxygen before each round of sampling. Parameters measured in the field included water temperature, conductivity, dissolved oxygen, and pH. Grab water samples were collected for laboratory analysis of *E. coli*, chlorophyll *a*, dissolved nutrients [nitrate+nitrite, nitrite, ammonium, dissolved inorganic phosphate (DIP)], and total (unfiltered) nutrients [total Kjeldahl nitrogen (TKN) and total phosphorus (TP)]. A Secchi disk was also used to determine Secchi disk depth and total water depth.

E. coli analyses were conducted using the Colilert-18 method. Analysis of samples usually began less than 6 hr after collection in a National Environmental Laboratory Accreditation Program (NELAC)-certified laboratory - Wetlands Research Laboratory, University of West Florida (State of Florida Certification # E71969). Fifteen samples exceeded a 6 hr hold time; these analyses began within 9 hr of collection. Sixty mL of water were filtered through GF/F filters (nominal pore size 0.7 µm) for dissolved nutrients and the filter was used for chlorophyll *a* analysis. Filters and filtrate were frozen until analysis. Total nutrient samples (125 mL) were preserved with sulfuric acid and refrigerated until analysis. Total nutrient samples were only collected between August 23 and November 9, 2022. Filters were extracted with 90% acetone for chlorophyll *a* and read on a fluorometer as in Welshmeyer (1994). Filtrate was analyzed for nitrate+nitrite as in Schnetger and Lehners (2014), ammonium as in Holmes et al. (1999), and nitrite and DIP as in Parsons et al. (1984). TKN and TP were analyzed following EPA methods 351.2 and 365.4, respectively. TKN includes ammonium, dissolved organic nitrogen, and particulate nitrogen. TP includes inorganic and organic phosphorus, both particulate and dissolved.

The presence/absence of vegetation, trash, non-native materials, utility easements, and the general condition of the creek or riverbanks were noted. Plants such as trees, shrubs, herbaceous and emergent species which could be readily identified at each site were noted. The number of invasive and native species were totaled for each site over all the visits. Forty-two native and eleven invasive species were identified across all locations. The condition and type of road, slope from the nearest hilltop, and if rocks were used to stabilize the banks of the waterway were noted. We collected information about the condition of the surrounding area including land use, condition and types of waterway crossings, and length of crossings. Also recorded were the type of bridge crossing, the materials used for elevating the platform, the location of the pilings, if the pilings could impede woody material as it moves downstream, and the platform elevations. The team used a clinometer to determine slope of the approaching road (always looking downstream) and a Vortex laser range finder to determine the length of the bridge. The team also collected the ambient temperature of the road structure where the waterbody crossed. Shaded and unshaded ground temperature was measured using a laser temperature gun.

Rainfall data were downloaded from the National Weather Service site at Atmore, AL for the Perdido stations; Billingsley, AL for the lower stations in the Conecuh and Yellow/Shoal; and Troy, AL for the upper Conecuh stations (National Oceanic and Atmospheric Administration, 2022). Three on-line tools were used to identify watersheds, creek order, elevation at and surrounding topography of sampling locations. These tools included Environmental Response Management Application (ERMA) developed by NOAA, USGS topographic maps accessed by Gaia Maps, and Google Earth. We used the Strahler (1952) stream order classification method to describe the sampling sites we visited for this study. A first order creek refers to the first emergence of a groundwater seep or drainage way on the landscape. The

confluence of two, first order drainage ways, become a second order, and so on. The low topographic relief of the study area created a dendritic pattern within these watersheds.

Correlation analyses of water quality parameters were done using the R package, ggally (Schloerke et al. 2022). Plots were created in the R package ggplot2 (Wickham 2016). Geometric means of *E. coli* MPN were calculated for each station to compare with EPA standards. Total nitrogen (TN) was calculated by converting nitrate+nitrite from µM to mg N/L and adding to TKN values.

Results

Climate

Only four sampling dates had measurable precipitation in the 48 hours prior to sampling. Three of those dates occurred in late summer and one in October (Table 2). Monthly precipitation during the study period was generally below average except in August (NOAA, 2023).

Table 2 – *Precipitation in Upper Watershed Regions*

Date	Watershed: Sampling Run and Rain Source	48-Hr Precipitation (cm)
6/7/2022	Perdido[A]	0
6/15/2022	Middle[B]	0
6/22/2022	Upper[C]	0
7/12/2022	Perdido[A]	6.78
7/19/2022	Middle[B]	0
8/3/2022	Upper[C]	1.17
8/23/2022	Perdido[A]	3.05
8/29/2022	Middle[B]	0
9/7/2022	Upper[C]	0
10/12/2022	Perdido[A]	0
10/18/2022	Middle[B]	0
10/26/2022	Upper[C]	1.42
11/2/2022	Perdido[A]	0
11/14/2022	Upper[C]	0
11/9/2022	Middle[B]	0

Note. [A] NOAA Climatological Data for Atmore, AL (https://www.weather.gov/wrh/Climate?wfo=mob)
[B] NOAA Climatological Data for Billingsley, AL (https://www.weather.gov/wrh/Climate?wfo=bmx)
[C] NOAA Climatological Data for Troy, AL (https://www.weather.gov/wrh/Climate?wfo=bmx)

Water Quality

Water temperature was highest in the summer and lowest in October and November (Figure 2). The variability in temperature in each watershed during the same sampling run was

generally low, between 2 and 3 °C, except in the Conecuh watershed. In June, the Conecuh C site was between 4 and 8 °C warmer than the other sites sampled on that date. Streams in Eglin Air Force Base (AFB) sampled between 1999 – 2004 had a much lower annual temperature range, between 17.8-23.3 °C (Thom 2005).

Conductivity was usually less than 100 µS/cm at most locations (Figure 3). Values ranged from 14-195 µS/cm with lower values in the Yellow/Shoal watershed. The highest values occurred at two locations in the Perdido watershed (Perdido Creek and Hollinger Creek) and two in the Conecuh watershed (Conecuh River E and Persimmon Creek). These locations also had high ranges of conductivity. All sites were below the EPA Coastal Plain ecoregion benchmark of 500 µS/cm characteristic of reference sites in the region (U.S. EPA, 2020). However, references sites in Eglin AFB typically had much lower conductivities from 15 to 20 µS/cm between 1999-2004 (Thom, 2005).

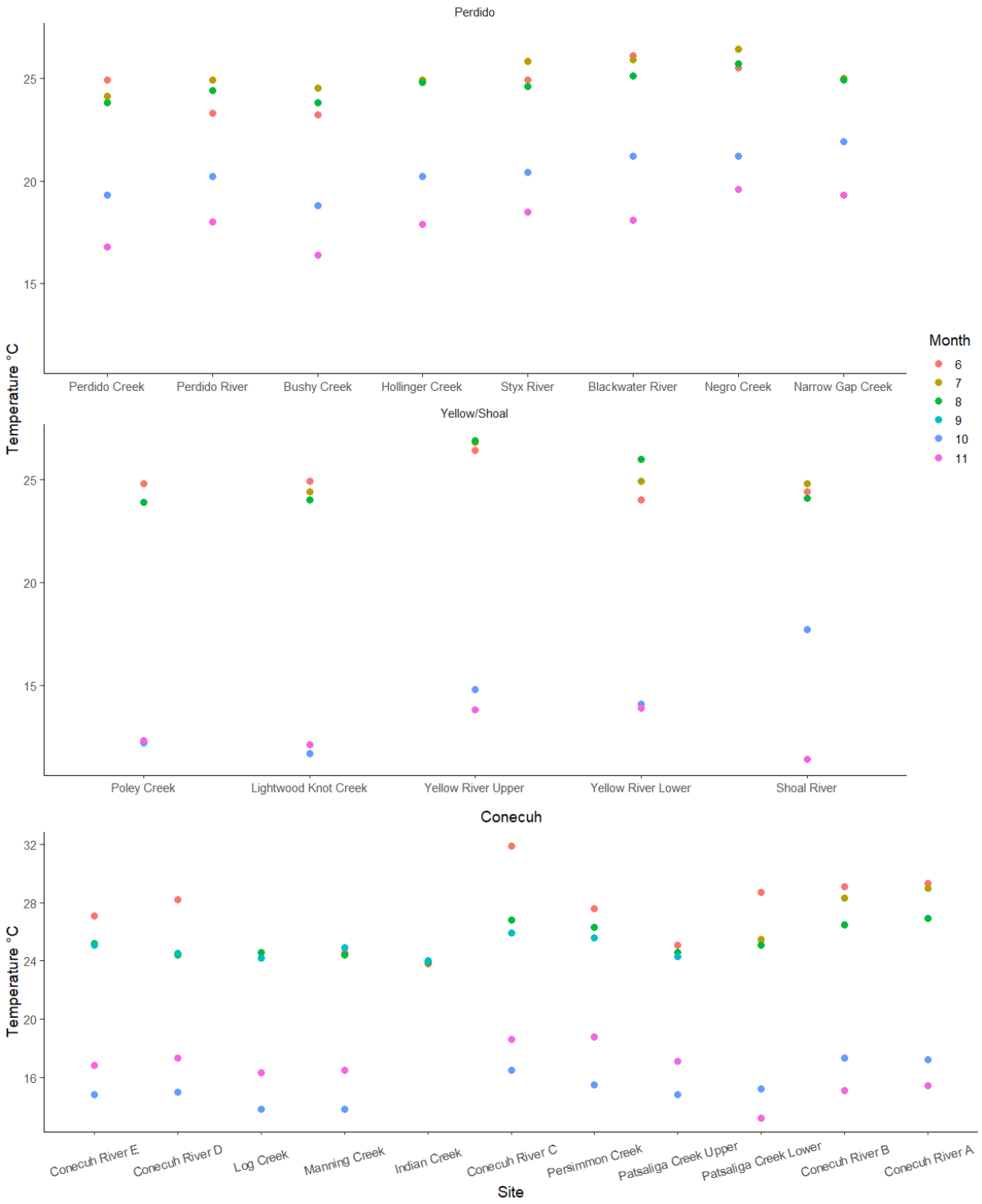


Figure 2 - *Water Temperature at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watershed. Note the change in scale between panels.*

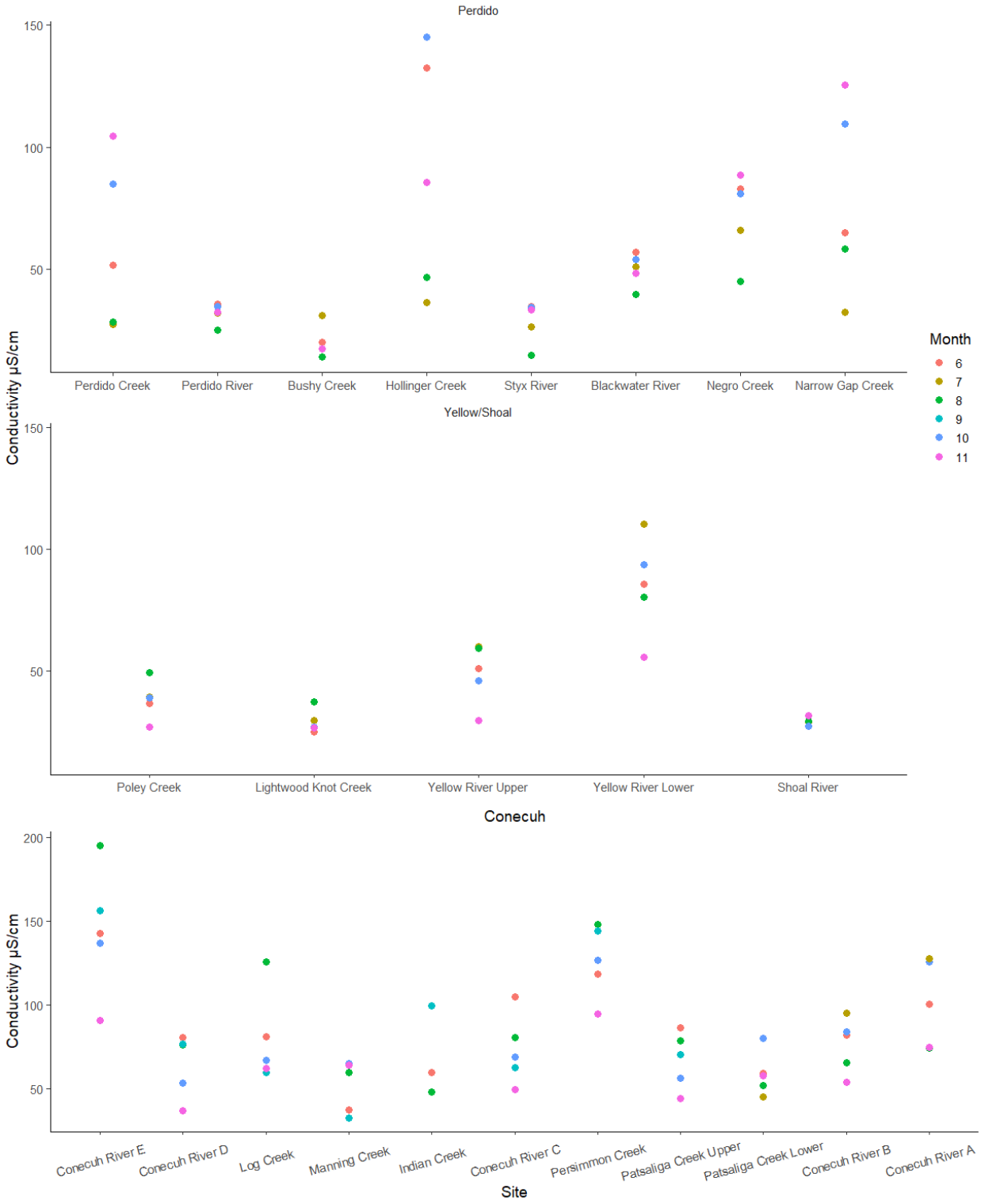


Figure 3 - *Conductivity at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh Watersheds (Lower Panel) as in Figure. 2*

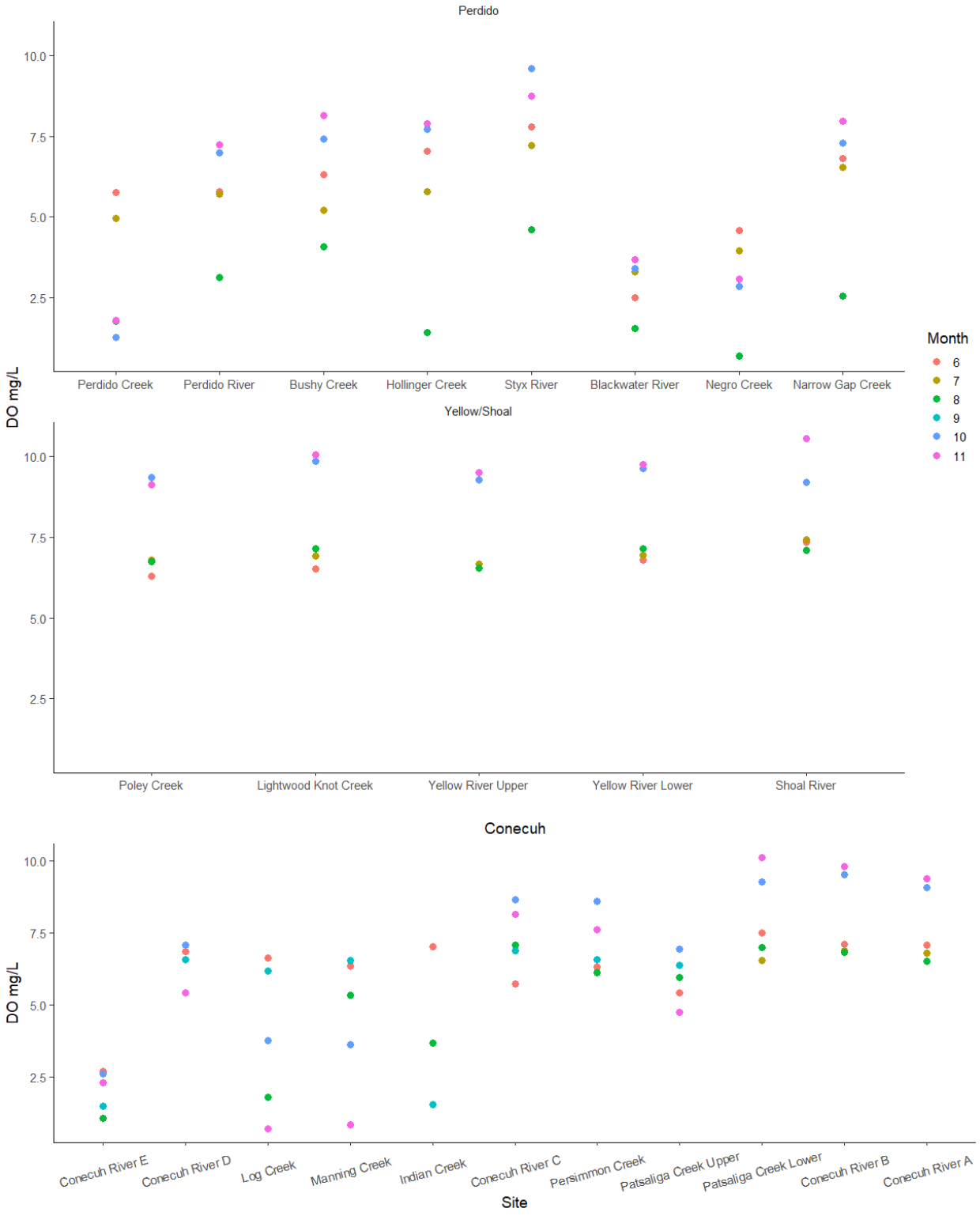


Figure 4 - *Dissolved Oxygen at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watersheds as in Figure 2*

Dissolved oxygen concentrations ranged from less than 1 mg/L to 10.6 mg/L (Figure 4). Concentrations were generally higher during the cooler months (Supplemental Figure 1). In contrast, dissolved oxygen in the Eglin AFB streams averaged 8.32 and had a range from 6.68 to 8.94 (Thom, 2005). While there was a negative correlation between dissolved oxygen and temperature at all sites (r=-0.31, p<0.001), this relationship was driven by the Yellow/Shoal sites (r=-0.97, p<0.001), which also had the overall highest dissolved oxygen values. This was not solely driven by the relationship between temperature and concentration, since dissolved percent saturation and temperature were also correlated (r=-0.75, p<0.001). Perdido Creek and Conecuh River E had multiple values less than 3 mg/L. Occasional low values also occurred at several locations in the Conecuh and Perdido watersheds, with some low values occurring in November at Log and Manning Creeks. Dissolved oxygen criteria for freshwater is 5 mg/L for early life stages and sensitive species and 3 mg/L for warm water systems (U.S. Environmental Protection Agency, 1986). Across the entire dataset (118 samples), 32 samples (27%) had values less than 5 mg/L with 18 samples (15%) having values less than 3 mg/L.

Streams in the Panhandle often have low pH values due to poor buffering capacity (Wolfe et al. 1988). The range in pH values across all locations and sampling dates was between 4.65 and 8.33 (Figure 5). Most sites had values between 6 and 7. Indian Creek had the lowest pH value at 4.65 and was either at or below 6.5 during all sampling trips. Shoal River had the biggest range in pH values, from 5.5 to 8.3. Streams in Eglin AFB ranged from 4.56 to 6.08 with an average of 5.47.

Shading by the tree canopy and flowing water often lead to low chlorophyll-*a* in small streams. The median value across all sampling sites and dates was 1.3 µg chl*a*/L, with most samples less than 2 µg chl*a*/L (Figure 6). Four locations had high concentrations: Perdido Creek,

Conecuh River E, Log Creek, and Indian Creek. These locations had multiple dates with high values, some exceeding 20 µg chla/L. There was no consistent difference between summer and fall and no relationship to temperature or land use. Perdido Creek and Conecuh River E are predominantly rural, while agriculture predominated at Log Creek and silviculture at Indian Creek. As part of the nutrient criteria development process, EPA's recommended nutrient criteria for Southeastern coastal plain rivers and streams was 0.4 µg chl*a*/L (EPA, 2000). Across all sampling sites and dates, 104 samples (88%) were above the 0.4 µg chl*a*/L criterion.

All nitrite values were less than 1.6 µM and usually less than 5% of the nitrate+nitrite values (data not shown). Nitrate+nitrite values ranged from detection limits (0.05 µM) to 378 µM (Figure 7). Hollinger Creek had the highest values in June, October, and November. Perdido Creek, Narrow Gap Creek, Lightwood Knot Creek, and Conecuh River A, B and C also had high values, above 40 µM, particularly in October. Nitrate+nitrite concentrations were positively correlated with conductivity in the Perdido watershed (r=0.77, p<0.001), but negatively correlated with conductivity in the Yellow/Shoal watershed (r=-0.40, p<0.05).

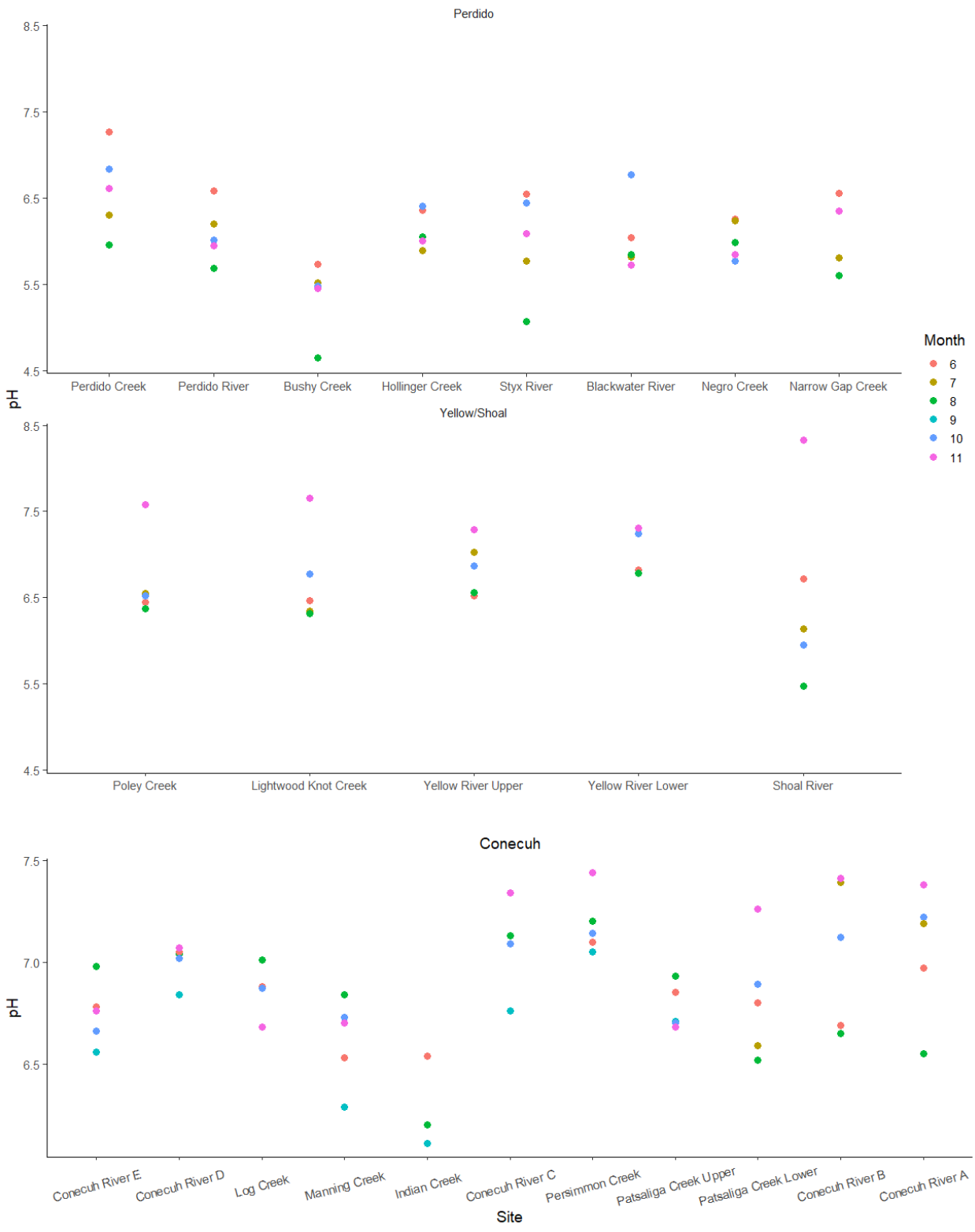


Figure 5 - *pH at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watersheds as in Figure 2. Note the change in scale between panels.*

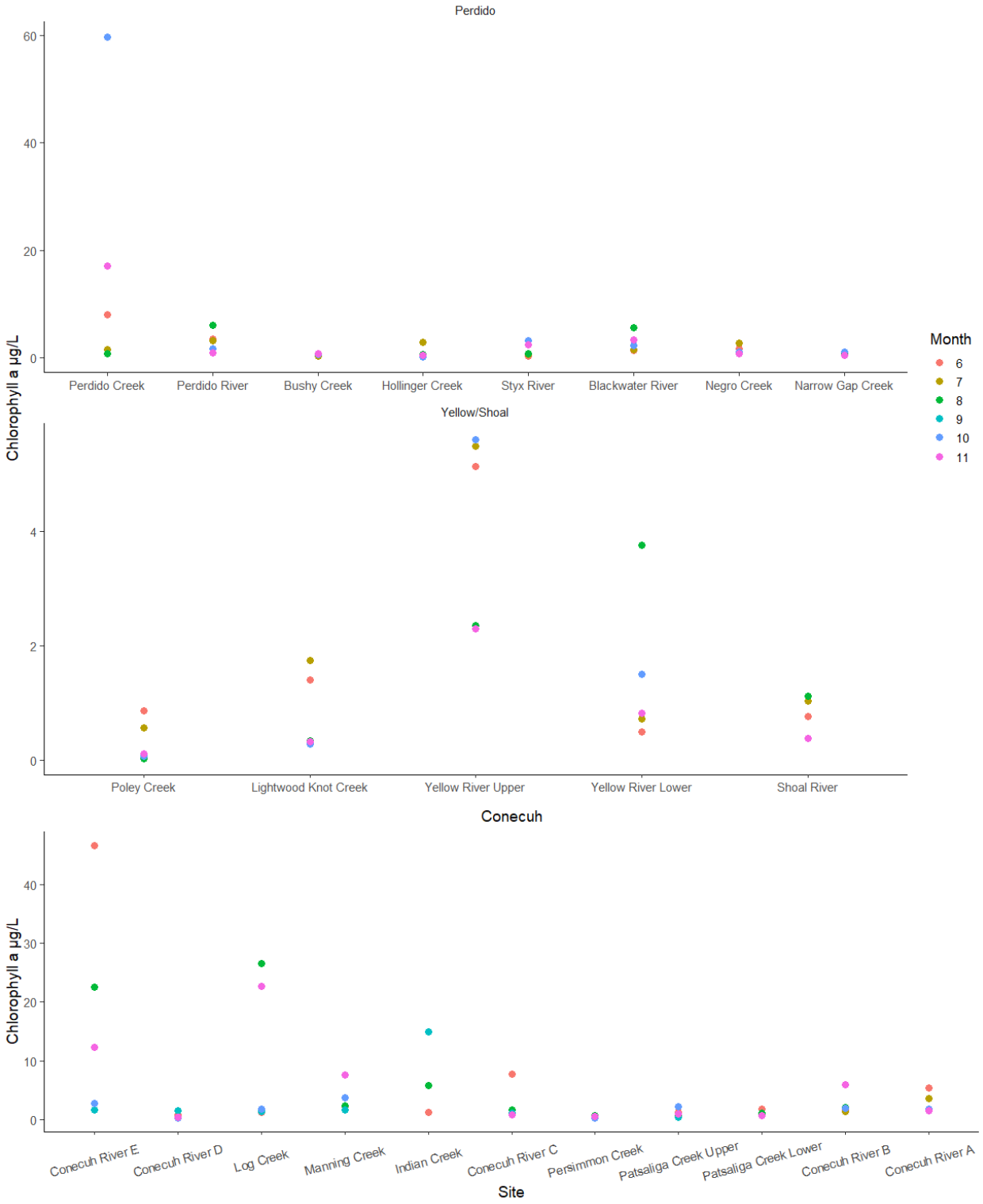


Figure 6 - *Chlorophyll a at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watersheds as in Figure 2. Note the change in scale between panels.*

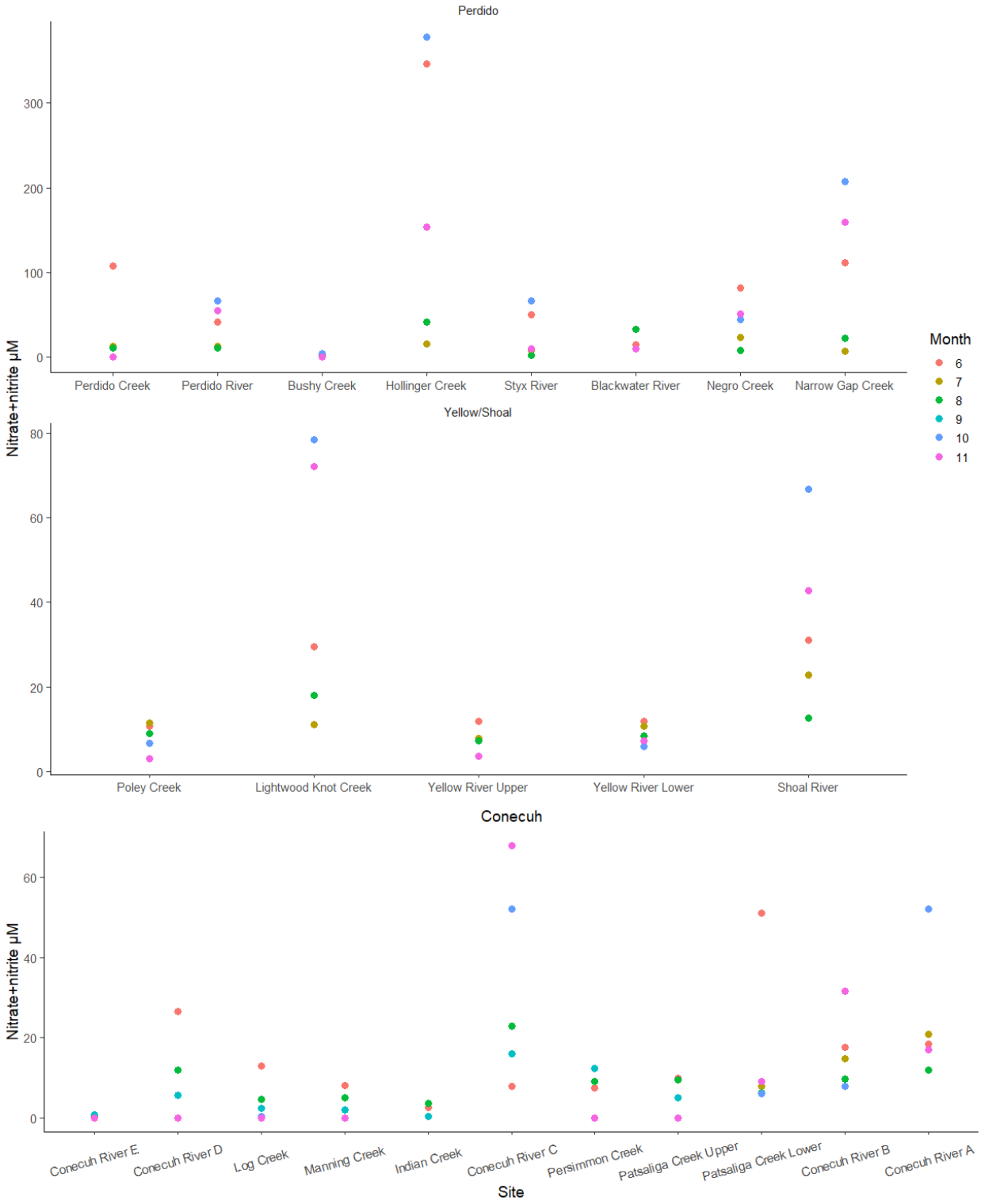


Figure 7 - *Nitrate+nitrite at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watersheds as in Figure 2. Note the change in scale between panels.*

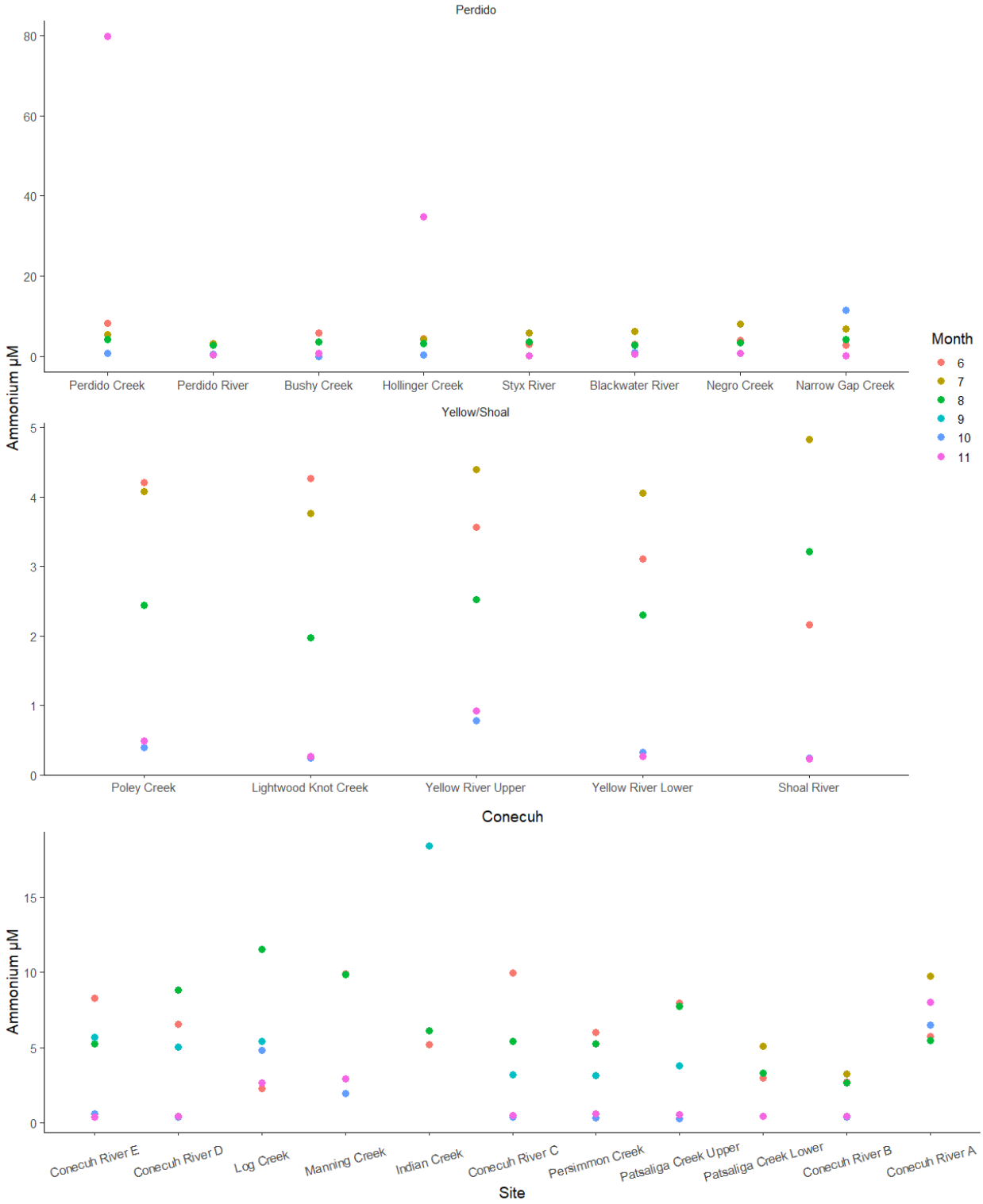


Figure 8 - *Ammonium (µM) at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watersheds as in Figure 2. Note the change in scale between panels.*

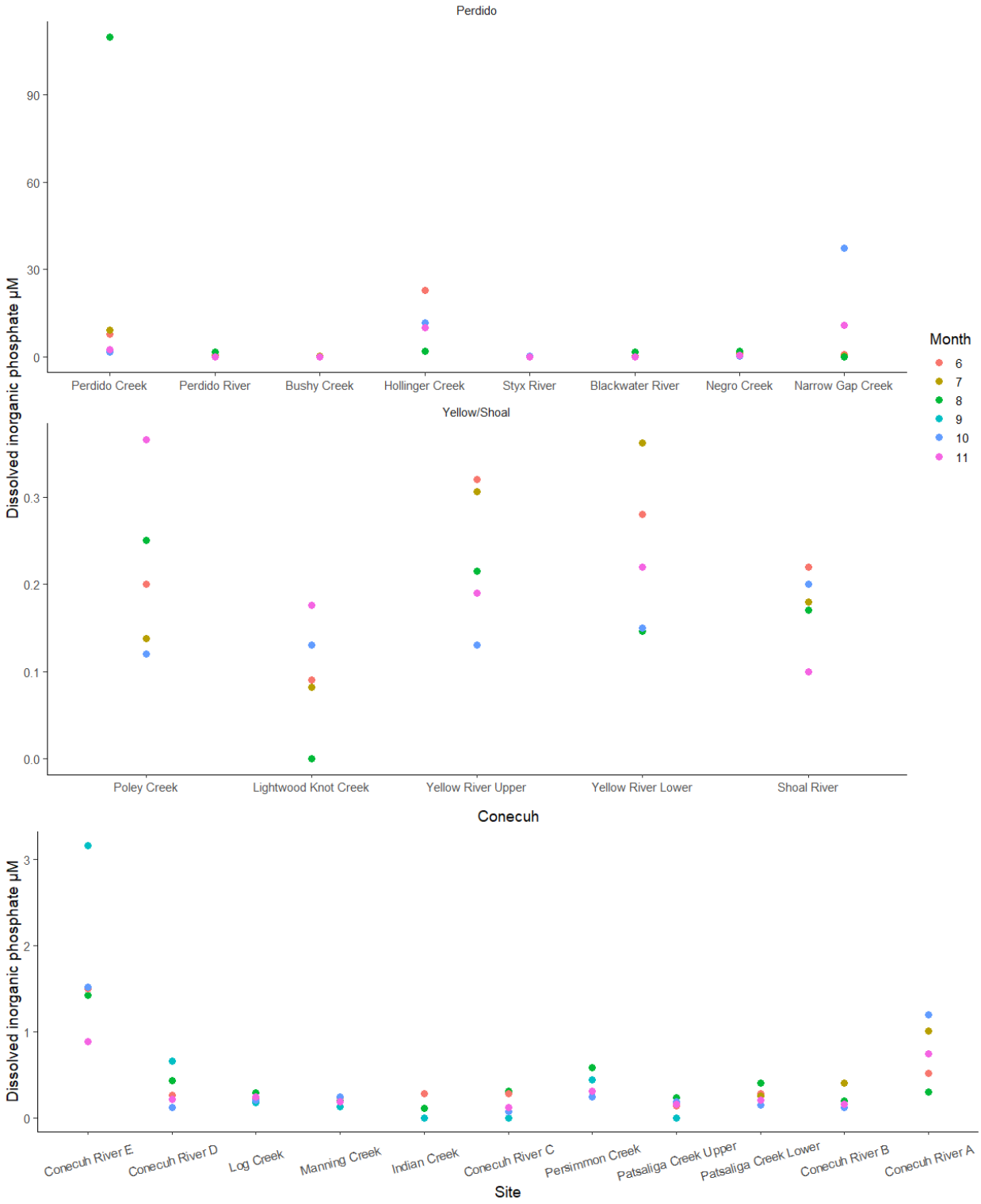


Figure 9 - *Dissolved Inorganic Phosphate (µM) at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watersheds as in Figure 2. Note the change in scale between panels.*

The range in ammonium concentrations was less than nitrate+nitrite, between 0.1 and 35 µM (Figure 8). The median across all sites and sampling dates was 3.3 µM. The highest concentrations were observed at Hollinger Creek, Blackwater River, Indian Creek, and Log Creek. In contrast to nitrate+nitrite, ammonium concentrations were positively correlated with temperature in both Conecuh (r = 0.46, p<0.001) and Yellow/Shoal watersheds (r=0.87, p<0.001). In the Conecuh watershed, ammonium was also positively correlated with conductivity (r=0.36, p<0.01) and with chlorophyll *a* (r=0.42, p<0.01). High dissolved nutrient concentrations are often the result of nonpoint source runoff from agriculture or urban environments and can stimulate phytoplankton productivity. In addition to nonpoint source runoff, particularly from manure, microbial decomposition of organic matter produces ammonium within the system.

DIP concentrations were generally low across all sites and sampling dates, with a median of 0.25 µM (Figure 9). Values ranged from below detection (0.05 µM) to a high of 39 µM at Narrow Gap Creek in October and 12.5 µM in November. Perdido Creek, Hollinger Creek and Conecuh River E were also higher than most other sites. DIP and conductivity were positively correlated in the Conecuh (r= 0.66, p<0.001) and Perdido watersheds (r=0.54, p<0.001). DIP and nitrate+nitrite were also positively correlated in the Perdido watershed (r=0.61, p<0.001).

TKN values ranged from detection limits (<0.1 mg N/L) to 2.28 mg N/L for samples collected (no samples collected before August 23) (Figure 10). The highest values occurred in Perdido Creek. Manning Creek also had high values. TKN and corresponding nitrate+nitrite values were summed to estimate total nitrogen. The EPA National Rivers and Streams Assessment benchmark for good conditions in coastal plain streams is 0.624 mg N/L (EPA, 2020). Calculated TN exceeded the standard in 46% of the samples collected.

TP was below the detection limit (<0.1 mg P/L) in 84% of the samples (Figure 11). Sites with detectable concentrations were Conecuh River E, Narrow Gap Creek, Hollinger Creek, Manning Creek, and Perdido Creek, with Narrow Gap Creek having the highest value (1.2 mg P/L) in October. These locations would be classified as poor based on the EPA National Rivers and Streams Assessment benchmark (EPA, 2020).

About 85% of TSS concentrations were below 20 mg/L, with values ranging from 0.9 to 85 mg/L (Figure 12). Locations with multiple dates above 20 mg/L included Indian Creek, Manning Creek, Log Creek, and Lower Patsaliga Creek. All of these sites were in the Conecuh watershed. TKN and TSS were positively correlated at all sites (Conecuh: r=0.58, p<0.001, Yellow/Shoal: r=0.71, p<0.01, Perdido: r= 0.69, p<0.001). TSS and chlorophyll *a* were also positively correlated in Perdido (r=0.38, p<0.05).

The median value of *E. coli* samples was 180 MPN/100 mL and ranged from 10 to 4610 MPN/100 mL (Figure 13). Twenty percent of the samples collected were above the 410 MPN/100 mL standard for a single sample. These values exceeding the standard occurred at 16 of the 24 sampling locations. Geometric means were above the 126 MPN/100 mL standard at 16 locations, with Lightwood Knot Creek, Poley Creek, and Log Creek having the highest values (Table 3). The locations in the Conecuh River (Conecuh River A, B, and E) and Persimmon Creek had the lowest geometric means. *E. coli* and conductivity were negatively correlated in the Conecuh watershed (r= -0.34, p<0.05). TSS and *E. coli* were positively correlated in the Conecuh (r= 0.67, p<0.001) and Yellow/Shoal watersheds (r=0.77, p<0.001).

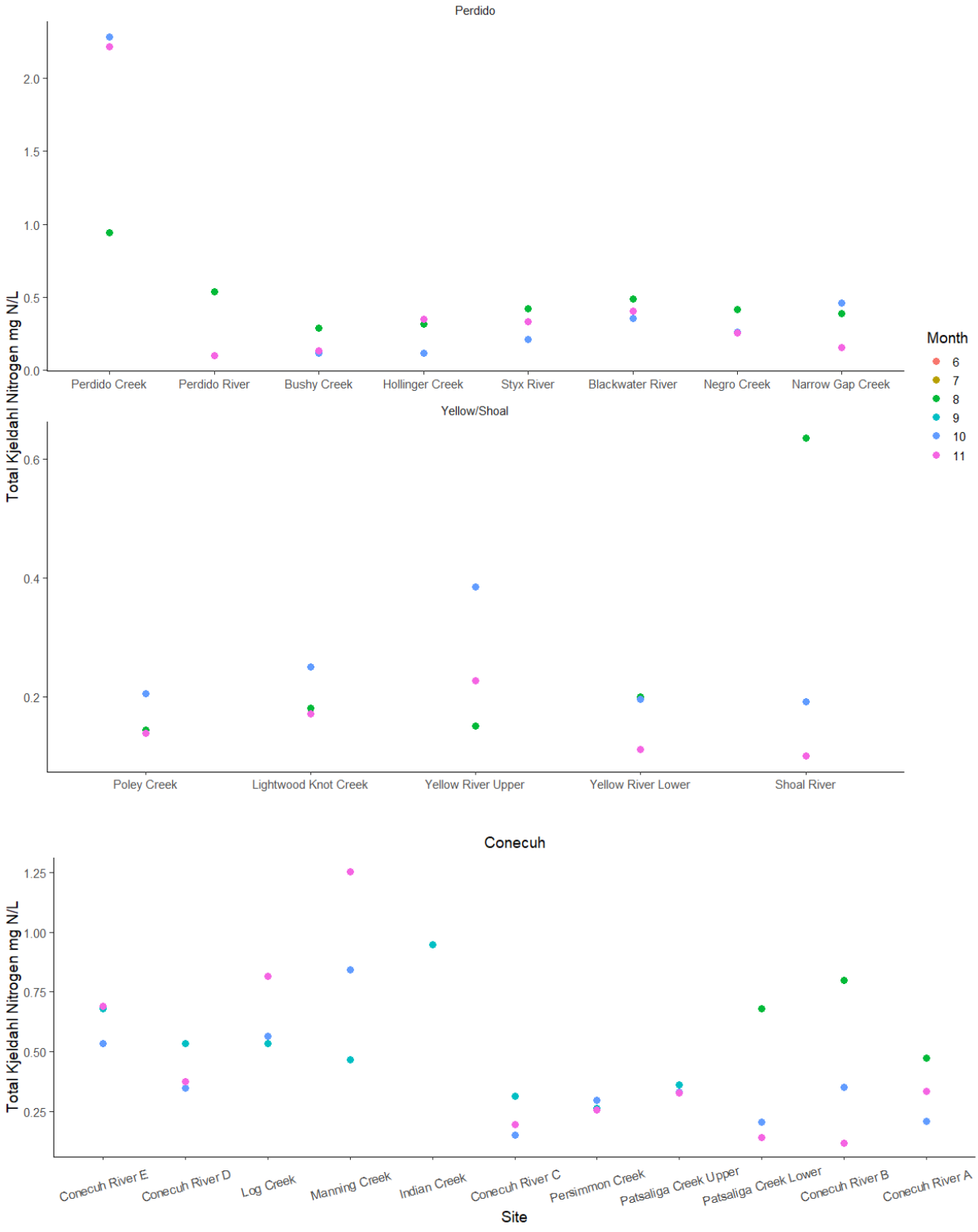


Figure 10 – *Total Kjeldahl Nitrogen at Sampling Locations in Perdido (Upper Panel), Yellow/Shoal (Middle Panel), and Conecuh (Lower Panel) Watersheds as in Figure 2*

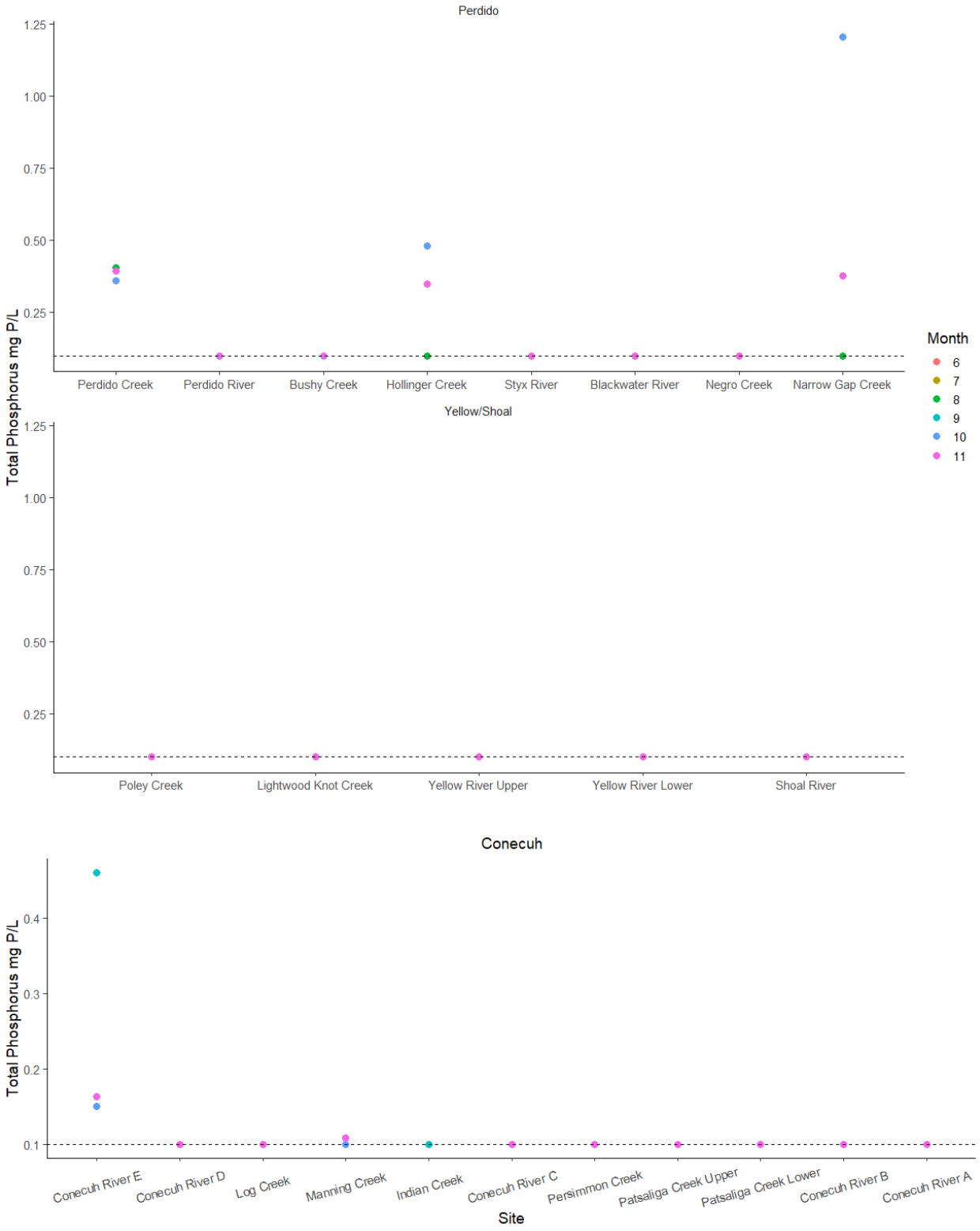


Figure 11 - *Total phosphorus at Sampling Locations in Perdido (Upper Panel) and Conecuh (Lower Panel) Watersheds as in Figure 2. Black dashed line indicates detection limit.*

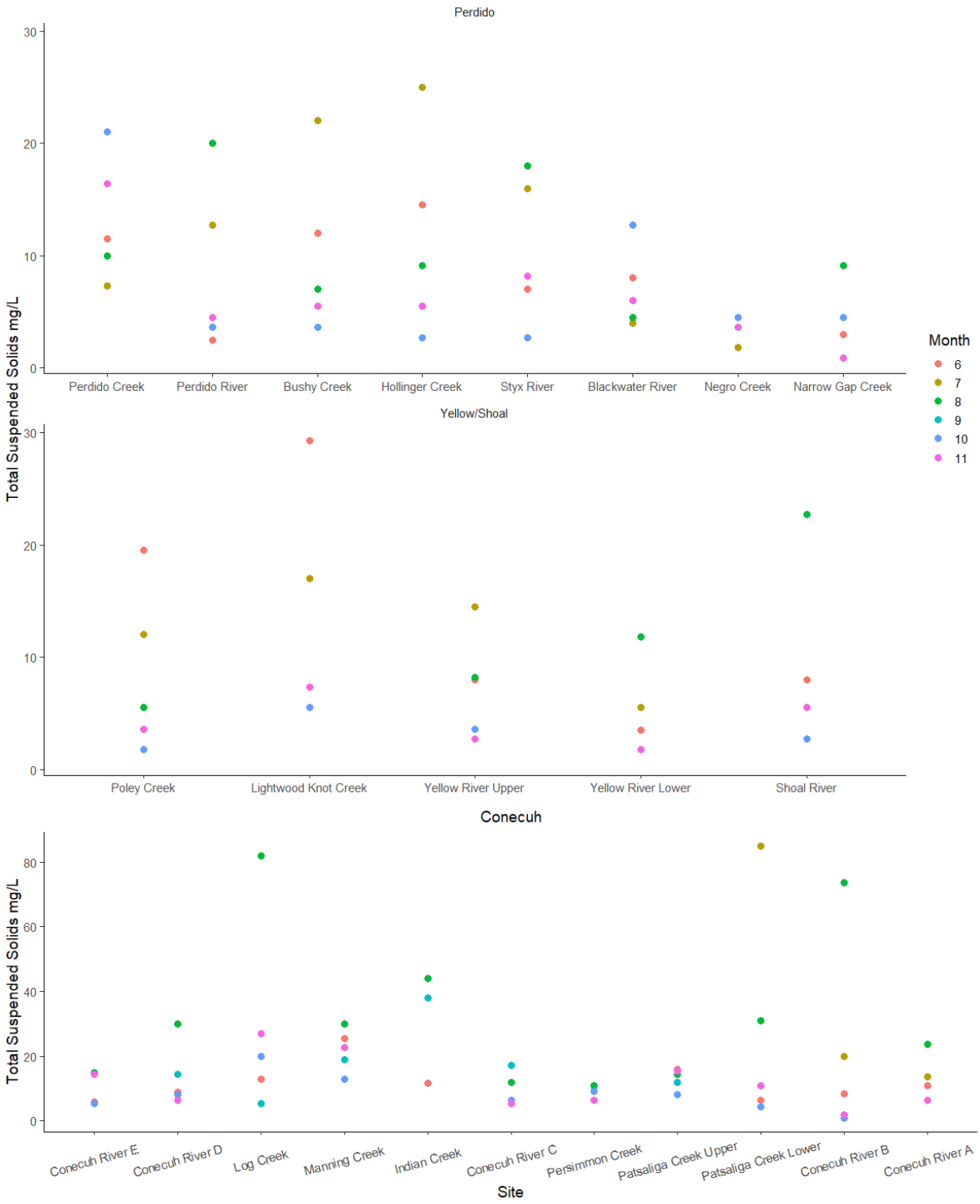


Figure 12 - *Total Suspended Solids at Sampling Locations in Perdido (upper panel), Yellow/Shoal (middle panel), and Conecuh (Lower Panel) Watersheds as in Figure 2*

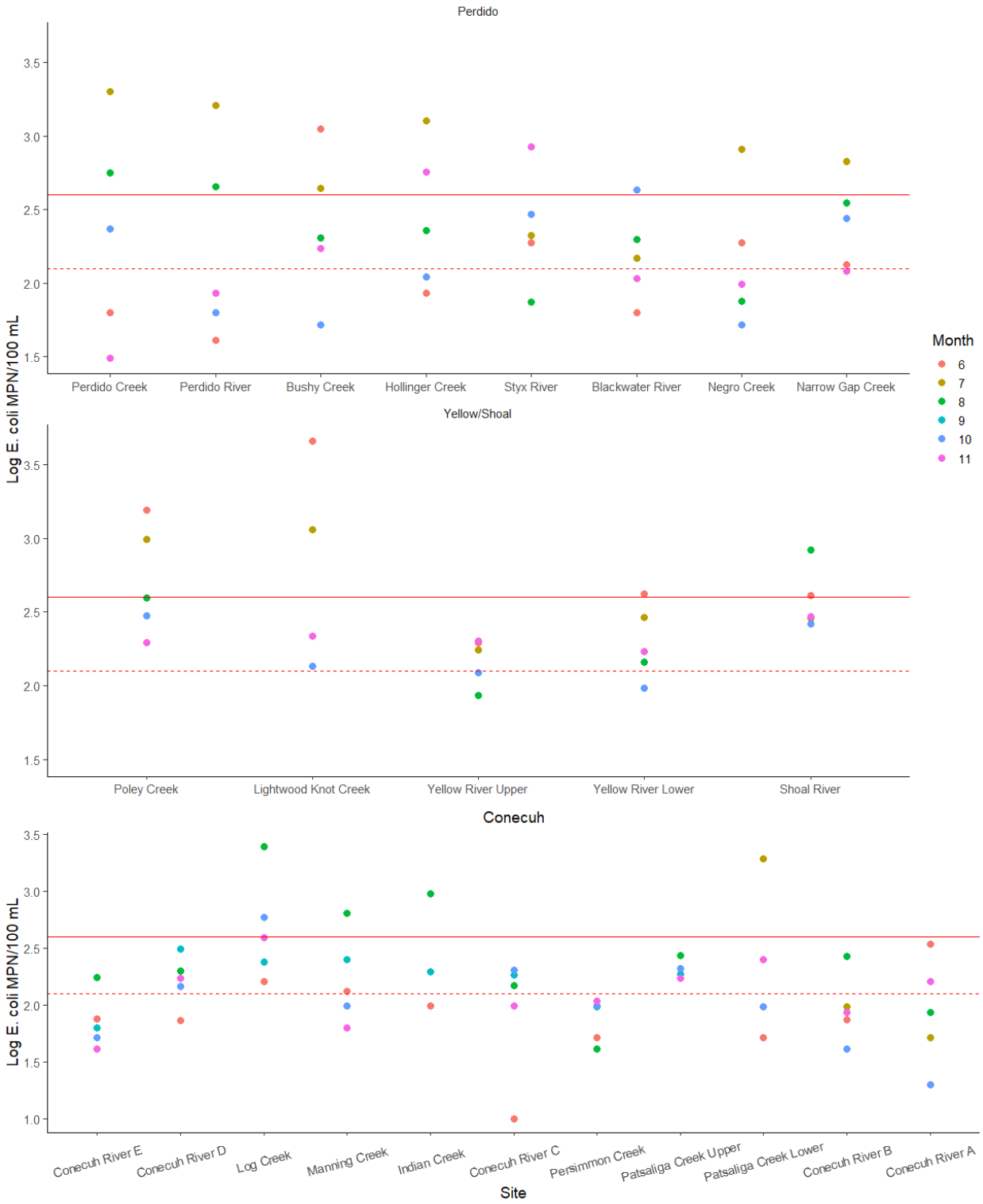


Figure 13 - *Log Transformed E. coli at Sampling Locations in Perdido (Upper Panel) and Conecuh (Lower Panel) Watersheds as in Figure 2. Note. Red solid line is the log of 410 MPN/100 mL and red dashed line is log of 126 MPN/100 mL.*

Table 3 - *Geometric Mean of E. coli Values*

Watershed	Station name	Geometric Mean MPN/100 mL	Number of samples
Perdido	Perdido Creek	220	5
Perdido	Perdido River	174	5
Perdido	Bushy Creek	147	5
Perdido	Hollinger Creek	273	5
Perdido	Styx River	236	5
Perdido	Blackwater	153	5
Perdido	Negro Creek	142	5
Perdido	Narrow Gap Creek	253	5
Yellow/Shoal	Shoal River	378	5
Yellow/Shoal	Poley Creek	514	5
Yellow/Shoal	Lightwood Knot Creek	507	5
Yellow/Shoal	Yellow Upper	149	5
Yellow/Shoal	Yellow Lower	196	5
Conecuh	Conecuh B	93	5
Conecuh	Conecuh A	87	5
Conecuh	Conecuh E	71	5
Conecuh	Conecuh D	163	5
Conecuh	Log Creek	467	5
Conecuh	Manning Creek	168	5
Conecuh	Indian Creek	265	3
Conecuh	Conecuh C	89	5
Conecuh	Persimmon	74	5
Conecuh	Patsaliga Creek Upper	199	5
Conecuh	Patsaliga Cr Lower	189	5

Vegetation

The number of easily visible plant species ranged between a low of 3 at Yellow River Lower and a high of 26 species at Conecuh River E. The most common native trees were Oaks

(*Quercus spp.),* Pines (*Pinus*), Maples (*Acer*) and Cypress (*Taxodium)*. The most common native shrubs and herbaceous plants were Wax Myrtle (*Myrica)*, Elderberry (*Sambucus),* and Golden Rod (*Solidago*). The most common invasive species were Chinese Tallow (*Sapium)*, Cogon grass (*Imperata),* and Chinese privet (*Ligustrum*). Seven stations across the three watersheds had exclusively native plants at the crossings: Bushy, Poley, and Log Creeks (three 3rd order), Conecuh River E, Indian Creek (two 2nd order), Conecuh D (4th order), and lower Yellow River (5th order). Lower Yellow River may have fewer invasive species due to surrounding conservation lands, where management efforts try to control invasive plants and animal species. In contrast, three of the seven species at the Styx River (Perdido watershed), a 5th-order system with a power line easement and a road crossing, were invasive, with Cogon grass the dominant species intermingled between hardened rock banks. Hollinger and Negro Creeks also had high numbers of invasives with 4 invasive species out of 14 and 15 total species, respectively. Tree canopy cover was not continuous across these landscapes due to road crossings and power line easements. Larger sections of the Conecuh, Yellow and Shoal rivers (>4th order) had no tree canopies over the water along the main stem of the system. Restoration and preservation of native species is a challenge due to competition with invasive species. Invasives can be easily spread by seeds carried in stormwater throughout the watershed.

Woody material was absent in the 5th- and 6th-order systems (Styx, Lower Yellow, Shoal and Conecuh C, B and A). Natural deadfall is an important component in watershed health, as it provides habitat for aquatic species and increases bank stability. Streams of lower orders in natural lands (not silviculture) had native plant communities, minimal disturbances, and good sinuosity. However, they also had the most trash.

Stream bottom conditions

Rainfall in September and October was about 40% below the long-term average. Low water in the stream revealed otherwise concealed conditions of the stream bottom and riverbank (Table 4). At several sites, the creeks became ephemeral in nature, allowing the team to walk upstream and note the condition of the stream bed. Bottom type has a major impact on the benthic community with calcifying organisms such as clams and mussels preferring karst (limestone) bottoms in these low pH streams.

The Conecuh watershed was the largest visited during this study. Elevation at the uppermost station was 447 ft above sea level. The Patsaliga sites, 4th-order streams at both stations, appeared to have a karst bottom at the lower station, although this could not be verified. As the Conecuh flows south towards Florida, its elevation drops to 96 ft at the Conecuh B location, it becomes more sinuous, and it develops a wider floodplain. Virtually every bend in the river had a large sand bar. At Conecuh A, the elevation is 67 ft above sea level and the banks are heavily degraded, perhaps due to sand mining activities upstream. In the Yellow/Shoal watershed, the northernmost site had an elevation of 298 ft at Lightwood Knot Creek, which may also be a karst-bottom creek. Poley Creek was 254 ft above sea level. The Asian clam, *Corbicula*, was found at the upper Yellow River station in October and November. The Shoal River, in Florida, had an elevation of 140 ft at the sampling station. It should be noted that the highest elevation in Florida is nearby Paxton (334 ft), which is approximately 14 miles northeast of the Shoal sampling station. The smallest watershed sampled for this study was the Perdido system. Perdido Creek was the northernmost station sampled, at 308 ft above sea level.

Table 4 - *Stream Order, Type of Bridge Crossing, Condition of Stream Bottom, Elevation Change from Bridge to Road at Station Locations*

Watershed	Creek name	Stream Order	Bridge Crossing Type	Stream Bottom condition	Right Bridge Approach °	Left Bridge Approach °
Perdido	Perdido Creek	2	Culverts	Cement - fines	0	0
Perdido	Perdido River	3	Bridge	Natural - fines and sand	2	6
Perdido	Bushy Creek	3	Bridge	Natural - fines and sand	0	0
Perdido	Hollinger Creek	1	Bridge	Natural - fines and sands	0	0
Perdido	Styx River	5	Bridge	Natural - sands	0	0
Perdido	Blackwater	2	Bridge	Natural - fines and sands	0	0
Perdido	Negro Creek	2	Culverts	Metal - fines	0	0
Perdido	Narrow Gap Creek	3	Bridge	Natural - fines and sand	0	0
Yellow/Shoal	Shoal River	4	Bridge	Natural - sandy	0	0
Yellow/Shoal	Poley Creek	3	Bridge	Natural - fines and sandy	0	8
Yellow/Shoal	Lightwood Knot Creek	3	Bridge	Augmented - rocks on natural bottom (disturbed)	5	3
Yellow/Shoal	Yellow Upper	4	No Bridge	Natural - sandy	0	0
Yellow/Shoal	Yellow Lower	5	Bridge	Natural - course sand	0	0
Conecuh	Conecuh B	6	Bridge	Natural - some fines and sandy	0	0
Conecuh	Conecuh A	6	Bridge	Natural - course sand	0	0
Conecuh	Conecuh E	2	Bridge	Natural - fines	4	5
Conecuh	Conecuh D	4	Bridge	Natural - fines	0	0
Conecuh	Log Creek	3	Bridge	Natural - fines and sand	0	0
Conecuh	Manning Creek	3	Wooden bridge	Natural - fines and sand	0	0
Conecuh	Indian Creek	2	Wooden bridge	Natural - fines and sands	0	0
Conecuh	Conecuh C	4	Bridge	Natural - sandy	0	0
Conecuh	Persimmon	4	Bridge	Natural - fines and sandy	0	6
Conecuh	Patsaliga Creek Upper	4	Bridge	Natural - fines and sandy	1	2
Conecuh	Patsaliga Creek Lower	4	Bridge	Natural - perhaps karst bottom	0	0

Infrastructure

During this study, the team sampled off older bridges, many cement but some wooden, and one damaged logging bridge which was closed to vehicular traffic (Table 4). At some locations, culverts rather than crossings were placed to connect upstream and downstream portions of waterbodies. The settling or shifting of culverts can lead to fragmentation of the streams. Poorly placed bridge supports or culverts can hinder movement of woody material, often leading to buildup upstream of the bridge (Johnson et al., 2002). Similarly, bridge spans which cause pinch points may result in flooding upstream or scouring around crossings (Johnson et al., 2002). In addition, the fragmentation, whether a road or power line easement, altered the system by vegetative clearing and some sort of hardening. Hardening created thermal shifts, which vegetation could have mitigated.

In June and July, the temperature differences between a bridge surface and a nearby wooded area could be as large as 11.2 °C. By October and November, this phenomenon was not as pronounced. Thermal emissions from heated stormwater from roadways, bridges, rocks, and riprap have the potential to alter the temperatures in streams, thereby diminishing the water quality though lower oxygen content and road debris (Johnson et al., 2002).

Conclusions

These results provide a baseline of conditions in the upper watersheds of Perdido, Conecuh, and Yellow/Shoal. Physical and chemical water quality parameters such as conductivity and pH had very few extreme values and were typical of conditions in the region. While most values of dissolved oxygen were above the EPA standard critical oxygen conditions, two locations (Perdido Creek and Conecuh River E) had multiple readings below 3 mg/L.

High dissolved nutrient concentrations, total nutrients, and chlorophyll *a* were observed at several locations. Locations in the Perdido watershed with high nutrients, chlorophyll *a*, or both were Perdido Creek, Hollinger Creek, and Narrow Gap Creek. Locations in the Conecuh watershed with high nutrients or chlorophyll *a* were Conecuh River E, Log Creek, Manning Creek, and Indian Creek. Locations in the Yellow/Shoal watershed rarely had high nutrients or chlorophyll *a*.

E. coli levels were often high at most of the locations sampled in all three watersheds. Only five locations (Persimmon Creek, Conecuh River A, B, C, and E) had a geometric mean below the EPA recreational standard of 126 MPN/100 mL. Some of the highest values occurred in the Yellow/Shoal watershed, particularly Poley and Lightwood Knot Creeks.

Most locations had invasive plant species along the streambanks. Surprisingly, some locations with native vegetation also had poor water quality, such as Conecuh E, Indian Creek, and Log Creek. We observed that some bridge crossings resulted in fragmentation of streams during low flow periods.

Acknowledgements

We thank Anthony Alberda, Haley Gancel, Amanda Croteau, Caitlin Turnbull, Andrew Williams, and Mackenzie Rothfus who assisted in the field sampling. We thank Jeremy Bosso and John Harmuth for *E. coli* analyses. Mitchell Alexis, Madison Harvey, Isabella Orrantia, Kelly Humphreys, and Mackenzie Rothfus assisted with laboratory analysis. We thank Jan Macauley for copy editing an earlier version of this manuscript.

References

Blaustein, R. J. (2008). Biodiversity hotspot: The Florida panhandle. *BioScience*, 58(9), 784-790. https://doi.org/10.1641/b580904

ERMA. 2015. Web Application: Gulf of Mexico Environmental Response Management Application, National Oceanic and Atmospheric Administration. Retrieved: January, 24, 2023, from http://erma.noaa.gov/Gulf of Mexico

Florida Geological Survey. (1965). Water resources of Escambia and Santa Rosa Counties, Florida.

Folkerts, G. W. (1982). The Gulf-Coast pitcher plant bogs. *American Scientist*. 70(3), 260–267.

Gaia Topographic Maps, https://www.gaiagps.com/

Gulf Coastal Plain Ecosystem Partnership. (2006). *Stewardship of Aquatic Resources for the Gulf Coastal Plain Ecosystem Partnership: an aquatic management plan*.

Hillel, D. (1982). *Introduction to soil physics.* Academic Press.

Holmes, R.M., Aminot, A., Kérouel, R., Hooker, B.A., & Peterson, B. J. (1999). A simple and precise method for measuring ammonium in marine and freshwater ecosystems. *Canadian Journal of Fisheries and Aquatic Sciences,* 56, 1801-1808.

Johnson, P. A., Hey, R. D., Brown, E. R., & Rosgen, D. L. (2002). Stream Restoration in the vicinity of bridges. *Journal of the American Water Resources Association*, 24(4), 274-281.

Livingston, R.J. (2003). *Trophic organization in coastal systems.*

Meyer, J. L., Strayer, D. L., Wallace, J. B., Eggert, Helfman, G. S., & Leonard, N. E. (2007). The Contribution to Headwater Streams to Biodiversity in River Networks. *Journal of the American Water Resources Association,* 43(1), 19.

National Oceanic and Atmospheric Administration. (2022). Environmental Response Management Application (ERMA) [Data set]. https://erma.noaa.gov/National Oceanic and Atmospheric Administration. (2023). *Local Climatological Data (LCD)* [Data set]. https://www.ncdc.noaa.gov/cdo-web/datatools/lcd

National Oceanic and Atmospheric Administration. (2023). *National Weather Service* [Data set]. https://www.weather.gov/

Northwest Florida Water Management District (NWFWMD) Perdido River and bay SWIM plan. October 2017. Program Development Series 17-07.

Olinger, L.W., Rogers, R.G., Force, P.L., Todd, T.L., Mullings, B.L., Bisterfeld, F.T., and Wise, L.A. (1975). *Environmental and recovery studies of Escambia Bay and the Pensacola Bay system, Florida.* U.S. Environmental Protection Agency. EPA 904/9-76-016.

Parsons, T. R., Maita, Y. & Lalli, C. M. (1984). *A manual of chemical and biological methods for seawater analysis.* Pergamon Press.

Schloerke B, Cook D, Larmarange J, Briatte F, Marbach M, Thoen E, Elberg A, Crowley J (2022). GGally: Extension to 'ggplot2'. https://ggobi.github.io/ggally/, https://github.com/ggobi/ggally.

Schnetger, B., & Lehners. C. (2014). Determination of nitrate plus nitrite in small volume marine water samples using vanadium (III) chloride as a reduction agent. *Marine Chemistry,* 160, 91-98.

Soil Survey Staff. (1999). *Soil taxonomy: A basic system of soil classification for making and interpreting soil surveys.* (2nd ed.). Natural Resources Conservation Service. U.S. Department of Agriculture Handbook 436.

Thom, T.A. (2005). *Factors Influencing Biological Communities and Stream Assessments in Southeastern Coastal Plain Streams, USA.* PhD. Dissertation. University of Georgia.

U.S. Department of Agriculture, Natural Resources Conservation Service. (2022). *Land resource regions and major land resource areas of the United States, the Caribbean, and the Pacific Basin.* U.S. Department of Agriculture, Agriculture Handbook 296.

U.S. Census. (2020). *https://www.census.gov/programs-surveys/decennial-census/decade/2020/2020-census-results.html.* Date accessed:2022-12-19

U.S. Environmental Protection Agency. (1986). *Ambient aquatic life water quality criteria for dissolved oxygen (freshwater).* EPA 440/5-86-003.

U.S. Environmental Protection Agency. (2000). *Ambient Water Quality Criteria Recommendations: Information Supporting the Development of State and Tribal Nutrient Criteria. Rivers and Streams in Nutrient Ecoregion XII.* EPA 822-B-00-021.

U.S. Environmental Protection Agency. (2012). *Recreational Water Quality Criteria.* Office of Water Report 820-F-12-058.

U.S. Environmental Protection Agency. 2020. *National Aquatic Resource Surveys. National Rivers and Streams Assessment 2013–2014.* (Data and metadata files). Available from: http://www.epa.gov/national-aquatic-resource-surveys/data-national-aquatic-resource-surveys. Date accessed:2022-12-19.

Wallace, J.B., & Benke, A. C. (1984). Quantification of Wood Habitat in Subtropical Coastal Plain Streams. *Canadian Journal of Fisheries and Aquatic Sciences*. 41,1643-1652.

Welshmeyer, N.A. (1994). Fluorometric analysis of Chlorophyll a in the presence of chlorophyll and pheopigments. *Limnology and Oceanography.* 39, 1985-1992.

Wickham, H. (2016). ggplot2: Elegant Graphics for Data Analysis. Springer-Verlag New York.

Wolfe, S. H., Reidenaur, J.A., and Means, D.B. (1988) An Ecological Characterization of the Florida Panhandle. US Dept of the Interior, FWS Biological Report 88.

Appendix A

Perdido Sampling Site Characteristics

The Perdido River originates in Escambia County, AL and flows about 71 km southward before entering Perdido Bay. The river and bay form the boundary between Alabama and Florida, with roughly 75% of the watershed located in Alabama and the remaining 25% in Florida (Figure A1). The upper watershed is rural, with most land uses as natural lands, silviculture, or agricultural row crops such as cotton, corn, peanuts, or soybeans. In Alabama, the middle portion of the watershed is undergoing a conversion from natural lands to agriculture (mainly sod farms) and pockets of new housing. In Florida, the middle portion of the watershed is being converted from natural lands or farms to high density housing. The growth spurt in Florida is being propelled by new industry and commercial development. The Perdido River Watershed encompasses an area of 323,749 square hectares.

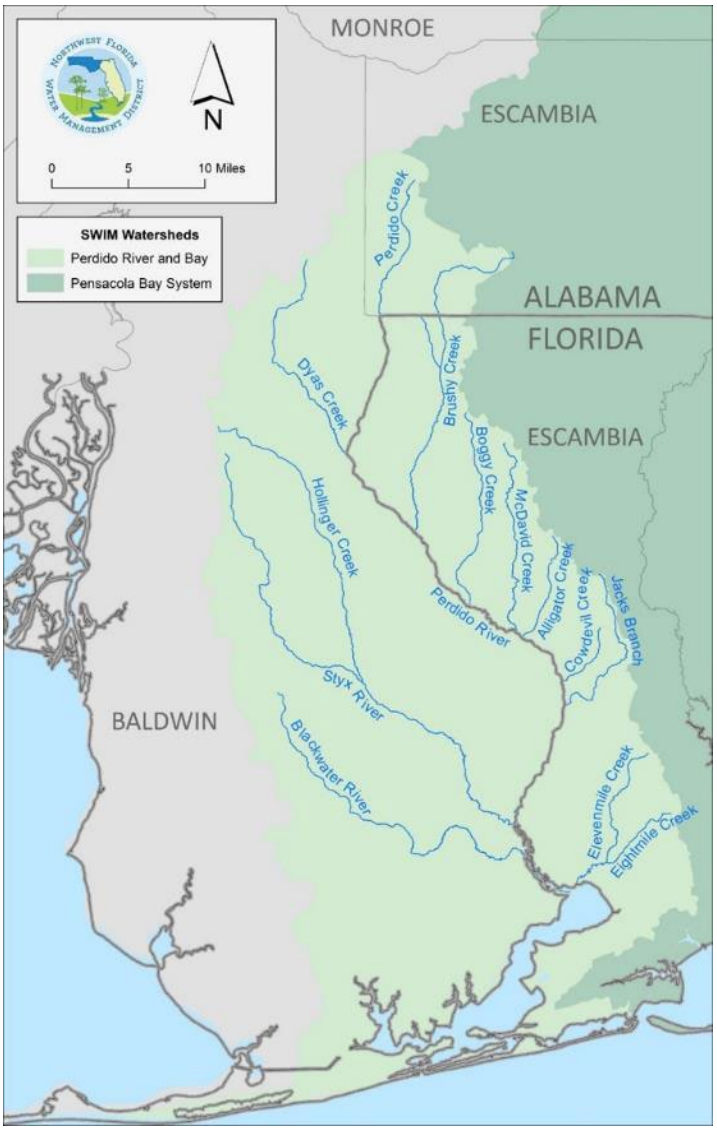


Figure A1 - *Map of the Perdido Bay Watershed reproduced from NWFWMD (2017).*

Perdido Creek

Figure A2 -*Perdido Creek, Perdido Watershed, Lat/Long 31.12509, -87.56354, Escambia County, Alabama*

Perdido Creek (Figure A2) originates approximately1.93 km east-northeast from the sampling location on private property. The sampling station is a 2nd-order creek in a rural area surrounded by agriculture (corn) and silviculture (pine) (Figure A3). A sand-mining operation is 1.6 km away from the sampling site. Two small trailer parks are also located within 1.6 km of the site. The creek is bisected by Alabama County Road 1, a paved two-lane road with two 3-ft cement culverts connecting the creek. The riparian zone is fragmented by the culverts. The elevation at the sampling station is 94.2 m and relatively flat. Upstream of the sampling site is a pine plantation. The downstream area is in a natural state and overgrown with grape (*Vitis spp.)* and smilax (*Smilax spp.)* vines. The creek was turbid and not flowing during some of the sampling trips (Figure A4). Frogs, turtles, minnows, and a bluegill were observed. Rocks were observed near the culverts and trash was noted along the roadside and in the creek. Native plants

included pine (*Pinus spp.*), oak (*Quercus spp*.), wax myrtle (*Morella spp.*), cypress vine (*Ipomoea spp.*), and goldenrod (*Solidago spp*). Cypress vine and goldenrod were in bloom during some trips. Invasive plants included Chinese privet (*Ligustrum sinense*) and Chinese tallow (*Sapium sebiferum*).

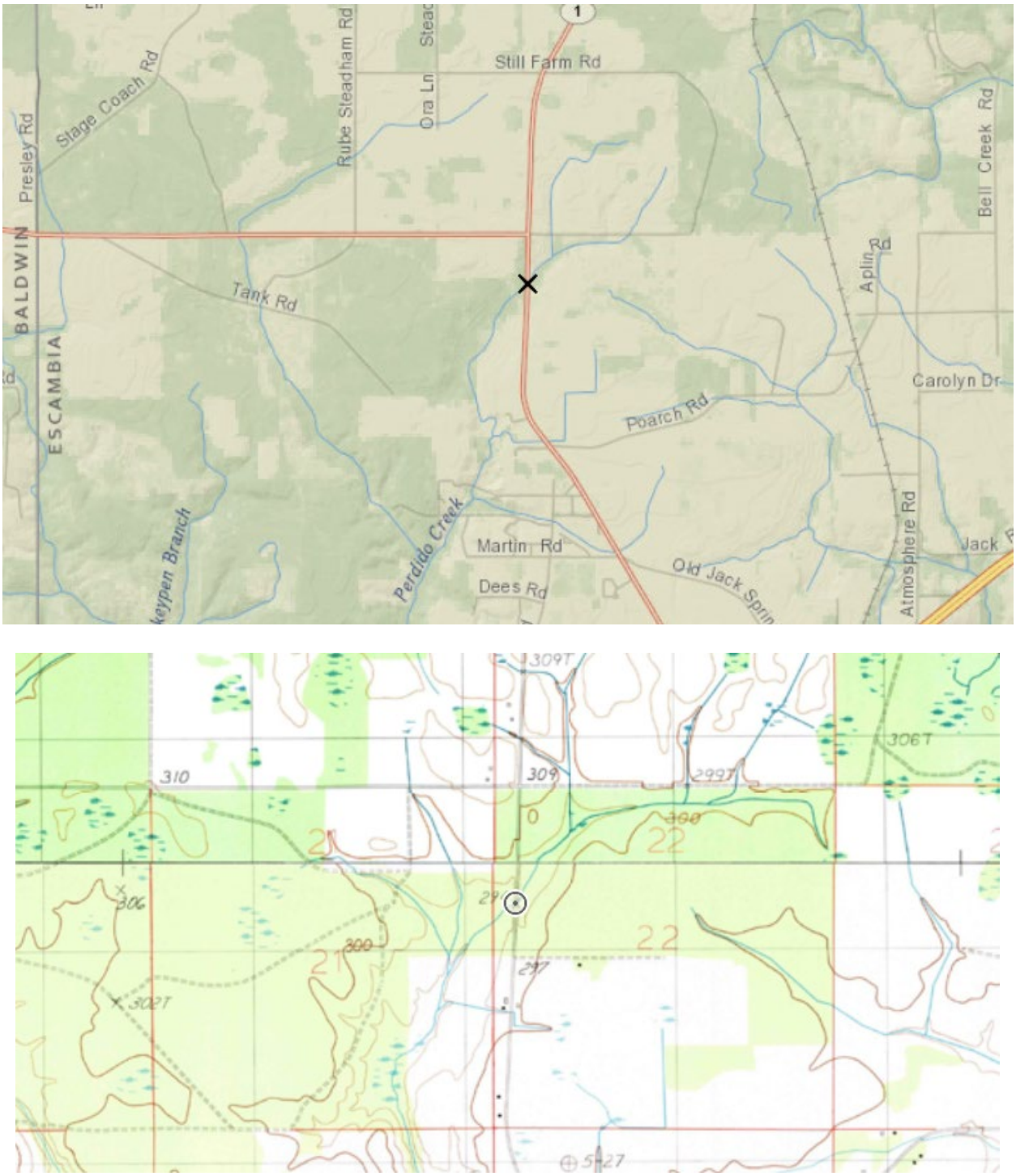


Figure A3 – *Maps of Perdido Creek Sampling Site*

View looking upstream (wet)

View of culvert (wet)

View looking downstream.

View looking upstream (dry)

View of culvert (dry)

View looking downstream

Figure A4 - *Photos of Perdido Creek Sampling Site*

Perdido River

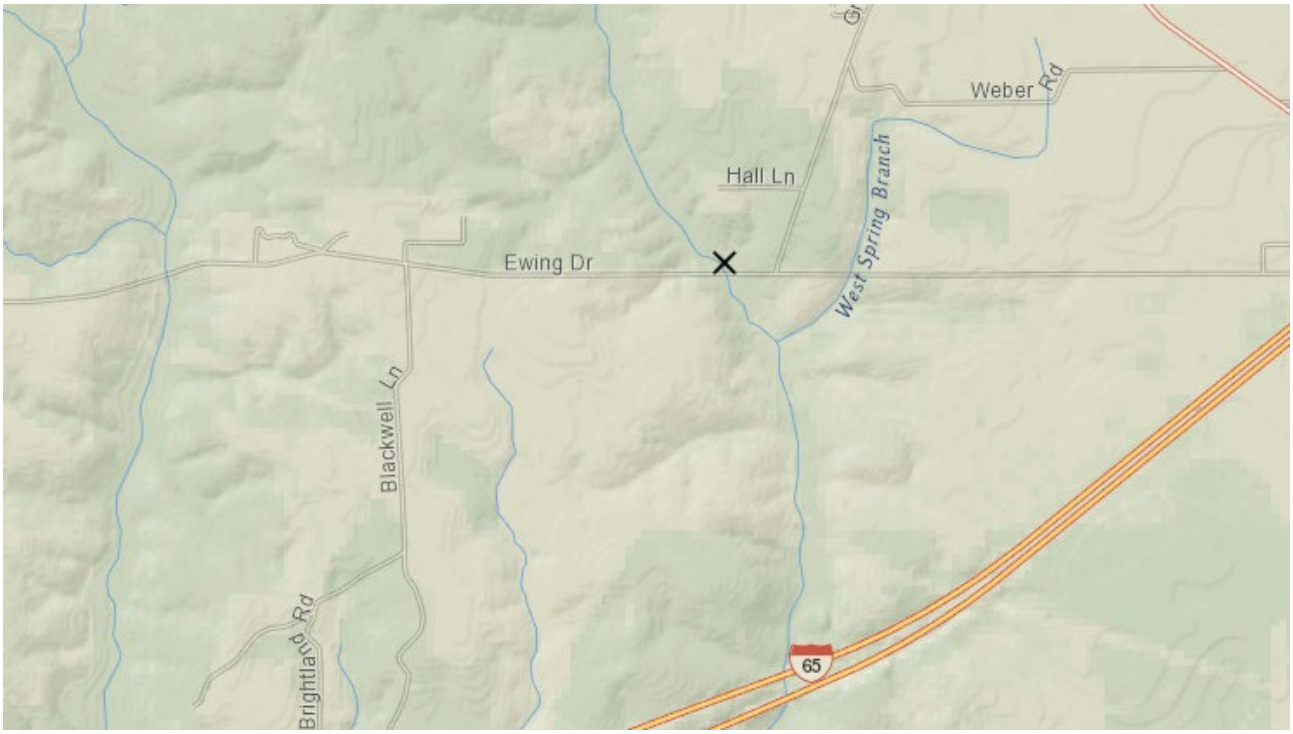


Figure A5 - *Perdido River, Perdido Watershed, Lat/Long 31.08163, -87.57012, Escambia County, Alabama*

The Perdido River is a 3rd-order system at this sampling station (Figure A5). It originates approximately 5.63 km north-northeast and flows swiftly southward through silviculture (pine) and natural lands. The river flows through a braided tulip poplar and bay swamp which has several channels. Small hummocks were observed upstream in the swamp. The tree canopy upstream covers the river and no submerged aquatic vegetation was observed. Downstream, the river canopy is open at the right-of-way before re-entering the dense forest canopy.

Samples were collected from an old, cement bridge with wooden pilings, accessed by a two-lane paved road (Figures A5 and A6). The bridge length (bank to bank) was 36 m, but the creek width was 24 m. Upstream from the bridge, several small channels converged as they flowed under the bridge and became organized into a single channel downriver. The bridge has a

natural bottom, which allows the river to meander without obstruction downstream. The elevation at this bridge site is approximately 82.3 m, with the bridge located at a dip in the terrain (Figure A7). When looking downstream, the adjacent road rises 6° to the west and 2° to the east. Road temperatures (41.2°C) were taken during the July 12, 2022 sampling event and were 11°C higher than the adjacent wooded area (30.2°C).

Bridge Structure (downstream)

Perdido River (looking upstream)

Perdido River (downstream side)

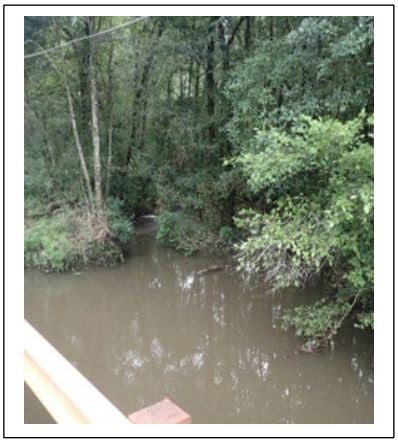


Figure A6 - *Photos of Perdido River Sampling Site*

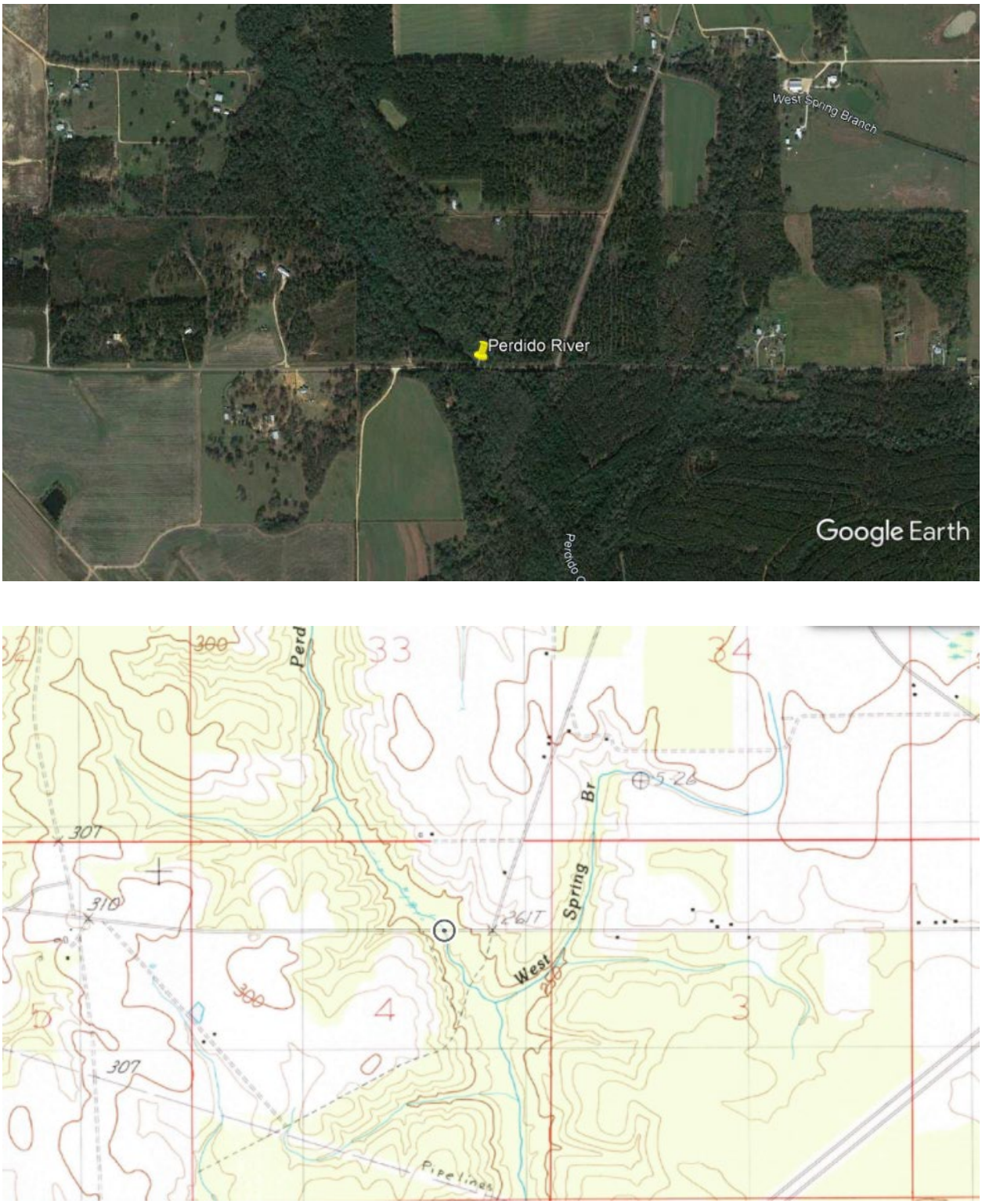


Figure A7 - *Maps of Perdido River Sampling Site*

Bushy Creek

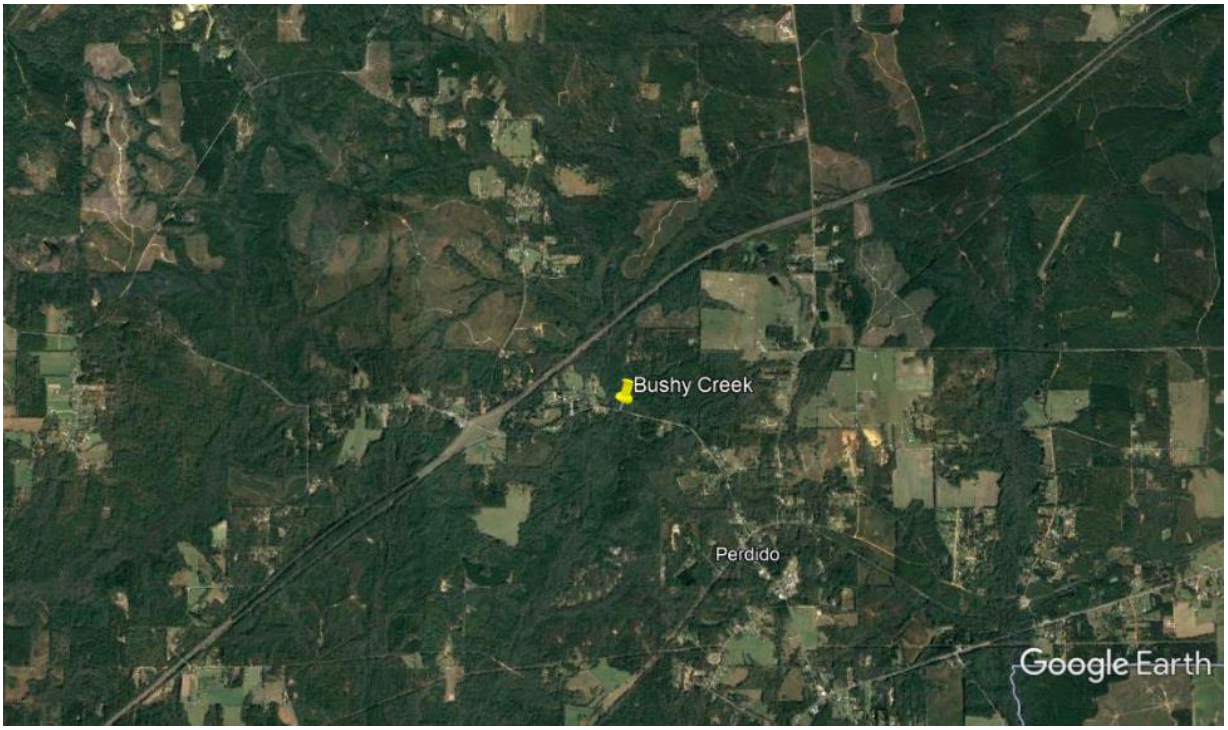


Figure A8 - *Bushy Creek, Perdido Watershed, Lat/Long 31.02143º N, -87.64120º W, Baldwin County, Alabama*

Bushy Creek (Figures A8 and A9) is a 3rd-order creek at this station and flows downstream to join Dyas Creek. Dyas Creek is the northernmost tributary entering the mainstem of the river. Most of the landscape within a 1.6 km radius is a combination of natural lands and silviculture. Interstate 65 and County Road 47 are within this 1.6 km radius. The road leading to the bridge is a two-lane paved road and the bridge is cement on cement pilings. Riprap was used to protect the pilings and the creek bank.

The elevation of the creek at this site is approximately 61 m and is accessed by a long bridge (57 m) on a two-lane, paved road. Upstream, a large wetland was fragmented by this bridge, resulting in an area of approximately18 m (left when looking downstream) with low to no flow, but 19 m (right when looking downstream) with swift flow, which was the location chosen for the sampling site. The creek is shallow (<1 m), has both submerged and emergent aquatic vegetation (Tapegrass, *Vallisneria americana* and Golden Club, *Orontium spp*). It has a sandy bottom and a riparian zone with a mature canopy of trees that keeps the creek shaded (Figure A9).

Looking Upstream

Looking Downstream

View of Bridge

Figure A9 - *Map and Photos of Bushy Creek Sampling Site*

Hollinger Creek

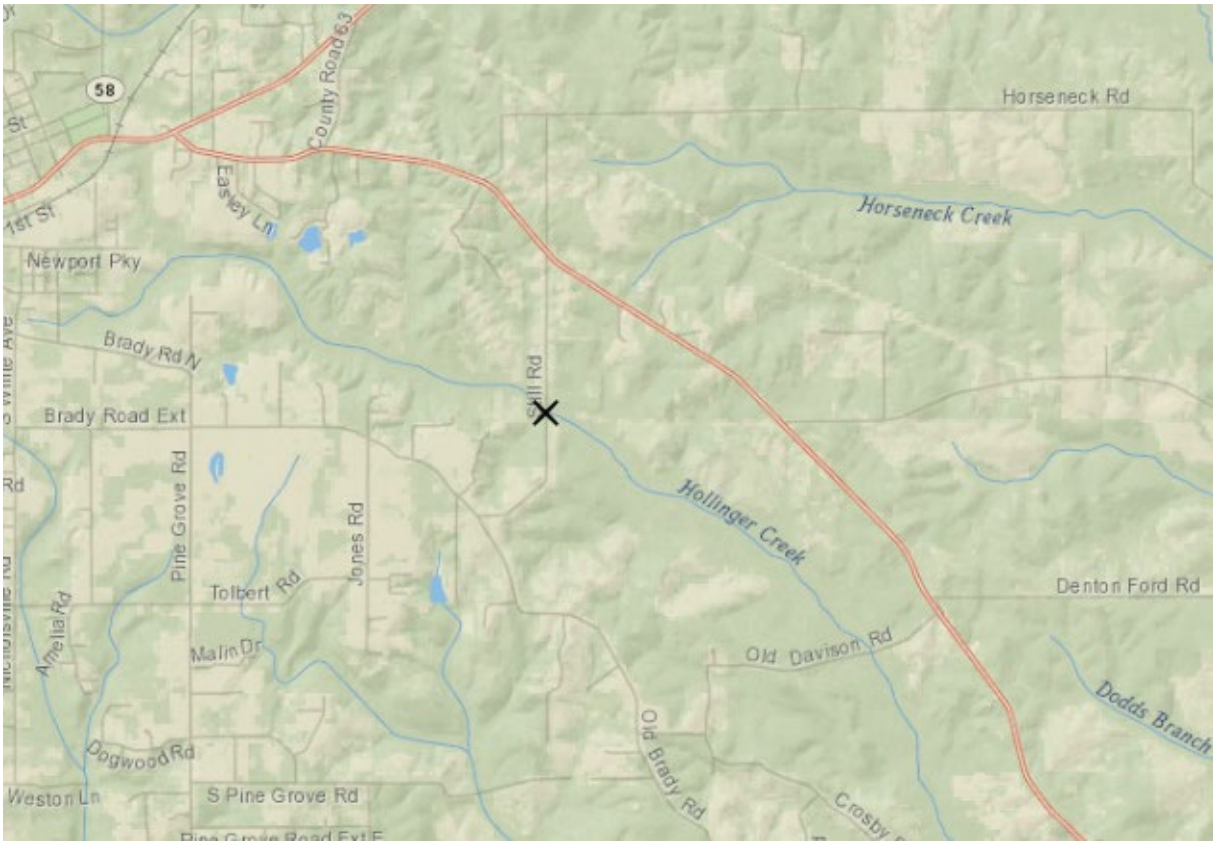
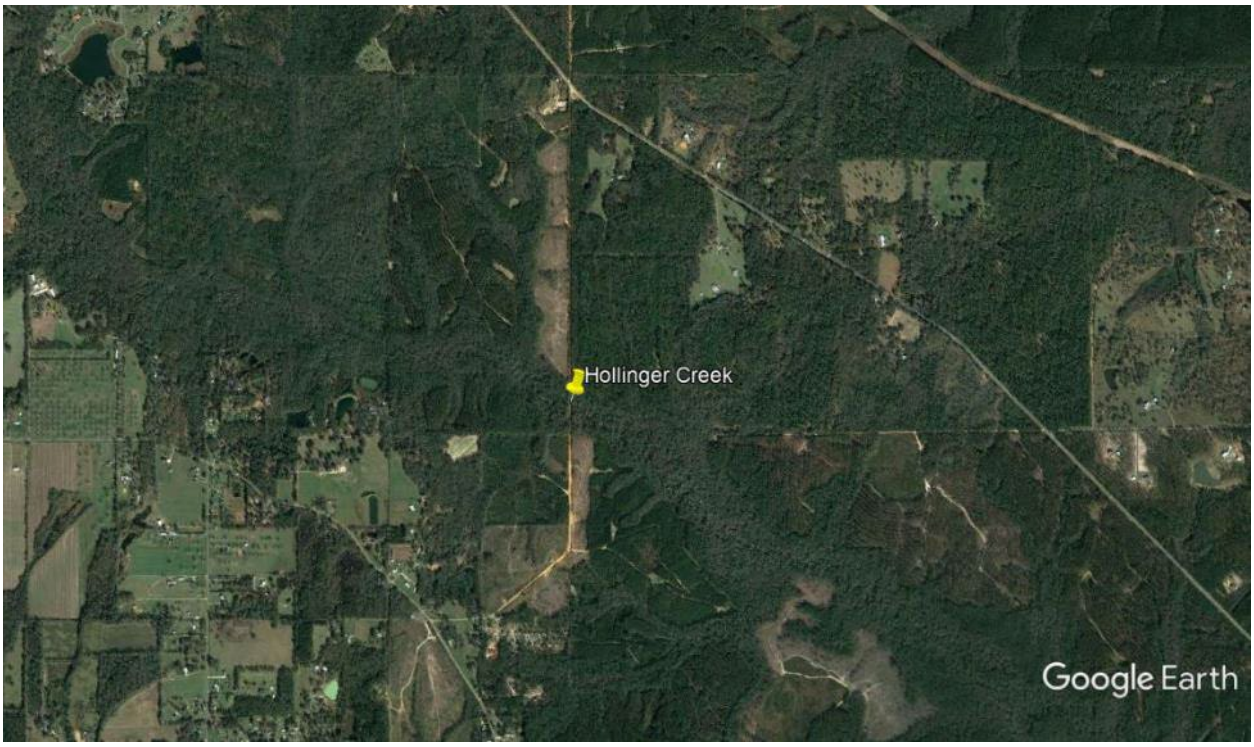


Figure A10 - *Hollinger Creek, Perdido Watershed, Lat/Long 30.86851 N, -87.71728 W, Baldwin County, AL*

Hollinger Creek (Figure A10) originates from east-southeast of Bay Minette, AL and is a 1st-order creek at the sampling site on Still Road, which is an unpaved dirt road in a rural setting. The surrounding area is mostly in a natural state with several small stands (20-40 ha) of silviculture outside of the riparian zone. A few small farmsteads are within 1.6 km of the sampling station, with most of their farm fields facing Still Road.

The site elevation is approximately 64 m above sea level. This location is relatively isolated (Figure A11). The bridge crossing the creek is a narrow, two-lane cement structure, positioned on six 'I-beams' and supported by wooden poles. The creek has a natural bottom, but

our team observed trash, including mattresses, tires, and several plastic bags, which may have been household debris, thrown near the creek banks. Hollinger Creek at Still Road was 1.2 m deep and had a good flow rate. A large bay swamp with well-vegetated banks was fragmented by the bridge crossing (Figure A12). Near the road, mainly along the disturbed edges, invasive species including *Albizia spp* (mimosa), *Ligustrum spp* (privet), and *Ligodium spp* (Japanese climbing fern) were observed.



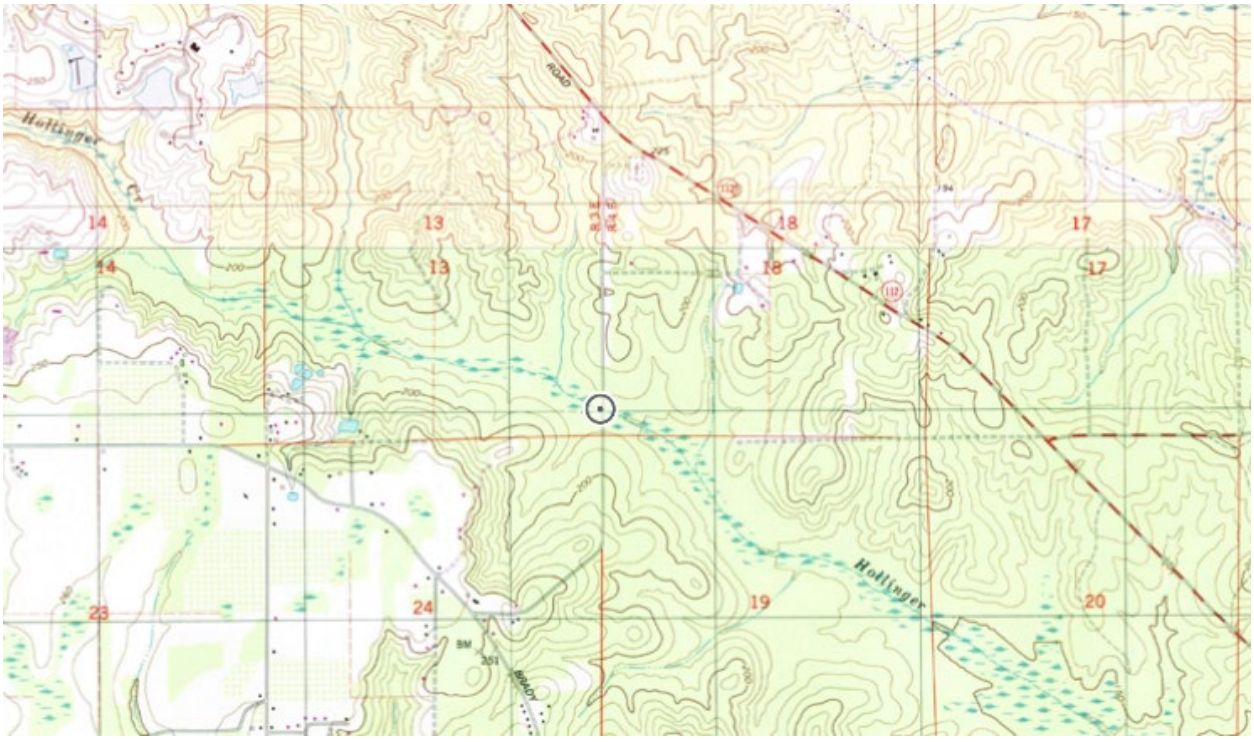


Figure A11 - *Maps and Photos of Hollinger Creek Sampling Site*

Looking Upstream Bridge in Still Road Looking Downstream

Figure A12 - *Maps and Photos of Hollinger Creek Sampling Site*

Styx River

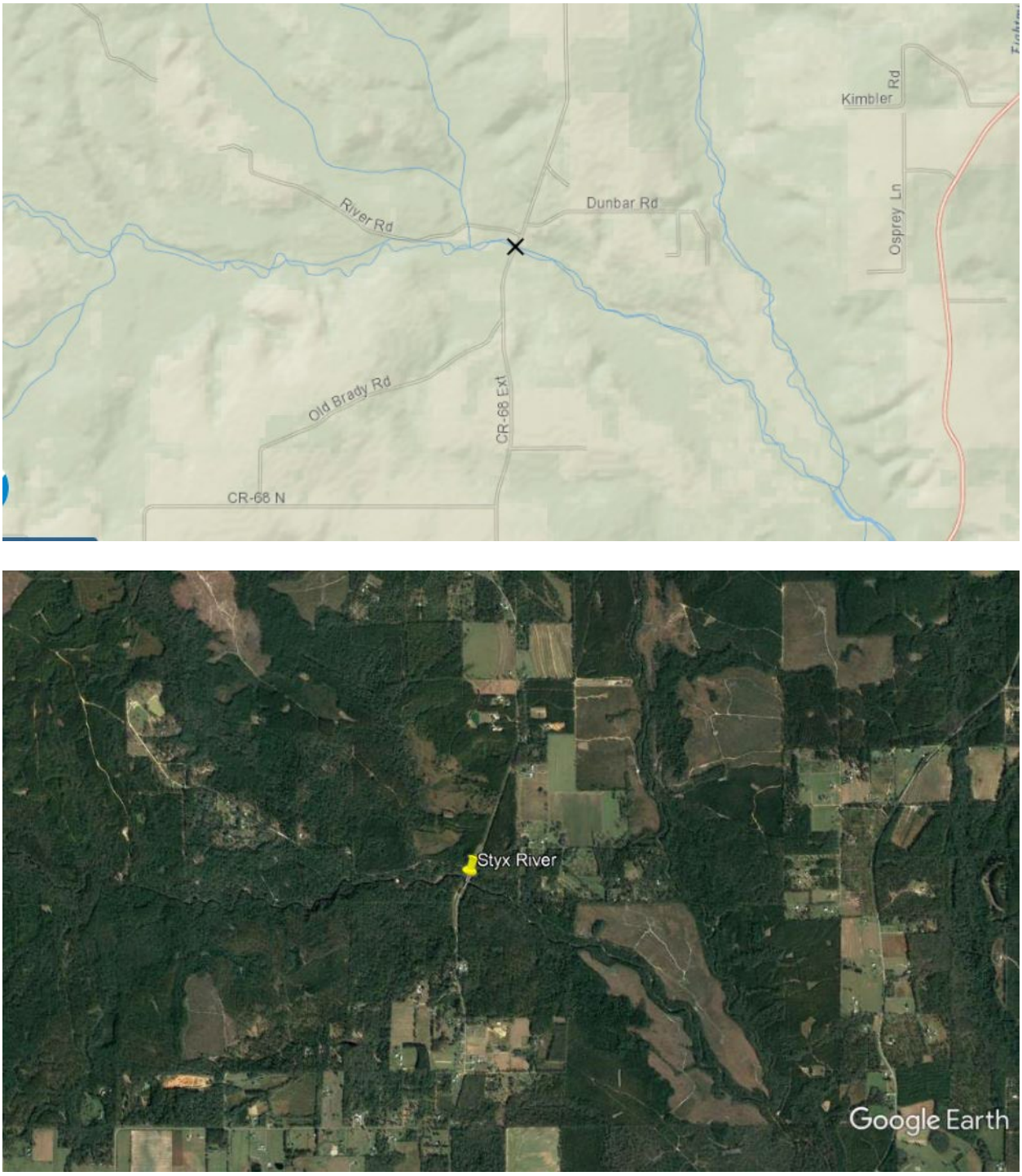
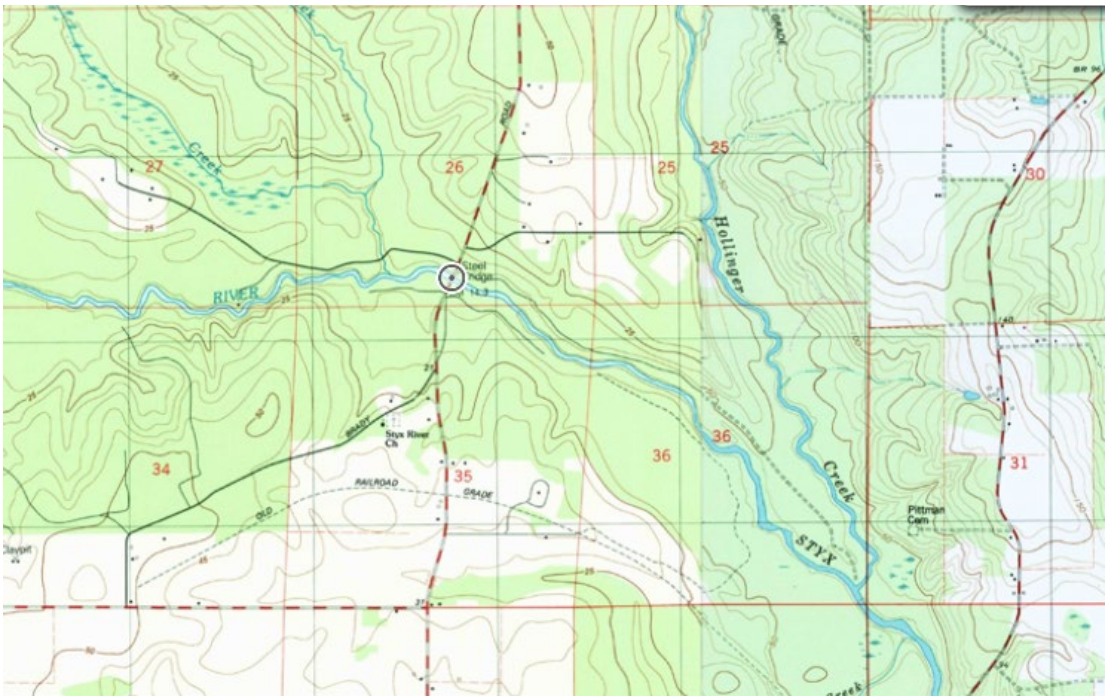


Figure A13 - *Styx River, Perdido Watershed, Lat/Long 30.66405 N, -87.63924 W, Baldwin County, AL*

The Styx River (Figure A13) converges with Hollinger Creek approximately 3.2 km downstream from this sampling site. Prior to joining Hollinger Creek, the Styx River is a 5th-order system which also forms just south of Bay Minette. Roughly 40% of the watershed in a 1.6 km radius is agricultural (corn and soybean), whereas the remaining approximately 60% is comprised of natural lands.

In areas that have been cleared in the vicinity of the river, a substantial riparian buffer has been maintained. Small sand pits were observed throughout the area where sand mining may have been attempted in the past. The convergence of the Styx River and Hollinger Creek represents the largest tributary and drainage system entering the Perdido River from the west. The elevation at this site is approximately 20 m above sea level and the stream velocity was high. The river was muddy during every visit to the site. Approximately 10.5 km west-northwest from the sampling station is a manmade lake (impounded 1st- and 2nd-order streams), which is adjacent to Steelwood Country Club. A power line easement runs parallel to the bridge on the upstream side and all the banks of the river at the bridge and easement were lined with large amounts of riprap (Figure A14). Upstream and downstream, outside of the bridge disturbance, the riparian vegetation was dominated by *Quercus spp* (oak), *Pinus spp* (pine), *Acer spp* (maple), *Liquidambar spp* (sweetgum), *Magnolia spp* (sweet bay), and *Nissa spp* (water tupelo).



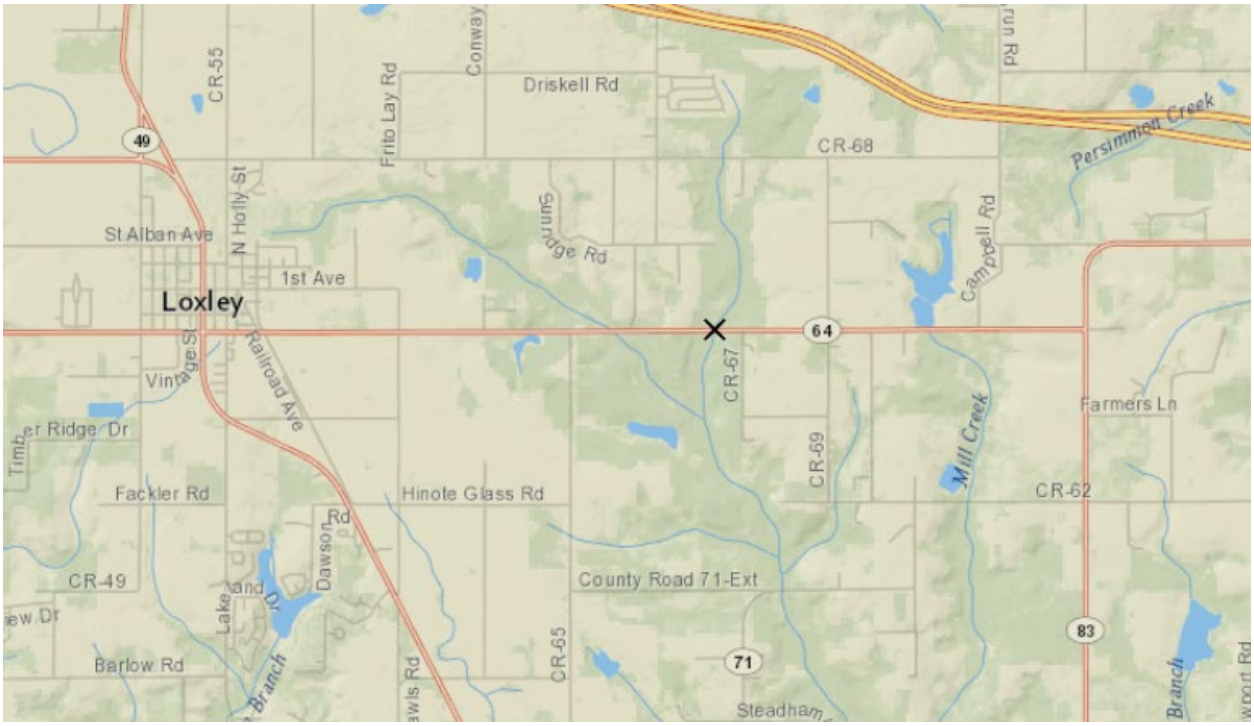
Looking Upstream

Looking Downstream

Banks of the Styx River

Figure A14 - *Map and Photos of Styx River Sampling Site*

Blackwater River, Perdido



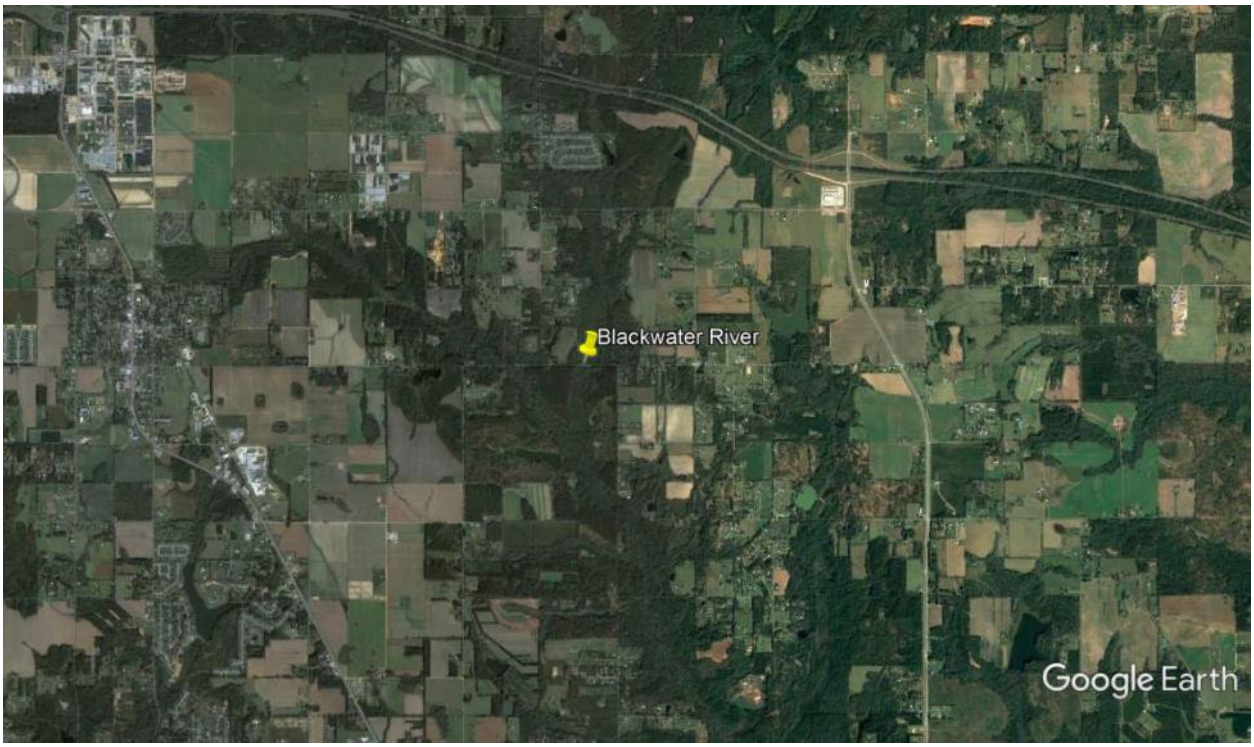


Figure A15 - *Blackwater River, Perdido Watershed, Lat/Long 30.61866 N, -87.7028 W, Baldwin County, AL*

The Blackwater River (Figure A15) is the third and last major tributary to enter the Perdido River mainstem from the west. The sampling station represents a 2nd-order creek, which originates south of I-10 and approximately 2.57 km north of the site (Figure A16). The creek emerges from a dense, sweet bay wetland system, flowing under a two-lane bridge with a natural bottom. The area within a 1.6 km radius is undergoing suburban development as well as a conversion from rural to agricultural, specifically sod farming. The elevation at this site is 41.75 m. The water was very quiet with little flow apparent. The riparian zone was intact (Figure A17). The vegetation was composed of oaks, maples, and the occasional cypress (*Taxodium spp*). The river was very dark with tannins.

Figure A16 - *Map of the Blackwater River Sampling Site*

Looking Upstream Looking Downstream Looking towards bridge

Figure A17 - *Photos of the Blackwater River Sampling Site*

Negro Creek

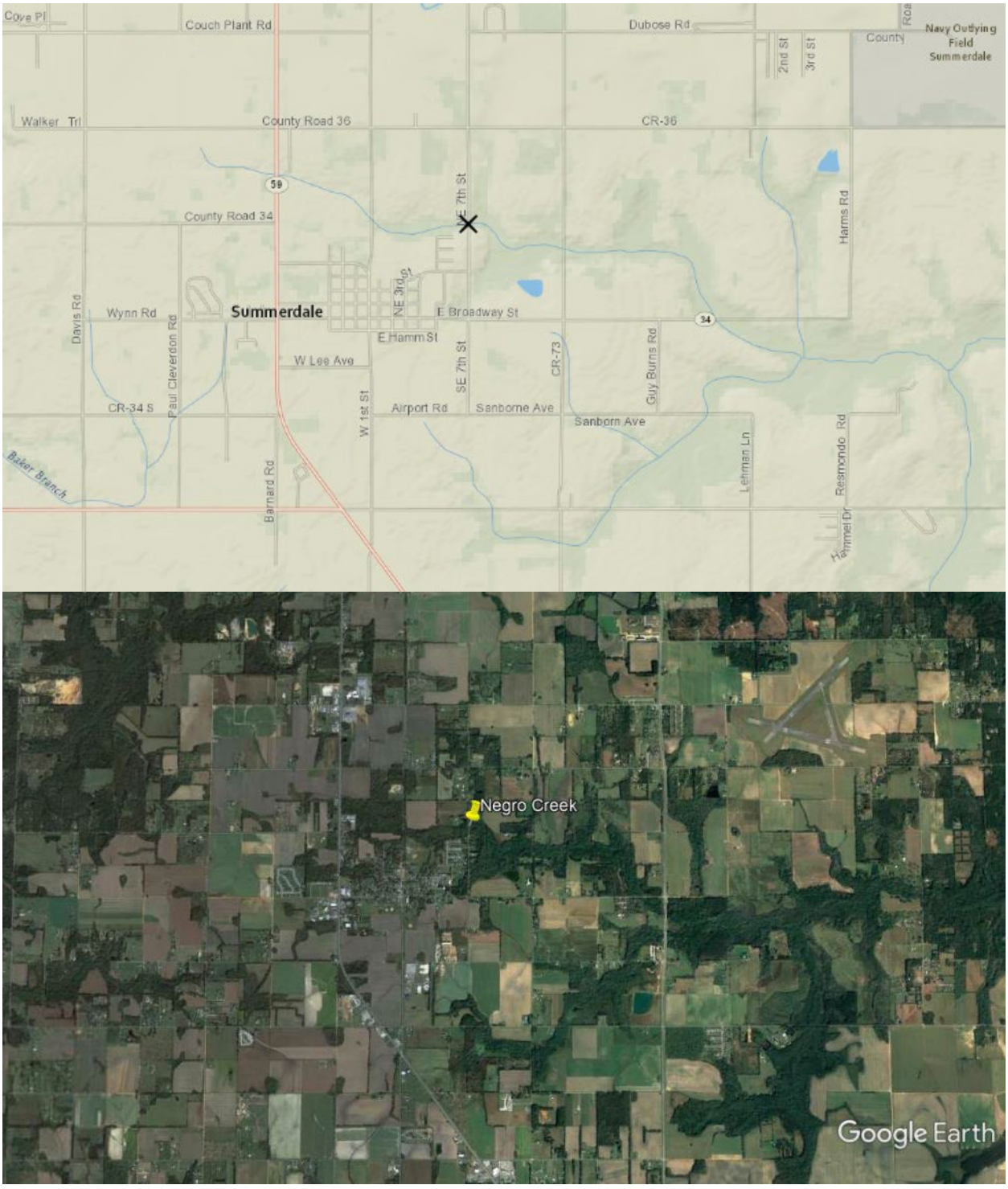


Figure A18 - *Negro Creek, Perdido Watershed, Lat/Long 30.49442 N, -87.69163 W, Baldwin County, AL*

Negro Creek (Figure A18) is a small, 2nd-order creek which drains the surrounding community of Summerdale towards the east. The community of Summerdale, AL, population approximately 1,500 (2020 census), is located within a 1.6 km radius east-southeast of the sampling station. The creek flows through agricultural lands and is fragmented by road crossings and culverts numerous times before it converges with Maurice Creek (from the southeast) and another unnamed creek south of Maurice Creek. Together they flow eastward to join the Blackwater River, which is a large tributary entering the lower Perdido River. Several of the creek crossings have culverts, including the sampling station, which had four 5-ft culverts conveying water from one side of a bay gall swamp to the other (Figure A19). The road has fragmented the original swamp, which, in turn, has resulted in the creek rerouting itself. The elevation at this site is 37 m above sea level and the surrounding topography is very flat.

Downstream Side of Road

Creek Channel

Looking Upstream

Figure A19 - *Map and Photos of Negro Creek Sampling Site*

Narrow Gap Creek

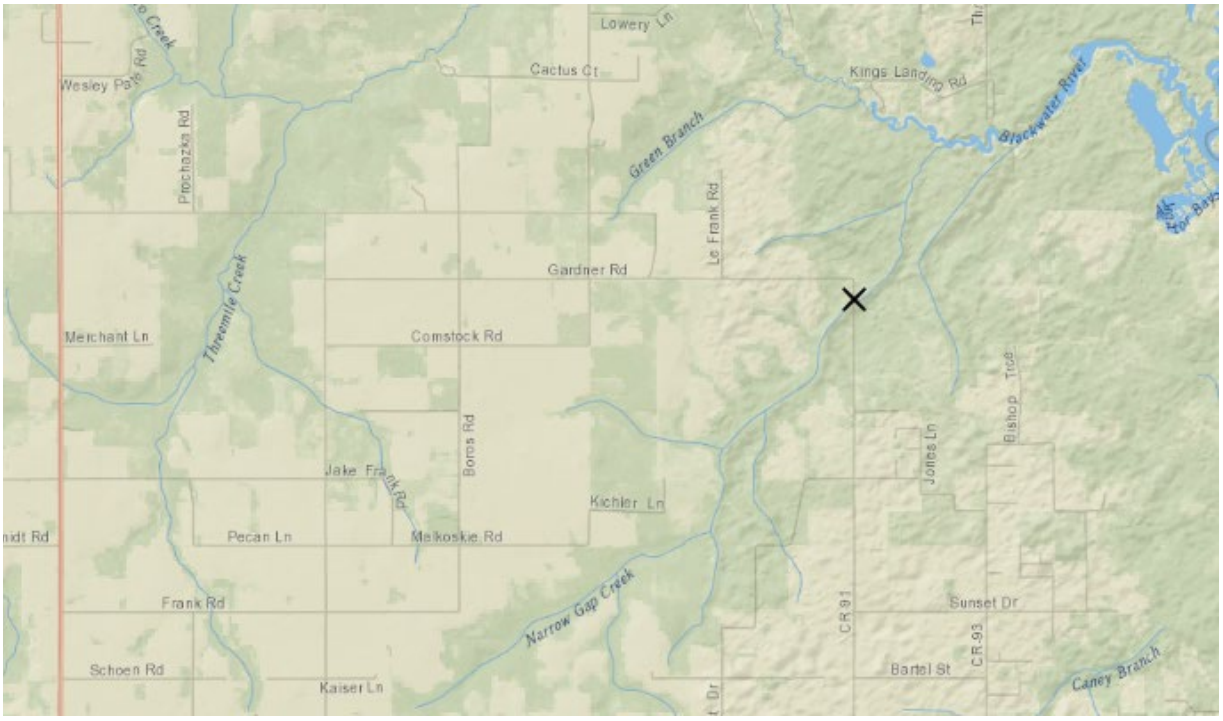
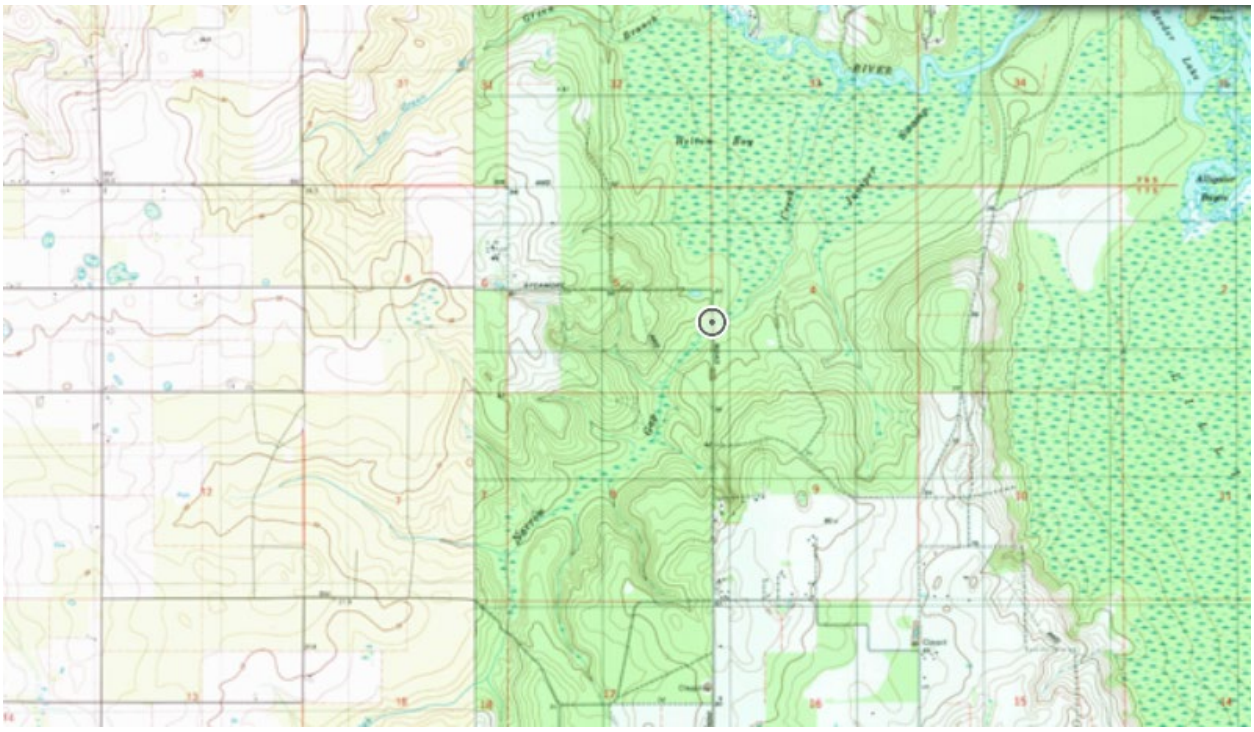


Figure A20 - *Narrow Gap Creek, Perdido Watershed, Lat/Long 30.46336, -87.48052, Baldwin County, Alabama*

The Narrow Gap Creek site (Figure A20) is located within conservation lands (Forever Wild Land Trust) and is a 3rd-order creek. The creek originates roughly 5 miles west-southwest from the sampling station and flows into Helton Bay and Juniper Swamp before flowing into the lower Blackwater River. Negro Creek enters the Blackwater River approximately 9.7 km upstream from this site. The elevation at this site is approximately 15 m above sea level. Roughly 95% of the area within a 1.6-km radius is natural land. A small culvert (approximately one foot in diameter) located on the southeast side of the road and creek flows over rocks before entering the creek (Figure A21). The tree canopy was mature and in excellent shape. The forest appears to be on a fire rotation cycle, with evidence of a burn within the last two years observed in a nearby upland area.



Looking Upstream

Looking Downstream

Culvert

Figure A21 - *Map and Photos of Narrow Gap Creek Sampling Site*

Appendix B

Conecuh Sampling Site Characteristics

The Escambia/Conecuh River (Figure B1) originates in Union Springs, AL and travels approximately 386 km before discharging into Escambia Bay. The watershed encompasses 1,093,757 square hectares, 110,075 of which are in Florida. Described as a classic alluvial river, the Escambia/Conecuh carries a heavy sediment load and an average annual discharge of 6,300 cubic feet per second (cfs). Flow rates vary based on rainfall closer to the coast, with the upper portion of the watershed generally recharging the groundwater basin.

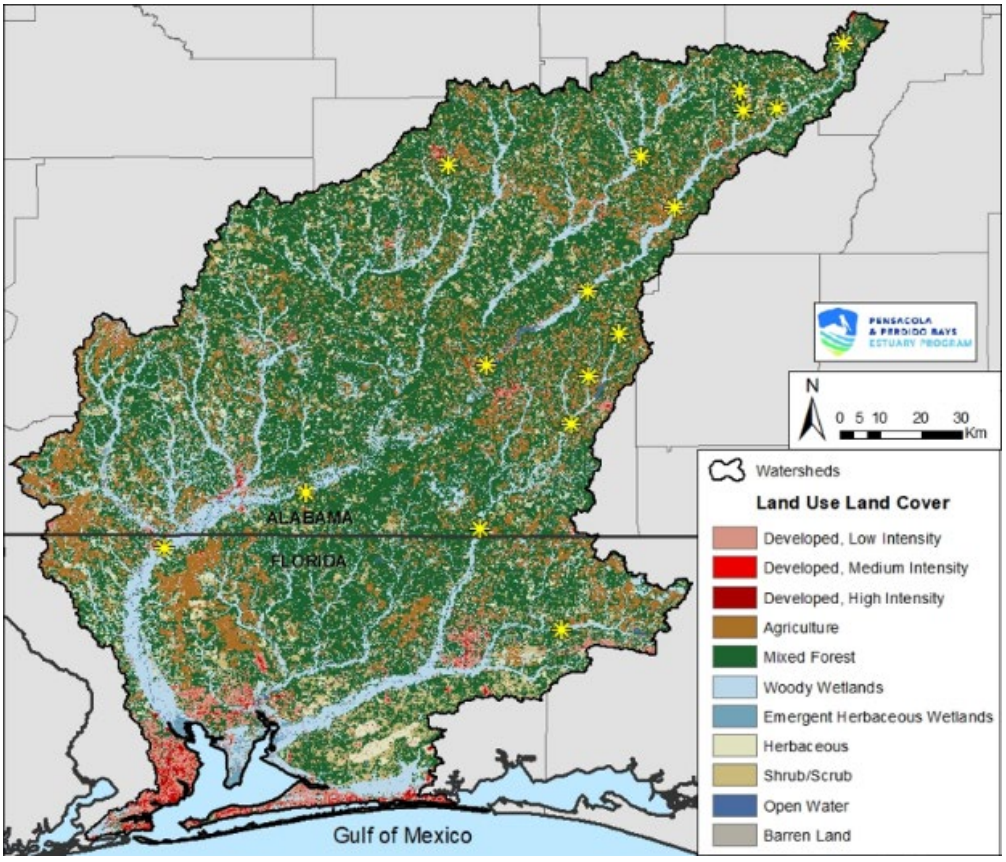


Figure B1 - *Map of the Pensacola and Perdido Bays Land Use and Land Cover from Pensacola and Perdido Bays Estuary Program*

Conecuh River E

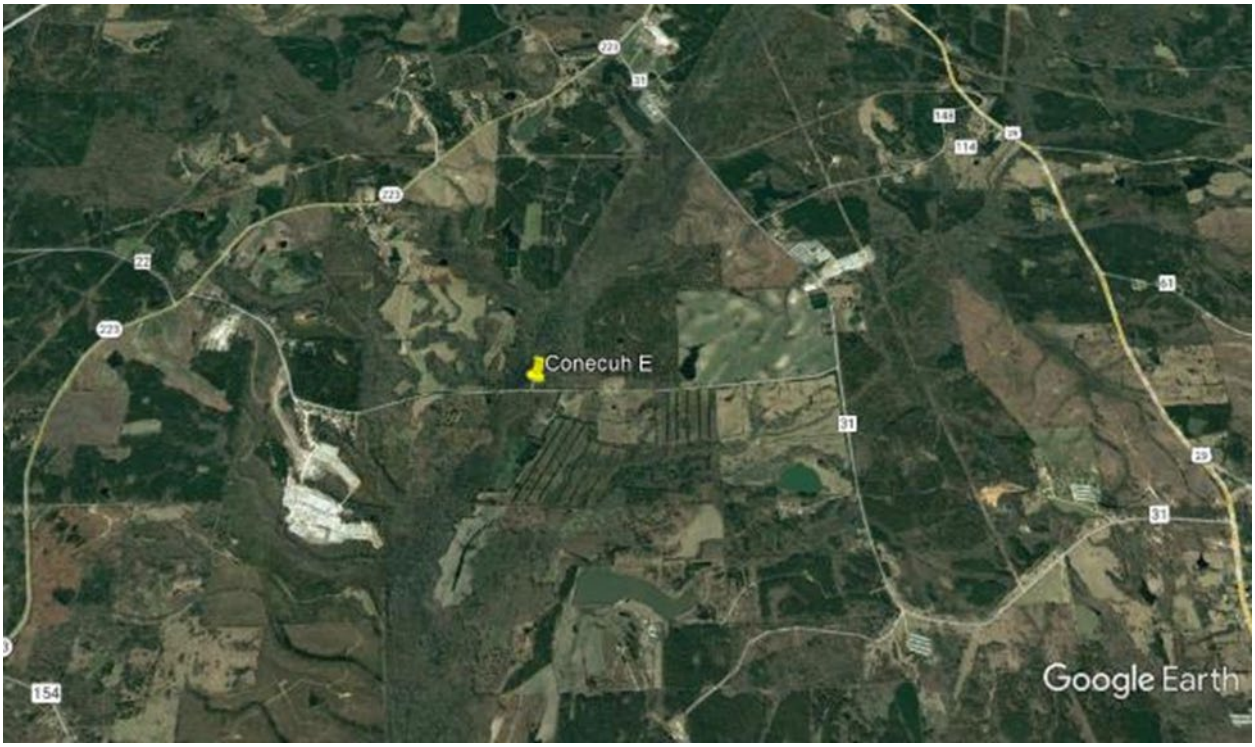


Figure B2 - *Conecuh E, Conecuh River Watershed, Lat/Long 32.08169, -85.73517, Bullock County, Alabama*

Sampling station Conecuh E (Figure B2) represents the uppermost portion of the Conecuh River watershed, which was sampled for this study. The actual headwaters are approximately 6.4 km north of this site. At this station, the river is a 2nd-order creek with a very low flow. Over the study period, the vegetation on the adjoining banks grew together, forming a floating carpet. The area is a mix of natural lands and agriculture and would be classified as rural (Figure B3). The station is a cement bridge with three pilings, accessed by a two-lane, paved road. The station is 136 m above sea level and the bridge fragments (constricts) a large wetland area, which appears to be three distinct channels that all flow and convene at the bridge. County Road 22 has been built on an elevated ridge and approximately 0.48 km of lowland swamp borders the road.

The bridge is 58 m in length. The left access road to the bridge is 272 m to the highest point, with a slope of 5º (when looking downstream). The right access road is 747 m to the highest point, with a slope of 4º. The bridge has a natural bottom and is 3 m in depth, which may be a result of the volume of water moving through this area. The upstream side of the bridge is a large, low-lying, wetland area with three distinct channels (originating from the west, north, and east) and small, elevated, vegetated areas in between each channel. The upstream and downstream waters were quiet during the five visits to the site. On each visit, more vegetation from the downstream banks was growing towards the middle of the channel. By the last visit the vegetation had almost grown together to cover the water. Ample duckweed filled the interstitial areas (Figure B4).

The area surrounding this station has a few small, private farmsteads and one large, agricultural business growing ornamental plants for large box stores (BonniePlants.com). A series of greenhouses are located west-southwest of the sampling station.

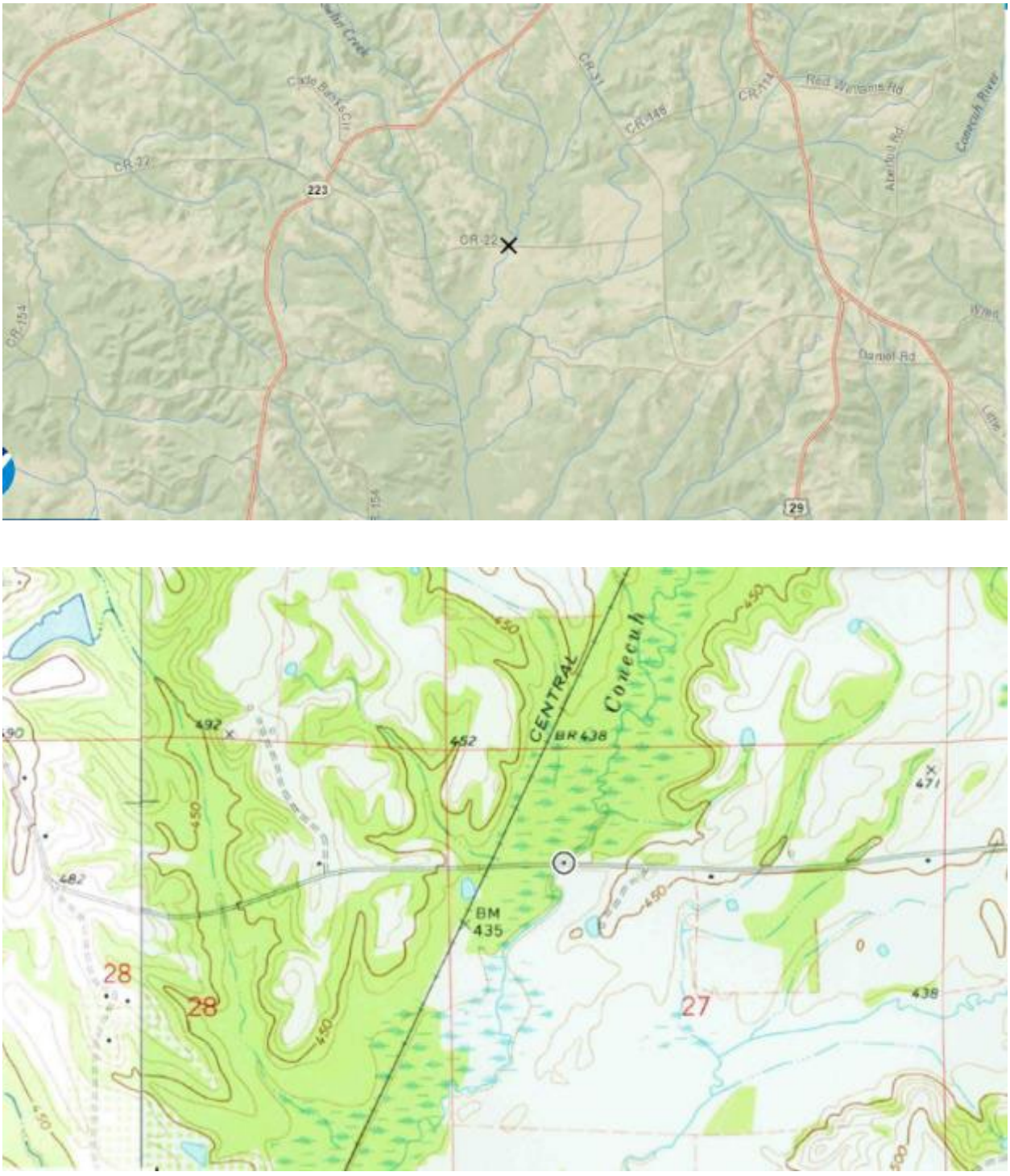


Figure B3 - *Maps of Conecuh E Sampling Site*

Looking Downstream June 2022

Looking Downstream November 2022

Upstream looking west

Looking upstream from middle

Upstream looking east

Figure B4 - *Photos of Conecuh E Sampling Site*

Conecuh River D

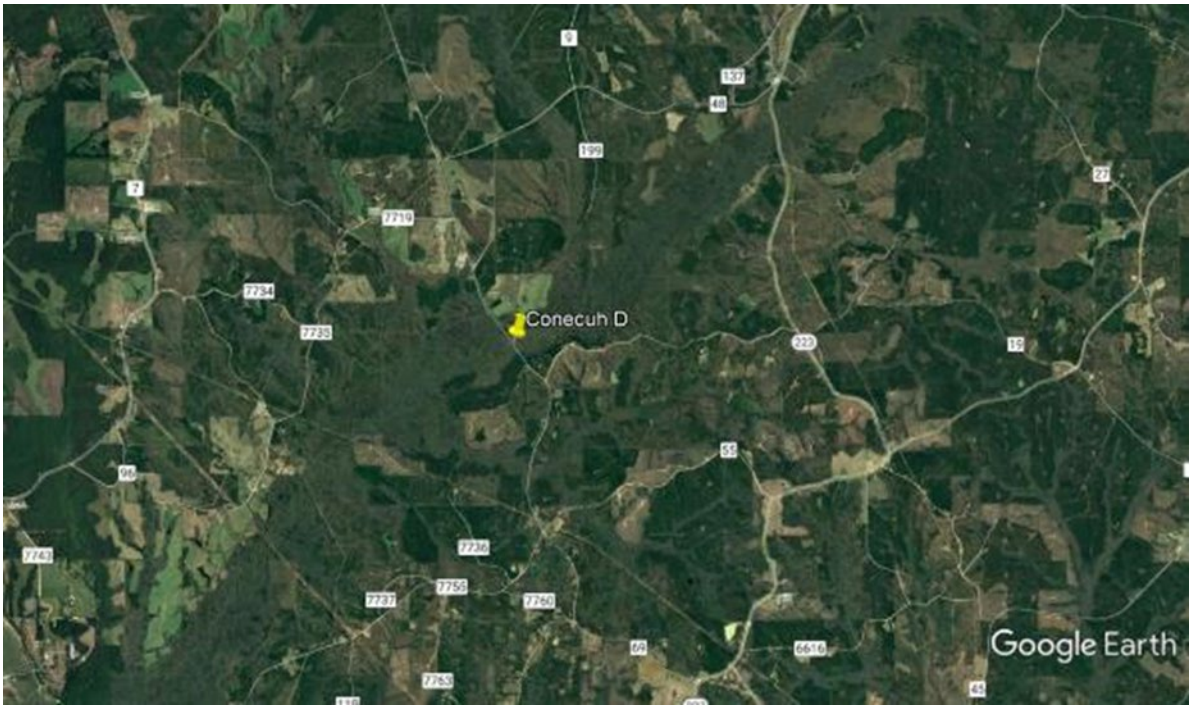


Figure B5 - *Conecuh D, Conecuh River Watershed, Lat/Long 31.92230, -85.86093, Pike County, AL*

The sampling station Conecuh D (Figure B5) is approximately 24 km downstream of Conecuh E. This site is in a thickly forested area with a dense canopy shading the station (Figure B6). The river is 4th order at this site and the floodplain is approximately 1.1 km wide. A two-lane, paved road leads to a bridge 88 m long, and the main channel is 22 m in width. The road approaching the bridge is flat and lower than the bridge, so no slope was recorded. The remnants of an old boat ramp (left side when facing downstream) are visible. The river makes a bend next to the bridge. Within 1.6 km of the site, the area is rural and mostly natural land. Several farms have chicken houses nearby, but only one was observed within the 1.6 km radius.

The bridge is supported by six cement pilings, which are both in the river and on the banks. Rocks were observed near the bridge supports but not elsewhere. The elevation at this site is 118 m (above sea level) (Figure B7).

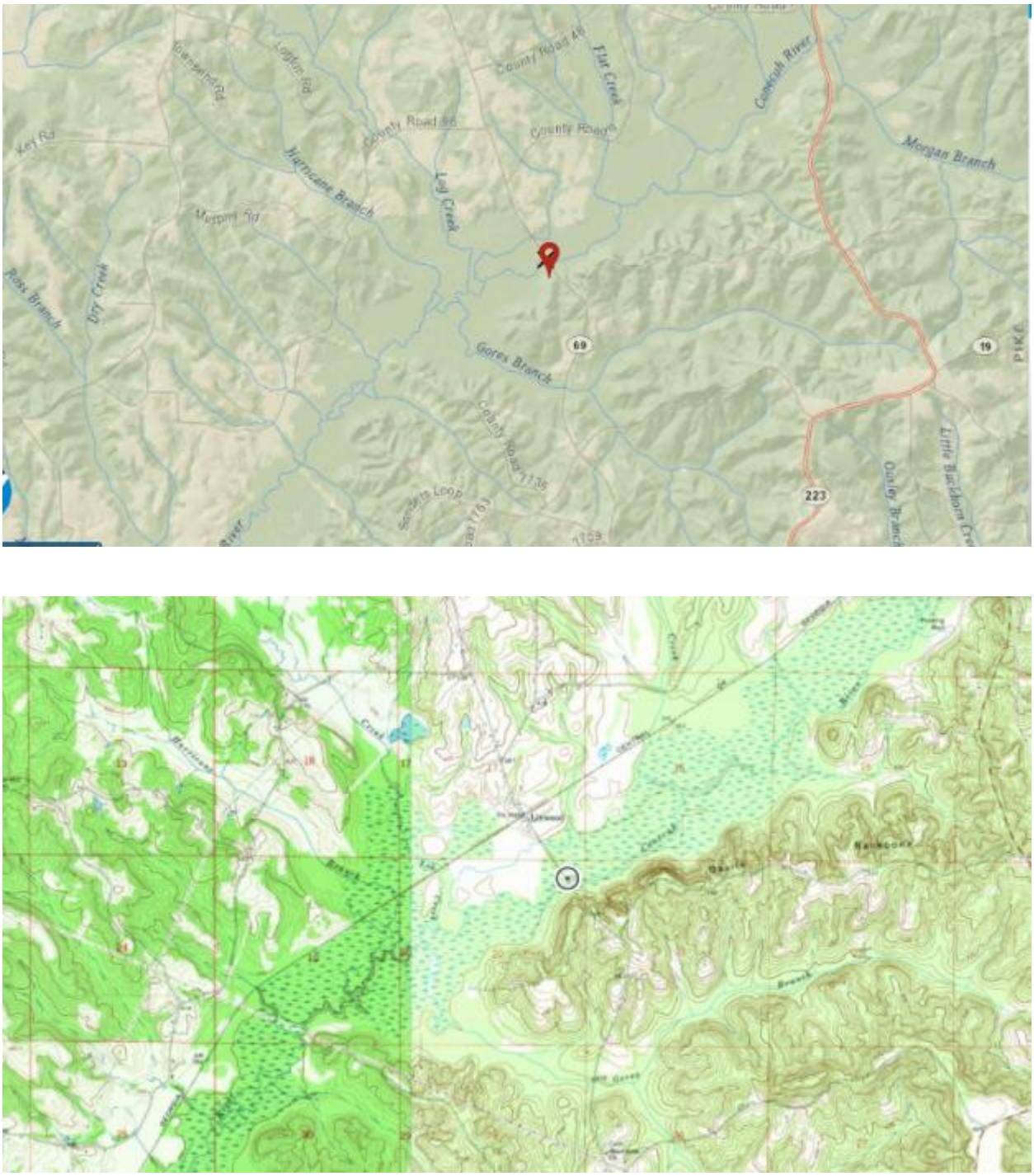


Figure B6 - *Maps of Conecuh D sampling site*

View Upstream

Figure B7 -*Photos of Conecuh D sampling site*

Log Creek

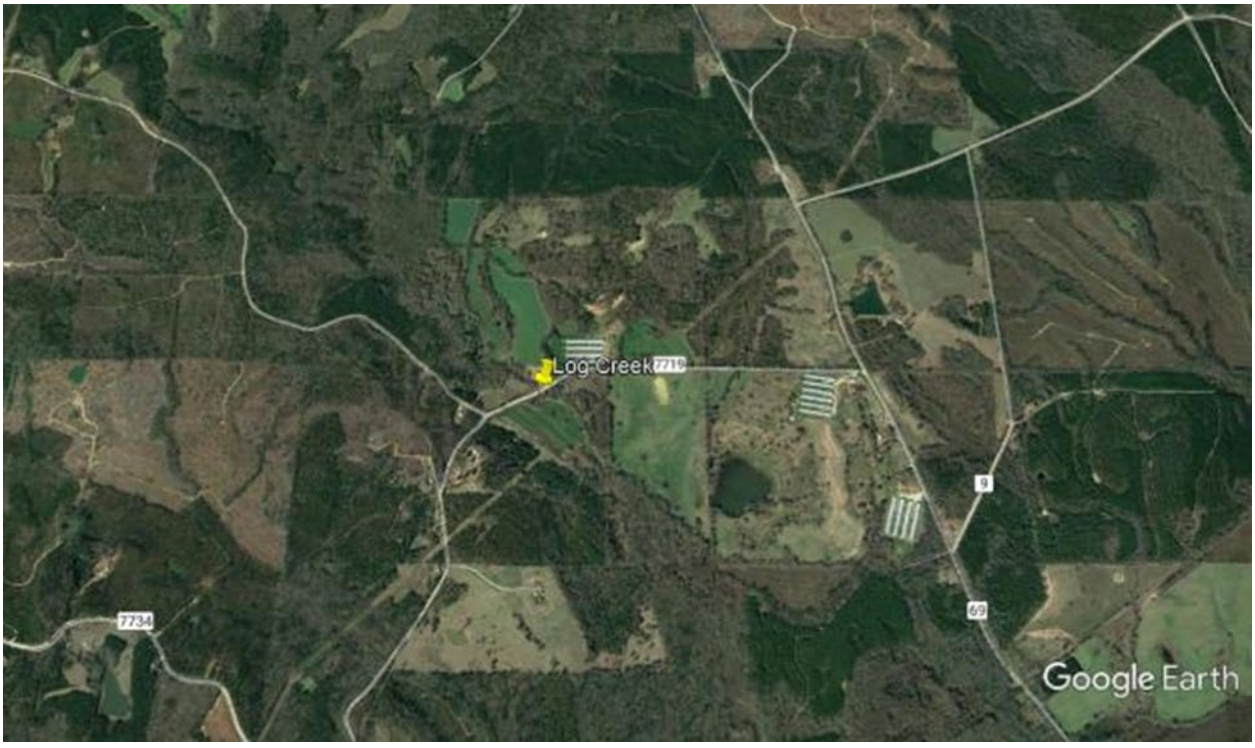


Figure B8 - *Log Creek, Conecuh River Watershed, Lat/Long 31.93760, -85.88347, Pike County, AL*

Log Creek is a tributary of the Conecuh River and enters the river downstream of station Conecuh D (Figure B8). This location is in a farming community, accessed on a dirt road between chicken houses and agricultural fields. The bridge is an unusually wide cement bridge, almost oversized but perhaps designed to accommodate large farming equipment. The bridge has a natural bottom and is supported by two cement pilings with rocks placed around the bridge supports.

The creek is filled with sediment and, on the last two visits, had almost no flow. The farm fields upstream and downstream were cleared, leaving virtually no vegetative buffer (Figure B10). Cattle and horses were observed and smelled at this site.

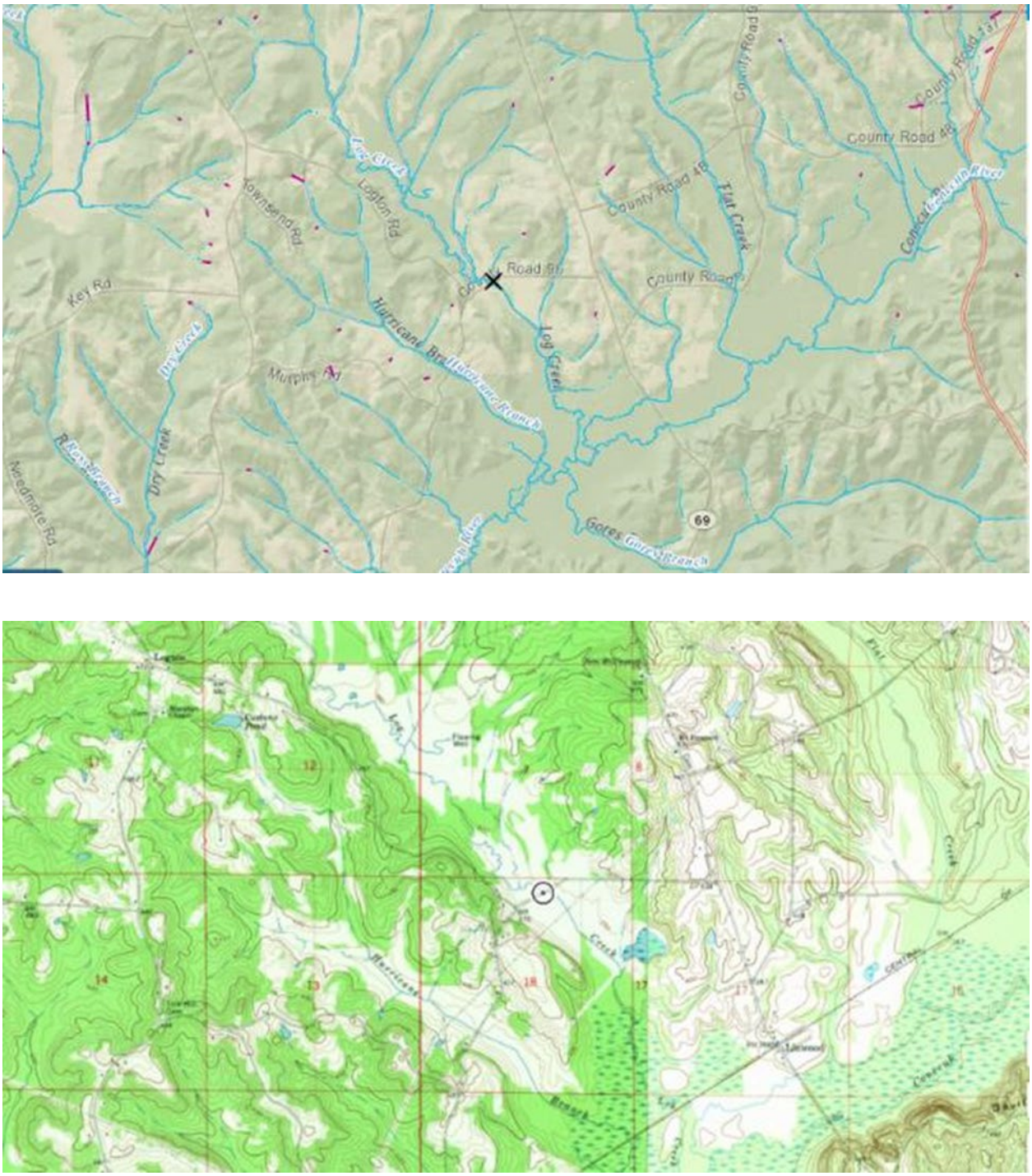


Figure B9 - *Maps of Log Creek Sampling Site*

Looking downstream

Adjacent farm field

Looking upstream

Figure B10 - *Photos of Log Creek Sampling Site*

According to the topo maps, several upstream tributaries have flowing springs feeding them, but little to no flow was observed during times when the site was visited. The site is 117 m above sea level and is listed as a 3rd-order creek. Within 1 km of the station were natural lands and farmsteads, including several chicken houses.

Indian Creek

Figure B11 - *Indian Creek, Conecuh River Watershed, Lat/Long 31.97675, -85.96422, Pike County, AL*

Indian Creek (Figure B11) is a 2nd-order creek located approximately 4.827 km due north of the Manning Creek station and converges with Manning Creek approximately1.6 km downstream of this station (Fig B12). This creek was dry during the last two visits. This station is in a floodplain, accessed by a dirt road and likely built by a logging company. The bridge has rotted out and the dirt road has been closed to drive-through traffic. It was possible to access the bridge on foot and collect a representative sample during earlier visits when the creek was flowing.

The pilings and wood used to build the bridge were treated with creosote. As with Manning Creek, the site had been used to discard trash, including a large flat-screen television. The creek bed was a natural bottom made up of white sand.

This station is 130 m above sea level and upstream of a large floodplain. Several of the nearby property owners have cleared their properties, leaving a slender ribbon of riparian areas intact near creeks. Within 1.6 km of the station, one-third of the land is within the boundary of Lockheed Martin, one-third is in a floodplain and natural areas, and one-third is in private ownership and evidently clearcut for agriculture fields (Figure B13).

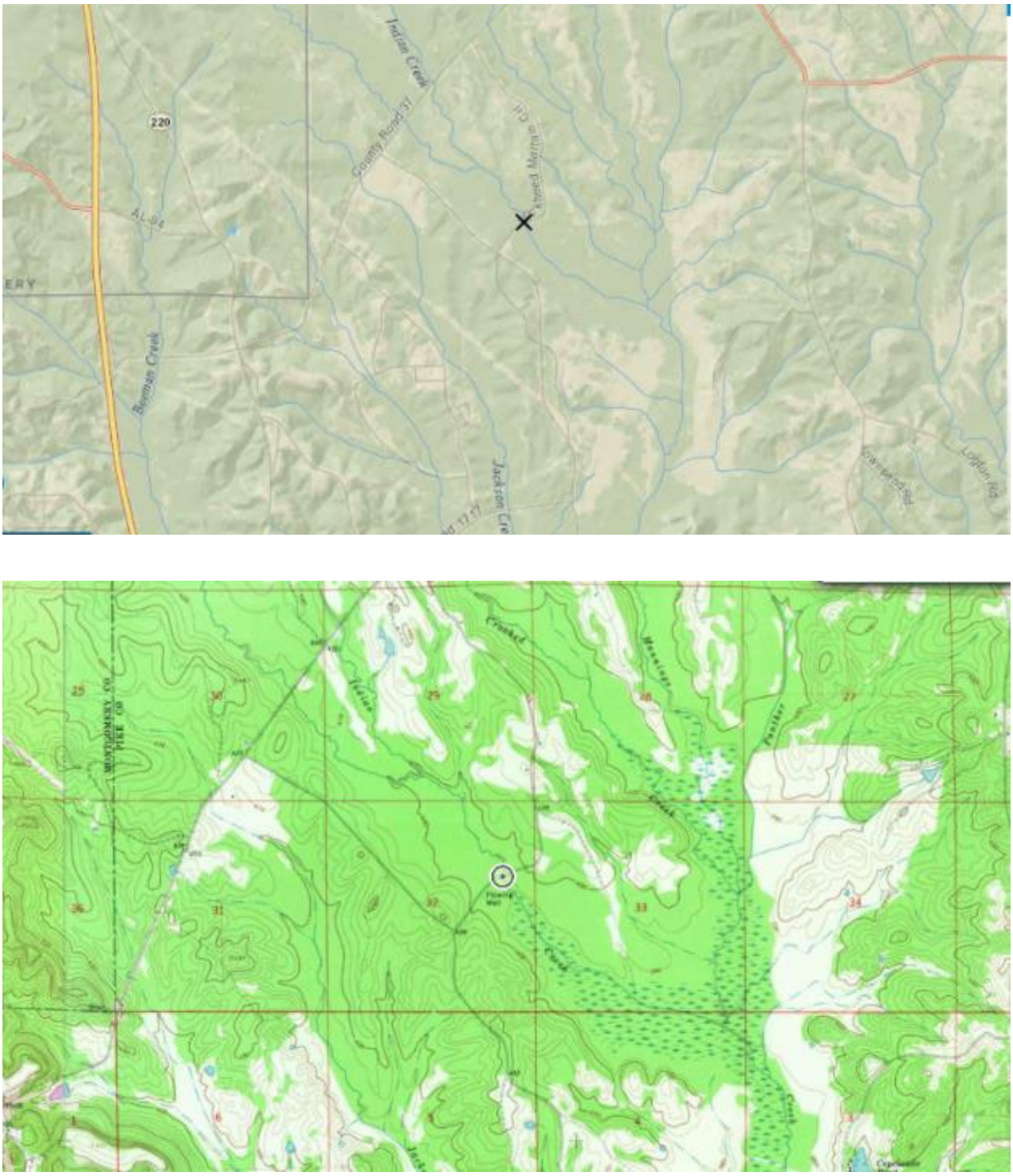


Figure B12 - *Maps of Indian Creek Sampling Site*

The pictures in Figure B13 show: the Indian Creek bridge that was our sampling station (A), the creek during summer (B), the creek bank as the rains stopped (C), cardinal flowers

which grew in the adjacent ditches (D), the same location as Photo C after the creek went dry (E), and the creek bed upstream after the leaves had fallen from the trees (F). Note the height of the creek bank was approximately six feet at bank full, and the root system was stabilizing the tree. White sand had accumulated behind the tree (F).

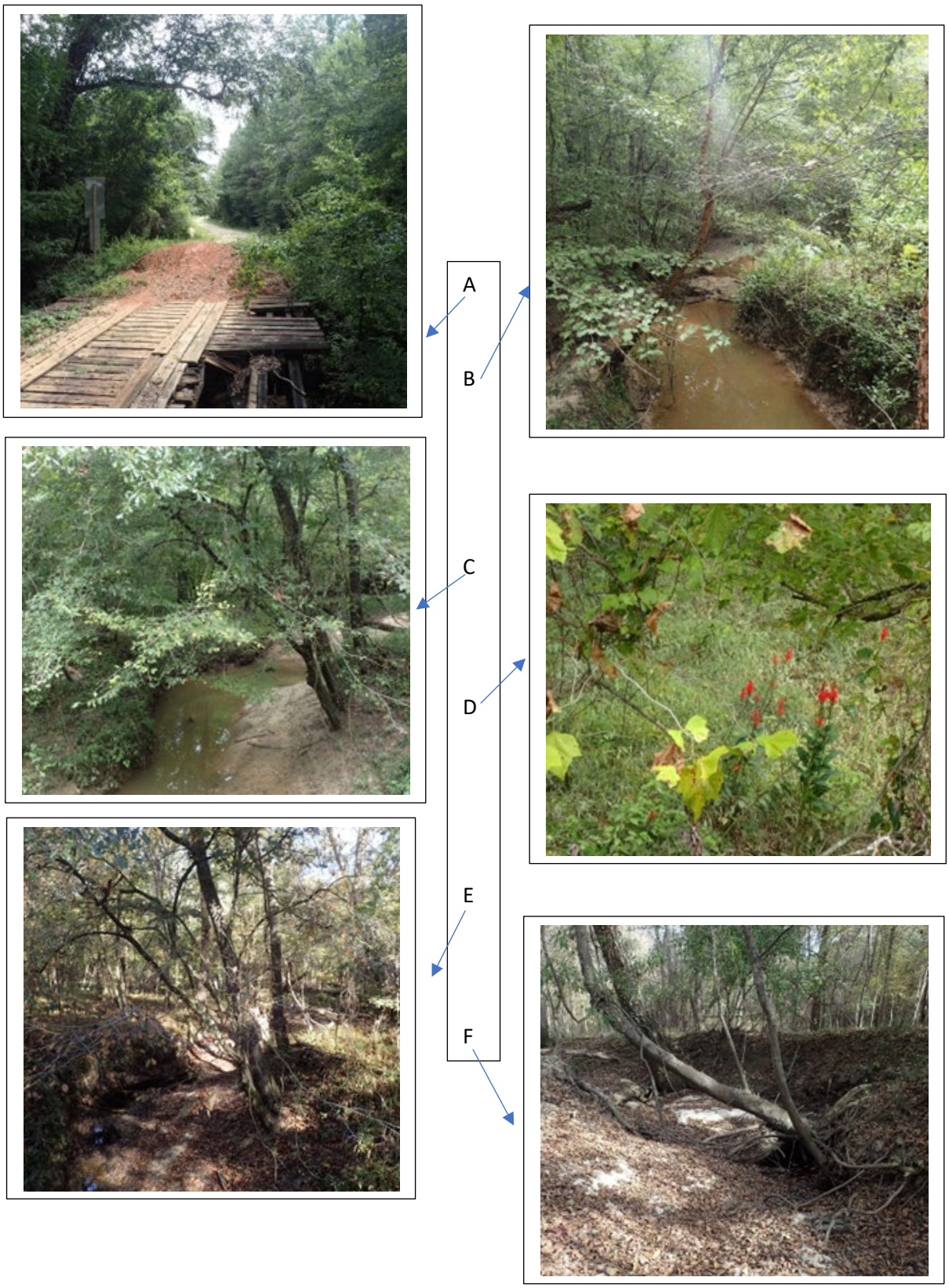


Figure B13 - *Photos of Indian Creek Sampling Site*

Manning Creek

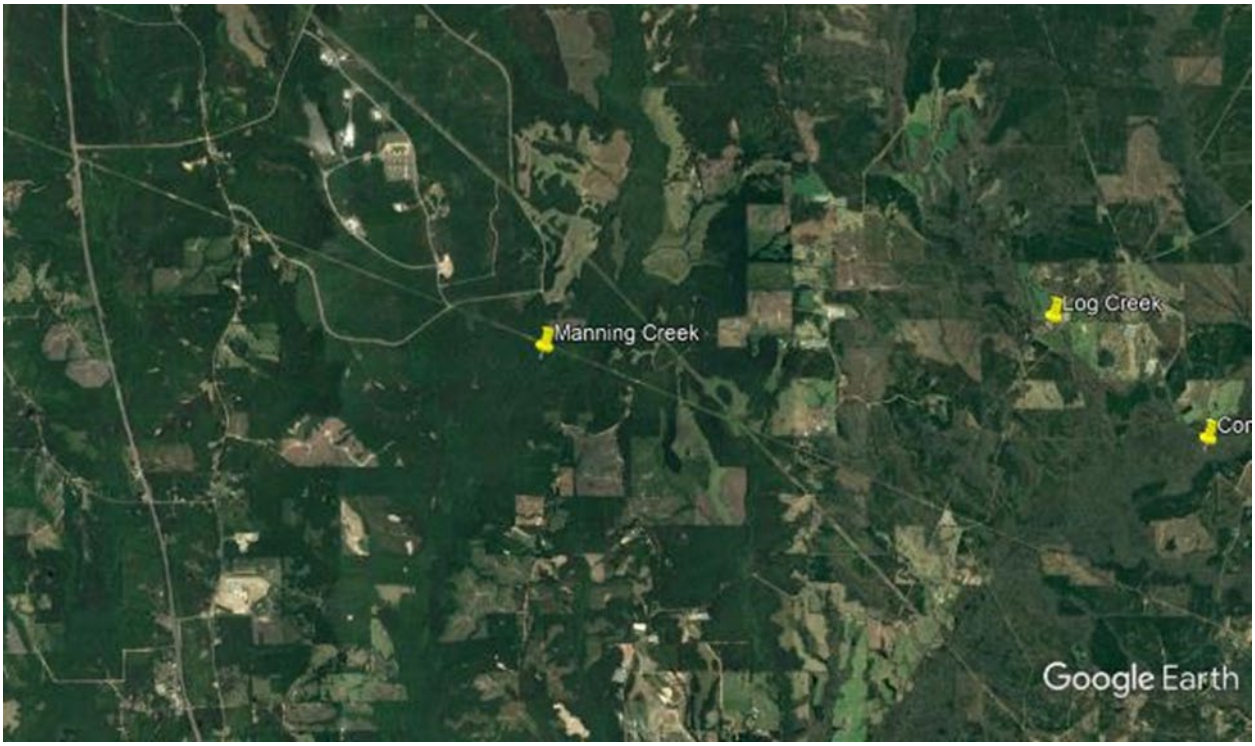


Figure B14 - *Manning Creek, Conecuh River Watershed, Lat/Long 31.93379, -85.95758, Pike County, AL*

This site is in a forested area only accessible by dirt roads. Manning Creek (Figure B14) is a 3rd-order creek at this site. The station is in a floodplain that appears to have been logged for pine in the last 30 years. The current canopy is mature and made up of cypress, maple, oak, and magnolia, but absent of any pine. Manning Creek joins the Conecuh River six miles downstream and is buffered by an extensive floodplain (Figure B15).

The site is located at an elevation of 120 m, and the bridge is made of wood, much like a logging crew would build to cross a small creek. The pilings and wood used to build the bridge were treated with creosote. The creek has evidence of trash, including several tires and the

remnants of oyster shells. Several log jams have accumulated on the upstream side and gotten caught on the bridge pilings.

During the last two of five visits, the creek has behaved like an ephemeral creek, going dry in several areas. Our team went upstream and found a deep hole, which may be fed by groundwater, and collected our sample. The site was deep enough to support several different fish, including gambusia and small bream. The banks of the dried creek bed were white sand and dusted with finer soils. The creek bed was well established by a root network of mature trees that lined the banks.

The road evidently washed out prior to the study period and was repaired by the placement of four large, round four-foot metal culverts installed level with the floodplain and firmed up with clay. Water was never observed flowing through the culverts.

Lockheed Martin has a large, fenced-off parcel (approximately 1,457 hectares), which has guarded security access from CR 37 or CR 7717. The Manning Creek site is approximately 0.8 km due south of this property.

Figure B16 shows the floodplain surrounding the Manning Creek station (A), looking downstream from the sampling site (note the tire in the water) (B), looking upstream (C), looking downstream (same location as Photo B, note the tire) (D), looking at the wooden bridge (E), and the large, metal culverts placed on a washed-out portion of road (F).

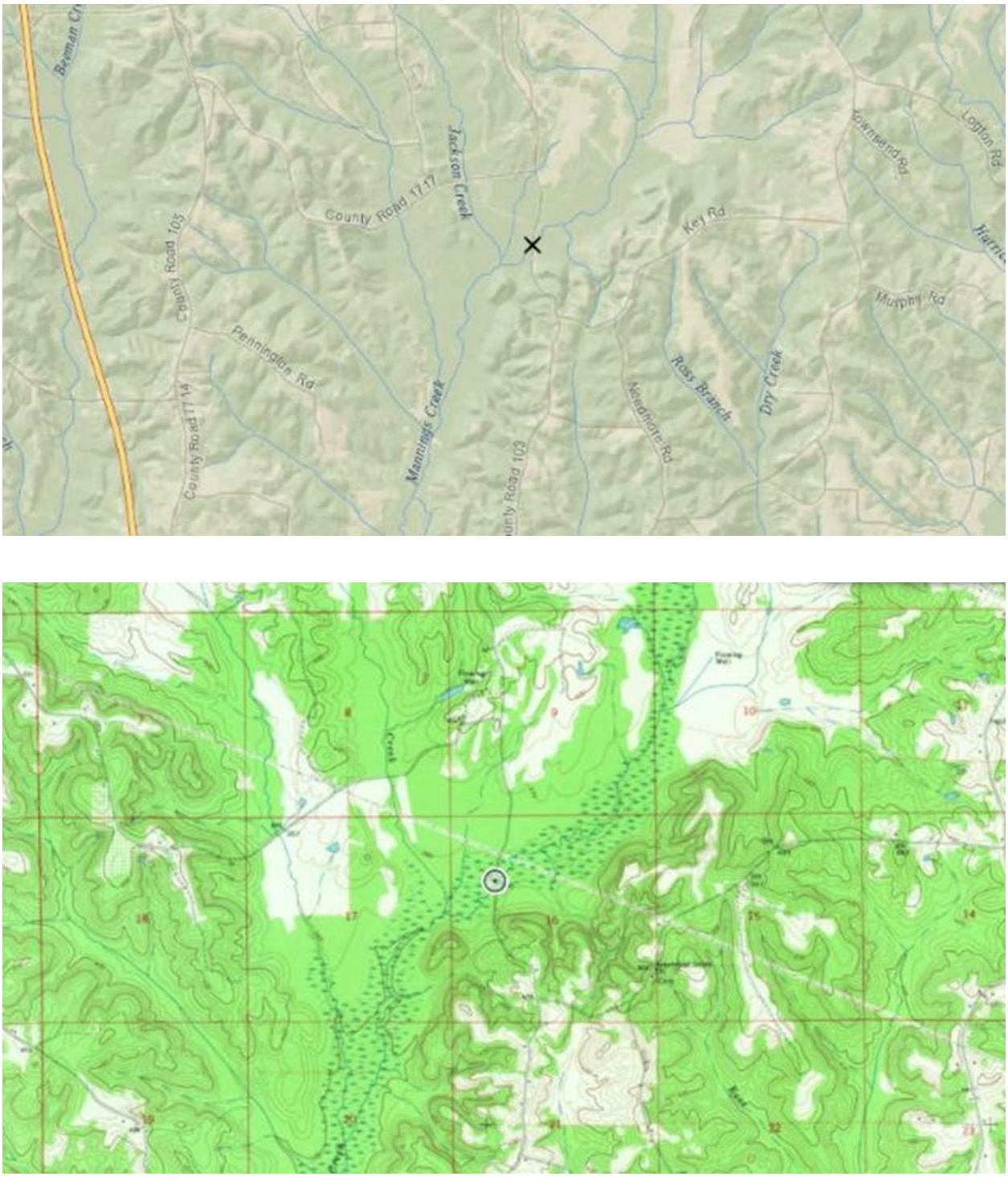


Figure B15 - *Maps and Photos of Manning Creek Sampling Site*

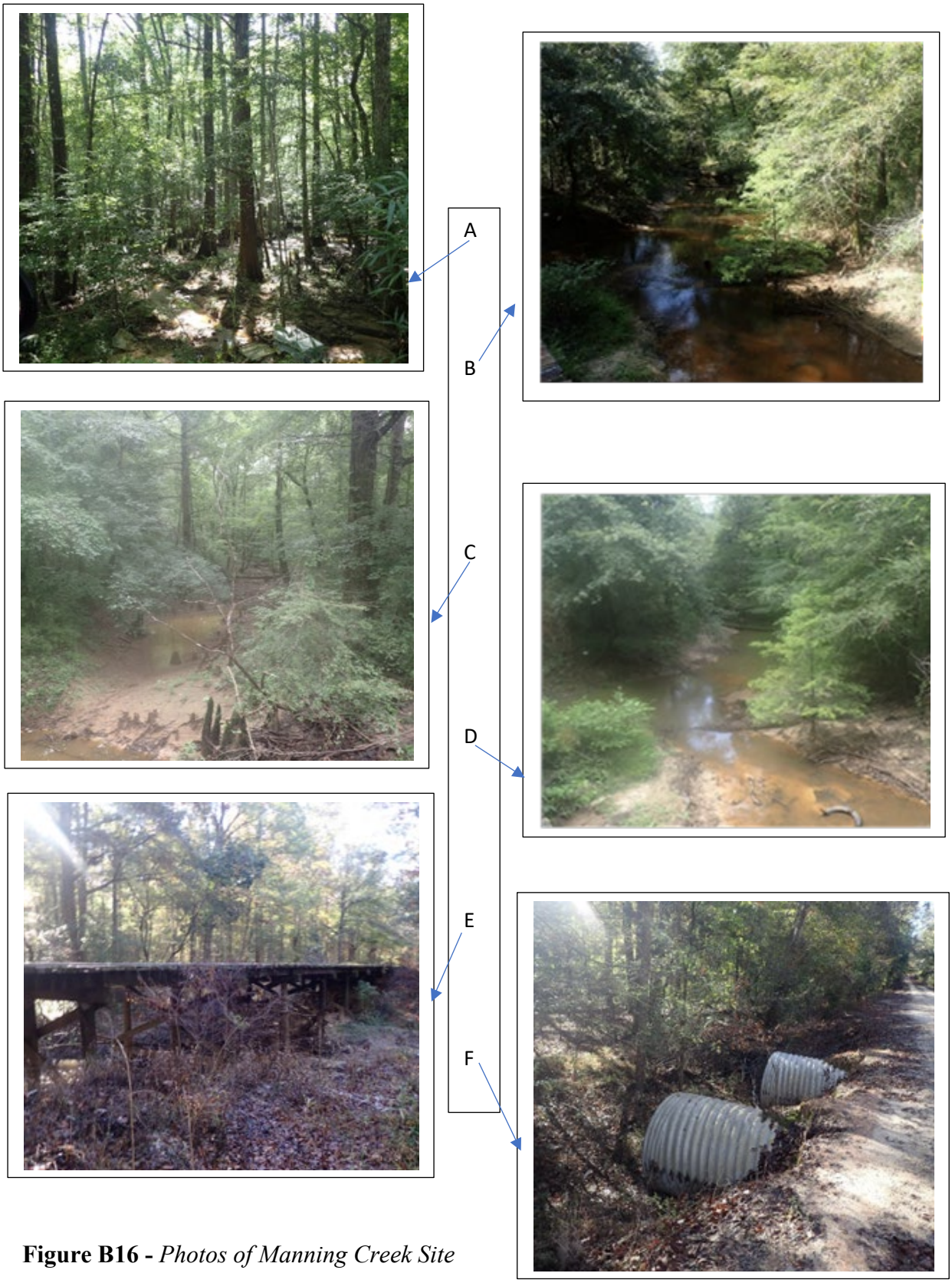


Figure B16 - *Photos of Manning Creek Site*

Conecuh River C

Figure B17 - *Conecuh River C, Conecuh River Watershed, Lat/Long 31.71972, -86.10745, Pike County, AL*

The Conecuh River station C (Figure B17) is located within 1.6 km of the town of Goshen, AL, (population 269, US Census, 2020) and is classified as a 4th-order system at this site. This station is located on the abandoned cement bridge, which remains standing north of and adjacent to the newer cement bridge located on Conecuh Street. The sampling bridge is 180 m in length and spans the mainstem of the river (39 m bank-to-bank) and the adjacent floodplain and secondary creek, which receives overflow water from the river during heavy rain events. The floodplain is approximately 0.8 km wide at the sampling station.

The main river channel is incised into the streambed and very shallow, with a swift flow and lacking woody material. A power line easement runs parallel (upstream) to the abandoned bridge, while the new bridge is located downstream. The river is 90 m above sea level. The tall

bridges (abandoned and in-use) are supported by cement pilings anchored in the river. The bottom is natural and sand in nature.

The abandoned bridge was observed to support several small shrubs including *Morus spp.* (mulberry bush) and wild *Prunus spp* (plums). Wildflowers have also become established within the cracks on the bridge, including wild daisies and Spanish needle. The site appears to be a popular hangout with locals, as graffiti was updated between visits.

The riverbanks were lined with mature trees including *Taxodium spp.* (cypress), *Acer spp.* (maple), and *Quercus spp.* (oak), whereas further upland, *Pinus spp*. (pine) was visible. The abandoned bridge approach was covered in *Pueraria spp*.(kudzu), which by the end of the study had covered the road and spilled over the bridge to cover the nearby and adjacent trees.

Located within 1.6 km of the station to the west is the town of Goshen, AL, and to the east are several small farms. Located upstream approximately 1.2 km is a large poultry farm with six chicken houses (Figure B18).

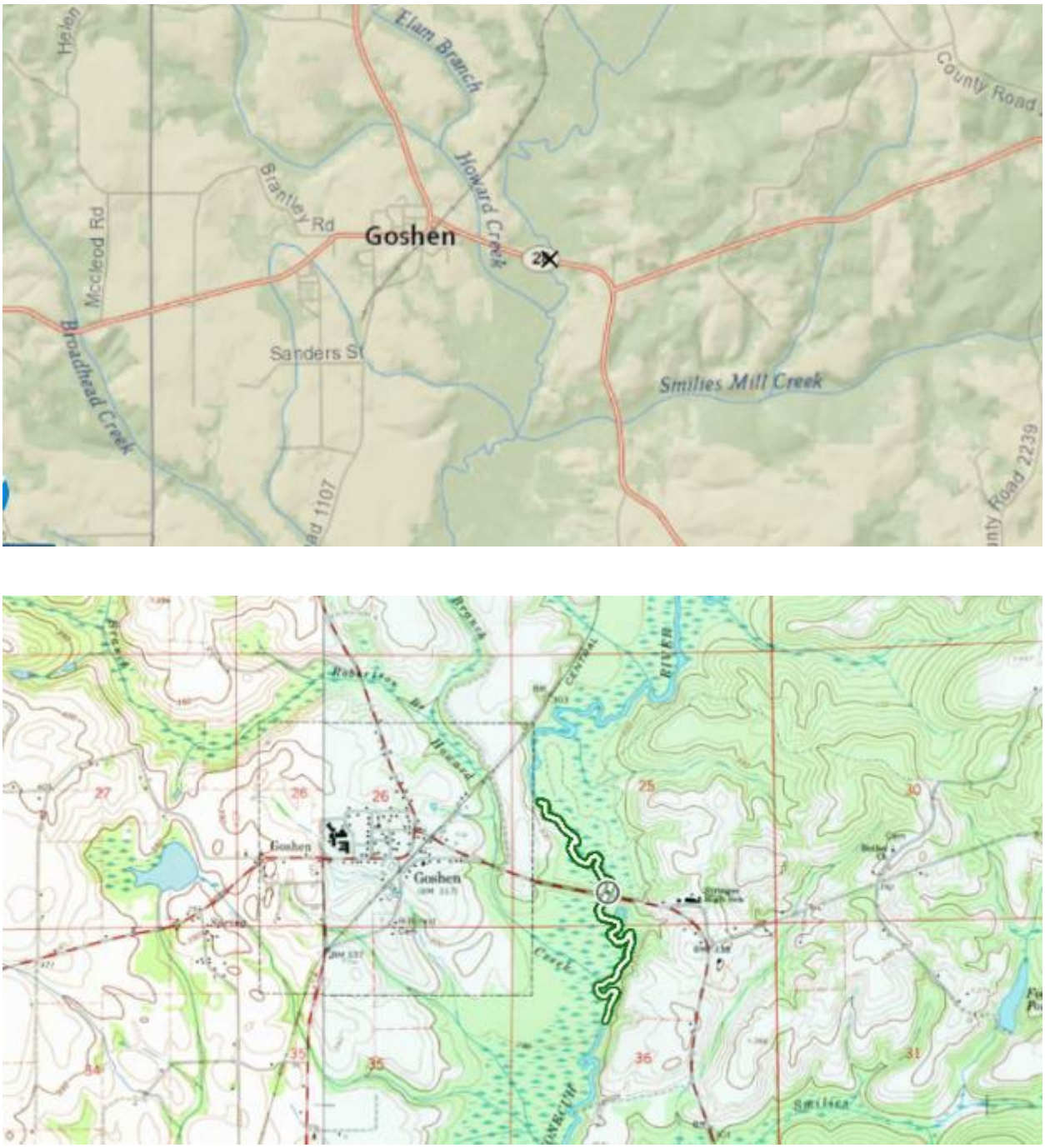


Figure B18 - *Maps of the Conecuh C Sampling Site*

The pictures in Figure B19 were taken during the sampling visits: looking upstream from the abandoned bridge in Aug 2022 (note the power line easement) (A), looking east on the abandoned bridge (B), view looking downstream from the sampling location (note the view is

blocked by the new bridge) (C), looking eastward at the new bridge pilings and the river bank condition (D), looking down onto the floodplain channel which became cut off from the mainstem of the river during the end of the study (E), and view of the abandoned bridge approach at the end of summer (note the entire road leading to the bridge is covered in kudzu) (F).

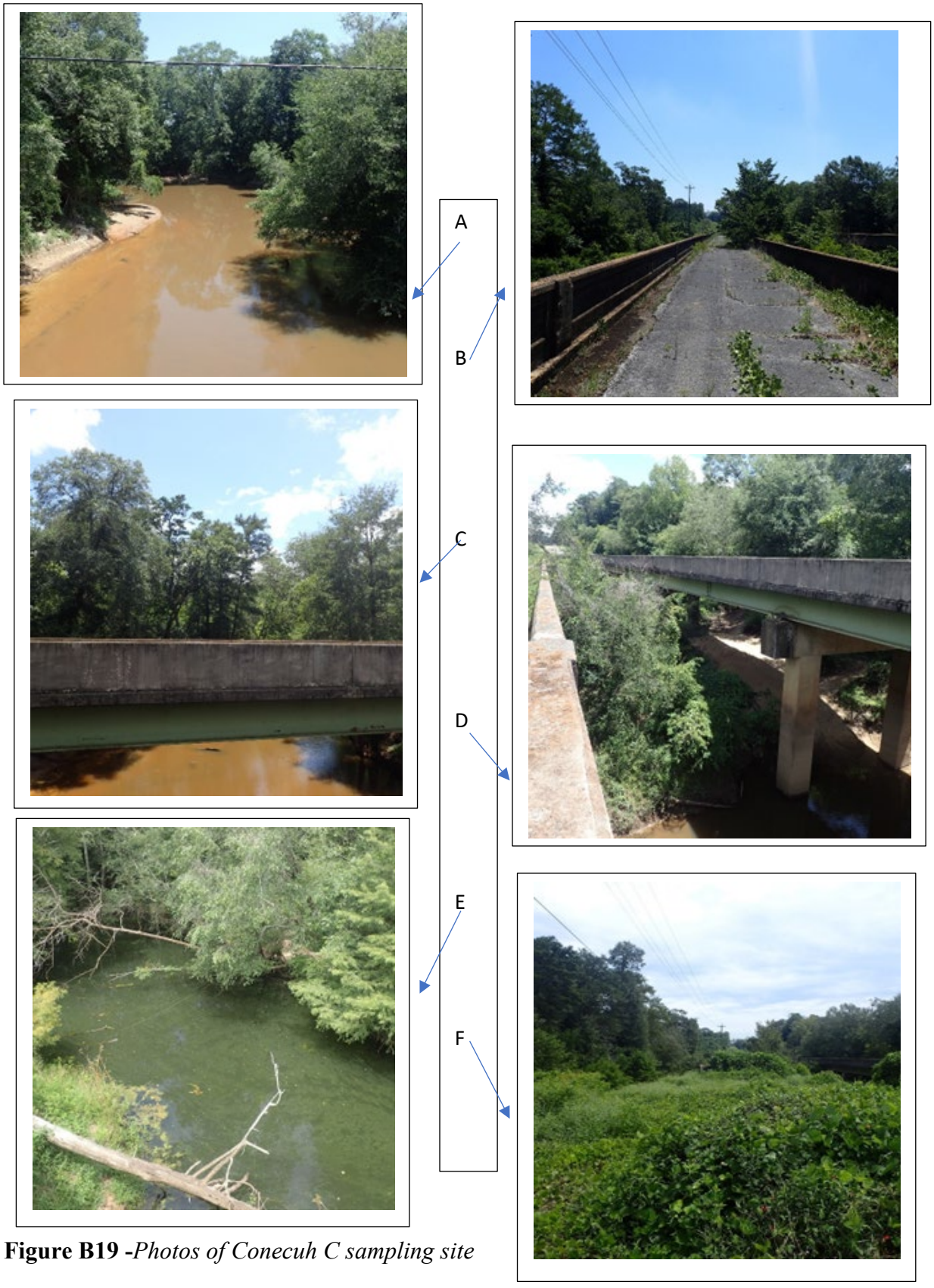


Figure B19 -*Photos of Conecuh C sampling site*

Patsaliga Creek Upper

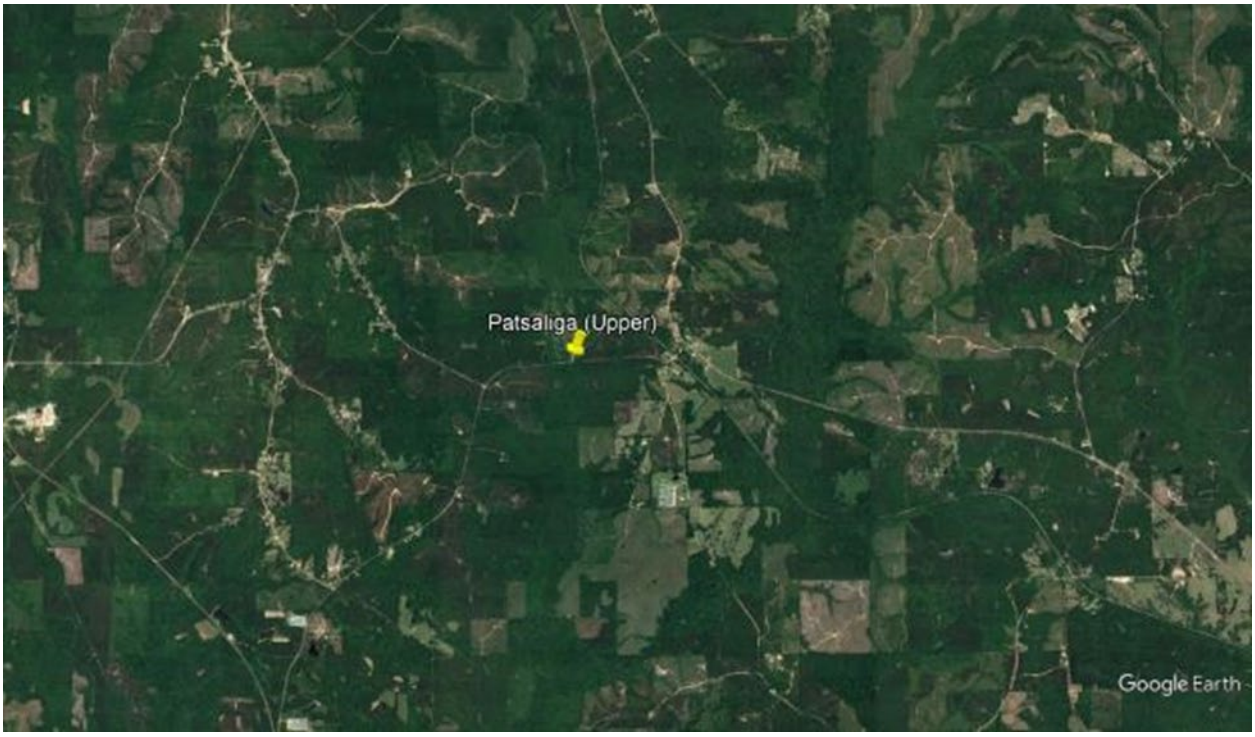


Figure B20 - Patsaliga Creek Upper, Conecuh River Watershed, Lat/Long 31.90780, -86.17527, Pike County, AL

The Patsaliga Creek Upper (Figure B20) is a 4th-order stream located in a forested area accessed by a two-lane paved road. The cement bridge is 33 m wide and supported by two T-shaped cement pillars. The left bridge approach was 267 m from the nearest hilltop at a 2^{o} slope. The right bridge approach was virtually level.

The sampling station is 110 m above sea level (Figure B21). Within 1.6 km of the site, the area is rural, with 80% in natural lands or pine plantation. Two farmsteads in the 20% portion of the managed lands have impounded 1st-order creeks to make farm ponds. These two impounded creeks would flow into Patsaliga Creek, one through a pine plantation, the other through forest before joining the creek downstream of the sample site. A rail line passes within

0.4 km of the sampling area and is adjacent to the dam for the upper impounded creek/farm pond.

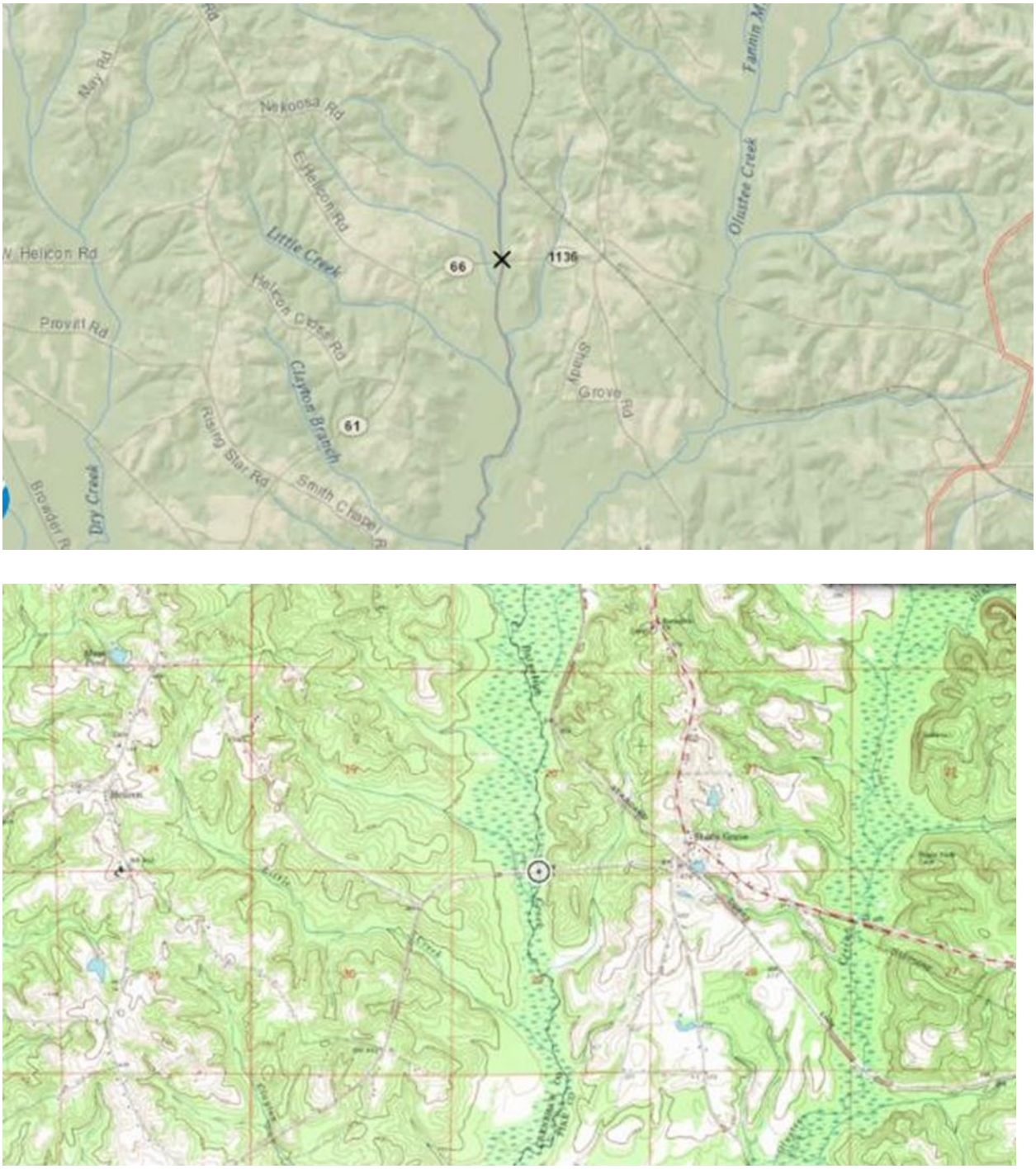


Figure B21 – Maps of Patsaliga Creek Upper

The sampling area is in a dense canopy of mature trees, mainly *Taxodium spp.* (cypress), *Quercus spp.* (oak), and *Acer spp.* (maple). Invasive species observed included *Albizia spp.* (mimosa). The creek had a very low flow during the last two visits and was blanketed in leaves at our last sampling.

The photographs in Figure B22 were taken during the sampling efforts and characterized the creek as the area began to experience drought conditions. Column 1: top picture is upper Patsaliga Creek looking downstream, bottom picture is a view of the creek looking upstream during dry weather. Column 2: top picture is the same upstream view following a rain event, middle picture shows the condition of the creek bank during low flow (note the bank is stable, no rocks, and the tree roots are stabilizing the system), and bottom picture shows the creek (looking upstream) during summer with a mature canopy and well shaded.

Figure B22 - *Photos of Patsaliga Creek Upper Sampling Site*

Patsaliga Creek Lower

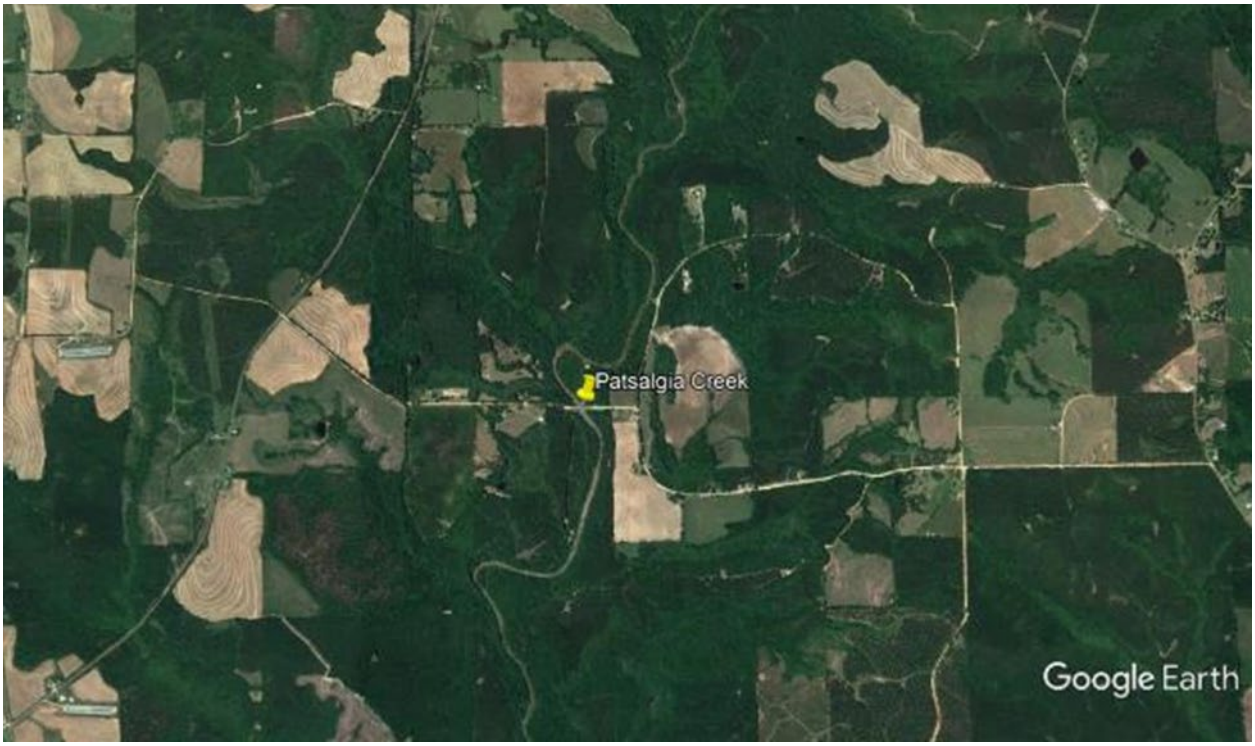


Figure B23 - *Patsaliga Creek Lower, Conecuh River Watershed, Lat/Long 31.44095, -86.53748, Covington County, AL*

Patsaliga Creek Lower (Figure B23) is a 4th-order stream at this sampling site and is at an elevation of 66 m (Figure B24). The cement bridge is tall and raised higher than the dirt road that runs between several farms and provides access. The bridge is 79 m in length and spans the entire width of the creek. The area is very rural, with multiple farms dotting the countryside within a mile of the sampling station. Invasive species observed included kudzu and mimosa.

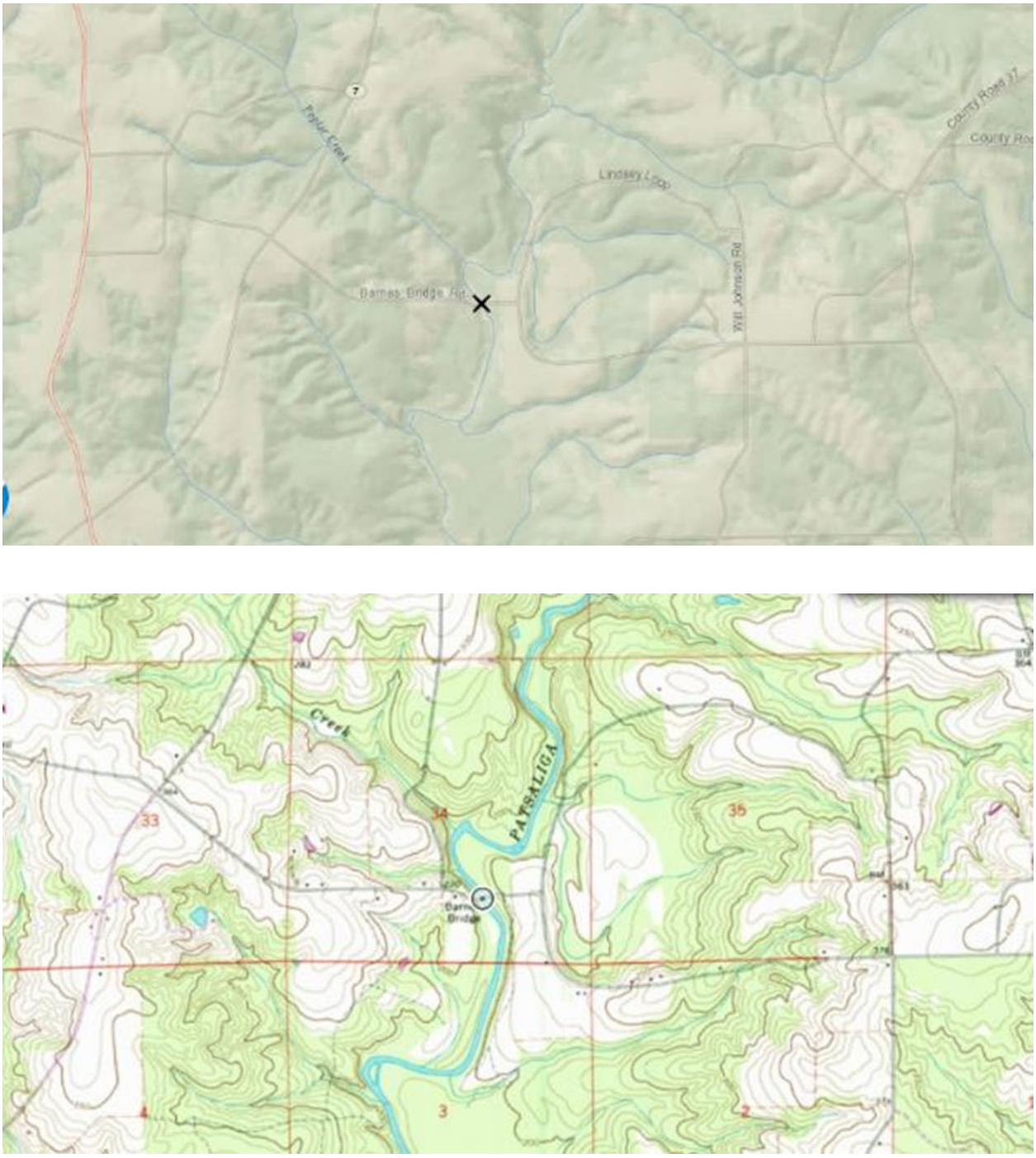


Figure B24 – *Maps of Patsaliga Creek Lower*

Looking Upstream | Looking down at roots during drought | Looking downstream

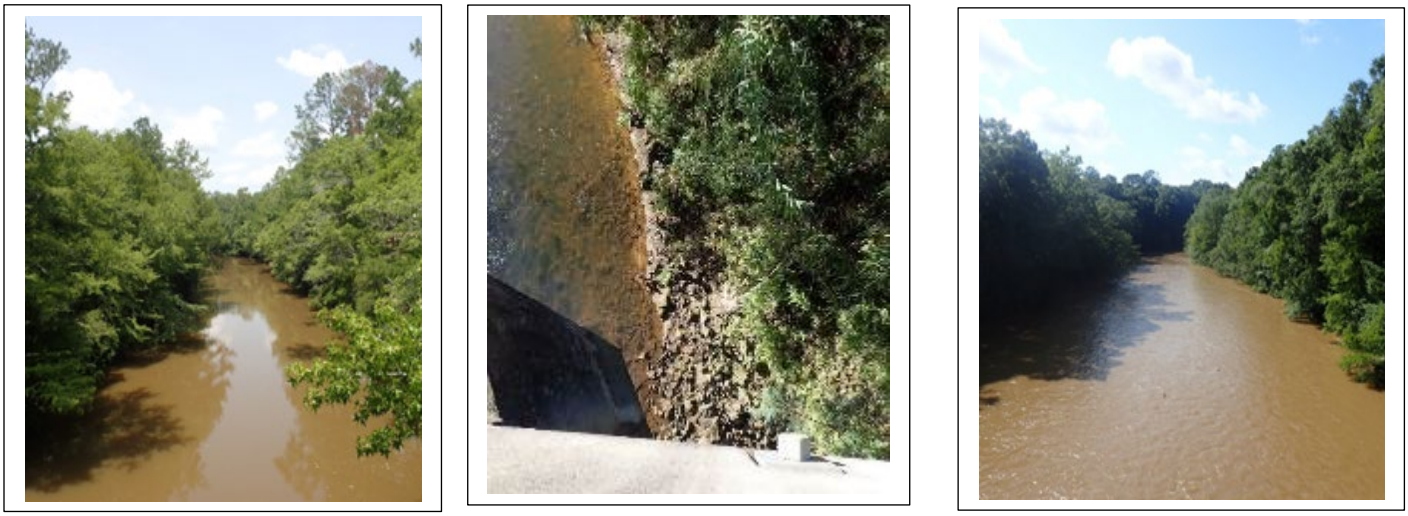


Figure B25 - *Photos of Patsaliga Creek Lower Sampling Site*

The creek is very shallow and has obvious riffles visible both upstream and downstream. The creek appears to have a bedrock of limestone, which could not be verified since safe access could not be determined. The banks along the creek are well vegetated with mature cypress, oaks, and red maples. The root network along the banks became visible when our sampling period entered a drought and was observed to be grown together with ferns filling the voids (Figure B25).

Persimmon Creek

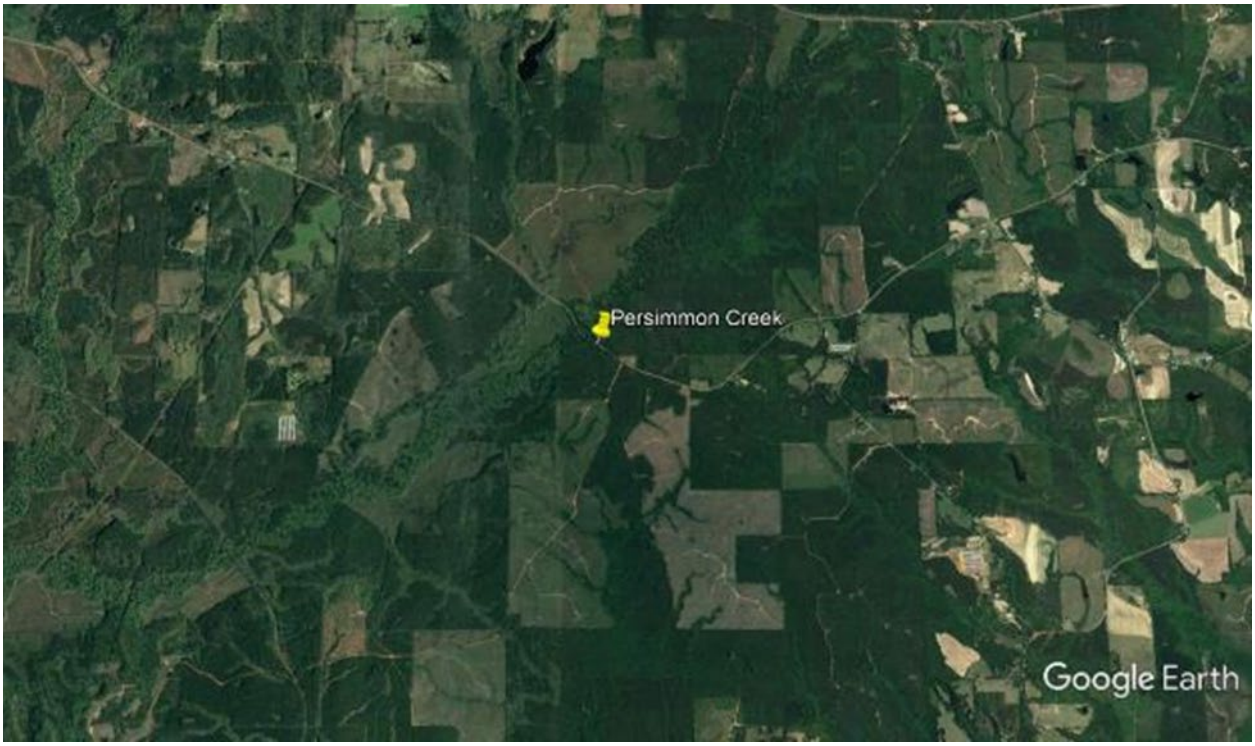


Figure B26 - *Persimmon Creek, Conecuh River Watershed, Lat/Long 31.60539, -86.66365, Butler County, AL*

Persimmon Creek (Figure B26) is a 4th-order creek that has its headwaters in Fort Deposit, AL, roughly 40 km north of this sampling station. The creek is approximately 82 m above sea level at this site and is upstream of the confluence of Marshy Creek, which is another 4th-order creek (Figure B27). Together, Persimmon Creek and Marshy Creek flow downstream to join the Sepulga River, which is a 5th-order river and a large tributary of the Conecuh River. The Sepulga River converges with the Conecuh River approximately 17.7 km upstream of the Conecuh B sampling station.

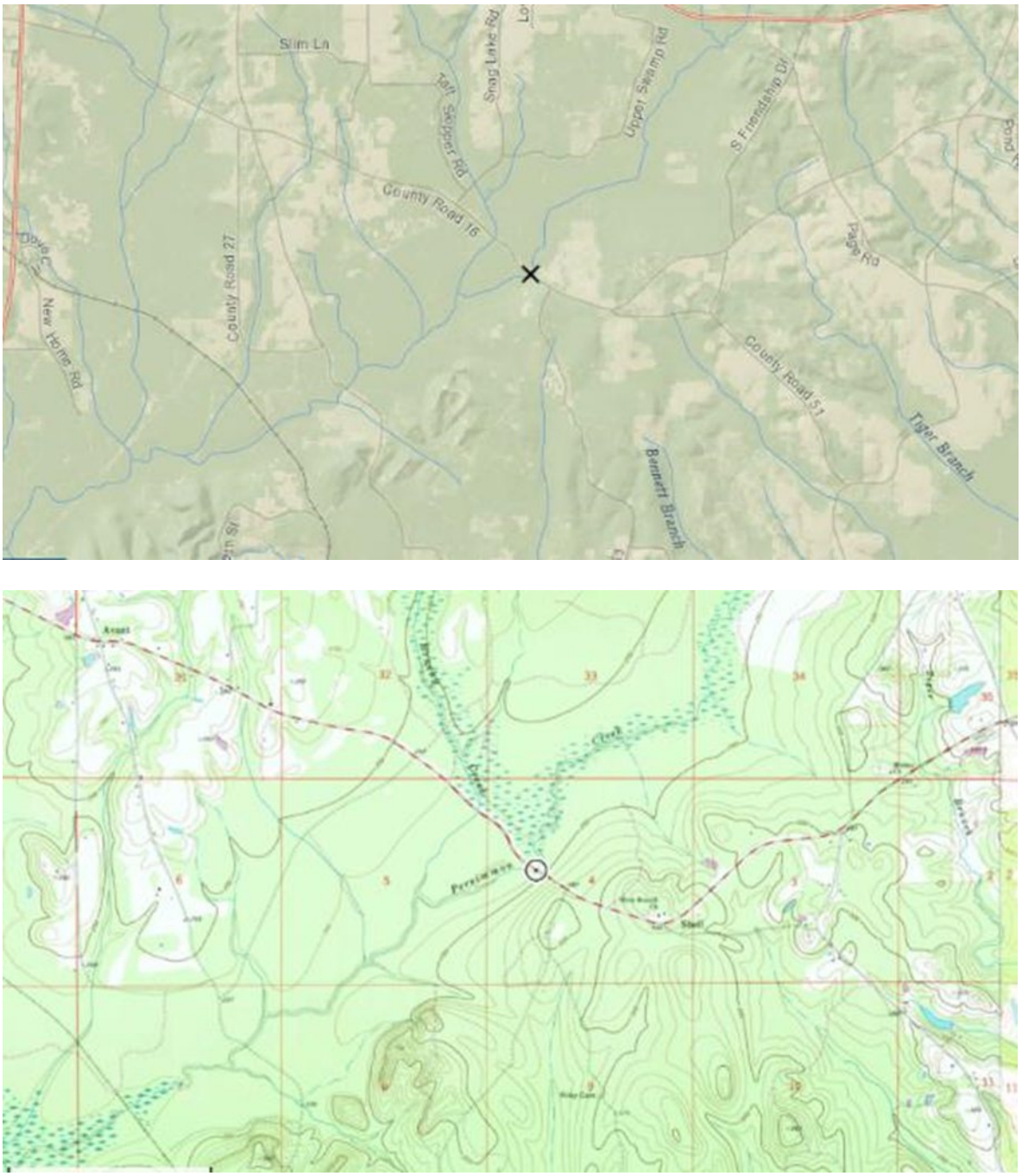


Figure B27 – *Maps of Persimmon Creek*

Persimmon Creek station is in a rural, wooded, low-lying floodplain accessed by a two-lane paved road. The bridge is cement, with metal pillars embedded in cement blocks placed on the creek bed. The river bottom is natural. Upstream, the remnants of an old bridge are visible, and a flat portion of cement (from the old bridge) is positioned so water from upstream flows over it and creates a waterfall before flowing under the new bridge. The bridge is 37 m in length, while the creek channel is 19 m (bank-to-bank). Looking downstream, the bridge approach from the left is 252 m to the nearest hilltop with a 6º slope. The right approach is virtually flat.

The floodplain is lined with cypress, *Petula spp* (river birch), maple, and oak. Several large pines were also observed in the vicinity. Leaf litter blanketed the floodplain during the last visit to the site.

The photographs in Figure B28 were taken during the sampling efforts and characterized the creek as the area began to experience drought conditions. Column 1: top picture is upper Patsaliga Creek looking downstream, bottom picture is a view of the creek looking upstream following a rain event. Column 2: top picture is the same upstream view during low water (note the waterfall which is flowing over the remains of an old cement bridge), middle picture shows the condition of the creek bank during low flow (note the bank is stable and no rocks have been used to stabilize the system), and bottom picture shows the bridge structure with ample room to accommodate flood stage without constriction.

Figure B28 - *Photos of Persimmon Creek Sampling Site*

Conecuh River B

Figure B29 - *Conecuh B, Conecuh River Watershed, Lat/Long 31.09690, -86.91926, Escambia County, AL*

The Conecuh River is a 6th-order stream at station Conecuh B (Figure B29). The elevation at this site is 29 m above sea level. The floodplain extends almost 1.6 km from the mainstem in each direction. Hwy 4 crosses the river as a two-lane, paved road, with an approximately 300 m bridge that spans the river and parts of the floodplain (Figure B30. The river is approximately 75 m wide at the bridge and was accessible by sampling at a boat launch.

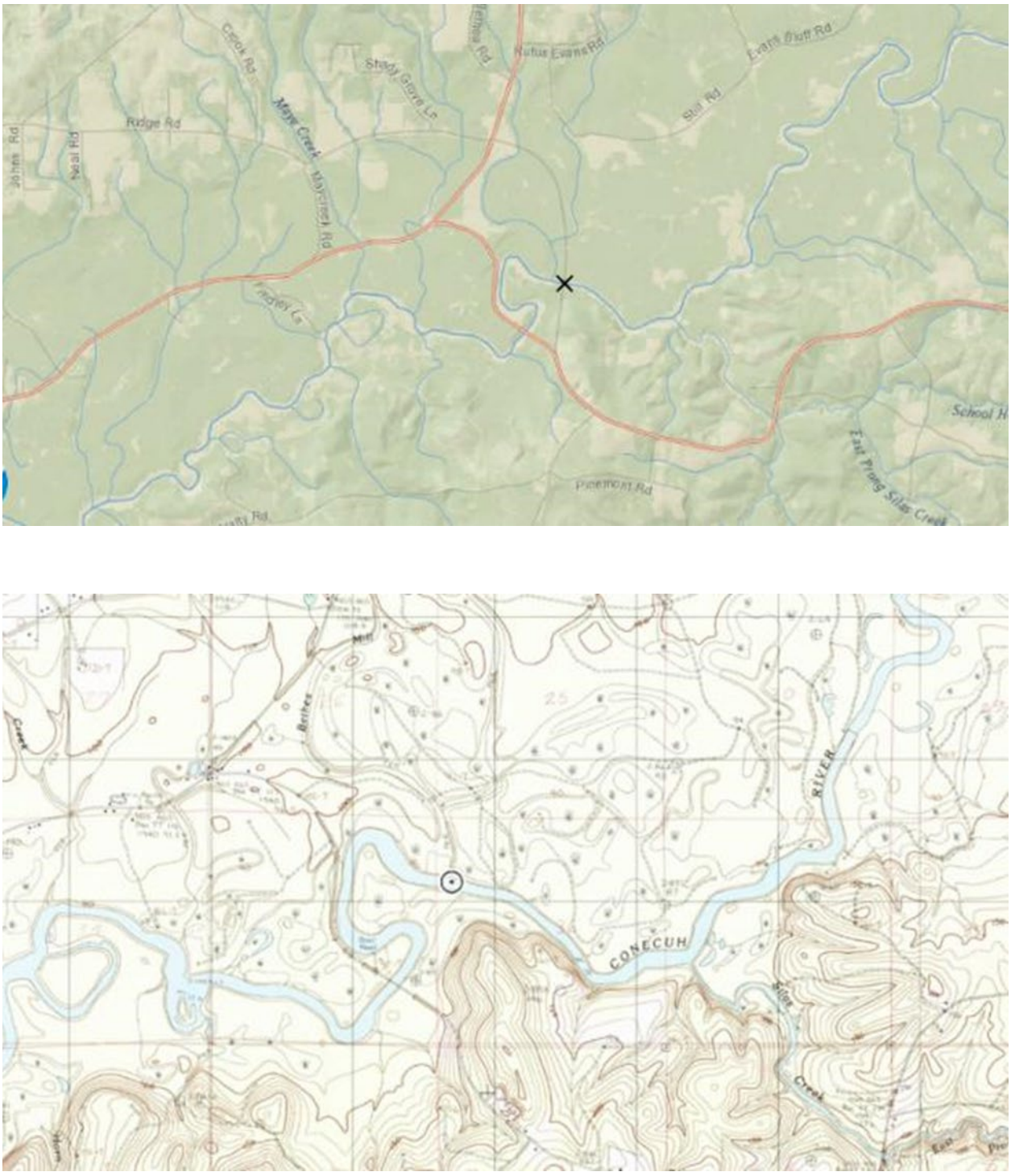


Figure B30 – *Maps of Conecuh B*

The site has a significant amount of sediment accumulating above and below the station, including a sandbar that was forming in the middle of the main channel and became visible during low flow. River birch have become established along the far bank during the last period

of low water levels. Other vegetation noted included maples, willows, oaks, *Platanus spp*. (sycamores), *Liquidambar spp.* (sweet gum), *Chamaecyparis spp*. (cedars), *Populus spp.* (poplars), and pines. The bridge is very high with the approaching roadways at a lower elevation than the bridge itself (Figure B31).

View across river, note sandbar View upstream View downstream

Figure B31 - *Photos of the Conecuh River B Sampling Site*

Conecuh River A

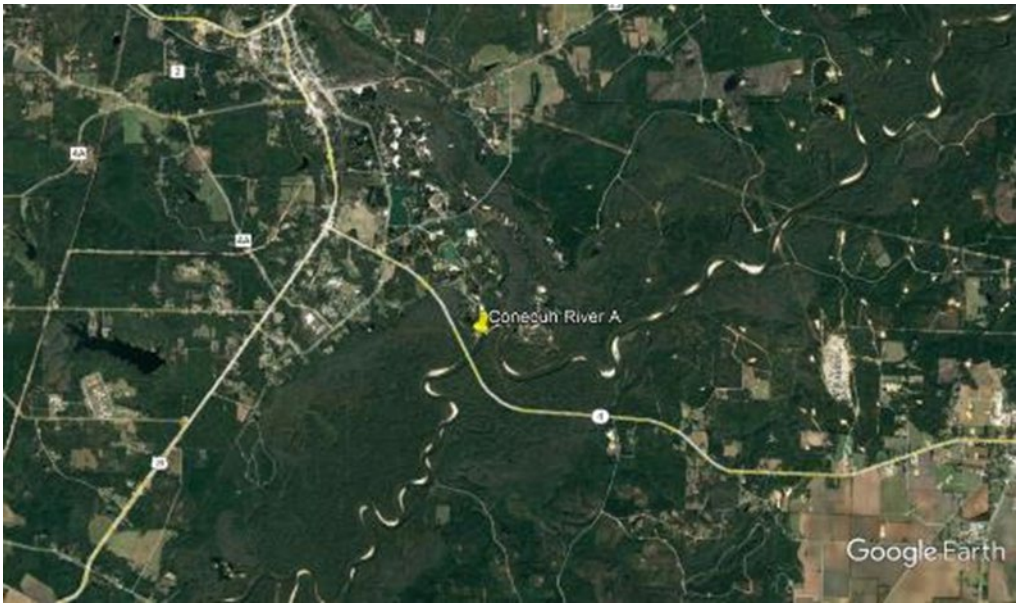


Figure B32 - *Conecuh River A (old BFA Station), Conecuh River Watershed, Lat/Long 30.96731, -87.23376, Escambia County, FL*

Conecuh River A (Escambia River in Florida) is 20.4 m above sea level and is classified as a 6th-order river at this sampling station. The river has been altered by sand-mining activities during the last three to four decades, resulting in large plugs of sediments moving downstream, readily visible in the Google Earth image (Figure B32).

The wooden remnants of a bridge upstream of the sample site are still visible. The station, which is also a boat launch, is accessed by a dirt road that has not been graded in some time. During heavy rain events, the dirt road is often underwater since the boat launch is in the riparian zone. Residual sand carried by flowing water was observed dusting the wooden boat dock and the surrounding area. Large boulders and rocks have been placed to maintain and stabilize the shoreline. A large eddy can be observed swirling upstream of the boat launch. The river is swift and shallow at this station.

Within 1.6 km of the sampling station are numerous sand-mining operations and the tributary known as Big Escambia Creek, where a large-scale stream restoration project took place (circa 1990s). After a sand-mining operation blew out ponds, tremendous smothering occurred downstream and caused the river to partially reroute itself. The river is 76 m wide at this station, and the FL Hwy 4 bridge can be seen just downstream of this site. The vegetation is dominated by *Salix spp*. (willows) and river birches closest to the river, with oaks, sycamores, and maples located more upland.

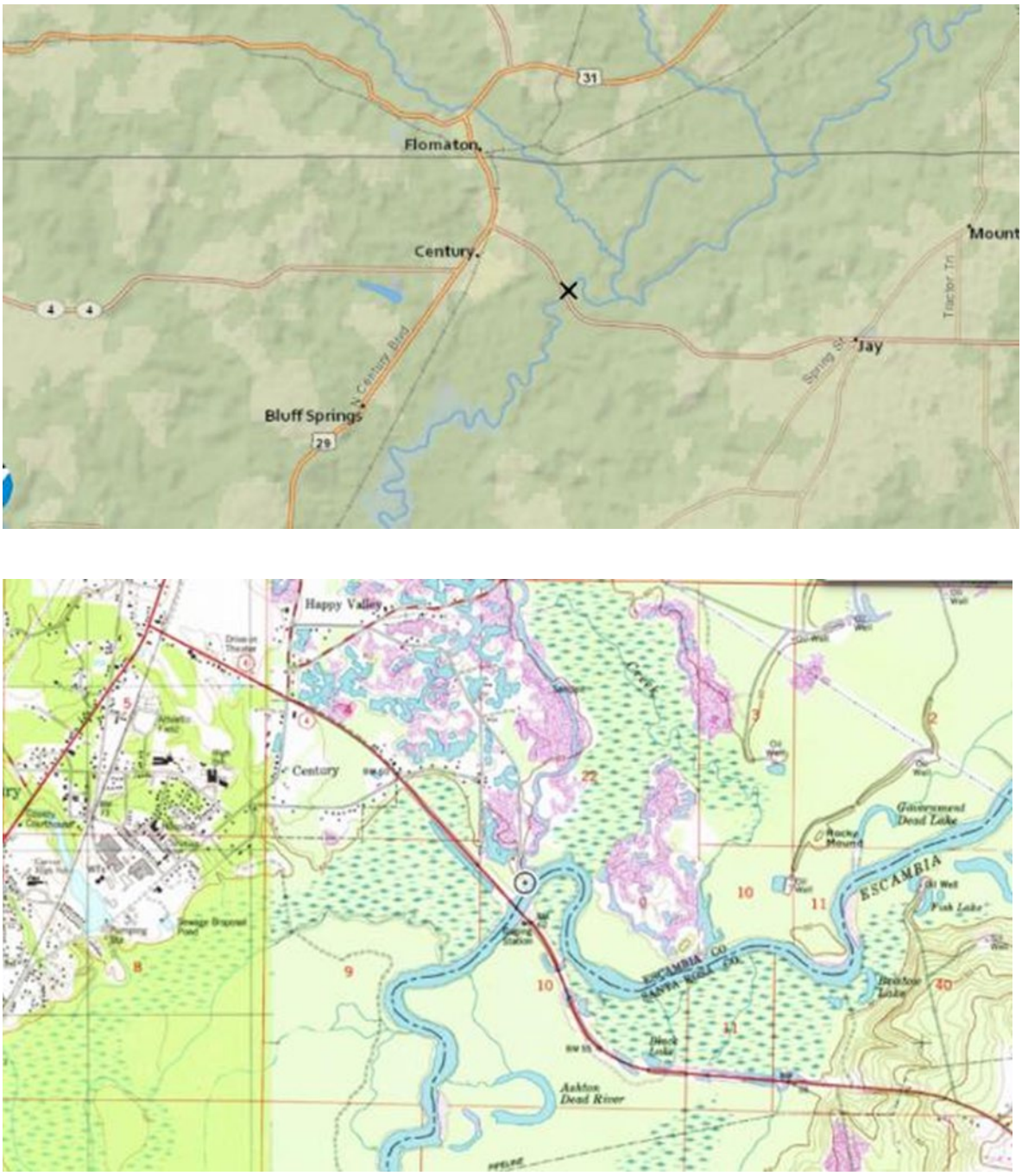


Figure B33 – *Maps of Conecuh River A*

The nearest communities are Century, FL and Flomaton, AL (Figure B33). Both communities are located within 4.8 km west-northwest and northwest of the sampling station.

Figure B34 contains pictures taken during this study. Photo A shows the view downstream at the Escambia River (aka Conecuh River) boat launch. Note the remnants of the old wooden bridge and rocks in the background. Similar view looking downstream towards the Hwy 4 Bridge (B), looking upstream from the sampling station (C), looking across the river from the sampling station (note the power line easement crossing the river just below this station) (D), looking across the boat launch area to the far bank (note the riprap to stabilize the bank is covered with sand deposited during the last flood event) (E), and looking up the boat ramp (also the sampling station) and realizing this area is often underwater during floods (F).

Figure B34 - *Photos of Conecuh A Sampling Site*

Appendix C

Yellow and Shoal River Watersheds

The Yellow/Shoal River (Figure B1) originates in Covington County, AL and flows approximately 148 km before entering Blackwater Bay in Florida. The watershed drains 353,535 square hectares, of which 222,740 are within Florida. The Yellow River travels through portions of the Alabama Western Highlands and through Okaloosa and Santa Rosa Counties before entering the bay, while the Shoal River, the largest tributary to the Yellow, enters the Yellow near Crestview, FL. The Yellow/Shoal are classified as sand bottom rivers, which are shallow and fast flowing. Both rivers have wide riparian zones and once they converge, flow through a large portion of Eglin Air Force Base. The Shoal River is designated as an Outstanding Florida Water (OFW) by the Florida Department of Environmental Protection (FDEP). At the mouth of the river, the Shoal enters the Yellow River Aquatic Marsh Preserve, which is a designated portion of the East Bay System and is again classified as an OFW.

Lightwood Knot Creek

Lightwood Knot Creek is a 3rd order stream and 90.8m elevation at the sampling location (Figure C1). The headwaters to this creek are ~12.8 km north in a mainly rural and agriculture community (Figure C2). The riparian zone is well buffered and intact. The cement bridge is on a 2-lane paved road, and is ~46 m wide. The cement piles support the structure and afford the creek a natural bottom. A powerline easement parallels the bridge just upstream. Looking downstream, the right bridge approach has a 5^{o} drop in slope from the visible hill top (a distance of ~588 m), while the left bridge approach has a 3^{o} drop in slope from the hilltop (a distance of ~161 m).

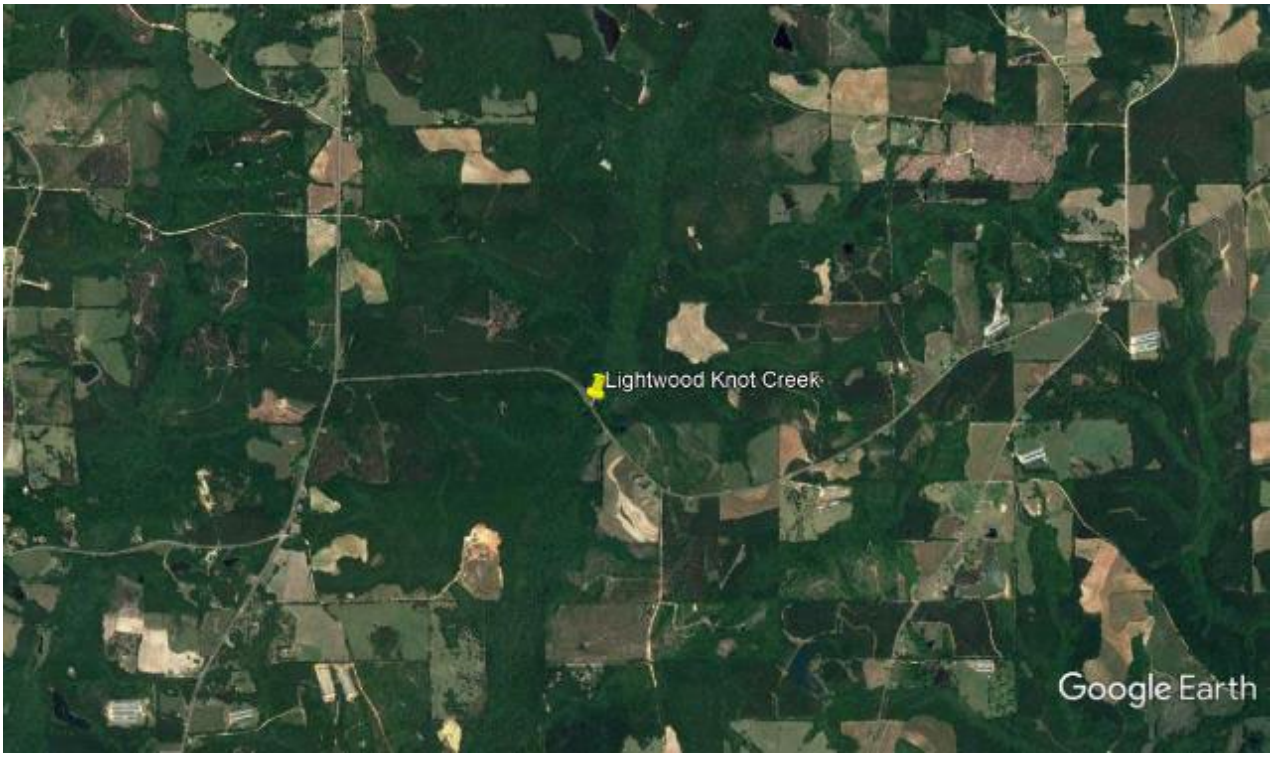


Figure C1 -*Lightwood Knot Creek, Yellow River Watershed, 31.39677, -86.24295, Covington County, AL*

The creek is daylighted by the powerline and bridge easements, and appear to have been widened. The banks have been heavily rocked, and despite not being native to the region, rocks seem to be uniformly scattered across the bottom from bank to bank, and upstream to downstream.

Vegetation includes bald cypress, red maple and oaks along the shore, and *Ligustrum spp*. (privet) along the edges. Aquatic vegeration includes *Orontium spp (*golden club).

Within 1.6 km of the site, the area has several small farms, which have row crops in their fields. Roughly 8 kms downstream from the sampling station, Lightwood Knot Creek is dammed up and becomes Lake Frank Jackson, a large ~4 km lake inside a state park with a golf course.

The state park is located just north of the city of Opp, AL. ~2.1 kms downstream from the dam, Poley Creek and Lightwood Knot Creek converge and flow downstream another 4.8 km before entering the Yellow River mainstem.

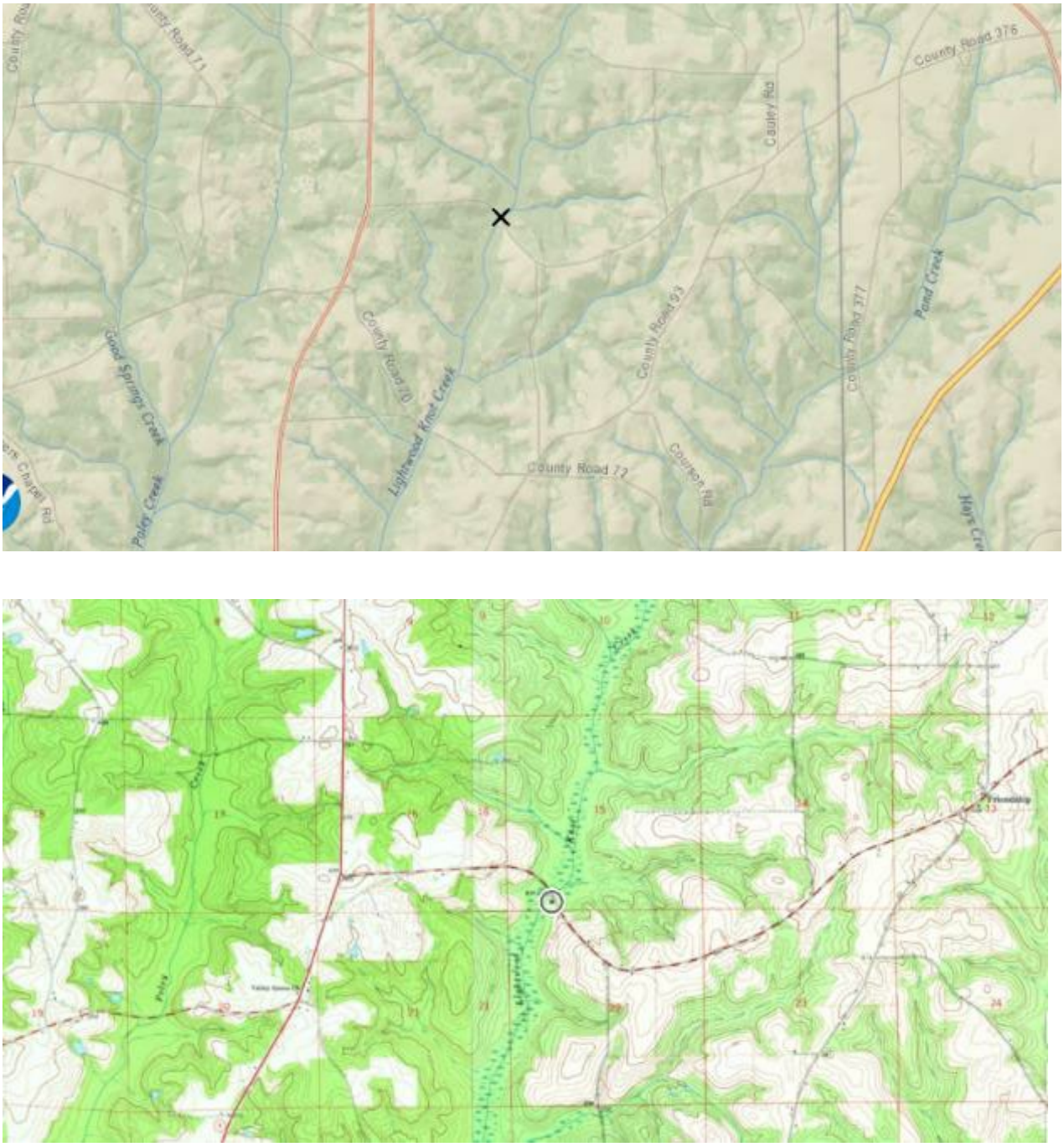


Figure C2 -*Maps of Lightwood Knot Creek*

Figure C3 illustrates site conditions during the study. Photo A, looking upstream from the bridge, note the number of rocks used to stabilize the bank; the creek was shallow enough to see the creek bed was lined with rocks (B); looking downstream from the bridge (C); collecting data (D); upstream side of bridge during low flow conditions (E); and vegetation taking root on mud bank during low flow conditions (F).

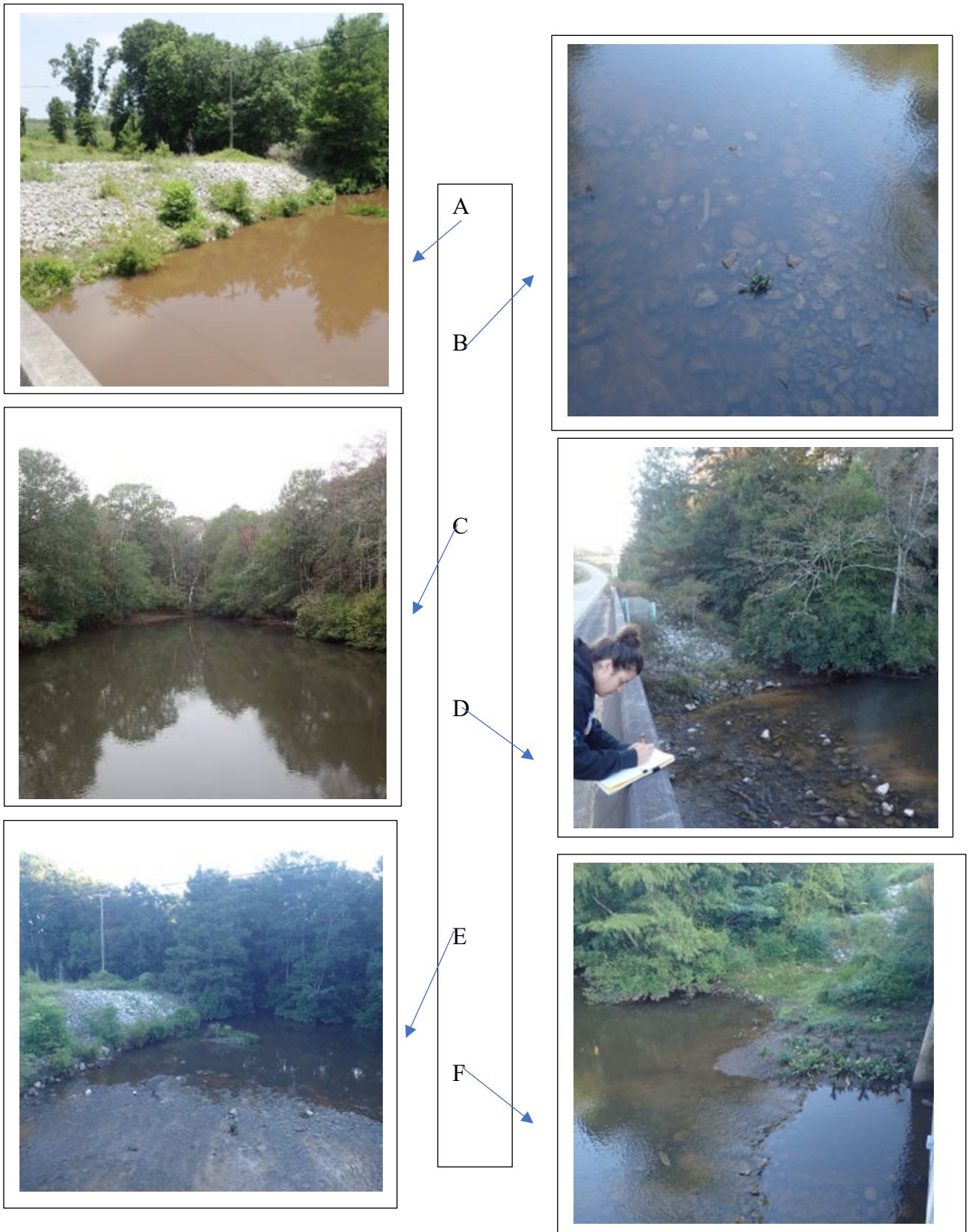


Figure C3 -*Photos of Lightwood Knot Creek*

Poley Creek

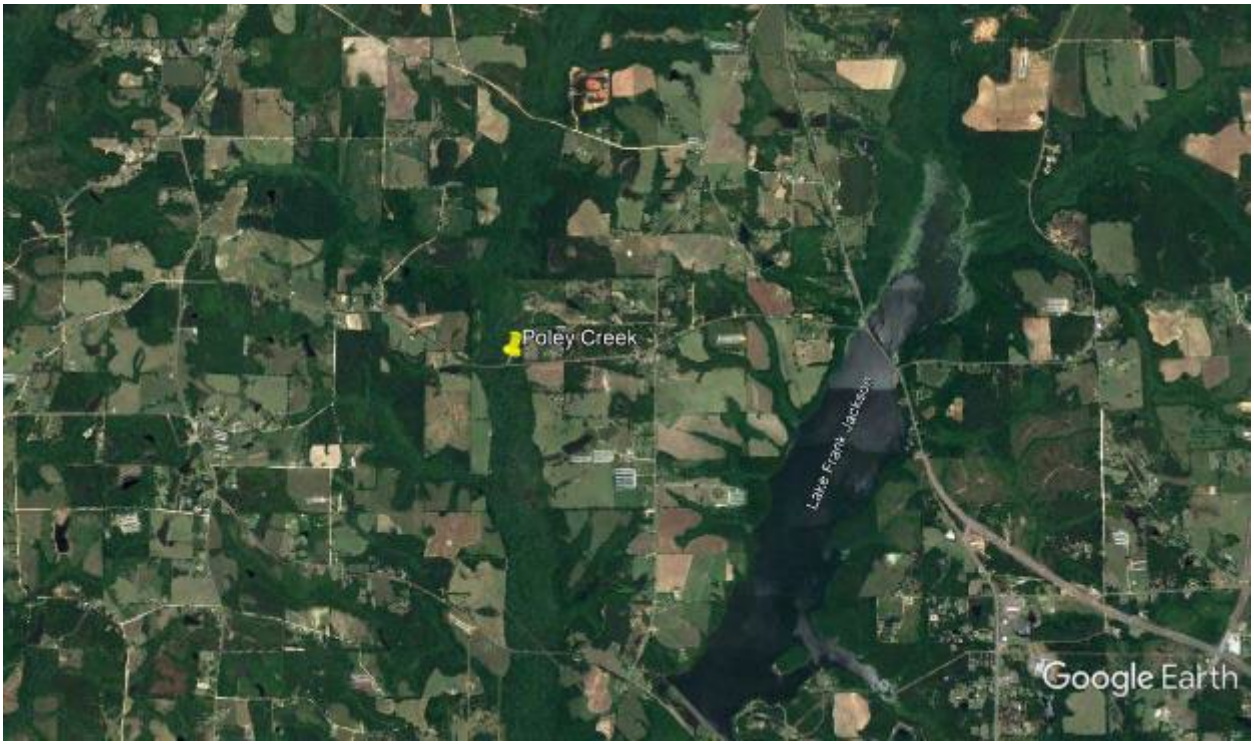


Figure C4 - *Poley Creek, Yellow River Watershed, 31.32619 N, -86.30121 W, Covington County, Alabama*

Poley Creek station is located near the small community of Opine, AL (Figure C4). At this station, Poley Creek is a 3rd order stream at an elevation of ~77m above sea level. The riparian zone is roughly 450m wide at the bridge crossing and appears to be well buffered all the way up to the headwater creeks, ~16 km north of this station.

Looking downstream (note old bridge pilings with vegetation in the water)

View of the bridge

Looking upstream

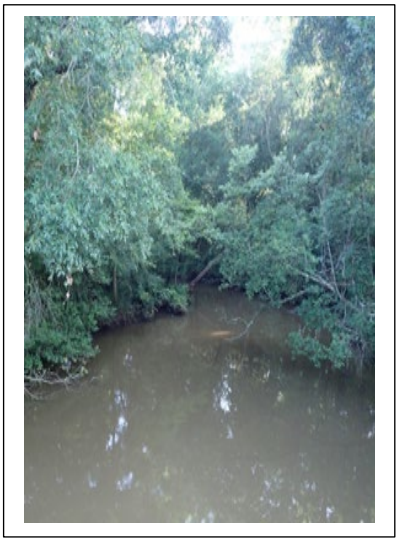


Figure C5 -*Photos of Poley Creek*

The bridge span is 59m in length and is serviced by a paved 2-lane road. The bridge is cement with 3 cement pilings, and the creek has a natural bottom. Remnants of an old wooden bridge can be seen on the downstream side (Figure C5). While looking downstream, the left bridge approach is ~8º while the right approach does not appear elevated and the road curves out of sight.

The creek is well shaded both upstream and downstream with a mature canopy of pine and oaks. Privet, an invasive shrub, was observed in disturbed areas.

Outside of the riparian zone and within a mile of the sampling station are several small farmsteads, three of which to the east have impounded smaller creeks to make lakes on their property (Figure C5). Several large chicken houses are located southeast of the sampling station, also within a mile of the site.

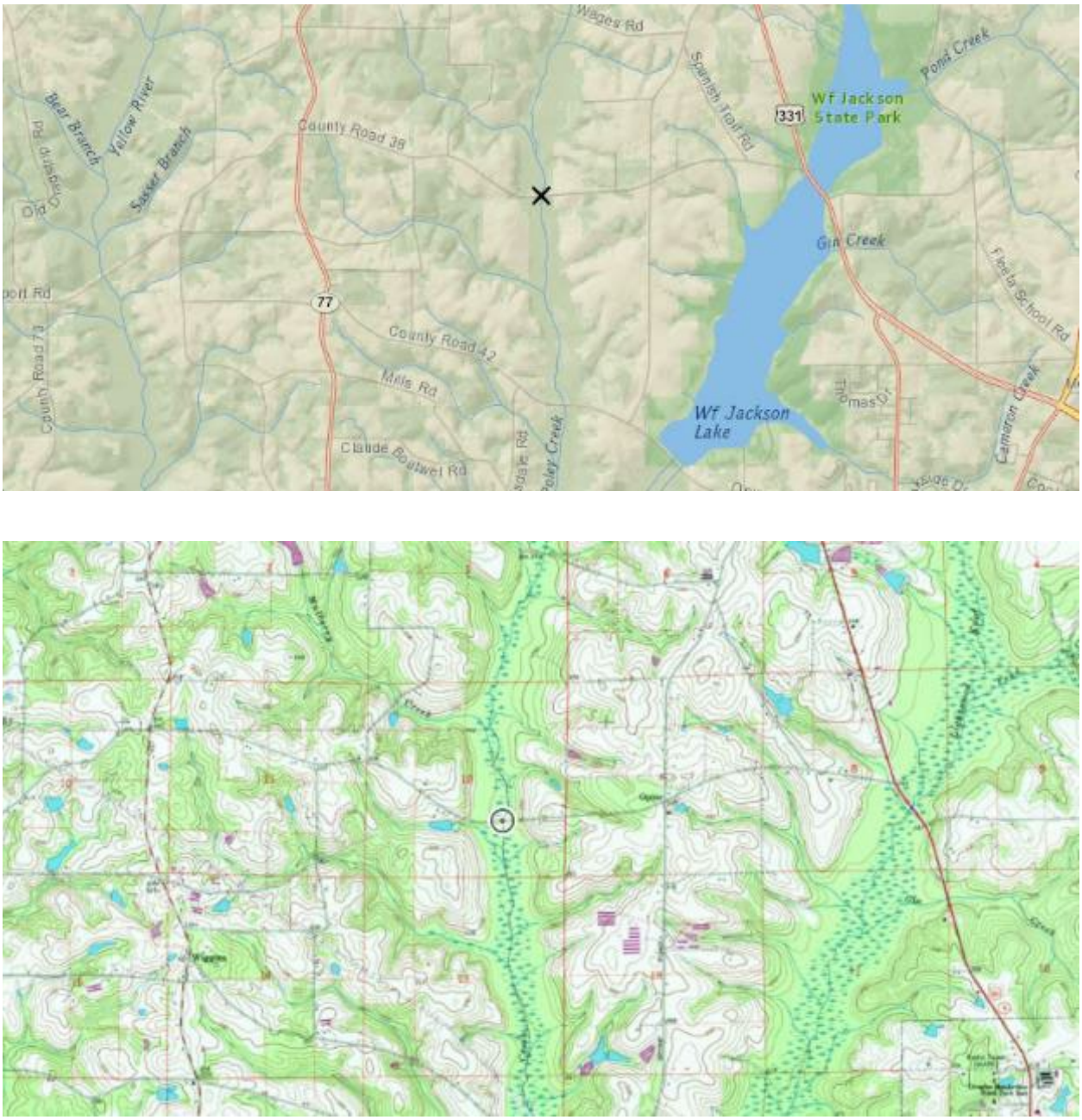


Figure C5 – *Maps of Poley Creek*

Yellow River Upper

Figure C6 - *Yellow River Upper, Yellow River Watershed, 31.21379, -86.35746, Covington County, AL*

The Yellow River Upper station is located ~5 km downstream from where Lightwood Knot Creek and Poley Creek converge with the Yellow River (Figure C6). This station is accessed by a dirt road located between farming communities (silviculture) that lead to the remnants of an old wooden bridge.

At this station, the Yellow River is a 4th order creek system surrounded by natural lands and small farms (Figure C7). The creek has a gravel bottom and clay outcroppings were observed, and is buffered on both sides of the river by dense forest. The Asian clam, corbicula, was observed at the sampling station. Just upstream from the sampling site, the river forks and

flows around an island which appears to be established in the remains of a log jam, perhaps the remnants of the old wooden bridge (Figure C8).

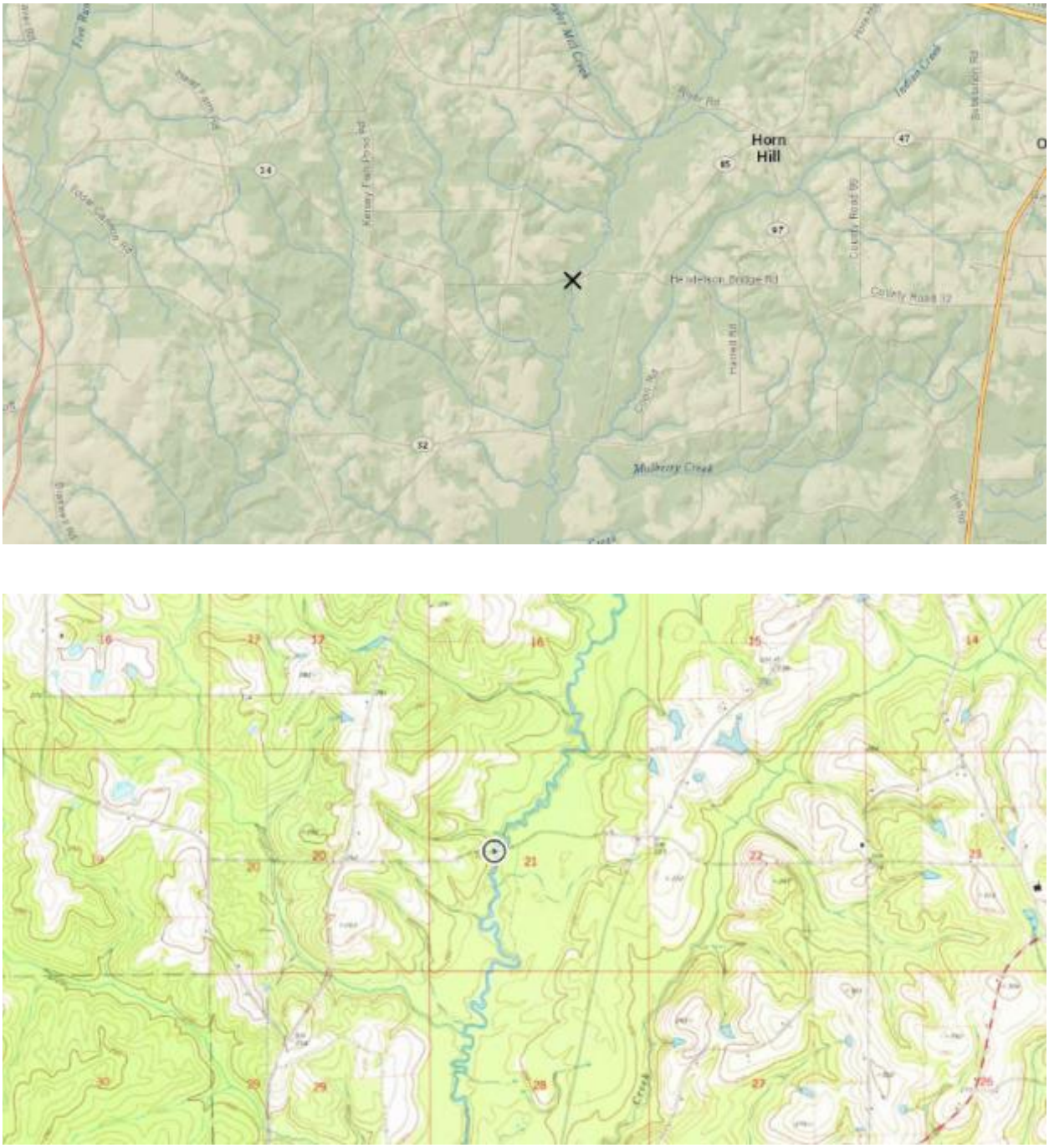


Figure C7 – *Maps of Yellow River Upper station*

Looking upstream Looking towards small island Looking downstream

Figure C8 – *Photos of Yellow River Upper station*

The station is located at an elevation of 66 m above sea level. During this sampling effort, the field to the south was cleared of vegetation and partially burned. A minimal buffer of 10-12m between the end of the dirt road and the creek was observed. Small seepage areas were also noted and flowing towards the river despite being in a dry period for the last three sampling efforts.

Yellow River Lower

At this station, the Yellow River is at an elevation of 39 km and except for ~3.2 km, borders the Conecuh National Forest to the west from the previous Yellow River Station. The Yellow River at Given's Bridge is a 5th order system, and the bridge spans a length of 104m of river and floodplain (Figures C9 and C10). The river is ~33m wide and was accessed from the shore at a boat launch. Very little woody material was observed in the system at this site.

Figure C9 - *Yellow River Lower, Yellow River Watershed, 31.01033, -86.53727, Covington County, AL*

View looking downstream

View looking across the river

View looking upstream

Figure C10 - *Photos of Yellow River Lower station*

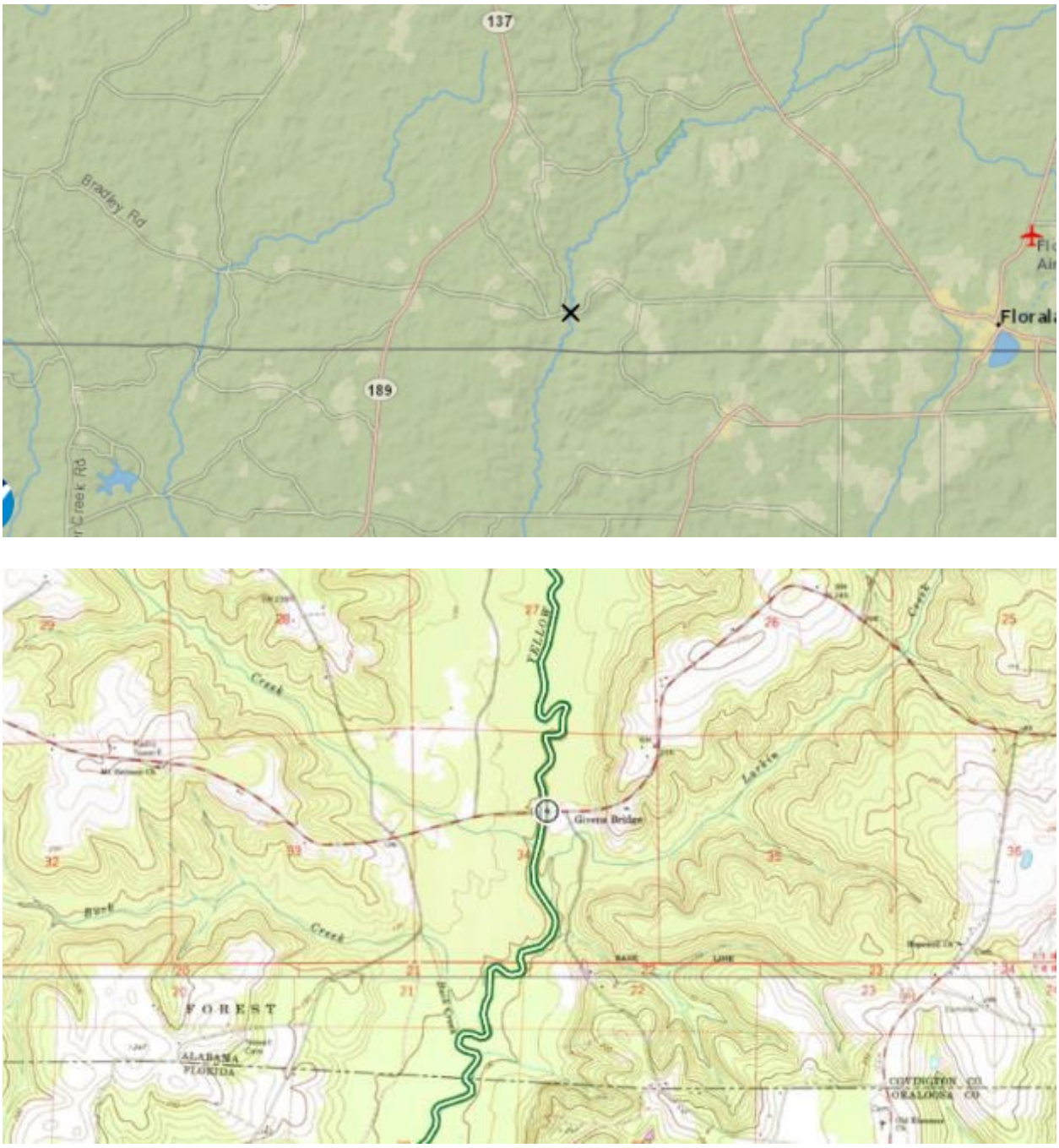


Figure C11 – *Maps of Yellow River Lower station*

AL Hwy 4 is a paved two-lane road which leads to the cement bridge which has three-wide rectangular cement pilings. The river is lined with cypress, willows, river birch and

maples. Directly across from the boat launch area is a straight dredged canal, which leads to the flood plain.

Within 1.6 km of the site, the area remains rural, but it should be noted that between the upper and lower Yellow River Stations, along Hwy 4, a large, forested area has been cleared and is being converted to solar panels and a power-grid station. Hwy 4 is located ~ 1.6 km north of the FL-AL state line (Figure C11).

Shoal River

Figure C12 - *Shoal River, Yellow River Watershed, Lat/Long 30.78591 N, -86.35877 W, Walton County, Florida*

The Shoal River is a 4th order stream, and 42 m elevation at this location (Figure C12). Located in a rural, forested area northwest of the community of Mossy Head and east of Crestview, Florida. The watershed influencing the Shoal River at the sample station is confined

to the area north of Hwy 90 and east to Glendale, FL, (Walton County) (Figure C13). The river is shallow and flowing swiftly. The site is located along a 2-lane paved road, on a bridge which is 22m in length and supported by pilings in the river, with a natural sandy bottom. The road approaching from both sides is relatively flat. A potable water pipe (active) is affixed to the bridge at road level on the downstream side of the bridge.

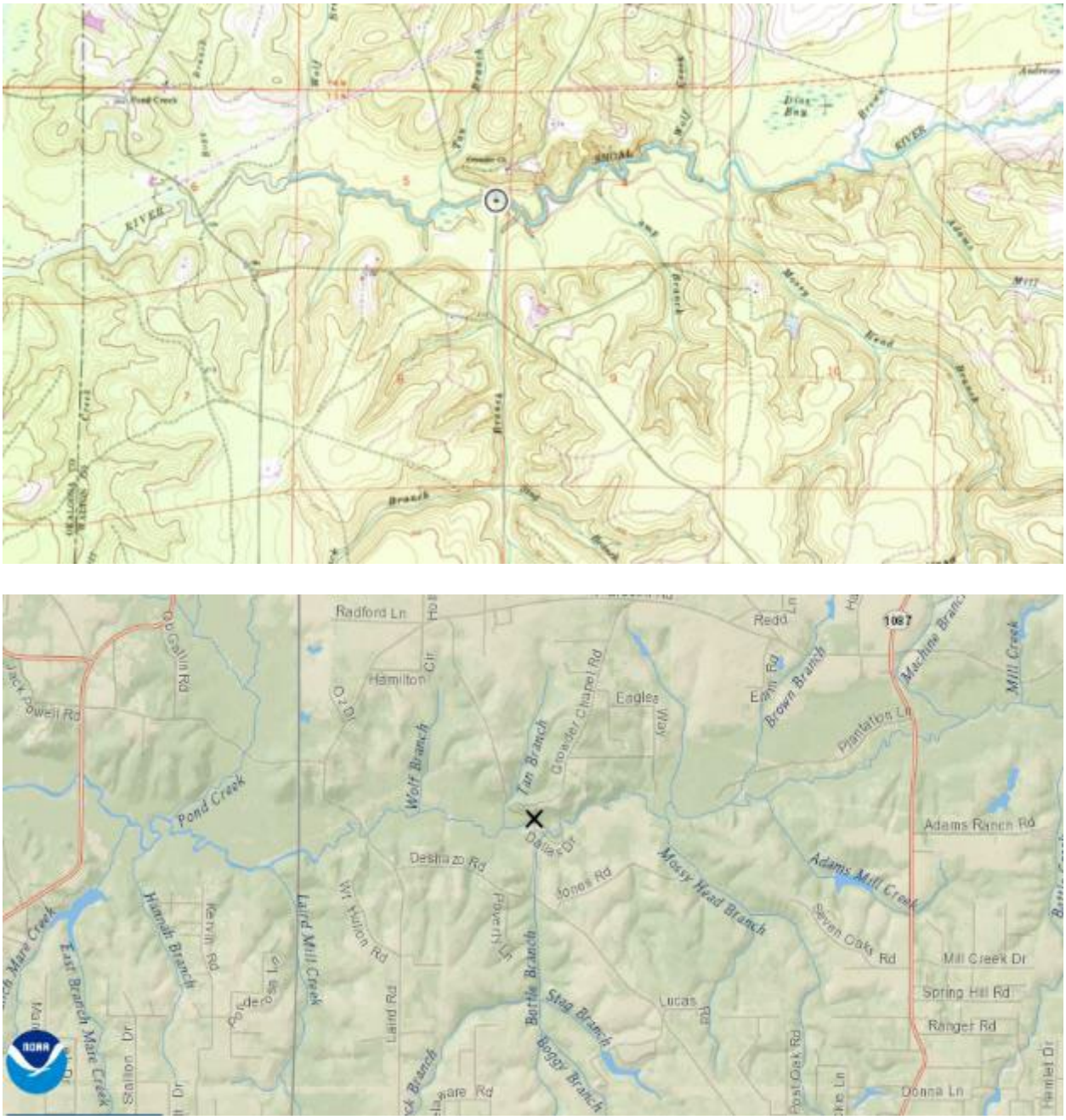


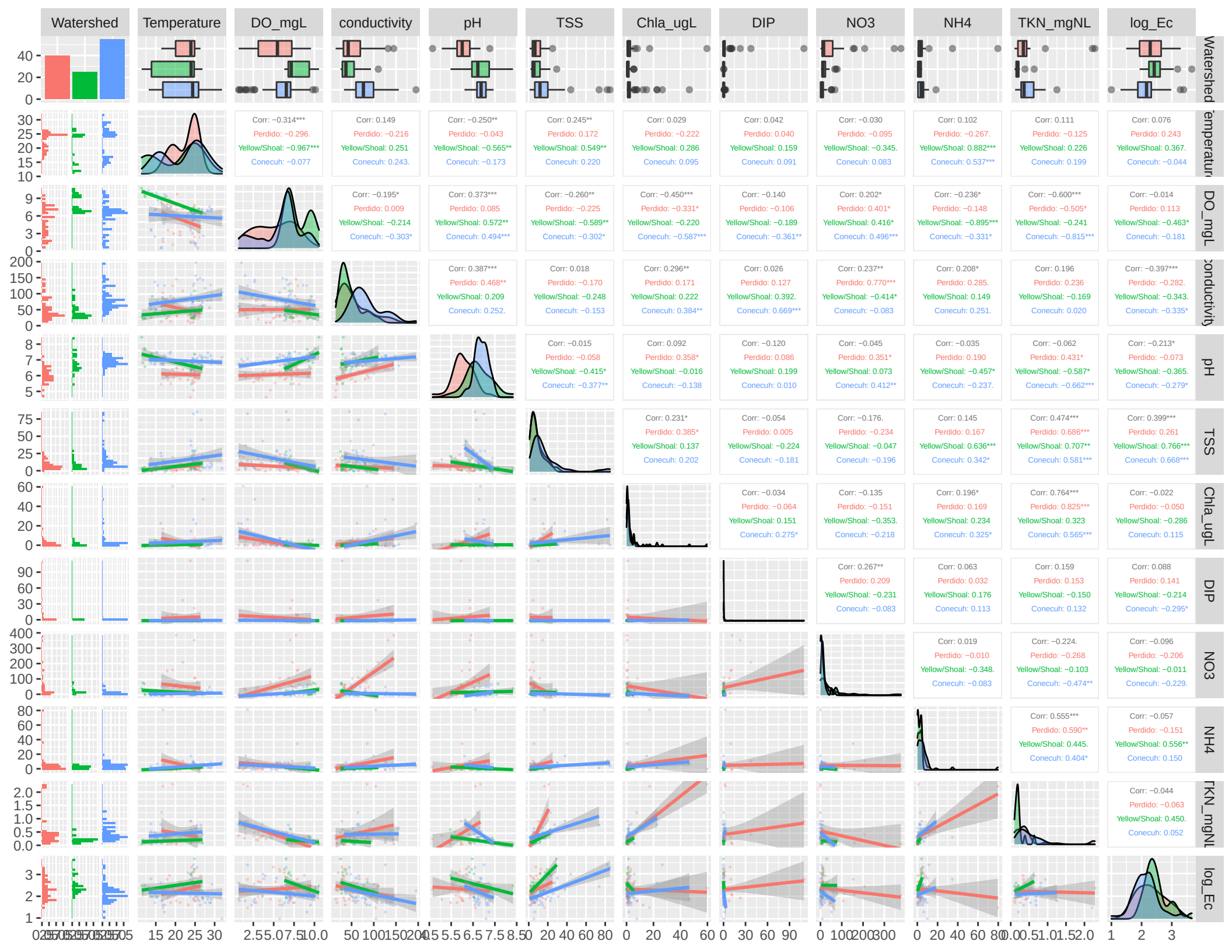
Figure C13 – *Maps of Shoal River station*

View looking downstream View of sediments on bridge View looking upstream

Figure C14 - *Photos of Shoal River*

Within 1 km of the sample site, northwest, is a powerline easement, and 1.75 km southeast of the site is a sand mining operation. The river is well shaded by the tree canopy and is only daylighted by the bridge crossing (Figure C14). The river has an abundance of woody material visible both upstream and downstream from the bridge. The riparian zone is thick with native trees including bald cypress, *Myrica spp.(*wax myrtle), red maple, sweet bay magnolia, sand pine, slash pine, and oaks. Invasive species include *Sapium spp*. (popcorn trees).

Supplemental Figure 1 – Correlation matrix of environmental parameters: temperature (°C), Dissolved Oxygen (DO) (mg/L), conductivity (µS/mc), pH, Total Suspended Solids (TSS) (mg/L), Chlorophyll a (Chla) (µg/L), Dissolved inorganic phosphate (DIP) (µM), Nitrate+nitrite (NO3) (µM), Ammonium (NH4) (µM), Total Kjeldahl Nitrogen (TKN) (mg N/L), and the log of *E. coli* (MPN/100 mL). Pearson correlation coefficients are reported in top right for all values (black), Perdido Watershed values (red), Yellow/Shoal Watershed values (green) and Conecuh Watershed values (blue). Significance level at 0.05 represented by *, at 0.01 by ** and at 0.001 by ***. Distributions of values are shown in diagonal cells and leftmost column. Best fit correlation line is shown in bottom left.


Watershed
Temperature
DO_mgL
conductivity
pH
TSS
Chla_ugL
DIP
NO3
NH4
TKN_mgNL
log_Ec
Corr: −0.314***
Perdido: −0.296.
Yellow/Shoal: −0.967***
Conecuh: −0.077
Corr: 0.149
Perdido: −0.216
Yellow/Shoal: 0.251
Conecuh: 0.243.
Corr: −0.250**
Perdido: −0.043
Yellow/Shoal: −0.565**
Conecuh: −0.173
Corr: 0.245**
Perdido: 0.172
Yellow/Shoal: 0.549**
Conecuh: 0.220
Corr: 0.029
Perdido: −0.222
Yellow/Shoal: 0.286
Conecuh: 0.095
Corr: 0.042
Perdido: 0.040
Yellow/Shoal: 0.159
Conecuh: 0.091
Corr: −0.030
Perdido: −0.095
Yellow/Shoal: −0.345.
Conecuh: 0.083
Corr: 0.102
Perdido: −0.267.
Yellow/Shoal: 0.882***
Conecuh: 0.537***
Corr: 0.111
Perdido: −0.125
Yellow/Shoal: 0.226
Conecuh: 0.199
Corr: 0.076
Perdido: 0.243
Yellow/Shoal: 0.367.
Conecuh: −0.044
Corr: −0.195*
Perdido: 0.009
Yellow/Shoal: −0.214
Conecuh: −0.303*
Corr: 0.373***
Perdido: 0.085
Yellow/Shoal: 0.572**
Conecuh: 0.494***
Corr: −0.260**
Perdido: −0.225
Yellow/Shoal: −0.589**
Conecuh: −0.302*
Corr: −0.450***
Perdido: −0.331*
Yellow/Shoal: −0.220
Conecuh: −0.587***
Corr: −0.140
Perdido: −0.106
Yellow/Shoal: −0.189
Conecuh: −0.361**
Corr: 0.202*
Perdido: 0.401*
Yellow/Shoal: 0.416*
Conecuh: 0.496***
Corr: −0.236*
Perdido: −0.148
Yellow/Shoal: −0.895***
Conecuh: −0.331*
Corr: −0.600***
Perdido: −0.505*
Yellow/Shoal: −0.241
Conecuh: −0.815***
Corr: −0.014
Perdido: 0.113
Yellow/Shoal: −0.463*
Conecuh: −0.181
Corr: 0.387***
Perdido: 0.468**
Yellow/Shoal: 0.209
Conecuh: 0.252.
Corr: 0.018
Perdido: −0.170
Yellow/Shoal: −0.248
Conecuh: −0.153
Corr: 0.296**
Perdido: 0.171
Yellow/Shoal: 0.222
Conecuh: 0.384**
Corr: 0.026
Perdido: 0.127
Yellow/Shoal: 0.392.
Conecuh: 0.669***
Corr: 0.237**
Perdido: 0.770***
Yellow/Shoal: −0.414*
Conecuh: −0.083
Corr: 0.208*
Perdido: 0.285.
Yellow/Shoal: 0.149
Conecuh: 0.251.
Corr: 0.196
Perdido: 0.236
Yellow/Shoal: −0.169
Conecuh: 0.020
Corr: −0.397***
Perdido: −0.282.
Yellow/Shoal: −0.343.
Conecuh: −0.335*
Corr: −0.015
Perdido: −0.058
Yellow/Shoal: −0.415*
Conecuh: −0.377**
Corr: 0.092
Perdido: 0.358*
Yellow/Shoal: −0.016
Conecuh: −0.138
Corr: −0.120
Perdido: 0.086
Yellow/Shoal: 0.199
Conecuh: 0.010
Corr: −0.045
Perdido: 0.351*
Yellow/Shoal: 0.073
Conecuh: 0.412**
Corr: −0.035
Perdido: 0.190
Yellow/Shoal: −0.457*
Conecuh: −0.237.
Corr: −0.062
Perdido: 0.431*
Yellow/Shoal: −0.587*
Conecuh: −0.662***
Corr: −0.213*
Perdido: −0.073
Yellow/Shoal: −0.365.
Conecuh: −0.279*
Corr: 0.231*
Perdido: 0.385*
Yellow/Shoal: 0.137
Conecuh: 0.202
Corr: −0.054
Perdido: 0.005
Yellow/Shoal: −0.224
Conecuh: −0.181
Corr: −0.176.
Perdido: −0.234
Yellow/Shoal: −0.047
Conecuh: −0.196
Corr: 0.145
Perdido: 0.167
Yellow/Shoal: 0.636***
Conecuh: 0.342*
Corr: 0.474***
Perdido: 0.686***
Yellow/Shoal: 0.707**
Conecuh: 0.581***
Corr: 0.399***
Perdido: 0.261
Yellow/Shoal: 0.766***
Conecuh: 0.668***
Corr: −0.034
Perdido: −0.064
Yellow/Shoal: 0.151
Conecuh: 0.275*
Corr: −0.135
Perdido: −0.151
Yellow/Shoal: −0.353.
Conecuh: −0.218
Corr: 0.196*
Perdido: 0.169
Yellow/Shoal: 0.234
Conecuh: 0.325*
Corr: 0.764***
Perdido: 0.825***
Yellow/Shoal: 0.323
Conecuh: 0.565***
Corr: −0.022
Perdido: −0.050
Yellow/Shoal: −0.286
Conecuh: 0.115
Corr: 0.267**
Perdido: 0.209
Yellow/Shoal: −0.231
Conecuh: −0.083
Corr: 0.063
Perdido: 0.032
Yellow/Shoal: 0.176
Conecuh: 0.113
Corr: 0.159
Perdido: 0.153
Yellow/Shoal: −0.150
Conecuh: 0.132
Corr: 0.088
Perdido: 0.141
Yellow/Shoal: −0.214
Conecuh: −0.295*
Corr: 0.019
Perdido: −0.010
Yellow/Shoal: −0.348.
Conecuh: −0.083
Corr: −0.224.
Perdido: −0.268
Yellow/Shoal: −0.103
Conecuh: −0.474**
Corr: −0.096
Perdido: −0.206
Yellow/Shoal: −0.011
Conecuh: −0.229.
Corr: 0.555***
Perdido: 0.590**
Yellow/Shoal: 0.445.
Conecuh: 0.404*
Corr: −0.057
Perdido: −0.151
Yellow/Shoal: 0.556**
Conecuh: 0.150
Corr: −0.044
Perdido: −0.063
Yellow/Shoal: 0.450.
Conecuh: 0.052